

**WVDOH Standards Committee Meeting**  
**Tuesday, June 2, 2026**  
**Meeting Location: 190 Dry Branch Drive, Charleston, WV**

Also meeting virtually via Google Meet. Email distribution includes instruction.

**Old Business:** Standards discussed at the April 2026 meeting are below.

ITEM	Champion
<p><b>4<sup>th</sup> time to Committee. Discussed in December, February, April, June</b></p> <ul style="list-style-type: none"> <li>• DD-644-<i>Asphalt Pavement</i></li> <li>• DD-646-<i>Pavement Design Guide</i></li> <li>• DD-647-<i>Life-Cycle Cost Analysis for Pavement Design</i></li> <li>• DD-648-<i>Alternate Design and Alternate Bidding of Pavements</i></li> </ul> <p>The revisions include updated links, reference documents, and adds new standards for pavement design. Revision adjusts analysis periods to reflects recent updates to AASHTO 93.</p> <p style="color: red;">These items have been revised to address comments and incorporate language for the LCCA report since the last meeting.</p>	K. Welch
<p><b>2<sup>nd</sup> time to Committee. Discussed in April, June</b></p> <ul style="list-style-type: none"> <li>• DD-105-<i>Specification, Standards, Manuals, and Material Procedure Approval Process</i></li> </ul> <p>The revision clarifies the work and standard operating procedures for the Publications Section following the reorganization and other departmental changes.</p> <p style="color: red;">This item has been updated since the last meeting separating the publication type and committee structures for Standards and Manuals.</p>	S. Boggs
<p><b>2<sup>nd</sup> time to Committee. Discussed in April, June</b></p> <ul style="list-style-type: none"> <li>• DD-622-<i>Intersections on Rural Divided Highways</i></li> <li>• DD-625-<i>Interchange Warrants</i></li> </ul> <p>The revision updates references to outdated 2011 AASHTO's A Policy on Geometric Design of Highways and Streets to the current 2018 edition, ensuring alignment with the latest national geometric design standards:</p> <p style="color: red;">DD-622 has been updated since the last meeting, this includes a minor changing of a straight through arrow to a right turn pavement arrow on page 3.</p>	S. Boggs
<p><b>2<sup>nd</sup> time to Committee. Discussed in April, June</b></p> <ul style="list-style-type: none"> <li>• DD-662- <i>Guardrail</i></li> </ul> <p>The revision reflects coordination between WVDOH and FHWA and is intended to ensure that adequate grading is completed prior to terminal installation so that these systems function as designed.</p>	S. Boggs

**New Business:**

ITEM	Champion
<p><b>1<sup>st</sup> time to Committee</b></p> <ul style="list-style-type: none"> <li>• Life Cycle Cost Analysis (LCCA) Report</li> </ul> <p>The LCCA report evaluates the long-term economic efficiency of competing pavement design alternatives (asphalt vs. concrete) in accordance with FHWA</p>	K. Welch

<p>guidelines. Specifically, the report demonstrates the methodology used to calculate the Net Present Value of Future Costs (C-factor). The report will be incorporated into DD-647 and DD-648, reviewed and approved annually, and published on the Publications Page. This effort is being completed at management's request.</p>	
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WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 644  
ASPHALT PAVEMENT

Insert Approval Date  
Supersedes July 6, 2022

This Design Directive (DD) provides guidance on selecting asphalt pavement mix design methods and types of asphalt pavement. It also provides descriptions of situations that require polymer-modified asphalts, and methods for calculating quantities and types of materials that are to be used.

### TYPES OF ASPHALT MIX DESIGNS

Marshall Asphalt Mix Design: Bruce Marshall developed the “Marshall” method of asphalt mix design in the late 1930’s for the Mississippi Highway Department. This method has been used by the WVDOT since the 1970’s.

Superpave Asphalt Mix Design: “Superpave” stands for Superior Performing -Asphalt Pavements. It represents an improved system for specifying the components of asphalt concrete, asphalt mixture design and analysis, and asphalt pavement performance prediction. The Strategic Highway Research Program (SHRP) developed the Superpave asphalt pavement mix design method in the early 1990’s.

### ASPHALT PAVEMENT MIX DESIGN TYPE SELECTION

Superpave asphalt mixture types are to be used for the following type projects:

1. New construction of multilane divided highways where the mainline pavement is asphalt pavement.
2. Overlay or 3R type projects on existing multilane divided highways where the asphalt pavement overlay is three (3) inches or more.
3. Overlay type projects on existing National Highway System (NHS) highways where the asphalt pavement overlay is three (3) inches or more.
4. Projects on other highways were approved by the Deputy State Highway Engineer Chief Engineer of Development or Operations.

Either Superpave or Marshall asphalt mixture types may be utilized on projects with design ESALs less than 3 million. Marshall Mixtures shall not be used on projects with greater than or equal to 3 million Marshall asphalt mixture types are permitted on all other projects.

### SPECIFICATION SELECTION CRITERIA

There are three (3) specifications available when identifying the asphalt requirement for projects. Specifications Sections 401, 402 and 410 shall be used based on project criteria.

- Section 401 is the standard asphalt pavement specification, covering most roadways.
- Section 402 is utilized for roadways needing polish resistant aggregates to promote skid resistance. Section 402 shall be used for the surface course on projects with a current ADT of 3000 or more vehicles per day.
- Section 410, “Percent Within Limits”, is a specification for use when there is a need

for performance related results. This Specification uses mathematical models to quantify relationships between quality characteristics and product performance. These characteristics include mat density, asphalt content, bond strength and others, with samples taken directly from the roadway. Acceptance according to Section 410 (PWL) shall be limited to the top two (2) layers of the pavement, scratch and P&L do not count as a-pavement layers. Other materials below the top two (2) layers shall be accepted in accordance with sSection 401.

Section 410 (PWL) of the Specification shall be used on the following project types:

1. New Construction where the mainline is asphalt pavement.
2. Overlay projects on existing multilane divided highways.
3. Overlay projects on any National Highway System (NHS) routes, as found on the Divisions website using the latest version of the “Annual Roadway Inventory Statistics”.
4. Projects on other highways where approved by the Deputy State Highway Engineer Chief Engineer of Development or Operations.

Additionally, a project must meet all of the following specific requirements for the use of Section 410:

1. ~~Projects~~The layer-exceeds 5,000 tons ~~in either of the top two asphalt layers~~-(scratch and P&L do not count as layers)
2. The overall width of asphalt equals or exceeds 20 feet in width
3. Project paving is continuous for a minimum of 1500 feet
4. Posted speeds ~~equal to or~~-greater than 35-mph

Section 410 shall not be specified if cities or areas with a high density of utilities are within the project limits. The Specifications in Section 401 and 402 shall be used for all other projects.

#### **DETERMINATION OF EQUIVALENT SINGLE AXLE LOAD (ESAL)**

The “ESAL Calculator” program shall be used to calculate the ~~20-year~~ projected design ESALs for all projects unless one of the following applies.

1. The “ESAL Calculator” program produces a value exceeding 10,000,000.
2. When a traffic study has been performed. (i.e. When traffic movements or traffic counts are provided by the Traffic Modeling and Analysis Unit of the Planning Division-)
3. On roadway realignment projects that exceed 1000 feet of relocated roadway.
4. When there is an expected development in the area that may change or alter the nature or character of the expected traffic. (i.e. Shopping centers, schools, etc.)
5. The project is on the CRTS (Coal and Resource Transportation System).

The ESAL Calculator program can be obtained from the West Virginia Department of Transportation's ~~Engineering Publications and Manuals~~Materials Toolbox website at <http://www.transportation.wv.gov/highways/engineering/Pages/Manuals.aspx> https://transportation.wv.gov/highways/mcst/Pages/tbox.aspx, then under the “Pavementing” heading choose “ESAL Calculator”.

When the ESAL Calculator program cannot be used to calculate the ESALs, then the ESALs or the percentage of traffic in each of the 13 classes shall be obtained from the Traffic Monitoring Unit of the ~~Performance Management Group~~ Traffic Engineering Division. The Traffic Monitoring Unit can be emailed at [TMATrafficMonitoring@wv.gov](mailto:TMATrafficMonitoring@wv.gov). The designer is cautioned

that the development of appropriate data to establish accurate ESAL estimates should be requested prior to the Design Study Office Review (if there is one) or prior to the Preliminary Field Review (if there was not a design study).

Projects shall show the projected design ESALs on the general notes and the typical section sheets showing the pavement details.

## SURFACE PREPARATIONS

Milling is used to remove surface distresses, create a better bond for an overlay, restore cross slope, and maintain vertical geometric properties, such as bridge clearance, guardrail height, and grade with gutter area. Milling shall be the preferred method of correcting deviations to the road surface prior to resurfacing.

When milling is specified by the contract, the thickness of milling specified by the Designer shall be at least 1/4" inch into the layer just below the layer(s) being removed. The intent is to mill off entire layers, and not leave any partial layers.

Section 415 of the Specifications, *Milling of Asphalt Pavement Surfaces*, contains three (3) types of milling: Standard Milling, Fine Milling, and Micromilling. These are differentiated primarily by the carbide tooth spacing, typically 15, 8, and 5 mm respectively, resulting in finer textured surfaces. These milling types specify the final surface texture prior to any overlay. The following describes the conditions in which the designer should use each type of milling:

- Standard Milling: Used as the default milling of asphalt pavement. It is intended ~~to be used when the Division plans to remove existing asphalt pavement to correct deviations less than 1 inch, without a high level of profile and slope control.~~ for general removal of existing asphalt pavement in preparation for resurfacing or overlay, or to restore pavement section to a specified depth. Standard milling is appropriate where high levels of profile and slope control are not required.
- Fine Milling: Used when the Division intends to overlay the milled surface with a two (2) inch or less asphalt course. It shall also be used when the contract contains pay items from Section 410 of the Specifications, *Asphalt Base and Wearing Courses, Percent Within Limits (PWL)*. It is intended to be used when control of the profile and slope of the milled surface is important. Fine milling shall only be used if there is a minimum of 5,000 SY of fine milling.
- Micro Milling: Used for smoothness correction, skid correction, bump and/or grade corrections on existing or newly paved surfaces. This milling is typically less than ~~an~~ one (1) inch. It is not intended to be used when additional asphalt will be placed on the milled surface.

If fine milling is needed and multiple milling passes are necessary, standard milling shall be used to cut down to one (1) inch above the final prepared surface. The designer shall document in the plans the estimated thickness of each type of milling.

## ASPHALT MATERIAL (TACK COAT)

Asphalt Material (Tack Coat) (Section 408) shall be specified for placement on all existing pavement prior to placing asphalt pavement. If the designer can anticipate phased construction where part of the base or intermediate course will be open to traffic prior to final lift placement additional Asphalt Material should be included.

## SCRATCH

Scratch Course is normally used in rehabilitation or resurfacing projects that do not contain a milling item. Scratch should be used to correct rutting and other deviations up to about one (1) inch when the milling operation will cause an unnecessary disruption to the traveling public. If milling is performed on the project, Scratch Course shall not be used.

Scratch Course can be placed over the entire project or to the limits established by the designer. If the Scratch Course is not to be placed over the full width of the project, it shall be specified full lane width increments. Although Scratch Course can be placed over the entire project, it is not a constant thickness layer. The term "Scratch Course" comes from the method of placement of this item. The paving equipment is set to drag on or "scratch" the high areas of the existing pavement, only depositing material in the low areas; thereby creating a smooth surface on which to place the next layer of asphalt pavement.

Scratch course may be specified as a 9.5 mm or a 4.75 mm mix. Scratch Course shall be shown on the plan typical sections as a line without a thickness or application rate. Scratch Course is not included in the structural design of the pavement.

Scratch Course shall not be used on new construction.

## PATCH AND LEVEL

Patching and Leveling is to be placed at various locations throughout the project to remove irregularities in the existing pavement, such as dips, or to raise the outside edge of the existing pavement to provide a uniform template prior to placing a base or wearing course. Patching and Leveling shall not be specified as a continuous layer or course to be placed over the full width and length of the project.

Patching and Leveling shall be used only in resurfacing or rehabilitation projects, not in the construction of new pavements. It shall be specified when the deviations in the existing pavement are one (1) inch or greater in depth.

Patching and Leveling shall be shown on the plan typical sections as a layer with thickness specified as "variable - 2" maximum lift thickness. No application rate shall be shown. Patching and Leveling thickness is not included in the structural design of the pavement.

## OVERBANDING LONGITUDINAL JOINTS

Longitudinal joint construction in asphalt pavements is a critical phase of construction. This affects structural integrity and results in premature failure of the asphalt pavements. Overbanding makes joints less susceptible to deterioration from water and other external factors.

Projects meeting the criteria for Specifications Section 401 Lot by Lot shall require longitudinal joints to be overbanded using PG 64S-22 binder. Plan documents shall require a minimum of six (6) inches in width (three (3) inches on each side of the joint), centered over the joint, at a thickness of 1/16 inch, in accordance to section 401.13.3 and 403 of the Specification. Longitudinal joints shall be overbanded using PG 64S-22 binder. Plan documents shall require a minimum of six (6) inches in width (three (3) inches on each side of the joint), centered over the joint, at a thickness of 1/16 inch, in accordance with Section 403.8 of the Specifications. Overbanding of constructed joints is a separate bid item and shall be included in the plans and quantities.

Projects meeting the criteria for Specifications Section 410 shall not require overbanding.

## PERFORMANCE GRADED (PG) BINDER TYPE SELECTION

Binder Selection will be based on the design ESAL estimate for all projects.

Binder	ESALs
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PG64S-22	<20 million
PG64H-22	20 million — 30 million
PG64E-22 (Polymer Modified Binder)	>30 million (See PMA Section)

While rare, for colder areas of the state, a lower binder grade of PG 58S-28 may be appropriate. If unsure, the designer can contact the Asphalt ~~Section Group~~ of Materials Control, Soils, and Testing Division at [DOHasphalt@wv.gov](mailto:DOHasphalt@wv.gov).

~~When using anything other than PG64S-22, t~~The binder grade shall be provided on both the general notes sheet and the typical section sheet(s) showing the pavement details.

PG 64S-22 binder may be used in asphalt placed below the top two (2) lifts in any pavement section. Scratch course and patching and leveling are not identified as lifts. PG 64H-22 and PG64E-22 shall not be used in Marshall mix designs.

Polymer Modified Asphalts (PMA) or Non Standard Grade: The binder PG 64E-22, which is a polymer-modified binder, is required to be used in the following cases:

1. Projects estimating more than 30 million ESALs.

~~1.2.~~ For the surface lift on roadways facilitating access to industrial parks, warehouses, production facilities, etc.

~~2.3.~~ High Performance Thin Overlay (HPTO) asphalt pavement in accordance with Special Provision 496. ~~Since PG-64E-22 is required by the Special Provision a plan note is not required.~~

A binder grade associated with a higher ESAL count may be used, at the discretion of the ~~responsible e~~Engineer, on projects where the pavement exhibits severe rutting or shoving problems due to heavy traffic conditions, such as:

1. Intersections with very heavy truck traffic
2. Truck climbing lanes and ramps

PMAs have shown great success as being a long-term solution to severe rutting problems. Due to the additional cost of a PMA, it shouldn't be used on any project without first repairing base failures and removing excessively rutted pavement. PMA shall generally be used only in the skid surface mix (preferably a 12.5 mm mix) but may also be used in the underlying courses depending on the severity of the traffic conditions. Always use the preferred thickness from the Superpave asphalt pavement recommended lift thickness tables as a minimum thickness when using PMA. Any mix design to be used as a scratch course shall not be specified to use PMA.

PMA Pavement quantities shall be used in increments of 400 tons due to minimum requirements necessary for ordering of material.

~~PG-64S-22 binder should be used in asphalt placed below the top two lifts in any pavement section. Scratch course and patching and leveling are not identified as lifts.~~

## PAVEMENT STRUCTURE

Bottom Courses: When developing the overall pavement thickness, it is recommended the designer use 25 mm mix as the bottom lifts. When a 25mm mix is to be used on a ~~s~~Section 410 (PWL) project, acceptance of the 25mm layer(s) shall be in accordance with ~~s~~Section 401.

~~Where Marshall is permitted, a Marshall Type 2 Base Course shall be specified instead of a Type 1 Base when the total base course thickness is less than or equal to 3.25 inches.~~

Intermediate Courses: On new construction or multi-lift projects a Superpave 19mm or Marshall Type 2 base mixture shall be utilized below the surface course to promote smoothness in the -final pavement.

Surface Courses: The wearing course is a single constant thickness layer to be placed over the entire pavement surface. The wearing course is the riding surface on which traffic travels. A Superpave 4.75 mm, 9.5mm, or 12.5mm or Marshall Type 1 or Type 3 Wearing mixture is the mix type to be used as the surface course. PMA can also be used if traffic warrants. A Marshall Type 4 Wearing is intended for use in heavy truck traffic situations, note that a wearing 4 is a visually coarse mixture.

Section 402 shall be used for the surface course on projects with a current ADT of 3000 or more vehicles per day. Only Superpave 9.5mm and 12.5mm mixtures and Marshall Type 1 and Type 4 wearing mixtures shall be specified as a skid resistant mix.

A Wearing 3 or 4.75 mm mix shall only be used for pavement preservation applications or as a surface course over an intermediate course in multi-lift applications. High performance thin overlays shall may be used for pavement preservation on roads with ADT of 3000 or more vehicles per day.

### **SUPERPAVE MIX TYPE LIFT THICKNESS RECOMMENDATIONS**

The following table provides a list of Mix Type recommendations for the designer to use when preparing pavement lift thicknesses for the typical section. Pavement designs provide an overall thickness of asphalt pavement and the designer is generally left to make the decision on bottom, intermediate, and surface course thickness. The designer should use recommendations found in the Pavement Structure section, as well as minimum and maximum thicknesses -from the table.

For Marshall Base Courses, it is recommended that in multi-lift pavements when Type 1 Base Course is used, an intermediate course (the top lift of base course) be a Type 2 to improve the smoothness of the finished pavement. This would eliminate the use of a Scratch Course prior to placing the surface course.

<b><u>Recommended Lift Thickness for Asphalt Pavement</u></b>				
<b><u>Marshall Mix Type</u></b>	<b><u>Superpave Mix Type (mm)</u></b>	<b><u>Minimum (inches)</u></b>	<b><u>Maximum (inches)</u></b>	<b><u>Preferred<sup>Note1</sup> (inches)</u></b>
<u>Wearing 3</u>	<u>4.75</u>	<u>5/8</u>	<u>1</u>	<u>5/8</u>
<u>Wearing 1</u>	<u>9.5</u>	<u>1.5</u>	<u>2.0</u>	<u>1.5<sup>Note2</sup></u>
<u>=</u>	<u>12.5</u>	<u>1.5 2.0</u>	<u>2.5</u>	<u>2.0</u>
<u>Wearing 4/Base 2</u>	<u>19</u>	<u>2.25</u>	<u>3.5</u>	<u>2.5</u>
<u>=</u>	<u>25</u>	<u>3.0</u>	<u>4.0</u>	<u>3.5</u>
<u>Base 1</u>	<u>=</u>	<u>3.25</u>	<u>5.0</u>	<u>4.0</u>

Note 1: Minimum Thickness with Polymer Modified Binders

Note 2: 1½ inch thickness on resurfacing projects where the Wearing Course is the only asphalt pavement material being placed exclusive of Patching & Leveling and Scratch Courses.

<b>Recommended Lift Thickness for Superpave Asphalt Pavement</b>			
<b>Mix Type (mm)</b>	<b>Minimum (inches)</b>	<b>Maximum (inches)</b>	<b>Preferred<sup>Note 1</sup> (inches)</b>
4.75	5/8	1.0	5/8
9.5	1.5	2.0	1.5
12.5	1.5	2.5	2.0
19	2.25	3.5	2.5
25	3.0	4.0	3.5

Note 1: Minimum Thickness with Polymer Modified Binders

**MARSHALL MIX TYPE RECOMMENDATIONS**

~~A. Marshall Bottom and Intermediate Courses (Base Courses): It is recommended that in multi lift pavements when Type 1 Base Course is used, an intermediate course (the top lift of base course) be a Type 2 to improve the smoothness of the finished pavement. This would eliminate the use of a Scratch Course prior to placing the surface course.~~

<b>Recommended Lift Thickness (inches) for Marshall Base Courses</b>			
<b>Mix Type</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Preferred</b>
2	2.0	3.0	2.0
1	3.25	5.0	4.0

~~B. Marshall Wearing Courses: The wearing course is a single lift constant thickness course to be placed over the entire pavement surface.~~

<b>Recommended Lift Thickness (inches) for Marshall Wearing Courses</b>			
<b>Mix Type</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Preferred</b>
3	0.5	0.75	5/8
1	1.0*	1.5*	1.0*
4	2.0	2.0	2.0

~~\* 1½ inch thickness on resurfacing projects where the Wearing Course is the only asphalt pavement material being placed exclusive of Patching & Leveling and Scratch Courses.~~

**PLAN REQUIREMENT**

Projects will show the 20-year projected design ESALs on both the general notes sheet and the typical section sheet(s) showing the pavement details. This includes new construction, reconstruction, AND resurfacing projects (including ALL bridge replacement projects regardless of the length of pavement placed). The design ESALs shall be shown for the mainline and all other affected roadways where more than 500 feet of pavement is being placed.

The aggregate used in asphalt mixtures can be either primarily stone and gravel, or slag. The aggregate used is up to the eContractor, and typically depends on what the eContractor has readily available that also meets mix requirements. Mixes with the two (2) aggregate types have different densities; as such, estimated weight quantities will be different for mixes with each aggregate type. Alternates for these two shall be listed in the plans, and the eContractor will bid appropriately.

The following is an example of how to list alternate asphalt pavement items in plans:

- BB1 401001-042 SUPERPAVE ASPHALT BASE CRSE, SG, TY 25, TN
- BB2 401001-043 SUPERPAVE ASPHALT BASE CRSE, S, TY 25, TN

## **PLAN REQUIREMENTS WHEN USING MARSHALL MIX DESIGN**

~~In addition to the requirements listed above, projects using Marshall asphalt pavement, including District-designed projects, will designate the use of “Medium Marshall Mix Design” or “Heavy Marshall Mix Design” as well as the design ESALs on both the general notes sheet and the typical section sheet(s) showing the pavement details. The designer should note that the terms “Medium” and “Heavy” refer to Equivalent Single Axle Loads (ESALs), and not to the quality of the asphalt pavement. After determining the ESALs, the mix design type shall be determined from the following criteria:~~

~~Medium Marshall Mix Design: This design is intended for use on local service roads or rural resurfacing projects with a 20-year projected design ESALs of less than 3,000,000.~~

~~Heavy Marshall Mix Design: This design is intended for use on new construction projects and on projects with a 20-year projected design ESALs of equal to or greater than 3,000,000.~~

## **QUANTITY ESTIMATING**

Asphalt Pavement: The quantity for asphalt pavement shall be estimated at 1.98 ton/cy for stone and gravel mixes, 1.89 ton/cy for slag mixes and 2.10 ton/cy for steel slag mixes.

Patching And Leveling: The quantity for Patching and Leveling Course shall be estimated by multiplying the nominal depth of the irregularity to be repaired plus 3/4 inch by the irregularity’s surface area. Then the conversion rates of 1.98 ton/cy for stone and gravel mixes, 1.89 ton/cy for slag mixes and 2.10 ton/cy for steel slag mixes will be utilized.

Scratch Course: The quantity for Scratch Course shall be estimated at a thickness of ~~one-half~~ 1/2 inch (0.028 ton/sy) for the entire area to be covered with Scratch Course. If the Specification allows, Scratch Course may alternatively be estimated by the square yard. Scratch Course shall not be used if there is Milling on the project, or if there are more than two lifts of asphalt being placed.

Asphalt Material (Tack Coat): The quantity for Asphalt Material (Tack Coat) shall be estimated using the undiluted rates as indicated in Table 408.11 in the Specifications. No application rate will be shown on the typical sections.

Smoothness: If a project meets the requirements of subsection 720.6 of the Specifications, smoothness testing shall be requested by the designer through the Request Form available at MCS&T’s Tool Box at <https://transportation.wv.gov/highways/mcst/Pages/tbox.aspx>. If the test results are available, the results shall be included in the PS&E submittal. If not available, then the request for testing shall be included in the PS&E submittal. If the results arrive before letting, then the results shall be included in an amendment. If too late for an amendment, then the results shall be provided to the District Construction Engineer.

## **SPECIAL SITUATIONS**

General: The Specifications have been written to account for the majority of the situations that would occur during construction. However, there are always special situations that require the designers’ attention.

Specification requirements shall only be altered after careful consideration and when, in

the opinion of the designer, there is no practical way for the work to be performed in accordance with the Specifications and a project specific special provision shall be developed as outlined in DD-105.

Compaction: The specification density requirement in the ~~of the~~ Specifications shall not be modified when asphalt pavement is placed at normal paving widths. It is possible that asphalt pavement will be placed in certain areas of the project where densities of this magnitude cannot be obtained. These areas usually have an irregular shape, which will not allow the proper use of compaction equipment. Listed below is a situation where the density specification may be modified by plan note and the plan note to be used.

Situation	Plan Note
Concrete pavement repair Note3	Compaction testing shall be in accordance with the Lot-by-Lot method and the rollerpass method shall not be used for acceptance testing for compaction. The <del>e</del> Engineer may reduce the target density requirement if the <del>e</del> Contractor has made every reasonable effort at obtaining the required density.

Note3: If the proper density is not obtained during placement, traffic will continue to compact the asphalt pavement in the pavement repair area, causing additional settlement. This will be very noticeable because the surrounding overlay will be placed on the existing concrete pavement, which is rigid and will not settle.

When overlaying Portland Cement Concrete Pavement (PCCP) the concrete is sometimes in need of repair. Whether this is an initial overlay or a subsequent overlay, the designer shall examine the extent of the needed PCCP repairs and evaluate whether to repair with Patch and Level, to perform proper concrete pavement repairs, or to remove the PCCP through rubblization or another process prior to the asphalt overlay. The use of Patch and Level is restricted to those projects with a few shallow repairs when the cost of mobilization for concrete repairs is high. PCCP removal should be considered only when the existing pavement is extremely distressed. In addition to compaction, consideration shall be given to smoothness, temporary traffic control, and long term impacts to the traveling public.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS

**DESIGN DIRECTIVE 646**  
**PAVEMENT DESIGN GUIDE**

Insert Approval Date  
Supersedes November 1, 2023

A pavement design will be completed for all projects requiring pavement (excepting certain Resurfacing, Restoration, and Rehabilitation projects), in accordance with the Division of Highways' Design Directive 641, *Pavement Type Selection Guide*.

This Design Directive (DD) provides a means to standardize the process to design and evaluate pavement designs throughout all development units of the West Virginia Division of Highways (WVDOH).

## 10. INTRODUCTION

Pavement design is a combination of engineering and economic analyses, which provides data to assist in choosing a cost-effective pavement structure and thickness. The engineering analysis consists of a pavement structural design procedure with consideration of "other factors" which may influence the thickness of the pavement section. The 1993 AASHTO *Guide for the Design of Pavement Structures and 1998 Supplemental* allows for these "other factors", both principal and secondary, which will be considered along with the engineering and economic data to select the pavement section for the project. The principal factors have a major influence on the thickness of the pavement section. The secondary factors will be used to evaluate the designed thickness.

This Guide outlines the process for pavement design for new or reconstructed pavement structures and rehabilitation projects. It provides guidance in the design approach for the cost comparison, the use of design parameters and discusses principal factors to be utilized in making a selection of a pavement type for design. This guide is provided in compliance with Title 23, Code of Federal Regulations Part 626. The following list provides other sources of information related to this DD:

- *West Virginia Division of Highways Pavement Design Manual*, 1997
- *AASHTO Mechanistic-Empirical Pavement Design Guide*, 2000 (and associated software)
- Westergaard Equations (for design of concrete slabs)
- Asphalt Pavement Alliance *PerRoad* software

The *designer* may also use engineering judgment based on past performance of other pavements in the project area, provided the pavements are of the same type, the geotechnical data, traffic characteristics, etc. are similar. Coordination with the Pavement Management System Section in the Operations Division is essential to gather information on past performances of differing types of pavement and rehabilitations in the different geological regions of the State.

~~If the criteria listed below are true then consider an *analysis period* of 50 years or more along with the design of a “perpetual pavement” or a “long life pavement”. Additionally, the *Mechanistic-Empirical Pavement Design Guide* (M-E PDG) software should be used to verify the results of the *DARWin* analysis when the following situations are true:~~

- ~~• ESAL values are greater than 30,000,000~~
- ~~• *DARWin* software indicates that an asphalt pavement is greater than 13 inches~~
- ~~• When Plain Jointed Portland Cement Concrete Pavement (PCC) is 10 inches or thicker.~~

~~**NOTE:** The *M-E PDG* is not yet approved by AASHTO; however, it may be used if the designer is both familiar with it and can obtain the required material property values.~~

~~The *PerRoad* software from the Asphalt Pavement Alliance gives the thickness of an asphalt pavement known as a “Perpetual Pavement”, which is a pavement with a structural performance period greater than 50 years. Ride ability overlays still must be considered with a perpetual pavement. These overlays are “mill and fill” overlays where the thickness milled out is replaced with an identical thickness of asphalt. PCC pavements with a structural performance period more than 50 years are known as “long life pavements” and thicknesses are given by the Westergaard Equations. While the thicknesses are given by these equations, PCC pavements designed by this method must have full depth, tied PCC shoulders for lateral support, as the equations assume that the edge of the PCC pavement has adequate lateral support so the slabs do not spread apart. These PCC pavements also require ride ability rehabilitation techniques to be performed throughout the 50-year lifespan of the pavement.~~

~~In general, a minimum 40-year *analysis period* shall be used unless the conditions for a “perpetual pavement” or “long life pavement” are met. In this case, an analysis period of at least 50 years will be considered. The conditions for the use of a 50-year analysis period are listed in paragraph four of “Section 10” of this DD.~~

## 20. PAVEMENT DESIGNS

Pavement designs shall be required for all pavement types with LCCA when more than one type of pavement is to be considered in the pavement type selection procedure. See DD-641, *Pavement Type Selection Guide*, for the criteria to be used for this determination.

An LCCA is not required on projects where pavement replacement or reconstruction is less than 1,000 feet on a single roadway segment or less than 500 feet of each bridge approach roadway. In these cases, the pavement design process can be based on engineering judgment; however, *pavement designs* shall be *required* on all other project types, with the exception of rehabilitation projects. The project manager shall give due consideration to selected *pavement segments*, considering in-kind replacement, adjacent pavement type and condition, past pavement performances as described in “Section 10” above, and future improvements when exercising judgment during the design process.

The asphalt overlay thickness for rehabilitation projects is to be based on historic practices utilized by the West Virginia Division of Highways, engineering judgment supported by a field review of the existing pavement and the past performance of asphalt overlays on similar projects, or if necessary a pavement design in accordance with this DD.

## 1. PRINCIPAL FACTORS

“Principal factors” are those which can have a major influence on the design. Some of these factors are included in the basic design procedures as they influence the structural requirements of the pavement design or sub-grade or the embankment treatments. In such cases, they are assigned an economic value for comparative purposes. The following discussion documents Division policies and practices for principal factors not considered in basic design procedures.

### a. Traffic

Shifts occur in the economic activity of manufacturing and service industries throughout the state. These activities should be considered as factors affecting the proposed alternative and required method for construction of the selection. In urban areas or on roadways with heavy traffic, the need to minimize disruptions may be a major consideration.

### b. Soils Characteristics

The design is to give full consideration to any unusual soils characteristics. Subsurface exploration is an essential part of the design process which includes investigation, sampling and testing, identification of materials types and the distribution of soils materials throughout the project. Based on past experience, the characteristics of the roadbed soils have been found to have a major influence on pavement performance.

### c. Recycling

It is the Division's policy to promote recycling of existing roadway materials. The current edition of the *West Virginia Division of Highways Standard Specifications, Roads and Bridges* allows recycled materials to be incorporated in the pavement section.

## 30. RESPONSIBILITIES AND SELECTION PROCEDURES

The project manager will perform the design analysis utilizing appropriate software for all pavement alternates, when applicable. The analysis period shall be the same for each type of pavement with pavement rehabilitation strategies developed to give an equivalent performance.

The project manager will document the “principal factors” as they relate or apply to the project. Weighing the factors and any related costs along with the costs of alternates from the LCCA, a pavement design and bidding method will be submitted to the [Deputy State Highway Engineer](#) ~~Chief Engineer~~ of Development for approval. Refer to DD-647, *Life-Cycle Cost Analysis for Pavement Design*, for more information concerning LCCA.

## 40. SAFETY

All projects, whether new construction, reconstruction or rehabilitation, will have skid resistant properties suitable for the needs of traffic. Refer to DD-644, *Asphalt Pavement*, for related criteria.

## 50. GENERAL TYPES

Consider the following types of pavement alternates:

### A. Rigid

The pavement will be jointed Portland Cement Concrete (PCC) as required by the design parameters, current design policy, or as selected by use of DD-641, *Pavement Type Selection Guide*. Joint spacing shall be in accordance with details set forth in the current edition of the *WVDOT/DOH Standard Details, Volume 1*.

### B. Flexible

Flexible pavement will be asphalt. *Applications* and asphalt *mix types* shall be in accordance with DD-644, *Asphalt Pavement*.

### C. Base Courses

Base course(s) will be specified as per DD-643, *Use of Aggregates and Filter Fabric*.

### D. Shoulders

Joint spacing on PCC shoulders shall match the spacing of the mainline pavement. For both PCC and asphalt pavements, the paved shoulder thickness shall match the mainline pavement section for:

- Urban arterials
- Projects with an ADT of 6,000 and truck traffic of 15% or greater
- Projects with an ADT greater than 15,000

## 60. PERFORMANCE PERIOD ~~—NEW PAVEMENTS~~

Performance periods are a determined time during which condition and performance are measured and evaluated. The recommended performance period for Flexible Pavement is twenty (20) years and twenty-two (22) years for Rigid Pavement. Recommended values from Table 1 of this DD are to be used unless project-specific information is available and approved by the Deputy State Highway Engineer of Development.

~~Performance periods for new pavements will be selected based on past design practices, experiences, and a review of pavement data.~~

~~The WVDOT's current historical data regarding the initial performance period of original asphalt pavements indicates an average of 18 years to the first rehabilitation. This may be extended by as much as 4 years if one of the following is true:~~

- ~~• The initially constructed asphalt pavement utilized a polymer binder in at least the top 4 inches of the asphalt mix.~~
- ~~• A rut-resistant base (such as a Superpave 19 mm, 25 mm, 37.5 mm mix, or a combination of these) was used to the elevation of the bottom of the surface course and the surface course utilized has a polymer binder.~~

~~The WVDOT's current historical data indicates an average initial performance period of 22 years for original PCC pavements.~~

## 70. ~~PERFORMANCE PERIOD—REHABILITATION~~

~~Rehabilitation projects are to be based on performance periods as described below. These performance periods vary by rehabilitation techniques (asphalt overlays vs. Concrete Pavement Restoration (CPR)) as well as original pavement types (asphalt vs. PCC).~~

~~Performance periods of subsequent asphalt overlays over asphalt pavements vary from 8 to 12 years (based on WVDOH historic data), which may be extended by up to 4 years when a polymer binder is used in at least the top 4 inches of the final pavement thickness.~~

~~Performance periods of subsequent rehabilitations over PCC pavements range between 10 and 14 years for Concrete Pavement Restoration techniques (based on national experience), and 6-10 years for asphalt overlays (based on WVDOH historic data), which may be extended by up to 4 years when a polymer binder is used for the entire thickness of the asphalt overlay mix. An additional four years should not be anticipated with minimal thickness polymer wearing course overlays.~~

~~The designer is cautioned to investigate all available historical data regarding past pavement performance, including overlays, when determining pavement rehabilitation schemes for the LCCA of newly constructed pavements. This is also true when considering rehabilitation schemes for existing pavements. The Pavement Management Systems Section of Operations Division is to be consulted for guidance in this matter.~~

## **780. TRAFFIC DATA**

Traffic factors for growth rates, equivalent single axle loads (ESAL), and directional distribution percentage are to be obtained from the Traffic Modeling and Analysis Unit of the Planning Traffic Engineering Division.

## **890. ROADBED SWELLING AND FROST HEAVE**

Recommended values from Table 1 of this DD are to be used unless project-specific information is available and approved by the Deputy State Highway Engineer Chief Engineer of Development.

## **9100. SERVICEABILITY**

Recommended values from Table 1 of this DD are to be used unless project-specific information is available and approved by the Deputy State Highway Engineer Chief Engineer of Development.

## **1010. MATERIALS PROPERTIES**

~~Effective roadbed soil resilient modulus data are to be obtained from Materials Control, Soil and Testing Division. Soil samples are normally obtained during the design phase; however, if a paving project is to be bid after the grading has been completed and enough time is available to perform in-place testing of the sub-grade, the Designer should request the Materials Control, Soils, and Testing Division to re-test the sub-grade prior to designing the final pavement section.~~

Recommended values from Table 1 of this DD are to be used unless project-specific information is available and approved by the Deputy State Highway Engineer Chief Engineer of Development.

The designer may choose to obtain the effect roadbed soil resilient modulus data themselves or utilize the information found in the 1993 AASHTO Pavement Design Guide.

## **1120. PAVEMENT STRUCTURAL CHARACTERISTICS**

Recommended values from Table 1 of this DD are to be used unless project-specific information is available and approved by the Deputy State Highway Engineer Chief Engineer of

Development.

## **1230. PAVEMENT THICKNESS**

The final pavement thickness will be based on the structural analysis. The minimum layer thickness will be consistent with standard construction methods and/or material requirements. For all pavement types, the total design thickness shall be rounded up to the nearest half-inch. Refer to DD-644, *Asphalt Pavement*, for information on pavement layer thickness criteria for asphalt pavements.

## **130. REHABILITATION PROJECTS**

The Division recognizes that there are a variety of rehabilitation methods and strategies available to restore pavements. As all factors that influence pavement performance and life expectancy have not been quantified, the latest information and recommendations from the Pavement Management System Section of Operations Division should be considered in the selection type and process outlined herein.

The asphalt overlay thickness for overlay types of rehabilitation projects is to be based on historic practices utilized by the West Virginia Division of Highways, engineering judgment supported by a field review of the existing pavement and the past performance of asphalt overlays on similar projects, or if necessary a pavement design in accordance with this DD.

**In situations where the use of an asphalt overlay as the rehabilitation method is questionable, the following process can be used to select the rehabilitation method best suited to the project:**

### **A. Project Evaluation**

The type of pavement rehabilitation to be considered begins with an evaluation of pavement distress, smoothness or ride-ability and consideration of general conditions within the proposed project area. For asphalt pavement, distress evaluations are based on the amount of rutting, longitudinal cracks, transverse cracks, alligator cracks, and smoothness. For concrete pavements, the distress will be measured on the basis of the amount of faulting, longitudinal cracking, transverse cracking, pumping, joint deterioration and smoothness. This information will normally be available from pavement management inventories collected by the Pavement Management Section of Operations Division. Project conditions will be gathered based on a field review by the project manager.

### **B. Project Analysis**

Upon completion of evaluations, alternative solutions will be considered for the project. The following alternates considered by the designer may vary with the type of pavement being overlaid, the amount of distress and smoothness values. The alternates will be analyzed as to their constructability, performance period, initial agency costs, and life cycle costs. The performance periods may be chosen by the designer from the ranges given below, considering project specific information. ~~input from other Division and District personnel, and the Pavement Management Section of Operations Division will consider the vertical clearances, traffic control, and construction conflicts.~~

**NOTE:** Full and partial depth patching are normally considered maintenance and occur prior to rehabilitation. Maintenance performed at a separate time and under a

separate contract is not included in rehabilitation; however, full and partial patching performed in conjunction with an overlay *is* included in the LCCA and the rehabilitation project.

## 1. Original PCC Pavements

### a. All Phases of Rehabilitation

#### i. Concrete Pavement Restoration Techniques

~~A performance period of up to 14 years may be considered when Concrete Pavement Rehabilitation (CPR) techniques are selected.~~ These techniques may be as follows:

- a) Joint and crack repair (full and partial depth) for spalling or faulting joints
- b) Diamond grinding for IRI improvement

More information for the designer concerning joint repair and diamond grinding can be obtained at the Federal Highway Administration's website at the following address: <http://www.fhwa.dot.gov/pavement/guid.cfm>. This page conveys links to technical guidance papers for all types of pavements, rehabilitation techniques and materials, among other pertinent information.

If reconstruction is determined to be the preferred design after a thorough field evaluation of the existing pavement and consultation with the Pavement Management System Section, then the required initial performance period shall be as described in "Section 70" of this DD for the type of pavement selected.

#### ii. ~~Superpave and Marshall Mix Designs~~

~~If reconstruction is determined to be the preferred design after a thorough field evaluation of the existing pavement and consultation with the Pavement Management System Section, then the required initial performance period shall be as described in "Section 70" of this DD for the type of pavement selected.~~

#### iii. Concrete Overlays

~~The service life of a concrete overlay is up to the designer and can range from 10-40 years and is designed to provide the selected extended performance.~~ The overlay can be either bonded or unbounded depending on the pavement condition and desired service life. More information for the designer can be obtained from the following web address: <http://www.fhwa.dot.gov/pavement/concrete>

#### iv. Asphalt Pavement on Rubblized PCC pavement

Asphalt pavement on rubblized PCC pavements should be designed as new, full-depth pavements. It is critical to properly assess the conditions under the concrete slabs and the uniformity of the rubblized layer to ensure the desired performance of the asphalt

pavement. Based on the subsurface exploration, specify the technique location, and dimensions of subgrade stabilization in the plans. If required, proper subgrade stabilization will guarantee a constructible pavement, improve performance, and reduce expensive change orders.

## 2. Original Asphalt Pavements

### a. All Phases of Rehabilitation

#### i. Superpave and Marshall Mix Designs

The asphalt overlay thickness for these types of rehabilitation projects is to be based on historic practices utilized by the West Virginia Division of Highways engineering judgment supported by a field review of the existing pavement and the past performance of asphalt overlays on similar projects, or if necessary a pavement design in accordance with this DD.

~~An 8 to 12 year performance period is appropriate and may be extended up to 4 years if the top 4 inches of the final pavement thickness (after the overlay is applied) has a polymer binder in the asphalt mix(s), or a large stone rut resistant base (such as a Superpave 19 mm, 25 mm, 37.5 mm mix, or a combination of these) was used to the elevation where the surface course was applied.~~

~~If reconstruction is determined to be the preferred design after a thorough field evaluation of the existing pavement and consultation with the Pavement Management System Section, then the required initial performance period shall be as described in “Section 70” of this DD for the type of pavement selected.~~

#### ii. Whitetopping (Overlaying with Concrete Pavement)

**No “ultrathin” whitetopping will be permitted. Only unbonded whitetopping overlays with a 5-inch minimum thickness will be permitted.**

Whitetopping overlays may be designed for a 10 to 20-year service life.

The following FHWA publication provides guidance and references for use of whitetopping on asphalt pavements:  
<http://www.fhwa.dot.gov/pavement/concrete>

### C. Project Design

The design strategy will be to bring the Present Serviceability Index up to near the initial value of 4.2. The design of overlays will be in accordance with methods previously outlined.

### D. Project Implementation

Rehabilitation projects will be initiated on an annual program in accordance with pavement management data and the budget.

Table 1 - Pavement Design Inputs			
Input	Range of Input	Recommended for West Virginia	
<b>Design Variables</b>			
Analysis Period (Years)		<u>50 (See Note 1)</u>	
Initial Performance Period (Years)	0.1 to Analysis Period	Flexible Pavement: <del>20+8</del> (if polymer binder used add 4 years) Rigid Pavement: 22	
<b>Traffic Variables</b>			
Growth Rate/Year	-9.99 to 99.99%	Data from the Traffic Modeling and Analysis Unit of the Planning Division	
Type of Growth Rate	Simple or Compound	Compound	
Initial Yearly 18-kip ESAL's (Both Directions)		Data from the Traffic Modeling and Analysis Unit of the Planning Division	
Directional Distribution Factor	1% - 100%	<del>50%-100%</del> (See Note 2)	
Lane Distribution Factor	1% - 100%	<u>Number of Lanes in Each Direction</u>	<u>Percent in Design Lane</u>
		<u>1</u>	<u>100</u>
		<u>2</u>	<u>80-100</u>
		<u>3</u>	<u>60-80</u>
		<u>4</u>	<u>50-75</u>
Overall Standard Deviation	0.001 - 0.999	Flexible Pavement: 0.45 Rigid Pavement: 0.35	
Reliability	50% - 99.99%	<3000 ADT <del>&amp; Low Truck Traffic:</del> 85% 3000 - 6000 ADT: 90% >6000 ADT: 95%	
<b>In-Situ Variables</b>			
Roadbed Swelling:			
	Vertical Rise	0.00 - 99.99"	0
	Probability	0 - 100%	0
	Rate Constant	0 - 0.30	0
Frost Heave:			
	Serviceability Loss	0 - 5	0.5
	Probability	0 - 100%	100% (See Note 13)
	Rate per Day	0 - 50 mm	2.5 mm (See Note 13)
<b>Performance Criteria - Present Serviceability Index</b>			
Initial	0 - 5.0	4.2	
Terminal	0.01 - 3.99	<del>&lt;3000 ADT: 2.3</del> >3000 ADT: 2.5 <del>&lt;3000 ADT: 2.3</del>	
<del>Note 1: A minimum 40-year analysis period shall be used unless the conditions for a 50-year analysis period are met. These conditions are described in paragraph 4 of "Section 10" of this DD.</del>			
<del>Note 2: The Traffic Analysis Section of the Program Planning and Administration Division has applied the Directional Distribution Factor when the traffic data is submitted.</del>			
Note 13: Use for frost-susceptible conditions. Other values are appropriate when conditions warrant.			

Table 1 (Continued)				
Input	Range of Input	Recommended for West Virginia		
<b>Material Properties</b>				
Effective Roadbed Soil Resilient Modulus	<u>2700 – 7300 psi</u>	<u>Data from Materials Control, Soils, and Testing Division 4500 psi</u>		
Effective Modulus of Subgrade Reaction		Calculated in DARWin software		
Pavement Layer Characteristics		HMA Elastic Modulus = 450,000 psi		
		PCC = 4,200,000 psi		
		Crushed Agg. Base Course = 36,000 psi		
		Free-Draining Base = 200,000 psi		
PCC Modulus of Rupture		660 psi		
Flexible Pavement Layer Coefficients	Wearing Courses:	<u>w/ PMA (PG 64E-22)</u>	<u>Superpave: 4.75, 9.5, 12.5mm</u>	<u>0.54 (Note 2)</u>
			<u>Marshall: Type 1, 3, 4</u>	
				All mixes without PMA: 0.44 <b>(Note 35)</b>
	Base Courses:	<u>Superpave: 19mm Marshall: Type 2</u>		<u>0.44 (Note 2)</u>
		<u>Superpave: 25mm Marshall: Type 1</u>		<u>0.4 (Note 2)</u>
			Crushed Agg. Base Course: 0.14	
			Free-Draining Base: 0.30 (See <b>Note 34</b> )	
		<u>Rubblized Concrete: 0.22</u>		
		Broken/Seated Concrete Pavement: Good Condition: 0.35 Poor Condition: 0.14		
<b>Pavement Structural Characteristics</b>				
HMA Pavement:				
	Drainage	0.40 - 1.40	1.00	
	Free-Draining Base	0.40 - 1.40	1.20	
Rigid Pavement:				
	Drainage	0.70 - 1.25	1.00	
	Free-Draining Base	0.70 - 1.25	1.20	
	Load Transfer with tied shoulders	2.30 - 2.90	2.60	
	Load Transfer without Tied Shoulder	2.9 - 3.2	3.20	
	Loss of Support	0.00 - 3.00	0.00	
<b>Base Course Thickness</b>				
Crushed Agg. Base Course		<u>4 - 12 in</u>	6.0"	
Free-Draining Base Course		<u>4 - 8 in</u>	4.0"	

**Note 24:** ~~The designer may choose to evaluate the pavement condition and utilize layer coefficients found in the 1993 AASHTO Pavement Design Guide.~~

~~2% Asphalt content or Type I cement with a minimum of 150 pounds per cubic yard.~~

**Note 35:** ~~2% Asphalt content or Type I cement with a minimum of 150 pounds per cubic yard. The designer may choose to evaluate the pavement condition and utilize layer coefficients found in the 1993 AASHTO Pavement Design Guide.~~

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS**DESIGN DIRECTIVE 647**  
**LIFE-CYCLE COSTS ANALYSIS FOR PAVEMENT DESIGN**

Insert Approval Date  
Supersedes September 6, 2023

This Design Directive (DD) gives guidance for the Division of Highways' (DOH) policy on Life-Cycle Cost Analysis (LCCA) for pavements.

This DD provides a means to standardize the process required to analyze and report the pavement design Life-Cycle Costs throughout all development units of the DOH. The general procedure for performing the LCCA is detailed herein. References for more in-depth LCCA analyses are also given.

**10. General**

The purpose of an LCCA for a particular pavement design within a defined *pavement segment* is to evaluate the overall long-term economic efficiencies of competing design alternates. Initial (construction) and discounted future (future rehabilitations, user, etc.) costs over the projected life of the pavement are added together to obtain a Net Present Value (NPV) for each *pavement type* selected. This process improves decisions concerning the utilization of limited funding for pavement in a construction project within a *pavement segment*.

The WVDOH LCCA Report documents the methodology and resulting C-Factor. The report is prepared by the Pavement Analysis and Evaluation Section within the Materials Control, Soils, and Testing (MCS&T) Division and submitted annually to the Standards and Manuals Committee for review and approval. The current version is published on the WVDOH Publications webpage (Design Directive page) at MCS&T.

**20. Life-Cycle Cost Analysis (LCCA)**

~~The WVDOH generally follows the LCCA methodology recommended in the FHWA Pavement Division's interim technical bulletin *Life-Cycle Cost Analysis in Pavement Design— in Search of Better Investment Decisions*, 1998. The publication number for this document is FHWA-SA-98-079 and is available electronically at <https://www.fhwa.dot.gov/pavement/lcca/lccafact/isdde.dot.gov/OLPFiles/FHWA/013017.pdf>. It contains standard procedures for estimating and comparing the long-term costs of asphalt and Plain Jointed Portland Cement Concrete (PCC) pavements over an analysis period under specified traffic and environmental conditions. methodologies consistent with FHWA and AASHTO guidance for pavement design investment analysis. These methodologies provide standard procedures for estimating and comparing the long-term costs of asphalt and Plain Jointed Portland Cement Concrete (PCC) pavements over a defined analysis period under specified traffic and environmental conditions. Supporting concepts are included in FHWA's *Life-Cycle Cost Analysis in Pavement Design* (FHWA-SA-98-079), where applicable. The WVDOH uses an analysis period of at least 40 ~~fifty~~ (50) years for both the asphalt and PCC pavements. See DD-641, *Pavement Type Selection Guide*, for more information regarding pavement type selection parameters, and DD-646, *Pavement Design Guide*, for information concerning the design of the~~

pavement structure itself.

The WVDOH generally follows the FHWA's recommendations for LCCA input data unless local data is available. Local input data includes, but is not limited to, traffic characterization, duration of construction, and construction costs. It is important to note that only differential costs are considered between alternates in the LCCA.

The Life Cycle Cost Analysis, if required per DD-641, will be performed on each *pavement segment* upon receipt of necessary soils data, existing pavement cores, and traffic data.

The base bid quantities for grading will be for the thicker pavement section. The *designer* may allow a lower profile grade but hold the cross-section to avoid additional earthwork. The profile grade can be lowered by using a straight horizontal taper rate of 0.25%. This will occur at, but not be limited to, the ends of structures and at tie-ins to existing pavements. If the *designer* does not allow a lower profile grade, bid items for adjusting the grade must be added to the contract and included in the LCCA for that particular alternate; however, the contractor will not be permitted to raise the profile grade above that shown for the thickest pavement alternate. Costs common to each pavement alternate such as mobilization, signing/pavement marking, grading, drainage, rights-of-way, utility relocation, etc. are not included.

User delay costs are another important element in LCCA. Estimation of user delay costs follows ~~the procedures in Life Cycle Cost Analysis in Pavement Design—In Search of Better Investment Decisions, 1998~~ FHWA LCCA guidance and accepted industry practices for pavement investment analysis. The user delay costs considered are the differential costs between competing alternates such as work zone costs including duration, setting traffic control, resetting traffic control for construction phasing, etc. User delay costs can differ by pavement type. The designer must carefully examine all facets of the planned work to accurately estimate user delay costs. Routine maintenance is not included in this analysis.

User costs are further divided into the *working day* and *non-working day* daily user costs. In most cases, the travel capacity of a construction zone on a *working day* is less than the capacity on a *non-working day*. For the purposes of this Directive, a *non-working day* is any day throughout the course of construction that traffic is not impeded in any way by lane/shoulder closures. User costs associated with *non-working days* are excluded from the analysis.

If the LCCA is performed on an entire pavement segment and the segment is not being fully constructed in one contract, then the result of the analysis will be pro-rated using the contract length divided by the entire *pavement segment* length. See DD-648, *Alternate Design Alternate Bidding of Pavements*, for more information on this matter.

### **30 Alternate Design Alternate Bid (ADAB)**

The ADAB bid process is described in greater detail in DD-648.

### **40 Steps in LCCA**

A standard procedure has been developed to perform the LCCA analysis. The *project manager* is responsible for the LCCA, using software ~~that is specifically designed for use with Life Cycle Cost Analysis in Pavement Design—In Search of Better Investment Decisions, 1998~~ and methodologies developed for pavement life-cycle cost analysis consistent with FHWA guidance and accepted. The following steps are to be followed:

#### 40.1 Project Selection

Criteria to be used for evaluating projects for inclusion in the LCCA process are described in DD-641.

#### 40.2 Alternative Pavement Design Strategies

See DD-646 for selection of alternate design strategies and for information on the pavement design and rehabilitation process itself. The analysis period shall be at least 50 years.

The designer will develop reasonable design strategies for each alternative based on past pavement performance; that is, an initial pavement structure followed by a series of rehabilitations to cover the analysis period. The analysis period will be the same for each alternative considered.

#### 40.3 Performance Period

Performance periods for new pavements will be selected based on past design practices, and a review of pavement data. WVDOT's current historical data regarding the initial performance period of original asphalt pavements indicates an average of twenty (20) years to the first rehabilitation. WVDOT's current historical data indicates an average initial performance period of twenty-two (22) years for original PCC pavements.

Rehabilitation projects are to be based on performance periods as described below and vary by rehabilitation techniques and original pavement types:

- Asphalt overlays over asphalt pavements have performance periods ranging from eight (8) to twelve (12) years based on historical data.
- Concrete pavement restoration (CPR) techniques on concrete pavements have performance periods ranging from ten (10) to fourteen (14) years based on national experience.
- Asphalt overlays on concrete pavements have performance periods ranging from six (6) to ten (10) years based on historic data.

Rehabilitation projects are to be based on performance periods as described below. These performance periods vary by rehabilitation techniques (asphalt overlays vs. concrete pavement restoration (CPR)). Performance periods of subsequent asphalt overlays over asphalt pavement vary from 8 to 12 years based on historical data. Performance periods of subsequent rehabilitations over PCC pavements range between 10 and 14 years for concrete pavement restoration techniques (based on national experience), and 6-10 years for asphalt overlays (based on WVDOT historic data).

The designer is cautioned to investigate all available historical data regarding past pavement performance, including overlays, when determining pavement rehabilitation schemes for the LCCA of newly constructed pavements. This is also true when considering rehabilitations schemes for existing pavements. The Pavement Management Systems Sections of Operations Division is to be consulted for guidance in this matter.

#### ~~40.3~~40.4 Estimate Agency Cost

Initial agency costs of the pavement section are the construction costs incurred by the WVDOT. These are official estimates prepared by the Division's *designer* or *project manager*. See the latest issue of DD-707, Development of Engineer's Estimate, for more information regarding the development of the official cost estimate.

Future agency costs are the costs incurred by the WVDOT to overlay, rehabilitate, or reconstruct the roadway in the ~~40-~~fifty (50) year (or longer) analysis period specified. All of these future costs must be considered in the LCCA for each pavement type considered for use.

#### **40.440.5 Estimate User Costs**

User costs are estimated ~~according to the recommendations made in *Life-Cycle Cost Analysis in Pavement Design—In Search of Better Investment Decisions*, 1998 using methodologies consistent with FHWA LCCA guidance and accepted industry practices~~. As stated above, only work zone user costs are estimated in the LCCA process. Estimation of user costs requires three steps: calculate the appropriate daily user costs, determine the duration of the construction activities and apply the daily user costs to the expected duration of the construction.

Data used for computation of LCCA user delay costs will be obtained from the Traffic Engineering Division and the Planning Division. The *designer* will be responsible for compiling all the required information from these sources and running the aforementioned program.

#### **40.540.6 Compute Net Present Value (NPV)**

In the broadest sense, LCCA is a form of economic analysis used to evaluate the long-term economic efficiency between investment options; therefore, the NPV of cash flow is calculated.

Economic analysis focuses on the relationships between costs, timings of costs, and discount rates employed. Once all costs and their timings have been developed, future costs must be discounted to the year of initial construction (the “base year”) and added to the initial cost (the construction estimate cost) to determine the NPV for each LCCA alternate. ~~Again, more information on the calculation and use of NPV is available in *Life-Cycle Cost Analysis in Pavement Design*, 1998. The designer is encouraged to consult this publication. Software designed from this publication. The designer is encouraged to consult applicable FHWA LCCA guidance and accepted industry practices regarding the calculation and use of NPV. Approved software or tools developed for pavement life-cycle cost analysis will be used to determine the NPV of all cash flows.~~

Once completed, all LCCA’s should be subjected to a sensitivity analysis. Sensitivity analysis is a technique used to determine the influence of major LCCA inputs, assumptions, projections, and estimates on the various LCCA results. In a sensitivity analysis, major input values are varied over a reasonable range of values, while ~~all of the~~ other variables remain constant. The input variables may then be ranked according to their effect on the results. This allows the designer to ~~subjectively get a feel for~~ evaluate the impacts of the variability of individual inputs on overall LCCA results.

Sensitivity analyses, at a minimum, evaluate the influence of the discount rate on LCCA results. The discount rate accounts for the time value of money. It takes into account fluctuations in the inflation and interest rates to show the actual rate of increase in the value of money over time. Using the discount rate allows the designer to use today’s dollars in the LCCA. The higher the discount rate, the lower the present value of future cash flows. The discount rate to be utilized in all LCCA’s will be the average of the five (5) most recent latest effective thirty (30)-year value of *real treasury interest rates or treasury notes and bonds of specified maturities* as given in the United States’ Office of Management and Budget’s *Circular A-94*, Appendix C. Averaging five (5) interest rates reduces the impacts

of short-term volatility and creates a more stable, reliable valuation. A table summarizing the past history of and giving the latest years' rate can be found on the current United States Office of Management and Budget website.is available at <http://www.whitehouse.gov/omb/circulars/a094/disehist.pdf>.

If the *designer* finds that any LCCA is sensitive to a particular input, then the *designer* is to perform LCCA's utilizing a reasonable range of that input, and submit these results to the Deputy State Highway Engineer ~~Chief Engineer~~ of Development in the package required by DD-641.

## 50. Comments

As projects utilizing LCCA are *let to construction*, their associated unit bid prices will be monitored to determine any trends in costs. Also, salvage values will not be considered in the LCCA's.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS

DESIGN DIRECTIVE 648  
ALTERNATE DESIGN AND ALTERNATE BIDDING OF PAVEMENTS

Insert Approval Date  
Supersedes September 6, 2023

This Design Directive (DD) gives guidance on the West Virginia Division of Highways' (WVDOH) policy on *alternate design and alternate bidding* (ADAB) of pavements.

Use of this DD provides a means to standardize the process required to utilize ADAB for pavements throughout all development units of the DOH; however, this DD does not detail the procedure for designing pavements and performing life-cycle cost analyses (LCCA), but references to publications written in detail concerning these subjects are given for the *designer's* use.

#### 10. General

The objective of the ADAB process is to promote more cost-effective usage of highway construction funds. This is achieved by allowing contractors to select the *pavement type* constructed through the bidding process; consequently, increasing competition as well as making that competition more equitable. The Federal Highway Administration's (FHWA) Technical Advisory: "Use of Alternate Bidding for Pavement Type Selection, T 5040.39 December 20, 2012 can be accessed at: <https://www.fhwa.dot.gov/pavement/t504039.cfm>. Memorandum: Clarification of FHWA Policy for Bidding Alternate Pavement Type on the National Highway System, November 13, 2008, can be accessed at: <http://www.fhwa.dot.gov/pavement/081113.cfm>.

The ADAB process requires the WVDOH to consider future roadway rehabilitation, traffic control associated with that rehabilitation, and user delay costs. The process utilizes traditional *life-cycle cost analysis* (LCCA) concepts to model the cost of pavement section alternatives over a selected performance period. The selection process is then accomplished through an ADAB procedure, which essentially allows the bidder with the lowest *life-cycle costs* (LCC) to determine which pavement type will be constructed. See DD-647, *Life-Cycle Cost Analysis of Pavements*, for more information concerning LCCA.

The C-factor utilized in the ADAB process is established in accordance with DD-647 and the current approved WVDOH LCCA Report.

To accomplish the ADAB process, the "A + B + C" bidding method is utilized for all bids submitted. Factor "A" is the contractor's bid, factor "B" is the time *in days* to construct the initial pavement, and factor "C" is the *net present value* (NPV) of all future rehabilitation costs, plus the NPV of *present* and *future* user costs for the pavement's analysis period. The lowest bidder is identified by adding "A + C".

The time factor "B" is not normally added to the contractor's bid. This factor may be used on projects that consist of total pavement reconstruction in order to capture the user costs associated with the initial construction. This *time factor* is usually zero (0) because most projects are on new alignments, and traffic is not impeded during the initial construction of a project.

If a particular project is not approved by the Deputy State Highway Engineer Chief Engineer of Development or ~~the FHWA's Special Experimental Projects No. 14 — Alternative~~

~~Contracting (SEP-14) for the ADAB process~~, then the *designer* is to consider the following to recommend a *pavement type only* for approval:

- The LCCA
- *Secondary factors* as described in DD-641, *Pavement Type Selection Guide*, Section 40
- Sound engineering judgment

~~If the ADAB process is approved on any particular project, the designer may be required to submit a request to the FHWA headquarters, through the local office, to approve the use of ADAB on a project by project basis under the FHWA's SEP-14.~~

~~The following FHWA website contains additional information concerning SEP-14 submittals: [www.fhwa.dot.gov/programadmin/contracts/sep\\_a.cfm](http://www.fhwa.dot.gov/programadmin/contracts/sep_a.cfm)~~

## 20. Criteria for Selection of Projects for the ADAB Procedure

Section 30 of DD-641 describes the criteria to be followed for selection of projects that will use the ADAB procedure for bidding of alternate pavement types.

## 30. Alternate Design and Alternate Bid (ADAB)

The ADAB bid model is accomplished by adding a factor “C” to each contractor’s base bid factor “A”. Factor “C” represents future rehabilitation and user delay costs for a particular pavement alternate. The implementation of ADAB, in general, may result in comparing multiple competing pavement structures with differing total thicknesses between the top of the sub-grade and the final pavement surface. A threshold of 20 percent in the difference of the NPV of the LCCA is a reasonable zone within which pavement types can compete.

**In a contract in which the pavement is bid by the ADAB procedure, both the *asphalt* and the *Jointed plain concrete* pavements shall be bid as a *pavement system* in square yards (sy). The *pavement system* is the entire pavement section, including fine grading, sub-grade, base and pavements. This approach allows an equal bidding process.**

**The life-cycle cost adjustment factor “C” is derived from the WVDOH LCCA report in accordance with DD-647.**

**Note: The contract documents will include price adjustment factors for fuel, asphalt, and cement.**

## 40. Steps in ADAB

A standard procedure has been developed to perform the ADAB analysis. This procedure has the following steps.

### 40.1 Project Selection

Criteria to be used for evaluating projects for inclusion in the ADAB process are described in DD-641, as mentioned in “Section 20” above.

### 40.2 Alternative Pavement Design Strategies

Refer to DD-641 for selection of alternate design strategies for the chosen analysis period, and DD-646, *Pavement Design Guide* for information regarding the pavement design process.

### 40.3 Estimate Agency Costs

Initial agency costs are the construction costs incurred by the WVDOH. These are official estimates prepared by the Division's *designer* or *project manager*. See the latest issue of DD-707, *Development of Engineer's Estimate*, for more information regarding the development of the official cost estimate.

Future agency costs are the costs incurred by the WVDOH to overlay, rehabilitate, or reconstruct the roadway in the ~~40-fifty~~ (50) year (or longer) *analysis period* specified. All of these future costs must be considered in the LCCA for each pavement type considered for use.

### 40.4 Estimate User Delay Costs

See DD-647 for more information concerning computation of user delay costs.

### 40.5 Compute Net Present Value (NPV)

Refer to DD-647 for more information concerning computation of the NPV for each pavement alternate considered.

### 40.6 Analyze Results And Calculate Life-Cycle Cost Adjustment Factor "C"

After the total NPV for each alternate is computed, the results are then compared. If the difference in the total NPV between the lowest two alternates is greater than twenty (20) percent, the alternate with the lower total NPV only is selected for bidding. The *designer* shall eliminate any pavement alternate that is considered, in the *designer's* judgment, to be impracticable for the project. Otherwise, alternate pavement designs will be included in the bidding documents and a *life-cycle cost* adjustment factor "C" will be included in the *schedule of prices* for each alternate.

The *life-cycle cost adjustment* factor, "C", is calculated as  $C = \text{total NPV of the LCCA} - \text{construction cost}$ . The C-factor is established in accordance with DD-647 and the current approved WVDOH LCCA report. As part of the ADAB process, this "C" factor will be added to the contractors' bid. The lowest bidder identified by adding the "C" factor to the contractors' base bid "A" factor; thus, the lowest total is then selected.

If the LCCA is performed on an entire *pavement segment* and the *segment* is not being fully constructed in one contract, then the "C" factor will be pro-rated using the project length divided by the entire *pavement segment* length.

If the "C" factors are essentially equal (1% or less of the lowest cost initial *pavement section*) for all of the paving alternates considered, then "C" factors do not need to be added to the contractor's bids in order to determine the low bid.

Refer to "Section 30" of this DD for information on the handling of multiple pavement types in both the LCCA and bidding processes.

## 50. Comments

As Projects utilizing LCCA are *let* to construction, their associated unit bid prices are monitored to determine any trends in costs. Also, salvage values are not to be considered in the LCCA's.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS

**DESIGN DIRECTIVE 105**  
**PUBLICATION DEVELOPMENT AND APPROVAL PROCESS**

Insert Date

Supersedes November 6, 2024

## 1. PURPOSE

This Design Directive establishes procedures for preparing, reviewing, approving, and publishing West Virginia Division of Highways (WVDOH) Specifications, Special Provisions (SPs), Standards, Manuals, and Material Procedures (MPs). These publications define the technical requirements, procedures, and policies used by the Division for planning, design, construction, maintenance, and materials management.

The directive applies to the following publication types:

- Specifications & Special Provisions
- Standards & Manuals (e.g., Design Directives, Standard Details, Structure Directives, etc.)
- Manuals (e.g., Construction Manual, Drainage Manual, Consultant Services Manual, etc)
- Material Procedures

## 2. ADMINISTRATIVE AUTHORITY

All WVDOH publications shall be administered by the Materials Control, Soils & Testing Division (MCS&T). MCS&T is responsible for:

- Coordinating review of proposed publications and revisions
- Administering the applicable review committees
- Coordinating approval through the Division and review with the Federal Highway Administration (FHWA), when applicable
- Publishing approved documents on the Division's webpage

## 3. CHAMPION RESPONSIBILITIES

A Champion is responsible for developing and presenting proposed publication(s) or revision(s), including:

- Preparing the draft and electronically submitting it to the Committee Chairperson, along with information on the provision and a brief description of the proposed revision for inclusion in the agenda packet.
- Coordinating with subject matter experts, internal staff, industry, and public comments and updating the draft as necessary. The Champion may need to work outside of committee meetings to address comments and progress the item through the review process.
- Presenting it to the committee for review and approval. The Champion may designate a knowledgeable proxy to attend meetings if unavailable.

Failure to participate or provide required updates in a timely manner may result in removal of the item from the committee agenda.

#### 4. COMMITTEE STRUCTURE

Each publication type is reviewed by its designated committee.

- Specification Committee
- ~~Standards and Manuals~~ Committee
- Manuals Committee
- Materials Procedure Committee

Voting Members: One representative from:

- Contract Administration Division
- Engineering Division
- Materials Control, Soils and Testing Division
- Operations Division
- Traffic Engineering Division

Quorum: Minimum of three (3) voting members present.

Approval: Majority vote of present voting members; Chairperson may break tie votes.

Non-Voting Members: May include FHWA, industry representatives, contractors, and technical experts.

Open Government Compliance: All committees shall operate in accordance with the West Virginia Open Government Meeting Act. Meetings shall be properly noticed, agendas published in advance, votes recorded, minutes maintained, and open to the public.

#### 5. COMMITTEE REVIEW PROCESS

**5.1 Two-Meeting Minimum:** Proposed items shall normally be presented at a minimum of two (2) committee meetings before being voted upon. Depending upon their complexity, controversy, or the level of comments, items may be held for additional review and updates as needed to address comments, revisions, or other required steps to ensure proper committee review.

**5.2 Minor or Editorial Changes:** Changes determined to be minor or editorial may be approved after one (1) meeting. Minor changes do not alter technical intent and include:

- Editorial corrections (spelling, grammar, formatting)
- Updated references, links, or organizational titles
- Clarifications that do not change technical intent

Any voting member or FHWA representative may request that a minor change be treated as substantive, requiring two (2) meetings.

**5.3 Chairperson Authority:** The Committee Chairperson manages meetings, determines readiness for vote, and may designate changes as minor or substantive. The Chairperson ensures the review process remains efficient while maintaining compliance with policy.

**5.4 Comment Deadlines:** Committee members shall review proposed items prior to the scheduled meeting. Comments must be submitted to the Chairperson in advance to allow the Champion time to address them. Late comments may be addressed during the meeting at the Chairperson's discretion, and, if appropriate, may be subject to a vote.

## 6. FHWA COORDINATION

FHWA is invited to participate in committee meetings and is provided meeting notices and agenda packets for review. FHWA may attend meetings and provide comments as part of the review process.

Following committee action, the publication is forwarded through the Division and submitted to FHWA for approval, as applicable.

## 7. EMERGENCY OR EXCEPTIONAL APPROVAL PROCESS

When urgent circumstances or project needs do not allow sufficient time for the committee review process, as defined in subsection 5 of this DD, a proposed item may be submitted through the Division chain of command to the State Highway Engineer for approval.

This process should be used only in exceptional circumstances when delaying the change would negatively impact project delivery, safety, or operations.

The submission shall include:

- Description of the proposed change
- Reason the standard committee process cannot be followed
- Project(s) affected
- Draft language of the proposed provision or revision
- Supporting background or justification

Items approved through this process should be presented by the Champion at the next meeting for information and record and may be incorporated into the next formal revision.

Emergency or exceptional approval process items are to be used only for the singular project for which it was approved. If the emergency or exceptional approved item is desired to be used among other projects, it must pass through the normal committee processes.

## 8. PUBLICATION AND DISTRIBUTION

Approved publications will be posted to the appropriate WVDOH webpages and distributed to district offices and impacted stakeholders. Materials Control, Soils & Testing Division shall maintain current electronic access to all publications.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS  
~~DESIGN DIRECTIVE~~

**DESIGN DIRECTIVE 622**  
**INTERSECTIONS ON RURAL DIVIDED HIGHWAYS**  
*INSERT NEW DATE*  
*Supersedes October 3, 2012*

~~Attached is the West Virginia Department of Transportation, Division of Highways' Intersections on Rural Divided Highways guide. It shall be used on all applicable projects.~~

~~Attachment~~

**INTERSECTIONS ON RURAL DIVIDED HIGHWAYS**

Turn lanes are to be provided for intersections on rural divided highways in accordance with the attached drawing and the requirements as listed below. All references to pages, tables and exhibits herein are contained in the ~~2011~~ 2018 AASHTO publication "A Policy on Geometric Design of Highways and Streets".

**LEFT TURNS**

Left-turn lanes are to be provided on all rural divided highways. Where the design hourly volume (DHV) for the turn from the through roadway is equal to or greater than thirty (30), a taper, a deceleration lane, and a storage bay (minimum 100 feet long) shall be provided.

**RIGHT TURNS**

Where the DHV is less than thirty (30), an appropriate turning radius will be provided.

Where the DHV from the through roadway is equal to or greater than thirty (30) and less than 100 a right-turn taper shall be provided. An appropriate turning radius will be provided at the end of the taper.

When the DHV turning right is 100 or greater and/or the DHV on through lanes in one direction is 500 or greater, a deceleration lane and taper will be provided.

In certain situations where right-turn traffic movement delays cause problems with through traffic, a storage length (min. 100 feet) must be considered.

**MEDIAN CROSSOVERS**

A four (4) lane rural facility should have adequate median width to provide for protected left turns.

Where a median crossover is provided along a superelevated multi-lane highway with a median less than eighteen (18) feet wide and without provisions for a storage lane, the profile grade shall be carried in the center of the median.

Where a median crossover is provided along a superelevated multi-lane highway with a median of eighteen (18) feet or more and/or where a storage lane is provided, separate profile grades shall be carried for each set of lanes. A differential in grade lines (bifurcation) shall be used where

required to provide a smooth median crossover grade, with the desirable grade being ~~2~~ two percent (2%) toward the low side. Excessive bifurcation is not desirable due to the possibilities of future widening of the roadway and possible future intersections being constructed on the roadway.

See Figure ~~9-59~~ 9-43 “Above Minimum Design of Median Openings (Typical Bullet-Nose Ends)”, page ~~9-155~~ 9-123 of the ~~2011~~ 2018 AASHTO publication "A Policy on Geometric Design of Highways and Streets".

WVDOH uses a control radius of seventy-five (75) feet for the design of median openings.

## INTERSECTION DETAILS

Special details are required for all intersections. The pavement and shoulders shall be contoured to assure that superelevation, drainage, aesthetics, safety features and other aspects of the design have been properly considered. Pavement elevations will be indicated at ten (10)-feet foot intervals around the returns and on the centerline of the side roads.

# DRAFT

## INTERSECTIONS ON DIVIDED HIGHWAYS

**Note 1:**  
R Is To Be Determined From

Table 9-15 Pages 9-57 to 9-59, And Table 9-16 Pages 9-60 to 9-63, Use As Applicable, Chapter 9, Subsection 6,

Of The 2018 AASHTO "A Policy on Geometric Design Of Highways and Streets." Use As Applicable.

**Note 2:**

Minimum Taper Length 300' Min. For Curved Roadways With Design Speeds  $\geq 50$  MPH.

See Figures 9-49 9-34a and 9-34b For L And R Values.

**Note 3:**

Auxiliary Lanes Should Have Same Width As Through Lanes.

**Note 4:**

When a Non Curbed Typical Is Used A Straight Taper May Be Utilized.

**Note 5:**

R Is To Be Determined From Figure 9-59, 9-43, WVDOT Uses Min. Radius Of 75 Feet.

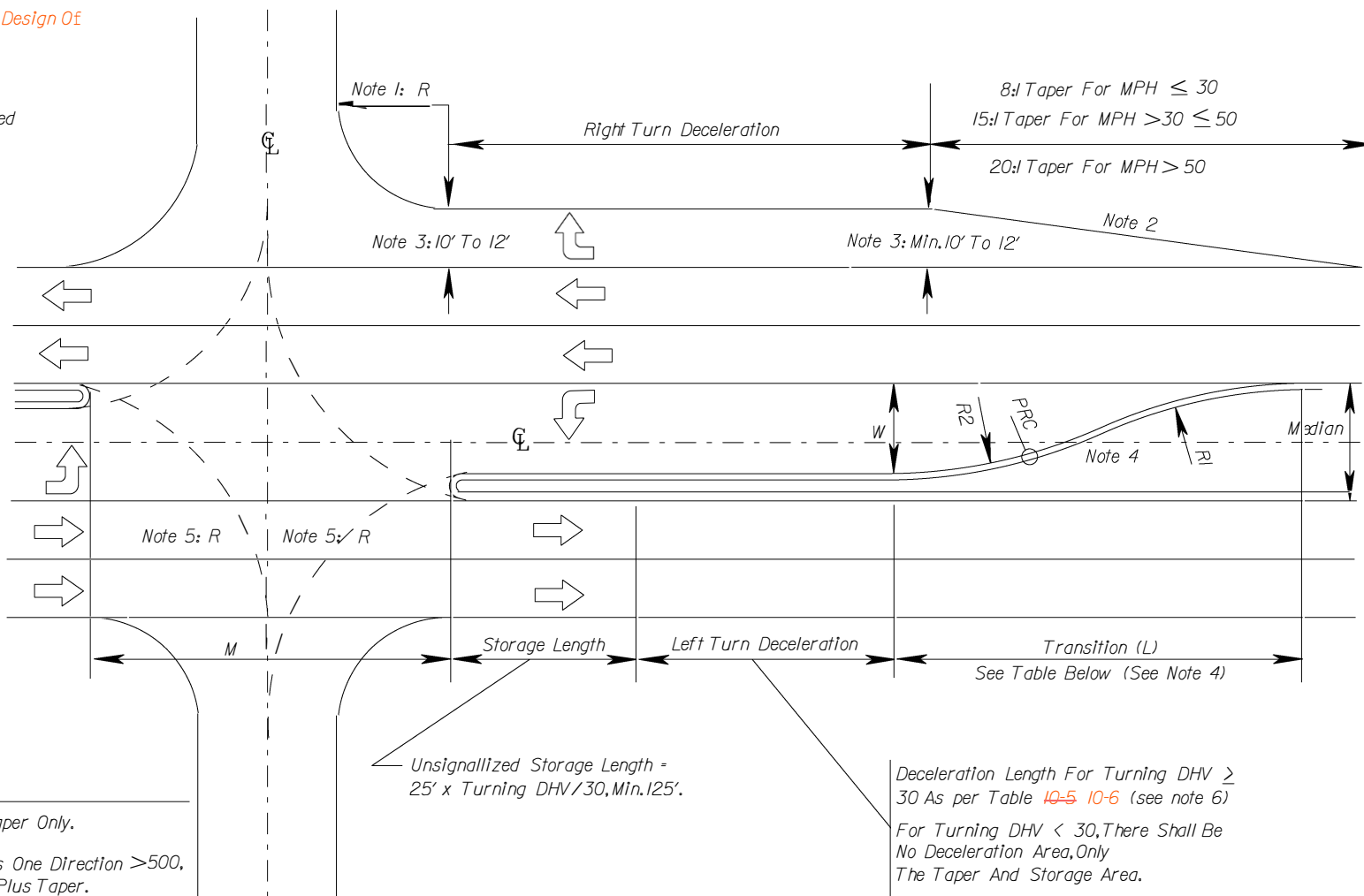
**Note 6:**

For Turning DHV  $> 30$  to 100, One Half (1/2) Of The Transition Length May Be Considered Part Of The Deceleration Length.

### RIGHT-TURN LANE

For Turning DHV  $\geq 30$ , But  $< 100$ , Use Taper Only.

For Turning DHV  $\geq 100$  And/Or Thru Lanes One Direction  $> 500$ , Deceleration Length (As Per Table 10-5-10-6) Plus Taper.



Unsignalized Storage Length =  $25' \times \text{Turning DHV} / 30$ , Min. 125'.

Deceleration Length For Turning DHV  $\geq 30$  As per Table 10-5 10-6 (see note 6)  
For Turning DHV  $< 30$ , There Shall Be No Deceleration Area, Only The Taper And Storage Area.

Turn Lane Width (W)	Transition (L)								
	30 MPH or Less			> 30 MPH to 50 MPH			> 50 MPH		
	8:1 Taper			15:1 Taper			20:1 Taper		
	L	RI	R2	L	RI	R2	L	RI	R2
12	96	262	131	180	906	453	240	1,606	803
11	88	240	120	165	828	414	220	1,470	735
10	80	218	109	150	752	376	200	1,338	669

Note - Median opening (M)

Is Dependent On R.

See Table 9-27 Min. Design Of Median Openings. (75' Control Radius)

DD-622

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS  
**DESIGN DIRECTIVE**

**DESIGN DIRECTIVE 625**  
**INTERCHANGE WARRANTS**  
*INSERT NEW DATE*  
*Supersedes June 18, 2014*

This purpose of this Design Directive is to provide guidance for determining whether to construct at-grade intersections or interchanges on roadways classified as expressways for the West Virginia Division of Highways. Information is given to aid the designer in choosing between an at-grade intersection or an interchange based on design-year traffic combined with sound engineering judgment. A procedure and a table for the warrant determination are given.

*Attachment*

**10. Introduction and Background**

Traffic signals are not safety devices; rather they function by alternately assigning the right of way to conflicting traffic streams. Signals are thus the most restrictive form of traffic control device.

When one of these traffic streams is traveling at a high speed (55 mph or greater) there may be safety issues involved with interrupting it. The presence of the signal can cause intersection capacity problems by itself. The steps that must be taken to assure good traffic operations can further degrade the intersection's capacity.

~~————The goal of the West Virginia Division of Highways (WVDOH) is to place as few signals as possible on expressway type facilities. Agreement was reached with the Federal Highway Administration in 1982 to use what are called the “Bleyl Numbers” for the design year traffic at an intersection. The “Bleyl Numbers” were defined by Robert Bleyl, who was the State Traffic Engineer in Utah at the time of the definition of the numbers. He utilized the Minimum Vehicular Volume (Warrant 1) and the Interruption of Continuous Traffic (Warrant 2) in the 1961 Manual of Uniform Traffic Control Devices (MUTCD) to define the numbers. In the 2000 or later issues of the MUTCD these two warrants were combined into Warrant 1, Eight Hour Vehicular Volume with Conditions A and B. The attached table is based on Table 4C-1 of the 2003 MUTCD.~~

~~————It is this warrant that the WVDOH will utilize to predict the future need for a traffic signal at any intersection on an expressway facility. The “Bleyl Numbers” table is attached to and made a part of this Design Directive.~~

The goal of the West Virginia Division of Highways is to minimize the installation of traffic signals on expressway-type facilities. For purposes of evaluating the future need for signalization on expressway facilities, WVDOH utilizes the Eight-Hour Vehicular Volume warrant (MUTCD Warrant 1), modified through application of the “Bleyl Numbers”. The attached Bleyl Numbers table, derived from the applicable MUTCD vehicular volume warrant, shall be used to predict the design year need for signalization at expressway intersections.

If the warrant analysis shows that there is greater than a 95% probability that a signal will be required in the design year, then an interchange rather than an at-grade intersection, should be considered for construction at the time the facility is built. Other factors conforming to sound

engineering judgment must be considered also. See Section 30 of this DD.

A traffic signal is NOT an interim measure for the future construction of an interchange. The signal which is warranted in the design year may or may not be warranted at the time of construction and opening to traffic of the facility, or for many years to come. Unwarranted signals have the potential to cause significant safety and delay problems at any intersection on any roadway, but especially at intersections on expressways.

## 20. Procedure

The designer is to follow the following steps to determine whether an interchange may be warranted instead of an at-grade intersection.

- A. Acquire the design Average Annual Daily Traffic (AADT) volumes (20 or 25 years into the future from the predicted year of the facility opening to traffic) for each intersection on the new or reconstructed expressway facility. This information is obtained from the Traffic Modeling and Analysis Unit of the Planning Division, and is the same future year ADT data that is shown in the Design Designation block on the project's Title Sheet. See DD-802.
- B. Compare these projected AADT's to the volumes shown in the attached table, by utilizing the number of lanes on the approach roadways, Major and Minor, as determined by the Designer. The expressway is normally the major road, but the designer may determine otherwise as long as the decision is documented to the project file. Satisfaction of the appropriate volumes indicates there is a 95% probability that a traffic signal will be warranted in the design year, in which case an interchange should be considered instead of an at-grade intersection.
- C. Verify the conclusion reached in Step "B" above by dividing the AADT values used in that step by two (2), and comparing the result to eight times the required hourly warrant values.
- D. Furnish the results of the analysis to the Traffic Engineering Division for verification, and for possible consideration of other factors that may affect the analysis, such as trucks, speed, pedestrians and/or bicyclists, which may affect the installation or operation of a signal.
- E. Upon verification of the analysis by the Traffic Engineering Division, copies of all analyses and documentation are to be placed in the project file, as well as the Master File.

## 30. Other Considerations

There are other items that the Designer must consider after the determination is made that an interchange is or is not to be considered at any particular intersection. These include costs of right-of-way, utility relocation, future cost of construction versus the cost to construct the interchange at the present time, etc.; maintenance of traffic; environmental impacts; adjacent development; the impact the interchange will have upon the existing roadway and traffic network; etc. More conditions that the designer must examine are contained ~~on Pages 10-3 through 10-5 in Chapter 10 of the 2011~~ 2018 issue of the AASHTO publication "A Policy on Geometric Design of Highways and Streets".

After careful consideration of these and all other possible factors by the Designer, the conclusion that an interchange may not be possible to construct where one is warranted by this DD may be reached, or an intersection may be constructed where an interchange is warranted.

All factors, to include the warrant, are to be considered when the decision is made to build an at-grade intersection or an interchange at any intersection along expressway-type facilities. There is

a possibility that a grade-separated mainline roadway with a two-way connector road (crossover to one side required on the mainline) could be constructed instead of a full interchange or full crossover to both sides. It is crucial that documentation of the reasons for the decision be placed in the project file and the Master File.

TABLE OF BLEYL NUMBER VALUES									
NUMBER OF LANES FOR MOVING TRAFFIC ON EACH APPROACH		DESIGN YEAR AADT PROJECTIONS				EIGHT TIMES HOURLY MUTCD WARRANT VOLUME			
<b>Warrant 1, Condition A - Minimum Vehicular Volumes</b>									
MAJOR	MINOR	MAJOR		MINOR		MAJOR		MINOR	
1	1	9,600	<i>6,700</i>	5,750	<i>4,000</i>	4,000	<i>2,800</i>	1,200	<i>840</i>
2 OR MORE	1	11,550	<i>8,100</i>	5,750	<i>4,000</i>	4,800	<i>3,360</i>	1,200	<i>840</i>
2 OR MORE	2 OR MORE	11,550	<i>8,100</i>	7,700	<i>5,400</i>	4,800	<i>3,360</i>	1,600	<i>1,120</i>
1	2 OR MORE	9,600	<i>6,700</i>	7,700	<i>5,400</i>	4,000	<i>2,800</i>	1,600	<i>1,120</i>
<b>Warrant 1, Condition B - Minimum Vehicular Volumes</b>									
MAJOR	MINOR	MAJOR		MINOR		MAJOR		MINOR	
1	1	14,400	<i>10,100</i>	2,900	<i>2,050</i>	6,000	<i>4,200</i>	600	<i>424</i>
2 OR MORE	1	17,300	<i>12,100</i>	2,900	<i>2,050</i>	7,200	<i>5,040</i>	600	<i>424</i>
2 OR MORE	2 OR MORE	17,300	<i>12,100</i>	3,850	<i>2,700</i>	7,200	<i>5,040</i>	800	<i>560</i>
1	2 OR MORE	14,400	<i>10,100</i>	3,850	<i>2,700</i>	6,000	<i>4,000</i>	800	<i>560</i>
<b>NOTES:</b>		1. See Section 4C of the <del>2003</del> <b>MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES (MUTCD), 11<sup>th</sup> Edition.</b> 2. The higher of the two <b>(2)</b> minor approach volumes is to be used in the analyses. 3. The italicized values represent a reduction to 70% of the volumes corresponding to the MUTCD warrant. This reduction is taken where the major street speed is greater than 40 mph or the intersection lies in an isolated community with a population of less than 10,000.							

**WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS  
DESIGN DIRECTIVE**

**DESIGN DIRECTIVE 662**  
**GUARDRAIL**  
*INSERT NEW DATE*  
*Supersedes June 1, 2017*

Attached is the West Virginia Department of Transportation, Division of Highways' policy for the type, location, and termination of guardrail on highway projects. Designers shall incorporate these requirements in all contract plans.

~~Attachment~~

**GUARDRAIL DESIGN POLICY**

**TYPE AND CLASS OF GUARDRAIL:**

Type 1 Guardrail (Galvanized Steel Deep Beam) shall be specified on all new projects except Type 5 (Double-Faced Type 1) will be specified when double-faced guardrail is required.

The "Classes" of guardrail are as follows:

- Class I: 6'-3" post spacing with blocks
- Class II: 12'-6" post spacing with blocks
- Class III: 12'-6" post spacing without blocks
- Class IV: 3'-1½" post spacing without blocks
- Class V: 3'-1½" post spacing with blocks

On National Highway System (NHS) projects, all guardrail specified shall be Class I.

For projects not on the NHS, the class shall be in accordance with the following table, unless otherwise directed.

<b>DESIGN YEAR ADT</b>	<b>Low Volume Road 399 or less</b>	<b>400 or Greater or Multi-Lane</b>	
<b>DESIGN/OPERATING SPEED*</b>	25 MPH	Less than 40 MPH	40 MPH or Greater
<b>CLASS</b>	III, IV**	II, V**	I, V**

\*Design speed shall be used when specifying guardrail for a new highway. The higher of Operating speed or Speed Limit shall be used when specifying guardrail for an existing highway. The operating speed shall be obtained from the Traffic Engineering Division.

\*\* 3'-1½" post spacing provides lower guardrail deflection for locations with obstacles 4' or less behind the guardrail. A minimum 25' length of Class V should be used for obstacles. Other means of reducing deflection should also be considered.

## APPROACH END TERMINALS:

Under ideal circumstances, all guardrail should be terminated outside the clear zone. In most cases, this cannot be accomplished requiring the installation of an approach end terminal.

The design of approach end terminals must be done on a case-by-case basis. When specifying an approach end terminal, the designer must ~~insure~~ ensure that the location at which the approach end terminal is specified provides the proper width, run out area, and cross slopes to allow proper installation of the approach end terminal.

The designer shall also include borrow excavation quantities, as necessary, to construct the grading required for approach end terminal installations (e.g., CST, FET, and TET) in accordance with the applicable Standard Detail Sheets. The grading limits and slopes shown on the Standard Details shall be used to determine the required earthwork quantities.

When Class I Guardrail must be terminated within the clear zone, a Manual for Assessing Safety Hardware, latest edition, (MASH) approved approach end terminal as discussed below shall be specified. All end terminals on NHS projects ~~to be let to construction after June 30, 2018,~~ shall conform to the latest edition of MASH. When Class II or Class III Guardrail must be terminated in the clear zone, an approved approach end terminal need not be specified; however, the guardrail shall be flared away from traffic. The minimum width of flare should be 4'-0". This information will be shown on the plan sheet.

The clear zone can be defined as the area available for use by errant vehicles starting at the edge of the traveled way and terminating at the closest obstruction. The width of the clear zone must be established for each project based on the type of highway, operating speed, traffic volume and roadside geometry. Refer to DD-606, Non-NHS 3R Policy and Chapter 3 of the AASHTO "Roadside Design Guide", current approved edition, (RDG), for more information on determination of the clear zone.

## NHS PROJECTS:

The standard approach end terminal is the Cut Slope Terminal (CST) as detailed on Standard Sheets GR4 through GR4B. If the use of a CST is not possible then the designer should use, in order of preference, a Flared End Terminal (FET) or Tangent End Terminal (TET) as detailed on Standard Sheets GR5 or GR6 respectively.

Both the CST and the FET require flared installation, as well as modifications to the normal shoulder slope in the area of the flare. The FET also requires grading behind the guardrail. In order to accommodate these installations, consideration must be given to drainage. When the treatments, especially the CST, are placed on the downstream end of a cut, an inlet and carrier pipe may be necessary to drain the cut ditch.

The TET, which does not require a flare, is currently available. Its use should be limited to cases where high traffic volumes and high speeds exist, and the above treatments are impractical or not feasible.

The TET shall have a 4'-0" minimum offset from the inside edge of the extruder terminal to the outside edge of the traveled way. For narrow existing shoulders that have an offset of 5'-0" or less from the face of rail to the edge of the traveled way, the rail and terminal may be flared from the normal face of rail. The flared offset distance shall be 1'-0" at a taper rate of 25:1 or 50:1, which yields flare lengths of 25'-0" or 50'-0" respectively.

## **NON-NHS PROJECTS:**

The NHS criteria will be used when Class I Guardrail is specified. As previously stated when Class II or Class III Guardrail is used, an approved approach end terminal need not be specified; however, the guardrail shall be flared away from traffic. The minimum width of flare should be 4'-0". This information will be shown on the plan sheet.

## **3R PROJECTS:**

Guardrail design for resurfacing, restoration and rehabilitation projects shall conform to the criteria previously established for NHS projects or Non-NHS projects, whichever is applicable. The following information is intended to supplement these criteria.

Guardrail design for 3R projects presents unique challenges to the designer such as limited shoulder width and limited run out area at approach end terminals. The designer should not accept the location of the existing guardrail and end terminals as being correct and simply replace them with new material. The designer's goal should be improved safety.

The approach end terminals, as described above, shall be specified on 3R projects, if applicable, based on the class of guardrail being installed. On all NHS 3R projects, the approach end terminals in the project area shall be upgraded to a CST, FET, or TET as previously described. On all Non-NHS 3R projects requiring Class I Guardrail, NHS criteria will be used. This may require that additional work be specified such as site grading, which may require a quantity of borrow excavation, or raising the elevation of the adjacent ditch line. It may be necessary to extend the guardrail beyond the point of theoretical need in order to place the approach end terminal in a location where it can be installed in accordance with the appropriate Standard or Special Detail. The designer is encouraged to eliminate short gaps between runs of guardrail especially when the approach end terminal cannot be installed in accordance with the appropriate Standard or Special Detail. This decision would be influenced by the cost of the end terminals versus the cost of the guardrail.

On Non-NHS 3R projects where the FET or the TET is the desired end terminal, but cannot be installed in accordance with Standard Detail Sheet due to lack of run out area behind the end terminal, the following guidance shall apply:

The area immediately behind and beyond the approach end terminal should be reasonably traversable and free from fixed-object hazards to the extent practicable. If a clear run out path is not attainable, this area should at least be similar in character to upstream unshielded roadside areas.

Ownership and storage location of any guardrail removed and stored (Item 607010) will be indicated in the plans by a General Note.

## **SPECIAL TRAILING END TERMINALS:**

The Special Trailing End Terminal (STET) shall be specified when Class I Guardrail is specified; and, the guardrail is outside the clear zone of the opposing traffic. Generally, this will be on divided highways.

When the guardrail is not located outside the clear zone of the opposing traffic, it shall be designed as an approach end. The guidelines as mentioned in the Approach End Terminals Section are to be followed.

## **BRIDGE TRANSITIONS:**

When the bridge shoulder width is less than the roadway shoulder width, a transition in the guardrail on the approach end and trailing end of the bridge is required. These transitions should occur on 15:1 straight tapers. There shall be a minimum of 12'-6" of standard guardrail between the bridge transition guardrail and the tapered guardrail.

## **BRIDGE TRANSITIONS – CONNECTIONS:**

The Thrie-Beam Guardrail Bridge Transition-Connection Detail, as shown on Standard Sheet GR11, is to be used on all new projects when transitioning approach end guardrail to a concrete shape. New bridges will have a vertical concrete face as detailed in the plans.

Existing bridges that do not have the proper vertical concrete end post, as shown on Standard Detail Sheet GR11, will require the installation of the Modified Concrete End Post. Special Detail Sheets for the Modified Concrete End Post can be obtained from the Engineering Division.

Guardrail that must tie to new or existing bridges that have steel guardrail parapets rather than concrete parapets shall tie directly to the steel guardrail parapet.

The post spacing of the approach guardrail shall be equal to or less than the post spacing of the guardrail on the bridge. If the post spacing of the approach guardrail is greater than the post spacing of the bridge guardrail, the post spacing of the approach guardrail shall be decreased by one-half every twenty-five feet until the post spacing of the approach guardrail and the bridge guardrail are equal.

## **THEORETICAL POINT OF NEED, WARRANTS, AND LENGTH OF NEED:**

The best available guide for guardrail theoretical point of need determination and warrants is the RDG. It shall be used on all projects.

An assumed encroachment angle for a vehicle leaving the highway will be used for length of need determination in lieu of the run-out lengths as shown in the RDG. When a vehicle is approaching the obstacle, this angle will be 8 degrees for NHS projects and 15 degrees for Non-NHS projects. When the trailing end is being considered, this angle will be 15 degrees for all projects. The use of these angles should be limited to tangent or near tangent sections of roadway. Scaling as demonstrated in Section 5.6.4 and Figure 5-48 of the RDG should be used in other cases. Results shall be documented in the project files.

The designer is cautioned to fully investigate each guardrail/end treatment installation to assure that the runout area is free of obstacles, including cut or fill slopes, and is traversable. The guardrail/end treatment installation may have to be lengthened to protect secondary obstacles behind the installation. See Section 8.3.3.3 of the RDG for more information.

## **GUARDRAIL LOCATION IN RELATION TO THE SHOULDER SLOPE (P.I.):**

On new designs where Class I or Class II Guardrail is specified, the P.I. shall be offset 1'-0" from the back of the guardrail post. The post will be between the P.I. and the edge of pavement.

On new designs where the typical has not been set and Class III Guardrail is specified, the P.I. shall be offset 2'-0" from the face of the guardrail. The guardrail will be between the P.I. and the edge of pavement.

## **GUARDRAIL LOCATION - 3R PROJECTS:**

On Interstate and APD 3R projects, the guardrail offset from edge of pavement shall be as originally constructed.

On all other 3R projects, the back of the guardrail post shall preferably be set at 1'-0" from the P.I. If this results in restricting the usable shoulder width, 8'-0" long posts shall be specified and the guardrail shall be placed at its prior location.

## GUARDRAIL HEIGHT:

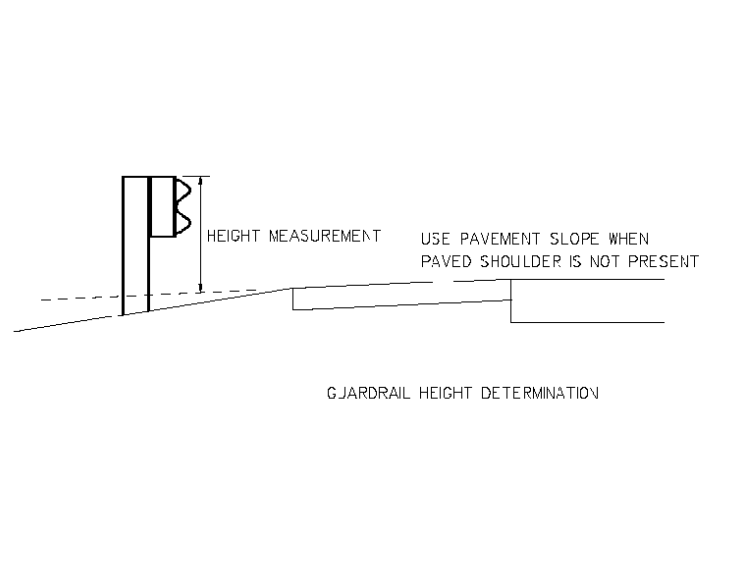
In accordance with the revised standard details regarding guardrail height, all new guardrail shall be 2'-1" to center of the W-beam section (31" to top of rail), per the following guidelines:

- Existing guardrail and end treatments with no other deficiencies are acceptable at current height.
- New installations and replacement sections, that do not tie to existing guardrail shall be 31" height.
- New installations, replacement sections, or remove and reset sections that tie to existing guardrail will generally be "in kind" with regard to height. Guardrail height will taper as necessary to existing elements per standard details.
- The Roadside Design Guide, currently adopted edition, shall be used to determine disposition of existing guardrail with regard to height for remove and reset sections on overlay and 3R projects. For these projects, guardrail having a top-of-rail height of 26 1/2" or higher (AFTER the overlay is placed) may remain as is.
- The above guidelines generally apply to end treatments, with the following notes:

Special Trailing End Terminal is acceptable at both 28-1/2" and 31" height.

Approach Terminals – Use Approved Product List for each height. Separate lists will be maintained for both 28-1/2" and 31" height.

CST Terminal – Transition guardrail down to 28-1/2" height before terminal



**SECTION BREAK**

**NEW BUSINESS ITEMS**

DRAFT

# Life Cycle Cost Analysis 2025

July 23, 2025

\*Revised: March 18, 2026\*

Developed By:

Pavement Analysis and Evaluation Section  
Materials Control, Soils & Testing Division  
West Virginia Division of Highways

## **1.0. Introduction**

In an effort to encourage pavement competition in West Virginia, the Division of Highways (DOH) has elected to use the Alternate Design Alternate Bid (ADAB) process as outlined in Design Directive (DD) 648 (December 2024) to assist with non-project specific cost evaluation. The Design Directives can be found online on the Materials Division's website at the following link:

<https://transportation.wv.gov/highways/mcst/Pages/specifications.aspx>

## **2.0. Alternate Design Alternate Bid of Pavements**

As discussed in DD 648, the ADAB process uses the  $A + B + C$  method. Factor A is the contractor's bid on the Letting day. Factor B is the number of days to construct the initial pavement and is not normally added to the contractor's bid. Factor B may be used on projects that consist of total pavement reconstruction in order to capture the user costs associated with the initial construction. This time factor is usually zero (0) because most projects are on new alignments, and traffic is not impeded during the initial construction of a project. Factor C is the Net Present Value (NPV) of all future maintenance and rehabilitation costs, known as the Life Cycle Cost Factor (C Factor). The lowest bidder is identified by adding  $A+C$ .

The C factor is governed by our DD 647. Each different pavement type and maintenance program is used to calculate a different C factor for the specific pavement and maintenance program to be used. For this general Life Cycle Cost Analysis, two pavement types were considered, full depth asphalt and plain jointed concrete pavement. Two scenarios of asphalt maintenance and rehabilitation were considered, and one scenario for the Portland cement concrete (PCC) pavement.

## **3.0. Life Cycle Cost Analysis**

To determine the performance-based cost of a general section of roadway all maintenance, rehabilitation, and preservation work done during the expected life of the roadway must be considered in addition to the initial cost of construction. In accordance with WV DD-647, this process was done using WV DOH historical project costs and FHWA's RealCost 3.0 software.

### **3.1. Initial Costs**

When using RealCost, the software must include an initial cost of construction. The contractor's bid amount is entered as zero since the goal is calculation of future costs.

### **3.2. Net Present Values**

Preservation, maintenance, and rehabilitation costs were established as inputs for the life-cycle cost analysis. For concrete preservation, concrete pavement repair (CPR) projects were analyzed. Outlier projects, projects under 1 mile in length and projects dated less than 2015 were removed from calculating the average cost. It was established that a value of \$321,000 per lane-mile would be used.

The same process was also followed for micro surfacing, ultra thin overlay and high performance thin overlays (asphalt preservation) projects and mill and fill projects (rehabilitation). The resulting values established were \$87,000 per lane-mile for asphalt preservation and \$228,000 per lane-mile for 2" mill and fill, and \$398,000 per lane-mile for 4" mill and fill. The timing for these treatments is based on data, experience, and discussions with the districts and Industry.

It was also established that a routine maintenance cost of \$15,000 per lane-mile on a 4-year cycle be used on asphalt and \$30,000 per lane-mile on an 8-year cycle for concrete to account for maintenance-type work (e.g. crack sealing, minor patching, etc.).

Additional inputs for the LCCA include:

1. Using a 50-year analysis life. DD-648 requires at least 40 years, previous LCCA calculations for the WV DOH have used 50 years.
2. A discount rate of 1.4%. The Office of Management and Budget Circular A-94 was revised in 2024. The document states that programs with durations longer than 30 years may use the 30-year interest rate. Due to previous discount rates being negative, a five-year rolling average was used instead. A copy of OMB Circular A-94 as well as the discount rates of previous years can be found in Attachment 4.

The preservation, maintenance, and rehabilitation costs used to establish the inputs for the life-cycle cost analysis are listed in Attachment 1. All of this information was entered into the RealCost 3.0 software for analysis. Inputs for each pavement and maintenance type can be seen in Attachment 2. The calculations and results of the life-cycle cost analysis can also be found in Attachment 3. After the analysis, the recommended C factors are:

**Table 3.1**  
Calculated C Factors (Rounded)

<b>Activity</b>	<b>Life Cycle Cost Factor (per lane mile)</b>
Asphalt with Preservation	\$608,000
Concrete with CPR	\$515,000
Asphalt with Mill and Fill	\$716,000

**4.0. Conclusion**

As this analysis is not project specific, no pavement and maintenance type will be recommended. Per DD 648, if the difference in the total NPV between the lowest two alternates is greater than 20 percent, the alternate with the lower total NPV only is selected for bidding. The designer shall eliminate any pavement alternate that is considered, in the designer’s judgment, to be impracticable for the project. Otherwise, alternate pavement designs will be included in the bidding documents and a life-cycle cost adjustment factor “C” will be included in the schedule of prices for each alternate.

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## Attachments:

1. WV DOH Historical Project Costs
2. RealCost 3.0 Inputs
3. Calculated C Factors
4. OMB Circular No. A-94 and Discount Rates

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Attachment 1:

WV DOH Historical Project Costs

Preservation										Average: \$87,000	
Proj Key	Name	Project ID	Length	Lanes	Lane Miles	Treatment	Bid Cost	Bid Cost / LM			
2015001610	ALT 10 - CEDAR CREST	1536312	1.75	2	3.5	CapeUltra-Thin	\$217,129.29	\$62,036.94			
2016001226	CHEAT RD MICROSEAL	1635436	2.19	2	4.38	CapeUltra-Thin	\$259,801.88	\$59,315.50			
2016001218	FLEMINGTON ROAD	1635428	1.5	2	3	CapeUltra-Thin	\$218,824.93	\$72,941.64			
2015001400	MELISSA - BARBOURSVILLE	1531412R1	2.56	2	5.12	CapeUltra-Thin	\$447,746.68	\$87,450.52			
2017000021	NEW HILL RD	1700526	2.11	2	4.22	CapeUltra-Thin	\$328,563.96	\$77,858.76			
2016001221	ROMINES MILL RD - WV 20 MICROSURFACE	1635431	4.65	2	9.3	CapeUltra-Thin	\$798,587.37	\$85,869.61			
2017000020	ROWLESBURG - KINGWOOD RD	1700525	4	2	8	CapeUltra-Thin	\$542,489.00	\$67,811.13			
2015001602	SALT ROCK - SMITH CREEK	1536306R1	2.13	2	4.26	CapeUltra-Thin	\$344,823.55	\$80,944.50			
2016001220	SHINNSTON - ENTERPRISE ROAD	1635430R1	3.05	2	6.1	CapeUltra-Thin	\$442,340.65	\$72,514.86			
2015001398	WAYNE COUNTY LINE - WV 10	1531408	4.36	2	8.72	CapeUltra-Thin	\$501,699.79	\$57,534.38			
2015001449	CSX O/P BR - MILTON	1532343	5.04	4	20.16	HPTO	\$1,950,543.22	\$96,753.14			
2015001437	FIFTH STREET - HAL GREER	1532331	2.26	4	9.04	HPTO	\$1,020,058.22	\$112,838.30			
2015001438	KY STATE LINE - KENOVA	1532332	1.15	4	4.6	HPTO	\$609,982.04	\$132,604.79			
2017000037	31ST STREET	1700530	2.71	4	10.84	Micro Surface (Double)	\$1,220,221.90	\$112,566.60			
2019000089	BIRCH RIVER - BRAXTON CO	2019000089	3.07	4	12.28	Micro Surface (Double)	\$1,256,081.51	\$102,286.77			
2018000249	BRADLEY - MT HOPE RD + 1	1804526	3.42	4	13.68	Micro Surface (Double)	\$953,222.53	\$69,680.01			
2016001227	BRIDGEPORT - BRUSHYFORK	1635437	1.46	2	2.92	Micro Surface (Double)	\$224,800.09	\$76,986.33			
2018000217	CLINTONVILLE - ALTA RD	1803827	3	4	12	Micro Surface (Double)	\$581,670.03	\$48,472.50			
2018000252	DEERWALK - SAND HILL	1804529	5.13	4	20.52	Micro Surface (Double)	\$1,396,468.98	\$68,054.04			
2023280030	GOODWINS CHAPEL - VA STATE LINE	2023280030	7.15	4	28.6	Micro Surface (Double)	\$2,937,628.00	\$102,714.27			
2015001445	I 70, DALLAS PIKE MICROSURFACING	1532339	2.98	4	11.92	Micro Surface (Double)	\$886,669.81	\$74,385.05			
2017000086	MARRTOWN - 7TH ST. RESURFACING	1701827R1	3.16	4	12.64	Micro Surface (Double)	\$1,596,385.36	\$126,296.31			
2017000217	MINERAL WELLS - STAUNTON RESURFACING	1703733R1	3.22	4	12.88	Micro Surface (Double)	\$1,086,392.44	\$84,347.24			
2018000817	MINGO CO LINE - HOLDEN	1818427R1	2.78	4	11.12	Micro Surface (Double)	\$1,391,045.98	\$125,094.06			
2018000216	N. MARTINSBURG - SPRING MILLS	1803826R1	3.3	4	13.2	Micro Surface (Double)	\$989,987.02	\$74,999.02			
2020000524	PEACH TREE ORCHARD - MUDDLETY	2020000524R1	1.93	4	7.72	Micro Surface (Double)	\$1,037,394.90	\$134,377.58			
2020000513	SAM BLACK - RUSTY BRIDGE	2020000513	2.45	4	9.8	Micro Surface (Double)	\$1,294,462.79	\$132,088.04			
2020000483	STONE GAP-COURTHOUSE RD	2020000483	4.71	4	18.84	Micro Surface (Double)	\$1,868,898.24	\$99,198.42			
2019000088	US 52 - MERCER MALL RD + 3	2019000088	3.15	4	12.6	Micro Surface (Double)	\$1,098,300.15	\$87,166.68			
2018000184	VIRGINIA LINE - US 52	1803728	2.9	4	11.6	Micro Surface (Double)	\$1,062,817.30	\$91,622.18			
2016001212	3RD AVENUE	1634725R2	1.61	3	4.83	Ultra-Thin	\$587,949.89	\$121,728.76			
2017000042	ADAMS AVENUE	1700535	1.07	4	4.28	Ultra-Thin	\$319,986.25	\$74,763.14			
2017000040	CEREDO - KENOVA	1700533	2.94	3	8.82	Ultra-Thin	\$1,160,167.40	\$131,538.25			

# DRAFT

Proj Key	Name	Project ID	Length	Lanes	Lane Miles	Treatment	Bid Cost	Bid Cost / LM
2015001427	CHAPMANVILLE - BOONE COUNTY LINE	1532227	2.86	4	11.44	Ultra-Thin	\$1,627,229.72	\$142,240.36
2016000006	CHAPMANVILLE - STRIKER FORK	1536317	2.3	2	4.6	Ultra-Thin	\$373,595.23	\$81,216.35
2015001532	ELKVIEW - WALGROVE	1534124	2.9	2	5.8	Ultra-Thin	\$261,735.78	\$45,126.86
2015001428	ESTEP - TURTLETOWN	1532228	2.85	4	11.4	Ultra-Thin	\$1,345,346.01	\$118,012.81
2015001415	FOUNTAIN PLACE - LOGAN	1532113	2.27	4	9.08	Ultra-Thin	\$589,537.40	\$64,927.03
2015001443	I 470, BETHLEHEM MICROSURFACING	1532337	2.82	4	11.28	Ultra-Thin	\$816,183.00	\$72,356.65
2015001444	I 70, MIDDLE CREEK MICROSURFACING	1532338R1	5.68	4	22.72	Ultra-Thin	\$1,296,366.69	\$57,058.39
2015001533	KELLYS CREEK - SISSONVILLE	1534123	3.65	2	7.3	Ultra-Thin	\$273,938.41	\$37,525.81
2015001516	KOPPERSTON - BOLT ROAD	1526008	5.75	2	11.5	Ultra-Thin	\$924,453.76	\$80,387.28
2015000798	MCCAULEY - SINKS/MICROSURFACE	1508308	3.42	4	13.68	Ultra-Thin	\$909,153.68	\$66,458.60
2020000063	OHIO RIVER-MARTOWN	2020000063	4.34	4	17.36	Ultra-Thin	\$2,262,959.00	\$130,354.78
2015001529	RED HOUSE HILL	1534104R1	3.18	2	6.36	Ultra-Thin	\$234,986.29	\$36,947.53
2019000094	SAULSBURY - MINERAL WELLS	2019000094	4.53	4	18.12	Ultra-Thin	\$1,400,046.90	\$77,265.28
2015001439	STAUNTON AVENUE - 7TH STREET RESURFACING	1532333R1	2.14	4	8.56	Ultra-Thin	\$920,200.80	\$107,500.09
2015001495	WALLBACK - LEFT HAND RESURFACING	1533408R2	8.35	2	16.7	Ultra-Thin	\$591,992.36	\$35,448.64

2" PWL

Average: \$228,000

Proj Key	Name	Project ID	Length	Lanes	Lane Miles	Treatment	Bid Cost	Bid Cost / LM
2015001431	ARNOLD CREEK - SMITHBURG	1532325	4.08	4	16.32	PWL/ThinOverlay	\$2,092,626.96	\$128,224.69
2020000544	BEAR RUN-ELLENBORO	2020000544	5.31	4	21.24	PWL/ThinOverlay	\$5,764,599.35	\$271,402.98
2015001426	CANEY - CHAPMANVILLE	1532226	2.61	4	10.44	PWL/ThinOverlay	\$3,171,569.41	\$303,790.17
2020000822	CHARLES TOWN - HALLTOWN	2020000822	2.35	4	9.4	PWL/ThinOverlay	\$1,264,873.35	\$134,560.99
2015000338	CRAWLEY CRK - CANEY BRANCH	1509202	3.44	4	13.76	PWL/ThinOverlay	\$3,599,425.95	\$261,586.19
2017000085	DALLISON - DEER WALK	1701826	1.83	4	7.32	PWL/ThinOverlay	\$1,099,950.60	\$150,266.48
2019000285	EAST PARK - EAST FAIRMONT	2019000285	2.09	4	8.36	PWL/ThinOverlay	\$2,112,403.63	\$252,679.86
2020000459	ELLENBORO-PENNSBORO	2020000459	3.21	4	12.84	PWL/ThinOverlay	\$3,486,086.00	\$271,502.02
2017000485	ELM GROVE - TRIADELPHIA	1705903R1	2.42	3	7.26	PWL/ThinOverlay	\$1,540,288.15	\$212,160.90
2017001522	GLEN DALE RESURFACING	1731832	1.63	2	3.26	PWL/ThinOverlay	\$950,419.68	\$291,539.78
2015001440	GOSHEN RD - UFFINGTON BRIDGE	1532334R1	3.73	4	14.92	PWL/ThinOverlay	\$2,593,587.43	\$173,832.94
2020000051	GRAND CENTRAL AVE	2020000051	2.99	4	11.96	PWL/ThinOverlay	\$2,898,089.60	\$242,315.18
2020000062	GREENWOOD-ARNOLDS RUN	2020000062	4.37	4	17.48	PWL/ThinOverlay	\$3,388,543.62	\$193,852.61
2020000515	HART'S RUN - TUCKAHOE	2020000515	1.59	4	6.36	PWL/ThinOverlay	\$2,428,649.43	\$381,863.12
2017000088	HOOKERSVILLE - POWELL MTN. ROAD	1701829	4.21	4	16.84	PWL/ThinOverlay	\$3,779,588.67	\$224,441.13
2012001472	INTERSTATE 81/RESURFACING	1234711R1	3.7	4	14.8	PWL/ThinOverlay	\$2,440,384.08	\$164,890.82
2020000473	INWOOD - TABLERS STATION	2020000473	2.67	4	10.68	PWL/ThinOverlay	\$2,420,372.44	\$226,626.63
2020000542	JACKSON CO LI-ROCKPORT	2020000542	3.38	4	13.52	PWL/ThinOverlay	\$2,510,212.85	\$185,666.63
2017000087	LEWISBURG ROAD	1701828	2.44	4	9.76	PWL/ThinOverlay	\$2,346,833.62	\$240,454.26
2015001441	LOST CREEK - QUIET DELL	1532335	4.49	4	17.96	PWL/ThinOverlay	\$2,587,823.41	\$144,088.16
2019000096	LUXEMBURG RD-BAKER	2019000096R1	5	4	20	PWL/ThinOverlay	\$3,979,853.70	\$198,992.69
2015001436	MARYLAND ROAD	1532330	2.03	5	10.15	PWL/ThinOverlay	\$1,384,566.99	\$136,410.54
2020000059	MILLER RDG MEADOW RIVER	2020000059	2.93	4	11.72	PWL/ThinOverlay	\$3,238,020.46	\$276,281.61
2020000134	N RIVER RDLUXEMBURG	2020000134	3.04	4	12.16	PWL/ThinOverlay	\$1,941,553.42	\$159,667.22
2017000209	OAKWOOD RD. - WV 61	1703725	1.24	4	4.96	PWL/ThinOverlay	\$1,875,995.73	\$378,224.95
2015000339	PARKERSBURG - DRY RUN	1509201	2.01	4	8.04	PWL/ThinOverlay	\$1,588,011.50	\$197,513.87
2020000539	PENNSBORO-GREENWOOD	2020000539	3.12	4	12.48	PWL/ThinOverlay	\$2,424,438.03	\$194,265.87
2019001270	RABBIT HILL-CROSS CREEK RD	2019001270	1.35	4	5.4	PWL/ThinOverlay	\$1,336,843.69	\$247,563.65
2020000488	REST AREA - INWOOD	2020000488R1	2.78	4	11.12	PWL/ThinOverlay	\$2,682,766.31	\$241,255.96
2015000320	ROCKPORT - SAULSBURY RESURFACING	1508402	4.77	4	19.08	PWL/ThinOverlay	\$2,780,002.20	\$145,702.42

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Proj Key	Name	Project ID	Length	Lanes	Lane Miles	Treatment	Bid Cost	Bid Cost / LM
2015001447	SAM BLACK CHURCH - CLINTONVILLE	1532341	2.46	4	9.84	PWL/ThinOverlay	\$2,438,096.58	\$247,774.04
2019000091	SINKS BRIDGE-WARDENSVILLE	2019000091R1	1.98	4	7.92	PWL/ThinOverlay	\$1,504,878.00	\$190,009.85
1611810	TEAYS VALLEY - CROSS LANES	1611810R1	9.11	2	18.22	PWL/ThinOverlay	\$4,356,957.27	\$239,130.48
2015000260	TUPPERS CRK - FAIRPLAIN	1507851	10.76	4	43.04	PWL/ThinOverlay	\$12,070,744.66	\$280,454.10
2015000336	US 50 - WV 31	1508401	7.4	4	29.6	PWL/ThinOverlay	\$4,008,082.05	\$135,408.18
2015000925	WALLBACK - BIG OTTER	1520101	2.67	4	10.68	PWL/ThinOverlay	\$2,472,031.51	\$231,463.62
2015001442	WINCHESTER AVE - KING ST	1532336	1	6	6	PWL/ThinOverlay	\$614,947.53	\$102,491.26
2020000087	WOLF SUMMIT - ADAMSTON ROAD	2007000	6.38	4	25.52	PWL/ThinOverlay	\$7,029,318.70	\$275,443.52
2019000087	WSS - VIRGINIA LINE	2019000087	2.42	4	9.68	PWL/ThinOverlay	\$3,795,380.71	\$392,084.78
2023340022	YOUNGS MONUMENT-BIRCH RIVER ROAD	2023340022	4.87	5	24.35	PWL/ThinOverlay	\$9,478,437.59	\$389,258.22

# DRAFT

## 4" PWL

Average: \$398,000

Proj Key	Name	Project ID	Length	Lanes	Lane Miles	Treatment	Bid Cost	Bid Cost / LM
2019000093	BURNSVILLE - WESTON RD	2019000093	3.55	4	14.2	PWL/ThickOverlay	\$4,660,390.05	\$328,196.48
2023430009	WOOD COUNTY - BEAR RUN	2023430009	8.04	4	32.16	PWL/ThickOverlay	\$14,984,984.00	\$465,951.00

# DRAFT

## CPR

Proj Key	Name	Project ID	Length	Lanes	Lane Miles	Treatment	Bid Cost	Average: \$321,000	Bid Cost / LM
2017000944	MT PLEASANT ESTATES REHABILITATION	1722608	1.11	2	2.22	CPR	\$848,800.80		\$382,342.70
2017000225	AIRPORT RD - GLADE CREEK BR	1703830R1	5.49	5	27.45	CPR	\$4,179,798.86		\$152,269.54
2019000092	BRAGG - SANDSTONE RD	2019000092	4.87	5	24.35	CPR	\$3,087,499.65		\$126,796.70
2020000448	DAVIS CR-OAKWOOD	2020000448	2.24	4	8.96	CPR	\$6,275,600.35		\$700,401.82
2017001666	HARMON CREEK - PENNSYLVANIA STATE LINE	2017001666	2.71	4	10.84	CPR	\$5,422,568.47		\$500,236.94
2019001341	I-77-AIRPORT RD	2019001341	4.1	4	16.4	CPR	\$5,382,600.00		\$328,207.32
2017001423	MONONGALIA BLVD - STEWARTSTOWN RD	1729232	2.76	4	11.04	CPR	\$4,402,943.68		\$398,817.36
2015000711	WEIRTON - HARMON CREEK	1505802	1.96	4	7.84	CPR	\$2,774,021.93		\$353,829.33
2021000027	GREEN SULPHUR - DAWSON	2021000027	6	5	30	CPR	\$4,736,400.00		\$157,880.00
2015001432	BUCKHANNON - ELKINS ROAD	1532326	4.52	4	18.08	CPR	\$1,915,080.51		\$105,922.59

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Attachment 2:

RealCost 3.0 Inputs

### INPUT WORKSHEET

#### 1. Economic Variables

Description	Value
Value of Time for Passenger Cars (\$/hour)	
Value of Time for Single Unit Trucks (\$/hour)	
Value of Time for Combination Trucks (\$/hour)	

#### 2. Analysis Options

Description	Value
Include User Costs in Analysis	No
Include User Cost Remaining Life Value	No
Use Differential User Costs	No
User Cost Computation Method	Calculated
Include Agency Cost Remaining Life Value	No
Traffic Direction	Both
Analysis Period (Years)	50
Beginning of Analysis Period	2026
Discount Rate (%)	1.4
Number of Alternatives	3

#### 3. Project Details

Description	Value
State Route	
Project Name	2025 Life Cycle Cost
Region	
County	
Analyzed By	Kiana Welch
Mileposts	NA
Begin	
End	
Length of Project (miles)	0
Comments	

#### 4. Traffic Data

Description	Value
AADT Construction Year (total for both directions)	
Cars as Percentage of AADT (%)	100
Single Unit Trucks as Percentage of AADT (%)	
Combination Trucks as Percentage of AADT (%)	
Annual Growth Rate of Traffic (%)	
Speed Limit Under Normal Operating Conditions (mph)	
No of Lanes in Each Direction During Normal Conditions	
Free Flow Capacity (vphpl)	
Rural or Urban Hourly Traffic Distribution	
Queue Dissipation Capacity (vphpl)	
Maximum AADT (total for both directions)	
Maximum Queue Length (miles)	

### 5. Construction

Description	Value
<b>Alternative 1</b>	Asphalt w/Preservation & Mill&Fill
<b>Number of Activities</b>	6

Description	Value
<b>Activity 1</b>	HMA New Construction
Agency Construction Cost (\$1000)	0
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	120
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	10
Activity Structural Life (years)	50
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 2</b>	Preservation (10)
Agency Construction Cost (\$1000)	87
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	5
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	8
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		

Third period of lane closure		
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Description	Value
<b>Activity 3</b>	Preservation (18)
Agency Construction Cost (\$1000)	87
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	5
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	8
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 4</b>	4" Mill&Fill (26)
Agency Construction Cost (\$1000)	398
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	30
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	10
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 5</b>	Preservation (36)
Agency Construction Cost (\$1000)	87
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	5
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	8
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 6</b>	Preservation (44)
Agency Construction Cost (\$1000)	87
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	5
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	8
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Alternative 2</b>	Concrete w/CPR
<b>Number of Activities</b>	3

Description	Value
<b>Activity 1</b>	PCC New Construction
Agency Construction Cost (\$1000)	0
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	120
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	26
Activity Structural Life (years)	50
Maintenance Frequency (years)	8
Agency Maintenance Cost (\$1000)	30
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 2</b>	CPR & Diamond Grind (26)
Agency Construction Cost (\$1000)	321
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	30
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	14
Activity Structural Life (years)	
Maintenance Frequency (years)	8
Agency Maintenance Cost (\$1000)	30
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 3</b>	<b>CPR &amp; Diamond Grind (40)</b>
Agency Construction Cost (\$1000)	321
User Work Zone Costs (\$1000)	
Work Zone Duration (days)	30
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	14
Activity Structural Life (years)	
Maintenance Frequency (years)	8
Agency Maintenance Cost (\$1000)	30
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Alternative 3</b>	Asphalt w/Mill&Fill
<b>Number of Activities</b>	5

Description	Value
<b>Activity 1</b>	HMA New Construction
Agency Construction Cost (\$1000)	0
User Work Zone Costs (\$1000)	NA
Work Zone Duration (days)	120
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	15
Activity Structural Life (years)	50
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 2</b>	2" Mill&Fill (15)
Agency Construction Cost (\$1000)	228
User Work Zone Costs (\$1000)	NA
Work Zone Duration (days)	30
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	10
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 3</b>	2" Mill&Fill (25)
Agency Construction Cost (\$1000)	\$228.00
User Work Zone Costs (\$1000)	NA
Work Zone Duration (days)	30
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	10
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 4</b>	2" Mill&Fill (35)
Agency Construction Cost (\$1000)	\$228.00
User Work Zone Costs (\$1000)	NA
Work Zone Duration (days)	30
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	10
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Description	Value
<b>Activity 5</b>	2" Mill&Fill (45)
Agency Construction Cost (\$1000)	\$228.00

User Work Zone Costs (\$1000)	NA
Work Zone Duration (days)	30
No of Lanes Open in Each Direction During Work Zone	1
Activity Service Life (years)	10
Activity Structural Life (years)	
Maintenance Frequency (years)	4
Agency Maintenance Cost (\$1000)	15
Work Zone Length (miles)	
Work Zone Speed Limit (mph)	
Work Zone Capacity (vphpl)	
Traffic Hourly Distribution	Week Day 1

<i>Inbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

<i>Outbound Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)</i>	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

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Attachment 3:

Calculated C Factors

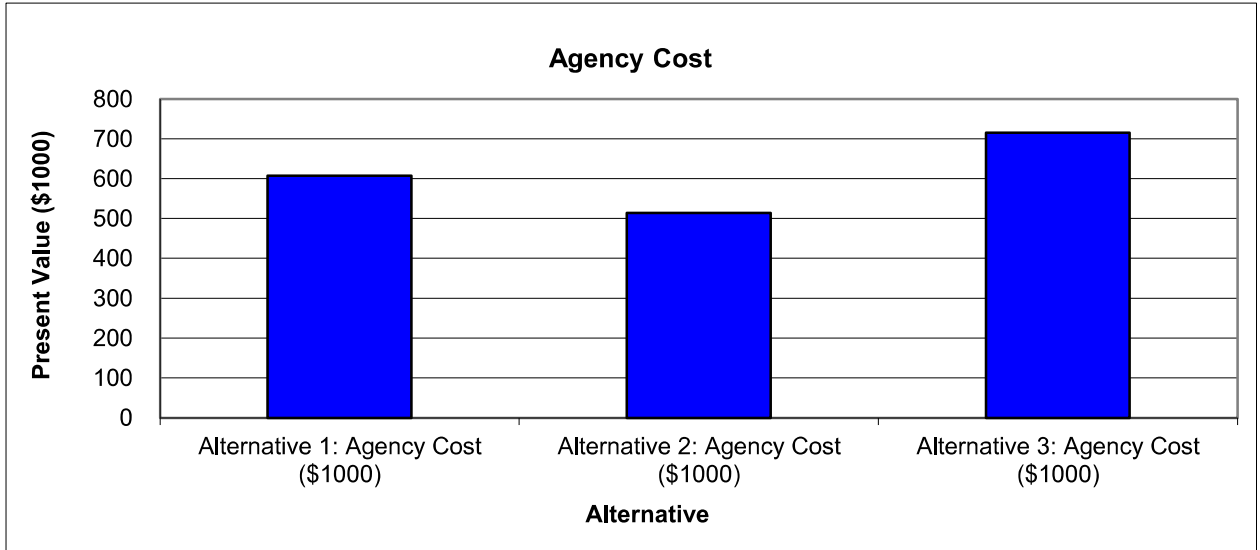
**Table 1. Cost Result Summary**

Description	Alternative 1: Agency Cost (\$1000)	Alternative 1: User Cost (\$1000)	Alternative 2: Agency Cost (\$1000)	Alternative 2: User Cost (\$1000)	Alternative 3: Agency Cost (\$1000)	Alternative 3: User Cost (\$1000)
Undiscounted Sum	\$866.00	\$0.00	\$792.00	\$0.00	\$1,062.00	\$0.00
NPV	\$607.18	\$0.00	\$514.13	\$0.00	\$715.04	\$0.00
EUAC	\$16.97	\$0.00	\$14.37	\$0.00	\$19.98	\$0.00

Lowest NPV Agency Cost	Alternative 2
Lowest NPV User Cost	Alternative 1

**Table 2. Expenditure Stream**

Year	Alternative 1: Agency Cost (\$1000)	Alternative 1: User Cost (\$1000)	Alternative 2: Agency Cost (\$1000)	Alternative 2: User Cost (\$1000)	Alternative 3: Agency Cost (\$1000)	Alternative 3: User Cost (\$1000)
2026	-	-	-	-	-	-
2027	-	-	-	-	-	-
2028	-	-	-	-	-	-
2029	-	-	-	-	-	-
2030	\$15.00	-	-	-	\$15.00	-
2031	-	-	-	-	-	-
2032	-	-	-	-	-	-
2033	-	-	-	-	-	-
2034	\$15.00	-	\$30.00	-	\$15.00	-
2035	-	-	-	-	-	-
2036	\$87.00	-	-	-	-	-
2037	-	-	-	-	-	-
2038	-	-	-	-	\$15.00	-
2039	-	-	-	-	-	-
2040	\$15.00	-	-	-	-	-
2041	-	-	-	-	\$228.00	-
2042	-	-	\$30.00	-	-	-
2043	-	-	-	-	-	-
2044	\$87.00	-	-	-	-	-
2045	-	-	-	-	\$15.00	-
2046	-	-	-	-	-	-
2047	-	-	-	-	-	-
2048	\$15.00	-	-	-	-	-
2049	-	-	-	-	\$15.00	-
2050	-	-	\$30.00	-	-	-
2051	-	-	-	-	\$228.00	-
2052	\$398.00	-	\$321.00	-	-	-
2053	-	-	-	-	-	-
2054	-	-	-	-	-	-
2055	-	-	-	-	\$15.00	-
2056	\$15.00	-	-	-	-	-
2057	-	-	-	-	-	-
2058	-	-	-	-	-	-
2059	-	-	-	-	\$15.00	-
2060	\$15.00	-	\$30.00	-	-	-
2061	-	-	-	-	\$228.00	-
2062	\$87.00	-	-	-	-	-
2063	-	-	-	-	-	-
2064	-	-	-	-	-	-
2065	-	-	-	-	\$15.00	-
2066	\$15.00	-	\$321.00	-	-	-
2067	-	-	-	-	-	-
2068	-	-	-	-	-	-
2069	-	-	-	-	\$15.00	-
2070	\$87.00	-	-	-	-	-
2071	-	-	-	-	\$228.00	-
2072	-	-	-	-	-	-
2073	-	-	-	-	-	-
2074	\$15.00	-	\$30.00	-	-	-
2075	-	-	-	-	\$15.00	-
2076	-	-	-	-	-	-
-	-	-	-	-	-	-



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Attachment 4:

OMB Circular No. A-94 and Discount Rates

APPENDIX C  
(Revised November 14, 2024)

DISCOUNT RATES FOR COST-EFFECTIVENESS, LEASE PURCHASE,  
AND RELATED ANALYSES

**Effective Dates.** This appendix is updated annually. This version of the appendix is valid for calendar year 2025. A copy of the updated appendix can be obtained in electronic form through the OMB home page at <https://www.whitehouse.gov/wp-content/uploads/2025/01/CircularA-94AppendixC.pdf>. The text of the Circular is found at <https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-94.pdf>, and a table of past years' rates is located at <https://www.whitehouse.gov/wp-content/uploads/2025/01/CircularA-94DiscountHistory.pdf>. Updates of the appendix are also available upon request from OMB's Office of Economic Policy ([a94@omb.eop.gov](mailto:a94@omb.eop.gov)).

**Nominal Discount Rates.** A forecast of nominal or market interest rates for calendar year 2025 based on the economic assumptions for the 2026 Budget is presented below. These nominal rates are to be used for discounting nominal flows, which are often encountered in lease-purchase analysis.

**Nominal Interest Rates on Treasury Notes and Bonds  
of Specified Maturities (in percent)**

<u>3-Year</u>	<u>5-Year</u>	<u>7-Year</u>	<u>10-Year</u>	<u>20-Year</u>	<u>30-Year</u>
3.7	3.8	3.9	4.1	4.4	4.4

**Real Discount Rates.** A forecast of real interest rates from which the inflation premium has been removed and based on the economic assumptions for the 2026 Budget is presented below. These real rates are to be used for discounting constant-dollar flows, as is often required in cost-effectiveness analysis.

**Real Interest Rates on Treasury Notes and Bonds  
of Specified Maturities (in percent)**

<u>3-Year</u>	<u>5-Year</u>	<u>7-Year</u>	<u>10-Year</u>	<u>20-Year</u>	<u>30-Year</u>
1.5	1.6	1.8	1.9	2.2	2.3

Analyses of projects with terms different from those presented above may use a linear interpolation. For example, a four-year project can be evaluated with a rate equal to the average of the three-year and five-year rates. Projects with durations longer than 30 years may use the 30-year interest rate.

November 14, 2024

## APPENDIX C

### BUDGET ASSUMPTIONS

Nominal Treasury Interest Rates for Different Maturities  
(from the annual budget assumptions for the first year of the budget forecast)

Calendar Year	3-Year	5-Year	7-Year	10-Year	20-Year	30-Year
1979	9.7	9.2	9.1	9.0	N/A	8.9
1980	10.9	10.6	10.6	10.6	N/A	10.4
1981	13.4	12.8	12.6	12.2	N/A	11.8
1982	12.8	13.1	13.2	13.3	N/A	13.0
1983	9.5	9.8	10.0	10.2	N/A	10.3
1984	9.8	10.0	10.1	10.3	N/A	10.4
1985	10.3	10.7	10.8	11.0	N/A	11.0
1986	8.6	8.8	8.8	8.9	N/A	9.1
1987	6.3	6.5	6.6	6.7	N/A	7.0
1988	7.3	7.7	7.8	8.0	N/A	8.1
1989	7.8	8.1	8.2	8.3	N/A	8.2
1990	7.4	7.5	7.6	7.7	N/A	7.8
1991	7.2	7.4	7.4	7.5	N/A	7.7
1992	6.1	6.5	6.7	7.0	N/A	7.1
1993	5.6	6.0	6.3	6.7	N/A	6.8
1994	5.0	5.3	5.5	5.7	N/A	5.8
1995	7.3	7.6	7.7	7.9	N/A	8.1
1996	5.4	5.5	5.5	5.6	N/A	5.7
1997	5.8	5.9	6.0	6.1	N/A	6.3
1998	5.6	5.7	5.8	5.9	N/A	6.1
1999	4.7	4.8	4.9	4.9	N/A	5.0
2000	5.9	6.0	6.0	6.1	N/A	6.3
2001	5.4	5.4	5.4	5.4	N/A	5.3
2002	4.1	4.5	4.8	5.1	N/A	5.8
2003	3.1	3.6	3.9	4.2	N/A	5.1
2004	3.0	3.7	4.2	4.6	5.4	5.5
2005	3.7	4.1	4.4	4.6	5.2	5.2
2006	4.7	4.8	4.9	5.0	5.3	5.2
2007	4.9	4.9	4.9	5.0	5.1	5.1
2008	4.1	4.3	4.4	4.6	4.9	4.9
2009	2.7	3.3	3.7	4.2	4.7	4.5
2010	2.3	3.1	3.5	3.9	4.4	4.5
2011	1.4	1.9	2.4	3.0	3.9	4.2
2012	1.6	2.1	2.5	2.8	3.5	3.8
2013	0.5	1.1	1.5	2.0	2.7	3.0
2014	1.0	1.9	2.5	3.0	3.6	3.9
2015	1.7	2.2	2.5	2.8	3.1	3.4
2016	2.0	2.4	2.7	2.9	3.2	3.5
2017	1.4	1.7	1.9	2.1	2.5	2.8
2018	2.3	2.5	2.6	2.6	2.8	3.0
2019	3.3	3.3	3.4	3.4	3.5	3.6
2020	1.6	1.7	1.8	2.0	2.3	2.4
2021	0.2	0.3	0.6	0.8	1.5	1.7
2022	1.3	1.6	1.9	2.1	2.5	2.6
2023	4.0	3.8	3.8	3.9	4.2	4.2
2024	4.5	4.4	4.4	4.4	4.7	4.7
2025	3.7	3.8	3.9	4.1	4.4	4.4

## Real Treasury Interest Rates

Calendar Year	3-Year	5-Year	7-Year	10-Year	20-Year	30-Year
1979	2.8	3.4	4.1	4.6	N/A	5.4
1980	2.1	2.4	2.9	3.3	N/A	3.7
1981	3.6	3.9	4.3	4.4	N/A	4.8
1982	6.1	7.1	7.5	7.8	N/A	7.9
1983	4.2	4.7	5.0	5.3	N/A	5.6
1984	5.0	5.4	5.7	6.1	N/A	6.4
1985	5.9	6.5	6.8	7.1	N/A	7.4
1986	4.6	5.1	5.6	5.9	N/A	6.7
1987	2.8	3.1	3.5	3.8	N/A	4.4
1988	3.5	4.2	4.7	5.1	N/A	5.6
1989	4.1	4.8	5.3	5.8	N/A	6.1
1990	3.2	3.6	3.9	4.2	N/A	4.6
1991	3.2	3.5	3.7	3.9	N/A	4.2
1992	2.7	3.1	3.3	3.6	N/A	3.8
1993	3.1	3.6	3.9	4.3	N/A	4.5
1994	2.1	2.3	2.5	2.7	N/A	2.8
1995	4.2	4.5	4.6	4.8	N/A	4.9
1996	2.6	2.7	2.8	2.8	N/A	3.0
1997	3.2	3.3	3.4	3.5	N/A	3.6
1998	3.4	3.5	3.5	3.6	N/A	3.8
1999	2.6	2.7	2.7	2.7	N/A	2.9
2000	3.8	3.9	4.0	4.0	N/A	4.2
2001	3.2	3.2	3.2	3.2	N/A	3.2
2002	2.1	2.8	3.0	3.1	N/A	3.9
2003	1.6	1.9	2.2	2.5	N/A	3.2
2004	1.6	2.1	2.4	2.8	3.4	3.5
2005	1.7	2.0	2.3	2.5	3.0	3.1
2006	2.5	2.6	2.7	2.8	3.0	3.0
2007	2.5	2.6	2.7	2.8	3.0	3.0
2008	2.1	2.3	2.4	2.6	2.8	2.8
2009	0.9	1.6	1.9	2.4	2.9	2.7
2010	0.9	1.6	1.9	2.2	2.7	2.7
2011	0.0	0.4	0.8	1.3	2.1	2.3
2012	0.0	0.4	0.7	1.1	1.7	2.0
2013	-1.4	-0.8	-0.4	0.1	0.8	1.1
2014	-0.7	0.0	0.5	1.0	1.6	1.9
2015	0.1	0.4	0.7	0.9	1.2	1.4
2016	0.3	0.6	0.8	1.0	1.2	1.5
2017	-0.5	-0.3	0.0	0.1	0.5	0.7
2018	0.6	0.6	0.7	0.7	0.9	1.0
2019	1.3	1.3	1.3	1.4	1.5	1.5
2020	-0.4	-0.3	-0.2	0.0	0.3	0.4
2021	-1.8	-1.6	-1.4	-1.1	-0.5	-0.3
2022	-1.2	-0.6	-0.3	0.0	0.4	0.5
2023	1.2	1.3	1.4	1.5	2.0	2.0
2024	2.2	2.2	2.2	2.3	2.5	2.5
2025	1.5	1.6	1.8	1.9	2.2	2.3

## APPENDIX D

### Real Discount Rates

Years	Risk-Free Rate	Social Discount Rate	
1972-1991	N/A	10.0	Note: This rate appeared in the main Circular.
1992-2022	N/A	7.0	Note: This rate appeared in the main Circular.
2023-2025	2.0	3.1	

**WVDOH Manuals Committee Meeting**  
**Tuesday, June 2, 2026**  
**Meeting Location: 190 Dry Branch Drive, Charleston, WV**

Also meeting virtually via Google Meet. Email distribution includes instruction.

**Old Business:** Manuals discussed at the April 2026 meeting are below.

ITEM	Champion
<p><b>2<sup>nd</sup> time to Committee. Discussed in: April, June</b></p> <ul style="list-style-type: none"> <li>• <b><i>Drainage Manual – Chapter 6: Culverts</i></b></li> </ul> <p>This is an update to Chapter 6 Culverts. The revision incorporates the changes implemented by the “Technical Engineering Memo – Driveway Conduit Placement” issued January 2023</p>	D. Holmes


**New Business:**

ITEM	Champion
<p><b>1<sup>st</sup> time to Committee</b></p> <ul style="list-style-type: none"> <li>• <b><i>Construction Manual: Section 110 – Change Orders</i></b></li> </ul> <p>The revision makes changes to ensure cohesive communication between FHWA, the WVDOH, and the project during the review and approval procedure by outlining the chain of command.</p>	D. Jarvis

**DRAFT**



## **Chapter 6 Ditches**



West Virginia  
Department of Transportation  
Division of Highways  
Drainage Manual

DRAFT

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## CHAPTER 6 DITCHES

### 6.1 INTRODUCTION

Roadway ditches are V or trapezoidal shaped channels lined with grass, concrete, rock, or manufactured protective linings. They are generally designed to convey the design discharge and resist erosion of the in-situ soil. Higher discharge amounts than the design criteria may be necessary when a ditch intercepts offsite drainage. Ditches may also drain subsurface water from the base of the roadway which is conveyed through underdrains.

Ditch design is accomplished by the selection of a cross-section geometry, horizontal alignment, grade, and protective linings to convey the design discharge via the allowable depth. The selection is then examined using a lower, more frequent discharge to avoid erosion before the lining is considered viable.

### 6.2 DESIGN POLICY

Roadway ditches shall be designed to collect rainfall runoff from the roadway right of way (pavement surface, median area, cut and embankment fill slopes), contributory drainage areas outside of the right of way, and possible natural water course flow sources. These ditches shall convey the flow in a manner which minimizes the potential for adverse effects on the roadway.

The designer shall use the following general policies as a guide to plan, select, and design ditches placed along roadways:

- Ditches shall be located by adhering to the cross-section geometry of the WVDOH Design Directive 601. Modifications shall consider the clear zone requirements and take advantage of the terrain.
- Ditches shall be hydraulically designed.
- Ditch linings shall be designed to be structurally stable.
- Permanent erosion control matting shall not be used in a ditch where the frequent removal of sediment is anticipated.
- Ditches and ditch outlets shall be designed to consider construction and maintenance costs, maintenance access, risk of lining failure, traffic safety, and environmental considerations.

### 6.3 DESIGN CRITERIA

Design criteria are controlled by geometric and safety standards applicable to the roadway project. The following criteria shall apply to the hydraulic design and stability of ditches:

### **6.3.1 FREQUENCY**

Median, roadside, and secondary ditches shall be designed to carry onsite runoff from the roadway right of way for a frequency (probability of occurrence) of 10% or a return period of 10 years.

### **6.3.2 SIZE AND SHAPE**

Roadside and median ditches shall be designed to be triangular or trapezoidal in shape with side-slopes specified by the typical roadway section (Design Directive 601). The bottom width of trapezoidal ditches shall vary depending on the capacity required. Consideration shall be given to achieving the project clear zone when sizing a ditch.

If significant flow from offsite is carried within a roadside ditch, then the ditch shall be sized to carry the design discharge for the offsite drainage area. For example, an offsite discharge may flow into a roadside ditch, then to a culvert crossing perpendicular to the roadway. The design discharge would be defined by the culvert crossing at the end of the ditch which may require a higher design discharge (such as 4% or a 25-year return period).

A Rockfall Catchment Area Ditch (RCAD) is constructed to retain falling rock. These ditches typically have long 24-foot fore-slopes with a 1-foot flat bottom and a steep backslope. The RCAD will have similar hydraulic conveyance as compared to the standard geometry of Design Directive 601. Coordinate with the roadway designer and the geotechnical engineer when a RCAD ditch is part of the design and include the modified ditch geometry in the hydraulic calculations.

### **6.3.3 FLOW DEPTH**

The maximum flow depth in a median ditch shall be 0.6 feet or 7.2 inches.

The maximum flow depth in a roadside ditch shall be 1 foot and shall not exceed a depth which is 1.5 feet below the edge of the shoulder. Roadside ditches along low volume roads may be exempted from this standard to enable a cost-effective design. The flow depth shall not be higher than the lowest elevation of the roadway subgrade. If “flooding the subgrade” cannot be avoided, then pavement underdrain should be used (see Section 5.3.2.11).

### **6.3.4 LONGITUDINAL SLOPE**

The longitudinal slope of a median or roadside ditch shall not be less than 0.5 percent. Flatter slopes may be permitted with the use of concrete pavement within the ditch. In general, the longitudinal slope of the ditch shall be sufficient to satisfy the minimum velocity criteria.

### **6.3.5 MINIMUM FLOW VELOCITY**

The flow velocity in a median or roadside ditch shall not be less than 0.5 foot per second when ditch is flowing at one-third of the design flow depth.

### **6.3.6 DITCH INLETS AND MAXIMUM SPACING**

Inlets with the WVDOH standard Type G grates ranging in size from 32" X 38" to 60" X 66" are primarily used in median and roadside ditches. The Type 1 Grate has 1" bars, 2" on center. The type 2 grate has 1" bars, 4" on center.

The maximum pipe length between inlets shall not be greater than 400 feet to allow for maintenance access. Upon WVDOH approval, this distance may be extended up to 100 feet to enable practical drainage layouts. See design criteria for access structures in Chapter 5, Section 5.2.7.

### **6.3.7 SECONDARY DITCHES**

Secondary ditches are drainage structures which may reside at the top or toe of cut slopes and at the bottom of embankments. These are usually used to separate offsite drainage from the median or roadside ditch system. The need for secondary ditches should be determined by factors such as:

- Protection of the median or roadside ditch system.
- Directed conveyance of runoff to a temporary sediment basin.
- Separation of runoff due to environmental requirements.
- Lessen the contributing drainage area or concentration of runoff.
- Maintenance of existing drainage patterns

Pipe flumes and cascades may also be considered as options to convey offsite drainage from steep slopes. See the culvert design criteria in Chapter 8 (Section 8.3).

### **6.3.8 ROUGHNESS COEFFICIENT SELECTION**

The Manning's roughness coefficient for ditch protection should be based on the condition that represents the minimum resistance to flow. This value shall be selected with consideration of a variation with flow depth and whether vegetative linings will be maintained (mowed or unmowed). Values for ditches with vegetative linings that cannot be mowed due to their location (such as ditches located at the bottom of steep embankments) shall be selected based on the condition that provides the maximum resistance to flow. This yields a higher flow depth and a higher shear stress.

Roughness coefficient for vegetative linings shall be selected from the ranges shown in Table 6-1. Vegetative ditch linings should consist of seed mixture Type B with the use of Type C-1 in areas viewable and traversable by traffic. More information on the standard seed mixtures can be obtained from Section 652 of the WVDOH standard specifications. For flat longitudinal ditch slopes a higher value within the range should be selected. Roughness coefficient for non-vegetative linings shall be based on the material type and flow depth as shown in Table 6-2.

**Table 6-1**

**Manning’s Roughness Coefficient for Vegetative Ditch Linings**

<b>WVDOH Grass Seed Mixture</b>	<b>Minimum roughness coefficient. n</b>	<b>Standard roughness coefficient n</b>	<b>Maximum roughness coefficient n</b>
Type B (mowed)	0.036	0.042	0.050
Type C-1 (mowed)	0.030	0.036	0.040
Type C-2 (mowed)	0.022	0.027	0.033
Type B (unmowed)	0.050	0.090	0.140
Type C-1 (unmowed)	0.050	0.080	0.120
Type C-2 (unmowed)	0.025	0.030	0.040

**Table 6-2**

**Manning’s Roughness Coefficient for Non-Vegetative Ditch Linings**

Material Type	Manning’s Roughness Coefficient, n		
	Depth Range (ft) 0 – 0.5	Depth Range (ft) 0.5 – 2.0	Depth Range (ft) > 2.0
<b>Rigid</b>			
Concrete	0.015	0.013	0.013
Grouted Rock	0.040	0.030	0.028
<b>Unlined</b>			
Bare Soil	0.023	0.020	0.020
Rock Cut	0.045	0.035	0.025
<b>Rock (D<sub>50</sub>)</b>			
4-inch	0.090	0.058	0.035
6-inch	0.104	0.069	0.035
12-inch	-	0.078	0.040

Source: *Design of Roadside Channels with Flexible Linings, HEC-15, FHWA, 1988*

**6.3.9 DITCH PROTECTION**

The selection of vegetative lining with or without temporary or permanent erosion control matting shall be based on permissible shear stress criteria. Proper installation of matting is critical to its performance. The design drawings shall stress that matting must be installed in strict accordance with the manufacturer’s specifications to facilitate a correct installation.

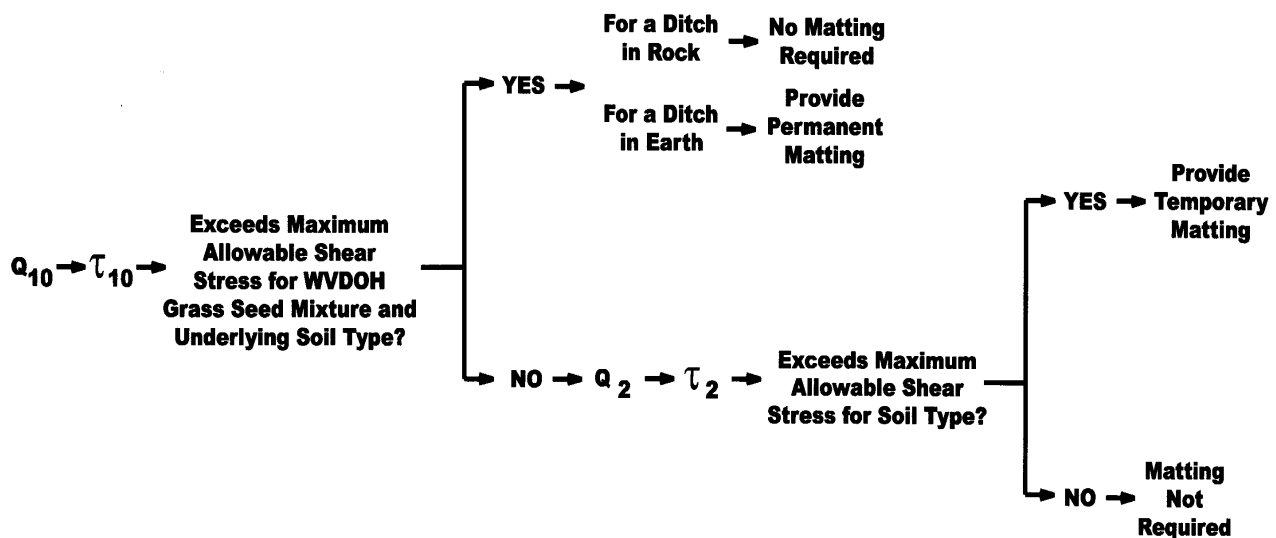
Rock linings shall be designed based on permissible shear stress criteria. This type of lining should not be placed within the highway clear zone; however, it may be permitted to protect existing ditches in the clear zone that have eroded into deep gullies. It also may be permitted where pavement resurfacings have created deep ditches provided that the top 6 inches of rock does not have sizes exceeding 4 inches in diameter. A filter layer shall be used between the underlying soil and the rock lining to prevent erosion at the rock soil interface (refer to specification 218). An acceptable standard aggregate filter layer is 6” of #467 stone placed underneath the entirety of the rock lining. The designer can refer to federal publication HEC-15, Section 6.4.3 for the design procedure for granular rock filters. Standard drawings for rock linings, filter layers, and concrete gutters are shown in the WVDOH Standard Details.

### 6.3.10 DESIGN METHODS

Ditches shall be analyzed for depth, shear stress, and minimum velocity at appropriate intervals by solving Manning’s equation. Ditches should typically be analyzed at 50-foot intervals. Additional points of analysis may be required due to change in slope, inflow from other channels or pipes, a change in channel material, or a sudden increase in drainage area. Shear stress examination is shown in Figure 6-1. It should be noted that even if the ditch is in rock, one side of the ditch consisting of fill will not be able to withstand the shear stresses comparable to rock. Ditch design charts, programs, or nomographs may be used, provided the sources are documented and the data is presented in Form 6-1. The FHWA program Hydraulic Toolbox is recommended for ditch and ditch lining design.

Where design discharges exceed 50 cubic feet per second, the design of rock linings shall be based on FHWA’s HEC-11. For additional design guidance see HEC-23 Chapter 5 and Design guidelines 4 and 16.

**Figure 6-1**  
**Ditch Analysis Flowchart**



### 6.3.11 DRIVEWAY CONDUIT

The design goal for a driveway conduit placement is to convey the approaching and departing ditch flow with consistency (depth, velocity, and flow state) and without flooding the adjacent roadway subgrade. As a roadside ditch approaches a driveway, the conduit shall be sized and placed at a depth to meet the goal. The tables of Section 6.4.4 provide minimum guidelines for the roadside ditch (side slopes of 2:1) approaching and departing a driveway. These tables were created using typical site scenarios according to the type of property the driveway serves. The driveway conduit can be designed as a culvert for a more accurate hydraulic

representation of its function for the rainfall runoff. This may reduce the required roadside ditch depth when compared to the tables.

The approaching and departing ditch width (away from the conduit) should be a minimum width equal to the diameter. The approaching and departing grade should be the same as the conduit grade for a minimum distance equal to the conduit length. The preferred distance of equal grade is one equivalent to the bordering length of the property adjacent to the DOH right-of-way. In some cases, a consistent ditch grade approaching, through, and departing the driveway conduit may not be possible. The use of a flatter grade may benefit by creating a reduction in flow velocity; however, flow state changes can cause ditch erosion or aggradation due to sedimentation. The same flow state (subcritical or supercritical flow) should be present on both sides of the conduit. See Chapter 5, Section 5.3.6.9 regarding a change in the state of flow.

Driveways which intersect a roadway at a downgrade shall not discharge rainfall runoff from the driveway surface onto the adjacent sidewalk, shoulder, or traveled way. The preferable driveway profile should include a vertical sag curve prior to intersecting the adjacent roadway. If this profile cannot be achieved, the driveway surface flow shall be intercepted by a cross drain (refer to the Overland Flow Inlet Capacity Section of Chapter 5). See Section 10.4 and Figures 9A and 9B of the published Manual on Rules and Regulations for Constructing Driveways on State Highway Rights-of-Way.

The placement of the driveway conduit shall not alter the natural water course.

## 6.4 DESIGN GUIDELINES

### 6.4.1 MANNING’S EQUATION

Uniform flow exists in a channel when there is no change in velocity, the channel is straight, and without variance in slope or cross section along its length. Under this condition the acceleration is zero and the streamlines are straight. Uniform flow exhibits a constant velocity head with an energy grade line and water surface slope parallel to the channel bottom. When flow is uniform, the depth in the channel is referred to as normal depth. Uniform flow conditions can be assumed within ditches because they generally exhibit the above conditions within the analysis intervals and have prismatic shapes (triangular or trapezoidal). Therefore, Manning’s equation can be used to compute the velocity and normal depth for ditches.

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

n = roughness coefficient

R = Hydraulic Radius = A/P (ft)

A = Cross-sectional area of flow (ft<sup>2</sup>)

P = Wetted Perimeter of the cross-section (ft)

S = Slope of the energy grade line (ft/ft)

For a given discharge, normal depth is calculated by expressing A in terms of depth (d) and then solving for depth by trial and error. The slope of the energy grade line (S) can be approximated as the channel slope.

### 6.4.2 PERMISSIBLE SHEAR STRESS

Permissible shear stress is the force required to initiate movement of the ditch boundary material. The permissible shear stress or tractive force approach became recognized in the 1950's, based on research conducted by the US Bureau of Public Roads and later developed by the USDA Soil Conservation Service. This method is physically based and focuses on stresses developed at the interface between flowing water and the materials forming the ditch boundary. Factors such as the vegetative stiffness, density, height, ditch geometry, flow depth, and flow velocity of are considered. The ditch slope is an important parameter in determining the shear stress and it is generally dictated by the roadway profile. Ditches with slopes steeper than 2% will generally flow in a supercritical state and have higher shear stresses. Shear stress in a ditch is not uniformly distributed along the wetted perimeter. It is proportional to the depth of flow. The failure criteria for the lining material are represented by a single shear stress value that is applicable over a wide range of ditch slopes and shapes.

The maximum shear stress shall be used for the design of ditch protection, and it shall not exceed the permissible shear stress of the selected lining material. The maximum shear stress in a straight ditch occurs on the bed and is given by:

$$\tau_p = \gamma d S$$

$\tau_p$  = Permissible soil shear stress (lb/ft<sup>2</sup>)

$\gamma$  = Unit weight of water (62.4 lb/ft<sup>3</sup>)

d = depth of flow (ft)

S = Energy slope assumed equal to the ditch average bed slope (ft/ft)

Flow in a bend creates secondary currents which impose higher shear stresses on the ditch side slopes. As shown in Figure 6-2, at the beginning of the bend the maximum shear stress is near the inside and then moves towards the outside as flow leaves the bend. The maximum shear stress in a bend is a function of the ratio of ditch curvature to the top water surface width ( $R_c/T$ ). As the bend becomes sharper (as  $R_c/T$  decreases), the maximum shear stress in the bend increases as shown in Chart 6-1.

The maximum shear stress in a ditch bend is given by:

$$\tau_p = K_b \tau_d$$

$\tau_p$  = Permissible soil shear stress (lb/ft<sup>2</sup>)

$\tau_d$  = Maximum shear stress in an equivalent straight section of ditch (lb/ft<sup>2</sup>)

$K_b$  = Ratio of channel bend to bottom shear stress

$K_b$  can be determined from the following equation:

$$K_b = 2.38 - 0.206 \left( \frac{R_c}{T} \right) + 0.0073 \left( \frac{R_c}{T} \right)^2$$

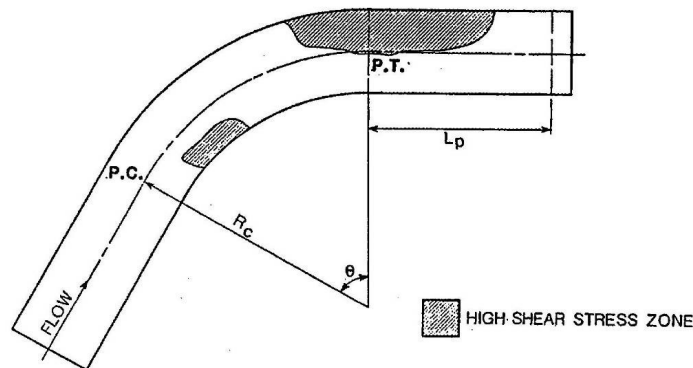
$R_c$  = radius of curvature of the bend to the ditch centerline (ft)

$T$  = Top water surface width (ft)

$K_b = 2$  for  $R_c/T \leq 2$

$K_b = 10$  for  $10 \geq R_c/T$

**Figure 6-2**  
**Shear Stress Distribution in a Bend**



Source: *Design of Roadside Channels with Flexible Linings, HEC-15, FHWA, 2005*

The increased shear stress caused by the bend persists a distance  $L_p$ , downstream of the bend. Chart 6-2 can also be used to determine the required protection length downstream of ditch bends.

The protection length downstream of the bend is given by the following equation:

$$L_p = 0.60 \left( \frac{R_c^7}{n_b} \right)$$

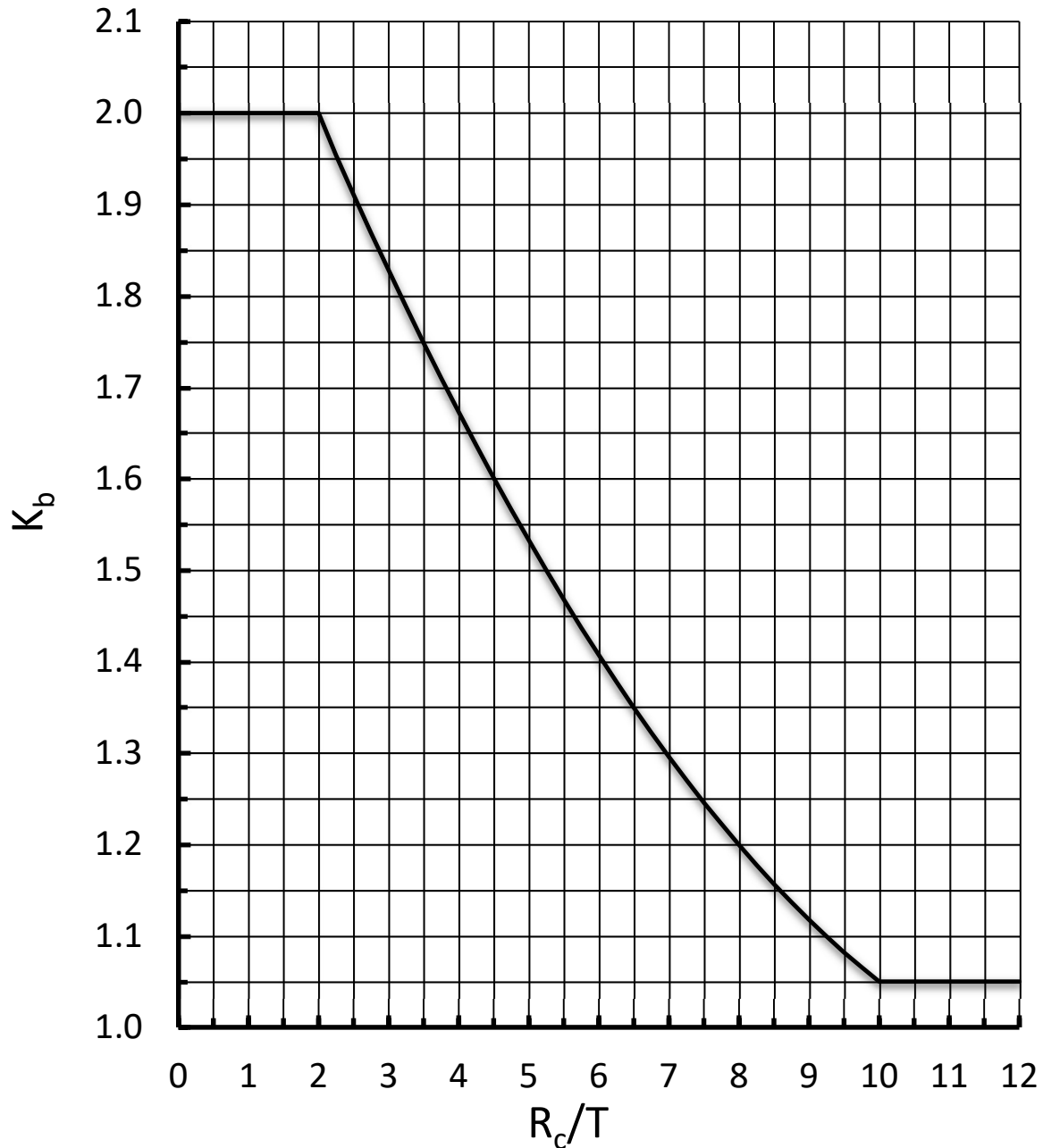
$L_p$  = Protection length downstream of bend (ft)

$R$  = Hydraulic radius of the ditch (ft)

$n_b$  = Manning's roughness coefficient in the bend

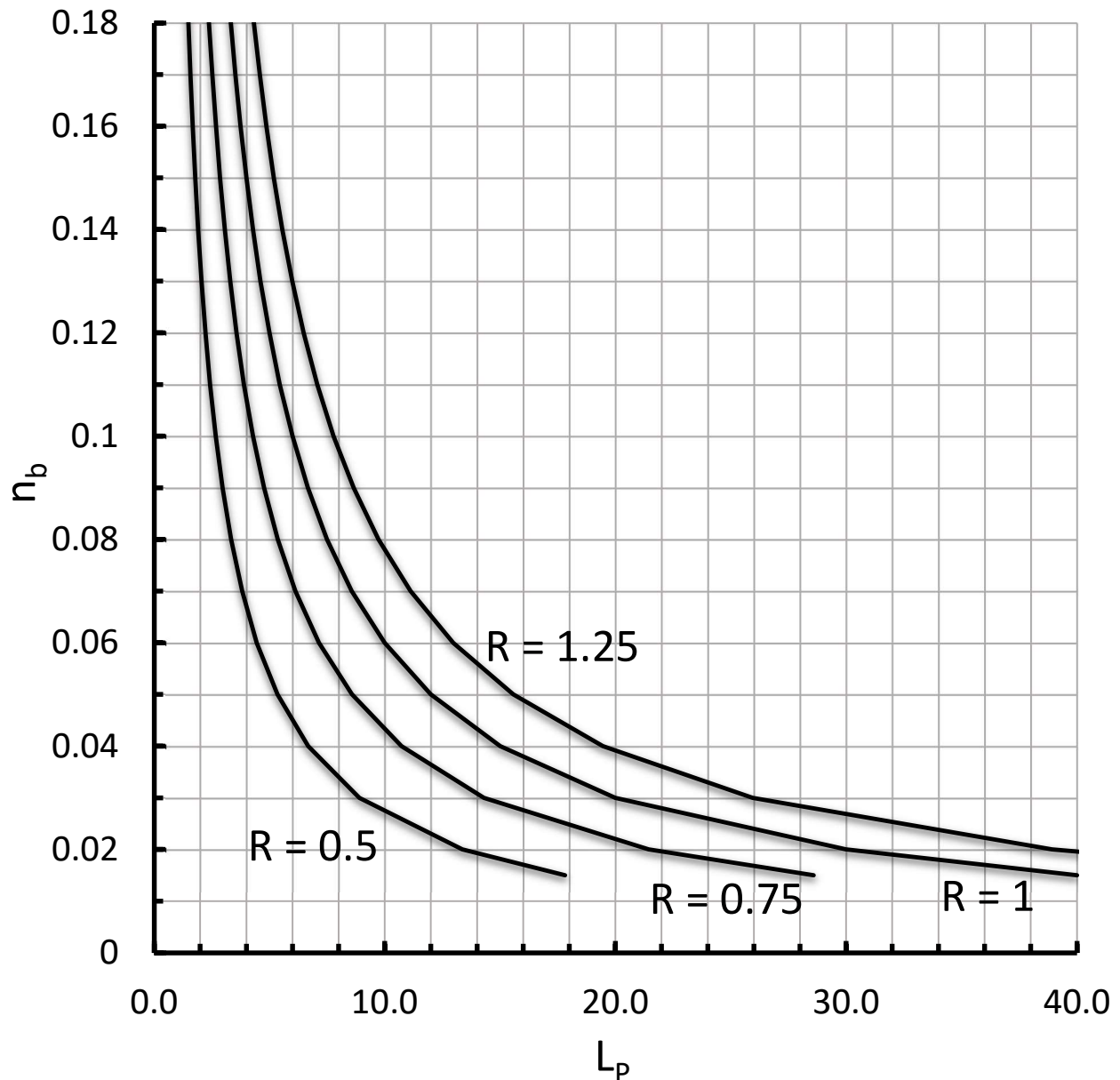
**Chart 6-1**

**$K_b$  Ratio of Channel Bend to Bottom Shear Stress**



Source: *Design of Roadside Channels with Flexible Linings, HEC-15, FHWA, 2005*

**Chart 6-2**  
**Protection Length  $L_p$  Downstream of Ditch Bend**



Source: *Design of Roadside Channels with Flexible Linings, HEC-15, FHWA, 2005*

### 6.4.2.1 PERMISSIBLE SHEAR STRESS FOR SOIL

Erosion of the soil boundary occurs when the effective shear stress exceeds the permissible soil shear stress. Permissible soil shear stress is a function of particle size, cohesive strength, and soil density. The permissible soil shear stress is needed to determine whether temporary matting will be used before vegetation is established. In most cases, the use of temporary matting is

good practice; however, in certain cases the existing soil will stand up to the lower return period storm for the temporary situation. This soil stress value is intended to support the judgment of not using temporary matting.

A clay soil can behave like a solid, semi-solid, plastic solid, or liquid depending on the amount of water in the soil. The water contents corresponding to the transitions between these states are known as the Atterberg Limits. Each of the Atterberg limits varies with the clay content, type of clay mineral, and ions (cations) contained in the clay. The Atterberg plastic limit (PL) and liquid limit (LL) are used to classify a soil. The plastic limit is the amount of water in the soil that transitions it from the semi-solid state to the plastic state. The liquid limit is the amount of water in the soil that transitions it from the plastic state to the liquid state. The difference between the liquid and plastic limits is known as the plasticity index ( $PI = LL - PL$ ). This index indicates the range in moisture content over which the soil is in a plastic state. In this state the soil can be deformed and still hold together without crumbling. A PI greater than 20 is considered high and indicates that a considerable amount of water can be added before the soil reaches the liquid state. The plasticity index correlates with strength, deformation properties, and insensitivity.

### Non-Cohesive Soils

The erodibility of coarse non-cohesive soils (defined as soils with a plasticity index of less than 10) is due mainly to particle size. The permissible shear stress for fine grained, non-cohesive soils is estimated at 0.02 lb/ft<sup>2</sup>. For coarse grained, non-cohesive soils the value ranges between 0.02 lb/ft<sup>2</sup> and 0.8 lb/ft<sup>2</sup>. If a gradation is available, the coarse-grained value is determined by:

$$\tau_p = 0.4 D_{75}$$

$\tau_p$  = Permissible soil shear stress (lb/ft<sup>2</sup>)

$D_{75}$  = Soil size where 75% of the material is finer (in)

### Cohesive Soils

Cohesive soils are largely fine grained, and their permissible shear stress depends on cohesive strength and soil density. Cohesive strength is associated with the plasticity index (PI), which is the difference between the liquid limit and plastic limit of the soil. Soil density is a function of the void ratio. A simplified approach for estimating permissible soil shear stress is illustrated in Figure 6-3.

**Figure 6-3**  
**Permissible Shear Stress for Cohesive Soil**

		Stress Range (lb/ft <sup>2</sup> )	
Fine Grained	10 < PI < 20	0.03 to 0.09	
	20 < PI	0.08 to 0.09	
Cohesive Soil Clay	20 < PI	0.12	
	10 < PI < 20	0.10 to 0.15	
Coarse Grained	20 < PI	0.15	

**6.4.2.2 PERMISSIBLE SHEAR STRESS FOR SOIL WITH VEGETATION**

Grass linings are generally suitable for protecting ditches with gradients up to 10 percent and with side-slopes flatter than 3H:1V. The combined effects of the soil permissible shear stress and the effective shear stress transferred through the vegetative lining results in a permissible shear stress for the vegetative lining.

Table 6-3 provides the permissible shear stress values for the WVDOH Standard Specification seed mixtures. Vegetative ditch linings should consist of seed mixture Type B with the use of Type C-1 in areas viewable and traversable by traffic. Type C-2 may be used in areas next to the roadway in an urban setting.

The computed maximum shear stress value is compared to the permissible shear stress for the selected category of grass lining/seed mixture and underlying soil type. This is accomplished by determining the maximum depth in the ditch and computing the shear stress at the bed. If the permissible shear stress of the selected grass lining and underlying soil type is greater than the computed maximum shear stress at the bed, the grass lining is considered adequate. If the grass lining is determined unacceptable, another seed mixture with a higher permissible shear stress should be selected. The use of permanent erosion control matting should also be considered to supplement the grass lining if shear stress values are at the maximum permissible limit.

If the design situation requires more detail, see HEC-15 2005 Edition, Section 4.3.3. A soil sample will be required and tested to provide the soil grain roughness, plasticity index, void ratio, gradation, and ASTM soil classification.

**Table 6-3**  
**Permissible Shear Stresses for Grass Linings**

WVDOH Grass Seed Mixture	Permissible Shear Stress (lbs/ft <sup>2</sup> )	Underlying Soil Type
Type B (mowed)	1.0	non cohesive and cohesive
Type C-1 (mowed)	1.0	non cohesive and cohesive
Type C-2 (mowed)	0.35	non cohesive and cohesive
Type B (unmowed)	3.2	non cohesive
	4.2	cohesive
Type C-1 (unmowed)	3.2	non cohesive
	4.2	cohesive
Type C-2 (unmowed)	0.53	non cohesive
	0.70	cohesive

**6.4.2.3 PERMISSIBLE SHEAR STRESS FOR MATTING WITH VEGETATION**

The Erosion Control Technology Council refers to Erosion Control Mats as Rolled Erosion Control Products (RECP). RECPs are defined as temporary, or degradable, and long-term or non-degradable materials designed and manufactured to reduce soil erosion and assist in the growth, establishment, and protection of vegetation. Matting is classified as either temporary or permanent based on performance and durability.

Temporary Matting – Temporary, degradable matting is composed of materials that are designed to break down leaving a vegetative lining behind. They are typically constructed of straw, jute, and coconut fibers in one or two layers. Pure straw matting is not recommended for use in ditch design.

There are two types of temporary matting that are acceptable for use in ditches. Each is classified by their effective lifespan and permissible shear stress (Table 6-4). The first type usually consists of a 70% straw to 30% coconut fiber matrix that is stitched together with a biodegradable thread between two layers of biodegradable jute netting. This type typically has an effective life span of about 18 months. The second type usually consists of a 100% coconut fiber inner layer between two layers of biodegradable jute netting. This type typically has a slightly longer effective life span of about 24 months.

The permissible shear stress value for the permanent condition shall be the same as that for the vegetation and underlying soil after matting has biodegraded. The design shear stress for the

temporary condition shall be one caused by a discharge for a two-year recurrence interval storm (see Figure 6-1). The matting shall resist the shear stress for the temporary condition.

**Table 6-4**

**Permissible Shear Stresses for Temporary Matting**

Matting Type	Permissible Shear Stress for Temporary Matting (lbs/ft <sup>2</sup> )
Straw and Coconut matrix	2.0
Coconut only layer	2.2

Permanent Matting - Long term, non-degradable or permanent matting is composed of materials that are designed to enhance vegetative growth and extend the erosion control performance of grass linings. WVDOH permanent matting types are covered in the standard specifications in section 715.24. Each type is specified by ASTM test methods describing minimum mat thickness, tensile strength, elongation, porosity, resiliency, and ultraviolet stability. Acceptance of other permanent matting for use on a project shall be based upon meeting the state specification and provided certified test data justifying adherence to those specifications.

Permissible shear stress values for each permanent matting type in vegetated and non-vegetated states are given in Table 6-5. Permissible shear stress for the non-vegetated state is considerably less than the values for the vegetated state and will usually control the design. When the maximum shear stress exceeds the maximum permissible shear stress of the grass lining with permanent matting, stronger materials such as rock or concrete lining should be considered.

**Table 6-5**  
**Permissible Shear Stresses for Permanent Matting**

Matting Type	Permissible Shear Stress for Permanent Matting (lbs/ft <sup>2</sup> )	
	Vegetated (Evaluate for Q <sub>10</sub> )	Non-vegetated (Evaluate for Q <sub>2</sub> )
Type A	4	1
Type B	6	1.5
Type C	8	2

While matting has been shown to be effective in protecting vegetated ground surfaces, it is not appropriate in all locations Matting should not be used in:

- Ditches where maintenance is likely due to sediment build up. Pulling ditches with matting can result in loss of contact with the soil or loss of the matting completely.
- Uneven surfaces where ground contact of the matting will not be continuous.
- Rocky soils where anchorage is difficult.
- Non-vegetated applications
- Severe slopes
- Ditches with continuous flow
- Unfertile soils
- Shoreline applications with high wave action

It is important that the installation of temporary or permanent matting follow the manufacturers' guidelines. The permissible shear stress values depend upon proper installation.

**6.4.2.4 PERMISSIBLE SHEAR STRESS FOR ROCK LINING**

Ditches within rock cut sections shall not require a determination of a permissible shear stress.

Mannings roughness value (n) is based on the design depth.

The procedure for determining the proper characteristic size of rock lining shall follow that of Hydraulic Engineering Circular-15, Chapter 6, September 2005. The latest version of the FHWA Hydraulic Toolbox uses the methods of HEC-15 and may be utilized for design calculations. Equation 6.8 of that document shall be used to size the lining for the bottom of the ditch when the grade of the ditch is less than 5 percent. Equation 6.11 of that document shall be used when the grade of the ditch is greater than 10 percent. This equation provides the characteristic size

of rock lining for the channel bottom and the channel sides. For slopes between 5 and 10 percent, both equations will be applied, and the larger characteristic size of rock lining shall be used for design.

For ditch gradients less than 5 percent, the rock lining design process can be simplified when limiting the  $D_{50}$  to 4, 6, or 8 inches by examining the shear stress. The permissible shear stress values in Table 6-6 shall be used to obtain the required characteristic size of the lining for rock linings in ditches with gradients less than 5 percent. These permissible values are compared to the maximum shear stress along the bottom of the ditch (see Section 6.4.2).

**Table 6-6**  
**Permissible Shear Stresses for Rock Lining with Less than 5% Grade**

Rock (D <sub>50</sub> ) inches	Permissible Shear Stress (lbs/ft <sup>2</sup> )
4	1.6
6	2.4
12	4.8

The shear stress on the sides of the ditch is less than the maximum shear stress occurring on the ditch bottom. The stability of a side slope lining is a function of the side slope and the angle of repose of the lining material. This essentially results in a lower permissible shear stress on the side slope than on the bottom. These two counterbalancing effects lead to the following equation to obtain the required characteristic size of the lining (D<sub>50</sub>) for rock linings in ditches with side-slopes steeper than 3H:1V.

$$(D_{50})_{SIDES} = \frac{K_1}{K_2} (D_{50})_{BOTTOM}$$

K<sub>1</sub> = side to bottom shear stress ratio

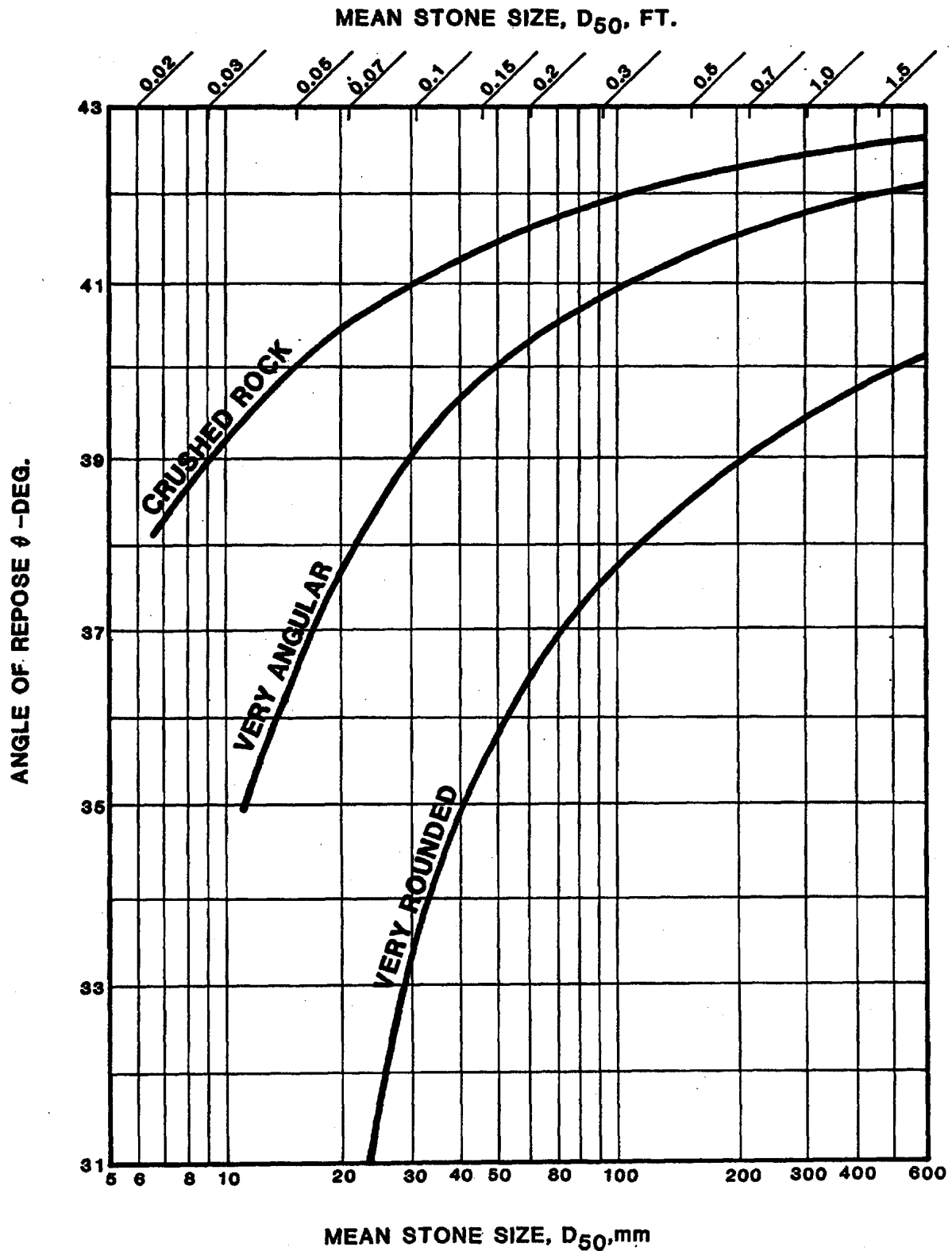
K<sub>2</sub> = tractive force ratio

The angle of repose for different rock shapes (Θ) and sizes is presented in Chart 6-3. Chart 6-4 is used to obtain the ratio of the shear stress on the side-slopes to the shear stress on the bottom of the ditch (K<sub>1</sub>). Values needed to obtain this shear stress ratio are the ratio of the bottom width of ditch (B) to flow depth (d) and the ditch side-slope (Z). Chart 6-5 is used to obtain the tractive force ratio (K<sub>2</sub>) based on the angle of the side-slope and the angle of repose of the rock lining. Rock should be graded so that it follows a smooth size distribution curve and the spaces between the larger stones are filled in an interlocking fashion by the smaller stones. Most gradations that fall in the range of D<sub>100</sub>/D<sub>50</sub> = 3.0 and D<sub>50</sub>/D<sub>20</sub> = 1.5 are considered acceptable.

The rock should be angular rather than rounded, flat, or slab-like. An approximate guide to a stone shape is that neither the breadth nor the thickness should be less than one-third of its length. The thickness of the rock lining should equal the diameter of the largest rock size in the gradation. For most gradations, this will mean a rock lining thickness equal to 1.5 to 3.0 times the mean rock diameter (D<sub>50</sub>).

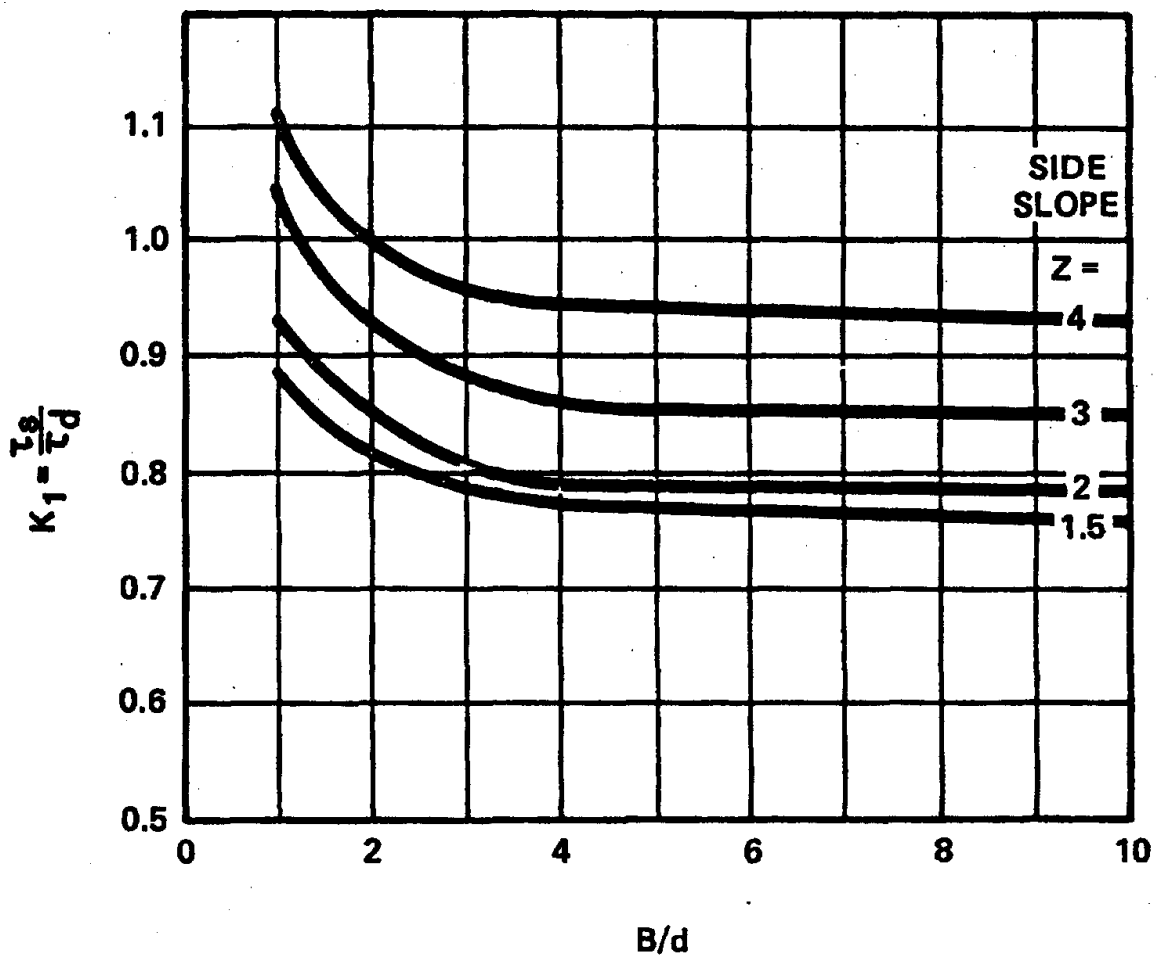
If the rock lining design is not performed using the shear stress comparison with Table 6-7 or the ditch gradient is greater than 5 percent, using Varying n value with respect to the flow depth.

**Chart 6-3**  
**Rock Lining: Angle of Repose**



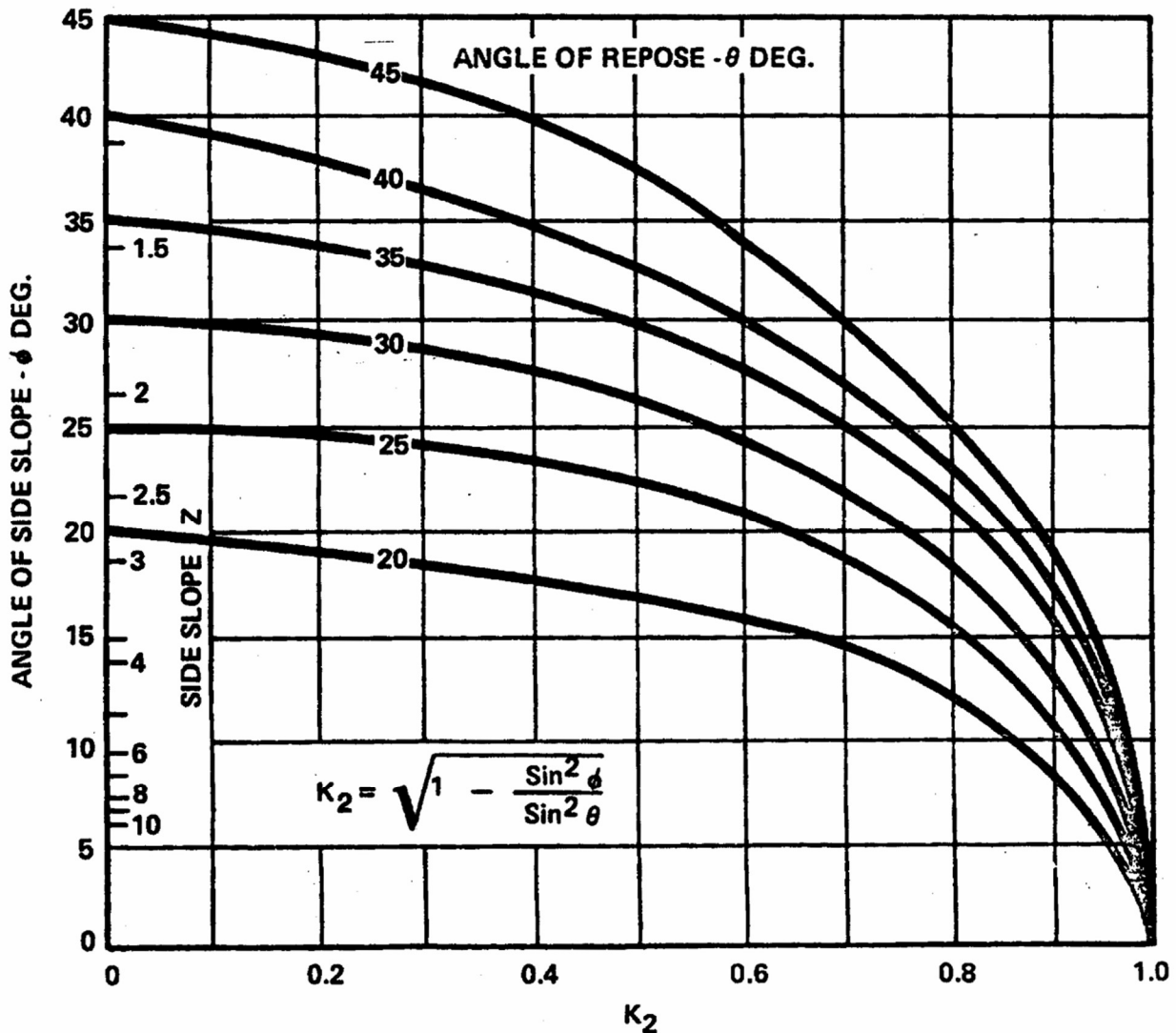
Source: *Design of Roadside Channels with Flexible Linings*, HEC-15, FHWA, 1988

**Chart 6-4**  
**Rock Lining: Side to Bottom Shear Stress Ratio  $K_1$**



Source: *Design of Roadside Channels with Flexible Linings, HEC-15, FHWA, 1988*

**Chart 6-5**  
**Rock Lining: Tractive Force Ratio  $K_2$**



Source: *Design of Roadside Channels with Flexible Linings, HEC-15, FHWA, 1988*

### 6.4.3 DITCH INLET CAPACITY

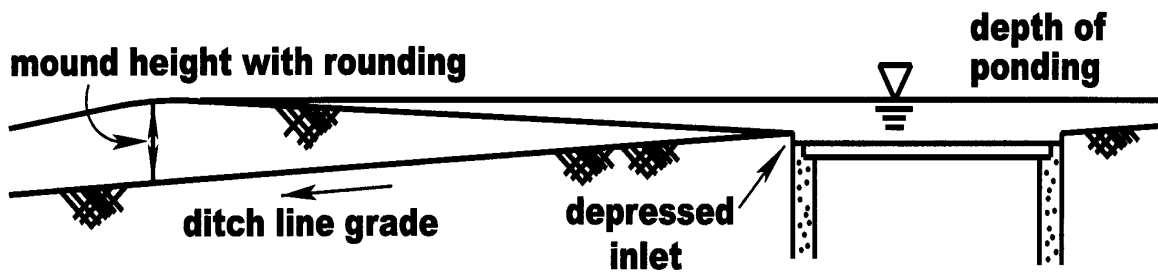
It is important to note that ditches are designed for a return period of 10 years; therefore, the grate inlet capacity should be based on the 10-year storm. As stated in Section 6.3.6, ditch inlets use Type G grates. These inlets are installed with a 1-foot-high mound down grade of the grate at eight to ten feet (see WVDOH standard details and Table 6-7). This installation results in the determination of capacity as if it were in a sag vertical curve (see Section 5.3.4.8).

Chart 6-7 through Chart 6-20 were developed from equations in HEC-22. These charts provide the interception capacity for standard Type G grates ranging in size from 32" X 38" to 60" X 66" according to the average depth of flow over the grate. The average depth is used in case the

choice is made to install the grate on the incline of the mound. This type of installation may be useful for a roadside ditch in an area where a large amount of natural litter is present.

The amount of available ponding depth should be checked for each inlet as this will depend on the grade of the ditch line it resides (see Figure 6-4). In most cases, the maximum allowable depth within the ditch (see Section 6.3.3) or the maximum allowable inlet spacing will control the ponding at the inlet. However, the ponding depth should be checked to ensure that it does not adversely affect the roadway pavement subgrade. Table 6-7 shows the amount of available ponding depth for ditch slopes of 0.5% to 7.5%. A depressed inlet may be installed to provide additional ponding depth. For slopes greater than 7.5% a special detail for the inlet mound will be needed as the standard detail provides little to no ponding depth at such steep slopes.

**Figure 6-4**  
**Profile View of Ponding Depth at a Type G Inlet**



**Table 6-7**  
**Type G Inlet Available Ponding Depth**

Ditch Grade (%)	Horizontal Distance to Top of Mound (ft)	Available Ponding Depth (0.5" loss due to mound rounding) (in)
0.5	10	10.9
1	10	10.3
2	10	9.1
3	10	7.9
4	9	7.2
5	9	6.1
6	8	5.7
7	8	4.8
7.5	8	4.3

Overtopping of the inlet mound shall not be allowed, but it may be calculated for a check storm. This overtopping discharge would be calculated using equations for flow over a broad crested

weir according to the depth of flow over the mound. The inlet capacity charts can be used to determine the ponding depth that causes the mound overflow.

In a case where a Type G inlet is used in a rural roadside ditch or an urban ditch without a mound down grade it is treated as an inlet on grade (meaning bypass flow can occur). The ditch flow is primarily all frontal flow if the width of the grate is equal to the bottom width of the ditch. If the width of the ditch bottom is wider than the width of the grate there will be some side flow (see Figure 6-5).

As stated in Chapter 5 (see Section 5.3.4.4), the total intercepted flow capacity of an inlet grate is:

$$Q_i = E Q$$

E = total efficiency of a grate

Q = total gutter flow (ft<sup>3</sup>/s)

With total efficiency as:

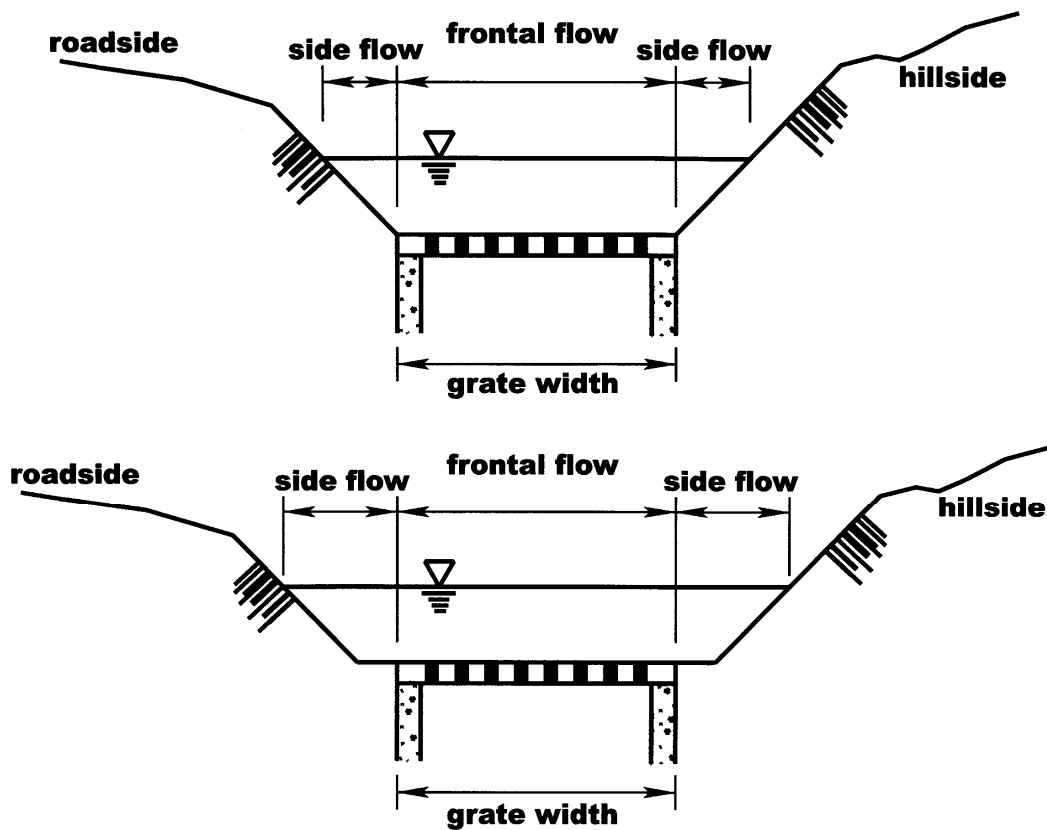
$$E = R_f E_o + R_s ( 1 - E_o )$$

R<sub>f</sub> = ratio of frontal flow intercepted to total frontal flow

R<sub>s</sub> = ratio of side flow intercepted to total side flow

E<sub>o</sub> = ratio of frontal flow to total gutter flow

**Figure 6-5**  
**Frontal and Side Flow for Type G Inlets without the Mound**



The interception efficiencies for frontal and side flow for Type G grates are obtained from Chapter 5, Chart 5-7, and Chart 5-8, respectively. The ratio of frontal flow to total gutter flow ( $E_o$ ) for a trapezoidal channel is shown in Chart 6-6 and obtained from the following equation:

$$E_o = W / (B + d z)$$

W = width of the grate (ft)

B = bottom width of the channel (ft)

d = depth of flow (ft)

z = horizontal distance of side slope to a rise of 1 ft vertical (ft)

For a trapezoidal channel, Manning's equation becomes:

$$Q = \frac{1.486}{n} (Bd + z d^2) \left( \frac{Bd + z d^2}{B + 2 d \sqrt{z^2 + 1}} \right)^{0.67} S_L^{0.5}$$

n = roughness coefficient

S<sub>L</sub> = bed slope (ft/ft)

This equation can be used to solve for depth of flow knowing the flow amount at any point in the ditch (usually obtained by the Rational Method). See Section 5.3.4.4 in Chapter 5 for more specific information on calculating inlet capacity on grade using frontal (R<sub>f</sub>) and side (R<sub>s</sub>) flow efficiencies.

The flow area is needed to determine the average velocity within the ditch. It is calculated as the area of a trapezoid (four-sided shape consisting of two parallel sides). The average velocity is required to determine the frontal flow and side flow efficiencies R<sub>f</sub> and R<sub>s</sub>, respectively.

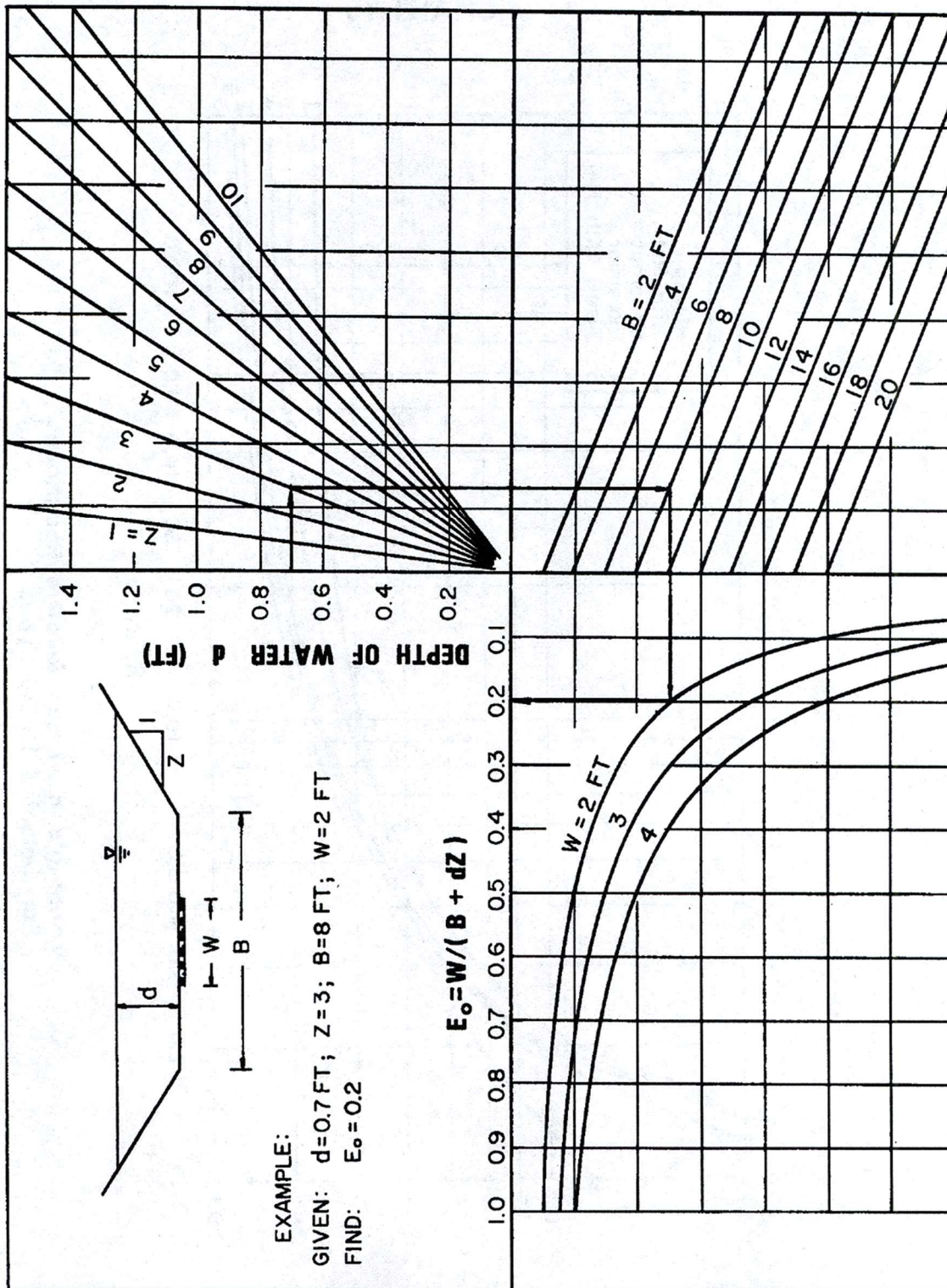
$$A = \frac{1}{2} d (B + T)$$

T = top width of the flow, ft

Flanking inlets may be necessary if the roadside ditch alignment has a sag vertical curve, and the mounding detail is not used. The designer shall examine the possibility of flooding the roadway subgrade if the grate should become completely blocked at the sag. The flanker inlets will most likely be the same as that of the sag inlet for grate installations without the mounding detail. See Section 5.3.4.10 in Chapter 5 for more information.

As stated in Section 5.3.4.7 a grate inlet in a sag location operates as a weir to depths that are dependent on the size of the grate and as an orifice at greater depths. Charts 6-12 through 6-24 give the value for interception capacity (Q<sub>i</sub>) for an average depth over the grate (d<sub>AV</sub>) in weir flow based on the effective perimeter (P) in feet and in orifice flow based on the effective clear open area of the grate (A) in square feet.

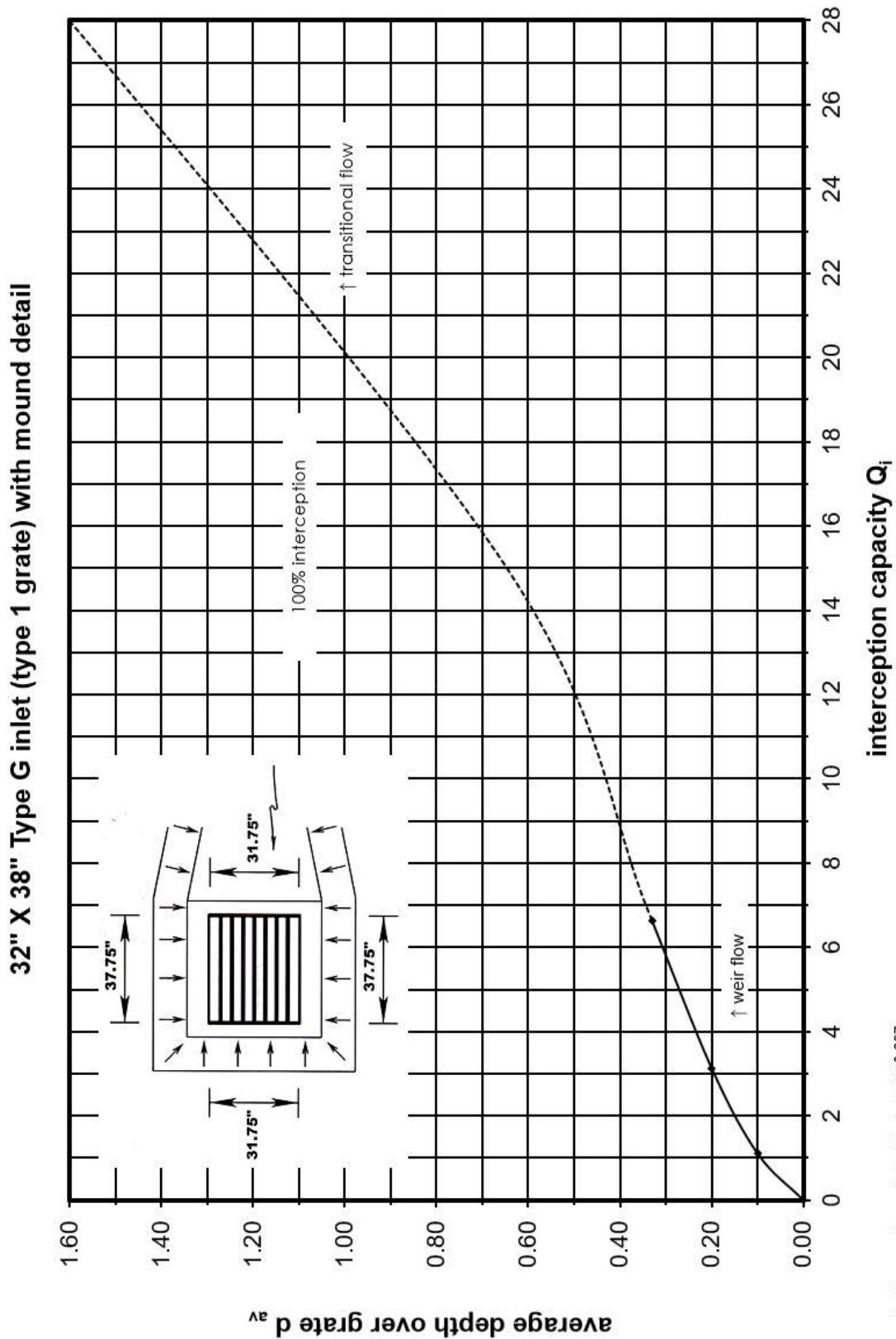
**Chart 6-6**  
**Frontal Flow / Total Flow for a Trapezoidal Channel**



Source: Urban Drainage Design Manual, HEC-22, FHWA, August 2001

Chart 6-7

32" X 38" Type G grate inlet with mounding detail (Type 1 grate)



weir flow  $d_{av} = (Q / (3 P))^{0.667}$   
 orifice flow  $d_{av} = 1 / (2 * g) * (Q / (0.67 A))^2$

Chart 6-8

36" X 42" Type G grate inlet with mounding detail (Type 1 grate)

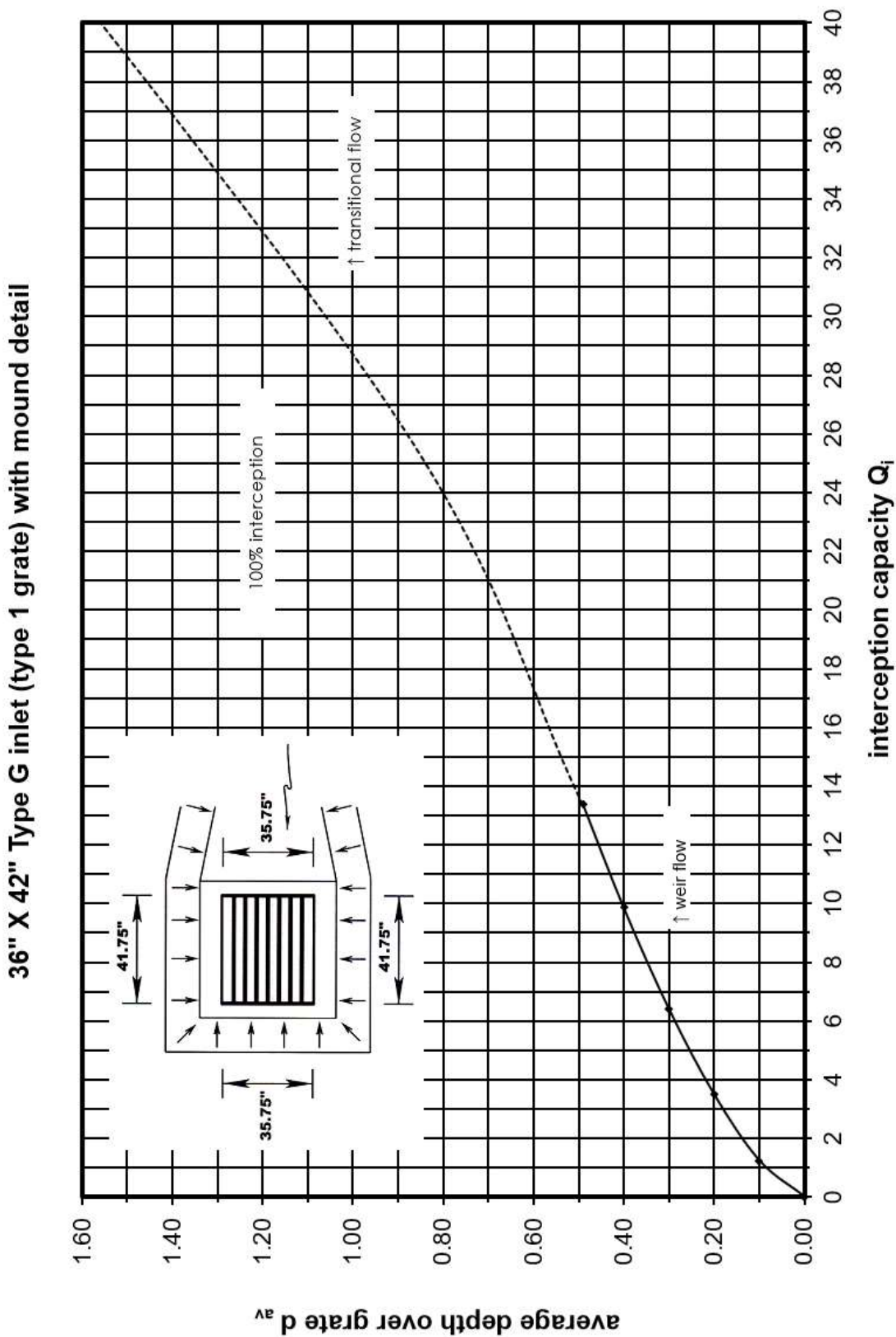


Chart 6-9

42" X 48" Type G grate inlet with mounding detail (Type 1 grate)

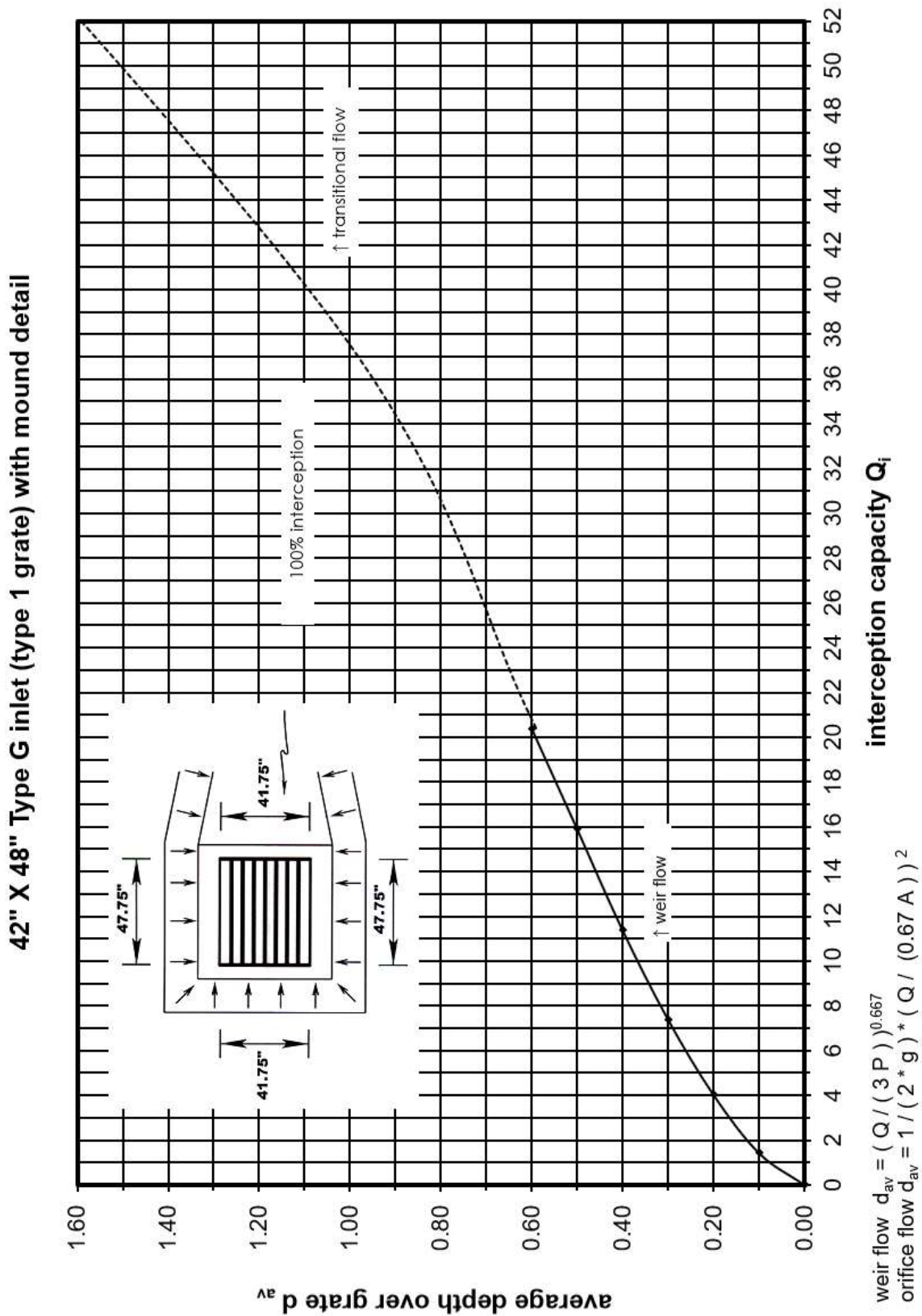
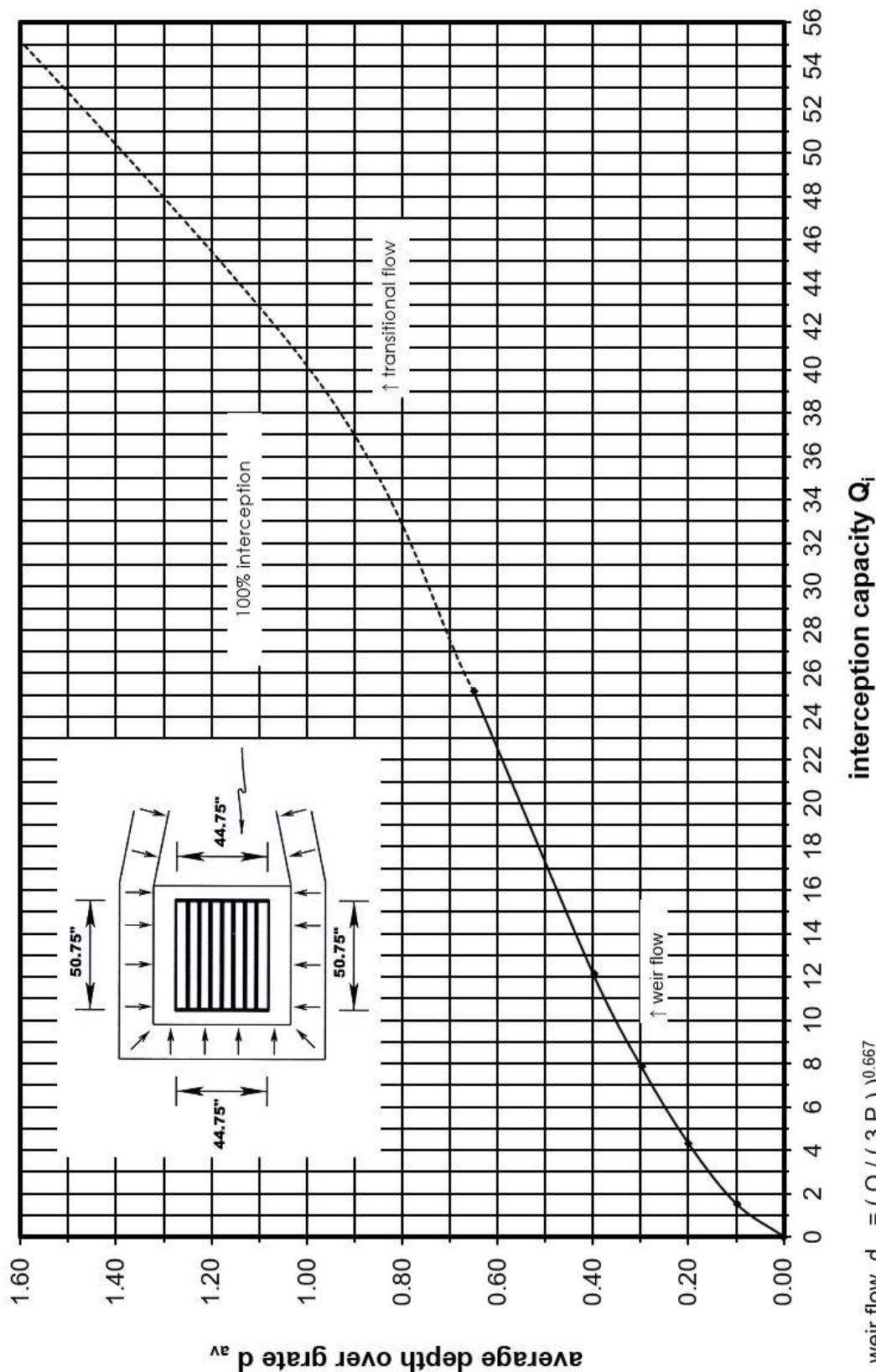


Chart 6-10

45" X 51" Type G grate inlet with mounding detail (Type 1 grate)

45" X 51" Type G inlet (type 1 grate) with mound detail



weir flow  $d_{av} = (Q / (3 P))^{0.667}$   
 orifice flow  $d_{av} = 1 / (2 * g) * (Q / (0.67 A))^2$

**Chart 6-11**

**48" X 54" Type G grate inlet with mounding detail (Type 1 grate)**

**48" X 54" Type G inlet (type 1 grate) with mound detail**

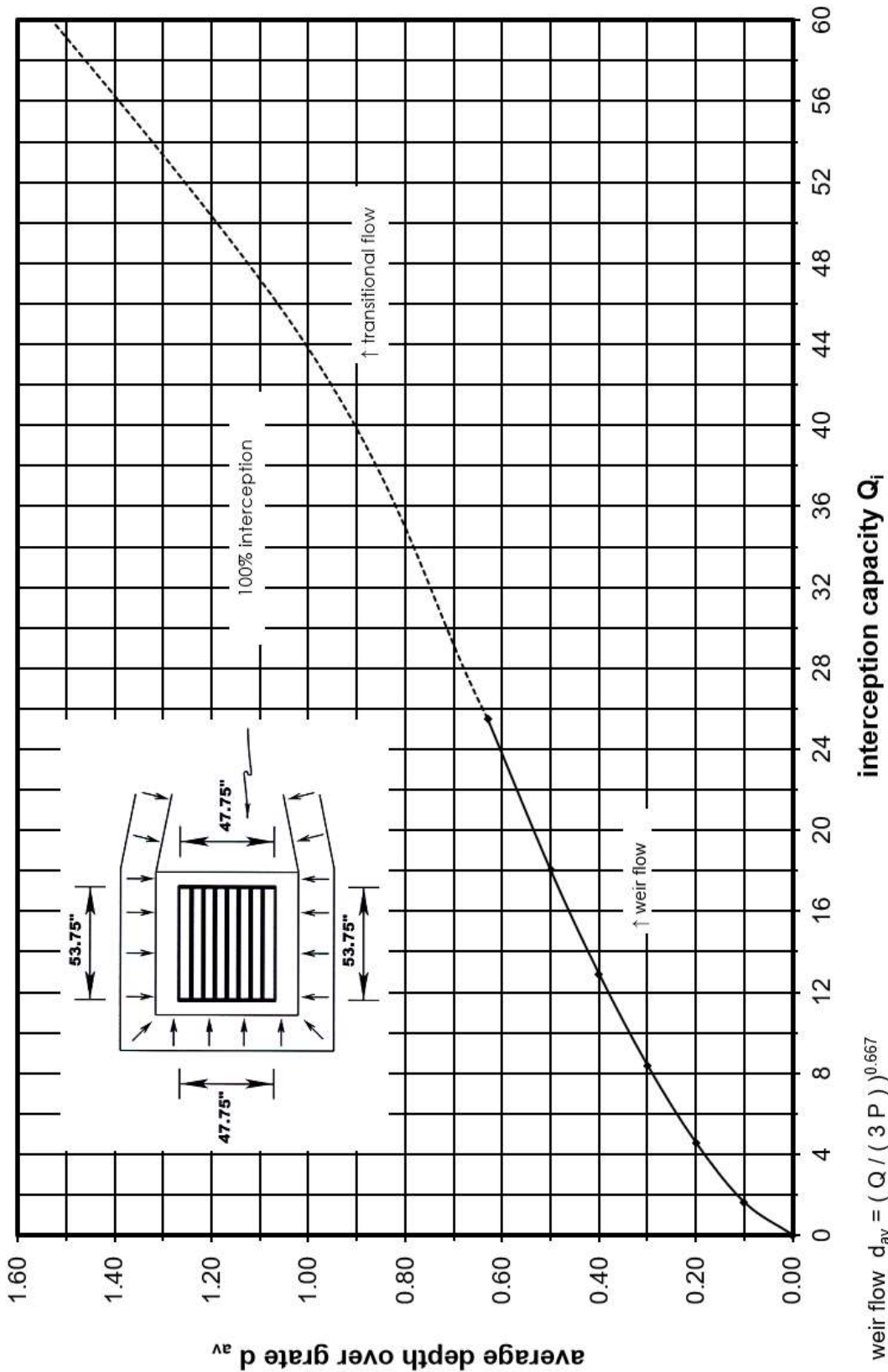
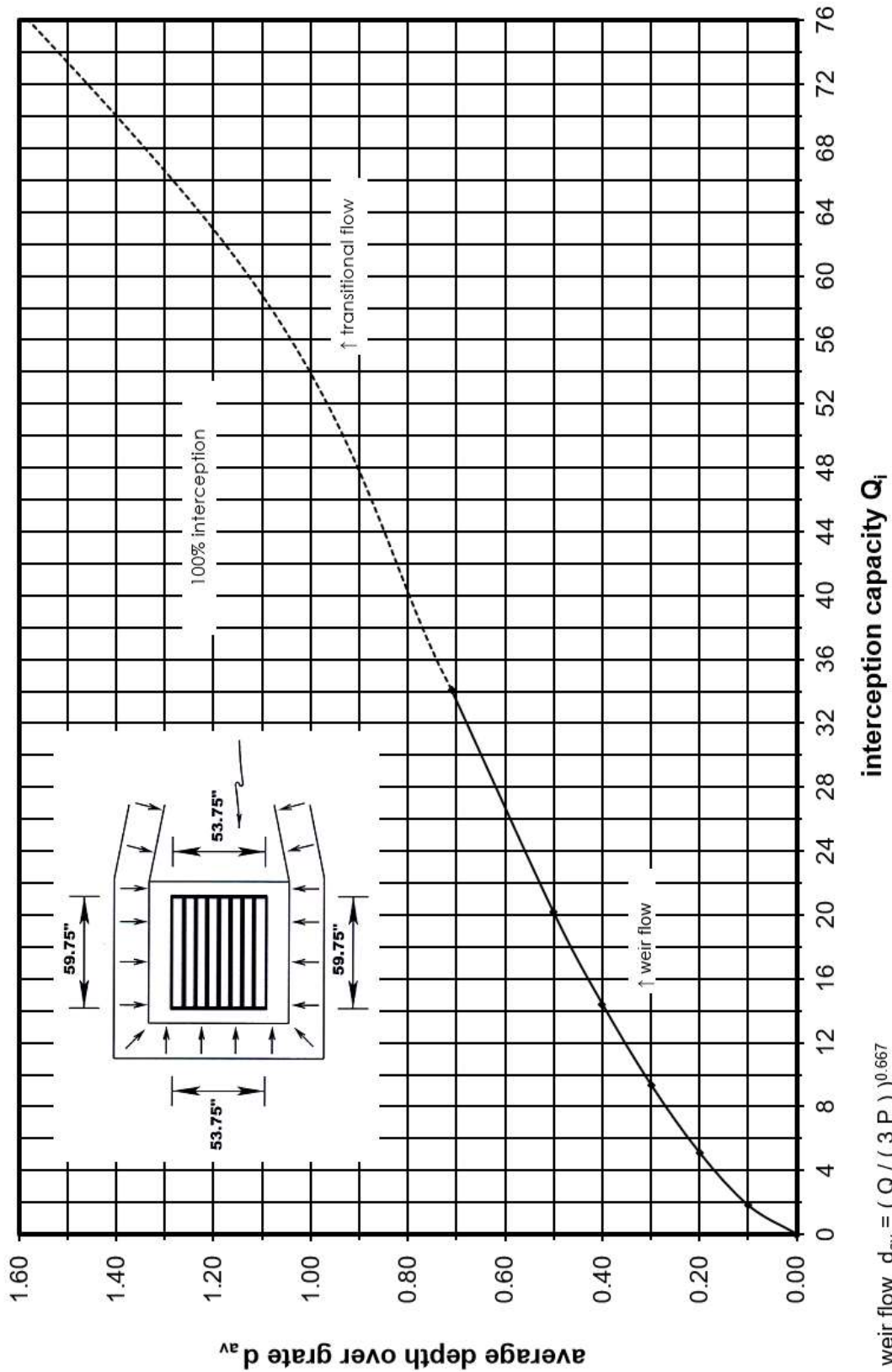


Chart 6-12

54" X 60" Type G grate inlet with mounding detail (Type 1 grate)

54" X 60" Type G inlet (type 1 grate) with mound detail

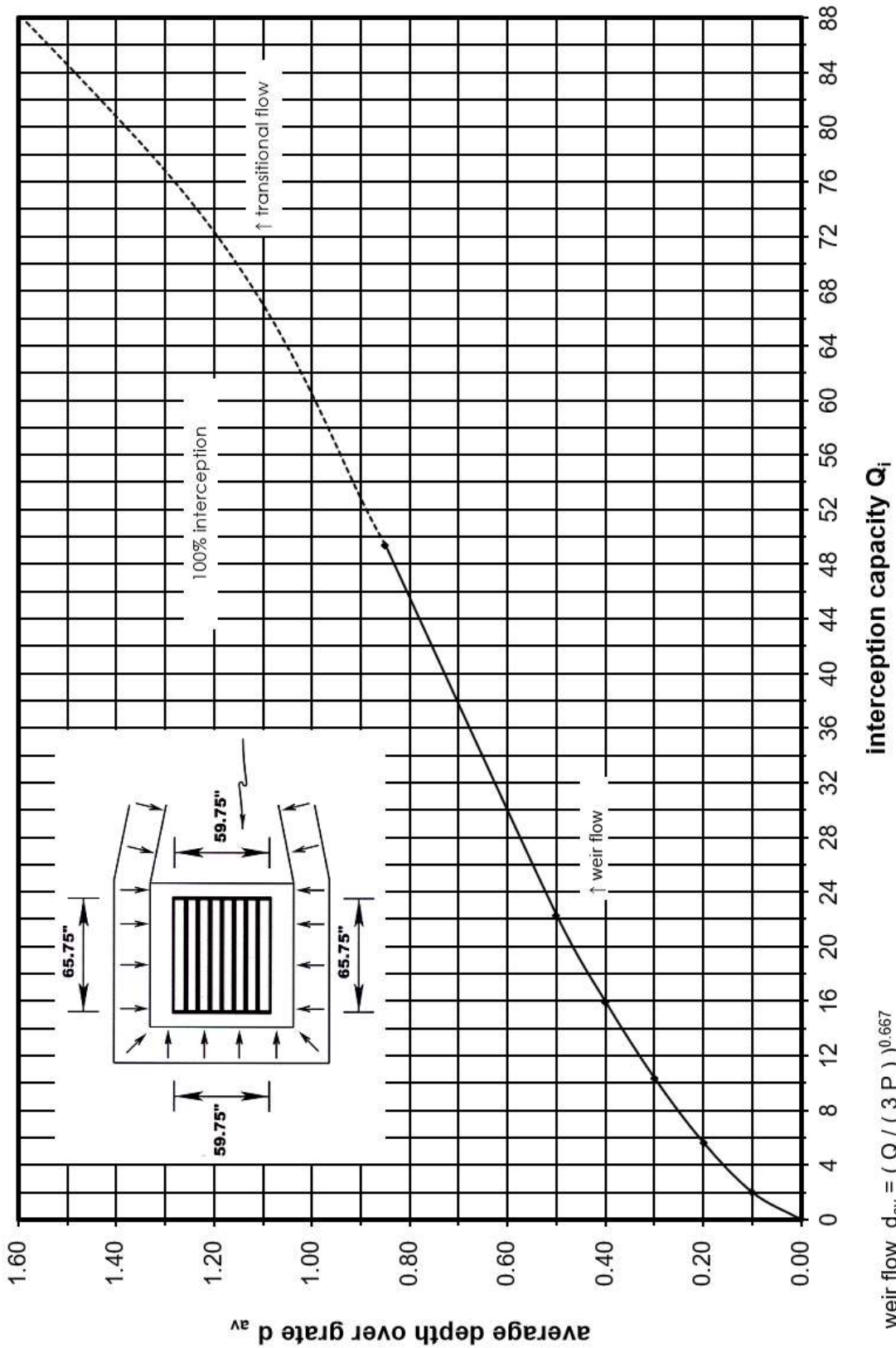


weir flow  $d_{av} = (Q / (3P))^{0.667}$   
 orifice flow  $d_{av} = 1 / (2 * g) * (Q / (0.67 A))^2$

Chart 6-13

60" X 66" Type G grate inlet with mounding detail (Type 1 grate)

60" X 66" Type G inlet (type 1 grate) with mound detail



interception capacity  $Q_i$

weir flow  $d_{av} = (Q / (3 P))^{0.667}$   
 orifice flow  $d_{av} = 1 / (2 * g)^{0.5} * (Q / (0.67 A))^{0.5}$

Chart 6-14

32" X 38" Type G grate inlet with mounding detail (Type 2 grate)

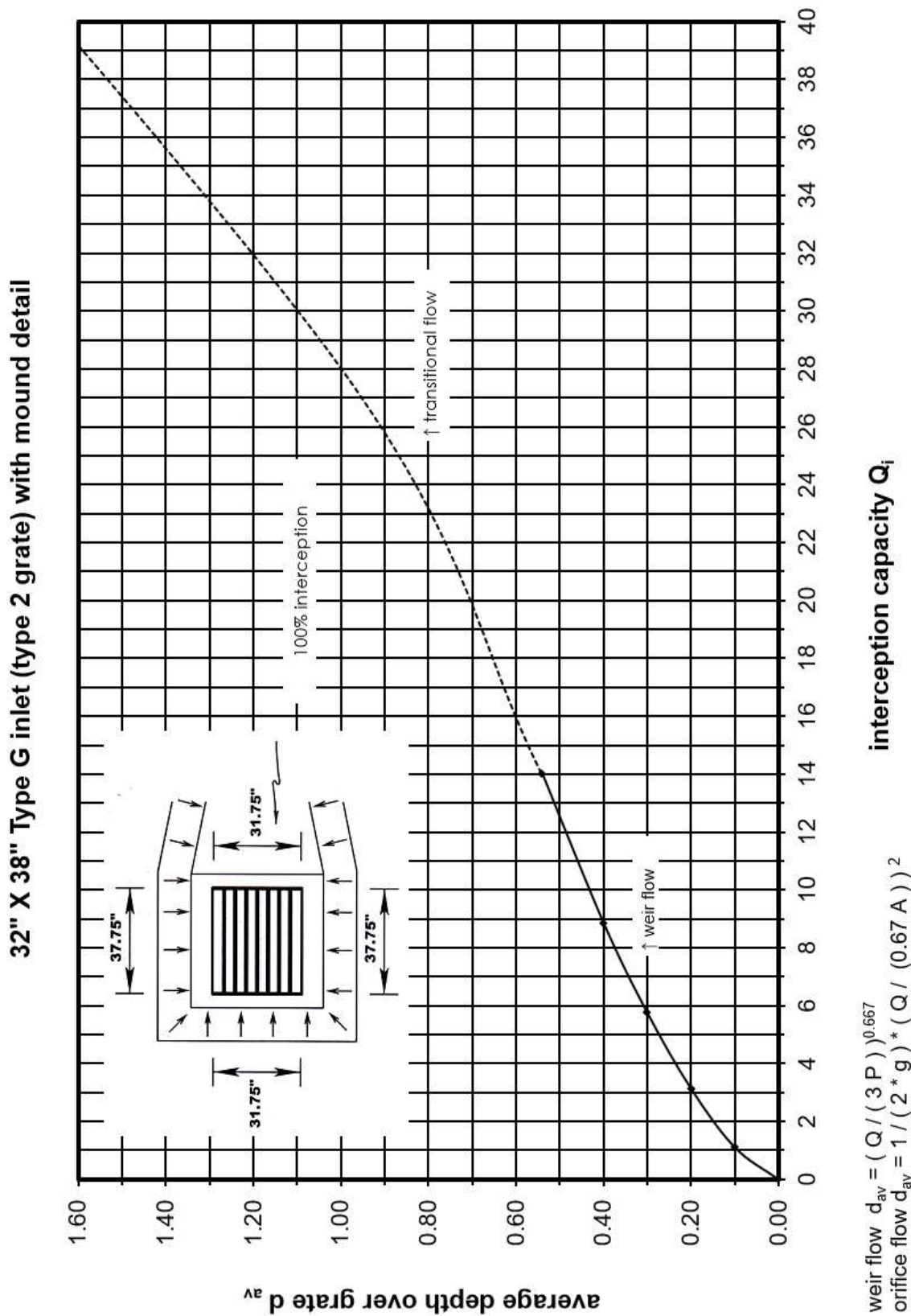
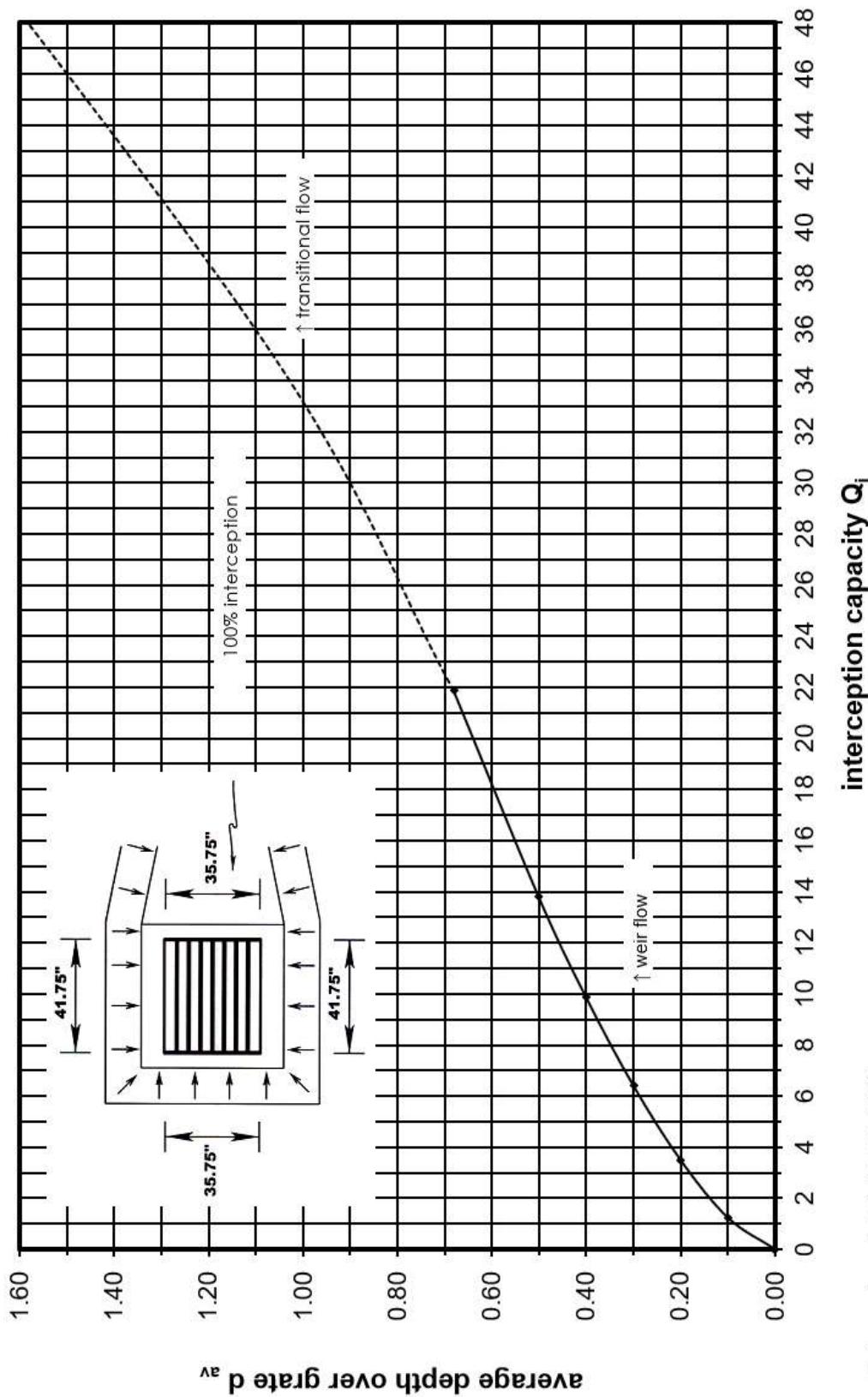


Chart 6-15

36" X 42" Type G grate inlet with mounding detail (Type 2 grate)

36" X 42" Type G inlet (type 2 grate) with mound detail



weir flow  $d_{av} = (Q / (3 P))^{0.667}$   
 orifice flow  $d_{av} = 1 / (2 * g) * (Q / (0.67 A))^2$

Chart 6-16

42" X 48" Type G grate inlet with mounding detail (Type 2 grate)

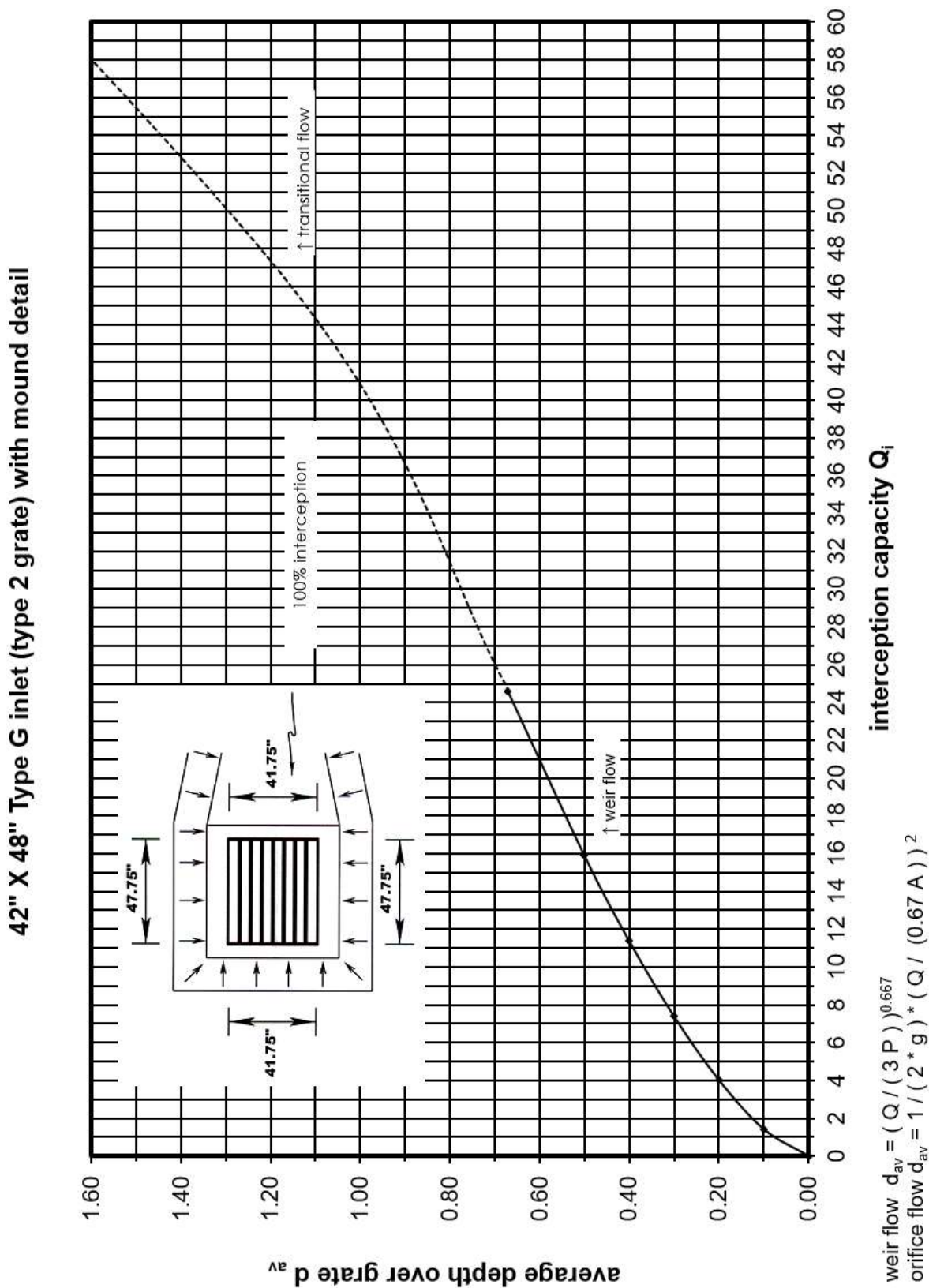


Chart 6-17

45" X 51" Type G grate inlet with mounding detail (Type 2 grate)

45" X 51" Type G inlet (type 2 grate) with mound detail

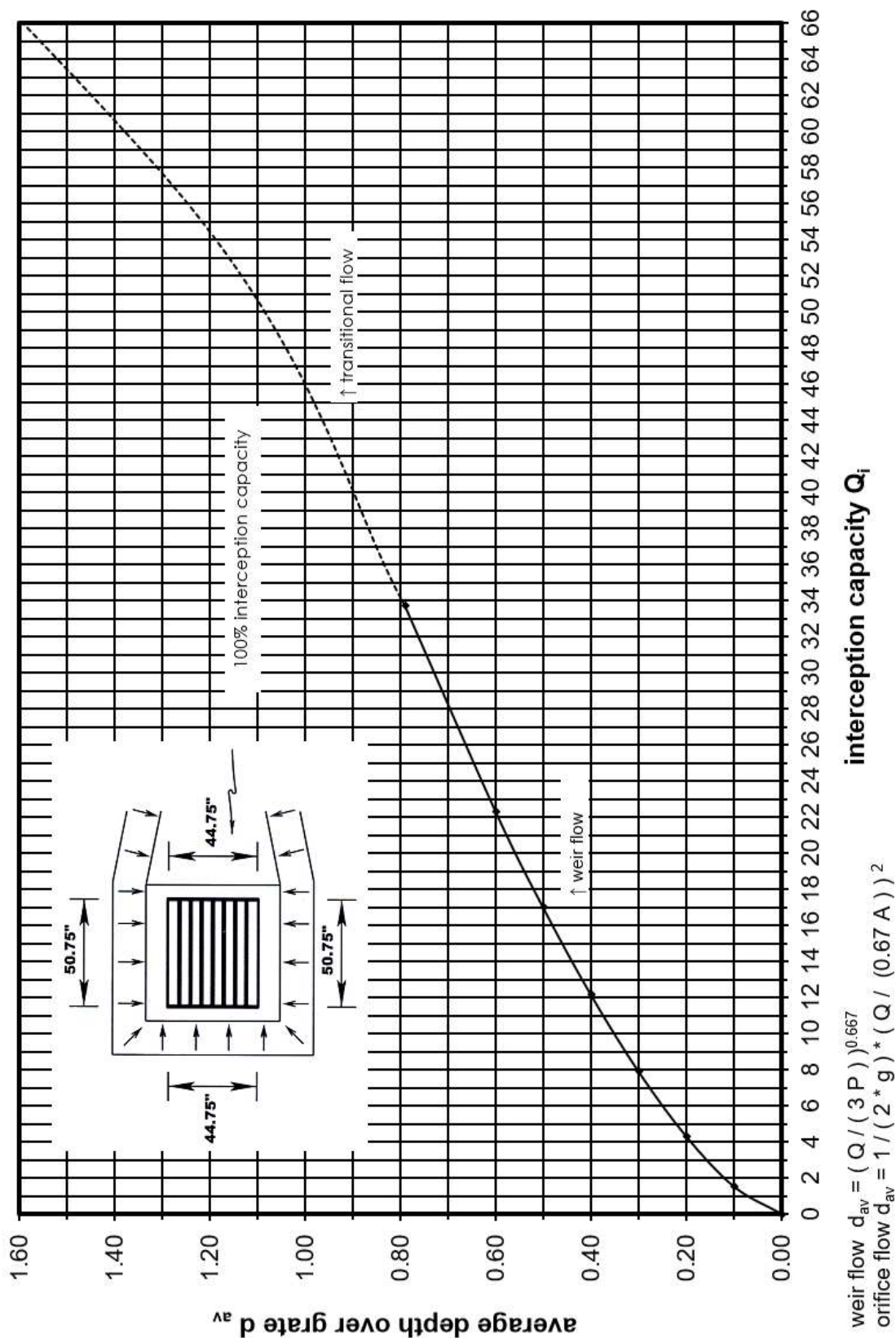


Chart 6-18

48" X 54" Type G grate inlet with mounding detail (Type 2 grate)

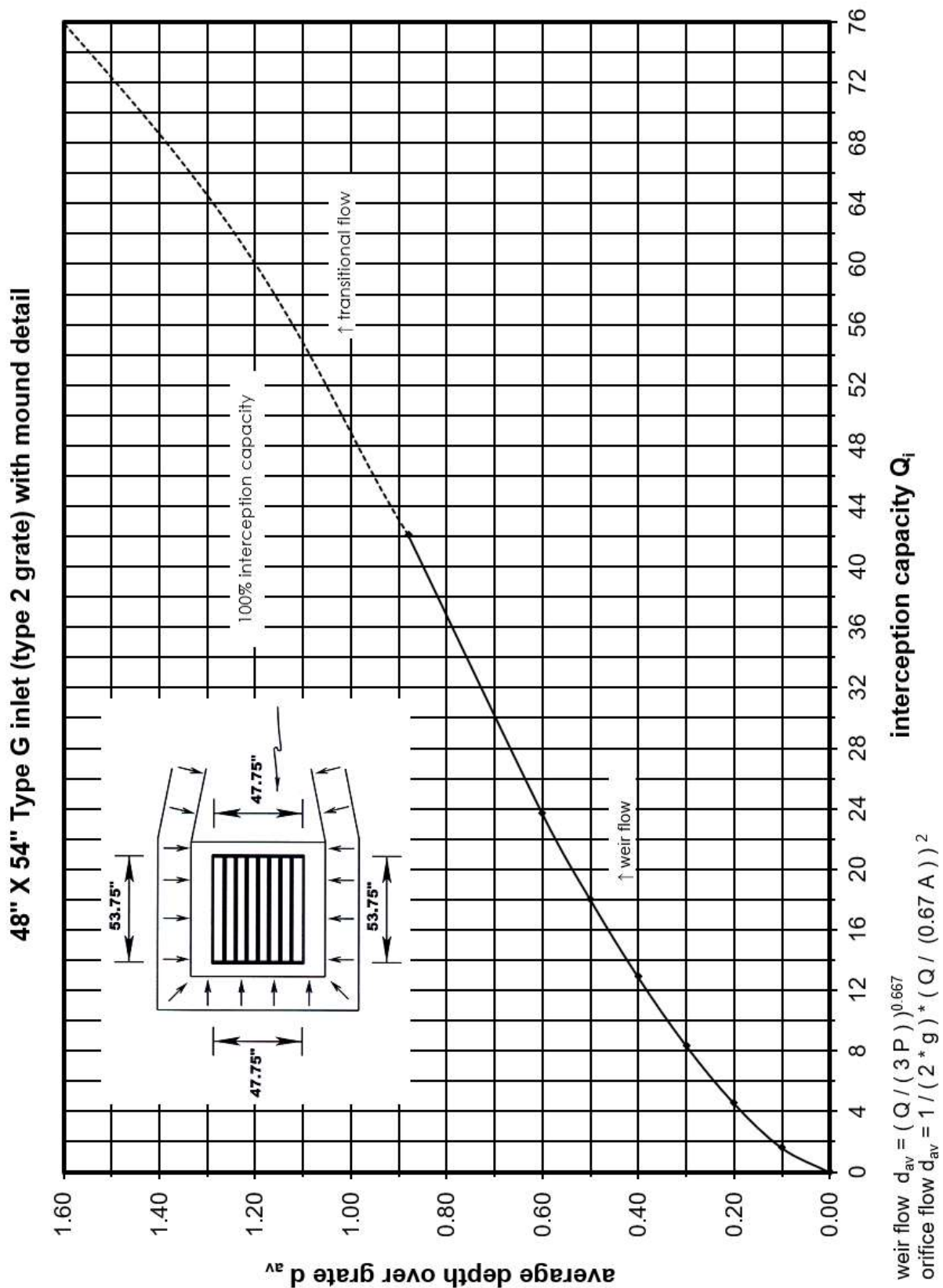
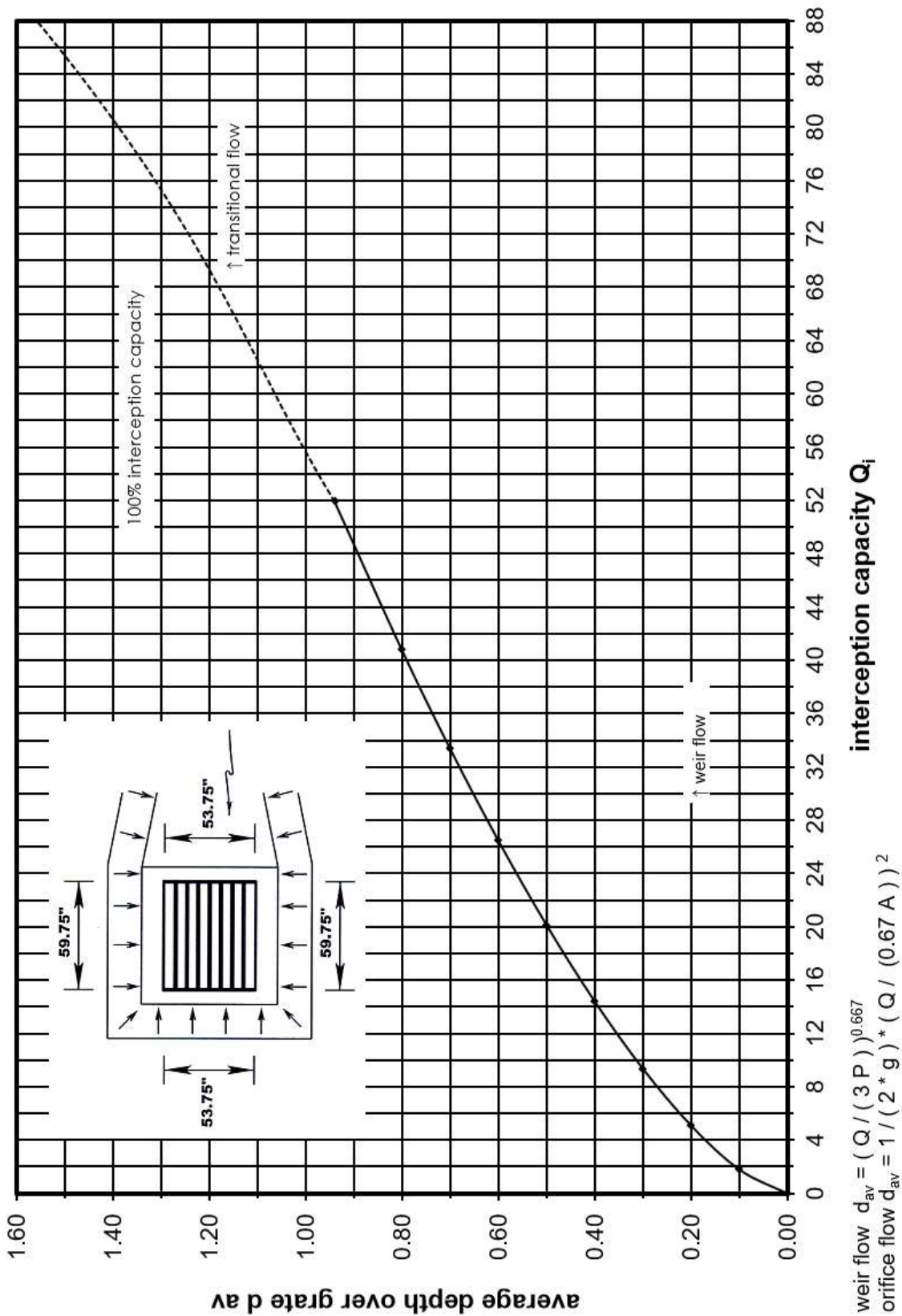


Chart 6-19

54" X 60" Type G grate inlet with mounding detail (Type 2 grate)

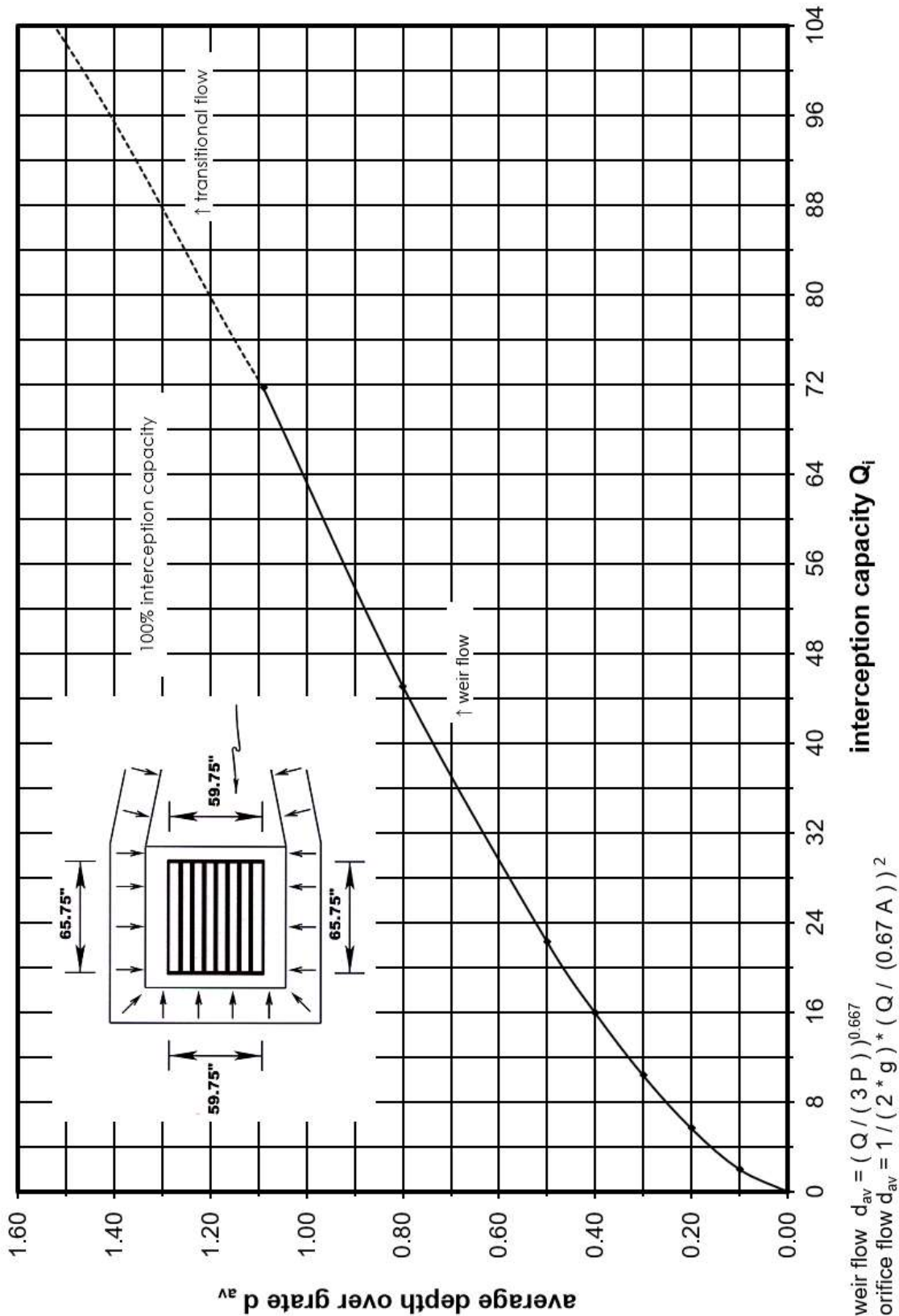
54" X 60" Type G inlet (type 2 grate) with mound detail



**Chart 6-20**

**60" X 66" Type G grate inlet with mounding detail (Type 2 grate)**

**60" X 66" Type G inlet (type 2 grate) with mound detail**



### 6.4.3.1 DITCH INLETS AND STORM SEWER CONSIDERATIONS

Storm sewers connecting ditch inlets shall be subject to the same rules and guidance as stated in Section 5.3.6. Section 5.3.6.1 states that under ordinary conditions storm drains should flow at a depth of 0.8 times the pipe diameter or equivalent at the design discharge. It may not be economically feasible to provide this much capacity when ditch inlets are involved. Pipe size between the inlets may be limited due to available cover or earthwork requirements for installation (such as pipes in ditches along high cut slopes). Limitations such as these may require special circumstances that allow the pipes connecting the inlets to flow above 0.8D at the design storm.

It is important to be mindful when several ditch inlets are connected by conduit (thus creating a storm sewer), and a large offsite drainage area flows to one of the inlets in the system. For example: an offsite flow enters a ditch inlet from an area oriented perpendicular to the roadway. The inlet that accepts the offsite flow is connected to the ditch storm sewer paralleling the roadway and the proceeding inlets continue to accept only roadway and adjacent cut slope area runoff. The storm drain conduit leaving the offsite flow inlet is designed as a culvert. The remaining storm drainpipe to the outlet shall also be designed for a culvert flow as conduit size shall not decrease in the downstream direction. See Section 5.2.6 for additional information.

### 6.4.4 DRIVEWAY CONDUIT

The cover above the conduit shall be at least 6 inches. The cover height is defined from the crown of the conduit to the bottom of the subgrade of the adjacent roadway pavement. The tables in this Section use historical pavement designs. If a culvert analysis is used for the driveway conduit, a reasonable assumption of roadway pavement thickness and with a 6-inch subgrade thickness shall be noted. When plastic conduit is used for a commercial/industrial driveway, a Type F trench shall be required according to the published DOH Standard Details.

Driveways which approach a roadway at a downgrade and cannot provide a sag vertical curve to divert surface rainfall runoff shall use an inlet to intercept the runoff. A slot drain type of inlet along the top of the conduit may be used to intercept rainfall runoff under the following conditions:

- The driveway grade toward the adjacent roadway is less than 9%.
- The driveway is in a suburban area with small yards and only the driveway surface contributes flow to the slot drain.
- The driveway is within a commercial/industrial area, is 16 feet wide or greater, and has an impervious contributing drainage area of 0.04 acre (such as an area of 40 feet by 40 feet or 20 feet by 80 feet) or less.
- The potential for a quantity of natural debris on the driveway surface is low.

Where a slot drain cannot be utilized, a box and grate drain shall be used to intercept rainfall runoff. An 8- 10- or 12-inch-wide Type A grate can be used (the width is the dimension parallel to the flow direction). In areas where bicycle traffic is present, a Type C grate shall be used. A gravel driveway which slopes toward the adjacent roadway shall require a box and grate drain.

A driveway access which meets any of the following conditions is re-classified as a culvert and it shall be hydraulically designed according to the standards of Chapter 8.

- Crosses continuously moving flow (perennial in nature) with a defined bed and bank full depth and an ordinary high-water mark (a vegetation break just above the bottom of the channel).
- A driveway location with a contributing drainage area of 20 acres or greater.
- The size of the driveway conduit exceeds 36 inches in diameter. A maximum size of 42 inches is allowed in the case of a 14 to 20-acre suburban area with a high amount of impervious surface.

Values for the following tables were determined by representative drainage areas for a typical ground cover and slope likely serving a driveway in WV. The range of area runoff flows were determined based on three categories of acreage. The middle value within this range was applied for a 35-foot-long metal pipe at a 2-2.5% slope projecting from the driveway side slope to be conservative. The headwater was then placed against representative pavement thicknesses (infusing the influence of the ADT) from previously designed projects in residential and urban/commercial areas. The resultant ditch depths were rounded to the nearest 0.25 feet.

#### **6.4.4.1 RESIDENTIAL DRIVEWAY CONDUIT**

The minimum size of a residential driveway conduit shall be:

- 15 inches for access to a single property with 1 acre or less of contributory drainage area.
- 18 inches for access to a single or multiple properties with more than 1 acre of contributory drainage area.

Apartment complexes consisting of three buildings or less are considered to represent a residential classification.

The approaching and departing ditch depth and top width dimensions should be according to the tables below for the bordering length of the property that is adjacent to the DOH right-of-way (or equal to the conduit length). Table 6-8 provides dimensions according to the predominant land cover of a single property (maximum 1 acre) which contributes rainfall runoff. For a single property that may contribute more than one acre of runoff refer to Table 6-9.

The minimum ditch depth accounts for the headwater created at the inlet end of the driveway conduit for a representative flow from a watershed area with the primary ground cover noted. If

the inlet headwater is less than the diameter plus 6 inches, the minimum cover of 6 inches will determine the ditch depth.

**Table 6-8**

**Residential Driveway Ditch Approaching and Departing/Single Property**

Area in acres	Primary Ground Cover	Conduit Diameter	Minimum Ditch Depth	2:1 Side Slope Ditch Top Width	1.5:1 Side Slope Ditch Top Width
		inches	feet	feet ft-inch	feet ft-inch
0-1	Forested or Grasses	15	3	13.25' 13'-3"	10.25' 10'-3"
0-1	Impervious Surface	18	3.25	14.5' 14'-6"	11.25' 11'-3"

Table 6-9 provides dimensions according to the predominant land cover of multiple properties (for a maximum of 20 acres) that contribute rainfall runoff to the driveway location. The blank spaces in the table denote values where large depths would be necessary due to high headwater values on smaller pipes. In these instances, larger pipes must be used due to the higher rainfall runoff flow amounts. Notice the ditch top width based on the depth required to guard the adjacent pavement from the 10-year storm reaching the subgrade. Longitudinal width for the placement of the ditch leading to and from the driveway should account for the required ditch top width. Ditch side slopes of 1.5:1 may be necessary but are not provided on the table.

**Table 6-9**

**Residential Driveway Ditch Approaching and Departing/Multiple Properties**

Acres	Primary Ground Cover	18" Conduit		24" Conduit		30" Conduit		36" Conduit		42" Conduit	
		Min Ditch Depth	Top Width 2:1 Side Slopes	Min Ditch Depth	Top Width 2:1 Side Slopes	Min Ditch Depth	Top Width 2:1 Side Slopes	Min Ditch Depth	Top Width 2:1 Side Slopes	Min Ditch Depth	Top Width 2:1 Side Slopes
		ft ft-inch	ft	ft ft-inch	ft	ft ft-inch	ft	ft ft-inch	ft	ft ft-inch	ft
1-5	Forested or Grasses	3.5' * 3'-6"	15.5'	4.0' * 4'-0"	18'	4.5' * 4'-6"	20.5'	-----	-----	-----	-----
1-5	Suburban with Yards	4.0' ** 4'-0"	17.5'	4.0' * 4'-0"	18'	4.5' * 4'-6"	20.5'	-----	-----	-----	-----
1-5	Impervious Surface	-----	-----	4.75' ** 4'-9"	21'	4.5' * 4'-6"	20.5'	-----	-----	-----	-----
5-14	Forested or Grasses	-----	-----	5.25' ** 5'-3"	23'	4.5' * 4'-6"	20.5'	-----	-----	-----	-----
5-14 14-20	Suburban with Yards Forested or Grasses	-----	-----	-----	-----	5.25' ** 5'-3"	23.5'	5.0' * 5'-0"	23'	-----	-----
14-20	Suburban with Yards	-----	-----	-----	-----	-----	-----	6.5' ** 6'-6"	29'	5.5' ** 5'-6"	25.5'

\* Depth is based on the conduit diameter plus the minimum cover of 6 inches.

\*\* Depth is based on the headwater at the conduit inlet.

**6.4.4.2 COMMERCIAL OR INDUSTRIAL DRIVEWAY CONDUIT**

The minimum size of a commercial or industrial driveway conduit shall be 18 inches. The side slopes of the ditch approaching and departing the conduit shall be 2:1 or flatter. The approaching and departing ditch depth and top width dimensions shall be according to Table 6-10 for the bordering length of the property adjacent to the DOH right-of-way.

Apartment complexes consisting of more than three buildings are considered to represent a commercial or industrial classification.

If an increase in rainfall runoff occurs due to the development of the property requesting/using access, the flow increase shall be the responsibility of the developer. Post development flow which approaches DOH right-of-way shall be equal to or less than the predevelopment flow. This criterion includes flow that is initially directed away from the right of way but will affect DOH right-of-way within a short distance downstream. The increase in runoff should be detained by in-line,

above ground, or below ground detention via a stormwater management system outside of DOH right-of-way.

Flow from the property requesting/using access shall not be discharged into a DOH drainage system via a closed connection. A closed connection shall be classified as a subsurface or piped connection to a DOH conduit, culvert, storm sewer pipe or system, manhole, or drop inlet. Municipal Separate Storm Sewer Systems (MS4) policy implies that the discharger is defined by the ownership of an outlet location. The DOH could be viewed as the discharger of a flow source originating outside of right-of-way, thus responsible for any pollutants within the flow from an adjacent property.

Table 6-10 provides dimensions according to the predominant land cover (for a maximum of 20 acres) that contribute rainfall runoff to the driveway location.

**Table 6-10**

**Commercial or Industrial Driveway Ditch Approaching and Departing**

Acres	Primary Ground Cover	18" Conduit		24" Conduit		30" Conduit		36" Conduit		42" Conduit	
		Min Ditch Depth	Top Width 2:1 Side Slopes	Min Ditch Depth	Top Width 2:1 Side Slopes	Min Ditch Depth	Top Width 2:1 Side Slopes	Min Ditch Depth	Top Width 2:1 Side Slopes	Min Ditch Depth	Top Width 2:1 Side Slopes
		ft ft-inch	ft	ft ft-inch	ft	ft ft-inch	ft	ft ft-inch	ft	ft ft-inch	ft
1-5	Forested or Grasses	4.0' * 4'-0"	17.5'	4.25' * 4'-3"	19'	4.75' * 4'-9"	21.5'	-----	-----	-----	-----
1-5	Suburban with Yards	3.75' * 3'-9"	16.5'	4.25' * 4'-3"	19'	4.75' * 4'-9"	21.5'	-----	-----	-----	-----
1-5	Impervious Surface	4.5' ** 4'-6"	19.5'	4.25' * 4'-3"	19'	4.75' * 4'-9"	21.5'	-----	-----	-----	-----
5-14	Forested or Grasses	-----	-----	5.0' * 5'-0"	22'	4.75' ** 4'-9"	21.5'	-----	-----	-----	-----
5-14	Suburban with Yards	-----	-----	-----	-----	4.75' ** 4'-9"	21.5'	5.25' * 5'-3"	24'	-----	-----
14-20	Forested or Grasses	-----	-----	-----	-----	5.5' ** 5'-6"	24.5'	5.25' * 5'-3"	24'	-----	-----
14-20	Suburban with Yards	-----	-----	-----	-----	-----	-----	6.25' ** 6'-3"	28'	5.75' * 5'-9"	26.5'

\* Depth is based on the conduit diameter plus the minimum cover of 6 inches.

\*\* Depth is based on the headwater at the conduit inlet.

## 6.5 DESIGN APPROACH

Each project is unique, but the following six basic design steps are normally applicable:

Step 1: Establish the roadside plan.

- Collect available site data including possible offsite flows and underlying soil and rock materials.
- Obtain or prepare existing and proposed plan-profile layout.
- Determine the roadside and median ditch outlets.
- Draw the drainage divides for each outlet location.
- Layout the proposed ditches and analysis intervals.

Step 2: Select initial ditch cross-section.

- Select initial ditch depth, side slopes, and bottom width.
- Identify constraints that may restrict cross-section design such as clear zone requirements, right-of-way limits, utilities, existing drainage facilities, and environmentally sensitive areas.

Step 3: Select initial longitudinal gradient.

- Plot initial grade on plan-profile layout.
- Consider influence of type of lining on grade.

Step 4: Check flow capacity and adjust ditch size, as necessary.

- Compute 10-year design discharge at the downstream end of the ditch analysis interval.
- Select roughness coefficient and the maximum allowable depth criteria.
- Compute flow depth using Manning's equation to check ditch capacity.
- If ditch capacity is inadequate, possible adjustments include increasing bottom width, using flatter side slopes, increasing longitudinal gradient, providing smoother lining, installing drop inlets and parallel storm drain pipe to supplement ditch capacity.
- Provide smooth transitions at changes in ditch cross-sections.

Step 5: Determine channel protection lining needed.

- Select a lining and determine the permissible shear stress.
- Calculate the maximum shear stress in the ditch and check if the lining is adequate. If the maximum shear stress in the ditch is more than the permissible shear stress of the lining, consider the following options: use more resistant lining, such as concrete or rock,

decrease longitudinal slope, use drop structures, increase channel width, or decrease channel side slopes.

Step 6: Analyze outlet points and downstream effects.

- Identify adverse impacts such as increased erosion or flooding to downstream properties that may result from discharge at the ditch outlet. Possible adverse impacts could include increase in discharge, increase in velocity, concentration of sheet flow, change in outlet water quality, and diversion of flow from the watershed.
- Mitigate adverse impacts as required. Mitigation activities could include the following possibilities: enlarging the receiving channel to accommodate increased flows, installing storm water detention structures, installing energy dissipaters to control high velocities, providing erosion protection for the downstream receiving channel, and installing sedimentation or infiltration basins.

The use of Form 6-1 is recommended for recording the design calculations. This form does not cover ditch protection calculations for bends and steep longitudinal gradients.



## **6.6 REFERENCES**

- (1) Design of Roadside Channels with Flexible Linings, Hydraulic Engineering Circular-15 (HEC-15), Federal Highway Administration, September 2005
- (2) Design of Riprap Revetment, Hydraulic Engineering Circular-11 (HEC-11), Federal Highway Administration, March 1989
- (3) Erosion Control Technology Council, Internet Website: <https://www.ectc.org/recps>
- (4) Hydraulic Design of Flood Control Channels, EM 1110-2-1601, Engineer Manual, U.S. Army Corps of Engineers, July 1, 1991
- (5) AASHTO Drainage Manual, American Association of State Highway Transportation Officials (AASHTO), 2014

**SECTION BREAK**

**NEW BUSINESS ITEMS**

## SECTION 110 CHANGE ORDERS *(Amended XX/XX/XXXX)*

Section 110 presents DOH policies and procedures on documenting, preparing, and processing Change Orders. Adherence to these procedures will ensure that agreements on the scope, necessity, and basis of payment for all modifications and extra work are properly documented. See Section 105.6 of this manual for information on how AASHTOWare Project and SiteManager is used to prepare and process Change Orders.

### **110.1-GENERAL**

**110.1.1-Legal Basis** The Division reserves the right to make any necessary alterations to the Contract Plans and Specifications or to the quantities of work provided they are within the scope of the original Contract. Although the Specifications provide for changes in quantities and performance of unforeseen work for which there is no price included in the Contract, Federal and State laws specifically require that no work be performed unless funds have been properly authorized for payment. The District will not pay the Contractor for extra work until the District receives a Supplemental Authorization.

**110.1.2-Overview of Purpose** It is impractical to specify in Contract documents exact quantities of labor, materials, and equipment. Therefore, procedures have been established for necessary changes for modifications and extra work through Change Orders. Consider the following:

1. **Change Order**. A Change Order authorizes an increase, decrease, addition, or deletion of an item(s) or adds prices not included in the original Proposal. These documents are normally developed in cooperation with the Contractor, the Division, and FHWA, as applicable, and reflect all changed items that would affect Contract costs and the completion date. See Section 110.3 of this manual for information on Change Orders.
2. **Contract Time**. Any additional time required due to a Change Order will be documented on a separate Change Order and will be considered for a Contract Time Extension (see Section 105.3 of this manual).

**110.1.3-Types of Change Orders** A Change Order is a general term referring to either a Supplemental Agreement or a Force Account Work Order. These terms are defined in Section 101 of the Specifications. Each type is used for a different purpose and is based primarily on the extent and nature of the changed condition as follows:

1. **Supplemental Agreement**. A Supplemental Agreement is a type of Change Order used for the following purposes:
  - a. To provide a unit price for items not included in the original Proposal;
  - b. If major Contract items require a change in quantity in excess of 25% of the

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- original and there is a demonstrable change in cost to the Contractor;
  - c. If there is an addition, deletion, or revision of the contract specifications;
  - d. If any item is non-performed; and/or
  - e. For any changes to the contract time.
2. **Force Account Work Order**. A Force Account Work Order will only be initiated and used when it is necessary to accomplish work not described by the contract specifications and which a price cannot be agreed upon by the Division and Contractor. This type of work can most effectively be described by hours of Labor, the furnishing of Material, and hours of Equipment use, plus a percentage (LME) as detailed in the Specifications. The Project Engineer/Supervisor must exercise strict controls and detailed records to administer this type of Change Order.

Section 109.4 of the Specifications specifies the provisions. See Section 104.1.2.1 of the Construction Manual, for justification of the Force Account work and Section 110.3.3 for additional information.

**110.1.4-AASHTOWare Project (AWP)** Change Orders, if required, must be prepared and processed as described in Sections 110.2 and 110.3 of this manual. AASHTOWare Project is used to generate Change Orders, either Supplemental Agreements or Force Account Work Orders.

## **110.2-DRAFT OF CHANGE ORDER**

**110.2.1-Need** If a condition warrants a contract modification or extra work, the Project Engineer/Supervisor will immediately notify the District Construction Engineer before taking further action. District personnel will notify the Contract Administration Division. All proposed Contract modifications and extra work require a Change Order.

Change Orders are required on non-exempt Federal-Aid projects under either of the following two conditions:

1. **Major Changes/Extra Work**. On non-exempt and concurrence Federal-aid projects, FHWA must provide advance written approval of all major changes or major extra work in the Contract Plans and Specifications except, when emergency or unusual conditions warrant, FHWA may provide advance verbal approval with subsequent binding written concurrence. A major change or major extra work is defined as a project change or extra work that would significantly affect the cost to the Federal Government or alter the termini, character, or scope of the work. See Section 110.3.2.1 for types of modifications that represent major changes and major extra work including required documentation.
2. **Minor Changes/Extra Work**. On non-exempt and concurrence Federal-aid projects, FHWA must approve all minor changes and minor extra work. This includes modifications in construction items within the scope of the Contract Plans and Specifications when such modifications are required during the normal progress of construction. Approval may be given retroactively at the discretion of FHWA.

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**110.2.2-Preparation** The Project Engineer/Supervisor is responsible for preparing Change Orders and employing the requisite features of AASHTOWare Project. See Section 105.6 of this manual. The following discusses documentation requirements.

**110.2.2.1-Contacts** On the General Change Order explanations, list the name and organization of all District, Division, and FHWA (if applicable) personnel contacted relative to the proposed modification or extra work. On non-exempt and concurrence Federal-aid projects, the Change Order must document agreements by FHWA personnel.

**110.2.2.2-Items, Quantities, Unit Prices** List each item of work entailed by the proposed modification or extra work, the estimated quantity, and the agreed unit price. Also list any Contract item underrun(s) resulting from the proposed modification or extra work (e.g., payment of material taken into Division inventory should include a decrease in the planned items of work that caused the unused material).

**110.2.2.3-Location and Necessity of Work** List the following related to the location and necessity of work on the Change Order:

1. **Location.** Indicate stations with applicable baseline and offset notations for each item of work entailed by the proposed modification or extra work. Modifications or extra work, resulting from revision of the planned project termini, require evidence that the Contract Administration Division has been advised of the revision.
2. **Necessity.** Indicate the reason in sufficient detail to ensure that the proposed modification or extra work is necessary.
3. **Federal-Aid Reimbursement.** Include the status of eligibility for Federal-aid reimbursement for each Contract modification. The following options are available:
  - a. Eligible for Federal funds pending submission and evaluation of cost data;
  - b. Partially eligible for Federal funds pending submission and evaluation of cost data;
  - c. Ineligible for Federal funds; or
  - d. Other (explain).

On exempt Federal-aid projects, the eligibility for Federal-aid reimbursement indicated for each Contract modification will follow FHWA policy.

4. **Contract Time Evaluation Method.** Include the method of Contract time evaluation for each Contract modification. The following options are available for each Contract modification:
  - a. Additional working days to the Contract time allowance are not applicable; or
  - b. Additional working days to the Contract item allowance will be granted on the basis of the actual working days charged for performing the work under the agreement provided the work is judged to be the controlling operation.

See Section 105.3 of this manual for additional information on documenting Contract time extensions.

**110.2.2.4-Justification of Quantities** The documentation required to substantiate estimated quantities is dependent upon the method of measurement of the proposed modification or extra work. Consider the following guidelines:

1. **Area or Volume Measurement.** Include calculations to substantiate added, increased or decreased quantities. A sketch or drawing is often necessary to show the details of the proposed modification or extra work. As applicable, include the following additional information:
  - a. **Proposal Quantity Items.** Calculations must contain signatures, not just initials, of District Office and project personnel verifying the accuracy of dimensions, computation method and resultant quantity. Detailed drawings must accompany the calculations.
  - b. **Unclassified Excavation/Borrow Items.** Calculations must include a volume breakdown station by station.
2. **Linear Measurement.** Include data such as stationing and applicable baseline and offset notations, top and bottom elevations, bar details, etc.
3. **Weight Measurement.** Include data such as stationing, average widths and depth, typical sections, application rates, conversion factors, etc. As-built quantities require notation that properly executed tickets are in the project file.
4. **Unit Measurement.** Include data such as stationing and applicable baseline and offset notations for each unit.
5. **Lump Sum Measurement.** The following documentation requirements will apply to lump sum measurements:
  - a. **Contract Item Revision.** Include calculations based upon proposal bid amount, plan quantity, and the proposed extra or deducted quantity to substantiate the proposed payment or deduction.
  - b. **Force Account Work Basis.** Include reason for performance of work on a Force Account Work basis in addition to applicable Labor, Materials Used, and Equipment (LME) records. Use Force Account Work procedures to establish the method of measurement for contract modifications or extra work only when necessary. Possible reasons for the performance of work on a Force Account Work basis are:
    - i. Negotiations with the Contractor fail to produce agreement on the price of a new work item;
    - ii. The extent of work is unknown;
    - iii. The work is of such character that determination of a reasonably accurate price is not achievable; and/ or
    - iv. Emergency in nature.
6. **Revised Method of Measurement.** This applies to such situations as “original versus in-place” and “volume versus weight.” Include data to substantiate that applicable shrink/swell or other conversion factors are representative of the applicable material and verification of the Contractor’s agreement with the factors. Revision of the method of measurement from volume to weight also revises the type of payment documentation required from calculations to properly executed weigh tickets.

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However, the material and construction method documentation required to substantiate compliance with the original Contract Plans and Specifications remains unchanged.

7. Inventoried Material. For payment for material incorporated into DOH inventory, include a copy of an executed DOH-5 documenting that the material was received by DOH and invoices showing the Contractor's actual cost of the material. Payment of this type should include a decrease in the planned item(s) of work that caused the unused material. See Section 109.2.4 of this manual for additional information.

**110.2.2.5-Justification of Unit Prices** The documentation required to substantiate unit prices is dependent upon the type of action taken for each item of the proposed modification or extra work. Consider the following guidelines:

1. Adjustment at Unit Price. Modifications or extra work resulting in increased or decreased quantities of major contract items at unit bid price require evidence that the provisions set forth in Section 104.11 of the Specifications were considered, if applicable.
2. Addition of Items. If items are added to the original Contract, include detailed provisions for material requirements, construction methods, method of measurement, and basis of payment for all added items not included in the contract specifications. Attach a copy of any written evidence submitted by the Contractor or prepared by DOH to support the unit prices. Include a cost analysis that verifies that unit prices for added items are reasonable. Examples of methods used to justify unit prices are as follows:
  - a. Verification of the accuracy of the cost breakdown submitted by the Contractor noting any special conditions;
  - b. Comparison with unit prices of similar Contract items noting any special conditions;
  - c. Comparison with average bid prices noting any special conditions;
  - d. Comparison with unit prices of same Contract items(s) on other projects (indicate project numbers) within the area or DOH prices on Purchase Order Contracts for similar work and/or materials noting any special conditions; and
  - e. Preparation of a cost breakdown for estimated labor, material, equipment, and administrative costs required to perform the work.

**110.2.3-Review and Approval** ~~In order to ensure that any proposed modification or extra work as detailed in Section 110.3.1 follows Division and FHWA (if applicable) policies, the following approval levels will be followed~~~~Project personnel may not be fully aware of the nature or magnitude of the comments made by Division or FHWA personnel regarding the proposed modification or extra work. Therefore, the following procedures will apply for the review and approval of the Change Order:~~

1. The Project Engineer/Supervisor will ~~generate submit a draft of ththe~~ Change Order, including necessary attachments, according to established procedures and then Submit for Approval ~~to the following personnel for review, approval, and/or comments.~~

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2. The District Area Engineer/Supervisor will review, ~~District Construction Office Manager, District Construction Engineer, Regional Finalization Coordinator, FHWA Regional Engineer (if applicable) and Regional Construction Engineer will review~~ the Change Order, in a timely manner, for accuracy and compliance with established procedures. The Change Order will then be Approved or Rejected as necessary.
3. The District Construction Engineer will continue to review the Change order and Approve or Reject as necessary.~~The Regional Construction Engineer will verify that the agreements reached, and comments made by Division and FHWA personnel are accurately represented on the Change Order.~~
4. The Regional Construction Engineer will continue to review the Change Order, verifying that agreements reached and comments made by the Division personnel are accurately represented and Approve or Reject as necessary.~~The District Construction Office Manager will verify that the Change Order complies with the documentation procedures noted in Section 110.2.2 including the verification of applicable calculations.~~
5. The District Office Manager will verify that the Change order complies with the documentation procedures noted in Section 110.2.2 including verification of applicable calculations and Approve or Reject as necessary.~~Upon approval of the Draft Change Order, the Office Manager will place the Change Order into Pending Status.~~
6. FHWA will Approve or Reject non-delegated Federal projects or Project of Division Interest (PODI) as necessary. All other Change Orders will be approved or rejected at this level by the Regional Contract Management role.
7. The Contractor will review the Change Order and Approve or Reject as necessary.
8. The Regional Contract Management Coordinator will review the Change order and Approve or Reject as necessary. For monetary changes less than \$200,000.00 and Time extensions less than 30 days this will be the final approval level.
9. The Director of Contract Administration will review monetary changes greater than or equal to \$200,000.00 and Time Extensions greater than or equal to 30 days to Approved or Reject as necessary.
- 5-10. The Deputy State Highway Engineer – Construction will review monetary changes greater than or equal to \$200,000.00 and Time Extensions greater than or equal to 30 days to Approve or Reject as necessary. This will be the final approval of these Change orders.

## **110.3-CHANGE ORDERS**

This section outlines DOH procedures for preparing and processing Change Orders. Adherence to these procedures will ensure that Change Orders are properly executed. Every Change Order must be approved in Draft (see prior section, Section 110.2).

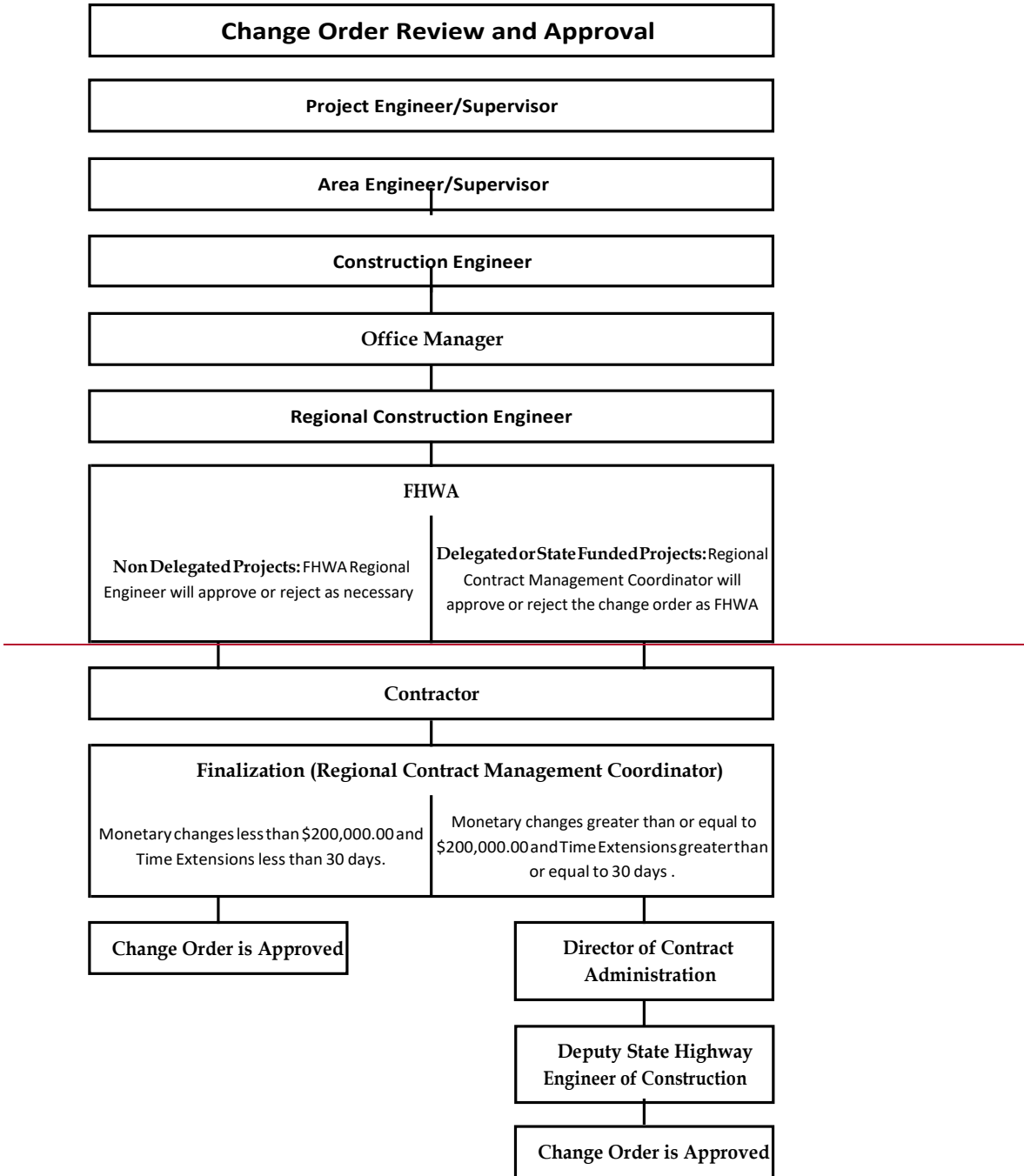
**110.3.1-Need** All modifications or extra work require an approved Change Order. The Contract modifications and extra work that require the preparation and approval of a properly executed Change Order are as follows:

1. Addition of items not included in the original Contract including items of work performed on an LME Force Account Work basis;
2. Revisions to Contract item quantities under either of the following two conditions:

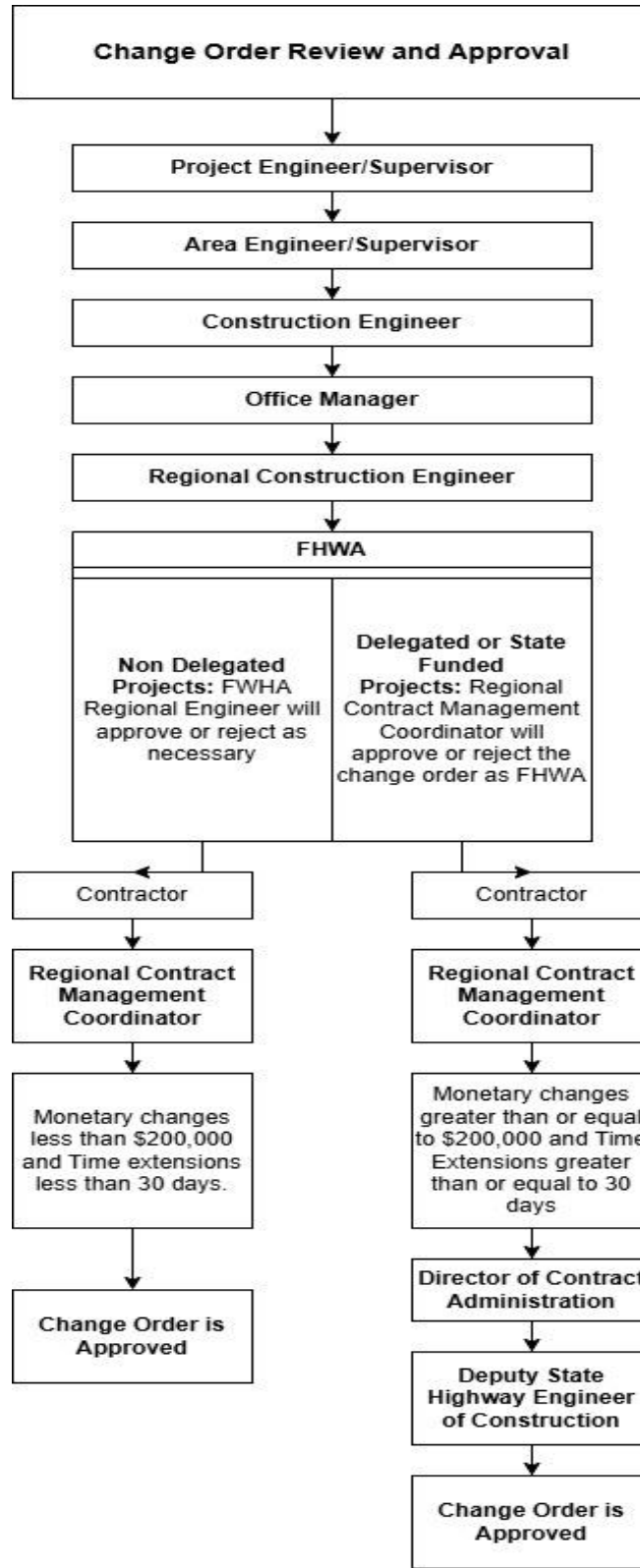
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- a. As needed to update the original funding authorized for contingencies; or
- b. As required in conjunction with approved Value Engineering/Practical Design Proposals;
3. Revisions to the contract specifications and/or Plans that, in the opinion of the District Construction Engineer, will significantly change the cost or alter the termini, character, or scope of the work under the Contract. See Section 104.11 of the Specifications for circumstances that constitute a significant change;
4. Assessment of price reductions that were established by District Materials Reports and/or special evaluations by DOH; and
5. Modifications that include a Contract time extension.

**110.3.2-Processing and Approval** ~~Figure 110 illustrates the processing flowchart for Change Orders on Federal-aid projects or State funded projects. Figures 110A and 110B illustrate processing flowcharts for Change Orders for non-exempt Federal-aid projects or State funded and exempt aid projects. The following subsections presents further discussion on processing and approval procedures.~~

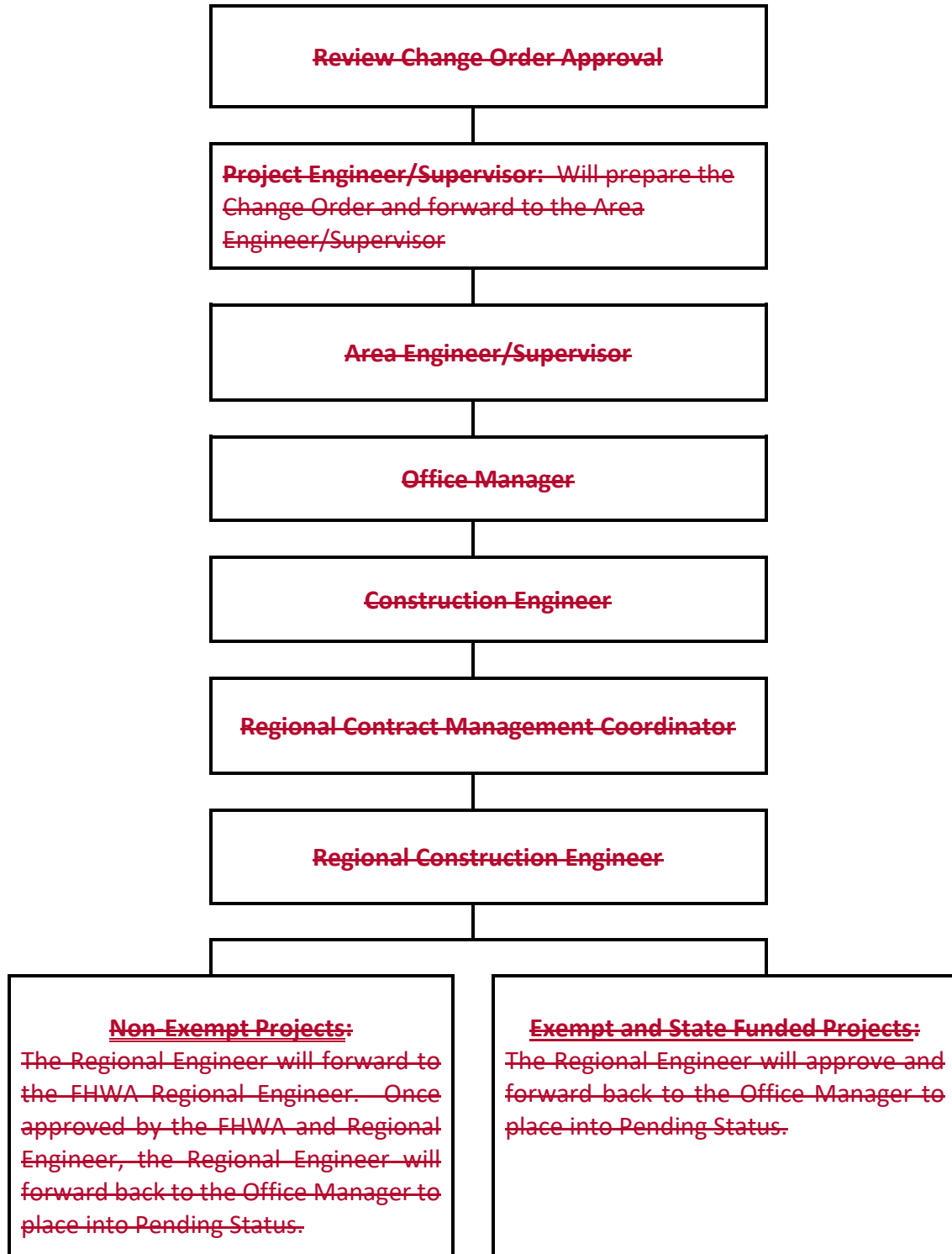


PROCESSING FLOW CHART FOR CHANGE ORDER  
REVIEW/APPROVAL  
Figure 110



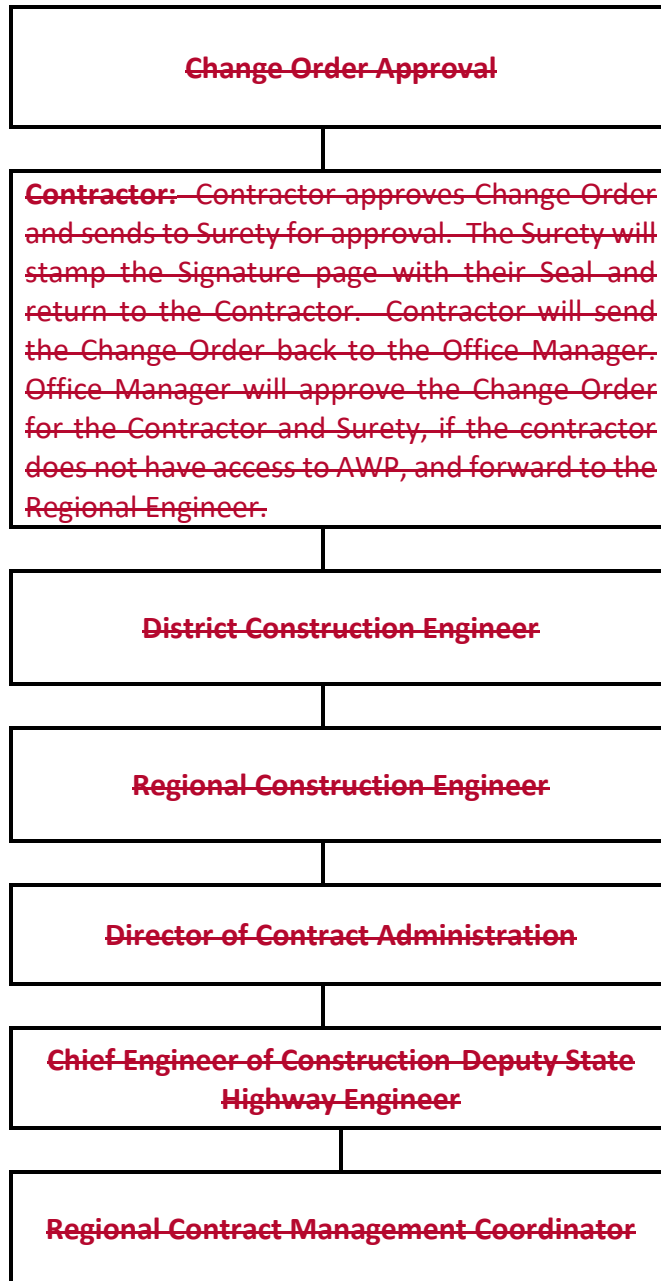
**PROCESSING FLOW CHART FOR CHANGE REVIEW / APPROVAL**

**Figure 110**



**PROCESSING FLOW CHART FOR  
CHANGE ORDERS IN REVIEW STATUS**

**Figure 110A**



**PROCESSING FLOW CHART FOR  
CHANGE ORDERS  
Figure 110B**

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**110.3.2.1-Exempt/Non-Exempt Federal-Aid Projects** Modifications and extra work on ~~exempt/non-exempt~~ Federal-aid projects generally require prior written concurrence ~~and before preparing a~~ Change Order. However, there are exceptions as follows:

1. Emergency Conditions. In emergency situations or unusual conditions, it may be necessary to request advance verbal approval from FHWA with the intent that FHWA provide the Division with a subsequent binding written concurrence in the form of a Change Order for the modification or extra work. The basis of the verbal agreement will be acceptable rates, and the basis of the Change Order.
2. Minor Changes/Extra Work. Retroactive formal FHWA approval with a Change Order is permissible for minor changes and Minor extra work on non-exempt Federal- aid projects.
3. Major Changes/Extra Work. For the discussion that follows, major change or major extra work will be defined as a change that will significantly affect the cost of the project or alter the termini, character, or scope of the work. The following actions represent major changes or major extra work for which prior written approval from WVDOT management is required:
  - a. revision of design details (including standard details) pertaining to geometry, drainage, structures, excavation, embankment, signing, and safety appurtenances, or pavement (main roadway, ramps, frontage roads, cross roads, or detours);
  - b. revision of planned access control, project termini, right-of-way limits and/or easements;
  - c. revision of the Standard Specifications, Supplemental Specifications, and/or project specific Special Provisions, including any change in material type or quality;
  - d. revision of contract time resulting from contract changes or extra work;
  - e. LME Force Account Work, Value Engineering Proposals, and contract claim settlements; and
  - f. revision of the Contract value by a monetary value of \$200,00.00 or more. ~~of any item by an amount greater than ±\$12,500.~~

~~For major changes and major extra work on non-exempt Federal-aid projects, a Change Order (i.e., prior written FHWA concurrence) is necessary to ensure consideration of Federal participation. When applicable, submit revised plan sheets to FHWA for approval prior to distribution. Before commencement, a Change Order must be executed to formally document agreement between the Division and FHWA in the following areas:~~

- ~~a. Necessity of the proposed work;~~
- ~~b. Scope of the proposed work; and~~
- ~~c. Basis of payment.~~

See Figure ~~110110B~~ for approval process.

~~**110.3.2.2-Sequencing** Change orders are submitted sequentially for each project as shown by the following example:~~

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- ~~Change Order No. 1 -- Supplemental Agreement No. 1~~
- ~~Change Order No. 2 -- LME Force Account Work Order No. 1~~
- ~~Change Order No. 3 -- Supplemental Agreement No. 2~~
- ~~Change Order No. 4 -- LME Force Account Work Order No. 2~~

**110.3.2.2-110.3.2.3-Administrative Charges** Administrative charges will not be required for Change Orders necessitated by price reductions or increases for changes in the work or materials requested by the Contractor or DOH. However, many contract specifications provide for non-conforming materials to be accepted and remain in place with an appropriate price adjustment. These price adjustments fall into one of the following two categories:

1. **Within Specification Limits**. Price reductions that fall within the Price Adjustment Limits of the contract specifications are placed on an Estimate as an adjustment without an administrative charge.
2. **Outside Specification Limits**. A special evaluation of the non-conformance must be made if the non-conforming material is outside the limits of the contract specifications. Price reductions that fall outside the Price Adjustment Limits require further effort by DOH. Thus, a \$200.00 administrative fee will be charged for each adjusted price.

## **110.3.3-Labor, Materials, and Equipment (LME) Force Account Work Orders**

**110.3.3.1-Purpose** A LME Force Account Work Order will be used only when it is necessary to accomplish work not covered by contract specifications but most effectively described by hours of Labor, the furnishing of Material, and hours of Equipment use, plus a percentage as detailed in the Specifications. Section 109.4 of the Specifications details the provisions and responsibilities associated with LME Force Account Work.

**110.3.3.2-Processing and Approval** See Section 110.2 of this manual for the documentation needed, and Section 105.6 for the AASHTOWare Project processing features related to Change Orders. Prior DOH and, on Federal-aid projects, FHWA concurrence as well as approval of equipment rental rates must be obtained in accordance with the procedures discussed in Section 110.3.2 of this manual. In accordance with the specifications, supporting data for the amount of insurance, B&O taxes, and bond will be submitted by the Contractor with the properly executed Change Order.

**110.3.3.3-Daily Report Records** When work is performed on an LME Force Account Work basis, the Project Engineer/Supervisor must exercise strict controls to ensure that the work is being performed properly and as efficiently and rapidly as is practical. The Project Engineer/Supervisor must ensure that the labor and equipment being charged to the work are actually needed and efficiently employed, and that the materials being charged are actually and properly placed. Consider the following guidelines when administering LME Force Account Work Orders:

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1. Daily Work Report. LME Force Account Work records will be maintained daily on specific LME Force Account Work worksheets. The DWR LME worksheets should include separate daily entries on LME Force Account Work labor, materials, and equipment. Each LME worksheet will contain the following minimum information:
  - a. Location of the work;
  - b. Quantity and type of labor and equipment being used;
  - c. Type and quantity of materials used;
  - d. Hours worked;
  - e. Description of work performed;
  - f. Estimate of the amount of work completed each day; and
  - g. Any additional information helpful in describing the work accomplished.
2. Records of Work Performed. At the end of each day's operation, the Contractor's representative and the Project Inspector will compare their records for agreement on the work performed and materials used that day. The Project Inspector must make duplicate copies of these records, and each copy should be signed by both the Project Inspector and the Contractor's Project Superintendent, or designee. One (1) copy will be forwarded to the Project Engineer/Supervisor and one (1) copy to the Contractor. To comply with these provisions, records of LME Force Account Work must be maintained daily, and representatives of both DOH and the Contractor must agree to each day's work by signature. See Section 105.5 of this manual for additional information.
3. Estimates. Generally, payment for LME Force Account work will be paid for by a Change Order. However, for larger Force Accounts, partial payments may be made by Contract Adjustments and then subtracted off after the Change Order has been approved. Such payments are substantiated by information on the LME Force Account Work Order. Refer to AASHTOWare manual for more information and requirements of Force Account Work. The approved LME Force Account Work Order must be placed in ProjectWise to support payment.