Annual Revisions to the SUDAS Design Manual
2021 Edition

If you want to update your printed manual, please print this packet and follow the instructions below. The current edition of the manual, with the latest revisions fully incorporated, can be found on our website - www.iowasudas.org.

Please remove the old sheets and place the revised sheets in your manual. Some pages are completely new and do not replace an existing sheet. Also, some pages do not contain revisions, but are included due to changes on the other side of the sheet or a change in the page number. **PLEASE READ CAREFULLY - PAY ATTENTION TO THE SECTION NUMBER!** Included shading to help distinguish between chapters. Questions can be directed to Beth Richards, SUDAS Program Coordinator, at 515-294-2869 or brich@iastate.edu.

Chapter	***Section***	***pg #***	***Summary of Revision(s)***
Manual introductory info			Updated the Contributors and Acknowledgments page and the general table of contents. *Note - if you want to replace the small business card for the spine of your manual, you can print a copy from our website.*
1	ENTIRE CHAPTER	ALL	Updated the chapter based on current practices.
2	Table of Contents	i-ii	Minor formatting correction.
	2A-2, B, 2, a	1-2	Updated Iowa DOT Local Systems I.M. reference.
	2A-4	1-4	Corrected references.
	2E-2	9-10	Error corrections.
	2E-2	13-16	Error corrections.
4	4C-1, B	1-2	Revised water main LUST interaction.
	4C-1, E, 3	3-4	Clarified fire hydrant clear space requirements.
5	Table of Contents	i-iv	Updated to reflect changes made in Chapter 5.
	5C-1	3-6	Added a minimum street width alternative for agencies who have a larger fire apparatus.
	5C-2	ALL	Updated to reflect new lane width and capacity relationships. Added language to meet 2018 Fire Code.
	5D-1, A	1-2	Minor correction.
	5E-1, I	13-14	Minor corrections.
	5G-2	13-14	Formatting corrections.
	5I-2, B, 2	1-2	Updated hyperlink.
	5I-3	ALL	Addressed re-establishment of the pavement following cutting of core holes in pavements for utility locations.
	5I-4, B	1-2	Updated hyperlink.
	5J-1, C, 1, b	9-10	Deleted the temperature requirement per Iowa DOT's revisions.
	5L-3	5-8	Added a note stating the distance may be adjusted based on lot dimensions or zoning code.
	5L-4, B and C	1-4	Updated point of width measurement, established width based on number of garage stalls, clarified joint driveway width, and updated distance from intersection.
	5M-1, C and E	7-10	Updated references.
	5O-1, D & E	1-2	Updated references.

6	6D-1, G	9-10	Updated references.
	6D-1, I	13-14	Updated references.
	6E-1, E & F	7-10	Updated references.
	6F-1, F, 2	5-6	Minor correction.
	6H-1, B, 2, b	3-4	Minor correction.
7	7E-10, B	1-2	Changed “Office of Bridges and Structures” to “Bridges and Structures Bureau.”
	7E-27, B	1-2	Updated hyperlink.
9	9B-4, C	1-2	Updated reference title.
	9D-1, B	1-2	Updated hyperlink.
11	11C-1, B, 6, a	7-8	Updated name of MnDOT reference.
12	12A-4, E	1-2	Updated Iowa DOT Specifications reference.
	12B-2	ALL	Changed “Office of Design” to “Design Bureau” (multiple times) and other minor corrections.
13	Table of Contents	i-ii	Added page numbers that were mistakenly missing.
14	14C-2, A, 2, a	3-4	Updated reference.
	14C-2, A, 2, b	7-8	Minor correction.
	14D-1	1-2	Deleted inactive hyperlink.

Contributors and Acknowledgments

In 2020, SUDAS staff held many meetings to accomplish the various revisions reflected in the 2021 versions of the SUDAS manuals. These revisions would not have been possible without the efforts of the SUDAS technical committee members. The SUDAS program's success is also due to the dedication of the district committees and Board of Directors. Keeping the SUDAS manuals current is an ongoing, cooperative effort, involving hundreds of people who volunteer their time and expertise. It is not possible to acknowledge each of these volunteers individually, but we appreciate them all.

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1B Plan Development

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1D Detailed Plans for Construction of Public Improvements

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1G Products

General Information

A. Purpose

The SUDAS Design Manual has been prepared as a mechanism to implement uniform design standards, procedures, and regulations for the preparation of urban improvement construction plans. These improvements are those that meet any of the following:

1. Are initiated, designed, and constructed by or under the supervision of the jurisdiction as a public improvement and maintained by the jurisdiction.

2. Are initiated, designed, and constructed by the private owner/developer's private engineer and contractor. Upon acceptance of the improvements by the jurisdiction, the improvements are operated and maintained by the jurisdiction.

Those improvements that require review and approval by the jurisdiction, but will remain under private ownership, may be required to follow the SUDAS Design Manual. Each jurisdiction will decide if these types of improvements are to follow the SUDAS Design Manual.

B. Definitions

See the SUDAS Standard Specifications (referred to as SUDAS Specifications) Section 1010 for definitions and a list of abbreviations.

Construction Inspector or Observer: The person or persons appointed by either the project engineer or the jurisdictional engineer to inspect all materials used and all work done. Such inspection may extend to any or all parts of the work and to the preparation or manufacture of the materials to be used. The inspector is not authorized to revoke, alter, enlarge, or relax the provisions of the specifications. The inspector will keep the project engineer and the jurisdictional engineer informed as to the quality and progress of the work and the manner in which it is being done.

Jurisdictional Engineer: The licensed professional engineer designated by the jurisdiction to carry out the provisions of the SUDAS Design Manual and the jurisdiction's design supplement, if applicable.

Project Engineer: The licensed professional engineer who is legally responsible for the design and/or administration of the project.

C. Intent of the SUDAS Design Manual

The values contained herein are considered fundamental concepts of basic design criteria that will serve as a framework for satisfactory design on new improvements. The project engineer is encouraged to develop the design based on this framework and tailored to particular situations that are consistent with the general purpose and intent of the design criteria through the exercise of sound engineering judgment. Situations may arise that require special considerations. Therefore, to eliminate hardships or problems, the jurisdiction may choose to vary the design criteria, procedures, and regulations. Jurisdictions may have a written design supplement that identifies specific modifications from this manual.

Should variances from the SUDAS Design Manual, or the jurisdiction's design supplement, be required, the reason for the variance should be documented by the project engineer and evaluated on a case-by-case basis by the jurisdictional engineer. Documentation could be included on the construction plans or as required by the jurisdiction.

The design standards as described for new improvements may not be attainable for restoration and rehabilitation projects. Each project of this type must be considered individually to determine if these design standards apply.

The SUDAS Design Manual and the jurisdiction's design supplement should be used for the preparation of all design plans for new improvements or major reconstruction submitted by the project engineer for jurisdictional review. The jurisdiction will review all submittals for general compliance with the specific design criteria, procedures, and regulations. Approval by the jurisdiction does not relieve the project engineer from the responsibility of ensuring that the calculations, design, and plans are accurate; complying with the SUDAS Design Manual; applying sound engineering judgement, and fitting the needs of a particular project.

The technical criteria not specifically addressed in the SUDAS Design Manual should follow the provisions of each jurisdiction's own policy or criteria and sound engineering practice. The design standards outlined in this manual are to be considered minimum design standards and a project constructed of entirely minimum standards may not be acceptable to the jurisdiction.

D. Organization of the Manual

The SUDAS Design Manual is organized into chapters. The chapters include general information, report documentation, plan design, and federal and state requirements. The manual provides a compilation of readily available literature relevant to the design of urban facilities.

E. Jurisdiction and Agencies

The SUDAS Design Manual and applicable design supplements apply to participating local governments except where superseded by state and federal requirements.

F. Amendment and Revisions

The standards and criteria will be amended as new technology is developed and/or experience gained in the use of the SUDAS Design Manual indicates a need for revision. The revisions will be adopted and jurisdictional engineers will monitor the performance and effectiveness of the design standards and will recommend changes and/or amendments through the SUDAS program as needed. Updates to individual design supplements will be the responsibility of each jurisdiction, if applicable.

G. Enforcement Responsibility

Each jurisdiction is responsible for enforcing the adopted provisions of the SUDAS Design Manual and their design supplement, if applicable.

H. Interpretation

The jurisdiction will determine the interpretation and application of the SUDAS Design Manual and their design supplement. Section 1B-1 includes classifications of improvements for a clearer understanding of general policy.

I. Innovation

Nothing in the SUDAS Design Manual limits the designer's use of new and innovative technology. Each alternative proposed utilizing new or unproven technology must receive approval from the jurisdiction prior to implementation. Any materials meeting the technical specifications should be allowed unless specifically prohibited by the jurisdiction.

Classifications of Improvements

A. Sanitary Sewer

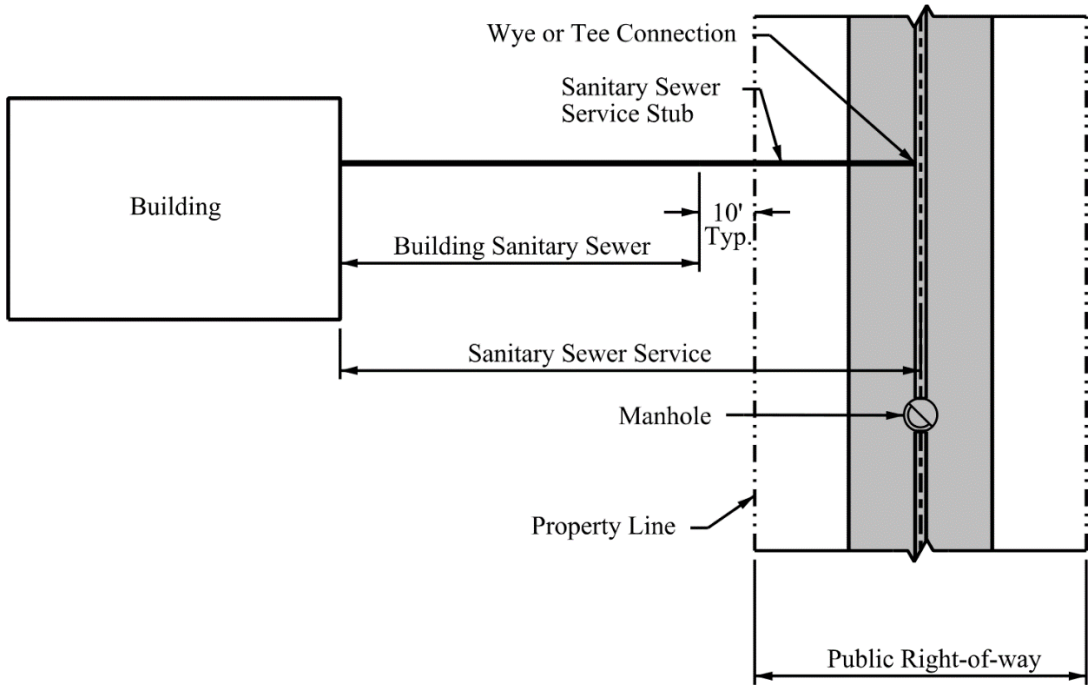
1. **Public Sanitary Sewer:** A sewer used to receive and convey sanitary sewage to another public trunk sewer or a sanitary interceptor sewer. This sewer is owned and maintained by the jurisdiction and is constructed on public property or on private property with an easement held by the jurisdiction. See Chapter 3 for more information.

   Construction Standard: SUDAS Specifications. Iowa DNR permit required.

2. **Sanitary Sewer Service Stub:** The portion of the sanitary sewer service that is within the public right-of-way to a designated point beyond the right-of-way line (typically 10 feet) as specified by the jurisdictional engineer. The sanitary sewer stub may be constructed in conjunction with the sanitary sewer construction and capped until the building sanitary sewer is constructed. Check with the local jurisdiction to determine if the sanitary sewer service stub is public or private and the exact permit and construction requirements. See Section 3C-1 for more information.

   Construction Standard: SUDAS Specifications and the jurisdiction's plumbing code. Jurisdiction plumbing permit may be required.

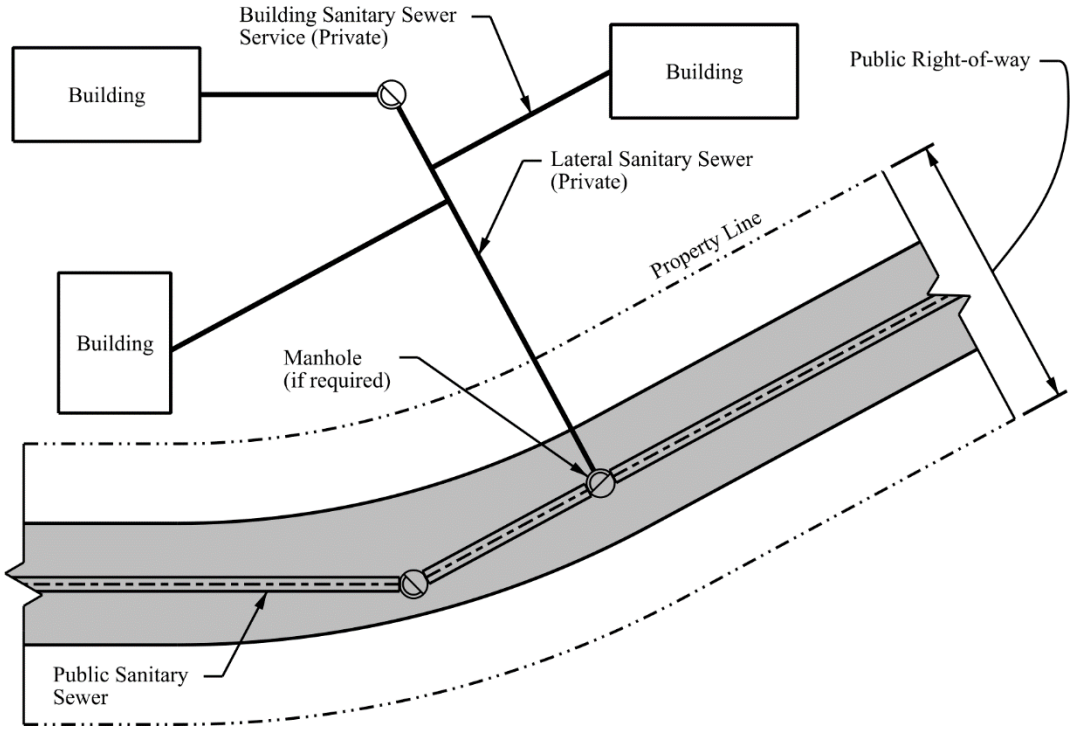
Figure 1B-1.01: Example of Sanitary Sewer Service



3. **Private Lateral Sanitary Sewer:** A sewer used to convey sanitary sewage from one or more sanitary sewer services. This sewer is limited to providing service to one owner or homeowner's association. This sewer is to be owned and maintained by a single person or entity and constructed on private property controlled by the owner or homeowner's association. Approval for the use of a private sanitary sewer should be obtained from the jurisdiction. For location of private lateral sanitary sewer, see Figure 1B-1.02. See Section 3C-1 for more information on sizing the lateral.

   Construction Standard: SUDAS Specifications and the jurisdiction's plumbing code. Jurisdiction plumbing permit and Iowa DNR permit may be required.

Figure 1B-1.02: Example of Lateral Sanitary Sewer



4. **Sanitary Sewer Lift Station:** A facility used to convey sanitary sewage from one or more sanitary sewers that cannot be conveyed by gravity flow to or within the public sewer system. This facility may be owned and maintained privately or by the jurisdiction. If to be maintained by the jurisdiction, this facility is constructed within the right-of-way, on property deeded to the jurisdiction, or on private property with an easement held by the jurisdiction.

   Construction Standard: SUDAS Specifications. Iowa DNR permit required.

B. Water Mains

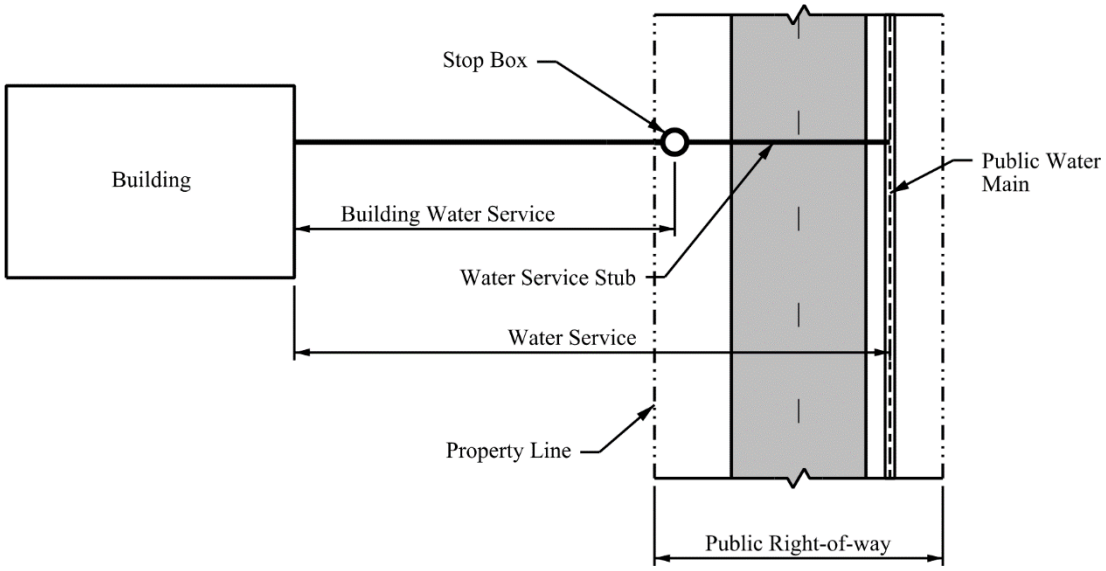
1. **Public Water Main:** A water main is used to distribute water to consumers for domestic, commercial, industrial, and/or firefighting purposes. The main is owned by the jurisdiction, water works, or an approved public/private water utility corporation or association. See Chapter 4 for additional information.

   Construction Standard: SUDAS Specifications. Iowa DNR permit required.

2. **Water Service Stub:** The water service stub is comprised of the piping and related appurtenances including the corporation, installed from the public water main to the stop box or as specified by the jurisdictional engineer. The water service stub may be constructed in conjunction with the water main and capped until the building water service is constructed. Check with the local jurisdiction to determine if the water service stub is public or private and the exact permit and construction requirements. For location of the water service stub, see Figure 1B-1.03. See Section 4C-1 for more information.

   Construction Standard: SUDAS Specifications. Jurisdiction plumbing permit may be required.

Figure 1B-1.03: Example of Water Service



3. **Private Water Main:** A private water main is used to distribute water for domestic and firefighting purposes to only one owner or homeowner's association. This private water main and appurtenances (valves, fire hydrants, etc.) are to be owned and maintained by only one party and constructed on private property controlled by the owner or homeowner's association. Approval for the use of private water mains must be obtained from the jurisdiction. The approval agreement must address the ability of the fire department to access the fire hydrants and stipulate who is to maintain the fire hydrants and valves. If the hydrants and valves are to be privately maintained, an annual log of maintenance activities should be filed with the jurisdiction. Metering of water flowing through the private water main will be subject to the jurisdiction's water metering requirements. See Chapter 4 for additional information.

   Construction Standard: SUDAS Specifications and the jurisdiction's water works and/or rural water association standards. Jurisdiction plumbing permit and Iowa DNR permit may be required.

C. Drainage Facilities

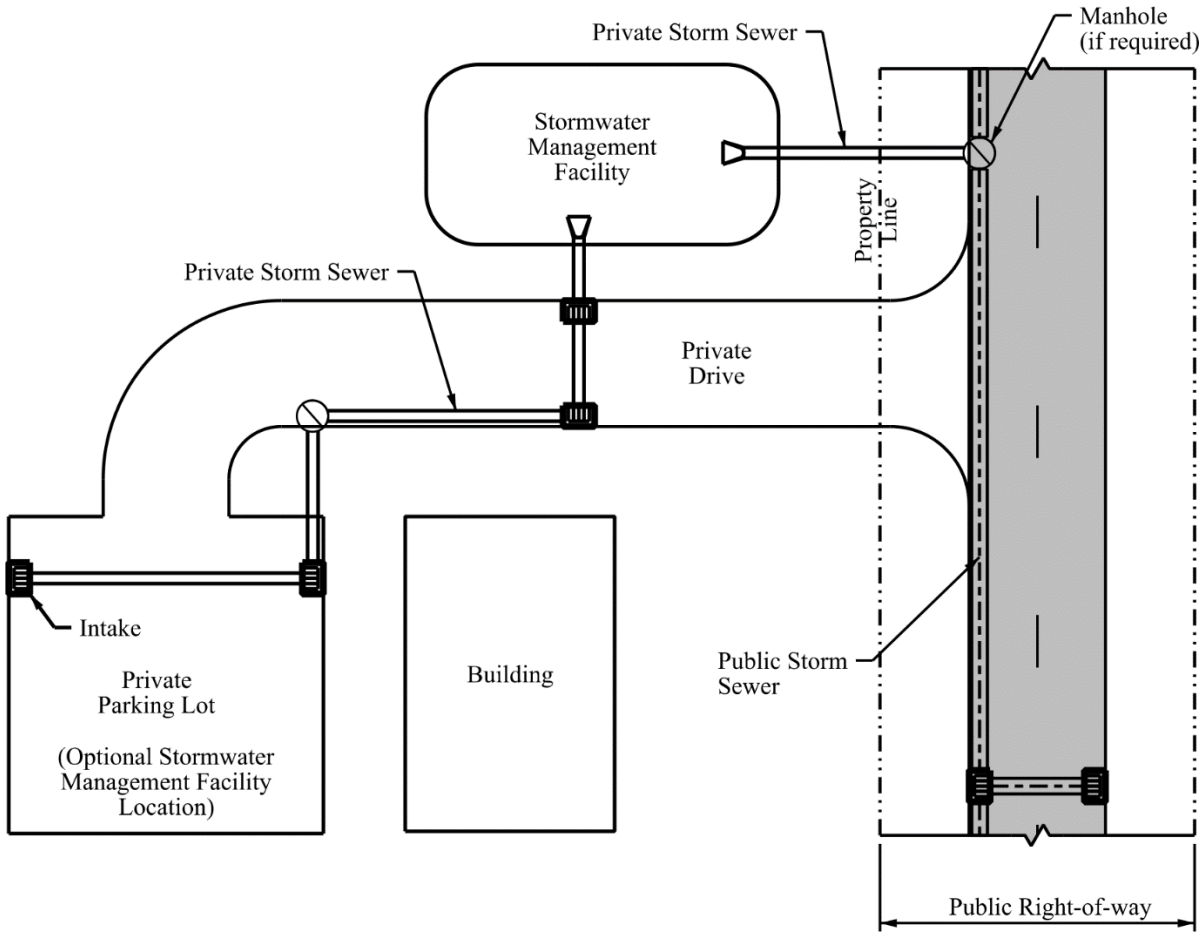
1. **Public Storm Sewer:** A storm sewer is used to convey stormwater runoff to an acceptable outlet. This sewer is owned and maintained by the jurisdiction and constructed on public property or on private property with an easement held by the jurisdiction. See Chapter 2 for additional information.

   Construction Standard: SUDAS Specifications. Federal and state permits may be required.

2. **Private Storm Sewer:** A private storm sewer is used to convey stormwater from private property to a public storm sewer, natural drainage way, or other acceptable outlet. This sewer is located on private property and maintained by only one party or homeowner's association. These sewers should be designed to fit within the jurisdiction's overall drainage system. Easements are to be obtained when crossing other private property. Drainage area limits for private storm sewers of large sites will be examined on a case by case basis by the jurisdiction. Manholes may be required for the connection of the private storm sewer to the public system. For location of private storm sewer, see Figure 1B-1.04. See Chapter 2 for additional information.

   Construction Standard: SUDAS Specifications. Jurisdiction plumbing permit and/or federal and state permits may be required.

Figure 1B-1.04: Example of Public and Private Storm Sewers

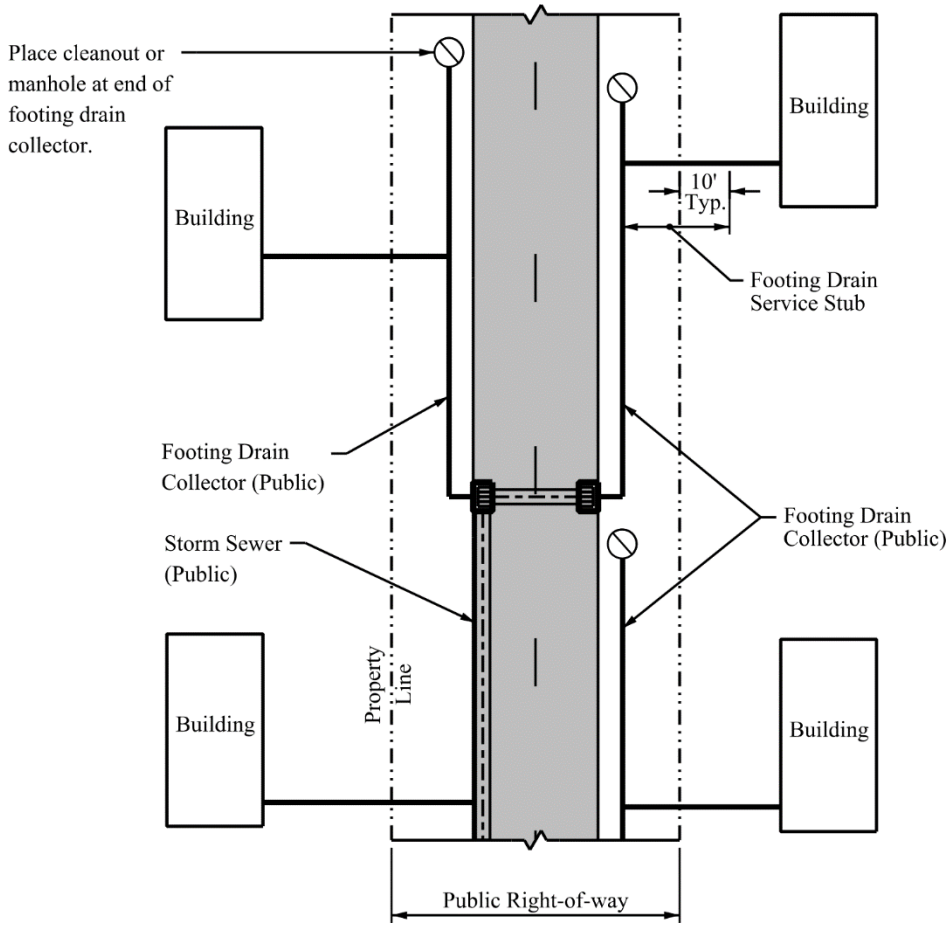


3. **Footing Drains:** A footing drain collector is used to convey ground water from private footing drains to a public storm sewer or drainage way. This footing drain collector is owned and maintained by the jurisdiction and constructed on public property or on private property with an easement held by the jurisdiction. For location of footing drain collector, see Figure 1B-1.05.

4. **Footing Drain Service Stub:** A footing drain service stub extends from the storm sewer or footing drain collector to a designated point beyond the right-of-way line (typically 10 feet) as specified by the jurisdictional engineer. The footing drain service stub may be constructed in conjunction with the storm sewer and capped until the building footing drain is constructed. Check with the local jurisdiction to determine if the footing drain service stub is public or private and the exact permit and construction requirements. For location of footing drain service stubs, see Figure 1B-1.05.

   Construction Standard: SUDAS Specifications.

Figure 1B-1.05: Example of Footing Drain



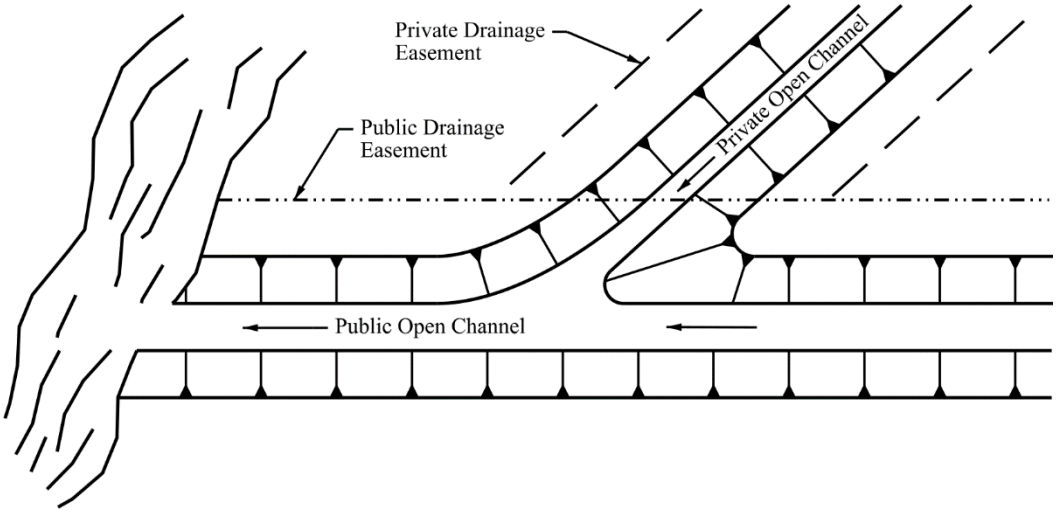
5. **Public Open Channel:** A natural channel improvement or channel required by the jurisdiction as a component of a planned drainage system that conveys stormwater drainage across public property or public easement. Public open channels should be designed to accommodate the jurisdiction's overall drainage system's needs. Public open channels are owned by the jurisdiction or within an easement held by the jurisdiction. For location of open channel, see Figure 1B-1.06.

   Construction Standard: SUDAS Specifications. Contact Iowa DNR for potential 401 Water Quality and NPDES permit requirements; U.S. Army Corps of Engineers for 404 permit.

6. **Private Open Channel:** An open drainage way, swale, or channel used to convey stormwater drainage to the public drainage system or other acceptable outlet. Private open channels may be allowed on a case-by-case basis. The channel should be designed to accommodate the jurisdiction's overall drainage system needs with respective easements that will serve more than one property and will be located on private property and maintained by one or more private entity(ies). Design grades must be established to eliminate low points, prevent erosion, and maintain the design flow of water. The open channel may discharge directly into a stream or other waterway. For location of private open channel, see Figure 1B-1.06.

   Construction Standard: SUDAS Specifications. Federal and state permits may be required.

Figure 1B-1.06: Example of Open Channel



7. **Stormwater Management Facilities:** Stormwater management facilities are installed to mitigate the higher rate of stormwater runoff generated from development activities. In addition, specific requirements for improvement to stormwater quality may be required by the jurisdiction. Design considerations should be given to prevent damages to the development site, streams, drainage ways, streets, storm sewers, and downstream property. The stormwater management facilities should be designed to accommodate the jurisdiction's overall drainage system needs while meeting the jurisdiction's adopted design standards. The stormwater management facility may be developed on public (if approved) or private property. If the facility is on private property but maintained by the jurisdiction, an agreement must be executed that establishes responsibility for general maintenance of the basin as well as the maintenance of the stormwater elements of the basin. If the stormwater facility is to be maintained by a private entity, such as a homeowner's association, an agreement must be developed that addresses required maintenance activities and records of those activities. (See Chapter 2 for details).

   Construction Standard: SUDAS Specifications. Federal and Iowa DNR permit may be required.

D. Erosion and Sediment Control

Construction site erosion and the subsequent sediment deposits are a common problem for off-site drainage systems and can potentially cause damage to adjacent property as well. The Federal Clean Water Act established requirements including the National Pollutant Discharge Elimination System (NPDES) to regulate discharges and reduce pollution of the nation's waterways.

These requirements are being implemented by the Iowa DNR and jurisdictions who have been designated as municipal separate storm sewer systems (MS4) communities. For construction projects, an NPDES General Permit No. 2 from the Iowa DNR is required for any site that disturbs and exposes one acre of land or more. A permit is also required for projects that will disturb one or more acres as part of a common plan of development, even if there will not be one acre of disturbed ground exposed at any given time. The permit requires preparation of a stormwater pollution prevention plan (SWPPP) that must clearly identify all potential sources of stormwater pollution and describe the methods to be used to reduce or remove the contaminants from stormwater runoff. In addition to the Iowa DNR, MS4 agencies may also have a permit process. It is necessary to check with the jurisdictional engineer to determine what, if any, information is needed for the local agency permit. See Chapter 7 for additional information.

Construction Standard: SUDAS Specifications. Iowa DNR permit. Jurisdiction permit may be required.

E. Entrances

Access to private property is the responsibility of the property owner. The owner is responsible for obtaining the appropriate permits for entrance modifications.

Construction Standard: SUDAS Specifications. Jurisdiction permit required.

F. Streets

1. **Public Street:** This classification of street is owned and maintained by the jurisdiction and constructed on dedicated street right-of-way. See Chapter 5 for detailed description of each roadway system element.

   Construction Standard: SUDAS Specifications or Iowa DOT for federal aid routes.

2. **Private Street:** A street that is restricted to use by only one owner or homeowner's association and is available for use by emergency vehicles. This classification of street is located on private property and maintained by only one party or homeowner's association. Private streets should meet all applicable geometric requirements for the given operating speed and pavement thickness requirements for the type of traffic, requirements for fire lanes and emergency services, but may not comply with public standards in other elements, such as right-of-way width. Approval for the use of private streets must be obtained from the jurisdiction.

   Construction Standard: SUDAS Specifications. Jurisdiction permit may be required.

G. Utilities

1. **Franchise Utility:** A jurisdiction may grant a franchise to erect, maintain, and operate underground and overhead plant and systems. These systems could be for electric light and power, heating, telephone, cable television, water works, gas, or other utilities within the jurisdiction. Construction of said facilities could be in the public right-of-way, public easements on private property, or private easements on private property. Location of franchised utilities should take into account the future right-of-way needs based on the ultimate classification of the street. Upon receipt of a written notice from the jurisdiction, the owner of a franchised utility must remove the utility from the jurisdiction's right-of-way or relocate it within the right-of-way in a timely manner as established by the jurisdiction. If easements are obtained for the utilities, it is recommended these easements be obtained in the name of the jurisdiction. All franchise utility installations should abide by the same design and construction requirements as other improvements. See Section 9A-1 for more information. Permits from the jurisdiction may be required.

2. **Public and Non-franchised Utility:** The jurisdiction may allow the installation of public and non-franchised utilities in public right-of-way upon review of the proposed improvements and approval by the jurisdiction. Such improvements may include, but not be limited to, water mains constructed by a water board, electric facilities constructed by an electric board, stormwater facilities, storm sewers, fiber optic lines, communication lines, irrigation systems, and other miscellaneous installations. Permits may be required by the jurisdiction.

   Ensure the installation of such facilities in public right-of-way does not damage or infringe on the usefulness of existing or planned public facilities. Upon receipt of a written notice from the jurisdiction, the owner of a public and non-franchised utility must remove the utility from the jurisdiction's right-of-way or relocate it within the right-of-way in a timely manner as established by the jurisdiction.

3. **Utility Conflicts:** Franchised, public, and non-franchised utilities are expected to cooperate in relocation of facilities that are in conflict. It is critical that the utilities be given as much advance notice as possible. The project engineer should coordinate with each utility agency or company to determine location and elevation of all utilities located within the project area. If any existing utilities conflict with the proposed project, the project engineer should contact the utility company and work to resolve the conflict in order to keep the project on schedule. If the conflicts are unable to be resolved, the project engineer should bring the matter to the attention of the jurisdictional engineer.

H. Accessibility

Where sidewalks and shared use paths are provided, they must be constructed or reconstructed so they are accessible for all users according to the Americans with Disabilities Act. All construction or reconstruction of accessible facilities must comply with the Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (also known as the Public Right-of-Way Accessibility Guidelines or PROWAG) and the jurisdiction’s transition plan. Sidewalk and shared use path construction on private property must include an easement to the jurisdiction for use and maintenance or an agreement providing for public use and an acceptable level of maintenance by private parties. See Chapter 12 for additional information.

Construction Standard: SUDAS Specifications.

Preliminary Plan/Information Development

A. General

Prior to initiating design of a project, several elements need to be investigated in order to prevent a redesign after the first submittal to the jurisdiction and the subsequent rejection of that submittal.

One of the first elements to determine is whether the project being designed is a public improvement or a private contract. A public improvement involves construction work under control of a governmental entity that is paid for in whole or part by governmental funds. It may be vertical infrastructure, which includes buildings and all appurtenant structures, utilities, incidental street improvements, sidewalks, site development, trails, and parking facilities. Or it may be horizontal infrastructure, which includes street, bridge, culvert, and utility work not defined as vertical infrastructure. Formal definitions and further information can be found on the Iowa DOT's website.

Further information and requirements related to public contracts may be found in the following Iowa Code sections:

- Publication requirements: 362.3
- General Obligation bonding: 384.23 - 384.36
- Special Assessments: 384.37 - 384.67
- Iowa Bidders Preference: 73.1 - 73.2; 73A.21(4)
- Engineering Documents: 542B.16
- Contract Letting Procedures: 26.1 - 26.15, 314.1, 384.103
- Sales Tax Exemption: 423.3
- Surety Bonds, Retainage, Payment: 573.1 - 573.28

The private contract work can involve facility design that ultimately will be transferred to the jurisdiction and thus must meet the requirements of the jurisdiction, or facility design that must meet the requirements of the jurisdiction but will remain a private facility.

B. Bidding Public Improvements

For public improvement contracts involving estimated construction costs over the bid threshold values, either established according to Chapter 314.1 (2) of the Iowa Code or the jurisdiction's requirements or on those private contracts required by the jurisdiction, a licensed engineer in the State of Iowa must certify the construction plans and specifications. Additional information can be found on the Iowa DOT's website.

If the jurisdiction is going to be the contracting authority and formal bids are required, the plans and specifications must be completed and ready for the jurisdiction to meet specific timing. The jurisdiction's governing body must approve the plans and specifications at a public hearing if the project's estimated costs exceed the bid threshold and advertise the proposed public improvement. The advertisement includes posting a public notice to bidders no less than 13 and not more than 45 days before the date of filing bids in a relevant contractor plan room service with statewide circulation, in a relevant construction lead generating service with statewide circulation, and on an internet site sponsored by either the jurisdiction or a statewide association that represents governmental entities. These timeframes may impact the document submittal and review process if

specific dates must be met. Formal procedures for opening bids should be established in consultation with the city attorney.

In general, the plans and specifications will be developed for a project identifying specific materials and processes to accomplish the work. The SUDAS Specifications allow the contractor to choose some materials unless the jurisdiction has limited that ability. Other contracts include bidding specific alternates. This allows the jurisdiction to select a particular material or process based on a predetermined method of analysis. The elements to be used in the analysis should be identified within the special provisions of the contract as a means of minimizing controversy.

Some contracts may be set up to have a base bid with a series of bid alternates. This is handled in the project by listing the alternates as separate work items. If this process is used, the project special provisions should identify how the bid alternates will be considered for contract award.

C. Specific Jurisdictional Requirements

As a part of initiating a project that will be submitted to a jurisdiction for review/approval, it is important to ascertain if the jurisdiction has special requirements, such as:

- Supplemental information/requirements for the SUDAS Design and Specifications Manuals?
- Any local jurisdiction master plan?
- Who is the jurisdiction's contact for this project?
- Specific design software or a specific version of the software?
- Specific layer designations for the electronic plans?
- Are 3-D plans required and what should the submittals include?
- Specific legend requirements to be used on the construction plans?
- Specific requirements for survey data collection?
- Specific plan sheet designations and plan organization requirements (i.e. colored plans, sheet size, etc.)?
- Specific requirements for vertical and horizontal scale on the construction plans?
- Specific construction plan submittal requirements, such as number of printed sets and media type?
- Submittal and review process?
- Specific products to be used or prohibited?
- Specific review/approval process if a new technology is proposed?
- If not stipulated in the supplemental information, how far should utility services extend beyond the right-of-way line?
- Are manholes required where private storm sewers are connected to the public storm sewer system?
- Minimum width requirements for permanent utility easements or a specific form for the easement?
- Requirements for a permanent easement for access to and maintenance of fire hydrants on a private fire line?
- Permitting authority from the Iowa DNR for sanitary sewer and water main construction projects? If so, do you have special permit forms?
- Specific information/criteria needed on the as-built plan?
- Criteria for changes to plans and submittal of variances to design elements?

Other elements that are specific to the type of project may need to be determined. One method to get the needed information is to schedule a pre-project planning meeting with the jurisdiction staff.

Submittal Procedures

A. Construction Plans and Specifications Submittal Procedure

1. **General:** Project engineers and developers seeking approval and acceptance of civil engineering reports, construction plans, and site plans are required to follow the procedures as established by each jurisdiction. These procedures are generally outlined in this section. The adherence to these procedures will assist in an efficient review of engineering plans and reports. Each jurisdiction reserves the right to modify certain procedures to fit their unique situation.

2. **Pre-submittal Meetings:** Each jurisdiction may conduct pre-submittal meetings at which developers may ask questions and obtain direction and/or information from the jurisdiction's staff. These meetings may be used by the developer to obtain very basic information about procedures, practices, or standards as a basis on which to begin development planning. Alternatively, the applicant may use the meeting as a final check by staff to verify a specific type of application is complete.

3. **Submittal of Public Improvement and Development Plan Application:** The development plan application, site plans, revised site plans, and other public improvements submitted to the jurisdiction for any project, subdivision, or planned unit development, whether residential, retail, commercial, or industrial, should include drawings for public improvements including any impact reports. Initial plan submittals must be marked as "Draft" or "Not for Construction."

4. **Engineering Review Objective:** The primary objective of the jurisdictional engineer is to ensure conformance with the adopted codes, standards, and master plans, as well as to ensure coordination with adjacent projects, developments, and landowners. The jurisdictional engineer also completes the initial review and issues comments according to the schedule prescribed by the jurisdiction to prevent delaying further review by other agencies or impact any other scheduling, such as subdivision platting.

5. **Results of Engineering Review:** After the review is completed, the check prints and comments report will be returned to the project engineer.

6. **Revision of Engineering Plans and Reports:** The project engineer will make all the revisions requested on the original plans/report and re-submit until all comments are sufficiently addressed. Seriously deficient plans may require several reviews prior to approval.

7. **Revision of Plans and Reports:** When submitting revised plans, drawings, or reports to the jurisdictional engineer, the re-submittal must contain the following.

   a. The revised plans for review.

   b. All check prints from previous reviews with copies of the previous plans. Notations should be made after each comment if the correction was made or justification why a comment is not valid.

   c. If fees are applicable, they must accompany the application.

   If all of the above are not submitted, the re-submittal may be returned without further action until such time as the submittal is complete.

8. **Order of Processing:** The following policy regarding order of processing (priority) will be used for all submittals. Applications are normally processed on a first come basis.

   a. Final media for approval.

   b. Resubmittal, complete package.

   c. Initial submittal, complete package.

   When plans are returned to the project engineer for lack of adequate information, or in the event of re-platting or major site plan revisions after the initial review, the re-submittal will be considered a new submittal rather than a return. A thorough technical review will be started by the jurisdiction when adequate information is provided.

9. **Approved Plans:** When plans or reports have been conditionally approved by the jurisdictional engineer, the project engineer should submit a minimum of two 11 by 17 inch copies (or as required by the jurisdiction) of the final plans, certified according to the Iowa Code. Meet the jurisdictional engineer's requirements to ensure all lettering and details are legible. Final construction plans are to be filed as a PDF file on a disk, flash drive, by email, cloud storage, or other form of media as required by the jurisdiction. If the project relates to a development, original engineering plans for public improvements may be approved by the jurisdictional engineer, only after the approval of the preliminary plat, the land dedication, and the subdivision improvements agreement associated with property.

B. Updates to Previously Approved Plans

1. Construction plans, pavement design reports, drainage reports, site plans, and other documents are approved initially for 12 months, or as specified by the jurisdiction. If not constructed during this time period, they automatically become void and must be updated to current criteria before any further permits can be issued. The jurisdictional engineer may grant an extension to the construction plans, pavement design reports, and drainage report validity period; provided a) the development plan, construction plans, or reports have not substantially changed, and b) that other conditions affecting the development site have not substantially changed or do not require a modification to approved plans or specifications.

2. Whenever updates or revisions to previously approved construction plans, specifications, or drainage reports are necessary, the project engineer will submit updates or revisions through the normal document submittal process. After all jurisdictional engineer comments and revisions have been incorporated, the construction plans or reports containing revisions may be submitted for approval.

C. Submittal Checklist

At a minimum, the following documents should be submitted for review and approval when preparing final construction plans for public improvements or private improvements subject to approval by the jurisdiction.

1. Street plan and profile.
2. Storm sewer plan and profile, including details for all structures and material specifications.
3. Culvert plan, profile, and construction detail for structures.
4. Permanent traffic signing and striping plan.
5. Pavement design where required.
6. Grading and erosion control plan.
7. Sanitary sewer plan and profile including details for all structures, material specifications, and sewer treatment agreement with sewer capacity calculations. Completed permit forms.
8. Water construction plans as approved by the governing jurisdiction or utility with a water supply agreement and completed permit forms. If these plans represent lines to be installed with the proposed roadways, the plans must be approved by the jurisdictional engineer.
9. Plan for traffic control during construction.
10. Engineering review and approval fee, if required.
11. All appropriate permits from the jurisdiction and state and federal agencies.
12. Identification of right-of-way and permanent or temporary easements along with any conditions of use.
13. Stormwater management plan and SWPPP.
14. Geotechnical report.
15. Accessible pedestrian facility plans and documentation.
16. Design variance, if applicable.

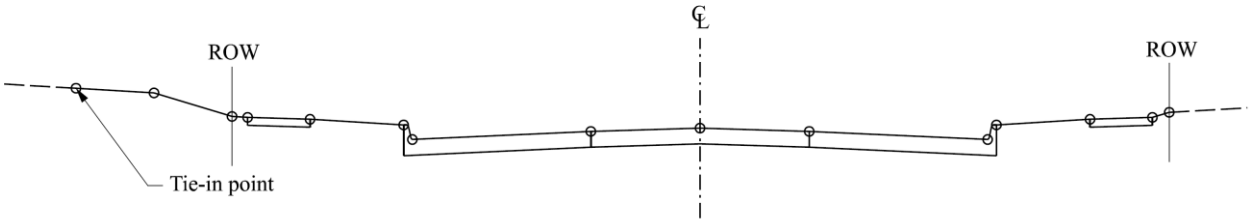
Detailed Plans for Construction of Public Improvements

A. Public Improvement Plan Sheet Requirements

Detailed reproducible plans, certified by a licensed professional engineer in the State of Iowa, should be filed with the jurisdiction for all work involved in public improvement contracts and/or agreements.

When providing computer aided design (CAD) files, ensure they contain all break lines used to develop a 3D file showing coordinates (x,y,z) needed to accurately represent the paper design plans. Break lines should be shown according to the cross-section below. In addition, break lines within the 3D file should indicate all locations within the project limits where there is a change of slope.

The 3D file should be available to potential bidders at the same time that the paper plans are available to the bidders and filed with the jurisdiction. A disclaimer statement should also be included that indicates the paper copy on file with the agency is the official copy and the contractors are responsible for constructing the project to those plans.



Detailed plans should comply with the following general requirements.

1. **Plan Organization:** Plan sheets should be arranged consistently from one plan set to another. In general, the sheets should be arranged according to Table 1D-1.01, which is consistent with Iowa DOT plans, where possible.

   Different plan sheet arrangements may be used to better identify such elements as utility conflicts, temporary pavement markings in conjunction with staging, or others that will provide greater clarity to the contractor. Verify with jurisdiction how to designate plan sheets.

Table 1D-1.01 - Plan Organization

Page Number	SUDAS Description	Iowa DOT Description (Iowa DOT Design Section 1F-1)
A	Title Sheets	Title Sheets
B	Typical Cross-sections and Details (including as-built typical cross-sections)	Typical Cross-sections and Details (including as-built typical cross-sections)
C	Quantities and General Information	Quantities and General Information
CD	*Not typically used*	Drainage Structure Quantities Tabulation
CS	*Not typically used*	Geotechnical Quantities Tabulation
D	Mainline Plan and Profile Sheets	Mainline Plan and Profile Sheets
E	Side Road Plan and Profile Sheets; Open Channel Profile Sheets	Side Road Plan and Profile Sheets
ED	*Not typically used*	Drainage Channel and Dike Plan and Profile Sheets
F	*Not typically used*	Detour Pavement, Temporary Pavement Sheets
G	Survey Sheets (reference ties and bench marks)	Survey Sheets (reference ties and bench marks)
H	Right-of-way Sheets	Right-of-way Sheets
J	Traffic Control and Staging Sheets	Traffic Control and Staging Sheets
K	Landscaping Sheets	Interchange Sheets
L	Geometric, Staking, and Jointing Sheets	Geometric, Staking, and Jointing Sheets
M	Buried Pipe Sheets	Storm Sewer Sheets
MSA	*Use M instead of MSA*	Sanitary Sewer Sheets
MWM	*Use M instead of MWM*	Water Main Sheets
MIT	Wetland Sheets	Wetland Sheets
N	Traffic Signal Sheets	Traffic Signal Sheets
P	Lighting Layout Sheets	Lighting Layout Sheets
Q	Soil Sheets	Soil Sheets
QR	*Not typically used*	Soil Borrow Sheets
R	Erosion and Sediment Control (SWPPP)	Sediment Control Quantities Tabulations
RR	*Not typically used*	Erosion Control Plan Sheets
RU	*Not typically used*	Erosion Control Detail Sheets
S	Sidewalk Sheets	Sidewalk Sheets
SPS	*Not typically used*	Bridge Plan Soils Sheets
T	Earthwork Quantity Sheets	Earthwork Quantity Sheets
U	Design Detail Sheets, Modified Standards, and Detail Sheets	Design Detail Sheets, Modified Standards, and Detail Sheets
V	*Not typically used*	Bridge and Culvert Situation Plans
W	Mainline Cross-sections	Mainline Cross-sections
X	Side Road Cross-sections	Side Road Cross-sections
Y	*Not typically used*	Ramp Cross-sections
Z	*Not typically used*	Detour Cross-sections

All of the above mentioned sheets will not necessarily occur in every plan, but those that do should remain in the same relative order and use the letter designation listed above.

2. **Plan Sheet Material:** Plans filed with the jurisdiction should be on media designated by the jurisdiction.

3. **Plan Sheet Size:** Check with the jurisdiction for appropriate plan sheet sizes.

4. **Title Sheet:** The following information should be shown when applicable.

   a. Project name and vicinity map showing general location.

   b. Jurisdiction's name.

   c. Small scale vicinity map showing project location.

   d. Index (a complete sheet index is to be shown).

   e. File number/project number/contract number (to be provided by the jurisdiction).

   f. Engineer's firm name and address.

   g. Signature line for jurisdiction authority.

   Sample:

   REVIEWED:

   _____

   Jurisdiction Authority Title Date

   h. Sheet number and total number of sheets.

   i. All official plans should be certified according to the requirements set forth by the Iowa Engineering and Land Surveying Examining Board.

   j. Note that projects should be constructed according to the SUDAS Standard Specifications and any applicable supplemental specifications provided by the jurisdiction.

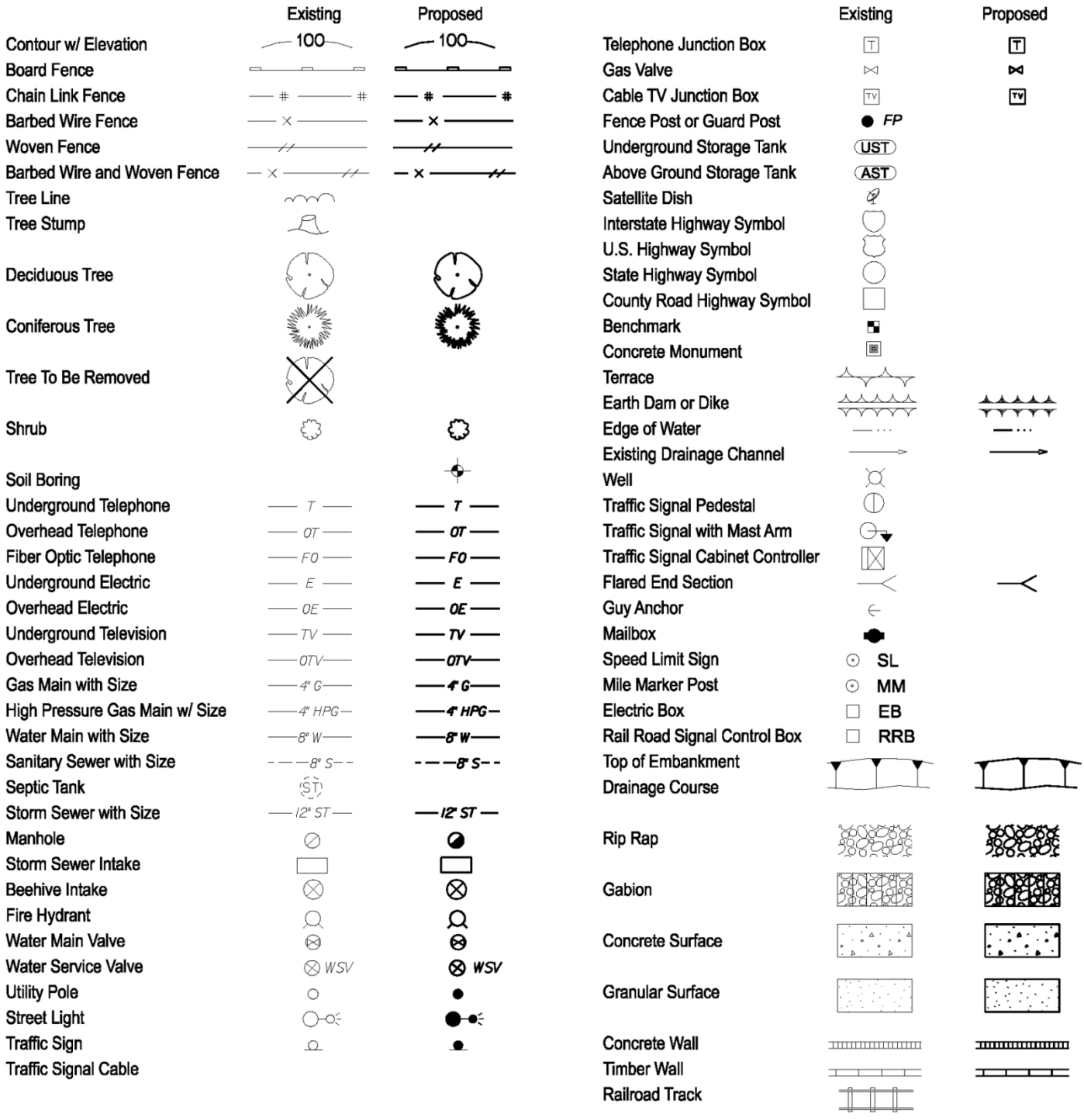
   k. Listing of standards (if applicable).

   l. Owner/developer (if applicable).

   m. Legend (see Figure 1D-1.01 for sample legend).

      The jurisdictional engineer may require different legends depending on the designated design software package. The project engineer should ensure that the completed design plan complies with the jurisdiction's requirements for symbols and the design information to be placed on specific layers within the software program.

Figure 1D-1.01: Sample Legend



5. **Title Block:** Place the following information on the right edge or bottom of the sheet.

    a. The name of the project

    b. Project engineer

    c. Sheet title

    d. Date

    e. Space that denotes revisions

    f. Page numbers

    g. Names or initials of persons designing, detailing, and checking plans

6. **Plan Scale:** Scale to be approved by the jurisdictional engineer. A bar scale is required on each drawing.

B. General Information to be Shown on the Construction Plans

1. Beginning (B.O.P.) and ending (E.O.P.) of project.

2. Street names.

3. Right-of-way widths and legal descriptions as required.

4. Legend and abbreviations as part of title sheet requirements.

5. Adequate witnesses and horizontal and vertical controls so surveyor can lay out project plans. Show all controls at actual locations on the plans. Benchmarks and ties.

6. Lot numbers, subdivision names, and project numbers, as applicable.

7. Lot dimensions (along right-of-way or easements).

8. North arrow up or to the right, when applicable.

9. Existing and proposed utilities, including type, size, and location.

10. Proposed improvement locations, dimensions, and stations.

11. Station Bar (reference all improvements to same stationing). Stationing from left to right or bottom to top.

12. Existing trees, fences, walks, drainage structures, open channels, pavements, buildings, and other obstacles or improvements that could reasonably affect the work area.

13. Survey line or reference line shown on plan view with stations increasing from west to east or south to north, when practical.

14. Quantity estimate - separate sanitary sewer, storm sewer, other utilities, and paving quantities shown if they are detailed on same plan. Include estimate reference information listing any special requirements for each bid item.

15. Easements, both temporary and permanent.

16. Cross-sections - for subdivisions, existing and proposed finished contours may also be used.

17. Special details and special notes when required.

18. Plan view and profile. Profile should line up with plan stations whenever possible.

19. Plans for development work should contain a general note to construct the project according to the SUDAS Specifications and any supplemental specifications of the jurisdiction.

20. Make reference to soils report.

21. Traffic control signs and markings will follow the latest edition of the MUTCD. When it is required by the jurisdiction to maintain traffic during construction, show stage construction and special requirements on the plans. If required, show signing, street closures, and/or detours on traffic control sheet.

22. Permanent signing.

23. SWPPP and temporary and permanent erosion control measures proposed.

24. Other information deemed necessary by the engineer certifying the plans.

C. Detailed Sanitary and Storm Sewer Plans

1. Stationing, location, and type of all manholes, intakes, or other structures.

    a. Show structure designation on the plans.

    b. Show location on the plans and reference survey line or centerline.

    c. Comply with the SUDAS Specifications for the type of structure required.

2. Details should be shown for all structures that are not standard in the SUDAS Specifications.

3. Plan and profiles of all sewer lines and existing and proposed ground line above sewer.

4. Size, length, and grade of sewers in profile.

5. Type of pipe materials and strengths, if different from SUDAS Specifications, or if specific materials are required.

6. Invert elevations at all intakes, manholes, and other structures in profile.

7. Location, size, and type of all sewer stubs, wyes, or tees. Reference stub locations to lot corners. When risers are to be installed, show riser location and size.

8. Estimates should include all length of pipe stubbed out from structures.

9. Rim elevations of manholes, intakes, and other structures.

10. Ensure all castings comply with the jurisdictional requirements on sewers to be maintained by the jurisdiction.

11. Manholes should be identified with a numbering system on plan and profile. Structure sizes and casting sizes to be included by schedule or note on the plans.

12. Class of pipe bedding.

13. Existing utilities or other underground features that could reasonably affect the construction and maintenance of the sewer.

14. Storm sewer design calculations need to be submitted showing drainage area, flow patterns, and flows for design storms. (Hydraulic grade line data).

15. Show storm sewer outlet protection dimensions and locations where apron guards are required.

D. Detailed Open Channel and Drainageway Plans

1. Stationing and flow line elevation at beginning and end of open channel construction.

2. Plan and profile of drainage open channel.

3. Size, type, length, and grade of open channel and alignment.

4. Typical sections showing open channel dimensions, backslopes, and invert and slope treatment.

5. Invert elevations at all structures.

6. All special structures detailed on plans.

7. Criteria for hydraulic design data and elevations.

8. Cross-sections and contour map showing existing ground and finished grade.

9. Permanent and temporary erosion controls.

E. Detailed Paving Plans

1. Minimum 100 feet station intervals and profile elevations at a minimum of 50 feet intervals on tangents and 25 feet intervals at curves. Show station of the centerline of all intersecting streets.

2. Show street profiles and existing ground elevations in the profile view and the curb line in the plan view. The profile should show top of curb tangent grades, vertical curve data, and grade break data. Label any cross slope transitions and special shaping areas.

3. Pavement width (back-to-back).

4. All radii at returns (may be specified in general note if all radii are same).

5. Expansion joint locations, if applicable, on plan view.

6. Horizontal curve data should include centerline PC, PT, PI, delta angle, arc length, degree of curve, tangent length, and radius.

7. Typical cross-section showing baseline, referenced profile, subgrade treatment, pavement thickness, jointing, sidewalk, parking slope, foreslopes, backslopes, cross slopes, any break in ground line or grade, right-of-way line, and dimension of the location of the roadway with the right-of-way line.

8. Vertical curve data should include station and elevation of PI, PC, PT, K-value, low point, and length of curve. Elevations should be given on curves at 25 foot spacing.

9. Intersection details showing drainage and typical joint patterns, if applicable.

10. Location and type of standard sidewalk ramps.

11. Special subgrade or pavement treatment.

12. Location of existing pavement, including elevation and grades.

13. Pavement marking plan, if applicable.

F. Grading Plans/Erosion Control Plans

1. Survey control data.

2. Cross-sections and/or existing and proposed contours and spot elevations, as required.

3. Storm sewer/detention appurtenances.

4. Vicinity map showing haul routes with dates, if any, and borrow areas.

5. Total site area (disturbed area) with construction staging to minimize the area disturbed at any one time.

6. Stationing as it relates to paving plans, sewer, or drainageway plans.

7. Geometric dimensions.

8. Soils data and soil boring location(s) when applicable.

9. Erosion control information and location of any special erosion control measures such as silt fences, silt traps and basins, rip rap or gabions, vegetation and trees to remain, stockpile areas, terraces, contour furrows, temporary diversions, grading phases, etc. See Chapter 7 for a detailed listing of the required contents of Iowa DNR Stormwater Pollution Prevention Plan.

10. Topsoil stockpile and stabilization measures and vegetation areas to be preserved.

G. Water Main Plans

The plans for water mains and appurtenances should show all appropriate physical features adjacent to the proposed water mains along with horizontal and vertical controls and hydrant coverage. Other utilities such as sanitary and storm sewers, manholes, etc. should be shown on the plans with horizontal and vertical separation distances. Design details for other utilities that do not affect the water main should not be shown on water main plans.

1. Stationing, location, and type of all fittings, valves, and fire hydrants.

2. Details should be shown for all items that are not standard in the SUDAS Specifications.

3. Plan and profiles of all water lines and the existing and proposed ground line above the water main.

4. Size, length, and grade of water mains in profile.

5. Type of pipe materials and strengths if different from the SUDAS Specifications or if specific materials and fire hydrants are required.

6. Elevations at all structures in profile.

7. Location, size, and type of all water service stubs. Stub locations should be referenced to lot corners.

8. Estimates should include length of pipe stubbed out from valves.

9. Fire hydrants should be identified with numbering system on plan and profile.

10. Class of pipe bedding if different than the SUDAS Specifications.

11. Existing utilities or other underground features that could reasonably affect the construction and maintenance of the water main.

H. Railroad Crossings

If a railroad crossing is within the project limits, the project engineer should notify the railroad with a copy of the plans and specifications a minimum of 4 months prior to the project letting. If the project limits contain construction of railroad facilities that will be performed by the railroad's forces, the project engineer will state this in the contract documents. The contract documents will state the contractor's limits of responsibility and allow sufficient time in the schedule for the work to be accomplished by the railroad; and that the contractor must coordinate its activities with the railroad or any subcontractors the railroad mandates using during construction. The contractor must be made aware of any permit and insurance requirements imposed by the railroad.

The project engineer should notify the railroad of the following, immediately after awarding the contract:

1. Federal Railroad Administration (FRA) crossing number*

2. Jurisdiction project number

3. Contractor's name, mailing information, and phone number

4. Contractor's contact person

5. Anticipated start date

6. Number of working days

7. Number of days it is believed the contractor will impact the railroad.

8. Date of preconstruction meeting

* For help in identifying the FRA number, see Iowa DOT Office of Rail Transportation's Highway-Railroad Crossing Identifiers webpage.

I. ADA Ramps

1. Ramp design must comply with PROWAG requirements or justification acceptable to the jurisdictional engineer.

2. Delineate all ramp components including ramps, turning spaces, transitions, passing spaces, detectable warning panels, and special shaping areas.

3. Show elevations at top and bottom of ramps, corners of turning spaces and transition areas, and all grade breaks.

4. Show table of slope and distance between all critical points.

Items to be Specified on Plans or in Contract Documents

The SUDAS Specifications specify many items and methods that can be used for the construction of improvements. Following is a list of items in the SUDAS Specifications that are to be noted on the construction drawings and/or in the special provisions whenever there is to be a deviation from the standard requirements of the specifications. This information may include specifying pipe sizes and materials, who is responsible for providing compaction testing, as well as many others.

The project engineer should review the following list and the SUDAS Specifications to make sure all items that are necessary to construct the project are specified on the plans and/or in the special provisions. Please note - this list is not all-inclusive.

Section 2010 - Earthwork, Subgrade, and Subbase

2010, 1.08 D, 1, a	Specify whenever the depth of cut for stripping and salvaging topsoil is other than 8 inches.
2010, 1.08, E	Specify the class of excavation as Class 10, Class 12, or Class 13.
2010, 1.08, E, 1, b, 2)	When the truck count method is to be used for measuring Class 10 or Class 13 excavation, specify if the shrinkage factor is other than 1.35.
2010, 1.08, E, 4	Specify whenever stripping, salvaging, and spreading 8 inches of topsoil is NOT a pay item and is included in the payment of Class 10, Class 12, or Class 13 Excavation.
2010, 1.08, F, 1	Specify whenever below grade excavation (core out) will NOT be measured and paid as extra work.
2010, 1.08, J, 3	Specify whenever removal of pipe and conduits will include capping.
2010, 1.08, L	Specify when the Contractor is responsible for compaction testing.
2010, 2.01	Specify use of compost-amended or off-site topsoil if on-site topsoil is NOT to be used.
2010, 2.02, C, 3	Specify the limits of Class 13 excavation.
2010, 2.04, C, 5	Specify whenever Type 2 geogrid is to be used in lieu of Type 1.
2010, 3.03, F, 1	Specify the desired depth for removal of unsuitable or unstable materials.
2010, 3.04, D	Specify whenever Type A compaction is to be used in lieu of compaction with moisture and density control.

2010, 3.05	Specify whenever and where unsuitable soils will be allowed in the right-of-way.
2010, 3.06, A	Specify if granular stabilization materials or subgrade treatment is to be used in lieu of select subgrade materials.
2010, 3.07	Specify the type of subgrade treatment (lime, cement, fly ash, asphalt, geogrid, or geotextiles) to be used.
2010, 3.07, A, 1	Specify the depth and rate of incorporation of the subgrade treatment material (lime, cement, fly ash, or asphalt).
2010, 3.07, A, 2	Specify the areas requiring subgrade treatment.
2010, 3.08, B	Specify the type and depth of subbase.
2010, 3.09, A	Specify when the Contractor is responsible for compaction testing.
Figure 2010.102	Specify whenever Type A compaction is desired in lieu of compaction with moisture and density control.

Section 3010 - Trench Excavation and Backfill

3010, 1.08, F	Specify when the Contractor is responsible for trench compaction testing.
3010, 2.03, B	Specify whenever Class V material can be used as other than topsoil.
3010, 2.06, D	Specify if foamed cellular concrete may be substituted for flowable mortar.
3010, 3.05, A, 6	Specify if concrete, flowable mortar, CLSM, or foamed cellular concrete is to be used in lieu of other bedding materials.
3010, 3.05, B, 1, a	Specify if granular bedding material is to be used for pressure pipes.
Figure 3010.101	Specify when over-excavation and foundation stone will be required.
Figure 3010.105	Specify when and where to install a waterstop.

Section 3020 - Trenchless Construction

3020, 2.02, A	Specify the wall thickness of casing pipe. See Section 9C-1.
3020, 2.02, C	Specify inside diameter of casing pipe.
3020, 2.05, B	Specify where special fill materials will be used.
3020, 3.04, A, 2, b	Specify the installation deviation tolerances of casing pipe if different than those included.

3020, 3.04, A, 2, b, 2), b) Specify the minimum depth of pressurized pipe.

3020, 3.04, D	Specify when to fill the annular space between the carrier and casing pipe with flowable mortar, CLSM, or foamed cellular concrete.

Section 4010 - Sanitary Sewers

4010, 1.08, A, 1, c	Specify if a pipe lining is to be used.
4010, 1.08, A, 2, c	Specify if a pipe lining is to be used.
4010, 1.08, B, 1, c	Specify if a pipe lining is to be used.
4010, 1.08, B, 2, c	Specify if a pipe lining is to be used.
4010, 1.08, E	Specify the distance beyond the right-of-way line that the sanitary sewer service stub is to extend, if other than 10 feet.
4010, 1.08, H, 3	For removal of sanitary sewer, specify if capping is required.
4010, 2.01, A, 1	For solid wall PVC pipe, 8 inch to 15 inch, specify if SDR 35 may be used.
4010, 2.01, C, 2, a	For corrugated PVC, 8 inch to 10 inch, specify if a minimum pipe stiffness of 46 psi may be used.
4010, 2.02, A	Specify when joint restraints for ductile iron pipe force mains are required.
4010, 2.02, B	Specify when restrained joints are required for PVC force mains.
4010, 2.02, E, 2	Specify the color of plastic post used for tracer wire station.
4010, 3.02, B, 7	Specify the location for installation of wye or tee service fitting.
4010, 3.05, B, 2	Specify the location for any installation of a tracer wire station in addition to each end of the force main.
4010, 3.06, A	Specify the locations for installation of sanitary sewer service stub.
4010, 3.06, C	Specify the distance beyond the right-of-way line that the sanitary sewer service stub is to extend, if other than 10 feet.
4010, 3.06, C, 3	Specify the depth of sanitary sewer service stub at its termination, if other than 10 to 12 feet.
4010, 3.06, C, 5	Specify method of marking the end of the sanitary sewer service line.
4010, 3.08, B, 2	Specify when to fill an abandoned sanitary sewer with flowable mortar, foamed cellular concrete, or CLSM.
4010, 3.10	Specify where to provide sanitary sewer cleanouts.

Section 4020 - Storm Sewers

4020, 1.08, D, 3	Specify if capping is required for removal of storm sewer.
4020, 2.01, A, 3	Specify when to use a rubber O-ring or profile gasket in lieu of a tongue and groove joint wrapped with engineering fabric.

4020, 2.01, B, 3	Specify when to use a rubber O-ring or profile gasket in lieu of a tongue and groove joint wrapped with engineering fabric.
4020, 2.01, C, 3	Specify when to use a rubber O-ring or profile gasket in lieu of a tongue and groove joint wrapped with engineering fabric.
4020, 2.01, G, 1, d	Specify gage of corrugated metal pipe, if other than Iowa DOT Standard Road Plan DR-104.
4020, 2.01, I, 2	Specify gage of coated corrugated metal pipe, if other than Iowa DOT Standard Road Plan DR-104.
4020, 3.04, A	Specify any special linear trench drain installation requirements.
4020, 3.05, B, 2	Specify the use of a rubber O-ring or profile gasket.
4020, 3.06	Specify where to install pipe aprons, apron footings, and apron guards.
4020, 3.09, B, 2	Specify when to fill a line to be abandoned with flowable mortar, foamed cellular concrete, or CLSM.

Section 4030 - Pipe Culverts

4030, 2.01, C, 5	Specify gage of the structural plate culverts, if other than Iowa DOT Standard Road Plan DR-104.
4030, 3.02, A	Specify the locations to install pipe aprons.
4030, 3.02, B	Specify the locations to install apron footings.
4030, 3.02, E	Specify the locations to install apron guards.
Figure 4030.225	Specify when to extend the bottom cross bar through the apron.

Section 4040 - Subdrains and Footing Drains

4040, 1.08, A, 3	Specify the use of engineering fabric.
4040, 1.08, E	Specify the distance beyond the right-of-way that the storm sewer service stub is to extend, if other than 10 feet.
4040, 3.01, A, 1	Excavate trench and provide pipe bedding and backfill as shown on the figures. Install engineering fabric if specified in the contract documents.
4040, 3.02, B	Specify the use of engineering fabric.
4040, 3.03, A	Specify the locations to install footing drain service stubs.
4040, 3.03, C	Specify the distance beyond the right-of-way that the footing drain service stub is to extend, if other than 10 feet.

Figure 4040.231	For Type 1 subdrains, specify Case A, B, or C. For Type 2 subdrains, specify Case D or E and the pipe diameter. When using Case A or Case D, specify the distance from back of curb. For both types, specify when engineering fabric is to be used.
Figure 4040.232	Specify the type of subdrain cleanout to be used.
Figure 4040.233	Specify when to use a CMP outlet.

Section 4050 - Pipe Rehabilitation

4050, 1.07, B	Specify if water will not be provided for cleaning and installation of cured-in-place pipe by the Jurisdiction at no cost.
4050, 1.08	Specify if bypass pumping is not included in the measurement and payment of other bid items. *Applies to C, 1, c; D, 3; E, 1, c; E, 2, c; F, 1, c; F, 2, c; F, 3, c; and F, 4, c.* {Note - 1.08, G is the bid item for bypass pumping}.
4050, 1.08, A, 1, c	Specify if unit price will include disposal and associated costs for all debris removed from sewer.
4050, 1.08, E, 2, a	Specify the length of service pipe to line.
4050, 2.01, C, 2	Specify if the CIPP structural requirements are not fully deteriorated conditions.
4050, 2.01, Table 4050.01	Specify the ovality reduction factor and height of soil above pipe.
4050, 2.02, B	Specify the CIPP point repair liner length.
4050, 2.02, C	Specify if the ovality is a value other than 2%.
4050, 2.03, A, 1	Specify the distance the tube should extend from the sewer main into the service.
4050, 2.03, B, 2	Specify the service liner length.
4050, 2.03, E, 1	Specify if the cured-in-place service liner should be designed following different assumptions than those described in Table 4050.02.
4050, 2.03, Table 4050.02	Specify the depth of cover for each service repair location.
4050, 2.04, C	Specify when to provide a root deterrent chemical to control root regrowth.
4050, 2.07, B	Specify the materials to use for pipe replacement.
4050, 3.01, A, 6	Specify if the Contractor is to pay for disposal fees.
4050, 3.05, B, 1	Specify the length of the CIPP service repair.
4050, 3.06, B, 2	Specify if the length of the service line grouting plug should be a length other than 18 inches.
4050, 3.07, C, 1	Specify the materials to use for the replacement pipe.

Section 4060 - Cleaning, Inspection, and Testing of Sewers

4060, 2.01, B, 3	Specify the type of recording media that will be used to record the inspection.
4060, 3.03, A, 1	Specify whenever video inspection of storm sewers is not desired.

Section 5010 - Pipe and Fittings

5010, 1.08, C	Specify whether measurement of fittings will be made by count or by weight.
5010, 2.01, A, 1, b	Specify the minimum wall thickness for PVC pipe sizes over 24 inches.
5010, 2.01, A, 2	Specify joint type for PVC pipe if other than push-on.
5010, 2.01, B, 1, b	Specify the minimum wall thickness for DIP sizes over 24 inches.
5010, 2.01, B, 4	Specify joint type for DIP if other than push-on.
5010, 2.04, C	Specify when thrust blocks will be used for pipe sizes greater than 16 inches in diameter.
5010, 2.07, B	Specify the materials to use for water service pipe and appurtenances.
5010, 3.01, A, 3	Specify the lines and grades to install pipe with fittings.
5010, 3.01, A, 8	For pipes larger than 16 inches, specify when concrete thrust blocks are required in addition to restrained joints.
5010, 3.06, E	Specify the locations to install ground rods if other than adjacent to connections to existing piping.
5010, 3.07, B	Specify where to construct utility line supports.
5010, 3.08	Specify when the change of piping material is to be on the inside of the structure wall.
Figure 5010.101	Specify when to use the alternate method of thrust blocks at dead ends.

Section 5020 - Valves, Fire Hydrants, and Appurtenances

5020, 1.08, I, 3	Specify if the fire hydrant assembly is to be delivered to the Contracting Authority.
5020, 1.08, J, 3	Specify if the valve is to be delivered to the Contracting Authority.
5020, 1.08, K, 3	Specify if the valve box is to be delivered to the Contracting Authority.
5020, 2.01, A, 2	Specify whenever the opening direction for valves is clockwise.
5020, 2.01, D, 7	Specify the locations to use tapping valve assemblies.
5020, 2.02, B	Specify allowable manufacturer(s) of fire hydrant assemblies.

5020, 2.02, C, 5	Specify whenever the opening direction for fire hydrant assemblies is clockwise.
5020, 2.02, C, 6	For fire hydrant assemblies, specify the operating nut, pumper nozzle, nozzle threads, and main valve nominal opening sizes.
5020, 2.03, A	Specify the type of flushing device (blowoff) to be used.
5020, 2.03, B, 2	Specify the allowable manufacturer(s) for valve boxes.
5020, 3.02	Specify where to install and how to construct flushing device (blowoff).
5020, 3.04, D	Specify if exterior of a new fire hydrant barrel section will be painted a color other than matching the existing fire hydrant.

Section 6010 - Structures for Sanitary and Storm Sewers

6010, 1.08, A, 3	Specify if a manhole lining is to be used.
6010, 2.05, B, 2, b	Specify the use of engineering fabric.
6010, 2.06, B	Specify when to use a concentric cone on sanitary sewer manholes.
6010, 2.11, B, 1	Specify if sanitary sewer manhole exterior is to be coated.
6010, 2.11, B, 2	Specify whenever sanitary sewer manhole lining is required.
6010, 2.13, A, 1	Specify if steps are to be provided in manholes or intakes less than or equal to 20 feet deep.
6010, 3.01, D	Specify if intake lids are NOT to be set to match the longitudinal slope of the adjacent street.
6010, 3.01, J	Specify the type of casting to use for manholes and intakes, except for intakes that have a specific casting type identified on the figures. Specify if casting frame is to be attached to the structure with bolts.
6010, 3.02, B, 2	Specify if reinforcing steel is to lap other than 36 diameters.
6010, 3.04, A, 1	Specify when to install casting extension rings.
6010, 3.04, B, 3	Specify when existing casting may be reinstalled for minor adjustment of existing manhole or intake.
6010, 3.04, C, 4	Specify when existing casting may be reinstalled for major adjustment of existing manhole or intake.
6010, 3.05, C, 1, a	Specify whenever a knockout opening is allowed in lieu of a cored opening.
6010, 3.05, C, 1, b	Specify if sanitary sewer service is NOT required to be maintained at all times when connecting a sanitary sewer to existing manhole or intake.
6010, 3.05, C, 3	Specify whenever a knockout opening is allowed in lieu of a cored opening.

6010, 3.06, A	Specify if removal of manhole or intake is other than to a minimum of 10 feet below top of subgrade in paved areas or 10 feet below finished grade in other areas.
6010, 3.06, B, 3	Specify when to fill abandoned pipe line with flowable mortar or controlled low strength material.
Figure 6010.501	Specify when Type Q grate is to be used in lieu of Type R.
Figure 6010.502	Specify when Type Q grate is to be used in lieu of Type R.
Figure 6010.603	Specify when Type Q grate is to be used in lieu of Type R.

Section 6020 - Rehabilitation of Existing Manholes

6020, 2.02, A	Specify the thickness of the in-situ manhole replacement wall.
6020, 2.02, C	Specify whenever the Contractor is required to provide a PVC or PE plastic liner for in-situ manhole replacement.
6020, 3.01, C	Specify when the use of a urethane chimney seal is allowed.
6020, 3.02, B, 3	Specify whenever a plastic liner is to be installed in an in-situ manhole replacement.

Section 6030 - Cleaning, Inspection, and Testing of Structures

6030, 3.04, A, 1	Specify when exfiltration testing is required for sanitary sewer manholes in lieu of vacuum testing.

Section 7010 - Portland Cement Concrete Pavement

7010, 2.01, E	Specify the use of an intermediate aggregate for concrete.
7010, 2.01, L, 2	Specify the type of performed expansion jointing filler or sealer to use if NOT using a resilient filler.
7010, 2.02, A, 1	Specify the type of Class C or Class M mix to use.
7010, 2.02, C, 2	Specify the type and amount of supplementary cementitious material in the mix.
7010, 3.01, C, 1, c	Specify the use of stringless paving.
7010, 3.02, H, 5, a	Specify when a textured finished surface other than an artificial turf or burlap drag is desired (i.e. surface tining).
7010, 3.02, H, 5, b	Specify when surface tining is required. *Note - longitudinal tining is listed as the default.*
7010, 3.02, I, 1, a	Specify when the use of a linseed oil solution is required.
7010, 3.02, J, 1, a	Specify the type and locations for construction of joints.

7010, 3.02, J, 2, i	Specify when to use wet sawing for dust control.
7010, 3.02, J, 3, a	Specify the location of longitudinal and transverse construction joints.
7010, 3.02, J, 4, a	Specify the location of expansion joints.
7010, 3.07, C, 2, a	Specify when the use of a profilograph for pavement smoothness is required.
Figure 7010.101	Specify when to use Detail D-1, D-2, or D-3.

Section 7011 - Portland Cement Concrete Overlays

7011, 2.01, L, 1	Specify the mass per unit area.
7011, 3.02, E, 3, a	Specify the high spots in the existing asphalt surface to be milled.

Section 7020 - Hot Mix Asphalt Pavement

7020, 1.08, A & B	Specify if measurement of HMA pavement is by ton or square yard.
7020, 1.08, C & D	Specify if measurement of HMA base widening is by ton or square yard.
7020, 3.05, B, 1	Specify when the use of profilograph for pavement smoothness is required.
7020, Table 7020.05	Specify if the field laboratory air voids target value is other than 4%.

Section 7021 - Hot Mix Asphalt Overlays

7021, 2.04, A	Specify the asphalt binder grade.
7021, 3.01, A	Specify the milling depth, cross-section, or profile.

Section 7030 - Sidewalks, Shared Use Paths, and Driveways

7030, 1.08, H, 2	Specify whether granular surfacing for driveways will be computed in square yards or tons.
7030, 1.08, I, 1	Specify whenever the Contractor will be responsible for concrete compression or HMA density testing.
7030, 2.03, A	Specify color and surface texture of clay brick pavers, or select from samples submitted by the Contractor.
7030, 2.03, B	If concrete pavers are to be used, specify the material requirements.
7030, 2.04, B	Specify the use of a pre-mixed high performance cold mix in lieu of an HMA setting bed.
7030, 2.06	Specify the use of colored cement for brick/paver joint filler.
7030, 3.01, A-C	Specify removal limits of sidewalks, shared use paths, driveways, bricks, and curbs.

7030. 3.01, E	Specify the locations to grind or saw existing curbs to install sidewalks, shared use paths, and driveways.
7030, 3.04	Specify the line and running slope to construct sidewalks and shared use paths. Specify the cross slope.
7030, 3.04, F, 2, a, 1)	Specify the spacing for transverse joints in shared use paths, if other than equal to the width of the shared use paths.
7030, 3.05	Specify the cross slope.
7030, 3.06, A, 2	Specify the cross-section and patterns to use for brick sidewalks with a concrete base.
7030, 3.11, A	Specify when testing will be the Contractor's responsibility.
Figure 7030.101	Specify the radius for commercial and industrial driveways. Specify when a 'B' joint is to be provided at the back of curb. Specify the driveway width. Specify when a 5 foot sidewalk is to be constructed through the driveway.
Figure 7030.102	Specify the radius for commercial and industrial driveways. Specify the driveway width. Specify when a 5 foot sidewalk is to be constructed through the driveway.
Figure 7030.104	Specify parking grading slope and property slope if different than 4:1.
Figure 7030.201	If a special grade is required for parking slopes, specify the grade. Specify the width of the sidewalk.
Figure 7030.202	Specify one of the curb details for Class A sidewalk.
Figure 7030.203	Specify the brick sidewalk pattern. Specify the jointing of the concrete base.
Figure 7030.205	Specify the use of a BT-3, KT-2, or expansion joint.

Section 7040 - Pavement Rehabilitation

7040, 1.08, K, 3	Specify the use of waterproof bonding material with pavement core replacement.
7040, 2.01, A, 1	Specify if patches are <u>not</u> constructed as standard patches.
7040, 2.01, A, 2	Specify the use of calcium chloride in high early strength patching.
7040, 2.01, B	Specify if an HMA mixture other than a minimum Low Traffic (LT) mixture is desired.
7040, 2.01, C, 5	Specify the use of soil sterilant for crack and joint filler material.
7040, 2.01, G	Specify if a subbase material other than modified subbase is desired.
7040, 2.01, K	Specify the length and diameter of epoxy coated dowel bars.
7040, 3.01, C	Specify the dimensions of full depth and partial depth patches.
7040, 3.01, F	Specify seeding or sodding the area outside the pavement.

7040, 3.02, A, 1	Specify when a second saw cut is required.
7040, 3.02, C, 6	Specify the locations of joints.
7040, 3.03, B, 2	Specify when to tool the joint.
7040, 3.04, J	Specify when pavement smoothness testing is required.
7040, 3.05, B	Specify the depth to mill the pavement area.
7040, 3.05, D	Specify if materials removed are not the property of the Contractor.
7040, 3.06, B, 3	Specify when to clean wet sawn joints.
7040, 3.06, C, 2	Specify the level to heat, handle, and apply joint filler material.
7040, 3.07, A, 3	Specify when to apply soil sterilant.
7040, 3.07, B, 2	For cracks wider than 1 inch, specify when to utilize additional methods to clean cracks of old crack filler.
7040, 3.07, C, 2	For cracks 1/4 inch to 1 inch in width, specify when to utilize additional methods to clean cracks of old crack filler.
Figure 7040.102	Specify the use of a 'CD' joint.
Figure 7040.105	Specify the use of filter fabric. Specify the type of subbase.

Section 7050 - Asphalt Stabilization

7050, 1.02	Specify the crown of the pavement.
7050, 2.01, B	Specify the type of aggregate required.
7050, 3.03, A	Specify the depth of existing roadway surface to reclaim, if other than 4 inches.
7050, 3.07	Specify the type of surface treatment to apply.

Section 7060 - Bituminous Seal Coat

7060, 1.08 A & B	Specify measurement of bituminous seal coat is in area or units.
7060, 2.01, A	Specify the cover aggregate size.
7060, 2.01, B	Specify bituminous material if different than CRS-2P.
7060, 3.02, A, 1	Specify when to patch and joint fill hard surfaced streets.
7060, 3.04, B	Specify the application rate for spreading binder bitumen, if other than shown in the table.
7060, 3.04, D	Specify the application rate for spreading cover aggregate, if other than shown in the table.

7060, 3.06, B, 2	Specify the rate for spreading binder bitumen for two course seal coats.
7060, 3.06, B, 3	Specify the size of aggregate and the rate for spreading cover aggregate for two course seal coats.
7060, 3.07	Specify if sweeping of rural pavements is not necessary.

Section 7070 - Emulsified Asphalt Slurry Seal

7070, 1.02, B	Specify the application of fine or coarse slurry mixtures.
7070, 2.01, B	Specify when to use crushed aggregates.
7070, 2.02, A	Specify the amount of asphalt emulsion to blend with the aggregate.
7070, 3.01, B, 1, b	Specify the width of slurry mixture application.
7070, 3.02, A	Specify when to complete pavement patches and joint or crack filling for surface preparation.
7070, 3.02, C	Specify if water flushing for surface preparation is not allowed.
7070, 3.03, C	Specify the rate of applying the slurry seal, if other than 10 to 18 pounds per square yard for fine aggregate and 15 to 22 pounds per square yard for coarse aggregate.
7070, 3.03, F	Specify when to apply a burlap drag.
7070, 3.05, E	Specify if strip slurry treatment is to be placed in two separate operations.

Section 7080 - Permeable Interlocking Pavers

7080, 2.02, A	Specify either slotted or perforated underdrain pipes.
7080, 2.02, B	Specify the size of collector pipe if other than 6 inch diameter is desired.
7080, 2.03, C	Specify the size of lateral pipe if other than 4 inch diameter is desired.
7080, 3.02, A	Specify the elevation and grade for the excavation area.
7080, 3.02, B	Specify the use and location of underdrains.
7080, 3.03, A	Specify the use of engineering fabric over completed subgrade.
7080, 3.04, A, 5	Specify cleanout locations.
7080, 3.04, A, 7	Specify the use of underdrain cleanout pipes and observation wells.
7080, 3.04, B, 1	Specify underdrain lateral pipe locations.
7080, 3.05, A	Specify the thickness of storage aggregate.
7080, 3.05, C	Specify the storage aggregate elevation.

7080, 3.06, C	Specify the need to proof roll the filter aggregate.
7080, 3.09	Specify the installation pattern of the pavers.

Section 7090 - Cold-in-Place Pavement Recycling

7090, 2.02	Specify the required strength of the recycled pavement section.
7090, 3.01, B, 1	Specify the width and depth to mill the existing pavement material.
7090, 3.01, B, 2	Specify the use of an asphalt foaming system.
7090, 3.08, C	Specify if the compacted recycled roadway does not have to be within 6 inches of the established centerline.

Section 7091 - Full Depth Reclamation

7091, 2.02	Specify the required strength of the reclaimed pavement section as specified in the contract documents.
7091, 3.01, B, 1	Specify the width and depth to reclaim.
7091, 3.01, B, 2	Specify the use of an asphalt foaming system.
7091, 3.05, A	Specify if multiple passes are required.
7091, 3.09, C	Specify if the compacted, reclaimed roadway does not have to be within 6 inches of the established centerline.
7091, 3.11	Specify when to complete microcracking.
7091, 3.12	Specify the use of an HMA interlayer.

Section 8010 - Traffic Signals

8010, 1.08, B, 3	Specify if pedestrian equipment is required with temporary traffic signal.
8010, 2.01, A, 1, c	Specify if a message besides “TRAFFIC SIGNAL” will be required on the handhole cover.
8010, 2.01, B, 3, a, 2)	Specify solvent welded, socket type fittings for use other than PVC conduit and fittings.
8010, 2.01, C, 6, a	Specify the mode type, size, and number of fibers for fiber optic cable required.
8010, 2.01, C, 6, p	Specify the type of fiber distribution panel if a panel other than one capable of terminating a minimum of 24 fibers is desired.
8010, 2.01, C, 6, t	Specify the use of fusion splice continuous fiber runs or branch circuit connections in splice enclosures.

8010, 2.02, B, 2, c	Specify the voice message to be used for accessible pedestrian signal push button stations.
8010, 2.02, D, 9	Specify the type of mounting for microwave vehicle detectors.
8010, 2.03, A	Specify the use of traffic monitoring systems.
8010, 2.03, B	Specify the use of fiber optic hub cabinet.
8010, 2.03, C, 2, b	Specify the location to mount the antenna for a wireless interconnect network, if other than near the top of the signal pole nearest the controller cabinet.
8010, 2.04, A, 2, b	Specify dimensions and type of aluminum cabinet riser to be used.
8010, 2.04, A, 2, g	Specify accommodations of phasing and expansibility of cabinet back panel positions.
8010, 2.04, C	Specify the use of emergency vehicle preemption system.
8010, 2.05, A, 1, a	Specify the color of vehicle traffic signal head assembly housing.
8010, 2.05, B, 1, a	Specify the color of pedestrian traffic signal head assembly housing.
8010, 2.05, C, 1, a	Specify the mast arm length and vertical pole height.
8010, 2.05, C, 1, f	Specify where to use a combination street lighting/signal pole. Specify if the luminaire arm is to be mounted somewhere other than the same vertical plane as the signal arm.
8010, 2.05, D, 1, a	Specify the vertical pole height of the traffic signal pedestal pole.
8010, 2.05, F, 3	Specify the street name sign dimensions, letter height and font, and sheeting.
8010, 3.01, B, 3, c	Specify if boring pits are allowed to be closer than 2 feet to the back of curb.
8010, 3.01, C, 9, c	Specify if the conduit cables could be pulled through intermediate junction boxes, handholes, pull boxes, pole bases, or any conduit opening.
8010, 3.01, C, 9, g	Specify how much cable slack to provide in each handhole, junction box, and cabinet.
8010, 3.01, C, 9, h	Specify installation of fiber optic accessories.
8010, 3.01, D, 1	Specify the foundation excavation size, shape, and depth.
8010, 3.02, C	Specify the installation of video detection camera system.
8010, 3.03, A	Specify the installation of traffic monitoring system.
8010, 3.03, B	Specify the installation of fiber optic hub cabinet.
8010, 3.04, A, 1	Specify the installation of controller cabinet and auxiliary equipment.

8010, 3.04, B	Specify the installation of controller.
8010, 3.04, C	Specify the installation of UPS battery backup system.
8010, 3.04, D	Specify the installation of emergency vehicle preemption system.
8010, 3.06	Specify construction of temporary traffic signal.
Figure 8010.104	Specify the length of rectangular detector loop.
Figure 8010.105	Specify the number of signals, signs, and spacing.

Section 8020 - Pavement Markings

8020, 3.02, A, 3, c	Specify lane widths.
8020, 3.02, B, 2	Specify if pavement surface will not be cleaned with a rotary broom or street sweeper.
8020, 3.02, D	Specify if pavement is to be grooved prior to placing marking tape.
8020, 3.02, G, 2	Specify when to place pavement markings in a groove cut into the pavement surface.

Section 8030 - Temporary Traffic Control

8030, 1.08, A, 3	Specify when to include portable dynamic message signs, temporary barrier rail, temporary flood lighting, and pilot cars in the traffic control lump sum bid item.
8030, 2.04, B	Specify if something other than precast concrete units are to be used for temporary barrier rail.
8030, 3.01, C	Specify the locations to place temporary barrier rail.
Figure 8030.117	Specify the use of auxiliary lighting or audible information devices.
Figure 8030.118	Specify the use of a crash cushion to separate the temporary sidewalk from vehicular traffic.
Figure 8030.119	Specify the use of auxiliary lighting or audible information devices.

Section 9010 - Seeding

9010, 2.01, B	Specify PLS, which shall not be less than the accumulated total.
9010, 2.02	Specify seed mixture in the contract documents.
9010, 2.03, A, 2	Specify if fertilizer is not to be applied for temporary conventional seeding.
9010, 3.01, A	Specify when aerial application of seed and fertilizer is desired.
9010, 3.01, M	Specify the use of a no-till attachment if desired.

9010, 3.04, E, 4, a	Specify if winter dormant seeding is required.
9010, 3.10, B	Specify when a warranty for seeding is required.

Section 9020 - Sodding

9020, 2.04	Specify when contractor is not to provide water and watering equipment.

Section 9030 - Plant Material and Planting

9030, 1.03, E	Specify when the contractor is to submit a schedule of unit prices for each size and variety of tree, shrub, and ground cover plant.
9030, 2.01, A, 4	Specify whenever plants in rows do not need to be matched in form or size.
9030, 2.01, E, 1	Specify where to use bare root plants.
9030, 3.05	Specify when tree drainage wells are needed.
9030, 3.08, A	Specify when tree wrapping is required.
9030, 3.12, B	Specify when a warranty for plants is required.
Figure 9030.102	Specify when tree wrapping is required.

Section 9040 - Erosion and Sediment Control

9040, 1.08, A, 1	Specify if the Contractor will be responsible for the SWPPP preparation.
9040, 1.08, A, 2	Specify if the Contractor will be responsible for the SWPPP management.
9040, 1.08, B	Specify thickness for compost blankets.
9040, 1.08, E, 1	Specify the width of temporary RECP.
9040, 1.08, I	Specify if level spreaders are not to be removed.
9040, 1.08, L, 1, c	Specify the use of anti-seep collars.
9040, 1.08, O	Specify measurement for stabilized construction entrance in square yards or tons.
9040, 2.02, B	Specify the use of filter berms or compost blankets.
9040, 2.03	Specify the use of filter material in areas other than filter socks and filter berms.
9040, 2.06, A	Specify diameter for open weave, degradable netting if other than 9 inches is required.
9040, 2.07, A, 2	Specify if using RECP for permeable check dam.
9040, 2.08, A	Specify length of pressure-treated timber for level spreaders.

9040, 2.11, A	Specify class of concrete if not Class C.
9040, 2.11, B	Specify riser diameter for sediment basin outlet structures.
9040, 2.11, C, 1	Specify the number, diameter, and elevation of the holes in the riser of the dewatering device in sediment basin outlet structures.
9040, 2.11, D	Specify barrel diameter of the sediment basin outlet structures.
9040, 2.11, E	Specify riser diameter for anti-vortex device.
9040, 3.02, D	Specify if weekly erosion and sediment control site inspections are not required as a part of SWPPP management.
9040, 3.05, B	Specify depth of compost blankets.
9040, 3.06, A	Specify when the filter berm is not to be installed along the contour.
9040, 3.06, C	Specify when a vegetated berm is required.
9040, 3.07, A, 1	Specify the size and length of filter sock.
9040, 3.07, A, 3	Specify when the filter sock is not to be installed along the contour.
9040, 3.07, B	Specify when to remove the filter sock.
9040, 3.08, A, 2	Specify if placement of seed and fertilizer is to be accomplished before installation of temporary rolled erosion control products.
9040, 3.08, A, 3	Specify if placement of seed and fertilizer is to be accomplished on the anchor trench.
9040, 3.08, B, 1	Specify if placement of seed and fertilizer is to be accomplished before installation of temporary rolled erosion control products.
9040, 3.09, B	Specify when to remove the wattle.
9040, 3.10, A, 2	Specify when to provide an RECP under the check dam.
9040, 3.10, D	Specify when to remove check dams.
9040, 3.12, C	Specify the excavated depth behind the level spreader.
9040, 3.12, E	Specify the minimum depth of depression before accumulated sediment is removed.
9040, 3.15, B, 1	Specify the number, diameter, and configuration of holes in the riser section of sediment basin outlet structures.
9040, 3.17	Specify the size and elevations of sediment traps.
9040, 3.18, A, 1	Specify when the silt fence material is not to be installed along the contour.

9040, 3.19, E	Specify when to install subgrade stabilization fabric prior to placing crushed stone.
9040, 3.19, F	Specify the thickness and dimensions of crushed stone for stabilized construction entrance.
Figure 9040.101	Specify if compost blankets are vegetated or unvegetated.
Figure 9040.102	Specify size of berm if slope is steeper than 3:1. Specify berm placement locations in uncompacted windrow perpendicular to the slope. Specify filter sock diameter.
Figure 9040.105	Specify diameter of wattle. Specify space between wattles.
Figure 9040.107	Specify height between engineering fabric and crest on the rock check dam.
Figure 9040.108	Specify total height of diversion.
Figure 9040.109	Specify excavated depression depth.
Figure 9040.110	Specify the rock thickness (T), width (W), and length (L) for rip rap apron for pipe outlet onto flat ground.
Figure 9040.111	Specify the rock thickness (T), width (W), and length (L) for rip rap apron for pipe outlet into channel.
Figure 9040.112	Specify diameter of pipe for temporary pipe slope drain. Specify A, B, and C anchoring options.
Figure 9040.113	Specify barrel length and diameter for sediment basin without emergency spillway. Specify when anti-seep collars are required.
Figure 9040.114	Specify barrel length and diameter for sediment basin with emergency spillway. Specify when anti-seep collars are required.
Figure 9040.115	Specify elevations and dimensions for sediment basin dewatering device. Specify perforation configurations. Specify diameter of discharge pipe barrel.
Figure 9040.116	Specify riser diameter for anti-vortex device.
Figure 9040.117	Specify when anti-seep collars are required.
Figure 9040.118	Specify width of sediment trap.
Figure 9040.119	Specify spacing of post installation for silt fence.

Section 9050 - Gabions and Revet Mattresses

9050, 1.08, A, 3	Specify PVC coating for gabions.
9050, 1.08, B, 3	Specify PVC coating for revet mattresses.
9050, 2.01	Specify when double twisted wire baskets are <u>not</u> required.

9050, 2.02	Specify when to use welded wire baskets.
9050, 2.05	Specify when to use anchor stakes. Specify the length of anchor stakes.
9050, 3.01, A	Specify when to cut and reshape the area behind a proposed gabion wall to allow for placement of the wall.
9050, 3.01, E	Specify the placement, compaction, and dimensions of granular subbase materials.
9050, 3.04, A	Specify special details of gabion wall installation including height, slope of wall, gabion setback, special backfill materials, and tieback requirements.

Section 9060 - Chain Link Fence

9060, 1.08, A, 3	Specify PVC coating for chain link fence.
9060, 1.08, B, 3	Specify the use of barbed wire for gates.
9060, 1.08, C, 3	Specify the type of barbed wire supporting arm.
9060, 2.01, D, 2	Specify the PVC coating color.
9060, 2.02, A, 2	Specify the nominal diameter of fence height for post use, if other than shown in the table.
9060, 2.05, A	Specify the type of arm configuration for barbed wire supporting arms.
9060, 2.07, A	Specify the type, height, and width of gates.
9060, 3.01, A	Specify fence location and height.
9060, 3.01, B, 2, a	Specify post holes dimensions.
9060, 3.01, B, 2, e	Specify the required brace-post assembly.
9060, 3.01, G	Specify when to use barbed wire.
9060, 3.01, G, 1	Specify the installation of barbed wire, if other than 3 parallel wires on each barbed wire supporting arm on the outside of the area being secured.
9060, 3.01, H	Specify the installation requirements for gates.
9060, 3.01, I, 1	Specify the installation of electrical grounds.
9060, 3.02	Specify when all fences, including posts and footings, are <u>not</u> to be removed from within work areas.
9060, 3.03, A	Specify the height of temporary fence.
Figure 9060.101	Specify the fence fabric width. Specify when to install fence on the roadway side of the right-of-way.

Figure 9060.103	Specify the length of the sidewalk.

Section 9070 - Landscape Retaining Walls

9070, 2.01, B	Specify the depth of limestone slabs, if other than 8 inches.
9070, 3.01, B	Specify the excavation line and grade.

Section 9071 - Segmental Block Retaining Walls

9071, 3.01, B	Specify the excavation line and grade.
9071, 3.02, B	Specify leveling pad materials.
9071, 3.02, C	Specify the elevation and orientation.
9071, 3.02, D, 1	Specify the use of subdrains.

Section 9072 - Combined Concrete Sidewalk and Retaining Wall

9072, 2.01, A, 3	Specify the type of expansion joint, if resilient filler is not desired.
9072, 3.01, B	Specify the excavation line and grade.
9072, 3.04	Specify the formation of rustications.

Section 9080 - Concrete Steps, Handrails, and Safety Rail

9080, 2.04, B	Specify when to galvanize handrail and safety rail.
9080, 2.04, C	Specify when to apply powder coat to steel, galvanized steel, or aluminum handrail and safety rail.
9080, 3.02, A, 1	Specify the length of rail.
Figure 9080.103	Specify the field painting of safety rail.

Section 10,010 - Demolition

10,010, 1.07, A	Specify when the use of explosives is allowed.
10,010, 3.08, D	Specify when the removal and disposal of all brush, shrubs, trees, logs, downed timber, and other yard waste on the site is not desired.
10,010, 3.08, E	Specify when the removal of all retaining walls is not desired.
10,010, 3.11	Specify what materials are required to be recycled from the demolition site.

Section 11,010 - Construction Survey

11,010, 1.02	Specify any additional items to be included in construction survey work.
11,010, 3.02, D	Specify if property limits are to be marked.
11,010, 3.04	Specify which land corners, property corners, permanent reference markers, and benchmarks are to be replaced.

Section 11,040 - Temporary Sidewalk Access

11,040, 3.02, A	Specify locations to construct temporary granular sidewalks.
11,040, 3.03, B	Specify locations to locate temporary longitudinal channelizing devices.
Figure 11,040.102	Specify when to install orange construction safety fence between the top of the bottom rail and the bottom of the top rail.

Incidental or Included Items

Items that are necessary to properly complete construction, including work and materials, and are not pay items. The following is a list of items in the SUDAS Specifications that are considered incidental to other work unless specified as a pay item on the plans or in the contract documents. Please note - this list is not all-inclusive.

Section 2010 - Earthwork, Subgrade, and Subbase

2010, 1.08, A, 3 — Clearing and Grubbing (by units)
Placement of backfill in area where roots have been removed, and removal and disposal of all materials.

2010, 1.08, B, 3 — Clearing and Grubbing (by area)
Removal and disposal of all materials and placement of backfill in area where roots have been removed.

2010, 1.08, D, 2, c — Topsoil, Compost-amended
Furnishing and incorporating compost.

2010, 1.08, E, 3 — Excavation, Class 10, Class 12, or Class 13

a. Site preparation for, and the construction of, embankment, fills, shoulder backfill, and backfill behind curbs.
b. Overhaul.
c. Finishing the soil surface, including roadways, shoulders, behind curbs, side ditches, slopes, and borrow pits.
d. Repair or replacement of any fences that have been unnecessarily damaged or removed.
e. Compaction testing, as specified in the contract documents.

2010, 1.08, F, 3 — Below Grade Excavation (Core Out)
Equipment, tools, labor, disposal of unsuitable materials, dewatering, drying, furnishing, and placement of foundation materials as required by the Engineer, compaction and finishing of the excavated area, and all incidental work as may be required.

2010, 1.08, G, 3 — Subgrade Preparation
Excavating, manipulating, replacing, compacting, and trimming to the proper grade.

2010, 1.08, H, 3 — Subgrade Treatment
Furnishing, placing, and incorporating the subgrade treatment material (cement, asphalt, fly ash, lime, geogrid, or geotextiles).

2010, 1.08, I, 3 — Subbase
Furnishing, placing, compacting, and trimming to the proper grade.

2010, 1.08, J, 1, c — Removal of Structures
Removal and disposal of structures.

2010, 1.08, J, 2, a, 3) — Removal of Known Box Culverts
Removal and disposal of known box culverts.

2010, 1.08, J, 2, c, 3) — Removal of Known Pipe Culverts
Removal and disposal of known pipe culverts.

2010, 1.08, J, 3, a, 3) — Removal of Known Pipes and Conduits
Removal, disposal, and plugging, if specified, of pipes and conduits.

Section 3010 - Trench Excavation and Backfill

3010, 1.08, A — General

1. Standard trench excavation.
2. Removal and disposal of unsuitable backfill material encountered during standard trench excavation.
3. Removal of abandoned private utilities encountered during trench excavation.
4. Furnishing and placing granular bedding material.
5. Placing and compacting backfill material.
6. Dewatering including, but not limited to, all equipment such as generators, pumps, rock for sump pits, discharge piping, and any extra excavation needed to facilitate dewatering according to stormwater regulations, as applicable.
7. Sheeting, shoring, and bracing.
8. Adjusting the moisture content of excavated backfill material to the range specified for placement and compaction.

3010, 1.08, C, 3 — Trench Foundation
Removal and disposal of over-excavated material required to stabilize trench foundation; and furnishing, hauling, and placing stabilization material.

3010, 1.08, D, 3 — Replacement of Unsuitable Backfill Material
Furnishing, hauling, and placing backfill material.

3010, 1.08, E, 3 — Special Pipe Embedment or Encasement
Furnishing and placing all required special pipe embedment or encasement materials.

Section 3020 - Trenchless Construction

3020, 1.08 — All items of work contained in this section are incidental to the underground utility pipe being installed and will not be paid for separately.

Section 4010 - Sanitary Sewers

4010, 1.08, A, 1, c — Sanitary Sewer Gravity Main, Trenched
Trench excavation; dewatering; furnishing and installing pipe; pipe lining (if specified); furnishing, placing, and compacting bedding and backfill material; wyes and other fittings; pipe joints; pipe connections; testing; and inspection.

4010, 1.08, A, 2, c — Sanitary Sewer Gravity Main, Trenchless
Furnishing and installing pipe; pipe lining (if specified); trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; pipe connections; testing; and inspection.

4010, 1.08, B, 1, c — Sanitary Sewer Gravity Main with Casing Pipe, Trenched
Furnishing and installing both carrier pipe and casing pipe, pipe lining (if specified); trench excavation, dewatering, furnishing bedding material, placing bedding and backfill material, furnishing and installing annular space fill material, casing spacers, pipe connections, testing, and inspection.

4010, 1.08, B, 2, c — Sanitary Sewer Gravity Main with Casing Pipe, Trenchless
Furnishing and installing both carrier pipe and casing pipe; pipe lining (if specified); trenchless installation materials and equipment; pit excavation; dewatering; and placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; pipe connections; testing; and inspection.

4010, 1.08, C, 1, c — Sanitary Sewer Force Main, Trenched
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill; wyes and other fittings; pipe joints; testing; and inspection.

4010, 1.08, C, 2, c — Sanitary Sewer Force Main, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; pipe connections; testing; and inspection.

4010, 1.08, D, 1, c — Sanitary Sewer Force Main with Casing Pipe, Trenched
Furnishing and installing both carrier pipe and casing pipe; trench excavation; dewatering; furnishing, placing, and compacting bedding and backfill material; furnishing and installing annular space fill material; casing spacers; pipe connections; testing; and inspection.

4010, 1.08, D, 2, c — Sanitary Sewer Force Main with Casing Pipe, Trenchless
Furnishing and installing both carrier pipe and casing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; pipe connections; testing; and inspection.

4010, 1.08, E, 3 — Sanitary Sewer Service Stub
Trench excavation; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; tap; fittings; testing; and inspection.

4010, 1.08, F, 3 — Sanitary Sewer Service Relocation
Removal of existing pipe, trench excavation, furnishing new pipe and bedding material, placing and compacting bedding and backfill material, connection back to existing service, compaction, testing, and inspection.

4010, 1.08, G, 3 — Sewage Air Release Valve and Pit
Excavation; furnishing, placing, and compacting bedding and backfill material; and testing.

4010, 1.08, H, 3 — Removal of Sanitary Sewer
Removal, disposal, and capping (if specified) of pipe; and furnishing, placing, and compacting backfill material.

4010, 1.08, I, 3 — Sanitary Sewer Cleanout
Plug at the end of the main, fittings, riser pipe, cap with screw plug, casting, and concrete casting encasement.

4010, 1.08, K, 3 — Sanitary Sewer Abandonment, Plug
Trench excavation (if necessary), cutting pipe (if required), furnishing and placing plug materials, and placing and compacting backfill material.

4010, 1.08, L, 3 — Sanitary Sewer Abandonment, Fill and Plug
Trench excavation (if necessary), cutting pipe (if required), furnishing and placing pipe fill material, furnishing and placing plug materials, and placing and compacting backfill material.

Section 4020 - Storm Sewers

4020, 1.08, A, 1, c — Storm Sewer, Trenched
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; joint wrapping; wyes and other fittings; pipe joints; pipe connections; testing; and inspection.

4020, 1.08, A, 2, c — Storm Sewer, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; pipe connections; testing; and inspection.

4020, 1.08, B, 1, c — Storm Sewer with Casing Pipe, Trenched
Furnishing and installing both carrier pipe and casing pipe; trench excavation; dewatering; furnishing, placing, and compacting bedding and backfill material; furnishing and installing annular space fill material; casing spacers; pipe connections; testing; and inspection.

4020, 1.08, B, 2, c — Storm Sewer with Casing Pipe, Trenchless
Furnishing and installing both carrier pipe and casing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; pipe connections; testing; and inspection.

4020, 1.08, C, 3 — Linear Trench Drain
Furnishing and installing the linear trench drain including all appurtenances; furnishing and placement of PCC transition; furnishing, excavation, and backfill of discharge pipe; connection to manhole or intake, if required; installation of apron, if required.

4020, 1.08, D, 3 — Removal of Storm Sewer
Removal, disposal, and capping (if specified) of pipe; and furnishing, placing, and compacting backfill material.

4020, 1.08, F, 3 Storm Sewer Abandonment, Plug
Trench excavation (if necessary), cutting pipe (if required), furnishing and placing plug materials, and placing and compacting backfill material.

4020, 1.08, G, 3 Storm Sewer Abandonment, Fill and Plug
Trench excavation (if necessary), cutting pipe (if required), furnishing and placing pipe fill material, furnishing and placing plug materials, and placing and compacting backfill material.

Section 4030 - Pipe Culverts

4030, 1.08, A, 1, c Pipe Culvert, Trenched
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; connectors; testing; and inspection.

4030, 1.08, A, 2, c Pipe Culvert, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation, dewatering, and placing and compacting backfill material; pipe connections; testing; and inspection.

4030, 1.08, B, 3 Pipe Apron
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; connectors; and other appurtenances.

4030, 1.08, C, 3 Footings for Concrete Pipe Aprons
Excavation; dewatering; reinforcing steel; concrete; furnishing and installing apron; furnishing, placing and compacting bedding and backfill material.

Section 4040 - Subdrains and Footing Drain Collectors

4040, 1.08, A, 3 Subdrain
Trench excavation, furnishing and placing bedding and backfill material, engineering fabric (when specified), connectors, and elbows and tees. The length of elbows and tees of the pipes installed will be included in the length of pipe measured.

4040, 1.08, B, 3 Footing Drain Collector
Trench excavation, pipe, wyes, tap, fittings, and furnishing and placing bedding and backfill material.

4040, 1.08, D, 3 Subdrain or Footing Drain Outlets and Connections
Pipe, non-shrink grout, coupling bands, and rodent guards for pipes 6 inches or smaller.

4040, 1.08, E, 3 Storm Sewer Service Stub
Trench excavation, furnishing bedding material, placing bedding and backfill material, tap, fittings, and plugs.

Section 4050 - Pipe Rehabilitation

4050, 1.08, A, 1, c — Pre-Rehabilitation Cleaning and Inspection
Pre-cleaning CCTV inspection, light sewer cleaning, debris removal and transport, post cleaning CCTV inspection for Engineer review, and identification and logging of active service taps. If specified in the contract documents, unit price also includes disposal and associated costs for all debris removed from sewer.

4050, 1.08, A, 2, c — Additional Sewer Cleaning
Heavy sewer cleaning; root cutting; deposit cutting; and removing, transporting, disposing, paying associated costs for all debris removed from sewer, and post cleaning CCTV inspection for Engineer review.

4050, 1.08, B, 3 — Remove Protruding Service Connections
Removal of protruding service connections and debris removal.

4050, 1.08, C, 1, c — CIPP Main Lining
Furnishing and installing the liner and appurtenances, CCTV inspection immediately prior to lining, bypass pumping unless otherwise specified, sliding foil, post-lining CCTV inspection, and all costs associated with the public information and notification program.

4050, 1.08, C, 2, c — Building Sanitary Sewer Service Reinstatement
Reinstating sanitary sewer service connections, removal of debris, and coordination with service owners.

4050, 1.08, C, 3, c — CIPP End Seal
End seal and installation.

4050, 1.08, D, 3 — CIPP Point Repair
Furnishing and placing point repair liner, bypass pumping unless otherwise specified, sewer cleaning, removal of obstructions, debris removal, pipe preparation, and pre and post repair CCTV inspection.

4050, 1.08, E, 1, c — CIPP Service Pipe, Connection
Furnishing and placing service connection liner, bypass pumping unless otherwise specified, documentation, and all costs associated with the public information and notification program.

4050, 1.08, E, 2, c — CIPP Service Repair, Partial Pipe
Furnishing and installing service repair liner, bypass pumping unless otherwise specified, documentation, and all costs associated with the public information and notification program.

4050, 1.08, F, 1, c — Pressure Testing of Mainline Sewer Joints
Bypass pumping unless otherwise specified, control testing, and documentation.

4050, 1.08, F, 2, c — Injection Grouting of Mainline Sewer Joints
Bypass pumping unless otherwise specified, material testing, pressure testing after grouting, re-grouting of failed joints, and documentation. Unit price does not include the quantity of chemical grout used.

4050, 1.08, F, 3, c — Pressure Testing of Service Connections
Bypass pumping unless otherwise specified, and documentation.

4050, 1.08, F, 4, c — Injection Grouting of Service Connections
Bypass pumping unless otherwise specified, material testing, pressure testing after grouting, and documentation. Unit price does not include the quantity of chemical grout used.

4050, 1.08, F, 5, c — Chemical Grout
Grout additives; root inhibitor; and supplying, mixing, and measurement of chemical grout.

4050, 1.08, G, 3 — Bypass Pumping
Development and submittal of the bypassing plan, all staffing, equipment, and appurtenances necessary to accomplish the approved bypassing plan, including reserve equipment.

4050, 1.08, H, 1, c — Spot Repairs (by Pipe Replacement)
Uncovering and removing existing pipe and furnishing and placing bedding and backfill material for replacement pipe.

4050, 1.08, H, 2, c — Spot Repairs (by Linear Foot)
Furnishing and installing replacement pipe and connections.

Section 4060 - Cleaning, Inspection, and Testing of Sewers

4060, 1.08 — Cleaning, inspecting, and testing sanitary sewers, storm sewers, pipe culverts, and rehabilitated pipes (including video inspection) are incidental to other project costs and will not be paid for separately.

Section 5010 - Pipe and Fittings

5010, 1.08, A, 1, c — Water Main, Trenched
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; tracer system; testing; disinfection; and polyethylene wrap for ductile iron pipe and for fittings.

5010, 1.08, A, 2, c — Water Main, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; tracer system; testing; and disinfection.

5010, 1.08, B, 1, c — Water Main with Casing Pipe, Trenched
Furnishing and installing both carrier pipe and casing pipe; trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; casing spacers; furnishing and installing annular space fill material; tracer system; testing; and disinfection.

5010, 1.08, B, 2, c — Water Main with Casing Pipe, Trenchless
Furnishing and installing both carrier pipe and casing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; tracer system; testing; and disinfection.

5010, 1.08, C, 1, c	Fitting (by count) Restrained joints and thrust blocks.
5010, 1.08, C, 2, c	Fitting (by weight) Restrained joints and thrust blocks.
5010, 1.08, D, 3	Water Service Stub (by each) Water service corporation; service pipe; curb stop; stop box; trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; and installation of tracer wire system for non-metallic service pipe.
5010, 1.08, E, 1, c	Water Service Stub (by length), Water Service Pipe Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; and installation of tracer wire system for non-metallic service pipe.

Section 5020 - Valves, Fire Hydrants, and Appurtenances

5020, 1.08, A, 3	Valve (Butterfly or Gate) All components attached to the valve or required for its complete installation, including underground or above ground operator, square valve operating nut, valve box and cover, valve box extension, and valve stem extension.
5020, 1.08, B, 3	Tapping Valve Assembly Tapping sleeve, tapping valve, the tap, valve box and cover, valve box extension, and valve stem extension.
5020, 1.08, C, 3	Fire Hydrant Assembly The fire hydrant, barrel extensions sufficient to achieve proper bury depth of anchoring pipe and height of fire hydrant above finished grade, and components to connect the fire hydrant to the water main, including anchoring pipe, fittings, thrust blocks, pea gravel or porous backfill material, and fire hydrant gate valve and appurtenances, except tapping valve assembly if used.
5020, 1.08, E	Measurement and payment for minor adjustment of an existing valve box by raising or lowering the adjustable valve box is incidental.
5020, 1.08, G, 3	Valve Box Replacement Removal of existing valve box; excavation; furnishing and installing new valve box; backfill; compaction; and all other necessary appurtenances.
5020, 1.08, H, 3	Fire Hydrant Adjustment Removal and reinstallation of the existing fire hydrant; furnishing and installing the extension barrel section and stem; and all other necessary appurtenances.
5020, 1.08, I, 3	Fire Hydrant Assembly Removal Excavation, removal of the fire hydrant, hydrant valve, thrust block, delivery of the fire hydrant assembly to the Contracting Authority (if specified), capping of the pipe, backfill, compaction, and surface restoration to match the surrounding area.

5020, 1.08, J, 3 Valve Removal
Excavation, removal of each valve, replacing the removed valve with pipe and connections if required or capping the former valve connection, delivery of the valve to the Contracting Authority (if specified), backfill, compaction, and surface restoration to match the surrounding area.

5020, 1.08, K, 3 Valve Box Removal
Excavation, removal of each valve box, delivery of the valve box to the Contracting Authority (if specified), backfill, compaction, and surface restoration to match the surrounding area.

Section 5030 - Testing and Disinfection

5030, 1.08 Testing and disinfection of water systems is incidental to the construction of pipe and fittings.

Section 6010 - Structures for Sanitary and Storm Sewers

6010, 1.08, A, 3 Manhole
Excavation; furnishing and installing pipe; lining (if specified); furnishing, placing, and compacting bedding and backfill material; base; structural concrete; reinforcing steel; precast units (if used); concrete fillets; pipe connections; infiltration barriers (sanitary sewer manholes only); castings; and adjustment rings.

6010, 1.08, B, 3 Intake
Excavation; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; base; structural concrete; reinforcing steel; precast units (if used); concrete fillets; pipe connections; castings; and adjustment rings.

6010, 1.08, C, 1, c Internal Drop Connection
Cutting the hole and installing a flexible watertight connector, providing and installing the receiving bowl, flexible coupler between the bowl and the drop pipe, the PVC drop pipe, pipe brackets and bolts, the bottom elbow, repair of fillet if required, and a splash guard if required.

6010, 1.08, C, 2, c External Drop Connection
The connection to the manhole and all pipe; fittings; concrete encasement; and furnishing, placing, and compacting bedding and backfill material.

6010, 1.08, E, 3 Manhole or Intake Adjustment, Minor
Removing existing casting and existing adjustment rings, furnishing and installing adjustment rings, furnishing and installing new casting, and installing new infiltration barrier (sanitary sewer manholes only).

6010, 1.08, F, 3 Manhole or Intake Adjustment, Major
Removal of existing casting, adjustment rings, top sections, and risers; excavation; concrete and reinforcing steel or precast sections; furnishing and installing new casting; installing new infiltration barrier (sanitary sewer manholes only); placing backfill material; and compaction.

6010, 1.08, G, 3 — Connection to Existing Manhole or Intake
Coring or cutting into the existing manhole or intake, pipe connectors, grout, and waterstop (when required).

6010, 1.08, H, 3 — Remove Manhole or Intake
Removal of casting, concrete, and reinforcement; plugging pipes; filling remaining structure with flowable mortar; and placing compacted fill over structure to finished grade.

Section 6020 - Rehabilitation of Existing Manholes

6020, 1.08, A, 1, c — Infiltration Barrier, Rubber Chimney Seal
All necessary compression or expansion bands and extension sleeves as necessary to complete chimney seal.

6020, 1.08, A, 2, c — Infiltration Barrier, Molded Shield
Sealant.

6020, 1.08, B, 3 — In-situ Manhole Replacement, Cast-in-place Concrete
Handling of sewer flows as required to properly complete the installation, invert overlay as recommended by the manufacturer, replacement of existing casting with a new casting, and testing the manhole upon completion.

6020, 1.08, C, 3 — In-situ Manhole Replacement, Cast-in-place Concrete with Plastic Liner
Handling of sewer flows as required to properly complete the installation, invert overlay as recommended by the manufacturer, replacement of existing casting with a new casting, sealing at the frame and cover, sealing pipe penetrations as recommended by the manufacturer, and testing the manhole upon completion.

6020, 1.08, D, 3 — Manhole Lining with Centrifugally Cast Cementitious Mortar Liner with Epoxy Seal
Handling of sewer flows during lining operations as required to properly complete the installation, and replacement of the existing casting with a new casting.

Section 6030 - Cleaning, Inspection, and Testing of Structures

6030, 1.08 — Cleaning, inspection, and testing of structures are incidental to construction of structures and will not be paid for separately.

Section 7010 - Portland Cement Concrete Pavement

7010, 1.08, A, 3 — Pavement, PCC
Final trimming of subgrade or subbase, integral curb, bars and reinforcement, joints and sealing, surface curing and pavement protection, safety fencing, concrete for rigid headers, boxouts for fixtures, and pavement smoothness testing.

7010, 1.08, E, 3 — Curb and Gutter
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.

7010, 1.08, F, 3 — Beam Curb
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.

7010, 1.08, G, 3 — Concrete Median
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.

7010, 1.08, H, 3 — PCC Railroad Crossing Approach
Excavation for modified subbase and subdrain, furnishing and installing subdrain, furnishing and installing subdrain outlet or connection to storm sewer, furnishing and installing porous backfill material, furnishing and installing fiber board barrier, furnishing and placing modified subbase material, furnishing and installing reinforcing steel and tie bars, furnishing and placing concrete, furnishing, placing, and compacting HMA.

7010, 1.08, I, 3 — PCC Pavement Samples and Testing
Certified plant inspection, pavement thickness cores, profilograph pavement smoothness measurement (when required by the contract documents), and maturity testing.

7010, 1.08, K, 3 — PCC Pavement Widening
Final subgrade/subbase preparation, integral curb, bars and reinforcement, joints and sealing, surface curing and pavement protection, safety fencing, concrete for rigid headers, boxouts for fixtures, and pavement smoothness.

Section 7011 - Portland Cement Concrete Overlays

7011, 1.08, A, 1, c — PCC Overlay, Furnish Only
Furnishing the concrete mixture and delivery to the project site.

7011, 1.08, A, 2, c — PCC Overlay, Place Only
Integral curb, bars and reinforcement, joints and sealing, finishing and texturing, surface curing and pavement protection, safety fencing, concrete for rigid headers, boxouts for fixtures, and pavement smoothness testing.

7011, 1.08, A, 3, c — Surface Preparation for Bonded PCC Overlay
Sandblasting, shot blasting, scarification, and surface cleaning.

7011, 1.08, A, 4, c — Surface Preparation for Unbonded PCC Overlay
Scarification and surface cleaning.

7011, 1.08, A, 5, c — HMA Separation Layer for Unbonded PCC Overlay
HMA mix, including asphalt binder.

7011, 1.08, A, 6, c — Geotextile Fabric Separation Layer for Unbonded PCC Overlay
Cleaning surface and furnishing, placing, and securing the geotextile fabric separation layer.

Section 7020 - Hot Mix Asphalt Pavement

7020, 1.08, A, 3 — Pavement, HMA (by ton)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.

7020, 1.08, B, 3 — Pavement, HMA (by square yard)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.

7020, 1.08, C, 3 — HMA Base Widening (by ton)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.

7020, 1.08, D, 3 — HMA Base Widening (by square yard)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.

7020, 1.08, E, 3 — HMA Railroad Crossing Approach
Excavation for modified subbase and subdrain, furnishing and installing subdrain, furnishing and installing subdrain outlet, furnishing and installing porous backfill material, furnishing and installing fiber board barrier, furnishing and placing modified subbase material, furnishing and applying tack coat, furnishing, placing, and compacting HMA.

7020, 1.08, I, 3 — HMA Pavement Samples and Testing
Certified plant inspection, pavement thickness cores, density analysis, profilograph pavement smoothness measurement (when required by the contract documents), and air void testing.

Section 7021 - Hot Mix Asphalt Overlays

7021, 1.08, A, 3 — HMA Overlay (by ton)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.

7021, 1.08, B, 3 — HMA Overlay (by square yard)
Asphalt mix with asphalt binder, tack coat, construction zone protection, and quality control.

Section 7030 - Sidewalks, Shared Use Paths, and Driveways

7030, 1.08, A, 3 — Removal of Sidewalk, Shared Use Path, or Driveway
Sawing, hauling, and disposal of materials removed.

7030, 1.08, B, 3 — Removal of Curb
Hauling and disposal of materials removed.

7030, 1.08, C, 3 — Shared Use Paths
Subgrade preparation, jointing, sampling, smoothness testing and correction, and testing.

7030, 1.08, D, 3 — Special Subgrade Preparation for Shared Use Paths
Water required to bring subgrade moisture content to within the required limits.

7030, 1.08, E, 3 — Sidewalk, PCC
Minor grade adjustments at driveways and other intersections, subgrade preparation, formwork, additional thickness at thickened edges, jointing, sampling, smoothness testing and correction, and testing.

7030, 1.08, F, 3 — Brick/Paver Sidewalk with Pavement Base
Subgrade preparation, pavement base, setting bed, neoprene asphalt adhesive for asphalt setting bed, setting the bricks/pavers, installing weep holes and associated materials, and sand/cement joint filler.

7030, 1.08, G, 3 — Detectable Warning
Steel bar supports and manufactured detectable warning panels.

7030, 1.08, H, 1, c — Driveway, Paved
Excavation, subgrade preparation, jointing, sampling, and testing.

7030, 1.08, H, 2, c — Driveway, Granular
Excavation and preparation of subgrade.

Section 7040 - Pavement Rehabilitation

7040, 1.08, A, 3 — Full Depth Patches
Sawing, removing, and disposing of existing pavement and reinforcing; restoring the subgrade; furnishing and installing tie bars and dowel bars; furnishing and placing the patch material, including the asphalt binder and tack coat; forming and constructing integral curb; surface curing and pavement protection; joint sawing and filling; and placing backfill and restoring disturbed surfaces.

7040, 1.08, B, 3 — Subbase Over-excavation
Removal of existing subbase or subgrade, disposal of materials removed, furnishing and placing subbase material, and any additional excavation required for subbase placement.

7040, 1.08, C, 3 — Partial Depth Patches
Sawing, removing, and disposing of existing pavement; furnishing tack coat or bonding agent; furnishing and placing the patch material; curing; joint filling (PCC patches only); placing backfill; and restoring disturbed surfaces.

7040, 1.08, D, 3 — Crack and Joint Cleaning and Filling, Hot Pour
Furnishing crack and joint filler material and routing, sawing, cleaning, and filling joints or cracks.

7040, 1.08, E, 1, c — Crack Cleaning and Filling, Emulsion
Furnishing emulsified crack filler material, cleaning cracks, placing soil sterilant, and filling cracks.

7040, 1.08, E, 2, c — Hot Mix Asphalt for Crack Filling
Cleaning, applying tack coat, and furnishing and placing HMA for crack filling.

7040, 1.08, F, 3	Diamond Grinding Diamond grinding pavement, testing for smoothness according to the contract documents, and removal of slurry and residue from the project site.
7040, 1.08, G, 3	Milling Milling pavement; furnishing water; and salvaging, stockpiling, and removing cuttings and debris.
7040, 1.08, H, 3	Pavement Removal Sawing, breaking, removing, and disposing of existing pavement and reinforcing steel.
7040, 1.08, I, 3	Curb and Gutter Removal Sawing, breaking, removing, and disposing of existing curb and gutter.
7040, 1.08, J, 3	Dowel Bar Retrofit Cutting the slots, preparing the slots, placing and grouting the bars, and curing the surface.
7040, 1.08, K	Core Hole Cutting and Replacement Cutting the core hole, vacuum excavation, furnishing and placing backfill material and pavement, or replacing the pavement core using waterproof bonding material, if specified.
7040, 1.08, L	Required sampling and testing for pavement repair and rehabilitation work is incidental to other project costs and will not be paid for separately.

Section 7050 - Asphalt Stabilization

7050, 1.08, A, 3	Asphalt Stabilization Furnishing and spreading imported material, applying and incorporating asphalt stabilization, blending of the materials, grading and compacting the blended materials, and final clean up.

Section 7060 - Bituminous Seal Coat

7060, 1.08, A, 3	Bituminous Seal Coat (by area) Surface preparation including protection of street fixtures; furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts; and final clean up.
7060, 1.08, B, 1, c	Bituminous Seal Coat (by units), Cover Aggregate Surface preparation including protection of street fixtures; furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts; and final clean up.
7060, 1.08, B, 2, c	Bituminous Seal Coat (by units), Binder Bitumen Furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts; and final clean up.

Section 7070 - Emulsified Asphalt Slurry Seal

7070, 1.08, A, 3 — Emulsified Asphalt Slurry Seal (by area)
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts.

7070, 1.08, B, 1, c — Emulsified Asphalt Slurry Seal (by units), Aggregate
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts.

7070, 1.08, B, 2, c — Emulsified Asphalt Slurry Seal (by units), Asphalt Emulsion
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts.

Section 7080 - Permeable Interlocking Pavers

7080, 1.08, B, 3 — Engineering Fabric
Placing and securing filter fabric and any overlapped areas.

7080, 1.08, C, 3 — Underdrain
Furnishing and placing pipe, cleanouts, observation wells, and pipe fittings.

7080, 1.08, D, 3 — Storage Aggregate
Furnishing, hauling, placing, and compacting storage aggregate.

7080, 1.08, E, 3 — Filter Aggregate
Furnishing, hauling, placing filter, and compacting aggregate.

7080, 1.08, F, 3 — Permeable Interlocking Pavers
Testing, furnishing and placing bedding course, furnishing and installing permeable interlocking pavers, furnishing and placing joint/opening fill material, refilling joint after 6 months, and pavement protection.

7080, 1.08, G, 3 — PCC Edge Restraint
Final trimming of subgrade or subbase, bars and reinforcement, joints and sealing, surface curing and pavement protection, safety fencing, and boxouts for fixtures.

Section 7090 - Cold-in-Place Pavement Recycling

7090, 1.08, A, 3 — Cold-in-Place Recycling
Milling and sizing of existing asphalt layers; protecting street fixtures; development of a job mix formula; adding and mixing recycling agents and additives, if required; supplying and incorporating water; compacting the reclaimed mix; shaping of the mix; completing secondary compaction, if required; removing any loose or excess material; and final clean up.

7090, 1.08, B, 3 — Bituminous Recycling Agents
Furnishing and placing of materials and mixing the agent into the recycled mix.

7090, 1.08, C, 3 — Chemical Recycling Additives
Furnishing and placing of materials and mixing the agent into the recycled mix.

Section 7091 - Full Depth Reclamation

7091, 1.08, A, 3 — Full Depth Reclamation
Pulverizing and sizing of existing asphalt layers; incorporating and mixing of existing underlying materials; protecting street fixtures; development of a job mix formula; adding and mixing stabilizing agents and additives, if required; compacting the reclaimed mix; shaping of the mix; removing any loose or excess material; curing; and final clean up.

7091, 1.08, B, 3 — Mechanical Stabilization Agents
Furnishing and placing of aggregate and blending of the aggregates.

7091, 1.08, C, 3 — Bituminous Stabilization Agents
Furnishing and placing of materials and mixing the agent into the reclaimed mix.

7091, 1.08, D, 3 — Chemical Stabilization Agents
Furnishing and placing of materials and mixing the agent into the reclaimed mix.

7091, 1.08, F, 3 — Interlayer for Cement Stabilized Base
Surface cleaning, furnishing, and placing of the specified interlayer.

Section 8010 - Traffic Signals

8010, 1.08, B, 3 — Temporary Traffic Signal
Furnishing, installing, maintaining, and removing poles; wiring; traffic signal control equipment including pedestrian equipment if specified; all modifications of signal timing due to changes in construction staging; relocation of trailer mounted temporary traffic signal systems; placement in another physical location to address changes in construction staging; and all appurtenances.

Section 8020 - Pavement Markings

8020, 1.08, B, 3 — Painted Pavement Markings, Solvent/Waterborne
Reflectorizing spheres, layout, surface preparation, and application of marking paint.

8020, 1.08, C, 3 — Painted Pavement Markings, Durable
Layout, surface preparation, and application of marking paint.

8020, 1.08, D, 3 — Painted Pavement Markings, High-Build
Layout, surface preparation, and application of marking paint.

8020, 1.08, E, 3 — Permanent Tape Markings
Layout, surface preparation, and application of marking tape.

8020, 1.08, F, 3 — Wet, Retroreflective Removable Tape Markings
Layout, surface preparation, application, and removal.

8020, 1.08, G, 3 — Painted Symbols and Legends
Layout, surface preparation, and application of each symbol and legend.

8020, 1.08, H, 3 — Precut Symbols and Legends
Layout, surface preparation, and application of each symbol and legend.

8020, 1.08, I, 3 — Temporary Delineators
Installation and removal of delineators.

8020, 1.08, J, 3 — Raised Pavement Markers
Installation and removal of pavement markers.

8020, 1.08, K, 3 — Pavement Markings Removed
Pavement marking removal and waste material collection, removal, and disposal.

8020, 1.08, L, 3 — Symbols and Legends Removed
Symbol and legend marking removal and waste material collection, removal, and disposal.

8020, 1.08, M, 3 — Grooves Cut for Pavement Markings
Layout, cutting grooves, collection and disposal of removed material, and additional groove width and transition length beyond the pavement marking dimensions.

8020, 1.08, N, 3 — Grooves Cut for Symbols and Legends
Layout, cutting grooves, and collection and disposal of removed material.

Section 8030 - Temporary Traffic Control

8030, 1.08, A, 3 — Temporary Traffic Control
Installation, maintenance, and removal of temporary traffic control; total roadway closures with installation and removal of detour signing as shown in the contract documents; removal and reinstallation or covering of permanent traffic control devices that conflict with the temporary traffic control plan; monitoring and documenting traffic control conditions; and flaggers. When required in the contract documents, the following are also included in traffic control unless a separate bid item is provided: portable dynamic message signs, temporary barrier rail, temporary flood lighting, and pilot cars.

Section 9010 - Seeding

9010, 1.08, A, 1, c — Conventional Seeding, Seeding
Removal of rock and other debris from the area; repairing rills and washes; preparing the seedbed; furnishing and placing seed, including any treatment required; furnishing and placing fertilizer and mulch; and furnishing water and other care during the care period, unless these items are bid separately.

9010, 1.08, B, 3 — Hydraulic Seeding, Seeding, Fertilizing, and Mulching
Removal of rock and other debris from the area; repairing rills and washes; preparing the seedbed; furnishing and placing seed, including any treatment required; furnishing and placing fertilizer and mulch; and furnishing water and other care during the care period, unless these items are bid separately.

9010, 1.08, C, 3 Pneumatic Seeding, Seeding, Fertilizing, and Mulching
Removal of rock and other debris from the area; repairing rills and washes; preparing the seedbed; furnishing and placing seed, including any treatment required; furnishing and placing fertilizer and mulch; and furnishing water and other care during the care period, unless these items are bid separately.

9010, 1.08, D, 3 Watering
Water, pumps, meters, equipment, water tanker/container, transportation, hoses, and sprinklers.

9010, 1.08, E, 3 Warranty
All work required to correct any defects in the original placement of the seeding for the period of time designated.

Section 9020 - Sodding

9020, 1.08, A, 3 Sod
Preparation of sod and sodbed, stakes, fertilizing, watering, maintenance, and clean-up. Also includes any necessary sod replacements during maintenance period.

Section 9030 - Plant Material and Planting

9030, 1.08, A, 3 Plants (by count)
Delivery, excavation, installation, watering, placing backfill material, mulching, wrapping, staking or guying, herbicide, maintenance during the establishment period, and replacements.

9030, 1.08, B, 3 Plants (by count), With Warranty
Delivery, excavation, installation, watering, placing backfill material, mulching, wrapping, staking or guying, herbicide, maintenance during the establishment and warranty periods, and replacements.

9030, 1.08, C, 3 Plants (by lump sum)
Delivery, excavation, installation, watering, placing backfill material, mulching, wrapping, staking or guying, herbicide, maintenance during the establishment period, and replacements.

9030, 1.08, D, 3 Plants (by lump sum), With Warranty
Delivery, excavation, installation, watering, placing backfill material, mulching, wrapping, staking or guying, herbicide, maintenance during the establishment and warranty period, and replacements.

9030, 1.08, E, 3 Tree Drainage Wells
Excavation, furnishing and placing rock, engineering fabric, and placing backfill material.

Section 9040 - Erosion and Sediment Control

9040, 1.07, C	When applicable, conduct all operations in compliance with the Iowa DNR NPDES General Permit No. 2. Labor, equipment, or materials not included as a bid item, but necessary to prevent stormwater contamination from construction related sources, are considered incidental. Incidental work related to compliance with the permit may include, but is not limited to: hazardous materials protection, fuel containment, waste disposal, and providing employee sanitary facilities.
9040, 1.08, A, 1, c	SWPPP Preparation Development of a SWPPP by the Contractor meeting local and state agency requirements, filing the required public notices, filing a Notice of Intent for coverage of the project under the Iowa DNR NPDES General Permit No. 2, and payment of associated NPDES permit fees.
9040, 1.08, A, 2, c	SWPPP Management All work required to comply with the administrative provisions of the Iowa DNR NPDES General Permit No. 2; including record keeping, documentation, updating the SWPPP, filing the Notice of Discontinuation, etc. Item also includes weekly inspections required to satisfy the provisions of General Permit No. 2, unless otherwise specified in the contract documents.
9040, 1.08, D, 1, c	Filter Socks, Installation Anchoring stakes.
9040, 1.08, D, 2, c	Filter Socks, Removal Restoration of the area to finished grade and off-site disposal of filter socks and accumulated sediment.
9040, 1.08, E, 3	Temporary RECP Excavation, staples, anchoring devices, and material for anchoring slots.
9040, 1.08, F, 1, c	Wattles, Installation Anchoring stakes.
9040, 1.08, F, 2, c	Wattles, Removal Restoration of the area to finished grade and off-site disposal of wattle and accumulated sediment.
9040, 1.08, G, 1, c	Check Dams, Rock Engineering fabric.
9040, 1.08, G, 2, a, 3)	Check Dams, Manufactured, Installation Anchoring stakes.
9040, 1.08, G, 2, b, 3)	Check Dams, Manufactured, Removal Restoration of the area to finished grade and off-site disposal of manufactured check dam and accumulated sediment.
9040, 1.08, H, 3	Temporary Earth Diversion Structures Removal of the structure upon completion of the project.

9040, 1.08, I, 3	Level Spreaders Maintaining the spreader during the period of construction and removal upon completion of the project, unless otherwise specified in the contract documents.
9040, 1.08, J, 3	Rip Rap Engineering fabric.
9040, 1.08, K, 3	Temporary Pipe Slope Drains Excavation, furnishing and installing pipe and pipe aprons, grading, and removal of the slope drain upon completion of the project.
9040, 1.08, L, 1, c	Sediment Basin, Outlet Structure Concrete base, dewatering device, anti-vortex device, outlet pipe, and anti-seep collars (if specified).
9040, 1.08, L, 2, c	Sediment Basin, Removal of Sediment Dewatering and removal and off-site disposal of accumulated sediment.
9040, 1.08, L, 3, c	Sediment Basin, Removal of Outlet Structure Dewatering and off-site disposal of the outlet structure, concrete base, emergency spillway, and accumulated sediment.
9040, 1.08, M, 1, c	Sediment Trap Outlet, Installation Engineering fabric.
9040, 1.08, M, 2, c	Sediment Trap Outlet, Removal of Sediment Dewatering and removal and off-site disposal of accumulated sediment.
9040, 1.08, M, 3, c	Sediment Trap Outlet, Removal of Device Dewatering and off-site disposal of sediment trap outlet and accumulated sediment.
9040, 1.08, N, 1, c	Silt Fence or Silt Fence Ditch Check, Installation Anchoring posts.
9040, 1.08, N, 2, c	Silt Fence or Silt Fence Ditch Check, Removal of Sediment Anchoring posts.
9040, 1.08, N, 3, c	Silt Fence or Silt Fence Ditch Check, Removal of Device Restoration of the area to finished grade and off-site disposal of fence, posts, and accumulated sediment.
9040, 1.08, O, 1, c	Stabilized Construction Entrance (by Square Yard) Subgrade stabilization fabric.
9040, 1.08, O, 2, c	Stabilized Construction Entrance (by Ton) Subgrade stabilization fabric.
9040, 1.08, P, 1, c	Dust Control, Water Furnishing, transporting, and distributing water to the haul road.
9040, 1.08, R, 3	Turf Reinforcement Mats (TRM) Excavation, staples, anchoring devices, and material for anchoring slots.

9040, 1.08, T, 1, c — Inlet Protection Device, Installation
Removal of the device upon completion of the project.

9040, 1.08, T, 2, c — Inlet Protection Device, Maintenance
Removal and off-site disposal of accumulated sediment.

9040, 1.08, U, 3 — Flow Transition Mat
Anchoring devices.

Section 9050 - Gabions and Revet Mattresses

9050, 1.08, A, 3 — Gabions
Furnishing and assembling wire mesh baskets, PVC coating (if specified in the contract documents), fasteners, furnishing and placing gabion stone, engineering fabric, and anchor stakes.

9050, 1.08, B, 3 — Revet Mattresses
Furnishing and assembling wire mesh baskets, PVC coating (if specified in the contract documents), fasteners, furnishing and placing mattress stone, engineering fabric, and anchor stakes.

Section 9060 - Chain Link Fence

9060, 1.08, A, 3 — Chain Link Fence
Posts, fabric, rails, braces, truss rods, ties, tension wire, tension bands, tension bars, grounds, fittings, PVC coating (if specified in the contract documents), excavation of post holes, and concrete encasement of posts.

9060, 1.08, B, 3 — Gates
Gate rails, fabric, stretcher bars, braces, vertical stay, hinges, latches, keepers, drop bar lock, center gate stop, and barbed wire (if specified).

9060, 1.08, C, 3 — Barbed Wire
Furnishing and installing all necessary strands of barbed wire, anchors, and barbed wire supporting arms.

9060, 1.08, D, 3 — Removal and Reinstallation of Existing Fence
Removing vegetation; removing all fence fabric, appurtenances, posts, and gates; removal of concrete encasement from posts; storage of the removed fencing materials to prevent damage; reinstallation of the posts, gates, and fabric, including all appurtenances; and replacement of any fence parts that are not able to be salvaged and reinstalled. Replace items damaged from Contractor's operations with new materials, at no additional cost to the Contracting Authority.

9060, 1.08, E, 3 — Removal of Fence
Off-site disposal of fence (including posts, concrete encasement of posts, gates, grounds, and barbed wire) and placing and compacting backfill material in post holes.

9060, 1.08, F, 3 — Temporary Fence
Furnishing, installing, and removing posts, fabric, ties, and fittings.

Section 9070 - Landscape Retaining Walls

9070, 1.08, A, 3 — Modular Block Retaining Wall
Excavation, foundation preparation, furnishing and placing wall units, geogrid (if necessary), leveling pad, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, granular backfill material, suitable backfill material, and shoring as necessary.

9070, 1.08, B, 3 — Limestone Retaining Wall
Excavation, foundation preparation, furnishing and placing leveling pad, limestone, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, suitable backfill material, and shoring as necessary.

9070, 1.08, C, 3 — Landscape Timbers
Excavation, foundation preparation, furnishing and placing leveling pad, landscape timbers, spikes, reinforcing bar, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, suitable backfill material, and shoring as necessary.

Section 9071 - Segmental Block Retaining Walls

9071, 1.08, A, 3 — Segmented Block Retaining Wall
Design by a Licensed Professional Engineer in the State of Iowa, excavation, foundation preparation, furnishing and placing wall units, geogrid, leveling pad, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, suitable backfill material, and shoring as necessary.

9071, 1.08, C, 3 — Granular Backfill Material
Furnishing, transporting, placing, and compacting material.

Section 9072 - Combined Concrete Sidewalk and Retaining Walls

9072, 1.08, A, 3 — Combined Concrete Sidewalk and Retaining Wall
Excavation; foundation preparation; furnishing and placing concrete and reinforcing steel; joint material; subdrain; porous backfill material; suitable backfill material; finishing disturbed areas; and shoring as necessary.

Section 9080 - Concrete Steps, Handrails, and Safety Rail

9080, 1.08, A, 3 — Concrete Steps
Reinforcement, expansion joint material, and preparation of subgrade.

9080, 1.08, B, 3 — Handrail
Posts, mounting hardware or concrete grout, and finishing (painted, galvanized, or powder coated).

9080, 1.08, C, 3 — Safety Rail
Posts, pickets, mounting hardware, epoxy grout, and finishing (painted, galvanized, or powder coated).

Section 10,010 - Demolition

10,010, 1.08, A, 3 — Demolition Work
Removal of trees, brush, vegetation, buildings, building materials, contents of buildings, appliances, trash, rubbish, basement walls, foundations, sidewalks, steps, and driveways from the site; disconnection of utilities; furnishing and compaction of backfill material; furnishing and placing topsoil; finish grading of disturbed areas; placing and removing safety fencing; removal of fuel and septic tanks and cisterns; seeding; and payment of any permit or disposal fees.

10,010, 1.08, B, 3 — Plug or Abandon Well
Obtaining all permits; plug or abandon private wells according to local, state, and federal regulations.

Section 11,010 - Construction Survey

11,010, 1.08, A, 3 — Construction Survey
The costs of resetting project control points, re-staking, and any additional staking requested beyond the requirements of this section.

11,010, 1.08, B, 3 — Monument Preservation and Replacement
Property research and documentation, locating monuments prior to construction, replacement of disturbed monuments, and preparation and filing of the monument preservation certificate.

Section 11,020 - Mobilization

11,020, 1.07, B — When the proposal form does not include a bid item for mobilization, all costs incurred by the contractor for mobilization are incidental to other work and no separate payment will be made.

11,020, 1.08, A, 3 — Mobilization
The movement of personnel, equipment, and supplies to the project site; the establishment of offices, buildings, and other facilities necessary for the project; and bonding, permits, and other expenses incurred prior to construction.

Section 11,040 - Temporary Sidewalk Access

11,040, 1.08, A, 3 — Temporary Pedestrian Residential Access
Supplying and placing granular material, continuous maintenance of granular surface, removal of temporary granular sidewalk, and restoring disturbed surfaces to a condition equal to that which existed prior to construction.

11,040, 1.08, B, 3 — Temporary Granular Sidewalk
Excavation, grading, timber edging, supplying and placing granular material, continuous maintenance of granular surface, removal of temporary granular sidewalk, and restoring disturbed surfaces to a condition equal to that which existed prior to construction.

11,040, 1.08, C, 3 — Temporary Longitudinal Channelizing Device
Construction, placement, maintenance, and removal of the device.

Section 11,050 - Concrete Washout

11,050, 1.08, A, 3 Concrete Washout
Providing concrete washwater containment, collection, and disposal.

Bid Items

Below is a list of units of measurements/payment and the abbreviations used in the bid item list.

UNITS	Units of Measurement/Payment	UNITS	Units of Measurement/Payment
ACRE	Acres	SF	Square Feet
CY	Cubic Yards	SQ	Squares
EACH	Each	STA	Stations
LB	Pounds	SY	Square Yards
LF	Linear Feet	TON	Tons
LS	Lump Sum	UNIT	Units
MGAL	1,000 Gallons		

A. Standard Bid Items

The following is a list of suggested standard bid items based on the SUDAS Specifications. The four digits first mentioned in the item number below reference the SUDAS Specifications Section; measurement and payment descriptions are included in subsection 1.08. Please note, some of the items below require additional information, such as type, size, width, thickness, etc.

Item Number	Item Description	Unit
Section 2010 - Earthwork, Subgrade, and Subbase		
2010-A	Clearing and Grubbing	UNIT
2010-B	Clearing and Grubbing	ACRE
2010-C	Clearing and Grubbing	LS
2010-D-1	Topsoil, On-site	CY
2010-D-2	Topsoil, Compost-amended	CY
2010-D-3	Topsoil, Off-site	CY
2010-E	Excavation, Class 10, Class 12, or Class 13	CY
2010-G	Subgrade Preparation	SY
2010-H	Subgrade Treatment, ____ (Type)	SY
2010-I	Subbase, ____ (Type)	SY
2010-J-1	Removal of Structure, ____ (Type)	EA
2010-J-2-a	Removal of Known Box Culvert, ____ (Type), ____ (Size)	LF
2010-J-2-c	Removal of Known Pipe Culvert, ____ (Type), ____ (Size)	LF
2010-J-3-a	Removal of Known Pipe and Conduit, ____ (Type), ____ (Size)	LF
2010-K-1	Filling and Plugging of Known Pipe Culverts, Pipes, and Conduits, ____ (Type), ____ (Size)	LF
2010-L	Compaction Testing	LS

Item Number	Item Description	Unit
Section 3010 - Trench Excavation and Backfill		
3010-B	Rock Excavation	CY
3010-C	Trench Foundation	TON
3010-D	Replacement of Unsuitable Backfill Material	CY
3010-E	Special Pipe Embedment or Encasement	LF
3010-F	Trench Compaction Testing	LS
Section 4010 - Sanitary Sewers		
4010-A-1	Sanitary Sewer Gravity Main, Trenched, ____ (Type), ____ (Size)	LF
4010-A-2	Sanitary Sewer Gravity Main, Trenchless, ____ (Type), ____ (Size)	LF
4010-B-1	Sanitary Sewer Gravity Main with Casing Pipe, Trenched, ___ (Type), ___ (Size)	LF
4010-B-2	Sanitary Sewer Gravity Main with Casing Pipe, Trenchless, ___ (Type), ___ (Size)	LF
4010-C-1	Sanitary Sewer Force Main, Trenched, ____ (Type), ____ (Size)	LF
4010-C-2	Sanitary Sewer Force Main, Trenchless, ____ (Type), ____ (Size)	LF
4010-D-1	Sanitary Sewer Force Main with Casing Pipe, Trenched, ____ (Type), ____ (Size)	LF
4010-D-2	Sanitary Sewer Force Main with Casing Pipe, Trenchless, ____ (Type), ____ (Size)	LF
4010-E	Sanitary Sewer Service Stub, ____ (Type), ____ (Size)	LF
4010-F	Sanitary Sewer Service Relocation	EA
4010-G	Sewage Air Release Valve and Pit	EA
4010-H	Removal of Sanitary Sewer, ____ (Type), ____ (Size)	LF
4010-I	Sanitary Sewer Cleanout	EA
4010-K	Sanitary Sewer Abandonment, Plug	EA
4010-L	Sanitary Sewer Abandonment, Fill and Plug	LF
Section 4020 - Storm Sewers		
4020-A-1	Storm Sewer, Trenched, ____ (Type), ____ (Size)	LF
4020-A-2	Storm Sewer, Trenchless, ____ (Type), ____ (Size)	LF
4020-B-1	Storm Sewer with Casing Pipe, Trenched, ____ (Type), ____ (Size)	LF
4020-B-2	Storm Sewer with Casing Pipe, Trenchless, ____ (Type), ____ (Size)	LF
4020-C	Linear Trench Drain	LF
4020-D	Removal of Storm Sewer, ____ (Type), ____ (Size)	LF
4020-F	Storm Sewer Abandonment, Plug	EA
4020-G	Storm Sewer Abandonment, Fill and Plug	LF
Section 4030 - Pipe Culverts		
4030-A-1	Pipe Culvert, Trenched, ____ (Type), ____ (Size)	LF
4030-A-2	Pipe Culvert, Trenchless, ____ (Type), ____ (Size)	LF
4030-B	Pipe Apron, ____ (Type), ____ (Size)	EA
4030-C	Footing for Concrete Pipe Apron, ____ (Type), ____ (Size)	EA
4030-D	Pipe Apron Guard	EA
Section 4040 - Subdrains and Footing Drain Collectors		
4040-A	Subdrain, ____ (Type), ____ (Size)	LF
4040-B	Footing Drain Collector, ____ (Type), ____ (Size)	LF
4040-C	Subdrain Cleanout, ____ (Type), ____ (Size)	EA

Item Number	Item Description	Unit
4040-C	Footing Drain Cleanout, ____ (Type), ____ (Size)	EA
4040-D	Subdrain Outlets and Connections, ____ (Type), ____ (Size)	EA
4040-D	Footing Drain Outlets and Connections, ____ (Type), ____ (Size)	EA
4040-E	Storm Sewer Service Stub, ____ (Type), ____ (Size)	LF
Section 4050 - Pipe Rehabilitation		
4050-A-1	Pre-Rehabilitation Cleaning and Inspection, ____ (Size)	LF
4050-A-2	Additional Sewer Cleaning	HOUR
4050-B	Remove Protruding Service Connections	EA
4050-C-1	CIPP Main Lining	LF
4050-C-2	Building Sanitary Sewer Service Reinstatement	EA
4050-C-3	CIPP End Seal	EA
4050-D	CIPP Point Repair, ____ (Size)	EA
4050-E-1	CIPP Service Pipe, Connection, ____ (Size)	EA
4050-E-2	CIPP Service Repair, Partial Pipe, ____ (Size)	EA
4050-F-1	Pressure Testing of Mainline Sewer Joints, ____ (Size)	EA
4050-F-2	Injection Grouting of Mainline Sewer Joints, ____ (Size)	EA
4050-F-3	Pressure Testing of Service Connections, ____ (Size)	EA
4050-F-4	Injection Grouting of Service Connections, ____ (Size)	EA
4050-F-5	Chemical Grout	EA
4050-G-3	Bypass Pumping	LS
4050-H-1	Spot Repairs by Pipe Replacement	EA
4050-H-2	Spot Repairs by Pipe Replacement	LF
Section 5010 - Pipe and Fittings		
5010-A-1	Water Main, Trenched, ____ (Type), ____ (Size)	LF
5010-A-2	Water Main, Trenchless, ____ (Type), ____ (Size)	LF
5010-B-1	Water Main with Casing Pipe, Trenched, ____ (Type), ____ (Size)	LF
5010-B-2	Water Main with Casing Pipe, Trenchless, ____ (Type), ____ (Size)	LF
5010-C-1	Fitting, ____ (Type), ____ (Size)	EA
5010-C-2	Fitting, ____ (Type), ____ (Size)	LB
5010-D	Water Service Stub, ____ (Type), ____ (Size)	EA
5010-E-1	Water Service Pipe, ____ (Type), ____ (Size)	LF
5010-E-2	Water Service Corporation, ____ (Type), ____ (Size)	EA
5010-E-3	Water Service Curb Stop and Box, ____ (Type), ____ (Size)	EA
Section 5020 - Valves, Fire Hydrants, and Appurtenances		
5020-A	Valve, ____ (Type), ____ (Size)	EA
5020-B	Tapping Valve Assembly, ____ (Size)	EA
5020-C	Fire Hydrant Assembly	EA
5020-D	Flushing Device (Blowoff), ____ (Size)	EA
5020-F	Valve Box Extension	EA
5020-G	Valve Box Replacement	EA

Item Number	Item Description	Unit
5020-H	Fire Hydrant Adjustment	EA
5020-I	Fire Hydrant Assembly Removal	EA
5020-J	Valve Removal	EA
5020-K	Valve Box Removal	EA
Section 6010 - Structures for Sanitary and Storm Sewers		
6010-A	Manhole, ____ (Type), ____ (Size)	EA
6010-B	Intake, ____ (Type), ____ (Size)	EA
6010-C-1	Internal Drop Connection	EA
6010-C-2	External Drop Connection	EA
6010-D	Casting Extension Ring	EA
6010-E	Manhole Adjustment, Minor	EA
6010-E	Intake Adjustment, Minor	EA
6010-F	Manhole Adjustment, Major	EA
6010-F	Intake Adjustment, Major	EA
6010-G	Connection to Existing Manhole	EA
6010-G	Connection to Existing Intake	EA
6010-H	Remove Manhole	EA
6010-H	Remove Intake	EA
Section 6020 - Rehabilitation of Existing Manholes		
6020-A	Infiltration Barrier, ____ (Type)	EA
6020-B	In-situ Manhole Replacement, Cast-in-place Concrete	VF
6020-C	In-situ Manhole Replacement, Cast-in-place Concrete with Plastic Liner	VF
6020-D	Manhole Lining with Centrifugally Cast Cementitious Mortar Liner with Epoxy Seal	VF
Section 7010 - Portland Cement Concrete Pavement		
7010-A	Pavement, PCC, ____ (Thickness)	SY
7010-E	Curb and Gutter, ____ (Width), ____ (Thickness)	LF
7010-F	Beam Curb	LF
7010-G	Concrete Median	SY
7010-H	PCC Railroad Crossing Approach	SY
7010-I	PCC Pavement Samples and Testing	LS
7010-K	PCC Pavement Widening, ____ (Thickness)	SY
Section 7011 - Portland Cement Concrete Overlays		
7011-A-1	PCC Overlay, Furnish Only	CY
7011-A-2	PCC Overlay, Place Only	SY
7011-A-3	Surface Preparation for Bonded PCC Overlay	SY
7011-A-4	Surface Preparation for Unbonded PCC Overlay	SY
7011-A-5	HMA Separation Layer for Unbonded PCC Overlay	SY
7011-A-6	Geotextile Fabric Separation Layer for Unbonded PCC Overlay	SY

Item Number	Item Description	Unit
Section 7020 - Hot Mix Asphalt Pavement		
7020-A	Pavement, HMA	TON
7020-B	Pavement, HMA, ____ (Thickness)	SY
7020-C	HMA Base Widening	TON
7020-D	HMA Base Widening, ____ (Thickness)	SY
7020-E	HMA Railroad Crossing Approach	SY
7020-I	HMA Pavement Samples and Testing	LS
Section 7021 - Hot Mix Asphalt Overlays		
7021-A	HMA Overlay	TON
7021-B	HMA Overlay, ____ (Thickness)	SY
Section 7030 - Sidewalks, Shared Use Paths, and Driveways		
7030-A	Removal of Sidewalk	SY
7030-A	Removal of Shared Use Path	SY
7030-A	Removal of Driveway	SY
7030-B	Removal of Curb	LF
7030-C	Shared Use Path, ____ (Type), ____ (Thickness)	SY
7030-D	Special Subgrade Preparation for Shared Use Path	SY
7030-E	Sidewalk, PCC, ____ (Thickness)	SY
7030-F	Brick/Paver Sidewalk with Pavement Base	SY
7030-G	Detectable Warnings	SF
7030-H-1	Driveway, Paved, ____ (Type), ____ (Thickness)	SY
7030-H-2	Driveway, Granular	SY or TON
7030-I	Sidewalk Assurance Testing	LS
7030-I	Shared Use Path Assurance Testing	LS
7030-I	Driveway Assurance Testing	LS
Section 7040 - Pavement Rehabilitation		
7040-A	Full Depth Patches	SY
7040-B	Subbase Over-excavation	TON
7040-C	Partial Depth Patches	SF
7040-D	Crack and Joint Cleaning and Filling, Hot Pour	LF
7040-E-1	Crack Cleaning and Filling, Emulsion	LF
7040-E-2	Hot Mix Asphalt for Crack Filling	TON
7040-F	Diamond Grinding	SY
7040-G	Milling	SY
7040-H	Pavement Removal	SY
7040-I	Curb and Gutter Removal	LF
7040-J	Dowel Bar Retrofit	EA
7040-K	Core Hole Cutting and Replacement	EA
Section 7050 - Asphalt Stabilization		
7050-A	Asphalt Stabilization	SY

Item Number	Item Description	Unit
Section 7060 - Bituminous Seal Coat		
7060-A	Bituminous Seal Coat	SY
7060-B-1	Cover Aggregate, ____ (Size)	TON
7060-B-2	Binder Bitumen	GAL
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7070-A	Emulsified Asphalt Slurry Seal	SY
7070-B-1	Aggregate, ____ (Size)	TON
7070-B-2	Asphalt Emulsion	GAL
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7080-C	Underdrain, ____ (Type), ____ (Size)	LF
7080-D	Storage Aggregate	TON
7080-E	Filter Aggregate	TON
7080-F	Permeable Interlocking Pavers, ____ (Type)	SY
7080-G	PCC Edge Restraint, ____ (Type), ____ (Size)	LF
Section 7090 - Cold-in-Place Pavement Recycling		
7090-A	Cold-in-Place Recycling	SY
7090-B	Bituminous Recycling Agents	GAL
7090-C	Chemical Recycling Additives	TON
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7091-A	Full Depth Reclamation	SY
7091-B	Mechanical Stabilization Agents	TON
7091-C	Bituminous Stabilization Agents	GAL
7091-D	Chemical Stabilization Agents	TON
7091-E	Microcracking	SY
7091-F	Interlayer for Cement Stabilized Base, ____ (Type), ____ (Thickness)	SY
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8020-G	Painted Symbols and Legends	EA
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Item Number	Item Description	Unit
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9040-D-1	Filter Sock, ____ (Size)	LF
9040--D-2	Filter Sock, Removal	LF
9040-E-0	Temporary RECP, ____ (Type)	SY
9040-F-1	Wattle, ____ (Type), ____ (Size)	LF
9040-F-2	Wattle, Removal	LF
9040-G-1	Check Dam, Rock	TON
9040-G-2-a	Check Dam, Manufactured, ____ (Type), ____ (Size)	LF
9040-G-2-b	Check Dam, Manufactured, Removal, ____ (Type)	LF
9040-H-0	Temporary Earth Diversion Structure, ____ (Type), ____ (Size)	LF
9040-I-0	Level Spreader	LF
9040-J-0	Rip Rap, ____ (Type)	TON
9040-K-0	Temporary Pipe Slope Drain, ____ (Type), ____ (Size)	LF
9040-L-1	Sediment Basin, Outlet Structure, ____ (Size)	EA
9040-L-2	Sediment Basin, Removal of Sediment	EA
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Item Number	Item Description	Unit
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9040-M-3	Sediment Trap Outlet, Removal of Device	EA
9040-N-1	Silt Fence or Silt Fence Ditch Check	LF
9040-N-2	Silt Fence or Silt Fence Ditch Check, Removal of Sediment	LF
9040-N-3	Silt Fence or Silt Fence Ditch Check, Removal of Device	LF
9040-O-1	Stabilized Construction Entrance	SY
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9040-P-2	Dust Control, Product	SY
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9050-A	Gabions, ____ (Type)	CY
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9060-A	Chain Link Fence, ____ (Type), ____ (Size)	LF
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9060-D	Removal and Reinstallation of Existing Fence, ____ (Type), ____ (Size)	LF
9060-E	Removal of Fence	LF
9060-F	Temporary Fence, ____ (Type), ____ (Size)	LF
Section 9070 - Landscape Retaining Walls		
9070-A	Modular Block Retaining Wall	SF
9070-B	Limestone Retaining Wall	SF
9070-C	Landscape Timbers	SF
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9071-A	Segmental Block Retaining Wall	SF
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9072-A	Combined Concrete Sidewalk and Retaining Wall	CY
Section 9080 - Concrete Steps, Handrails, and Safety Rail		
9080-A	Concrete Steps, ____ (Type)	SF
9080-B	Handrail, ____ (Type)	LF
9080-C	Safety Rail	LF

Item Number	Item Description	Unit
Section 10,010 - Demolition		
10,010-A	Demolition Work	LS
10,010-B	Plug or Abandon Well	EA
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11,010-A	Construction Survey	LS
11,010-B	Monument Preservation and Replacement	LS
Section 11,020 - Mobilization		
11,020-A	Mobilization	LS
Section 11,030 - Temporary Services During Construction		
11,030-A	Maintenance of Postal Service	LS
11,030-B	Maintenance of Solid Waste Collection	LS
Section 11,040 - Temporary Sidewalk Access		
11,040-A	Temporary Pedestrian Residential Access	SY
11,040-B	Temporary Granular Sidewalk	SY
11,040-C	Temporary Longitudinal Channelizing Device	LF
Section 11,050 - Concrete Washout		
11,050-A	Concrete Washout	LS

B. Supplemental Bid Items

When a new bid item needs to be created, the following format is suggested:

1. If the bid item falls within a SUDAS Specifications Section, but is not identified in SUDAS, use the four digit section number, followed by 999, then a letter. For example, if you want to add a new bid item for sanitary sewers, use 4010-999-A.

2. If the bid item generally falls within a SUDAS Specifications Division (broader category), but is not identified as a particular SUDAS Specifications Section, use the division number, followed by 999, then a letter. For example, if you add pipe bursting and want the bid items organized with the other pipe items, use 4999-A. Or if a supplemental specifications section has been created, the first four digits should match the numbers used in the supplemental. In that instance, it is suggested to use the division number as the first digit, followed by a 9, and then the next numbers as you see fit.

3. If the bid item does not fall within a SUDAS Specifications Division or Section, use 0000, followed by 999, then a letter. For example, 0000-999-A.

4. When making modifications to a standard SUDAS bid item, be sure to address such modifications in the estimate reference notes.

Public Improvement Contracts

A. General

Public improvements contracts should be used to ensure construction of all public improvements to the standards provided by the jurisdiction. These contracts may also be used between the developer, contractor, and the jurisdiction for private subdivision or site developments. After the plans and the contract have been given jurisdictional approval, changes should not be made in the design or scope of work without addenda or a change order approved by the jurisdiction.

If the change involves engineering details shown on the plans, the original plans should be modified by the project engineer and should accompany a change order. Work on portions of the project involved in the change order should not be performed until the change order is approved by the jurisdiction.

B. Contract Documents

The project engineer should use the contract documents required by the jurisdiction. Sample contract document forms are available on the SUDAS website at www.iowasudas.org.

The following items are typically included in the contract documents:

1. Notice to Bidders and Notice of Public Hearing

2. Instructions to Bidders

3. Proposal
   - Part A - Scope of Work
   - Part B - Acknowledgement of Addenda
   - Part C - Bid Items, Quantities, and Prices
   - Part D - General
   - Part E - Additional Requirements
   - Part G - Identity of Bidder
   - Proposal Attachments

4. Bid Bond

5. Contract and Contract Attachment

6. Performance, Payment, and Maintenance Bond

C. Pre-construction Meeting

A coordination meeting regarding the project construction should be held after the award of the contract or selection of the preferred contractor and prior to the work beginning. Either the project engineer or the jurisdictional engineer should conduct the meeting depending on who is responsible for the construction administration. Regardless of who conducts the meeting, the groups invited should include at least the following:

- Funding source representative
- Contractor
- Subcontractors
- Project engineer(s)
- Jurisdictional engineer or representative
- Jurisdictional right-of-way representative
- All utilities potentially impacted by the project
- Railroad representatives, if applicable

At a minimum, the following items should be identified and discussed:

- Funding source requirements
- Who will be subcontractors and what bid items will they be responsible for
- Who are material suppliers and do they have certified products
- Submission of available shop drawings
- Name, address, email address, and phone number for the following:
  - Contractor's project supervisor
  - Subcontractor's project supervisors
  - Project engineer
  - Project construction inspector
  - Jurisdictional engineer or representative
  - 24 hour traffic control contact
  - 24 hour erosion control contact
  - Railroad contact, if applicable
- Project dates and staging schedule, if applicable
- Potential impacts to existing or future utilities
- Review of available right-of-way and any permanent or temporary easements along with any restrictions or special requirements related to adjacent properties
- Review of adjacent property owner needs
- Review construction staking needs if the jurisdiction is responsible for the staking
- Traffic control and detours
- Permitting requirements
- If the work is done under a public contract, discuss payment schedule
- Discuss responsibility for and items to be included on the as-built plans

At the end of the meeting, if all submittals have been made and accepted, the Notice to Proceed could be issued.

D. Materials and Shop Drawings

The project engineer is responsible to review all material submittals and any shop drawings required for the project. The contractor should submit the information as early in the project as possible and the project engineer should complete review of the submittals in an expedited manner so as to not impact the project schedule. Copies of material certifications and approved shop drawings should be included with the as-built plan submittal.

Plans of Record

A. General

As-built plans are required for public improvements that are to be maintained by the jurisdiction, in addition to sidewalk ramps within the public right-of-way and stormwater management facilities.

If the plans of record are not completed by the jurisdiction or the jurisdiction's consultant, specific instructions for completion of the plans of record must be included in the construction contract documents. For non-jurisdictional led projects, such as site developments or subdivisions, the developer must arrange for completion of the plans of record and they must be submitted prior to the work being accepted by the jurisdiction.

Contact the jurisdictional engineer to verify any special requirements beyond this list. Horizontal variations greater than 1 foot must be shown dimensionally or by modified stationing; horizontal variations of 10 feet or greater must be shown graphically.

Submit the as-built plans in the same PDF format as the original plans and use the same legend. Show the date(s) of the as-built survey. Show as-built elevations adjacent to the design elevation, if different.

B. Information to be Shown on Plans of Record

1. General:

a. Final quantities.

b. Plans of record certification or label.

c. Any other information deemed necessary by the jurisdictional engineer.

d. Location and elevation of any drainage tiles or other utilities encountered.

e. Scanned copies of approved material lists and shop drawings.

f. GPS coordinates for all structures, valves, hydrants, fixtures, and any other element identified by the jurisdictional engineer.

2. Paving Plans:

a. Pavement width and all radii at returns, if different from the design.

b. Stationing from the beginning to the end of the construction. Stationing of intakes, manholes, centerline of intersecting streets, and driveways.

c. Cross-sections will generally not be required. However, if the jurisdiction has reason to believe that the plans do not accurately reflect the field conditions, the jurisdiction may require as-built cross-sections.

d. Show any changes in pavement grade or horizontal and vertical curves.

e. Centerline stationing and offset for any lane drops or additions.

3. Sewer Plans:

a. Invert elevations of all pipes at manholes, structures, inlets, outlets, and rim elevations.

b. Lengths, type, and sizes of all pipes.

c. Stationing, location, and type of all structures and begin and end construction.

d. Location of all wyes, tees, or stubs and riser lengths.

e. Structure number system to be labeled for each structure with stationing, location, and type for all structures, cleanouts, and plugs.

4. Drainage Open Channel Plans:

a. Finished grade or flow line profile of open channel and, if required, cross-sections.

b. Invert elevations or flow lines of culverts, drop structure inlets, and outlets.

c. Stationing, location and type of inlets, outlets, structures, and begin and end construction.

5. Water Main Plans:

a. Locations and depths of all pipes, fittings, valves, and fire hydrants.

b. Lengths, type, and sizes of all pipes.

c. Stationing and location and type of all water service stubs. Stub locations should be referenced to lot corners.

d. Fire hydrant number system to be labeled for each hydrant.

e. Length of pipe stubbed out from valves.

f. Existing utilities or other underground features that could reasonably impact the maintenance of the water main.

6. Stormwater Management Facilities:

a. Outlet configuration including location and elevation.

b. Cross-sections and volume of all detention or retention basins.

c. As-built volume vs. design volume of all basins.

d. Elevation of all overflow locations or devices.

7. Sidewalks and Curb Ramps:

a. Elevations at the top and bottom of curb ramps, turning spaces, transition areas, and grade breaks. Smart levels may be used to show finished slopes if approved by the jurisdictional engineer.

b. Table showing as-built slope and distance between all critical points.

c. Table showing cross slope of sidewalk on 25 feet intervals.

d. Location of detectable warning panel with respect to the back of curb or shoulder.

e. Detectable warning width with respect to the width of the pedestrian way.

f. Method or equipment used to determine as-constructed elevations and slopes.

8. Traffic Signals:

a. Location of all underground conduit.

b. Location of all poles and handholes.

c. Mounting heights of mast arms, traffic signal heads, luminaires, if applicable, and pedestrian heads.

d. Location of pavement detector loop type, size, and location, if applicable.

e. All shop drawings, products, and material documentation.

9. Utilities: The project engineer is not required to locate utilities that are not part of or affected by the construction project or private utility lines that were installed by the utility company

Products

The SUDAS Specifications do not reference proprietary products. Specific technical specifications are included as a means of identifying products that will be acceptable for the project requirements.

To verify compliance with the SUDAS Specifications, engineers must work with contractors to identify products that meet the current technical specifications and that meet the project needs. If a new product is proposed for use on a project, the engineer can establish their own special provisions to allow the use of the specific product, whether it meets the SUDAS Specifications or not. If the new product does not meet the current technical specifications and the engineer feels the product has consistent application on similar projects, they can bring it forward to their SUDAS district committee. The engineer must be willing to discuss their use of the product and how they see the product benefiting the urban public works projects being developed around the state.

Once a new product is proposed, the members of the district committees from across the state are asked to give their input as to whether the product has statewide appeal and if standard specifications should be written. If that response is favorable, specifications are drafted and taken around to the next set of district meetings. Compliance with national standards met by other similar products is important to the group's deliberations.

If there is a favorable recommendation from the district committees, the change is brought to the Board of Directors for a vote and possible inclusion in a future edition of the SUDAS Specifications.

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Stormwater Regulations and Permitting

A. Iowa Drainage Law and Resources

Chapter 468 of the Iowa Code covers a majority of Iowa's drainage law with respect to landowner rights and responsibilities. This chapter covers the establishment and operation of drainage districts as well as laws governing modifying, diverting, or blocking existing drainage ways.

The Iowa Drainage Law Manual (http://www.ctre.iastate.edu/pubs/drainage_law/), developed by the Center for Transportation Research and Education (now the Institute for Transportation) at Iowa State University, summarizes drainage laws as described in the Iowa Administrative Code and provides practical solutions to common drainage problems.

B. Regulated Activities

In Iowa, two agencies administer permit programs for protecting the state's water resources and ensuring their wise use. Some local government agencies have also established permit programs related to land subdivision and land disturbing activities. The primary agencies are:

1. **The Iowa DNR:** Iowa DNR administers permit programs for conserving and protecting Iowa′s water, recreational, and environmental resources, and for the prevention of damage resulting from unwise floodplain development. In addition, Iowa DNR has jurisdiction over sovereign lands and waters, and certain fee title lands of the state, and land below the ordinary high water mark on meandered streams and lakes.

    a. **General Permit No. 2:** For "stormwater associated with industrial activity for construction activities" (land disturbing 1 acre or more). Construction activities that result in the disturbance of 1 acre or more of ground cover are required to obtain an NPDES general permit normally associated with earthwork, grading, or any other non-agricultural land-disturbing activity. The goal of the permit is to reduce the amount of sediment being transported from construction site by stormwater runoff.

    b. **Other Iowa DNR Permits:** (relating to protection of water and recreational sources or adjacent lands):
        1) **Floodplain Construction Permits:** Iowa DNR has authority to regulate construction on all floodplains and floodways in the state. http://www.iowadnr.gov/water/floodplain/index.html. Local governments may have obtained transfer of this jurisdiction from Iowa DNR.
        2) **Construction Permits:** Pursuant to the Iowa Code, no person, association, or corporation can build or erect a pier, wharf, sluice, piling, wall, fence, obstruction, building, or erection of any kind, upon or over any state-owned land or water under the jurisdiction of Iowa DNR, without first obtaining a permit from Iowa DNR. http://www.iowadnr.gov/InsideDNR/RegulatoryAir/ConstructionPermits.aspx.
        3) **Special Permits:** Projects involving a standard recreational boat dock require authorization by Iowa DNR. Permits are also required by commercial operations removing sand or aggregate from meandered streams. http://www.iowadnr.gov/

2. **The US Army Corps of Engineers (USACE):** The USACE has authority over public waterways. This includes intrastate lakes, rivers, streams, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, all impoundments of waters and tributaries of waters identified above.

   a. **Clean Water Act Section 404 Permit Program:** Prior to conducting work on or in a regulated water of the U.S., a Section 404 permit must first be obtained from the USACE. Additional information on the 404 program may be found in the Iowa DOT Local Systems I.M. No. 4.130.

   b. **Wetlands:** Wetlands are defined as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Wetlands have three essential characteristics, all of which must be present for an area to be identified as a wetland. This includes hydrophytic (water-loving) vegetation, hydric soils, and wetland hydrology
      1) **Wetland Delineation:** Identification of Section 404-regulated wetlands requires wetland delineation by the USACE, the EPA, or by submission of a wetland delineation report to the USACE by a qualified wetland specialist. Wetland delineation is often requested or contracted by a property owner who needs to know restrictions on the development or use of the land. In particular, a property owner may need wetland delineation when seeking an individual or general permit.
      2) **Wetland Mitigation:** Every effort should be made at the beginning of a project to avoid or minimize impacts. Any project that does not meet the conditions of any one of the Nationwide Permits must be sent to the USACE and probably will require satisfactory mitigation for the loss of wetlands. Mitigation is defined as wetland restoration, creation, enhancement, or preservation for the purpose of compensating for unavoidable wetland losses in advance of development actions, when such compensation cannot be achieved at the development site or would not be as environmentally beneficial.

3. **Joint Application:** Given the regulatory relationship between the Iowa DNR and the USACE, certain projects require authorization from both agencies before work can commence. Construction, excavation, or filling in streams, lakes, wetlands, or floodplains may require permits from both agencies. Specifically, State Section 401 water quality certification is mandatory for all projects requiring a Federal Section 404 permit. In order to simplify this process, a joint application form has been developed for the permit process for any of the following activities:
   - Cutting the bank of a river or stream
   - Any excavation or dredging in a stream or channel
   - Channel changes or relocations (including stream straightening)
   - Construction of any permanent dock, pier, wharf, seawall, boat ramp, beach, intake, or outfall structure on a stream, river, or lake
   - Placement of any fill, rip rap, or similar material in a stream, river channel, or lake
   - Construction of a dam across any waterway
   - Placement of fill, construction of levees, roadways, and bridges; and similar activities on a floodplain
   - Construction of buildings on a floodplain

   The joint application form and instructions are available on the Iowa DNR website (www.iowadnr.gov); search for "Sovereign Lands Construction Permit."

Project Drainage Report

A. Purpose

The purpose of the project drainage report is to identify and propose specific solutions to stormwater runoff and water quality problems resulting from existing and proposed development. The report must include adequate topographic information (pre- and post-development) to verify all conclusions regarding offsite drainage. Unless known, the capacity of downstream drainage structures must be thoroughly analyzed to determine their ability to convey the developed discharge.

The drainage report and plan will be reviewed and approved by the Jurisdictional Engineer prior to preparation of final construction drawings. Approval of these preliminary submittals constitutes only a conceptual approval and should not be construed as approval of specific design details. The Project Engineer may be required by law to submit the drainage report and plan to the Iowa DNR and/or USACE. An application for a permit to construct will follow the Iowa DNR and NPDES applicable permit requirements and USACE rules and regulations, and the application will be the responsibility of the Project Engineer.

B. Instructions for Preparing Report

1. Include a cover sheet with project name and location, name of firm or agency preparing the report, Professional Engineer's signed and sealed certification, and table of contents. Number each page of the report.

2. Perform all analyses according to the intent of professionally recognized methods. Support any modifications to these methods with well documented and industry accepted research.

3. It is the designer's responsibility to provide all data requested. If the method of analysis (for example, a computer program) does not provide the required information, then the designer will select alternative or supplemental methods to ensure the drainage report is complete and accurate.

4. Acceptance of a drainage report implies the Jurisdiction concurs with the project's overall stormwater management concept. This does not constitute full acceptance of the improvement plans, alignments, and grades, since constructability issues may arise in plan review.

5. Use all headings listed in the contents (Section 2A-4, C). A complete report will include all the information requested in this format. If a heading listed does not apply, include the heading and briefly explain why it does not apply. Include additional information and headings as required to develop the report.

6. This manual does not preclude the utilization of methods other than those referenced, nor does it relieve the designer of responsibility for analysis of issues not specifically mentioned.

C. Contents

The following information contains summaries for hydrology and detention (see Tables 2A-4.01, 2A-4.02, and 2A-4.03), as well as design considerations for the preparation of project drainage reports. They are provided as a minimum guide and are not to be construed as the specific information to be supplied on every project drainage report, and other information may be required. Existing and proposed conditions for each development will require analysis unique to that area.

1. Site Characteristics:

a. Pre-development Conditions: Describe pre-developed land use, topography, drainage patterns (including overland conveyance of the 100 year storm event), storm sewer, ditches, and natural and man-made features. Describe ground coverage, soil type, and physical properties, such as hydrologic soil group and infiltration. If a geotechnical study of the site is available, provide boring logs and locations in the appendix of the report. If a soil survey was used, cite it in the references.

For the pre-development analysis where the area is rural and undeveloped, a land use description reflecting current use is typical; however, the jurisdiction may apply more stringent requirements due to downstream drainage conditions. In addition, some jurisdictions require use of pre-settlement (meadow) conditions for all development. The jurisdiction should be contacted to determine what pre-development conditions are required.

b. Post-development Conditions: Describe post-developed land use and proposed grading, change in percent of impervious area, and change in drainage patterns. If an existing drainage way is filled, the runoff otherwise stored by the drainage way will be mitigated with stormwater detention, in addition to the post-development runoff.

c. Contributing Off-site Drainage: Describe contributing off-site drainage patterns, land use, and stormwater conveyance. Identify undeveloped contributing areas with development potential and list assumptions about future development runoff contributed to the site.

d. Floodways, Floodplains, and Wetlands: Identify areas of the site located within the floodway or floodplain boundaries as delineated on Flood Insurance Rate Maps, or as determined by other engineering analysis. Identify wetland areas on the site, as delineated by the National Wetlands Inventory, or as determined by a specific wetland study.

e. Pre-development Runoff Analysis:

1) Watershed Area: Describe overall watershed area and relationship between other watersheds or sub-areas. Include a pre-development watershed map in the report appendix.

2) Time of Concentration: Describe method used to calculate the time of concentration. Describe runoff paths and travel times through sub-areas. Show and label the runoff paths on the pre-development watershed map.

3) Precipitation Model: Describe the precipitation model and rainfall duration used for the design storm. Typical models may include one or more of the following:

a) NRCS Type-II Distribution.
b) Huff Rainfall Distribution. Select the appropriate distribution based on rainfall duration.
c) Frequency-Based Hypothetical Storm.
d) Rainfall Intensity Duration Frequency (IDF) Curve.
e) User-defined model based on collected precipitation data, subject to the Jurisdictional Engineer's approval. Total rainfall amounts for given frequency and duration should

be obtained from Bulletin 71, "Rainfall Frequency Atlas of the Midwest" (see Section 2B-2). Bulletin 71 supersedes Technical Paper Number 40, "Rainfall Frequency Atlas of the United States."

4) **Rainfall Loss Method:** List runoff coefficients or curve numbers applied to the drainage area. The Green-Ampt infiltration model may also be used to estimate rainfall loss by soil infiltration.
5) **Runoff Model:** Describe method used to project runoff and peak discharge. Typical models are as follows:
   a) Use the Rational Method for drainage areas up to 40 acres, and where flow routing is not required. Often used in storm sewer design. See Section 2B-4 for explanation of limitations.
   b) As an alternative to the Rational Method, the SCS (NRCS) Peak Flow Method may be used.
   c) For drainage areas where flow routing is required, use one of the following methods:
      - TR-55 Tabular Hydrograph Method (WIN-TR-55)
      - TR-20 Model (Computer Program for Project Formulation Hydrology).
      - Routines contained in HEC-1 or HEC-HMS computer models
      - Regression Equations and other hydrologic models approved by the Jurisdiction
   d) TR-20 Methods are not recommended for small drainage areas less than 20 acres.
6) **Summary of Pre-development Runoff:** Provide table(s) including drainage area, time of concentration, frequency, duration, peak discharge, routing, and accumulative flows at critical points where appropriate.

2. Post-development Runoff Analysis:

a. Watershed Area: Describe overall watershed area and sub-areas. Discuss if the post-development drainage area differs from the pre-development drainage area. Include a post-development watershed map.

b. Time of Concentration: The method used will be the same as used in the pre-development analysis. Describe change in times of concentration due to development (i.e. change in drainage patterns). Show and label the runoff paths on the post-development watershed map.

c. Precipitation Model: Storm event, total rainfall, and total storm duration will be the same as used for the pre-development model.

d. Rainfall Loss Method: Method will be the same as pre-development analysis. Describe the change in rainfall loss due to development.

e. Runoff Model: The runoff method will be the same as used in the pre-development analysis, except for variables changed to account for the developed conditions.

f. Summary of Post-development Runoff:

1) Provide table(s) including drainage area, time of concentration, frequency, duration, and peak discharge. Summarize in narrative form the change in hydrologic conditions due to the development. Provide a runoff summary using Tables 2A-4.01 and 2A-4.02.
2) Post-developed discharge should take into account any upstream offsite detention basins and undeveloped offsite areas assumed to be developed in the future with stormwater detention.

3) Calculate the allowable release rate from the site, based on two conditions:
   a) After development, the release rate of runoff for rainfall events having an expected return frequency of 2 years and 5 years should not exceed the existing, pre-developed peak runoff rate from those same storms.
   b) For rainfall events having an expected return frequency of 10 years to 100 years, inclusive, the rate of runoff from the developed site should not exceed the existing, pre-developed peak runoff from a 5 year frequency storm of the same duration. The allowable discharge rate may be restricted due to downstream capacity. Include this calculation in the Executive Summary.
4) Describe assumptions made for portions of the drainage area that are not included in the current development area.

3. Stormwater Conveyance Design:

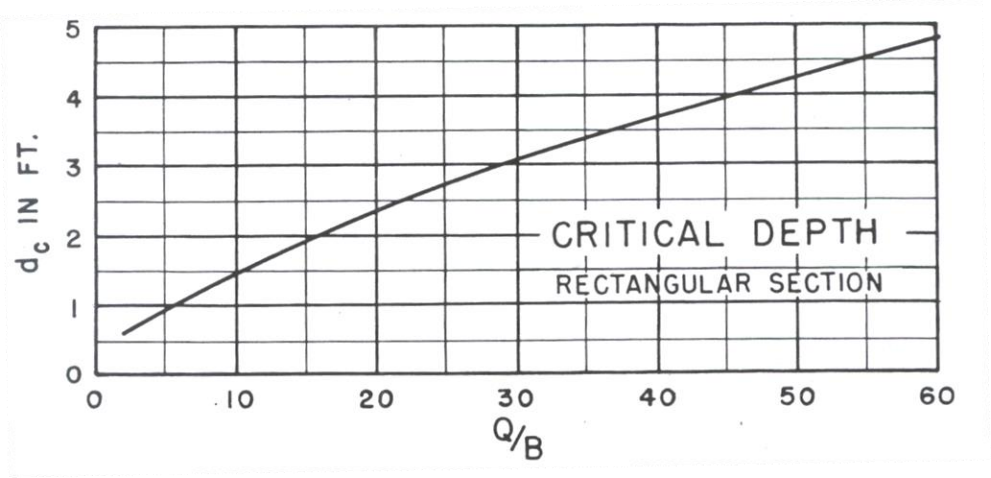
a. Design Information References: At a minimum, all stormwater conveyances will be designed according to this manual. The following references may be used for supplemental design information:
1) Federal Highway Administration (2009) *Urban Drainage Design Manual*. Hydraulic Engineering Circular No. 22, Washington D.C.
2) Federal Highway Administration (2005) *Design of Roadside Channels with Flexible Linings*. Hydraulic Engineering Circular No. 15, Washington D.C.
3) Federal Highway Administration (2005) *Hydraulic Design of Highway Culverts*. Hydrologic Design Series Number 5, Washington D.C.
4) US Geological Survey (1968) *Measurement of Peak Discharge at Culverts by Indirect Methods*. Book 3, Applications of Hydraulics, Washington D.C.
5) American Society of Civil Engineers (1993) *Design and Construction of Urban Stormwater Management Systems* Manual of Practice No. 77, New York, N.Y.

b. Storm Sewer:
1) List design criteria, including storm event and runoff model. Describe the hydraulic grade line and whether pressure flow or surcharging is possible. Provide a graphic of the hydraulic grade line.
2) List design criteria for intake size and spacing. Describe the anticipated gutter flow and spread at intakes.
3) List any special considerations for subdrain design, such as high water tables.
4) Provide tables of storm sewer (inlet and pipe) and intake design data.
5) Water spread on the street for intake design year and 100 year elevation in all streets in which the curb is overtopped.

c. Culverts:
1) Describe culvert capacity, inlet or outlet control conditions, and estimated tailwater and headwater. Determine if 100 year or lesser storm event will flood roadway over culvert.
2) Sketch a contour of the 100 year headwater elevation on a topographic map and/or grading plan. This delineated 100 year flood elevation is used to determine drainage easement and site grading requirements.

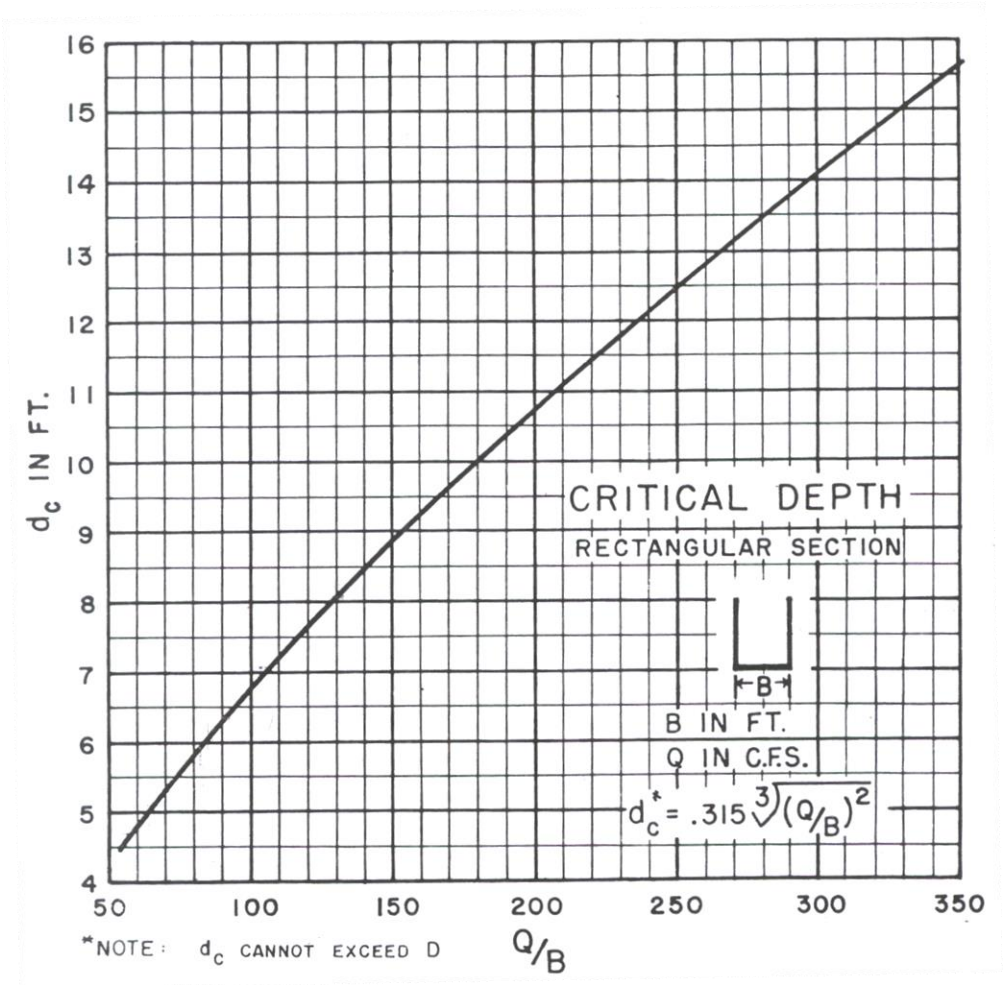
d. Open Channel Flow - Swales and Ditches:
1) Describe swale and ditch design. State the assumed Manning's roughness coefficients. State the anticipated flow velocity and whether it exceeds the permissible velocity based on soil types and/or ground coverage. If the permissible velocity is exceeded, describe channel lining or energy dissipation.

Figure 2E-2.04A: Critical Depth Box Culvert



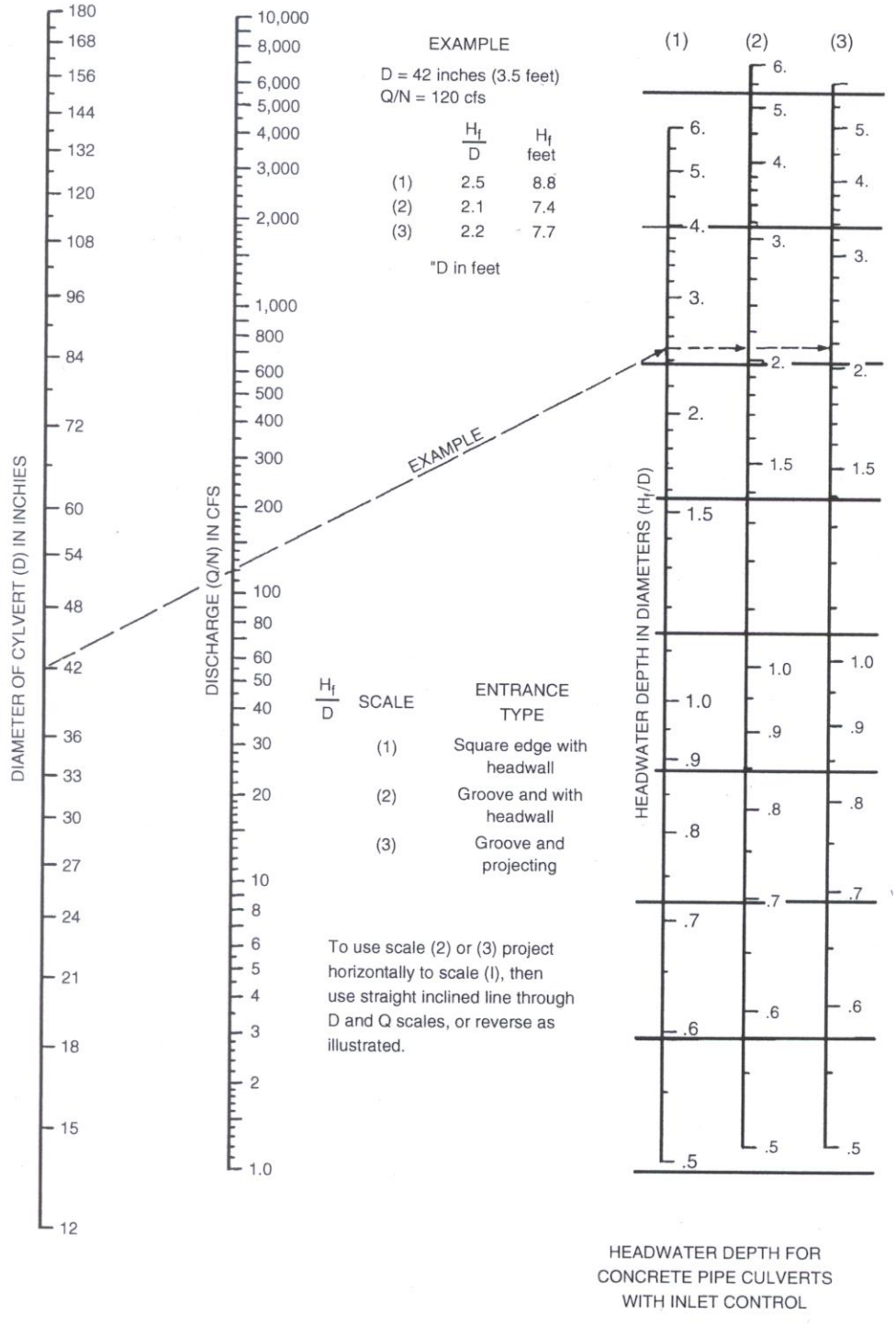
Source: *Hydraulic Design of Highway Culverts*, FHWA

Figure 2E-2.04B: Critical Depth Box Culvert



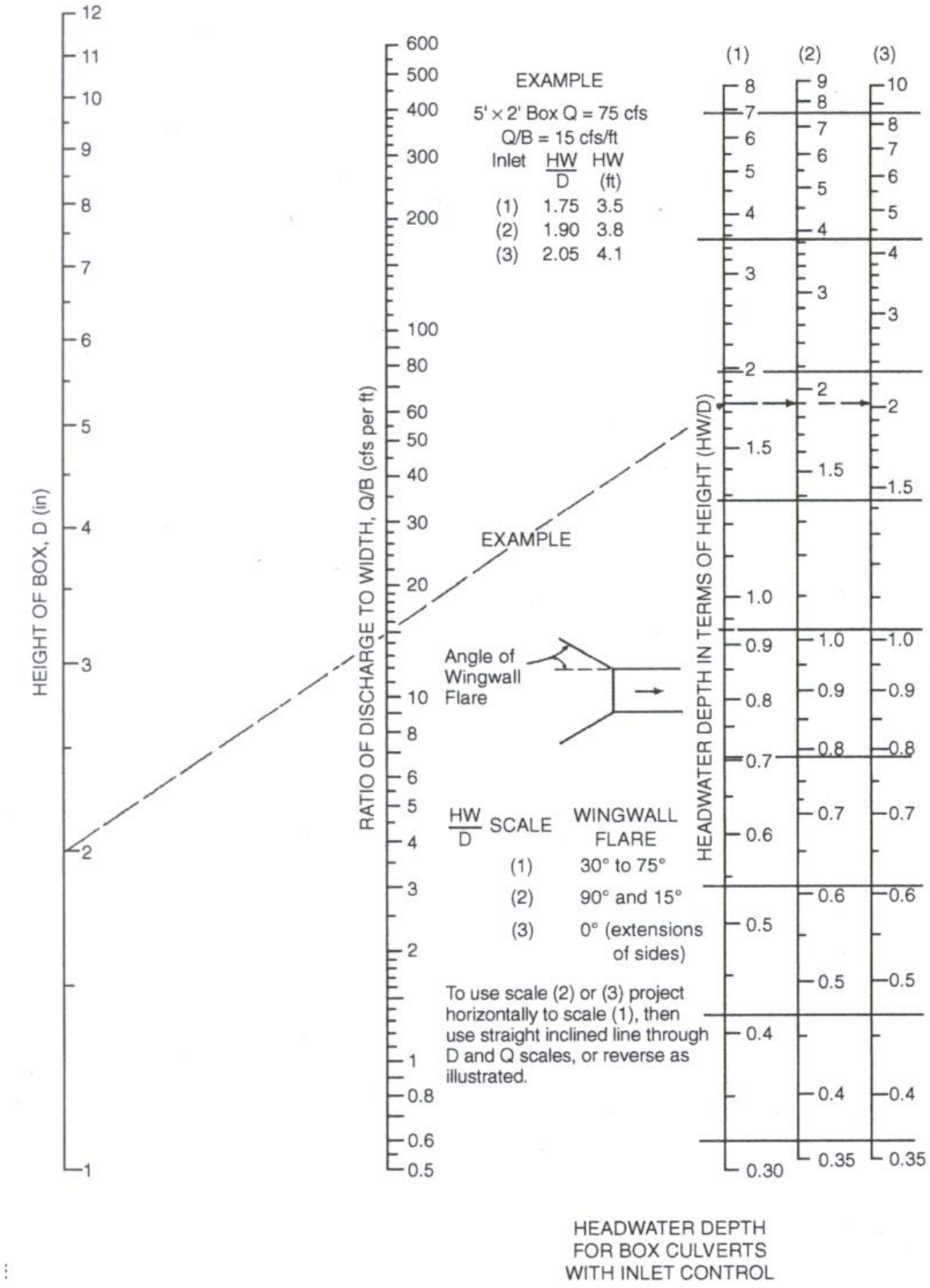
Source: *Hydraulic Design of Highway Culverts*, FHWA

Figure 2E-2.05: Inlet Control Nomograph



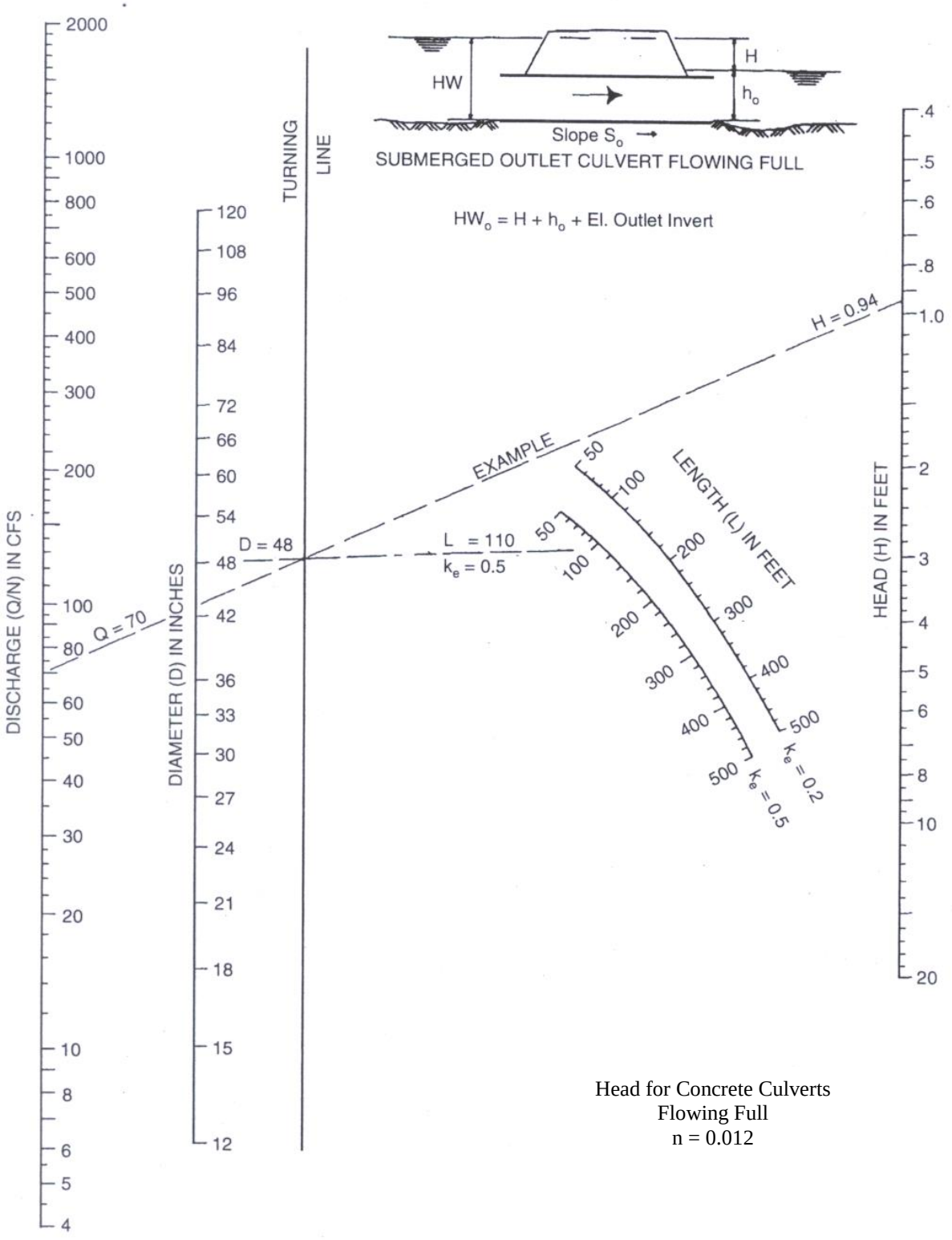
Source: *Hydraulic Design of Highway Culverts*, FHWA

Figure 2E-2.08: Inlet Control Nomograph



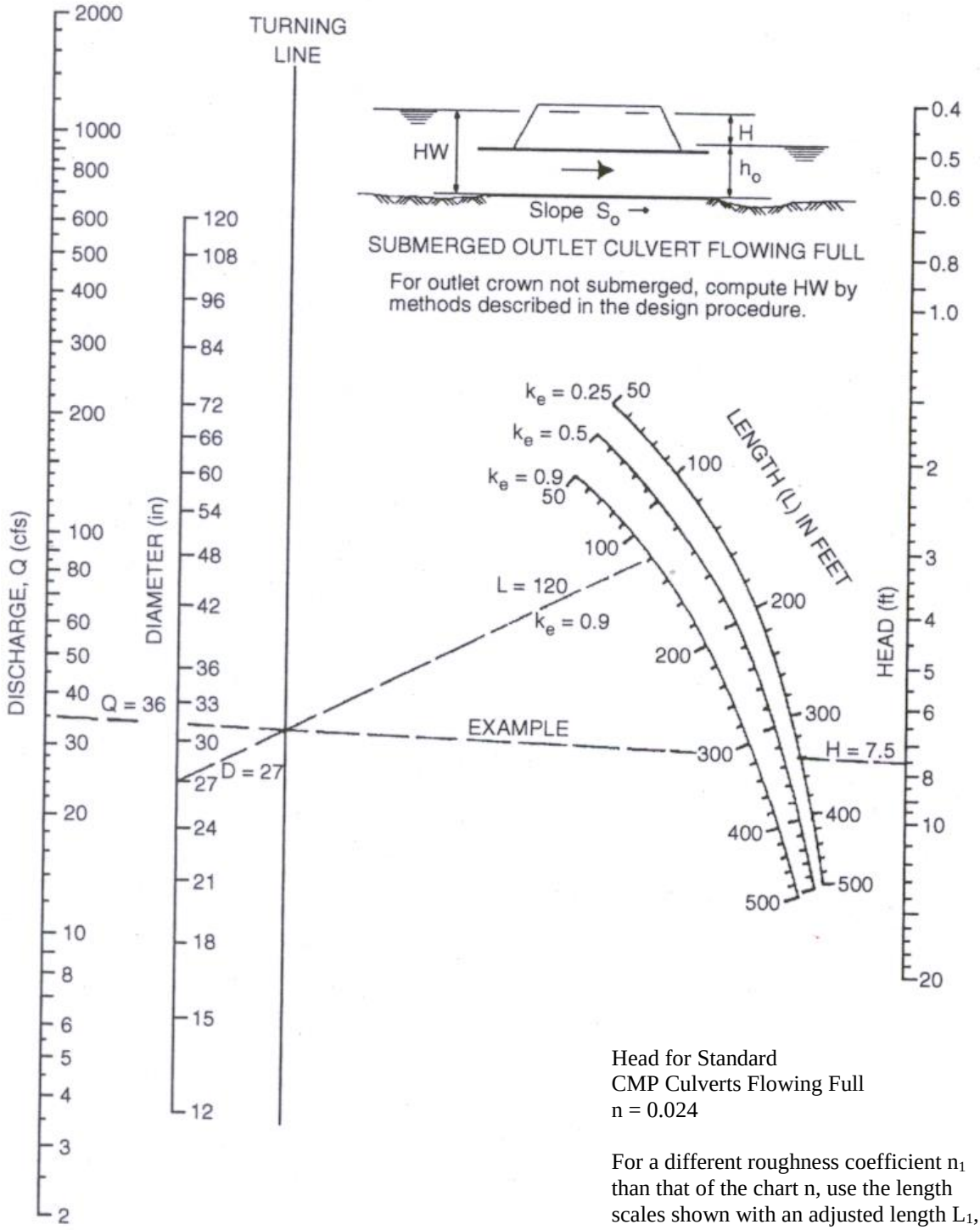
Source: *Hydraulic Design of Highway Culverts*, FHWA

Figure 2E-2.09: Outlet Control Nomograph



Source: *Hydraulic Design of Highway Culverts*, FHWA

Figure 2E-2.10: Outlet Control Nomograph



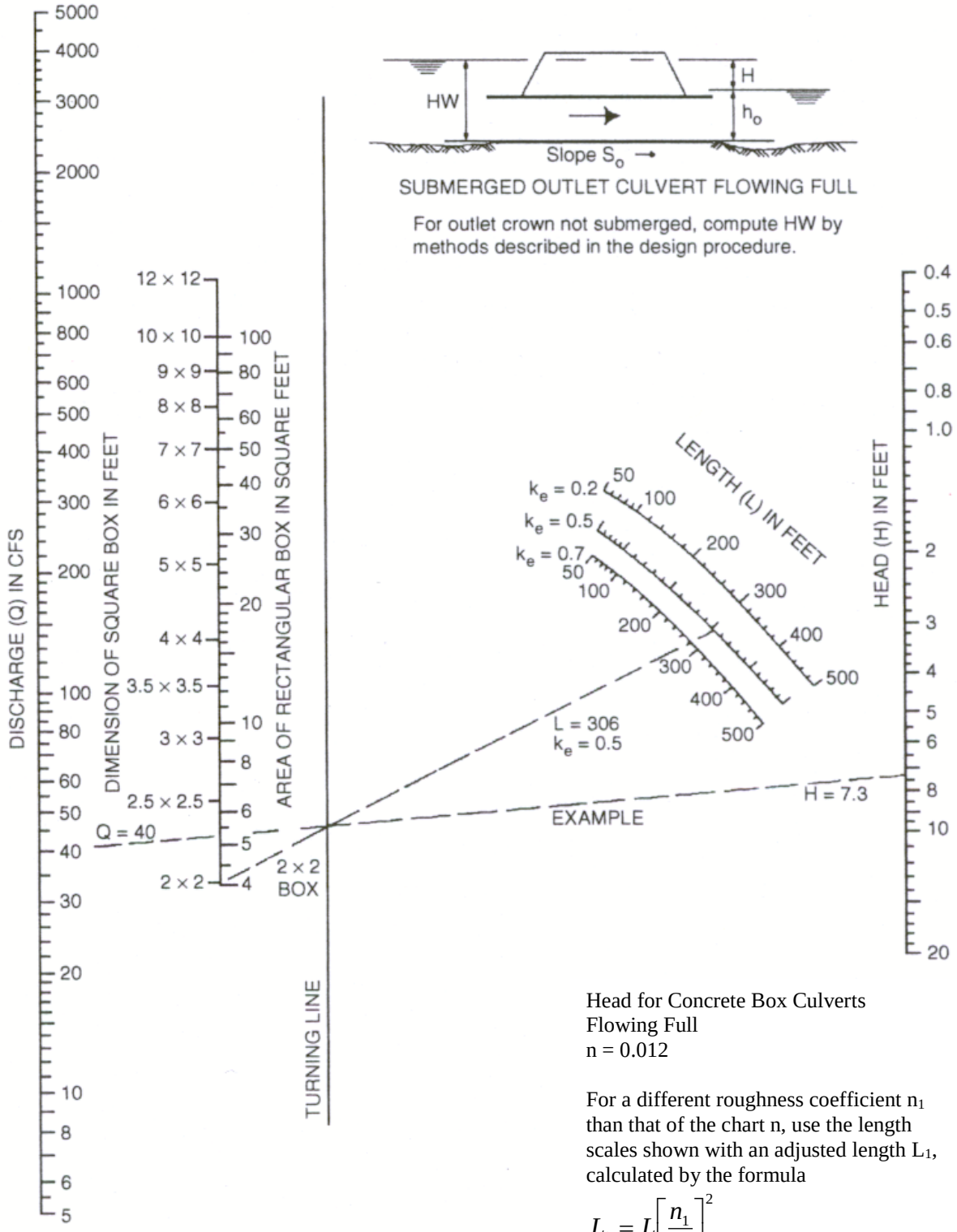
Head for Standard
CMP Culverts Flowing Full
n = 0.024

For a different roughness coefficient n_1 than that of the chart n, use the length scales shown with an adjusted length L_1, calculated by the formula

$$L_1 = L\left[\frac{n_1}{n}\right]^2$$

Source: *Hydraulic Design of Highway Culverts*, FHWA

Figure 2E-2.11: Outlet Control Nomograph



Head for Concrete Box Culverts
Flowing Full
n = 0.012

For a different roughness coefficient n_1 than that of the chart n, use the length scales shown with an adjusted length L_1, calculated by the formula

$$L_1 = L\left[\frac{n_1}{n}\right]^2$$

Source: *Hydraulic Design of Highway Culverts*, FHWA

Facility Design

A. General

Water mains and appurtenances, including hydrants and valves, should be provided along all streets including connections to and extensions from existing water systems.

The location and spacing of water mains and their appurtenances is not only important for service and fire protection, but also maintenance requirements. Figures 4C-1.02 through 4C-1.03 show guidelines for the location of these facilities.

B. Water Mains

1. Water main pipe will typically be either polyvinyl chloride (PVC) pipe or ductile iron pipe (DIP); and meet AWWA Standards.

   Designers should use the Iowa DNR's website to determine if there are any leaking underground storage tanks (LUST) sites within 500 feet of the proposed water main: https://facilityexplorer.iowadnr.gov/facilityexplorer.

   Where distribution systems and service connections are installed in areas of known groundwater contaminated by volatile organic compounds (LUST), pipe and joint materials (non-PVC pipe) that do not allow permeation of the volatile organic compounds must be used.

   The Iowa DNR requires underground storage tank (UST) owners to meet specific design requirements for USTs installed within 1,000 feet of a community water system. The Project Engineer should determine if there is an UST within 1,000 feet of the project area. If so, the Designer should determine the need to design the water mains to prevent future permeation of any volatile organic compounds into the water system. There are various elements to consider, some of which include soil types, groundwater table depth, size of the UST, age of the UST, etc.

   Consult with manufacturers concerning permeation of the pipe walls, jointing materials, valve seats, etc.

2. Water mains should be extended to the plat or property boundaries, to the next street, or as directed by the Jurisdiction.

3. New main installation should be located in the parking area (between the curb and the property line) of the right-of-way and minimum of 4 feet behind the curb. Where possible, water mains should be located along the south and east sides of the street.

4. Dead-ends should be minimized by looping mains whenever possible. Dead-ends should terminate with an approved flushing device (blowoff, hydrant, flushing hydrant). They may terminate with an approved fire hydrant when adequate pressure is available at required flows. For maintenance considerations and when adequate fire flows are not available, flushing hydrants may be allowed by the Jurisdiction with the hydrant outlet sized and arranged to prevent the attachment of fire hoses. Unless required by a Jurisdiction, permanent inline shut-off valves

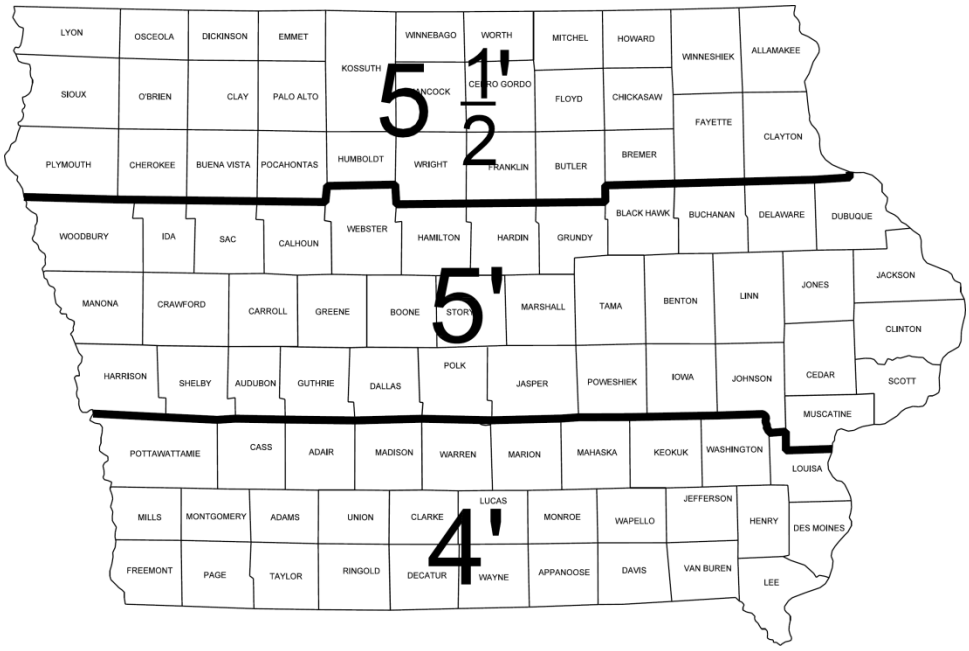
should not be placed at the end of dead-end mains. A valve may be placed one or two pipe lengths back from the end of the project. No services should be placed past the valve. These

pipes will provide sufficient support for the valve and allow a future extension to be made without impacting current water customers.

5. Water mains and extensions should be designed with a minimum cover as indicated on Figure 4C-1.01, unless more or less cover has been approved by the Jurisdictional Engineer. Greater depths of cover, surface loading conditions, or unusual trench conditions may require a stronger class of pipe according to the AWWA Standard regarding the type of pipe being installed. Where a dip must be placed in a main in order to pass under another utility, the length of the deeper main should be kept to a minimum, and bends should be considered to affect the desired offset.

6. Water mains should be adequately protected from corrosive soil environments. Comply with AWWA C105. Complete soil testing or check with the Jurisdictional Engineer to determine if corrosive soils are present within the project area. If so, include polyethylene encasement for ductile iron pipe, valves, and fittings or use of other nonmetallic pipe materials. If nonmetallic materials are used, be sure to provide polyethylene encasement for fittings and valves. In severe instances, cathodic protection may be required.

Figure 4C-1.01: Minimum Depth of Cover for Water Main Installation



C. Blowoffs

A blowoff or approved flushing device is required on all dead-end mains where a hydrant is not installed. The minimum riser assembly size should be no less than 2 diameter sizes smaller than the diameter of the water main. The flushing device should be sized to provide flows that will give a velocity of at least 2.5 feet per second in the main being flushed. When the water main is extended, the blowoff should be removed. A new valve should be placed between the existing and extended main.

D. Valves

1. As a minimum, valves should be located at intersections, such that only one unvalved pipe exists at the intersection. Valves should be equally spaced, if possible, with spacing no more than 800 feet in residential areas and no more than 400 feet in high density residential, commercial, and industrial areas. (See Figures 4C-1.02 through 4C-1.03 for valve locations at intersections).

2. Valves should not be located in the sidewalk line or in driveways.

3. All valves should be installed with valve boxes. Use slide type valve boxes in paved areas and screw type in all other areas. A screw type valve box that is located in an area to be paved should be changed to a slide type valve box as a part of the paving program.

4. No valves (except blowoff valves) should be placed at the end of a dead-end main unless required by a Jurisdiction. A valve should be installed between the existing main and new main when the main is extended. Intermediate valve locations between the end of a dead-end main and last valved street intersection may be required by the Jurisdiction to provide required valve spacing.

5. A tapping sleeve and valve should be used when making a perpendicular connection to an existing main.

6. If the project area has high water pressure, usually exceeding 100 psi, it may be appropriate to install system pressure relief valves as opposed to individual building controls. The potential for using a system pressure reducing valve is limited by the interconnected nature of a distribution system. Check with the Jurisdiction to determine the potential need for use of pressure reducing valves.

E. Fire Hydrants

1. Hydrants should comply with AWWA C502. The connecting pipe between the supply main and the hydrants should be a minimum of 6 inches in diameter and be independently valved. Fire hydrants should not be installed on water mains that do not provide a minimum pressure.

2. Hydrant drains should not be connected to or located within 10 feet of sanitary sewers.

3. Locations of fire hydrants are governed by the rules and regulations of the Iowa DNR and the local Jurisdiction and by the following principles. Satisfy each principle in the order they are listed. See Figures 4C-1.02 through 4C-1.03 for typical hydrant locations.

    a. Locate fire hydrants within 25 feet of each street intersection, measured from an end of a street paving return.

        Locate fire hydrants outside street paving returns. Avoid conflicts with storm sewers, intakes, and sidewalks. Whenever possible, locate fire hydrants at the high point of the intersection.

    b. Locate fire hydrants between street intersections to provide spacings of no more than 450 feet in single family residential districts and no more than 300 feet in all other districts. Coverage radii for structures as noted below should be checked when determining hydrant placement.

        Vary spacings slightly to place fire hydrants on extensions of property lines. When hydrants are required between intersections, they should be located at the high point of the main for air release or at a significant low point for flushing on the downhill side of an in-line valve.

When street curvature or grid patterns places a proposed protected structure at an unusual distance from the fire hydrant, the coverage radius should not exceed 300 feet in single family residential districts and 150 feet in all other districts. The Jurisdiction's fire marshall may have additional private fire protection requirements.

c. On cul-de-sac streets, hydrants should be located at the intersection of the cul-de-sac street and cross-street and the end of the cul-de-sac.

   1) For cul-de-sacs between 300 feet and 500 feet in length, an additional hydrant should be located at the mid-block.

   2) For cul-de-sacs greater than 500 feet in length, hydrants should be placed at near equal spacings, but not exceeding the spacings described above.

d. Hydrants must be located to provide the required fire flows. ISO evaluates fire hydrant locations within 1,000 feet of the test location, measured along the streets as fire hose can be laid, to evaluate the availability of water for fire protection. Hydrant capacity is credited as shown in the following table:

Hydrant Location	Credited Capacity
Within 300' of location	1,000 gpm
Within 301' to 600' of location	670 gpm
Within 601' to 1,000' of location	250 gpm

e. Locate fire hydrants to maintain a 3 foot clear space around the circumference of the fire hydrant to create unobstructed access for the fire department.

F. Water Service Stubs

Water service stubs for each building or platted lot should be provided, including corporation stop, service line, and curb stop (shut-off) with box. Check with the Jurisdiction to determine appropriate placement location. In no case should the shut-off be in the sidewalk. Avoid locations where driveway approaches are likely to be constructed in the future.

G. Separation of Water Mains from Sewer Mains

The following comply with the Iowa Department of Natural Resources separation requirements.

1. **Horizontal Separation of Gravity Sewers from Water Mains:** Separate gravity sewer mains from water mains by a horizontal distance of at least 10 feet unless:
   - the top of a sewer main is at least 18 inches below the bottom of the water main, and
   - the sewer is placed in a separate trench or in the same trench on a bench of undisturbed earth at a minimum horizontal separation of 3 feet from the water main.

   When it is impossible to obtain the required horizontal clearance of 3 feet and a vertical clearance of 18 inches between sewers and water mains, the sewers must be constructed of water main materials meeting the requirements of SUDAS Specifications Section 5010, 2.01. However, provide a linear separation of at least 2 feet.

2. **Separation of Sewer Force Mains from Water Mains:** Separate sewer force mains and water mains by a horizontal distance of at least 10 feet unless:
   - the force main is constructed of water main materials meeting a minimum pressure rating of 150 psi and the requirements of SUDAS Specifications Section 5010, 2.01, and
   - the sewer force main is laid at least 4 linear feet from the water main.

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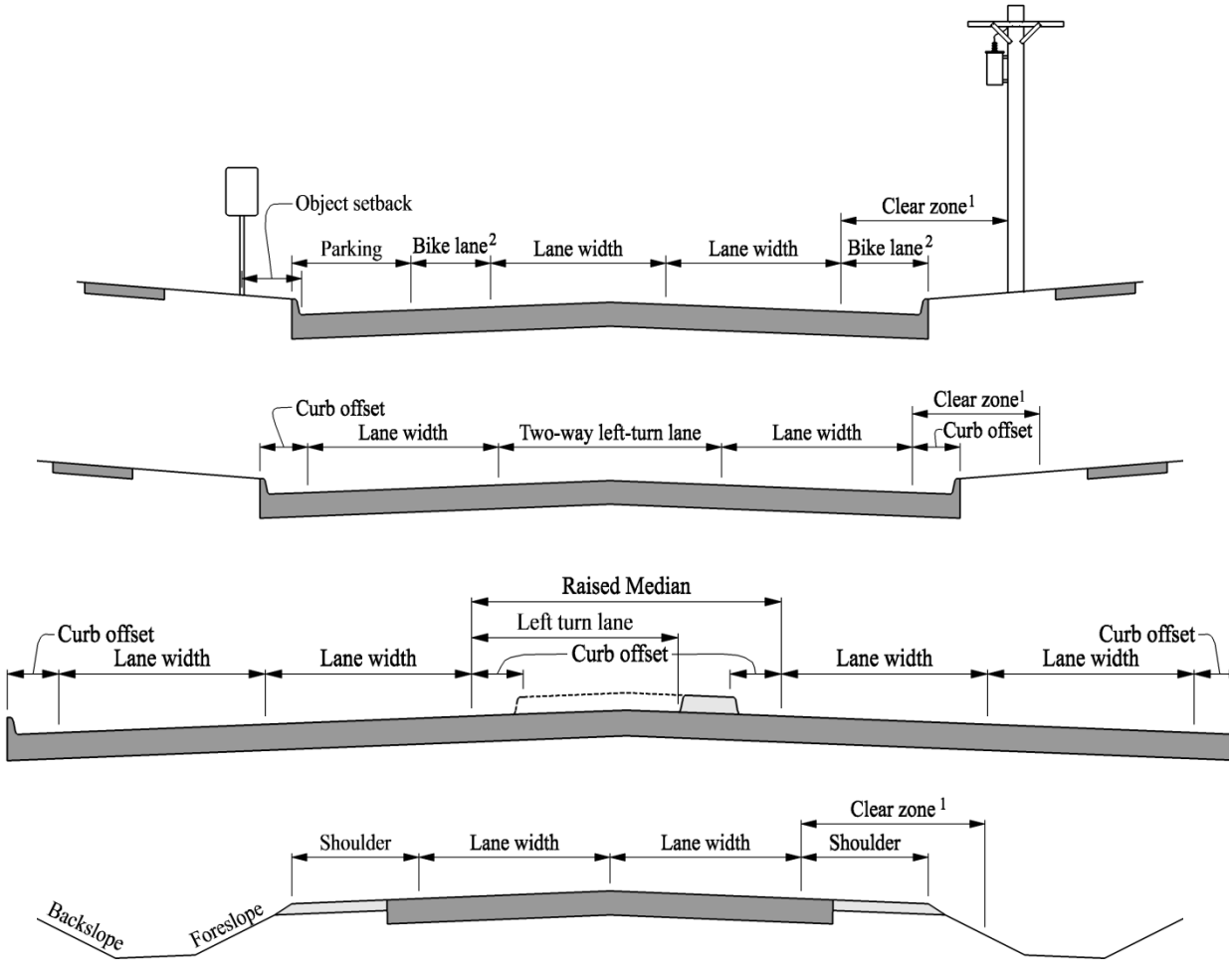
C. Roadway Design Tables

The following figures illustrate the location of various design elements of the roadway cross-section as specified in Tables 5C-1.01 and 5C-1.02.

Figure 5C-1.01: Roadway Design Elements



[1] Clear zone is measured from the edge of the traveled way.
[2] See Chapter 12 for bike lane requirements.

Table 5C-1.01: Preferred Roadway Elements

Elements Related to Functional Classification

Design Element	Local		Collector		Arterial	
	Res.	***C/I***	***Res.***	***C/I***	***Res.***	***C/I***
General						
Design level of service[1]	D	D	C/D	C/D	C/D	C/D
Lane width (single lane) (ft)[2]	10.5	12	12	12	12	12
Two-way left-turn lanes (TWLTL) (ft)	N/A	N/A	14	14	14	14
Width of new bridges (ft)[3]	See Footnote 3					
Width of bridges to remain in place (ft)[4]	----------	----------	----------	----------	----------	----------
Vertical clearance (ft)[5]	14.5	14.5	14.5	14.5	16.5	16.5
Object setback (ft)[6]	3	3	3	3	3	3
Clear zone (ft)	Refer to Table 5C-1.03, Table 5C-1.04, and 5C-1, C, 1					
Urban						
Curb offset (ft)[7]	2	2	2	3	3	3
Parking lane width (ft)	8	8	8	10	N/A	N/A
Roadway width with parking on one side[8]	26/27/31[9]	34	34	37	N/A	N/A
Roadway width without parking[10]	26	31	31	31	31	31
Raised median with left-turn lane (ft)[11]	N/A	N/A	19.5	20.5	20.5	20.5
Cul-de-sac radius (ft)	45/48[12]	45/48[12]	N/A	N/A	N/A	N/A
Rural Sections in Urban Areas						
Shoulder width (ft)						
ADT: under 400	4	4	6	6	10	10
ADT: 400 to 1,500	6	6	6	6	10	10
ADT: 1,500 to 2000	8	8	8	8	10	10
ADT: above 2,000	8	8	8	8	10	10
Foreslope (H:V)	4:1	4:1	4:1	4:1	6:1	6:1
Backslope (H:V)	4:1	4:1	4:1	4:1	4:1	4:1

Res. = Residential, C/I = Commercial/Industrial

Elements Related to Design Speed

Design Element	Design Speed, mph[13]							
	25	***30***	***35***	***40***	***45***	***50***	***55***	***60***
Stopping sight distance (ft)	155	200	250	305	360	425	495	570
Passing sight distance (ft)	900	1090	1,280	1,470	1,625	1,835	1,985	2,135
Min. horizontal curve radius (ft)[14]	198	333	510	762	1,039	926	1,190	1,500
Min. vertical curve length (ft)	50	75	105	120	135	150	165	180
Min. rate of vertical curvature, Crest (K)[15]	18	30	47	71	98	136	185	245
Min. rate of vertical curvature, Sag (K)	26	37	49	64	79	96	115	136
Minimum gradient (percent)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Maximum gradient (percent)	5	5	5	5	5	5	5	5

Note: For federal-aid projects, documentation must be provided to explain why the preferred values are not being met. For non-federal aid projects, the designer must contact the Jurisdiction to determine what level of documentation, if any, is required prior to utilizing design values between the "Preferred" and "Acceptable" tables.

Table 5C-1.01 Footnotes:

[1] Number of traffic lanes, turn lanes, intersection configuration, etc. should be designed to provide the overall specified LOS at the design year ADT. Two LOS values are shown for collectors and arterials. The first indicates the minimum overall LOS for the roadway as a whole; the second is the minimum LOS for individual movements at intersections.

[2] Width shown is for through lanes and turn lanes.

[3] Bridge width is measured as the clear width between curbs or railings. Minimum bridge width is based upon the width of the traveled way (lane widths) plus 4 feet clearance on each side; but no less than the curb-face to curb-face width of the approaching roadway. Minimum bridge widths do not include medians, turn lanes, parking, or sidewalks. At least one sidewalk should be extended across the bridge.

[4] See Table 5C-1.02, for acceptable values for width of bridges to remain in place.

[5] Vertical clearance includes a 0.5 foot allowance for future resurfacing.

[6] Object setback does not apply to mailboxes constructed and installed according to US Postal Service regulations, including breakaway supports.

[7] Values shown are measured from the edge of the traveled way to the back of curb. Curb offset is not required for turn lanes. On roadways with an anticipated posted speed of 45 mph or greater, mountable curbs are required. For pavements with gutterline jointing, the curb offset should be equal to or greater than the distance between the back of curb and longitudinal gutterline joint.

[8] Parking is allowed along one side of local or collector streets unless restricted by the Jurisdiction. Some jurisdictions allow parking on both sides of the street. When this occurs, each jurisdiction will set their own standards to allow for proper clearances, including passage of large emergency vehicles. Parking is normally not allowed along arterial roadways.

[9] For local, low volume residential streets, two free flowing lanes are not required and a 26 foot or 31 foot (back to back) roadway may be used where parking is allowed on one side or both sides respectively. For higher volume residential streets, which require two continuously free flowing traffic lanes, a 31 foot or 37 foot roadway should be used for one sided or two sided parking respectively. The minimum street width with parking on one side stipulated in the 2018 International Fire Code is 27 foot back to back. Some jurisdictions allow narrower street widths in low density residential areas due to the size of their firefighting apparatus.

[10] Some minimum roadway widths have been increased to match standard roadway widths. Unless approved by the Jurisdiction, all two lane roadways must comply with standard widths of 26, 31, 34, or 37 feet.

[11] Median width is measured between the edges of the traveled way of the inside lanes and includes the curb offset on each side of the median. Values include a left turn lane with a 6 foot raised median as required to accommodate a pedestrian access route (refer to Chapter 12) through the median (crosswalk cut through). At locations where a crosswalk does not cut through the median, the widths shown can be reduced by 2 feet to provide a 4 foot raised median.

[12] The minimum cul-de-sac radius stipulated by the 2018 International Fire Code is 48 feet. Some jurisdictions allow lesser radii due to the size of their firefighting apparatus.

[13] It is preferred to select a design speed that is at least 5 mph greater than the anticipated posted speed limit of the roadway. Selecting a design speed equal to the posted speed limit may also be acceptable and should be evaluated on a project by project basis, subject to approval of the Engineer.

[14] Values for low design speed (<50 mph) assume no removal of crown (i.e. negative 2% superelevation on outside of curve). Radii for design speeds of 50 mph or greater are based upon a superelevation rate of 4%. For radii corresponding to other superelevation rates, refer to the AASHTO's "Green Book."

[15] Assumes stopping sight distance with 6 inch object.

Table 5C-1.02: Acceptable Roadway Elements

Elements Related to Functional Classification

Design Element	Local		Collector		Arterial	
	Res.	***C/I***	***Res.***	***C/I***	***Res.***	***C/I***
General						
Design Level-of-Service[1]	D	D	D/E	D/E	D/E	D/E
Lane width (single lane) (ft)[2]	10	11	11	11	11	11
Two-Way Left-Turn Lanes (TWLTL) (ft)	N/A	N/A	12	12	12	12
Width of new bridges, (ft)[3]	See Footnote 3					
Width of bridges to remain in place (ft)[4]	20	22	24	24	26	26
Vertical clearance (ft)[5]	14.5	14.5	14.5	14.5	14.5	14.5
Object setback (ft)[6]	1.5	1.5	1.5	1.5	1.5	1.5
Clear zone (ft)	Refer to Table 5C-1.03, Table 5C-1.04, and 5C-1, C, 1					
Urban						
Curb offset (ft)[7]	1.5[8]	1.5[8]	1.5[8]	1.5[8]	2	2
Parking lane width (ft)	7.5	7.5	7.5	9	10	10
Roadway width with parking[9, 11]	26/31[10]	31	31	34[11]	34	34
Roadway width without parking[11]	26[10]	26	26	26	26	26
Raised median with left-turn lane (ft)[12]	N/A	N/A	18	18	18.5	18.5
Cul-de-sac radius (ft)	45	45	N/A	N/A	N/A	N/A
Rural Sections in Urban Areas						
Shoulder width (ft)						
ADT: under 400	2	2	2	2	8	8
ADT: 400 to 1,500	5	5	5	5	8	8
ADT: 1,500 to 2,000	6	6	6	6	8	8
ADT: over 2,000	8	8	8	8	8	8
Foreslope (H:V)[13]	3:1	3:1	3:1	3:1	4:1	4:1
Backslope (H:V)	3:1	3:1	3:1	3:1	3:1	3:1

Res. = Residential, C/I = Commercial/Industrial

Elements Related to Design Speed

Design Element	Design Speed, mph[14]							
	25	***30***	***35***	***40***	***45***	***50***	***55***	***60***
Stopping sight distance (ft)	155	200	250	305	360	425	495	570
Passing sight distance (ft)	900	1,090	1,280	1,470	1,625	1,835	1,985	2,135
Min. horizontal curve radius (ft)[15]	198	333	510	762	1,039	833	1,060	1,330
Min. vertical curve length (ft)	50	75	105	120	135	150	165	180
Min. rate of vert. curve, Crest (K)[16]	12	19	29	44	61	84	114	151
Min. rate of vert. curve, Sag (K)	26	37	49	64	79	96	115	136
Min. rate of vert. curve, Sag (K) based on driver comfort/overhead lighting[17]	14	20	27	35	44	54	66	78
Minimum gradient (percent)[18]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Maximum gradient (percent)[19]	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I
Local	12	10	12	9	11	9	11	9	10	8	9	8	N/A	N/A	N/A	N/A
Collector	12	9	11	9	10	9	10	9	9	8	8	7	N/A	N/A	N/A	N/A
Arterial	N/A	N/A	9	9	8	8	8	8	N/A	7	N/A	7	N/A	6	N/A	6

R = Residential, C/I = Commercial/Industrial

Geometric Design Elements

A. Level of Service

Level of service (LOS) is a measure of the operating conditions of a roadway facility. LOS is based upon traffic performance related to speed, travel time, freedom to maneuver, traffic interruptions, and comfort and convenience. The LOS ranges from A (least congested) to F (most congested). Refer to the Highway Capacity Manual for a more thorough discussion of the LOS concept.

Based upon the traffic capacity analysis, the number of lanes, turn lanes, and intersection controls should be selected to provide a design with the desired LOS for the design year traffic. Design year traffic is based upon a 20 year traffic projection. The current Highway Capacity Manual and the current AASHTO "Green Book" should be used for traffic projections and to determine the number of lanes and intersection configuration at the desired LOS.

The LOS for the roadway overall is based upon Average Daily Traffic (ADT), while the LOS at signalized intersections is based upon the peak hourly volume (PHV).

As a planning tool, refer to the generalized service volume tables in FHWA's *Simplified Highway Capacity Calculation Method for the Highway Performance Monitoring System* (https://www.fhwa.dot.gov/policyinformation/pubs/pl18003/hpms_cap.pdf).

The 2010 Highway Capacity Manual, issued in 2013, indicates there is no reduction in lane capacity until the lane width is less than 10 feet. For lanes less than 10 feet wide, the adjustment factor is 0.96.

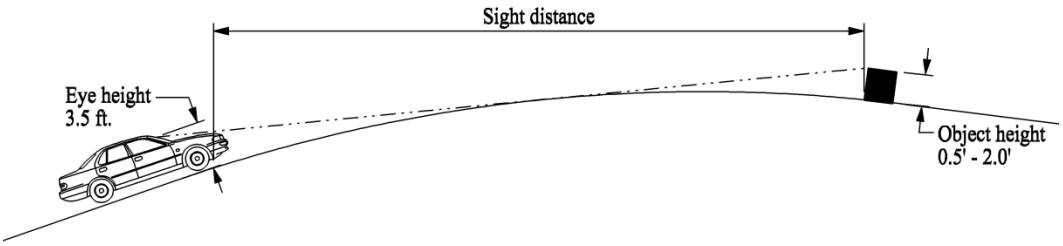
B. Sight Distance

The following information is taken from the 2004 AASHTO "Green Book." The Project Engineer should check the current edition of the AASHTO "Green Book" when specific information is needed to verify values provided.

1. **Stopping Sight Distances:** The minimum stopping sight distance is the distance required by the driver of a vehicle traveling at the design speed to bring the vehicle to a stop after an object on the road becomes visible. This distance directly affects the length and rate of curvature for vertical curves.

   The method for measuring stopping sight distance on vertical curves assumes a height for the driver's eye and a height for an object in the road. For a crest vertical curve, the sight distance is the distance at which an object in the road appears to the driver over the crest of the curve.

Figure 5C-2.01: Vertical Sight Distance Determination



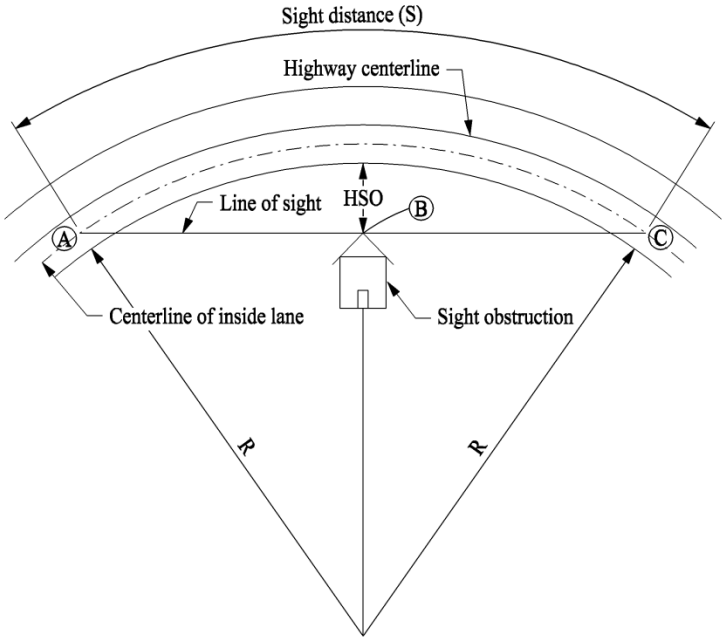
Stopping sight distance is calculated based upon an assumed height of the driver's eye and an assumed height of an object in the roadway. For all sight distance criteria, the height of the driver's eye is assumed to be 3.5 feet above the surface of the road, as recommended by AASHTO. Tables 5C-1.01 and 5C-1.02 in Section 5C-1 assume two different values for the height of the object in the roadway. The "Acceptable" values in Table 5C-1.02 use a 2 foot object height according to the current edition of the AASHTO "Green Book." The "Preferred" values in Table 5C-1.01 assume an object height of only 6 inches. This lower object height was the design value used in previous versions of the AASHTO "Green Book." The results of assuming a smaller object height for the preferred values in Table 5C-1.01 are higher required K values and longer vertical curves.

2. **Sight Distance on Horizontal Curves:** The horizontal alignment must provide at least the minimum stopping distance for the design speed at all points. This includes visibility around curves and roadside encroachments.

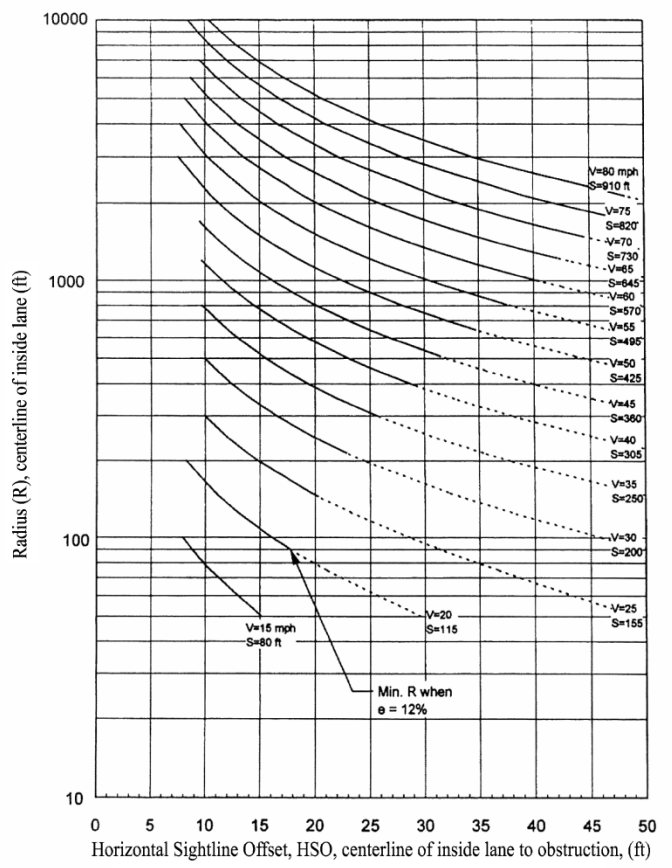
   Where there are sight obstructions such as walls, cut slopes, buildings, fences, bridge structures, or other longitudinal barriers on the inside of curves, an adjustment in the minimum radius of the curve may be necessary. In no case should sight distance be less than the stopping sight distance specified in Tables 5C-1.01 and 5C-1.02 in Section 5C-1. The sight distance design procedure should assume a 6 foot fence (as measured from finished grade) exists along all property lines except in the sight distance triangles required at all intersections.

   Available sight distance around a horizontal curve can be determined graphically using the method shown in Figures 5C-2.02 and 5C-2.03 below. From the center of the inside lane (Point A), a line is projected through the point on the obstruction that is nearest to the curve (Point B). The line is then extended until it intersects the centerline of the inside lane (Point C).

Figure 5C-2.02 and Figure 5C-2.03: Sight Distances for Horizontal Curves



HSO = Horizontal Sightline Offset



Source: Adapted from AASHTO "Green Book," 2004 Edition, Exhibits 3-53 and 3-54

3. **Passing Sight Distance:** Passing sight distance is the minimum sight distance that must be available to enable the driver of one vehicle to pass another safely and comfortably without interfering with oncoming traffic traveling at the design speed. Two lane roads should provide adequate passing zones at regular intervals. Minimum passing sight distances are shown in Tables 5C-1.01 and 5C-1.02 in Section 5C-1.

   Passing sight distance is measured between an eye height of 3.5 feet and an object height of 3.5 feet. On straight sections of roadway, passing sight distance is determined primarily by the vertical curvature of the roadway. On horizontal curves, obstructions adjacent to the roadway on the inside of the curve can limit sight distance. This is most common in a cut section where the adjacent terrain projects above the surface of the roadway. Passing sight distance should be verified using the methods described in the current edition of the AASHTO "Green Book."

4. **Intersection Sight Distance:** In addition to the stopping sight distance provided continuously in the direction of travel on all roadways, adequate sight distance at intersections must be provided to allow drivers to perceive the presence of potentially conflicting vehicles. Sight distance is also required at intersections to allow drivers of stopped vehicles to decide when to enter or cross the intersecting roadway. If the available sight distance for an entering or crossing vehicle is at least equal to the appropriate stopping sight distance for the major road, then drivers have sufficient sight distance to anticipate and avoid collisions. However, in some cases, this may require a major road vehicle to slow or stop to accommodate the maneuver by a minor road vehicle. To enhance traffic operations, intersection sight distances that exceed stopping sight distances are desirable along the major road.

   Each intersection has the potential for several different types of vehicular conflicts. The possibility of these conflicts actually occurring can be greatly reduced by providing proper sight distance and appropriate traffic controls. Each quadrant of an intersection should contain a triangular area free of obstructions that might block an approaching driver's view of potentially conflicting vehicles. This clear area is known as the sight triangle.

   a. **Sight Triangles:** Proper sight distance at intersections is determined through the establishment and enforcement of sight triangles. The required dimensions of the legs of the triangle depend on the design speed of the roadways and the type of traffic control provided at the intersection. Two types of clear sight triangles are considered in intersection design: approach sight triangles and departure sight triangles.
      1) **Approach Sight Triangles:** Approach sight triangles allow the drivers at uncontrolled or yield controlled intersections to see a potentially conflicting vehicle in sufficient time to slow or stop before colliding within the intersection. Although desirable at all intersections, approach sight triangles are not needed for intersections approaches controlled by stop signs or traffic signals.
      2) **Departure Sight Triangles:** A second type of clear sight triangle provides sight distance sufficient for a stopped driver on a minor-road approach to depart from the intersection and enter or cross the major road. Departure sight triangles should be provided in each quadrant of each intersection approach controlled by a stop sign.

      At signalized intersections, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. Left turning vehicles should have sufficient sight distance to select gaps in oncoming traffic.

      The recommended dimensions of the sight triangles vary with the type of traffic control used at an intersection because different types of controls impose different legal constraints on drivers and, therefore, result in different driver behavior. The AASHTO "Green Book"

contains the required procedures, equations, and tables for determining the required sight distance under various intersection and traffic control configurations.

b. Identification of Sight Obstructions within Sight Triangles: Within a sight triangle, any object at a height above the elevation of the adjacent roadways that would obstruct the driver's view should be removed or lowered if practical. Such objects may include buildings, parked vehicles, highway structures, roadside hardware, hedges, trees, bushes, unmowed grass, tall crops, walls, fences, and the terrain itself. Particular attention should be given to the evaluation of clear sight triangles at intersection ramp/crossroad intersections where features such as bridge railings, piers, and abutments are potential sight obstructions.

The determination of whether an object constitutes a sight obstruction should consider both the horizontal and vertical alignment of both intersecting roadways, as well as the height and position of the object. In making this determination, it should be assumed that the driver's eye is 3.5 feet above the roadway surface and that the approaching vehicle to be seen is 3.5 feet above the surface of the intersecting road.

C. Horizontal Alignment

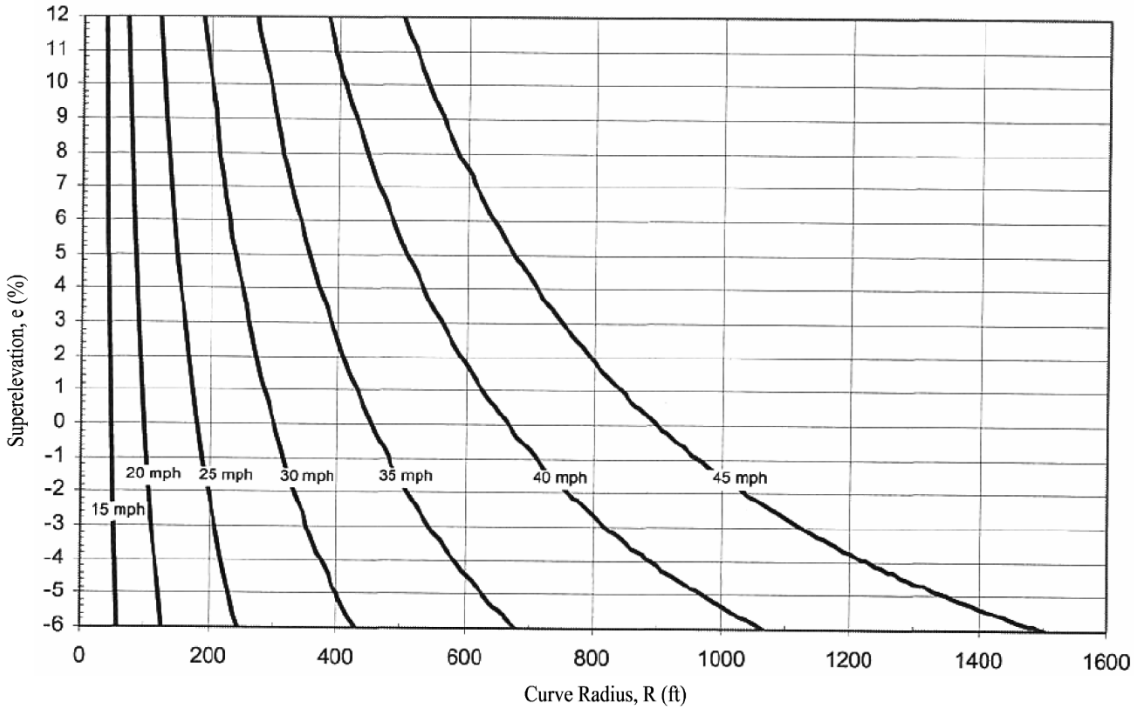
1. Roadway Curvature and Superelevation: On urban streets where operating speed is relatively low and variable, the use of superelevation for horizontal curves can be minimized. Although superelevation is advantageous for traffic operation, in urban areas the combination of wide pavements, the need to meet the grade of adjacent properties, the desire to maintain low speed operation, the need to maintain pavement profiles for drainage, and the frequency of cross streets and driveways and other urban features often combine to make the use of superelevation impractical or undesirable. Generally, the absence of superelevation on low speed urban streets is not detrimental to the motorist and superelevation is not typically provided on urban streets with a design speed of 45 mph or less.

The preferred radii shown in Section 5C-1, Table 5C-1.01 assume that a normal crown is maintained around a horizontal curve. With a standard 2% pavement cross-slope, this effectively results in a negative 2% superelevation for the outside lane. For roadways with a cross-slope other than 2%, including four lane and wider sections that utilize a steeper cross-slope for the outside lanes, the required curve radius should be determined from the guidance provided in the current AASHTO "Green Book" or from Figure 5C-2.04 below.

While superelevation on low speed urban roadways is not desirable, it may be necessary in situations where site conditions require a horizontal curve that cannot sustain traffic with the negative superelevation that results from maintaining the normal crown. For these situations, superelevation equal to the normal cross-slope may be provided for the outside lane. Section 5C-1, Table 5C-1.02 assumes the adverse crown in the outside lane of a curve is removed. For a roadway with a normal 2% cross-slope, this results in a superelevation of 2% across the width of the pavement. For roadways with cross-slopes other than 2%, the required radius and the resulting superelevation should be determined from the guidance provided in current AASHTO "Green Book" or from Figure 5C-2.04 below. The maximum superelevation for low speed urban roadways should not exceed the normal cross-slope or a maximum of 3%.

For roadways with design speeds of 50 mph or greater, superelevation of the roadway is acceptable and expected by motorists. The radii provided in Section 5C-1, Tables 5C-1.01 and 5C-1.02 are based upon superelevation rates of 4% and 6% respectively. The maximum superelevation rate in urban areas should not exceed 6%.

Figure 5C-2.04: Superelevation, Radius, and Design Speed for Low Speed (<50mph) Urban Street Design



Source: AASHTO "Green Book," 2004 Edition, Exhibit 3-17

2. **Intersection Alignment:** The centerline of a street approaching another street from the opposite side should not be offset. If the offset cannot be avoided, the offset should be 150 feet or greater for local streets. The centerline of a local street approaching an arterial or collector street from opposite side should not be offset unless such offset is 300 feet or greater.

3. **Adding, Dropping, or Redirecting Lanes:**

   a. **Dropping or Redirecting Through Lanes:** When dropping a lane, the minimum taper ratio to be used should be determined by the following formula, or from Table 5C-2.01:

      L = WS for velocities of 45 mph or more

      $L = \frac{WS^2}{60}$ for velocities of 40 mph or less.

      L = Minimum length of taper.
      S = Numerical value of posted speed limit or 85th percentile speed, whichever is higher.
      W = Width of pavement to be dropped or redirection offset.

      Preferably, taper ratios should be evenly divisible by five. Calculations that result in odd ratios should be rounded to an even increment of five. The table below utilizes the formulas to determine the appropriate taper ratio for dropping a 12 foot wide lane. The ratio remains constant for a given design speed while the length varies with the pavement width.

The procedure for determining minimum taper ratios for redirecting through lanes is the same as for lane drops, except for design speeds over 45 mph the use of reverse curves rather than tapers is recommended.

Table 5C-2.01: Length and Taper Ratio for Dropping 12 Foot Lane

Design Speed (mph)	25	30	35	40	45	50	55	60
Taper Ratio	10:1	15:1	20:1	25:1	45:1	50:1	55:1	60:1
Length (feet)	120	180	240	300	540	600	660	720

b. Adding Through or Turn Lanes: For design speeds of 45 mph or greater, a 15:1 lane taper should be used when adding a left or right turn lane. For design speeds less than 45 mph, a 10:1 taper may be used.

For design speeds less than 45 mph, shorter tapers that are squared off or taper at 1:1 may provide better "targets" for approaching drivers and give more positive identification to an added through lane or turn lane. For turn lanes, the total length of taper and deceleration length should be the same as if a standard taper was used. This results in a longer length of full width pavement for the turn lane. This design provides increased storage that may reduce the likelihood turning vehicles will back up into the through lane during peak traffic periods. The use of short taper sections must be approved by the Engineer.

Figure 5C-2.05: Adding or Dropping Lanes

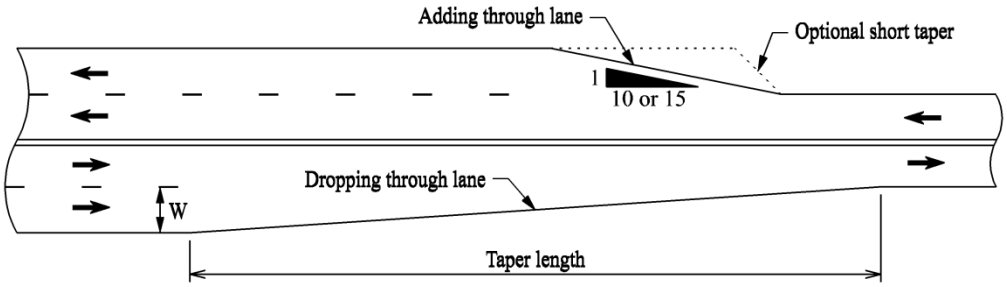
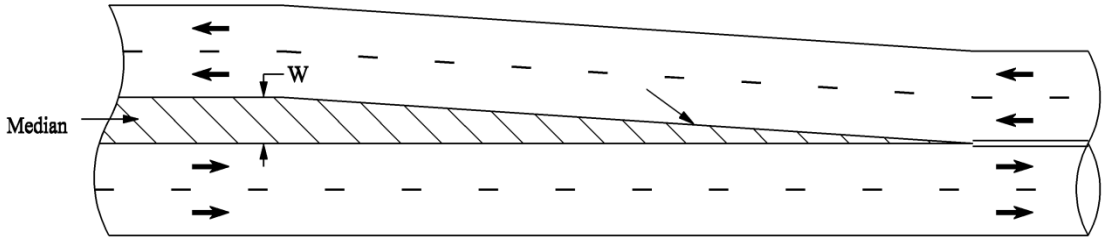


Figure 5C-2.06: Redirecting Through Lanes



D. Vertical Alignment

1. **Minimum Grades:** Flat and level grades on uncurbed pavements are preferred when the pavement is adequately crowned to drain the surface laterally. However, with curbed pavements, longitudinal grades must be provided to facilitate surface drainage. A typical minimum grade is 0.5%, but a grade of 0.4% may be used in isolated areas where the pavement is accurately crowned and supported on firm subgrade. The minimum allowance grade for bubbles and cul-de-sacs is 1%. Particular attention should be given to the design of stormwater inlets and their spacing to keep the spread of water on the traveled way within tolerable limits. Roadside channels and median swales frequently require grades steeper than the roadway profile for adequate drainage.

2. **Maximum Grades:** Grades for urban streets should be as level as practical, consistent with the surrounding terrain. The maximum design grades specified in Section 5C-1, Table 5C-1.02 should be used infrequently; in most cases grades should be less than the maximum design grade.

   Where sidewalks are located adjacent to a roadway, a maximum roadway grade of 5% is desirable. ADA requirements allow sidewalks adjacent to a roadway to match the running grade of the roadway, regardless of the resulting grade. However, sidewalk accessibility is greatly enhanced, especially over long distances, when grades are limited to 5% or less. It is recognized that meeting limitations will not be possible or practical in many situations; however, an attempt should be made to limit roadway grades to this level, especially in areas with high levels of anticipated pedestrian usage.

3. **Maximum Grade Changes:** Except at intersections, the use of grade breaks, in lieu of vertical curves, is not encouraged. However, if a grade break is necessary and the algebraic difference in grade does not exceed 1%, the grade break will be considered by the Engineer.

4. **Vertical Curves:** Vertical curves should be simple in application and should result in a design that is safe, comfortable in operation, pleasing in appearance, and adequate for drainage.

   The major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed. Minimum stopping sight distance should be provided in all cases. Wherever economically and physically feasible, more liberal stopping sight distances should be used. Furthermore additional sight distance should be provided at decision points.

   a. **Crest Vertical Curves:** Minimum lengths of crest vertical curves as determined by sight distance requirements are generally satisfactory from the standpoint of safety, comfort, and appearance. Figure 5C-2.06 shows the required length of crest vertical curve to provide stopping sight distance based upon design speed and change in grade.

   b. **Sag Vertical Curves:** Headlight sight distance is generally used as the criteria for determining the length of sag vertical curves. When a vehicle approaches a sag vertical curve at night, the portion of highway lighted ahead is dependent on the position of the headlights and the direction of the light beam. A headlight height of 2 feet and a 1 degree upward divergence of the light beam from the longitudinal axis of the vehicle is commonly assumed. For safety purposes, the sag vertical curve should be long enough that the light beam distance is the same as the stopping sight distance. Figure 5C-2.07 specifies the required sag curve length to meet the sight distance assumptions made above.

For both sag and crest vertical curves with a low algebraic difference in grade, sight distance restrictions may not control the design of the curve. In these cases, rider comfort and curve appearance are the primary considerations for vertical curve design. Generally, vertical curves with a minimum length (in feet) equal to three times the design speed (in mph) are acceptable.

If a roadway has continuous lighting, the length of sag vertical curve (L) may be based on passenger comfort instead of headlight sight distance. Use the following equation for the curve length:

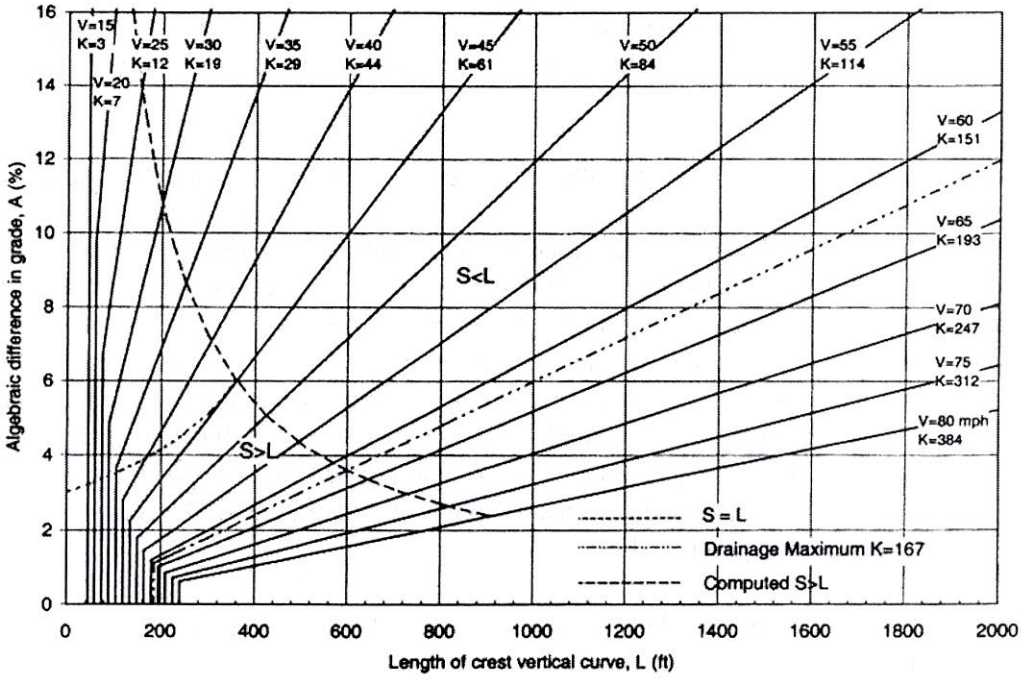
$$L = \frac{AV^2}{46.5}$$ where A = algebraic difference in grades, %
V = design speed, mph

(Equation 3-51 AASHTO Greenbook, 2011)

Drainage considerations also affect the design of vertical curves where curbs are utilized. Both crest and sag vertical curves that have a grade change from positive to negative (or vice versa) contain a level area at some point along the curve. Generally, as long as a grade of 0.30% is provided within 50 feet of the level area, no drainage problems develop. This criterion corresponds to a K value of 167 and is indicated by a dashed line in Figures 5C-2.06 and 5C-2.07 below. K values greater than 167 may be utilized, but additional consideration should be given to drainage in these situations.

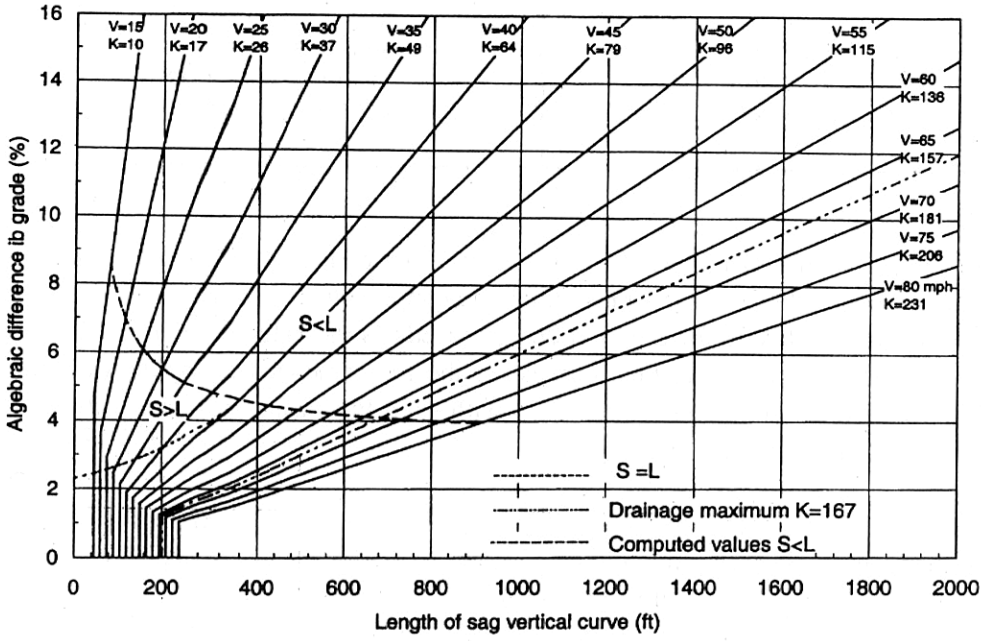
$$K = \frac{\mathrm{L(ft)}}{(g_2 - g_1)}$$ where g_1 and g_2 are in percent

Figure 5C-2.06: Design Controls for Crest Vertical Curves
for Stopping Sight Distance and Open Road Conditions



Source: "Green Book," Exhibit 3-71, 2004

Figure 5C-2.07: Design Controls for Sag Vertical Curves, Open Road Conditions



Source: "Green Book," Exhibit 3-78, 2004

5. **Intersection Grades:** The grade of the "through" street should take precedence at intersections. At intersections of roadways with the same classifications, the more important roadway should have this precedence. Side streets are to be warped to match through streets with as short a transition as possible, which provides a smooth ride. Consideration must be given to minimize sheet flow of stormwater across the intersection due to loss of crown on the side street.

   Carrying the crown of the side street into the through street is not allowed. In most cases the pavement cross-slope at the warped intersection should not exceed the grade of the through street.

   The maximum desirable grades of the through street at the intersection and the side street cross-slope should be 2% and should not exceed 3%. The maximum desirable approach grade of the side street should not exceed 4% for a distance of 100 feet from the curb of the through street.

   Establishing intersection spot grades by matching "curb corners" of intersecting streets is not recommended since it may result in an undesirable travel path from the through street to the side street because of the resulting bump on the side street centerline. At sidewalk curb ramps in intersections, the street grades may need to be warped at the curb line to ensure the resulting cross-slope at the bottom of the ramp does not exceed 2%. A detail of the jointing layout with staking elevations should be shown on the plans.

   ADA regulations set specific limits for crosswalk cross-slopes that directly impact street and intersection grades. ADA regulations limit the cross-slope to 2% (measured perpendicular to the direction of pedestrian travel) for crosswalks that cross a roadway with stop control (stop sign) at the intersection. For roadways without stop control (through movement or traffic signal) the cross-slope of the crosswalk is limited to 5%. Effectively, this requirement limits street grades to a maximum of 2% or 5% depending on intersection controls.

   For steep roadways without stop control, construction of a flattened "table" may be necessary to reduce the street grade to 5% or less at the location of the crosswalk. Crosswalk tables at these

locations must utilize vertical curves, appropriate for the design speed, to avoid a sudden change in grade at the intersection that could cause vehicles to bottom out or lose control.

For steep roadways with stop control, construction of a flattened "table" may utilize grade breaks or shortened vertical curves to reduce the street grade to 2% or less at the location of the crosswalk. A check should be made to verify that vehicles will not bottom out when traveling over the crosswalk table.

E. Pavement Crowns

The following typical pavement crowns are straight line cross-slope and are desirable sections.

1. **Urban Roadways (Curb and Gutter):** For streets with three or fewer travel lanes, the pavement crown should be 2%.

   For streets with four or more travel lanes, the pavement crown for all inside lanes, including left turn lanes, should be 2%. In order to reduce stormwater spread, the pavement crown for the outside lanes should be 3%.

   For all streets, auxiliary right turn lanes will have varying pavement crowns depending on the desired drainage pathway.

2. **Rural Roadways:** For pavement crowns, a 2% cross-slope is normal with 4% shoulder slope. Iowa DOT Standard Road Plans should be checked for Federal Aid, Farm to Market, and Secondary Roads.

F. Lane Width

The lane width of a roadway greatly influences the safety and comfort of driving. Narrow lanes force drivers to operate their vehicles closer to each other laterally than they would normally desire, resulting in driver discomfort, lower operating speeds, and reduced roadway capacity.

Tables 5C-1.01 and 5C-1.02 in Section 5C-1 indicate minimum lane widths based upon the roadway classification and adjacent land use. In addition to the lane width, a separate offset distance to the curb is required. This curb offset is not included in the lane widths listed.

Auxiliary lanes and turn lanes at intersections should be as wide as the adjacent through lanes. The width for turn lanes is measured to the face of curb. Because motorists are slowing in anticipation of making a turning movement, drivers are comfortable operating their vehicle closer to an adjacent obstacle (curb); therefore, turn lanes do not require a curb offset.

G. Two-way Left-turn Lanes (TWLTL)

Two-way left-turn lanes work well where design speeds are relatively low (25 to 50 mph) and there are no heavy concentrations of left turning traffic. The width of TWLTLs should be limited to a maximum of 14 feet to discourage left-turning motorists from pulling out into the TWLTL and stopping perpendicular to the direction of traffic, while they wait for oncoming traffic to clear.

H. Raised Median Width

A median is defined as the portion of a roadway separating opposing directions of the traveled way. The median width is expressed as the dimension between the edges of the traveled way and includes the left turn lanes, if any are present (refer to Section 5C-1, Figure 5C-1.01). The principal functions of a median are to separate opposing traffic, allow space for speed changes and storage of left turning and U-turning vehicles, minimize headlight glare, and provide width for future lanes. For maximum efficiency, a median should be highly visible both night and day and contrast with the traveled way lanes.

At unsignalized intersections on rural divided highways, the median should generally be as wide as practical. However, in urban areas, narrower medians appear to operate better at unsignalized intersections. If right-of-way is restricted, a wide median may not be justified if provided at the expense of a narrowed border area. A reasonable border width is needed to adequately serve as a buffer between private development along the road and the traveled way. Narrowing the border area may create operational issues similar to those that the median is designed to avoid. In addition, wide medians at signalized intersections result in increased time for vehicles to cross the median. This can lead to inefficient signal operation. Therefore, in urban areas, it is recommended that median width be only as wide as necessary to accommodate left turn lanes. Wider medians should only be used where needed to accommodate turning and crossing maneuvers by larger vehicles.

Medians and boulevards are not normally used on collector streets. However, when allowed, the median or boulevard should conform to the same design standards as set forth for arterial streets.

Median widths are also affected by sidewalk and crosswalk locations. Where a crosswalk cut through is present or proposed, medians (exclusive of any turn lanes) must be a minimum of 6 feet wide to comply with ADA regulations. These regulations require the placement of a 2 foot wide strip of detectable warnings at the curb line on both sides of the median. The detectable warnings must be separated by a minimum 2 foot strip without detectable warnings. Where the median has no curb, the detectable warnings must be placed along the edge of the roadway. At locations where a raised median is stopped short of the crosswalk, the 6 foot raised median and associated detectable warnings are not required, and a standard 4 foot raised median section may be used.

I. Bridges

The bridge widths listed in Section 5C-1, Tables 5C-1.01 and 5C-1.02 represent the clear roadway width (width between barrier rail faces). The widths shown do not account for barrier rail widths, sidewalk, recreational trails, etc.

For existing bridges, a structural analysis should be conducted. The existing bridge should be able to accommodate legal loads. Bridge guardrail should be upgraded if necessary.

J. Clear Zone

The AASHTO Roadside Design Guide (RDG) defines the clear zone as “the total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope, and/or a clear runout area. The desired width is dependent upon the traffic volumes and speeds and on the roadside geometry.”

The intent of the clear zone is to provide an errant vehicle that leaves the roadway with an unobstructed recovery area. This area, including medians on divided roadways, should be kept free of all unyielding objects, including utility and light poles, culverts, bridge piers, sign supports, and

any other fixed objects that might severely damage an out of control vehicle. Any obstruction that cannot be placed outside of the clear zone should be shielded by traffic barriers or guardrails.

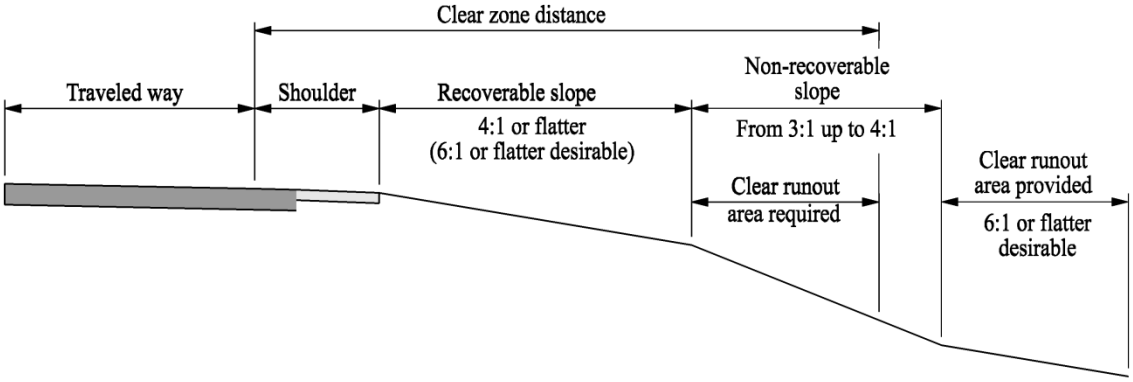
According to the AASHTO RDG, the width of this area varies based upon traffic volumes, design speed, and embankment slope.

Embankment slopes can be classified as recoverable, non-recoverable, or critical. Embankment slopes of 4:1 and flatter are considered recoverable. Drivers who encroach on recoverable slopes can generally stop their vehicles or slow them enough to return to the roadway safely.

A non-recoverable slope is defined as one that is passable, but from which most motorists will be unable to stop or to return to the roadway easily. Vehicles on such slopes are likely to reach the bottom before stopping. Embankments between 3:1 and 4:1 generally fall into this category. Since many vehicles will reach the toe of these slopes, the clear zone distance cannot logically end on a non-recoverable slope, and a clear runout area at the base of the slope is required. Fixed objects should not be present on a non-recoverable slope.

A critical slope is one on which a vehicle is likely to overturn. Slopes steeper than 3:1 generally fall into this category. If a slope steeper than 3:1 begins closer to the traveled way than the suggested clear zone, a barrier might be warranted if the slope cannot be flattened.

Figure 5C-2.08: Clear Zone Components



Source: Adapted from *Roadside Design Guide*, 2006

For horizontal curves, an adjustment factor may be applied to the clear zone width taken from Section 5C-1, Tables 5C-1.03 or 5C-1.04. This adjustment is only required at selected locations. Widening the clear zone should be considered along the outside of curves when crash history suggests the need for additional clear zone width, or whenever the radius of the curve is less than 2,860 feet, the design speed is 55 mph or greater, and the curve occurs on a normally tangent alignment (one where the curve is preceded by a tangent more than a mile in length).

The clear zone along an urban section may contain minor obstructions (traffic signs, mailboxes, etc.). In addition, along lower (<40 mph design speed) urban roadways, larger objects designed to "break-away" when struck by a vehicle may also be located within the clear zone (light poles, cast-iron fire hydrants, etc.). All objects, however, should be kept free from the object setback zone as described in the next section.

K. Object Setback

Like clear zone, object setback is intended to provide an area adjacent to the roadway that is clear of obstructions. However, the purpose of the object setback is to provide an operational clearance to increase driver comfort and avoid a negative impact on traffic flow. It also improves aesthetics, provides an area for snow storage and, in areas with curbside parking, provides a clear area to open car doors.

As discussed in the previous section on clear zone, minor obstructions and larger "breakaway" objects may be located in the clear zone on lower speed roadways (<40 mph design speed), but must be kept free from the object setback. Mailboxes constructed and installed according to US Postal Service regulations, including breakaway supports, may be located within the object setback area.

Additional object setback, as measured from the back of curb, may be required around radii at intersections and driveways in order to provide sufficient clearance to keep the overhang of a truck from striking an object.

L. Border Area

Border area is the area between the roadway and the right-of-way line and is sometimes referred to as the "parking" in urban areas. The grade for the border area is normally 1/2 inch per foot. The border area between the roadway and the right of way line should be wide enough to serve several purposes including provision of a buffer space between pedestrians and vehicular traffic, sidewalk space, and an area for both underground and above ground utilities such as storm sewer, traffic signals, parking meters, and fire hydrants. The border area also provides snow storage and aesthetic features such as grass or other landscaping features. The border width ranges from 14 to 16 feet, including the sidewalk width. Traffic signals, utility poles, fire hydrants, and other utilities should be placed as far back of the curb as practical for safety reasons. Breakaway features should be built when feasible and as an aid to safety considerations.

Table 5C-2.02: Preferred Border Area

Street Classification	Border Area Width (feet)
Major/minor arterial	16
Collector	14.5
Local streets	14

M. Curbs

1. **Curb Offset:** The curb offset is measured from the back of curb to the edge of the lane. The curb offset increases driver comfort and roadway safety. The presence of the curb, and potential vehicle damage and loss of control resulting from striking the curb, causes drivers to move away from the curb, reducing the effective width of the through lane. Due to this driver reaction, and to accommodate the flow of drainage and intake structures, an offset between the curb and the edge of the traveled way is provided.

   The curb offset widths specified in Section 5C-1, Tables 5C-1.01 and 5C-1.02 do not necessarily indicate the width of the curb and gutter or the location of a longitudinal joint; however, the width of the curb and gutter can affect the required width of the curb offset. The presence of a longitudinal joint near the curb (gutterline jointing) can be a limiting factor for usable lane width as some drivers are uncomfortable driving on or near the joint line. This is especially true for HMA roadways with PCC curb and gutter. For pavements with a longitudinal joint line near the

gutter, the curb offset should be equal to or greater than the width of the curb and gutter section. In addition, grates and special shaping for curb intakes and depressions for open-throat intakes should be located within the curb offset width and should not encroach into the lane.

2. **Curb and Gutter:** Typically, a curb and gutter cross-section should consists of a 6 inch high, 6 inch wide curb with a concrete gutter section. If the design speed is 40 mph or below, an 8 inch curb may be used for certain arterial and collector streets. For design speeds greater than 40 mph, a 1 foot wide, 6 inch high sloped curb with a minimum 2 foot gutter offset should be used.

N. Parking Lane

Where curbed sections are used, the curb offset width may be included as part of the parking lane.

1. Parking lanes are not allowed on arterial streets.

2. Although on-street parking may impede traffic flow, parallel parking may be allowed by the Jurisdiction on urban collectors where sufficient street width is available to provide parking lanes.

3. Parking lane width determinations should include consideration for the potential use of the lane as a through or turn lane for moving traffic either during peak hours or continuously. If this potential exists, additional parking width should be provided.

O. Cul-de-sacs

A local street open at one end only should have a cul-de-sac constructed at the closed-end. The 2018 International Fire Code stipulates a minimum cul-de-sac radius of 48 feet however some jurisdictions allow lesser radii due to the size of their fire apparatus. The minimum radius for cul-de-sacs is 45 feet, which may be increased in commercial areas or if significant truck traffic is anticipated. The border area around the cul-de-sac should be the same as the approach street. The transition radius with the approach street will be 50 feet for residential streets and 75 feet for commercial and industrial streets.

P. Shoulder Width

Shoulders accommodate stopped vehicles, emergency use, and provide lateral support of the subbase and pavement. In some cases, the shoulder can accommodate bicyclists. Where no curb and gutter is constructed a soil, granular, or paved shoulder will be provided.

Desirably, a vehicle stopped on the shoulder should clear the pavement edge by 2 feet. This preference has led to the adoption of 10 feet as the desirable shoulder width that should be provided along high volume facilities. In difficult terrain and on low volume highways, usable shoulders of this width may not be practical.

Where roadside barriers, walls, or other vertical elements are used, the graded shoulder should be wide enough that these vertical elements can be offset a minimum of 2 feet from the outer edge of the usable shoulder. It may be necessary to provide a graded shoulder wider than used elsewhere on the curved section of a roadway or to provide lateral support for guardrail posts and/or clear space for lateral dynamic deflection required by the particular barrier in use. On low volume roads, roadside barriers may be placed at the outer edge of the shoulder; however, a minimum of 4 feet should be provided from the traveled way to the barrier.

Q. Intersection Radii

Minimum curb return radii are shown in Table 5C-2.03 below. Where truck traffic is significant, curb return radii should be provided according to the current AASHTO "Green Book;" turning templates are used in this design. The Iowa DOT has an Iowa truck vehicle that can be used to check the proposed radii for truck routes.

Table 5C-2.03: Curb Return Radii Based Upon Roadway Classification

Roadway Classification	Arterial	Collector	Local - Commercial/ Industrial	Local - Residential
Arterial	Special*	Special*	30'	30'
Collector	Special*	30'	30'	25'
Local - Commercial/Industrial	30'	30'	25'	25'
Local - Residential	30'	30'	25'	25'

*Special design required. Use turning templates.

R. Pavement Thickness

Refer to Section 5F-1 for pavement thickness determination and design.

S. References

American Association of State Highway and Transportation Officials (AASHTO). *A Policy on Geometric Design of Highways and Streets* ("Green Book"). Washington, DC. 2004.

American Association of State Highway and Transportation Officials (AASHTO). *Roadside Design Guide*. 3rd ed. Washington, DC. 2006.

Des Moines Area Metropolitan Planning Organization (MPO). *Des Moines Area Daily Directional Capacities At Level of Service D*. Des Moines. 2000.

Asphalt Pavement Mixture Selection

A. Scope

This section is intended for the engineers and technicians who specify asphalt paving material criteria for urban projects, generally ranging from low to medium volume, up to 10M ESALs. Vehicle volumes exceeding 10M $ESAL_{20}$, or projects outside of these design standards, may require more detailed design and/or expert consultation. The section provides a step-by-step process for determining the appropriate mixture criteria and gives the designer additional background information on specific mixture criteria. The section is intended to assist in selecting the mixture criteria that best satisfy the project demands and limitations. Statewide use of this section will improve the standard application of current accepted gyratory mix design technology. According to AASHTO and Iowa DOT Materials I.M. 510, mixture selection involves the use of a 20 year design life whereas pavement thickness design is based on a 50 year design life.

B. Definitions

Equivalent Single Axle Load (ESAL): A standard unit of pavement damage created by a single pass of a vehicle axle.

Car axle = 0.0002 ESAL 18kip truck axle = 1.0 ESAL 24kip truck axle = 3.0 ESAL

$ESAL_{20}$: Estimated cumulative ESALs over a 20 year period.

N: The number of gyratory compaction revolutions at which HMA mixture properties are measured. N_{des} represents 20 years of traffic loading.

Gyratory Mix Design: A laboratory process for achieving desired pavement performance by determining the optimum proportions of aggregates and asphalt binder for hot mix asphalt using a SHRP Superpave gyratory compactor.

Lift Designation (Surface, Intermediate, Base): The terms for the lifts in the hot mix asphalt pavement structure. The surface lift is the top lift, about 1 1/2 inches thick. The intermediate lift(s) is one or more lifts placed under the surface lift, generally 2 to 4 inches thick. The base lift(s) is all mixture placed below the intermediate lift, generally limited to full depth construction.

Modified Asphalt Binders: For design traffic levels greater than 1,000,000 ESALs (High, Very High, and Extremely High), the binders may need to be modified and thus may be more costly.

Nominal Maximum Aggregate Size (NMAS): The mixture size designation used for the combined aggregate gradation. Defined as one sieve size larger than the first sieve to retain more than 10%.

Performance Graded (PG): National asphalt binder grading system, developed by AASHTO, based on high and low pavement operating temperatures (°C). A PG binder is identified using a nomenclature of PG XXYY, followed by an ESAL designation (L, S, H, V, E). The XX is the high pavement temperature in degrees Celsius in which the binder should resist rutting. The YY, in negative Celsius, is the low pavement temperature in which the binder should resist cracking. For example, a PG 58-28S should resist rutting to 58 °C and cracking of the pavement to a temperature of -28 °C under standard (0.3 M to 1 M ESALs) traffic loading.

C. Design Checklist

Designers should follow the steps below to ensure that the material criteria selected will best meet the needs of the project and the constraints of the owner agency.

1. **Determine the Level of Traffic Forecasted for the Next 20 Years:** Both current and future traffic levels are needed to determine the appropriate asphalt mixture for the project. Even if the project is not expected to remain in place for 20 years, the material selection levels are based on 20 year values. Common values are average daily traffic (ADT) for the current year, ADT for the 20 year forecast, and percent trucks. In addition to these annualized daily values, the designer should consider potential seasonal high truck volumes, and give particular attention to point sources and future development areas that may generate heavy truck volumes, like quarries, industrial parks, and bus lanes. Seasonal truck volumes may reflect a rate of pavement loading well in excess of the annualized values.

2. **Understand the Pavement Section Design or Rehabilitation Strategy:** In order to make the proper mixture selection, the designer must have knowledge of the proposed pavement construction or rehabilitation and intended pavement performance. The thickness of the pavement will also affect the material and mixture selection. Particular parameters include required structural thickness, existing pavement cross section and condition (dominant distress patterns), traffic patterns and speed, and past maintenance.

3. **Determine the Regional Climate Conditions:** Iowa's 1 day low pavement temperature ranges approximately 5°C from north to south. Adjusted for 98% reliability, the values range from -28 °C to -24 °C. The 7 day high pavement temperature across the state only varies by 3 °C. These values are computed from daily high air temperatures. Adjusted for 98% reliability, the pavement temperature values range from 56 °C to 59 °C. Climate details for a specific location can be obtained from the LTPPB software package available on the FHWA website (https://infopave.fhwa.dot.gov/). See Figures 5D-1.01 and 5D-1.02.

4. **Compute the Anticipated 20 Year Pavement Loading:** The design pavement loading is the starting point for selecting the material and mixture selection criteria. The design pavement loading is measured in ESALs, not ADT. To determine the design ESALs on the project, use the traffic conditions from Step 1 and compute the $ESAL_{20}$. Use the examples outlined in Examples 5D-1.01 and 5D-1.02, for two lane, two way traffic; use Example 5D-1.03 for urban multi-lane situations. Design ESAL levels for asphalt criteria selection are divided into relatively large brackets. While a firm understanding of the traffic and pavement loading is important, good approximations of truck traffic are normally sufficient to determine the design requirements.

5. **Identify Any Special Conditions that Impact the Pavement:** The standard selection process is based on high speed traffic with a broad distribution of vehicle types. There are numerous special conditions that may, through engineering judgement, require changes in the standard pavement materials/mixture selection. These special conditions are outlined below.

    a. **Heavy Trucks:** If the pavement's history has regularly been impacted by heavy trucks, the designer may consider increasing either the binder grade through the designation of a higher design traffic loading, the mix designation (ESAL level), or both. Typical examples of this condition are routes adjacent to quarries, grain elevators, or regional commercial freight distribution centers.

c. SUDAS Concrete Mix Proportioning Specifications: The concrete mixes currently used in Iowa were developed in the 1950s. Classes A, B, and C were specified for concrete paving. As originally developed, Classes A and B, with minimum design compressive strengths of 3,500 psi and 3,000 psi respectively, were utilized for rural county paving. Class C concrete, with a higher compressive strength of a minimum of 4,000 psi and a w/cm ratio of less than 0.45, was the standard for primary roads. With its history of proven performance, Class C concrete is now the standard for all concrete road paving in Iowa. In areas where early opening strength is desired, such as intersections and driveways, an M mix can be substituted for C mix. M mix has a higher cement content, which accelerates the heat of hydration and set time of the concrete.

Unless the designer otherwise specifies, the contractor can choose any of the Iowa DOT Class C mixes and the materials that are allowed within the specifications. Generally, economy, workability, and availability of materials are key factors in the decision making process of the contractor and the concrete supplier.

Iowa DOT Materials I.M. 529 establishes the mix proportions for the various concrete mixes used by the Iowa DOT and SUDAS. Each mixture has specific requirements for the coarse and fine aggregates as well as the type of cement, including SCMs. The mix proportions include unit volumes for all materials.

If the concrete mix for a project is specifically needed to address joint durability, consideration should be given to the C-SUD mixes that are included in Table 4 of Iowa DOT Materials I.M. 529. Two main differences highlight these mixes. The first is the water-cement ratio. Using a lower water-cement ratio will create lower paste permeability and higher strength. The basic w/c ratio is 0.40 with the maximum set at 0.42. In addition to the w/c ratio, use of pozzolanic materials (SCMs) for substitution of cement will improve freeze-thaw durability in the presence of deicers. Consideration should be given to provide cement replacement rates of 20-25% Class F fly ash or 30-35% Class C fly ash or a combination of 20% slag and 20% Class C fly ash.

1) Mix Designation:
Example: C-4WR-S35

- The first letter indicates the class of concrete
- The first number indicates the percentages of fine aggregate and coarse aggregate
  - 2 is composed of 40% fine and 60% coarse
  - 3 is composed of 45/55
  - 4 is composed of 50/50
  - 5 is composed of 55/45
  - 6 is composed of 60/40
  - 7 is composed of 65/35
  - 8 is composed of 70/30
  - 57 is composed of 50/50
- The WR indicates water reducer is used in the mixture
- SCMs are then indicated with their percentage of cementitious material substitution. C and F fly ashes are indicated with a C and F, respectively. GGBF slag is indicated with an S. The percentage of substitution is indicated after the SCM letter.
- The example designates a Class C concrete mix, a combined aggregate composed of 50% fine aggregate and 50% coarse aggregate, water reducer admixture, and 35% GGBF slag cementitious material substitution.

2) **Mix Proportions:** Iowa DOT Materials I.M. 529 provides material proportioning for the various Iowa DOT concrete mixes and includes basic absolute volumes of cement, water, air, and fine and coarse aggregate per unit volume of concrete (cy/cy). Target and maximum w/cm ratios are provided for each of the mix classes. Also included is guidance for calculation of fly ash and GGBF slag cementitious material substitution of cement.
3) **Admixtures:** Sources of Iowa DOT approved admixtures are provided in Iowa DOT Materials I.M. 403, along with their maximum dosages. Generally, the maximum dosages are as recommended by the manufacturers. Do not exceed the maximum dosages according to the manufacturer's recommendations.

3. **Modification of the Standard Concrete Mix Specifications:** While care should be exercised, achieving the required properties in the concrete may require making adjustments to the materials selected, to materials proportions, or even to other factors such as temperature, as follows.

a. Workability: Water content, proportion of aggregate and cement, aggregate properties, cement characteristics, admixtures, and time and temperature can be adjusted to achieve the desired workability. The slump test (ASTM C 143 / AASHTO T 119) is most often used to measure the workability of fresh concrete.

b. Stiffening and Setting: The rates of stiffening and setting of a concrete mixture are important because they affect its ability to be placed, finished, and sawed. Stiffening and setting can be affected by the following in the concrete mixture: cementitious materials, chemical admixtures, aggregate moisture, temperature, and water-cementitious materials (w/cm) ratios.

c. Bleeding: Techniques can be used to prevent and minimize bleeding. These techniques (Kosmatka 1994) include reducing the water content, w/cm, and slump; increasing the amount of cement or supplementary cementitious materials in the mix; increasing the fineness of the cementitious materials; using properly graded aggregate; and using certain chemical admixtures such as air-entraining agents may reduce bleeding.

d. Air-void System: The air-void system is important to concrete durability in environments subject to freezing and thawing. It includes total air content, spacing factors, and specific surface. The air-void system can be controlled with cement, supplementary cementitious materials, aggregates, and workability. The air-void system in the field will be affected by changes in the grading of the aggregate, water, admixture dosage, delays, and temperature.

e. Density: Conventional concrete used in pavements has a density in the range of 137 to 150 lb/yd^3. Density varies depending on the amount and density of the aggregates, the amount of entrained air, the amount of water, and the cement content. Density is affected by the following factors: density of the material in the mixture, mostly from coarse aggregates; moisture content of the mixture; and relative proportions of the materials, mainly water.

f. Strength: Strength and rate of strength gain are influenced by water-cementitious materials ratio, cement chemistry, SCMs, chemical admixtures, aggregates, and temperature. Changes in the environmental conditions and variation in materials, consolidation, and curing affect the strength at a specified age and affect strength development with age. Increased temperatures will increase early strength but may decrease long-term strength gain.

g. Volume Stability: Concrete experiences volume changes as a result of temperature and moisture variations. To minimize the risk of cracking, it is important to minimize the tendency to change in volume by considering paste content, aggregates, and curing.

Table 5G-2.02: Summary of Joints
(Derived from the Iowa DOT Design Manual, Section 7A-2, Tables 1 and 2)

	Type			Method of Load Transfer				Thermal Movement				
Joint	Transverse	Longitudinal	Isolation/Expansion	Aggregate Interlock	Key	Tie Bar	Dowel Bar	Doweled to allow movement	Tied to prevent movement	Isolation/Expansion joint allows movement	Lack of reinforcing allows movement	**Comments**
B	X	X									X	Used between dissimilar materials or when other joints are not suitable.
C	X			X							X	Transverse joint used when T < 8 inches.
CD	X			X			X	X				Transverse joint used when T ≥ 8 inches.
CT	X			X		X			X			Specialty tied contraction joint.
DW	X					X			X			Used by contractor as a stopping point.
HT	X					X			X			Used at the end of rigid pavement prior to placement of second slab.
RD	X						X	X				Joint between new and existing pavements, dowels are used.
RT	X					X			X			Joint between new and existing pavements, tie bars are used.
BT-1		X							X			Longitudinal joint used when T < 8 inches, interchangeable with L-1 depending on paving sequence.
BT-2		X							X			Used when L-2 and the KT-2 are not possible, T ≥ 8 inches.
BT-3		X							X			Joint used between new and existing pavements. Tie bars are used when T ≥ 8 inches.
BT-4		X							X			Joint used between new and existing pavements. Tie bars are used when T ≥ 8 inches.
BT-5		X							X			Joint used between new and existing pavements. Tie bars are used when T < 8 inches.
K		X			X						X	T > 8 inches, minimal usage.
KS		X			X				X			Used in reinforced pavements.
KT-1		X			X				X			Longitudinal joint used when T < 8 inches, interchangeable with L-1 depending on paving sequence.
KT-2		X			X				X			Longitudinal joint used when T ≥ 8 inches, interchangeable with L-2 depending on paving sequence.
KT-3		X			X				X			Longitudinal joint used when T ≥ 8 inches, interchangeable with L-3 depending on paving sequence.
L-1		X		X					X			Longitudinal joint used when T < 8 inches, interchangeable with BT-1.
L-2		X		X					X			Longitudinal joint used when T ≥ 8 inches, interchangeable with KT-2 depending on paving sequence.
L-3		X		X					X			Longitudinal joint used with pavements of large width, interchangeable with KT-3 depending on paving sequence.
CF	X		X							X		4 inch expansion joint.
E	X	X	X							X		1 inch expansion joint.
ED	X		X				X	X		X		1 inch doweled expansion joint.
EE	X		X				X	X		X		2 inch doweled expansion joint.
EF	X		X				X	X		X		4 inch doweled expansion joint.
ES			X							X		Used in curb to match expansion joint in pavement.

D. Transverse Dowel Bar Size and Length

Table 5G-2.03 reflects the dowel bar size and length based on the pavement thickness. This information was obtained from the Portland Cement Association, the American Concrete Paving Association, and American Highway Technology. The SUDAS and Iowa DOT Specifications call for dowels when the slab is 8 inches or greater. Dowels are typically set at 12 inch spacing. The designer should note that a dowel bar that is too small induces high bearing stresses and causes the concrete matrix around the dowel to deteriorate or elongate. Elongation of the dowel bar hole then reduces the load transfer capabilities. Under special circumstances, smaller diameter and different shaped dowel bars may be used in thinner slabs.

Table 5G-2.03: Dowel Bar Size and Length

Pavement Thickness (inches)	Dowel Size (diameter in inches)	Dowel Length (inches)
8	1 1/4	18
9	1 1/4	18
10	1 1/2	18
11	1 1/2	18
12	1 1/2	18

E. Jointed Reinforced Concrete Pavements

Jointed reinforced concrete pavements (JRCP), sometimes referred to as distributed steel reinforcing, are not commonly used in Iowa jurisdictions. However, variations of JRCP are used effectively by several jurisdictions in Iowa. Therefore, the following is provided as an explanation of JRCP.

JRCPs utilize bar mats between transverse joints. Typically, the bar mats extend full width across the pavement, but with traditional JRCPs, they do not extend through the transverse joints. JRCPs use many of the same types of joints as jointed plain concrete pavements (JPCP), but the tie bars for longitudinal joints are replaced with the bar mats. Transverse joints, including doweled joints, are the same for both types of pavements since the bar mats of traditional JRCP do not extend through the transverse joints. Because of the bar mats, transverse joint spacing can be much longer than with JPCP, usually 27 feet to 45 feet. JRCP should not be confused with continuously reinforced pavement, which has very few or no joints.

JRCPs are used primarily to control cracking of concrete pavements, to provide for load transfer between joints, and to maintain the structural integrity of the slab between transverse joints. Just like JPCPs, random cracking of JRCPs may still occasionally occur even though the steel is present. The steel serves to hold the cracks close together, thus preventing the progressive opening of the cracks over time.

The added cost of the additional reinforcement for JRCPs is often offset by specifying a somewhat thinner slab. However, as pointed out by the American Concrete Institute (ACI), “the use of reinforcing steel will not add to the load-carrying capacity of the pavement nor compensate for poor subgrade preparation or poor construction practices.” By holding random cracks tightly closed, it will maintain the shear resistance of the slab, and, consequently, will maintain its load carrying capacity. This improves the ride when the vertical displacement is controlled.

As mentioned previously, several jurisdictions in Iowa specify a variation of JRCP. The Iowa variations of JRCP typically include extending the longitudinal reinforcing bars through the ‘C’ plain transverse contraction joints. When ‘CD’ doweled transverse joints are specified, the longitudinal

Pavement Preservation Process

A. Pavement Deterioration

The concept behind pavement preservation is to treat pavements while they are still in good condition and without serious structural damage. Successive, systematic treatments will extend the service life and delay the more expensive major reconstruction project. In order to apply the appropriate preventative maintenance treatment at the optimum time, the history and the current condition of a pavement section must be evaluated. Preventative maintenance techniques address the pavement surface condition and do not impact the structural capacity of the pavement. If the structural carrying capacity is affecting the condition of the roadway, it is probably not a candidate for preventative maintenance and it is best to program as a reconstruction project. The causes of any pavement deterioration for various types of pavements must be accurately determined. Typical causes of deterioration for each pavement type include the following:

1. **Flexible Pavements:** Flexible pavements, hot mix asphalt, or other bituminous pavements are affected by traffic, environmental/aging, material problems, and moisture intrusion. These elements impact the pavement in different ways:

    a. **Traffic:** Traffic can lead to load related distresses, such as rutting or fatigue cracking in the wheel paths. Fatigue can lead to development of potholes. Also polishing of the surface leads to friction loss.

    b. **Environmental/Aging:** The environment and aging can lead to oxidation of the asphalt, block cracking, and raveling. Environmental elements can also cause the development of thermal cracks, which are seen as regularly spaced transverse cracks.

    c. **Material Problems:** Material problems include bleeding, shoving, stripping, and surface deformation.

    d. **Moisture Infiltration:** Moisture infiltration can cause further breakdown of existing cracks and thus increased roughness.

2. **Rigid Pavements:** For rigid PCC pavements, the general causes of deterioration include traffic loading, environmental factors, material problems, construction problems, joint deterioration, and moisture infiltration.

    a. **Traffic:** Traffic can lead to load related distress, such as mid-slab cracking, pumping, faulting, and corner breaks. Polishing and the subsequent loss of friction is also traffic related.

    b. **Environmental and Materials:** D-cracking and alkali-silica reactivity (ASR) are material problems. Freeze-thaw action and poor entrained air can affect joint stability.

    c. **Construction Problems:** Construction quality can cause cracking and surface defects in the form of map cracking and spalls.

d. Joint Deterioration: Incompressible materials in the joint from poor joint seal maintenance can cause joint spalls.

e. Moisture Infiltration: Moisture can lead to further breakdown of cracks and spalls and increased roughness. It can also contribute to pumping, transverse joint faulting, and corner breaks.

B. Evaluating Pavement Conditions

Numerous pieces of information need to be examined in order to determine if the pavement section is a candidate for preventative maintenance and the selection of the type of treatment that best meets that pavement section's needs. The extent of the evaluation process will vary depending on the roadway classification and the type of project. In each case, once the information is compiled, engineering judgment must be applied to determine the correct treatment to use to address the distresses exhibited by each section of pavement.

1. **Background Data:** Obtain data from project files, such as original design parameters, construction information regarding materials, subgrade/subbase information, current traffic data, and maintenance activities undertaken on that roadway section. This information can sometimes be difficult to locate if a good record system has not been established, but as much information as possible should be compiled. Discussions with agency engineering and maintenance staff members can potentially fill in gaps in records.

2. **Existing Condition:** Undertake a visual site inspection to obtain information about the condition of the pavement. Ascertain information on what types of distress are exhibited by the pavement section. Note any restrictions such as right-of-way limitations, presences of bridges, drainage problems, and obstructions.

   The specific severity and extent of each type of pavement distress should be examined closely. Additional field testing such as falling weight deflectometer (FWD), pavement cores, friction testing, splash and spray, and materials testing may be necessary. The extent of the additional testing may be dependent on the roadway classification. Much of this information should be contained in a pavement management system (PMS). The PMS can be in many forms including a sophisticated computer program, a relatively simple spreadsheet, or notes accumulated by maintenance personnel.

   The Iowa DOT has a program of data collection on all roads in the state and is one source of pavement condition information. The program in administered by the CTRE program at The Institute for Transportation at Iowa State University. Information can be accessed at https://ctre.iastate.edu/ipmp/. It is necessary to undertake additional effort to convert the raw data to useable information.

3. **Future Projections:** It is also important to evaluate any future changes that may be expected for each roadway section. Changes in adjacent land use or improvements to area roadways could impact the traffic volume and the vehicle mix of a roadway section. Long-range transportation planning documents should provide this information. This information is critical to understanding the service life expectancy of the existing pavement and then the subsequent preventative maintenance treatments to match that service life.

Preventative Maintenance Treatment Type Selection

A. Introduction

Once all of the background, existing pavement condition, and future changes have been determined for a pavement section, the appropriate preventative maintenance treatment or treatments can be selected. Professional engineering judgment is critical in order to analyze the available data and select the most effective treatment. The selection of the most appropriate treatment must also take into consideration the availability of qualified contractors and the availability of quality materials to accomplish the work. In some instances, a combination of treatments may be needed to maintain the pavement in good condition.

In addition to the technical analysis, it is important to complete a financial review that will compare the various treatment types, their expected service life, and the associated costs. Comparisons can be made by calculating a simplified annualized cost through dividing the estimated cost of the treatment by the expected service life of each treatment type.

B. Flexible Pavement Treatment Types

Several traditional preventative maintenance treatments are available for flexible pavements. These include:

- Crack filling
- Crack sealing
- Full/partial depth patches
- Fog seals
- Slurry seals
- Microsurfacing
- Bituminous seal coats
- Milling
- Thin overlays

The above treatments will be described in greater detail. Additional treatments are available, but generally involve use of proprietary materials or processes or are not included in this manual. If appropriate, designers should include some of these other treatments in their analyses. These treatments are only effective if there are no structural problems with the pavement or the supporting subbase/subgrade.

1. **Crack Filling:** Crack filling is a good treatment method for reducing intrusion of moisture through the pavement slab. It will assist in reducing further crack deterioration, associated roughness, and rutting. Crack filling will traditionally involve minimal preparation and use of lower quality bituminous materials. Treatment should occur during cool, dry weather, which will provide for wider crack widths. Proper cleaning and a dry condition are the key to achieving good performance and maximizing service life. Cracks should be cleaned to a depth of 3 inches. Crack filling material is generally an asphalt emulsion since actually sealing of the crack is not

expected. Crack filling is appropriate for non-working cracks between 1/4 inch and 1 inch wide. The potential exists for increased roughness and loss of surface friction if the joint is overfilled. See SUDAS Specifications Section 7040, 3.07. Service life is from 2 to 4 years.

2. **Crack Sealing:** Crack sealing is effective at reducing moisture intrusion in the pavement as well as minimizing the amount of incompressible materials in the cracks. It differs from crack filling in that it is used on working cracks and involves crack routing, substantial crack preparation, and higher quality sealant material. Crack sealing is appropriate for cracks between 1/4 inch and 3/4 inch wide. Use on longitudinal or transverse cracks with little or no secondary cracking or raveling at the crack face. Proper crack preparation and cleaning are essential to optimal performance. Saw or rout cracks to a minimum 3/8 inch width and a depth of 1/2 inch. The width and depth may be adjusted depending on the sealant to be used. Clean cracks of existing joint filler material, vegetation, dirt, or other foreign material. See SUDAS Specifications Section 7040, 3.06. Service life is from 2 to 8 years.

3. **Full/Partial Depth Patches:** Patches restore a pavement's structural integrity and improve its ride. Partial depth patches address distress in the upper one-third of the pavement slab. Slab removal may be accomplished by sawing and jackhammer or by milling. Minimum partial patch depth is 2 inches and maximum depth is 1/2 of the slab thickness. Prior to placement of patch material, clean partial depth patch area and ensure it is dry. Cover entire patch area with tack coat. Lifts should not exceed 3 inches in thickness with the top lift 2 inches or less. Ensure the final compacted surface is level with or not more than 1/8 inch above the surrounding pavement. Full depth patches will address various types of more structural distress, such as broken down thermal cracks. Apply tack coat to all vertical edges. Maximum lift thickness is 3 inches with the top lift being 2 inches or less. Compact intermediate lifts with a roller or vibratory compactor, depending on patch size. Compact final lift with steel-wheeled finish roller. Ensure final compacted surface is level with or not more than 1/8 inch above the surrounding pavement. See SUDAS Specifications Section 7040, 3.02 and 3.03. Patches are often completed in advance of a surface treatment. Service life is from 3 to 15 years.

4. **Fog Seals:** Fog seals are applications of diluted emulsion without a cover aggregate and are used to seal the pavement, inhibit raveling, and slightly enrich hardened or oxidized asphalt. Application rates vary from 0.05 to 0.10 gallons per square yard. If necessary, vegetation control should be completed in advance of the treatment. Ensure pavement is clean and dry prior to application. See Section 5I-4 for additional information. Fog seals can have a negative effect on friction and stripping in susceptible asphalts. Service life is from 1 to 3 years.

5. **Slurry Seals:** Slurry seals are effective at sealing low-severity cracks, waterproofing the pavement, and restoring friction. Slurry seals also address raveling, oxidation, and hardening of asphalt. They are a mixture of crushed, well-graded aggregate, a mineral filler, and asphalt emulsion that is spread across the full width of the pavement or it can be used as a strip treatment for low areas and cracks. Thickness is generally less than 1/2 inch. The slurry is basically placed one aggregate layer thick. Allow a minimum of 7 days cure time before applying permanent pavement markings. See Section 5I-4 and SUDAS Specifications Section 7070. Service life is 3 to 6 years.

6. **Microsurfacing:** Microsurfacing corrects or inhibits raveling and oxidation of the pavement, improves surface friction, reduces moisture infiltration, addresses low to medium severity bleeding, and can be used to fill surface irregularities and ruts up to 1 1/4 inch deep. Microsurfacing materials are similar to slurry seals except that microsurfacing uses latex modified asphalts versus an emulsified asphalt. Application of the microsurfacing is by specialized equipment using an augured screed. Microsurfacing typically breaks within a few

minutes of placement and can carry traffic after about an hour. See Section 5I-4. Service life is 4 to 7 years.

7. **Bituminous Seals Coats:** Seal coats, also sometimes known as chip seals, are effective at improving surface friction, inhibiting raveling, correcting minor roughness and bleeding, and sealing the pavement surface. Bituminous seal coats are also used to address longitudinal, transverse, and block cracking, as well as sealing medium severity fatigue cracks. Seal coats can be applied in multiple layers to address more serious problems. Asphalt emulsion is applied directly to the pavement surface and is followed by the application of aggregate chips that are immediately rolled to embed them into the emulsion. Application rates depend upon the aggregate gradation and maximum size. Loose chips may be a problem on higher speed roadways. Fog seals may be used in conjunction with seal coats to provide a greater degree of binding for the aggregates. See Section 5I-4 and SUDAS Specifications Section 7060. Single layer service life is 4 to 6 years.

8. **Milling:** Milling is used to reduce pavement irregularities and to produce a uniform surface. Milling should be considered if rutting is at a level of 1/4 inch or more. Milling is used in conjunction with other surface treatments, such as slurry seals and microsurfacing in addition to thin asphalt overlays, and is not suggested to be used as a final stand-alone treatment. It can be used to restore proper grades and pavement cross-slopes. For best results, the milling depth should match the lift thickness of the exiting pavement. See Section 5I-4 and SUDAS Specifications Section 7040, 3.05.

9. **Thin Overlays:** Thin overlays are placed in a single lift less than 1 1/2 inches thick. The overlay is expected to improve rideability, surface friction, profile, crown, and cross slope. In addition, specific distress types of low severity cracking, raveling, roughness, low severity bleeding, and low severity block cracking are improved. Thin overlays dissipate heat rapidly and rely on timely compaction to be successful. Dense-graded, open-graded, and stone-matrix mixes may be used. See SUDAS Specifications Section 7020. Service life is 7 to 10 years.

C. Rigid Pavement Treatment Types

Several preventative maintenance treatment types are available to address pavement distresses in PCC pavements. These include:

- Crack sealing
- Joint resealing
- Partial depth patches
- Full depth patches
- Dowel bar retrofit
- Diamond grinding
- Pavement undersealing/stabilization
- Pavement slab jacking
- Concrete overlays

These are the traditional preventative maintenance treatment types. Other less frequently used treatments are available to address specific distress needs.

1. **Crack Sealing:** Crack sealing is accomplished to reduce moisture intrusion and retard the rate of deterioration of the cracks. It is accomplished by thorough preparation and placement of high quality materials. It is used on random transverse and longitudinal cracks of low to medium severity where the crack width is less than 1/2 inch. Proper preparation of the crack and placement of the sealing material are critical for attainment of the expected 4 to 8 year service

life. The sealant material is critical to the success of the operation. Thermoplastic (rubberized asphalt) and thermosetting (silicone) sealants are the usual materials. The crack should be routed to 3/8 inch wide and 1/2 inch deep. The crack should be thoroughly cleaned and dried prior to application of the sealant. Refacing the sides of the crack with sandblasting is recommended. See SUDAS Specifications Section 7040, 3.06.

2. **Joint Resealing:** Joint resealing is important to minimize moisture in the joint and the subgrade/subbase, in addition to minimizing the intrusion of incompressible materials into the joint. Proper resealing of joints will reduce faulting, pumping, and spalling. Removal of the old sealant material and cleaning of the joint prior to resealing are critical. Removal of the old joint material can be accomplished by using a rectangular joint plow, diamond saw, or high-pressure water blast. Following refacing of the joint with a diamond bladed saw, the joint should be cleaned with high pressure air or water. Immediately prior to sealant application, the joint should be blown again with high pressure air to remove any sand, dust, or other incompressible that may remain in the joint. The joint must be dry and clean as joint sealant material is applied. See SUDAS Specifications Section 7040, 3.06. Service life is 4 to 8 years.

3. **Partial Depth Patches:** Partial depth patches are used to address spalling and surface scaling, as well as other problems in the top one-third of the pavement slab. Repair materials are selected based on available curing time, ambient temperature, size and depth of the repair, and cost. The materials are generally classified as cementitious, polymers, or bituminous. Rapid cure and high strength proprietary products are also available. It is critical to identify the limits of the weakened concrete so the patch can connect to sound concrete. The actual extent of the deterioration is often greater than what is visible at the surface. The removal area should extend a minimum of 3 inches beyond the deteriorated area in all directions. The patch area can be prepared by chipping with a lightweight jackhammer, milling with a carbon tipped milling machine, and sawing the edges of the patch and removal with a lightweight jackhammer. The patch area should be square or rectangular in shape and in line with existing joint patterns. The repair area must be swept, sandblasted, and air blasted to ensure a clean, dry patch area. Sandblasting is very effective at removing any dirt, oil, thin layers of unsound concrete, and laitance. Bonding agents are generally required for the patch materials. Sand-cements grouts consisting of one part sand and one part Type III cement with sufficient water to create a thick, creamy consistency have proven successful. Epoxy bonding agents can also be used with PCC and proprietary patching materials. Compressible joint materials must be used against the adjoining slab or to extend an existing joint through the patch area. The compressible material should extend 1 inch below and 3 inches beyond the repair boundaries. It may be possible to saw the joint through the patch, but timing is very critical. Since partial depth patches have large surface areas compared to their volume, it is very important to apply a curing compound as soon as the water has evaporated from the surface. The curing compound should be applied at 1.5 to 2 times the normal rate. The final step is resealing of the joint. See SUDAS Specifications Section 7040, 3.03. Service life of a well done partial depth patch is 5 to 15 years.

4. **Full Depth Patches:** Typical PCC pavement distresses that can be addressed by full depth repairs include transverse cracking, corner breaks, deteriorated joints, and blowups. Full depth repairs are an effective means for restoring the rideability and structural integrity of deteriorated PCC pavements. Long lasting full depth repairs are dependent upon selecting appropriate locations, effective load transfer design, and correct construction procedures, including finishing, texturing, and curing the patch. If the pavement exhibits a materials related deficiency, such as D-cracking, the service life of the patch will be short. Sizing the patch is critical to its success. Distressed areas should be identified and marked. Extent of the patch area may have to be adjusted if a period of time passes between initial identification and actual work activity. It may be necessary to do coring and deflection studies to identify the extent of deterioration below the slab surface. Full depth patches should be a minimum of 6 feet long and a full lane wide. All

joints through or adjacent to full depth patches must be re-established. Connect patches to make one large patch if the patches are 8 to 10 feet from each other in a single lane. The load transfer technique used in the patch should match the load transfer technique in the existing slab. Full depth repairs could be used in conjunction with diamond grinding to correct any roughness problems. See SUDAS Specifications Section 7040, 3.02. Service life is expected to be from 10 to 15 years.

5. **Dowel Bar Retrofit:** Dowel bar retrofit (DBR) is a method of load transfer restoration. It is used on non-doweled plain jointed concrete pavements. A successful dowel bar retrofit project will enhance pavement performance by reducing pumping, faulting, and corner breaks. Pavements with structurally adequate slab thickness, but exhibiting significant loss of load transfer due to poor aggregate interlock or base/subbase/subgrade erosion, are good candidates for DBR. It will also retard deterioration of transverse joints and cracks. Typical design includes three or four dowels inserted into the pavement at joints in each wheel path. The size of the dowel bar varies from 1 inch to 1 1/2 inches in diameter according to the slab thickness. See SUDAS Figure 7010.101. The slots are generally 3 feet long, centered on the joint or crack. The slot must be long enough to allow the dowel to lie flat in the slot without hitting the curve of the saw cut. The width of the slot should be 2.5 inches and the depth sufficient to position the center of the dowel at the mid-depth of the slab. The slot must be parallel to the centerline of the pavement slab so the dowels do not lock up pavement movements. The dowel assembly will have end caps to facilitate movement and a compressible insert to form the joint across the slot. The slot filler materials are the critical element to a successful installation. Desirable properties include little or no shrinkage, similar coefficient of thermal expansion as the existing concrete, good bond strength, and the ability to gain strength rapidly. Concrete with Type III cement, sand, and 3/8 inch maximum sized aggregate can be used or there are proprietary products available. Dowel bar retrofit projects often include following up with diamond grinding. All transverse joints should be re-established by sawing over the joint and through the fill board. The joint should then be prepared and sealed. Dowel bar retrofit projects will allow the original service life of the pavement to be restored.

6. **Diamond Grinding:** Diamond grinding is the removal of a thin layer of pavement surface using closely spaced diamond saw blades. It is used to improve ride quality by eliminating joint and crack faulting. In addition, surface friction, transverse cross slope, and tire/pavement noise are improved. It does not address structural problems or material related distress. Structural problems, such as pumping, corner breaks, and working transverse cracks, must be addressed before grinding. If joint/crack faulting exceeds 1/4 inch, the project may not be a candidate for diamond grinding. The blade spacing and width of groove are dependent on the hardness of the aggregate. As the aggregates get softer, the width of the land area and groove get larger. The depth of cut should be set so that 95% of the area is ground. The surface distresses will redevelop if the root cause of the distress is not corrected prior to diamond grinding. Thus, it may be necessary to complete full and partial depth patches, load transfer restoration, and slab stabilization prior to grinding. See SUDAS Specifications Section 7040, 3.04. Service life varies from 5 to 15 years, depending on the hardness of the aggregates and the level of structural distress correction completed prior to grinding.

7. **Pavement Undersealing/Stabilization:** Slab stabilization is pressure insertion of a flowable material to restore support beneath PCC slabs. It fills existing voids but does not lift the slab. Pavement stabilization restores pavement support, reduces pavement deflections, and reduces progression of pumping, faulting, and corner breaks. Slab stabilization must be completed prior to significant pavement damage. The main issue with slab stabilization is identifying where the voids are located and the extent of the voids. Distress surveys and deflection testing are necessary. Deflections may be measured using a FWD or by using a loaded truck with gauges placed at the corners of the slab. Other methods, such as ground penetrating radar or

thermography, are also available. Pozzolan-cement grout and polyurethane are the most common materials used for slab stabilization. Other proprietary products are available. It is important to only apply the material at locations where voids exist. If it is placed in areas without voids, the material can induce pressure points and actually increase the pavement deterioration. Once the area of the void is determined, the grout insertion holes can be drilled. Holes should be placed as far as possible from cracks and joints. Holes should be placed close enough to achieve flow from one insertion hole to another. Service life is from 5 to 10 years, depending on the level of truck traffic.

8. **Pavement Slab Jacking:** Slab jacking consists of the pressure insertion of a grout or polyurethane material beneath the PCC slab as a means of raising the slab to a smoother profile. Slab jacking is normally used to correct localized settlement areas, such as over culverts or at bridge approaches. It should not be used to correct faulted joints. Grout insertion holes should be a minimum of 12 inches from a transverse joint or the edge of the slab. Holes should be spaced 6 feet or less center-to-center. It is critical to monitor the amount of lift performed at each location. The slab should not be lifted more than 1/4 inch at a time so that excessive stresses are prevented and slab cracking minimized. Uniform positioning of the grout holes is also important. Work should start from the lowest point of the section being raised and proceed out to the edges of the settled area in a repeating pattern. Materials for slab jacking are typically stiffer than those used for slab stabilization. Cement grout and polyurethanes are typically used.

9. **Overlay:** Concrete overlays exist for all types of pavements, including concrete, asphalt, and composite. Thickness for preservation projects are generally between 3 to 4 inches. Similar to other concrete pavements, overlays require uniform support and effective management of movement. The overlay type can be bonded or unbonded. Bonded overlays are used to eliminate surface distresses when the existing pavement is in good structural conditions. Bonded overlays utilize the existing pavement as an integral part of the new monolithic system and thus thorough surface preparation is critical. Unbonded overlays are essentially a new pavement over a stabilized base (the old pavement). A bond breaker, such as a thin asphalt layer or a layer of non-woven geotextile, is needed between the existing pavement and the overlay. Typically, overlays are constructed using standard concrete mixes and standard construction techniques. Fibers may be added to the concrete mix for additional strength. Joints in bonded concrete overlays must match those in the existing pavement. Service life of concrete overlays is 15 to 20 years. Visit the National Concrete Pavement Technology Center's website (https://cptechcenter.org/) for more publications on concrete overlays.

D. Vacuum Excavation Core Holes

Re-establishing pavement integrity following a utility investigation involving cutting a core hole in the pavement and vacuum extracting the soil subgrade to locate an underground utility is often problematic. Full depth patches should be done according to SUDAS Specifications Figures 7040.101 and 7040.102 for PCC pavements and Figure 7040.103 for HMA pavements. Figure 7040.107 provides for alternative approaches if approved by the jurisdiction.

A critical decision is the determination of the technique to rebuild the subgrade. Adequately filling and compacting the excavation area is difficult due to the relatively small core hole. Coring out the full pavement patch area to the depth of the utility and compacting it to pavement subgrade standards is one method. Consideration could be given to requiring flowable mortar or a similar product to fill the hole as an alternative.

The jurisdiction will designate the process of filling and pavement replacement.

E. References

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Thin Maintenance Surfaces

A. General

Seal coats, slurry seals, microsurfacing, and fog seals are termed thin maintenance surfaces or TMS. These thin maintenance surfaces can be a cost effective approach to maintaining flexible pavements. Studies have shown that agencies can maintain a city street or county road network in better condition at lower costs through the use of TMS. Project selection, treatment selection, and timing are critical to the use of TMS.

Since TMS do not involve increasing the structural carrying capacity of a street, it is vitally important to apply the appropriate treatment prior to the start of pavement deterioration. Pavement condition, traffic volumes, materials availability, roadway classification, and local preference must be evaluated before determining the type of TMS to use. General uses for TMS are noted in the following table:

Criteria	Seal Coat	Slurry Seal	Microsurfacing
Traffic Volume:			
Low (< 2,000 vpd)	Recommended	Recommended	Recommended
Medium (2,000 to 5,000 vpd)	Marginal	Marginal	Recommended
High (> 5,000 vpd)	Not Recommended	Not Recommended	Recommended
Bleeding	Recommended	Recommended	Recommended
Rutting	Not Recommended	Recommended	Recommended
Raveling	Recommended	Recommended	Recommended
Cracking			
Slight	Recommended	Recommended	Recommended
Moderate	Recommended	Not Recommended	Not Recommended
Low Friction	May improve	May Improve	May Improve
Snowplow Damage	Most susceptible	Moderately susceptible	Least susceptible

Source: Jahren, 2003

Design of these TMS treatments must take into account the type of pavement distress that is being addressed with the proposed project. It may be necessary to complete crack filling, patching, or other maintenance activities prior to implementing the TMS.

B. Seal Coat

A seal coat is a single layer of asphalt binder that is covered by embedded aggregate with its primary purpose to seal fine cracks in the underlying pavement and retard water intrusion into the pavement and subgrade/subbase. The aggregate protects the asphalt binder layer and provides macrotexture for improved skid resistance. Seal coating is also a cost effective way to address bleeding and raveling. Most often, the asphalt binder is an emulsion. Cutback asphalts may be used as well. Emulsified asphalt is a mixture of liquid asphalt and water. A cutback is a mixture of liquid asphalt and a distillate, such as kerosene or fuel oil. The aggregates are typically less than 1/2 inch in size.

One of the most critical factors in the design is to determine the quantities of asphalt binder and aggregate. The goal should be to have the single layer of stone 70% into the asphalt binder layer with

little or no stones to clean up. In order to attain that goal, the designer must take into account the traffic volume; the absorption of the binder into the cover aggregate; the texture of the existing pavement; and size, shape, and gradation of the aggregate. Seal coat projects have an expected life span of 4 to 6 years.

Seal coating is recommended for low and medium volume roadways with low speeds due to the increased chance for insurance claims for vehicle damage from the loose rock as traffic volumes and speed increases. In addition, the impact to the public is compounded on high volume roadways due to the time the facility is out of service, generally 24 hours. As traffic volumes increase, it becomes more critical to include very high quality, durable aggregates in the mix design.

Selection of the asphalt binder is important to the success of the project. Although cutback asphalts can be used, their use has rapidly declined over the years due to the costly and harmful solvents used. Typically, asphalt emulsions are used. They are made up of asphalt cement, water, and an emulsifying agent (surfactant). The asphalt cement is typically in the same range as is used for hot mix production and makes up about 2/3 of the volume of the binder. Water provides the medium to keep the asphalt in suspension. The surfactant (usually soap) causes the asphalt particles to form tiny droplets that remain in suspension in the water, and it determines the electrical charge of the emulsion. It is important that the emulsion and the aggregate have opposite electrical charges in order to maximize the bond between the emulsion and the aggregate. Since most aggregates have a negative charge, emulsions such as CRS-2P with a positive (cationic) charge are used.

Cover aggregate should be clean and dust free to maximize adherence. A uniform gradation of hard, durable aggregate will increase the resistance to impact from traffic and snowplows. Aggregate application needs to follow binder application very closely. The cover aggregate should be applied so it is only one layer thick. Excess aggregate increases the chance for dislodging properly embedded aggregate during the cleanup operation, as well as increasing the potential for vehicle damage. The aggregate may be gravel, crushed stone, or a mixture. Cubical shaped aggregate is preferable to flat aggregate. Flat and elongated aggregates can be susceptible to bleeding due to traffic causing the flat chips to lie on their flattest side. If flat aggregate is used and the binder is applied too thick, the pavement will bleed; if it is too thin, the pavement will ravel. Angular aggregate is preferable to round aggregate because angular aggregate chips tend to lock together.

One of the problems with seal coats is the generation of dust from the aggregate. One way to address the dust problem is to pre-coat the aggregate. Pre-coating involves applying either a film of paving grade asphalt or a specially formulated pre-coating bitumen to the aggregate. The use of pre-coated aggregate improves aggregate bonding properties, as well as reducing dust. It also shortens the required curing time and vehicle damage from loose aggregate. Fog seals may also be used to address dust problems and to cover the “gravel road” appearance of seal coat. Fog seals are generally a 50-50 mix of emulsion and water. It is important to recognize that skid resistance may be compromised with the use of fog seals.

Many design tools are available. One of the most often used is the Minnesota Seal Coat Handbook. Another source is the Thin Maintenance Surfaces Manual developed by the Institute for Transportation at Iowa State University.

A uniformly applied tack coat is essential to the success of thin lift overlays. Raveling and slipping of the surface course at the interface with the existing pavement are problems when tack coats are insufficient or applied in streaks.

With the thin lift thickness, it is difficult to isolate the density of the overlay from the density of the underlying pavement. Thus, in most cases, a rolling pattern is established. To date, experience has shown that three passes with a vibratory steel-wheeled roller provides appropriate density.

As noted, the performance of thin lift overlays will depend on traffic, climate, underlying pavement quality, surface preparation, materials, and construction quality. In colder climates such as in Iowa, special attention needs to be paid to thermal cracking and damage created by snowplows.

c. Interlayers: HMA interlayers can be placed prior to the HMA overlay to minimize reflective cracking from the underlying pavement. An asphalt interlayer is a specially designed lift of HMA placed over a pavement and under an asphalt overlay. The asphalt interlayer is usually about 1 inch thick and uses a highly polymerized asphalt binder (PG 58-34E), fine aggregates, and a higher than normal asphalt cement content to develop a flexible layer. The interlayer will have the elasticity to resist and partially absorb the tension, shear, and bending exerted on the pavement. The asphalt interlayer assists in retarding reflective cracking of the HMA overlay caused by movement of the underlying pavement. The asphalt interlayer also helps keep additional moisture from penetrating through any cracks that are reflected and thus delaying any further deterioration of the pavement structure.

The condition of the underlying pavement is critical. If an underlying pavement has deteriorated or become unstable, it may be necessary to do removal and patching or placement of a leveling course with standard HMA prior to placement of the interlayer. Due to the higher cost, the asphalt interlayer should not be used as a leveling course.

2. Crack and Seat with HMA Overlay: Cracking and seating with HMA overlay is considered a major rehabilitation. Crack and seat will typically reduce the occurrence and severity of reflection cracks in the asphalt surface overlay. The existing concrete is broken with a guillotine or segmental type breaker to produce hairline cracks at approximately 3 to 4 foot spacing. The cracked slabs are then seated by use of a weighted roller to reestablish support between the underlying subbase or subgrade and the existing pavement. The roller is usually a rubber tired piece of equipment with a minimum gross load of 30 tons.

Crack and Seat - Photo courtesy of Antigo Construction

In urban areas, a full depth saw cut along the curbline is required prior to conducting crack and seat operations. In addition, a guillotine style breaker should be used with caution where structures are near the roadway. Impacts from the large single breaker can vibrate structures and cause concerns for property owners. A segmental breaker results in lower magnitude vibrations and is recommended for crack and seat projects in urban areas.

3. **Rubblizing with HMA Overlay:** Rubblizing of an existing concrete pavement and placement of an HMA overlay is an optional major rehabilitation method. This process includes breaking up the concrete pavement into small pieces and rolling it into place to produce a sound base, which prevents reflective cracking in the asphalt surface. Rubblizing a concrete pavement successfully is predicated on having a stable subgrade so the concrete material does not intermix with the subgrade. In urban areas, care must be taken not to damage utilities with minimal cover. The final surface is HMA overlay.

Rubblizing - Photo courtesy of Antigo Construction

It may be necessary to work with the rubblizing contractor to establish a 100 to 200 foot test section as a means of determining the effectiveness of the rubblization. The goal is to break the existing PCC pavement into pieces with a nominal maximum size of 4 inches. In certain circumstances, the designer may allow larger pieces but they should not exceed 12 inches in size and should only be allowed for a limited area. It may be appropriate to require the contractor to excavate a test pit (4 feet by 4 feet) to assure that the PCC has been fractured throughout its entire thickness and that the bond between any steel and the concrete has been broken.

The displacement of the rubbilized pieces into the subgrade should be minimized. A steel drum vibratory roller having a minimum gross weight of 10 tons is required to compact the rubbilized pavement.

In areas of soft subgrade, it may be necessary to remove the pavement and patch with 2 inch limestone chokestone. Geogrid may be used under the patch rock to add additional support.

A 2 inch to 3 inch rock interlayer of 3/4 inch roadstone may be placed on the rubbilized concrete and rolled prior to placing the HMA overlay if surface variations remain after rolling. The use of the interlayer provides a more stable work platform and enhances the overlay's ability to stop reflective cracking.

D. References

American Association of State Highway and Transportation Officials (AASHTO). 1993. *Guide for Design of Pavement Structures.* American Association of State Highway and Transportation Officials, Washington, DC.

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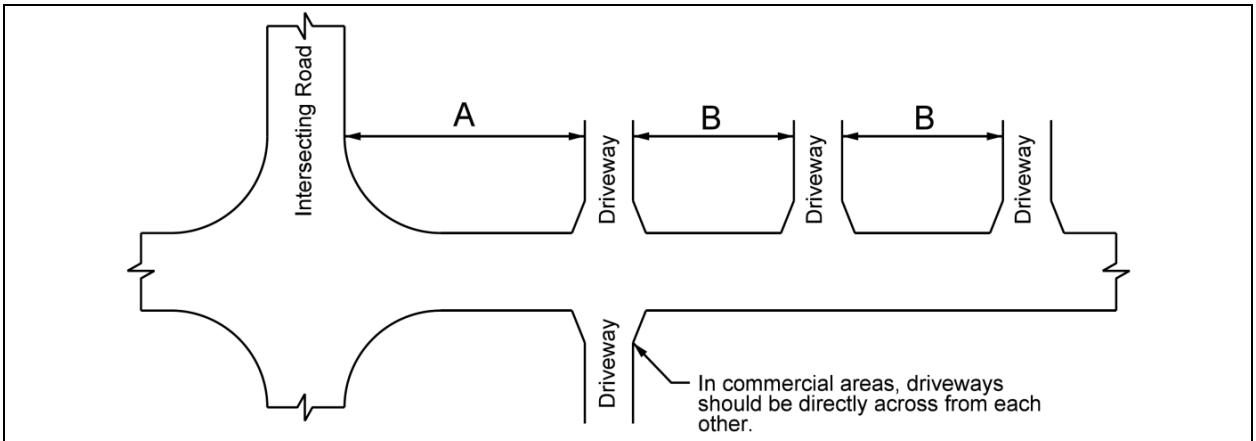
American Concrete Pavement Association (ACPA). 2014a. *Bonded Concrete on Asphalt (BCOA) Calculator*. American Concrete Pavement Association, Rosemont, IL. (Web Link)

American Concrete Pavement Association (ACPA). 2014b. *StreetPave 12: Structural Design Software for Street and Road Concrete Pavements*. American Concrete Pavement Association, Rosemont, IL. (Web Link)

Table 5L-3.05: Minimum Distance between Driveways or from Intersecting Streets



	Minor Arterial			Collector			Local		
	Res. Area	***C/ I Area***	***Ag Area***	***Res. Area[3]***	***C/I Area***	***Ag Area***	***Res. Area[3]***	***C/I Area***	***Ag Area***
A. Minimum intersection clearance[1]	145’	170’	300’	100’	100’	300’	75’	75’	150’
B. Minimum driveway spacing[2]	100’	200’	300’	75’	100’	300’	---[4]	---[4]	150’

Res = Residential, C/I = Commercial/Industrial

[1] Values are measured from the back of the curb, intersecting road to the adjacent driveway near edge. Distance may be adjusted due to lot dimension or zoning code.

[2] Values are measured between driveway edges.

[3] One access drive allowed per lot. Depending on lot size, an additional drive may be allowed upon approval of the Jurisdiction.

[4] See Jurisdictional Engineer for local requirements.

4. Access Spacing for State Primary Roads: In rural areas, travel speeds are usually 55 mile per hour and above. This means that driveway spacing in rural areas must be longer to provide for a safe driving environment. On state highways, spacing is also longer because the routes are primarily designed to carry through traffic rather than to serve as property access routes. The more important a route is for through traffic and commerce, the longer the spacing between driveways. The following table shows the State of Iowa's standards for its highway system.

Table 5L-3.06: Iowa DOT Access Control - Minimum Spacings

State Highway Priority	Minimum Spacing Between Driveways	Number of Driveways Per Mile
Priority I (Full Access Control)	Interchanges at roads	N/A
Priority II (Four Lane Divided)	2,640' (minimum)[1] 5,280' (preferred)[1]	2 2
Priority III	1,000' rural (minimum)[1] 1,320' rural (preferred)[1]	4 4
Priority IV(a) Priority IV(b)	600' rural (≥ 45 mph) 300' urban (≤ 40 mph)	8 16
Priority V (Access Right Acquired Between 1956 to 1966)	1 access per 1,000' of frontage not exceeding 2,000'	2 to 5
Priority VI	Safety and need	Varies

[1] Access allowed only at interchanges and selected at-grade locations

5. **Access Spacing for County Roads:** On county roads, the spacing standard should also depend on the nature of the road, e.g. how important the road is for through traffic. Even on the lowest functional levels, some sort of driveway spacing standard is important for traffic safety.

Table 5L-3.07: County Road Minimum Access Spacings

County Road Route Type	Minimum Spacing Between Driveways	Number of Driveways Per Mile
Minor arterials	600'	9
Collectors	300'	18
Local traffic service	150'	36

6. **Additional Access Spacing Considerations:**
   - At a minimum, the upstream corner clearance should be longer than the longest expected queue at the adjacent intersection.
   - High speed, high volume roadways need longer corner clearances whereas the corner clearance on a local street can be much shorter.
   - Residential streets - driveways on corner lots should be located on the lesser street and near the property line most distant from the intersection.
   - Typically, all elements of an access drive, including the radii should be within a property frontage.
   - At a minimum, all driveway geometrics should be along the frontage of the property served by the driveway.
   - On major roadways, the corner clearance should be at least as long as the stopping sight distance so that vehicles turning corners can make safe stops when encountering entering traffic.
   - Encourage owners of adjacent properties to construct joint-use driveways in lieu of separate driveways.
   - Encourage a property owner to replace two or more driveways with a single driveway (or fewer driveways).
   - For adjacent properties, locate joint access on the property line. Reciprocal easements must be executed.

D. Remove Turning Traffic from Through-traffic Lanes (Principle 8)

All driveway and intersection geometrics require that turns be made at very slow speeds and hence result in high speed differentials. Providing auxiliary lanes (left-turn and right-turn bays) is the most effective means of limiting the speed differential. This is especially important on high volume and high speed roadways.

The several methods by which turning vehicles can be removed from through traffic lanes are:

- Install isolated left-turn bay
- Install a nontraversable median with left-turn bays
- Install right-turn deceleration bay
- Install right-turn lane
- Install a continuous two-way left-turn lane (TWLTL)

1. **Turn Lane Warrants for Urban/Suburban Areas (Unsignalized):** Providing left and/or right turn lanes can significantly improve the operation and safety of an intersection. They allow turning vehicles to exit the through traffic lane with reduced speed differential and provide queue storage without interference with through traffic. Rear-end and side-swipe collisions are greatly reduced. Capacity is increased and delay decreased.

   General information regarding improvements for intersections, including guidelines for including left and right turn lanes, can be found in NCHRP Report 457. More specific information and warrants for installation of left turn lanes is presented in NCHRP Report 745.

   In general, the decision to provide turn lanes should be based on safety rather than just capacity. Where practical, left turn lanes should be provided at median openings on divided roads, regardless of projected traffic volumes.

2. **Rural Turn Lane Warrants and Right Turn Deceleration Length (Unsignalized):** See Iowa DOT's Design Manual, Chapter 6 - Geometric Design.

3. **Three Lanes with TWLTL:** Three lane roadway designs can be effectively used in situations where there are low to moderate levels of through traffic, yet there are concerns about conflict points and crashes caused by left-turning traffic. The upper limit for using a three lane design is about 17,000 vehicles per day of traffic. Three lane designs are ideal where right-of-way width is limited due to existing land development or other constraints. Three lane roads can either be designed that way originally or can be created by widening an existing two lane route or by modifying an existing four lane undivided route.

4. **Five lanes with TWLTL:** When the average daily traffic (ADT) on a street exceeds about 17,000 vehicles per day, four lane roadways with raised medians or five lane roadways with TWLTL are more appropriate designs. The limit for five lane roadway (with TWLTL) is approximately 24,000 ADT. TWLTL should generally not be used in situations where there are more than four total through lanes.

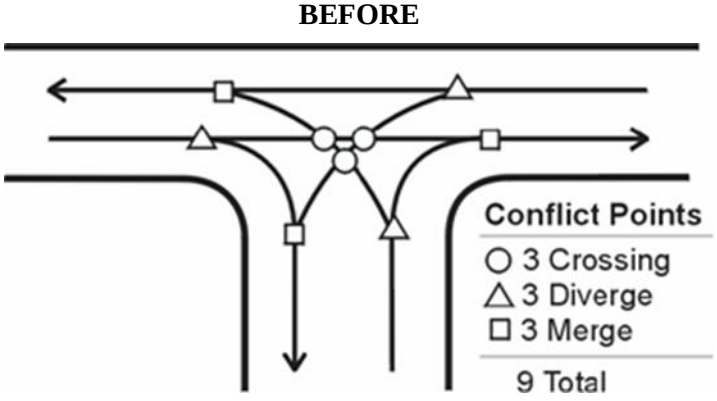
E. Use Nontraversable Medians to Manage Left Turn Movements (Principle 9)

The majority of access-related crashes involve left turns. Providing nontraversable medians limits and defines locations of left turns, thereby improving safety. Full access median openings that allow left turns from all directions are best provided at signalized intersections and unsignalized junctions of arterial and collector streets. Providing median closures or partial access medians at other intersections and access points reduces the number and types of conflicts.

1. **Median Closures:** Median openings should be considered for closure where:
   - A safety or operational problem is evident and an appropriate retrofit cannot be made.
   - Median width is less than 11 feet, thereby not allowing for construction of left turn lanes.
   - The left-turn bay of a nearby signalized intersection needs to be extended.
   - A pattern of left-turn crashes is evident.
   - Heavy pedestrian use is predicted or crashes involving pedestrians have occurred at the intersection.

   Implementation of a median closure involves providing a section of median of the same design as existing on either side of the opening. The following should be considered during design:
   - Tree lines, building lines, and lighting may head drivers into believing the median can be crossed.
   - Visual cues should be provided to clearly inform drivers that the opening has been closed.
   - The need for visual cues is especially critical during nighttime hours where a four way intersection previously existed or there are access drives directly opposite each other.
   - Minimum 4 feet median width face-to-face of curbs is recommended.
   - Select and locate landscaping materials to delineate the median while considering potential sight distance obstructions.

Figure 5L-3.04: Two Lane Roadway Conflict Points at Typical Three Way Intersection or Driveway



Driveway Design Criteria

A. General

For efficient and safe operations, access drives and minor public street intersections can be improved by the following:

- Smooth vertical geometrics
- Adequate driveway throat width and curb return radii
- Provide adequate sight distance
- Additional egress lane
- Quality driveway construction
- Define the ingress and egress sides of the access drive

Refer to NCHRP Report 659 - Guide for the Geometric Design of Driveways for supplemental information.

B. Width Measurement

1. The width of an entrance with a radius return or with a flared taper that connects to a curb and gutter roadway is measured at the back of the sidewalk, or, if no sidewalk exists, at the right-of-way line. Measure the driveway width of an opening with a large curb radius meeting the widths shown in Table 5L-4.01 at the end of the radius if it extends onto private property. The curb opening may exceed the maximum allowable width of the entrance to accommodate the allowable radius or taper.

2. The width of an entrance that connects to a rural roadway (no curb and gutter) is measured across the top of the entrance at the culvert line or at the location where a culvert would normally be placed.

C. Dimensions

Figure 5L-4.01: Entrance Dimensions

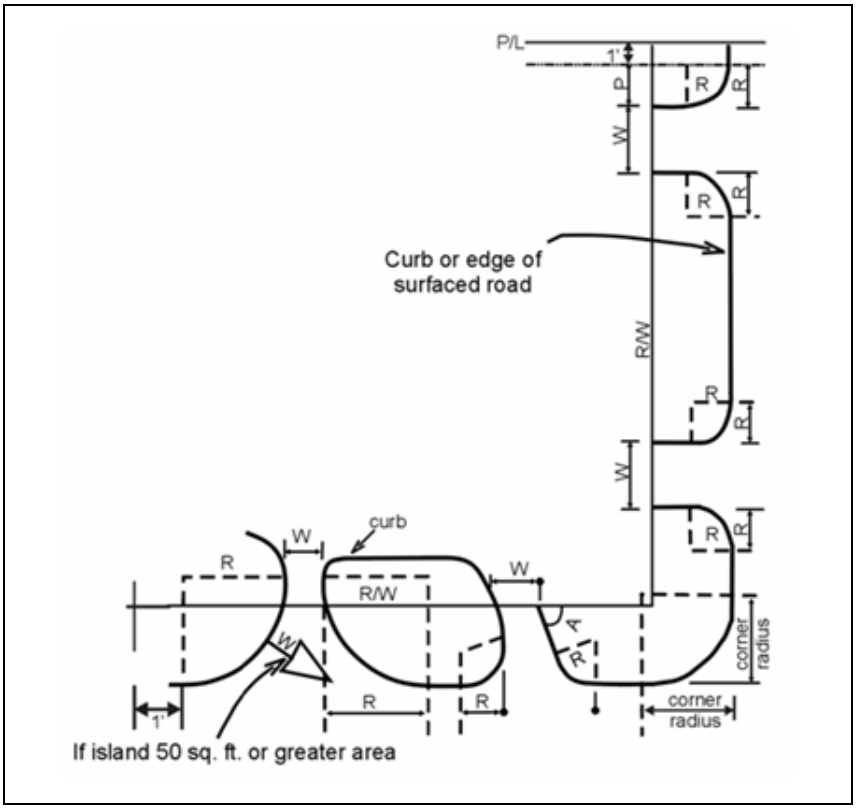


Table 5L-4.01: Driveway Dimensions[1]
(all dimensions are in feet)

Dimension Reference (See Figure 5L-4.01)		Major Arterial Street				Minor Arterial Street				Collector (Major and Minor)				Local Street			
		Residential	Commercial	Industrial	Agricultural	Residential	Commercial	Industrial	Agricultural	Residential	Commercial	Industrial	Agricultural	Residential	Commercial	Industrial	Agricultural
Width																	
Minimum	W	15	24	24	20	15	24	24	20	10	24	24	20	10	24	24	20
Maximum		30	45	45	30	30	45	45	30	24	40	45	30	**	32	40	30
Right-turn Radius[2]																	
Minimum	R	10	10	25	25	10	10	25	25	10	10	25	25	10	10	10	20
Maximum		25	35	50	35	25	35	50	35	25	35	50	35	15	20	30	35
Min. Acute Angle[3]	A	60°	70°	70°	70°	60°	70°	70°	70°	60°	70°	70°	70°	60°	70°	70°	70°
Pref. Acute Angle		90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°
Min. Pavement Thickness (inches)	T	6/8	7/9	*	6	6	7	*	6	6	7	*	6	6	7	*	6

[1] Major entrances require special design.
[2] 3 to 5 foot flares (F) may be used for residential and agricultural entrances.
[3] Any variation from 90° will be evaluated on a case by case basis. The minimum acute angle (measured from the edge of the pavement) is 60°.
* Requires special design.
** Maximum width of 12 feet per garage stall up to a total maximum of 36 feet except when located on a cul-de-sac bulb where the maximum width is 24 feet. See jurisdiction policy for specific requirements.

1. The width (W) shown applies to rural routes and city streets including neighborhood business, residential, and industrial streets. For residential drives on local streets, joint entrances centered on property lines or structures built with a shared garage wall, the maximum driveway width for each property will be 24 feet measured at the right-of-way line. For joint entrances, any landscaping between the drives will count toward the 24 foot maximum width. The landscaping width will be equally shared between the two properties. In rural areas (open ditch roadways) widths for paved entrances should include an additional 4 feet for shoulders (minimum 2 feet shoulders each side).

2. The radius (R) for agricultural uses will vary according to the following intersecting acute angles:

Table 5L-4.02: Agricultural Acute Angle and Radius

Acute Angle	Acute Radius Decrease (feet)	Obtuse Radius Increase (feet)
85° to 90°	0	0
75° to 85°	5 feet	5 feet
65° to 75°	5 feet	10 feet
60° to 65°	10 feet	15 feet

Where the entrance radius specified is greater than the distance between the back of curb and the front edge of the sidewalk the radius may be reduced to meet the available space but should be no less than 10 feet. An option to the radius under this condition is the use of flared entrances. When a flare is used, it should be 3 to 5 feet wide and should be constructed from the back of curb to the sidewalk. If no sidewalk exists, flares should be 10 feet long.

3. For individual properties, the number of entrances should be as follows:

   a. Single Family (SF) Residential: Each SF residential property is limited to one access point. However, where houses are located on corner lots, have extra wide frontage, or on heavy traveled roadway more than one access point may be allowed to eliminate backing out on a heavily traveled roadway. See jurisdiction policy for specific requirements.

   b. Multi-family (MF) Residential: Access is determined by information provided by the Owner/Developer in a Traffic Impact Report and by comments generated during the Jurisdiction Engineer's review and acceptance of that report.

   c. Commercial: Commercial property having less than 150 feet of frontage and located mid-block is limited to one access point to the street. An exception to this rule may be where a building is constructed in the middle of a lot and parking is provided for each side of the building. A second access point may be allowed for commercial property having more than 150 feet of frontage. For commercial property located on a corner, one access to each street may be allowed, provided dimensions are adequate from the intersecting street to the proposed entrance. (See Section 5L-3 - Access Location, Spacing, Turn Lanes, and Medians).

   d. Industrial: Access is determined on a case-by-case basis. The Jurisdiction will consider good traffic engineering practice and may require information to be provided by the applicant in a Traffic Impact Report. (See Section 5L-3 - Access Location, Spacing, Turn Lanes, and Medians).

e. Agricultural: Access with adequate frontage may be authorized with more than two accesses at not less than 300 feet intervals provided a minimum distance of 30 feet is maintained from the inlet and outlet of two adjacent culverts.

In all cases, the location of the access will be such that the taper or radius does not extend beyond the extension of the property line. In general, all construction must occur only on the property owner's frontage.

4. Minimum acute angle (A) is measured from the edge of pavement and is generally based on one-way operation. For two-way driveways, and in high pedestrian activity areas, the minimum angle should be 70 degrees. Entrances should be placed at 90 degrees whenever possible.

5. The entrance pavement thickness (T) is based on the following:

PCC - Class "A" or "C" - 4,000 psi
HMA - Greater than or equal to 100K ESAL (optional for rural area).

For those entrances not paved, 6 inches (min.) of Class "A" gravel should be required.

D. Sight Distance

1. Sight distance is based upon AASHTO stopping sight distance criteria. However, the height of an object is increased from 2.0 feet to 3.5 feet to acknowledge an approaching vehicle as the "object" of concern. Therefore, sight distance at an access location is measured from the driver's height of eye (3.5 feet) to the height of approaching vehicle (3.5 feet).

2. An access location should be established where desirable sight distance is available, as shown below.

Table 5L-4.03: Desirable Sight Distances

Design Speed (mph)	**Intersection Sight Distance (feet)**	
	Left Turn from Stop	***Right Turn from Stop and Crossing Maneuver***
55	610	530
50	555	480
45	500	430
40	445	385
35	390	335
30	335	290
25	280	240

Note: the sight distances shown above are for a stopped passenger car to turn onto or cross a two lane roadway with no median and grades of 3% or less. For conditions other than those stated, refer to the 2004 AASHTO "Green Book" for additional information.

Source: Based on Exhibit 9-55 and Exhibit 9-58 of the 2004 AASHTO "Green Book."

3. On a four lane divided primary highway where access is proposed at a location not to be served by a median crossover, sight distance is required only in the direction of the flow of traffic.

Sidewalks that are set back from the curb are safer than if the sidewalk is located at the back of curb. Street furniture and landscaping can add character and improve safety for sidewalks that are located at the back of curb. Providing seating areas within the sidewalk area can further enhance the urban environment and encourage pedestrian activity.

11. **Turn Lanes:** Turn lanes located at intersections provide opportunities for vehicles to exit the through lanes and improve capacity of the street. Two Way Left Turn Lanes (TWLTL) provide the opportunity to access midblock driveways without causing backups in the through lanes. Turn lanes also allow faster speeds in the through lanes so a trade-off with safety exists especially at intersections.

    Width of turn lanes should reflect the character of the traffic. Dedicated left and right turn lane widths should match the width of the lanes on the street. Local streets should not provide separate turn lanes. TWLTL should be a minimum of 12 feet wide because of the presence of through traffic on each side.

12. **Medians:** Medians provide for access management, pedestrian refuge, and additional space for landscaping, lighting, and utilities. Use of medians and the functions provided are dependent upon the width of available right-of-way and the other types of facilities that are included. The minimum width for pedestrian refuge is 6 feet. The minimum width of a median for access control and adjacent to left turn lanes is 4 feet. The minimum width for landscaped medians is 10 feet. Greater widths provide more opportunities for more extensive landscaping.

13. **Transit:** Bus service within the state is limited to the larger metropolitan areas. Currently there are a number of fixed route systems in the state. Smaller communities do not have fixed route service due to lack of demand. Children, elderly, and low-income people are the primary users of a fixed route transit system. In addition to system reliability, use of transit systems as a viable commuting option is directly dependent on the frequency of service and the destinations within the fixed route. To have a successful transit system, stops must be within walking or biking distance of residential areas to attract riders and it must have major retail, employment, and civic centers along its route system.

    Transit stops should be located on the far side of intersections to help reduce delays, minimize conflicts between buses and right turning vehicles, and encourage pedestrians to cross behind the bus where they are more visible to traffic. Far side stops also allow buses to take advantage of gaps in vehicular traffic.

    Bus turn out lanes are also best located on the far side of intersections. These turn outs free up the through lanes adjacent to the bus stop. Transit bulb outs are more pedestrian friendly than turnouts because they provide better visibility of the transit riders, as well as potentially providing space for bus shelters without creating congestion along the sidewalk. With buses stopping in the through lane, bulb-outs also provide traffic calming for the curb lane.

14. **Traffic Signals:** Traffic signals are not usually considered an element of complete streets, but they have many components with direct implications for complete streets. The timing, phasing, and coordination of traffic signals impacts all modes. Well-planned signal cycles reduce delay and unnecessary stops at intersections, thus improving traffic flow without street widening. Traffic signal timing can be designed to control vehicle operating speed along the street and to provide differing levels of protection for crossing pedestrians.

    The flashing don't walk pedestrian phase should be set using a 3.5 feet per second walking speed and the full pedestrian crossing time (walk/flashing don't walk) set using 3.0 feet per second. Some agencies representing the elderly are indicating that the overall walking speed should be 2.7

feet per second to cover a larger portion of the elderly population. ADA accessible pedestrian signal elements, such as audible signal indications, should be included in all new pedestrian signal installations and any installations being upgraded. See Section 13A-4, F for more information on accessible pedestrian signals.

15. **Summary:** The table below summarizes some of the critical design elements that should be examined if a complete streets project is implemented. Other geometric elements can be found in Table 5C-1.02. Some of the lane width values shown in the table below differ from the acceptable values from Section 5C-1 because the expectation is that the complete street environment includes the potential for on-street parking and/or bicycle lanes. Adjustments in the values may be necessary to accommodate large volumes of trucks or buses. Contact the Jurisdictional Engineer if design exceptions are being considered.

Table 5M-1.01: Preferred Design Elements for Complete Streets

Classification	**Local**				**Collector**						**Arterial**					
Posted Speed (mph)	25		30		25		30		35 and Up		25		30		35 and Up	
Land use[1]	*Res.*	*C/I*	*Res.*	*C/I*	*Res.*	*C/I*	*Res.*	*C/I*	*Res.*	*C/I*	*Res.*	*C/I*	*Res.*	*C/I*	*Res.*	*C/I*
Travel lane width (ft)[2]	10[3]	11	10	11	11	11	11	11	11	12	11	11	11	12	12	12
Turn lane width (ft)	--	--	--	--	11	11	11	11	11	12	11	11	11	12	12	12
Two-way left-turn lanes width (ft)	--	--	--	--	12	12	12	12	12	12	12	12	12	12	12	12
Curb Offset (ft)[4]	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	2	2	2	2	2
Parallel parking width (no buffer) (ft)[5]	8	8	8	8	8	9	8	9	9	9	10	10	10	10	10	10
Curb radii (ft)[6]	15	15	15	15	15	25	15	25	25	30	15	25	15	25	25	30
Bicycle lane width (ft)[7]	--	--	--	--	5	5	5	5	5	5	5	5	5	5	5	5

[1] Res. = Residential, C/I = Commercial/Industrial
[2] Minimum sharrow lane width is 13 feet.
[3] For low volume residential streets, two free flowing lanes are not required. They can operate as yield streets if parking is allowed on both sides and vehicles are parked across from each other.
[4] Curb offset, less the width of the curb, may be used in the parallel parking lane width.
[5] For arterial or high speed collectors, the parallel parking stall width may be reduced if a minimum 3 feet wide buffer strip is included.
[6] Curb radii may be adjusted based on design vehicle, presence of bicycle lanes or parking lanes, and the number of receiving lanes. Encroachment of turning vehicles into opposing lanes is not allowed.
[7] If paving is integral without a longitudinal gutter joint, the curb offset, less the width of the curb, may be used as part of a bicycle lane.

D. Traffic Calming

Traffic calming is different from but related to complete streets philosophies. Through design measures, traffic calming aims to slow traffic down to a desired speed. By slowing vehicular traffic, biking and pedestrian activities are made safer.

It is absolutely critical that traffic calming measures recognize the need to maintain access for emergency vehicles. Unless the situation is unusual, realizing slower speeds involves a series of traffic calming measures. However, too many measures along a street is likely to divert vehicles to adjacent streets and just move the problem or frustrate drivers to the point of complaining to the level necessary for removal of the traffic calming measures. Because of the anticipation that traffic will be just displaced to adjacent streets, it is very important to study a larger area than a single street when evaluating traffic calming measures.

Many design elements will accomplish traffic calming. These include the following.

- Reduction in lane widths:
  - Short medians
  - Bulb outs
  - Lane striping
- Lateral shifts
  - Chicanes
- Raised/tabled intersections
- Raised/tabled cross walks
- Speed humps or speed cushions
- Traffic circles
- Radar speed signs

Choosing the design elements to use for a particular area will depend on the neighborhood context and the specific concern to be addressed. Prior to evaluating alternative measures, stakeholders must be educated so they can have meaningful involvement. The evaluation needs to involve all stakeholders in the definition of the problem. If possible, all stakeholders, including drivers, pedestrians, bicyclists, and area property owners, would achieve some level of agreement on the traffic calming plan prior to implementation.

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Railroad Crossings

A. Railroad Crossing Improvements

Improvements to railroad crossings can take several forms. These include closing of an existing crossing, improvements to the existing crossing, and separating the roadway from the railroad tracks. Potential improvements to existing crossings include installation of adequate signage, signals, and signals with gate arms.

The local jurisdiction must use judgment in the selection process for crossing improvements. Several factors weigh into the selection process including the amount and speed of traffic on the roadway and railroad, available sight distance, and safety benefits. Traffic control systems for railroad-highway grade crossings must comply with the Manual on Uniform Traffic Control Devices (MUTCD).

The Jurisdiction should contact the offices of Rail Transportation and Local Systems at the Iowa DOT for any agreements and requirements that must be followed.

B. Railroad Crossing Construction

When railroad crossings are required on streets subject to heavy loads, an approved high quality grade crossing material should be installed. Some railroads may require an asphalt separation between the header and the crossing to allow for easier railroad maintenance of the crossing. Some railroads may require that the crossing material be installed by their own forces, with the costs borne by or shared with the local jurisdiction. Example railroad crossing approaches are included in Figures 1 and 2. In all cases, the railroad should be contacted for their specific crossing requirements.

C. Working with a Railroad

Working with a railroad company requires coordination at numerous steps along the planning, design, and construction process. A list of potential coordination steps follows; however, these requirements differ for each company and should be verified early in the planning process.

Phase	Possible Coordination Required
Planning	Right of entry permit for survey Coordination regarding potential modifications/improvements
Design	Right of Entry Permit for Survey Utility Accommodation Permit Maintenance Consent Agreement Coordination regarding crossing material and safety elements
Construction	Railroad Protective Liability Insurance Right of Entry for Construction Railroad Flaggers

D. Railroad Related Agencies in Iowa

Two governmental agencies are involved in regulating railroad activities within the State of Iowa. Additional information about these organizations is available at their respective websites:

Iowa DOT, Rail Transportation
https://iowadot.gov/iowarail/
800 Lincoln Way
Ames, Iowa 50010
515-239-1140

Federal Railroad Administration
Region 6 Office
http://www.fra.dot.gov/
901 Locust Street – Suite 464
Kansas City, MO 64106
816-328-3840

E. Railroad Companies in Iowa

Currently there are 18 railroads operating within the State of Iowa. These include three Class I railroad companies, Amtrak, and several regional and local railroads. The Iowa DOT maintains a website with links to the websites of the freight railroads operating within the state (https://iowadot.gov/iowarail/Iowa-Freight-Rail/Profiles).

a. Soils that do not Exhibit any Measurable Cohesion: Treat as coarse grained soil; base compaction on the relative density.

b. Soils that do Exhibit Measurable Cohesion: Treat as fine-grained soil; base compaction on the Proctor Density Test.

c. Inter-grade Soils: Conduct both Relative Density and Proctor Density Tests; base compaction on the test method yielding the highest maximum density.

G. Embankment Soils

SUDAS classifies Iowa cohesive soils into select subgrade materials, suitable soils, or unsuitable soils, depending on soil index properties and Proctor test results. See Section 6E-1 - Subgrade Design and Construction for more information.

1. **Select Subgrade Soils:** Select materials (see Section 6E-1 - Subgrade Design and Construction) or subgrade treatments (see Section 6H-1 - Foundation Improvement and Stabilization) may be used in the prepared subgrade (the top 12 inches immediately below the pavement or subbase, if present) to provide adequate volumetric stability, low frost potential, and good bearing capacity as it relates to the California Bearing Ratio (CBR ≥ 10).

2. **Suitable Soils:** Suitable soils are used throughout the fill and under the prepared subgrade. Suitable soils may be used in the prepared subgrade if they meet the requirements of select subgrade soils or are stabilized to meet those requirements (i.e., CBR ≥ 10). Suitable soils must meet all of the following conditions:

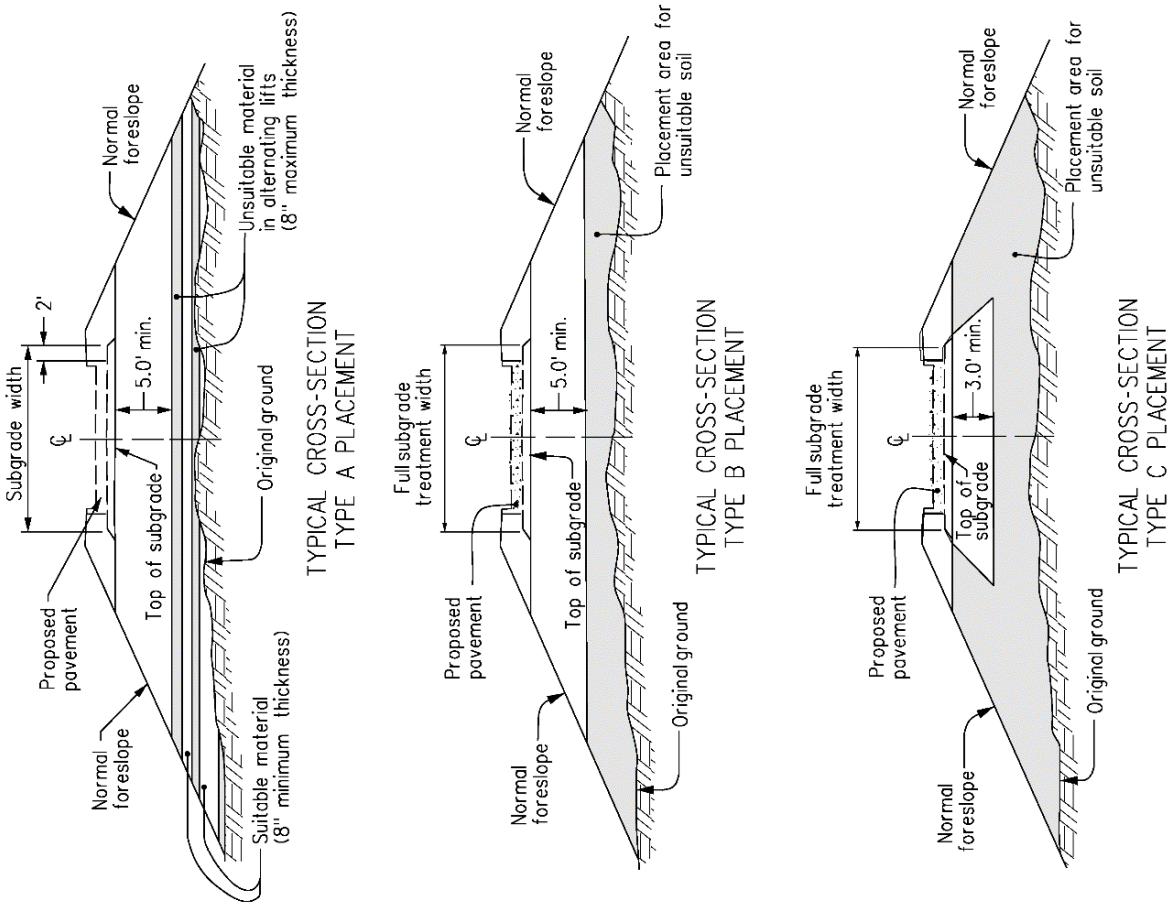
   a. Standard Proctor Density ≥ 95 pcf

   b. Group index < 30 (AASHTO M 145)

3. **Unsuitable Soils:** The SUDAS Specifications do not allow use of unsuitable soils in the right-of-way. However, there may be situations where the Engineer might consider the placement of unsuitable soils in the right-of-way. The Iowa DOT allows this placement. Figure 6D-1.04, modified from Iowa DOT Standard Road Plan EW-102, illustrates Iowa DOT's guidance for the use of unsuitable soils in an urban embankment section.

Figure 6D-1.04: Placement of Unsuitable Soils

Placed 4 feet below subgrade in fills outside curbline	1. Broken PCC in 6 inch sizes or smaller (pulverized HMA may be used as subgrade replacement)
Type A Placement Place in layers (8 inch max. thickness) 5 feet below subgrade and 2 feet outside curbline in fills. Provide alternate layers of suitable soils or soils other than A-7 or A-5 containing 3% or more carbon)	1. Shale 2. A-7-5 or A-5 soils having a density greater than 86 pcf but less than 95 pcf (ASTM D 698 Standard Proctor Density).
Type B Placement Placed 5 feet below subgrade and outside curbline in fills	1. A-7-6 (Plasticity index of 30 or greater) 2. Residual clays (overlying bedrock) regardless of classification.
Type C Placement Placed 3 feet below subgrade in fills (may be placed 2' feet outside of curbline).	1. All soils other than A-7-5 or A-5 having a density of 95 pcf or less (ASTM D 698 Standard Proctor Density). 2. All soils other than A-7 or A-5 containing 3% or more carbon.
Slope dressing only	1. Peat or muck 2. Soils with a plasticity index of 35 or greater 3. A-7 or A-5 (AASHTO) having a density less than 85 pcf (ASTM D 698 Standard Proctor Density)



Source: Modified version of Iowa DOT's Standard Road Plan EW-102.

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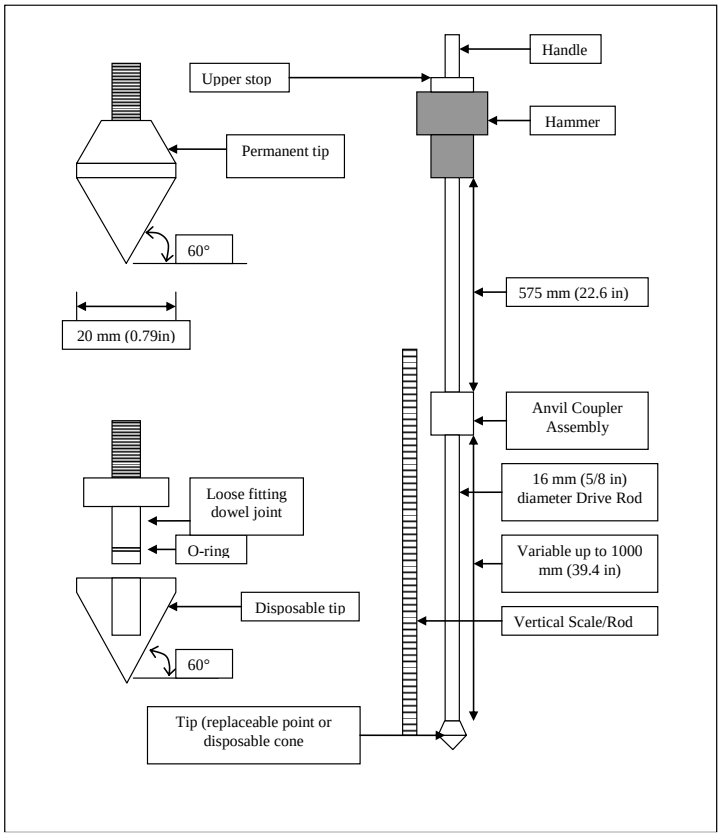
Figure 6E-1.05: DCP Design and Cone Tip Details



b. Relationship of M_R and k-value: An approximate relationship between k and M_R published by AASHTO is fairly straightforward.

$k = M_R/19.4$

where

k = modulus of subgrade reaction (psi/inch)
M_R = roadbed soil resilient modulus of the soil as determined by AASHTO T 274.

c. Relationship of CBR, MR, and k-value: See approximate relationships in Table 6E-1.01.

E. Subgrade Construction

1. General: The most critical element for subgrade construction is to develop a CBR of at least 10 in the prepared subgrade using on-site, borrow, or modified soil (see Section 6H-1 - Foundation Improvement and Stabilization). Uniformity is important, especially for rigid pavements, but the high level of subgrade support will allow the pavement to reach the design life.

In most instances, once heavy earthwork and fine grading are completed, the uppermost zone of subgrade soil (roadbed) is improved. The typical improvement technique is achieved by means of mechanical stabilization (i.e., compaction). Perhaps the most common problem arising from deficient construction is related to mechanical stabilization. Without proper quality control and quality assurance (QC/QA) measures, some deficient work may go unnoticed. This is most common in utility trenches and bridge abutments, where it is difficult to compact because of

vertical constraints. This type of problem can be avoided, or at least minimized, with a thorough plan and execution of the plan as it relates to QC/QA during construction. This plan should pay particular attention to proper moisture content, proper lift thickness for compaction, and sufficient configuration of the compaction equipment utilized (weight and width are the most critical). Failure to adequately construct and backfill trench lines will most likely result in localized settlement and cracking at the pavement surface.

2. **Compaction:** Compaction of subgrade soils is a basic subgrade detail and is one of the most fundamental geotechnical operations for any pavement project. The purpose of compaction is generally to enhance the strength or load-carrying capacity of the soil, while minimizing long-term settlement potential. Compaction also increases stiffness and strength, and reduces swelling potential for expansive soils.

   a. **Density/Moisture:** The most common measure of compaction is density. Soil density and optimum moisture content should be determined according to ASTM D 698 (Standard Proctor Density) or ASTM D 4253 and D 4254 (Maximum and Minimum Index Density for Cohesionless Soils). At least one analysis for each material type to be used as backfill should be conducted unless the analysis is provided by the Engineer.

      Field density is correlated to moisture-density relationships measured in the lab. Moisture-density relationships for various soils are discussed in Part 6A - General Information. Optimal engineering properties for a given soil type occur near its compaction optimum moisture content, as determined by the laboratory tests. At this state, a soils-void ratio and potential to shrink (if dried) or swell (if inundated with water) is minimized.

      For pavement construction, cohesive subgrade soil density should satisfy 95% of Standard Proctor tests, with the moisture content not less than optimum and not greater than 4% above optimum. For cohesionless soils (sands and gravel), a minimum relative density of 65% should be achieved with the moisture content greater than the bulking moisture content.

   b. **Strength/Stiffness:** Inherent to the construction of roadway embankments is the ability to measure soil properties to enforce quality control measures. In the past, density and moisture content have been the most widely measured soil parameters in conjunction with acceptance criteria. However, it has been shown recently that density and moisture content may not be an adequate analysis. Therefore, alternate methods of in-situ testing have been reviewed. The dual mass Dynamic Cone Penetrometer (DCP) is a method for estimating in-place stability from CBR correlations.

   c. **Equipment:** Several compaction devices are available in modern earthwork, and selection of the proper equipment is dependent on the material intended to be densified. Generally, compaction can be accomplished using pressure, vibration, and/or kneading action. Different types of field compaction equipment are appropriate for different types of soils. Steel-wheel rollers, the earliest type of compaction equipment, are suitable for cohesionless soils. Vibratory steel rollers have largely replaced static steel-wheel rollers because of their higher efficiency. Sheepsfoot rollers, which impart more of a kneading compaction effort than smooth steel wheels, are most appropriate for plastic cohesive soils. Vibratory versions of sheepsfoot rollers are also available. Pneumatic rubber-tired rollers work well for both cohesionless and cohesive soils. A variety of small equipment for hand compaction in confined areas is also available. Table 6E-1.03 summarizes recommended field compaction equipment for various soil types.

Table 6E-1.03: Recommended Field Compaction Equipment

Soil	First Choice	Second Choice	Comment
Rock fill	Vibratory	Pneumatic	--
Plastic soils, CH, MH	Sheepsfoot or pad foot	Pneumatic	Thin lifts usually needed
Low-plasticity soils, CL, ML	Sheepsfoot or pad foot	Pneumatic, vibratory	Moisture control often critical for silty soils
Plastic sands and gravels, GC, SC	Vibratory, pneumatic	Pad foot	--
Silty sands and gravels, SM, GM	Vibratory	Pneumatic, pad foot	Moisture control often critical
Clean sands, SW, SP	Vibratory	Impact, pneumatic	--
Clean gravels, GW, GP	Vibratory	Pneumatic, impact, grid	Grid useful for over-size particles

Source: Rollings and Rollings 1996

The effective depth of compaction of all field equipment is usually limited, so compaction of thick layers must be done in a series of lifts, with each lift thickness typically in the range of 6 to 8 inches.

The soil type, degree of compaction required, field compaction energy (type and size of compaction equipment and number of passes), and the contractor's skill in handling the material are key factors determining the maximum lift thickness that can be compacted effectively. Control of water content in each lift, either through drying or addition of water plus mixing, may be required to achieve specified compacted densities and/or to meet specifications for compaction water content.

Proof-rolling with heavy rubber-tired rollers is used to identify any remaining soft areas. The proof-roller must be sized to avoid causing bearing-capacity failures in the materials that are being proof-rolled. Proof-rolling is not a replacement for good compaction procedures and inspection. An inspector needs to be present onsite to watch the deflections under the roller in order to identify soft areas. Construction equipment such as loaded scrapers and material delivery trucks can also be used to help detect soft spots along the roadway alignment. It is very difficult to achieve satisfactory compaction if the lift is not on a firm foundation.

3. **Overexcavation/Fill:** The installation of structural features (e.g., sewer, water, and other utilities) adjacent to or beneath pavements can lead to problems during or following construction. Proper installation of such utilities and close inspection during construction are critical.

   A key element in the installation of these systems is proper compaction around and above the pipe. Granular fill should always be used to form a haunch below the pipe for support. Some agencies are using flowable fill or controlled low strength material (CLSM) as an alternative to compacted granular fill. Without this support feature, the weight above the pipe may cause it to deform, creating settlement above the pipe, and often pipe collapse. Even if a sinkhole does not appear, leaks of any water-bearing utility will inundate the adjacent pavement layers, reducing their support capacity.

   Pavement problems also occur when improper fill is used in the embankment beneath the pavement system. Placement of tree trunks, large branches, and wood pieces in embankment fill must not be allowed. Over time, these organic materials decay, causing localized settlement, and

they eventually form voids in the soil. Again, water entering these voids can lead to collapse and substantial subsidence of the pavement section. Likewise, placement of large stones and boulders in fills create voids in the mass, either unfilled due to bridging of soil over the large particles or filled with finer material that cannot be compacted with conventional equipment. Soil above these materials can migrate into the void space, creating substantial subsidence in the pavement section. These issues can be mitigated with well-crafted specifications that will prohibit the use of these types of materials.

Transitions between cut zones and fill zones can also create problems, particularly related to insufficient removal of weak organic material (clearing and grubbing), as well as neglect of subsurface water movements. A specific transition also occurs at bridge approaches. These problems are typically related to inadequate compaction, usually a result of improper compaction equipment mobilized to the site or lack of supervision and care (e.g., lift placement greater than compaction equipment can properly densify).

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F. Influence of Aggregate Properties on Permeability of Pavement Bases

The drainability of a pavement subbase is measured using the coefficient of permeability, denoted as k, which defines the quantity of water that flows through a material for a given set of conditions. The quantity of flow through a given medium increases as the coefficient of permeability increases.

The coefficient of permeability is defined as "the rate of discharge of water at 20° C under conditions of laminar flow through a unit cross-sectional area of a soil medium under a unit hydraulic gradient" (Thornton and Leong 1995). Coefficient of permeability measured in pavement subbases is denoted as hydraulic conductivity, which has the same units as velocity, and is expressed in units of length per time (cm/sec or feet per day). (Note: 1 cm/s = 2835 feet per day). Various properties that influence hydraulic conductivity of a pavement subbase include: gradation and shape of aggregate, hydraulic gradient, viscosity of the permeant, porosity and void ratio of the mix, and degree of saturation (Das 1990).

1. **Effect of Gradation and Shape of Aggregate:** According to Cedergren (1974), the life of a poorly drained pavement is reduced to one-third or even less of the life of a well drained pavement.

   Miyagawa (1991) conducted both laboratory and in-situ hydraulic conductivity tests on a wide range of pavement subbases in Iowa. Laboratory test results indicate that crushed limestone has higher hydraulic conductivity with a range of 7,000 to 36,900 feet per day, compared to crushed concrete with a range of about 340 to 12,780 feet per day. A procedure was developed to obtain a relative idea of in-situ hydraulic conductivity tests. This consisted of coring out an approximately 4 inch diameter hole to a depth of 4 to 5 inches, filling the hole with 1 liter of water, and measuring the time taken to drain the water from the hole. Compared to laboratory test results, in-situ tests produce on the order of 20 to 1,000 feet per day. This reduction is believed to be a result of changes in gradation during compaction of the subbase material.

2. **Thickness Design for Achieving Desired Drainability:** The major sources of water in pavement systems are surface infiltration, ground water seepage, and melting of ice lenses. A complete pavement drainage system is typically composed of an aggregate subbase, subdrains, and connections to storm sewage systems (see Section 6G-1 - Subsurface Drainage Systems). A positive drainage system should transport water from the point of infiltration to the final exit (transverse drains) through material having high hydraulic conductivity and should eliminate any conditions that would restrict the flow (Moulton 1980).

G. Construction Methods

Benefits of using open-graded permeable subbase layers are widely accepted throughout the world. But working with open-graded material in the field and obtaining a workable platform for the overlying surface is not yet well defined. According to White et al. (2004), significant segregation of fines is observed on subbase projects in Iowa, thus contributing to the high variation (coefficient of variation = 100%) in the measured in-place permeability. To reduce segregation, the following construction operations were recommended:

- A motor grader with a sharp angle (i.e., 45 degrees), should be used to push the aggregate transversely from a center windrow/pile, instead of spreading the aggregate material longitudinally along the pavement section (Pavement Technology Workshop 2000).
- When recycled PCC is used for granular subbases, construction traffic on the subbase should be minimized.
- A motor grader with GPS-assisted grading (i.e., stakeless grading control should be used to prepare the final surface for paving), rather than trimming equipment.

If trimming equipment must be used, the aggregate should be delivered to the site with sufficient water content (7% to 10%) to bind the fines during trimming to prevent segregation.

The key to a properly constructed subbase is keeping the material uniformly moist and homogeneously blended. The amended subbase material may be placed and trimmed with an auto-trimmer or dumped from trucks and spread with a motorgrader. The placement and compaction should be completed to minimize segregation and with a minimal increase in fines.

H. Quality Control/Quality Assurance Testing

1. In-situ Measurement of Stability of Aggregate Subbase:

a. Dynamic Cone Penetrometer (DCP) Test: DCP is an instrument designed for rapid in-situ measurement of the structural properties of existing pavements with unbound granular materials (Ese et al.1994). The cone penetration is inversely related to the strength of the material. DCP test is conducted according to ASTM D 6951 (Standard Test Method for Use of Dynamic Cone Penetrometer in Shallow Pavement Applications), which was first released in 2003. This test involves measurement of penetration rate per each blow of a standard 17.6-pound hammer, through undisturbed and/or compacted materials. Primary advantages of this test are its availability at lower costs and ease to collect and analyze the data rapidly (See Section 6E-1 - Subgrade Design and Construction, for more information).

b. Clegg Impact Hammer Test: This test was standardized in 1995 as ASTM D 5874, (Standard Test Method for Determination of the Impact Value IV of a Soil). This is a simple and rapid in-situ test that can be performed on subbase and subgrade materials. This test method is suitable to evaluate the strength characteristics of soils and soil aggregates having maximum particle size less than 1.5 inches (ASTM D 5874).

c. GeoGauge Vibration Stiffness Test: The GeoGauge is a 22 pound electro-mechanical instrument, which provides a direct measure of in-situ stiffness (MN/m) and modulus (MPa). The test is a simple non-nuclear test on soils and granular materials that can be performed without penetrating into the ground.

d. Portable Falling Weight Deflectometer (PFWD) Test: The PFWD test is a simple and rapid non-destructive test that does not entail removal of pavement materials, and hence is often preferred over other destructive methods. In addition, the testing apparatus is easily transported. Layer moduli can be back-calculated from the observed dynamic response of the subbase surface to an impulse load.

e. Falling Weight Deflectometer (FWD) Test: The FWD is a trailer-mounted system that is similar to the PFWD but generally imparts a higher load pulse to simulate vehicle wheel loads. FWD tests are normally performed on the pavement surface, but, with special testing criteria, they can be performed directly on granular base layers and can be used to back-calculate layer moduli up to about 6 feet deep. FWD results are often dependent on factors such as the particular model of the test device, the specific testing procedure, and the method of back-calculation (FAA 2004).

characteristics of the soil are to be improved.

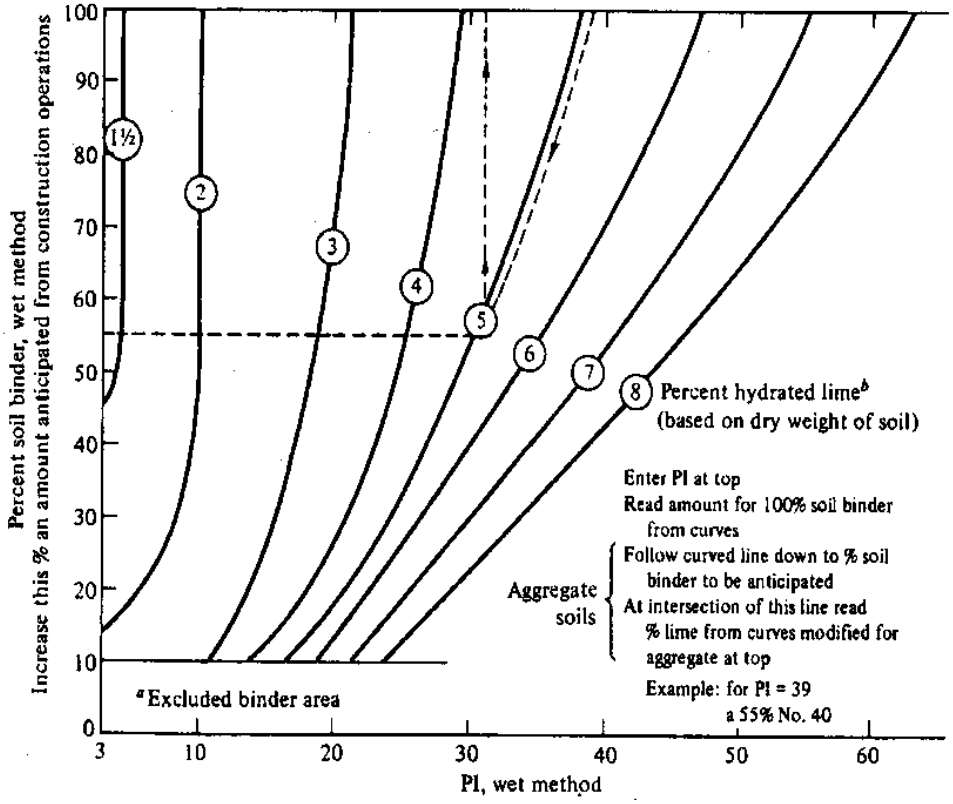
For successful lime stabilization of clay (or other highly plastic) soils, the lime content should be from 3 to 8% of the dry weight of the soil, and the cured mass should have an unconfined compressive strength increase of at least 50 psi after a 28 day curing period over the uncured material. The optimum lime content should be determined with the use of unconfined compressive strength and the Atterberg limits tests on laboratory lime-soil mixtures molded at varying percentages of lime. The lime-stabilized subgrade layer should be compacted to a minimum density of 95%, as defined by Standard Proctor density. The minimum strength requirement for this material is a function of pavement type and the importance of the layer within the pavement structure.

When soils are treated properly with lime, it has been observed that the lime-soil mixture may be subject to durability problems caused by the cyclic freezing and thawing of the soil.

Lime-fly ash stabilization is applicable to a broader range of soils because the cementing action of the material is less dependent on the fines contained within the soil. However, long-term durability studies of pavements with lime-fly ash stabilization are rather limited.

Soils classified as CH, CL, MH, ML, SM, SC, and GC with a plasticity index greater than 10 and with at least 25% passing the No. 200 sieve potentially are suitable for stabilization with lime. Hydrated lime, in powder form or mixed with water as slurry, is used most often for stabilization. Figure 6H-1.02 can be used to estimate the design lime content for a subgrade. The quantities found from this chart should be used as a guideline, and laboratory testing mix design studies should be conducted for specific applications. Additional information can be obtained in the National Lime Association's Lime Stabilization Construction Manual (1972).

Figure 6H-1.02: Recommended Amounts of Lime for Stabilization of Subgrade and Bases



Source: National Lime Association 1972

a. Cement Stabilization: Portland cement is used widely for stabilizing low-plasticity clays, sandy soils, and granular soils to improve the engineering properties of strength and stiffness. Increasing the cement content increases the quality of the mixture. At low cement contents, the product is generally termed cement-modified soil. A cement-modified soil has improved properties of reduced plasticity or expansive characteristics and reduced frost susceptibility. At higher cement contents, the end product is termed soil-cement. Higher cement contents will unavoidably induce higher incidences of shrinkage cracking caused by moisture/temperature changes.

For soils to be stabilized with cement, proper mixing requires that the soil have a PI of less than 20 and a minimum of 45% passing the No. 40 sieve. However, highly plastic clays that have been pre-treated with lime or fly ash are sometimes suitable for subsequent treatment. For cement stabilization of granular and/or non-plastic soils, the cement content should be 3 to 10% of the dry weight of the soil, and the cured material should have an unconfined compressive strength of at least 150 psi within seven days. The Portland cement should meet the minimum requirements of AASHTO M 85. The cement-stabilized subgrade should be compacted to a minimum density of 95%, as defined by AASHTO T 134. Only fine-grained soils can be treated effectively with lime for marginal strength improvement.

b. Asphalt Stabilization: Generally, asphalt-stabilized soils are used for subbase construction. Use of asphalt as a stabilizing agent produces different effects, depending on the soil, and may be divided into three major groups:

1) Sand-asphalt, which produces strength in cohesionless soils, such as clean sands, or acts as a binder or cementing agent
2) Soil-asphalt, which stabilizes the moisture content of cohesive fine-grained soils
3) Sand-gravel asphalt, which provides cohesive strength and waterproofs pit-run gravelly soils with inherent frictional strength. The durability of asphalt-stabilized mixtures generally can be assessed by measurement of their water absorption characteristics.

c. Fly Ash Stabilization: Fly ash and similar materials can be used in the stabilization of clay soils either in place of lime or cement or in combination with lime and cement. Generally, the use of fly ash and similar materials reduces the shrink-swell properties of the soils. Additionally, the act of drying the soil facilitates soil compaction. These materials are used with clay-type soils that are above the optimum water content.

3. Characteristics of Stabilized Soils: The improvement of subgrade or unbound aggregate by application of a stabilizing agent is intended to cause the improvements outlined above. These improvements arise from several important mechanisms that must be considered and understood by the pavement designer. Subgrade stabilizing agents may fill or partially fill the voids between the soil particles. This reduces the permeability of the soil by increasing the tortuosity of the pathways for water to migrate through the soil. Reduction of permeability may be relied upon to create a waterproof surface to protect underlying, water-sensitive soils from the intrusion of surface water. This mechanism must be accompanied by other aspects of the geometric design into a comprehensive system. The reduction of void spaces may also tend to change the volume change under shear from a contractive to a dilative condition. The stabilizing agent also acts by binding the particles of soil together, adding cohesive shear strength, and increasing the difficulty with which particles can move into a denser packing under load. Particle binding serves to reduce swelling by resisting the tendency of particles to move apart. The particles may be bound together by the action of the stabilizing agent itself (as in the case of asphalt cement), or may be cemented by byproducts of chemical reactions between the soil and stabilizing agent (as in the case of lime or portland cement).

Rip Rap

Source: Mississippi State University

BENEFITS

	L	M	H
Flow Control		■	
Erosion Control		■	
Sediment Control			
Runoff Reduction			
Flow Diversion			

Description: Rip rap is a common method of protecting a channel downstream of a storm sewer or culvert outlet from erosion. A layer of crushed stone placed on the bottom and sides of the channel protects the channel and dissipates the energy of the high velocity flow.

Typical Uses: Used at the outlet of storm sewer pipes, roadway and driveway culverts, and at any point concentrated runoff enters a channel.

Advantages:
- Widely used method of erosion protection.
- Materials are readily available in most areas.
- Effective at reducing scour when properly designed and installed.

Limitations:
- Commonly undersized.
- Not aesthetically pleasing.
- May not be adequate for flows from large pipes (>48 inches).
- May be higher cost due to limited availability of stone.

Longevity: Temporary or permanent

SUDAS Specifications: Refer to Section 9040, 2.09 and 3.13

A. Description/Uses

The most common method of protecting a channel at an outlet is to place a layer of crushed stone along the bottom and sides of the channel. The purpose of the stone is to protect the channel until the outlet flow loses sufficient velocity and energy, so that erosion will not occur in the downstream channel. Rip rap is provided by constructing a blanket of crushed stone, to a specified depth at the outlet. The layer of the stone is constructed so that the top is flush with the invert elevation of the outlet pipe. The stone should be placed on a layer of engineering fabric to protect the underlying soil from the erosive action of the churning water.

For larger pipes, or for discharges from pipes with large head pressures, greater protection may be required. Additional protection can be provided by constructing a rock-lined plunge pool, stilling basin, or through the use of concrete energy dissipaters (see Chapter 2 - Stormwater).

B. Design Considerations

The following design information only applies to the design of rock protection at outlets. It does not apply to rock lining of channels or streams. In addition, the design of rock plunge pools or stilling basins, and other types of energy dissipaters is not covered in this section. Refer to the Federal Highway Administration Hydraulic Engineering Circular No. 14 (HEC-14), "Hydraulic Design of Energy Dissipators for Culverts and Channels" for information on designing these structures.

The Iowa DOT Culvert Program (version 2.0) includes three methods of designing rock protection at the outlet of culverts. The methods include HEC-14 rip rap basins, U.S. Army Corps of Engineers scour hole design and U.S. Bureau of Reclamation plunge basin design. This program is available online and can be obtained from the Iowa DOT's Bridges and Structures Bureau.

The steps below describe the method of designing rip rap:

1. **Tailwater Depth:** The first step is to find the tailwater depth at the pipe outlet, corresponding to the appropriate design-year storm event for the outlet structure (see Chapter 2 - Stormwater) for design criteria for various structures). Normally, the tailwater depth is found by determining the normal depth in the channel using Manning's equation (see Chapter 2 - Stormwater). If downstream restrictions such as a culvert, dam or channel constriction exist, a more thorough analysis is required.

   If the tailwater is less than half of the discharge flow depth (pipe diameter or box height if flowing full) it is classified as a *minimum tailwater condition.* If the tailwater is greater than or equal to half of the discharge flow depth, it is classified as a *maximum tailwater condition.* The tailwater condition will determine which figure (Figure 7E-10.03 or 7E-10.04) to use to find the necessary rock size and apron dimensions.

   Pipes that outlet onto flat areas without a well-defined channel can be assumed to have a minimum tailwater condition.

   If the tailwater condition cannot be easily determined for a channel, the apron should be designed for the maximum tailwater condition as a conservative approach.

2. **Stone Size:** As the discharge flows over the crushed stone, the flow imposes shear stresses on the individual stones. Since the stones are only held in place by the force of gravity, they must have sufficient mass to prevent them from being dislodged by the force of the flowing water. For rip rap design, the crushed stone material is selected based upon its average, or d_{50}, diameter. The d_{50}

Rock Chutes and Flumes

BENEFITS

	L	M	H
Flow Control	■	■	
Erosion Control	■	■	■
Sediment Control			
Runoff Reduction			
Flow Diversion			

Description: Rock chutes and flumes are devices used to convey concentrated flows down an embankment or slope to a lower level without causing erosion.

Typical Uses: Commonly used as a permanent feature at the release point where runoff enters a ditch, stream, or lake. They are also used as a temporary measure to stabilize the inlet slope to a sediment trap or basin.

Advantages:
- Stabilizes slopes and areas where high flow volumes occur.
- Prevents further erosion at entrance to sediment removal devices, reducing the required cleanout frequency.

Limitations:
- May not be considered aesthetically pleasing for permanent installations.
- May be a relatively expensive measure for temporary structures.
- Requires careful construction practices.
- Difficult to maintain level, especially through freeze-thaw cycles.

Longevity: Permanent

SUDAS Specifications: Refer to Section 9040, 2.09 and 3.13

A. Description/Uses

Rock chutes are devices used to stabilize the inlet slopes to sediment traps, sediment basins, rivers, ponds, lakes, and other drainage structures. The chutes consist of a rock-lined channel constructed on a steep slope.

Proper construction of the rock chute is imperative to its performance. The chute must be carefully notched into the ground to the thickness of the rock, to ensure positive drainage into the chute from the edges. If drainage into the chute from the edges is not provided, runoff will flow along the top of the chute, creating the potential for scouring under the chute.

After constructing the chute to the appropriate cross-section, a layer of engineering fabric is usually placed to protect the underlying soils. Crushed stone of the size or weight specified is then placed over the fabric, creating a stable surface to transport large flows down steep grades.

B. Design Considerations

The design of a rock chute is dependent on several factors including: the steepness of the slope; the shape of the channel; the volume and velocity of the water; the size of the rip rap material; and the downstream tailwater.

In order to simplify the process of designing and sizing a rock chute, a spreadsheet has been developed by the Iowa Division of the National Resource Conservation Service (NRCS). This spreadsheet is available on the internet and may be accessed from the following address: https://www.nrcs.usda.gov/wps/portal/nrcs/ia/technical/engineering/nrcs142p2_008213/.

For permanent structures, an articulated or modular block system may also be considered. These products may be more aesthetically pleasing than a rock chute. Many can be vegetated to hide or mask the underlying armoring. Design information for these products is available from their respective manufacturers.

Installation of a turf reinforcement mat (TRM) might also be considered as an alternative to a rock chute (see Section 7E-18)

C. Application

Rock chutes should be considered at all locations where an elevation drop may create flow velocities that exceed the ability of the existing ground surface (bare or vegetated) to prevent erosion.

D. Maintenance

If designed and installed properly, maintenance of rock chutes is normally minimal. If the chute is left over a winter, it should be inspected in the spring to ensure that it is level. Any movement caused by freeze-thaw should be corrected.

Ductile Iron Pipe

A. Introduction

Ductile iron pipe is used primarily as water main, but is also used as force main and for some specialized gravity flow situations. Since the pipe is constructed of ductile iron, it can deflect without failing and behaves similar to a flexible plastic pipe. However, ductile iron pipe has some additional properties that warrant a slightly different design methodology than previously described for flexible plastic pipes.

B. Pipe Design

The first step in analyzing a ductile iron pipe for structural capacity is to determine what pipe thickness to use. Currently, there are two different pipe classifications for ductile iron pipe: Pressure Class and Thickness Class. SUDAS requires Thickness Class 52 pipe for all water main 24 inches or smaller. Unlike PVC pipe, ductile iron pipe does not follow a standardized diameter ratio (DR), so there is no easy method of determining the wall thickness based upon diameter. Pipe standard AWWA C151 indicates the nominal wall thicknesses for Class 52 pipe. However, the values listed in the AWWA standard are not the values used for design purposes. The AWWA values include a casting allowance to ensure that negative thickness deviations do not occur during the casting process. The casting allowance varies from 0.05 to 0.09 inches, depending on diameter. A service allowance of 0.08 inches is also included in the wall thickness to account for material loss from the pipe over its service life. These values are subtracted from the stated wall thickness to determine the design thickness.

Once the design thickness of the pipe is known, the pipe can be analyzed for deflection. Just like flexible pipes, ductile iron can undergo significant deflections without damage. However, the allowable deflection for ductile iron pipe is normally limited to 3%. This limitation is imposed to protect the cement-mortar lining on the inside of ductile iron water pipe.

In addition to deflection limitations, the ring bending stress in the pipe must also be determined. Maximum ring bending stress occurs at the invert of the pipe. If the stress exceeds the yield stress of the ductile iron material, the pipe will undergo permanent deformation.

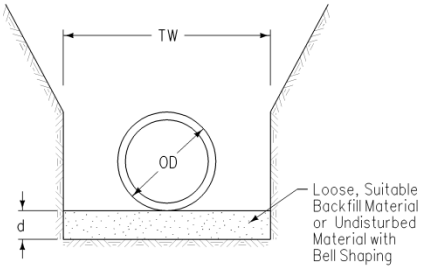
The equations and procedures for determining pipe deflection and ring bending stress are provided in the Ductile Iron Pipe Research Association's (DIPRA) publication "Design of Ductile Iron Pipe."

C. Bedding

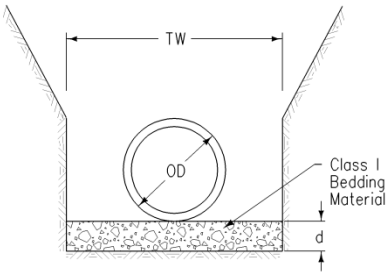
For shallow installations, ductile iron pipe can be installed without granular bedding material. However, the sidewall support from granular bedding material allows ductile iron pipe to carry greater loads then the pipe could by itself. This is an important consideration for deep installations. For example, the maximum depth of bury for a 24 inch Thickness Class 52 ductile iron pipe in a Class P-1 bedding (native soil) is 16 feet. The allowable depth of bury for the same pipe in a Class P-3 bedding (crushed stone encasement) is 38 feet.

Figure 9B-4.01 shows the standard bedding classes for pressure pipe installations. Refer to Section 9B-3 - Flexible Pipes, regarding bedding requirements for ductile iron pipe when used in a gravity flow installation.

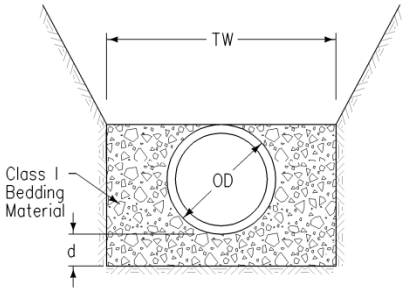
Figure 9B-4.01: Pressure Pipe Bedding Types



Class P-1



Class P-2



Class P-3

Utility Cut Restoration

A. General

Utility cuts are made in existing pavement sections to install a myriad of utilities and to repair those that experience maintenance needs. Once a utility cut is made in the pavement, the restoration materials and process will have a significant impact on the life of the pavement patch. When a utility cut is made, the native material surrounding the perimeter of the trench is subjected to loss of lateral support. This leads to loss of material under the pavement and bulging of the soil on the trench sidewalls into the excavation. Subsequent refilling of the excavation does not necessarily restore the original strength of the soils in this weakened zone. The weakened zone around a utility cut excavation is called the "zone of influence." Poor performance of pavements over and around utility trenches on local and state systems often causes unnecessary maintenance problems due to improper backfill placement (i.e., under compacted, too wet, too dry). It has been reported that the life of a utility cut replacement patch is only 2 to 3 years. The costs of repairing poorly performing utility cut restorations can potentially be avoided with a better understanding of proper material selection and construction practices. In addition to the resources spent by the public agency to maintain the pavement patch area, there is a significant impact to the traveling public due to rough streets and the traffic interruptions that occur frequently when maintenance activities are occurring.

The improper use and placement of backfill materials and failure to provide for the loss of lateral support of the trench walls are the primary causes of pavement patch failure.

While planning of utility modifications can be accommodated as part of a larger project, frequently these excavations occur at odd-hours and with no advance notice to repair a facility (i.e., water main break). It is therefore important to plan ahead to help ensure that desirable methods are used to restore utility trenches, even when weather, timing, or other factors may be less than ideal.

B. Background

The Iowa Highway Research Board (IHRB) commissioned two projects focusing on how best to reconstruct utility trenches. The goal of the projects has been to mitigate the negative effects utility trenches have on the surrounding roadway pavement. The two studies are described below.

- IHRB Project TR-503 (2005) Utility Cut Repair Techniques - Investigation of Improved Cut Repair Techniques to Reduce Settlement in Repaired Areas
- IHRB Project TR-566 (2010) Utility Cut Repair Techniques - Investigation of Improved Utility Cut Repair Techniques to Reduce Settlement in Repaired Areas, Phase II

The above reports can be accessed at the following websites:

- www.intrans.iastate.edu
- https://iowadot.gov/research/reports-publications/reports-library

The research identified the following problems with current trench restoration methods:

- Large equipment bearing on the trench edges (causing damage to the trench sidewalls and the remaining pavement)

- 2 to 4 foot lifts of backfill material
- Sporadic compaction of the backfill lifts
- Utilizing native, saturated material in the excavation in an attempt to clean the excavation site
- General lack of density and moisture quality control

The research identified three modes of failure for the utility trenches.

- Settlement of utility cut restoration, caused by poor compaction and wet/frozen conditions
- A "bump" forming over the restoration, resulting from uplift or settlement of surrounding soil
- Weakening of the surrounding soils

Many of the studied patches showed signs of failure within 2 years.

C. Factors Affecting Patch Performance

1. **Compaction:** Proper compaction of the non-manufactured backfill material is a critical element of good trench construction. Use of granular backfill has previously been thought of as a means to achieve an acceptable level of trench compaction with a minimal level of effort; however, that is not the case. Even with granular materials, the material should be placed in lifts not exceeding 12 inches in thickness. Each lift of granular material should receive an appropriate level of compactive effort to achieve a minimum relative density of 65%. If cohesive soils are used in the top 2 feet to match existing subgrade materials, the soil should be placed in 8 inch lifts and compacted to 95% of Standard Proctor Density for that soil.

   Backfill materials are often compacted using large compaction equipment, which is placed close to the edges of the cut, resulting in damage to pavement surfaces around the perimeter of the excavation. Note Figure 9D-1.01. It is important to keep equipment away from the edges of the trench.

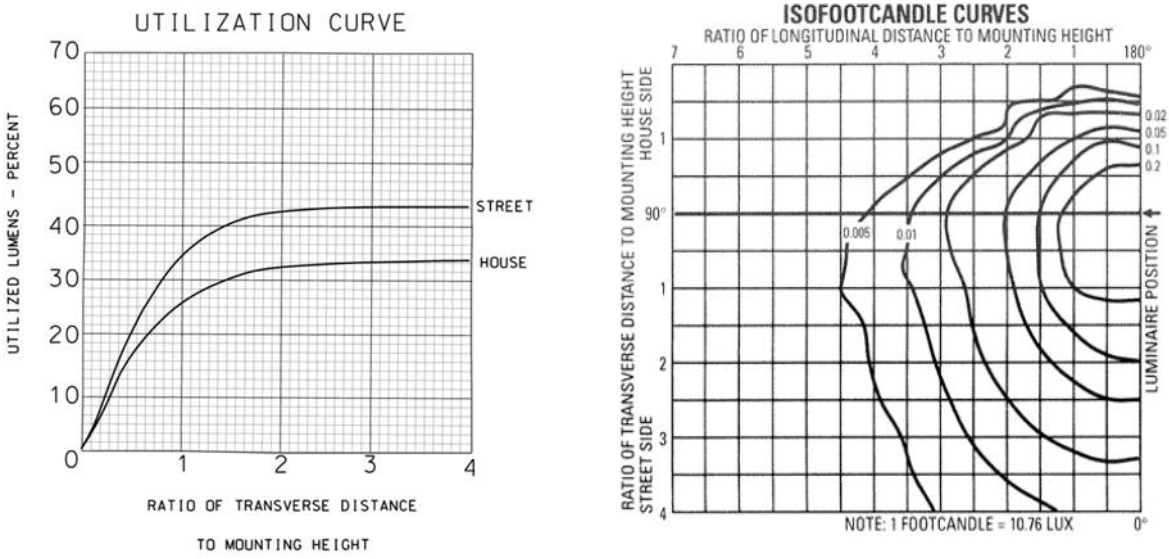
Figure 9D-1.01: Cracking Pavement Surrounding the Utility Cut Area Because of Construction Equipment Getting Too Close to the Edge of the Open Cut

Source: IHRB Project TR-566

6. **Checking for Design Adequacy:** All of the above selected elements are formed into a design concept or model. The next step is to perform calculations to verify the chosen equipment and layout to meet the design criteria. For many years, manual calculations were the only methods used to determine the resulting design illumination and uniformity. Numerous software programs have been developed and are available to automate the calculation process.

   a. **Manual Calculation Method:** The most popular manual calculation method is the coefficient of utilization and isofootcandle plot method. As the name implies, two pieces of graphical information are required, a coefficient of utilization curve and an isofootcandle plot. These are developed by luminaire manufacturers and are required for the calculation process. Examples of such are shown in Figure 11C-1.02. The coefficient curve is a quantitative description of the percentage of total lumens emitted from the fixture that will land on or be utilized to illuminate the street below based on the street width and relative position of the luminaire to the street.

Figure 11C-1.02: Typical Luminaire Utilization and Isofootcandle Plots



Rather than repeat the process here, the designer is recommended to visit and access Minnesota DOT Roadway Lighting Design Manual, Chapter 4. The discussion in this document provides a good step-by-step description of the manual calculation process.

   b. **Computer Modeling Method:** There are numerous programs available, both purchased and free to model lighting installations and perform photometric calculations. Some software packages can be very sophisticated with the ability to create such things as shade plots and shade and shadow renderings to closely represent what the human eye would see. For the design purposes described herein, all that is required of the software is to take luminaire photometric data and perform point-by-point calculations on a defined plane and be able to export the numerical results.

   The first requirement is to create a computer model of the street to be lit. For most situations, this involves defining the width and length of the street. Most of the lighting programs have drawing tools to create the model directly in the program. If an electronic representation of the street is available from a computer-aided design file such as that created by AutoCAD or Microstation, this can be imported into the lighting program to form the model. Once this is done, the designer will "place" luminaires spatially above the model surface locating them with the desired mounting height and overhang from the street edge.

For each luminaire type to be considered, the designer needs to acquire a photometric file that describes the photometry or lighting distribution characteristics of the luminaire. These files are generated by the manufacturer through laboratory testing. They are text files containing a defined array of light intensity values (candela) in standardly defined spatial directions emanating from the luminaire. The files are commonly referred to as IES photometric files (or IES files) since the standard was developed by the Illuminating Engineering Society (IES). The files are readily available from the manufacturer's website at no cost.

The files are imported into the program to model the performance of the selected luminaires. The candela values in the file are typically based on a default lamp lumen value of 1,000 lumens. The designer will be required to input the proper initial lamp lumen value, which will scale the intensity values accordingly. For LED luminaires however, the file usually contains the actual initial lumen value of the luminaire assembly since the LEDs are not necessarily a removable modular element of the luminaire. In any case, the designer is cautioned to verify the proper lumen value is used. Also, the designer will need to enter the lumen maintenance factor for each luminaire model.

The final task is to define a calculation area by drawing a region on the street model surface. Confirm with the municipality to determine any potential requirements for defining the calculation area. The width of the area could be back of curb to back of curb for example, or it could be right-of-way to right-of-way to calculate the illumination from building face to building face in a downtown business district. Within this area, the designer will create a calculation grid that is a defined set of points on the surface, at which the lighting level will be calculated. Typical calculation point grids are a 10 feet by 10 feet or a 5 feet by 5 feet rectangular array. More points in the calculating area will usually yield more accurate results but require more computer processing time. For a small area, this is not a problem, but if the designer has created a large area, the time may be significant. The RP-8-14 recommends locating two grid lines per lane, one-quarter of the distance from each lane line. It continues to indicate that points along the gridlines should not be placed further than 5 meters (16 feet) apart and have at least 10 calculation points located between each luminaire. This applies for both luminance and illuminance methods.

The program utilizes the superposition principal to perform the calculation. The program will step through each point and calculate the luminance/illuminance contribution at that point on the model surface from each luminaire defined in the model. Each of these contribution values are simply added together to get the overall illumination at that point. Once all of the points are calculated, the program determines the average value of all of the points in the grid, giving the average luminance or illuminance of the entire surface. The program then uses the point with the lowest value to calculate the average-to-minimum uniformity ratio.

A clear advantage of using computer modeling is the ease in which the designer can make changes to the luminaire layout model and obtain the luminance or illuminance results for different scenarios. For example, the designer could change luminaire, type, wattage, mounting height, or position; or any combination of these to optimize the lighting design and minimize the energy consumption.

Most available lighting design software packages contain pre-defined street models or "wizards" for quick luminaire spacing optimization. This allows a designer to simply input a luminaire at a mounting height, a street width, a mounting pattern (one-side, each side staggered, etc.), and target design criteria, and have the program calculate the optimum longitudinal luminaire spacing.

Pedestrian Facilities During Construction

A. Introduction

When projects impact pedestrians, it is important for the engineer to develop a temporary traffic control plan for pedestrians, including those with disabilities. For Iowa DOT projects, see Iowa DOT Design Manual Section 9A-5 for temporary traffic control plans. The applicable guidelines for the temporary traffic control plan are the July 26, 2011 "Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way" (PROWAG) and the Manual on Uniform Traffic Control Devices (MUTCD).

According to PROWAG, when a pedestrian circulation path is temporarily closed for construction or maintenance activities, an alternate pedestrian access route complying with sections 6D.01, 6D.02, and 6G.05 of the MUTCD shall be provided (R205). However, MUTCD (Section 6D.01) also requires knowledgeable persons to conduct appropriate evaluations or use engineering judgment in determining temporary traffic controls for pedestrian circulation paths. This section includes guidance on conducting the evaluation when an alternate pedestrian access route may not be practical.

B. Evaluating Pedestrian Needs

The initial design activity should be to determine the level of the accessibility of the current pedestrian circulation path within the area of the project and the adjacent areas. The impact to the pedestrian circulation path, including transit stops, from the construction or maintenance activity needs to be determined. Develop pedestrian accommodations to provide the best accessibility practical through all stages of work. Consider obtaining local input through a public meeting or contact with residents or public officials to see where additional accessibility needs should be addressed (e.g. senior centers, medical facilities, schools, public facilities, etc.).

Whenever possible, the work should be done in such a manner that does not create a need to detour pedestrians from existing routes. Pedestrians rarely observe detours and the cost of providing accessibility and detectability might outweigh the cost of maintaining a continuous route through the construction zone (MUTCD 6D-01). All methods should be given consideration, including providing alternate means of traversing the construction zone. If pedestrians are to be directed through the construction zone, safety as well as accessibility must be addressed. If a pedestrian detour is developed, it should replicate the accessibility of the existing route.

C. Facility Options

To address the impacts to the pedestrian circulation path, including transit stops, consider the following:

- Develop a temporary traffic control plan to guide the pedestrians through the construction zone.
- Close the pedestrian circulation path through the construction zone.
- Close the pedestrian circulation path through the construction zone; develop a detour route consistent with the accessibility features present in the pedestrian circulation path being closed.
- Provide alternate means for pedestrians to traverse the construction zone, such as free accessible shuttles or other forms of assistance.

D. Barricades, Channelizing Devices, and Signs

Pedestrian barricades and channelizing devices shall comply with sections 6F.63, 6F.68, and 6F.71 of the MUTCD.

1. **Barricades:** Barricades are used for pedestrian circulation path closures. See Iowa DOT Specifications Section 2528.

2. **Channelizing Devices:** The designer should consider the safety of pedestrians and vehicles when choosing channelizing devices.

   a. **Type A:** Type A devices are redirective barriers designed for highway applications. These devices are suitable when pedestrians are routed into the travel way and allow for the most protection for pedestrians from vehicular intrusion.

   b. **Type B:** Type B devices are crashworthy but do not redirect vehicles. These devices are designed to minimize risks associated with flying debris.

   c. **Type C:** Type C devices include any device that meets ADA requirements for channelizing pedestrians and may not be crashworthy. These devices are for locations where vehicular intrusions are unlikely (e.g. closed roads, when there is a separation between pedestrians and vehicular traffic, or where vehicular traffic is at low speeds).

3. **Signs:** See Iowa DOT Standard Road Plan TC-601 and TC-602.

E. Temporary Pedestrian Facilities

Temporary pedestrian facilities should comply with the other sections within this chapter to the extent practical. It is strongly recommended that detour routes be on paved surfaces.

Temporary pedestrian facility surfaces must be firm, stable, and slip resistant. Granular surfacing for short term, temporary pedestrian facilities is acceptable. The granular surfacing material should be well graded, such as Class A road stone (Iowa DOT Specifications Section 4109, Gradation No. 8) or special backfill (Iowa DOT Specifications Section 4109, Gradation No. 30). Maintenance of the temporary pedestrian facility surface to meet the firm, stable, slip resistant, and minimum width is required at all times. The temporary pedestrian facility surface must be removed and a permanent pedestrian facility must be replaced prior to the end of the construction season.

F. Utility Construction

If the pedestrian circulation path is disturbed during utility construction, the requirements of this section and Section 12A-2 shall apply.

Shared Use Path Design

A. Accessible Shared Use Path Design

1. **General:** Applicable portions from the following draft documents were used to develop this section.

   a. **AASHTO Bike Guide:** The fourth edition (2012) of the AASHTO "Guide for the Development of Bicycle Facilities" (or *AASHTO Bike Guide*). References made to the *AASHTO Bike Guide* within this section are shown in parentheses, e.g. (AASHTO 5.2.1).

   b. **AGODA:** The June 20, 2007 Proposed Architectural Barriers Act "Accessibility Guidelines for Outdoor Developed Areas" (AGODA). This document is primarily used for shared use paths designed as bicycle facilities.

   c. **PROWAG:** The July 26, 2011 "Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way," also known as the Public Right-of-Way Accessibility Guidelines or PROWAG. This document is primarily used for shared use paths designed as sidewalks.

2. **Documenting Exceptions:** If the project cannot fully meet the minimum requirements included within this section, a document should be developed to describe why the minimum requirements cannot be met. It is recommended that this document be retained in the project file. For local agency projects administered through Iowa DOT, a certification with supporting documentation shall be submitted to the Iowa DOT administering office. The certification shall be as prescribed by the Iowa DOT and signed by a registered professional engineer or landscape architect licensed in the State of Iowa. For Iowa DOT projects, contact the Design Bureau, Methods Section.

B. Shared Use Path Categories

1. **Type 1:** A shared use path adjacent or in close proximity to the roadway and functions similar to a sidewalk. In rural cross-sections, these paths would be at the top of the foreslope. These paths are generally used for transportation purposes.

2. **Type 2:** A shared use path similar to Type 3, except they serve as a transportation route to facilities that fulfill a basic life need, provide access to a program or service, or provide a safe route for non-drivers.

3. **Type 3:** A shared use path in independent right-of-way or not in close proximity to the roadway. Although Type 3 paths may fulfill a transportation function, these paths primarily serve a recreation and fitness benefit.

One shared use path project may have different combinations of Type 1, Type 2, and/or Type 3 segments, based on location and function. If Federal or State funding is being used on a project, the funding application should identify where Type 1, Type 2, or Type 3 segments will be used.

C. Shared Use Path Design Elements

The following considerations should be used as a guide when designing shared use paths.

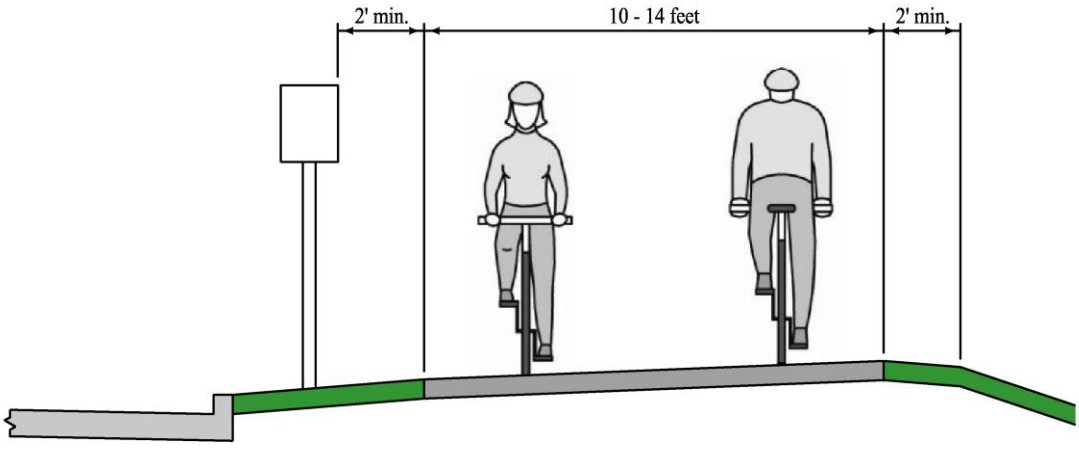
1. **Width:** A bicyclist requires a minimum of 4 feet and a preferred 5 feet of essential operating space based upon their profile. The typical path width is 10 feet to accommodate two-way traffic. Consider wider paths (11 to 14 feet) when at minimum one of the following is anticipated:
    - User volume exceeding 300 users within the peak hour.
    - Curves where more operating space should be provided.
    - Large maintenance vehicles.
    - There is a need for a bicyclist to pass another path user while maintaining sufficient space for another user approaching from the opposing direction. 11 feet is the minimum width for three lanes of traffic.

    Path width can be reduced to 8 feet where the following conditions prevail:
    - Bicycle traffic is expected to be low.
    - Pedestrian use is generally not expected.
    - Horizontal and vertical alignments provide well-designed passing and resting opportunities.
    - The path will not be regularly subjected to maintenance vehicle loading conditions.
    - A physical constraint exists for a short duration such as a utility structure, fence, etc.

    Path widths between 8 and 5 feet should be avoided; paths less than 5 feet do not meet ADA requirements.

    If segregation of pedestrians and bicycle traffic is desirable, a minimum 15 foot width should be provided. This includes 10 feet for two-way bicycle traffic and 5 feet for two-way pedestrian traffic. (AASHTO 5.2.1).

Figure 12B-2.01: Typical Cross-Section of Two-Way Shared Use Path on Independent Right-of-Way



Source: Adapted from *AASHTO Bike Guide* Exhibit 5.1

2. **Minimum Surface Thickness:** For Iowa DOT projects, contact the Pavement Design Section in the Design Bureau for a pavement determination. For local agency projects administered through Iowa DOT, Iowa DOT will accept the thickness design as determined by the engineer.

For local projects, the pavement depth for both PCC and HMA pavements should have a minimum of 4 inches and a recommended thickness of 5 inches; if pavement thickness is proposed to be less than 4 inches, a pavement determination should be completed and documented.

3. **Cross Slope:** Shared use paths must have the capabilities to serve people with disabilities.
   a. **Type 1 and Type 2:** Cross slopes shall not exceed the requirements in Section 12A-2.
   b. **Type 3:** A 1.5% cross slope is recommended, but cross slopes should be a minimum of 1% and shall not exceed 5%. Cross slopes greater than 2% should be sloped to the inside of the horizontal curve regardless of drainage conditions. On unpaved paths, cross slopes may increase up to 5% due to the need of draining water off the path. On rare bicycle only facilities, the path does not need to meet accessibility guidelines and the cross slope can be between 5% and 8%. Cross slope transition should be comfortable for the user; therefore, a minimum transition length of 5 feet for each 1% change in cross slope should be used.

4. **Separation of Roadway and Path:** A separation should be provided between a two-way shared use path and the adjacent roadway to demonstrate to both the bicyclist and the vehicle driver that each facility is independent of the other. This is particularly important at night. If the separation from the face of the curb or the edge of the traveled way to the near edge of the path is less than 5 feet, a barrier or railing is recommended. The barriers or railings need not be of the size and strength to redirect errant motorists unless a crashworthy barrier is needed due to high speeds and clear zone requirements. Barriers at other locations serving only as a separation should be the height of standard guardrail.

   If needed, barriers and railings should be used, but since they can create considerable concerns in urban areas due to aesthetics, visibility, and maintenance problems, it may be necessary to initiate the documenting exceptions process (Section 12B-2, A, 2). The separation between the face of the curb and the path should be maximized, but with the presence of the curb, some landscaping area, and street lighting, the overall objectives of the separation can be satisfied.

5. **Lateral and Vertical Clearance:** Perhaps the most critical factor in developing safe and comfortable shared use path facilities is the provision of adequate clearance to a wide variety of potential obstructions that may be found along a prospective route. Guidelines for lateral and vertical clearance are particularly important in view of the wide range of riding proficiency that is found among riders. Clearance consideration must include:

   a. **Lateral Clearances to Fixed and Movable Obstructions:** A 2 foot minimum graded area with a 6:1 maximum cross slope (i.e., shoulder area) should be provided for clearance from lateral obstructions such as trees, poles, and bridge abutments measured from the edge of the pathway. The MUTCD requires a 2 foot minimum clearance to the sign face of post-mounted signs.

      If a barrier or rail is necessary, a minimum of 1 foot lateral offset from the edge of the path is desirable. Barriers terminating within 2 feet of the edge of the path should be marked with object markers. It is undesirable to place the pathway in a narrow corridor between 2 fences for long distances.

      A designer may want to consider that a typical ambulance width (including mirrors) is 11 feet.

      When minimum clearance cannot be achieved, refer to Section 12A-3 for protruding object requirements; refer to the *AASHTO Bike Guide* for mitigation measures, such as pavement markings, delineation, and signing.

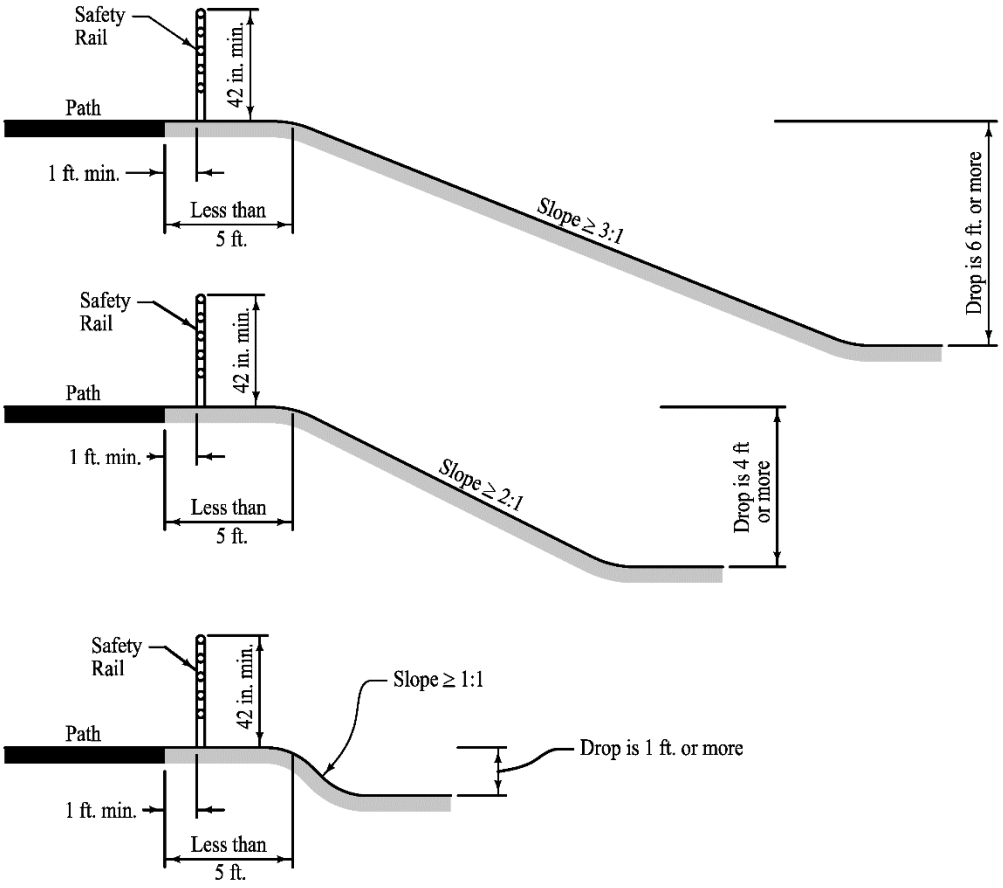
b. Vertical Clearances to Overhead Obstructions: The minimum vertical clearance is 10 feet. In some situations, such as tunnels and bridge underpasses, the vertical clearance should be greater than 10 feet in order to accommodate maintenance and emergency vehicles. In constrained areas, AASHTO allows the vertical clearance to obstructions to be a minimum of 8 feet. (AASHTO 5.2.1).

Refer to Section 12A-3 for legal requirements in low clearance situations.

6. **Shoulder Width and Slope:** The minimum graded shoulder width is 2 feet. The maximum shoulder area cross slope is 6:1.

7. **Safety Rail:** Safety rail should be a minimum of 42 inches in height. Provide safety rails at the outside of a structure. On steep fill embankment as described below, provide a safety rail or widen the shoulder area to 5 feet. (AASHTO 5.2.1)
   - Slopes 3:1 or steeper with a drop of 6 feet or greater.
   - Slopes 3:1 or steeper adjacent to a parallel body of water or other substantial obstacle.
   - Slopes 2:1 or steeper with a drop of 4 feet or greater.
   - Slopes 1:1 or steeper with a drop of 1 foot or greater.

Figure 12B-2.02: Safety Rail between Path and Adjacent Slope



See Iowa DOT Design Manual Section 12B-10 for guidance on safety rails.

Source: Adapted from *AASHTO Bike Guide* Exhibit 5.3

8. Design Speed and Alignments:

a. Type 1: Grades shall meet the requirements of Section 12A-2.

b. Type 2: Grades shall be less than or equal to 5% and all other Type 3 requirements should be met.

c. Type 3: There is no single design speed that is recommended for all paths. In general, a minimum design speed of 18 mph should be used, unless posted for slower speeds or in areas of steeper decline, in which case the design speed should be adjusted according to Table 12B-2.01. (AASHTO 5.2.4)

Table 12B-2.01: Minimum Design Speed and Horizontal Alignment

Terrain	Design Speed (mph)	Minimum Radius[1] (Horizontal Curve) (feet)
Grades less than 2%	18	60
Grades less than or equal to 5%	25	115
Grades 6% and more	30	166

[1] Based on 20 degree maximum lean angle

Source: *AASHTO Bike Guide* 5.2.4

The minimum radius of curvature negotiable by a bicycle can be calculated using the lean angle of the bicyclist or the superelevation and coefficient of friction of the shared use path. The minimum radii of curvature for a paved path are shown in Table 12B-2.02 based on lean angle of the cyclists.

Table 12B-2.02: Minimum Radii for Lean Angle of Cyclists

Design Speed (mph)	Minimum Radius (feet)
12	27
14	36
16	47
18	60
20	74
25	115
30	166

Source: *AASHTO Bike Guide* Exhibit 5.6

The minimum radii of curvature for a paved path based on superelevation should be calculated per the equations shown in the *AASHTO Bike Guide*. (AASHTO 5.2.2, 5.2.5, 5.2.6, and 5.2.8).

Table 12B-2.03 and Figure 12B-2.03 should be used to determine the minimum clearance necessary to avoid line-of-sight obstructions for horizontal curves. The lateral clearance (horizontal sight line offset or HSO) can be obtained from Table 12B-2.03, given the stopping sight distance from Equation 12B-2.01 and the proposed horizontal radius of curvature. Lateral clearances on horizontal curves should be calculated based on the sum of

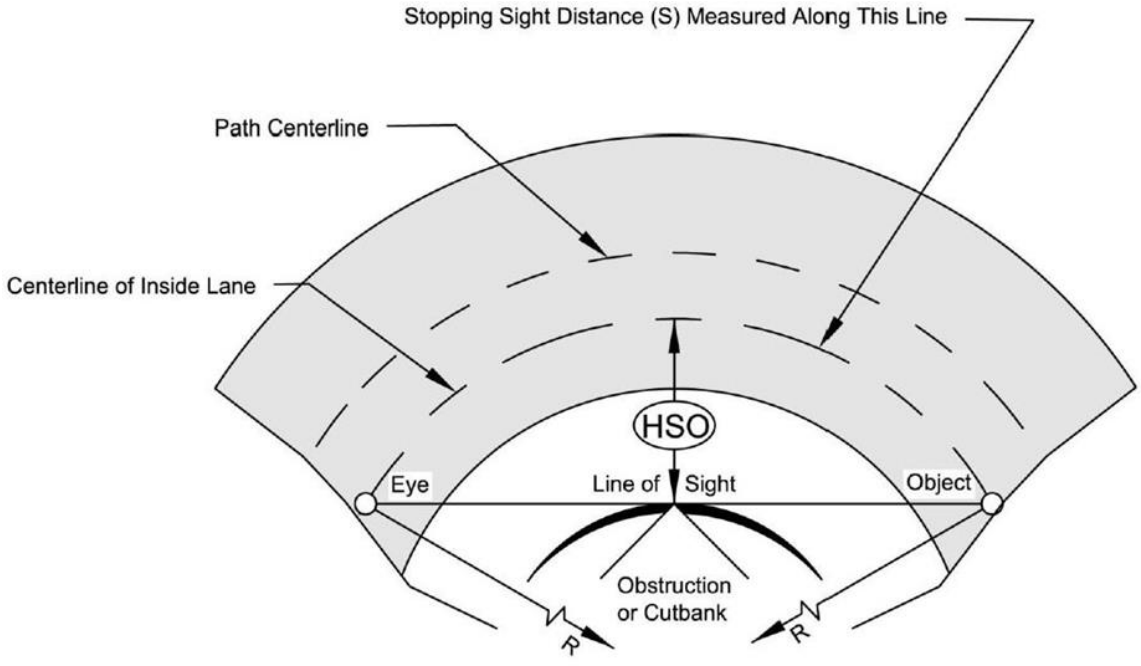
the stopping sight distances for both users traveling in opposite directions around the curve because bicyclists have a tendency to ride near the middle of narrow paths.

Table 12B-2.03: Minimum Lateral Clearance (Horizontal Sightline Offset or HSO) for Horizontal Curve

R	S= Stopping Sight Distance (ft)														
(ft)	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300
25	2.0	7.6	15.9												
50	1.0	3.9	8.7	15.2	23.0	31.9	41.5								
75	0.7	2.7	5.9	10.4	16.1	22.8	30.4	38.8	47.8	57.4	67.2				
95	0.5	2.1	4.7	8.3	12.9	18.3	24.7	31.8	39.5	48.0	56.9	66.3	75.9	85.8	
125	0.4	1.6	3.6	6.3	9.9	14.1	19.1	24.7	31.0	37.9	45.4	53.3	61.7	70.6	79.7
155	0.3	1.3	2.9	5.1	8.0	11.5	15.5	20.2	25.4	31.2	37.4	44.2	51.4	59.1	67.1
175	0.3	1.1	2.6	4.6	7.1	10.2	13.8	18.0	22.6	27.8	33.5	39.6	46.1	53.1	60.5
200	0.3	1.0	2.2	4.0	6.2	8.9	12.1	15.8	19.9	24.5	29.5	34.9	40.8	47.0	53.7
225	0.2	0.9	2.0	3.5	5.5	8.0	10.8	14.1	17.8	21.9	26.4	31.3	36.5	42.2	48.2
250	0.2	0.8	1.8	3.2	5.0	7.2	9.7	12.7	16.0	19.7	23.8	28.3	33.1	38.2	43.7
275	0.2	0.7	1.6	2.9	4.5	6.5	8.9	11.6	14.6	18.0	21.7	25.8	30.2	34.9	39.9
300	0.2	0.7	1.5	2.7	4.2	6.0	8.1	10.6	13.4	16.5	19.9	23.7	27.7	32.1	36.7
350	0.1	0.6	1.3	2.3	3.6	5.1	7.0	9.1	11.5	14.2	17.1	20.4	23.9	27.6	31.7
390	0.1	0.5	1.2	2.1	3.2	4.6	6.3	8.2	10.3	12.8	15.4	18.3	21.5	24.9	28.5
500	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10.0	12.1	14.3	16.8	19.5	22.3
565		0.4	0.8	1.4	2.2	3.2	4.3	5.7	7.2	8.8	10.7	12.7	14.9	17.3	19.8
600		0.3	0.8	1.3	2.1	3.0	4.1	5.3	6.7	8.3	10.1	12.0	14.0	16.3	18.7
700		0.3	0.6	1.1	1.8	2.6	3.5	4.6	5.8	7.1	8.6	10.3	12.0	14.0	16.0
800		0.3	0.6	1.0	1.6	2.2	3.1	4.0	5.1	6.2	7.6	9.0	10.5	12.2	14.0
900		0.2	0.5	0.9	1.4	2.0	2.7	3.6	4.5	5.6	6.7	8.0	9.4	10.9	12.5
1000		0.2	0.5	0.8	1.3	1.8	2.4	3.2	4.0	5.0	6.0	7.2	8.4	9.8	11.2

Source: *AASHTO Bike Guide* Exhibit 5.10

Figure 12B-2.03: Components for Determining Horizontal Sight Distance



Source: *AASHTO Bike Guide* Exhibit 5.9

For vertical alignment, use the preferred maximum segment length shown in Table 12B-2.04 whenever possible. Using the acceptable and allowed criteria should only be done when the engineer considers the ability of the users. For example, long rural segments would generally serve more physically capable users who have selected the path and could navigate the steeper grades over longer lengths.

Table 12B-2.04: Vertical Alignment

Grade Range	Maximum Segment Length (feet)		
	Preferred	***Acceptable***[1]	***Allowed***[2]
< 5%	Any length	Any Length	Any Length
≥ 5% and < 8.33%	--	50	200
≥ 8.33% and < 10%	--	30	30
≥ 10% and < 12.50%	--	--	10

[1] Derived from AGODA Section 1016 (Outdoor Recreation Access Routes)

[2] Derived from AGODA Section 1017 (Trails)

The minimum length of vertical curve needed to provide minimum stopping sight distance at various speeds on crest vertical curves is presented in Table 12B-2.05. The eye height of the typical adult bicyclist is assumed to be 4.5 feet. For stopping sight distance calculations the object height is assumed to be 0 inches. (AASHTO 5.2.7). Equation 12B-2.01 can also be used to determine the minimum length of crest vertical curve necessary to provide adequate sight distance.

Equation 12B-2.01

$$S > L \quad L = 2S - \frac{200(\sqrt{h_1}+\sqrt{h_2})^2}{A}$$

$$S > L \quad L = 2S - \frac{200(\sqrt{h_1}+\sqrt{h_2})^2}{A}$$

$$L > S \quad L = \frac{AS^2}{100(\sqrt{2h_1}+\sqrt{2h_2})^2}$$

where:

L= Minimum length of vertical curve (ft)
A = Algebraic grade difference (percent)
S = Stopping sight distance (ft)
h_1 = Eye height (4.5 feet for a typical bicyclist)
h_2 = Object height (0 ft)

Table 12B-2.05: Minimum Length of Crest Vertical Curve Based on Stopping Sight Distance

A	S=Stopping Sight Distance (ft)														
(%)	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300
2												30	70	110	150
3								20	60	100	140	180	220	260	300
4						15	55	95	135	175	215	256	300	348	400
5					20	60	100	140	180	222	269	320	376	436	500
6				10	50	90	130	170	210	267	323	384	451	523	600
7				31	71	111	151	191	231	311	376	448	526	610	700
8			8	48	88	128	168	208	248	356	430	512	601	697	800
9			20	60	100	140	180	220	260	400	484	576	676	784	900
10			30	70	110	150	190	230	270	444	538	640	751	871	1000
11			38	78	118	158	198	238	278	489	592	704	826	958	1100
12		5	45	85	125	165	205	245	285	533	645	768	901	1045	1200
13		11	51	91	131	171	211	251	291	578	699	832	976	1132	1300
14		16	56	96	136	176	216	256	296	622	753	896	1052	1220	1400
15		20	60	100	140	180	220	260	300	667	807	960	1127	1307	1500
16		24	64	104	144	184	224	264	304	711	860	1024	1202	1394	1600
17		27	67	107	147	187	227	267	307	756	914	1088	1277	1481	1700
18		30	70	110	150	190	230	270	310	800	968	1152	1352	1568	1800
19		33	73	113	153	193	233	273	313	844	1022	1216	1427	1655	1900
20		35	75	115	155	195	235	275	315	889	1076	1280	1502	1742	2000
21		37	77	117	157	197	237	277	317	933	1129	1344	1577	1829	2100
22		39	79	119	159	199	239	279	319	978	1183	1408	1652	1916	2200
23		41	81	121	161	201	241	281	321	1022	1237	1472	1728	2004	2300
24	3	43	83	123	163	203	243	283	323	1067	1291	1536	1803	2091	2400
25	4	44	84	124	164	204	244	284	324	1111	1344	1600	1878	2178	2500

The line between the shaded and un-shaded portions of the table shows when the stopping sight distance is equal to the length of the crest vertical curve.

Source: *AASHTO Bike Guide* Exhibit 5.8

9. **Stopping Sight Distance:** Shared use paths must be designed with adequate stopping sight distance along the entire path to provide users with the opportunity to see and react to unexpected conditions. The distance needed to bring a path user to a fully controlled stop is a function of the user's perception and braking reaction time, the initial speed, the coefficient of friction between the wheels and the pavement, the braking ability of the user's equipment, and the grade. Minimum stopping sight distances can be determined using Equation 12B-2.02. Stopping sight distance must be provided along the entire length of the pathway and should be checked at all horizontal and vertical curves. (AASHTO 5.2.8).

$$S = \frac{V^2}{30(f \pm G)} + 3.67V$$ **Equation 12B-2.02**

where:

S = Stopping sight distance (ft)
V = Velocity (mph)
f = Coefficient of friction (use 0.16 for a typical bicycle)
G = Grade (ft/ft) (rise/run)

10. **Accessibility Requirements:** For construction of curb ramps and placement of detectable warnings, see Section 12A-2 to ensure ADA compliance.

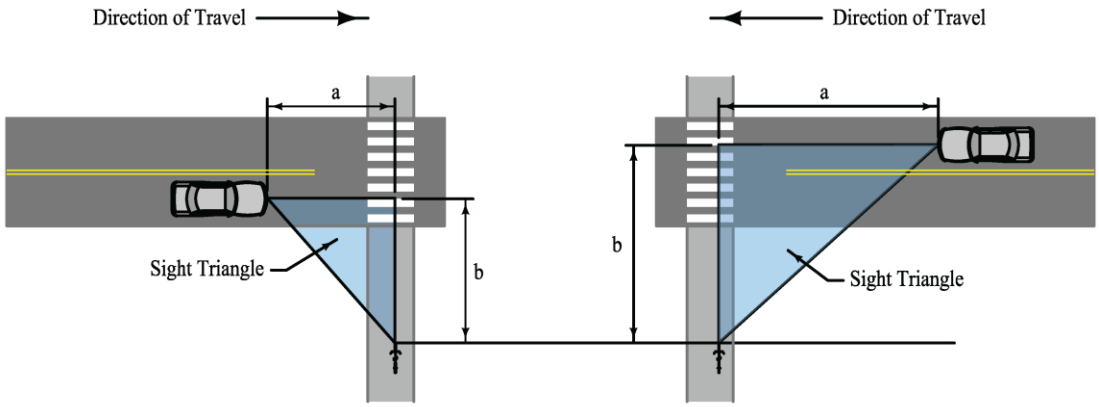
D. Intersection Sight Distance

1. **General:** Intersection sight distance is a fundamental component in the selection of appropriate control at a midblock path-roadway intersection. The least restrictive control that is effective should be used. The line of sight is considered to be 2.3 feet above the path surface.

   Roadway approach sight distance and departure sight triangles should be calculated using motor vehicles, which will control the design criteria. (AASHTO 5.3).

2. **Approach Sight Distance:** Pathway approach sight distance should be determined by the fastest path user, typically the adult bicyclist. If yield control is to be used for either the roadway approach or the path approach, available sight distance adequate for a traveler on the yield controlled approach to slow, stop, and avoid a traveler on the other approach is required. The roadway leg (a) of the sight triangle is based on the ability of a bicyclist to reach and cross the roadway if they do not see a conflict (see Figure 12B-2.04). Similarly, the path leg (b) of the sight triangle is based on the ability of a motorist to reach and cross the junction if they do not see a conflict (see Figure 12B-2.04). If sufficient sight distance is unable to be provided by the yield sight triangle described above, more restrictive control should be implemented.

Figure 12B-2.04: Yield Sight Triangles



Source: Adapted from *AASHTO Bike Guide* Exhibit 5.15

$$a = 1.47V_{Road}\left(\frac{S}{1.47V_{Path}} + \frac{w + L_a}{1.47V_{Path}}\right)$$

Equation 12B-2.03
Length of Roadway Leg of Sight Triangle

$$b = V_{Path}\left(\frac{1.47V_e - 1.47V_b}{a_i} + \frac{w + L_a}{0.88V_{Road}}\right)$$

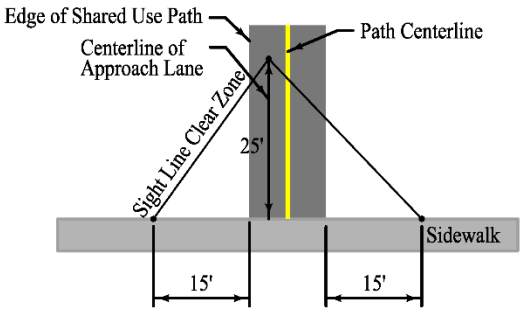
Equation 12B-2.04
Length of Path Leg of Sight Triangle

where:

a = Length of leg of sight triangle along the roadway approach (ft)
b = Length of leg of sight triangle along the path approach (ft)
w = Width of the intersection to be crossed (ft)
L_a = Design vehicle length
For Equation 12B-2.03: Typical bicycle length = 6 ft
For Equation 12B-2.04: Design vehicle length (ft)
V_{Path} = Design speed of the path (mph)
V_{Road} = Design speed of the road (mph)
S = Stopping sight distance for the path user traveling at design speed
V_e = Speed at which the motorist would enter the intersection after decelerating (mph) (assumed 0.60 x road design speed)
V_b = Speed at which braking by the motorist begins (mph) (same as road design speed)
a_i = motorist deceleration rate (ft/s^2) on intersection approach when braking to a stop is not initiated (assume -5.0 ft/s^2)

3. **Path-Sidewalk Intersection:** At an intersection of a shared use path and a sidewalk, a clear sight triangle extending at minimum 15 feet along the sidewalk must be provided. Refer to Figure 12B-2.05. If two shared use paths intersect, the same process for the roadway-path intersection should be used.

Figure 12B-2.05: Minimum Path-Sidewalk Sight Triangle



Source: Adapted from *AASHTO Bike Guide* Exhibit 5.16

E. Surface

It is important to construct and maintain a smooth riding surface on shared use paths. Shared use path pavements should be machine placed. Surface texture is needed but care must be exercised not to cause operational problems with too little or too much texture. Broom finish or burlap drag concrete surfaces are preferred over trowel finishes. Joints shall be sawed, not hand tooled.

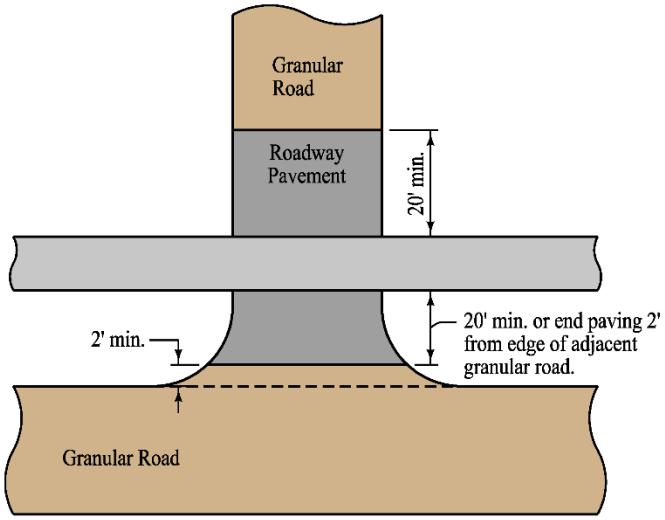
1. **Type 1 and Type 2:** Type 1 and Type 2 shared use paths shall be paved.

2. **Type 3:** Hard, all-weather pavement surfaces are preferred to unpaved surfaces due to the higher service quality and lower maintenance. Type 3 shared use paths should be paved; however, a granular surface may be allowed. If a granular surface is used, it must be maintained to be firm, stable, and slip resistant.

F. Crossings at Unpaved Surfaces

When crossing an unpaved roadway, alley, or driveway, a minimum of 20 feet in addition to the path width should be paved on each side of the path to reduce the amount of gravel tracked onto the path. If edge of parallel unpaved roadway is less than 20 feet from the closest edge of the path, only pave to within 2 foot of edge of the parallel unpaved roadway. The thickness of the path and adjacent roadway paving should be designed to accommodate vehicular traffic and meet the requirements of the agency responsible for the roadway.

Figure 12B-2.06: Crossing at Unpaved Surface



G. At-grade Railroad Crossing

Whenever it is necessary to cross railroad tracks with a bicycle, special care must be taken. The crossing should be at least as wide as the approaches of the shared use path. Whenever possible, the crossing should be straight and between 90 and 60 degrees to the rails. The greater the crossing angle deviates from being perpendicular, the greater the chance that a bicyclist's front wheel may be trapped in the flangeway causing a loss of control. (AASHTO 4.12).

H. Drainage

Drainage structures underneath paths should typically be designed to the same design year storm as the roadway drainage structures. When a Type 3 shared use path is built on a berm, consider the drainage needs of that path. For shared use paths constructed on slopes, drainage design should take into account control of the runoff from the slope. For higher flows it may be necessary to develop parallel ditches and culverts under the path. Drainage designs should also provide for low flows and seepage from the slope. Due to the potential for accidents from buildup of algae from low flows and side hill seepage, the need for subdrains or other treatments on the high side of the path should be evaluated.

1. **Urban Areas:** The minimum recommended pavement cross slope of 1% usually provides enough slope for proper drainage. Sloping in one direction, usually toward the street, instead of crowning is preferred and usually simplifies the drainage and surface construction. However, care must be exercised not to trap water on the high side of the shared use path, particularly in curved areas. (AASHTO 5.2.11).

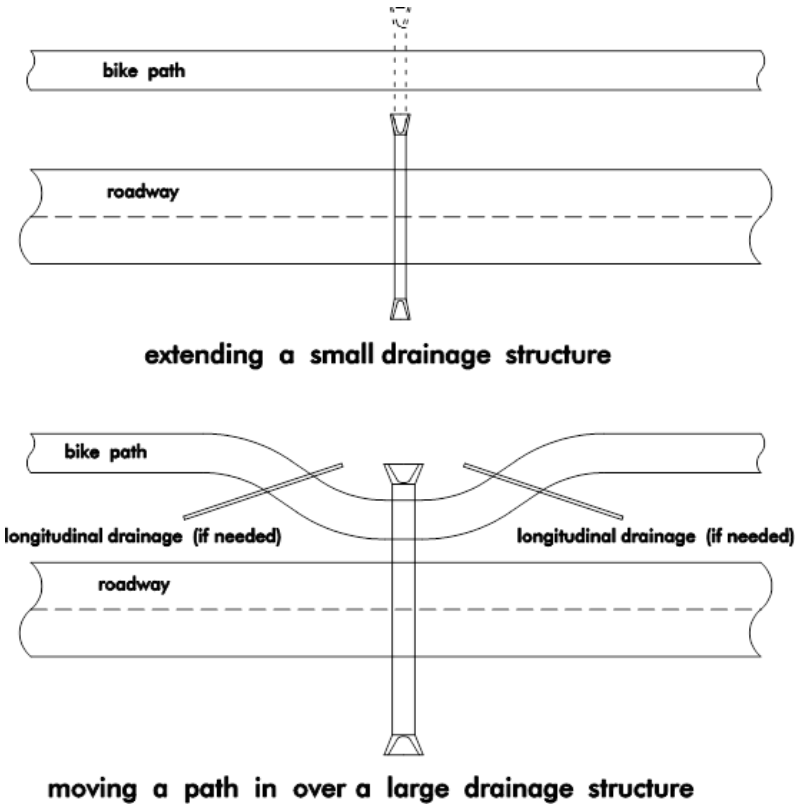
2. **Rural Areas:** The best way to accomplish drainage underneath a shared use path is by extending smaller structures under the path or moving the path closer to the roadway to cross larger structures, see Figure 12B-2.07.

   For paths placed on the backslope, smaller drainage structures (normally pipes less than 60 inches and box culverts less than 5 feet by 4 feet) should be extended through the path. For larger culverts, the path should be moved in to cross the structure and then moved back out to the backslope. If this is done, longitudinal drainage will have to be provided where the path crosses

the ditch. Depending upon how close the path comes to culvert openings, safety railing may be needed on the culverts.

For paths on the foreslope, culverts should be extended as necessary.

Figure 12B-2.07: Accommodating Drainage Structures



I. Structure Design

The minimum width for a shared use path on a new roadway bridge, widened roadway bridge, or separate pedestrian structure is 10 feet. Through conversations with the Iowa Bicycle Coalition, this was determined to be adequate width in most situations. If heavy use is anticipated, such as near a school, a 12 or 14 foot wide path should be used. If a separate shared use path structure is to be constructed, it should have a 5% maximum running grade.

If widening a bridge or building a new structure is beyond the scope of a project, it may be possible to use an existing sidewalk as a path. The path should be separated from vehicular traffic with a barrier. Signage may be necessary instructing cyclists to dismount before crossing the bridge. For Iowa DOT administered projects, the designer should contact the Design Bureau and the Traffic and Safety Bureau for further assistance if considering a narrowed path across a bridge.

J. Pavement Markings

Ladder or zebra pavement markings per MUTCD are recommended at crosswalks. Other pavement markings are not required, except as mitigation strategies. (AASHTO 5.4).

K. Signing

All signs should be retroreflective and conform to the color, legend, and shape requirements described in the MUTCD. In addition, guide signing, such as to indicate directions, destinations, distances, route numbers, and names of crossing streets should be used. In general, uniform application of traffic control devices, as described in the MUTCD, should be used and will tend to encourage proper bicyclist behavior. (AASHTO 5.4).

L. Lighting

Fixed-source lighting reduces conflicts along shared use paths and at intersections. In addition, lighting allows the bicyclist to see the shared use path direction, surface conditions, and obstacles. Lighting for paths is important and may be considered where heavy nighttime riding is expected (e.g., paths serving college students or commuters) and at roadway intersections. Lighting should be considered through underpasses or tunnels and when nighttime security could be a problem. Where special security problems exist, higher illumination levels may be considered. Light standards (poles) should meet the recommended horizontal and vertical clearances. (AASHTO 5.2.12).

Table of Contents

Chapter 13 - Traffic Control

13A Traffic Signals

13B Work Zone Traffic Control

While the pulled-in-place installation method can be successfully utilized, the inversion method may be better suited for pipelines that have high levels of infiltration through the pipe joints or cracks. The pulled-in-place and inversion methods work equally well for lining pipes whose defects are more structural in nature.

e. Curing and Hardening the CIPP Liner: Regardless of the method of installation, the newly installed liner is then cured by applying heat. Typically, this is done by heating and circulating the water used to invert and expand the tube, or by applying pressurized steam to the line. The applied heat causes the thermosetting resin in the felt to cure or harden. This changes the resin from a liquid to a solid. After the resin has cured, the CIPP is cooled, resulting in a new pipe with a slightly smaller inside diameter, but of the same general shape as the original pipe.

f. Completion: The ends of the CIPP are trimmed off, and the service laterals are reopened. Reopening the service connections can be done by man-entry for larger diameters or robotically for smaller diameters. Normally, a small dimple is left in the liner directly over each service connection, allowing them to be easily located and reopened. However, the number and locations of the service connections should be noted during the pre-lining televising process to ensure that all connections are reopened and to aid in locating those that are difficult to identify.

The result of the CIPP process is that a new pipe is formed within the existing sewer pipe. This new pipe reduces infiltration and adds structural integrity to the existing line. The expected service life of a cured-in-place liner is generally accepted to be 50 years.

2. CIPP Design: Cured-in-place pipe liners should be designed in accordance with ASTM F 1216 – "Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube." This standard is recognized by virtually all CIPP suppliers and contractors. The standard for the CIPP is all inclusive, covering material requirements, construction methods, and design parameters. The equations and definitions utilized in this section are taken from ASTM F 1216.

The first step in designing a CIPP project is identifying the condition of the existing pipe. ASTM F 1216 divides existing pipe conditions into two classes: partially deteriorated condition and fully deteriorated condition. The condition of the pipe affects the method of design that is utilized. According to ASTM F 1216, these conditions are defined as follows:

"*Partially deteriorated pipe* - the original pipe can support the soil and surcharge loads throughout the design life of the rehabilitated pipe. The soil adjacent to the existing pipe must provide adequate side support. The pipe may have longitudinal cracks and up to 10% distortion of the diameter. If distortion of the diameter is greater than 10%, alternative design methods are required" (see fully deteriorated pipe).

"*Fully deteriorated pipe* - the original pipe is not structurally sound and cannot support soil and live loads nor is expected to reach this condition over the design life of the rehabilitated pipe. This condition is evident when sections of the original pipe are missing, the pipe has lost its original shape, or the pipe has corroded due to the effects of the fluid, atmosphere soil or applied loads."

a. Design for Partially Deteriorated Gravity Pipe Condition: Generally, the partially deteriorated condition is used when the existing pipe is in good condition, but has leaky joints. For this reason, the liner is only designed to resist the hydrostatic loads due to groundwater, since the soil and live loads are still being supported by the original pipe. The required thickness of the liner is determined utilizing the following equations:

$$t = \frac{D_o}{\left[\frac{2KE_L C}{P_W(1-\nu^2)N}\right]^{1/3} + 1}$$

Equation 14C-2.01
(Note: this is a rearrangement of Equation X1.1 from ASTM F 1216)

where:

t = CIPP thickness, inches
D_o = Mean outside diameter of the CIPP, inches
K = enhancement factor of the soil and existing pipe, typically 7 (conservative), dimensionless
E_L = long term (time corrected) modulus of elasticity for CIPP, psi (see Section 14C-2, A, 1, b)
P_W = groundwater load (hydrostatic pressure), psi

$$P_W = \frac{H_W(\text{ft}) \times 62.4(\text{pcf})}{144\left(\text{in}^2/\text{ft}^2\right)} \text{ or } P_W = 0.433(H_W)$$ **Equation 14C-2.02**

H_W = Groundwater height above the top of the pipe, ft
ν = Poisson's ratio (0.3 average), dimensionless
N = factor of safety (normally 2.0), dimensionless
C = ovality reduction factor, dimensionless. See Table 14C-2.03, or

$$C = \left(\left[1-\frac{q}{100}\right] / \left[1+\frac{q}{100}\right]^2\right)^3$$ **Equation 14C-2.03**

q = percent ovality of original pipe - estimate from the CCTV inspection the amount of ovality (deflection from original round shape). Normally, the ovality will vary along the length of the line (use the most oval condition). The more ovality, the thicker the liner will need to be.

Table 14C-2.01: Ovality Reduction Cactor (based upon Equation 14C-2.03)

Ovality, q, %	Factor, C	Ovality, q, %	Factor, C
0	1.00	12	0.35
2	0.84	14	0.29
4	0.70	15	0.27
5	0.64	16	0.24
6	0.59	18	0.20
8	0.49	20	0.17
10	0.41		

Total external pipe load:

$$P_t = P_W + P_S + P_L$$ **Equation 14C-2.08**

where,

P_t = Total external pipe load, psi
P_W = Hydrostatic pressure, psi
P_S = Soil pressure, psi
P_L = Live load, psi

Once the total external load that the liner pipe must support has been determined, the liner thickness can be determined with Equation 14C-2.09.

$$t = \left[\frac{0.375\left(P_t \frac{N}{C} \right)^2 D_o^3}{E_L R_W B' E'_S} \right]^{1/3}$$

Equation 14C-2.09
(Note: this is a rearrangement of Equation X1.3 from ASTM F 1216)

where:

t = CIPP thickness, inches
P_t = Total pressure due to water, soil, and live load acting on CIPP, psi
N = factor of safety (normally 2.0), dimensionless
C = ovality reduction factor, dimensionless. See Table 14C-2.01, or Equation 14C-2.03
D_o = Mean outside diameter of the CIPP, inches
E_L = long term (time corrected) modulus of elasticity for CIPP, psi (see Section 14C-2, A, 1, b)
R_W = Water buoyancy factor, dimensionless (see Equation 14C-2.07)
B' = Empirical coefficient of elastic support, dimensionless

$$B' = \frac{1}{1 + 4\boldsymbol{e}^{-0.065H_S}}$$ **Equation 14C-2.10**

$\boldsymbol{e}$ = base of natural log = 2.718
H_S = soil height above top of pipe, feet
E'_S = Modulus of soil reaction, psi (see note below)

While most of the terms utilized in Equation 14C-2.09 should be known or could be calculated, the Modulus of Soil Reaction is a relatively subjective term. This is a variable that is used to reflect the amount of support being given to the new liner pipe from the surrounding soil. Since the surrounding soil is actually the host pipe, this value can be hard to determine. Use judgment after viewing the CCTV video of the sewer. Badly cracked pipe, missing bricks, and missing pipe are reasons to thicken the liner. Values to be used are between 500 psi (bad pipe, thick liner) and 2,000 psi (fair pipe, thinner liner).

For shallow pipes with little or no groundwater to contribute to the load, a minimum thickness check should be completed. This is a similar design condition as previously described for partially deteriorated pipe having no groundwater. For this special case, there is a provision in ASTM F 1216 that requires the CIPP to have a minimum pipe stiffness that is 1/2 that of the value specified in AWWA C950. Based upon this requirement, the minimum pipe thickness is checked by the following equation:

$$t \geq (D_o)\left(\sqrt[3]{\frac{1.116}{E}}\right)$$ **Equation 14C-2.11**

where:

t = CIPP thickness, inches
D_o = Outside diameter of CIPP
E = initial modulus of elasticity for CIPP

One final check of the design needs to be completed. As described for partially deteriorated pipe in the preceding section, the bending stresses need to be checked for pipes which are out of round. The bending stresses that a fully deteriorated pipe is expected to see over its life are calculated in the same manner as for a partially deteriorated pipe and are given by Equation 14C-2.05.

3. Project Considerations:

a. Contractor Review: Prior to bidding any CIPP project, it is always a good idea to review the project with an experienced CIPP contractor. There are construction and performance related limitations to the use of CIPP for pipeline rehabilitation. These limitations relate to the condition of the existing pipeline, the maximum practical thickness of the liner, and the point where CIPP lining is no longer a cost effective option. The contractor may be able to recommend alternatives to reduce the cost or improve the performance of a CIPP liner.

Before designing a project with unusual conditions (odd-shaped pipe, deep pipe, severely deteriorated pipe, difficult access, etc.), it may also be wise to meet with a local CIPP installation contractor, visit the site, and review the sewer tapes with the contractor.

b. Preparing Contract Documents for a CIPP Project: One of the most important things to consider when designing a CIPP liner and preparing the contract documents for the project is that there are a variety of different strength resins available. These different resins can be used in conjunction with different thicknesses of felt to produce multiple liner designs, which meet the requirements of a particular project. The point is to find the combination of resin strength and liner thickness that meets the requirements of the project and has the lowest cost.

For this reason, a single resin strength / liner thickness should not normally be specified on a particular project. Rather, multiple resin strengths / liner thicknesses should be allowed. The combination of resin and liner that is the most economical for one contractor may be different than that of another contractor.

There are two different ways to allow each contractor the flexibility of selecting their own resin/liner combination while assuring that the product being bid meets the requirements of the job. The first method is to allow the contractor to design the liner thickness themselves. If this is done, the engineer should state on the plans that the liner shall be designed in accordance with ASTM F 1216 (or F 1743 if pulled-in-place installation is allowed). In

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