BILL NO. 24-04 ORDINANCE NO. 24-04

An Ordinance Amending CHAPTER 405. Subdivision Regulations Article VII. Design Standards for Public Improvements Section 405.510 Design Standards by replacing it with an updated version of 405.510 Design Standards in the Code of Ordinances of the City of Battlefield, Missouri.

BE IT ORDAINED BY THE BOARD OF ALDERMEN OF THE CITY OF BATTLEFIELD, MISSOURI, AS FOLLOWS:

Section 1. That the attached Exhibit A "be added to the Code of Ordinances for the City of Battlefield after a public hearing held by the Planning and Zoning Commission and said recommendation provided as such to the City of Battlefield Board of Aldermen to approve the creation of such an ordinance.

Section 2. That if any section, subsection, sentence, clause, or phrase of this legislation is, for any reason, held to be unconstitutional, such decision shall not affect the validity of the remaining portions of this ordinance. The City of Battlefield, Missouri hereby declares that it would have passed this law, and each section, subsection, clause, or phrase thereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses, and phrases be declared unconstitutional.

Section 3. This ordinance shall be in full force and effect from and after its date of passage.

Passed and approved at a regular meeting of the Board of Aldermen of the City of Battlefield, Missouri, this 6th day of February 2024.

Mark Crabtree

Mark Crabtree- President of the Board

Attest:

Beth Anne West

Beth Anne West, Clerk

First Reading and Vote: 6 Ayes - Samantha Forbes, Zac Woods (via phone), Mark Crabtree, Rocky Compton, Tim Kelley Sr, and Jerry Shepard. 0 Nays. All Board members were present for the vote. 2-6-2024

Second Reading and Vote: 6 Ayes - Samantha Forbes, Zac Woods (via phone), Mark Crabtree, Rocky Compton, Tim Kelley Sr., and Jerry Shepard. 0 Nays. All Board members were present for the vote. 2-6-2024

Approved to Form: Paul Link

Paul Link-City Attorney

CITY OF BATTLEFIELD SEAL MISSOURI

TO: Mr. Tommy VanHorn
City Administrator – City of Battlefield

FROM: Dallas P. Joplin, PE, PTOE
Crawford, Murphy & Tilly (CMT)

CC: Battlefield Board of Alderman
Battlefield Planning & Zoning Commission

SUBJECT: Revised City of Battlefield Design Standards for Public Improvements

Mr. VanHorn,

Crawford, Murphy & Tilly (CMT) has completed updates and revisions to the City of Battlefield Design Standards for Public Improvements, previously updated in October 2002. The updates are inclusive of City Staff feedback. Significant changes were made to the existing standards to better reflect commonalities in design standards of the surrounding communities, specifically the City of Springfield, MO.

In revising the design standards, the City of Springfield's design standards were used as a baseline. Each section was reviewed and updated to provide a document suitable for use by the City of Battlefield. These updated standards were created based on engineering expertise and experience, with additional input from City staff providing a local perspective.

These revised design standards are a combination of both Springfield and Battlefield design standards, and will provide a more efficient design and development process for the City of Battlefield.

Respectfully submitted,

Dallas P Joplin, PE, PTOE
CMT Project Manager

Crawford, Murphy & Tilly
Centered in Value
1631 W Elfindale Springfield, Missouri 65807 PHONE 417.869.6009 FAX 417.869.8129 cmtengr.com Engineers and Consultants

CITY OF BATTLEFIELD DESIGN STANDARDS FOR PUBLIC IMPROVEMENTS

ADOPTED

STATE OF MISSOURI
DALLAS P.
JOPLIN
NUMBER
PE-2011015760
PROFESSIONAL ENGINEER

CITY OF BATTLEFIELD DESIGN STANDARDS

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1 DEFINITIONS AND POLICIES

1.1 DEFINITION OF TERMS, PHRASES, AND WORDS The definitions of this section apply specifically to 405.510 (Design Standards for Public Improvements). These definitions shall take priority in section 405.510 over differing definitions in other sections of Title IV Land Use (400 Zoning Code, 405 Subdivision Regulations, or 410 Floodplain Management).

1. **Alley.** A minor way which is used primarily for vehicular service access to the back or the side of properties otherwise abutting a street.

2. **Arterial Street (Primary).** A street or highway primarily intended to provide for high volume, moderate speed, and extended trip length traffic movement between major activity centers, with access to abutting property subordinate to major traffic movement.

3. **Arterial Street (Secondary).** A Street which interconnects with and augments the major arterial system. The secondary arterial is primarily intended to provide for moderate volume, moderate speed, and short to moderate trip length while providing partially controlled access to abutting property.

4. **Benchmark.** A permanent object of known elevation and location that is in an area where disturbance is unlikely.

5. **Block.** A piece or parcel of land entirely surrounded by public highways, streets, streams, railroad right-of-way, parks, or a combination thereof.

6. **Bridge.** A structure having a clear span greater than twenty (20) feet or a multiple span structure where the total length of the span is in excess of twenty (20) feet.

7. **City of Battlefield Standard General Conditions and Technical Specifications for Public Improvements.** The official General Conditions and Technical Specifications used on public city improvements within the City of Battlefield, Missouri. This document contains data for public improvements from the advertising stage of a project through the actual construction and acceptance of the project.

8. **Collector Street.** A street which collects and distributes traffic to and from local and arterial street systems. The collector is primarily intended to provide for low to moderate volume, low speed, and short length trips while providing access to abutting property.

9. **Consultant.** An individual, firm, association, partnership, corporation, or other legal entity registered in the State of Missouri and engaged in the practice of engineering or architecture.

10. **Corner.** A point of intersection of lines of two street curb faces extended into street intersection.

11. **Crosswalk.** A right-of-way, dedicated to or set aside for public use, which cuts across a block or street to facilitate pedestrian access to adjacent streets and properties.

12. **Cul-de-sac or Dead-end Street.** A minor street with only one outlet.

13. **Culvert.** A structure not classified as a bridge, which provides a conduit for drainage.

14. **Curb Return.** The portion of curb at the beginning of a driveway approach, which serves as a transition from the height of the curb to the level of the approach.

15. **Driveway.** An area intended for the operation of automobiles and other vehicles from the street right-of-way line to a garage, parking area, building entrance, structure, or approved use located on the property. Any dimensions relating to the width of a driveway or driveway surface shall be measured at the right-of-way line.

16. **Driveway Approach.** An area intended for the operation of automobiles and other vehicles giving access between a roadway and abutting property. The driveway approach includes the sum of the curb returns on each side of the driving surface, plus the driving surface.

17. **Easement.** A grant by the property owner to the public, a corporation, or persons of the use of land for specific purposes.

18. **Expressway.** A street or highway with limited and partially controlled points of access at arterial system intersections. The expressway is primarily intended to provide for high volume, moderate to high speed extended intra-city traffic between major activity centers with minimal impairment to movement.

19. **Freeway.** A divided highway with fully controlled access limited to grade-separated interchanges constructed at major thoroughfares. A freeway is primarily intended to provide for high-volume, high-speed intercity traffic movements.

20. **Gutter.** That portion of the driving surface of an improved street, driveway, approach, or other public way, which abuts the curb and provides for the runoff of surface drainage.

21. **Improved Street.** A public street having concrete curbs, or curb and gutters, or other such equivalent physical features, which serve to establish a permanent street grade.

22. **Intersection.** The general area where two or more roadways meet, join, or cross at a common point establishing an area within which vehicles traveling different roadways may come in conflict.

23. **Joint Driveway.** A driveway which provides access to a public street for more than one parcel of land.

24. **Local Street.** A street primarily providing direct access to abutting property and designed to accommodate low-volume, low-speed traffic.

25. **Lot.** An undivided tract or parcel of land under one ownership having access to a street, whether occupied or to be occupied by a building or building group together with accessory buildings, which parcel of land is designated as a separate and distinct tract and is identified by a tract or lot number or symbol in a duly approved subdivision plat filed of record.

26. **Owner.** The City of Battlefield, Missouri, its agents, employees, and representatives, with whom Contractor has entered into the Agreement and for whom the Work is to be performed.

27. **Parkway.** That portion of the street right-of-way between the edges of the roadway and the adjacent property line, or lines, on the same side of the street except any portion used for sidewalks.

28. **Preliminary Plat.** The preliminary map, drawing, or chart indicating the proposed layout of the subdivision initially required in the subdivision process.

29. **Property Description.** Description of a lot, tract, or parcel by metes and bounds, by reference to a plat or by reference to government survey.

30. **Property Line.** The boundary between two or more parcels of land.

31. **Public Improvements.** Those things that are constructed, installed, or performed on public land, or on land that is to become public in the subdivision process, including but not limited to street and alley pavement, curbs, storm drainage facilities, sidewalks, and sanitary sewers, and including the grading of such land.

32. **Reference Points.** Points of reference located by a survey of the project. The points are to be tied or referenced to at least three identifiable features.

33. **Right-of-Way.** A general term denoting public ownership or interest in land, usually in a strip, which has been acquired for or devoted to the use of a street or alley.

34. **Right-of-Way Line or Street Right-of-Way Line.** The boundary between any public street or alley and one or more parcels of private property.

35. **Roadway.** That area of a street intended and used for vehicular travel.

36. **Service Road.** A minor street which is parallel and adjacent to an arterial street, and which provides access to abutting properties and protection from through traffic.

37. **Shall, May.** The word "Shall" shall be deemed as mandatory. The word "May" shall be deemed as permissive.

38. **Sidewalk.** That paved portion of a parkway intended for the use of pedestrians.

39. **Sight Distance Triangle.** A triangular-shaped area of street right-of-way, generally acquired at major intersections to ensure adequate sight distance.

40. **Storm Water Detention Facility.** A drainage facility designed and constructed for the purpose of detaining storm water runoff to reduce downstream flows and/or reduce storm water pollutant levels.

41. **Streets.** "Street" is a way for vehicular traffic, whether designated as a street, highway, thoroughfare, parkway, throughway, road, avenue, boulevard, lane, place, or however otherwise designated.

42. **Subgrade.** The surface of a street on which a base course or riding surface is to be placed.

43. **Subdivision.** The division of land into two (2) or more lots, tracts, or parcels for the purpose of transfer of ownership or building development, or, if a new street or easement of access is involved, any division of a parcel of land. The term includes resubdivision and, when appropriate to the context, shall relate to the process of subdividing or to the land subdivided.

44. **Surveying.** The act of determining the positions of points on the earth's surface by means of measurement of distance, direction, and elevation.

45. **Tendering**. The legal transfer of ownership and maintenance responsibility of a public improvement to the City of Battlefield.

46. **Unimproved Street.** A street not having concrete curbs, or curbs and gutters, or other such equivalent physical features which serve to establish a permanent street grade.

47. **Vehicle.** Every device in, upon, or by which any person or property is, or may be transported, or drawn upon a street, except devices used exclusively upon stationary rails or tracks.

1.2 POLICIES

1.2.1 Minimum Standards for Design. The City Administrator or designee must approve all plans for public improvements within the City of Battlefield. This approval is a conceptual approval only and does not give detail approval to any particular design item or data shown on the plans, nor does it give approval for any deviation from City specifications unless that deviation is shown on the plans by a general note. The Engineer who sealed the plans is responsible for all lines and grades, field data, constructability of the design, and all other items affecting the project including compliance with the City specifications.

1.2.2 Variance from minimum standards.

All design requirements will be strictly adhered to unless written justification for a design variance, sealed by a professional engineer is presented and approved. This justification should be submitted along with the preliminary plat and variance applications which will be reviewed by the Planning and Zoning Commission and Board of Aldermen.

Should a request for a design variance occur after preliminary plat approval, the sealed justification for a design variance, variance application and any required amendment to the preliminary plat must be resubmitted to the Planning and Zoning Commission and Board of Aldermen for approval. Substantial changes would require a new preliminary plat.

1.2.3 Acceptance of Public Improvements. No streets, alleys, sanitary sewers, storm sewers, or other public improvements will be accepted or approved by either the Board of Aldermen, the City Administrator, or designee unless the improvements were constructed in accordance with Plans, Special Provisions, and Technical Specifications on record with the City.

1.2.4 Utility Location Policies

1.2.4.1 General. The following criteria has been established for the uniform treatment of the location or relocation of utility facilities within the right-of-way of the public street system in order to preserve the traffic-carrying capacity of the street and to minimize interference with normal maintenance operations. These requirements apply to all public and private utilities including power transmission, telephone, cable television, telegraph, water, gas, oil petroleum products, pipelines, and any other utility facilities (excluding Sanitary Sewers). The requirements apply to underground, surface, or overhead facilities located within or crossing street right-of-way. Exceptions to the requirements set forth will be considered when major utility extensions are proposed or when improvements by their size necessitate special consideration. All utilities installing any facilities in a public right-of-way must meet the requirements of the City and shall receive advance approval from the City Administrator or designee prior to commencing construction on a public right-of-way. In order to receive approval, an engineering drawing detailing the installation shall be required. This engineering drawing shall depict adequate data to determine location and impact on other facilities located in the public right-of-way.

In the case of reconstruction or rehabilitation where location of existing utilities will not be relocated and where breaks or normal maintenance is needed, the requirement for an engineering drawing shall be waived.

1.2.4.2 New Subdivisions – Residential. Parallel installations of overhead facilities within the street right-of-way are to be located within one (1) foot of the right-of-way line when proposed for construction on the same side of the street that sidewalks are constructed. Streetlights and poles used to support transverse crossings of the right-of-way shall not be located closer than two (2) feet of the curb or edge of roadway or paved shoulder. Poles, guys, anchors, braces, and other appurtenances for overhead facilities shall not encroach into sidewalk or streets. Parallel installation of overhead facilities and underground facilities, including meters, valves, and other appurtenances, within the street right-of-way, are to be located within a seven (7) foot area adjacent to the right-of-way line where no sidewalks exist. In no case will the City allow the facility to be constructed within the street pavement area except for valves necessary for tapping existing facilities, nor will it be allowed to conflict with the street drainage. Careful consideration must be given to the location of valves, meter boxes, and other appurtenances, so that interference with the sidewalk and street curb is held to a minimum. Minimum cover for all underground facilities shall be 24 inches.

1.2.4.3 New Subdivisions – Nonresidential. Parallel overhead and underground facilities are to be located within seven (7) feet of the right-of-way line. Streetlights and poles used to support transverse crossings of the right-of-way shall not be located closer than two (2) feet of the curb or edge of roadway or paved shoulder. Poles, guys, anchors, braces, and other appurtenances for overhead facilities shall not encroach into sidewalks or streets. Parallel installation of the underground facilities, including meters, valves, and other appurtenances, within the street right-of-way, are to be located within seven (7) feet of the right-of-way line. In no case will the City allow the facility to be constructed within the street pavement area except for valves necessary for tapping existing facilities, nor will it be allowed to conflict with the street drainage. Careful consideration must be given to the location of valves, meter boxes, and other appurtenances, so that interference with the sidewalk and curb is held to a minimum. The minimum cover shall be 24 inches or conforming to federal, state, or local agency requirements, whichever is greater.

1.2.4.4 Existing Subdivisions – Residential and Nonresidential. Plans developed for new underground or overhead facilities must be designed to take into account existing utilities, as well as possible future utilities. Where possible, corridors outlined in 1.2.4.2 and 1.2.4.3 are to be adhered to. Due to existing facilities, this may be impractical. Design based upon remaining corridor is encouraged, but it is understood local, state, and federal codes may make this impossible. Since existing conditions must be taken into account, deviation from the corridor requirements in 1.2.4.2 and 1.2.4.3. will be accepted in existing subdivisions.

1.2.5 Permits.

1.2.5.1 City Maintained Streets. All utility work and property improvements to be performed within the City right-of-way limits will require an excavation permit from the City Administrator or designee prior to the work being done by the contractor. In emergency situations where necessary repairs to an existing utility facility must be made immediately in order to protect the public health, safety, and welfare, a permit must be obtained as soon as possible once emergency repairs commences.

1.2.5.2 State Maintained Streets and Highways. All utility work to be performed on state-maintained facilities will require a permit from the Missouri Highway and Transportation Commission. All requirements of the state must be met.

1.2.5.3 Open Cutting or Boring of City Streets. As a general policy, no open cutting of the pavement will be permitted on the City's streets except special permission to open cut a street may be given when the street has not yet been constructed to the ultimate design or major maintenance or rehabilitation of the street surface is programmed within three (3) years of the open cut. Boring or other tunneling methods will be allowed on all City-maintained streets. In cases where a break, leak, or malfunction occurs in an existing facility, or when spot lowerings or connections are made in rehabilitation, open cutting will be allowed as necessary to repair or rehabilitate the facility.

As additional streets are constructed or improved to ultimate standards, open cutting will not be permitted on these facilities except where maintenance or repairs occur.

1.2.5.4 Backfilling and Repair of Utility Cuts. When open cutting of an existing or proposed street is approved, aggregate backfill conforming to City standards must be placed for the full trench depth and compacted in six (6)-inch layers across the street to within two (2) feet of the outside of the street curbs, as well as under all sidewalks, driveways, and other structures or pavements. Any damage to existing curbs, sidewalks, and other public improvements shall be repaired and/or replaced by the utility forces or contractor at their expense. Details for backfill and pavement repair for concrete pavement and asphalt pavement can be found in Figure ST-13 & Figure ST-13A.

1.2.5.5 Utilities Constructed Through Sanitary or Storm Sewer Structures. Any utility found in a sanitary or storm sewer structure during the course of that structure's rehabilitation or reconstruction shall be relocated outside of the structure. Further, any new utility will be prohibited from passing through any storm sewer structure regardless of the age of the structure, and regardless of the fact that there are existing utilities in the structure. Relocation expenses will be incurred by the utility in the sewer structure.

1.2.5.6 Reimbursement to Public Utilities. On Public Works' projects constructed either by contract or by City maintenance forces where conflicts occur with existing utilities, the utility company shall be required to relocate their existing utilities in accordance with the policies set forth in these Design Standards. Where the utility is privately owned, all costs related to the relocation will be borne by the utility.

Both the designer and the utility must make a good faith effort and agree on the approximate location of the utility. Disclaimer clauses will not be accepted as good faith effort. Charges for reimbursement must include credits for all salvageable materials and must not include costs for betterment.

2 PLAN PREPARATION

2.1 DRAWING STANDARDS

2.1.1 General. Drawings for all submissions shall be submitted electronically. Final approved drawings will be stamped and filed electronically and will be available for download after all requirements have been met and fees are paid. After filing, the original drawings shall become the property of the City of Battlefield. Drawings to comply with latest electronic document submittal standards.

2.1.1.1 Utilities. All utilities must be coordinated as necessary by the applicant.

2.1.1.2 State Highways. Projects involving state highways will require the approval of the Missouri Highway and Transportation Department.

2.1.1.5 File Type Standards.

- Only searchable PDF files are accepted for calculations, reports and other supporting documentation (non-drawing files).
- Both vector PDF and Design Web Format (DWF) files will be accepted for drawing files. Since AutoCAD software is commonly used to create drawing files, converting a DWG to DWF file print ready is the preferred secured file format. Files must be 2D DWF file print ready, i.e. setup properly for printing with title block, no extra data outside the print page area, etc. The DWF must be saved as AutoCAD version 10 or lower format.
- If you choose to create PDF files, you will need to convert your AutoCAD files to a vector PDF by using AutoDesk Vector Graphic Converter "DWG to PDF.pc3 Plotter Driver."

2.1.1.6 Electronic Stamps and Signature.

- All files must be electronically stamped with signature per Missouri Statues and Missouri Administrative Code. There are specific provisions for electronic signatures within the Rules and Regulations. Architects and Engineers are responsible for compliance with these rules.
- Electronic stamps and signatures must be inserted images on DWG files.
- Confer with the City Administrator or designee for electronic document submittal standards.

2.1.2 Drawing Scale. Engineering plan and profiles shall be prepared on a scale of 1" = 40' horizontal and 1" = 4' vertical. When requirements for detail necessitates a larger scale, a horizontal scale of 1" = 20' and 1" = 4' vertical may be used. Drainage area maps, construction details, cross sections, and contour maps shall be drawn to a scale suitable to show complete detail.

2.1.3 Elevation Datum. Elevations shown on plans shall be in the North American Vertical Datum of 1988. At least one National Geodetic Survey (NGS) or City of Battlefield benchmark shall be used to establish the project datum. At least one project benchmark shall be established on site or near the site. The project benchmark will be semi-permanent in nature and not easily disturbed. The NGS or City of Battlefield benchmark used, and the project benchmark established shall be noted on the first plan sheet of each project, and their location and elevation shall be clearly defined.

2.1.4 Stationing and North Arrow. The top of each plan sheet shall be either north or east, and a standard north arrow should be used.

The stationing on street plans and profiles shall be from left to right, but on drainage, sanitary sewer, and storm sewer plans, the stationing shall always begin at the low point.

2.1.5 Topography. When more than one drawing sheet is required for a project, an overlap of not less than 100 feet shall be provided.

Each project shall show at least 100 feet of topography on each side. Subdivision plans shall show at least 100 feet of topography outside the plat limits. All existing topography and any proposed changes, including utilities, telephone installations, etc., shall be shown on both the plan and profile portion of the drawing.

2.1.6 Revisions to Drawings. Revisions to filed drawings shall be clearly noted and shown within a revision cloud on the plan and noted within a revision block showing the nature of the revision and the date made.

2.1.7 Symbols. Typical symbols shall be used in the preparation of engineering drawings. Topography for which symbols have not been standardized shall be indicated and named on the plan and profile sheet. In utilizing the standard symbols for engineering plans, all existing utilities, telephone installations, sanitary and storm sewers, pavements, curbs, inlets, and culverts, etc., shall be shown with a broken line; proposed facilities with a solid line; land, lot, and property lines to be shown with a slightly lighter solid line. All easements must be shown, as well as the book and page number, if recorded.

2.1.8 Minimum Requirements. It shall be understood that the requirements outlined in these standards are minimum requirements and shall be applied when conditions, design criteria, and materials conform to the City specifications. When unusual subsoil or drainage conditions are encountered, an investigation should be made, and a special design prepared in conformance with good engineering practices.

2.1.9 Owner's Name. The title sheet must indicate the owner's name and address for whom the improvements are to be constructed.

2.1.10 Dimensions. Lot lines, dimensions, and subdivision name shall be shown where applicable.

2.1.11 Cover Sheet. All plans shall have a cover sheet showing the general location of the project in relation to the Battlefield City Street system. The cover sheet shall show the complete project area to a scale of 1" = 100' or an appropriate scale for small projects.

2.1.12 Box Culvert Design. When standard box culvert designs are referenced, the Engineer shall show and label in the drawings the size, spacing, and shape of the reinforcing and the dimensions of the structure. Box culverts should be designed for HS-20 loading at a minimum.

2.2 PRE-CONSTRUCTION REQUIREMENTS

2.2.1 Fees. After plans have been approved and filed by the City, it is the Developer's responsibility to pay all necessary fees prior to construction.

2.2.2 Copy of Contract. A detailed copy of the construction bid, showing unit costs for all items included in the contract, and showing the total contract value, must accompany the fee.

2.2.3 Start of Construction. No construction of public facilities shall be permitted prior to approval and filing of the plans and/or paying of fees. In addition, 24-hour notification must be given to the City prior to the commencement of any work on public facilities. No street construction will be permitted prior to completion of construction of all private and/or public utilities within the street right-of-way.

2.2.4 Easements. All easements required for construction, which are not included on the plan, shall be recorded and filed with the City prior to filing of original plan sheets.

3 SURVEY REQUIREMENTS

3.1 Horizontal Control. Establish accurate horizontal control on the proposed work site. Physical monuments such as large nails, iron pins, or other durable materials must be set, and accurate horizontal positions established on them. A positional tolerance error between any 2 points in the control network will not exceed 0.05’. A positional tolerance error between adjacent pairs of control monuments will not exceed 0.02’.

3.2 Vertical Control. Establish accurate vertical control on the proposed work site. The North American Vertical Datum of 1988 will be used, propagated from NGS or City of Battlefield benchmarks. The Benchmark used to establish vertical control will be listed on the plans. Elevations will be established on the same monuments used for horizontal control as well as 2 temporary benchmarks located in areas where they will not be disturbed by construction. A vertical tolerance error between adjacent pairs of control monuments will not exceed 0.01’. Overall, the error shall not exceed 0.05’ in 5000’. Some form of differential leveling with a spirit level will be used; trigonometric leveling or GPS derived elevations are not acceptable for establishing elevations on control monuments.

3.3 Topography. Topography shall include all surface features within the limits of the project such as buildings, curbs, trees, water valves, walls, etc. This may also include painted markings for subsurface utilities as well as utilities that are exposed by excavation for more accurate locations. Sizes of pipes, culverts, and conduits shall be noted. Elevations and horizontal positions of critical topographic features such as flow lines of box culverts, flow lines of sewer manholes, curbs and other hard surfaces must be accurate to within 0.05’ or better.

3.4 Contours. The vertical accuracy of contours shown on plans will be +/-0.5’ for contour intervals of 1 foot or more. The vertical accuracy of contours of less than 1-foot intervals will be +/- one half (1/2) the contour interval.

3.5 Boundary and Right-of-Way. All work relating to property corners, boundary lines, right of way lines, and calculated property lines will be done under the direct supervision of a Professional Land Surveyor licensed in the state of Missouri. The land surveyor will use the current City of Battlefield Subdivision Regulations for any boundary survey work related to design surveys.

4 EARTHWORKS

4.1 EMBANKMENT CONSTRUCTION All embankments required for construction of public streets and alleys must be compacted. The method of compaction and densities are as required in the latest revision of the City of Springfield, MO Standard General Conditions and Technical Specifications for Public Works Construction. All embankment construction shall have a minimum 4:1 (H:V) forward and back slopes. All trees, shrubs, and plants designated to remain within the public right-of-way shall be shown and clearly noted on the plans. The plans shall require that the public right-of-way be left in a finished and neat appearing condition.

4.2 SUBGRADE COMPACTION The plans shall require that the street subgrade for both public and private improvements be compacted as required in the latest revision of the City of Springfield, MO Standard General Conditions and Technical Specifications. All street sub-grades shall have at least 4” of compacted aggregate (meeting Type 1, Type 5 or Type 7 Aggregate Base requirements) base. Aggregate should extend 1’ - 0” outside the limits of the curb and gutter.

5 SANITARY SEWERS

5.1 GENERAL

5.1.1 Materials. All materials used in the construction of sanitary sewers shall conform to the latest revision of the City of Springfield, MO. Standard General Conditions and Technical Specifications for Public Improvements unless specifically designated otherwise by special provision drawings and prior approval is obtained.

5.1.2 Discrepancies. Where discrepancies between standard details, drawings and/or special provisions occur, the special provisions shall govern.

5.1.3 Structures. Whenever possible, structures shall be constructed as shown in the standard details. Structures other than those shown in the standard details shall be considered to be special structures and must be designed and detailed by the design engineer.

5.1.4 Construction on Fill. Where a sewer must be constructed on fill, a profile of the original undisturbed ground line along sewer centerline shall be shown. All sewers to be constructed on fill must have a special design approved by the City of Battlefield Administrator or his designate.

5.2 SANITARY SEWER DESIGN

5.2.1 Design Period. Sanitary sewer systems must be designed for the estimated ultimate tributary population. Consideration should be given to the maximum anticipated capacity of institutions and industries.

5.2.2 Design Factors. In determining the required capacities of sanitary sewers, the following factors shall be considered:

A. Maximum hourly quantity of sewage.
B. Additional sewage volume or waste from industrial plants
C. Ground water infiltration.

5.2.3 Design Basis.

5.2.3.1 Per Capita Flow. Sewer systems shall be designed based on the maximum hourly flow tributary to the proposed improvement determined using an average daily flow of 100 gallons per capita plus wastewater flow from industrial, major institutional, and commercial facilities, multiplied by a peaking factor derived from the following formula:

Peaking Factor (PF) = $(18+\sqrt{P}) \div (4+\sqrt{P})$
Where P = Population expressed in Thousands

Wastewater flow from industrial, major institutional, and commercial facilities can be converted to population equivalent by dividing the flow by 100 gallons per capita per day. The 100 gallons per capita figure is assumed to cover normal infiltration, but an additional allowance should be made where ground conditions are known to be unfavorable.

5.2.3.2 Alternative Method. When deviations from the foregoing per capita rates are warranted, a brief description of the proposed procedure to be used for the sewer design shall be included. It is recommended that 2,500 to 3,000 GPD per acre for single-family gross area exclusive of sewage or other waste from industrial plants.

5.2.4 Design Details.

5.2.4.1 Minimum Size. No public sewer shall be less than eight inches in diameter.

5.2.4.2 Location. Sewers shall be placed in street right-of-way where feasible. Plans shall show the stationing of all in-line tees.

5.2.4.3 Depth. Sewers shall be designed deep enough to prevent freezing, and to allow house connections to cross under water mains at such an elevation that the bottom of the water main is at least eighteen (18) inches above the top of the sewer line. If the proposed sewer is parallel to a water main, it shall be designed to provide a minimum 18-inch vertical clearance or a minimum 10-foot horizontal clearance from the water main. Unless approved by the City Administrator, no sewer shall be designed and/or constructed that will not provide a minimum depth of four (4) feet to top of pipe. All standard PVC sewer mains up to 12 feet deep shall be SDR 21, Class 200 pipe. All sewers over 12 feet deep shall have a minimum of 12 inches of aggregate bedding material over the top of the pipe. The engineer shall perform calculations to select pipe type and material for sewers exceeding 20 feet in depth.

5.2.4.4 Slope. All sewers shall be designed and constructed to give mean velocities, when flowing full, of not less than 2.0 feet per second, based on the Manning formula using an “n” value of 0.013.

5.2.4.5 Slope calculations and detailing. The slope on all sewer lines shall be calculated from inside wall of manhole to inside wall of manhole.

The following are the minimum slopes, which should be provided; however, slopes steeper than these are desirable.

Sewer Size	Minimum Slope in Feet per 100 Feet
8”	0.50
10”	0.35
12”	0.30
14”	0.17
15”	0.15
16”	0.14
18”	0.12
21”	0.10
24”	0.08

Designers are not allowed to increase the size of sewer pipes only to take advantage of flatter slopes.

Sewers shall be laid with uniform slope between manholes. The maximum slope for all main line sewer pipes shall be 35%. The minimum slope for all laterals shall be 1/8 inch per foot, unless otherwise approved.

5.2.4.6 Loading. All sewers shall be designed to prevent damage from superimposed loads. Proper allowance for loads on the sewer shall be made because of the width and depth of trench. Details for backfilling gravity and forced sanitary mains are shown in Figures SAN-28 and SAN-29

5.2.4.7 Grade through Manholes. A drop of 0.2 feet shall be shown through manholes. A drop of 0.5 feet minimum shall be shown through manholes where a Z-lok is required (pipe slope greater than 10%) The flow line of new sewer lines coming into a main sewer manhole should be at least one half the diameter of the trunk sewer above the flow line of the trunk sewer.

5.2.4.8 Increasing Size. When a smaller sewer joins a larger one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient.

5.2.4.9 Alignment. Sewers in streets should be placed in or near the center of the driving lane where possible. Sewers located at back property lines should be about three feet to one side of the property line and on the opposite side from pole lines or other utilities. The ends of sewer lines should extend at least fifteen feet beyond the property line of the last lot served, to provide room for the house connection with a tee below the manhole. Cutting corners and running diagonally across streets is not allowed.

A minimum permanent easement according to the table below is required.

Size of Pipe (Diameter)	Depth to Flowline	Overall Width of Permanent Easement (pipe in center of easement)
8 – 24 inches	0 – 12.0 feet	15 feet
	12.1 – 20.0 feet	20 feet
	> 20.0 feet	ES Approval Req.
Greater than 24 inches	Any Depth	ES Approval Req.

A temporary construction easement shall be provided, as necessary. All crossing and/or cutting of streets must be backfilled with granular material. All sewers with a trench wall within two feet of the back of the street curb shall be backfilled with granular material.

5.2.4.10 Non-typical Connections. Connections for Recreational Vehicles (RVs) and/or Food Trucks shall be a typical 4-inch diameter cleanout placed within 6 – 12 inches above grade with removable cap. Approximately 12-inches under the removable cap shall be a cross bar to prevent RV or Food Truck sewer hoses from falling into the public sewer line. A connection is required at every RV or Food Truck stall.

5.2.5 Relation to Water Mains or Storm Sewers

5.2.5.1 Horizontal Separation. Wherever possible, sewers should be laid at least 10 feet, horizontally, from any existing water main or storm sewer. Should local conditions prevent a lateral separation of 10 feet, a sewer may be laid closer than 10 feet to a water main or storm sewer if:

A. It is laid in a separate trench, or
B. It is laid in the same trench with the water mains or storm sewer located at one side on a bench of undisturbed earth, and
C. In either case the elevation of the top (crown) of the sewer is at least 18” below the bottom (invert) of the water main or storm sewer.

5.2.5.2 Vertical Separation. Whenever sanitary sewers must cross under water mains or storm sewers, the sanitary sewer shall be laid at such an elevation that the top of the sanitary sewer is at least 18” below the bottom of the water main or storm sewer. When the elevation of the sanitary sewer cannot be varied to meet the above requirement, the water main or storm sewer shall be relocated to provide this separation.

When it is not feasible to obtain proper vertical separation as stipulated above, the sewer must be constructed of SDR 21, Class 200 pressure water line pipe and must be pressure tested to water pipe standards at a pressure not less than 150 pounds per square inch to assure water tightness. The sewer pipe may be required to be installed in a steel casing or by bridging (SAN-33). A manhole must be located at each end of the pressure pipe; and the near side of the manholes can be no closer than ten (10) feet from the water main.

No water line shall pass through or come into contact with any part of a sanitary sewer manhole.

5.2.6 Manholes.

5.2.6.1 Location. Manholes shall be installed at all changes in grade, size, or alignment, at all intersections, and at intervals of not more than 400 feet for all sewers. Manholes shall not be placed in existing or proposed sidewalks without prior approval from the City Administrator or designee. Standard Four-Foot Diameter is shown in Figure SAN-3 and New Manhole on Existing Sewer Line is shown in Figure SAN-4.

5.2.6.2 Drop Type. A drop pipe shall be provided for a sewer entering a manhole at an elevation of 24” or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 24 inches, the invert shall be filleted to prevent solids deposition; manholes, where the difference in elevation between the incoming sewer and the manhole invert is greater than 24 inches but less than 36 inches will not be allowed See Figure SAN-6. Special design is required for connection to manholes with interior linings.

5.2.6.3 Diameter. The minimum diameter of manholes shall be 48 inches (4 feet) and shall conform to the latest revision of the City of Battlefield Standard General Conditions and Technical Specifications. All inside drop manholes shall have a minimum diameter of 60 inches (5 feet).

5.2.6.4 Manhole Covers. All sanitary sewer manhole covers shall be Type "A,” non-rocking, See Figure SAN-1 unless located within floodplain or prone to submersion. If located within floodplain or prone to submersion, use water-tight, hinged Pamrex, EJ 24” ERGO No. EJ001040013L01, or R-1743-LM (NF-1743915) lid and frame or approved equal. See Figure SAN-2.

5.2.6.5 Stationing and Elevation. Stationing and elevations should be shown at all M.H. locations and at the ends of casings.

5.2.7 Lamp holes. Lamp holes may be permitted upon the approval of the City Administrator or designee. Lamp holes will be permitted only in cases where the slope of the land will not permit a future extension of the sewer beyond the proposed lamp hole. The maximum length to the nearest manhole shall not be greater than 150 feet. Lamp holes will not be permitted within street surfaces. Tees not to be located within 5’ of the lamp hole riser. Lamp hole Standard Drawing is shown Figure SAN-13.

5.3 DRAWINGS AND DOCUMENTS TO BE SUBMITTED

5.3.1 Sewer Drawings. Sewer drawings shall be prepared on plans separate from other utilities. District, Section, and Public Improvements file numbers shall be obtained from the City.

5.3.1.1 Plan. The plan shall be at the top of the drawing. Standard symbols shall be used. A standard north arrow shall be located on each sheet (pointing up or to the left.)

A. Scale shall be 1" = 40' horizontal for undeveloped areas and 1" = 20' for developed areas.
B. Method of Indicating Location. Sewers and manholes within streets and adjacent developed areas shall be located in plan by dimensions from property markers or other well-defined physical features.

5.3.1.2 Profile. The profile shall be shown under the plan.

A. Scale. Scale shall be 1" = 4' vertical, and 1" = 40' horizontal for undeveloped areas and 1" = 20' for developed areas.
B. Grades. Established elevations of existing manholes shall be obtained from field surveys. Existing ground and proposed pavement over sewer shall be shown and labeled. Existing or proposed building floor elevations or sufficient ground elevations 100 feet either side of centerline shall be shown to determine required depth and slope of service lines.

5.3.1.3 Utilities. Existing and proposed utilities shall be accurately and clearly shown in the plan and profile. Elevations of existing utilities shall be obtained where the possibility of conflict exists.

5.3.1.4 Location and Design Information. A cover sheet shall be Sheet No. 1 of the drawings, indicating the entire area to be served by the proposed sewers and indicating the sheet number on which each segment of sewer line is drawn. The scale shall be 1" = 100'. When this cannot be done without attaching an extra drawing, then the scale will be 1" = 200'. Proposed district boundaries shall be shown with sufficient data that a written district boundary description may be described from it, and a written boundary shall be attached to the drawing. Also, all lots, blocks, and the location of proposed sewer lines shall be known. When the cover sheet will not show at least two well-known streets or routes, a small location map shall be added to the cover sheet showing the location of the project. Benchmarks based on USGS datum shall be shown on the drawings as per the Survey Requirements included in Chapter 3 of these Design Standards. The City will review the plans to determine its compatibility with the entire drainage area. The developer or owner's name shall be shown on the cover sheet along with the subdivision name.

5.3.2 Plan Review Checklist for Sanitary Sewers

Note: The following checklist is presented for Developer's convenience and is not all encompassing of the City's Design Standards.

General Information

Yes	NO	N/A	
◻	◻	◻	Copy of the replat, lot split, or council-approved preliminary plat conditions has been provided which includes public improvement requirements
◻	◻	◻	Plans sealed, signed, and dated by Professional Engineer
◻	◻	◻	City logo on all sheets
◻	◻	◻	Revisions noted
◻	◻	◻	Mains sized for drainage basin
◻	◻	◻	Offsite sewer easements provided (list Book and Page on Plans)
◻	◻	◻	Minimum finished floor elevations shown on the cover sheet and plan sheet and are based on: 1. Minimal lateral connection flow line elevation at main spring-line (four inches (4") above line of an eight inch (8") main). 2. Minimum lateral slope of ⅛ inch per foot. 3. Maintain 18 inches of cover over top of lateral. 4. Serve the entire lot based on existing and/or proposed contours. Note: All minimum finished floor elevations must be shown on the final plat
◻	◻	◻	Obtained State approval (if in state ROW)
◻	◻	◻	Obtained appropriate permit to build within a floodplain. If manholes are located in floodplain, specify waterproof lids.
◻	◻	◻	Submitted a sinkhole report and received a sinkhole permit in accordance with the sinkhole ordinance
◻	◻	◻	Submitted plans for Land Disturbance Permit
◻	◻	◻	Checked for proximity to brownfields or hazardous material
◻	◻	◻	If crossing a street or concrete ditch, will the street or storm sewer department allow the structure to be cut or will it need to be bored, appropriate details shown on the plans
◻	◻	◻	Are there special connection fees to be paid with the engineering and inspection fees
◻	◻	◻	Install two-way clean-out at R/W or edge of easement with tracer wire full length of lateral within R/W or easement

Title Sheet

Yes	NO	N/A	
◻	◻	◻	Name of subdivision/improvement shown
◻	◻	◻	Name, address, and zip code of developer/owner shown
◻	◻	◻	Location sketch shown:

☐ ☐ ☐ 1. Scale shown.
☐ ☐ ☐ 2. North arrow shown.
☐ ☐ ☐ 3. Two major streets shown.
☐ ☐ ☐ Site Plan shown:
☐ ☐ ☐ 1. Legal description given (subdivision and/or sewer district boundary)
☐ ☐ ☐ a. reference made to land tie, existing subdivision or other known point.
☐ ☐ ☐ b. bearings and distances shown on plan and in written form.
☐ ☐ ☐ c. elevation contours shown over the entire sewer district.
☐ ☐ ☐ d. lot lines and dimension shown.
☐ ☐ ☐ 2. Two City benchmarks referenced.
☐ ☐ ☐ 3. North arrow shown.
☐ ☐ ☐ 4. Correct scale shown (1" = 40' or other appropriate).
☐ ☐ ☐ Neighboring subdivision name and lot numbers shown if affected by sewer or needed for boundary description information.
☐ ☐ ☐ Consultant's name, address, zip code, and phone number shown.
☐ ☐ ☐ Manholes on title sheet labeled.
☐ ☐ ☐ Sections of the main indexed by sheet number.
☐ ☐ ☐ All applicable standard construction notes shown.
☐ ☐ ☐ The "One Call" stamp and phone number shown.

Plan and Profile Sheets

Plan:

Yes	NO	N/A	
☐	☐	☐	Scale shown (1" = 40' horizontal, 1" = 4' vertical for undeveloped areas, 1" = 20' horizontal, 1" = 4' vertical for developed areas)
☐	☐	☐	North arrows shown.
☐	☐	☐	Line types defined (if not in standards).
☐	☐	☐	Easements shown with Book/Page numbers.
☐	☐	☐	Names shown of all landowners affected by project.
☐	☐	☐	Manholes not shown in detention. If detention is necessary, specify manhole above detention rim and grading around manhole.
☐	☐	☐	New easements dimensioned and properly described.
☐	☐	☐	Length of sewer main is to be measured from inside wall of manholes (not center to center of manholes).
☐	☐	☐	Stationing of manholes and casing ends shown.
☐	☐	☐	All other existing and proposed utilities and structures appear to be shown.
☐	☐	☐	Stationing in 50-foot intervals.
☐	☐	☐	Main placed in center of parkway where possible, otherwise is within an easement or right-of-way. Easements should conform to Section 5.2.4.9.
☐	☐	☐	Manholes shown to not be within existing or proposed sidewalks unless approved by City of Battlefield.
☐	☐	☐	State Plane coordinates on manholes and angles at manholes shown with bearing reference.

□	□	□	Station, size, and length of service lateral and tee shown. Tee and lateral shown to be perpendicular to main within easement or R/W.
□	□	□	All end-of-line manholes shown to be 15 feet past property line.
□	□	□	If adding manhole to existing sewer, the immediate upstream and downstream manhole elevations shown as shot in field, and any service laterals shown.

Profile:

Yes	NO	N/A	
□	□	□	Stationing shown.
□	□	□	Scale shown (1" = 40', 1" = 4' for undeveloped areas, 1" = 20', 1" = 4' developed areas).
□	□	□	Stationing and elevation of manholes and casing ends shown.
□	□	□	All other existing and proposed utilities and structures to be shown.
□	□	□	Pipe slope, material, and size is shown.
□	□	□	Z-LOK connection specified where incoming or outgoing pipe grade is greater than 10% and manhole should have 0.5 feet of fall through invert.
□	□	□	Four feet (4') of cover maintained over all mains.
□	□	□	Plot minimum finished floor elevation at station shown on plan and show Lot number, size, and length of lateral.
□	□	□	SDR 21 PVC pipe used if less than 18 inches clearance between top of sanitary sewer and bottom of storm sewer. Sewer pipe may be required to be installed in steel casing or by bridging (SAN-33).
□	□	□	SDR 21 PVC pipe present from MH to MH if sanitary sewer less than 18 inches vertical clearance of a water main. Also, note the special testing procedures shown. (see Section 5.2.5.2).
□	□	□	Sewer main in steel casing if ground cover of 18 inches impossible to attain; concrete encasement acceptable at creek crossings.
□	□	□	Note to place fill prior to sewer installation shown where fill proposed to attain four (4) feet of cover.
□	□	□	Distance between manholes centers less than 400 feet.
□	□	□	Minimum slope for eight (8) inch main 0.5 percent.
□	□	□	Concrete anchors along main shown if slope exceeds 15 percent (see SAN-32).
□	□	□	Trench seal specified on both sides of creek crossings (See SAN-21).
□	□	□	Bank and channel protection specified at creek crossing.
□	□	□	Casing and boring details shown with a minimum boring slope of one percent (1%)
□	□	□	If utilizing existing sewer, all existing and proposed service connections are shown, and all manhole lid and flow line elevations are given.

5.4 SEWAGE PUMPING STATIONS (LIFT STATIONS)

5.4.1 General. A sewage pumping station shall consist of a wet well, sewage pumps, control systems, electrical systems (normal and emergency), superstructures, site security systems, grading, and access.

The purpose and goal of a sewage pumping station is to serve as a sewage collection point for development and to pump that sewage to a gravity sewer line serving the area using the most cost effective and reliable design for maintenance and operation.

Sewage pumping stations will only be considered when a 10-year life cycle cost-effective analysis comparing the construction, operation, and maintenance costs between proposed sewage pumping station and a reasonable gravity sewer alternative clearly indicates that gravity sewers are not economically feasible.

5.4.2 Buildings and Grounds.

5.4.2.1 Flooding. Sewage pumping stations shall not be subject to flooding due to storm water runoff. Structures and electrical and mechanical equipment shall be protected from physical damage by the 100-year flood and remain fully operational and accessible during the 25-year flood.

5.4.2.2 Fencing. A fence surrounding the pump station site shall be provided. The fence shall be eight (8) feet high (minimum) with a fourteen (14)-foot wide, double-leaf gate. The fence shall be located to provide ten (10) feet clearance between all pump station components and the fence perimeter. Fencing shall be galvanized chain link except where subdivision rules require wooden privacy fence. The gate shall be located so that entranceway does not go over manholes. The pump station and emergency generator unit shall be easily accessible for maintenance from the entranceway. The gate shall be set back at least twenty-five (25) feet from the edge of public street.

5.4.2.2.1 Sign. A sign containing the following wording shall be securely attached to the fence at a location clearly visible from the pump station access road:

Station Name & I.D. No. (Obtain from City)
Sewage Pumping Station
City of Battlefield
No Trespassing
In Case of Emergency or Alarm
Please Call (417) 883-5840 or 911

Wording shall be centered horizontally and vertically on the sign. The sign panel shall be standard gauge aluminum sheet, minimum 30-inches by 30-inches, with black letters on white background. Top four (4) lines shall be minimum 2-inch-high letters and bottom two (2) lines shall be minimum 1-inch-high letters.

5.4.2.3 Surfacing of Sewage Pumping, Lift Station Area. The area inside the fence must be constructed of six (6) inches of Type 1 aggregate, compacted according to City Specifications on a medium weight, non-woven geotextile, permeable vegetation barrier placed over the entire enclosed area.

Subgrade shall be graded to provide positive drainage away from building and structures. Maintain finished grade/surfacing a minimum of 6" below face of exposed concrete at locations around the perimeter of all structures. Slope subgrade and surfacing for adequate drainage. For all sidewalk's, running slope is not to exceed 5% and cross slope is not to exceed 2% in any direction. Embankment and drainage channels shall have a maximum slope of 4:1.

5.4.2.4 Accessibility to Site. The pump station must be accessible by an acceptable all-weather, hard-surface road meeting the same requirements as other roads in development. The road shall have a minimum driving surface width of 12-feet and maximum grade of 10%. Enough room shall be provided at the site to permit turning vehicles around. The junction of pump station road and public street shall have a minimum sixteen (16)-foot-long culvert of acceptable diameter in ditch if applicable.

5.4.2.5 Exterior Lighting. A weatherproof, pole or building mounted, exterior LED area lighting fixture with dusk-to-dawn operation shall be provided. The fixture shall be dimmable with the capability to provide an average range of illumination of one (1.0) footcandle over the entire site for security purposes and fifteen (15.0) footcandles over the wet well and equipment areas for maintenance purposes.

5.4.2.6 Control Building. All electrical switch gear and controls shall be mounted inside a weatherproof building with four (4) feet (minimum) clearance at front of electrical enclosures and a minimum ceiling height of eight (8) feet. The building may be masonry, pre-engineered metal, or pre-engineered fiberglass reinforced plastic (FRP) construction, as required by the City of Battlefield. The building shall be securely anchored to a minimum six-inch thick steel reinforced concrete floor designed to support applied loads. Buildings shall be provided with appropriate heating and ventilation equipment. Buildings for permanent stations shall also be provided with restroom facilities and shop sink with hot and cold-water supply. Construction details and technical specifications for the building shall be incorporated into the Plans and Special Provisions specific to that Project.

5.4.3 Design. The following items should be given consideration in the design of sewage pumping stations:

5.4.3.1 Type. Sewage pumping stations shall be non-clog, solids handling, suction type or submersible type. Grinder pumps will be considered by the City only in special cases if sufficient information is presented to justify their use. Built-in-place dry well/wet well-type stations may be acceptable for large stations and will be considered by the City on a case-by-case basis when one pump is 700 GPM or greater.

5.4.3.2 Structures. Pump station wet well, and valve vault shall be constructed of either pre-cast or poured-in-place reinforced concrete. Precast structures shall conform with ASTM C478 and ASTM C890. Poured-in-place structures shall conform with Chapter 6 of the General Conditions and Technical Specifications.

5.4.3.2.1 Buoyancy. Where high groundwater conditions are anticipated, buoyancy of the pump station structures shall be considered and, if necessary, adequate provisions shall be made for protection.

5.4.3.2.2 Separation. Wet and dry wells, including their superstructure, shall be completely separated. Common wall construction between wet and dry wells may be permitted provided there is no interconnection between the wet well and dry well atmospheres.

5.4.3.2.3 Pump Removal. Provision shall be made to facilitate removing pumps, motors, and other mechanical and electrical equipment.

- **A.** Submersible pump stations shall have a quick disconnect connection and guide rail lifting system for each pump. A stainless-steel lifting chain, with one end permanently attached to the pump-lifting bail and the other end secured to a stainless-steel hook at grade level, shall be provided for each pump.
- **B.** Dry well/wet well stations shall have a hoist and trolley system to lift and move the pumps to the access opening. System shall have a minimum lifting capacity equal to 150% of the maximum combined pump and motor weight.
- **C.** Suction lift stations shall have a lifting arm for removing motor and pump from base.
- **D.** Where pump station is enclosed in a building, the hoist and trolley system described above shall be capable of moving pumps and motors to the access doorway.

5.4.3.2.4 Access. Suitable and safe means of access shall be provided to dry wells of pump stations and shall be provided to wet wells containing either bar screens or mechanical equipment requiring inspection and maintenance. Stairways or ladders shall have rest landings at vertical intervals not exceeding ten (10) feet. Such stairways and ladders shall be OSHA compliant.

5.4.3.3 Pumps

5.4.3.3.1 Design. Pumps shall be designed so that it is not necessary to disconnect piping, valves, electrical circuits, and other appurtenances in the wet well when the pumps are removed for service or replacement.

5.4.3.3.2 Multiple Units. At least two (2) pumps shall be provided. If only two (2) units are provided, they must have the same capacity. Each pump shall be capable of handling the design peak hourly flow. Where more than two (2) units are provided, each unit must be of such capacity that with any one unit out of service the remaining units will have capacity to handle the design peak hourly flow.

5.4.3.3.3 Protection Against Clogging. Protection Against Clogging. Where the size of the lift station is 700 gpm or greater, a trash rack located below floor level shall be provided. Where screens are located below ground, facilities must be provided for handling screenings.

5.4.3.3.4 Pump Openings. Pumps shall be capable of passing spheres of at least three (3) inches in diameter. Pump suction and discharge openings shall be at least four (4) inches in diameter.

5.4.3.3.5 Priming. The pump shall be so placed that under normal operating conditions it will operate under a positive suction head except as specified for suction-lift stations. Each suction lift pump shall have a priming system independent from other pumps.

5.4.3.3.6 Intake. Each pump shall have an individual intake. Wet well design shall be such as to avoid turbulence near the intake.

5.4.3.3.7 Dry Well Dewatering. A separate sump pump shall be provided in the dry well to remove leakage or drainage with the discharge above the overflow level of the wet well. The sump pump discharge line shall be provided with dual check valves and coupling to facilitate sump pump removal for maintenance. Water ejectors connected to a potable water supply will not be approved. All floor and walkways surfaces shall have an adequate slope to a point of drainage.

5.4.3.3.8 Submersible Pump Seals. Tandem mechanical seals are required on submersible pumps. Seal faces shall be tungsten carbide.

5.4.3.4 Piping and Valves. Station piping shall be at least four (4) inches in diameter. A shut-off valve shall be placed on the discharge line of each submersible pump. For dry pit stations, shut-off valves shall also be placed on the suction line and discharge line of each pump.

A check valve with external spring (or weight) and lever shall be placed on each discharge line between the shut-off valve and the pump. Each check valve shall be equipped with a lever-operated micro switch for common alarm telemetering purposes. Valves on the discharge side of each pump shall be provided with instrument ports.

For submersible stations, these valves shall be located inside a valve vault separate from the wet well and shall be readily accessible for repairs. Dismantling joint fittings should be provided adjacent to valves to facilitate installation or removal of valves.

5.4.3.5 Wet Wells

5.4.3.5.1 Sizing. The design fill time and minimum pump cycle time shall be considered in sizing the wet well. The effective volume of the wet well shall be based on the design average daily flow determined in accordance with Section 5.2.3.1 of these Design Standards and a filling time not to exceed 30 minutes unless the facility is designed to provide flow equalization. The pump manufacturer's duty cycle recommendations shall be utilized in selecting the minimum cycle time. For constant speed pumps the minimum cycle volume shall be based on the following formula:

$$Vr_{min} = (T \, x \, Q) \div (4)$$

Where:

Vr_{min} = Required minimum pump cycle volume between pump-on and pump-off, gallons

T = Required time between pump starts, minutes

Q = Pump discharge capacity, gallons per minute

5.4.3.5.2 Grit. Where it may be necessary to pump sewage prior to grit removal, the design of the wet well should receive special attention and the discharge piping shall be designed to prevent grit settling in pump discharge lines of pumps not operating.

5.4.3.5.3 Divided Wells. Where continuity of pumping station operation is required, consideration shall be given to dividing the wet well into two sections, properly interconnected, to facilitate repairs and cleaning.

5.4.3.5.4 Sump. Wet well sump design shall provide for proper approach flow to the pumps and prevent accumulation of sediments. The wet well floor shall be sloped to direct flow toward the pump inlets with a minimum of localized swirl and air-entraining vortices and include fillets or benching to prevent sedimentation. For larger wet wells, a properly placed baffle wall close to the inlet should be considered to reduce the potential for localized swirl and vorticity. Water levels during pump cycling must be great enough suppress surface vortices yet lowered as much as possible at intervals to increase velocity and turbulence.

5.4.3.6 Ventilation. Adequate ventilation shall be provided for all pump stations. For submersible type stations, passive ventilation of the wet well will be adequate and shall consist of a 4-inch stainless steel or aluminum vent pipe extending at least 18-inches above top of wet well with a return bend and stainless-steel insect screen. In dry well/wet well stations, mechanical ventilation of the dry well is required. Mechanical ventilation of the wet well is also required when screens or other mechanical equipment requiring maintenance or inspection is located in the wet well. There shall be no interconnection between the wet well and dry well ventilation systems. In pits over fifteen (15) feet deep, multiple inlets and outlets are required. Dampers shall not be used on exhaust or fresh air ducts, and fine screens or other obstructions in air ducts shall be avoided to prevent clogging. Switches for operation of ventilation equipment shall be marked and located at grade level. Ventilation equipment and lighting shall be energized when access cover is open on dry well type stations. The fan wheel shall be fabricated from non-sparking material. Automatic heating and dehumidification equipment is required when station is located below grade level.

5.4.3.6.1 Wet Wells. Ventilation may be either continuous or intermittent. Ventilation, if continuous, shall provide at least twelve (12) complete air changes per hour; if intermittent, at least thirty (30) complete air changes per hour. Such ventilation shall be accomplished by the introduction of fresh air into the wet well by mechanical means.

5.4.3.6.2 Dry Wells. Ventilation may be either continuous or intermittent. Ventilation, if continuous, shall provide at least six (6) complete air changes per hour; if intermittent, at least thirty (30) complete air changes per hour.

5.4.3.7 Water Supply. Potable water shall be supplied; however, there shall be no physical connection between the potable water supply and a sewage pumping station. Potable water supply lines shall not be smaller than one (1) inch. A freeze-proof hydrant with hose bib and vacuum breaker shall be located within ten (10) feet of pumping station but not in the traffic path. The water supply to the pump station site shall be protected by a reduced pressure type backflow preventer. Backflow preventer piping shall be provided with unions and isolation valves to allow removal for maintenance.

5.4.3.8 Dry Well, Wet Well and Valve Vault Access. Suitable and safe means of access shall be provided to pump station dry wells, wet wells, and valve vaults. Access covers and frames shall be aluminum construction and sized to provide adequate clearance for removal of pumps, motors, and other equipment. Access cover frames shall be extruded aluminum angle frame with concrete anchors around the perimeter. Door leaves shall be ¼-inch aluminum diamond pattern plate, reinforced to support a minimum live load of 300 psf. Doors shall open to 90 degrees and automatically lock with an aluminum or stainless-steel hold open arm with release handle. Doors shall close flush with frame and be equipped with a flush drop handle for lifting and a non-corrosive locking bar. Hinges and all fastening hardware shall be stainless steel. Factory finish shall be mill finish aluminum. An alkali resistant bitumastic coating shall be applied to the frame exterior where it will contact concrete.

5.4.3.8.1 Fall Through Prevention System. Access openings shall be provided with a hinged safety grate system. Grate shall be aluminum construction, designed to support a minimum live load of 300 psf. Grate openings shall be 4-inches by 6-inches to allow for visual inspection and limited accessibility for maintenance purposes when the grate is closed. Grate shall open to 90 degrees and automatically lock with an aluminum or stainless-steel hold open arm with release handle. Hinges and all fastening hardware shall be aluminum or stainless steel. Grate shall have an OSHA safety yellow finish to increase visual awareness of the safety hazard.

5.4.3.9 Spare Parts. Pump stations are to be provided with two (2) mechanical seals and two (2) gasket kits to install with seals. If seal filters are used, six (6) spares are to be included. Two (2) complete sets of contacts and coils if equipped with full voltage starters, or one (1) RVSS/VFD if so equipped, and one (1) spare alternator relay or timer shall also be furnished.

5.4.3.10 Force Main Interface. A force main interface consisting of piping, a 45-degree “Y,” 45-degree elbow, and flanged plug valve, and male cam-lock coupling shall be provided.

A. All pipe and fittings shall be the same diameter and be the same material as the pump station piping.
B. The interface shall be constructed within a four-foot diameter, flat top manhole of required depth located external from but adjacent to the pump station.
C. A 30-inch by 30-inch aluminum access hatch and fall prevention system as described in Section 5.4.3.8 of these Standards shall be provided.
D. Special Requirements for Suction-Lift Pump Stations. In addition to the previously mentioned requirements for suction-lift stations, the following shall apply:
    a. (1) Priming. Suction-lift pumps shall have a reliable record of satisfactory operation and be installed with a single piece suction line braced to the side of wet well. Priming shall be by dual vacuum systems independent of each other.

(2) Capacity. Approval will be restricted to installations where total suction-lift does not exceed fifteen (15) feet.

5.4.3.11 General Electrical Requirements. All electrical equipment and wiring shall comply with the latest revision of the National Electrical Code (NEC). Particular attention shall be given to electrical equipment enclosed in places where gas may accumulate (hazardous areas). Submersible pumps are considered to be in a hazardous area and shall be rated for use in NEC Class 1, Division 1, Group C and D hazardous locations. This rating shall include pumps, removal systems, and controls. Vacuum primed pump controls systems must be operated through intrinsically safe relays for hazardous locations. All conduits shall be of galvanized rigid type and shall be installed below grade wherever possible. Dry-type transformers for 110-Volt utility service and control systems power shall be provided.

5.4.3.11.1 Service and Distribution. The primary power to the station shall be 480 Volt, 3 Phase, and shall be provided by connection to a commercial utility service.

A. A service entrance disconnect switch acceptable to the utility provider shall be provided between the pump station and the utility. Service entrance equipment, when installed, shall be provided with maximum available fault current labeling in accordance with NEC guidelines. The field labeling shall include the date the fault current calculation was performed and be of sufficient durability to withstand the environment involved.
B. 3-phase power distribution and 1-phase branch circuit panel boards shall be provided as necessary.
C. A dry-type transformer for 120/240-volt single phase utility service and control system power shall be provided.
D. Equipment shall have a withstand and closing rating in RMS symmetrical amperes greater than the available fault current at the site and be provided with field or factory arc flash labeling in accordance with NEC guidelines.
E. All conduit, fittings, and conduit bodies shall be galvanized rigid steel, PVC coated externally, and urethane coated internally, equal to OCAL or Robroy and shall be installed below grade wherever possible. Conduit passing from a hazardous area into a nonhazardous area shall be provided with a sealing fitting which shall be located at the boundary in accordance with NEC.

F. Types, sizes, ratings, and electrical characteristics of service and distribution equipment and accessories shall be indicated on the Plans and Special Provisions.

5.4.3.11.2 Emergency Operation. Provision of an emergency power supply for pumping stations shall be made and may be accomplished by connection of the station to a second independent public utility source or by provision of a stationary engine generator rated at 125% of total combined load of all pumps and auxiliary loads.

5.4.3.12 Controls. Control system shall automatically operate the pumps in a pump down, lead/lag, common off, mode of operation. Control of pumps shall be by the use of a conductance relay level sensing system equal to Multitrode level sensor, three (3) meters in length, with a MTIC controller. The controller shall have a minimum of 4 switches used to indicate “PUMPS OFF,” “LEAD PUMP ON,” “LAG PUMP ON,” and “HIGH LEVEL ALARM.” The control panel shall include automatic pump alternation to equalize operating time on all duplex components and provisions to prevent simultaneous starting of pumps. Provisions shall be made to bypass the alternator in the event that either pump is out of service for maintenance. On larger sewage pumping station installations other control systems may be required. One (1) hand-off-auto switch and elapsed time meter shall be provided for each pump and be operable through the control panel door. Elapsed time meters shall be calibrated in one-tenth (0.1) hour increments on all pumps.

5.4.3.13 Alarm and Monitoring Systems. Alarm systems shall be provided for all pumping stations. Equipment shall be a Mission Communications MyDro 150. All necessary equipment shall be provided to monitor and transmit the following conditions: 1. Pump No. 1 Running; 2. Pump No. 2 Running; 3. Pump No. 3 (if applicable); 4. High Wet Well Level; 5. Control Power Failure; 6. Transfer to Emergency Power Source; 7. Generator Running; 8. Common Alarm. Other alarm conditions may be required based upon pump station configuration and design such as grinder failure, dry well sump pump failure, or any cause of pump station malfunction.

5.4.3.13.1 Flow Metering. All sewage pumping stations shall be provided with flow metering. The flow meter shall be of the electromagnetic type and provide for transmitting of flow in full pipes. The flow tube shall be installed on the force main between two pipe flanges having the same nominal diameter as the flow meter end connections. A standard four-foot diameter manhole with removable flat top, and hinged frame and cover shall be installed around the force main and flow tube. The associated flow meter transmitter shall be installed in the control building housing the electrical switchgear. The transmitter shall contain all necessary circuitry to utilize the signal from the flow tube and display flow in gallons per minute and totalized flow in gallons. The transmitter shall include analog outputs to interface with the Alarm and Monitoring System specified in Section 5.4.3.13 above.

5.4.3.14 Emergency Power Supply. Provision of an emergency power supply for pumping stations shall be made and may be accomplished by connection of the station to at least two independent public utility sources, or by provision of in-place internal combustion engine equipment which will generate electrical energy unless a fail-safe gravity relief system can be incorporated into the wet well.

5.4.3.14.1 General. The power module shall consist of an engine, generator, and control panel assembly, all mounted with antivibration mounts onto a fabricated steel skid base with an integral weather/sound enclosure and, if applicable, a sub-base fuel tank. An automatic transfer switch (Refer to Section 5.4.3.15.4 of these Design Standards) shall be provided to automatically switch to emergency power in the event of commercial power failure. The engine generator shall be sized for starting all pumps and all auxiliary loads, with an additional 25% overload capacity at site altitude within the following parameters:

A. Minimum genset load allowed, 30% of rated capacity.
B. Maximum genset load allowed, 75% of rated capacity.
C. Maximum allowable voltage dip, 25%.
D. Maximum allowable frequency dip, 10%.
E. Site temperature, 50˚C.
F. Maximum allowable temperature rise, 125˚C/Class H.
G. Emissions, EPA Stationary Emergency Application.

The complete power module shall be factory assembled and factory tested to ensure that all controls and protective devices are in proper working order. The motor starting capability shall be tested by a simulation of the exact operating load, with certified test results provided. The power module must be coordinated with the starting characteristics of the pump motors plus axillary loads.

5.4.3.14.2 Engine. The engine shall be multi-cylinder, 4-cycle, 1800 RPM, water-cooled, equipped to operate on natural gas for units rated up to and including 100 kw, natural gas or diesel at City's discretion for units rated 100 kw to 150 kw, diesel for units rated over 150 kw, and include the following features and accessories:

A. Electronic governor to provide automatic engine-generator set frequency regulation of 5% from steady state no load to steady state full load.

B. Unit-mounted closed loop radiator system to properly cool the engine when generator set is delivering full rated load with 50˚C inlet air and provide protection to -20 degrees F. Guard rotating parts from accidental contact.

C. Low oil pressure, high water temperature, over-crank, and automatic over-speed shutdown devices.

D. Electric starter capable of three complete cranking attempts without overheating.

E. Positive displacement, mechanical, full pressure, lubrication oil pump.

F. Full flow lubrication oil filters with replaceable spin-on cannister elements, dipstick oil level indicator and oil drain.

G. Replaceable dry element air cleaner for heavy duty application.

H. Engine mounted battery charging alternator with solid-state voltage regulator.

5.4.3.14.3 Alternator. The alternator shall be a full 3-phase, 4-pole, self-excited, brushless, revolving field type with static exciter. It shall be self-regulated and designed specifically for motor starting application. The alternator shall be directly connected to the engine flywheel housing and driven through a semi-flexible driving flange to ensure permanent alignment. It shall have drip-proof construction. Voltage regulation shall be within plus or minus 5% of rated voltage from no load to full load. Insulation shall be Class H with a 120 degrees C maximum temperature rise. A completely wired and assembled generator control panel shall be furnished. It shall contain the following items:

A. A microprocessor-based controller with LCD display that will indicate voltage, current, and frequency.

B. A line circuit breaker for alternator output leads.

5.4.3.14.4 Automatic Transfer Switch. The automatic transfer switch shall be a mechanically held, double throw, open transition or break before making switch. The transfer action must be completely electrical and not rely on springs or counterweights. Operating coils must be momentarily energized from the source to which the load is being transferred. The switch must be interlocked both mechanically and electrically to prevent both sources from feeding the load at the same time. Electrical operation must not allow a neutral position. The main contacts of the transfer switch shall meet with a rolling and wiping action. They shall be copper with cadmium plating up to and including 100 amps and silver plating on all sizes above 100 amps. They shall be rated for all classes of load to 480-volt AC and equipped with blowout coils and arc chutes. They shall have air inrush current rating of 20 times rated current and an interrupting capacity of 1.5 times rated current. The transfer switch shall include auxiliary contacts to provide connection to the alarm system. It shall also have three voltage-sensitive relays with adjustable dropout of 70 to 80% and adjustable pickup of 90 to 100%. Upon sensing of under-voltage condition, the generator startup and transfer sequence shall be initiated automatically. Provision shall also be made to manually initiate the sequence. A programmable exerciser timer shall be provided to set week, day, time, and duration of generator set exercise period.

5.4.3.14.5 Engine Control Panel. The engine control panel is to include five (5) ten-second-on/10-second-off cranking cycles, a switch for testing the automatic operation, a switch for deactivating the automatic operation, and a microprocessor-based controller with an LCD display that will indicate oil pressure, coolant temperature, battery charging voltage, elapsed time meter, fail-to-start, line-power-on, and standby-power-on, protective shut-down, engine overspeed, low oil pressure, overload, high coolant temperature, manual start-run-stop switch, 0-60-second time delay on transfer Normal to Emergency, 0-30-minute time delay on transfer Emergency to Normal, 0-5-minute time delay after transfer to normal for engine cool down, contacts to signal emergency power on, contact to signal fail-to-start, and contact to signal protective shut-down and fail-to-start.

5.4.3.14.6 Placement. The unit shall be bolted in place. Facilities shall be provided for unit removal for purposes of major repair or routine maintenance.

5.4.3.14.7 Engine Location. The unit internal combustion engine shall be located above grade with exhaust muffler and outlet located inside of weatherproof housing. The muffler system shall be residential type or better.

5.4.3.14.8 Engine Cooling Ventilation. Engine housing shall have adequate ventilation to maintain a safe equipment operating temperature.

5.4.3.14.9 Emergency Power Generation. All emergency power generation equipment shall be provided with instructions indicating the essentiality of routinely and regularly starting and running each unit at full load.

5.4.3.14.10 Spare parts were discussed to be added with no verbiage.

5.4.4 Acceptance of Sewage Pumping Station

5.4.4.1 Shop Drawings. Shop drawings shall be submitted on sewage pumping stations, stand-by power source, and structures, and be approved prior to installation. One (1) electronic copy in portable document format (.pdf). Two (2) reviewed print copies will be returned to the Contractor.

5.4.4.2 Testing. Prior to acceptance of sewage pumping stations by the City, testing of each equipment item shall be required in the presence of the Contractor, a City representative, and the equipment manufacturer's representative. Final acceptance will not be made until all deficiencies are corrected and retesting is performed.

Diesel fueled generator units are to be run with site loads when NFPA testing results are supplied by the manufacturer. Natural/Propane Gas units to be run with a 2-hour load bank, 1-hour at 80% load and 1-hour at 100% load to test gas supply.

5.4.4.3 As-Builts. Prior to acceptance of operation of sewage pumping station, generator units, and other related appurtenances by the City, one (1) electronic copy of "As-Builts" in AutoCAD and portable document format (.pdf) and one (1) sets of prints of "As-Builts" shall be submitted.

5.4.4.4 Operation and Maintenance Manuals. Four (4) complete sets plus an electronic copy in portable document format (.pdf) of operational instructions shall be provided to include emergency procedures, maintenance schedules, maintenance manuals, and service manuals on all equipment. Special tools and such spare parts as may be necessary should be provided to the City for the facilities to be accepted. Such tools and spare parts shall be provided in duplicate pairs.

5.5 FORCE MAINS

5.5.1 Velocity. Force main pipe diameter shall be sized to provide a minimum velocity of two (2) feet per second with one pump operating and a maximum velocity of eight (8) feet per second with multiple pumps operating.

5.5.2 Sewage Combination Air Valve. A single body sewage combination air valve equal to APCO Series 440-shall be placed at high points in the force main to automatically exhaust large quantities of air during pipeline filling at system startup, automatically allow air to re-enter the pipeline to protect the pipeline against negative pressures during draining, and automatically release small pockets of air from the pipeline while system is operating under pressure to prevent air locking. A standard four-foot diameter manhole with removable flat top, hinged frame and cover, and interior corrosion protection per Figure SAN-31 shall be installed around force main and relief valve for maintenance access to valve.

5.5.3 Connection to Gravity System. The force main shall connect to the gravity sewer system at a point not more than two (2) feet above the flow line of the receiving manhole in a manner that provides a smooth transition of flow and minimizes turbulence. Corrosion protection for the interior of the receiving manhole, upstream manhole, and two downstream manholes shall be provided. At the City's discretion, corrosion protection may also be required for additional upstream and downstream manholes, depending on the potential for sulfide generation as discussed in Section 5.6.2. Corrosion protection of new manholes shall be accomplished by the monolithic spray-application of a high-build, solvent-free epoxy resin coating system. Surface preparation and product application and film thickness shall conform to the coating system manufacturer's recommendations. Rehabilitation of existing manholes to repair voids and restore structural integrity may be required prior to applying corrosion protection system. If required, rehabilitation of existing manholes shall be completed.

5.5.4 Design Pressure. The force main pipe and fittings shall be designed to withstand normal pressure and pressure surges (water hammer).

5.5.4.1 Design Friction Losses. Friction losses through force mains shall be based on the Hazen-Williams formula or other acceptable method. A C-factor of 120 shall be used for computation of force main friction losses. When initially installed, force mains will have a significantly higher C-factor. Higher C-factors should only be considered in calculating maximum power requirements.

5.5.5 Thrust Blocks. Concrete thrust blocking shall be provided at all bends, tee's, plugs, fittings, or other significant changes in direction. Thrust block locations shall be noted on both plan and profile views of the construction plans. Mechanical joint restraint devices should be considered in addition to concrete thrust blocks. See Concrete Thrust Block and Anchor Details Figure SAN-30 & Figure SAN-32.

5.5.6 Force Main Pipe. All force main pipe shall be PVC conforming to AWWA C900 and have minimum pressure rating of 200 psi (DR21) HDPE pipe will be considered by the City only in special cases provided sufficient information is presented to justify its use. If approved, material and installation requirements shall be addressed in the Plans and Special Provisions for the project.

5.5.7 Trace Wire and Detectable Marking Tape. A trace wire shall be installed the entire length of the force main. Trace wire shall be accessible from the surface at intervals not to exceed 1000-feet of developed pipe length apart, at each end of roadway crossings, and adjacent to all air valve vaults. Terminal/access boxes shall be at grade level, in-ground type specifically manufactured for such applications. Terminal boxes shall be installed flush with finished grade and centered in grade level reinforced concrete pad, minimum 18” by 18” by 6” thick, at locations approved by Engineer.

In addition to trace wire, a detectable marking tape specifically manufactured for marking and locating underground utilities shall be installed the entire length of the force main. Marking tape shall be installed directly over force main at a depth of 12- to 18-inches below finished grade.

A tracer wire is also required for all laterals. Tracer wire shall be installed in accordance with Figure SAN-25.

5.5.8 Depth. Force main pipe shall be designed and so constructed to provide a minimum depth of three (3) feet of cover over the top of the pipe.

5.5.9 Steel Casing. Force mains designed to cross public streets must be encased in steel casing conforming to ASTM A53 with a minimum yield strength of 35,000 psi and a minimum wall thickness of 0.25-inch. The casing inside diameter shall be at least 8-inches greater than the nominal diameter of the force main. Casing spacers shall be provided to permanently position the force main inside the casing and prevent any lateral or vertical movement. Force main joints inside casing shall be restrained to allow multiple pipe segments to be pushed or pulled without compressing or separating the assembled joints. Casing ends seals shall also be provided. See Figure SAN-15 for details casing spacers and ends seals.

5.5.10 Testing. Testing of the force main is required in accordance with the requirements of AWWA C-600. Testing pressure shall be: Total Design Head x 0.433 x 1.5, but not less than 150 psi. (Note: This must be shown on the Plans.)

6 STORM SEWERS

6.1 GENERAL

6.1.1 Scope. These design standards set forth the minimum requirements for design of storm drainage facilities on public right-of-way and private property in the City of Battlefield, Missouri. These standards shall apply to all subdivisions for which preliminary plats approved after the date of passage by the City of Battlefield, or building permit submittals, or grading permit applications which are received after the date of passage by the City of Battlefield.

6.1.2 Coordination with Other Jurisdictions. Where proposed storm drainage facilities are located on property adjoining other local government jurisdictions, design of storm drainage facilities shall include provisions to receive or discharge storm water in accordance with the requirements of the adjoining jurisdiction, in addition to meeting City of Battlefield requirements. In these cases, two (2) additional sets of plans shall be submitted and will be forwarded to the adjoining jurisdiction for review and comment.

6.1.3 Coordination with Transportation Facilities & Utilities. Planning and design of proposed storm drainage facilities must be compatible with proposed or existing utilities, highways, streets, roads, railroads, and other public facilities. Where other public facilities may be affected by proposed storm drainage facilities, plans for storm drainage facilities shall be forwarded to the appropriate agency for review and comment. No grading or construction of storm drainage facilities may commence without prior notification of the Missouri One Call utility warning system at 811 as required by State law.

6.1.4 Ownership and Maintenance.

- <u>Improvements on Public Road Right-of-Way.</u> Storm drainage improvements on public right-of-way shall, upon acceptance of the improvements by the City of Battlefield, become the property of the City of Battlefield and shall be maintained by the City of Battlefield.

- <u>Improvements on Private Property.</u> Storm drainage improvements on private property shall be maintained by the owner of the lot upon which the improvements are located, or by the subdivision Homeowners' Association for improvements located in common areas.

6.2 PLAN SUBMITTAL AND INSPECTIONS

6.2.1 General. This Chapter defines the minimum plan submittal and inspection requirements for private and public stormwater improvements.

6.2.2 Stormwater Construction Plans. Stormwater construction plans shall include a Title Sheet, Site Plan, Grading Plan, Detention and/or Water Quality Stormwater Control Measure (SCM) Plan, Storm Drain Plan, Details Plan and an Erosion and Sediment Control Plan. Submitting a complete set of stormwater construction plans will help reduce permit review time and is essential to effectively communicate to contractors what the engineer intends to be constructed. Often, poor construction plans or poorly constructed stormwater improvements result in ineffective stormwater systems and flooding problems.

Stormwater improvement projects will require the submittal of Stormwater Improvement Plans which must be designed to:

- Comply with detention and water quality requirements, per Chapters 6.7 and 6.8.
- Protect all structures from inundation and provide 2-feet of freeboard below any finished floor for the 100-year peak flow.
- Protect public streets from flooding, worsen flooding or cause the street to not meet the City's stormwater drainage criteria.
- Adequately discharge both onsite and offsite peak flows to a public right-of-way, drainage easement, or certified natural surface water channel.

6.2.3 Stormwater Report. A supplemental stormwater report that includes detailed drainage design computations must be submitted with stormwater construction plans. The stormwater report must include all details of the stormwater system including detention and water quality calculations and any other relevant hydraulic calculations required to ensure that the proposed stormwater system is designed in accordance with all City regulations. Stormwater calculations for pre-development and post-development conditions must be submitted for the 1, 10 and 100-year storm events to show that post development runoff peaks will not exceed predevelopment runoff peaks. All details of the routing procedure must be submitted with the report.

6.2.3.1 Project Description and Background. Provide the development name, address, and location along with any other relevant information to identify the specific location of said development such as nearest intersection or known landmark. State the type of development (i.e., commercial, residential, etc.), the overall size of the development, and if there are any plans for future development. State if there is any concentrated offsite stormwater runoff crossing the development and, if so, how the offsite runoff will be conveyed through the site. State if work is to be performed on a State or County Right-of-Way and provide written approvals from said agencies. State if site contains a sinkhole or is located in a sinkhole watershed. If so, provide a Sinkhole Evaluation Report in accordance with this manual. State if the development is located in the FEMA floodway or 1% annual floodplain and provide name of the receiving water body. A floodplain development permit will be required from the Building Department in accordance with the City's Floodplain Management Ordinance for any work in a FEMA floodplain. A jurisdictional determination and permit may also be required from the United States Army Corps of Engineers.

6.2.3.2 Detention Summary. State the existing and proposed percentage of impervious surfacing for the site. If there is an increase in impervious surfacing, state which method the development will use to meet the City's stormwater flood control regulations (i.e., Existing Detention, Stormwater Detention Buyout, or Stormwater Detention Construction).

6.2.3.2.1 Existing Detention. If an existing stormwater detention facility was previously constructed to serve a development, it must be shown that the proposed development is in conformance with the original design criteria of the existing detention facility. Runoff from the proposed development must drain directly to the existing detention facility or drain through drainage easements and/or street right of way to the detention facility. If runoff from the proposed development exceeds the existing detention facility design criteria, additional detention must be provided in accordance with current stormwater regulations.

6.2.3.2.2 Stormwater Detention Construction. If constructing a stormwater detention facility, provide a description of the facility (i.e., dry, wet) along with the facility location and the maximum amount of impervious surfacing the facility is designed to handle. State the design method used to size the detention facility and provide a summary of the proposed stormwater detention facility.

6.2.3.2.3 Emergency Overflow Spillway. An emergency overflow spillway will usually be needed in a detention basin to convey flows that exceed the primary outlet capacity or to direct overflows to a specific location. The SCS Type II, 24-hour storm event shall be used to design the emergency overflow spillway. If an emergency overflow spillway is needed, provide a summary of the spillway including the location, type, size, and flow capacity.

6.2.3.3 Water Quality Summary. Proposed developments must comply with the water quality requirements in Chapter 6.8, and developments draining to a sinkhole must also comply with the water quality requirements in Chapter 6.9. All new impervious surfacing must convey runoff into the water quality facility. State what type of water quality stormwater control measures (SCMs), also known as permanent BMPs, will be constructed along with the required water quality control volume.

6.2.3.4 Storm Drainage Collection and Conveyance System Summary. State how the development will collect and convey stormwater runoff. Provide a summary of the stormwater collection and conveyance system including the hydraulic method and design storm event used. State where the storm drainage system will discharge concentrated flows offsite (Public Right-of-Way, Drainage Easement or Certified Natural Surface Water Channel). Whenever possible, connect private drainage facilities to a public drainage system, which will require a public improvement plan or an excavation permit.

6.2.3.5 Stream Buffer Summary. Developments containing a natural channel with a drainage area of 40 acres or greater must comply with the stream buffer requirements in Chapter 6.6. State the category of stream and describe how the stream buffer requirements will be met.

6.2.4 Detailed Drainage Analysis. Provide detailed hydrologic and hydraulic stormwater computations in accordance with Chapters 6.3 through 6.11 of these standards showing that the proposed stormwater facilities meet current City stormwater regulations.

6.2.4.1 Calculation of Runoff. Stormwater runoff calculations shall be submitted in accordance with Chapter 6.3 of this manual. Provide Drainage Area Maps showing the overall drainage catchment areas for pre-development and post-development conditions.

The stormwater system design for developments shall consider runoff from offsite areas. For flood control planning and modeling, effects of detention should be disregarded except for publicly owned and maintained facilities with storage dedicated in perpetuity.

6.2.4.2 Streets, Inlets and Storm Drains. Street, Inlet and Storm Drain designs shall be submitted in accordance with Chapter 6.4 of this manual. Calculations shall be provided to show that the proposed storm drainage system will not exceed the allowable drainage encroachment within public streets, provides allowable types, sizes, and placement of inlets, and provides appropriate sizing and design of storm drains.

6.2.4.2.1 Streets. Provide drainage calculations showing that the proposed stormwater collection system meets the 2-year and 100-year street inundation criteria and the 25-year conveyance and hydraulic grade line gutter criteria.

6.2.4.2.2 Inlets. State the design rainfall event and type of inlets to be constructed. Provide a Drainage Area Inlet Map showing catchment areas and peak flow for each inlet. Provide calculations showing that the proposed drainage inlets will have the hydraulic capacity to capture peak flows. Inlets must be located to limit gutter flows to no more than 5 cubic feet per second (cfs) for the 2-year event and meet spread limitations based on the street classification. Inlets shall also be provided at all low points in the gutter grade or on the upstream side of intersections and crosswalks.

Other types of inlets including trench drains may be permissible if approved by the City. Private inlets may include other proprietary designs. The effects of inlet clogging must be considered. A fifty percent reduction in capacity shall be used for a single grate inlet and a ten percent reduction shall be used for a single curb opening inlet. A smaller reduction may be allowed in cases where multiple inlet units are accepted.

6.2.4.2.3 Storm Drains. State the design rainfall event. All public storm drains shall be designed to convey the 25-year storm event. Minimum and maximum velocities must be met in the 2 year and 100-year storm events. Provide pipe layouts and profiles showing location, pipe materials and sizes, slopes, lengths, vertical alignments, and crossings with other utilities. Storm sewer reports shall be submitted showing pipe lengths, deflection angles, junction types, runoff coefficients, intensities, inlet areas, flow rates, slopes, upstream and downstream elevations, Manning's n values, minor losses, hydraulic and energy grade lines, and velocities. If using the

Rational Method to calculate flow rates, antecedent moisture conditions shall be accounted for in the 25- and 100-year storm events.

6.2.4.3 Culverts and Bridges. Culvert and Bridge design shall be submitted in accordance with Chapter 2.5 of this manual.

6.2.4.3.1 Culverts. Provide profiles of culverts showing the vertical alignment, slopes, lengths, velocities, hydraulic and energy grade lines, and end treatment.

6.2.4.3.2 Bridges. Provide bridge dimensions, velocities, water surface profiles, backwater analysis, and freeboard.

6.2.4.4 Open Channels. Open Channel designs shall be submitted in accordance with Chapter 6.6 of this manual. Provide type of channel (i.e., Natural or Engineered), detailed profile and cross section, design flow rates and velocities, slope, freeboard, sediment loading, channel lining, outfall, and buffer zone information.

6.2.4.5 Detention for Flood Control. Stormwater flood control shall be submitted in accordance with Chapter 6.7 of this manual. Provide hydraulic detention design calculations.

6.2.4.6 Water Quality. Water quality calculations shall be submitted in accordance with Chapter 6.8 of this manual. Provide calculations showing the required Water Quality Control Volume for the site and the design calculations for the stormwater control measures (SCMs) used to meet the water quality requirements.

6.2.5 Submittal Requirements. This section describes the requirements for drawings and calculations for storm drainage facilities which must be submitted and approved prior to filing of final plats for subdivisions, issuance of commercial building permits or issuance of grading permits.

Review and approval of drawings and calculations by the City of Battlefield is conceptual in nature only and does not imply detailed approval to any particular design item or data shown on the drawings, nor does it give implied approval for any variance from any City of Battlefield regulations or design standards. The design professional whose seal appears on the plans is responsible for all lines and grades, field data, and constructability of the design in compliance with the City of Battlefield standards and regulations.

6.2.5.1 Subdivisions.

6.2.5.1.1 Submittal Requirements. Construction plans for storm drainage improvements required by the City of Battlefield Subdivision Regulations must be completed and approved by the City of Battlefield before the final plat can be filed or a grading permit can be issued for construction of the improvements. Construction plans must be submitted to the City of Battlefield. The following items must be submitted:

1. Two (2) sets of construction drawings, or the number currently specified in the Subdivision Regulations.
2. Two (2) copies of the Drainage Area Map.
3. Two (2) copies of computation sheets.
4. One (1) electronic copy of each of the above.

Incomplete submittals will be returned without review.

6.2.5.1.3 Construction Drawing Requirements.

6.2.5.1.3.1 General. Construction drawings for streets and storm drainage improvements shall be submitted as a single set of construction drawings titled as follows:

Paving and Storm Drainage Improvements
for
(Name of Subdivision)
a Subdivision in the City of Battlefield, Missouri

Construction drawings shall be bound in a set of consecutively numbered sheets. Each drawing must be signed by the City of Battlefield before the drawings are approved for construction. Construction drawings shall clearly show the location and, extent of proposed construction in relation to existing and proposed property lines, physical features, topography, and utilities, and shall include all details necessary to properly construct the proposed facilities. All construction drawings shall show the following:

- Title block, showing the name of the proposed project, drawing title, and drawing number.
- Name, address, and telephone number of the consultant.
- Seal of responsible design professional.
- A scale for each plan or detail.
- A north arrow for all full or partial site plans and maps.
- The Missouri One-Call utility locates symbol on all drawings involving earthwork.

6.2.5.1.3.2 Drawing Size. Unless otherwise approved in writing by the City of Battlefield, original drawings shall be thirty-four inches (34") wide by twenty-two inches (22") high with a one-half inch (½") clear border on the top, bottom, and right sides of the drawing, and a one and one-half inch (1 ½") clear border on the left side of the drawing. Lettering shall be in a size large enough to allow reproduction of legible half-size drawings for use in the field.

6.2.5.1.3.3 Required Information. The following information must be included in the construction drawings:

- General project information.
- Site boundary and dimensions.
- Grading plan.
- Plan of proposed storm drainage facilities.
- Sediment & Erosion Control Plan (SECP).
- Profiles for storm drainage improvements.
- Details of stormwater facilities.

It is not required that a separate drawing be prepared for each item listed above. The required information may be shown on the fewest number of drawings needed to present the information clearly and legibly, depending upon the size of the project and complexity of the proposed work.

6.2.5.1.3.4 Benchmarks. Benchmark references shall be noted on the drawings. Two (2) benchmarks shall be referenced.

6.2.5.1.3.5 General Project Information. The following general information must be shown on the first sheet of the construction drawings:

- Location map at a scale of 1" = 2000' (one inch equal two thousand feet), showing streets and roads of collector or greater classification and municipal boundaries within one thousand feet (1000') of the site.
- General Notes. See Figure SS-2
- Name, address, and telephone number of developer.
- Index to drawings.
- Benchmark data.
- Legal description of property.
- Key to symbols used in the drawings.
- Location plan.

Where the proposed construction site consists of a phase of an approved preliminary plat, a location plan shall be shown on the first sheet, or the sheet immediately following the cover sheet of the drawings. The location plan shall show the entire area and boundary of the preliminary plat and the location and boundary of the proposed phase within the preliminary plat. Location plan scale shall not be smaller than 1" = 200' (one-inch equals two hundred feet).

6.2.5.1.3.6 Site Boundary and Dimensions. The first or second drawing of the set must include a plan showing the site boundary and dimensions at a minimum scale of 1" = 100' (one-inch equals one hundred feet), and the following information:

- North arrow & graphic scale.
- Site boundary with dimensions and bearings.
- Proposed rights-of-way and lot lines with dimensions and bearings.

- Property lines and owners' names for all properties adjoining the site (property lines for adjoining properties need only extend one inch (1") actual scale, outside the site boundary).
- Location and dimensions of existing and proposed easements.
- Street names.
- Boundaries of cities and other political subdivisions.

6.2.5.1.3.7 Grading Plan. A grading plan for the entire site must be included in the drawings. The site boundary and dimension plan shall serve as the base for the grading plan. The grading plan shall show the following:

- Existing topographic contours at two foot (2') maximum intervals. Each fifth contour shall be drawn as an index contour by using a heavier line weight. Index contours must be labeled.
- Existing streets, transportation facilities, utilities, and storm drainage facilities.
- Existing physical features including waterbodies and watercourses, sinkholes, springs, and caves.
- Existing structures, pavements, sidewalks, tree masses, pavements, and fences.
- Proposed streets, transportation facilities, utilities, and storm drainage facilities.
- Proposed structures, sidewalks, and pavements.
- Proposed topographic contours. The line type used for proposed contours must be heavier than that used for existing grades and must have a different line type. Proposed contours shall be shown at two foot (2') maximum intervals. Each fifth contour shall be drawn as an index contour by using a heavier line weight. Index contours must be labeled.

6.2.5.1.3.8 Plan of Proposed Storm Drainage Facilities. An overall plan of the site showing all proposed storm drainage facilities shall be provided. The site boundary and dimension plan shall serve as the base for this plan. This plan may be superimposed upon the site grading plan, depending upon the size and complexity of the project, provided that clarity and legibility can be maintained. The plan of storm drainage facilities shall show the location of the following items:

- Detention basins.
- Sediment basins.
- Storm drain piping.
- Inlets.
- Junction structures.
- Open channels and swales.
- Other components of the storm drainage system.
- Horizontal location of all components of the storm drainage system, dimensioned to easements, right-of-way, or property lines. Where all components of the system cannot

be legibly dimensioned at the scale of the overall plan, enlarged plans of these areas shall be provided.

- Line numbers and structure reference numbers, as described below:
  - Beginning at each point of discharge from the site, the storm drainage system shall be organized into a system of “lines” for identification of profiles. Storm drainage lines shall be numbered in consecutive order, beginning with the number one (1). Inlets, outlets, junction structures, and other points of reference shall be designated by letters beginning at the downstream-most point in each line with the line number followed by the reference letter, beginning with the letter “A”; i.e., 1-A, 1-B, etc. Each line shall extend from the downstream point of discharge to the upstream-most element in the line, and shall include “non-constructed” elements, such as natural channels.
- Overflow routes identified.

6.2.5.1.3.9 Sediment & Erosion Control Plan (SECP). An overall plan of the site showing proposed sediment and erosion control measures shall be included in the construction drawings. The sediment and erosion control plan shall be superimposed upon the site dimension plan, grading plan, and storm drainage facilities plan. The sediment and erosion control plan shall also show the following:

- General limits of the area stripped of vegetation or disturbed by construction activities shall be shaded or otherwise clearly delineated.
- A summary table showing the total site area and the total area estimated to be disturbed.
- Location of temporary construction entrance(s).
- Proposed sediment containment measures: vegetative filter areas, straw bale dikes, silt fences, temporary containment berms, diversion berms, inlet protection, etc.
- Site stabilization measures, showing the type of surface stabilization to be provided in various areas of the site, whether sod, erosion control blanket, mulch, riprap, concrete, etc. If more than one (1) type of erosion control blanket or mulch, is specified, the different areas should be distinguished by use of varying shading or symbols.
- Seeding and mulching specifications, and allowable seasons for temporary and permanent seeding.
- Temporary and permanent erosion control measures, such as outlet protection, channel linings, riprap, or paved chutes, etc.
- General notes for sediment & erosion control. See Figure SS-3

6.2.5.1.3.10 Profiles. Profiles for all storm drainage lines shall be included in the construction drawings. Profiles may be drawn at horizontal scales of 1" = 10' (one-inch equals ten feet) to 1" = 50' (one-inch equals fifty feet), depending upon the length of line to be shown, and vertical scales of 1" = 2' (one-inch equals two feet) to 1" = 5' (one-inch equals five feet). Profiles shall be stationed starting at the downstream end with Station 0+00. Profiles shall be drawn continuously from the downstream to the upstream end, with breaks only as needed when the profile exceeds the drawing width. Profiles shall not be combined with street profiles. Wherever breaks are made, equation stations and elevations shall be called out. Profiles shall include the following:

- Reference grid lines showing elevations along the left or right vertical margin and stationing along the bottom margin.
- Existing grade at centerline with a dashed line, labeled “Existing Grade at Centerline”.
- Proposed grade at centerline with a solid line, labeled “Proposed Grade at Centerline”.
    - Where the difference in grade between the centerline and the edge of the easement in which the proposed improvement is located is one foot (1') or more, additional existing grade and/or finish grade profile lines may also be required along the easement lines. Additional profile lines shall be labeled as to location.
- Existing and proposed utility crossings, labeled as to type, e.g., “Proposed 8" sanitary sewer”, etc.
- Existing and proposed pavements, riprap, concrete linings, structures, foundations, or other features which would affect the grade of the proposed storm drain or channel. Both the top and bottom surface of pavements, foundations, etc. must be shown, in order that clearance is apparent. It is preferred that a shading or pattern be used.
- Profile of the proposed storm drain or channel invert, and the interior top of pipe or top of channel bank. For reinforced concrete pipe and reinforced concrete box culverts, the exterior top and bottom shall also be shown in the profile. The station and structure number shall be called out at each structure. Stations shall also be called out at each change of direction in the centerline, at points of horizontal curvature and tangency, and at changes in grade.
- The pipe or channel length in feet, and pipe or channel slope in percent.
- Invert elevations shall be called out for each structure, and at points of horizontal curvature and tangency. Incoming and outgoing invert elevations shall be shown.
- Incoming lines at structures and tees shall be shown and invert elevations called out.
- Where the vertical clearance is less than the minimum required, the actual clearance dimension shall be shown.
- Hydraulic grade line must be shown wherever storm drainage piping is under pressure flow conditions, and shall be labeled along with the return frequency of the storm for which the hydraulic grade line was calculated: e.g., “HGL25 for the 25-year storm”, etc.

6.2.5.1.3.11 Details. Enlarged plans and other details must be shown wherever necessary to clearly describe the location, dimensions, and grades for the proposed construction. Details shall be drawn in accordance with generally prevailing drafting standards. Details shall be drawn to conventional scales, unless noted as “Not to Scale”. Any scale distortions used for isometric or other views must be noted. Standard details included in these Design Standards may be referenced by note where available. The following details will typically be required:

- Typical trench cross section for storm drains lines.
- Typical cross sections for drainage channels, showing side slopes, design depth or water surface, freeboard, and type of lining.
- Typical cross-sections of retaining walls.
- Plan and sections for detention and sediment basin outlet structures.
- Enlarged plans of inlets or junction structures, where incoming piping is thirty inches (30") or greater in diameter, or connection is made at other than ninety (90) degrees.

6.2.5.1.4 Calculations. Supporting calculations for storm drainage facilities must be included in the plan submittal. Supporting calculations shall include the following:

- Drainage area map meeting the requirements set forth in the paragraph below.
- Summary table for inlet calculations.
- Summary table for storm sewer and channel design
- Hydraulic data for drainage channels with uniform flow.
- Water surface profile computations for drainage channels with gradually or rapidly varied flow.
- Calculations for detention facilities.
- Calculations for sediment basins and other sediment and erosion control facilities specified on the Sediment & Erosion Control Plan.
- Where required, calculations for directly connected impervious area, water quality capture volume, and stormwater quality best management practices (BMPs).

Drainage area maps must be provided for both on-site areas and off-site areas. Due to the difference in area, it will typically be necessary to provide a larger scale map for on-site drainage areas, and a smaller scale map for off-site drainage areas. Off-site drainage areas shall be shown on U.S.G.S. 7 ½ minute quadrangle maps at a minimum scale of 1" = 2000' (one-inch equals two thousand feet). Where more detailed or more current topographic maps are available, they must be used.

On-site drainage area maps shall be shown superimposed upon the site plan, with existing and proposed topographic contours shown. Drainage areas shall be clearly outlined on the map, and the identifying designation clearly shown. Drainage areas shall be given the same designation as the inlet or reference point to which they are tributary (i.e., drainage area 1-A is tributary to inlet 1-A). The schematic plan of the proposed storm drainage improvements shall be shown on the drainage area map. Both pre- and post-development drainage areas must be shown for each primary outfall from the site.

6.2.5.1.5 Revisions to Drawings. Prior to approval of the drawings by the City of Battlefield, drawings are considered preliminary, and revisions shall not be noted. Revision notes made by the consultant for his own records prior to plan approval must be made outside the drawing border along the left margin of the drawing. Any use of the construction drawings for bids or pricing which occurs prior to the plans being approved by the City of Battlefield, is solely at the risk of the developer.

Revisions made after the plans are signed must be noted in the revision block and must be replotted and signed by the City of Battlefield. When revisions are made, two (2) copies of the revised drawing must be submitted to the City of Battlefield for review. After the revision is approved, two (2) copies of the revised drawing shall be provided to the City of Battlefield. Revised areas must be clearly identified by clouding and noting with a symbol showing the revision number. The final revision noted shall be the as-built drawings.

6.2.5.1.6 As-Built Surveys and Drawings. When construction of the improvements is completed, the Engineer shall perform surveys to determine that the location, dimension, and grade of the drainage improvements is in substantial conformance with the approved plans. The location of improvements shall be checked by field survey to ensure that the improvements are completely located within the easements or rights-of-way which have been provided. The location of improvements which vary more than six inches (6") from the location shown on the approved plans, must be approved in writing by the City of Battlefield prior to approval. Elevations and grades shall be verified at the following locations:

- Center of access manhole or grate for junction structures and inlets.
- Inlet entry for side opening inlets (except curb opening inlets).
- Pipe and culvert inverts. For box culverts greater than five feet (5') wide, invert elevation shall be checked at each side of the inlet and outlet.
- Detention basin and sediment basin outlet structures.
- Maximum intervals of one hundred feet (100') and at grade changes in drainage channels (excluding roadside borrow ditches).
- Detention and sediment basins.

Elevations differing by more than one-tenth of a foot (0.1') from plan grades or five-hundredths of a foot (0.05') for detention basin outlet structures, must be approved in writing by the City of Battlefield prior to final approval. Dimensions must be verified for the following:

- Pipe diameter for circular pipe.
- Height and width for elliptical or arch pipe, or box culverts.
- Drainage channel cross-sections at maximum intervals of two hundred feet (200').
- Riprap or other erosion protection at pipe outlets.
- Overflow spillways and outlet structures for detention and sediment basins.
- Detention and sediment basin volume.

As-built information shall be shown on the approved plans in the same manner that revisions are noted on the drawings. As-built information shall be clouded and noted with a symbol showing the revision number. Where the as-built dimension or elevation does not differ from the plan, the plan dimension or elevation shall be clouded to signify that it has been verified.

6.2.5.2 Commercial Building Permits.

6.2.5.2.1 Submittal Requirements. Construction plans for storm drainage improvements must be completed and approved by the City Engineer, Building Inspector before the building permit can be issued. Storm drainage drawings and calculations shall be submitted to the Building Department along with the building plans. The following items must be submitted:

1. Two (2) sets of construction drawings.
2. Two (2) copies of the Drainage Area Map.
3. Two (2) copies of computation sheets.
4. One (1) electronic copy of all of the above.

Incomplete submittals will be returned without review.

6.2.5.2.2 Construction Drawing Requirements.

6.2.5.2.2.1 General. Construction drawings for storm drainage improvements may be submitted as a separate set of construction drawings or included in the building plans. Construction drawings shall clearly show the location and extent of proposed construction in relation to existing and proposed property lines, physical features, topography, and utilities, and shall include all details necessary to properly construct the proposed facilities. Linework and lettering shall be neat and clear. Original copies of the drawings shall be free from smudges, tears, folds, and other imperfections which affect the legibility of the drawing. All construction drawings shall show the following:

- Title block, showing the name of the proposed project, drawing title, and drawing number.
- Name, address, telephone number of consultant.
- Seal of responsible design professional.
- A scale for each plan or detail.
- A north arrow for all full or partial site plans and maps.
- The Missouri One-Call utility locates symbol on all drawings showing plans or details involving earthwork.
- A block for approval signature by the City of Battlefield, located in the lower right area of each drawing.

6.2.5.2.2.2 Drawing Size – Commercial Building Permits. Unless otherwise approved in writing by the City of Battlefield, original drawings shall be thirty-four inches (34”) wide by twenty-two inches (22”) high. Drawings shall have a one-half inch (½") clear border on the top, bottom, and right sides of the drawing, and a one and one-half inch (1 ½") clear border on the left side of the drawing. Lettering shall be of a large enough size to allow reproduction of legible half-size drawings for use in the field.

6.2.5.2.2.3 Required Information – Commercial Building Permits. The following information must be included in the construction drawings:

- General project information.
- Site boundary and dimensions.
- Grading plan.
- Plan of proposed storm drainage facilities.
- Sediment & Erosion Control Plan (SECP).
- Profiles for storm drainage improvements.
- Details of stormwater facilities.

It is not required that a separate drawing be prepared for each item listed above. The required information may be shown on the fewest number of drawings required to present the information clearly and legibly, depending upon the size of the project and complexity of the proposed work.

6.2.5.2.2.4 Benchmarks – Commercial Building Permits. For sites within the Springfield Urban Services Area, it is preferred that the City of Springfield benchmarks should be referenced. For sites outside this area, it is preferred that U.S.G.S. benchmarks be referenced. Assumed datum may be used provided that it is based upon assumed elevation of 100.0 (one hundred point zero), so as not to be confused with actual elevations from mean sea level. Benchmark references shall be noted on the drawings.

6.2.5.2.2.5 General Project Information – Commercial Building Permits. The following general information must be shown on the first sheet of the construction drawings:

- Location map at a scale of 1" = 2000' (one-inch equals two thousand feet), showing streets and roads of collector or greater classification and municipal boundaries, within one thousand feet (1000') of the site.
- General notes.
- Name, address, telephone number of owner or developer.
- Index to drawings.
- Benchmark data.
- Legal description of property.
- Key to symbols used in the drawings.

6.2.5.2.2.6 Site Plan – Commercial Building Permits. The drawings must include a plan showing the site boundary and dimensions, and existing and proposed utilities and improvements at a minimum scale of 1" = 100' (one-inch equals one hundred feet), including the following information:

- North arrow & graphic scale.
- Site boundary with dimensions and bearings.
- Rights-of-way and names of streets adjoining the site.
- Property lines and owners' names for all properties adjoining the site (property lines for adjoining properties need only extend one inch (1"), actual scale, outside the site boundary).
- Location and dimensions of existing and proposed easements.
- Boundaries of cities and other political subdivisions.
- Existing transportation facilities, utilities, and storm drainage facilities.
- Existing physical features including waterbodies and watercourses, sinkholes, springs, and caves.
- Existing structures, pavements, sidewalks, tree masses, pavements, and fences Proposed transportation facilities, utilities, and storm drainage facilities.
- Proposed buildings, incidental structures, structures such as retaining walls, sidewalks, pavements, and other proposed improvements.

6.2.5.2.2.7 Grading Plan – Commercial Building Permits. A grading plan for the entire site must be included in the drawings. The site plan shall serve as the base for the grading plan. The grading plan shall show the following:

- Existing topographic contours at two foot (2') maximum intervals. Each fifth contour shall be drawn as an index contour by using a heavier line weight. Index contours must be labeled.
- Proposed topographic contours. The line type used for proposed contours must be heavier than that used for existing grades and must have a different line type. Proposed contours shall be shown at two foot (2') maximum intervals. Each fifth contour shall be drawn as an index contour by using a heavier light weight. Index contours must be labeled.

6.2.5.2.3 Revisions to Drawings. Revisions made after the plans are signed must be noted in the revision block and must be initialed by the City of Battlefield prior to approval. When revisions are made, two (2) copies of the revised drawing must be submitted to the City of Battlefield for review. After the revision is approved, two (2) copies of the revised drawing shall be provided to the City of Battlefield. Revised areas must be clearly identified by clouding and noting with a symbol showing the revision number. The final revision noted shall be the as-built drawings.

6.2.5.2.5 As-Built Surveys and Drawings. When construction of the improvements is completed, the Engineer shall perform surveys to determine that the location, dimension, and grade of the drainage improvements is in substantial conformance with the approved plans. The location of improvements shall be checked by field survey to ensure that the improvements are completely located within the easements or rights-of-way which have been provided. The location of improvements which vary more than six inches (6") from the location shown on the approved plans must be approved in writing by the City of Battlefield prior to approval. Elevations and grades, and location and dimensions of improvements shall be verified and shown on as-built drawings. As-built surveys must be approved prior to the final approval of the building and issuance of a temporary or permanent occupancy permit.

6.2.5.3 Commercial Grading Permits. For sites upon which only grading and construction of utilities and/or drainage improvements are proposed, construction drawings and calculations shall be submitted to the City of Battlefield. The following items must be submitted:

1. Two (2) sets of construction drawings.
2. Two (2) copies of the Drainage Area Map.
3. Two (2) copies of computation sheets.
4. One (1) electronic copy of all the above.

6.2.6 Permits.

6.2.6.1 Land Disturbance Permit. A land disturbance permit must be obtained from the Missouri Department of Natural Resources (MDNR) for sites that disturb one or more acres and for sites that disturb less than one acre when part of a larger common plan of development or sale that will disturb a cumulative total of one or more acres over the life of the project. A land disturbance permit must also be obtained from MDNR and included in the Stormwater Pollution Prevention Plan (SWPPP). Upon approval of the SWPPP, the applicant will be notified to submit the required security, agreement, and permit fee. Prior to permit issuance, the applicant must schedule a pre-permit meeting with the Division. Following this meeting, the first phase of Best Management Practices (BMPs) can be installed. No other work is to occur other than what is needed to install the first phase of BMPs. The applicant must then schedule an initial Best Management Practice (BMP) inspection with the Division. If the initial BMP inspection is satisfactory, the permit is issued, and work may begin. Termination of the permit requires 70% uniform perennial grass growth, removal of all temporary BMPs, and removal of all sources of pollution associated with construction. When the site is ready for permit termination, the applicant must submit a Request for Termination form and a Release of Securities application. Staff will conduct a termination inspection. If the permit termination inspection is satisfactory, the permit will be terminated, and the security released.

6.2.6.2 Public Improvement Permit. Any stormwater improvement project that serves multiple properties or routes stormwater runoff from one property across another is defined as a public stormwater improvement project. Public stormwater improvement projects will require the submittal and approval of Public Stormwater Improvement Plans using City of Battlefield title Block. Once the Stormwater Construction Plans have been reviewed and approved, the developer will be notified to submit a signed, itemized bid for review. Upon approval of the bid, the applicant will be notified of the amount of the engineering and inspection permit fee. The engineering and inspection permit fee is a percentage of the amount of the construction cost from the approved bid. The engineering and inspection fee must be paid prior to the stormwater permit approval. The fee shall be made to the "City of Battlefield" and can be paid over the phone at (417) 883-5840 or in person at Battlefield City Hall, 5434 S. Tower Dr, 65619. After the engineering and inspection fee is paid, plans will be stamped, and construction may begin. The public stormwater improvements must be constructed, inspected, approved and operational prior to filing a final plat or issuance of a building permit. Alternatively, the final plat may be filed and building permits issued prior to construction of public stormwater improvements if an escrow is completed for the public improvements and a temporary plan is submitted, approved, and constructed that will provide for the conveyance and storage of stormwater during construction of the development without impacting adjacent properties. The escrow will not be returned until all public improvements are constructed, inspected, and approved. An application to Secure Public Improvements must be submitted for review and approval.

6.2.6.3 Stormwater Permit. A Stormwater (STM) permit is required for all private stormwater facilities, detention buyouts, and any work within a sinkhole or sinkhole watershed. The building inspector may require that certain stormwater improvements be constructed prior to issuance of a building permit when necessary to protect downstream properties from adverse stormwater impacts. Adverse impacts are defined as erosion and/or flooding caused by an increase in discharge, depth, or velocity or the discharge of pollutants, including sediment, downstream. The decision to require certain stormwater improvements to be constructed prior to issuance of the building permit will be based on the following factors:

- Size of the development
    - Is the site larger than one acre?
- Knowledge of existing stormwater problems downstream
    - Has the City received complaints about flooding or erosion from properties downstream?
- Existing stormwater facilities
    - Is there an existing detention basin on site?
    - Does the stormwater infrastructure downstream have capacity for frequent storm events (2-year)?
- Where the site drains
    - Does the site discharge onto another property or into City right of way?
- Sensitive area downstream
    - Does the site drain to a sinkhole?

In the event that it is infeasible to install stormwater improvements prior to issuance of the building permit, a phased approach is also permissible whereby a temporary plan may be submitted, approved, and constructed that will provide for the conveyance and/or storage of stormwater during construction of the development without impacting adjacent properties. Under this approach the building permit will be issued after all temporary stormwater controls shown on the approved plans are constructed and accepted. It may be permissible to issue a foundation permit in conjunction with the installation of temporary stormwater controls. No certificate of occupancy will be issued until all permanent stormwater improvements are constructed, inspected, approved, and operational.

6.2.6.4 Excavation Permit. An Excavation permit is required when excavating in the right-of-way or when connecting private stormwater improvements to a public stormwater system and public stormwater improvements are not required. An excavation permit must be obtained from the Building Department prior to excavation.

6.2.6.5 Floodplain Permit. For any construction work in a FEMA Floodplain, a Floodplain (FLD) Development permit is required from the Building Department prior to approval of the stormwater construction plans.

6.2.6.6 United States Army Corps of Engineers Permit. A United States Army Corps of Engineers (USACE) Jurisdictional Determination may be required to determine if a Section 404 permit is needed for work in a stream or waters of the United States.

6.2.7 Easements.

6.2.7.1 Drainage Easement. Drainage easement criteria shall be met in accordance with Chapter 6.10 of this manual. Drainage easements shall be provided when a private stormwater system is serving multiple properties or routes stormwater from one property across another. Drainage easements shall be shown on the construction plans and shall be of adequate size to contain the 100-year peak flow rate. If existing drainage easements are no longer needed, an Application for Relinquishment of Easement must be submitted to the Building Department and approved by the Battlefield Planning & Zoning Commission. Proposed drainage easements shall be submitted to the Battlefield Building Department for review and approval using the appropriate standard drainage easement form. Once the proposed drainage easements have been reviewed and approved, signatures may be obtained, and the documents returned to the City to be filed. All required drainage easements shall be obtained prior to construction.

6.2.7.2 Certified Natural Surface Drainage Channel. If runoff is proposed to discharge to a natural watercourse, a signed and sealed statement by a registered engineer must be made on the plans certifying that runoff discharges to a natural watercourse as defined by state law. This letter must be sent by the architect or engineer of record and must be sealed, signed, and dated by that professional. An example of an acceptable letter may be obtained from the Building Department.

6.2.8 Operation and Maintenance Plan and Agreement. A Stormwater Control Measure (SCM) operation and maintenance plan and agreement is required as a condition of stormwater permitting for construction of SCMs required to meet flood control detention requirements, water quality requirements, or zoning conditions. The SCM operation and maintenance plan and agreement must be prepared recorded with the Greene County Recorder of Deeds. Long-term operation and maintenance self-inspections and submittal of a self-inspection report is required annually. Self-inspections and reporting shall be conducted and submitted to the Building Department.

6.2.9 Construction Inspections. City staff will make periodic inspections of the construction of stormwater improvements and SCMs throughout the construction period and require that any non-conformities with the plans be addressed. The contractor may be required to schedule inspections at certain milestones to allow inspection of key aspects of SCMs.

6.2.10 As-Built Requirements. When construction of stormwater improvements is completed, the professional Engineer of Record shall sign, seal, and submit the following as-built information:

- For flood control detention SCMs, an as-built survey of the SCM and outlet structure. Report shall include a table with the following information (at minimum) for each return period:
    - Volume
    - Peak Discharge Rate (comparing pre-project to as-built condition)
    - Water Surface Elevation
- For SCMs to meet water quality requirements or zoning conditions, an as-built certification and as-built survey as specified in Chapter 6.8.
- As-built surveys must reference the same vertical datum as the original design.

6.2.11 Final Inspection and Approval of Improvements. Upon receipt of the required as-built information, City staff will review the same for substantial conformity with the plans. The Engineer of Record will be notified in writing of any deficiencies discovered during review of the as-built information. Upon correction of the noted deficiencies, the Engineer shall notify the City. Final approval of the improvements will be given upon approval of the as-built information.

6.3 CALCULATION OF RUNOFF

6.3.1 General. This policy describes methods which can be used to determine rates and volumes of stormwater runoff. It is important to remember that the physical relationship between precipitation and the rate and amount of runoff is very complex, and that computational methods which have been developed are empirical. When applying any hydrologic technique, the designer must be aware of its basic assumptions and limitations. Experience and good judgement must be used to evaluate the results.

6.3.2 Definitions.

Pre-project conditions - the topography, surface cover, and other hydrologic conditions in the watershed being considered as they exist prior to the proposed development.

Post-project conditions - the topography, surface cover, and other hydrologic conditions in the watershed as they will be after construction of the proposed development.

Fully urbanized conditions - the topography, surface cover, and other hydrologic conditions in the watershed as they will be after all areas in the watershed have been developed in accordance with current zoning designations, as provided in the Greene County Comprehensive Plan, or as can otherwise be reasonably anticipated.

6.3.3 Precision in Reporting Runoff. Runoff computations are based upon empirical methods and cannot be expected to give precise results. Results should always be rounded off or shown with a limited number of significant digits to avoid implying an accuracy greater than that which can be expected. Runoff rates and volumes should be rounded up to the nearest ten percent (10%) of the computed value.

6.3.4 Precipitation Data. Precipitation data used for computing runoff rates and volumes for use in the design of stormwater management facilities in the City of Battlefield are derived from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 8, Version 2, Precipitation-Frequency Atlas of the United States, Midwest States. Table 1 and 2 below provide depth and intensity values for various rainfall durations and frequencies in the Battlefield area.

Table 1: Rainfall Depth-Duration-Frequency Relationships from NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States.

Duration	Depth of Precipitation (in)						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
5 min.	0.38	0.43	0.53	0.61	0.72	0.81	0.90
10 min.	0.55	0.63	0.77	0.89	1.05	1.18	1.31
15 min.	0.67	0.77	0.94	1.08	1.28	1.44	1.60
30 min.	0.98	1.14	1.39	1.60	1.89	2.12	2.33
1 hr.	1.29	1.50	1.84	2.14	2.55	2.88	3.21
2 hr.	1.60	1.86	2.30	2.67	3.21	3.64	4.08
3 hr.	1.79	2.08	2.58	3.01	3.63	4.14	4.67
6 hr.	2.19	2.51	3.09	3.60	4.35	4.97	5.64
12 hr.	2.67	3.02	3.65	4.22	5.06	5.77	6.52
24 hr.	3.16	3.60	4.35	5.01	5.98	6.77	7.60
48 hr.	3.65	4.23	5.19	6.00	7.14	8.04	8.95
72 hr.	4.01	4.63	5.65	6..51	7.70	8.64	9.59

Table 2: Rainfall Intensity-Duration-Frequency Relationships from NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States

Duration	Intensity of Precipitation (in/hr)						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
5 min.	4.56	5.16	6.36	7.32	8.64	9.72	10.80
10 min.	3.30	3.78	4.62	5.34	6.30	7.08	7.86
15 min.	2.68	3.08	3.76	4.32	5.12	5.76	6.40
30 min.	1.96	2.28	2.78	3.20	3.78	4.24	4.68
1 hr.	1.29	1.50	1.84	2.14	2.55	2.88	3.21
2 hr.	0.80	0.93	1.15	1.34	1.61	1.82	2.04
3 hr.	0.60	0.69	0.86	1.00	1.21	1.38	1.56
6 hr.	0.37	0.42	0.52	0.60	0.73	0.83	0.94
12 hr.	0.22	0.25	0.30	0.35	0.42	0.48	0.54
24 hr.	0.13	0.15	0.18	0.21	0.25	0.28	0.32
48 hr.	0.08	0.09	0.11	0.13	0.15	0.17	0.19
72 hr.	0.06	0.06	0.08	0.09	0.11	0.12	0.13

6.3.4.1 Precipitation Distribution. When using the Kinematic Wave Method or SCS Method for runoff computations, the Huff rainfall distribution shall be used for the temporal distribution. The Huff distribution is presented in Table 3 and is expressed as cumulative percentages of total duration and total rainfall accumulation. Different families of Huff distribution curves are applicable to different drainage areas. Table 3 is applicable to drainage areas less than 10 square miles. For larger drainage areas, refer to the Rainfall Frequency Atlas of the Midwest (Huff and Angel 1992). Each family of curves consists of four storms (first quartile, second quartile, third quartile, and fourth quartile) that correspond to the quartile within the storm event when the bulk of the rainfall occurs. Storms with durations of 6 hours or less, 6 to 12 hours, 12 to 24 hours, and greater than 24 hours tend to be associated with the first-, second-, third-, and fourth-quartile storms, respectively (Huff and Angel 1992).

Table 3

Cumulative Storm Time (%)	Cumulative Storm Rainfall (%) for Given Storm Type			
	First Quartile (Duration £ 6 hours)	Second Quartile (6 < Duration £ 12 hours)	Third Quartile (12 < Duration £ 24 hours)	Fourth Quartile (Duration > 24 hours)
0	0	0	0	0
5	16	3	3	2
10	33	8	6	5
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92
100	100	100	100	100

6.3.4.2 Minimum Rainfall Duration. The rainfall duration should correspond to the maximum peak flow rate for the watershed being analyzed. A critical duration analysis should involve applying the hydrograph-based methods to events with durations ranging from 30 minutes to 24 hours to determine the duration that produces the largest peak runoff rate for the watershed. Guidelines for the minimum recommended storm duration based on watershed size are shown in Table 4 below. The guidelines are intended to preclude the use of short duration events that typically do not cover the corresponding watershed uniformly. The information in Table 4 should be considered as guidance for the minimum storm duration to use when calculating runoff and is not a replacement for a critical duration analysis.

Table 4

Watershed Size	Minimum Recommended Duration
<160 acres	30 min
160 acres - < 1 sq. mi.	1 hr.
1 sq. mi. - < 4 sq. mi.	2 hr.
4 sq. mil - < 8 sq. mi.	3 hr.
8 sq. mi. - < 16 sq. mi.	6 hr.
16 sq. mi. - < 32 sq. mi.	12 hr.
> 32 sq. mi.	24 hr.

6.3.5 Topographic Data. Topographic data utilized in determining drainage areas must be sufficiently detailed to allow computation of runoff with a reasonable degree of accuracy.

6.3.5.1 On-Site Drainage Areas. Topographic maps with a maximum contour interval of not more than one foot (1’) must be utilized for determining drainage areas within the development site. Topographic maps must show existing and proposed drainage facilities such as storm drains, culverts, road cuts, ditches and other physical features which affect the patterns of runoff on the site.

6.3.5.2 Off-Site Drainage Areas. Maps published by the U.S. Geological Survey having a maximum contour interval of ten feet (10') will generally be considered sufficiently accurate for use in determining drainage areas where no development has occurred. For small drainage areas where U.S.G.S. maps do not have a sufficient level of accuracy or where drainage patterns have been altered by development, the best available data should be used.

NOTE: Topographic information (five-foot (5') contour intervals) is available for certain portions of the area around the City of Springfield on the 1976 Springfield Planning Area maps. These maps should be used in determining off-site drainage areas, where more detailed maps are not available. Where no other topographic maps having sufficient detail to determine the drainage area in question are available, aerial photo maps available from the County Assessor's office should be used with drainage area limits and paths of flow determined in the field.

Regardless of the data used, it is the designer's responsibility to field verify that the drainage areas used are reasonably accurate.

6.3.6 Peak Runoff Rates.

- Drainage areas less than 100 acres. Where the tributary drainage area is less than one hundred (100) acres, and only the peak runoff rate is needed, the Rational Method may be used to compute the peak runoff rate as described below. Peak flow rates for designing inlets and conveyance facilities (storm drains and open channels) for most developments can be computed by this method.

- Urban drainage areas equal to or greater than 100 acres. Where the tributary drainage area is one hundred (100) acres or more, and only the peak flow rate is needed, the peak runoff rate shall be computed by any of the following methods:
    - Kinematic Wave Method
    - Soil Conservation Service TR-55, Graphical Peak Discharge Method. Hydrologic soil groups for soils listed in the Greene County soil survey are shown in the table in Section 6.3.9.1.
    - Unit hydrograph methods.

- Rural drainage areas equal to or greater than 100 acres. Peak runoff rates for rural watersheds equal to or greater than one hundred (100) acres shall be computed by any of the following methods:
    - Soil Conservation Service TR-55 Graphical Peak Discharge Method.
        - NOTE: This method is limited to a maximum time of concentration of ten (10) hours.
    - U.S. Geological Survey Technique for Estimating the 2- to 500-year Flood Discharges on Unregulated Streams in Rural Missouri.
    - Unit hydrograph methods

6.3.7 Peak Runoff Volumes. Runoff volumes shall be computed using Soil Conservation Service TR-55, or any of the unit hydrograph methods listed below.

6.3.8 Rational Method. The rational formula may be used to compute peak runoff rates only for drainage areas less than one hundred (100) acres. The rational method or variations of the rational method are not reliable for use in determining runoff volumes. The formula for the rational method is as follows:

$$Q = CIA \text{ , where}$$

Q = peak runoff rate for a design storm of recurrence interval, T, in cubic feet per second (cfs)
C = dimensionless runoff coefficient; recommended runoff coefficient values are given in Section 6.3.8.3. The value used shall be the composite value based upon the type

of surface coverage in the drainage area for the runoff condition being considered.

I = average rainfall intensity for a storm of recurrence interval, T, over a duration equal to or greater than the time of concentration for the contributing drainage area.

A = tributary watershed area in acres

The time of concentration utilized shall be determined for conditions under which the peak flow rate is calculated, i.e., pre-project conditions for the pre-project peak flow rate and post-project conditions for the post-project peak flow rate, etc.

The general procedure for Rational Method calculations for a single watershed is as follows:

1. Delineate the watershed boundary and calculate its area.
2. Define and measure the flow path from the upper-most portion of the watershed to the design point.
3. Calculate the slope for the flow path.
4. Calculate time of concentration, t_c.
5. Find the rainfall intensity, i, for the design storm using the calculated t_c as the duration.
6. Determine the runoff coefficient, C.
7. Calculate the peak flow rate from the watershed.

6.3.8.1 Assumptions. The basic assumptions made when the Rational Method is applied are:

1. The computed maximum rate of runoff to the design point is a function of the average rainfall rate for a duration equal to the time of concentration over the drainage area.
2. The depth of rainfall used is one that occurs from the start of the storm to the time of concentration. It has a level distribution over the duration of the rainfall, meaning the rainfall intensity is constant throughout the storm.
3. The maximum runoff rate occurs when the entire area is contributing flow. However, this assumption often should be modified when a more intensely developed portion of the watershed with a shorter time of concentration produces a higher rate of maximum runoff than the entire watershed with a longer time of concentration.

6.3.8.2 Time of Concentration.

The time of concentration is defined as the travel time from the hydraulically most distant point in the contributing drainage area to the point under study or the rainfall intensity averaging time. Time of concentration for use with the Rational Method may be computed by either of the two methods described below. The minimum time of concentration which shall be used is five (5) minutes.

The Soil Conservation Service Method, or other methods for which there is documentation in commonly accepted literature, shall be used in computing peak runoff rates for other methods.

a. Kirpich Formula.

$$t_c = 0.0078(\frac{L}{\sqrt{S}})^{0.77}$$, where

t_c = time of concentration in minutes
L = length of travel in feet
S = slope of the flow path from the remote part of the basin to the calculation point divided by the horizontal distance between the two points (ft./ft.)

The Kirpich equation is most applicable for undeveloped watersheds with well-defined channels, bare-earth overland flow, or flow in mowed channels. The following adjustment factors are recommended for other conditions (Chow et al. 1988):

- For flow in natural grassed channels, multiply by 2.
- For overland flow on concrete or asphalt surfaces, multiply by 0.4.
- For concrete channels, multiply by 0.2.

$$t_o = 0.83\left(\frac{N_k L}{S^{0.5}}\right)^{0.47}$$, where

N_k = coefficient of roughness, presented in Table 5 below
L = overland flow length (ft), maximum of 100 feet for undeveloped areas and 100 feet for developed areas
S = average overland slope (ft/ft)

Total time of concentration can be found using the following equation:

$$t_c = t_o + t_t$$

Table 5:

Surface Type	Nk
Smooth impervious surface	0.05
Smooth bare packed soil, free of stones	0.10
Poor grass, cultivated row crops, or moderately rough bare surfaces	0.20
Pasture or average grass cover	0.40
Deciduous timberland	0.60
Conifer timberland, deciduous timberland with deep forest litter, or dense grass cover	0.80

b. Soil Conservation Method. This method given in Chapter 3 of Soil Conservation Service TR-55 may be used to compute times of concentration. In using this method, it must be remembered that overland flow elements are limited to one hundred feet (100') in rural areas, and generally to one hundred feet (100') in urban areas. The designer must consider whether calculated runoff rates from directly connected impervious areas having a shorter time of concentration will exceed the runoff rate for the entire drainage area when pervious areas are included.

6.3.8.3 Runoff Coefficient. The runoff coefficient, C, represents the percentage of rainfall that becomes runoff. In a non-homogeneous drainage area, C should be calculated as an area-weighted composite of the different land uses in the watershed.

Table 6: Runoff Coefficients

By Surface Type - Use as Basis for Computation of Composite Runoff Coefficients			
Surface Type	**Runoff Coefficients**		
Asphalt, concrete pavement, roofs	0.95 - 1.0		
Gravel surfaces, compacted	0.85 - 0.95		
Gravel surfaces, not compacted	0.50 - 0.70		
Parks, golf courses, farms	0.10 - 0.20		
Lawns, pastures, hayfields			
Flat (< 2% slopes)	0.10 - 0.15		
Average (2 - 7% Slopes)	0.15 - 0.20		
Steep (> 7% slopes)	0.20 - 0.30		
Woods	0.05 - 0.15		
Composite Coefficients for Single Family Residential Areas			
Average lot size, 1/4 acre	Flat (<2%) slopes) 0.35 - 0.45	Average (2-7% slopes) 0.40 - 0.50	Steep (>7% slopes) 0.45 - 0.55
Average lot size, 1/3 acre	Flat (<2%) slopes) 0.30 - 0.40	Average (2-7% slopes) 0.33 - 0.43	Steep (>7% slopes) 0.40 - 0.50
Average lot size, 1/2 acre	Flat (<2%) slopes) 0.25 - 0.35	Average (2-7% slopes) 0.30 - 0.40	Steep (>7% slopes) 0.36 - 0.46
Average lot size, 1 acre	Flat (<2%) slopes) 0.20 - 0.25	Average (2-7% slopes) 0.25 - 0.30	Steep (>7% slopes) 0.60 - 0.38
Average lot size, 3 acres	Flat (<2%) slopes) 0.10 - 0.20	Average (2-7% slopes) 0.13 - 0.24	Steep (>7% slopes) 0.25 - 0.33

Note: The ranges of C values presented in Table 6 above are typical for return periods of 2 to 10 years and assume average antecedent moisture conditions. Higher values are appropriate for larger design storms.

Table 7: Multiplier for larger design storms

Recurrence Interval (years)	Adjustment Multiplier
25	1.1
50	1.2
100	1.25

6.3.9 Hydrograph Methods. When runoff rates must be known as a function of time, such as for reservoir routing computations or when the limitations of the methods listed above are exceeded, hydrograph methods must be used. Commonly accepted hydrograph methods are as follows:

U.S. Army Corps of Engineers HEC-HMS Flood Hydrograph Package.

Soil Conservation Service TR-55 and TR-20

Kinematic Wave Method

Other methods may be used upon written approval of the City of Battlefield, provided that they are documented in accepted engineering literature and are used within the limitations stated. Methods used for distribution of rainfall, determining precipitation losses, accounting for channel and reservoir storage effects, etc., shall be as prescribed in the literature for the selected method.

6.3.9.1 SCS Curve Number. The determination of the CN value for a watershed is a function of soil characteristics, hydrologic condition and cover, or land use. For watersheds with multiple soil types or land uses, an area-weighted CN should be calculated.

Table 8: Curve Number based on Hydrologic Soil Group

Cover Description	**Curve numbers for hydrologic soil group**			
Cover type and hydrologic condition	**A**	**B**	**C**	**D**
Idle lands (not yet developed)				
Pasture, grassland, or range - continuous forage for grazing: Good condition (ground cover > 75% and only occasionally grazed)	39	61	74	80
Meadow - continuous grass, protected from grazing, and generally mowed for hay	30	58	71	78
Woods-grass (50%-50%) combination, orchard or tree farm Other combinations can be calculated as composite of pasture and woods Good condition	32	58	72	79
Woods Good condition (i.e., woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Farmsteads - buildings, lanes, driveways, and surrounding lots	59	74	82	86

Table 9: Weighted Curve Number for watersheds with multiple soil types

Cover Description			Curve numbers for hydrologic soil group			
Cover type and hydrologic condition		**Average percent impervious area**	**A**	**B**	**C**	**D**
Fully developed urban areas (vegetation established)						
Open space (lawns, parks, golf courses, cemeteries, etc.)						
	Good condition (grass cover >75%)		39	61	74	80
	Fair condition (grass cover 50% to 75%)		49	69	79	84
	Poor condition (grass cover less than 50%)		68	79	86	89
Impervious Areas						
	Paved parking lots, roofs, driveways, compacted gravel, etc.					
	(excluding right-of-way)		98	98	98	98
Small open spaces within development or ROW:			72	82	87	89
Streets and roads:						
	Paved; curbs and storm sewers (including right-of-way)		90	93	95	97
	Paved; open ditches (including right-of-way)		83	89	92	93
	Gravel (including right-of-way)		76	85	89	91
	Dirt (including right-of-way)		72	82	87	89
Urban districts:						
	Commercial and business	85	89	92	94	95
	Industrial	72	81	88	91	93
Residential districts by average lot size:						
	1/8 acre or less (townhouses)	65	77	85	90	92
	1/4 acre	38	61	75	83	87
	1/3 acre	30	57	72	81	86
	1/2 acre	25	54	70	80	85
	1 acre	20	51	68	79	84
	2 acres	12	46	65	77	82
Developing urban areas:						
	Newly graded areas (pervious areas only, no vegetation)		77	86	91	94

6.3.10 USGS Regression Equations. For urban watersheds larger than 100 acres, the engineer should compare the peak flow rate determined from the critical duration analysis with the peak flow rate calculated using the USGS regression equations in The Estimation of the Magnitude and Frequency of Floods in Urban Basins in Missouri, 2010 (Southard 2010). These equations are summarized in Table 10 and are applicable for urban areas within Missouri that have drainage areas between 0.29 and 189 square miles and impervious areas between 2.3 and 46 percent. These equations do not apply when there is significant storage in the watershed. Although the resulting peak flow rates typically have a relatively high coefficient of variation, regression equations provide a useful reasonableness check for urban watersheds.

Table 10: USGS Regression Equations

Recurrence Interval	USGS Regression Equation (Q = estimated peak flow rate [cfs], A = drainage area [mi2], I = impervious area in percent)
2 - year	$Q_2 = 188DRNAREA^{0.599}10^{0.014IMPLNLCD01}$
5 - year	$Q_2 = 352DRNAREA^{0.592}10^{0.011IMPLNLCD01}$
10 - year	$Q_2 = 484DRNAREA^{0.594}10^{0.010IMPLNLCD01}$
25 - year	$Q_2 = 671DRNAREA^{0.599}10^{0.008IMPLNLCD01}$
50 - year	$Q_2 = 826DRNAREA^{0.604}10^{0.008IMPLNLCD01}$
100 - year	$Q_2 = 991DRNAREA^{0.608}10^{0.007IMPLNLCD01}$
500 - year	$Q_2 = 1420DRNAREA^{0.619}10^{0.006IMPLNLCD01}$

6.3.11 Off-Site and Adjacent Runoff. The design of a drainage system should consider the runoff from off-site and adjacent areas, recognizing their urban development potential. For hydrologic analysis, calculations for off-site areas should assume these areas are completely developed, even if they are undeveloped or have not yet reached their full development potential. For the purposes of calculations and modeling, land use for off-site areas should be based on City zoning and anticipated land use for these areas. For flood control planning and modeling, effects of detention should be disregarded except for publicly owned and maintained facilities with storage dedicated for perpetuity, unless otherwise approved by the City. Fully developed flows should be used for facility sizing and design. The City may request additional modeling including the effects of detention in the watershed, especially where timing of peak flow rates is a concern.

6.4 STREETS, INLETS, AND STORM DRAINS

6.4.1 General. This chapter contains design information and criteria for the design of urban stormwater collection and conveyance systems. This chapter specifies criteria for: the allowable drainage encroachment within public streets, allowable types, sizing, and placement of inlets, and sizing and design of storm drains.

6.4.2 Design Storms. The stormwater system, at a minimum, shall commence at the point where the 2-year flow rate for fully developed conditions equals or exceeds 5 cubic feet per second (cfs) or street spread/depth limitations are exceeded. The following criteria apply to the design of streets, inlets, and storm drains:

- The 2-year flow rate shall be calculated for the fully developed conditions to show that street inundation criteria are met.
- The hydraulic grade line (HGL) for the 25-year flow shall not exceed the elevation of the gutter for a pipe system within public right-of-way or a drainage easement and shall not exceed channel capacity with a freeboard of 6 inches for an open channel.
- All street storm drains and channels shall be designed to convey the 25-year flow with fully developed conditions.
- Inlet, storm drain, and channel capacity shall be designed so that the HGL from the 100-year flow under fully developed conditions meets street inundation criteria and all runoff is directed to the receiving detention basin or drainage system.
- Inlets and storm drain within parking lots shall be designed to limit ponding to 12 inches for a 100-year event.

In determining peak flow rates for design events for the design of streets, inlets, and storm drains, the effects of detention basins on adjacent properties may be accounted for if assurances that detention will be provided for perpetuity and maintenance is assured. Assurances must typically be provided through recorded documents with land use restrictions and maintenance responsibilities properly noted.

6.4.3 Street Drainage.

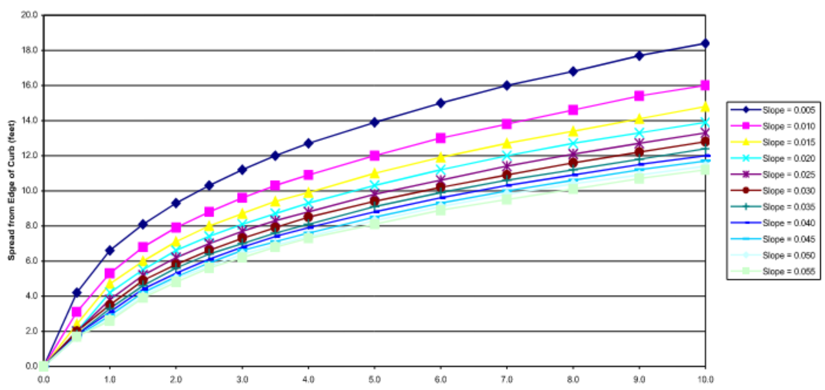
6.4.3.1 Allowable Inundation Depth and Spread. The purpose of limitations for inundation depth and spread is to ensure the safe travel of the public and emergency vehicle access. These limitations are based on the use classification of the street. The criteria used for inundation limitations are the minor storm event (2-year) and the major storm event (100-year). These criteria govern the design of the longitudinal street slope, inlet size, and inlet spacing. Table 11 below presents city street inundation criteria. For collector and arterial streets, no flow shall pass through an intersection for a 25-year or lesser event.

Table 11: City Street Inundation Criteria

Street Classification	Minor Storm (2-year)	Major Storm (100-year)
Local	• No flow from one side of street to another • No curb overtopping • Inlets spaced for a maximum spread of 8 feet from curb face with one clear 10-foot travel lane	• No curb overtopping
Collector	• No flow from one side of street to another • No curb overtopping • Inlets spaced for a maximum spread of 8 feet from curb face with on 12-foot travel lane clear for residential collectors, and two 10-foot travel lanes clear for non-residential collectors	• No curb overtopping
Arterial	• No flow from one side of street to another • No curb overtopping • For secondary arterials, inlets spaced for a maximum 12-foot spread with two 12-foot travel lanes open • For other arterials, inlets spaced for a maximum 6-foot spread with one full lane and one 8-foot lane clear in both directions	• No curb overtopping

6.4.3.2 Curb and Gutter Hydraulics. The required design standard for public streets includes curbs and gutter. The minimum allowable longitudinal slope for a public street is 0.5 percent. The maximum allowable longitudinal slope for a public street range is from 5 to 10 percent, depending on street classification. Standard gutter width is 2 feet, with a depth of 2 inches, resulting in a gutter cross slope of 0.0833 foot per foot (ft/ft). The standard cross slope for a public street is a ¼ inch per foot or approximately 2.1 percent. Gutter depression is 1.5 inches for typical Battlefield Street sections. A greater longitudinal slope results in higher velocities, less spread, and generally, higher inlet efficiencies.

6.4.3.2.1 Gutter Flow and Spread. Gutter flow and spread can be determined using Manning's equation for open channel hydraulics. Assuming the standard gutter and street cross-section found in the Design Standards, gutter flow can be determined by using the figure below.



6.4.3.3 Roadside Swales. Battlefield's standard for public streets in new developments is a curb and gutter section with enclosed storm drains. Other street sections, such as roadside swale sections or other Low Impact Development (LID) designs, will be considered on a case-by-case basis. A subdivision variance will be required through the subdivision approval process, and generally, the developer or property owners' association will be required to maintain all street rights-of-way and LID components. Alternative designs shall take into consideration topography and the proposed development and must adhere to the principles of containing the 100-year flow within the right-of-way or drainage easement and preventing erosion. Refer to Chapter 6.6, Open Channels, and Chapter 6.8, Water Quality, for more information on open channel hydraulics, grass swales, and LID techniques.

6.4.4 Inlets. Properly designed inlets are vital components of the urban stormwater collection and conveyance system. Inlets collect excess stormwater from the street, transition the flow into storm drains, and can provide maintenance access to the storm drain system. Inlets can be made of cast iron, steel, concrete, and/or pre-cast concrete and are installed on the edge of the street adjacent to the street gutter or in the bottom of a swale.

Inlets shall not have a vertical opening greater than 6 inches. If a larger opening is used, a steel bar with a minimum diameter of ¾ inch shall be placed in the opening so there is no vertical opening greater than 6 inches.

6.4.4.1 Inlet Locations. Inlets shall be provided at locations and intervals that shall have a minimum inflow capacity such that maximum flooding depths are not exceeded for the major or minor storm. Inlets shall be provided at all sump locations to prevent ponding of water. It is recommended that inlets be provided at street intersections upstream of pedestrian crosswalks. The spacing of inlets placed in addition to those required by geometric controls is governed by the allowable inundation criteria given in the table above in Section 6.4.3.1.

6.4.4.2 Inlet Types.

6.4.4.2.1 Standard Inlet Types.

6.4.4.2.1.1 Curb Opening Inlets. The standard curb opening used in Battlefield and Greene County has been very successful. However, there has been a considerable amount of confusion over inlet nomenclature. It is the intention of these standards to maintain commonly used terms while clarifying inconsistencies and confusion. The following standard curb inlet designations are recommended for use in City of Battlefield:

1. <u>SS-5 Inlet (Figure SS-10).</u> The standard SS-5 curb opening inlet shall refer to a shallow standard four foot by eight-foot (4' x 8') curb opening inlet with a seven foot (7') long opening, located over a storm drain with a riser pipe connecting the inlet with the storm drainpipe. Riser pipe capacities for use with SS-5 inlets are shown in Figure SS-11.

2. <u>SS-6 Inlet (Figure SS-12).</u> SS-6 inlet shall refer to a full depth standard four foot by eight-foot (4' x 8') curb opening inlet with a seven foot (7') long opening, which can also serve as a junction structure. Precast SS-6 inlets may be provided with a six inch (6") precast top, known as a SS-6 top, or an eighteen inch (18") deep precast top, known as a SS-8 top. The largest diameter pipe which can enter the short side of a SS-6 inlet is thirty inches (30").

3. <u>SS-6S Inlet.</u> SS-6S inlet shall refer to a ‘short’ SS-6 inlet, i.e., a full depth inlet with a four foot by four foot (4' x 4') exterior dimension and a three foot (3') long opening, which can also serve as a junction structure. SS-6S inlets are intended for use in sumps serving small areas.

4. <u>SS-6G Inlet (Figure SS-14).</u> SS-6G inlet shall refer to a SS-6 inlet modified to include a grate in the gutter. Grates used for SS-6G inlets shall be Deeter 2048L, Neenah R3076, or equal. Grates may not extend outward from the curb any further than the width of the standard gutter, which is two feet (2'). Vanes shall be oriented in the direction of gutter flow.

5. <u>Double Curb Inlets.</u> Where necessary to meet allowable flooding depth criteria, two (2) curb opening inlets may be placed side by side. An opening shall be provided in the common walls between the inlets to provide flow from one inlet to the other. The opening shall be a minimum of eighteen inches (18") high and shall extend the entire interior width of the inlet box.

6. Special Inlet Box Designs. Where necessary to accommodate large diameter pipes, curb opening inlets may be specially designed. Details of concrete dimensions and reinforcement shall be included in the drawings.

Curb opening inlets may be constructed of either pre-cast or cast-in-place concrete. Cast-in-place concrete construction shall meet the requirements of Chapter VII of the City of Springfield Technical Specifications or Public Works Construction.

6.4.4.2.1.2 Area Inlets.

1. Open-Side Drop Inlets, Type DI-1 (Figure SS-15). Open side drop inlets are intended for use in locations where open drainage channels, ditches, or swales terminate and flow enters the storm drain system, and flows range from ten (10) to one hundred (100) cubic feet per second. These inlets are preferred in order to minimize the risk of persons being swept into an open storm drain entrance.

   This inlet has a four foot by four-foot (4' x 4') exterior dimension and a maximum capacity of about eighteen (18) cfs per opening at a maximum allowable depth of two feet (2'). The designer must stipulate on the drawing the number of open sides to be provided, i.e., 'Type DI-1 w/2 sides open', etc. Interception capacity data for standard DI-1 inlets are shown in Figure SS-16.

   Where additional capacity is needed, larger inlet structures can be used, provided dimensions are detailed on the drawings and interception capacity calculations are submitted. The maximum allowable opening height is six inches (6"). For greater opening heights, a horizontal bar shall be placed across the opening at maximum six inches (6") intervals.

2. Grated Area Inlets. Grated area inlets may be provided in parking lots and lawn areas. The maximum ponding depth over grated inlets shall be twelve inches (12") for the major (100-year) storm. Concrete dimensions and reinforcement requirements for the inlet structure and the type of grate and frame to be used shall be specified in the drawings. Gratings shall be bicycle safe.

   It is recommended that a one and one half-inch (1.5") depression be provided for area inlets in paved parking areas to minimize standing water (See Figure SS-17). It is also recommended that a reinforced concrete paving apron be provided for two feet (2') around the inlet to prevent pavement failure and subsequent water ponding around the inlet.

6.4.4.2.2 Types of Inlets Allowed.

6.4.4.2.2.1 Public Streets.

1. Curb Opening Inlets. Standard curb opening inlets are required for use in public streets with curbs and gutter. Curb openings are not permitted, except in situations where the

drainage area is one-half (½) acre or less, and there is not sufficient grade to permit installation of a storm drainpipe.

2. Grated Inlets. In general, the use of grated inlets will not be permitted in streets since these generally require adjustment when streets are re-paved. Where conditions are such that curb inlets cannot intercept the required rate of flow necessary to control street flooding depth or to provide diversion of flow to detention, sedimentation, or infiltration basins, combination grate and curb opening inlets (Type SS-6G) may be used provided that the width of the grate is no greater than the gutter width. "Trench inlets" with vaned grates may be specified with approval of the City of Battlefield. Use of trench inlets will be permitted only when there is no practical alternative.

Other types of inlets will not be permitted unless approved by the City of Battlefield.

6.4.4.2.2.2 Outside of Public Right-of-Way. The type of inlets specified outside of public right-of-way is left to the discretion of the designer provided the following criteria are met:

1) Maximum flooding depths for the major or minor storm as set forth in Section 6.4.3.1, Table 1, are not exceeded.

2) General safety requirements set forth in Section 6.4.4.4 are met.

6.4.4.3 Inlet Interception.

6.4.4.3.1 Inlet Interception Capacities. Inlet capacities shall be determined in accordance with Federal Highway Administration HEC-12 or HEC-22. The gutter slope to be used for design of curb opening inlets located on vertical curves shall be the average gutter slope for twenty feet (20') upstream of the inlet. See Figure SS-5 & Figure SS-6.

Nomographs and methods presented in the Neenah Inlet Grate Capacities report may also be used where applicable. The use of commercial software utilizing the methods of HEC-12 or HEC-22 is acceptable.

6.4.4.3.2 Interception and Bypass Flow. It is generally not practical for inlets on slopes to intercept one hundred percent (100%) of the flow in gutters. Inlets must intercept sufficient flow to comply with street flooding depth requirements. Bypass flows shall be considered at each downstream inlet until all flow has entered approved storm sewers or drainageways.

6.4.4.3.3 Clogging Factors. The inlet capacities determined as required in this section should be reduced as follows to account for partial blockage of the inlet with debris. A clogging factor of 0.9 shall be used for curb opening inlets, and a clogging factor of 0.5 shall be used for grate inlets.

Inlet lengths or areas shall be increased as required to account for clogging.

6.4.4.4 General Safety Requirements. All inlet openings shall:

1. Provide for the safety of the public. The maximum allowable opening for standard curb opening inlets and open side drop inlets shall not exceed six inches (6") in height. The maximum bar spacing for grated inlets shall be six inches (6"). Where the height of the opening exceeds six inches (6"), a three-quarters inch (3/4") diameter galvanized steel bar, or other approved restriction shall be provided horizontally across the opening at mid-height, or at maximum intervals of six inches (6"). The maximum open spacing between bars for grated inlets shall be six inches (6") in any direction.

2. Be sufficiently small to prevent entry of debris which would clog the storm drainage system.
3. Be sized and oriented to provide for safety of pedestrians, bicyclists, etc.

6.4.5 Storm Drains. This section covers the design of closed piping for conveyance of storm drainage. Design of open channels and other conveyances is covered in other sections.

6.4.5.1 General. Storm drains convey runoff collected by the inlet system. The storm drain system includes inlets, pipes, channels, junctions, bends, outlets, and other appurtenances.

6.4.5.1.1 Horizontal Alignment. Except for crossings, storm sewers shall not be located under streets. Storm sewers paralleling curbed streets shall be located such that the outside edge of the pipe is six inches (6") minimum behind the back edge of the curb. Pipes shall be aligned in straight lines. Curved alignments are not allowed.

Storm sewers located on private property shall be located within drainage easements and shall be aligned parallel with property lines unless otherwise approved. Where storm drains exit the street right-of-way between residential lots, the pipe shall be extended a minimum of forty feet (40') past the front yard setback line, or to the estimated location of the rear of the dwellings, whichever is more. The outside edge of the pipe shall be located a minimum of five feet (5') from the easement line. Minimum easement widths are given in Table 12 below.

Table 12: Minimum Easement Widths

Minimum Easement Widths	
Inside Horizontal Dimension	**Minimum Easement Width**
15" - 48"	15 feet
54" - 72"	17.5 feet
84" & 96"	20 feet
Over 96"	Approval Required

6.4.5.1.2 Vertical Alignment. The recommended minimum slope for storm drain piping is 0.5% (five-tenths percent). Pipe grades may not be less than the minimum friction slope required to convey the design flow, unless specifically approved. Maximum recommended grade is 10% (ten percent). A properly designed anchorage may be required for grades above 10% (ten percent) and will be required for grades above 15% (fifteen percent). Storm drains shall have a design velocity range from a minimum of 2 fps for the 2-year event up to a maximum of 15 fps for the 100-year event.

When changing pipe diameters, the inside tops of the pipes shall be set at the same elevation. Pipe size shall never be reduced downstream even though pipe slope and theoretical capacity may increase. A minimum vertical drop of 0.2' (two-tenths feet) shall always be provided across a junction structure, unless otherwise approved.

Under or within two feet (2') of streets or paved areas, the top of the pipe shall be located a minimum of twelve inches (12") below the pavement or curb subgrade, or greater if required to meet minimum cover and strength requirements for the type of pipe specified to withstand an AASHTO HS-20 loading. Outside of paved areas, the top of the pipe shall be located a minimum of twelve inches (12") below finished earth grade. Box culverts or other relatively wide and flat conveyance structures may be required to have additional cover if deemed necessary to support grass or other vegetative cover.

The vertical clearance between storm drains and sanitary sewer and water lines shall be twenty-four (24”). In cases where twenty-four inches (24”) of vertical clearance cannot be attained, refer to the City of Battlefield Design Standards for Public Improvement for complete sanitary sewer separation requirements and contact the appropriate utility for water line separation requirements.

Vertical drops greater than 6 feet require a special design that addresses the need for structure protection and energy dissipation.

6.4.5.1.3 Pipes.

The minimum allowable inside diameter for any storm drainpipe on or connecting to storm drain piping in public right-of-way is fifteen inches (15"). The maximum allowable diameter is nine feet (9'), unless otherwise approved.

The minimum allowable slope for pipes less than 36 inches (36") in diameter is five percent 0.5 %, and the maximum allowable slope is fifteen percent (15%) unless hydraulic conditions govern.

Storm sewers may be constructed of any of the following materials:

Material	Symbol	Standard
Reinforced concrete round pipe	RCP	ASTM C-79, Cl III
Reinforced concrete elliptical pipe	RCEP	ASTM C-507
Reinforced concrete pipe-arch	RCPA	ASTM C-478
Precast concrete flared end sections	FES	ASTM C-76
Corrugated, galvanized steel round pipe	CMP	ASTM A-760 / AASHTO M-36
Corrugated, galvanize steel pipe-arch	CMPA	AASHTO M-167
Galvanized steel flared end sections	FES	ASTM A-760
Corrugated polyethylene pipe	CPP	ASTM D-1248
Cast-in-place reinforced concrete box culverts	RCB	MODOT Spec.
Precast concrete box culvert	RCB	ASTM-789

Cast-in-place concrete pipe, masonry, vitrified clay, or other pipe not shown above is not allowed unless specifically approved. Detailed information on structural and hydraulic properties of the type of pipe referred to above can be found in the Concrete Pipe Design Manual, the Handbook of Steel Drainage & Highway Construction Products, and manufacturer's information for corrugated polyethylene pipe.

Corrugated polyethylene pipe (CPP) is not allowed within the public right-of-way or public drainage easements, unless approved in writing by the City of Battlefield.

6.4.5.1.4 Junction Boxes or Manholes. A manhole or junction structure must be provided at each change in direction or grade of the piping, EXCEPT that bends may be located at junction structures to provide a perpendicular connection. Bends must be provided at junction structures if the angle of entry is less than sixty (60°) degrees. Pipes shall be aligned such that the direction of flow of any incoming pipe is not less than perpendicular to the direction of flow of the outflow pipe (i.e., flow "against the grain" shall be avoided).

Access manholes for junction structures shall not be located within the pavement area for public streets. Junction structures shall be located such that the outside edge of the access manhole is twelve inches (12") minimum behind the curb or from the edge of a retaining wall or other obstruction.

Access manholes shall be provided at a maximum of three hundred feet (300') spacing along the pipe.

Precast circular manholes, square cast-in-place or precast junction boxes, or inlets may be used for junction structures.

A standard Junction Box is shown in Figure SS-18.

6.4.5.1.4.1 Precast Manholes. Precast concrete manholes shall conform to the requirements of ASTM-C478. Cast-in-place circular manholes are not permitted. The following minimum manhole diameters shall be used:

Pipe Diameter	Minimum Inside Diameter of Manhole
15" - 24"	Four feet (4')
27" - 42"	Five feet (5')
48"	Six feet (6')
24" - 66"	Eight feet (8')
> 66"	Special junction structure

A minimum clearance of two feet (2') measured at the inside face of the manhole must be maintained between the outside edge of storm sewer pipes. See Figure SS-7

6.4.5.1.4.2 Junction Boxes. Square or rectangular junction boxes may be constructed of cast-in-place or precast concrete. Minimum horizontal dimensions for junction boxes are as follows:

Pipe Diameter	Minimum Inside Width of Junction Box
15" - 30"	Four feet (4')
36" - 42"	Five feet (5')
48"	Five feet six inches (5' 6")
54"	Six feet (6')
60"	Six feet six inches (6' 6")
66"	Seven feet (7')
72"	Seven feet six inches (7' 6")
>72"	Special approval required

Junction boxes shall not exceed eight feet (8') in depth measured from the interior invert of the junction box to the top of the junction box rim unless structural calculations are submitted and approved.

Precast junction structures shall have a maximum inside horizontal dimension of eight feet (8') and a maximum depth of eight feet (8') unless structural calculations are submitted and approved. Precast junction boxes shall be manufactured by Rose-Con Pipe, Springfield, Missouri or be approved by the City.

6.4.5.1.4.3 Ring and Covers for Inlets, Manholes, and Junction Boxes. Type A and Type C Ring and covers for storm sewers shall be used. See Figure SS-8 & SS-9 for details.

6.4.5.1.5 Bends and Transitions. As stated in Section 6.4.5.1.4, a manhole or junction structure must be provided at each change in direction or grade of the piping, EXCEPT that bends may be located at junction structures to provide a perpendicular connection. Bends must be provided at junction structures if the angle of entry is less than sixty (60°) degrees.

In cases where bends and transitions are acceptable, it may be necessary to provide gradual transitions in size or alignment to minimize energy losses and potential for blockage. When bends are necessary, bends at pipe joints should generally not exceed two degrees (2°) or otherwise cause unacceptable head losses in the system. Transitions should be gradual and should not decrease the size of the pipe in the downstream direction. Special structures that control head losses to an acceptable level may be necessary for other transitions.

6.4.5.1.6 Outlets. Storm sewer outlets shall be designed to allow expansion of flow and reduction of velocity, without undue risk of erosion downstream, and allowing for proper construction and maintenance of cut or embankment slopes at the outlet. A headwall or flared end section shall be provided at all pipe outlets. Flared end sections and headwalls shall have a toe-wall extending a minimum of eighteen inches (18") below grade at their downstream end to prevent undercutting.

An erosion resistant lining of concrete or grouted riprap shall be provided for a distance equal to five (5) times the diameter of the outlet pipe or the box culvert width, downstream of the headwall apron or flared end section. The width of the grouted riprap shall be a minimum of two (2) times the pipe diameter or box culvert width or five feet (5'), whichever is less. Where velocity exceeds fifteen feet (15') per second at the pipe outlet an energy dissipator may be required. Energy dissipators shall be designed as set forth in the ASCE design manual.

6.4.5.1.7 Clearance from Other Utilities.

1. Horizontal Clearance.

Utility	Minimum distance from outside edge of pipe to centerline
Storm Sewer	Inside diameter of largest pipe*
Sanitary Sewer	Five feet (5')
Water, gas, electric line, or other utility	Five feet (5')

* or greater, if needed to allow proper placement and alignment of flared end sections

2. Vertical Clearance. A minimum clear distance of eighteen inches (18") from any other utility line shall be maintained above or below the storm drainpipe, unless otherwise approved.

6.4.5.1.8 Other Appurtenances. Examples of other specialized appurtenances include flow splitters and deflectors and flap gates. Flow splitters separate incoming flow and send it in two or more directions. Flow deflectors minimize energy losses in manholes, junction chambers, and flow splitters. Flap gates may be placed on outlets to prevent backflow in areas subject to high tailwater or flood flow. These are structures that require individual consideration and specialized design prior to City acceptance.

6.4.5.2 Plan Requirements

Each storm drain line shown on the plan shall be numbered or lettered (Line 1, Storm 1, Line A, etc.). Structures in each line shall be numbered or lettered in sequence beginning at the downstream end of the line. Stationing shall begin at the downstream end of the line and proceed upstream. Branch lines shall be numbered consecutively moving in an upstream direction. A continuous profile shall be drawn for each storm drain line.

6.4.5.3 General Safety Requirements. The following safety criteria apply to all public storm drainage systems:

- Headwalls and wingwalls associated with storm drain outfalls shall include guardrails, handrails, or fencing in conformance with highway design safety standards and applicable building codes.
- Handrails shall be required in all areas where the drop from the headwall or wingwall exceeds thirty inches (30”). See the Design Standards for Public Improvements for handrail design standards. Refer to AASHTO standards for safety rails along designated bikeways.

- Trash racks should be considered at all entrances to storm drains, based on location and site conditions. Refer to *Public Safety Guidance for Urban Stormwater Facilities* (ASCE) for guidance. When used, inlet racks should have a minimum surface area of four times the open area of the culvert. Racks at outlets are generally discouraged.

6.4.5.4 Storm Drain Hydraulics.

6.4.5.4.1 General. The design of a storm drain system requires data including topography, drainage boundaries, soil types, and locations of any existing storm drains, inlets, and junction boxes. Identification of the type and location of utilities to identify potential conflicts must be completed early in the design process. The drainage area to each inlet shall be identified and the design flows calculated to determine the necessary pipe capacity.

Once the storm drain system is designed, the hydraulic capacity shall be evaluated for the design storms using energy grade line (EGL) calculations starting at the downstream terminus of the system. Hydraulic grade line (HGL) calculations shall be performed for the design storms. All

transitions, bends, entrance and exit conditions, tailwater conditions, and other losses shall be accounted for in HGL calculations.

6.4.5.4.2 Design Storm and Storm Drain Capacity.

Storm sewers shall be designed to convey the peak flow rate resulting from the required design storm having a rainfall intensity corresponding to the time of concentration at the point of interest, or a duration which produces the maximum runoff rate at the point of interest, depending upon the method used for computing runoff. It is preferred that storm sewers draining be designed for runoff rates computed by the Rational Method.

1. <u>Major (Emergency) System.</u>
   Total drainage area less than one (1) square mile: 25-year (4% AEP) storm

   Total drainage area one (1) square mile or more: 100-year (1% AEP) storm

   In cases where no overland relief area is provided for the difference between the 25- and 100-year storm, storm sewers shall be designed to convey the 100-year storm.

2. <u>Minor (Convenience) System</u>
   Storm sewers shall be designed to convey only intercepted flow necessary to maintain allowable street flooding depths. Reductions in peak flow rates to account for the effects of stormwater detention facilities located upstream will be allowed only in instances where the detention basin has been incorporated into an approved hydrologic model of the tributary watershed.

All storm drains shall be designed to convey the 25-year flow with the HGL no higher than the

gutter of the street, and the HGL for the 100-year flow no higher than the top of curb. Spread inundation criteria shall be met for the 2-year and 100-year flows, and all runoffs shall be directed to the downstream detention and/or drainage system appropriately.

6.4.5.4.3 Hydraulic and Energy Grade Line Calculations.

6.4.5.4.3.1 Energy Grade Line. The energy grade line is computed using the principle of conservation of energy and the energy equation for open channel or pressure flow, and is written as follows:

1. Open Channel Flow

$$z_1 + d_1 + \frac{{V_1}^2}{2g} = z_2 + d_2 + \frac{{V_2}^2}{2g} + H_L$$

2. Pressure Flow

$$z_1 + \frac{p_1}{\gamma} + \frac{{V_1}^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{{V_2}^2}{2g} + H_L$$

z = elevation (gravity) head, feet

d = depth of flow, feet

V = velocity of flow = Q/A, feet/second

P / γ = pressure head, feet

γ = unit fluid weight, pounds per cubic foot

H_L = total head loss, feet = $h_f + \Sigma h_m$

h_f = head loss due to friction, feet = L x S_f

L = pipe length, feet

S_f = pipe friction slope from Manning's Equation, feet/foot, $S_f = (\frac{Q}{C_1})^2$

C_1 = conveyance = $\frac{1.49}{n} AR^{2/3} S^{1/2}$

h_m = minor head loss, at entrance, exit, bends, and junctions, feet

D = pipe diameter, or vertical dimension, feet

Q_f = pipe capacity at full flow, cubic feet per second

V_f = velocity at full flow, feet/second

V = velocity, feet/second

6.4.5.4.3.2 Hydraulic Grade Line. Hydraulic grades are computed by subtracting the velocity head, $(\frac{V^2}{2g})$ from the energy head. When the velocity is zero, the hydraulic grade line coincides with the energy grade line.

6.4.5.4.4 Pipe Capacity. Storm sewers shall be designed to convey the peak flow rate from the design storm while maintaining allowable maximum and minimum velocities, and without surcharging which would adversely affect the performance of inlets or other components or the drainage system, or cause flooding of structures or streets.

Pipe capacity and velocity shall be computed using Manning's Equation:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$, where

Q = rate of flow, cubic feet per second

n = Manning's roughness coefficient

A = cross sectional area of flow, square feet

P = wetted perimeter, feet

R = hydraulic radius = A/P, feet

S = slope

Material	**n Value**
Reinforced Concrete Culvert (pipe or box)	0.013
CMP 2-2/3 in x 1/2 in. Annular Corrugations	0.021(1)
CMP 3 in x 1 in. Annular Corrugations	0.027(1)
Structural Plate CMP 6 in. x 2 in. Annular Corrugations (5 ft. dia.)	0.033
Polypropylene Pipe	0.012
PVC (Private development only)	0.012
HDPE (Private development only)	0.012

(1) Manning's n for helically corrugated CMP may be less in certain conditions

6.4.5.3.4 Head Loss Due to Pipe Friction. The friction loss, h_f, due to flow resistance in a storm sewer is calculated as $h_f = L \times S_f$ in which L is length of the sewer pipe (ft) and S_f is friction slope (ft/ft) typically taken as the bottom slope of the pipe as a simplifying assumption for partially full, gravity flow storm sewers.

6.4.5.3.5 Pipe Entrances. Minor head losses for pipe entrance are computed as follows:

$$h_c = K_c \frac{V^2}{2g}\text{, where}$$

Contraction coefficient, K_c = 0.5 (for square edge conditions)

$$h_e = K_e \frac{V^2}{2g}\text{, where}$$

Expansion coefficient, K_e = 1.0

Type of Entrance	**Entrance Coefficient, K_e**
1. Pipe entrance with headwall	
Grooved edge	0.20
Rounded edge (0.15D radius)	0.15
Rounded edge (0.25D radius)	0.10
Square edge (cut concrete and CMP)	0.40
2. Pipe entrance with headwall & 45° wingwall	
Grooved edge	0.20
Square edge	0.35
3. Headwall with parallel wingwall spaced 1.25D apart	
Grooved edge	0.30
Square edge	0.40
4. Projecting Entrance	
Grooved edge	0.25
Square edge	0.50
Sharp edge, thin wall	0.90

6.4.5.3.6 Pipe Junctions. Minor head losses for junction and manhole losses are computed as follows:

$$h_j = \frac{{V_2}^2}{2g} - K_j \frac{{V_1}^2}{2g}$$, where

Junction loss coefficient, K_j, for use in the foregoing equation is as defined in Figure SS-22. Other methods of computing junction and manhole losses are acceptable, provided they are documented in generally accepted literature.

6.4.5.3.7 Transitions. The energy loss due to a gradual pipe expansion, h_{LE}, is calculated as follows:

$$h_{LE} = K_e\left(\frac{{V_1}^2}{2g} - \frac{{V_2}^2}{2g}\right)$$, where

K_e = expansion loss coefficient from table below

V_1 = velocity upstream of the expansion (ft/s)

V_2 = velocity downstream of the expansion (ft/s)

The energy loss due to a gradual pipe contraction, h_{LC}, is calculated as follows:

$$h_{LC} = K_C\left(\frac{{V_2}^2}{2g} - \frac{{V_1}^2}{2g}\right)$$, where

K_c = contraction loss coefficient

V_1 = velocity upstream of the expansion (ft/s)

V_2 = velocity downstream of the expansion (ft/s)

In general, $K_C = 0.5K_e$.

D_2/D_1	Angle of Cone						
	10°	20°	45°	60°	90°	120°	180°
1.5	0.17	0.40	1.06	1.21	1.14	1.07	1.00
3	0.17	0.14	0.86	1.02	1.06	1.04	1.00

2.4.5.3.8 Bend Loss. The energy loss due to a bend, h_{LB}, is calculated as follows:

$$h_{LB} = 0.003\Delta(V_2/2g)$$

In which:

V = velocity in bend (ft/sec)

Δ = angle of curvature in degrees

6.4.5.3.9 Exit Loss. The energy loss at a storm sewer system outlet, h_{LO}, is calculated using the following equation:

$$h_{LO} = \frac{{V_o}^2}{2g} - \frac{{V_d}^2}{2g}\text{, where}$$

V_o = velocity in the outlet pipe (ft/sec)

V_d = velocity in the downstream channel (ft/sec)

When a storm sewer discharges into a reservoir, V_d = 0. For discharge to an open channel,

Manning's equation can be used to estimate V_d based on channel geometry and roughness.

6.5 CULVERTS AND BRIDGES

6.5.1 General. This chapter addresses the hydraulic function of culverts. The hydraulic function involves conveying surface water through embankments such as roadways and railroads. In addition to the hydraulic function, a culvert must support loads from construction equipment, highway, railroad, or other traffic. Therefore, culvert design involves both hydraulic and structural design considerations, though this chapter is focused strictly on the hydraulic aspects of culvert design.

Multiple factors have a bearing on the capacity and overall performance of a culvert. These include size, shape, material, as well as several other variables. Sizes and shapes of culverts may vary from small circular pipes to extremely large arch sections used in place of a bridge.

The material selected for a culvert is dependent upon various factors, such as durability, structural strength, roughness, bedding condition, abrasion and corrosion resistance, and water tightness. The most commonly used culvert materials are steel (smooth and corrugated) and concrete.

The inlet configuration is another factor that significantly affects the performance of a culvert. The inlet may consist of a culvert barrel projecting from the roadway fill or mitered to the embankment slope. Other inlets have headwalls, wingwalls, and apron slabs or may have standard end sections of concrete or metal.

The following is a list of culvert shapes and their applications:

- Circular – Most common culvert shape, for general use.
- Elliptical – Often used in lieu of circular pipe in situations where the available cover depth is limited.
- Arch - Suitable for locations where less obstruction to a waterway is preferred and where foundations are adequate for structural support.
- Box – Suitable for passing large flows and for a range of site conditions. A box or rectangular culvert lends itself more readily than other shapes to low allowable headwater situations since the culvert height may be decreased to satisfy the site constraints and the width (span) increased to accommodate flow capacity requirements.

6.5.2 Design Information. The hydraulic design of a culvert involves analyzing the required performance of the culvert to convey flow through an embankment, such as a road. The designer must select a design flood frequency, estimate the design discharge for that frequency, and set an allowable headwater elevation based on the selected design flood and headwater considerations.

The culvert size and type can only be selected after certain design criteria have been determined such as the design discharge, controlling design headwater, slope, tailwater, and allowable outlet velocity.

6.5.2.1 Discharge. The discharge used in culvert design is usually estimated on the basis of a preselected storm recurrence interval, and the culvert is designed to operate within acceptable limits of risk at that flow rate. The design recurrence interval should be based on the more restrictive criteria set forth in Table 13 below.

Table 13: Storm Recurrence Intervals

Criterion	Criterion Value	Design Storm Recurrence Interval
Drainage area above culvert	Less than 1 square mile	25-year
	1 square mile or greater	100-year
Roadway Classification	Smaller than secondary arterial	25-year
	Secondary arterial or greater	100-year

Notes:

1. For all roadways, culvert sizing should accommodate the design storm and also allow for one foot (1') of freeboard below the sag in the roadway or below the low chord of a bridge structure, whichever results in a lower Water Surface Elevation (W.S.E.).
2. For safety purposes, roadway culverts sized for the 25-year event should also be checked for the 100-year flow. If, during the 100-year event, flow overtops the roadway, then the velocity and depth must meet the following criterion:
   a. V * D is less than or equal to 4, where
      i. V = Velocity of flow in water overtopping roadway (ft/sec)
      ii. D = Depth of flow overtopping roadway (ft)
   b. If V * D is greater than 4, then the culvert capacity must be increased until V * D < 4 for the 100-year event.

6.5.2.2 Headwater Depth. Culverts frequently constrict the natural stream flow, which causes a rise in the upstream water surface. The elevation of the upstream water surface is termed headwater elevation. The headwater depth is measured from the invert of the culvert inlet to the water surface of the stream. In selecting the design headwater elevation, the designer should consider the following:

- Headwater/Culvert Depth ratio (HW/D) should not exceed 1.5 unless there is justification and sufficient measures are taken to protect the culvert inlet (for example, a concrete headwall).
- Anticipated upstream and downstream flood risks, for a range of return frequency events.
- Hazard to human life and safety (caused by exceeding the design headwater elevation).
- Damage to the culvert and the roadway.
- Traffic interruption.
- Low point in the roadway grade line.
- Roadway elevation above the structure.
- Elevation at which water will flow to the next cross drainage.
- Relationship of headwater depth to the stability of the embankment that the culvert passes through.

The designer should verify that the watershed divides are higher than the design headwater elevations. In flat terrain, drainage divides are often undefined or nonexistent, and culverts should be located and designed for the least disruption of the existing flow distribution.

6.5.2.3 Tailwater Depth. Tailwater is the flow depth in the downstream channel measured from the invert of the culvert outlet. A field inspection of the downstream channel should be made to determine whether there are obstructions that will influence the tailwater depth. Tailwater depth may be controlled by several factors, including the stage in a contributing stream, headwater from structure downstream of the culvert, reservoir water surface elevations, or other downstream features.

6.5.2.4 Outlet Velocity. The outlet velocity of a culvert, measured at the downstream end of the culvert, is usually higher than the maximum natural stream velocity. This higher velocity can cause streambed scour and bank erosion for a limited distance downstream from the culvert outlet.

Permissible velocities at the outlet will depend upon streambed type, and the type of energy dissipation (outlet protection) that is provided. As a general rule, the velocity at the downstream edge of a project right-of -way or downstream constraint should not be greater than the pre-construction velocity. Velocities must be non-erosive to the existing channel; otherwise, downstream improvements may be required by incorporating some type of outlet protection or energy dissipation device. Variations in shape and size of a culvert seldom have a significant effect on the outlet velocity.

6.5.3 Culvert Hydraulics.

6.5.3.1 Key Hydraulic Principles. When designing culverts, the Mannings's equation, Continuity Equation, and Energy Equation are the most essential. The three equations are shown below:

Mannings Equation:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$, where

Q = flow rate or discharge (cfs)
n = Manning roughness coefficient (unitless)
A = cross-sectional area of flow (sq ft)
R = hydraulic radius (ft)
S = longitudinal slope (unitless)

Continuity Equation:

$$Q = v_1 A_1 = v_2 A_2$$, where

Q = flow rate or discharge (cfs)
v = velocity (ft/sec)
A = cross-sectional area of flow (sq ft)

Energy Equation:

$$\frac{v^2}{2g} + \frac{p}{\gamma} + z + losses = constant$$, where

v = velocity (ft/sec)
g = gravitational acceleration (32.2 ft/sec^2)
p = pressure (lb./ft^2)

γ = specific weight of water (62.4 lb./ft^3)
(Note: p/γ = pressure head or depth of flow)
z = height above datum (ft)

6.5.3.1.1 Energy and Hydraulic Grade Lines.

The energy grade line, also known as the line of total head, is the sum of velocity head $v^2/2g$, the depth of flow or pressure head p/γ, and elevation above an arbitrary datum represented by the distance z. The energy grade line slopes downward in the direction of flow by an amount equal to the energy gradient H_L/L, where H_L equals the total energy loss over the distance L.

The hydraulic grade line, also known as the line of piezometric head, is the sum of the elevation z and the depth of flow or pressure head p/γ.

6.5.3.1.1.1 Closed Conduit Flow. For pressure flow in closed conduits, p/γ is the pressure head, and the hydraulic grade line falls above the top of the conduit as long as the pressure relative to atmospheric pressure is positive.

6.5.3.1.1.2 Open Channel Flow. For open channel flow, the term p/γ is equivalent to the depth of flow and the hydraulic grade line is the same as the water surface. Where open channel flow is established, the hydraulic grade line is the same as the water surface.

6.5.3.1.2 Inlet and Outlet Control.

There are two basic types of flow conditions in culverts: inlet control and outlet control. For each type of control, a different combination of factors is used to determine the hydraulic capacity of the culvert.

6.5.3.1.2.1 Inlet Control. A culvert operates under inlet control when the flow capacity of the culvert is controlled at the inlet by the following factors:

- Depth of headwater
- Inlet edge configuration
- Cross-sectional area
- Barrel shape (i.e., circular, elliptical, rectangular, etc.).

With inlet control, the culvert barrel usually flows only partially full. Inlets control for culverts occurs under two conditions:

1. Unsubmerged Inlet – The headwater depth is not sufficient to submerge the top of the culvert, and the culvert invert slope is supercritical. This is the less common condition of inlet control.

2. Submerged Inlet – The headwater submerges the top of the culvert, and the pipe does not flow fully. This is the more common condition of inlet control.

6.5.3.1.2.2 Outlet Control. If the headwater is high enough, the culvert slope sufficiently flat and the culvert sufficiently long, the control will shift from the inlet to the outlet. In outlet control, the discharge is a function of the inlet losses, the headwater depth, the culvert roughness, the culvert length, the barrel diameter, the culvert slope, the type of outlet and in some cases, the tailwater elevation. With outlet control, culvert hydraulic performance is determined by the following factors:

- Depth of headwater
- Inlet edge configuration
- Cross-sectional area
- Culvert shape
- Barrel slope
- Barrel length
- Barrel roughness
- Depth of tailwater

Outlet control for culverts occurs under two conditions:

1. Partially Full Conduit – The headwater depth is insufficient to submerge the top of the culvert, and the culvert slope is subcritical, resulting in the culvert flowing partially full. This is the less common condition of outlet control.
2. Full Conduit – The culvert flows full along its length. This is the more common condition of outlet control.

6.5.3.2 Energy Losses.

6.5.3.2.1 Inlet Losses. For inlet losses, the governing equations are the following:

$$Q = CA\sqrt{2gH} \text{ and } H_e = K_e \frac{v^2}{2g} \text{, where}$$

Q = flow rate or discharge (cfs)

C = contraction coefficient (dimensionless)

A = cross-sectional area (ft^2)

g = acceleration due to gravity, 32.2 (ft/sec^2)

H = total head (ft)

H_e = head loss at entrance (ft)

K_e = entrance loss coefficient (see Table 2 below)

v = average velocity (ft/sec)

Entrance Coefficient

Type of Entrance	Entrance Coefficient, K_e
1. Pipe entrance with headwall	
Grooved edge	0.20
Rounded edge (0.15D radius)	0.15
Rounded edge (0.25D radius)	0.10
Square edge (cut concrete and CMP)	0.40
2. Pipe entrance with headwall & 45° wingwall	
Grooved edge	0.20
Square edge	0.35
3. Headwall with parallel wingwall spaced 1.25D apart	
Grooved edge	0.30
Square edge	0.40
4. Projecting Entrance	
Grooved edge	0.25
Square edge	0.50
Sharp edge, thin wall	0.90

6.5.3.2.2 Friction Losses. Friction head loss for pipes flowing partially full can be determined from the Manning's equation reformulated to calculate head loss:

$$H_f = \left(\frac{29n^2L}{R^{4/3}}\right)\frac{v^2}{2g}\text{, where}$$

H_f = frictional head loss in culvert barrel (ft)

n = Manning roughness coefficient (unitless)

L = culvert length (ft)

R = hydraulic radius (=A/p) (ft)

A = cross-sectional area of culvert barrel (ft^2)

p = wetted perimeter of barrel (ft)

v = average velocity (ft)

g = acceleration due to gravity, 32.2 (ft/sec^2)

Friction head loss for turbulent flow in pipes flowing full can be determined from the Darcy-Weisbach equation.

$$H_f = f(\frac{L}{D})(\frac{v^2}{2g}) \text{ , where}$$

H_f = frictional head loss (ft)

f = friction factor (obtained from Moody's diagram)

L = culvert length (ft)

D = pipe diameter (ft)

v = average velocity (ft)

g = acceleration due to gravity, 32.2 (ft/sec^2)

6.5.3.2.3 Outlet Losses. For outlet losses, the governing equations are related to the difference in velocity head between the pipe flow and the downstream channel at the end of the pipe. The downstream channel velocity is usually neglected, resulting in the outlet losses being equal to the velocity head of full flow in the culvert barrel, given by the following equation:

$$H_o = \frac{v^2}{2g} \text{ ,}$$

H_o = outlet head loss (ft)

v = average velocity in culvert barrel (ft)

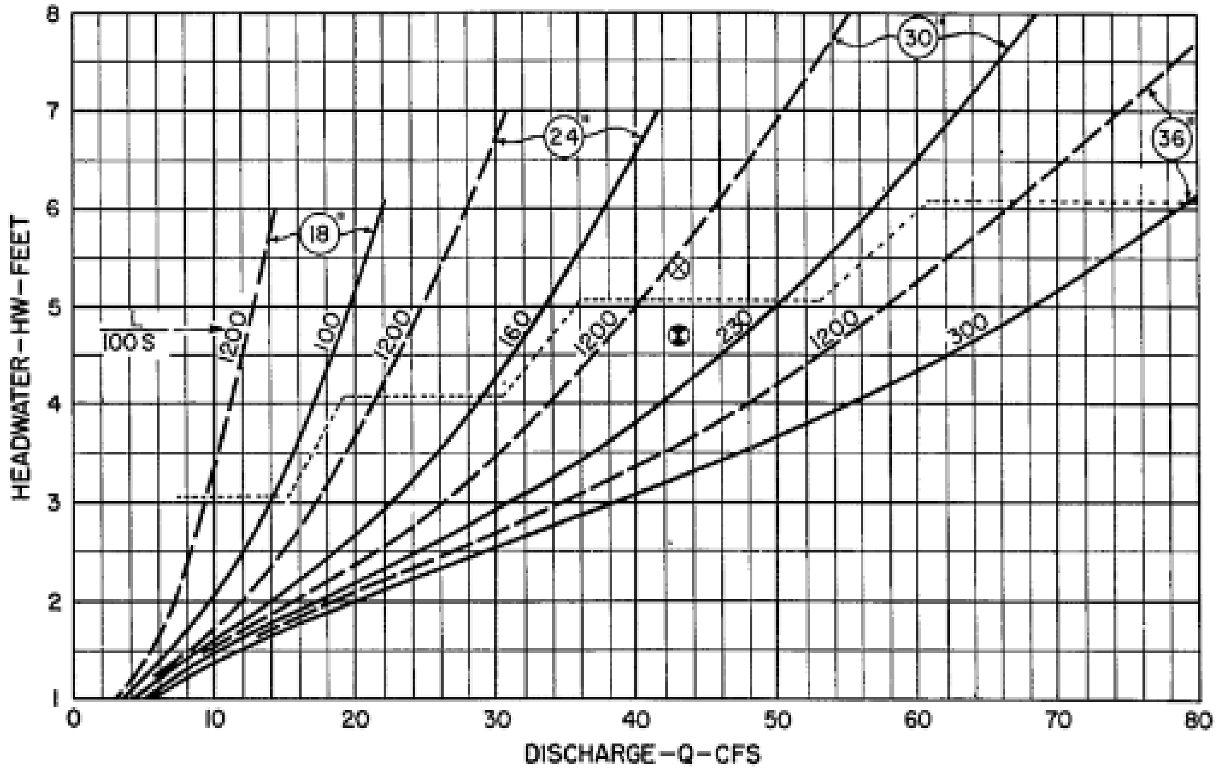
g = acceleration due to gravity, 32.2 (ft/sec^2)

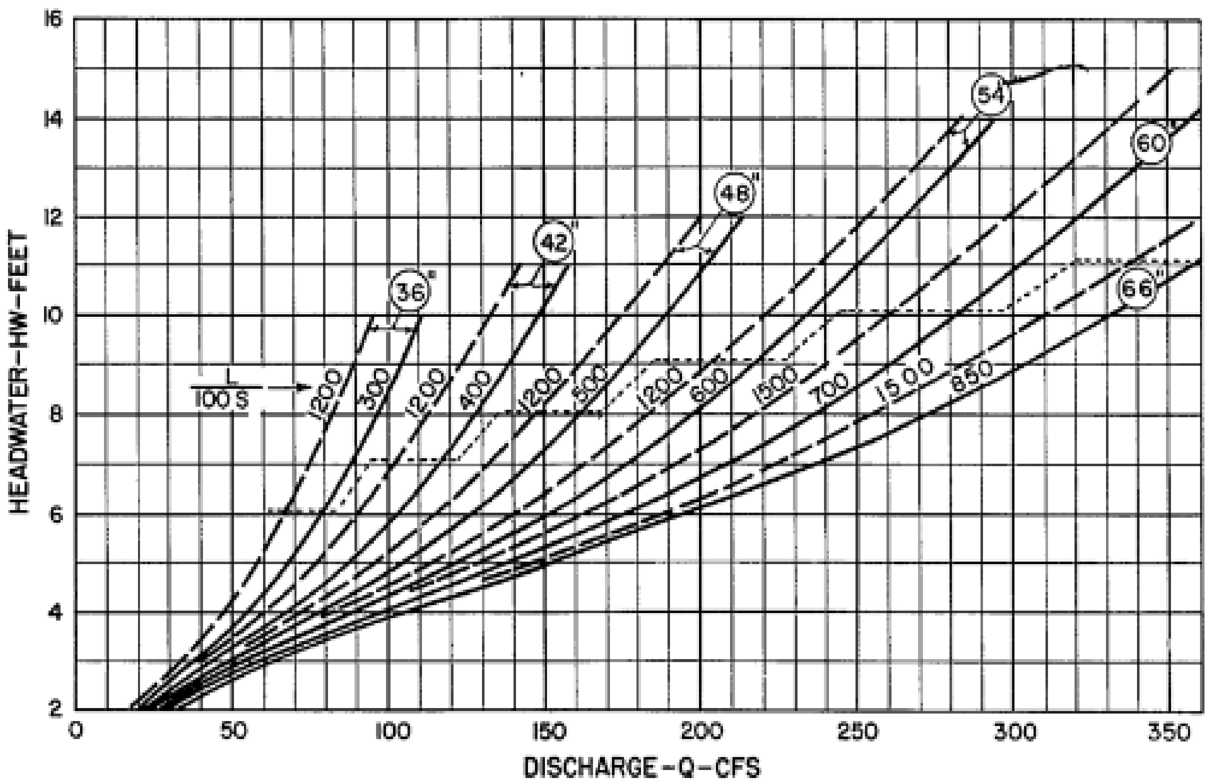
6.5.4 Culvert Sizing and Design. Culvert design involves trial and error to determine the proper culvert size and involves the following steps:

- Select a culvert shape, type, and size with a particular inlet end treatment.
- Determine a headwater depth for both inlet and outlet control given the design discharge, the grade and length of culvert, and the depth of water at the outlet (tailwater).
- Compare the largest depth of headwater (as determined from either inlet or outlet control) to the design criteria. If the design criteria are not met, continue trying other culverts.
- Estimate the culvert outlet velocity. Determine if there is a need for any special features such as energy dissipators, riprap protection, fish passage, trash/safety rack, etc.

The hydraulic design of culverts can be achieved using several different methods, including the following described in this chapter: capacity charts, nomographs, and computer applications.

6.5.4.1 Capacity Charts. Capacity charts can provide a good understanding of how culvert size requirements vary depending on multiple variables. Each chart contains a series of curves which show the discharge capacity per culvert barrel in cfs for each of several sizes of similar culvert types, given various headwater depths (measured in feet above the culvert invert at the inlet). Each culvert size is described by two lines: one solid and one dashed. The numbers associated with each line are the ratio of the culvert length, L, in feet, to 100 times the slope, s, in feet per foot (ft/ft) (100s). The solid line represents the division between outlet and inlet control. The dashed lines represent the maximum L/(100s) ratio for which the curves may be used without modification. Examples of capacity charts are shown below with the upper chart being for culvert diameters from eighteen to thirty-six inches (18” to 36”) and the bottom chart being for culvert diameters from thirty-six to sixty-six incher (36” to 66”) (refer to FHWA 2005a for capacity carts):


HEADWATER-HW-FEET
DISCHARGE-Q-CFS
L / 100 S
18"
24"
30"
36"
1200
100
160
230
300


HEADWATER-HW-FEET
DISCHARGE-Q-CFS
L / 100 S
36"
42"
48"
54
60"
66"
1200
300
400
500
600
1500
700
850

6.5.4.1.1 Culverts Under Inlet Control. For values of L/(100s) less than that shown on the solid line, the culvert is operating under inlet control. The headwater depth is determined from the L/(100s) value given on the solid line. The solid-line inlet-control curves are plotted from model test data. The dashed-line outlet-control curves were computed for culverts of various lengths with relatively flat slopes. Free outfall at the outlet was assumed; therefore, tailwater depth is assumed not to influence the culvert performance.

6.5.4.1.2 Culverts Under Outlet Control. For culverts flowing under outlet control, the head loss at the entrance is computed using the loss coefficients previously given, and the hydraulic roughness of the various materials used in culvert construction is considered in computing resistance loss for full or part-full flow.

Except for large pipe sizes, headwater depths on the charts extend to 3 times the culvert height. Pipe arches and oval pipe show headwater up to 2.5 times their height since they are used in low fills. The dotted line, stepped across the charts, shows headwater depths approximately twice the barrel height and indicates the upper limit of unrestricted use of the charts. Above this line the headwater elevation should be checked with nomographs or with computer programs. Also note, the headwater/culvert depth (HW/D) ratio should not exceed 1.5 unless there is justification and sufficient measures are taken to protect the culvert inlet.

The headwater depth given by the charts is actually the difference in elevation between the culvert invert at the entrance and the total head; that is, depth plus velocity head for flow in the approach channel. In most cases, the water surface upstream from the inlet is so close to this same level that the chart determination may be used as headwater depth for practical design purposes. Where the approach velocity is in excess of 3.0 ft/sec, the velocity head must be subtracted from the curve determination of headwater to obtain the actual headwater depth.

6.5.4.1.3 Capacity Chart Procedure. The procedure for sizing the culvert is summarized below.

- List design data: Q = flow or discharge rate (cfs), L = length of culvert (ft), allowable H_w = headwater depth (ft), s = slope of culvert (ft/ft), type of culvert barrel, and entrance.

- Compute L/(100s).

- Find the design discharge, Q in the appropriate capacity chart (refer to FHWA 2005a for capacity charts).

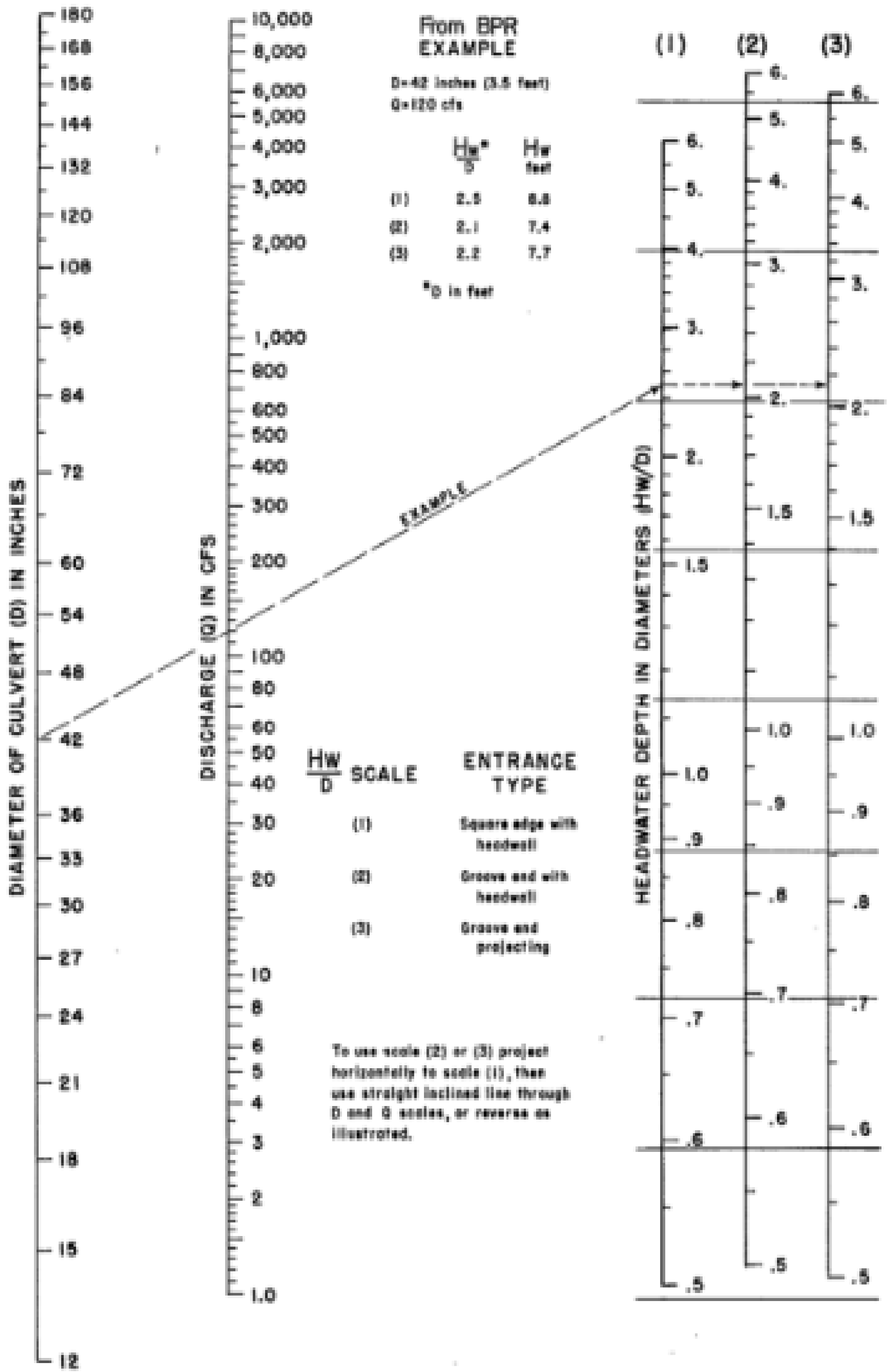
- Find the L/(100s) value for the smallest pipe that will pass the design discharge. If this value is above the dotted line shown in the example capacity charts above, use nomographs or computer programs to check headwater conditions.

- If L/(100s) is less than the value of L/(100s) given for the solid line, then the value of H_w is the value obtained from the solid line curve. If L/(100s) is larger than the value for the dashed outlet control curve, then special measures must be taken, and the reader is referred to FHWA 2005a.

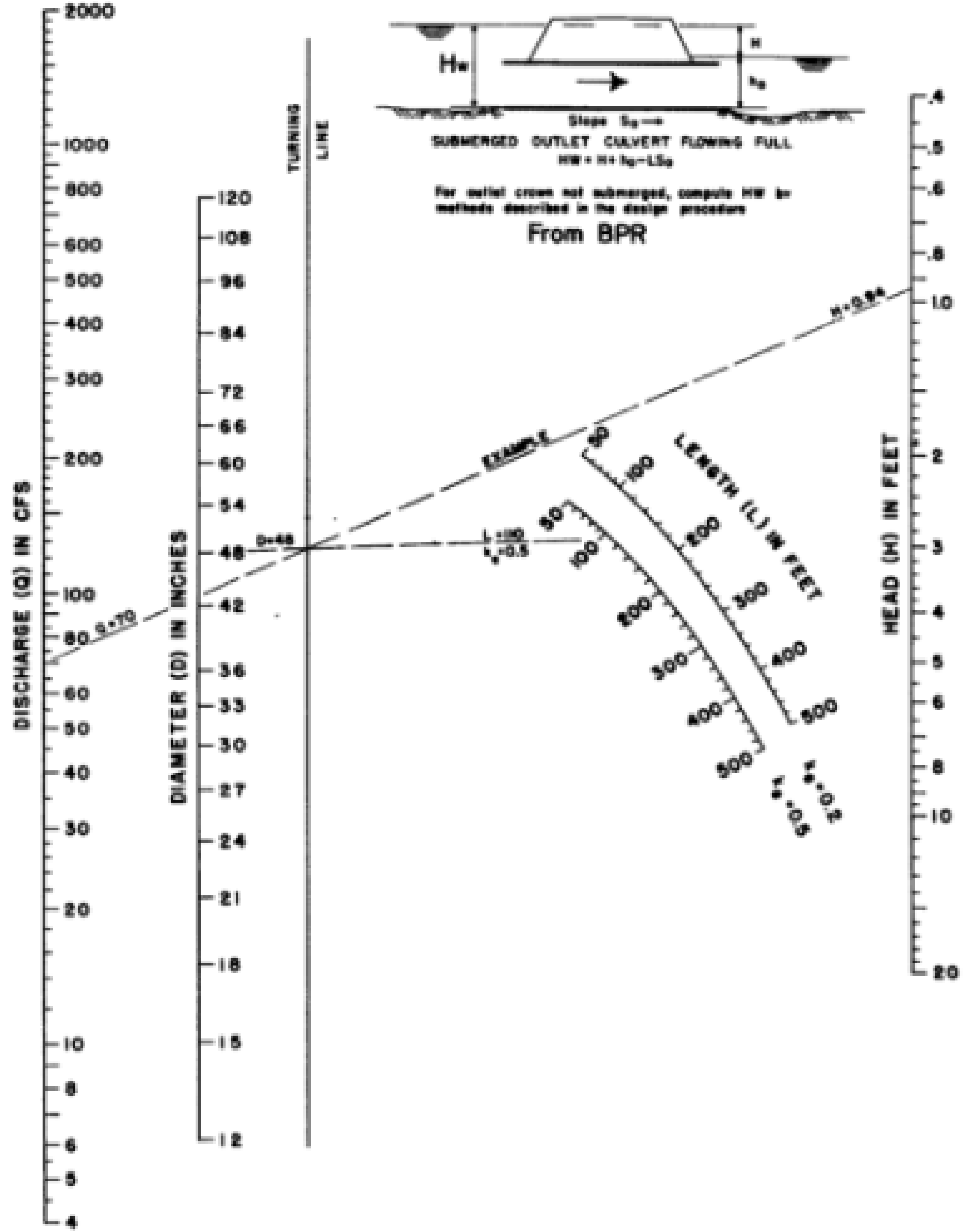
- Check the H_w value obtained from the charts with the allowable H_w. If the indicated H_w is greater than the allowable H_w, then try the H_w elevation from the next largest pipe size.

6.5.4.2 Nomographs. Examples of nomographs for designing culverts are presented in the two figures below with the first figure being an inlet control nomograph) and the second figure being an outlet control nomograph. The use of these nomographs is limited to cases where tailwater depth is higher than the critical depth in the culvert.

A disadvantage of the nomographs is that they require trial and error, whereas the capacity charts are direct. However, a disadvantage of the capacity charts is they can be used only when the flow passes through critical depth at the outlet. If the critical depth at the outlet is less than the tailwater depth, then the nomographs must be used. Both the capacity charts and nomographs shall give the same results if either of the two methods are used.


From BPR
EXAMPLE
D=42 inches (3.5 feet)
Q=120 cfs
Hw*/D Hw feet
(1) 2.5 8.8
(2) 2.1 7.4
(3) 2.2 7.7
*D in feet
DIAMETER OF CULVERT (D) IN INCHES
DISCHARGE (Q) IN CFS
HEADWATER DEPTH IN DIAMETERS (Hw/D)
EXAMPLE
Hw/D SCALE
ENTRANCE TYPE
(1) Square edge with headwall
(2) Groove end with headwall
(3) Groove end projecting
To use scale (2) or (3) project horizontally to scale (1), then use straight inclined line through D and Q scales, or reverse as illustrated.
(1) (2) (3)

Inlet Control Nomograph



Outlet Control Nomograph

6.5.4.2.1 Nomograph Procedure. The nomograph procedure for culvert design requires the use of both the inlet control and outlet control nomographs (refer to the respective figures above):

- List design data: Q (cfs), L (ft), invert elevations in and out (ft), allowable H_w (ft), mean and maximum flood velocities in natural stream (ft/sec), culvert type and entrance type for first selection.
- Determine a trial size by assuming a maximum average velocity based on channel considerations to compute the area, A = Q/V.
- Find H_w for trial size culvert for inlet control and outlet control. For inlet control, connect a straight line through D and Q to scale (1) of the H_w/D scales and project horizontally to the proper scale, compute H_w, and, if too large or too small, try another size before computing H_w for outlet control.
- Next, compute the H_w for outlet control. Enter the graph with the length, the entrance coefficient for the entrance type, and the trial size. Connect the length scale and the culvert size scale with a straight line, pivot on the turning line, and draw a straight line from the design discharge on the discharge scale through the turning point to the head scale (head loss, H). Compute H_w from the equation:

$$H_w = H + h_o - Ls$$, where

H_w= headwater depth (ft)

H = head loss (ft)

h_o = tailwater depth or elevation at the outlet of a depth equivalent to the location of the hydraulic grade line (ft)

L = length of culvert (ft)

s = slope of culvert (ft/ft)

For Tw greater than or equal to the top of the culvert: $h_o = T_w$

For Tw less than the top of the culvert: $h_o = \frac{d_c + D}{2}$ $or\ T_w$ (whichever is greater)

h_o = critical depth (ft)

d_c = critical depth (ft)

D = culvert diameter(ft)

T_w = tailwater depth (ft)

If T_w is less than d_c, the nomographs cannot be used, see Hydraulic Design of Highway Culverts (FHWA 2005a) for critical depth charts.

Compare the computed headwaters and use the higher H_w to determine if the culvert is under inlet or outlet control. If outlet control governs and the H_w is unacceptable, select a larger trial size and find another H_w with the outlet control nomographs. Since the smaller size of culvert had been selected for allowable H_w by the inlet control nomographs, the inlet control for the larger pipe need not be checked.

6.5.4.3 Computer Applications. Examples of computer applications that are acceptable by the City for the hydraulic design of culverts are:

- Federal Highway Administration (FHWA) HY-8 Culvert Analysis program (FHWA 2009): http://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/
- U.S. Army Corps of Engineers Hydrologic Engineering Center - River Analysis System (HEC-RAS): http://www.hec.usace.army.mil/software/hec-ras/

In addition to the public domain computer applications listed here, numerous proprietary computer applications are also available for the hydraulic design of culverts.

6.5.4.4 Design Considerations. Because of problems that arise from topography and other considerations, the actual design of a culvert installation is more difficult than the simple process of sizing culverts. The information in the procedure for design is only guidelines since the problems encountered are too varied and too numerous to be generalized. However, the actual process presented should be followed to ensure that a special problem is not overlooked.

6.5.4.4.1 Invert Elevations. After determining the allowable headwater elevation, the tailwater elevation, and the approximate culvert length, invert elevations must be assumed. Scour is not likely in an artificial channel such as a roadside ditch or a major drainage channel when the culvert has the same slope as the channel. To reduce the chance of failure due to scour, invert elevations corresponding to the natural grade should be used as a first trial. For natural channels, the flow conditions in the channel upstream from the culvert should be investigated to determine if scour will occur.

6.7.4.4.2 Culvert Diameter. After the invert elevations have been assumed, the diameter of

pipe that will meet the headwater requirements should be determined. Since small diameter pipes are often plugged by sediment and debris, it is recommended that pipe smaller than 18 inches not be used. Since the pipe roughness influences the culvert diameter, both concrete and corrugated metal pipes should be considered in design, if both will satisfy the headwater requirements.

6.5.4.4.3 Limited Headwater. If there is insufficient headwater elevation to obtain the required discharge, it is necessary to oversize the culvert barrel, lower the inlet invert, use an irregular cross section, or use any combination of the preceding to increase the discharge rate. If the inlet invert is lowered, special consideration must be given to scour. The use of gabions or concrete drop structures, riprap, and headwalls with apron and toe walls should be investigated and compared to obtain a proper design.

6.5.4.4.4 Culvert Outlet. The outlet velocity must be checked to determine if a significant scour will occur downstream during a major storm. If scour is indicated, refer to Section 6.5.6 of this chapter ("Protection Downstream of Culverts"). Under-designing the amount of outlet protection is not recommended for economizing during design and construction because downstream channel degradation can be significant, and the culvert outlet can be undermined.

6.5.4.4.5 Minimum Slope. To minimize sediment deposition in the culvert, the culvert slope must be equal to or greater than the slope required to maintain a minimum velocity. The slope should be checked for each design, and if the proper minimum velocity is not obtained, the pipe diameter may be decreased, the slope steepened, a smoother pipe used, or a combination of these employed to increase velocity.

6.5.5 Culvert Inlets. An often-overlooked fact is that a culvert cannot convey any more water than can enter the inlet. Frequently, culverts and open channels are carefully designed with full consideration given to slope, cross section, and hydraulic roughness, but without regard to the inlet limitations. Culvert designs using uniform flow equations rarely carry their design capacity due to limitations imposed by the inlet. The design of a culvert, including the inlet and the outlet, requires a balance between cost, hydraulic efficiency, purpose, and topography at the proposed culvert site. In situations where there is sufficient allowable headwater depth, a choice of inlets may not be critical, but where there are constraints such as limited headwater depth, erosion problems, or where sedimentation is likely, a more efficient inlet may be required to obtain the necessary discharge for the culvert.

Although the primary purpose of a culvert is to convey flows, a culvert may also be used to restrict flow. That is, a culvert can be used to discharge a controlled amount of water while the area upstream from the culvert is, for example, used for detention storage to reduce a storm runoff peak. For this case, an inefficient inlet may be the most desirable choice.

The entrance coefficient, K_e, is a measure of the hydraulic efficiency at the inlet with lower values indicating greater efficiency. Entrance coefficients recommended for use are given in Table 14 below.

Table 14: Entrance Coefficients

Type of Entrance	Entrance Coefficient, K_e
1. Pipe entrance with headwall	
Grooved edge	0.20
Rounded edge (0.15D radius)	0.15
Rounded edge (0.25D radius)	0.10
Square edge (cut concrete and CMP)	0.40
2. Pipe entrance with headwall & 45° wingwall	
Grooved edge	0.20
Square edge	0.35
3. Headwall with parallel wingwall spaced 1.25D apart	
Grooved edge	0.30
Square edge	0.40
4. Projecting Entrance	
Grooved edge	0.25
Square edge	0.50
Sharp edge, thin wall	0.90

6.5.5.1 Projecting Inlets. Projecting inlets shall not be used. Headwalls, wingwalls, and flared end sections should be used to maximize efficiency and minimize turbulence, head loss, and erosion.

6.5.5.2 Inlets with Headwalls. Headwalls may be used for a variety of reasons, including increasing the efficiency of the inlet, providing embankment stability, and providing embankment protection against erosion. The relative efficiency of the inlet varies with the pipe material used.

6.5.5.2.1 Corrugated Metal Pipe. A corrugated metal pipe in a headwall is essentially a square-edged entrance with an entrance coefficient of approximately 0.4. The entrance losses may be reduced by rounding the entrance. The entrance coefficient may be reduced as follows:

- Reduce to 0.15 for a rounded edge with a radius equal to 0.15 times the culvert diameter.
- Reduce to 0.10 for rounded edge with a radius equal to 0.25 times the diameter of the culvert.

6.5.5.2.2 Concrete Pipe. For tongue-and-groove or bell-end concrete pipes, little increase in hydraulic efficiency is realized by adding a headwall. The primary reason for using headwalls is for embankment protection and for ease of maintenance. The entrance coefficients for concrete pipe are:

- 0.2 (approximate) for grooved and bell-end pipe.
- 0.4 for cut concrete pipe.

6.5.5.2.3 Wingwalls. Wingwalls are used where the side slopes of the channel adjacent to the entrance are unstable and where the culvert is skewed to the normal channel flow. Little increase in hydraulic efficiency is realized with the use of wingwalls, regardless of the pipe material used and, therefore, the use should be justified for reasons other than an increase in hydraulic efficiency. For parallel wingwalls, the minimum distance between wingwalls should be at least 1.25 times the diameter of the culvert pipe.

6.5.5.2.4 Aprons. If high headwater depths are to be encountered, or if the approach velocity of the channel will cause scour, a short channel apron should be provided at the toe of the headwall. This apron should extend at least one pipe diameter upstream from the entrance, and the top of the apron should not protrude above the normal streambed elevation.

Culverts with wingwalls should be designed with a concrete apron extending between the walls.

Aprons must be reinforced to control cracking. For conditions where scouring may be a problem due to high approach velocities and special soil conditions such as alluvial soils, a toe wall is often desirable for apron construction.

6.5.5.3 Special Inlets. There is a large variety of inlets other than the common ones described. Among the other types of special inlets are special end-sections, which serve as both outlets and inlets, and which are available for both corrugated metal pipe and concrete pipe.

6.5.5.3.1 Corrugated Metal Pipe. Special end-sections for corrugated metal pipe add little to the overall cost of the culvert and have the following advantages:

- Less maintenance around the inlet.
- Less damage from maintenance work and from accidents compared to a projecting entrance.
- Increased hydraulic efficiency. When using design charts, charts for a square-edged opening for corrugated metal pipe with a headwall may be used.

6.5.5.3.2 Concrete Pipe. As is the case with corrugated metal pipe, concrete special end-sections may aid in increasing the embankment stability or in retarding erosion at the inlet. They should be used where maintenance equipment must be used near the inlet or where, for aesthetic reasons, a projecting entrance is considered too unsightly.

The hydraulic efficiency of this type of concrete inlet is dependent on the geometry of the end-section to be used. Where the full contraction to the culvert diameter takes place at the first pipe section, the entrance coefficient, K_e, is equal to 0.5, and where the full contraction to the culvert diameter takes place in the throat of the end-section, the entrance coefficient, K_e, is equal to 0.25.

6.5.5.3.3 Mitered Inlets. The use of mitered inlets is predominantly with corrugated metal pipe and its hydraulic efficiency is dependent on the construction procedure used. If the embankment is not paved, the entrance, in practice, usually does not conform to the side slopes, giving a projecting entrance with K_e = 0.9. If the embankment is paved, a sloping headwall is obtained with K_e = 0.60 and, by beveling the edges, K_e = 0.50.

Uplift is an important factor for a mitered inlet. It is not good practice to use unpaved embankment slopes where a mitered entrance may be submerged to an elevation one-half the diameter of the culvert above the top of the pipe.

6.5.5.3.4 Long Conduit Inlets. Inlets are important in the design of culverts for road crossings and other short sections of conduit; however, they are even more significant in the economical design of long culverts and pipes. Unused capacity in a long conduit will result in wasted investment. Long conduits are costly and require detailed engineering, planning, and design work. The inlets to such conduits are extremely important to the functioning of the conduit and must receive special attention. Most long conduits require special inlet considerations to meet the particular hydraulic characteristics of the conduit. Generally, on larger conduits, hydraulic model testing will result in better and less costly inlet construction.

6.5.5.4 Improved Inlets. Inlet edge configuration is one of the prime factors influencing the performance of a culvert operating under inlet control. Inlet edges can cause a severe contraction of the flow, as in the case of a thin edge, projecting inlet. In a flow contraction, the effective cross-sectional area of the barrel may be reduced to about one-half of the actual barrel cross-sectional area. As the inlet configuration is improved, the flow contraction is reduced, thus improving the performance of the culvert.

A tapered inlet is a flared culvert inlet with an enlarged face section and a hydraulically efficient throat section. Tapered inlets improve culvert performance by providing a more efficient control section (the throat). However, tapered inlets are not recommended for use on culverts flowing under outlet control because the simple beveled edge is of equal benefit. The two most common improved inlets are the side-tapered inlet and the slope-tapered inlet. FHWA (2005a) *Hydraulic Design of Highway Culverts* provides guidance on the design of improved inlets.

6.5.5.5 Inlet Protection. Inlets on culverts, especially on culverts to be installed in live streams, should be evaluated relative to debris control and buoyancy.

6.5.5.5.1 Debris Control. Accumulation of debris at a culvert inlet can result in the culvert not performing as designed. The consequences may be damage caused by inundation of the road and upstream property. The designer has three general options for addressing the problem of debris plugging a culvert:

- Retain the debris upstream of the culvert.
- Attempt to pass the debris through the culvert.
- Install a bridge to allow passage of debris past the embankment.

If the debris is to be retained by an upstream structure or at the culvert inlet, frequent maintenance may be required. The design of a debris control structure should include a thorough study of the debris problem and should consider the following factors:

- Type of debris
- Quantity of debris
- Expected changes in type and quantity of debris due to future land utilization.
- Stream flow velocity in the vicinity of culvert entrance
- Maintenance access requirements
- Availability of storage
- Maintenance plan for debris removal

Hydraulic Engineering Circular No. 9, *Debris Control Structures Evaluation and Countermeasures* (FHWA 2005b) should be used when designing debris control structures.

6.5.5.5.2 Buoyancy. The forces acting on a culvert inlet during flows are variable and indeterminate. When a culvert is functioning under inlet control, an air pocket forms just inside the inlet, which creates a buoyant effect when the inlet is submerged. The buoyancy forces increase with an increase in headwater depth under inlet control conditions. These forces, along with vortexes and eddy currents, can cause scour, undermine culvert inlets, and erode embankment slopes, thereby making the inlet vulnerable to failure, especially if deep headwater conditions are present.

In general, installing a culvert in a natural stream channel constricts the normal flow. The constriction is accentuated when the capacity of the culvert is impaired by debris or damage.

The large unequal pressures resulting from inlet constriction are, in effect, buoyant forces that can cause entrance failures, particularly on corrugated metal pipe with mitered, skewed, or projecting ends. The failure potential will increase with steepness of the culvert slope, depth of the potential headwater, flatness of the fill slope over the upstream end of the culvert, and the depth of the fill over the pipe.

Anchorage at the culvert entrance helps to protect against these failures by increasing the deadload on the end of the culvert, protecting against bending damage, and by protecting the fill slope from the scouring action of the flow. Providing a standard concrete headwall or end-wall helps to counteract the hydrostatic uplift and to prevent failure due to buoyancy.

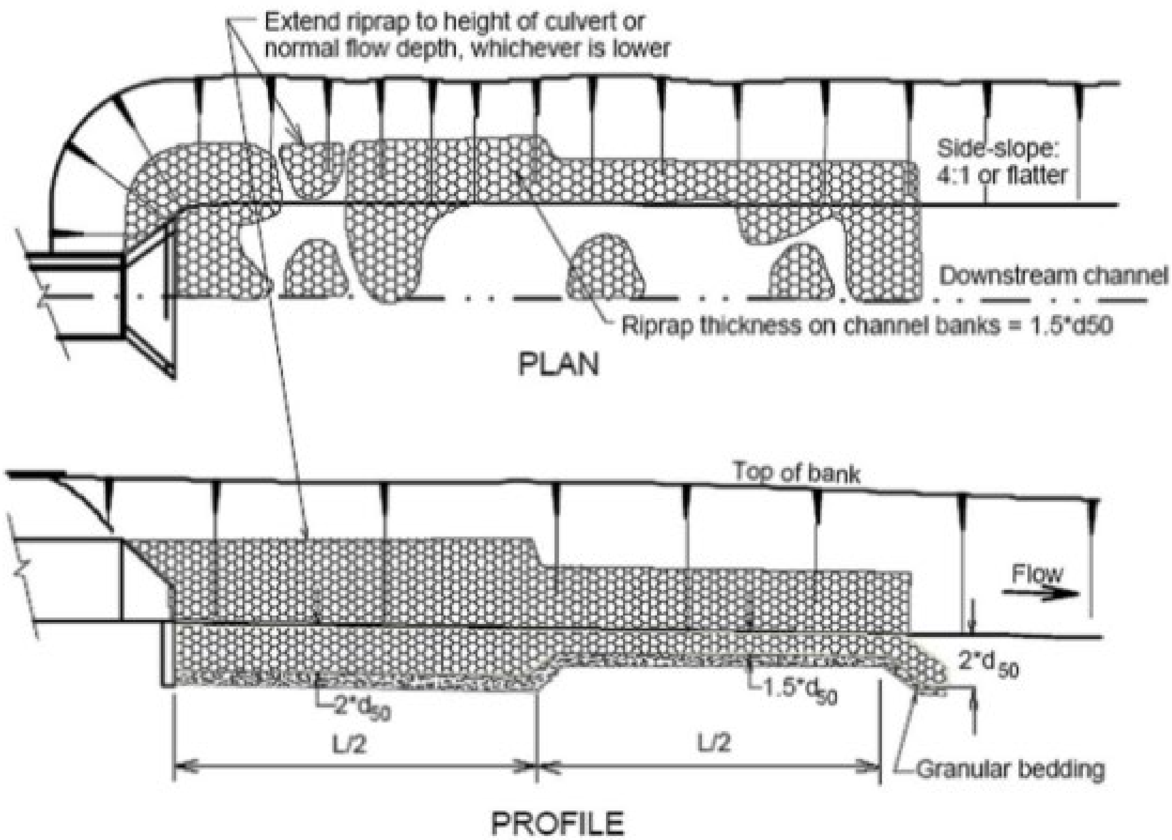
Because of a combination of high head on the outside of the inlet and the large region of low

pressure on the inside of the inlet due to separation, a large bending moment is exerted on the end of the culvert, which may result in failure. This problem has been noted in the case of culverts under high fills, on steep slopes, and with projecting inlets. In cases where upstream detention storage is necessary and headwater depth in excess of twenty feet (20’) is required to restrict discharge, it is recommended to reduce the culvert size rather than use an inefficient projecting inlet.

6.5.6 Protection Downstream of Culverts. In this section, two categories of erosion protection methods are addressed for the area downstream of culverts: riprap erosion protection at locations downstream of culvert outlets that are in-line with major drainage channels and energy dissipation structures.

6.5.6.1 In-Line Riprap Protection. Scour resulting from highly turbulent, rapidly decelerating flow is a common problem at conduit outlets. The riprap protection suggested below is for outlets from conduits and culverts with outlet Froude numbers up to 2.5.

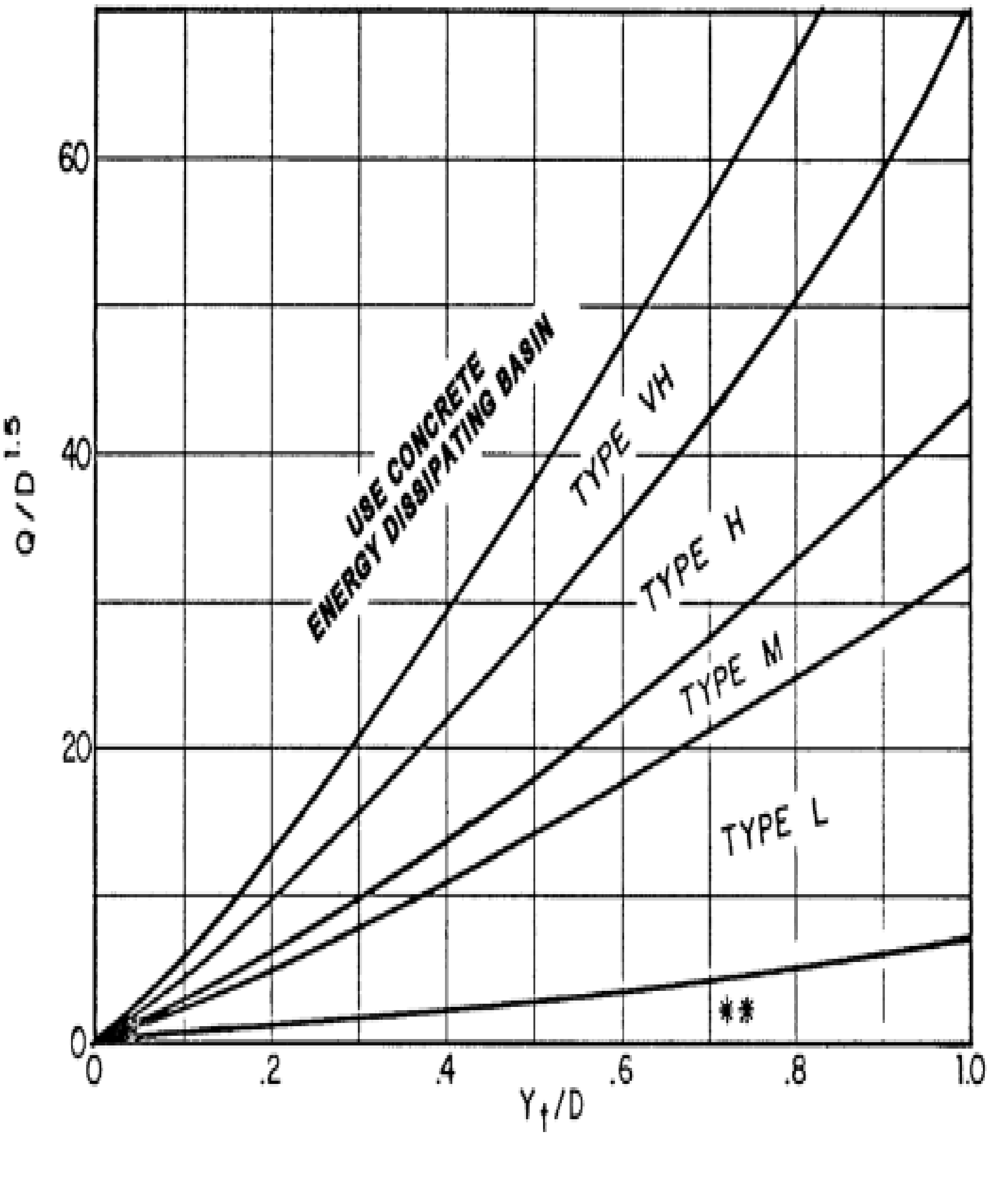
6.5.6.1.1 Configuration of Riprap Protection. The figure below illustrates typical riprap protection at the outlets of culverts and major drainageway conduits. The additional thickness of the riprap just downstream from the outlet is to assure protection from flow conditions that might precipitate rock movement in this region.



NOTES: 1. Headwall with wingwalls or flared end section required at all culvert outlets.
2. Cutoff wall required at end of wingwall aprons and end section. Minimum depth of cutoff wall = 2*d50 or 3-feet, whichever is deeper.
3. Provide joint fasteners for flared end sections.

6.5.6.1.2 Required Rock Size. The required rock size for erosion protection downstream from culvert outlets is selected depending on whether the culvert is circular or rectangular.

6.5.6.1.2.1 Circular Culvert Outlets. For circular culvert outlets, refer to the figure below for sizing of rock erosion protection downstream from circular culverts.



Use D_a instead of D whenever flow is supercritical in the barrel.
** Use Type L for a distance of 3D downstream.

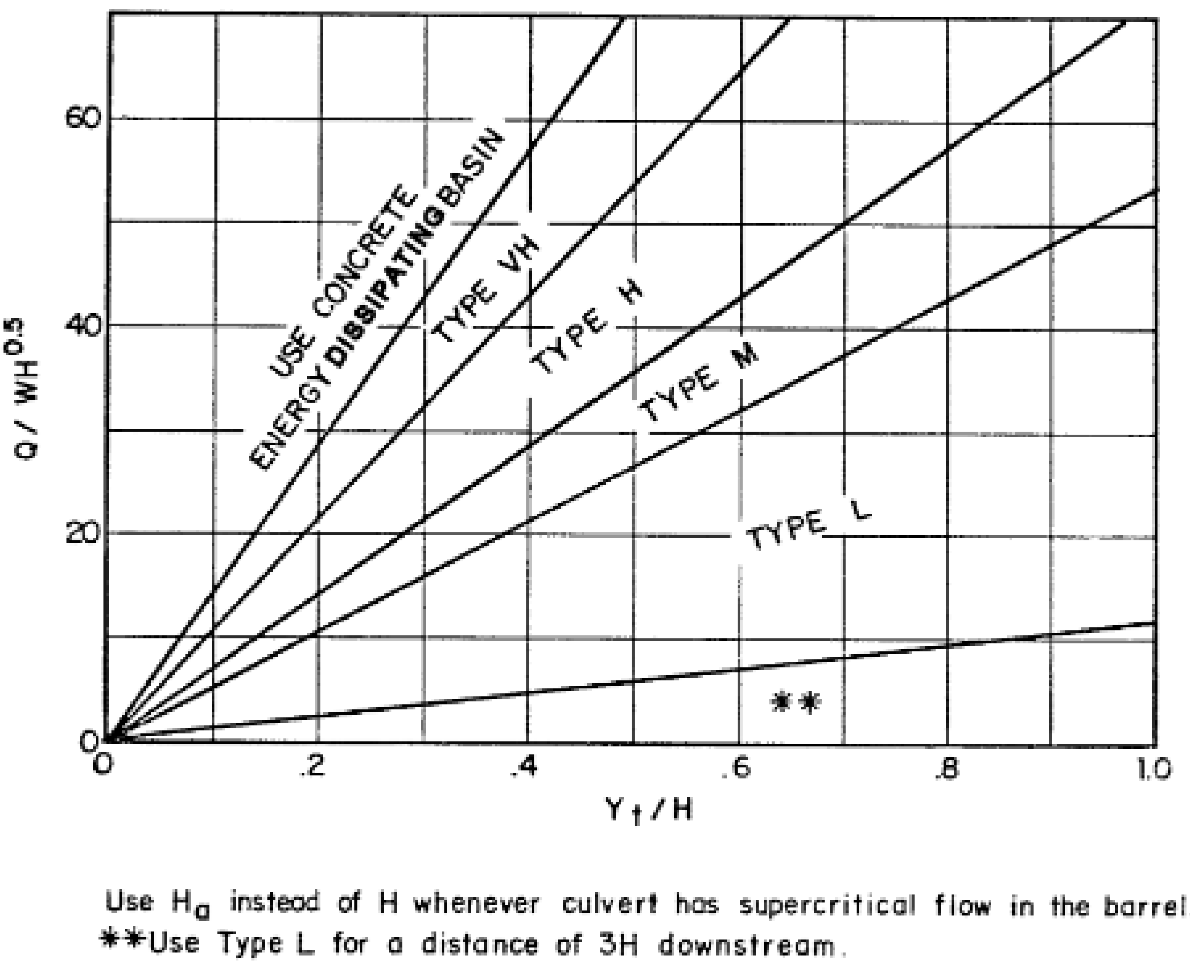
Circular culvert outlets figure parameters:

- Q = design discharge (cfs)
- D_c = diameter of circular culvert (ft)
- Y_t = tailwater depth (ft)

Circular culvert outlets figure notes:

- Valid for Froude parameter for circular culvert ($Q/D_c^{2.5}$) = 6 or less.
- In cases where Y_t is unknown or a hydraulic jump is suspected downstream of the outlet, use Y_t/D_c = 0.40.
- The rock size requirements shown on the figure above were determined assuming that the flow in the circular culvert is not supercritical. In cases where the flow is supercritical, calculate D_a using the equation below and substitute D_a for D_c:
    - $D_a = \frac{D_c+Y_n}{2}$, where
        - the maximum value of D_a shall not exceed D_c.
        - D_a = parameter to use in place of D_c when flow is supercritical
        - D_c = diameter of circular culvert (ft)
        - Y_n = normal depth of supercritical flow in the culvert

6.5.6.1.2.2 Rectangular Culvert Outlets. For rectangular culvert outlets, refer to the figure below for sizing of rock erosion protection downstream from circular culverts.



Rectangular culvert outlets figure parameters:

- Q = design discharge (cfs)
- W = width of rectangular conduit (ft)
- H = height of rectangular conduit (ft)

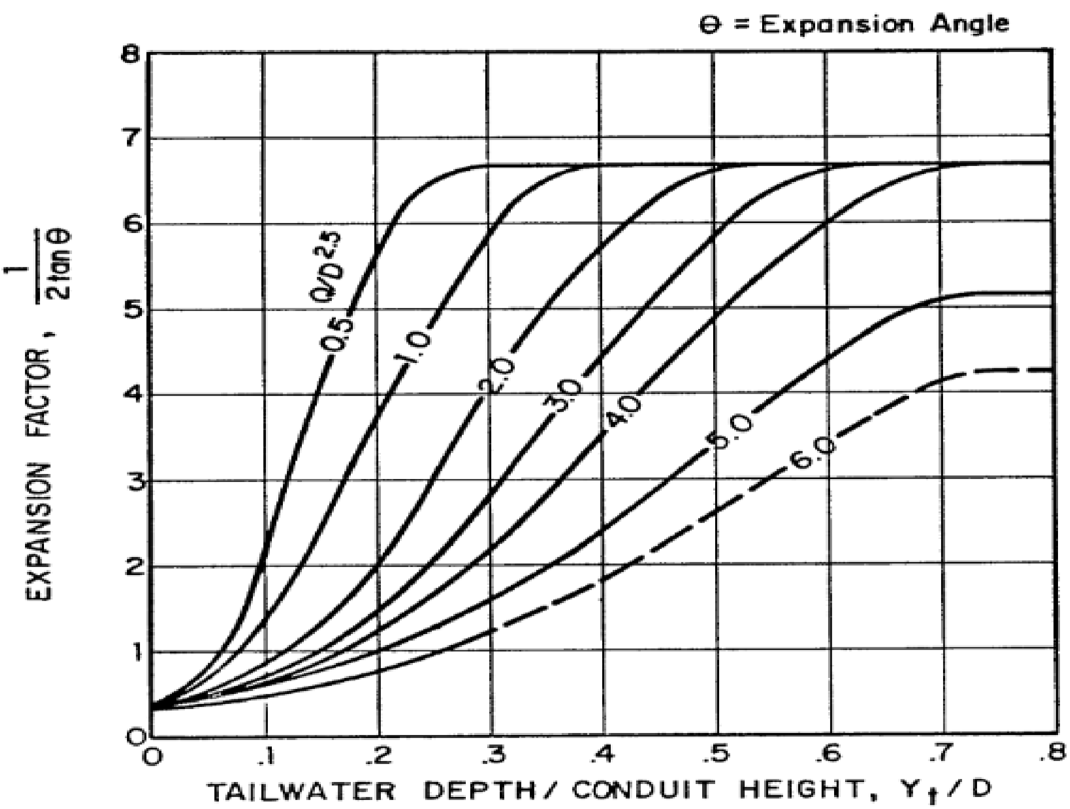
Rectangular culvert outlets figure notes:

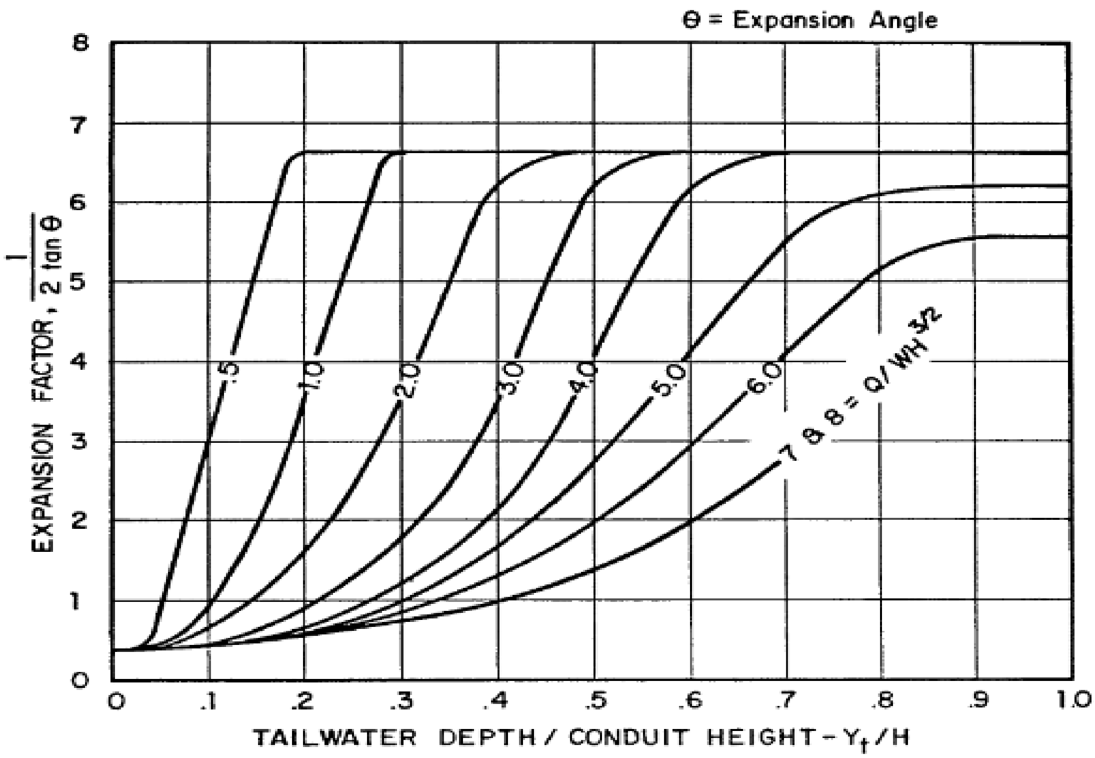
- Valid for Froude parameter for rectangular culvert ($Q/WH^{1.5}$) = 8.0 or less.
- In cases where Y_t is unknown or a hydraulic jump is suspected downstream of the outlet, use Y_t/H = 0.40.
- The rock size requirements shown on the figure above were determined assuming that the flow in the rectangular culvert is not supercritical. In cases where the flow is supercritical, calculate H_a using the equation below and substitute H_a for H:

- $H_a = \frac{H+Y_n}{2}$, where
  - the maximum value of H_a shall not exceed H
  - H_a = parameter to use in place of H when flow is supercritical
  - H = height of rectangular culvert (ft)
  - Y_n = normal depth of supercritical flow in the culvert

6.5.6.1.3 Extent of Protection. The length of the riprap protection downstream from the outlet depends on the degree of protection desired. If it is necessary to prevent all erosion, the riprap must be continued until the velocity has been reduced to an acceptable value.

The rate at which the velocity of a jet from a conduit outlet decreases once it has exited the culvert is not well known. For the procedure recommended here, it is assumed to be related to the angle of lateral expansion, θ, of the jet. The velocity is related to the expansion factor, (1/(2tanθ)), which can be determined directly using the two figures below (the first is for circular conduits and the second is for rectangular conduits), assuming that the expanding jet has a rectangular shape:





$$L_p = \left(\frac{1}{2tan\theta}\right)\left(\frac{A_t}{Y_t} - W\right) \text{ and } A_t = \frac{Q}{V}\text{, where}$$

L_p = length of protection (ft)

W = width of the conduit in (ft) (use diameter for circular conduits)

Y_t = tailwater depth (ft)

θ = the expansion angle of the culvert flow

Q = design discharge (cfs)

V = the allowable non-eroding velocity in the downstream channel (ft/sec)

A_t = required area of flow at allowable velocity (ft^2)

In certain circumstances, the culvert outlet equations may yield unreasonable results. Therefore, specific requirements for parameter values are described below:

- Circular Culverts
  - L_p should not be less than 3 D_c.
  - L_p should not be greater than 10 D_c whenever the Froude parameter ($Q/D_c^{2.5}$) is less than 6.0.
  - If the Froude parameter is greater than 6.0, increase the maximum L_p required by ¼ D_c for each whole number by which the Froude parameter is greater than 6.0.

- Rectangular Culverts
  - L_p should not be less than 3H
  - L_p should not be greater than 10H whenever the Froude parameter ($Q/WH^{1.5}$) is less than 8.0.
  - If the Froude parameter is greater than 8.0, increase the maximum L_p required by ¼ H for each whole number by which the Froude parameter is greater than 8.0.

6.5.6.1.4 Multiple Conduit Installations. The procedures outlined in Sections 6.5.6.1.1, 6.5.6.1.2, and 6.5.6.1.3 can be used to design outlet erosion protection for multi-barrel culvert installations by hypothetically replacing the multiple barrels with a single hydraulically equivalent rectangular conduit. The dimensions of the equivalent conduit may be established as follows:

- Distribute the total discharge, Q, among the individual conduits. Where all the conduits are hydraulically similar and identically situated, the flow can be assumed to be equally distributed; otherwise, the flow through each barrel must be computed.
- For all the culverts, compute the Froude parameter $Q_i/D_{ci}^{2.5}$ (circular conduit) or $Q_i/W_iH_i^{1.5}$ (rectangular conduit), where the subscript i indicates the discharge and dimensions associated with an individual conduit.
- If the installation includes dissimilar conduits, select the individual conduit with the largest value of the Froude parameter to determine the dimensions of the equivalent conduit.
- Make the height of the equivalent conduit, H_{eq}, equal to the height, or diameter, of the selected individual conduit.
- The width of the equivalent conduit, W_{eq}, is determined by equating the Froude parameter from the selected individual conduit with the Froude parameter associated with the equivalent conduit, (e.g., $Q/W_iH_{eq}^{1.5}$ is Froude parameter for equivalent rectangular conduit).

6.5.6.2 Energy Dissipation Structures. Rock protection downstream of conduit and culvert outlets is appropriate where moderate outlet conditions exist. However, in cases where high exit velocities or turbulence at culvert outlets will occur, the outlet structure must be designed to match the receiving stream conditions. Energy dissipation or stilling basin structures can provide a high degree of energy dissipation and are generally effective even with relatively low tailwater control. An energy dissipation structure should be considered if any of the following situations exist:

- High-energy dissipation efficiency is required, or where hydraulic conditions approach or exceed the limits for alternate designs.
- Low tailwater control is anticipated.
- Site conditions dictate use of an energy dissipation structure, such as public use areas, where plunge pools and standing water are unacceptable because of safety and appearance, or at locations where space limitations direct the use of a concrete structure.

Types of energy dissipation structures addressed in this section include impact stilling basins, pipe outlets to baffles chutes, and low tailwater basins.

Longer conduits with large cross-sectional areas are designed for significant discharges and often with high velocities requiring special hydraulic design at their outlets. Here, dam outlet and spillway terminal structure technology is appropriate (USBR 1987). Type II, III, or IV stilling basins, submerged buckets with plunge basin energy dissipators and slotted-grating dissipators can be considered when appropriate to the site conditions. For instance, a plunge basin may have applicability where discharge is to a wet detention pond or a lake.

6.5.7 Large Conduits and Bridges. The design criteria described above are for culverts that will be routinely designed in the City of Battlefield. For other applications, such as large circular or large rectangular culverts or bridge hydraulics, the reader is directed to the following references:

6.5.7.1 Large Circular Culverts or Large Rectangular Culverts.

- Open Channel Hydraulics (Chow 1959). This is a classic reference that is applicable since large culverts frequently function hydraulically as open channels.
- Federal Highway Administration *Hydraulic Design of Highway Culverts*, Hydraulic Design Series No. 5 (FHWA 2005a). This is the same standard reference used for the hydraulic design of smaller culverts.

6.5.7.2 Bridges.

- *Hydraulics of Bridge Waterways Hydraulic* Design Series No. 1(FHWA 1978). This is a good basic reference.
- *Design Manual for Engineering Analysis of Fluvial Systems for the Arizona Department of Water Resources* (SLA 1985). This is a prime reference on hydraulics and the three-level sediment transport analysis, with examples.
- American Association of State Highway and Transportation Officials, *Highway Drainage Guidelines* (AASHTO 2007). Chapter 7 of this document, the *Hydraulic Analysis for the Location and Design of Bridges*, provides a good overview of this topic.
- *Technical Advisory on Scour at Bridges* (FHWA 1988). This presents information similar to bridge hydraulics references 2 and 3 above, but in a workbook format, but in a simplified format.

6.6 OPEN CHANNELS

6.6.1 Overview. Natural and engineered open drainage channels are generally the primary component of the modern major conveyance system. The use of open systems and their integration into the existing topography is strongly preferred to the use of closed or lined systems, and early planning is necessary to accomplish this objective. When present, natural channels are the preferred system for managing stormwater. In areas of new development and infrastructure improvements, a channel is regarded as natural if it has the capacity to adjust either its bed or banks in response to changes in flow or sediment load. In areas being redeveloped, streams that have been previously disturbed are considered natural if they possess a free boundary capable of adjusting to changes in flow. Often, hydromodification in the watershed necessitates an engineered naturalized channel where contact with soil and vegetation occurs but the ability of the stream to meander is limited.

6.6.1.1 General. Except for roadside ditches and swales, open channels are nearly always a component of the major (emergency) drainage system. There are a number of factors which must be considered in determining whether to specify an open drainageway as opposed to an underground storm drain: material and installation cost, maintenance costs and problems, acceptability to the developer or home buyer, public safety, appearance, etc. Effective planning and design of open drainageways can significantly reduce the cost of storm drainage facilities, while enhancing the quality of the development.

In planning a subdivision, the designer should begin by determining the location and the width of existing drainageways. Streets and lots should be laid out in a manner to preserve the existing drainage system to the greatest degree practical. In addition to reducing the cost of the drainage system, sediment and erosion control costs will also be reduced. Constructed channels should be used only when it is not practical or feasible to utilize existing drainageways.

6.6.1.2 Definitions.

Critical depth, d_c - the depth of flow at which the specific energy is a minimum for a given flow rate and channel cross shape, and a unique relationship exists between depth and specific energy.

Normal depth, d_n - the depth at which uniform flow occurs when the discharge rate is constant. Friction and gravity forces are in balance.

Subcritical flow - lower energy, lower velocity flow, which occurs when the normal depth is greater than the critical depth. Subcritical flow is controlled by downstream conditions.

Supercritical flow - high energy, high velocity flow, which occurs when the normal depth is less than the critical depth. Supercritical flow is controlled by upstream conditions.

Froude number, $F_r = \frac{V}{\sqrt{gD}}$, where

D = hydraulic depth (feet) = A/T
A = cross sectional area of design flow (square feet)
V = average channel velocity (feet/second)
g = acceleration due to gravity (32.2 ft/s^2)
T = top width of flow (feet)

For supercritical flow, Fr > 1

For subcritical flow, Fr < 1
For critical flow, Fr = 1

Specific energy, E - the energy per unit weight of fluid, $E = d + \frac{V^2}{2g}$, where
E = specific energy in feet
V = average channel velocity (feet/second)
g = acceleration due to gravity (32.2 ft/s^2)
d = depth of flow in feet

Specific force, F_m - the sum of forces due to velocity plus hydrostatic pressure per unit weight of fluid, $F_m = \frac{Q^2}{gA} + A\bar{y}$, where
Fm = specific force in cubic feet
$\bar{y}$ = depth to center of gravity of the cross section in ft
Q = rate of flow in cubic feet per second
A = cross sectional area of flow in square feet

Conjugate depth (also known as alternate depth) – the corresponding subcritical or supercritical depth having the same value of specific energy or specific force.

6.6.1.3 Open Systems Requirements. One of the principles of sound urban stormwater management is the practice of preserving floodplains and natural channels associated with major waterways. In situations where it is not feasible to utilize the natural system of channels and floodplains, it is preferable for engineered systems to be open and vegetated where possible, rather than enclosed or concrete lined. When planning for open channels to serve a development, many important factors must be considered, such as:

- Public safety.
- Permitting.
- Cost, including capital expenses, operations, maintenance, and replacement.
- Right-of-way, access, and existing utilities.
- Protection of existing natural channels and their riparian corridors.
- The engineered channel and drainage easement for the design storm under full watershed development conditions and maximum potential peak flow.
- Sediment budgets, including conditions with upstream construction activity and providing for sediment transport competency.
- Watershed or development master plans.
- Existing or anticipated stream instabilities or meandering, particularly at the interface between natural and engineered channels.
- Appearance.
- Integration into community, including impact on property values.

6.6.1.4 Submittal Requirements. Open channel plan submittals must include detailed drawings, background calculations, and supporting information, including:

- Detailed plan and profile at the appropriate scale (profile shall include flow line and the top of each bank or channel wall).
- Water surface profiles (25- and 100-year).
- All design flow rates and velocities.
- Channel lining details, including seed and plant selection for vegetated channels.
- Buffer delineation.
- For natural channels, the completed geomorphic exhibit and channel stability matrix.
- Evidence that relevant permits have been obtained and associated requirements have been met.

6.6.1.5 Maintenance. All major drainageways and open channels shall be designed to allow regular maintenance. The designer shall consider access requirements for equipment necessary to maintain or replace walls, boulders, concrete mats, gabions, turf reinforcement mats (TRMs), etc. The responsible party must be financially and technically capable of providing long-term maintenance of facilities, including those that utilize concrete, grass, or other bioengineered configurations.

6.6.1.6 Safety. Public safety shall be the paramount consideration when designing open channel systems. Representative issues that must be considered include channel configurations that limit the risk of a fall into the channel and channel hydraulic designs that minimize the risk of hazardous conditions, such as high velocities and “reverse rollers” that can entrap a person downstream from a low head dam. All vertical walls greater than three feet (3’) in height shall have a safety fence or handrail if the wall is located where the public may be in close proximity. Warning signs may be necessary in areas with high risk. Channels that do not have vertical walls should be designed with side slopes of 3H:1V or flatter to allow for safe exit from the channel. In cases where this is not feasible, riprap slopes may have a slope of 2H:1V. All slopes that are to be maintained by motorized mowers shall be graded to 3H:1V or flatter. Slopes of 4H:1V or flatter are preferred for safety and aesthetic reasons.

6.6.2 Types of Flow. Open channel flow is commonly characterized according to variability with respect to time and space using the following terms:

- Steady flow – conditions at any point in a stream remain constant with respect to time (Daugherty and Franzini 1977).
- Unsteady flow – flow conditions (e.g., depth) vary with time.
- Uniform flow – the magnitude and direction of velocity in a stream are the same at all points in the stream at a given time (Daugherty and Franzini 1977). If a channel is uniform and resistance and gravity forces are in exact balance, the water surface will be parallel to the bottom of the channel for uniform flow.
- Varied flow – discharge, depth, or other characteristics of the flow change along the course of the stream. For a steady flow condition, flow is termed rapidly varied if these

characteristics change over a short distance. If characteristics change over a longer stretch of the channel for steady flow conditions, flow is termed gradually varied.

For the purposes of open channel design, flow is usually considered steady and uniform. For a channel with a given roughness, discharge, and slope, there is only one possible depth for maintaining a uniform flow. This depth is the normal depth. When roughness, depth, and slope are known at a channel section, there can only be one discharge for maintaining a uniform flow through this section. This discharge is the normal discharge.

6.6.2.1 Uniform Flow. Open channels having a design flow rate less than five hundred (500) cfs may be designed assuming uniform flow conditions in conjunction with computed headwater depths at culverts and other hydraulic structures or reservoir stages at detention and sediment basins. Water surface profiles using techniques for gradually varied flow may be required for design flow rates less than five hundred (500) cfs where accurate determination flooding depths is necessary to ensure flood safety.

Under steady state, uniform flow conditions channel capacity shall be computed using Manning's Equation:

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}, \text{ where}$$

Q = rate of flow, cubic feet per second
n = Manning's roughness coefficient
A = cross sectional area of flow, square feet
P = wetted perimeter, feet
R = hydraulic radius = A/P, feet
S = S_f = friction slope

Computations for all channels designed for uniform flow conditions shall indicate whether flow is subcritical, critical, or supercritical. It is preferred that channels be designed for subcritical flow conditions. Critical flow ($0.9 < Fr < 1.2$) should be avoided since flow is unstable. Where channels must be designed for supercritical flow and the Froude number is greater than two point five (2.5), the conjugate depth for specific force must be determined. Freeboard up to the conjugate depth may be required if necessary to provide adequate flood protection.

6.6.2.2 Mannings's Roughness Coefficient. When applying Manning's equation, the choice of the Manning's roughness coefficient, n, is the most subjective parameter. The minimum roughness coefficient shall be used for channel design to check for sufficient channel lining stability (velocity check) and the maximum roughness coefficient shall be used to check for hydraulic capacity and to check the minimum velocity to prevent the occurrence of standing water (flow rate check). Average roughness coefficient values shall be used for broader applications such as watershed modeling.

Average Roughness Coefficients

Channel Lining	Minimum	Average	Maximum
Earthen	0.020	0.025	0.300
Mowed grass	0.025	0.030	0.035
Grass - not mowed	0.030	0.035	0.040
Grass with brush/trees	0.040	0.050	0.060
Cobble bottom, grass/root side	0.030	0.040	0.050
Concrete - smooth	0.012	0.013	0.015
Concrete - rough	0.015	0.017	0.020
Riprap d_{50} 6 inches	0.032	0.035	0.038
Riprap d_{50} 9 inches	0.035	0.038	0.040
Riprap d_{50} 12 inches	0.380	0.040	0.042
Riprap d_{50} 18 inches	0.040	0.042	0.044
Riprap d_{50} 24 inches	0.042	0.044	0.047
Grouted boulders	0.025	0.032	0.400

6.6.2.1.2 Froude Number and Flow Regime. Another important characteristic of open channel flow is the state of the flow, often referred to as the flow regime. Flow regime is determined by the balance of the effects of viscosity and gravity relative to the inertia of the flow. The Froude number, F_r, is a dimensionless number that is the ratio of inertial forces to gravitational forces that defines the flow regime. Flow regimes are characterized as critical, subcritical, or supercritical, based on the Froude Number (equation listed above in 6.6.1.2).

6.6.2.1.2.1 Critical Flow. Critical flow is defined as flow with $F_r = 1.0$. Flows with F_r near 1.0 are considered unstable and are likely to tend toward phenomena such as hydraulic jumps and standing waves, which are both highly turbulent and lead to a higher risk of erosion or structural failure. Designs that result in F_r near 1.0 (> 0.8 and < 1.2) shall be avoided by adjusting the design of the cross-section, roughness, and slope.

Critical velocity, V_c, can be calculated from the critical hydraulic depth, d_c. For a rectangular channel, the critical flow depth is equal to the critical hydraulic depth ($y_c = d_c$), and the critical flow velocity is:

$$V_c = \sqrt{g y_c} \text{ , where}$$

V_c = critical velocity (ft/s)
g = acceleration of gravity = 32.2 ft/s^2
y_c = critical flow depth

6.6.2.1.2.2 Subcritical Flow. Subcritical flow is defined as flow with $F_r < 1.0$. These flows have the following characteristics relative to critical flows:

- Flow velocity is lower.
- Flow depth is greater.
- Hydraulic losses are lower.
- Erosive power is less.
- Behavior is easily described by relatively simple mathematical equations.
- Surface waves can propagate upstream.

Most stable natural channels have subcritical flow regimes. Consistent with the philosophy that the most successful artificial channels utilize characteristics of stable natural channels, major drainage design shall seek to create channels with subcritical flow regimes.

6.6.2.1.2.3 Supercritical Flow. Supercritical flow is defined as flow with $F_r > 1.0$. Supercritical flows shall be avoided wherever possible and have the following characteristics relative to critical flows:

- Flow velocity is higher.
- Flow depth is less.
- Hydraulic losses are higher.
- Erosive power is greater.
- Surface waves propagate downstream only.

In cases where supercritical flow cannot be avoided, concrete linings shall be utilized. The channel must be designed to safely dissipate energy so that the discharge to the downstream reach is in a non-erosive, sub-critical condition.

6.6.2.2 Gradually Varied Flow. Open channels having a design flow rate of five hundred (500) cfs or more and which are not relatively long with a uniform cross section, shall be designed for gradually varied flow. Manual computations shall be done using the Direct Step Method or Standard Step Method. Water surface profiles can be computed using the Corps of Engineers HEC-RAS Water Surface Profiles program or the Federal Highway Administration WSPRO program.

6.6.2.3 Rapidly Varied Flow. Rapidly varied flow conditions shall be avoided when possible. Where drop structures are required for grass lined or composite channels, the location of the hydraulic jump and the length of erosion protection to be provided shall be determined.

Check dams and other special hydraulic structures shall be designed as set forth in the ASCE Design Manual.

6.6.3 Channels.

6.6.3.1 Natural Channels.

6.6.3.1.1 Perennial Streams and Losing Streams. The stream channel of perennially flowing streams or intermittent streams classified as losing streams in the Missouri Clean Water Laws shall not be modified or channelized except where unavoidable to construct road crossings or to repair erosion and stabilize the stream channel.

Trees and vegetation shall not be removed within twenty-five feet (25') of the stream bank. Clearing of brush and undergrowth shall be minimal. It is preferred that existing vegetation remain within one hundred feet (100') of the stream bank. A typical natural channel cross section is shown in Figure SS-23.

Work within the stream channel may require a US Army Corp of Engineers (USACE) Department section404 permit.

6.6.3.1.2 Tributary Watercourses. Intermittent streams which have a defined channel should not be modified or channelized except where unavoidable for road crossings or to repair erosion and stabilize the stream channel. No clearing is permitted within twenty-five feet (25') of the stream bank except to remove underbrush and fallen timber.

Natural watercourses in which flow is broad and shallow, and which have no defined channel should not be modified or channelized. Removal of trees and vegetation within the watercourse should be avoided as much as practical.

6.6.3.1.3 Determining Flooding Limits for Watercourses. The area inundated by the peak flow from the 100-year (1% AEP) storm is considered to be the flooding area for any watercourse. An implicit drainage easement is considered to exist along the area inundated by the peak flow from the 1% AEP (100-year) storm.

For the purpose of preliminary planning and design, the approximate limits of the floodplain can be determined using approximate methods. In determining the capacity and depth of flow in natural watercourses, they shall be analyzed by selecting the most restrictive channel section for each reach and determining the normal depth by analyzing the channel as an irregular section using representative "n" values for each segment of the channel cross-section.

6.6.3.1.4 Development Guidelines. Where the width of the existing drainageway cannot accommodate the needs of the development, the fringe areas of the drainageway can be filled, and tributary watercourses may be channelized within the limitations described above. The combination of filling and channeling shall not increase the estimated high-water elevation for the 100-year (1% AEP) peak flow rate by more than one foot (1') over pre-project conditions at the upstream boundary or any point upstream of the site. Where the effects of increased frequency of flow or increased velocity may significantly affect the stability or the stream channel, measures such as grade checks, check dams or bank stabilization may be required.

6.6.3.2 Grass Channels. Grass lined channels shall have a minimum slope of 1% (one percent). The bottom slope may be decreased to 0.5% (five-tenths percent) if a concrete trickle channel is provided. In order to establish growth in the channel bottom, the bottom twelve inches (12") of the channel depth shall be lined with sod, or suitable erosion control blanket. A typical grass channel cross section is showing in Figure SS-24.

Manning's roughness coefficient ("n", also known as the retardance coefficient) for grass channels shall be determined based upon the product of the velocity and the hydraulic radius (V x R) using the chart shown in Figure SS-25. Retardance curve "C" shall be used in determining channel capacity. Retardance curve "D" shall be used in determining velocity.

6.6.3.3 Low Flow (Trickle) Channels. Trickle channels shall be provided in constructed grass channels (not natural channels) where base flow or perennial flow prevents the establishment or re-establishment of a sod bottom. A low-flow channel may be necessary under these conditions:

- Vegetated channels where:
  - Baseflow exists.
  - High peak runoff from developed areas may cause erosion of vegetated areas.
  - 1-year flow exceeds 5 cfs (for unreinforced grass only).
- All types of channel linings in locations where erosion could potentially occur, such as downstream of point discharges.

If conditions warrant a low-flow channel, the low-flow channel shall be designed to convey the 1-year flow under fully developed watershed conditions. Variations from this design must be justified by the hydrologic characteristics of the site.

Low-flow channel requirements vary by channel type, as listed below:

- In naturalized channels, low-flow channels typically are unlined. Depending on the projected stresses, riffle areas may require some reinforcement.
- In engineered grass-lined channels, riprap, boulders, or a soil-riprap mix for the low-flow channel lining can provide a stable, vegetated low-flow channel. Soil and riprap should be mixed prior to placement for these low-flow channels. Vegetated portions of the channel can remain dry and easy to mow and maintain.
- In engineered channels that are not grass-lined, low-flow channels may consist of riprap, boulders, or concrete, depending on site conditions.

Types of trickle channels are as follows:

6.6.3.3.1 Concrete Trickle Channels. A standard concrete Trickle Channel cross section is show in Figures SS-26 and SS-27. Trickle channel capacity shall be approximately five percent (5%) of the design flow rate. Concrete trickle channels may be unreinforced up to a total width of five feet (5'). For total widths of five feet (5') to ten feet (10'), the trickle channel shall be reinforced with 6 X 6-10-10 welded wire mesh. For widths greater than ten feet (10'), see requirements for concrete channels. Trickle channel alignment shall be the same as the overall channel alignment. Radii at changes in direction shall be the minimum radius required based upon the channel top width. Capacity of grass channels with trickle channels may be determined as a composite cross-section, or the additional capacity of the trickle channel can be ignored. Erosion potential at the grass/concrete interface should be checked. Shear stress or tractive force shall be determined as follows and shall be limited to the maximum values set forth below:

Shear force, $\tau = \lambda ds$, where

τ = unit shear stress (pounds per square foot)
λ = unit weight of water = 62.4 pounds per cf
s = channel slope (feet per foot)
d = distance from the water surface to the channel lining at the point of interest (feet)

Critical Sheer Stress

Granular Material	Critical Sheer Stress (τC) (pounds per square foot)
Boulders (100 cm) (39 in)	20.295
Boulders (75 cm) (30 in)	15.222
Boulders (50 cm) (20 in)	10.148
Boulders (25.6 cm) (11 in)	5.196
Riprap (6-8 in)	3.132
Cobbles (6.4 cm) (2.5 in)	1.299
Cobbles and shingles	1.100
Cobbles and shingles, clear water	0.910
Coarse sand (1 mm) (0.4 in)	0.015
Coarse gravel, noncolloidal (GW), clear water	0.300
Coarse gravel, noncolloidal (GW)	0.670
Gravel (2 cm) (0.78 in)	0.406
Fine gravel	0.320
Fine gravel, clear water	0.075
Fine sand (0.125 mm) (0.005 in)	0.002
Fine sand (0.125 mm) (SP)(0.005 in)	0.002
Fine sand (SW), (SP), colloidal	0.075
Fine sand, colloidal, (SW), (SP), clear water	0.027
Graded loam to cobbles, noncolloidal (GM)	0.660
Graded loam to cobbles, noncolloidal (GM), clear water	0.380
Graded silts to cobbles, colloidal (GC)	0.800

Graded silts to cobbles, colloidal (GC), clear water	0.430
Fine-Grained Material	**Critical Sheer Stress (τC) (pounds per square foot)**
Resistant cohesive (CL), (CH)	1.044
Stiff clay, very colloidal (CL)	0.460
Stiff clay, very colloidal (CL), clear water	0.260
Moderate cohesive (ML-CL)	0.104
Ordinary firm loam (CL-ML)	0.150
Ordinary firm loam (CL-ML), clear water	0.075
Alluvial silts, colloidal (CL-ML)	0.460
Alluvial silts, colloidal (CL-ML), clear water	0.260
Alluvial silts, noncolloidal (ML)	0.150
Alluvial silts, noncolloidal (ML), clear water	0.048
Sandy loam, noncolloidal (ML)	0.075
Sandy loam, noncolloidal (ML), clear water	0.037
Silt loam, noncolloidal (ML)	0.110
Silt loam, noncolloidal (ML), clear water	0.048
Shales and hardpans	0.670
Other Materials	**Critical Sheer Stress (τC) (pounds per square foot)**
Jute net	0.460
Plant cuttings	2.090
Well established dense vegetation to the normal low water	2.160
Geotextile (synthetic)	3.010
Large Woody Debris	3.130

Notes:

For non-cohesive soils, the table values are based on spherical particles and Shields equation (see Equation OC-8)

For cohesive soils, the values are based on limited testing as reported in Chow (1988) and U.S. Department of Agriculture Agricultural Research Service (USDA ARS) (2004).

Material type abbreviations:

Agriculture Agricultural Research Service (USDA ARS) (2004)

Material type abbreviations:

GW - Gravel, well graded	GC = Clayey gravel
SP - Sand, poorly graded	CL - Clay
SW - Sand, well graded	CH - Clay, high plasticity
GM - Silty gravel	ML - Silt

6.6.3.3.2 Other Types of Trickle Channels. Trickle channels of porous pavers, gravel filled Geo-web, submerged flow wetlands, natural stone and other materials can be specified, and are encouraged to improve aesthetics and water quality. However, assurance must be given that quality control will be maintained during construction and that adequate maintenance will be provided after construction. Complete computations and construction specifications must be submitted for alternative types of trickle channel linings.

6.6.3.4 Composite Channels. Many different channel shapes and lining types are possible. Different shapes and lining types can be combined in a composite design. In determining the capacity and depth of flow in composite channels, they shall be analyzed as an irregular section using representative "n" values for each segment of the channel cross-section. Velocity limitations set forth above shall be adhered to for each lining type. Allowable shear stress at the interface between grass or other erodible linings and erosion resistant linings may not exceed the maximum values. A typical section of a channel with a concrete inverts and grass slopes if shown in Figure SS-28.

6.6.3.5 Concrete Channels. Where velocities or slopes cannot be limited to values required for natural, grass, or composite channels due to right-of-way or other constraints, concrete channels may be utilized. Concrete channel shapes will typically be trapezoidal or rectangular. Other shapes may be used but are less efficient.

Crushed rock bedding and pore pressure relief are required whenever the lining height exceeds twelve inches (12"). Whenever the concrete channel bottom is wide enough to accommodate construction or maintenance equipment (generally eight feet (8') wide or more), it shall be designed to carry an HS-20 loading and shall be reinforced. Welded wire mesh or steel reinforcing bars shall be used.

Concrete channels shall be designed for subcritical flow where possible. Where flow is supercritical, the conjugate depth must be checked, and additional freeboard may be required. Where slopes must be decreased to provide stability or maintain subcritical flow, drop structures should be provided.

6.6.3.5.1 Trapezoidal Concrete Channels. The maximum side slopes shall be 2:1. Total channel depth is limited to three feet (3') unless otherwise approved. For depths greater than twelve inches (12"), the channel slopes shall be reinforced with 6 X 6-10-10 welded wire mesh. A typical trapezoidal concrete channel section is shown in Figure SS-29.

6.6.3.5.2 Rectangular Concrete Channels. Vertical side walls shall be reinforced to withstand earth pressure and other anticipated loads. Design for hydrostatic pressure is not required if weep holes are provided for relief. A toe wall extending a minimum of eighteen inches (18") below grade shall be provided at the downstream end of any concrete channel section and should be provided at maximum intervals of about one hundred feet (100') along the channel. A typical rectangular concrete channel section is shown if Figure SS-30.

6.6.4 Engineered Channel Design Criteria.

6.6.4.1 Flow Rate. Open channels shall be designed to convey the peak flow rate resulting from a storm having a rainfall intensity corresponding to the time of concentration at the point of interest or a duration which produces the maximum runoff rate at the point of interest, depending upon the method used for computing runoff. Open channels draining less than one hundred (100) acres can be designed for runoff rates computed by the Rational Method. The peak flow rate considered shall be determined using fully urbanized conditions in the watershed. Effects of detention basins in reducing peak flow rates in the upstream watershed will be considered only if the detention basins are included in a hydrologic model used to estimate the peak flow rate and provided the detention basins are located in permanent drainage easements. The design storm frequency shall be as follows:

Total drainage area less than one (1) square mile: 25-year (4% AEP)
Total drainage area one (1) square mile or more: 100-year (1% AEP)

Low-flow channels should generally be designed to convey the 1-year flow, although site conditions may justify a varied design that requires City approval. Any existing perennial intermittent base flows shall also be considered when designing low-flow channels.

6.6.4.2 Flow Regime. To protect channel stability and hydraulic performance, critical flow conditions shall be avoided. The Froude number, F_r, must be calculated for all unique sections of open channels for the 25-year flow. Calculating F_r for other frequency flows may be necessary to ensure channel stability. F_r must first be calculated using the minimum value of the Manning's roughness coefficient, n.

In general, the maximum allowable value of F_r is 0.8. However, if values greater than 0.8 are necessary due to site constraints, the channel shall be designed so that the flow is supercritical, with a F_r greater than 1.2. In such cases, the calculation should use the maximum value for Manning's roughness. For supercritical flows, calculation of the conjugate depth is necessary, and a well-accepted open channel hydraulics reference should be used. Designs with supercritical flows require the use of a concrete channel lining. In addition, such designs must avoid all obstructions, transitions, and curvature. It must be shown how adjacent properties will be protected from flooding should a hydraulic jump occur.

Under certain conditions, values of F_r between 0.8 and 1.2 may be allowed, and the requirement to calculate conjugate depths may be waived. This exception applies to channels with a 25-year design flow of 20 cfs or less when no potential hazards exist.

6.6.4.3 Velocity. The maximum average channel velocity shall be as follows for the design flow rate:

Channel Type	Minimum Velocity (2-year check)	Maximum Velocity (25-year check)
Grass, seed, and mulch	2 ft/s	4 ft/s
Grass, sod	2 ft/s	6 ft/s
Grass, TRM	2 ft/s	8 ft/s
Grass, pre-vegetated TRM	2 ft/s	10 ft/s
Manufactured hard lining	4 ft/s	12 ft/s
Riprap	4 ft/s	12 ft/s
Concrete	4 ft/s	18 ft/s

Where reduction in velocity due to a reduction in slope would allow a transition from a concrete to a grass-lined channel, a grouted riprap lining shall be provided from the point where the theoretical average channel velocity would be five feet (5') per second or less, for a distance downstream equal to five (5) times the theoretical top width of the grass channel. The height of the riprap lining shall be equal to the height of the concrete lining upstream.

6.6.4.4 Maximum Depth. Unless otherwise approved due to unavoidable physical or right-of-way constraints, the maximum depth for the 25-year storm shall be three feet (3') in constructed channels.

6.6.4.5 Slope

6.6.4.5.1 Longitudinal Slope. Unless otherwise approved due to unavoidable physical constraints, the minimum centerline grade for various channels shall be as follows:

- Concrete channels - 0.25%
- Composite channels with concrete inverts - 0.5%
- Grass channels - 1.0%
- Grass channels with concrete trickle channels - 0.5%
- Riprap and gabion channels - 1.0%
- All other channel types - Will be considered on a case-by-case basis.

6.6.4.5.2 Side Slopes. For concrete channels, non-vertical side slopes shall not have a slope steeper than 1H:1V, to allow for safe exit from the channel. An exception is allowed for short transitions between vertical and 1H:1V concrete channels.

A fence with a minimum height of four feet (4') shall be installed at the top of any slope steeper than 1H:1V for channels with a depth of three feet (3') or more, where homes, streets, parking lots, buildings, or other facilities cause people to be in close proximity.

6.6.4.6 Horizontal Alignment. The centerline of constructed channels shall be aligned parallel with property lines unless otherwise approved. A radius shall be provided whenever the alignment of a constructed channel changes by ten (10) degrees or more. The minimum centerline radius shall be three (3) times the top width of the design flow.
Horizontal curve data shall be shown on the plans.

6.6.4.7 Curvature and Superelevation. Curves shall only be used where it is shown they are necessary due to layout of the development or to create sinuosity and reduce longitudinal slope. Where curves are used, the centerline of curvature of the channel shall have a minimum radius of twice the top width of the design flow (25-year event), but not less than 100 feet.

Supercritical flow in an engineered open channel in an urban area may create hazardous conditions. Curvature shall not be used in a channel under these conditions. If curvature is proposed, it may be considered with an analysis of conjugate depths and potential hazards.

Velocities and depths are higher on the outside of open channel curves. This rise in water surface on the outside of a curve is referred to as superelevation. Superelevation must be calculated for all curves in open channels and accounted for in the design of the channel and freeboard. For subcritical flows, superelevation can be estimated by:

$$\Delta y = \frac{V^2 T}{2 g r_c}\text{, where}$$

Δy = difference in water surface elevation between the inner and outer banks of the channel in the bend (resulting from superelevation) (ft)
V = mean flow velocity (ft/s)
T = top width of the channel under design flow conditions (ft)
g = gravitational constant = 32.2 ft/s^2
r_c = radius of curvature (ft)

Velocity shall be calculated utilizing minimum roughness coefficient values. Because of this increase in velocity, it is often necessary to provide increased erosion protection along the outside of bends. Riprap shall be used when the velocity of the upstream reach for the 25-year storm is greater than 8 ft/s.

Increased erosion protection based on higher bend velocities shall apply to the outside half of the channel bottom and on the channel side slope for the entire length on the outside of the bend, plus a distance of two times the top width downstream of the bend. In cases where an outside bend in a grass-lined channel needs protection, riprap shall be covered, if possible, with soil and vegetation to provide a grassed-lined channel appearance. Buried riprap may lose vegetated cover in a major flood and require re-burial and revegetation.

6.6.4.8 Freeboard. For channels designed for subcritical flow conditions, a minimum of one foot (1') of freeboard shall be provided between the design high water elevation and the top of the channel. Freeboard shall be increased on the outside of curves according to the following formula:

$$h = \frac{V^2 T}{g r_c} \geq 0.5\, ft \text{ , where}$$

h = superelevation (feet)
V = average channel velocity (feet/second)
T = top width of flow (feet)
g = acceleration due to gravity (32.2 ft/s^2)
r_c = centerline radius of channel (feet)

For channels designed for supercritical flow, additional freeboard may be required depending upon the risk of damage which could occur if flow were to become subcritical due to debris or other obstructions.

For concrete channels, the required freeboard is 6 six inches (6”) above the 25-year water surface
For channels where the 25-year flow depth is 12 inches or less, the channel shall have a freeboard of 6 inches above the 25-year water surface. For all channel types, the 100-year water surface shall remain within the drainage easement.

In cases where curves exist, freeboard must be above the water surface calculated by adding the superelevation to the normal water surface elevation. Where design conditions are supercritical in nature, the freeboard should take into consideration the conjugation depths from hydraulic jumps.

6.6.4.9 Roadside Ditches
Roadside ditches shall be designed for a maximum depth of two feet (2') measured from the roadway shoulder and maximum 3:1 side slope. Roadside ditches shall be grass lined and shall conform to the same velocity requirements as grass lined channels. The bottom six inches (6") of the ditch depth shall be lined with sod or erosion control blanket, or the developer must assume maintenance responsibility for the ditch until growth is firmly established. A security agreement or performance bond will be required during the maintenance period. Where the full flow velocity in the ditch exceeds five feet (5') per second, a concrete ditch liner shall be provided. Typical sections of roadside ditches can be found in Figure SS-32.

6.6.4.10 Linings.

6.6.4.10.1 Riprap Lining. The use of riprap for channel linings is discouraged primarily due to poor construction practice. Because of the amount of labor required to properly place and chink stones into a stable mass, loose riprap is seldom stable. Further, gradations of stone tend to be highly variable and poorly controlled. Loose riprap is susceptible to silting in, encouraging growth of weeds and vegetation, and creating a maintenance and appearance problem. These problems can be partially overcome by grouting the riprap; however, construction practice for grouted riprap is equally poor resulting in a highly variable penetration by the grout.

Riprap linings are best specified for only short distances in zones where erosion potential is high. Where riprap is specified, it should be grouted to minimize maintenance problems, unless the installation is temporary. The maximum stone size should be twelve inches (12"). The riprap shall be laid over a non-woven filter fabric in order to prevent undercutting of the subgrade. A typical riprap lining is shown in Figure SS-31.

6.6.4.10.2 Other Types of Erosion Resistant Channel Linings. Designers are encouraged to use other types of linings in order to reduce costs and improve the appearance of drainage channels. Invert lining materials include concrete, reno mattresses, gravel filled Geo-web, Geo-web filled with lean concrete, etc. Sidewall lining materials include gabions, and precast concrete units, such as Keystone blocks, Loffelstein units, Windsor stone, and many other types of precast units. In specifying any type of these linings, the manufacturer's installation instructions shall be strictly followed.

6.6.4.11 Easements. All constructed channels shall be located within drainage easements. Natural channels draining five (5) or more acres shall be located in drainage easements. The minimum easement width shall be the top width of the 100-year peak flow rate. Adequate means of access shall be provided for maintenance equipment. Additional easement width shall be provided if required to provide maintenance access. No fences or obstructions of any type are permitted within drainage easements containing open channels.

6.6.4.12 Outfalls. Outfalls into channels must be designed with consideration given to the nature and condition of the receiving channel. Such outfalls shall be perpendicular to flow or directed downstream. Any protrusions of pipes or other structures into the channel must be trimmed flush with the main channel wall or bank.

Discharges into natural, vegetated, or reinforced vegetated channels shall be at the flow line, in a manner consistent with the channel outfalls for natural channels. Vegetated or reinforced vegetated channels are generally not capable of withstanding point discharges with high velocities; therefore, the incoming conveyance should be designed to minimize velocity. Energy dissipation, such as a headwall or riprap protection, shall be designed around the outfall to minimize bank, channel, or wall erosion. Energy dissipation in the main channel may be necessary to withstand the flows that occur there.

Discharges into channels lined with concrete or riprap generally require no special protection against erosion. Discharges into hard-lined channels should be a minimum of one foot above the flow line.

6.6.4.13 Utility Clearance. A minimum clear distance of twelve inches (12") vertically from any other utility line shall be maintained below the channel lining, unless otherwise approved. Utilities will not be permitted to cross through the channel flow area.

6.6.4.14 Plan Requirements. Each channel shown on the plan shall be numbered or lettered (Line 1, Storm 1, Line A, etc.). Channel segments shall be included in profiles of the storm sewer lines of which they are a component. Stationing shall begin at the downstream end of the channel and proceed upstream. Stations shall be called out on the plan and profile at all changes in direction or points of curvature and tangency.

6.6.5 Drop Structures. Where the channel slope must be decreased to provide stability, maintain subcritical flow, or reduce velocity to acceptable levels, drop structures may be provided. Grass lined channels shall be provided with erosion resistant linings downstream to the point at which the average channel velocity has returned to the allowable rate for the type of channel lining provided. Drop structures for vertical wall channels shall be designed in accordance with the ASCE Design Manual or the U.S. Bureau of Reclamation Design of Small Canal Structures. Drop structures for trapezoidal channels shall be designed in accordance with the City of Tulsa Design Criteria or King's Handbook of Hydraulics.

6.7 DETENTION FOR FLOOD CONTROL

6.7.1 General. This section covers the design of detention facilities whose primary purpose is to provide flood control by controlling rates of runoff. Detention facilities may also be utilized to improve the quality of urban stormwater runoff. Both flood control and water quality benefits can be provided in one (1) basin, if properly designed.

6.7.2 Policy. Prior to the development of the land, surface conditions provide a higher percentage of permeability and a longer time of concentration. With the construction of buildings, parking lots, etc., permeability and the time of concentration are significantly decreased, resulting in an increase in the rate, volume, and frequency of runoff.

These changes result in increased flooding risk to downstream structures since flooding depths will rise as the rate of runoff increases. The increased volume and frequency of runoff can cause erosion damage.

In order to minimize these effects, stormwater detention requirements have been established. All new non-agricultural construction is required to provide stormwater detention facilities. Detention requirements may be waived upon written approval of the City of Battlefield in any of the following cases:

1. Construction of such a facility would, due to timing of outflows, have an adverse effect on downstream properties by increasing peak rates of runoff, as demonstrated by engineering computations.
2. The developer enters into a written agreement with the County and affected property owners to provide storm drainage improvements downstream of the development in lieu of constructing on-site detention facilities as set forth below.
3. Due to the small size of the development, it can be demonstrated that the detention facility would result in no beneficial effect to downstream properties. Detention basins having a required volume of five thousand (5,000) cubic feet or less are considered as providing only marginal benefits.

In Cases 1 and 3 above, the City may, in the future, impose a fee in lieu of detention to be utilized for maintenance or improvement of storm drainage facilities in the same watershed in which the proposed development is located

Detention requirements cannot be waived if there are residential or other structures downstream of the site which have a high flooding risk.

6.7.2.1 Construction of Improvements in Lieu of Detention. In cases where channelization or other improvements can be shown to be more effective than detention in reducing the flooding hazard to downstream properties and where no adverse effects to downstream properties will result from construction of such improvements, the City may enter into an agreement with the applicant to accept compensation and/or construction of off-site improvements in lieu of constructing on-site detention facilities.

The developer's contribution will be determined based upon the net financial gain which the developer would realize if the detention facility were not built. This amount will generally be equal to the construction cost of the detention facility plus revenue from sale of additional lots or increased value of lots, less the cost of developing the lots, including utilities and streets, financing costs, sales costs, and reasonable profit.

Where the developer's contribution is not sufficient to construct the necessary improvements to completely remedy flooding problems to structures downstream, the City must demonstrate that the necessary funding has been secured prior to accepting payment or improvements in lieu of detention. Where the developer's contribution is more than the actual cost of the necessary improvements, the City shall retain the balance and such funds shall be utilized for planning or construction drainage improvements in the same watershed.

6.7.3 Definitions.
Pre-project conditions - the topography, surface cover, and other hydrologic conditions in the watershed being considered, as they exist prior to the proposed project.

Post-project conditions - the topography, surface cover, and other hydrologic conditions in the watershed as they will be after construction of the proposed project.

Fully urbanized conditions - the topography, surface cover, and other hydrologic conditions in the watershed as they will be after all areas in the watershed have been developed in accordance with current zoning designations, as provided in the City of Battlefield Comprehensive Plan, or as can otherwise be reasonably anticipated.

High flooding risk - residences or other structures will be defined as having a high flooding risk when the lowest point on the structure at which surface runoff may gain entry is located at, or below, the estimated flooding level which would result from a storm with an annual exceedance probability (AEP) of 10% (ten percent) or greater under conditions existing in the basin prior to development of the applicant's property (i.e. affected by the "10-year" storm for pre-project conditions).

Dry detention basin - a detention basin which holds water only during and shortly after runoff events.

Wet detention basin - a basin which contains a permanent impoundment of water. Flood storage volume is provided above the permanent water surface.

Retention basin - this term is often utilized for wet basins and basins which retain runoff for an extended period of time. The term "detention basin" will be used to refer to all such facilities in the City of Battlefield.

On-line detention basin - a basin which is located on the mainstream of a watercourse and which intercepts on-site as well as off-site flows.

Off-line detention facility - a basin or basins located outside of the primary watercourse, which usually allows off-site flows to pass through the site without passing through the detention basin. Where needed for peak flow reduction at the point of interest, a portion of the flow in the main watercourse may be intercepted and passed through the detention basin through the use of side-flow weirs or similar diversions.

6.7.4 Types of Detention. Detention basin facilities fall into two categories regarding ownership, design aspects, and maintenance. Facilities planned on an individual-site basis are referred to as on-site or private facilities. Facilities that are planned to serve multiple lots, a subdivision, or larger area are referred to as public or regional facilities. Requirements for detention basins may vary depending on the development situation, including:

- Single Lot Commercial: Generally, these are developments on lots that are not part of a subdivision. Basins shall be designed for full development of the lot based on zoning unless land use restrictions dictate less land is available for development. Construction of detention may be phased when only part of the lot is proposed to develop. In these cases, the location and size of detention facilities for fully developed conditions shall be located and documented.

- Residential or Commercial Subdivision: These are developments that involve the subdivision of property. One or more basins may be required depending on natural drainage patterns.
- Multiple Properties: Multiple properties or developments may be served by a regional basin that is not within the boundary of the development.

Generally, the type of detention is determined by the required design objectives and the appearance and function desired by the developer. Detention basins may fall into one of the following design types:

- Dry: Designed for several different frequency rainfalls for flood control only and drains over a relatively short period of time (<12 hours). The outlet is typically made up of orifices and/or weirs.
- Extended: Designed for pollutant removal and possibly flood control and drains over an extended period of time (24-48 hours). The outlet is typically made up of a filtered control as well as orifices and/or weirs.
- Wet: Contains a permanent pool of water and is designed for pollutant removal, flood control, and often aesthetics. May be designed to drain down to the permanent pool level over a short or long period of time.

Storage may also be present in features such as sinkholes and the upstream side of railroad and highway embankments. When planning a development along a major waterway, upstream existing storage should be accounted for when calculating existing flow rates but generally should not be accounted for when calculating ultimate future peak flow rates. Exceptions include storage that is dedicated for perpetuity and has adequate assurances for long-term maintenance.

In developments where an off-site area drains across the property, the developer must consider whether to construct the basin in-line and direct off-site runoff through the basin or construct it off-line and convey the off-site runoff so that it bypasses the basin. In-line and off-line storage are defined as:

- In-Line Storage: A facility located in-line with the drainageway that captures and routes the entire flood volume. A disadvantage with in-line storage is that it must be large enough to store and convey the total flood volume of the entire tributary catchment, including off-site runoff, if it exists. A U.S. Army Corps of Engineers (USACE) Section 404 permit for dredge and fill activities within the waters of the United States and a Section 401 Water Quality Certification from the Missouri Department of Natural Resources (MDNR) are typically required for in-line storage. The developer shall contact the USACE to determine permit requirements if an in-line basin is proposed.
- Off-Line Storage: A facility located off-line from the drainageway that receives runoff from a smaller drainage area or from a particular site. These facilities are often smaller but may require permitting similar to in-line storage facilities. For all types of basins, the designer should consider safety, aesthetics, and multi-purpose uses during both wet and

dry conditions. The use of other specialists such as landscape architects, biologists, and planners are encouraged to achieve these objectives.

6.7.5 Hydrologic and Hydraulic Design. Detention facilities should be designed and constructed in a manner to enhance the aesthetic and environmental quality of developments in the City as much as possible, adding to rather than detracting from property values. City of Battlefield encourages designs which utilize and enhance natural settings, provide good quality open space, and minimize disturbance and destruction of wooded areas, natural channels, and wetlands.

Where detention volume can be provided by utilizing natural valleys, existing wooded areas should be allowed to remain. Detention ponds do not have to be graded to geometric shapes or cleared of forested areas in order to comply with City requirements.

The use of landscaping and alternative materials to improve the appearance of spillways, outlet structures, erosion control, and energy dissipation structures is encouraged.

Detention basins may be designed to be "wet" or "dry". Parking lots may be utilized for detention storage, provided the maximum depth does not exceed twelve inches (12") during an event with a 1% exceedance probability. Underground detention storage may also be utilized. The use of rooftop detention is discouraged. Detention basins may be designed to be "on-line" or "off-line".

Large regional detention basins are more effective in providing flood control, as well as water quality benefits, than smaller facilities provided on each site. City of Battlefield currently has no program for regional detention. Where feasible, developers are encouraged to work together to provide common detention areas.

Detention basins shall be located within a single lot or property.

6.7.5.1 Easements. All detention basins serving more than one (1) lot or property shall be located within a drainage easement.

At a minimum, the easement shall include the area of the dam, the area downstream of the dam to a point twenty feet (20') downstream of the end of the outlet structure, including the area provided for erosion control or energy dissipation; and the area covered by the reservoir including freeboard, plus an additional twenty feet (20') around the perimeter.

Detention basins for a development may be located on adjoining property downstream from the development provided that a drainage easement is obtained and adequate means of maintenance access (including ingress/egress easements where necessary) is provided. The easement shall be granted to the developer or to the property owners' association. Where the detention basin does not immediately adjoin the development, a drainage easement covering the area inundated by the peak flow from the 1% AEP (100-year) storm shall be provided to connect the development site with the detention basin.

6.7.5.2 Design Methods.

6.7.5.2.1 Analytical Methods. Detention storage volume shall be determined by hydrograph methodologies and reservoir routing techniques. Preferred methods for use in detention basin design are those included in the Corps of Engineers HEC-1 Flood Hydrograph Package and the Soil Conservation Service's TR-55 and TR-20.

The designer may choose to use other methods than those listed above provided that the method is documented in generally accepted engineering literature and is used within the limitations stated for the method.

6.7.5.2.2 Computations for Small Sites. Where the site area is less than five (5) acres of one (1) and two (2) family dwellings, or where the site area for other zoning designations is less than two (2) acres, detention volume computations may be performed by the methods of the Soil Conservation Service TR-55.

Runoff volumes shall be computed for pre- and post-project conditions, and the required volume determined by subtracting the pre-project runoff volume from the post-project runoff volume. The outlet structure shall be designed to limit the runoff rate for the design storms to pre-project values at the stage where the required volume for each storm frequency is contained in the basin.

6.7.5.2.3 Design Storms. Detention basins shall be designed on the basis of multiple storm recurrence frequencies to ensure that they provide flood protection for both frequent storms and large infrequent storms. A minimum of three (3) recurrence frequencies, the 50%, 10% and 1% AEP storms (the "2-year, 10-year and 100-year" storms) must be considered.

The duration of the design storm used to compute the difference in runoff volume between pre-project and post-project conditions shall be that which produces the maximum rate of runoff at the point under consideration for post-project conditions. The minimum design storm duration utilized shall be one (1) hour.

6.7.5.2.4 Runoff Models. The runoff model must include the entire drainage basin upstream of

the proposed detention ponds. The model shall be prepared in sufficient detail to ensure that peak runoff rates are reasonably accurate. Runoff models shall be developed for the following cases:

- Case 1 – Pre-project conditions.
- Case 2 – Post-project conditions
- Case 3 – Fully urbanized conditions in the entire drainage basin.

Cases 1 & 2 are utilized to determine the required detention volume and the type of outlet structure to be provided and shall be analyzed for the three (3) storm recurrence frequencies required above. Detention facilities shall be designed such that peak outflow rates from the facility for Case 2 are no greater than the rates determined in Case 1 for each of the three (3) storm recurrence frequencies required. The storage volume provided shall not be less than the difference in total runoff volume between Case 1 and Case 2. Case 3 is used to determine the size of the overflow spillway. Case 3 needs only be analyzed for the 1% AEP ("100-year") storm. If downstream safety considerations warrant, it may be necessary to size a spillway for greater than a 100-year event.

6.7.5.2.5 Spillways and Outlet Structure Hydraulics. Outlet structures consist of culverts, weirs, orifices, and other hydraulic elements for which reliable data is available. Weir coefficients shall be as given in King's Handbook of Hydraulics. Coefficients for broad-crested weirs interpolated from the values given in King's Handbook are given in Table 15 below.

Table 15: Discharge Coefficients for Broad-Crested Weirs

Discharge Coefficients for Broad-Crested Weirs			
Depth (ft.)	Coefficient for 6" thick wall	Coefficient for 8" thick wall	Coefficient for 12" thick wall
0.20	2.80	2.77	2.69
0.25	2.83	2.79	2.70
0.30	2.86	2.80	2.71
0.40	2.92	2.84	2.72
0.50	3.00	2.90	2.74
0.60	3.08	2.95	2.75
0.70	3.19	3.03	2.80
0.75	3.25	3.08	2.83
0.80	3.30	3.12	2.85
0.90	3.31	3.16	2.92
1.00	3.32	3.20	2.98
1.25	3.32	3.25	3.11
1.50	3.32	3.29	3.24
1.75	3.32	3.31	3.27
2.00	3.32	3.32	3.30
2.50	3.32	3.32	3.31
>2.50	3.32	3.32	3.32

Capacity of broad-crested slot and V-notch weirs shall be determined by the following formula, developed by Joe Wilson, Kerry Scott, and Larry Wolf at the University of Missouri-Rolla:

$$Q = 0.86H + (3.65w + 5.82z)H^{1.5} \text{ , where}$$

Q = flow rate in cubic feet per second.

H = upstream head (ponded depth above slot invert plus any velocity head) in feet.

H = 6 feet maximum.

w = slot invert width perpendicular to flow, in feet.

0.333 < w < 2.0 feet.

z = slope of slot sides expressed in terms of z horizontal to 1 vertical.

0 < z < 0.6

Weir coefficients for trapezoidal weirs shall be determined based upon the ratio of headwater depth to crest width as shown in Figure SS-33.

Culvert capacities shall be determined using the methods in Federal Highway Administration HDS-5.

Weir coefficients for trapezoidal weirs where the depth of flow over the weir is small in comparison to the width of the weir crest shall be determined in accordance with Figure III-11 of Federal Highway Administration HDS-5.

Discharge coefficient for all orifice shapes shall be 0.6 (six tenths) unless supporting data is submitted for other values.

Where outlet structure capacities are determined automatically by the software used in performing the detention basin analysis, values included in the software package may be used provided they are generally accepted and properly documented.

6.7.6 Final Design Considerations.

6.7.6.1 Potential for Multiple Uses. When designing a detention facility, multi-purpose uses, such as active or passive recreation and wildlife habitat, are encouraged in addition to providing the required storage volume. Facilities used for recreation should be designed to inundate no more frequently than every two years. In certain situations, it may be beneficial to utilize a portion of a parking lot, along the fringe of a detention basin for additional flood volume storage. However, the depth of flooding in the paved areas shall not exceed twelve inches (12”) during an event with a one percent annual exceedance probability and the paved surfaces shall be outside of the area ponded by the water quality capture volume.

6.7.6.2 Detention Basin Location. Detention basins should be located at the natural low point of the site and must discharge to the natural drainage location to minimize downstream impacts.

6.7.6.3 Detention Basin Grading. Detention basin grading shall conform to the natural topography of the site to the maximum extent practical. Developments should be laid out around the existing waterways and the proposed detention basin. Layouts conforming to existing topography often reduce construction costs, land disturbance, and maintenance costs, and increase aesthetic quality. Existing slopes should be used to the maximum extent practical. Significant modifications to existing topography may require geologic impact studies and geotechnical analysis, particularly where shallow bedrock is believed to be present.

6.7.6.4 Geometry of Storage Facilities. The geometry of a detention facility depends on specific site conditions such as adjoining land uses, topography, geology, existing natural features, volume requirements, etc. The following criteria apply to the geometry of detention facilities:

- In some cases, to minimize erosion, a low-flow channel may be provided where the 2-year design flow exceeds 5 cfs. These are less desirable in water quality basins or where grass contact or infiltration is desired.
- Lining and surfaces shall be based on design velocities and flow characteristics in accordance with Chapter 6.6, Open Channels.
    - Riprap lining should be used only when design constraints prevent the channel design velocity from falling within the allowable range for vegetated channels.
    - Dry and extended detention basins shall have a vegetated bottom and side slopes unless design velocity or slope is not within the allowable range for vegetation.
- Where bedrock is encountered when excavating the detention basin, it is not required to excavate and remove the bedrock so long as the design of the basin can be altered to meet the City's standards.
- The water quality portion of a facility should be shaped with a gradual expansion from the inlet and a gradual contraction toward the outlet, thereby minimizing short-circuiting.
- Storage facilities shall not be any closer than five feet (5') from a building.

6.7.6.5 Embankments and Cut Slopes. The design for an embankment of a stormwater detention or retention storage facility should be based upon a site-specific engineering evaluation. The embankment should be designed to prevent catastrophic failure during the 100-year and larger storms. The following criteria apply in many situations:

6.7.6.5.1 Maximum and Minimum Slopes. The maximum slopes of excavated or embankments slopes shall be 3:1. 4:1 slopes are preferred. Natural slopes exceeding 3:1 may be utilized provided that they remain undisturbed. The minimum allowable slope on the bottom of the basin shall be 1% (one percent) unless a trickle channel is provided. The embankment's side slopes should be well vegetated, and riprap protection (or the equivalent) may be necessary to protect it from wave action and bank erosion.

6.7.6.5.2 Freeboard. For basins with a surface area of two (2) acres of less, a minimum freeboard of twelve inches (12") shall be provided above the design stage for the 1% AEP (100-year) storm. For surface areas greater than two (2) acres but less than ten (10) acres, two feet (2') of freeboard shall be provided. Greater depths of freeboard may be required for impoundments having a surface area greater than ten (10) acres.

6.7.6.5.3 Settlement. All earth fills should be free from unsuitable materials and all organic materials such as grass, turf, brush, roots, and other material subject to decomposition. The fill material in all earth dams and embankments should be compacted to at least 95 percent of the maximum density obtained from compaction tests performed by the Modified Proctor method in ASTM D698. Additional height should be considered to account for settlement, particularly for larger facilities.

6.7.6.5.4 Emergency Spillway. An emergency spillway shall be designed to convey flows that exceed the primary outlet capacity. The spillway shall be sized to safely pass the flow from the 100-year, 24-hour rainfall event with no overtopping of the embankment. The flow capacity of other components of the outlet works may be considered when designing the emergency spillway. An emergency spillway may be waived for embankments of two feet (2’) in height or less and no safety risks exist immediately downstream.

6.7.6.6 Spillways and Outlet Structures. Any type of outlet structure and overflow spillway can be utilized provided the required hydraulic characteristics of the structure can be maintained and provided that no undue maintenance burdens are placed upon the owner of the detention basin. Outlet structures and spillways shall be provided with an adequate stilling area downstream to reduce velocities to acceptable levels. Outlet structures shall be set back to a minimum distance from the downstream property line to allow for the pre-project velocity and spread of flow to be maintained at the downstream property line.

Where concrete or other types of retaining walls exceed three feet and six inches (3' 6") in height, a four feet (4') high chain link or solid fence must be provided.

Spillways and outlet structures shall be provided with toe-walls extending a minimum depth of eighteen inches (18") below finish grade at the upstream and downstream ends in order prevent undercutting.

Spillway sidewalls shall extend in height to the top of the dam.

6.7.6.7 Concrete Retaining Walls. The use of vertical retaining walls for detention basin impoundments is discouraged, due to cost and appearance considerations. However, concrete retaining walls are frequently utilized to minimize the area required for detention basins.

Where concrete retaining walls exceed three feet and six inches (3' 6") in height, a four feet (4') high chain link or solid fence must be provided. The maximum depth of detention basins using vertical walls shall be four feet (4').

Concrete retaining walls shall be designed to withstand earth and hydrostatic pressures. Walls longer than fifty feet (50') shall be provided with expansion and contraction joints at appropriate intervals.

6.7.6.8 Other Types of Retaining Walls. Where retaining walls must be utilized to conserve space, the use of other types of materials is encouraged in order to reduce costs and improve the appearance of detention basins. Alternative retaining wall materials include gabions and precast concrete units, such as Keystone blocks, Loffelstein units, Windsor stone, and many other types of precast units. In specifying any type of these linings, the manufacturer's installation instructions shall be strictly followed.

6.7.6.9 Earth Dams. Dams shall be constructed to the maximum slopes specified above. Dams shall be constructed of properly compacted earth fill and shall be keyed into existing ground to reduce the risk of leakage or failure.

Dams less than ten feet (10') in height shall be keyed in a minimum of two feet (2') below existing grade. Deeper keys may be required for taller dams.

The minimum embankment width at the top of the dam shall be three feet (3'). Greater widths may be required for dams exceeding ten feet (10') in height.

Dams greater than thirty-five feet (35') in height are subject to regulation by the State dam safety program and shall meet requirements of the dam safety program.

6.7.6.10 Wet Ponds. Where wet ponds are specified, the pond lining must be designed to retain water. Geologic conditions in Greene County frequently make it difficult for impoundments to hold water. Site soil conditions shall be evaluated by a soils engineer and an appropriate lining provided.

Wet ponds shall have a minimum permanent pool depth of four feet (4') to minimize algae growth. Designers and developers are encouraged to consult with the Missouri Department of Conservation regarding pond management techniques, stocking fish, etc.

6.7.6.11 Linings. Detention facilities may benefit from an impermeable clay or synthetic liner for a number of reasons. Stormwater detention and retention facilities have the potential to raise the groundwater level in the vicinity of the basin. If the basin is close to structures or other facilities that could be damaged by raising the groundwater level, consideration should be given to lining the pond. An impermeable liner may also be warranted in a retention basin where the designer seeks to limit seepage from a permanent pond. Alternatively, there are situations where the designer may seek to encourage seepage of stormwater into the ground. In this situation, a layer of permeable material may be warranted.

6.7.6.12 Inlets. Inlets shall incorporate energy dissipation and/or linings to limit erosion. In addition, forebays or sediment traps should be considered at significant inflow points to storage facilities to settle a significant portion of the sediment being delivered by stormwater to the facility. Forebays will need regular maintenance to reduce the sediment being transported and deposited on the storage basin's bottom.

6.7.6.13 Outlet Works. Outlet works should be sized and structurally designed to release at the specified flow rates without structural or hydraulic failure. A concentrated discharge to a natural channel shall have a property line setback of a minimum of 5 times the effective diameter of the conveyance structure.

6.7.6.14 Trash Racks. Trash racks should be sufficiently sized to not interfere with the hydraulic capacity of the outlet and must be designed in a manner that is protective of public health, safety, and welfare.

6.7.6.15 Vegetation. The type of vegetation specified for a newly constructed storage facility is a function of the frequency and duration of inundation of the area, soil types, whether native or non-native vegetation is desired, and other potential uses (park, open space, etc.) of the area. A planting plan should be developed for new facilities to meet their intended use and setting in the urban landscape. Generally, trees and shrubs are not recommended on dams or fill embankments.

6.7.6.16 Access. Access to the bottom, inflow, forebay, and outlet works areas shall be provided for maintenance vehicles.

6.7.6.17 Geotechnical Considerations. The designer must account for the geotechnical conditions of the site. These considerations may include issues related to embankment stability, geologic hazards, seepage, and other site-specific issues. It may be necessary to confer with a qualified geotechnical engineer during both design and construction, especially for larger detention and retention storage facilities.

6.7.6.18 Environmental Permitting and Other Considerations. The designer must account for environmental considerations surrounding the facility and the site during its selection, design, and construction. These can include regulatory issues such as:

- Whether the facility will be located in a jurisdictional wetland
- Whether the facility is to be located on a waterway regulated by the USACE as a “Water of the U.S.”
- Whether there are threatened and endangered species or habitat in the area

There are also non-regulatory environmental issues that should be considered. Detention

facilities can become breeding grounds for mosquitoes unless they are properly designed, constructed, and maintained. Area residents may object to facilities that impact riparian habitat or wetlands. Considerations of this kind must be carefully considered, and early discussions with relevant federal, state, and local regulators are recommended.

6.7.8 Ownership and Maintenance. The city of Battlefield provides no maintenance of detention facilities located on private property. Maintenance must be provided by the owner of the property upon which the detention basin is located. Where detention basins are located in common areas or adjoining off-site areas, the property upon which the basin is located shall remain in the ownership of the property owners' association. Where a property owners' association is formed, restrictive covenants which provide for collection of fees for maintenance of the detention facilities shall be filed in the office of the Greene County Recorder of Deeds. Restrictive covenants must be approved by the City legal counselor prior to filing of the final plat.

Maintenance considerations during design include the following:

- Bank slopes, bank protection, and vegetation types are important design considerations for site aesthetics and maintainability.
- Permanent ponds should have provisions for complete drainage for sediment removal or other maintenance. The frequency of sediment removal will vary among facilities, depending on the original volume set aside for sediment, the rate of accumulation, rate of growth of vegetation, drainage area erosion control measures, and the desired aesthetic appearance of the pond.
- Adequate dissolved oxygen supply in ponds (to minimize odors and other nuisances) can be maintained by artificial aeration. Use of fertilizer and pesticides adjacent to the permanent pool pond should be carefully controlled.
- French drains or the equivalent are almost impossible to maintain and should be used with discretion where sediment loads are apt to be high.
- Underground tanks or conduits designed for detention should be sized and designed to permit pumping. Multiple entrance points should be provided to remove accumulated sediment and trash.
- Detention facilities should be designed with sufficient depth to allow accumulation of sediment for several years prior to its removal.
- Permanent pools should be of sufficient depth to discourage excessive aquatic vegetation on the bottom of the basin, unless specifically provided for water quality purposes.
- Trash racks and/or fences are often used to minimize hazards. These may become eyesores, trap debris, impede flows, hinder maintenance, and, ironically, fail to prevent access to the outlet. On the other hand, desirable conditions can be achieved through careful design and positioning of the structure, as well as through landscaping that will discourage access (e.g., positioning the outlet away from the embankment, etc.). Creative designs, integrated with innovative landscaping, can be safe and can also enhance the appearance of the outlet and pond.
- To reduce maintenance and avoid operational problems, outlet structures should be designed with no moving parts (i.e., use only pipes, orifices, and weirs). Manually and/or electrically operated gates should be avoided. To reduce maintenance, outlets should be designed with openings as large as possible, be compatible with the depth-outflow relationships desired, and be designed with water quality, safety, and aesthetic objectives in mind. Outlets should be robustly designed to lessen the chances of damage from debris or vandalism. The use of thin steel plates as sharp-crested weirs should be avoided because of potential accidents, especially with children. Trash racks must protect all outlets, especially ones made of a thin plate.

6.7.9 Submittals. The following information must be submitted with detention basin designs:

1. Information regarding analytical methods and software to be used, including:
    a. Name of software to be used.
    b. Type and distribution of precipitation input.
    c. Method for determining precipitation losses.
    d. Type of synthetic hydrograph.
    e. Method for routing hydrographs.
    f. Method used for reservoir routing.
2. Map(s) showing sub-basin delineation, topography, presumed flow routes, and pertinent points of interest for pre-project, post-project, and fully urbanized conditions.
3. Map showing hydrologic soil types.
4. Routing diagram for each runoff model condition.
5. A summary of sub-basin characteristics used for program input.
6. Stage-area or stage-storage characteristics for the basin in tabular or graphic form.
7. Stage-discharge characteristics for the outlet structure and overflow spillway in tabular or graphic form; hydraulic data for weirs, orifices, and other components of the control structure.
8. A printout of the input data file.
9. A printout of program output, including plots of hydrographs. (These are intended to be the printer plots generated by the software.)

6.8 WATER QUALITY

6.8.1 General. This section covers the design of Best Management Practices (BMPs) to minimize the adverse effects of urban stormwater runoff on the quality of receiving waters.

The requirements of this section will apply to all new developments that drain into sinkholes. As the role which urban runoff from the Springfield metropolitan area plays in the quality of the James River and Table Rock Lake becomes better understood, it is anticipated that water quality requirements will be extended to watersheds of the James River and its tributaries. It is recognized that specific water quality standards, other than those contained in the Missouri Clean Water Laws, have not been developed or adopted for these receiving waters. The objective of this policy is not to meet specific reductions of targeted pollutants, but rather to provide a generally effective level of pollutant removal by using reasonable, cost-effective measures. The goal is to minimize, to the maximum extent practical, adverse impacts on the quality of the receiving water.

6.8.2 Water Quality Requirement. The water quality requirement is to reduce the discharge of pollutants by following the site planning and design principles and criteria described herein and managing the Water Quality Control Volume (WQCV) using approved stormwater control measures (SCMs) that reduce the discharge of pollutants through treatment or runoff reduction and are properly designed, constructed, and maintained. The water quality requirement applies to new development and redevelopment projects within the city limits of Battlefield that disturb 1 acre or greater, including projects less than 1 acre that are part of a larger common plan of development or sale that will disturb 1 or more acres over the life of the project.

6.8.2.1 Water Quality Capture Volume. Water quality BMPs shall be designed to capture the runoff from the 90th percentile rainfall for Greene County as well as to capture the first flush of pollutants from directly connected impervious areas within the proposed development. The required water quality capture volume (WQCV) to be used in design of extended wet and dry detention basins and other BMPs whose design is based upon capture and treatment of storm water, shall be the greater of the following:

- the first one-half inch (½") of runoff from the directly connected impervious area (DCIA) in the development, or
- the runoff resulting from total rainfall depth of one-inch (1") in twenty-four (24) hours over the entire development.

6.8.2.1.1 Short Cut Method. The Short Cut Method (Claytor and Schueler, 1996) computes R_v based on percent impervious cover. It is recommended when the site consists of predominately one type of land surface. The Short Cut Method uses the following equation to calculate the WQCV:

$$WQCV = (P)(R_v)(A)$$, where

WQCV = water quality capture volume (ft^3)
P = rainfall depth (ft) = 1 inch for new development or 0.5 inch for redevelopment
R_v = volumetric runoff coefficient = $0.05 + 0.009\mathrm{I}$
I = percent impervious cover (in percent, e.g., 80% = 80) (for redevelopment, use 100%)
A = total site area for new development or impervious area for redevelopment (acres)

6.8.2.1.2 Small Storm Hydrology Method. The Small Storm Hydrology Method (Claytor and Schueler, 1996) computes R_v based on the specific characteristics of the pervious and impervious surfaces of the drainage area. The R_v to be used for each cover type is provided in Table 16 below. The WQCV can be calculated using the following equation:

$$WQCV = (P)(weighted\ R_v)(A)$$, where

WQCV = water quality capture volume (ft^3)
P = rainfall depth (ft) = 1 inch
Weight R_v = $[(R_{v1} * A_1) + (R_{v2} * A_2) + \ldots (R_{vi} * A_i)]/A$
R_{vi} = volumetric runoff coefficient for cover type *i*
A_i = area of cover type *i* (acres)
A = total site area (acres)

Table 16: Volumetric Runoff by type of cover

Flat roofs and large unpaved parking lots	Pitched roofs and large impervious areas (large parking lots)	Small impervious areas and narrow streets	Urban pervious areas		Forest cover		
			Hydrologic Soil Group B	Hydrologic Soil Groups C & D	Hydrologic Soil Group B	Hydrologic Soil Group C	Hydrologic Soil Group D
0.84	0.97	0.7	0.11	0.21	0.03	0.4	0.5

6.8.2.2 Designing for Runoff Reduction and Targeted Pollutants. Development significantly increases the volume of runoff compared to pre-development conditions, contributing to increased pollutant loads and hydrologic stream impacts including erosion and aquatic habitat degradation. To address these impacts, consideration should be given to runoff reduction during site design and SCM selection and design. This can be accomplished through site planning and design techniques such as tree preservation and planting, natural area conservation, and minimizing grading and impervious surfaces, all of which contribute to runoff reduction. SCM selection and design can incorporate moderate to high performing runoff reduction SCMs and/or use a treatment train approach of more conventional SCMs such as vegetated filter strips, grass channels, and extended detention in series. The runoff reduction and pollutant removal performance of SCMs in series is greater than their use as stand-alone practices. Table 17 below gives typical runoff reduction percentages for SCMs. Volume reduction also has economic benefits, including potential reductions in storage requirements for minor and major events, reduced extent and sizing of conveyance infrastructure, and cost reductions associated with addressing channel stability issues.

Table 17: Typical Runoff percentages for SCMs

SCM	Runoff Reduction
Vegetated Filter Strip	
Natural Area	50-75%
Lawn/landscaping	25-50%
Grass Channel (meeting minimum residence time)	10-20%
Pervious Pavement	45-75%
Bioretention	40-80%
Extended Dry Detention Basin	0-15%
Extended Wet Detention Basin	0%
Constructed Wetland Pond	0%
Green Roof	45-60%

Proprietary SCMs	Based on site specific design
Rainwater Harvesting	40%; May be higher based on site specific design
Natural Area Conservation	% based on calculated WQCV credit (see Section 2.8.2.1.2)
Natural Area Restoration	% based on calculated WQCV credit (see Section 2.8.2.1.2)
Tree Preservation	% based on calculated WQCV credit (see Section 2.8.2.1.2)
Tree Planting	% based on calculated WQCV credit (see Section 2.8.2.1.2)

SCMs vary in their pollutant removal efficiencies for various pollutants. Common urban pollutants include nutrients, sediment, and bacteria. Most of the SCMs in this chapter are known to provide moderate to very good removal of sediment and nutrients. Typical effectiveness of SCMs for bacteria removal is generally not as good. SCM selection and design for commercial and industrial facilities should take into consideration pollutants specific to the facility such as heavy metals. Table 18 below gives the typical effectiveness of SCMs for targeted pollutants.

Table 18: Effectiveness of SCMs

SCM	Sediment/Solids	Nutrients	Total Metals	Bacteria
Vegetated Filter Strip	Good	Moderate	Good	Poor
Grass Channel	Good	Moderate	Good	Poor
Pervious Pavement	Very Good	Good	Good	Unknown
Bioretention	Very Good	Moderate	Good	Moderate
Extended Detention Basin	Good	Moderate	Moderate	Poor
Retention Pond	Very Good	Moderate	Moderate	Moderate
Constructed Wetland Pond	Very Good	Moderate	Good	Poor
Green Roof	Unknown	Unknown	Unknown	Unknown
Proprietary SCMs	Variable	Variable	Variable	Variable

6.8.2.3 Water Quality SCM Design in Floodplains. When developing in or near a floodplain, the bottom of the water quality SCM shall be above the 1-year flood elevation.

6.8.2.4 Water Quality Requirements for Sinkholes. The following requirements will apply to any new development within sinkhole drainage areas:

- Stormwater runoff from any new development for which the total impervious area exceeds ten percent (10%) of the total land area of the development, must be directed through an extended wet or dry detention basin, or other properly designed BMP, prior to discharge from the site.

- Runoff from fueling areas and other areas having a high concentration of pollutants will be required to be directed to a sand filter or other properly designed BMP which provides filtration as well as settling.

- The required volume for capture and treatment shall be designed as the water quality capture volume (WQCV).

- Detention storage must be provided to limit the peak flow rate from the fifty percent (50%) AEP (2-year) storm to pre-project values.

Detention facilities for peak flow control shall be designed as set forth in Chapter 6.7.

6.8.3 Water Quality Design Principles.

- Consider stormwater early. Stormwater site planning and design should be considered early in the concept phase of development. Site planning is a step that has typically received little attention from a stormwater design perspective. When considered early, strategies to meet stormwater requirements through low-cost practices that minimize runoff are most easily achieved, and SCM design issues are minimized.

- Minimize the amount of runoff. The total quantity of pollutants transported to receiving waters can be minimized most effectively by minimizing the amount of runoff. Both the quantity of runoff and the amount of pollutant wash-off can be minimized by reducing the amount of directly connected impervious area (DCIA). Impervious areas are considered connected when runoff travels directly from roofs, drives, pavement, and other impervious areas to street gutters, closed storm drains or concrete, or other impervious lined channels. Impervious areas are considered disconnected when runoff passes as sheet flow over grass areas, or through properly designed BMP's, prior to discharge from the site.

- Maximize contact with grass and soil. The opportunity for pollutants to settle out is maximized by providing maximum contact with grass and soil. Directing runoff over vegetative filter strips and grass swales enhances settling of pollutants as the velocity of flow is reduced. Infiltration of runoff into the soil is also increased.

- Maximize holding and settling time. According to ASCE, the most effective runoff quality controls reduce the runoff peak and volume. The next most effective controls reduce peak runoff rates only. For small storms, the runoff rate should not exceed the pre-project peak flow rate from the fifty percent (50%) AEP (2-year) storm. Most obnoxious pollutants (exceptions include water soluble nutrients and metals) can be settled out. By reducing the rate of outflow and increasing the time of detention storage, settling of pollutants and infiltration of runoff is maximized.

- Design for small, frequent storms. Drainage systems for flood control are designed for large, infrequent storm events. In contrast, stormwater quality controls must be designed for small, frequent storm events. In Greene County ninety percent (90%) of all twenty-four (24) hour rainfalls are one inch (1") or less. Most pollutants are washed off in the “first flush”, generally considered the first one-half inch (½”) of runoff.

- Utilize BMPs in series where possible. Performance monitoring of BMPs in Florida, Maryland, and Delaware has shown that the combined effect of providing several BMPs in a series can be much more effective in reducing the level of pollutants than providing a single BMP at the point of discharge. To the greatest extent practical, runoff should be directed first to vegetative filter strips, then to grass swales or channels, and then to extended detention basins, sand filters, etc.

- Incorporate both flood control and water quality objectives in designs, where practical. Incorporating both flood control and water quality criteria into a single stormwater management facility is not only possible but is encouraged. Whenever practical, combining several objectives, such as water quality enhancement and flood control, maximizes the cost-effectiveness of stormwater management facilities.

- Use open channels for conveyance. Natural channels should be preserved when feasible and stabilized if needed. Open, vegetated channels for site conveyance are preferred rather than enclosed or concrete lined channels and can be used to reduce or meet water quality requirements when properly designed.

- Protect karst features. Sinkholes, springs, caves, and other karst features require special protection to minimize groundwater contamination and instability. Site design and SCM selection should focus on small-scale, distributed practices and sheet flow to avoid concentrating large volumes of runoff which can result in collapses in karst areas.

- Design for industrial/high risk runoff and pollutant types. Site specific SCMs should be incorporated into sites with activities or materials that have the potential to discharge significant pollutant loads. Such sites are generally regulated under NPDES industrial stormwater permits and the location and type of potential pollutant sources should be considered during site design and selection of SCMs to aid in NPDES permit compliance. Site and building design should consider specific needs such as materials storage or operations that may require source controls and/or containment or treatment SCMs. Non-NPDES regulated sites may also have specific pollutant types or hot spots such as fueling stations that be considered when selecting and designing SCMs. Infiltration SCMs such as pervious pavement or bioretention may not be appropriate for sites with higher concentrations of hydrocarbons, metals, or other toxics unless an impermeable liner is provided to design the SCM for filtration only.

6.8.4 SCM Selection and Design Considerations. The following are general considerations when selecting and designing SCMs.

6.8.4.1 Physical Site Characteristics. Physical characteristics of a site should drive the site design and SCM selection, including topography, vegetation, soils, contributing drainage area, groundwater, baseflows, and karst features. A fundamental concept of low impact design (LID) is preservation and protection of site features including wetlands, drainageways, soils that are conducive to infiltration, tree canopy, etc., that provide water quality and other benefits. LID stormwater treatment systems are also designed to take advantage of these natural resources. For example, if a portion of a site is known to have soils with high permeability, this area may be well-suited for rain gardens or pervious pavement.

6.8.4.2 Space Constraints. Space constraints are frequently cited as feasibility issues for SCMs, especially for high-density development and redevelopment sites. In some cases, constraints due to space limitations arise because adequate space for SCMs is not considered early enough in the planning process. This is most common when a site plan for roads, structures, etc., is developed and SCMs are squeezed into the remaining spaces. The most effective and integrated SCM designs begin by determining areas of a site that are best suited for SCMs (e.g., natural low areas, areas with well-drained soils) and then designing the layout of roads, buildings, and other site features around the existing drainage and water quality resources of the site. Allocating a small amount of land to water quality infrastructure during early planning stages will result in better integration of water quality facilities with other site features. Often, green spaces can be dual purpose for meeting zoning open space/landscaping requirements and stormwater management.

6.8.4.3 Targeted Pollutants and SCM Processes. SCMs have the ability to remove pollutants from runoff through a variety of physical, chemical, and biological processes. The processes associated with a SCM dictate which pollutants the SCM will be effective at controlling. Pollutant load reduction is also affected by hydrologic processes. In addition to pollutant removal capabilities, many SCMs offer channel stability benefits in the form of reduced runoff volume and/or reduced peak flow rates for frequently occurring events. Brief descriptions of several key processes are listed for each SCM in Table 19 below.

Table 19: Key processes by SCM

SCM	Hydrologic Processes			Treatment Processes				
	Peak	Volume		Physical			Chemical	Biological
	Flow Attenuation	Infiltration	Evapo-transpiration	Sedimentation	Filtration	Straining	Adsorption/ Absorption	Biological Uptake
Grass Channel	I	S	I	S	S	P	S	S
Vegetated Filter Strip	I	S	I	S	S	P	S	S
Green Roof	P	S	P	N/A	P	N/A	I	P
Pervious Pavement	P	P	N/A	S	P	N/A	N/A	N/A
Bioretention	P	P[1]	S	P	P	S	S[2]	P
Extended Detention Basin	P	I	I	P	N/A	S	S	I
Retention Pond	P	I	P	P	S	S	P	P

P = Primary; S = Secondary; I = Incidental; N/A = Not Applicable

[1]Depending on presence and design of an underdrain

[2]Depending on soil media

6.8.4.4 Pretreatment. Forebays or other pretreatment is recommended and/or required for SCMs including extended detention and rain gardens. The purpose of forebays is to settle out coarse sediment prior to reaching the main body of the facility. It is extremely important that sediment loading be controlled for SCMs that rely on infiltration, including pervious pavement systems and rain gardens. Pretreatment can ensure long-term functionality and reduce maintenance of SCMs.

6.8.4.5 Volume Reduction. Site design and SCM selection and design should consider runoff volume reduction. Infiltration-based SCMs can be designed with or without underdrains, depending on soil permeability and other site conditions. The most substantial volume reductions are generally associated with SCMs that have permeable sub-soils and allow infiltration to deeper soil strata and eventually groundwater. For SCMs that have underdrains, there is still potential for volume reduction although to a lesser degree. As runoff infiltrates through SCM soils to the underdrain, moisture is retained by soils; the moisture eventually evaporates or is taken up by vegetation, resulting in volume reduction. Runoff that drains from these soils via gravity to the underdrain system behaves like interflow from a hydrologic perspective with a delayed response that reduces peak rates. Although the runoff collected in the underdrain system is ultimately discharged to the surface, on the time scale of a storm event there are volume reduction benefits.

Although effects of evapotranspiration are inconsequential on the time scale of a storm event, on an annual basis, volume reduction due to evapotranspiration in vegetated SCMs such as bioretention can be an important component of the hydrologic budget. Between events, evapotranspiration lowers soil moisture content, providing additional storage capacity for subsequent events. The volume reduction provided by a particular SCM type will be influenced by site-specific conditions and SCM design features.

6.8.4.6 Treatment Train. The term "treatment train" refers to multiple SCMs in series (e.g., a disconnected roof downspout draining to a grass channel draining to an extended detention basin). Engineering research over the past decade has demonstrated that treatment trains are one of the most effective methods for management of stormwater quality (WERF 2005). Advantages of treatment trains include:

- Multiple processes for pollutant removal. There is no "silver bullet" for a SCM that will address all pollutants of concern as a stand-alone practice. Treatment trains that link together complementary processes expand the range of pollutants that can be treated and increase the overall efficiency of the system for pollutant removal.
- Redundancy. Given the natural variability of the volume, rate and quality of stormwater runoff and the variability in SCM performance, using multiple practices in a treatment train can provide more consistent treatment of runoff than a single practice and provide redundancy in the event that one component of a treatment train is not functioning as intended.
- Maintenance. SCMs that remove trash, debris, coarse sediments, and other gross solids are a common first stage of a treatment train. From a maintenance perspective, this is advantageous since this first stage creates a well-defined, relatively small area that can be cleaned out routinely. Down-gradient components of the treatment train can be maintained less frequently and will benefit from reduced potential for clogging and accumulation of trash and debris.

6.8.4.7 Onsite and Subdivision SCMs. SCMs can be onsite, meaning they are located on the lot they are serving, or they can be in subdivision common areas or easements that serve multiple lots. SCMs that serve multiple lots can be an efficient means of meeting water quality requirements in a common facility that is often maintained by a property owners' association. However, a single subdivision SCM may not provide significant runoff volume reduction and does not provide the benefits of a treatment train approach. To achieve these benefits, an extended detention basin might be combined with downspout disconnection. Residential subdivisions usually already incorporate disconnection of roof runoff by directing downspouts to lawns. Disconnection of downspouts is an option for commercial buildings as well. Other options include vegetated filter strips for sheet flow from parking lots, grass channels to convey runoff to the extended detention basin, and other SCMs such as pervious pavement and rain gardens on the individual lots. This treatment train approach can reduce the WQCV and detention volume needed in the extended detention basin while providing volume reduction and a range of water quality treatment processes that will minimize hydromodification and provide better water quality than a stand-alone extended detention basin.

6.8.4.8 Integration with Flood Control. In addition to water quality, most projects will require detention for flood control, whether onsite or in a facility that serves multiple lots. It can be efficient to combine water quality and flood control facilities. Examples include extended detention basins and pervious pavement designed to provide the WQCV and flood control storage. SCMs can also reduce required detention volume through lower curve numbers and decreased time of concentration.

6.8.4.9 On-line SCMs and Offsite Drainage. On-line refers to locating a SCM such that runoff from upstream of the development flows through it. Generally, on-line SCMs to capture the WQCV are strongly discouraged, especially in a natural channel. It is preferable for natural channels to be preserved and SCMs to be located off-line. On-line SCMs may require federal and state permits under Section 404 of the Clean Water Act if located in a jurisdictional waterway. There may be situations where SCMs may be located in an area that receives some offsite drainage. This may be acceptable if the offsite drainage is minimal and will not affect the integrity and functionality of the SCM. In these cases, the SCM does not need to be sized for the WQCV for the offsite drainage but special design considerations may be needed to ensure the SCM can handle the offsite drainage while still providing the intended water quality treatment or volume reduction for the onsite drainage.

6.8.4.10 Land Use, Compatibility with Surroundings, and Safety. SCMs can add interest and diversity to a site, serving multiple purposes in addition to providing water quality functions. Gardens, plazas, rooftops, and even parking lots can become amenities and provide visual interest while performing water quality functions and reinforcing urban design goals for the neighborhood and community. The integration of SCMs and associated landforms, walls, landscapes, and materials can reflect the standards and patterns of a neighborhood and help to create lively, safe, and pedestrian-oriented districts. The quality and appearance of SCMs should reflect the surrounding land use type, the immediate context, and the proximity of the site to important civic spaces. Aesthetics will be a more critical factor in highly visible urban commercial and office areas than at a heavy industrial site. The standard of design and construction should maintain and enhance property values without compromising function (WWE et al. 2004).

Public access to SCMs should be considered from a safety perspective. The highest priority of engineers and public officials is to protect public health, safety, and welfare. SCMs must be designed and maintained in a manner that does not pose health or safety hazards to the public. As an example, steeply sloped and/or walled ponds should be avoided. Where this is not possible, emergency egress, lighting, and other safety considerations should be incorporated. Facilities should be designed to minimize mosquito breeding, which can be a nuisance and a public health concern (e.g., West Nile virus). The potential for nuisances, odors, and prolonged soggy conditions should be evaluated for SCMs, especially in areas with high pedestrian traffic or visibility.

6.8.4.11 Maintenance. Maintenance is an important consideration in SCM selection and should be considered early in the planning and design phase. Even when SCMs are thoughtfully designed and properly installed, they can become eyesores, breed mosquitoes, and cease to function if not properly maintained. SCMs can be more effectively maintained when they are designed to allow easy access for inspection and maintenance and take into consideration factors such as property ownership, type of maintenance, visibility, and vehicle and equipment access. An important consideration for a rain garden with plantings is whether the property owner can commit to maintaining it as a landscape feature that requires weeding, watering, and replacement of mulch just like other site landscaping. Selection of pervious pavement should consider the need for periodic vacuum sweeping.

6.8.5 Plant Selection. Landscaped SCMs are a good choice where landscaping is already required by the zoning regulations, such as interior and perimeter parking lot landscaping and buffer yard landscaping. Such areas can be designed as rain gardens, vegetated filter strips, grass channels, or in some cases, small extended detention basins. Vegetated filter strips, grass channels, and extended detention basins that are turf grass with trees and shrubs are generally easiest to maintain for most property owners because they will already be mowing other areas. Fully landscaped SCMs such as rain gardens with plantings and mulch require a higher level of commitment to maintain, including weeding and re-mulching. Often, non-SCM landscape beds around buildings get maintained very well but landscaped SCMs such as rain gardens get neglected. Fully landscaped SCMs should be designed with a plant palette and mulch that blends in with other landscape beds so that they get maintained equally well. Trees and shrubs are good options for ease of maintenance. When incorporating grasses and perennials, a simple plant palette of a few easily recognizable species will be easier to maintain. Native plants are best adapted to our region's climate and generally require minimal watering once established and no chemical fertilizers or pesticides. Many native plants are particularly well-suited for SCMs because they can withstand wet conditions followed by dry periods. Native plants also provide important habitat and food sources for insects, birds, and animals that play important roles in our ecosystem. For these reasons, Missouri native plants should be selected when choosing plants for SCMs. The native species is preferable, but cultivars of native plants are

acceptable and are sometimes preferred due to characteristics such as being more compact or more readily available. To provide additional flexibility, non-native plants may be used that are climate tolerant to the local hardiness zone. Any non-native species selected shall be non-invasive. Native plant information is available from the Missouri Grow Native! program (www.grownative.org).
Trees are highly recommended for SCMs, including rain gardens and the bottom of extended detention basins (with proper species selection and maintenance procedures to address clogging from leaves). Trees provide stormwater benefits through interception and evapotranspiration of rainfall, improved soil infiltration, and uptake of pollutants. Trees provide many other environmental, social, and economic benefits as well including improved air quality and increased property values.

6.8.6 Operation and Maintenance Plan and Agreement. Water quality SCMs are designed to reduce and/or treat runoff to reduce stormwater pollutant loads and therefore may require higher levels of maintenance to serve their designed functions. An operation and maintenance plan and agreement shall be submitted for approval by the City for all SCMs required to meet water quality requirements, flood control detention requirements, or zoning conditions in City code. Deficiencies identified through self-inspections or inspections by the City shall be addressed in a timely manner.

6.8.7 Stormwater Control Measures.

6.8.7.1 Vegetative Filter Strips. Vegetative filter strips consist either of areas of undisturbed vegetation in good condition, including trees, grass, sod, or other vegetative cover which meets the objectives for this BMP, or areas where new vegetation has been established. Vegetative filter strips shall be provided in areas of sheet flow only. The hydraulic loading for filter strips shall not exceed 0.05 cfs per lineal foot of filter strip length for the fifty percent (50%) AEP (2-year) storm (equal to the runoff per unit width from a four hundred feet (400') length of impervious area).
The minimum width of the filter strip shall not be less than twenty percent (20%) of the length of the sheet flow from the upstream impervious surface, and in no case shall be less than six feet (6'). The slope along the width of the filter strip shall not exceed 4:1 (25%).

Typical details for vegetative filter strips are shown in Figure SS-51.

6.8.7.2 Grass Swales. Grass swales may be provided to convey runoff from vegetative filter strips and impervious areas to BMP’s designed for capture and temporary storage of runoff. Design criteria for grass swales shall be as follows:

1. Maximum side slopes: 4:1.
2. Maximum longitudinal slope: 5%.
3. Minimum longitudinal slope: 1%.
4. Maximum velocity: 2 feet per second for peak flow from the 50% AEP (2-year) storm.

Roughness coefficients for use in the design of grass swales shall be determined as set forth in Section 6.6.2.2. Grass swales shall be lined with sod or seeded and covered with suitable erosion control blanket and mulch.
Typical details for grass swales are shown in Figure SS-52.

6.8.7.3 Directly Connected Impervious Area (DCIA). Impervious areas are considered connected when runoff travels directly from roofs, drives, pavement, and other impervious areas to street gutters, closed storm drains or concrete, or other impervious lined channels.

In order for an impervious area to be considered disconnected, runoff from the area must pass through a vegetative filter strip or other BMP meeting the requirements set forth in this section. For determining the amount of impervious area, the following assumptions shall apply in the absence of more detailed data:

Single Family Lots
Average roof area: 2500 square feet
Average drive area: 800 square feet
Average impervious area per lot: 3500 square feet

Duplexes and Patio Homes
Average roof area: 2500 square feet
Average drive area: 1600 square feet
Average impervious area per lot: 4500 square feet

Multi-Family, Commercial, and Other Areas
The amount of impervious area contained in multi-family, commercial, office and manufacturing developments shall be determined based upon the site plan for the development.

If gutter downspouts are directed to drain toward lawn areas, seventy-five percent (75%) of the roof area shall be considered disconnected.

Connected and disconnected impervious areas are illustrated in Figure SS-50.

6.8.7.4 Permeable Interlocking Concrete Pavers (PICP). Permeable interlocking concrete pavers are comprised of a layer of concrete pavers separated by joints filled with small stones. Water enters joints between solid concrete pavers and flows through an "open-graded" base, i.e., crushed stone layers with no small or fine particles. The void spaces among the crushed stones store water and infiltrate it back into the soil subgrade or into an underdrain. Some general design considerations are listed below:

- The design engineer shall reference the following resources published by the Interlocking Concrete Pavement Institute:
    - Permeable Interlocking Concrete Pavements Manual

    - Tech Spec 18: Construction of PICP Systems
    - The Permeable Design Pro software is recommended to aid in the design.
    - All are available at www.icpi.org.
- The paving units supplied to construct the PICP shall meet the requirements in ASTM C936 and be designed for use as PICP.
- Consideration should be given to the type of traffic loads placed upon the PICP. An engineer experienced with pavement design shall provide input on this aspect early in the design phase.
    - The minimum pavement section subject to vehicular traffic shall be (from top to bottom) 3-1/8-inch-thick paving units, 2-inch-thick bedding stone (typically ASTM No. 8 or 9 stone), 4-inch-thick layer of base stone (ASTM No. 57 or similar size), and a layer of subbase stone (ASTM No. 2 or similar size).
    - The thickness of the subbase will vary depending on storage and anticipated traffic loads as described in ICPI guidance literature. However, a minimum 6-inch-thick subbase will be required for all applications without an underdrain and 9-inch thick when using an underdrain. Alternate paving units and stone thicknesses may be proposed for residential uses or very light traffic loads. The paver joints shall be filled with aggregate meeting manufacturer's specs, typically ASTM No. 8.

6.8.7.5 Bioretention (Rain Garden). Bioretention and rain garden are often used interchangeably to refer to an engineered, depressed landscape area designed to filter, uptake, and infiltrate stormwater runoff through the natural processes of plants, microbes, and soil (APWA/MARC, 2012). The term bioretention refers to the ability of the biomass to retain stormwater and remove pollutants. Bioswale is another related term that often refers to a linear bioretention feature. Depending on in-situ soil and other design considerations, bioretention can be designed without an underdrain to allow full infiltration, or with an underdrain. During a storm, runoff ponds in the depressed, vegetated surface of the bioretention where a combination of processes occurs that includes evapotranspiration and pollutant uptake by plants and, depending on design, infiltration into the underlying in-situ soil and/or filtration through a porous bioretention soil mix before discharging through an underdrain. Bioretention is best suited for meeting the water quality volume requirement but may be designed to contribute towards meeting the flood control detention requirement as well if properly designed.

6.8.7.6 Extended Dry Detention Basins. Extended dry detention basins may be provided to capture and provide temporary storage for the required water quality capture volume. Extended dry detention basins shall be placed outside of the primary watercourses which allow off-site flows to pass through the development (i.e., “off-line”) where possible. Design criteria for extended dry detention basins shall be as follows:

1. <u>Volume.</u> Minimum volume shall be one hundred and twenty-five percent (125%) of the required water quality capture volume (WQCV). Detention basins for water quality may

be combined with detention basins for flood control. Effects of the WQCV may be considered in the design for flood control.

2. Drain time. The WQCV shall be released over a minimum period of twenty-four (24) hours and a maximum period of forty-eight (48) hours.
3. Outlet structure. Outlet structures shall consist of a perforated riser pipe, outlet pipe and gravel filter material as shown in Figure SS-52 and SS-53. The minimum allowable riser pipe diameter is eight inches (8"). The riser pipe shall be connected to an outlet pipe of equal of greater diameter. The outlet pipe shall have adequate capacity to carry the maximum rate of flow from the riser pipe. Material for the riser pipe shall be Schedule 40 PVC, ductile iron, or corrugated, galvanized metal. A removable cap shall be provided at the top of the riser pipe.

The cap shall have a one inch (1") diameter hole for air relief. The outlet pipe shall be bedded in firmly compacted clay, free of stones. For dams exceeding ten feet (10') in height, an anti-seep collar shall be provided around the pipe. The number of rows of perforations, number of perforations per row and diameter of perforations for the riser pipe shall be specified on the plans. Perforation pattern shall be determined based upon orifice calculations to provide for release of the WQCV over the specified time. Perforations shall meet the following requirements:

Minimum perforation diameter: 1/2 inch.
Maximum perforation diameter: 2 inches.

Minimum number of holes per row: 1
Maximum number of holes per row: 3

Minimum row spacing: 4 inches.
Maximum row spacing: 12 inches.

Where the basin is to be utilized as a water quality BMP only, twelve inches (12") minimum freeboard shall be provided above the WCQV.

A typical plan and section for extended dry detention basins is shown in Figure SS-55.

6.8.7.7 Extended Wet Detention Basins. Extended wet detention basins may be provided to capture and provide temporary storage for the required water quality capture volume. Extended wet detention basins shall be placed outside of the primary watercourses which allow off-site flows to pass through the development (i.e., “off-line”) where possible. Design criteria for extended wet detention basins shall be the same as for extended dry detention basins, with the following exceptions:

- The volume of the permanent pool should not be less than 1.0 to 1.5 times the WQCV.
- A bench area (littoral zone) with a width of ten feet (10') shall be provided as shown in Figure SS-56. It is preferred that emergent aquatic vegetation be provided in this zone.

- It is recommended that a minimum of twenty-five percent (25%) of the WQCV be provided in the upper eighteen inches (18") of depth. A maximum of fifty percent (50%) of the permanent pool volume shall be provided in the upper eighteen inches (18") of depth.
- The depth of the principal portion of the permanent pool shall be a minimum of four feet (4').
- It is preferred that a forebay meeting the same requirements as specified for dry detention basins, be provided.
- Where perforated riser pipes are not encased in gravel, only corrugated metal or ductile iron pipes may be used.

Where the basin is to be utilized as a water quality BMP only, twelve inches (12") minimum freeboard shall be provided above the WCQV.

A typical plan and section for extended wet detention basins is shown in Figure SS-56

6.8.7.8 Trickle (Low Flow) Channels. Trickle channels shall be provided to provide grade control and to minimize chronic wet areas. Trickle channels shall be constructed of six inch (6") stone or other porous medium.

A typical trickle channel cross section is shown in Figure SS-54

6.8.7.9 Sand Filters. Runoff from fueling plazas, vehicle maintenance areas, solid waste storage or transfer areas, and other areas having potentially high concentrations of contaminants shall be passed through a sand filter prior to discharge to receiving water. Total impervious area draining to a sand filter will generally be one (1) acre or less. Sand filters shall be provided with a sedimentation chamber and a filtration chamber.

A typical sand filter is shown in Figure SS-57

6.8.7.10 Other Structural SCMs. Constructed wetlands, porous pavements and other structural BMPs for which detailed design criteria can be documented in generally accepted literature can be provided in addition to, or in lieu of, the BMPs described above, provided the objectives of this section can be met. The use of infiltration basins and trenches is discouraged due to possible adverse impacts on groundwater.

6.8.8 Stormwater Control Measures – Basin Design Criteria.

6.8.8.1 Forebay. It is preferred that a forebay be provided to dissipate energy from incoming flows and to trap settleable sediment entering the basin. The forebay should be separated from the remainder of the basin by an earth dike. The top of the dike shall be set six inches (6") above the stage of the WQCV. Outflow from the forebay to the basin shall be through a gravel filter. The top of the gravel filter shall be set equal to the stage of the WQCV. The volume of the forebay shall be a minimum of ten percent (10%) and a maximum of twenty percent (20%) of the WQCV. The volume of the forebay is considered to be part of the required WQCV, not additional volume.

6.8.8.2 Length to Width Ratio for Detention Basins. The optimal length to width ratio for a water quality detention basin is four (4). The length to width ratio should be no less than two (2). The minimum allowable length to width ratio is one (1).

6.8.8.3 Overflow Spillways. Where the basin is to be utilized as a water quality BMP only, a spillway or outlet structure capable of passing the peak flow from a 1% AEP (100-year) storm for the drainage area upstream of the basin, shall be provided. The lowest point on the spillway or outlet structure shall be set at the top of the WCQV.

6.8.9 Operation and Maintenance. The city of Battlefield provides no maintenance of water quality BMPs located on private property. Maintenance must be provided by the owner of the property upon which the BMP is located. Extended detention basins and wetlands or other “capture and storage” BMPs shall be located within a single lot or property, within a designated drainage easement. Where BMPs are located in common areas or adjoining off-site areas, the property upon which the BMP is located shall remain in the ownership of the developer or property owners’ association. Where a property owners’ association is formed, restrictive covenants which provide for collection of fees for maintenance of the BMPs shall be filed in the office of the Greene County Recorder of Deeds. Restrictive covenants must be approved by the City legal counselor prior to filing of the final plat.

6.9 SINKHOLES AND KARST FEATURES

6.9.1 General. The City of Battlefield is located on the Springfield Plateau of the Ozarks physiographic region. The area is underlain by Mississippian Age limestone, which is highly susceptible to solutional weathering. This geology is commonly referred to as “karst” and is characterized by numerous sinkholes, losing streams, springs, caves, fracture trends, and other related features. As a result, a complex and often fragile interaction exists between surface and groundwater, requiring special consideration and protection. Development in areas with karst geology can present certain hazards, such as unstable soil foundation for structures, flood hazards, groundwater contamination, and public safety hazards related to collapses. Requirements, design standards, and methods to address these hazards and protect karst features are contained in this chapter.

The general policy in addressing karst hazards and features shall be based on the following stepped approach:

- Avoidance – Construction in or around karst features shall be avoided. Exceptions will be made only in situations where it can be conclusively demonstrated that there are no practical alternatives to such construction.
- Minimization – In cases where there is no practical alternative to avoid karst features, measures which will have minimal impact on the karst feature or receiving water may

be proposed. Plans for minimal alteration can be approved provided it is conclusively demonstrated that the proposed plan has the least impact to others or the environment.

- Mitigation – Potential impacts of construction on karst features and receiving waters must be studied and assessed, and recommendations made for mitigation of potential impacts upon flooding, structural stability, and groundwater quality before the development plan can be approved. The degree and sophistication of study required will increase in proportion to the potential impacts.

Because karst features can occur in carrying forms and severity, each feature must be addressed on an individual basis. However, for the purpose of establishing standards, sinkholes will be referred to in this chapter as being in one of two broad categories: solution sinkholes or collapse sinkholes.

- Solution sinkholes have a defined drainage area and will generally be shown on topographic maps as a depression. Development concerns related to solution sinkholes that must be addressed include flood hazards and soil stability within the geologic rim. When runoff from a development is draining to a solution sinkhole, impacts to groundwater quality must be addressed through water quality protection measures.
- Collapse sinkholes are areas of karst-related subsidence with no defined drainage area when occurring outside of a solution sinkhole. Collapse sinkholes can occur within a solution sinkhole and are commonly referred to as an "eye". Stabilization of collapse sinkholes requires a permit from the Building Department. A report by a qualified professional may be waived if the feature is a minor feature outside of the geologic rim of a solution sinkhole and no development is proposed in the area. For public health and safety reasons, small collapses outside of a solution sinkhole to be filled and stabilized in accordance with the City standard or recommendation of a qualified professional that is approved by the city.

6.9.2 Definitions.

Sinkhole: Any depression in the surface of the ground, with or without collapse of adjacent rock, that provides a means through which surface water can come into contact with subsurface water. Sinkhole depressions may be gradual or abrupt; they may or may not have a well-defined eye. While most sinkholes can be defined as the area within a "closed contour", some sinkholes, such as those located on the sides of hills and in stream valleys, may not. All sinkholes provide discreet points of recharge to groundwater.

Sinkhole Watershed: The ground surface area that provides drainage to the sinkhole. This area extends beyond the sinkhole depression and generally crosses property boundaries.

Virgin Sinkhole: A sinkhole which has never been altered or disturbed.

Altered Sinkhole: A sinkhole which has been filled, excavated, or otherwise disturbed.

Collapsed Sinkhole: A subsidence or cave-in of the ground surface caused when soil overburden can no longer be supported by underlying strata due to the presence of subsurface solution cavities.

Sinkhole Eye: Generally, a visible opening, cavity, or cave in the bottom of a sinkhole, sometimes referred to as a swallow hole.

Sinkhole Rim: The perimeter of the sinkhole depression. The sinkhole rim will generally vary in elevation.

Sinkhole Cluster Area: An area containing two (2) or more sinkholes located in close proximity, generally interconnected by groundwater conduits.

Terminal Sinkhole: The lowest sinkhole in a sinkhole cluster to which any surface water overflowing from other sinkholes in the cluster will flow.

Sinkhole Flooding Area: The area inundated by runoff from a storm with an annual exceedance probability of one percent (1%) and a duration of twenty-four (24) hours (eight inches (8") in Greene County).

Qualified Geologist: A person registered to practice geology according to the laws of the State of Missouri, and who by reason of technical education and experience has a background in the fundamentals of storm drainage and karst geology.

Qualified Professional Engineer: A person registered to practice engineering according to the laws of the State of Missouri, and who by reason of technical education and experience has a background in the fundamentals of storm drainage and karst geology.

Heavy Equipment: Motorized equipment having a gross weight of more than six (6) tons.

Light Equipment: Motorized equipment weighing six (6) tons or less.

6.9.3 Sinkhole Permit and Report Requirements. A grading permit must be obtained prior to any alteration of sinkholes or if any construction including the operation of any motorized equipment is within 100 feet of a cave, spring, or losing stream, or within 25 feet of a sinkhole rim, as defined by the most restrictive of the following: geologic rim as determined by a qualified professional engineer or geologist, topographic rim as determined by a qualified professional engineer or geologist, sinkhole rims shown on available sinkhole maps, or other best available data.

6.9.3.1 Permit Requirements. Application for a sinkhole permit requires the following:

1. A plan must be submitted containing measures to minimize impacts on the sinkhole. The plan shall contain a sinkhole evaluation, geologic evaluation, and flood evaluation, where applicable.
2. An analysis of the drainage from a development to a sinkhole must be provided.
3. In general, development within the rim of a sinkhole is prohibited; however, in special circumstances when no other practical alternative exists and documentation is provided in accordance with this chapter, the City engineer and Building inspector may approve development within the rim of a sinkhole provided the developer can demonstrate there will be no significant impacts upon flooding, stability of structures, water quality, or other natural resources on the site or adjoining properties.
4. For any land with a required sinkhole-related non-buildable area or restricted fill area, the developer shall place the following notes on the final subdivision plat and/or development plan:
    a. The sinkhole-related non-buildable areas or restricted fill areas shown on this plan have been determined based on the study and recommendation of a professional engineer or geologist. However, approval of this plan is not to be interpreted as any guarantee that future sinkhole activity will not occur due to either natural or human activities.
    b. Any sinkhole-related non-buildable area identified here has been determined to be unsuitable for any construction activity, and no buildings, parking areas, land disturbance or other structures shall be permitted within this area.
    c. Any sinkhole or restricted fill area identified here has been determined to be unsuitable for soil bearing foundation, and the entire structure of any building (including the floor system) constructed therein must be founded on solid rock, or as determined by the director of building development services.
    d. The lowest enclosed space of any structure within or adjacent to a sinkhole flooding area shall be a minimum of five (5) feet above the flooding elevation where there is no overflow from the sinkhole from the critical flood event, or one foot above the flooding elevation determined by the overflow elevation calculated for the critical flood event, whenever the difference between the topographic rim and flooding elevation is less than five (5) feet.
    e. Water quality protection measures must be provided.

6.9.3.2 Sinkhole Evaluation. A written evaluation including the following information shall be made for all development sites upon which sinkholes are fully or partially located. The sinkhole evaluation report must include the following items:

6.9.3.2.1 Site Plan and Area Map. The site plan must show the following item with respect to location of proposed construction, proposed or existing property lines, and existing structures:

1. <u>Sinkholes.</u>
    a. Location and limits of the area of the sinkhole depression as determined by field surveys or other reliable and accurate methods (location of sinkholes based

solely upon USGS 7-1/2 Minute Series Quadrangle Maps will not be considered sufficient unless field verified).

b. Location and elevation of the sinkhole eye or low point.
c. Topographic contours at maximum intervals of one foot (larger contour intervals may be used if deemed sufficiently accurate), and spot elevations sufficient to determine the low point on the sinkhole rim and the profile of the potential overflow area.
d. Minimum elevation at which floodwaters can gain entry to any existing structures located within or on the sinkhole rim.
e. Elevation of any roadway located within or adjacent to the sinkhole.

2. Other Geologic Features. Location of caves, springs, faults, fracture trends, and geologic mapping units based upon the information from the Greene County Resource Management Department or other reliable sources.

3. Sinkhole Flooding Area. See Section 6.9.3.2.2 below.

4. Existing Watercourses. Storm sewers, culverts, or other existing watercourses which drain into the sinkhole.
5. Proposed Discharge Points. The location type and size of all points at which concentrated discharges of stormwater into the sinkhole are proposed. The drainage area to each point of concentrated discharge shall be delineated on the plan and the size of drainage area noted.

6. Supply Sources. Existing and proposed wells or other water supply sources.

An area map showing the sinkhole watershed area must be provided. Where the site is located in a sinkhole cluster area, the map area shall be extended to include in the watershed area any sinkholes located downstream of the site which may receive overflow drainage from the site.

The approximate location of public or private water supply sources such as springs or wells within five hundred feet (500') of the site, and boundaries of any known recharge areas to wells, springs, or caves as determined from information available from the Greene County Resource Management Department, Watershed Committee of the Ozarks, Missouri Department of Natural Resources, Missouri Department of Conservation, or other reliable sources shall be shown.

6.9.3.2.2 Flooding Evaluation. Maximum estimated flooding elevations shall be determined for each sinkhole for both pre-project and post-project conditions, assuming no subsurface outflow from the sinkhole.

1. Runoff Volume. The volume of runoff considered shall be that which results from a rainstorm with an annual exceedance probability (AEP) of one percent (1%) (100-year

storm) and a duration of twenty-four (24) hours. The runoff volume shall be determined by the SCS Curve Number Loss Method.

2. Sinkhole Flooding Area. For sinkholes with a tributary drainage area small enough that it is unlikely the entire sinkhole would flood, the sinkhole flooding area can be conservatively estimated as the area below the low point on the sinkhole rim without further analysis.

   Where the estimated volume of runoff exceeds the volume of the sinkhole depression, the depth of overflow shall be estimated (using reservoir routing methods), and the sinkhole flooding area can be estimated as the area below the maximum flooding elevation. Where the volume of the sinkhole is sufficiently large that storage in the sinkhole depression will materially affect estimated outflow rates, reservoir routing can be performed, if desired, to determine the maximum flood stage in the sinkhole.

   In sinkhole cluster areas, the overflow volume shall be included in determining the maximum estimated flooding elevations in the next downstream sinkhole. This analysis shall continue downstream until the lowest sinkhole of the sinkhole cluster is reached or until overflow reaches a surface watercourse.

3. Flooding Considerations. No further flooding analysis will be required provided that the post-project flooding area of any sinkhole which receives drainage from the site is located entirely on the development site.

   If the post-development sinkhole flooding area is located fully or partially on another property, the following conditions apply:
   a. The post-development sinkhole flooding area shall be contained within a drainage easement restricting structures, and
   b. Any flow leaving the proposed development shall be contained within a drainage easement until it reaches the receiving sinkhole. This easement shall contain the runoff from the critical storm event with an annual exceedance probability of one percent (1%). The critical storm event is defined as the storm event with an annual exceedance probability of one percent (1%) that produces the highest peak flow, regardless of duration.
   c. Where it is not possible for a drainage easement to contain the sinkhole flooding area, it must be shown that:
      i. The proposed development will not cause a rise in the flood elevation within a reasonable tolerance (0.1 ft), or
      ii. The impacts of both the proposed development and any future developments in the watershed will not impact any existing structures or improvements and will not increase the flooding elevation by more than one foot. The increase in the flooding elevation shall be distributed proportionately based on watershed size e.g., if the development is twenty (20) percent of the watershed then they can increase the flooding

elevation by twenty (20) percent of one foot or 0.2 feet. This can be determined by calculating the runoff rates and volumes from the entire watershed, assuming fully developed conditions based on current zoning and potential future land use and calculating the resulting water surface elevation (WSE).

iii. The following alternatives, listed in order by preference, may be used individually or in combination, if needed, to comply with a or b:
    1. Stormwater Control Measures (SCMs) that reduce runoff volume such as bioretention, pervious pavements, etc. Small-scale, distributed practices are preferred over centralized, large-scale practices in karst areas.
    2. Detention Storage – Since traditional detention storage has little to no impact on the volume of runoff from a site, it is seldom the solution for impacting the WSE of an adjacent sinkhole. However, in the case where detention is warranted, the following conditions must be met:
        a. It must be shown that the peak basin outflow is less than the existing peak rate of runoff from the site and less than the discharge rate of the sinkhole. (See below).
        b. Compensatory excavation within the sinkhole flood area – Karst features can have a significant, and often unknown, impact on subsurface hydrology and groundwater quality. Therefore, compensatory excavation within the sinkhole flooding area will generally not be permitted. In rare cases, where there are exceptional conditions, alternative measures, such as compensatory excavation, may be permitted with the approval of the City engineer and Building Inspector provided the following conditions are satisfied:
            i. Such alternative creates no adverse impact on groundwater, sinkhole stability, flood conditions, or other properties. If, at the City's discretion, excavation to the sinkhole has the potential to cause an adverse impact, the City may deny the request to excavate within the sinkhole.
            ii. A comprehensive erosion and sediment control plan is developed to keep sediment confined to the excavation site. This plan would likely include additional control measures and inspection beyond the scope of a traditional plan.

The lowest enclosed space for all new structures within or adjacent to a sinkhole flooding area shall be:

A minimum of five (5) feet above the flooding elevation where there is no overflow from the sinkhole from the critical flood event, or

One-foot (1’) above the flooding elevation determined by the overflow elevation calculated for the critical flood event, whenever the difference between the topographic rim and flooding elevation is less than five (5) feet.

When existing improvements are below the 100-year flooding elevation, an evaluation of the impacts during higher frequency or shorter duration rainfall events may be required. It shall be shown that runoff rates and volumes from a proposed development will not increase the flooding frequency for any such structure or improvement.

4. Detailed Flooding Analysis. In cases where the conditions set forth in the section immediately above cannot be met, detention basins must be constructed outside of the sinkhole flooding area. The detention facility must have sufficient volume to store the increase in total runoff volume due to the development. Outflow rates cannot exceed pre-project values.

5. Determination of Discharge Capacity of Sinkhole. In the event that the discharge rate of a sinkhole needs to be estimated in order to size off-site detention, the following guidance is provided:
    a. The stage-discharge relationship for the sinkhole shall be estimated by monitoring the sinkhole during at least two storm events exceeding one inch (1”) of runoff in a 6-hour period.
    b. The sinkhole shall be monitored immediately after the storm event to document the stage at various times to better estimate the stage-discharge relationship.
    c. In sinkhole complexes, receiving or terminal sinkholes must also be analyzed if they receive overflow from upstream sinkholes.
    d. Rainfall depths and intensities shall be determined based on a recording rain gauge or readings from the nearest City of Springfield rain gauge at 15-minute intervals.
    e. The discharge rate shall be estimated by adjusting the stage-discharge relationship of the reservoir routing model until the reservoir stages in the model correlate with the observed stages in the sinkhole (within 0.1 feet).
    f. The maximum observed stage in the sinkhole shall be surveyed and photographs provided where debris lines are used as evidence of the maximum stage.
    g. The volume of runoff storage in the sinkhole(s) can be counted toward stormwater detention requirements, provided that erosion and sediment control and water quality requirements, in accordance with city code and this manual, are satisfied.

6. Diversion to Surface Watercourse. As an alternative, where feasible, increased post-project runoff may be diverted to a surface watercourse, provided that any increase in peak runoff rate in the receiving watercourse does not create or worsen existing

flooding problems downstream, and the diverted stormwater remains in the same surface watershed.

Storm sewers, open channels, and other appurtenances provided for diversions shall be designed in accordance with applicable sections of these Design Standards.

The effect of diverted water on downstream watercourses and developments, and requirements for additional detention facilities prior to release of runoff to the surface watercourses shall be determined as set forth in Chapter 6.7. Effects of the diversion shall be shown by reservoir routing analysis. Routing of excess runoff shall be considered satisfactory when it can be demonstrated that the post-project flooding elevation in the sinkhole is at least one foot (1') below the minimum elevation at which floodwaters can gain entry to any existing structures and does not exceed the pre-project flooding elevation by more than one foot (1') in any case.

6.9.3.3 Water Quality Protections. Sinkhole conduits provide direct recharge routes to groundwater. As a result, these conduits provide a route for polluted runoff to enter drinking water supplies that are otherwise protected and often being consumed with no treatment. Protection of water quality entering sinkholes protects the quality of area wells, caves, springs, and streams.

With regard to groundwater quality, three (3) factors must be considered: receiving groundwater use, relative groundwater contamination hazard associated with the proposed development, and water quality management measures to reduce pollutant levels.

1. Receiving Groundwater Use. The Sinkhole Evaluation Report shall identify whether the site lies within a critical area based upon information available from the Greene County Resource Management Department or other reliable sources. Where disagreements may arise over whether a site is located within a particular recharge area, dye tracing may be required for confirmation of the destination of water discharged through the sinkhole.
    a. Critical Areas. The following areas are classified as critically sensitive to contamination from urban runoff:
        i. Areas with one hundred feet (100') of private water supply wells.
        ii. Areas with three hundred feet (300') of public water supply wells.
        iii. Areas within five hundred feet (500') of springs used for public or private water supply.
        iv. Areas within one thousand feet (1000') of caves providing habitat to rare or endangered species such as the Ozark cavefish.

    The distances listed above may be extended in any instance where the recharge area for a well, spring, or cave has been determined by studies by a qualified engineer or geologist.

   b. Sensitive Areas. All other sinkhole areas will be classified as sensitive for groundwater contamination.

2. Groundwater Contamination Hazard. The relative potential for groundwater contamination will be classified as moderate, high, or very high depending upon the type of land use, development density, and the amount of directly connected impervious area.
   a. Moderate Hazard
      i. Residential developments on sewer, provided directly connected impervious areas discharging to the sinkhole is less than one (1) acre.
      ii. Parks and recreation areas.
      iii. Low density commercial and office developments provided directly connected impervious areas discharging to the sinkhole is less than one (1) acre.
      iv. Discharge from land disturbance areas less than one (1) acre.
   b. High Hazard
      i. Concentrated discharge from streets, parking lots, roofs and other directly connected impervious areas having an area greater than one (1) acre and less than five (5) acres.
      ii. Multifamily residential developments and higher intensity office developments provided the directly connected impervious areas discharging to the sinkhole is less than five (5) acres.
      iii. Discharge from land disturbance areas greater than one (1) acre and less than five (5) acres.
   c. Very High Hazard
      i. Collector streets in industrial and manufacturing zones, all arterial streets, and highways.
      ii. Railroads.
      iii. Concentrated discharge from streets, parking lots, roofs and other directly connected impervious areas having an area greater than five (5) acres.
      iv. Commercial, industrial, and manufacturing areas in Zoning Districts C-2, M-1, and M-2.
      v. Individual wastewater treatment systems.
      vi. Commercial feedlots or poultry operations.
      vii. Discharge from graded areas greater than five (5) acres.

3. Water Quality Management Measures. For sinkholes where the surrounding drainage area is small enough that the area draining to the sinkhole flows predominantly as "sheet flow", potential impacts on water quality can be addressed in many cases by erecting and maintaining reliable silt control barriers around the sinkhole during construction and providing a vegetative buffer area around the sinkhole to filter out potential contaminants.

Where inflow is concentrated, the degree of effort required to capture and filter out contaminants increases significantly. Concentrated inflow occurs naturally when the sinkhole watershed area reaches a sufficient size for watercourses leading into the sinkhole to form. Concentrated surface flows result as urbanization occurs due to construction of roads, storm sewers, and drainage channels. Subsurface flows can become concentrated through utility trenches. Required water quality management measures are as set forth below:

a. Moderate Hazard
   i. Sediment and Erosion Control

      Existing ground cover shall not be removed within twenty-five feet (25') of the sinkhole flooding area, and a silt barrier shall be erected and maintained around the outer perimeter of the buffer area. Vegetative cover must be of sufficient quality and density to provide desired filtration.

      A ditch check(s) will be required at each point where concentrated flow is discharged into the sinkhole.

   ii. Permanent Management Measures

      Where flow into the sinkhole occurs as sheet flow, water quality requirements can be satisfied by maintaining a permanent vegetative buffer area with a minimum width of twenty-five feet (25') around the sinkhole flooding area.

      Concentrated flows may be discharged into the sinkhole through grassed swales and channels designed for non-erosive velocities. Temporary erosion control measures such as sodding, or erosion control blankets shall be provided.

b. High Hazard
   i. Sediment and Erosion Control

      A sediment basin will be required at each point where concentrated flows are discharged into the sinkhole.

   ii. Permanent Management Measures

      Extended wet or dry detention basins shall be provided at all points of concentrated discharge. Other Best Management Practices may be specified provided that their performance is equal to that of extended detention basins.

c. Very High Hazard
   i. Sediment and Erosion Control

      A sediment basin will be required at each point where concentrated flows are discharged into the sinkhole. Specific limits may be placed on the area which can be graded at any one time and on the length of time allowed from initial disturbance to stabilization.

ii. Permanent Management Measures

Runoff from all areas must pass through extended wet or dry detention basins. Other Best Management Measures may be specified provided that their performance is equal to that of extended detention basins.

6.9.3.4 Development Requirements.

1. Stormwater Detention in Sinkholes

   Where flooding considerations and water quality considerations can be met, the volume of runoff storage in sinkholes can be counted toward stormwater detention requirements. Excavation within the sinkhole flooding area to provide additional detention storage is not allowed.

2. Modification of Sinkholes to Increase Outflow Rates

   Increasing outflow rates in sinkholes by excavating the sinkhole eye or installing disposal wells for diverting surface runoff to the groundwater system is prohibited, unless clear and imminent danger to public health and safety can be demonstrated.

3. Setback and Use Restrictions
   a. New construction of any of the following shall not be permitted within twenty-five feet (25') of the sinkhole rim, unless special measures are approved to address structural and water quality concerns:
      i. Commercial or industrial structures.
      ii. Streets, highways, or parking lots.
      iii. Storage yards for materials, vehicles, and equipment.
      iv. Sanitary sewer lines.

   b. New construction of any of the following may be permitted within the sinkhole rim provided that they are set back a minimum of twenty-five feet (25') of the sinkhole flooding area:
      i. Residential structures provided the lowest floor elevation is set a minimum of five (5’) feet above the sinkhole flooding elevation, or one foot (1') above the lowest elevation on the sinkhole rim, whichever is less, and provided that a statement of a qualified engineer is submitted indicating that foundation conditions are suitable for residential structures.
      ii. Swimming pools.
      iii. Underground utilities other than sanitary sewer, if provisions are made to prevent migration of groundwater along the trench.

c. Use of pesticides and fertilizers within twenty-five feet (25') of the sinkhole rim is prohibited, unless such usage is in accordance with a management plan approved by the City of Battlefield.
d. Use of heavy construction equipment is prohibited.
e. Recreational facilities such as hiking, jogging, and bicycling trails, playgrounds, exercise courses, and grass playing fields are permitted within the sinkhole flooding area provided they are not located within the eye of the sinkhole.
f. Clearing and pruning of trees and undergrowth, and limited grubbing of roots is permitted.
g. Landscaping and minor gardening is permitted outside of the sinkhole eye provided erosion and sediment discharge is limited through use of minimum tillage and mulches.
h. Construction of light incidental landscaping and recreational structures such as playground equipment, etc., is permitted except in the sinkhole eye.
i. Facilities which involve storage or handling of hazardous or toxic materials shall not be permitted in sinkhole watershed areas.
j. No public street shall be placed below an elevation of at least one foot (1') above the sinkhole flood elevation resulting from the 100-year, 24-hour rainfall with no outlet.

4. Collapsed Sinkholes

   Collapsed sinkholes may be stabilized and filled using approved techniques provided a sinkhole evaluation has been completed by a qualified engineer or geologist, and a Grading Permit is issued prior to construction. An example of such stabilization can be found in Figure SS-4

   The probable cause of the collapse and potential adverse impacts of filling the collapse shall be investigated and information submitted with the Grading Permit application.

6.9.4 Other Karst Features. In addition to sinkholes, other karst features shall be protected including caves, springs, losing streams, and exceptional geologic features.

6.9.4.1 Caves. Any cave feature that may be accepting or discharging water shall be treated as a sinkhole eye with all applicable restrictions and setbacks. No proposed construction shall be located within 100 feet (100') of a known cave alignment unless a report prepared by a qualified professional engineer or geologist is submitted and approved by the City of Battlefield, verifying that the cave will not be materially altered by the development, and sound foundations or the support for the development will not be subject to collapse or undue settling.

The entrances of caves shall be protected against unauthorized entry, while allowing for the unimpeded flow of groundwater and without disruption to habitat for cave-dwelling animal species. Plans for cave entrance protection must be approved by the City of Battlefield prior to construction.

6.9.4.2 Springs. No new construction will be permitted within one hundred feet (100') of a spring unless a report, prepared by a qualified engineer or geologist verifying that the quantity and quality of the spring flow will not be materially altered by the proposed construction, is submitted, and approved by the City of Battlefield.

6.9.4.3 Other Features. Developments containing any other significant karst features shall be designed to protect the features to the maximum extent practicable, shall take measures to protect all improvements from potential impacts, and shall take measures to protect the health, safety, and welfare of the public.

6.10 EASEMENTS AND MAINTENANCE

6.10.1 General. Drainage easements shall be provided for all conveyances of runoff to the public drainage system outside of public right-of-way. The public drainage system begins at the point where drainage from one property or public right-of-way drains onto another property or public right-of-way. The required easement widths and maintenance responsibilities for the drainage system are covered in this chapter.

Proper maintenance of stormwater control facilities is essential for effective flood control, water quality management, and the health, safety, and welfare of the public. Maintenance includes both routinely scheduled activities and non-routine repairs that may be required after heavy storm events or other unforeseen problems. Designing facilities with maintenance in mind is critical for long-term functionality. Successful long-term maintenance is dependent on many factors, including appropriate design, good access, a maintenance plan that is adequately developed and funded, and maintenance practices that are in accordance with good public works standards.

Easements for the storage and conveyance of stormwater and maintenance of the stormwater system may be established by any of the following methods:

- Identification on a recorded plat drawing.
- Recording the easement in written form (paper easement).
- Prescriptive easement. (Easements that a public entity inherently owns along waterways that are part of the public drainage system or have been historically improved and maintained by the public entity.)

This chapter provides a performance-based maintenance standard to maintain function and safety throughout the stormwater system. The guidelines provided herein to achieve this standard are not all-inclusive and should be applied with common sense and good engineering judgment.

6.10.3 Inspections. Regular inspections of stormwater control measures and drainage facilities are key to maintaining a properly functioning and safe drainage system. At a minimum, inspections should be made by property owners on an annual basis. In addition, inspections should occur on a regular basis, particularly after rainfall, to determine if any changes have occurred that require action to maintain the functionality and safety of the drainage system.

6.10.4 Easement Requirements. Drainage easements shall be provided for all public drainages flowing across any proposed development. Generally, private, onsite drainage does not require a drainage easement. In some cases, additional drainage improvements and easements may be required upstream or downstream of a new development to address potential impacts of the development.

6.10.4.1 Minimum Boundaries. Easements must be provided to contain the 100-year flow based on proposed elevation contours of the site and fully developed conditions of the contributing watershed. The minimum width of a required drainage easement is determined based on the type of drainage facility, as summarized in Table 20 below, assuming the improvement is centered within the easement. Additional width may be required for maintenance access.

Table 20: Minimum Easement Widths

Minimum Easement Widths	
Inside Horizontal Dimension	**Minimum Easement Width**
15" - 48"	15 feet
54" - 72"	17.5 feet
84" & 96"	20 feet
Over 96"	Approval Required

6.10.4.1.1 Enclosed System. Easements for an enclosed drainage system and constructed open channels must be adequate to allow for future maintenance of the structure, including its possible removal and replacement. Flowline depths greater than four feet (4”) may warrant widths exceeding these minimums. When the flowline depth of an enclosed drainage system or constructed open channel exceeds 4 feet, the drainage easement should extend from the edge of the structure for a distance equal to the depth of the flowline plus 1 foot (1’). If the enclosed system is designed for the 25-year flow and the 100-year flow results in an overflow on the ground surface, the required easement width will shall be governed by the width of the ground surface overflow if it is wider than the minimums listed in the table above.

6.10.4.1.2 Constructed Open Channels. Easements must be adequate to allow for future maintenance of the channel, including possible removal and replacement. In the case of vegetated channels, the easement shall cover the entire channel. In the case of structural channels, the easement shall extend five feet (5') beyond the outside edge of the top of the structure. When the flowline depth exceeds four feet (4'), the drainage easement should extend from the edge of the structure for a distance equal to the depth of the flowline plus 1 foot. In any event the width of the easement shall not be less than that required to contain the 100-year flow.

6.10.4.1.3 Natural Channels. Easements must be adequate to encompass the 100-year flood boundary under fully developed watershed conditions and the most restrictive flow conditions.

6.10.4.2 Land Use Restrictions. Drainage easements are areas that, based on engineering analysis, have been determined to be necessary for the conveyance of the 100-year flow, are anticipated to be inundated by the 100-year flood, or are necessary for the maintenance of the drainage system. These areas must be kept free and clear of obstructions that could impede the flow of water, development that could be damaged by inundation, or development that could create a safety risk or nuisance for the public. No grading or placement of fill, structures, fences, or parking lots shall be permitted within a drainage or detention easement without approval by the Building Inspector. Such approval may require an engineering analysis to clearly demonstrate any of the following:

- There will be no flooding impact on adjacent properties.
- The 100-year flood will remain within a drainage easement.
- No safety hazard or nuisance to the public will be caused.
- The drainage system can be properly maintained.
- For structures, the proposed structure must be properly flood-proofed as required by Building Development Services. When encroachment into the easement involves an enclosed structure, the area of encroachment shall be vacated as a drainage easement.
- For parking lots, there shall be no water depths in the area exceeding 12twelve inches (12") during the 100-year flood.

For fences, an exception will be made when it can be shown that reasonable action has been taken to allow for the conveyance of the 100-year flow, and the conditions listed above have been met. Chain link fences are generally considered to be acceptable in drainage easements with the exception of areas where concentrated flows exist, and vegetation or other debris may collect on the fence.

The City, as necessary to maintain the drainage system and the flow of water, retains the right to remove any structures, fences, fill, or parking lot or other facility used for the movement of Vehicular or pedestrian traffic placed within a drainage easement without approval of the Building Department.

The construction of buildings and other permanent structures over the public stormwater system should be avoided to the maximum extent practicable. Where no feasible alternative exists, a structure may be built over the public stormwater system upon the approval of the

City Administrator and execution and recording of a build over agreement on a form provided by the City which at a minimum shall specify the following:

- City shall have the right to repair, maintain and replace the stormwater infrastructure as may be necessary, including the right to enter property, excavate and remove portions of the building or structure as may be required to gain access to the stormwater infrastructure in connection with such work.

- Any damage to a building or structure resulting from repair, maintenance, or replacement of the stormwater infrastructure shall be the sole responsibility of the property owner.

6.10.5 Maintenance Responsibility. Maintenance of drainage facilities is generally the responsibility of the entity owning the facility. Maintenance responsibilities may be further clarified in other legally binding documents such as recorded final plats, recorded paper easements and subdivision covenants. Additionally, information regarding how the facility is to be maintained may be found in the original construction documents and approved operation and maintenance plan and agreement.

6.10.5.1 Subdivisions. Generally, all drainage facilities in new subdivisions that are outside the public right-of-way shall be maintained by a property owners association or the property owner. Larger facilities within a subdivision, such as detention basins, channels, and large boxes and pipes, shall be located within a Common Area that is owned and maintained by the association. The following statement shall be placed on all final plats:

All Common Areas shall be considered drainage easements. All Common Areas are to be maintained by the property owner's association. All drainage easements are to be maintained by the property owner.

Smaller facilities within a subdivision, such as small pipes and swales, are typically within a drainage easement maintained by the property owner. Generally, for facilities maintained by individual homeowners, the property owner must maintain the surface (trash pickup, mowing, minor erosion repair), and the City will correct major deficiencies such as structural failure of a box, pipe or wall, or a major erosion problem.

If the party with primary responsibility fails to properly maintain any drainage facility and the City has notified the party of the deficiency, the City shall have the right to enter the property in order to maintain the facility and charge the primary responsible party for any costs associated with the work.

6.10.5.2 Existing Facilities with No Easement. Existing drainage facilities that are not within a drainage easement shall be maintained by the property owner. On major waterways where it is determined the City has a prescriptive easement, the City may conduct maintenance in the form of brush or tree removal, removal of large amounts of debris or sediment, stream stabilization, or structural repairs. Maintenance may be conducted to maintain flow capacity, reduce pollution and sediment into the waterway, and maintain the safety, health, and welfare of the public.

If a drainage easement does not exist, the responsibility to maintain the facility falls to the property owner. The City may accept an easement from the property owner or assume maintenance responsibility through a prescriptive easement. In any case, minor maintenance of the surface, including mowing and trash pickup, is the responsibility of the property owner.

6.10.5.3 Major Drainage Facilities. Major drainage facilities include large channels, detention basins, hydraulic structures, and culverts.

6.10.5.3.1 Major Channels and Floodplains. Major drainage channels may be natural or constructed. Natural channels and their floodplains may consist of grass, trees, roots and other vegetation, cobble, boulders, bedrock, soil, or other natural materials. Constructed channels may consist of grass, concrete, riprap, blocks, or other materials. Maintenance requirements for each channel type are discussed below.

6.10.5.3.1.1 Natural Channels. Maintenance of natural channels and their floodplains should be conducted with great care. Natural channels can be dynamic in nature, and it can be difficult to predict how they will respond to changes made to them. In areas where the entire floodplain has been preserved as open space, natural channels can generally be left to move and change. Maintenance intervention may be necessary in cases where debris, sediment or channel movement is threatening the integrity of a structure, causing a potential flood hazard, or causing excessive erosion or stream degradation. In areas where development has encroached into floodplains or is near a natural channel, the channel and floodplain should be kept clear of debris, structures, fill, fences, and other potential blockages. Excessive vegetation growth should be controlled to maintain channel capacity and prevent damage to adjacent properties.

6.10.5.3.1.2 Constructed Channels. Maintenance of constructed channels must include maintaining the original design capacity and structural integrity of the channel. The channel capacity should never be decreased by maintenance activities unless a thorough engineering study has concluded the action is acceptable. Maintenance of concrete channels can include sediment removal, structural and sub-grade repairs, and vegetation control.

6.10.5.3.2 Enclosed Systems and Culverts. Box culverts and pipes shall be kept clear of debris and sediment. Any removed debris or sediment shall be hauled from the site rather than placed in the drainage system. Flushing shall be completed only when limited access makes it absolutely necessary. Any structural deficiencies such as cracked or damaged concrete shall be reported to the Building Department and corrected with the assistance of a qualified engineer.

6.10.5.3.3 Detention Basins. Detention storage includes dry detention, extended detention, and wet detention ponds. The following maintenance measures shall be implemented on all detention basins:

- Storage volume in basins must be preserved through regular maintenance and removal of sediment. Sediment should be removed, and the basin returned to design grades when either a sediment depth of six inches (6") exists or more than ten percent (10%) of the design volume has been lost. Sediment removal in wet ponds requires draining of the pond.
- The storage area and outlet structure shall be inspected to ensure that they are functional, free from debris and have no structural deficiencies in need of repair.
- Erosion of riprap, vegetation, or soil, particularly near discharge pipes into the basin, shall be repaired and restored to the original design.
- Vegetation and aesthetic features including fences, shrubs, trees, native grasses, and water quality vegetation shall be maintained to function and provide safety to the public.
- Basins should be inspected on an annual basis. Additional periodic inspections should be made, particularly after rainfall events, to ensure the basin meets the requirements of this chapter and is functional.
- Seed and mulch, sod, or other necessary erosion and sediment control best management practices (BMPs) shall be placed immediately after any excavation or grading is complete to minimize erosion and discharge of sediment to the drainage system.
- Routine maintenance to return a facility to its intended designed condition may be conducted without specific permission by the City. Modified designs shall be submitted to the City Engineer and Building Inspector.

6.10.5.3.4 Hydraulic Structures. Maintenance of hydraulic structures, including riprap, grade control structures, or any other structures in the drainage system, may include the following:

- Removal of debris, excessive vegetation, and excessive sediment.
- Replacing riprap or boulders and repairing grout and concrete.
- Inspecting adjacent banks and structures for erosion damage and repairing, as needed.
- Repairing guardrails and fences, as needed.

6.10.5.4. Water Quality SCMs. Water quality SCMs are designed to reduce and/or treat runoff to reduce stormwater pollutant loads and therefore may require higher levels of maintenance to serve their designed functions. An operation and maintenance plan and agreement shall be submitted for approval by the City for all SCMs required to meet the water quality requirements in Chapter 6.8. The operation and maintenance plan and agreement shall meet requirements set forth by the City Engineer Building Inspector and shall be recorded with the Greene County Recorder of Deeds. To ensure the long-term operation and maintenance of SCMs, the property owner shall conduct annual self-inspections of the SCMs and reporting of these inspections in accordance with schedules, inspection forms, and reporting procedures set forth by the City engineer. Deficiencies identified through self-inspections or inspections by the City shall be addressed in a timely manner.

6.10.5.5 Mowing and Vegetation Management. Property within the City is required to be mowed and maintained to meet the City Code.

6.11 EROSION AND SEDIMENT CONTROL

6.11.1 General. The goal of the regulation is to effectively minimize erosion and discharge of sediment from construction sites by application of relatively simple and cost-effective Best Management Practices (BMPs).

6.11.2 General Guidelines. General guidelines for erosion and sediment control are listed below. Sediment and erosion control plans must demonstrate consistency with these guidelines:

- Minimize the area disturbed by construction at any given time.
- Stabilize disturbed areas as soon as possible by re-establishing sod, other forms of landscaping, and completing proposed structures, pavements, and permanent storm drainage systems.
- Provide for containment of sediment until areas are stabilized.
- Provide permanent erosion control by constructing and maintaining the permanent storm drainage system and maintaining vegetative cover, pavements, and other surface coverings in good condition.
- Avoid environmentally sensitive areas. Streams, springs, sinkholes, lakes, or wetlands are easily affected by sediment from construction sites. Careful planning and additional controls are needed when construction sites are located in, or in close proximity, to these areas.
- Recognize sheet flow vs. concentrated flow. In areas where runoff occurs primarily as sheet flow, containment of sediment is relatively simple. In these areas, straw or hay bales, silt fences, and vegetative filter areas can be highly effective. Where flow is concentrated, containment of sediment becomes more difficult as the rate and volume of flow increases. In these areas, more elaborate controls such as sedimentation basins must be provided.
- Recognize temporary vs. permanent controls. The greatest potential for soil erosion occurs during construction.
    - Temporary controls are those which are provided for the purpose of controlling erosion and containing sediment until construction is complete. Temporary controls include straw or hay bale dikes, silt fences, erosion control blankets, etc., which are not needed after the area is stabilized.
    - Permanent controls consist of vegetative cover, riprap, concrete trickle channels, detention basins, etc., which will remain in place through the life of the development.
    - It is possible for the same feature to serve both a temporary and permanent purpose. The difference between temporary and permanent erosion control should be clearly recognized in preparing an erosion and sediment control plan.

6.11.3 Grading Permits.

6.11.3.1 Grading Permit Requirements. A Grading Permit must be obtained before any land is graded for non-agricultural purposes. Grading is defined as any excavation or filling or a combination thereof. Grading of agricultural land is considered non-agricultural whenever soil is excavated for sale off the site or soil from other properties is brought onto the site.

The City of Battlefield may waive the requirement for a Grading Permit in the following cases:

- Sites where one (1) acre or less is graded, provided the graded area is located a distance of twenty-five feet (25') or more from a spring, sinkhole, cave, wetland, watercourse, or floodplain, and where the proposed construction does not include the construction of stormwater detention basins or other drainage facilities.
    - Lots in new subdivisions will be considered part of the entire subdivision site area.
- The following activities, provided they are not located within twenty-five feet (25') of a spring, sinkhole, cave, wetland, or watercourse:
    - Grading for single family residences.
        - Lot grading done as a part of an overall subdivision plan to make lots buildable or prepare lots for sale is not exempt.
    - Grading and repair of existing roads or driveways.
    - Cleaning and routine maintenance of roadside ditches or utilities.
    - Utility construction where the width of the disturbed area for trench excavation and backfill is twenty feet (20') or less.
- Emergency construction required to repair or replace roads, utilities, or other items affecting the general safety and wellbeing of the public.

For emergency construction sites which would otherwise be required to obtain a permit and for which remedial construction will take more than fourteen (14) calendar days, application for the permit must be made within three (3) calendar days from the start of construction.

6.11.3.2 Permit Procedure. The following items must be submitted prior to issuance of a Grading Permit:

1. Completed grading permit application signed by the property owner or his legally authorized agent.
2. Grading permit fee.
3. An approved sediment and erosion control plan (SECP).
4. Performance bond or other required security.
5. For sites where five (5) acres or more of land are disturbed, a copy of the Missouri State Operating Permit.
6. Other State or Federal permits, if required.

6.11.3.3 Submittal and Approval Procedure.

1. Subdivisions - A sediment and erosion control plan (SECP) shall be submitted for review along with the plans for the subdivision improvements. Grading permits for subdivisions can be issued after approval of the plans for the subdivision improvements by the City of Battlefield, and the items listed above are received.

2. Buildings - Two (2) copies of the sediment and erosion control plan (SECP) shall be submitted to the Building Regulations Department along with the building plans. Grading permits can be issued after approval of the SECP by the City of Battlefield, and storm drainage plans and the items listed above are received.

3. Other Sites - Other sites include borrow and spoil areas, gravel mining areas, and any other sites where a subdivision plat or a building permit is not required. Two (2) copies of the sediment and erosion control plan (SECP) shall be submitted to the City of Battlefield for review. A grading permit can be issued after approval of the SECP by the City of Battlefield and the items listed above are received.

6.11.3.4 Sediment & Erosion Control Plan (SECP).

6.11.3.4.1 Professional Qualifications. Sediment and Erosion Control plans must be prepared by and bear the seal of an engineer, land surveyor, architect, landscape architect, or geologist registered to practice in the State of Missouri or by a Certified Professional in Erosion and Sediment Control (CPESC) who has attained certification by the Soil & Water Conservation Society. When the total area of the site exceeds five (5) acres, or the drainage area of any watershed for which an element of the plan must be designed exceeds five (5) acres, the plan must be prepared under the supervision of an engineer registered in Missouri.

6.11.3.4.2 Plan Requirements. The sediment and erosion control plan must be drawn to scale and must include the following items:

- Location map at a scale of 1" = 2000'.
- Legal description of property.
- North arrow and scale.
- One-Call utility notification symbol.
- Title block.
- Signature block for City of Battlefield approval.
- Design professional's seal. Existing topographic contours at five feet (5') maximum intervals.
- Proposed grades.
- Existing and proposed utilities.
- Existing ground covering (open areas, tree masses, etc.).
- Existing buildings, drives and pavements.

- Proposed buildings or other structures, drives, and pavements.
- Limits of area to be disturbed (shading preferred).
- Location of erosion and sediment controls.
- Details of non-standard erosion and sediment controls.
- Seeding & mulching requirements.
- Total site area, total disturbed area.
- Location of stockpile areas, staging areas, etc.
- Location of temporary construction entrance.

6.11.3.5 Bond Requirements.

6.11.3.5.1 Subdivisions. A security agreement or other form of security acceptable to the County in the amount of the value of the required sediment and erosion controls, including the storm drainage system, must be received prior to issuance of the grading permit.

6.11.3.5.2 Buildings. A security agreement or other form of security acceptable to the County in the amount of the value of the required sediment and erosion controls, including the storm drainage system, must be received prior to issuance of the grading permit.

6.13.3.5.3 Other Sites. Only cash bonds will be accepted for sites where a subdivision plat or building permit is not required. A cash bond is obtained by submitting the required bond amount to the City of Battlefield office in the form of cash, cashier's check, or money order, and obtaining a receipt.

6.11.3.5.4 Amount of Security. The amount of security will be one thousand dollars ($1,000.00) per graded acre for seeding and mulching, plus the estimated construction cost for permanent sediment and erosion control measures specified in the SECP. This includes all elements of the storm drainage system.

6.11.3.5.5 Release of Bond. Bond will be released one (1) year after seeding and mulching is complete, provided vegetation is firmly established. If vegetation is not firmly established at this time, the bond will be forfeited, and the work will be completed under the direction of the City.

Bonds may be released sooner if vegetation is firmly established. Vegetation will be considered firmly established when it has survived from the permanent seeding season in which it is placed to the next permanent seeding season and growth has been established on all eroded areas which have been noted for repair.

6.11.4 Other Permits.

6.11.4.1 NPDES Stormwater Permit. When the area of land disturbance is five (5) acres or more, an application for a stormwater discharge permit must be submitted to the Missouri

Department of Natural Resources. Permit requirements are set forth in 10 CSR 20-6.200 of the Missouri Clean Water Laws. For sites requiring a state permit, the following procedure applies:

1. The applicant submits MDNR forms E and G, the MDNR fee (with check made payable to "Director of Revenue")
2. MDNR reviews the application.
3. The sediment and erosion control plan are submitted to the City of Battlefield with a copy of the permit.
4. A City permit can be issued upon receipt of a copy of the State permit. Construction can commence only after issuance of the City grading permit.

6.114.2 "404" Permit. Grading activities in streams or wetlands may require a US Army Corps of Engineers (USACE) permit under Section 404 of the Clean Water Act. It is the obligation of the property owner or operator to contact the Corps of Engineers to determine whether a permit is required whenever working in these areas. A copy of the Corps of Engineers written determination, where applicable, shall be provided prior to issuance of the grading permit.

6.113.5 Design Standards and Criteria.

6.11.5.1 Grading.

6.11.5.1.1 Maximum Grades. Cut or fill slopes shall not exceed three (3) horizontal to one (1) vertical (3:1). 4:1 slopes are preferred where possible.

6.11.5.1.2 Maximum Height. Cut or fill slopes shall not exceed fifteen feet (15') feet in vertical height unless a horizontal bench area at least five feet (5') in width is provided for each fifteen feet (15') in vertical height.

6.13.5.1.3 Minimum Slope. Slope in grassed areas shall not be less than one percent (1%).

6.11.5.1.4 Construction Specifications. Construction of private and public streets must comply with specifications set forth. For all other areas, construction specifications stating requirements for stripping, materials, subgrade compaction, placement of fills, moisture and density control, preparation, and maintenance of subgrade must be included or referenced on the plans or accompanying specifications.

6.11.5.1.5 Spoil Areas. Broken concrete, asphalt, and other spoiled materials may not be buried in fills within proposed building or pavement areas. Outside of proposed building and pavement areas, broken concrete, asphalt, or stone may be buried in fills, provided it is covered by a minimum of two feet (2') of earth. Burying of other materials in fills is prohibited.

6.11.5.1.6 Stockpile Areas. Location of proposed stockpile areas shall be outlined in the plans and specifications for proper drainage included.

6.11.5.1.7 Borrow Areas. The proposed limits of temporary borrow areas shall be outlined in the plans and a proposed operating plan described in the SECP. At the time borrow operations are completed, the area shall be graded in accordance with the criteria set forth above and vegetation re-established.

6.11.5.2 Sediment Control.

6.11.5.2.1 Existing Vegetative Filter Area. Existing vegetative filter areas may be used where:

- Unconcentrated sheet flow occurs.
- An area of existing vegetation a minimum of twenty-five feet (25') in width can be maintained between the area to be graded and a property line, watercourse, sinkhole, spring, wetland, or waterbody.
- Existing ground slope is no greater than five to one (5:1) or twenty percent (20%).
- The existing vegetative growth is of sufficient density and in sufficiently good condition to provide for filtration of sediment.

The minimum width of the vegetative filter area shall be twenty percent (20%) of the width of the tributary area. Vegetative filter areas can be used as both a temporary and permanent practice.

6.11.5.2.2 Straw Bale Dike or Silt Fence. Containment areas constructed of hay or straw bales or silt fence may be provided in areas where:

- Unconcentrated sheet flow occurs.
- An area of existing vegetation a minimum of twenty-five feet (25') in width cannot be maintained between the area to be graded and a property line, watercourse, sinkhole, spring, wetland, or classified lake.
- The maximum width of cleared area upslope of the bale dike or silt fence is as set forth below:

Slope of Cleared Area %	Maximum width upslope of dike/silt fence (feet)
2 to 5	100
5 to 20	50
> 20	25

Either cereal grain straw or hay may be used for bale dikes. Silt fence may be used in lieu of hay or straw bales. Straw bale dikes must be installed level, that is, "along the contour", in order to avoid creating points of concentrated overflow. Straw/hay bale dikes and silt fences must be periodically inspected and replaced as necessary if deteriorated. Hay bale dikes and silt fences are temporary practices. Straw Bale dikes shall be constructed as shown in Figure SS-34. Silt fence shall be constructed as shown in Figure SS-35.

6.11.5.2.3 Temporary Containment Berm. Temporary containment berms may be used in lieu of straw bale dikes or silt fence, under the same conditions set forth above. An overflow area six inches (6") below the top of the berm and five feet (5') in length or an approved alternative must be provided for each two hundred feet (200') of berm length. The overflow area shall be lined with six (6) mil or thicker polyethylene plastic, six (6) ounces or heavier non-woven filter fabric, or other approved lining. Plastic and fabric liners shall be held in place by covering the perimeter with earth or weighing down with large rock or sandbags.

Containment berms and swales must be installed level, "along the contour”.
Accumulated sediment must be removed when it reaches one-third (1/3) of the berm height. Temporary containment berms and accumulated sediment must be completely removed after the tributary area is stabilized. Temporary containment berms shall be constructed as shown in Figure SS-36.

6.11.5.2.4 Inlet Protection. This practice consists of protecting the inlet perimeter or opening with straw bales, silt fence or sandbags. The purpose of this practice is to keep sediment from collecting in storm drains. This practice is also useful when site conditions prevent locating a sediment basin downstream of the storm sewer outfall. Inlet protection described in this paragraph cannot be used where blockage of the inlet opening would result in flooding of residential dwellings, buildings, streets or roads, or off-site property.

1. Curb Inlets. Curb inlets can be protected from sediment entry by placing sandbags over the inlet opening. Sandbags must be replaced when deteriorated and removed when the area has been stabilized. Accumulated sediment must be removed from the street after each rainfall. Curb inlet protection is shown in Figure SS-37.

2. Area Inlets. In paved areas, area inlets can be protected by placing gravel filled sandbags up to two (3) courses high around the perimeter of the inlet. Outside of paved areas or before pavement is placed, area inlets can be protected by installing a silt fence of straw bale dike around the inlet perimeter. Type DI-1 inlets can be protected by placing sandbags over the openings. Accumulated sediment must be removed prior to final approval. Area inlet protection is shown in Figure SS-38.

6.11.5.2.5 Diversion. Where flow must be diverted into sediment basins or other sediment retaining facilities, diversion berms or swales or other approved means of diverting runoff may be specified. Where sediment enters a street which is up-grade from an existing street, means must be provided to divert runoff to a sediment basin before discharge from the site. The method of diversion will vary depending upon the phase of construction. After initial grading, an earth berm can be used. This is no longer possible after the street subgrade is completed, and curbs are installed. After the street pavement is completed, sandbags can be used to divert the runoff into inlets for discharge into the sediment basin. Diversion of street runoff is show in Figure SS-39 and Figure SS-40.

6.11.5.2.6 Gravel Filter Dam. Where concentrated flow occurs and less than two (2) acres of tributary drainage area are graded (i.e., a sediment basin is not required) or where construction of a sediment basin is not feasible, a gravel filter dam shall be provided prior to discharge of runoff from the property.

Gravel filter dams consist of a layer of filter fabric and crushed rock covering the upstream side of a riprap dike. Riprap shall be six and twelve inches (6" and 12") in size. Filter fabric may be woven or non-woven, Mirafi 500X, Mirafi 150NL, or equal. The purpose of the filter fabric is to remove sediment particles as water flows through it. The layer of crushed rock provides additional filtration protects the filter fabric and holds it in place.

Where gravel filter dams are used as sediment basin outlets, one (1) square foot of filter fabric area shall be provided for each one thousand (1,000) cubic feet of storage. The minimum area provided shall be four (4) square feet.

Where gravel filter dams are used as ditch checks in channels, the gravel filter area shall extend throughout the width of the dam. Riprap stilling basins shall be provided downstream of the filter dam where discharge is to a grass channel.

Gravel filter dam details are shown in Figure SS-41 and Figure SS-42.

6.11.5.2.7 Sediment Basin. Sediment basins shall be provided for all areas where concentrated flow occurs from an area of five (5) or more acres and vegetative cover has been stripped from more than two (2) acres. Sediment basins shall be designed to detain the first one-half inch (½”) of runoff from the graded area for a period of at least twenty-four (24) hours (approximately two thousand (2,000) cubic feet per acre graded).

Sediment basins shall have an outflow control structure capable of providing the required detention time. Outflow control structures shall consist of a gravel filter dam or a perforated riser pipe. Sediment basins shall also be provided with an overflow structure capable of passing the peak flow rate for storms up to and including the 10% AEP (10-year) storm. The required sediment control volume shall be provided below the elevation of the overflow structure. One foot (1') of freeboard shall be maintained over the 10-year high water elevation.

Perforated riser pipes shall have a minimum diameter of eight inches (8") and shall be constructed of schedule SDR35 or stronger PVC pipe, galvanized corrugated metal pipe, or other approved pipe material. Riser pipes must be provided with a cap. Plans shall specify the height of the riser pipe above the basin floor, the number and spacing of rows of perforations, and the number and diameter of perforations per row. One and one-half inch (1 ½") crushed rock shall be placed around the riser pipes to act as a filter.

Outlet pipes shall have a minimum diameter of eight inches (8") and may be constructed of corrugated polyethylene pipe, corrugated metal pipe, SDR 35 or stronger PVC or reinforced concrete pipe. Overflow spillways must be constructed of riprap, concrete, or other approved, non-erodible material.

Detention ponds can be used for temporary sediment basins, provided it can be demonstrated that flood control requirements can be met as well as sediment control requirements. Accumulated sediment must be removed, and vegetation established prior to final release of security.

Typical sediment basin details are shown in Figure SS-43, Figure SS-44, and Figure SS-45.

6.13.5.3 Erosion Protection.

6.11.5.3.1 Seeding and Mulching. All disturbed areas must be re-vegetated before temporary sediment controls can be removed. Requirements for re-vegetated areas are as follows:

6.11.5.3.1.1 Topsoil. Spreading of topsoil is required for permanent seeding areas only. Topsoil stripped from the site shall be stockpiled for reuse. A minimum of four inches (4") loose depth (before rolling or compacting) of topsoil must be spread on the area to be seeded.

6.11.5.3.1.2 Lime. After topsoil is spread, lime shall be spread at the rate of eight hundred to nine hundred (800 to 900) pounds effective neutralizing material (ENM) per acre.

6.11.5.3.1.3 Fertilizer. Fertilizer shall be 13-13-13, (thirteen (13) pounds each of nitrogen, phosphorus, and potassium per one hundred (100) pounds) and shall be applied at a rate of four hundred to five hundred (400 to 500) pounds per acre.

6.11.5.3.1.4 Seed. Seed mix shall consist of sixty percent to eighty percent (60% to 80%) Kentucky 31 tall fescue and twenty percent to forty percent (20% to 40%) annual ryegrass. Purity shall be at least ninety-seven percent (97%), germination shall be at least eighty-five percent (85%). Seed mixture shall be applied at a rate of four hundred to five hundred (400 to 500) pounds per acre.

6.11.5.3.1.5 Mulch.

1. Type 1 Mulch. Where slopes are less than 4:1, cereal grain mulch is required at the rate of one hundred (100) pounds per one thousand (1,000) square feet (forty-five hundred (4,500) pounds per acre). Cereal grain mulch shall meet the requirements of Section 802 of the Missouri State Specifications for Highway Construction (State specifications) for Type 1 mulch. Mulch may be applied by hand; however, it must be evenly spread. It is preferred

that mulch be applied with a mechanical blower. Type 1 mulch must be thoroughly wetted after application.

2. Type 3 Mulch. Where slopes are 4:1 or greater, Type 3 mulch ("hydro-mulch") meets the requirements of Section 802 of the State specifications. Type 3 mulch shall be applied at a minimum rate of two thousand (2,000) pounds per acre.

6.11.5.3.1.6 Permanent Seeding Season. Permanent seeding seasons run from March 1 to June 1 and from August 15 to November 1. Where possible, operations shall be scheduled to allow final seeding during these periods. When seeding cannot be completed during these times, areas shall be seeded and mulched upon completion of grading with the amounts of lime, fertilizer, seed, and mulch specified above, regardless of the season. Any areas where growth has not been established shall be re-seeded during the next seeding season.

6.11.5.3.1.7 Temporary Seeding. Temporary seeding shall be applied to lot areas, building areas and other areas planned to receive other permanent coverings. Spreading of topsoil is not required in temporary seeding areas. Lime, fertilizer, seed, and mulch shall be applied at the rates specified above.

6.11.5.3.1.8 Maintenance. Areas seeded between March 1 - June 1 or between August 15 - November 1 must be maintained until growth is firmly established.

6.11.5.3.1.9 Other Specifications. Other seeding and mulching specifications may be used with the written approval of the City of Battlefield.

6.11.5.3.2 Cut and Fill Slopes. Cut and fill slopes shall be protected from erosion by construction of straw bale dikes, silt fences, diversion berms, or swales along the top of the slope. Where drainage must be carried down the slopes, pipe drains, concrete flumes, riprap chutes, or other impervious areas must be provided. Suitable erosion control measures such as riprap stilling basins, must be provided at the bottom of the slope. Diversions shall be maintained until permanent growth is firmly established on the slopes.

Typical diversion details are shown in Figure SS-46. Riprap chute details are shown in Figure SS-47.

6.115.3.3 Channels and Swales. Permanent channels and swales shall be provided with a stabilized invert.

6.113.5.3.4 Storm Sewer and Culvert Outlets. Erosion protection shall be provided at storm sewer and culvert outlets.

6.11.5.3.5 Ditch Checks. Straw bale ditch checks have proven to be generally ineffective due to improper installation and inability of bales to withstand the force of concentrated flow of water. Ditches, channels, and swales should be stabilized as soon as possible after grading by lining with erosion control blanket, sod, or installing permanent linings.

Where ditches, channels, or swales cannot be stabilized within thirty (30) days after grading, rock check dams or sandbag check dams must be provided. Rock check dams may be used in ditches with a design water depth of up to two feet (2') for the 2-year storm. Sandbag check dams may be used in ditches with a design water depth of up to one foot (1') for the 2-yearstorm.

Rock check dams are shown in Figure SS-48. Sandbag check dams are shown in Figure SS-49.

6.11.5.4 Temporary Construction Entrance. A minimum of one (1) temporary construction entrance is required at each site. Additional temporary entrance may be provided if approved. The location of each construction entrance shall be shown on the SECP. Only construction entrances designated on the sediment and erosion control plan may be used. Barricades shall be maintained if necessary to prevent access at other points until construction is complete.

Construction entrances shall be constructed of one and one-half inches (1 ½") clean crushed limestone and shall be a minimum of twenty-five feet (25') wide and fifty (50') feet long. Minimum thickness of crushed limestone surface shall be six inches (6"). Additional two-inch (2") lifts of crushed limestone shall be added at the discretion of the City if the surface of the initial drive deteriorates or becomes too muddy to be effective. In locations where an existing drive or street extends at least fifty feet (50') into the site, the existing drive may be designated as the construction entrance, and construction of a new gravel entrance is not required, unless job conditions warrant.

A permit must be obtained from the Greene County Highway Department for temporary construction entrances on County roads. A permit must be obtained from the Missouri Department of Transportation (MODOT) whenever the entrance is located on State right-of-way.

6.11.5.5 Cleaning Streets. Streets, both interior and adjacent to the site, shall be cleaned of sediment after each rainfall of one-half inch (½") or more and at the end of construction and prior to release of escrow.

6.11.5.6 Dust Control. The contractor will be required to use water trucks to wet haul roads and construction areas to minimize dust leaving the site when conditions warrant.

6.11.5.7 Sequencing and Scheduling. Costs of sediment and erosion control can be minimized if proper consideration is given to sequencing and scheduling construction. Any special sequencing and scheduling considerations must be noted on the SECP.

8 STREETS, ALLEYS, CUL-DE-SACS, AND INTERSECTIONS

8.1. STREETS

8.1.1 Street Construction. City streets shall be constructed of Portland Cement Concrete with integral curb (or concrete curb and gutter) or bituminous plant mix roadway with a concrete curb and gutter. Alley pavement shall be of either asphalt or concrete design, with an inverted crown and the curb omitted. Asphaltic streets will require bituminous or “full depth” asphalt base.

8.1.2 Roadway Sections. Typical roadway sections showing various widths of roadway and right-of-way and required thickness are as shown on Figure ST-1 included in these design standards. Expressways and Arterial Streets should be designed according to MoDOT Standards.

8.1.3 Street Design. In the preparation of street design, the following criteria must be observed. These controls are intended to be the absolute minimum (or maximum) permitted. Any design not meeting this requirement must have prior approval. Road classification greater than those listed should be designed according to MoDOT standards.

8.1.3.1 Grades.
Minimum 0.5% All Systems
Maximum Arterial 5%
Maximum Collector 8%
Maximum (Residential and Non-Residential) Local 10%
Maximum (Residential and Non-Residential) Alleys 10%

8.1.3.2 Vertical Curves. The length of vertical curves shall be no less than that determined by the formula:

L = KA, where:
L = Length of vertical curve
A = Algebraic difference in grades
K = Determined by following table:

Table of “K” Values	Crest	Sag
Arterial	61	79
Collector	44	64
Local Non-Residential	19	37
Local Residential	12	26

8.1.3.3 Centerline Radii and Superelevation.

Minimum centerline radii (R) and Maximum super elevation (E)		
Arterial	R = 600’	E=0.04
Collector	R = 400’	E=0.03
Local Non-Residential	R = 300’	E=0.02
Local Residential	R = 175’	E=0.02

*Minimum length of super elevation runout = 100’

8.1.3.4 Minimum Curb Radii at Intersections:

	Intersecting Residential Local	Street Non-Residential Local and Collector
Arterial	30'	50'
Collector	20'	30'
Local Residential	15'	20'
Local Non-Residential	20'	30'

8.1.3.5 Minimum Safe Stopping Sight Distance:

Arterial	325’
Collector	250’
Local Non-Residential	200’
Local Residential	150’

8.1.3.6 Minimum Safe Stopping Distance at Intersections:

Arterial	500’
Collector	450’
Local Non-Residential	300’
Local Residential	250’

8.1.3.7 Intersections. All curb returns shall be designed with a wheelchair ramp.
meeting the requirements of Figure ST-10 or Figure ST-11 included in these design standards. No drainage structures shall be allowed in the wheelchair path. Intersections shall be approached on all sides by leveling areas. Where the approach grade for either or both streets exceed 3 percent, the leveling area shall be a minimum length of 100 feet measured from the intersection of the edge of gutter flag or edge of road, within which no grade shall exceed a maximum of 3 percent with a maximum crossfall of 6” at the throat of the radius returns of the intersecting street. Right angle intersections shall be used whenever practicable. When local streets intersect collector or arterial streets, the angle of intersection of the street centerlines shall not be less than 75° A diagonal sight distance easement must be provided on the property lines substantially parallel to the chord of the curb radius.

Elevations at street intersections shall be computed by extending curb grades to the P.I. of the intersection of curbs. A minimum of 0.3 feet fall around a curb return is required. Elevations around the curb return and centerline stationing at all radius points shall be shown on the plan.

8.1.3.8 Plan. The following information shall be shown on the plan portion of each plan sheet:

- Width of right-of-way.
- Width of pavement (back-to- back of curbs).
- Curb and right of way radii with elevation and stationing.
- Location and size of existing utilities, meters, valves, poles, street markers, signs, traffic signals, trees, shrubs, drainage ditches, structures, storm sewers, easements, sanitary sewers, and manholes. The proposed location of any of the above must also be shown. Central angle, centerline radius, arc length, and tangent distance of horizontal curves. Stationing of beginning and end of paving, PC and PT stationing of curves and tie to lot corners. All lot dimensions.

8.1.3.9 Profile. The following information shall be shown on the profile portion of each plan sheet:

- Existing ground lines at the centerline with elevations shown at 50' intervals.
- Proposed grade at the centerline.
- Proposed top of curb elevation and stationing at areas where typical cross sections are not applicable.
- Centerline elevations and stationing at beginning and end of paving, beginning, end, and P.I. of vertical curves, and mid-ordinate of vertical curves.
- Elevation and station of low point of sags.
- Top of curb shall be noted.

8.1.3.10 Typical Section. A typical section shall be shown on the first plan sheet indicating:

- Pavement type, width, and thickness
- Crown
- Curbs
- Parkway Width and Cross Slope
- Right of way width
- Sidewalks

8.1.3.11 Cul-de-sacs. Information needed on cul-de-sacs is shown on Figure ST-5, included in these design standards. Details for Temporary Dead End and Permanent Dead Ends are shown Figure ST-19 & Figure ST-20.

8.1.3.12 Expansion Joints. Expansion joints in concrete paving shall be placed as shown on standard drawings at intersections unless otherwise shown on plans and at all structures crossing the roadway such as bridges, box culverts, etc. Expansion joints are required around junction boxes, inlets, etc. See Figure ST-3 & Figure ST-4.

8.1.3.13 Contraction Joints. Contraction joints in concrete paving shall be placed as shown on standard drawings at intervals of not more than 20 feet and not more than 20 feet from any expansion joint.

8.1.3.14 Longitudinal Joints. Longitudinal joints shall be placed as shown on the Standard Drawings.

8.1.3.15 Manholes. Manhole designation and elevation of top of manhole must be given when located within right-of-way.

8.1.3.16 Storm Sewers. Flow line elevations must be given for storm sewers within right-of-way.

8.1.3.17 Approaches existing streets. All approaches to existing curb and gutter streets shall be Portland Cement Concrete to Radius Point.

STREET RIGHT-OF-WAY AND CONSTRUCTION REQUIREMENTS

	Boulevard	Primary Arterial	Secondary Arterial	Collector	Non-Res. Local	Res. Local
Right of way – Normal	120’	110’	80	65	60’	50’
Pavement Width – Normal (Feet)	68’	68’	46	35	35	32
Sidewalk Requirements**	As Needed	Both Sides	Both Sides	Both Sides	One Side	One Side
Minimum Centerline Radius	To Be Designed	To Be Designe d	600’	400’	300’	175’

* Widening flared to the leaving side of opposite approaches

** Except in certain zoning districts, see Subdivision Regulations

RIGHT-OF-WAY TRIANGLE REQUIREMENTS

Intersection of / With	Expressway	Primary Arterial	Secondary Arterial	Collector	Non-Residential Local	Residential Local	Marginal Access
Expressway	A	A	A	B	B	B	B
Primary Arterial	A	A	A	B	B	C	C
Secondary Arterial	A	A	B	B	C	D	D
Collector	B	B	B	C	C	D	D
Non-Res. Local	B	B	C	C	C	D	E
Residential	B	C	D	D	D	E	E
Marginal Access	B	C	D	D	E	E	E

KEY:

A – 100’ X 100’ ROW triangle w/separate right turn lanes

B – 30’ X 30’ ROW triangle w/50’ corner radii

C – 10’ X 10’ ROW triangle w/30’ corner radii (or 15’ ROW radius)

D – 10’ X 10’ ROW triangle w/20’ corner radii (or 15’ ROW radius)

E – No ROW triangle w/15’ corner radii

9 TRANSPORTATION IMPACT STUDY

9.1 GENERAL

The Transportation Impact Study (TIS) will be completed in accordance with the Ozark Transportation Organization (OTO) Guidelines tiered approach. The goal of a TIS is to determine the impact of a development or redevelopment on the transportation system, which includes examining parking, multi-modal facilities, and the movement of cars, trucks, bicycles, and pedestrians around a site. Where deficiencies or issues are discovered, the TIS should identify feasible solutions to the problem(s).

Transportation Impact Study Tier Descriptions: The OTO's Transportation Impact Study parameters are sub-divided into five categories; an initial submittal and four study tiers as follows:

Study Tiers Thresholds Transportation Impact Study:

- Preliminary Transportation Assessment (Optional)
- Transportation Impact Study: Level I – under 100 peak hour trips, or fewer than 50 new dwelling units
- Transportation Impact Study: Level II – 100 to 499 peak hour trips
- Transportation Impact Study: Level III – 500 to 999 peak hour trips, or change in access to primary arterial or higher-class road (<1,000 peak hour)
- Transportation Impact Study: Level IV – 1,000 or more peak hour trips

The TIS must be prepared by a professional engineer registered in the State of Missouri, able to demonstrate experience with traffic impact analysis.

Checklists to assist in completing the study can be found in the OTO Toolbox for Transportation Impact Study Guidelines Policy Memo. A checklist is also provided there to assist in the completion of this study.

10 SIDEWALKS, CURB AND GUTTER, AND DRIVEWAYS

10.1 SIDEWALKS

10.1.1 General. Sidewalks are required on at least one side of residential streets and on both sides of collector and arterial streets. All newly constructed sidewalks shall meet the requirements of the most current ADA Standards for Accessible Design and Public Right of Way Accessibility Guidelines (PROWAG).

10.1.2 Design. Sidewalks are to be constructed using a minimum of 4 inches of Class "A" Portland Cement Concrete with a minimum 28-day compressive strength of 4,000-psi in accordance with The walks shall be constructed on 4 inches of Type 1, Type 5 or Type 7 rolled stone base extended 6 inches beyond the edges. Sidewalk sections for curb ramps and across residential drives shall be constructed with a 6-inch thickness, and 8 inches across commercial drives.

10.1.2.1 Sidewalk Plan. A plan must be prepared showing the sidewalk in plan, profile, location of ADA ramp, location and details of expansion joints, and typical cross section. This plan may be included as part of the street plan. For sidewalks to be constructed on unimproved streets, it is necessary to obtain sufficient field data to determine the probable future grade of the street curb and design the sidewalk accordingly. Additional right-of-way to accommodate the roadside drainage may have to be provided.

10.1.3 Location. The outside edge of the sidewalk shall be placed 1 foot inside the street right-of-way line. The green space between the sidewalk and back of curb shall be no less than 2 feet in width. In areas where 2 feet of green space cannot be achieved, sidewalk shall be placed adjacent to the back of curb.

10.1.4 Width. Sidewalks shall be a minimum width of 5 feet unless sidewalk is directly adjacent to street curb in which case the minimum width shall be 6 feet.

10.1.5 Sidewalk Cross-Section Grade. The maximum cross slope for sidewalks shall be 1:50 (2 percent). For sidewalks located across a driveway entrance, the driveway grade may need to be adjusted to meet this maximum. For commercial and other areas where a wide sidewalk creates grade problems for access drives, it should be noted that only the minimum sidewalk width of 4 feet must be constructed at a maximum 2 percent cross slope across the entrance. The remaining width of the sidewalk may be constructed at a grade closer to that of the drive. For commercial entrances, joint lines should delineate the portion of the sidewalk that crosses the driveway, so it is clear where the sidewalk crosses the entrance.

10.1.6 Longitudinal Grade. The grade of the sidewalk shall not exceed 5 percent, or the grade established for the adjacent roadway within the Right-of-Way.

10.1.7 Parkway and Drainage. The parkway cross-sectional grade (the area between the sidewalk and the street) shall be a minimum of 2 percent.

10.1.7.1 Drainage from properties adjacent to the sidewalk shall not drain across the surface of the sidewalk nor shall the grade of the sidewalk be constructed so that water would pond on the surface of the walk.

10.1.8 Obstructions. All obstructions are to be removed or relocated to provide a clear minimum horizontal width of 48 inches and a clear vertical height of 80 inches. In the case where the sidewalk must be shifted a 5:1 taper to and away from the obstruction with a straight section adjacent to the obstruction should be followed.

10.1.9 Retaining Walls. When the sidewalk construction requires the installation of retaining walls to maintain or support adjacent improvements, the detailed plans shall include the wall design. Unless otherwise approved by the City, all retaining walls should be located on private property.

10.1.10 Joints. The sidewalk shall be constructed such that panels are formed using control joints that are cut such that the resulting panel lengths are not less than four feet (4') nor greater than six feet (6'). Edges of the slab shall be edged with an edging tool that has a ¼-inch radius.

10.1.10.1 Expansion Joints shall be placed, between the sidewalk and all structures such as light standards, traffic light standards, traffic poles, columns, on each side of driveways, intersecting walks, utility covers, or other locations when against a substantial structure. Expansion joints should also be placed as close to each property line as reasonable and at intervals not greater than 100 feet. Preformed isolation joint material shall be installed and left one-half inch (1/2") below the surface to allow for the application of joint sealer.

10.1.10.2 Construction joints shall be installed at the end of each day's work and at other times when the process of depositing concrete is stopped for 30 minutes or more.

10.1.11 Ramps. Curb ramps are to be installed at all intersections and at certain mid-block locations on all new or reconstruction projects.

10.1.11.1 Running Slope. The running slope of curb ramps shall be 1:12 (8.33 percent) maximum.

10.1.11.2 Cross Slope. The cross slope of curb ramps shall be 1:50 (2.0 percent) maximum.

10.1.11.3 Landing. A minimum landing of 60 inches by 60 inches shall be provided at the top of the curb ramp. Running and cross slopes shall be a maximum of 1:50 (2.0 percent).

10.1.11.4 Flares. Flared sides with a maximum slope of 1:10 (10.0 percent), measured along the curb line, shall be provided where a circulation path crosses the curb ramp.

10.1.11.5 Surfaces. Storm sewer intakes, grates, access covers, or other appurtenances shall not be located on curb ramps, landings, and gutter areas within the pedestrian access routes. All ramps shall have a textured, non-skid surface.

10.1.11.6 Grade Breaks. Grade breaks shall not be permitted on curb ramps, landings or gutter areas within the pedestrian access route. The grade break between the gutter area and street at the foot of a curb ramp shall not exceed 13 percent.

10.1.11.7 Drainage. Drainage from properties adjacent to the sidewalk shall not discharge a concentrated flow across the surface of the sidewalk nor shall the grade of the landing or sidewalk be constructed that water would pond on the surface of the ramp.

10.1.11.8 Islands. Any raised islands in crossings shall be cut through level with the street or have curb ramps at both sides and a level area at least forty inches (48") long between the curb ramps in the part of the island intersected by the crossings.

10.1.12 Detectable Warning Surfaces. Detectable warning surfaces consisting of truncated domes aligned in a square grid pattern shall be provided where a curb ramp or landing connects to a crosswalk.

10.1.12.1 Location. The detectable warning surfaces shall be located so that the nearest edge is six inches (6") minimum to eight inches (8") maximum from the face of the curb line and the far edge is no more than five feet (5') from the back of curb line. The detectable warning surface shall extend a minimum of twenty-four inches (24") in the direction of travel and the full width of the curb ramp.

10.1.12.2 Dome Size. Truncated domes shall have a diameter of nine tenths inch (0.9") at the bottom, a diameter of four tenths inch (0.4") at the top, a height of two tenths inch (0.2") and a center-to-center spacing of two and thirty-five hundredths' inches (2.35") measured along diagonal of a square arrangement.

10.1.12.3 Visual Contrast. There shall be a minimum of seventy percent (70%) contrast in light reflectance between the detectable warning and the adjoining surface. The coloring shall be red and homogeneous and made an integral part of the detectable warning surface.

10.1.13 Design Checklist for Sidewalks

_____ Sidewalks shown in plan and profile on at least one side of residential streets and on both sides of collector and arterial streets (Check Subdivision Regulations for exceptions).

_____ Sufficient field data is shown for unimproved streets to determine probable future grade of street curb and sidewalks are designed accordingly.

_____ Typical cross sections shown with plan and profile.

_____ Outside edge of sidewalk is placed one foot (1’) inside of right-of-way line.

_____ 1/2-inch expansion joints are indicated on the plans.

_____ Sidewalk minimum width – sixty inches (60”) minimum thickness of four inch (4”) (or six inch (6”) when sidewalk crosses a residential driveway or eight inch (8”) when sidewalk crosses a commercial driveway or alleys) placed on four inches (4”) of compacted base stone extending six inches (6”) beyond the edges of the walk.

_____ Sidewalk cross slope not greater than 1:50 (2%).

_____ All ramp slopes are a maximum of 1:12.

_____ Maximum rise for any length of run is thirty inches (30”).

_____ Level landing areas provided at top and bottom of each run.

_____ Detectable warning system indicated on all curb ramps.

_____ Curb ramps provided wherever sidewalk crosses a curb.

_____ Minimum width of curb ramp is sixty inches (60”).

_____ Accessible crossing area indicated on any raised island crossing.

_____ Hand railing indicated where elevation change between sidewalk and adjacent grade is thirty inches (30”) or more.

_____ Drainage from properties adjacent to the sidewalk does not discharge a concentrated flow across the surface of the sidewalk and the grades of the sidewalk ramps do not allow areas of surface ponding.

10.2 CURB AND GUTTER

10.2.1 General. Curb and gutter are required on all public improvement street projects.

10.2.2 Design. Curb and gutter are to be constructed from Class “A” Portland Cement Concrete with a minimum 28-day compressive strength of 4,000-psi. The curb and gutter shall be constructed on four inches (4”) of Type 1, Type 5, or Type 7 rolled stone base extending a minimum of one foot behind the back of the curb section. The width of the curb and gutter is to be two feet (2’) sixty inches (6”). The curb height is to be six inches (6”), and the gutter cross slope is to be two inches (2”) in two feet (2’). The thickness of the gutter shall be six inches (6”) for residential streets and eight inches (8”) for collector streets and above. At driveway locations shown on the plans, the gutter profile is to be carried across the drive while the curb is depressed to match the driveway slope. If driveway locations are not shown on the plans, curbs cannot be depressed. See Figure ST-2

10.2.3 Expansion Joints. Bituminous preformed expansion joints, ½ inch thick and precut to the exact cross section of the curb and gutter shall be placed at all driveway and intersection radii and at intervals of not more than two hundred feet (200’).

10.2.4 Design Checklist for Curb and Gutter

_____ Curb and gutter is provided for on all improved streets.

_____ Street profile shows centerline elevations.

_____ Curb cross section shows curb height and width six inches (6”).

_____ Gutter thickness is shown as six inches (6”) for local residential streets.

_____ Gutter thickness is shown as eight inches (8”) for non-residential local streets and collector residential streets.

_____ Curb and gutter are constructed on four inches (4”) Type I rolled stone base extending a minimum of one foot behind the curb.

_____ Total curb and gutter width are shown as two feet six inches (2’6”).

_____ Gutter cross slope is one inch/ft (1) (except at ramp areas).

_____ one-half inch (½”) expansion joints indicated at all driveways and at intervals of not more than two=hundred feet (200’).

10.3 DRIVEWAYS

10.3.1 General. Driveway approaches are located to serve the operation of automobiles and other vehicles from the street pavement to a garage, parking area, building entrance, structure, or other approved use located on the property.

10.3.2 Residential Design. Residential driveway approaches shall be constructed using Class "A" Portland Cement Concrete with a minimum 28-day compressive strength of 4000-psi. All driveway pavement shall be constructed on four inches (4") of Type 1, Type 5, or Type 7 rolled stone base. When a driveway approach intersects an existing four-inch-thick sidewalk, the area of the sidewalk within the driveway area including both sides of the sidewalk transition sections to meet the drive elevation or eighteen inches (18"), whichever is greater, shall be removed and reconstructed with 6-inch-thick concrete. The cross slope of the sidewalk area is not to exceed 1:50 (2%). The grade of the driveway approach from the gutter line shall rise on a constant grade to the front edge (street side) of the sidewalk area. The slope of the driveway approach shall be at least 1:50 and not to exceed 1:8.
The width of residential driveway approaches shall not exceed thirty-two feet (32') without permission from the City Administrator or designee and shall not be less than fourteen feet (14') for new construction. The width of a driveway is measured at the Right-of-Way line. See Figure ST-8

10.3.3 Commercial Design. Commercial/non-residential driveway approaches shall be constructed 8 inches thick using Class "A" Portland Cement Concrete with a minimum 28-day compressive strength of 4,000-psi. All driveway pavement shall be constructed on four inches (4") Type 1, Type 5, or Type 7 rolled stone base. When a driveway approach intersects an existing 4-inch-thick sidewalk, the area of the sidewalk within the driveway area, including both sides of the sidewalk transition sections to meet the drive elevation or a minimum of eighteen inches (18") shall be removed and reconstructed with 8-inch concrete. The cross slope of the sidewalk area is not to exceed 1:50 (2%). The grade of the driveway approach from the gutter line shall rise on a constant grade to the front edge (street side) of the sidewalk area. The slope of the driveway approach shall be at least 1:50 and not to exceed grade shown in the following Table for various street classifications. The width of commercial driveway approaches shall not exceed 45 feet and shall not be less than 26 feet wide. The width of driveways is measured along the Right-of-Way line. One-Way driveways shall be a minimum of 14 feet and a maximum of twenty-two feet (22') wide. See Figure ST-9.

10.3.3.1 Table for determining the driveway grade for various street classifications.

Street Classification	Approach Grade	Maximum Grade Back of Sidewalk	Slope 10 feet of R/W
Major Arterial	2% to 4%	4%	-2% to 6%
Secondary Arterial	2% to 5%	5%	-3% to 7%
Collector	2% to 6%	6%	-4% to 8%
Non-Resident Local	2% to 8%	8%	-6% to 10%

10.3.4 Approach Location. Driveway spacing is restricted by the Battlefield Subdivision Regulations and the Battlefield City Code.

10.3.4.1 No driveway approach shall be permitted which will interfere with any existing parking meters, signs, traffic control devices, planting, cables, poles, guys, water mains, gas mains, or other public utilities.

10.3.4.2 No part of any driveway approach may be located within four feet (4') of a drop inlet or other drainage structure or a pedestrian ramp.

10.3.4.3 No part of any driveway approach shall be located within forty feet (40') of a point on the right-of-way opposite the end of a raised median.

10.3.4.4 Joint driveway approaches shall be permitted only if there is a perpetual mutual access agreement approved by the City Attorney and filed of record in the Greene County Recorder's Office.

10.3.4.5 All driveway approaches shall be located to meet the spacing shown in the following table and provide the following minimum clearances: Nearest edge of the driveway to nearest right-of-way line of alleys, ten feet (10'); nearest edge of the driveway to property line, 5 feet; on corner lots, nearest edge of the driveway to nearest right-of-way line of an intersecting street, twenty feet (20"), but in no case shall the driveway return extend closer than fifteen feet (15") to the intersection right-of-way line extended. Where sight distance triangles exist, the nearest edge of the driveway to nearest corner of triangle shall be at least twenty feet (20').

Access on Street		**Expressway**	**Primary Arterial**	**Secondary Arterial**	**Collector**	**Residential Local**	**Driveway**
Expressway	Approach	Not Permitted	Not Permitted	Not Permitted	Not Permitted	Not Permitted	Not Permitted
	Exit	Not Permitted	Not Permitted	Not Permitted	Not Permitted	Not Permitted	Not Permitted
Primary Arterial	Approach	350 ft*	300 ft*	250 ft*	200 ft	200 ft	440 ft
	Exit	250 ft	200 ft	200 ft	200 ft	200 ft	200 ft
Secondary Arterial	Approach	300 ft*	250 ft*	200 ft*	150 ft	150 ft	220 ft
	Exit	150 ft	150 ft	150 ft	150 ft	150 ft	220 ft
Collector	Approach	250 ft*	200 ft*	150 ft*	100 ft	100 ft	100 ft
	Exit	100 ft	100 ft	100 ft	100 ft	100 ft	100 ft
Residential Local	Approach	150 ft	100 ft	70 ft	50 ft	20 ft	20 ft
	Exit	70 ft	50 ft	30 ft	30 ft	20 ft	20 ft

***Where a median is on the Street, the recommended access restrictions for the approach side are the same as for the exit side.**

10.3.4.6 Edges of the driveway approach may be skewed so that the angle between the street right-of-way line and the edge of the driveway approach is not less than 60 degrees.

10.3.4.7 Radius of the driveway approach shall not, in any case, extend beyond the projection of the adjacent property line, extended perpendicularly to the right-of-way line.

10.3.4.8 The radius of a driveway return shall not extend beyond the right-of-way line or fifteen feet (15’), whichever is smaller.

10.3.5 Expansion Joints. The plans shall show bituminous one-half -inch (1/2”) thick preformed expansion joints to be placed at the right-of-way and sidewalk connections.

10.3.6 Existing Curb and Gutter. The plans shall show the existing curb and gutter section in front of a driveway (radius point to radius point) shall be saw cut full depth and removed before the driveway is constructed. The entire curb and gutter section would then be reconstructed with the same concrete and depth as the driveway approach.

10.3.7 Design Checklist for Driveways

_____ Existing and proposed driveway locations must be indicated on the plans.

_____ All driveway dimensions including slope and elevations/contours are shown.

_____ Locations of access drives, alleys, and intersections within two hundred fifty feet (250’) of site and across the street are shown.

_____ Driveway approach is located forty feet (40') beyond the end of a raised median.

_____ Show that driveway approaches do not interfere with any existing parking meters, signs, traffic control devices, plantings, cables, poles, guys, water mains, gas mains, or other public utilities.

_____ Show that all landscaping within five feet (5') of the street does not affect sight distance at the driveway.

_____ Copy of approved joint driveway approach agreement filed in the Greene County Recorder's Office.

_____ Width of residential driveway approach at right-of-way line is not less than twelve feet (12') or more than twenty-two feet (22'). The width of commercial driveway approach at the right-of-way line is not less than twenty-six feet (26') or more than forty-five feet (45').

_____ Approach not within four feet (4') of a drop inlet or other drainage structure or pedestrian ramp.

_____ Approach grade of driveway does not exceed the maximum allowed per the street classification.

_____ Nearest right-of-way of alley – ten feet (10').

_____ Nearest edge to property line – five feet (5').

_____ If corner lot, nearest edge to nearest right-of-way of intersecting street – twenty feet (20').

_____ Approach skewed to not less than sixty degrees (60^0) between street right-of-way line and the edge of the driveway approach.

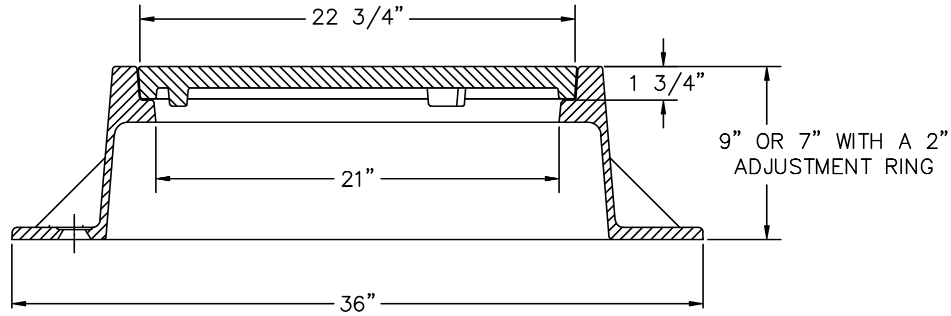
_____ Radius of driveway approach <u>not</u> extended beyond the projection of the adjacent property line.

_____ Radius of driveway return is designed for the classification of street and type of vehicle use.

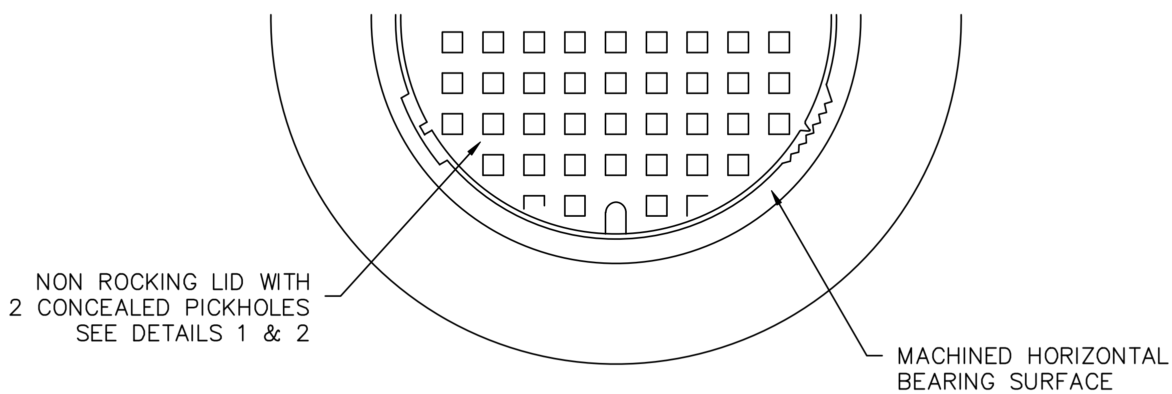
_____ Expansion joints indicated.

_____ Cross slope of sidewalk area within the driveway must not exceed 1:50 (2%).

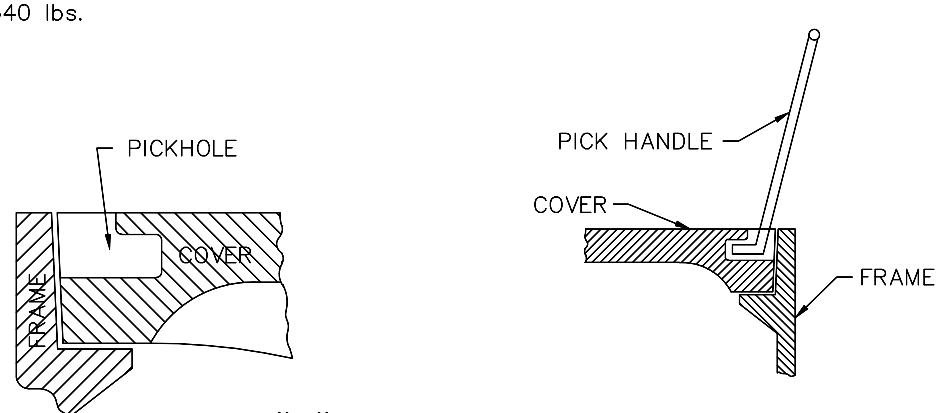
MANHOLE RING & COVER
TYPE "A"



TYPE "A" SECTION VIEW



TOTAL WEIGHT
RING AND COVER
TYPE "A" = 540 lbs.

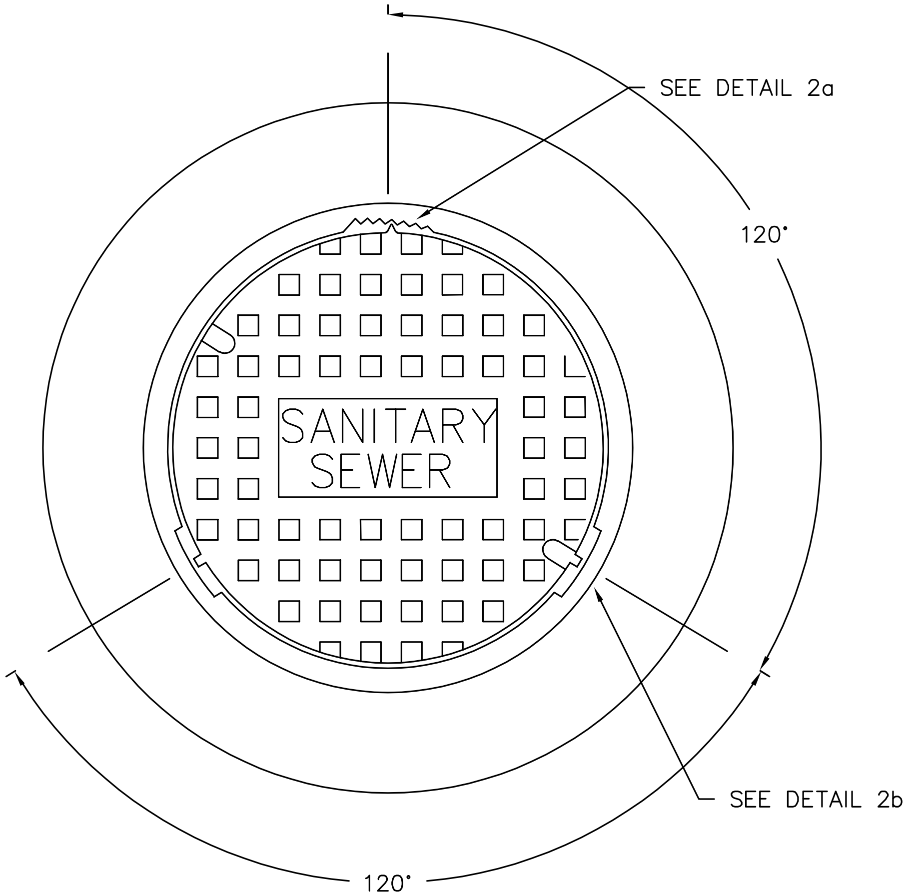


DETAIL "1" CONCEALED PICKHOLES

CITY OF BATTLEFIELD, MO	MANHOLE RING AND COVER (TYPE "A")	ADOPTED: XX/XX/2023 SAN-1

DETAIL "2" NON ROCKING COVER

SEE SAN-1 FOR TYPE "A" SECTION VIEW



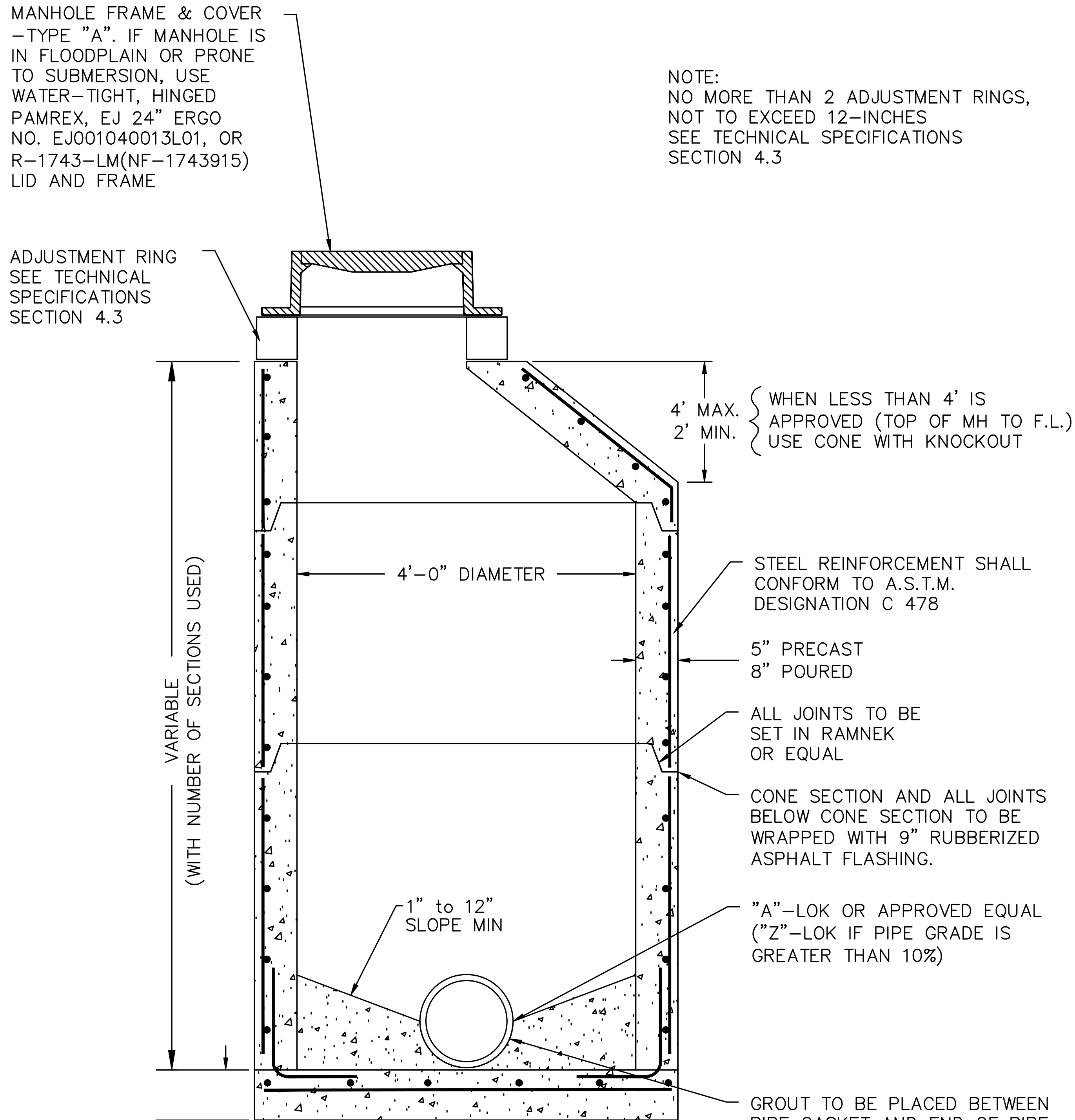
LOADS HS20
COMPONENT NOS.: FRAME NEENAH 1715-2001, LID 1715-XXXX
MATERIAL: CAST GRAY IRON ASTM A-48, CLASS 35B
FINISH: NO PAINT
WEIGHT: FRAME APPROX. 234#, LID APPROX. 127#

EACH OF THE 16 GROOVES IN THE GRADUATED RACK VARIES THE DIAMETER BY EQUAL AMOUNTS.

DETAIL 2a

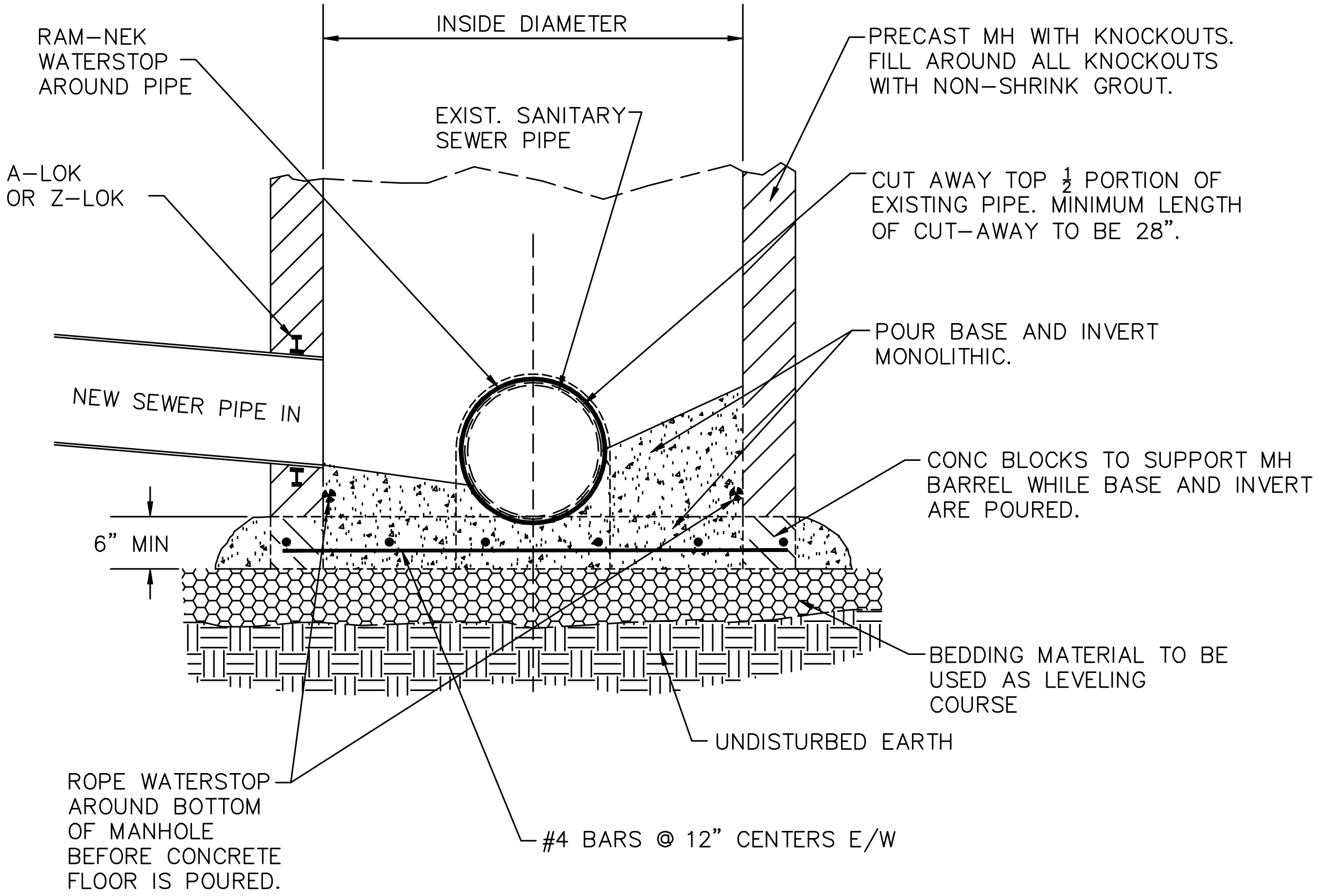
DETAIL 2b

CITY OF BATTLEFIELD, MO	MANHOLE RING AND COVER (NON-ROCKING)	ADOPTED: XX/XX/2023
		SAN-2

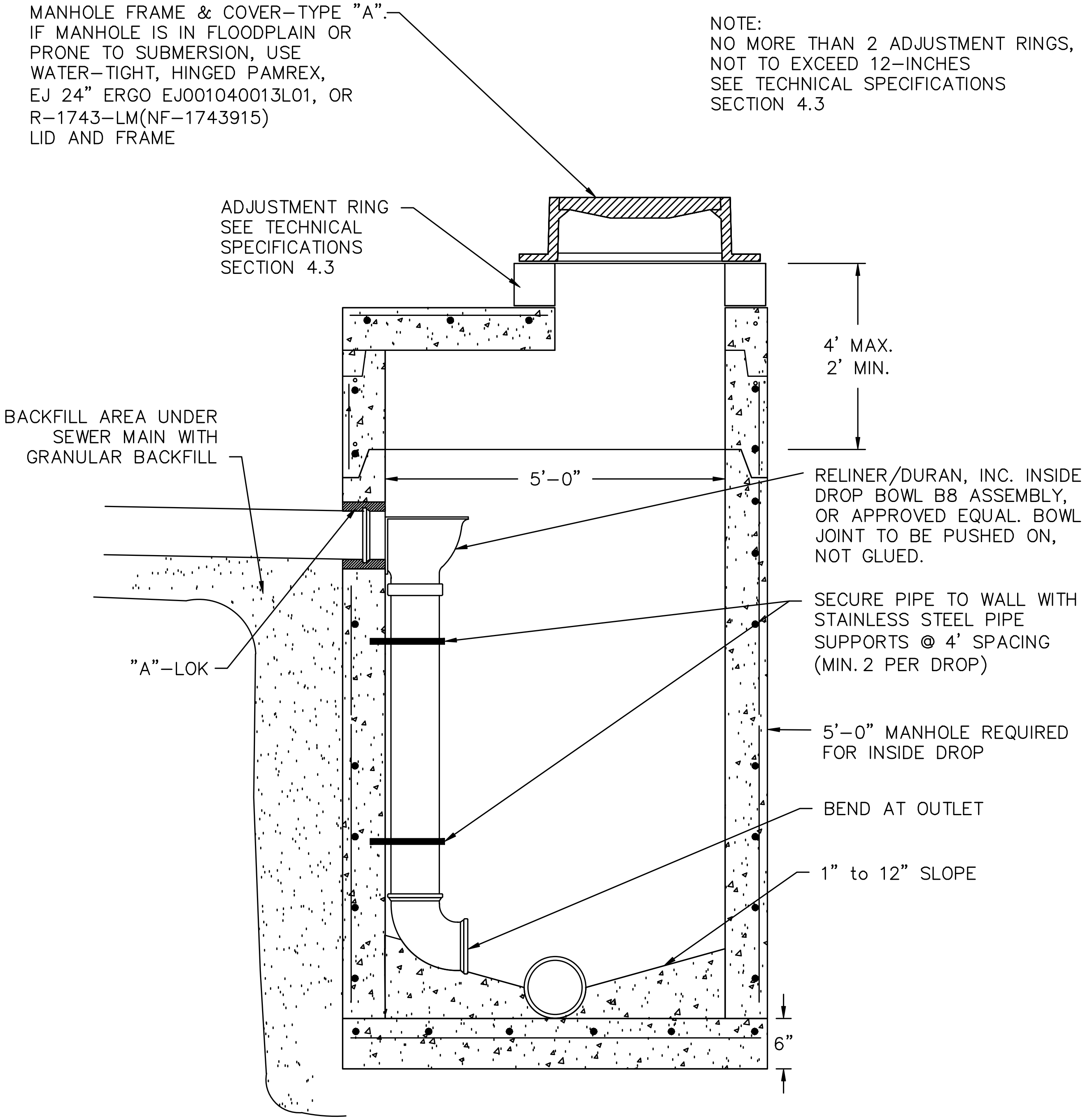


MANHOLE
8" TO 24" PIPE

CITY OF BATTLEFIELD, MO	STANDARD FOUR–FOOT DIAMETER MANHOLE	ADOPTED: XX/XX/2023
		SAN–3



CITY OF BATTLEFIELD, MO	NEW MANHOLE ON EXISTING LINE	ADOPTED: XX/XX/2023 SAN-4

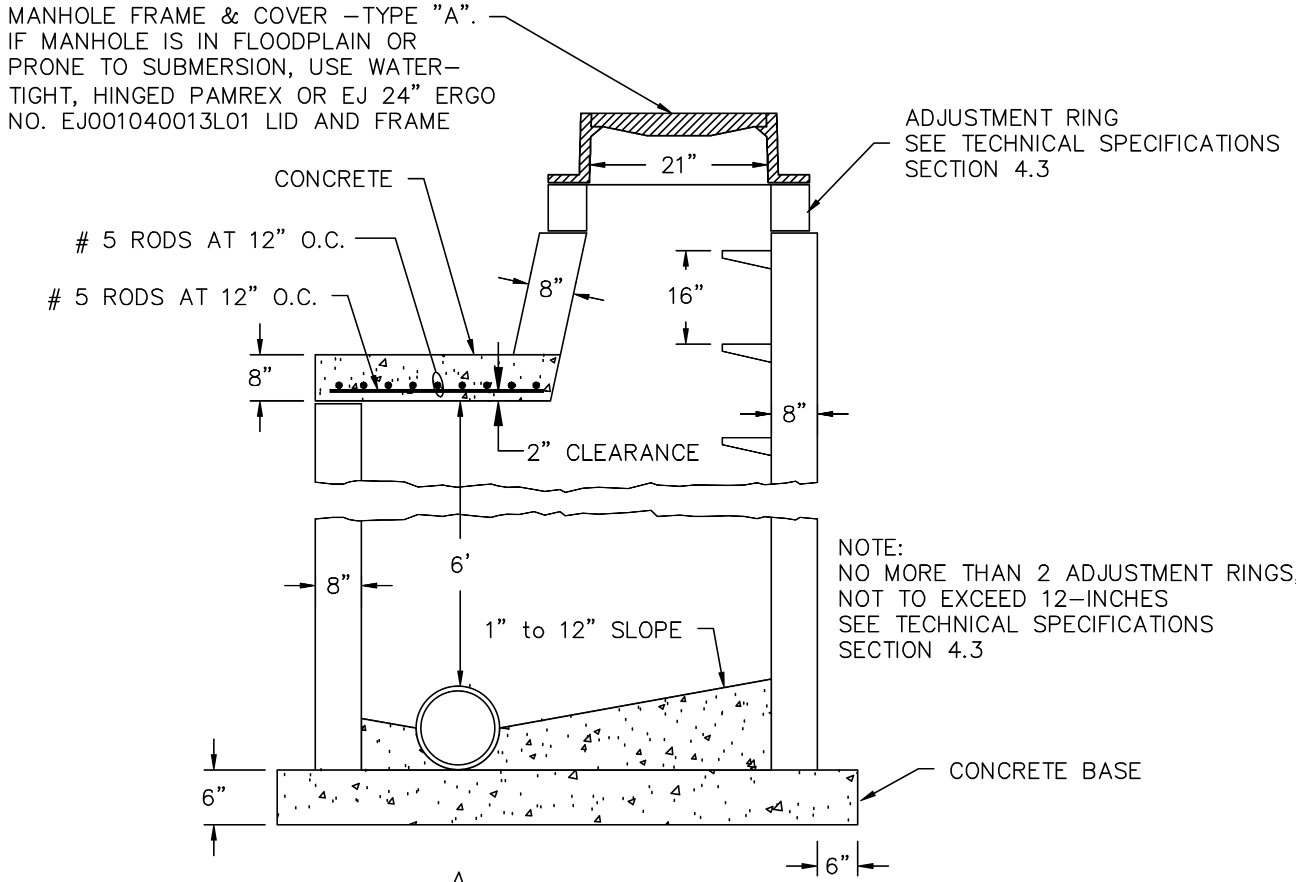


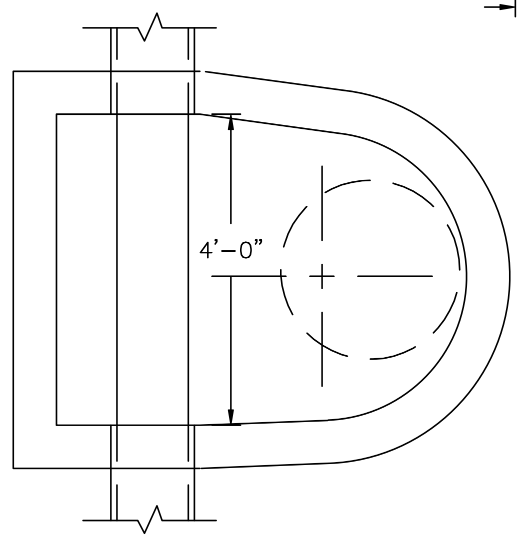
DISTANCE FROM PIPE INLET TO MANHOLE FLOWLINE FOR 8" PIPE.
0'–2' BUILD INSIDE FLUME
2'–3' SPECIAL DESIGN REQUIRED
3'– BUILD DROP MANHOLE

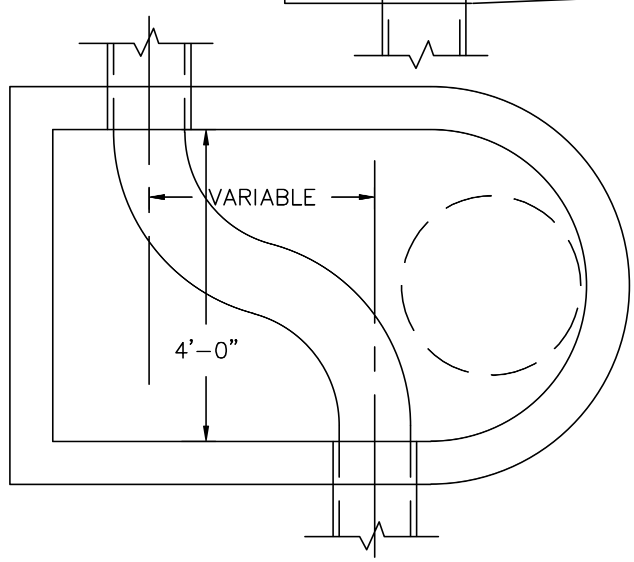
CONSTRUCTION METHODS FOR DROP MANHOLE TO BE SAME AS MANHOLE SAN–3

INSIDE DROP MANHOLE
8" TO 24" PIPE

CITY OF BATTLEFIELD, MO	INSIDE DROP MANHOLE	ADOPTED: XX/XX/2023
		SAN–6







NOTES:

1. WALLS SHALL BE POURED CONCRETE OR PRECAST.

2. THICKNESS OF WALLS TO BE INCREASED TO 12" AT 12' BELOW UNDERSIDE OF FRAME.

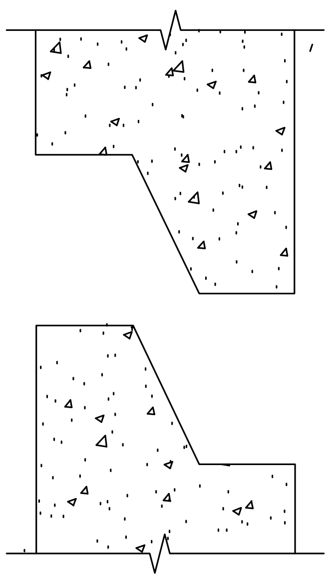
3. CONSTRUCTION METHODS TO BE SAME AS STANDARD MANHOLES.

CITY OF BATTLEFIELD, MO	OFFSET MANHOLE	ADOPTED: XX/XX/2023
		SAN–7

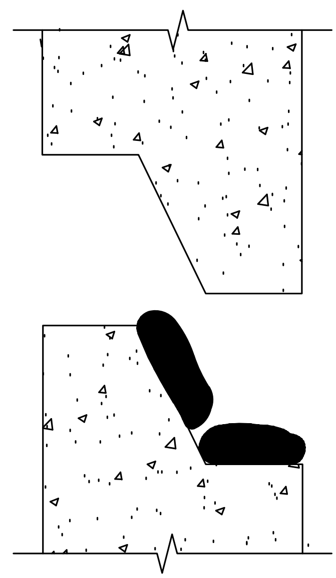
BITUMASTIC INSTALLATION (OR EQUAL)

SEALING OF TONGUE & GROOVE PRECAST MANHOLES

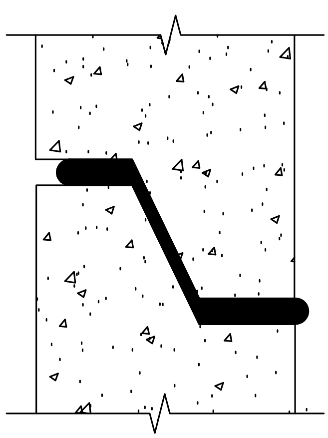
1. SURFACE PREPARATION (CLEANING)
   REMOVE ALL LOOSE PARTICLES, DUST, DIRT, ETC.



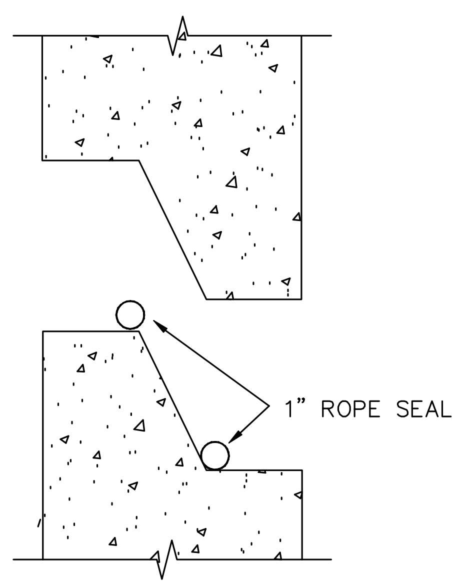
2. APPLYING BITUMASTIC SEAL
   PLACE BITUMASTIC ROPE OR EQUAL IN GROOVE.



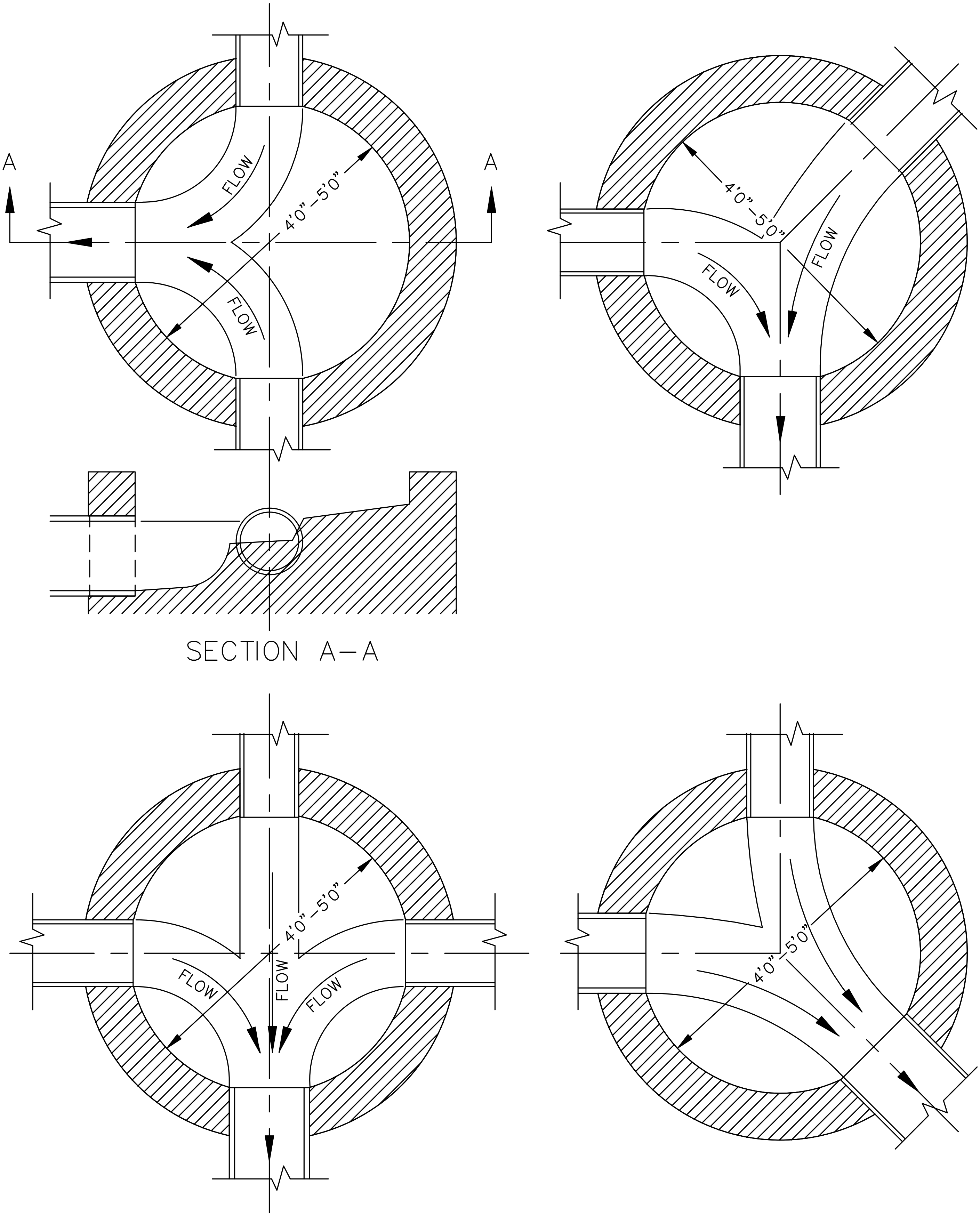
3. COMPLETION OF BITUMASTIC SEAL
   LOWER THE NEXT LENGTH OF PIPE (TONGUE INTO GROOVE) AND SEAL WILL BE ACCOMPLISHED BY WEIGHT OF PIPE.



APPLYING ROPE SEAL



CITY OF BATTLEFIELD, MO	GASKET SEALING DETAILS FOR PRECAST MANHOLES	ADOPTED: XX/XX/2023
		SAN-8

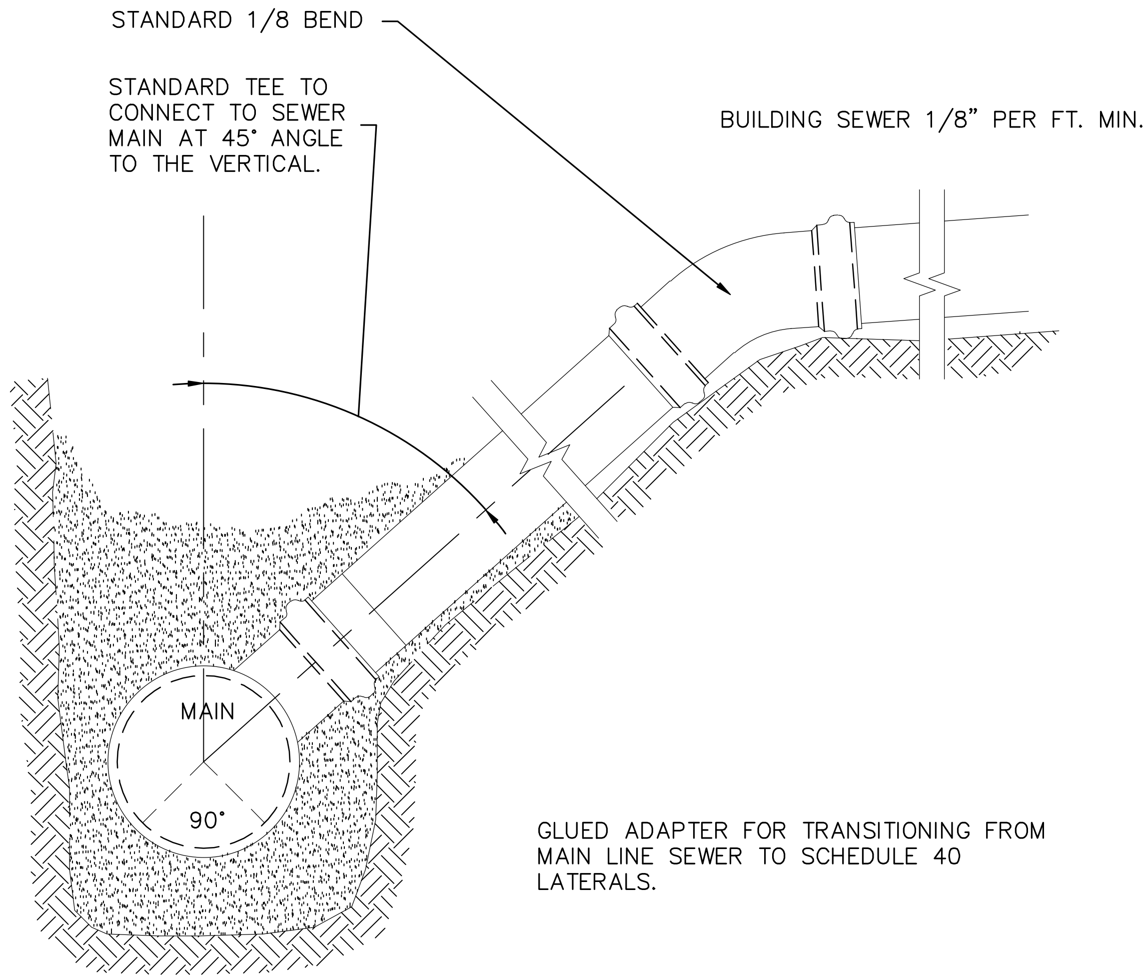


PIPES CANNOT ENTER MANHOLES AT ANGLES LESS THAN 90° TO EACH OTHER.

CITY OF BATTLEFIELD, MO	FLOWLINES FOR MANHOLE BASES	ADOPTED: XX/XX/2023
		SAN–9

NOTE:

MOULDED TEES ARE REQUIRED FOR ALL LATERALS ON NEW SEWER LINES. ALL LATERALS SHALL BE SCHEDULE 40 PIPE AND JOINTS SHALL BE GLUED WITH AN APPROVED ADHESIVE.

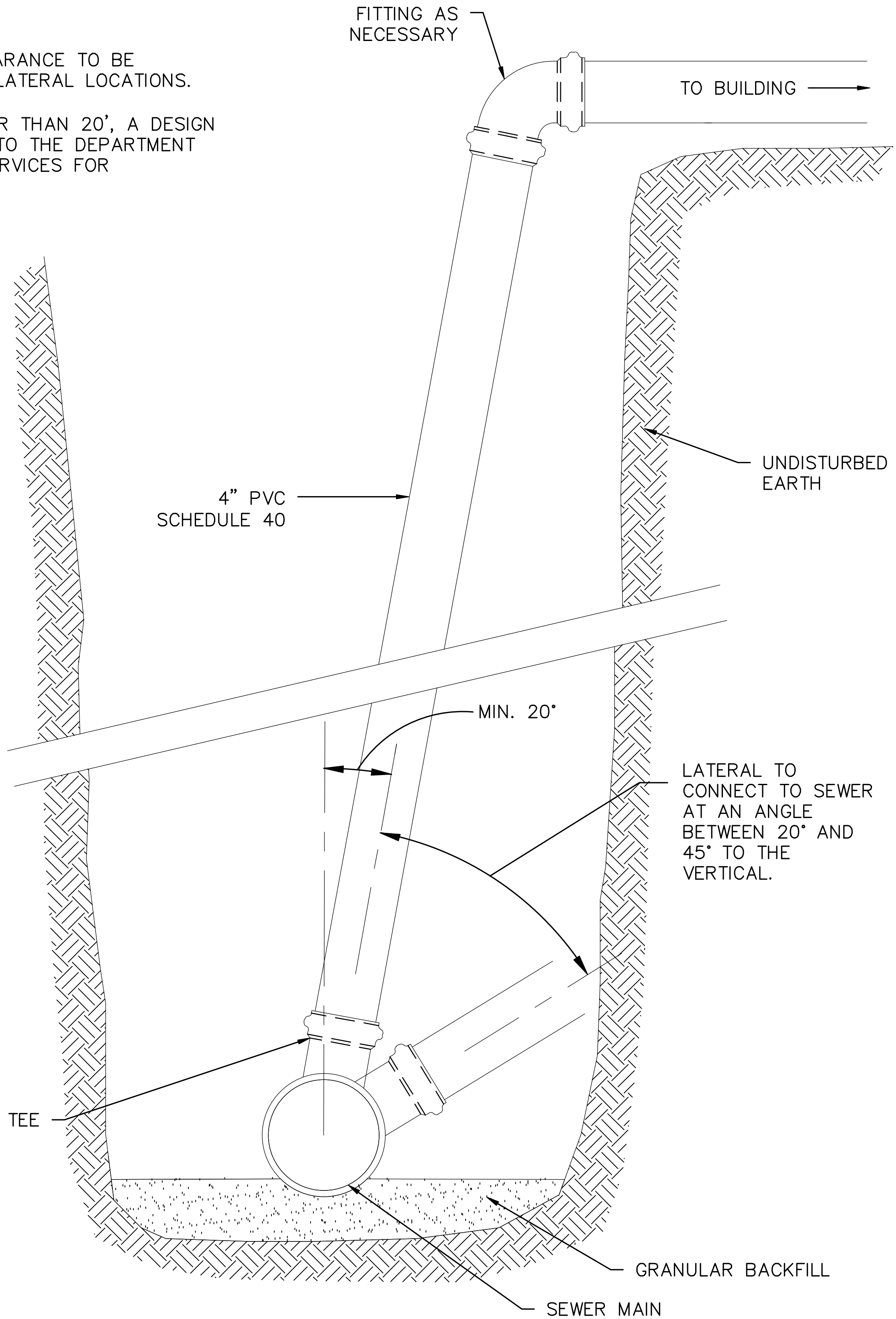


CITY OF BATTLEFIELD, MO	HOUSE CONNECTIONS – LESS THAN 12'	ADOPTED: XX/XX/2023 SAN–10

NOTE:

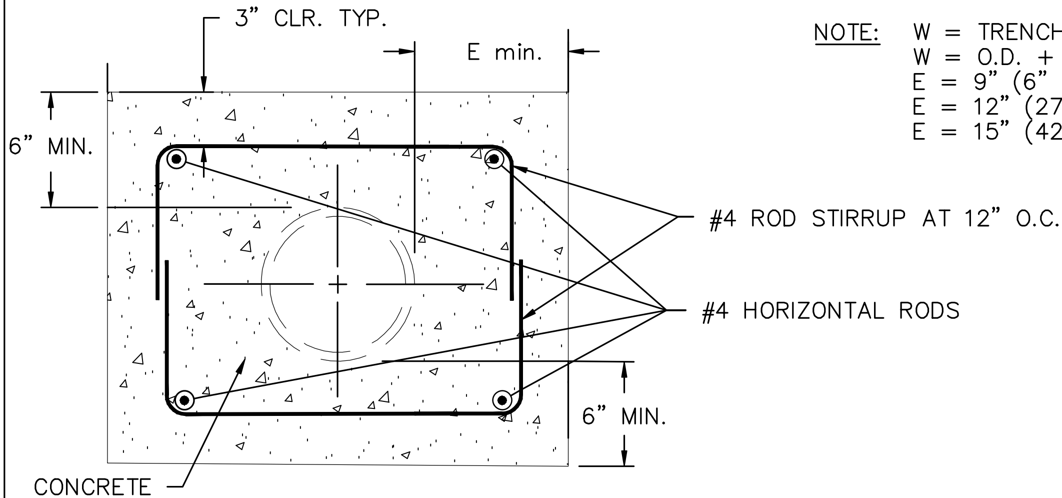
1. MINIMUM OF 2' CLEARANCE TO BE MAINTAINED BETWEEN LATERAL LOCATIONS.

2. FOR SEWERS DEEPER THAN 20', A DESIGN SHALL BE SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL SERVICES FOR APPROVAL.

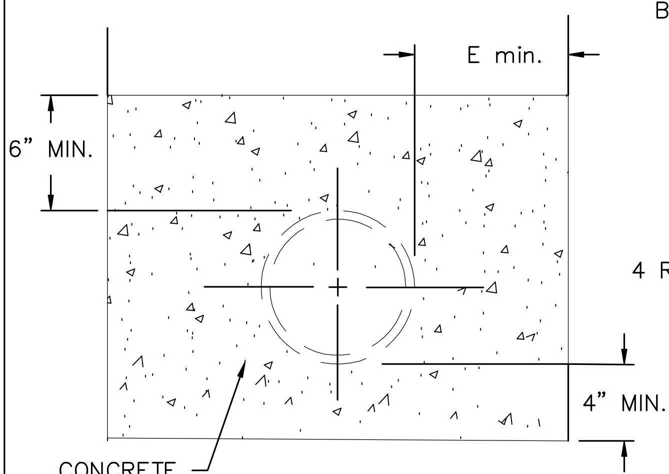


CITY OF BATTLEFIELD, MO	HOUSE CONNECTIONS – 12 FEET TO 20 FEET	ADOPTED: XX/XX/2023
		SAN–11

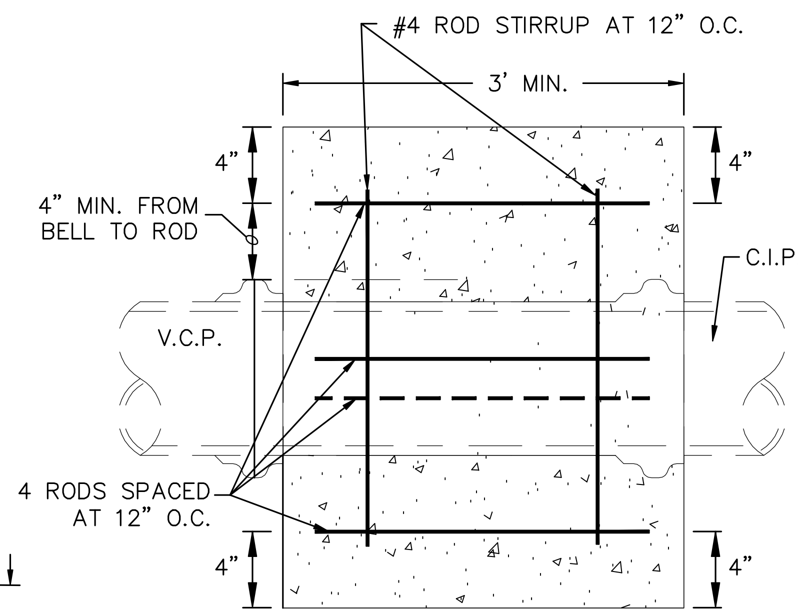
NOTE: W = TRENCH WIDTH
W = O.D. + 2E
E = 9" (6" to 24" PIPE)
E = 12" (27" to 36" PIPE)
E = 15" (42" to 72" PIPE)



REINFORCED
CONCRETE ENCASEMENT
IF ON SOIL



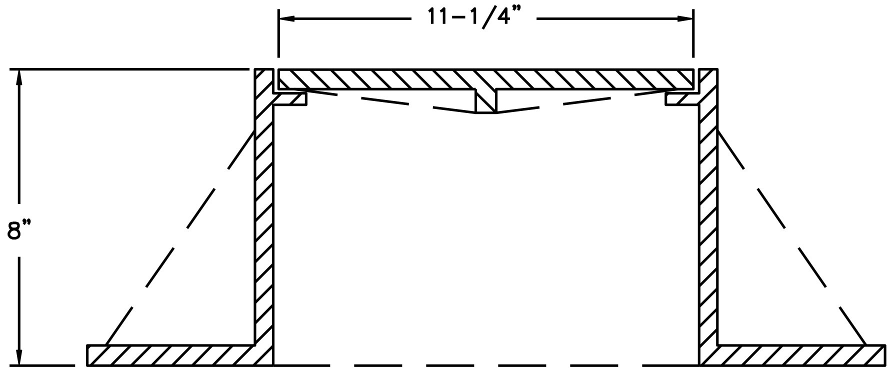
CONCRETE ENCASEMENT
IF ON BEDROCK



FOR 8" PIPE A V.C.P.–C.I.P. "ADAPTER"
FERNCO COUPLING OR EQUAL

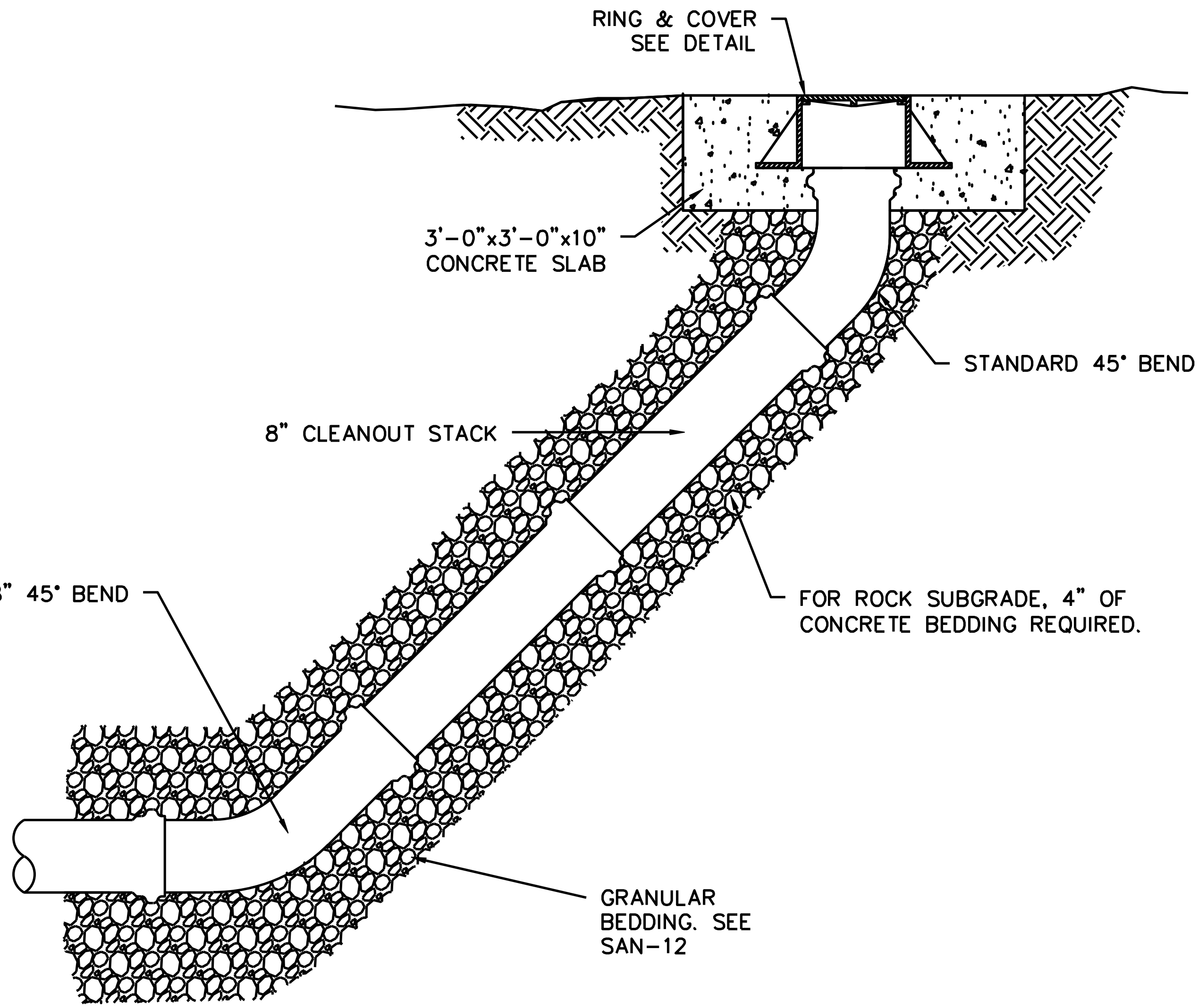
EXISTING V.C.P.–C.I.P.
JUNCTION ENCASEMENT

CITY OF BATTLEFIELD, MO	ENCASEMENT STANDARDS	ADOPTED: XX/XX/2023 SAN–12



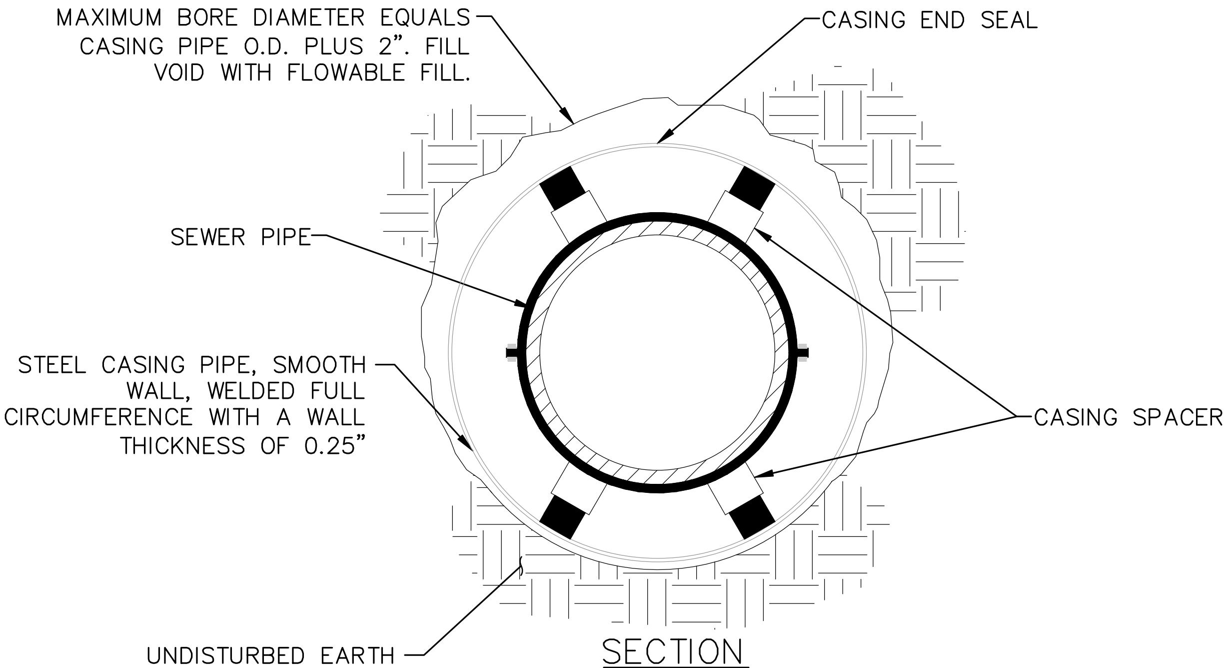
MINIMUM WEIGHT 90 lbs.
NEENAH R-1976 OR EQUAL

RING & COVER DETAIL

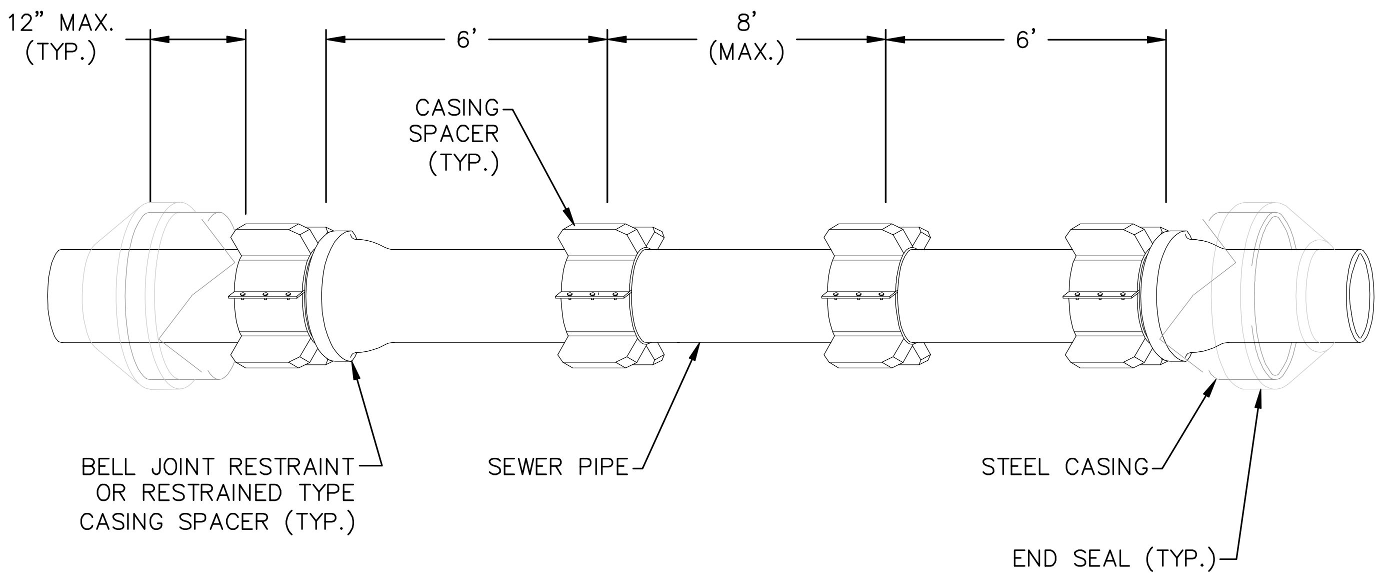


STANDARD CLEANOUT LAMPHOLE

CITY OF BATTLEFIELD, MO	LAMPHOLES	ADOPTED: XX/XX/2023
		SAN-13



SECTION

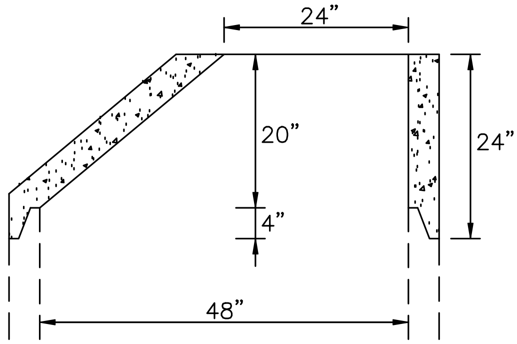


ELEVATION

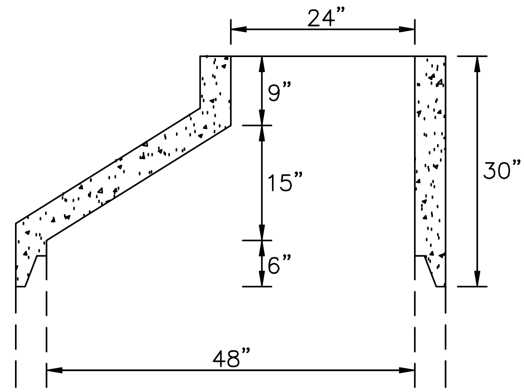
NOTES:

1. MINIMUM 1% DESIGN SLOPE ON CASING AND CARRIER PIPES.
2. SPACERS SHALL BE IN CONTACT WITH BELL OF COMPLETED PIPE JOINT.
3. NOMINAL DIAMETER OF WELDED STEEL CASING PIPE SHALL BE A MINIMUM OF 8" PLUS DIAMETER OF CARRIER PIPE. FOR CARRIER PIPES LARGER THAN 16", CASING SHALL BE ENGINEER DESIGNED.
4. IT IS THE DESIGNER AND CONTRACTOR'S RESPONSIBILITY TO ENSURE THE DIAMETER OF THE STEEL CASING IS LARGE ENOUGH TO ACCOMODATE THE CARRIER PIPE WITH APPROPRIATE SPACERS WITHOUT ADDING STRESS TO THE CARRIER PIPE.

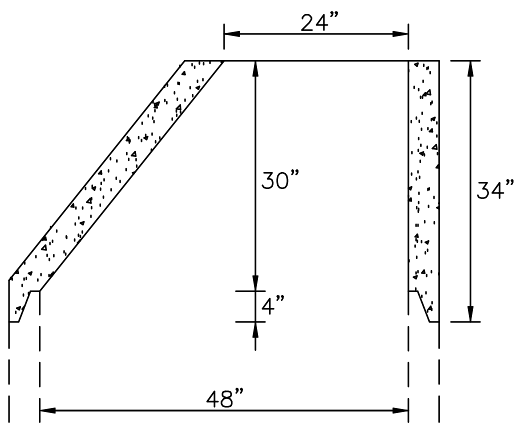
CITY OF BATTLEFIELD, MO	BORING DETAILS	ADOPTED: XX/XX/2023
		SAN–15



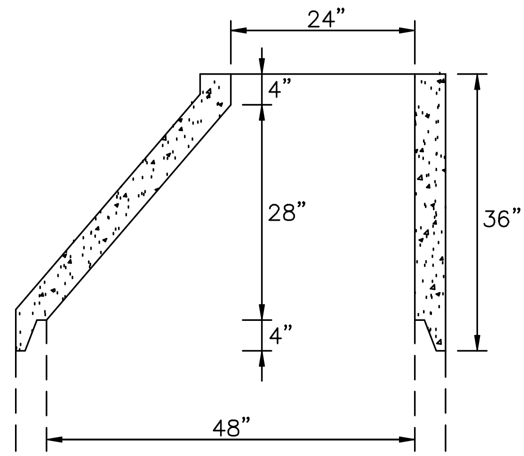
24" CONE



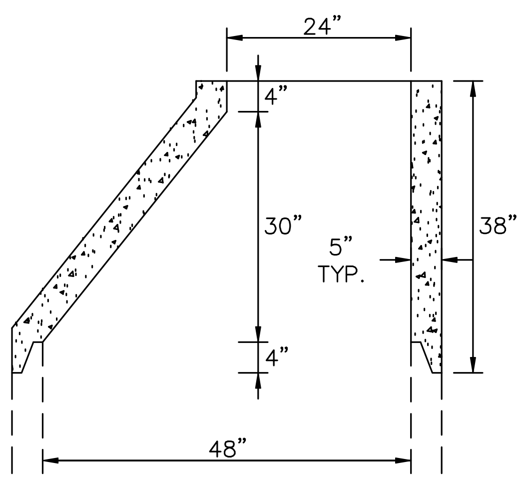
30" CONE



34" CONE



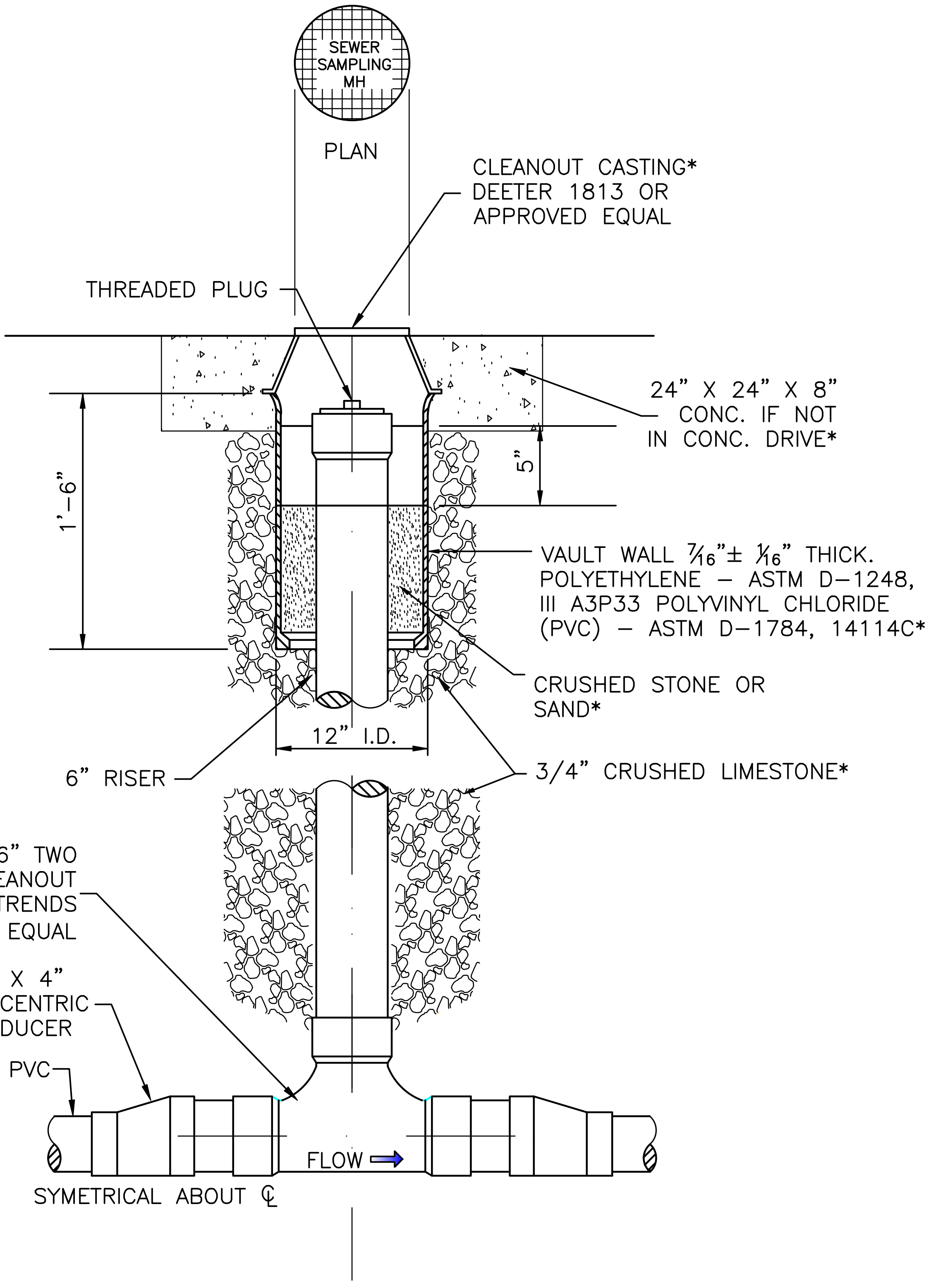
36" CONE



38" CONE

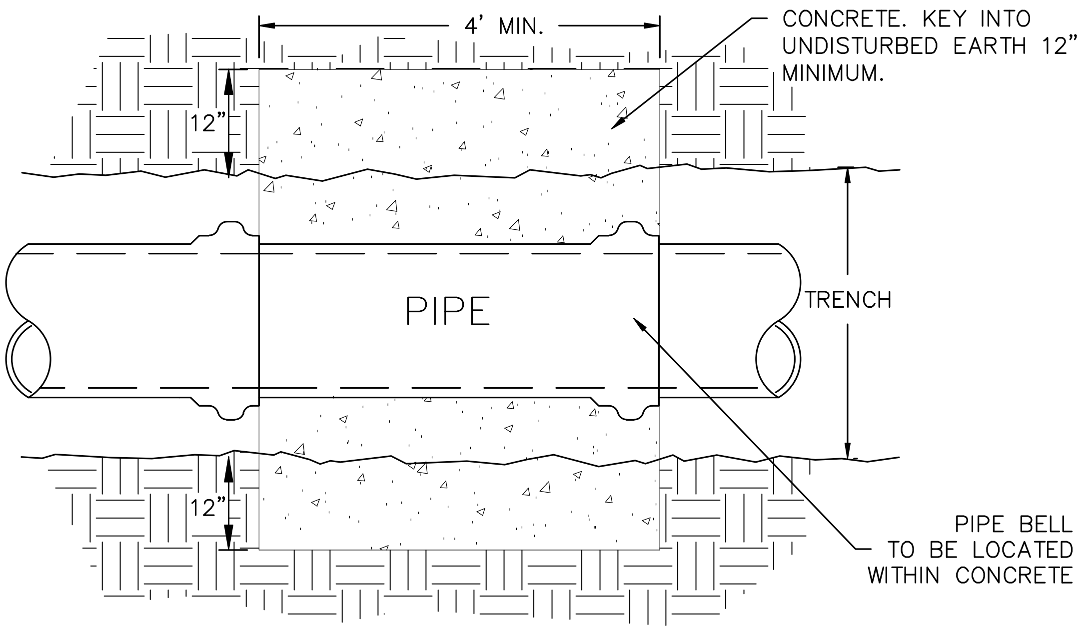
NOTE: WALL THICKNESS 5" TYP.

CITY OF BATTLEFIELD, MO	STANDARD CONE CONFIGURATION FOR MANHOLES	ADOPTED: XX/XX/2023
		SAN-16

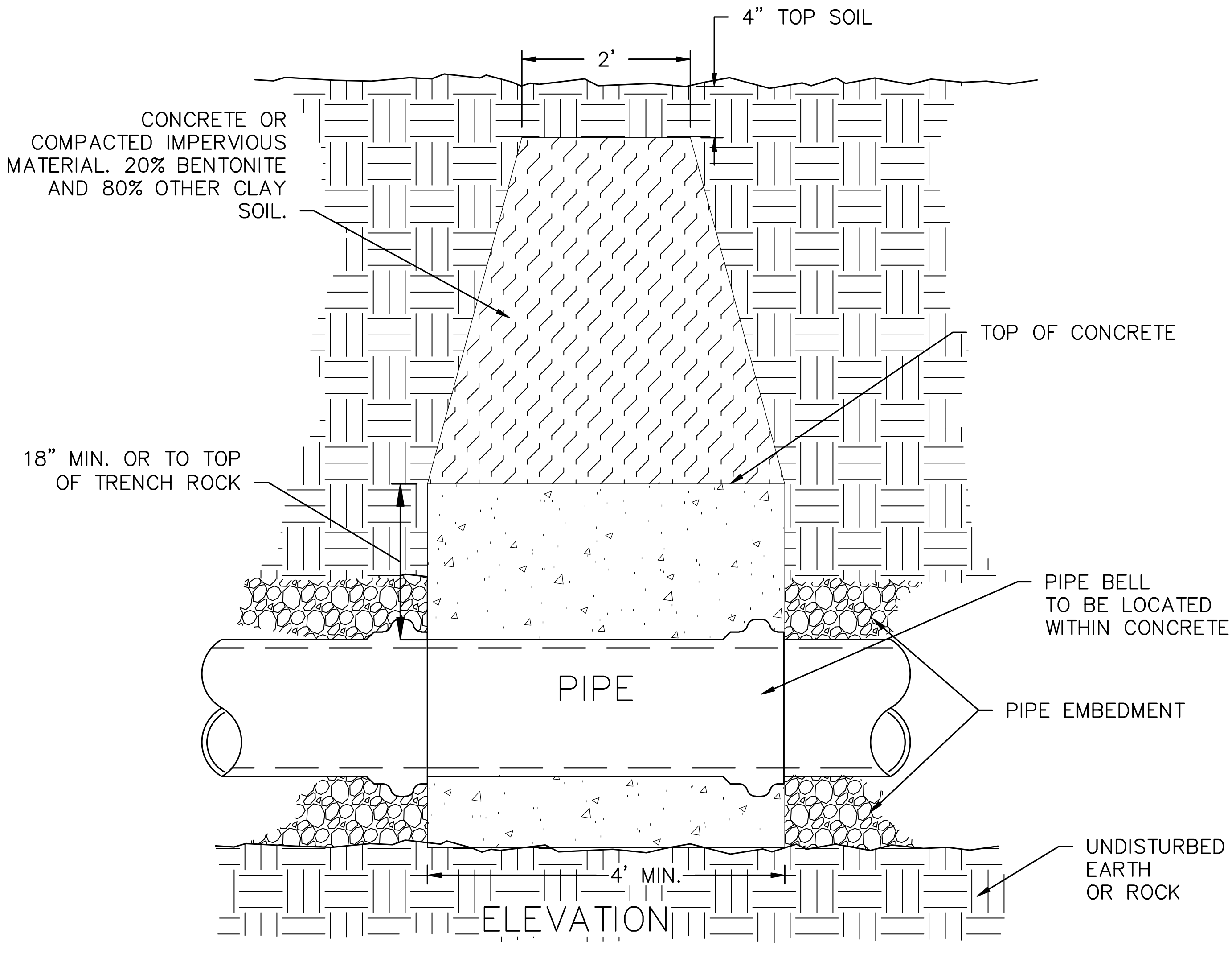


*NOT REQUIRED IF LOCATED INDOORS ON SITES WHERE NO OUTSIDE LOCATION IS AVAILABLE.
–NOT MAINTAINED BY THE CITY OF BATTLEFIELD

CITY OF BATTLEFIELD, MO	SAMPLING MANHOLE	ADOPTED: XX/XX/2023 SAN–19



TOP VIEW

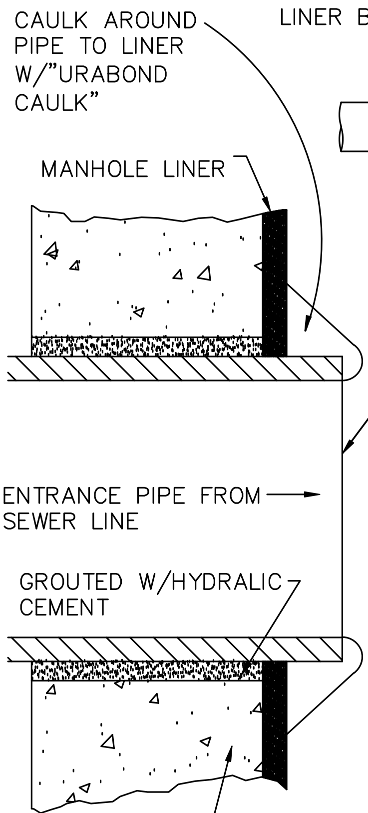


ELEVATION

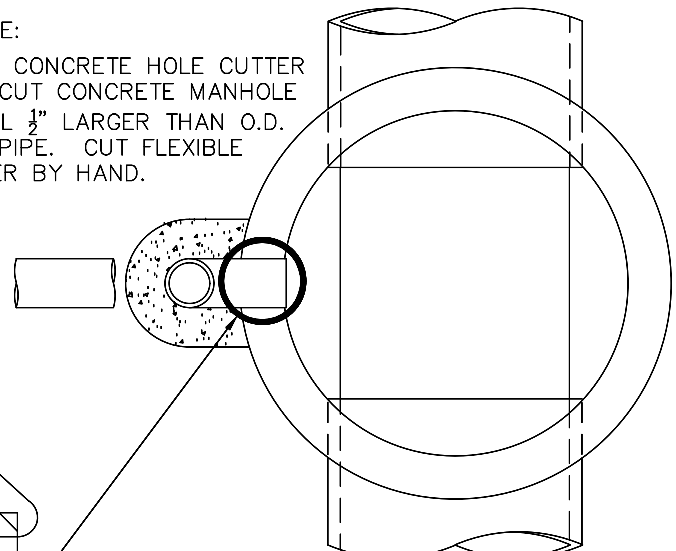
CITY OF BATTLEFIELD, MO	IMPERVIOUS TRENCH SEAL	ADOPTED: XX/XX/2023
		SAN-21

NOTE:

USE CONCRETE HOLE CUTTER TO CUT CONCRETE MANHOLE WALL $\frac{1}{2}$" LARGER THAN O.D. OF PIPE. CUT FLEXIBLE LINER BY HAND.



ENLARGED PIPE ENTRANCE



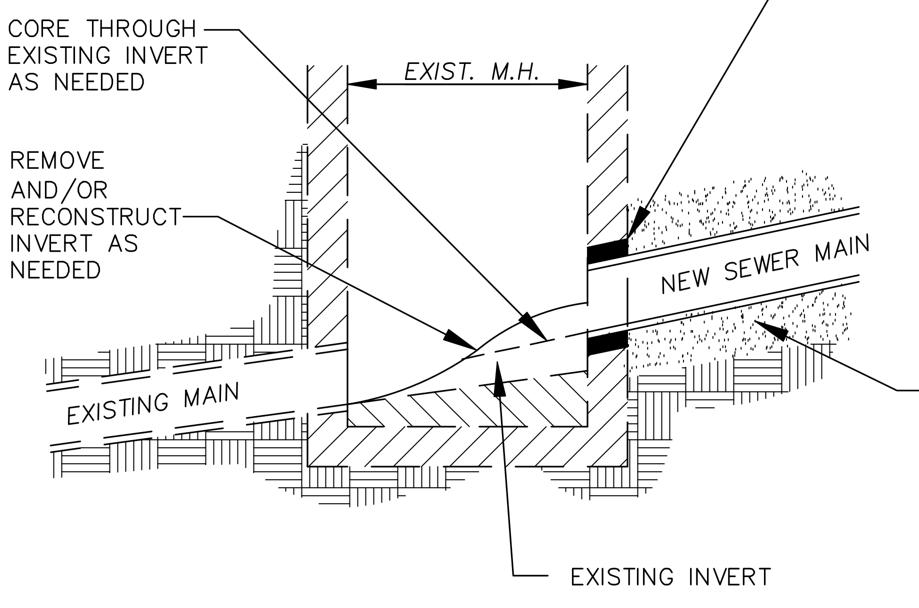
TOP VIEW

IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO REPAIR ANY DAMAGE TO PLASTIC LINER.

NOTE:

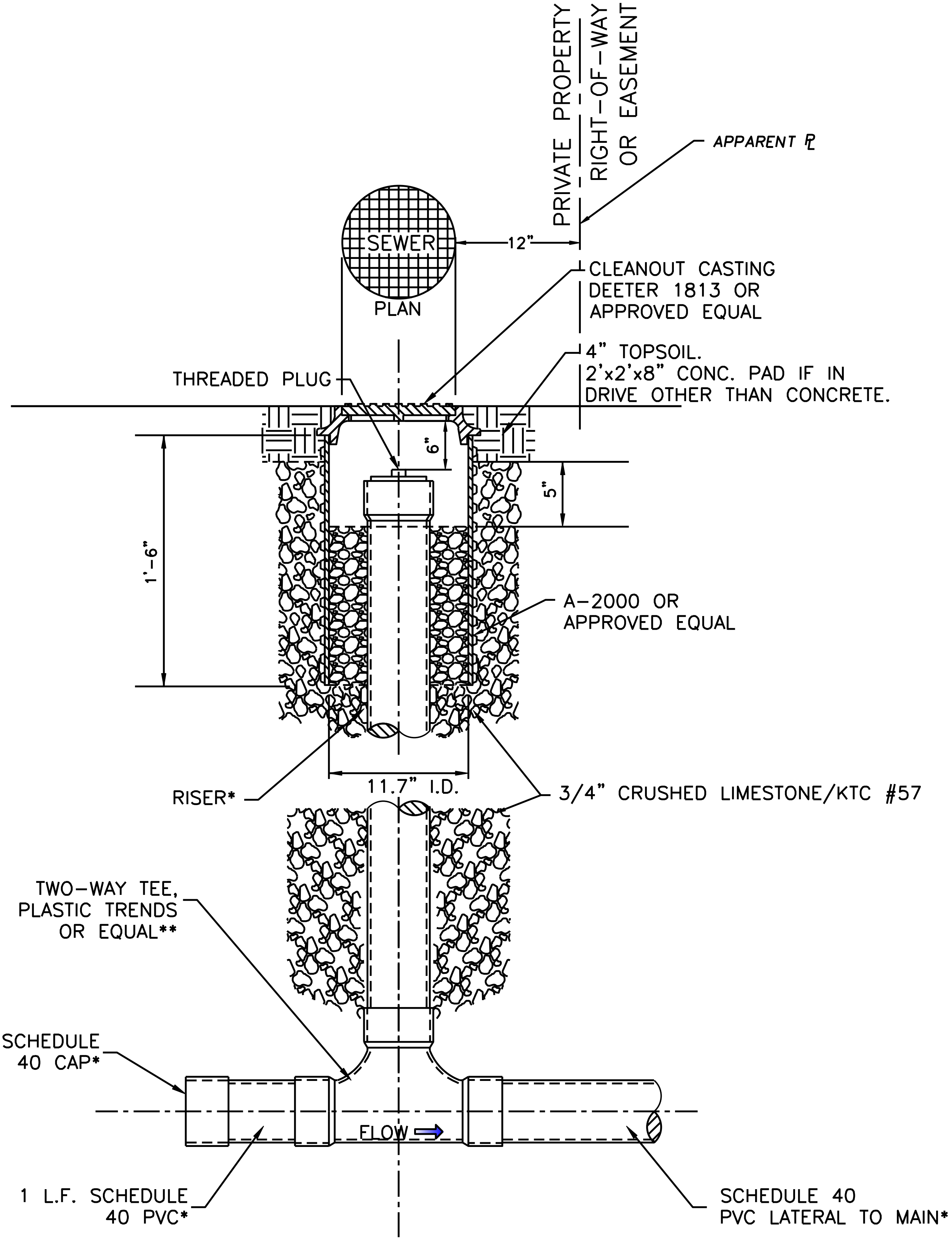
"URABOND CAULK" MFG. BY
POLYRESINS
P.O. BOX 158
SUN VALLEY, CA 91352

CITY OF BATTLEFIELD, MO	CONNECTION TO LINED MANHOLES	ADOPTED: XX/XX/2023
		SAN−22



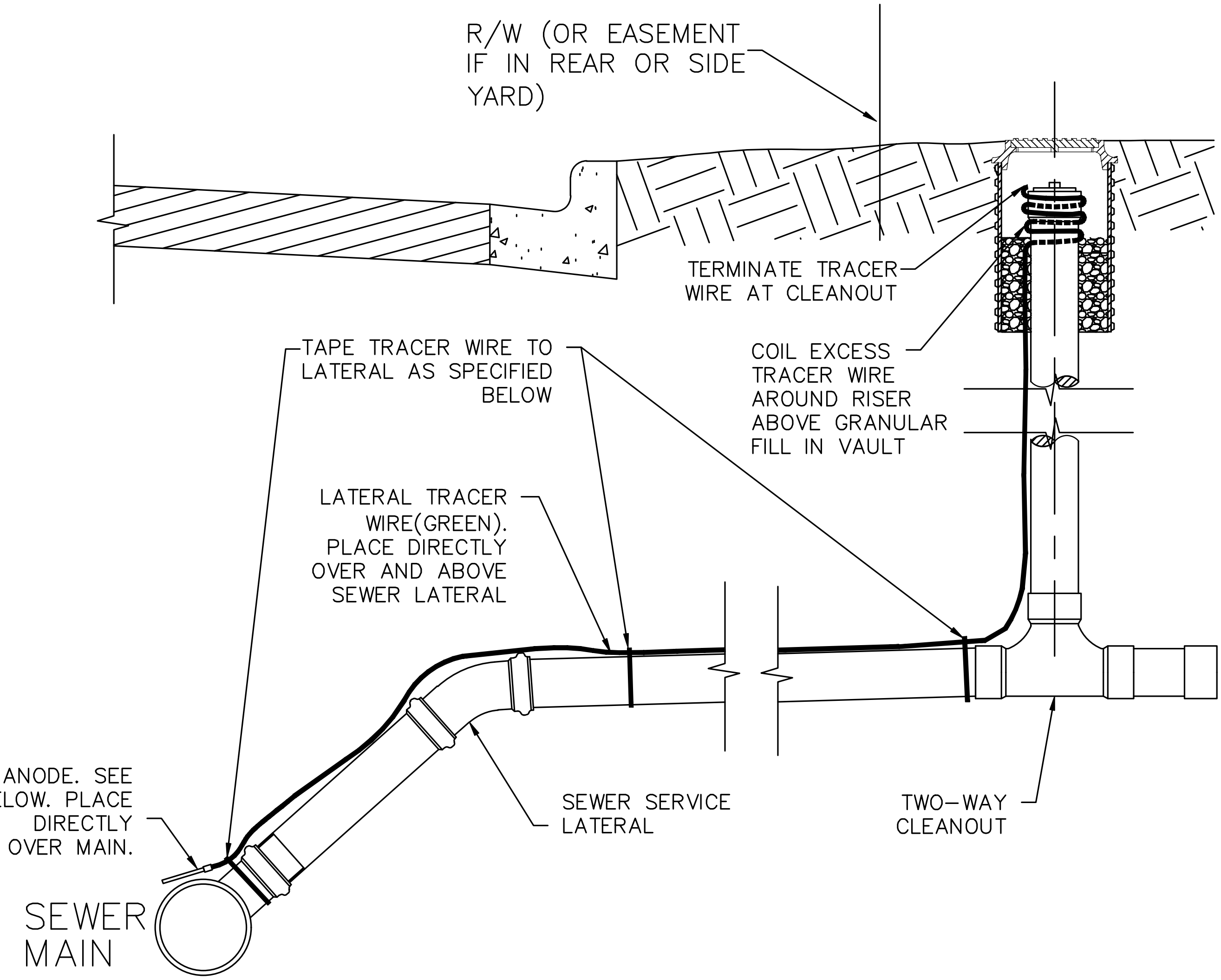
NOTE:
CORE EXISTING MANHOLE, USE INSERT A-LOK IF LESS THAN 10% GRADE (G3 COUPLING OR PSX DIRECT DRIVE GASKET IF PIPE GRADE IS GREATER THAN 10%) OR APPROVED EQUAL FOR PIPE CONNECTION TO MANHOLE: (1) LUBE & BEVEL PIPE (2) LUBE GASKET & (3) INSERT PIPE IN CENTER OF GASKET TO PROVIDE A WATERTIGHT COMPRESSION CONNECTION

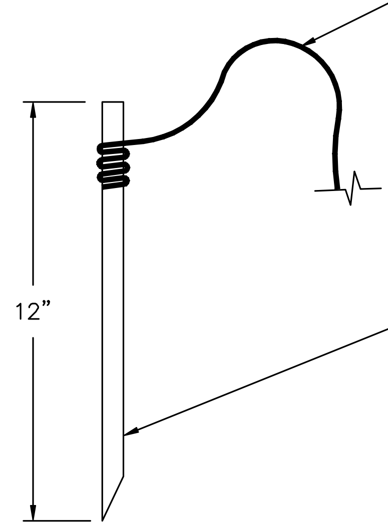
CITY OF BATTLEFIELD, MO	CONNECTION TO EXISTING MANHOLES	ADOPTED: XX/XX/2023
		SAN-23



NOTES:
-NOT MAINTAINED BY ENVIRONMENTAL SERVICES.
-ADJUST LATERAL DEPTH AS NECESSARY TO AVOID UTILITY CONFLICT.
* 4" OR 6" SCHEDULE 40 PVC.
** 4"X4" NO. #D1004; 6"X6" NO. #D1006 BY PLASTIC TRENDS.

CITY OF BATTLEFIELD, MO	TYPICAL CLEANOUT RISER	ADOPTED: XX/XX/2023
		SAN-24





WIRE

THE LOCATOR WIRE SHALL BE GREEN NO. 12 AWG COPPER CLAD STEEL(CCS). TO ALLOW FOR GRADE ADJUSTMENT, A MINIMUM OF 12" OF EXCESS WIRE SHALL BE COILED AT THE CLEANOUT FOR ALL WIRES.

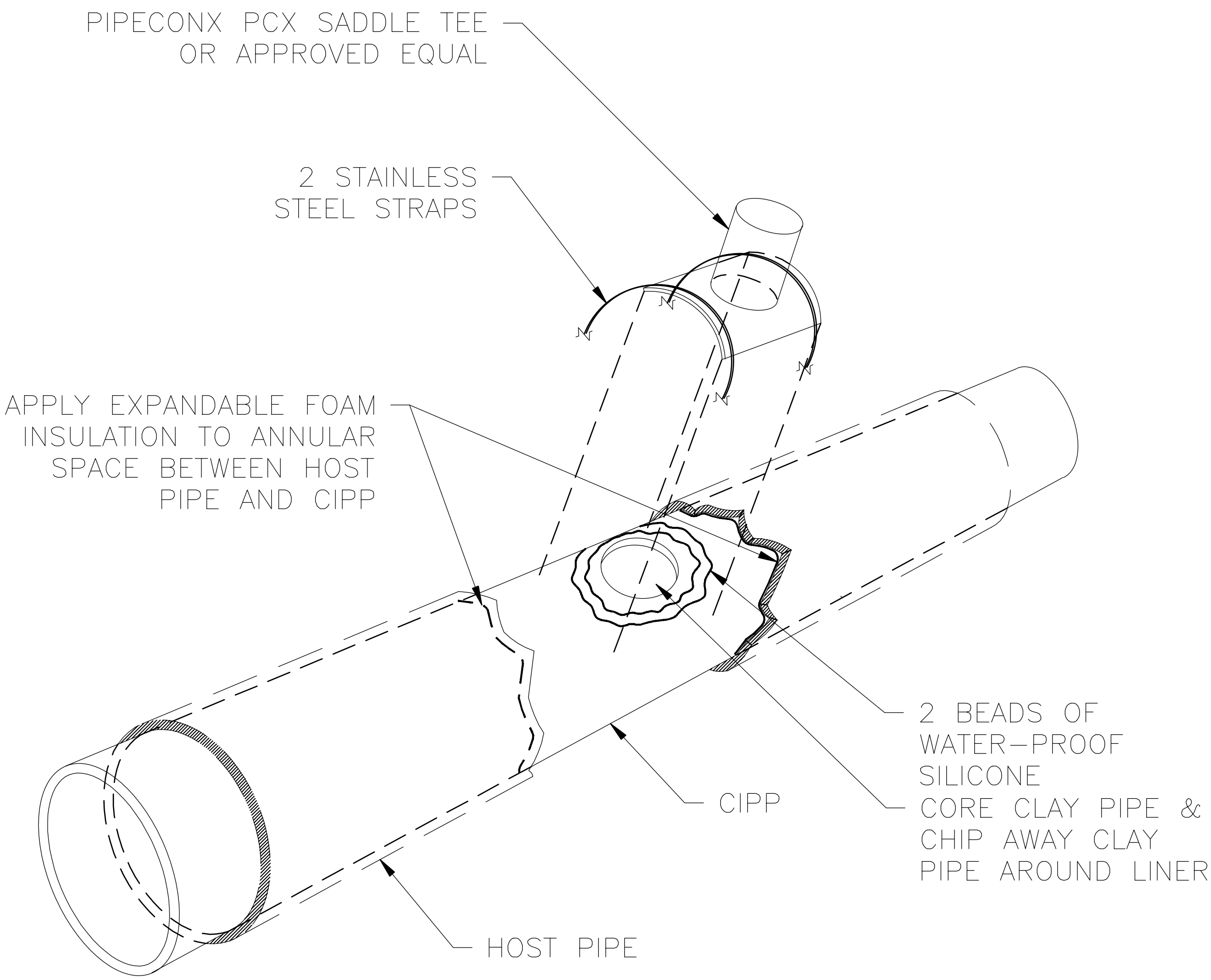
ANODES

THE ANODE SHALL BE ½ LB BARE ZINC OR MAGNESIUM. THE ANODES SHALL BE BURIED AT THE SAME ELEVATION AND IN CLOSE PROXIMITY TO THE SEWER LATERAL. THE ANODES SHALL BE CONNECTED TO THE GREEN NO. 12 AWG COPPER CLAD STEEL(CCS) WIRE. 1.315"Ø

TRACER WIRE DETAIL

CONDUCTIVE TYPE PIPE LOCATOR/TRACER WIRE SHALL BE INSTALLED TO LOCATE ALL SEWER LATERALS. THE WIRE SHALL EXTEND THE ENTIRE LENGTH OF THE PROPOSED LATERAL. THE WIRE SHALL BE INSTALLED DIRECTLY ON TOP OF THE PIPE AND SECURED TO THE LATERAL BY TAPE AT BASE OF RISER, SEWER MAIN AND EVERY 15'. CORROSION PROOF/FILLED WIRE CONNECTORS SHALL BE USED AT SPLICE LOCATIONS. ELECTRICAL TAPE SHALL BE USED AND NO BARE WIRE SHALL BE EXPOSED. TEST STATIONS SHALL BE INSTALLED INSIDE ALL CLEANOUT VAULTS AND EXISTING WIRES SHALL BE CONNECTED. ZINC OR MAGNESIUM ANODES SHALL BE ATTACHED AT BOTH THE BEGINNING AND THE END OF THE TRACER WIRE. A TYPICAL LAYOUT OF THE LOCATOR WIRE AND CLEANOUT IS PROVIDED IN THE FIGURE ABOVE. CONDUCTIVITY TO BE TESTED BEFORE ACCEPTANCE.

CITY OF BATTLEFIELD, MO	TRACER WIRE DETAIL	ADOPTED: XX/XX/2023 SAN-25

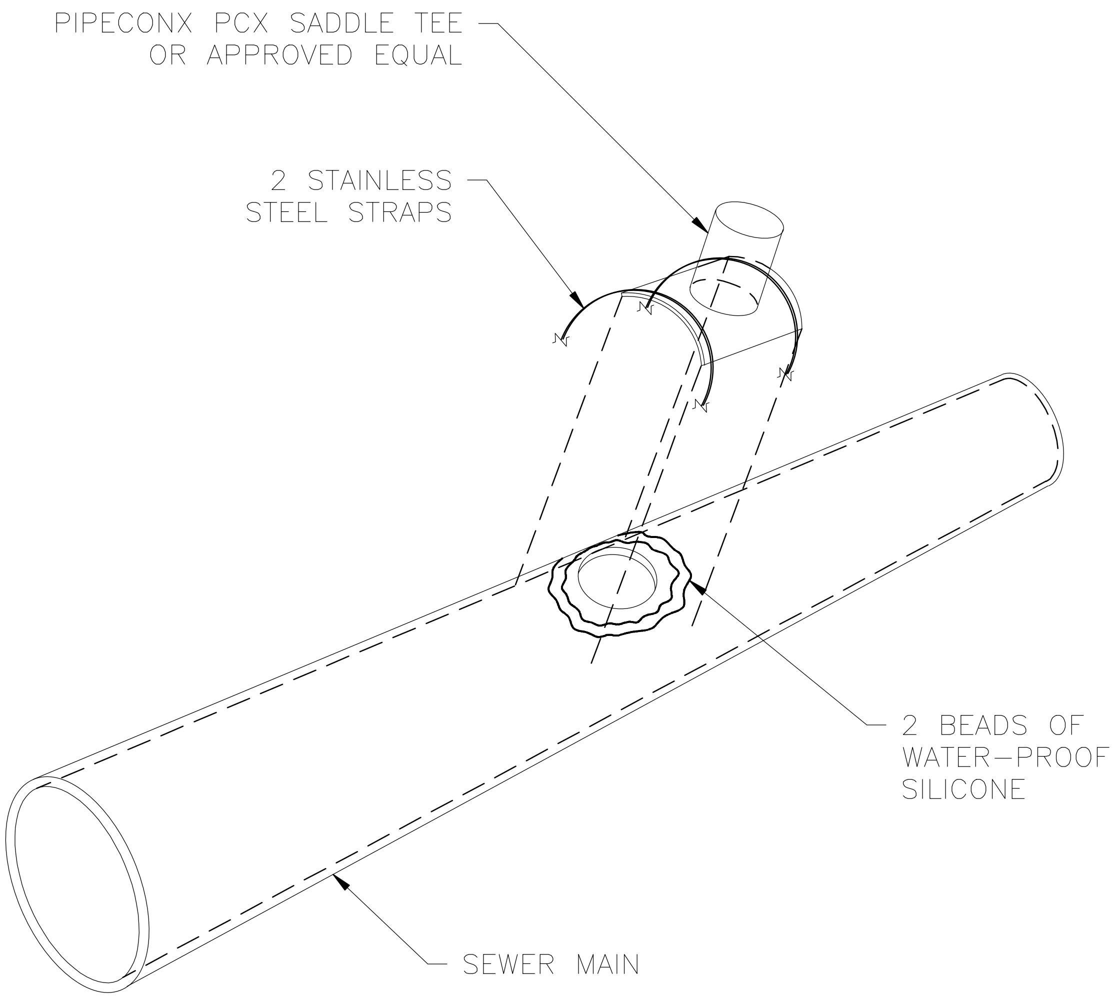


TAP FOR CIPP(CURED IN PLACE PIPE)

NOTE:

1. CORE CIPP LINED CLAY PIPE.
2. CHIP AWAY CLAY PIPE ONCE LINER IS VERIFIED.
3. APPLY 2 BEADS OF WATER–PROOF SILICONE AROUND CORE HOLE.
4. ATTACH PIPECONX PCX SADDLE.
5. SAVE COUPON FOR INSPECTOR.
6. TAKE AND SAVE PICTURE OF HOLE BEFORE INSTALLING SADDLE.

CITY OF BATTLEFIELD, MO	SADDLE CONNECTION TO CIPP LINED PIPE	ADOPTED: XX/XX/2023 SAN–26

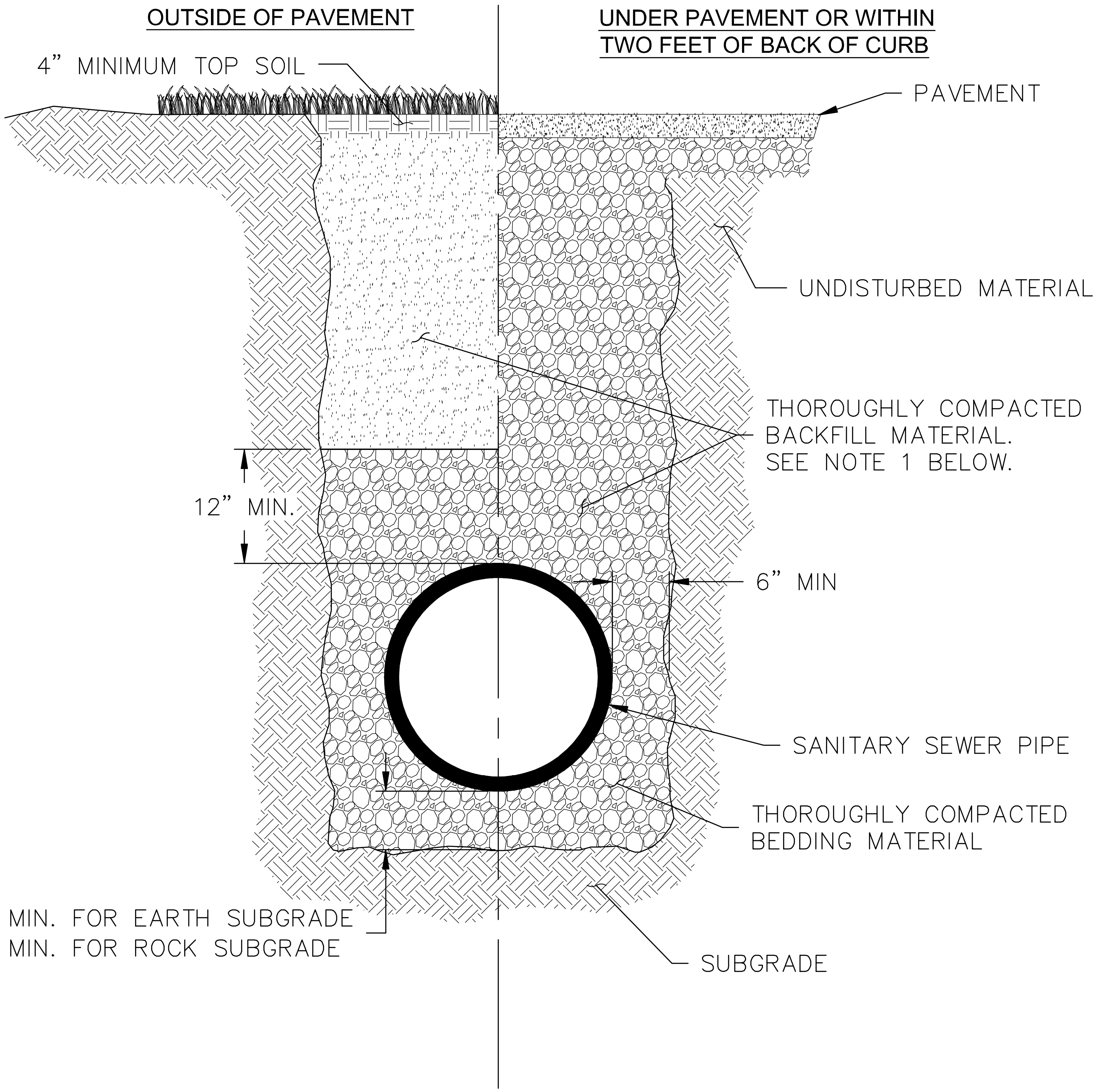


SADDLE TAP FOR SEWER MAINS

NOTE:

1. CORE PIPE.
2. APPLY 2 BEADS OF WATER-PROOF SILICONE AROUND CORE HOLE.
3. ATTACH PIPECONX PCX SADDLE.
4. SAVE COUPON FOR INSPECTOR.
5. TAKE AND SAVE PICTURE OF HOLE BEFORE INSTALLING SADDLE.
6. TEE TO BE INSTALLED AT 45° MAX.

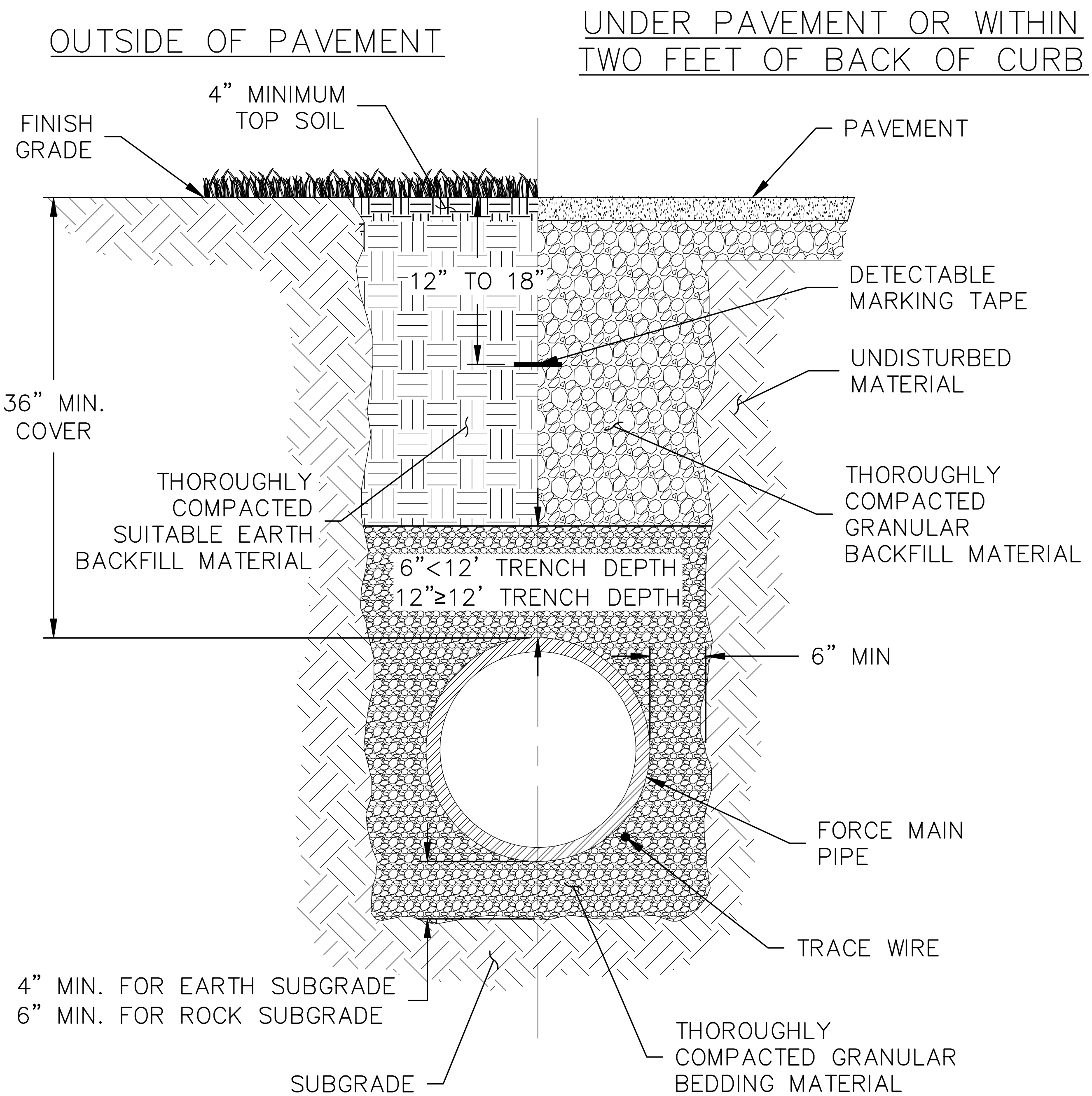
CITY OF BATTLEFIELD, MO	SADDLE CONNECTION TO SEWER MAIN	ADOPTED: XX/XX/2023
		SAN-27



NOTES:

1. BACKFILL AND BEDDING MATERIAL SHALL CONFORM TO CHAPTER 4 – SANITARY SEWERS OF THE CITY OF BATTLEFIELD GENERAL CONDITIONS AND TECHNICAL SPECIFICATIONS.
2. MINIMUM DEPTH OF BEDDING MATERIAL:
   $\frac{1}{4}$ PIPE DIAMETER BUT NEVER LESS THAN 4" BELOW THE PIPE IN EARTH, 6" BELOW IN ROCK AND A MINIMUM OF 12" ABOVE THE PIPE.

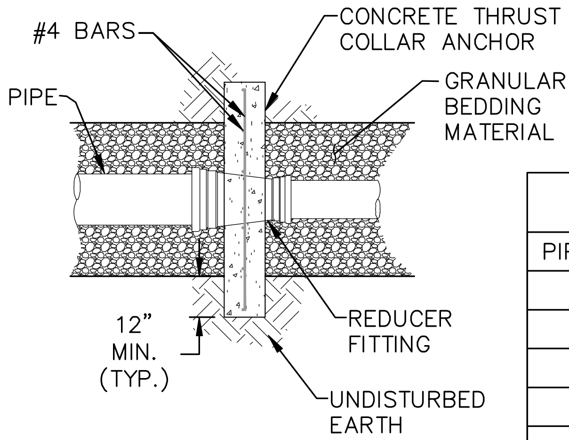
CITY OF BATTLEFIELD, MO	SEWER PIPE TRENCH DETAIL	ADOPTED: XX/XX/2023 SAN–28



NOTES:

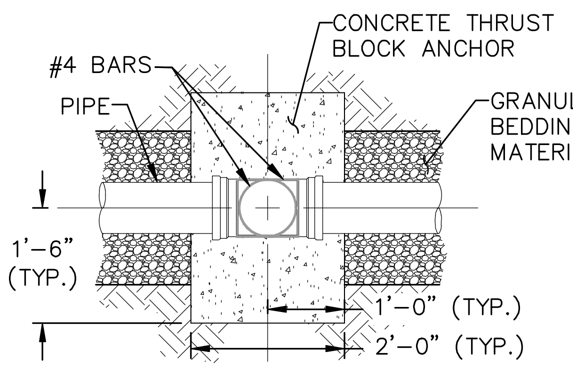
1. BEDDING AND BACKFILL MATERIAL SHALL CONFORM TO CHAPTER 4 – SANITARY SEWERS OF THE CITY OF BATTLEFIELD GENERAL CONDITIONS AND TECHNICAL SPECIFICATIONS.
2. MINIMUM DEPTH OF BEDDING MATERIAL:
   1/4 PIPE DIAMETER BUT NEVER LESS THAN 4" BELOW THE PIPE IN EARTH
   1/4 PIPE DIAMETER BUT NEVER LESS THAN 6" BELOW THE PIPE IN ROCK
   MINIMUM OF 6" ABOVE TOP OF PIPE FOR TRENCH DEPTHS LESS THAN 12'
   MINIMUM 12" ABOVE TOP OF PIPE FOR TRENCH DEPTHS GREATER THAN OR EQUAL TO 12'.
3. GRANULAR BACKFILL SHALL MEET THE REQUIREMENTS FOR BEDDING MATERIAL.

CITY OF BATTLEFIELD, MO	FORCE MAIN TRENCH DETAIL	ADOPTED: XX/XX/2023
		SAN–29

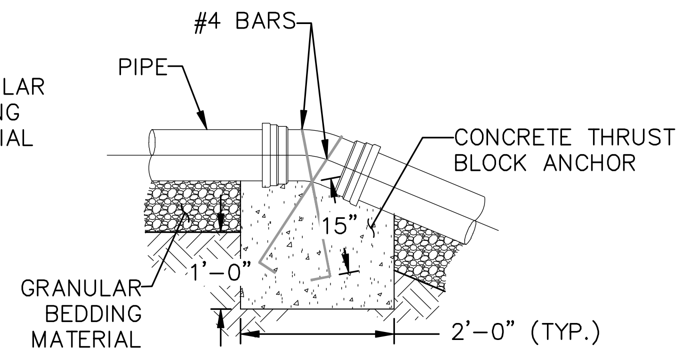


THRUST COLLAR

BLOCK BEARING AREA (SQ. FT.)				
PIPE SIZE	22 1/2°	45°	90°	"T", VALVE OR PLUG
4"	1	1	2	1.5
6"	1	2	4	3
8"	2	4	7	5
10"	3	6	11	8
12"	5	9	16	12

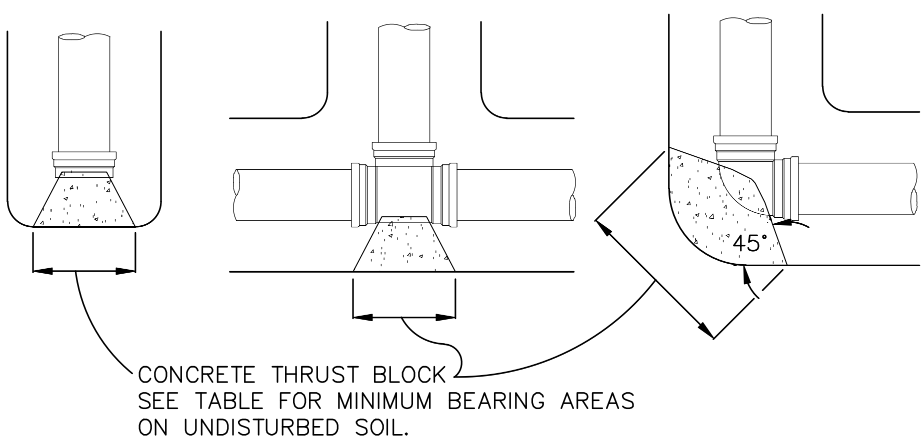


PLAN

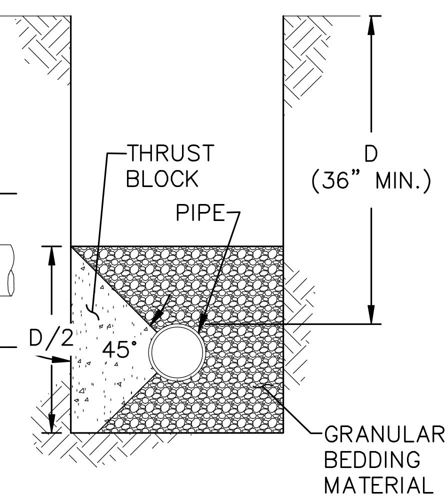


SECTION

VERTICAL FITTINGS



PLAN

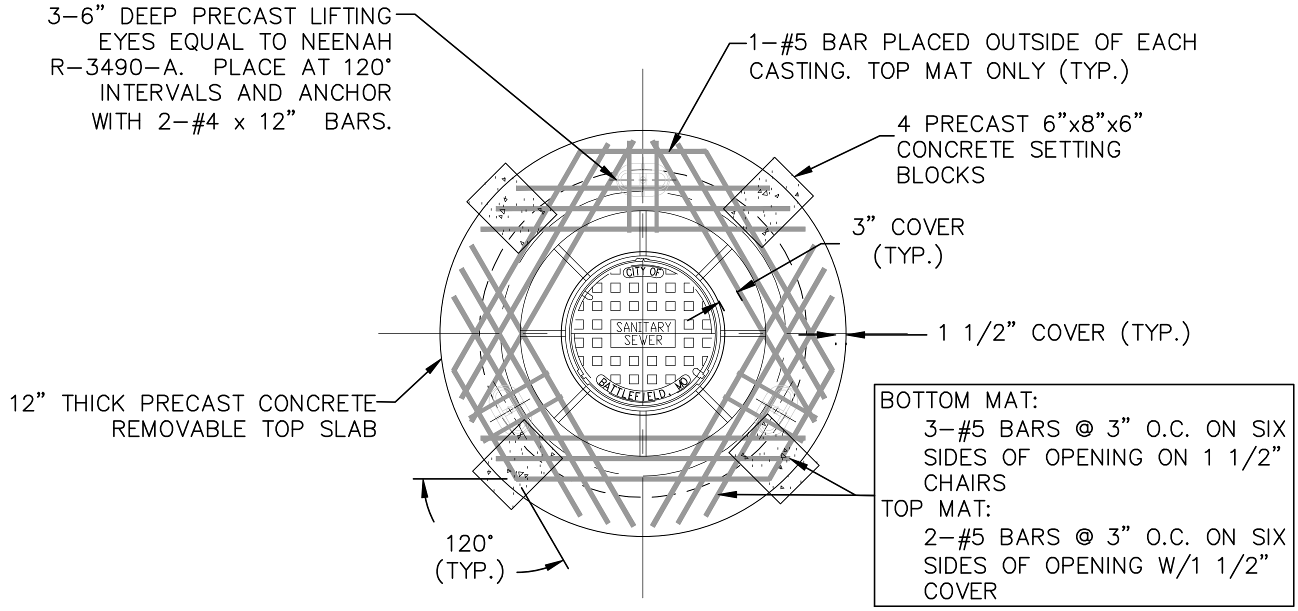


SECTION

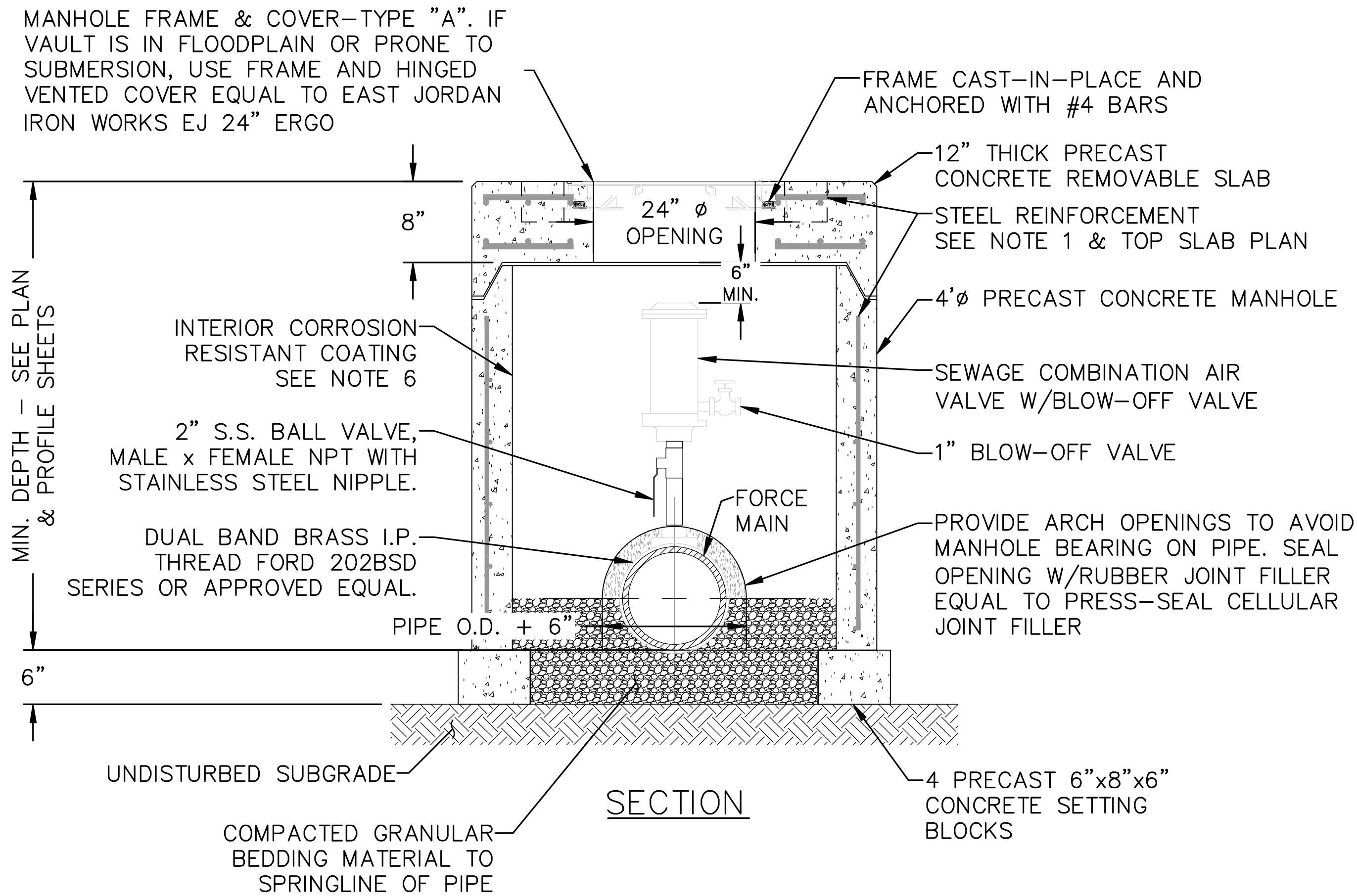
HORIZONTAL FITTINGS

NOTES:

1. ALL BURIED FITTINGS SHALL HAVE CITY CLASS A OR CLASS X CONCRETE THRUST BLOCKING, MINIMUM 4000 P.S.I. CONCRETE.
2. BLOCK TO BE POURED AGAINST UNDISTURBED EARTH WITH ADEQUATE BACKING TO PREVENT MOVEMENT OF FITTING.
3. DO NOT COVER BOLT HEADS, FLANGES OR GLANDS WITH CONCRETE. LEAVE SUFFICIENT CLEARANCE FOR MAINTENANCE.
4. WRAP ALL BURIED DIP PIPE, VALVES, AND FITTINGS WITH 8 MIL POLYETHYLENE. ENSURE WRAP EXTENDS BEYOND ALL FASTENERS.
5. FOR UNSTABLE SOIL CONDITIONS, VERIFY REQUIRED THRUST BLOCK DIMENSIONS WITH ENGINEER.



TOP SLAB

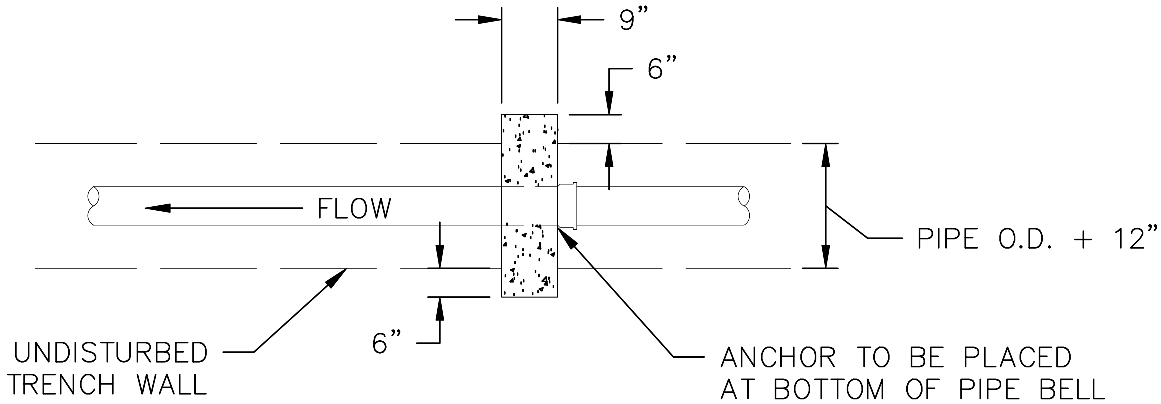


SECTION

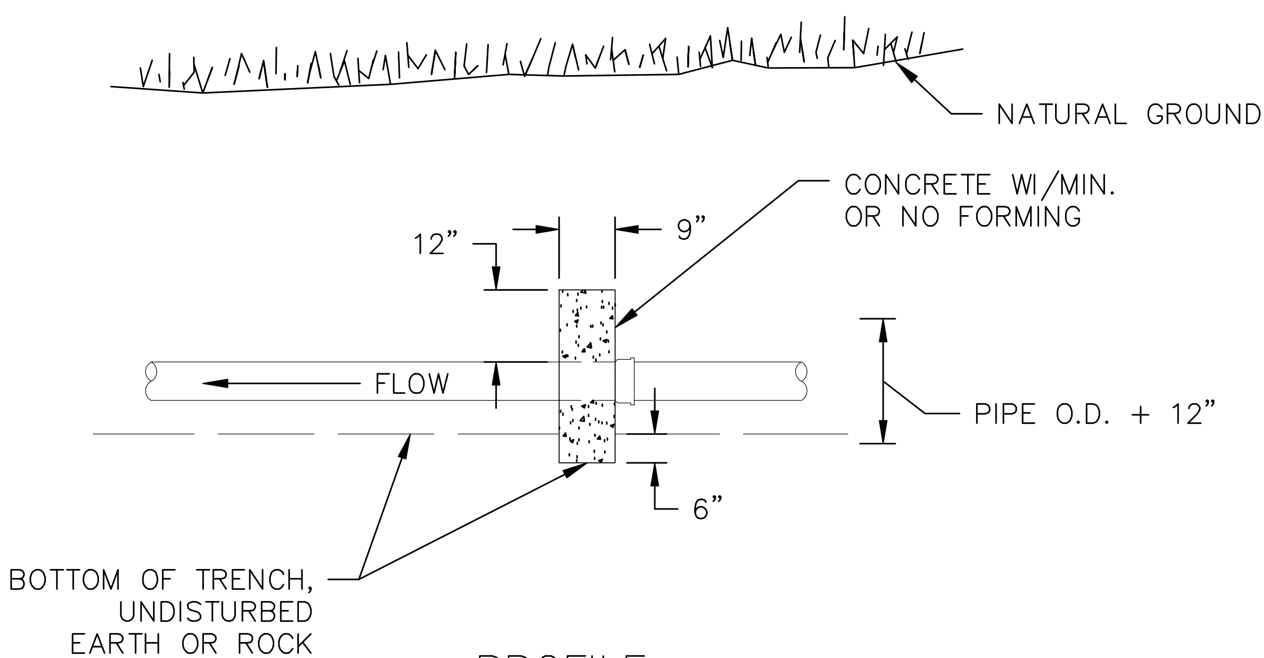
NOTES:

1. PRECAST CONCRETE MANHOLE & STEEL REINFORCEMENT SHALL CONFORM TO ASTM C478.
2. ALL JOINTS SHALL BE SET ON JOINT SEALER EQUAL TO CONSEAL BUTYL RUBBER SEALANT EXCEPT REMOVABLE TOP SLAB.
3. REPAIR ALL LIFTING HOLES WITH NON-SHRINK GROUT.
4. ALL EXPOSED EDGES SHALL HAVE A 3/4" CHAMFER.
5. EXTERIOR SHALL BE WATERPROOFED.
6. PROVIDE INTERIOR CORROSION RESISTANT COATING AS SPECIFIED IN SECTIONS 4.5.3 & 4.5.4.

CITY OF BATTLEFIELD, MO	AIR VALVE VAULT DETAILS	ADOPTED: XX/XX/2023 SAN-31



PLAN VIEW

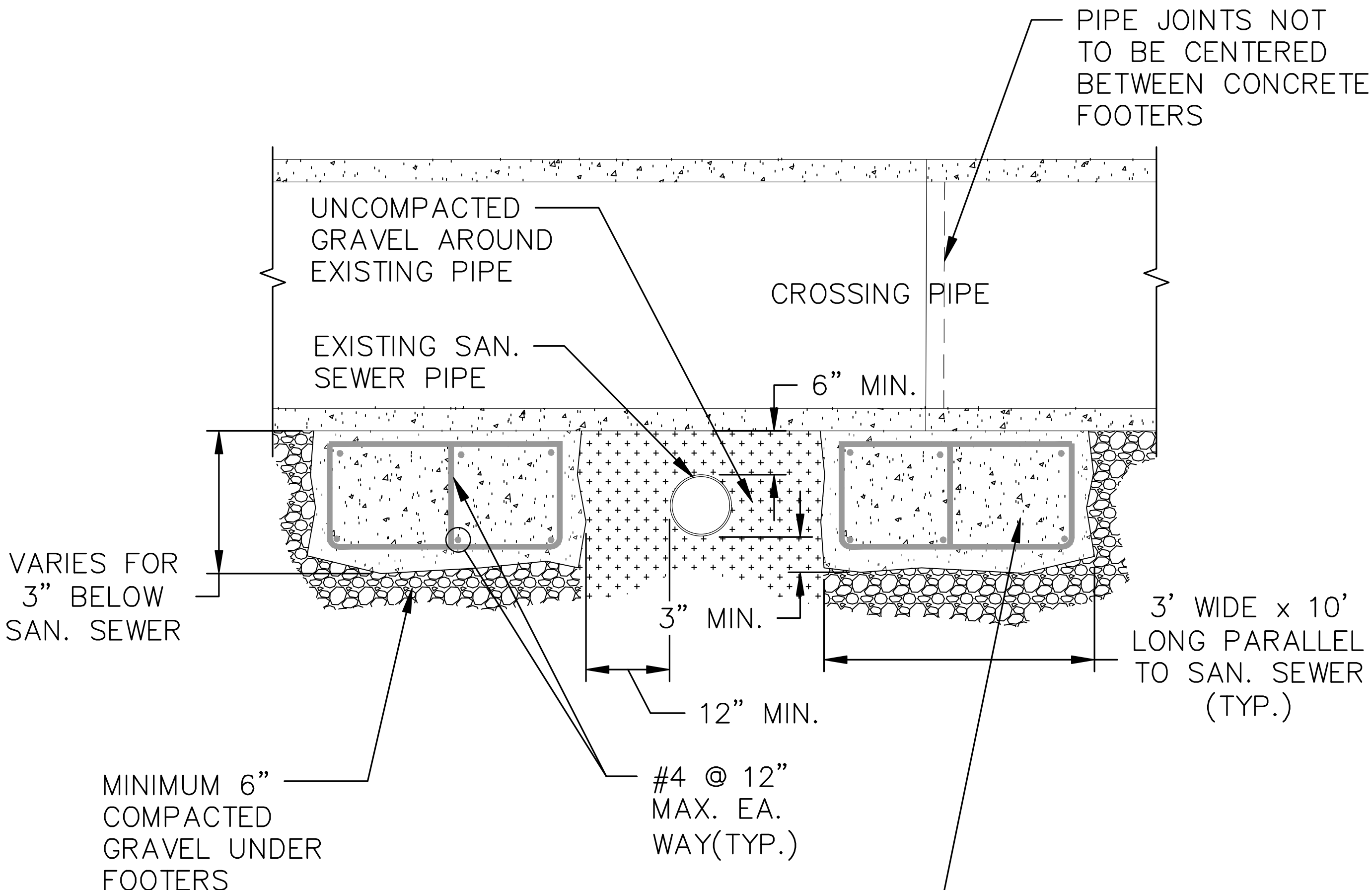


PROFILE

SLOPE	SPACING (LF)
15.0 TO 35.0%	NOT OVER 36 LF
35.1 TO 50.0%	NOT OVER 24 LF
>50%	NOT OVER 16 LF

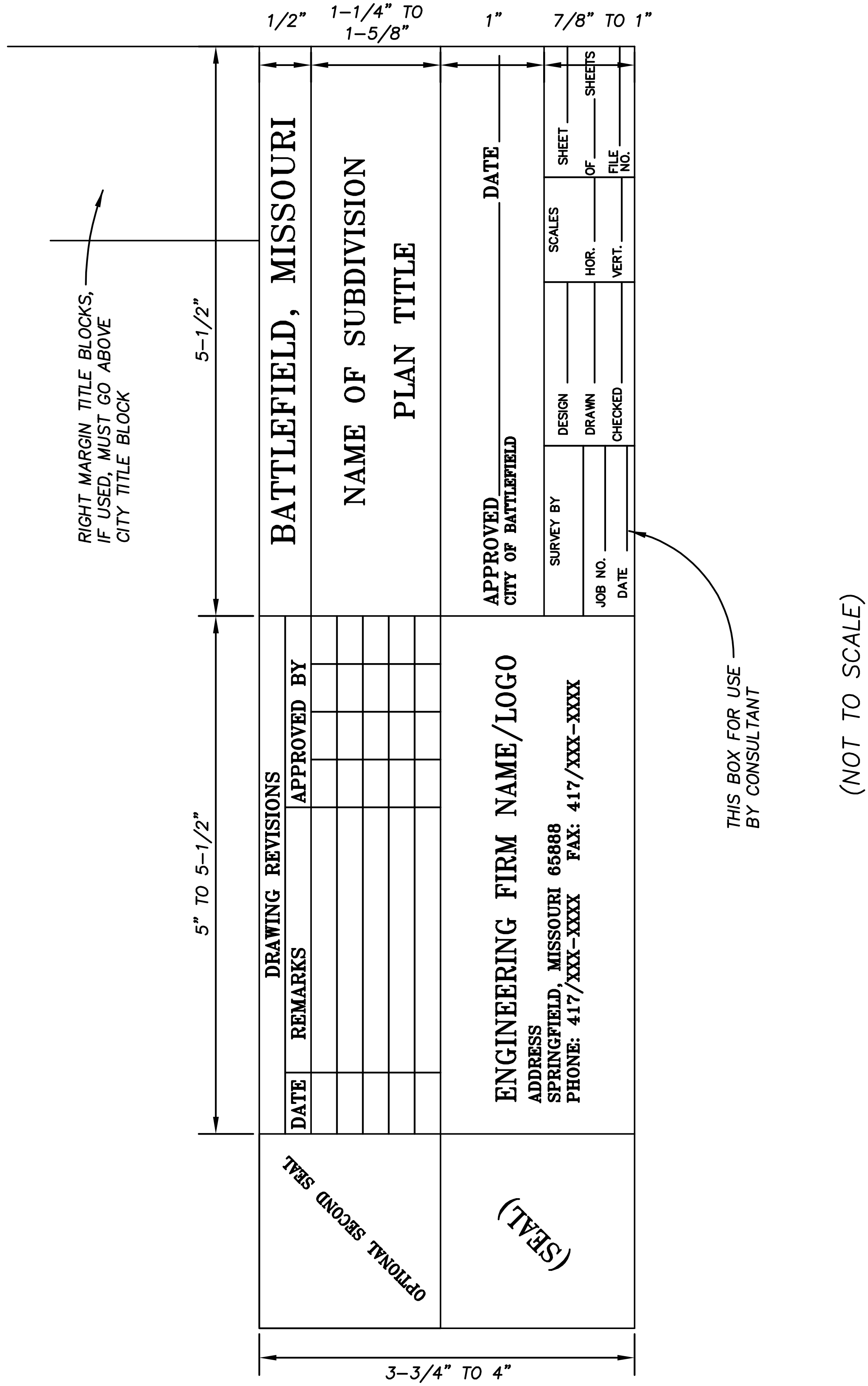
CITY OF BATTLEFIELD, MO	CONCRETE ANCHOR DETAIL	ADOPTED: XX/XX/2023
		SAN-32

NOTE: A CONCRETE SUPPORT/BRIDGE IS TO BE USED OVER AN EXISTING SANITARY SEWER PIPE WHEN AT LEAST 18" OF VERTICAL CLEARANCE CANNOT BE MAINTAINED.



INSTALL MINIMUM 3,000 PSI CONCRETE FOOTERS ON BOTH SIDES OF EXISTING SEWER PIPE CROSSING TO SUPPORT/BRIDGE OVER EXISTING SEWER PIPE. BACKFILL WITH GRAVEL PER CITY SPECS. CONCRETE FOOTERS CAN BE OMITTED WHERE VERTICAL PIPE SEPARATION > 18".

CITY OF BATTLEFIELD, MO	CONCRETE SUPPORT/ BRIDGE DETAIL	ADOPTED: XX/XX/2023 SAN-33



CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	STANDARD TITLE BLOCK FOR SUBDIVISION PLANS	ADOPTED: SS-1

GENERAL NOTES

1. All construction shall be done in accordance with the latest addition of the "City of Battlefield Design Standards for Public Improvements" and the "Missouri Standard Specifications for Highway Construction", unless otherwise noted.
2. Prior to beginning construction, a pre-construction conference must be held with the City of Battlefield. It is the Developer's responsibility to schedule this conference.
3. Prior to beginning construction, a grading permit must be obtained from the City of Battlefield. It is the Developer's responsibility to obtain this permit.
4. For sites where five (5) or more acres will be disturbed, a general permit for land disturbance activity must be obtained from the Missouri Department of Natural Resources before construction can begin. It is the Developer's responsibility to obtain this permit.
5. Other permits may be required for this construction. It is the Contractor's responsibility to determine which permits are applicable and to obtain any applicable permits not provided by the Developer.
6. If the Contractor's operations require work on or access across private property, it is the Contractor's responsibility to obtain written permission from the property owner to enter the property and to repair any damage to private property caused by his operations.
7. At the start of construction, or whenever work has been suspended, the Contractor shall contact the City of Battlefield (Phone 417-883-5840) at least wenty-four (24) hours prior to working at the site. Failure to do so may result in rejection of any work completed prior to contact.
8. The Contractor shall keep the subdivision neat and orderly at all times while construction is in progress. Access streets to the development shall be kept clean of mud, debris, paper and waste material at all times.
9. Construction access to the site shall be limited to the approved temporary construction entrance(s) shown on the Sediment & Erosion Control Plan (SECP).
10. Existing underground utilities will be shown by the Engineer in approximate locations as determined by existing plans and surface observations. It is the Contractor's responsibility to determine the exact horizontal and vertical location of existing underground facilities prior to beginning installation of new facilities. Contractor shall immediately contact the Engineer for instructions whenever any conflicts are discovered.
11. It is the Contractor's responsibility to correct any damage to underground utilities or other facilities which is caused by his operations.
12. Manhole covers, valve boxes, and other utility appurtenances shall not encroach on sidewalks, curbs or pavement. Where conflicts are discovered, the Contractor shall contact the Engineer for instructions prior to proceeding.
13. All disturbed areas shall be stabilized in accordance with the approved Sediment & Erosion Control Plan (SECP).

RECOMMENDED NOTES FOR SEDIMENT & EROSION CONTROL PLAN

This plan shows the location and details for primary sediment controls to be constructed. The contractor is responsible for controlling erosion and discharge of sediment from the site at all times during construction. The contractor shall provide necessary measures during all phases of his operations regardless of whether they are specifically noted on this plan and shall maintain and replace controls as necessary during the course of his operations.

Temporary construction entrance(s) and silt fences, straw bale dikes or other initial sediment controls shown on this plan must be installed prior to any other work.

Sediment basins shown on this plan must be installed within 10 calendar days after construction begins or as soon as 2 or more acres are disturbed, whichever occurs first.

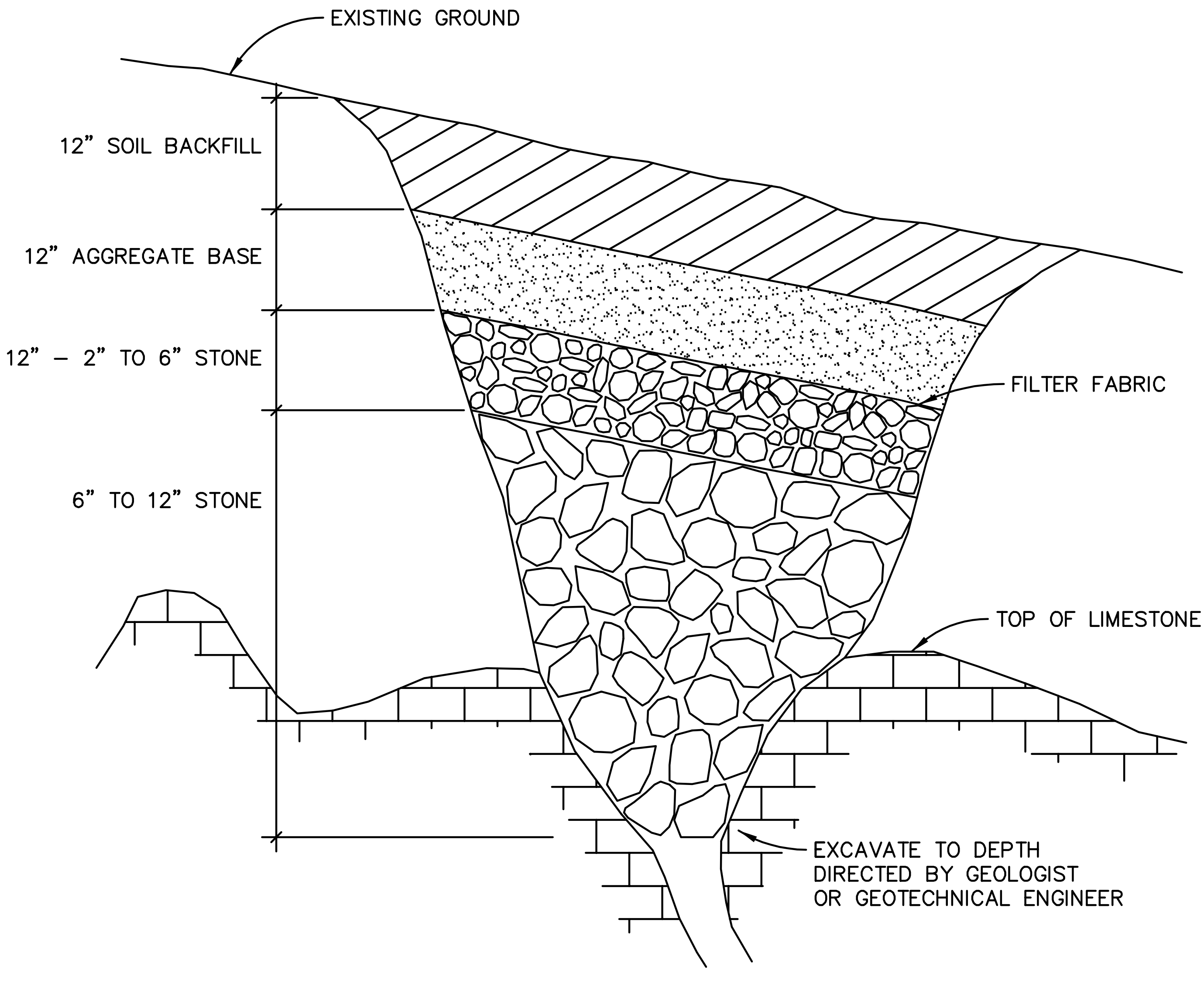
The contractor shall clean streets both interior and adjacent to the site, as needed after each rainfall, and at the end of construction.

The contractor is responsible for controlling dust during construction and shall water construction areas whenever conditions warrant.

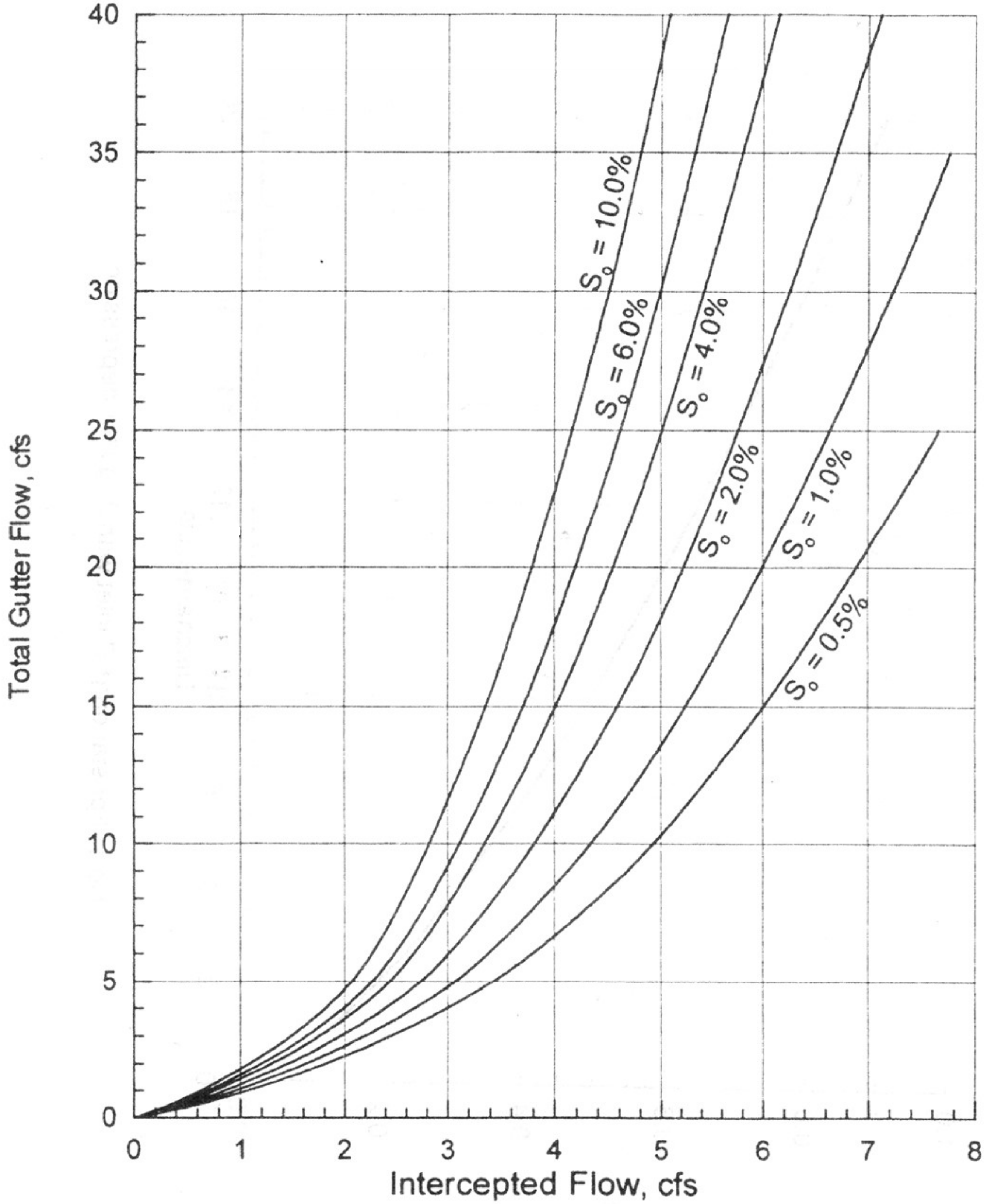
The contractor is responsible for cleaning accumulated sediment from storm drains prior to approval of construction.

All disturbed areas not receiving other permanent stabilization such as pavement, roofs, sod, etc., shall be seeded and mulched, as specified below before temporary sediment controls can be removed and prior to final approval of construction.

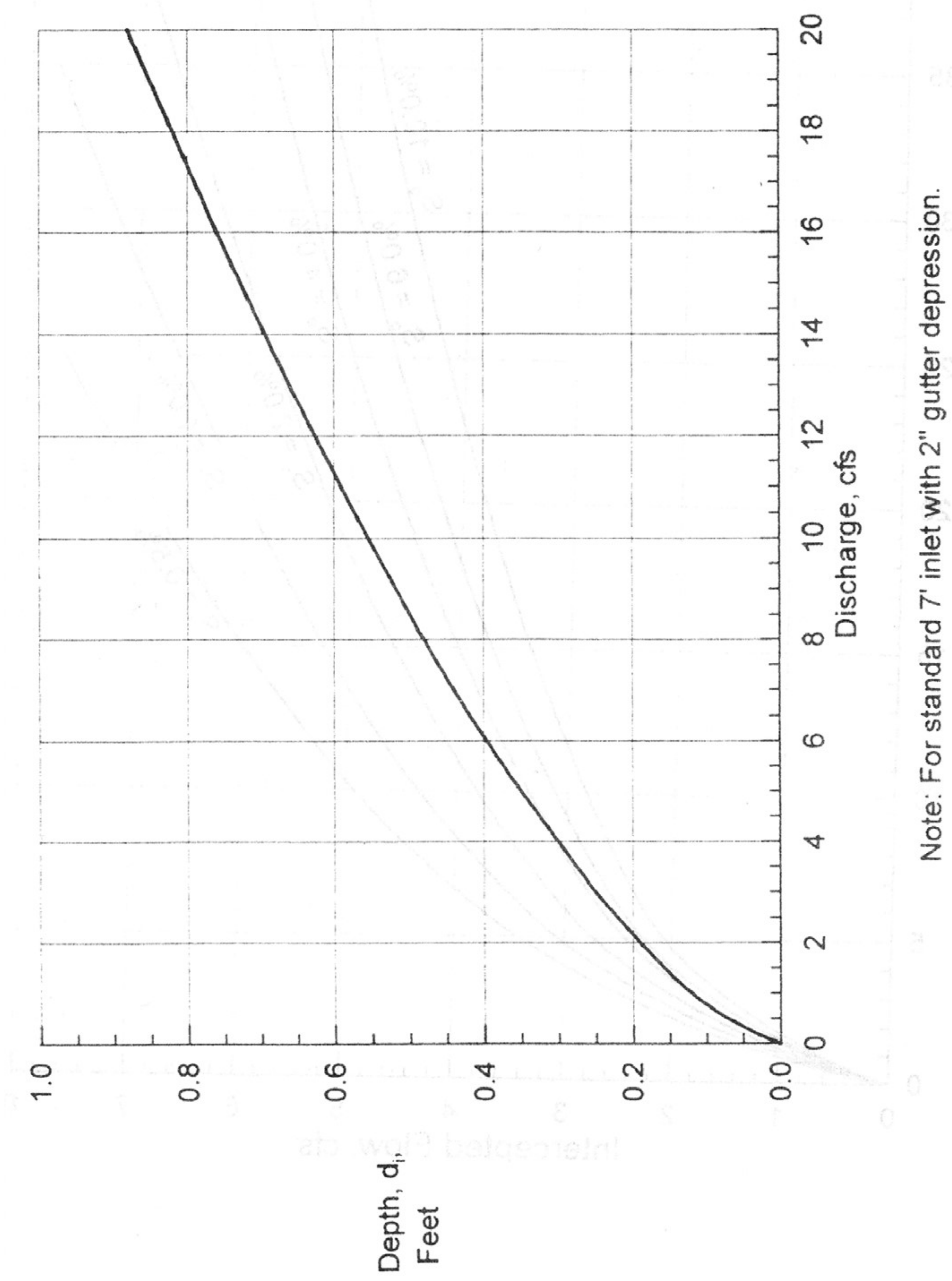
- A minimum depth of 4" of topsoil (prior to compacting) shall be spread on areas to be seeded.
- After topsoil is spread, line shall be spread at the rate of 800-900 pounds, effective neutralizing material (ENM) per acre.
- Fertilizer shall be spread at the rate of 400-500 pounds per acre, and shall be 13-13-13 nitrogen, phosphorus, and potassium.
- Seed mix shall consist of 60-80% Kentucky 31 tall fescue and 20-40% annual ryegrass (germination shall be at least 85%). Seed mix shall be spread at the rate of 400-500 pounds per acre.
- All areas to be seeded having slopes less than 4:1 shall be mulched with cereal grain mulch the rate of 100 pounds per 1000 square feet (4500 pounds per acre). Cereal grain mulch shall meet the requirements of Section 802 of the State Specifications for Type 1 mulch. Mulch may be applied by hand, however, it must be evenly spread. Type 1 much shall be thoroughly wetted immediately after application.
- Where slopes are 4:1 or greater Type 3 mulch ("hydromulch") meeting the requirements of Section 802 of the State Specifications shall be used. Type 3 mulch shall be applied at the rate of 2000 pounds per acre.
- Permanent seeding season runs from March 1st to June 1st and August 15th to November 1st. Seeding and mulching must be done whenever work is complete regardless of the season. Whenever seeding and mulch is installed outside of the permanent seeding season the contractor will be responsible for replanting and mulching any areas where growth has not become established during the next permanent seeding season.
- All areas must be maintained by the contractor until vegetation is firmly established. Vegetation will be considered firmly established when it has survived from the permanent seeding season in which it is placed, to the next permanent seeding season, and growth has been established on all eroded areas which have been noted for repair.
- Temporary seeding shall be at the same rates for seed, mulch and fertilizer specified above. Topsoil spreading is not required in areas designated to receive temporary seeding only.



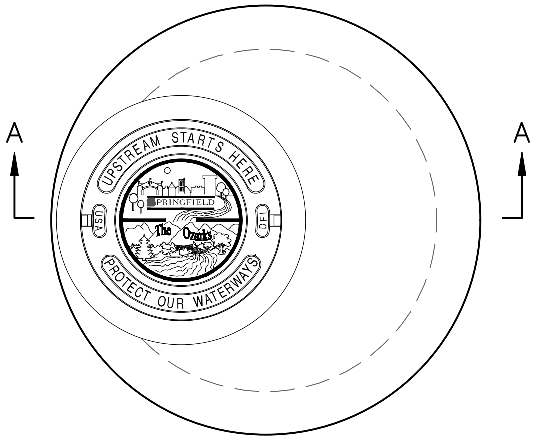
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	SINKHOLE COLLAPSE STABILIZATION	ADOPTED: SS-4



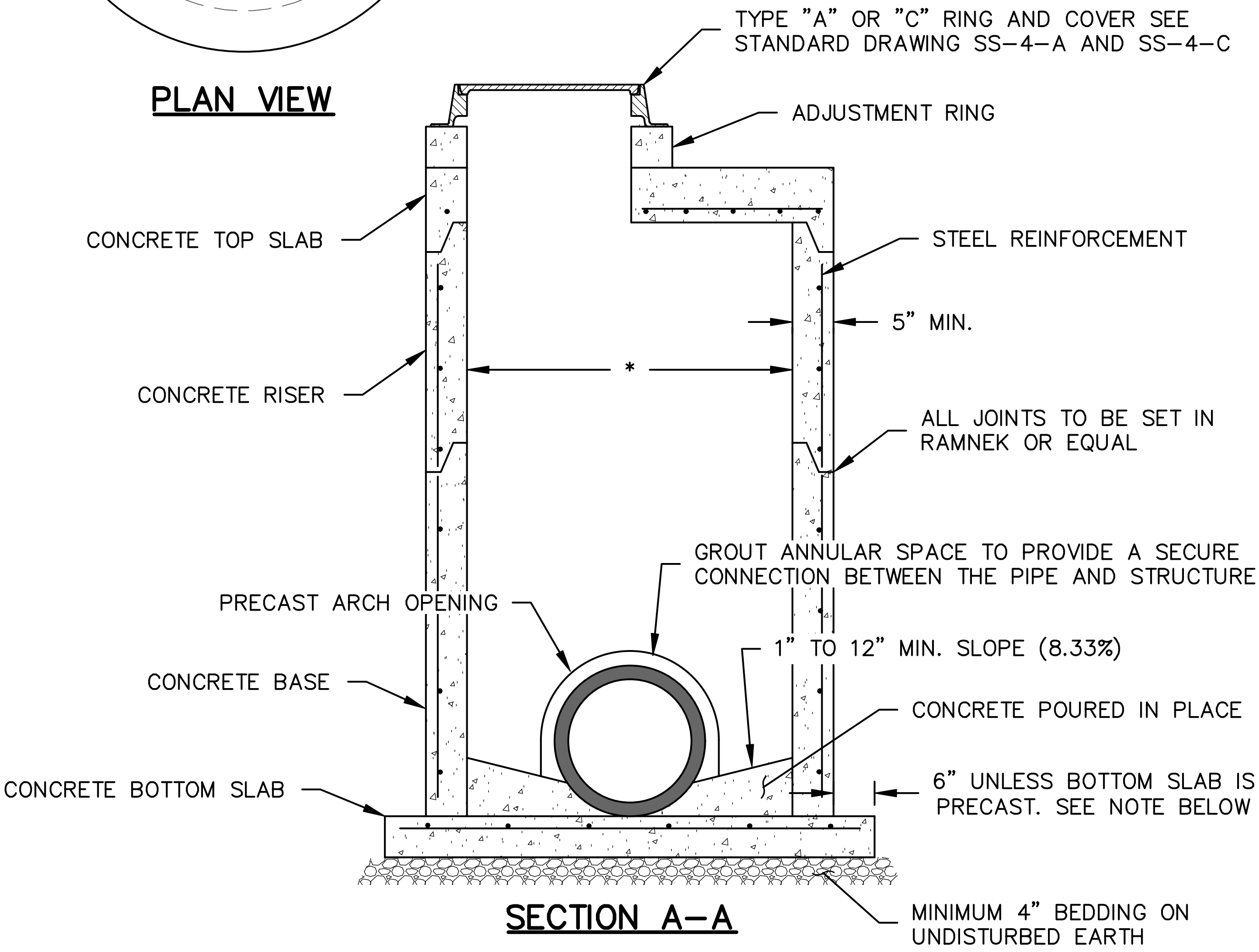
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	STANDARD CURB INLET INTERCEPTION CAPACITY	ADOPTED: SS-5



CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	STANDARD CURB INLET CAPACITY IN A SUMP	ADOPTED: SS-6



PLAN VIEW



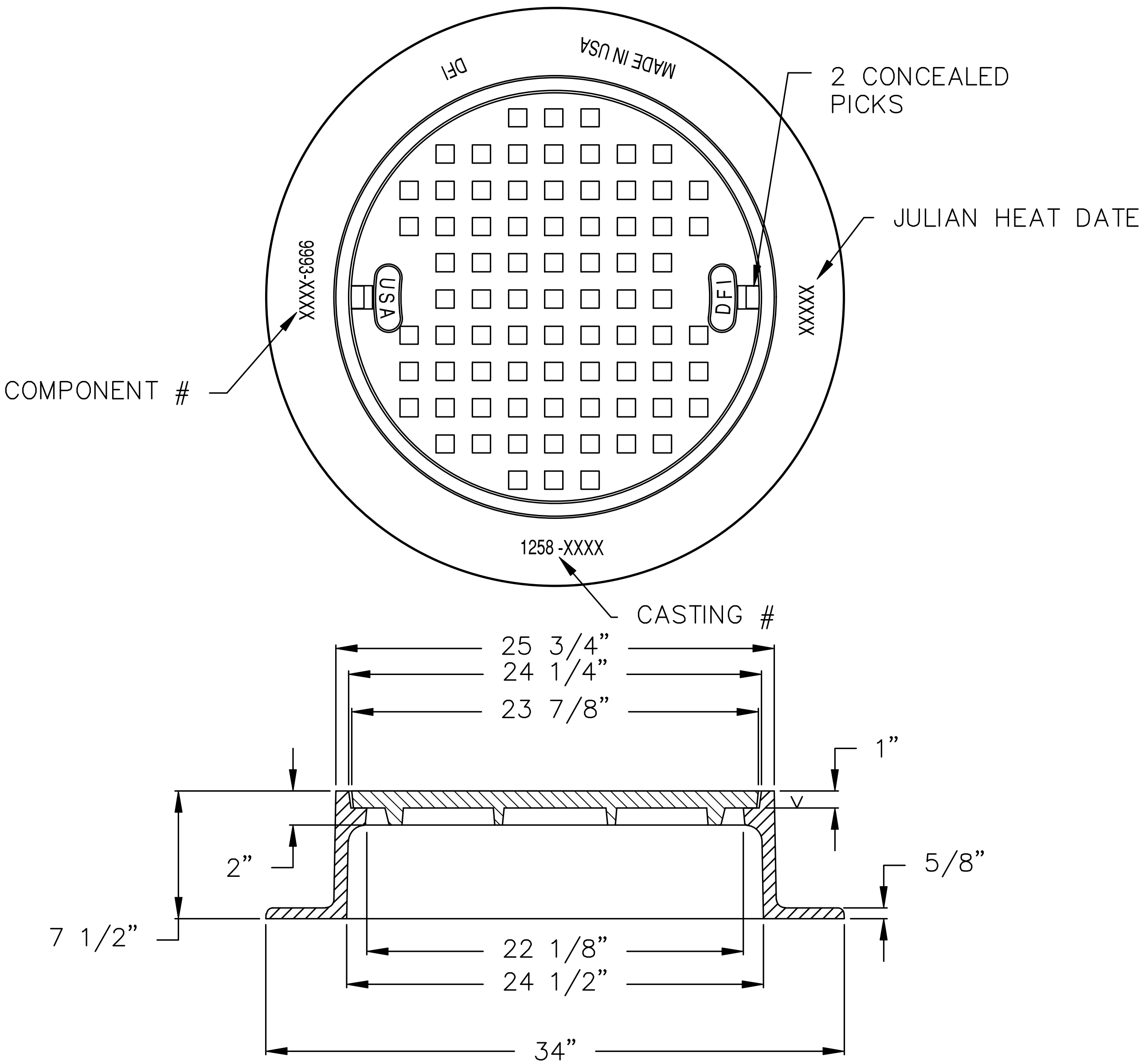
SECTION A–A

NOTES:
1. MANHOLE SHALL BE DESIGNED AND MANUFACTURED IN ACCORDANCE WITH ASTM C 478.
2. BOTTOM SLAB SHALL BE POURED IN PLACE. IF MANUFACTURER IS CONCERNED ABOUT STRUCTURAL INTEGRITY OF CONCRETE BASE DURING TRANSPORTATION THEN THE BOTTOM SLAB MAY BE PRECAST WITH CONCRETE BASE.
3. PIPE TO BE ON GRADE BEFORE BOTTOM SLAB IS CONSTRUCTED.
4. ALL PIPES SHALL FIT FLUSH AT SPRINGLINE WITH INSIDE FACE OF MANHOLE.
5. BOTTOM OF MANHOLE TO BE FILLED WITH CONCRETE FORMING CHANNELS TOWARD OUTLET PIPE FROM ALL INLET PIPES. CONCRETE SHALL BE FLUSH WITH INVERT OF OUTLET PIPE.
6. NO MORE THAN 2 ADJUSTMENT RINGS MAY BE USED AND SHALL NOT EXCEED 18 INCHES.
7. A MINIMUM CLEARANCE OF TWO FEET, MEASURED AT THE INSIDE FACE OF THE MANHOLE SHALL BE MAINTAINED BETWEEN THE OUTSIDE EDGE OF STORM SEWER PIPES..

PIPE DIAMETER	*MINIMUM INSIDE DIAMETER OF MANHOLE (SEE NOTE 7)
15" – 24"	FOUR FEET (4')
27" – 42"	FIVE FEET (5')
48"	SIX FEET (6')
54" – 66"	EIGHT FEET (8')

DEPARTMENT OF PUBLIC WORKS SPRINGFIELD, MO.	STORM SEWER MANHOLE	ADOPTED: 1–1–15 SS-7

RING & COVER DETAILS



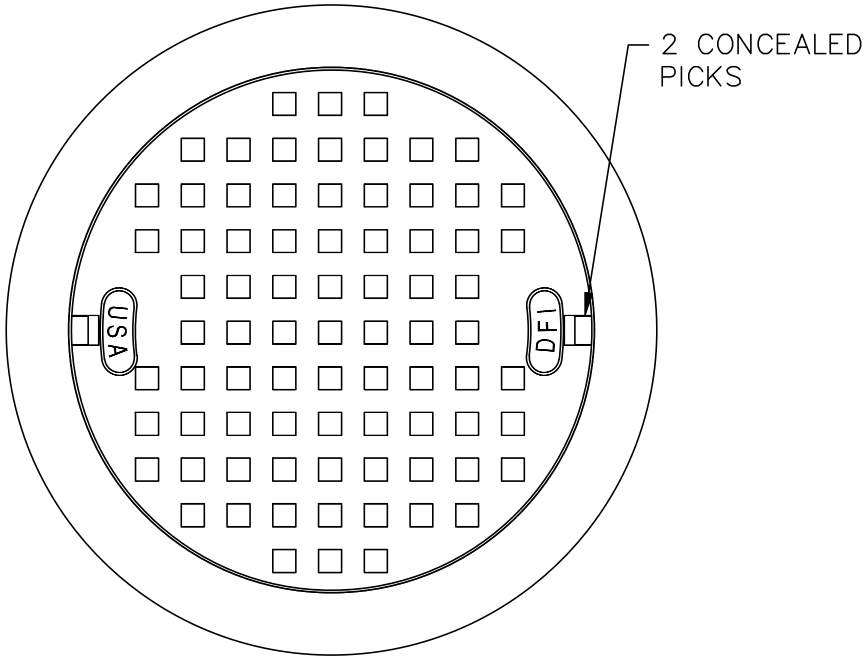
NOTE:
1. FURNISHED WITH MACHINED HORIZONTAL BEARING SURFACES.

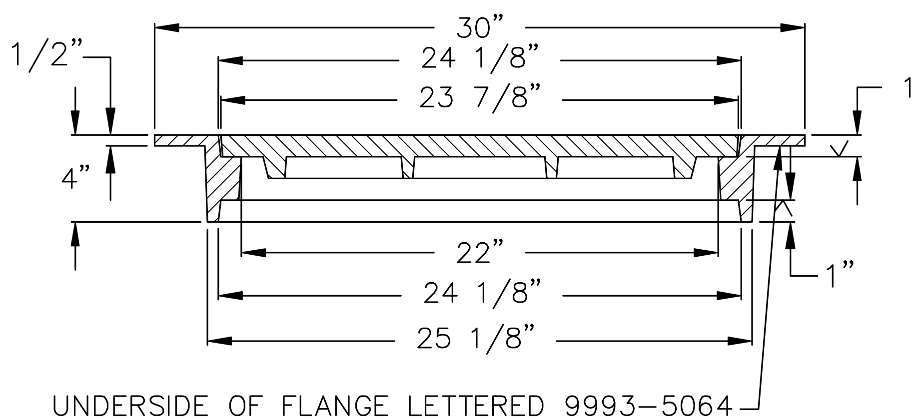
TYPE "A" RING & COVER

DEETER # 1258 RING & COVER, EAST JORDAN IRON WORKS #2420Z RING W/2408A COVER, SS-4-C INSTALLED FLANGE DOWN OR EQUAL

CITY OF BATTLEFIELD, MO	RING & COVER FOR STORM SEWER INLET	ADOPTED: XX/XX/2023
		SS-8

RING & COVER DETAILS





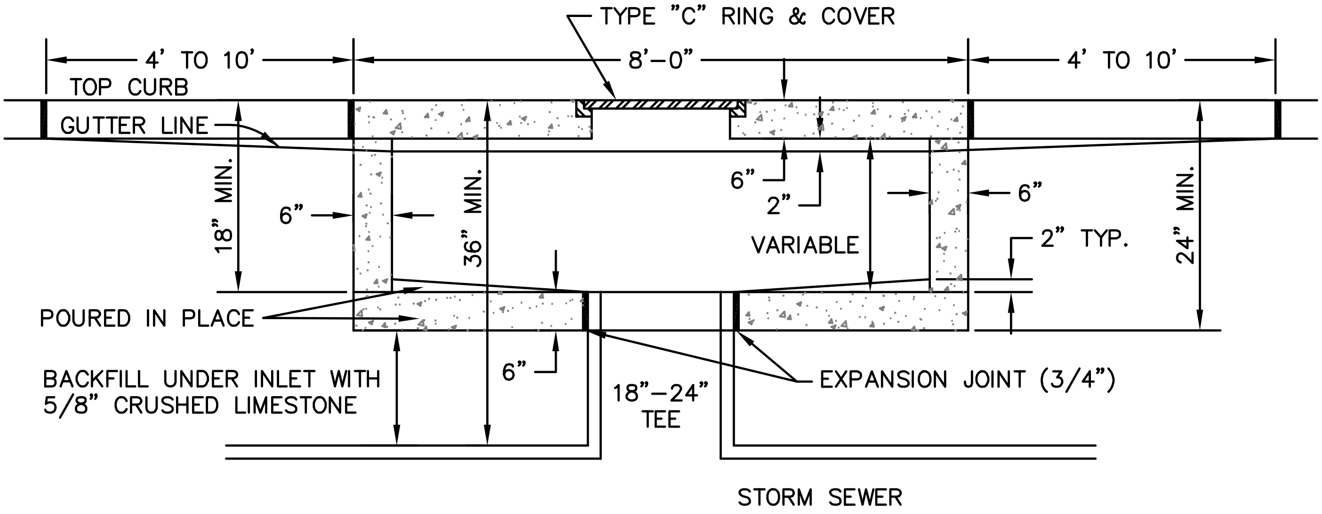
NOTE:

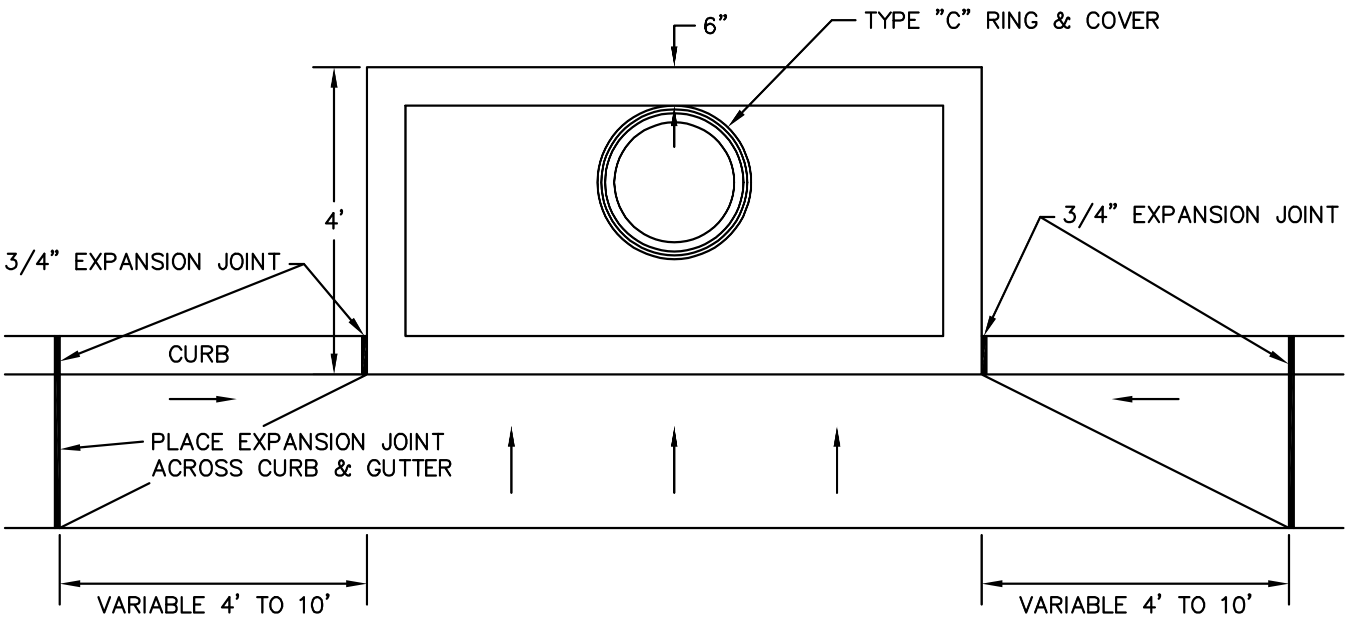
1. FURNISHED WITH MACHINED HORIZONTAL BEARING SURFACE.
2. RING IS REVERSIBLE AND CAN BE INSTALLED WITH FLANGE UP OR DOWN.

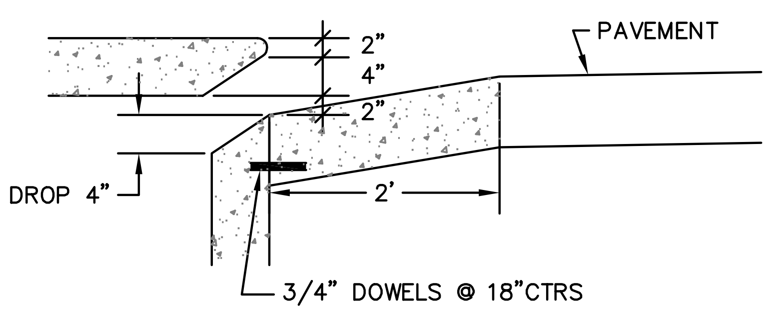
TYPE "C" RING & COVER FOR STORM SEWERS

DEETER # 1157 RING W/ #2018-A COVER, EAST JORDAN IRON WORKS #2425Z RING W/2408A COVER OR EQUAL

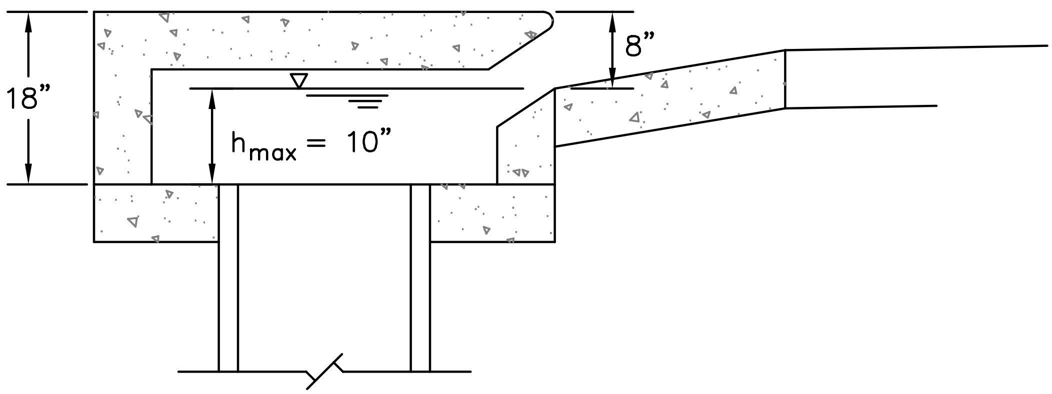
CITY OF BATTLEFIELD, MO	RING & COVER FOR STORM SEWER INLET	ADOPTED: XX/XX/2023
		SS-9







CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	SS–5 CURB OPENING INLET	ADOPTED: SS-10



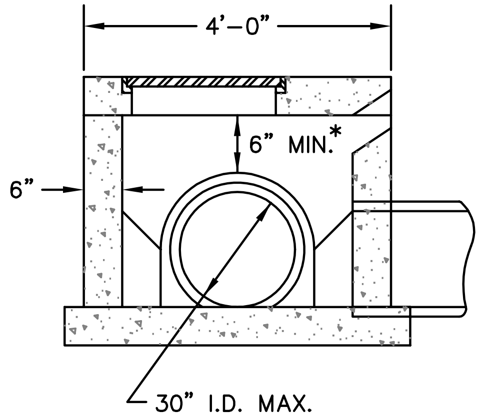
USE WEIR EQUATION $Q = Cw\ L\ h^{3/2}$

$Cw = 3.0$

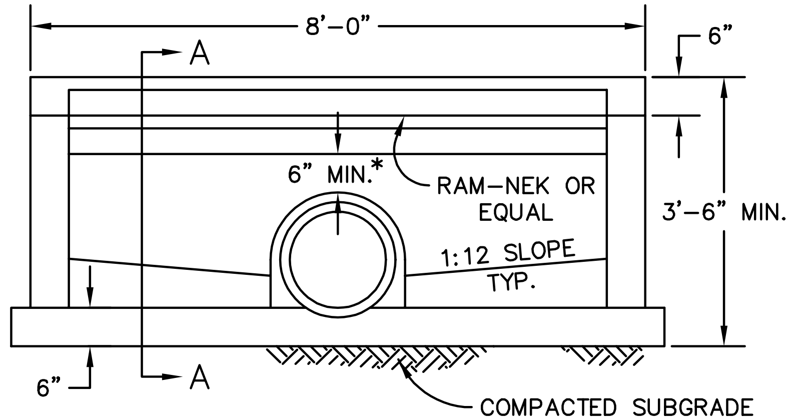
L = Pipe Circumference

RISER DIAMETER (in.)	$L = \pi D$ (ft.)	Q_{max} (cfs)
18	4.7	10.7
21	5.5	12.5
24	6.3	14.4

SS–5 CURB OPENING INLET RISER CAPACITY



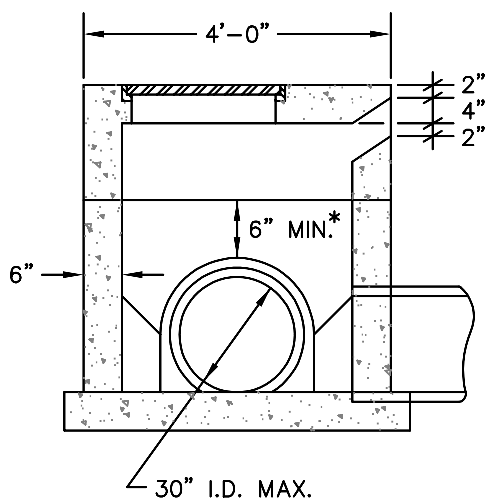
SECTION A–A



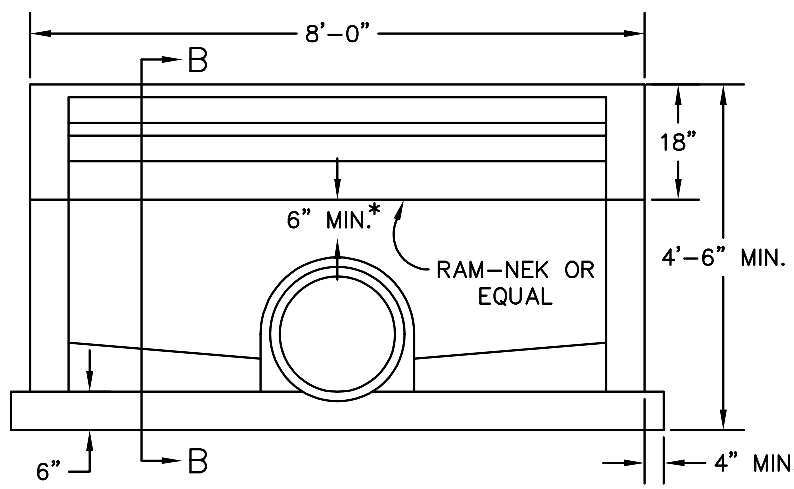
NOTE: #4 ø @ 10" C.C. (ALL WALLS, VERT. & HOR.)
SEE FIG. 108.10 FOR TOP SLAB REINFORCEMENT

6" PRECAST TOP

* NOTE: LESS CLEARANCE MAY BE ALLOWED PROVIDED ADEQUATE STRUCTURAL PROVISIONS ARE MADE TO PREVENT THE UNIT FROM CRACKING DURING DELIVERY AND INSTALLATION.



SECTION B–B



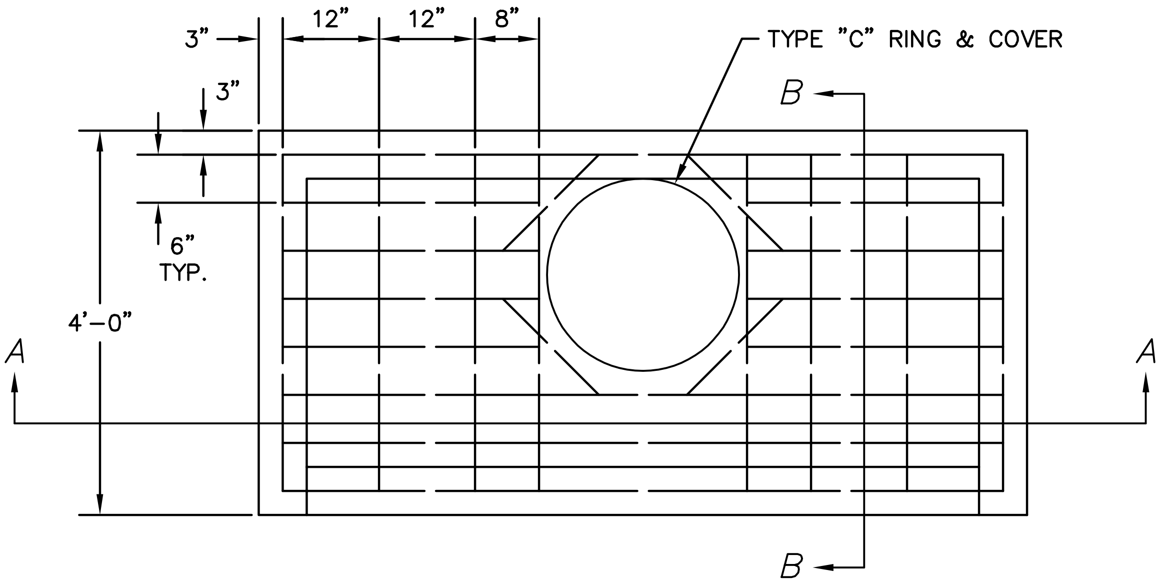
NOTE: #4 ø @ 10" C.C. (ALL WALLS, VERT. & HOR.)
SEE FIG. 108.10 FOR TOP SLAB REINFORCEMENT

18" PRECAST TOP

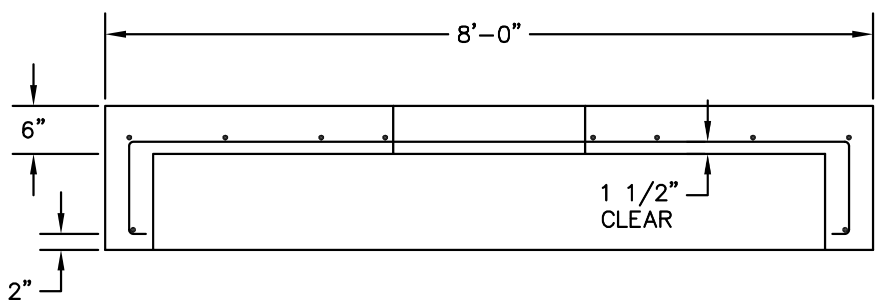
NOTES:

1. BOTTOM TO BE CAST IN PLACE.
2. PIPE TO BE ON GRADE BEFORE BOTTOM IS CONSTRUCTED.
3. FOR 6" TOP USE 4 – #4 ø DOWELS; ONE IN EACH CORNER W/ RAM–NEK OR EQUAL.
4. RAM–NEK ALL JOINTS (OR EQUAL).
5. 6" INVERT REQUIRED TO PREVENT SEDIMENTATION.

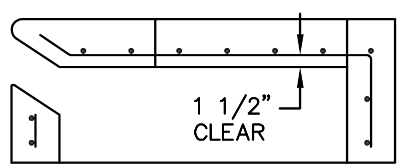
SS–6 CURB OPENING INLET



USE NO. 4 BAR THROUGHOUT



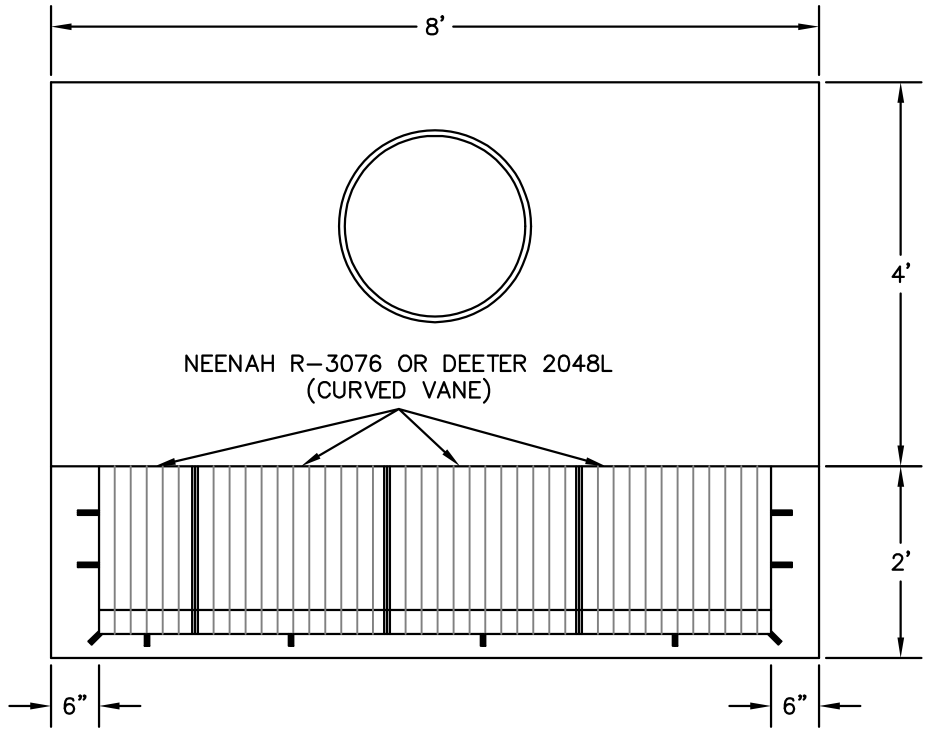
SECTION A–A



SECTION B–B

NOTE: "SS–8" TOP SHOWN, REINFORCEMENT
FOR 6" "SS–6" TOP SIMILAR

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	TYPICAL REINF. FOR PRECAST INLET TOPS	ADOPTED: SS-13

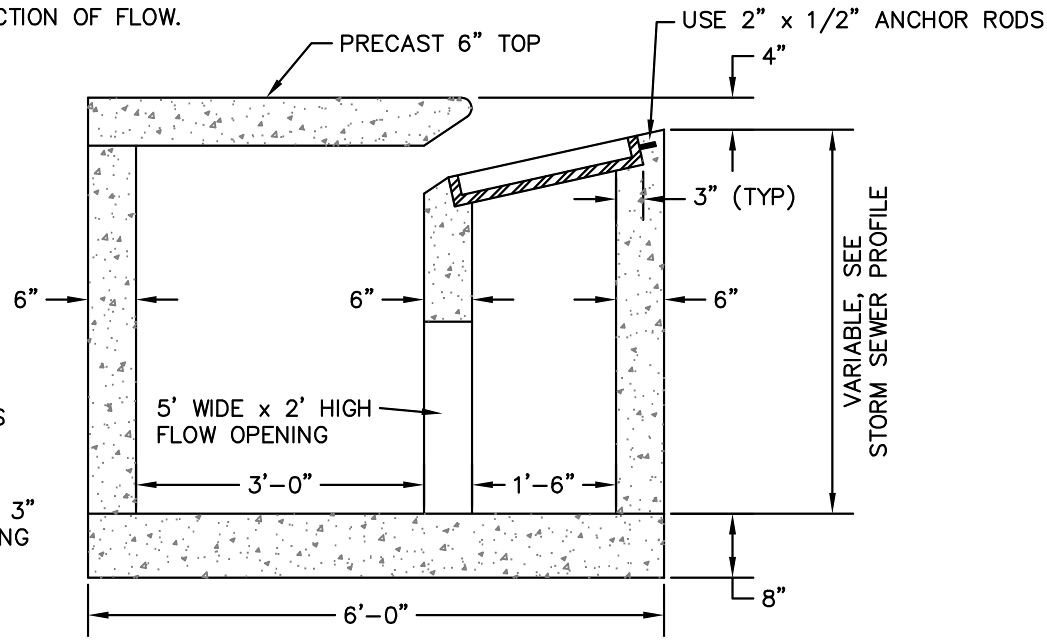


PLAN VIEW

NOT TO SCALE

NOTES:

1. WHEN USED WITH NON–GRATE INLETS, PLACE GRATE INLET DOWNSTREAM.
2. PLACE GRATES SUCH THAT VANES CURVE DOWNWARD IN DIRECTION OF FLOW.



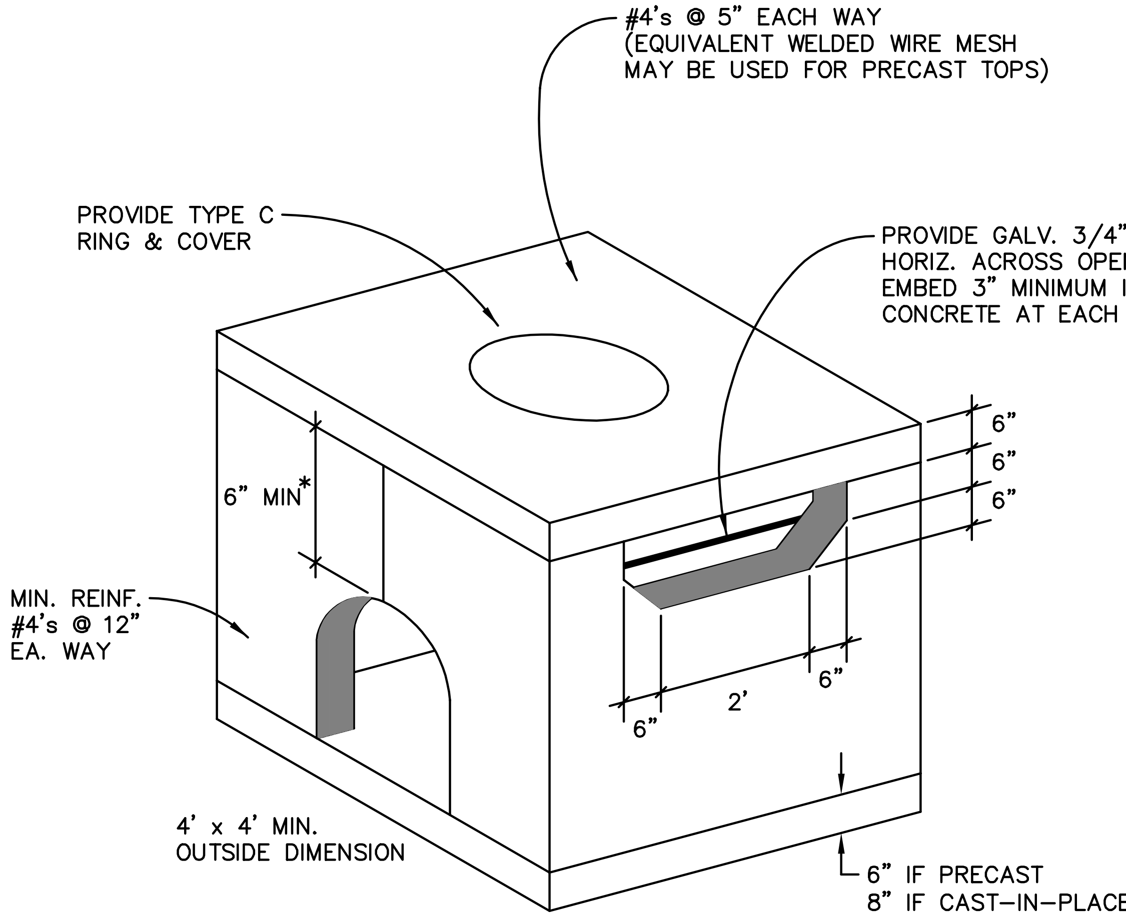
REINFORCE ALL WALLS WITH #4 @ 8" OCEW

INSTALL (2) #6 BARS 3" ABOVE TOP OF OPENING IN MIDDLE WALL

SECTION VIEW

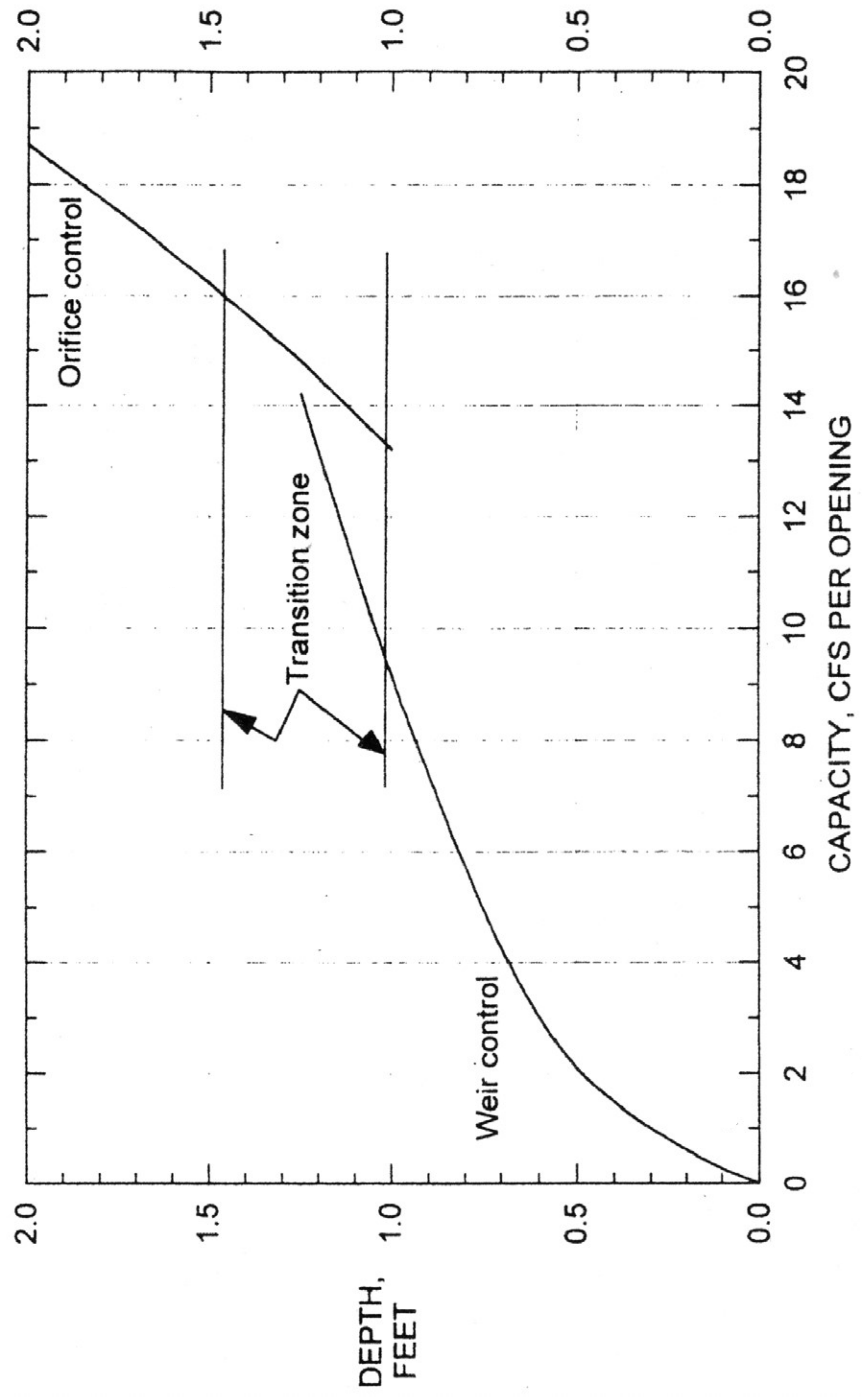
NOT TO SCALE

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	STANDARD SS–6G INLET	ADOPTED: SS-14



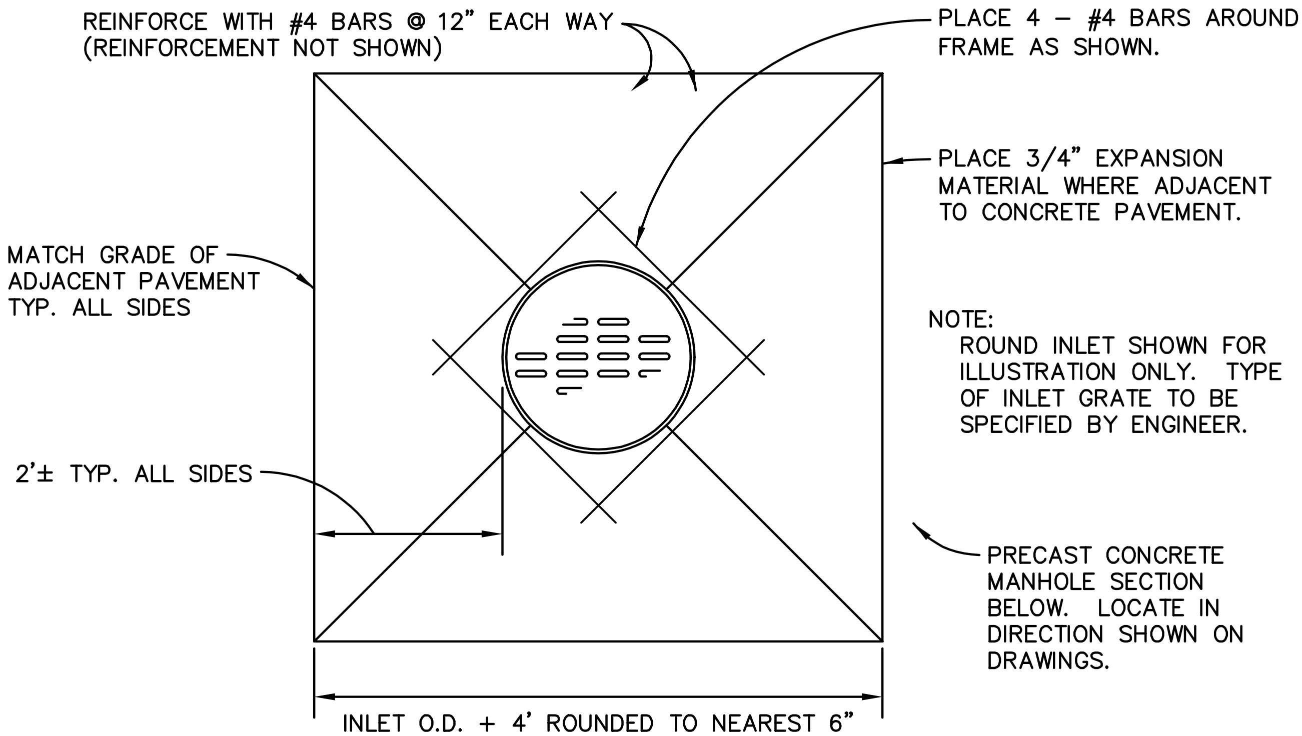
* LESS CLEARANCE MAY BE ALLOWED PROVIDED ADEQUATE STRUCTURAL PROVISIONS ARE MADE TO PREVENT THE UNIT FROM CRACKING DURING DELIVERY AND INSTALLATION.

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	STANDARD DI-1 INLET	ADOPTED: SS-15



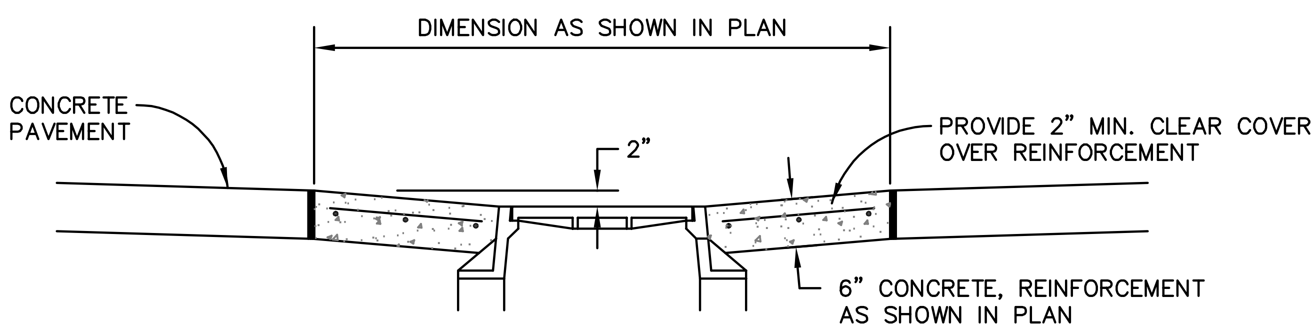
Note: Specify number of openings.
For 24" basewidth opening inlet only.

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	STANDARD DI–1 INLET CAPACITY	ADOPTED: SS-16



PLAN VIEW

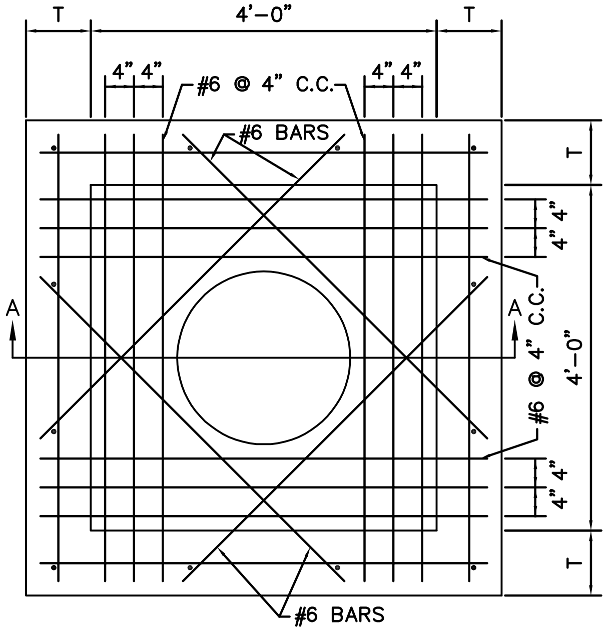
NOT TO SCALE



SECTION VIEW

NOT TO SCALE

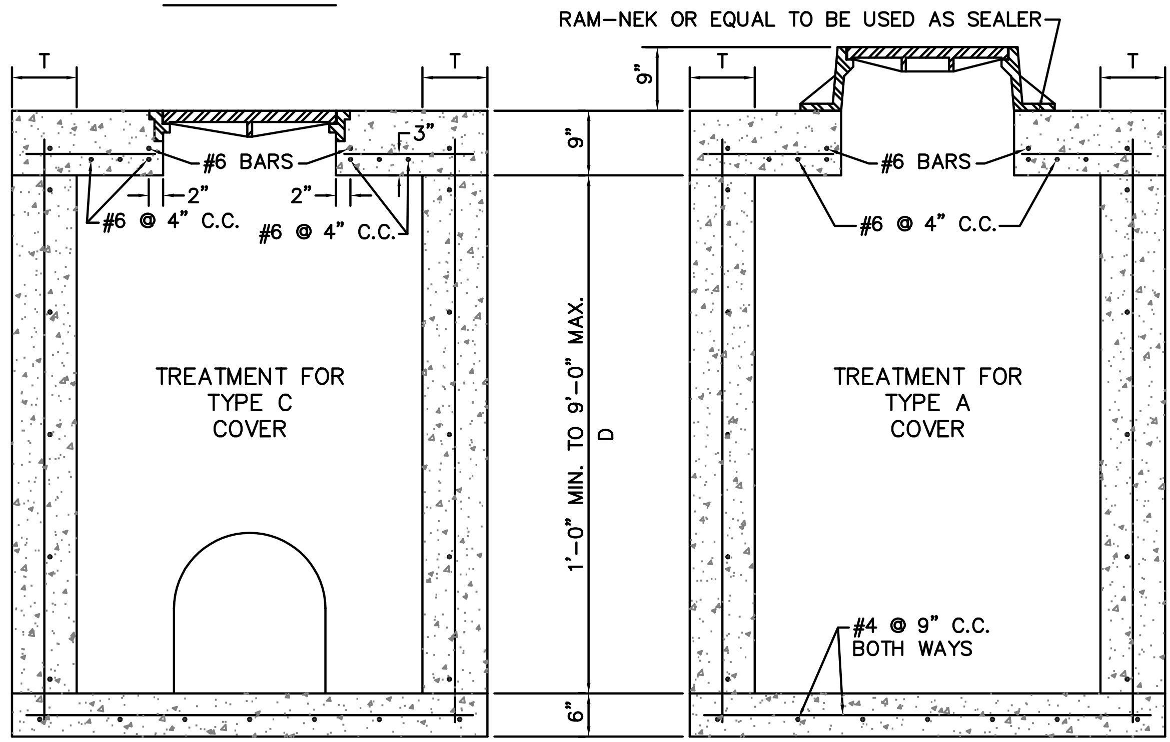
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	TYPICAL AREA INLET CONCRETE APRON	ADOPTED: SS-17



PLAN

STANDARD JUNCTION BOX				
TABLE OF REINFORCEMENT			WALL THICK.	CONC.
"D"	VERT. BARS	HOR. BARS	"T"	CU. YDS.
1'–0"	NONE	NONE	9"	1.93
2'–0"	"	"	9"	2.45
3'–0"	"	"	9"	2.98
4'–0"	"	"	9"	3.50
5'–0"	12 #5 @ 18" C.C. 5'–11" EACH	20 #4 @ 14" C.C. 5'–2" EACH	9"	4.03
6'–0"	12 #5 @ 18" C.C. 6'–11" EACH	20 #4 @ 17" C.C. 5'–2" EACH	9"	4.55
7'–0"	20 #5 @ 12" C.C. 7'–11" EACH	24 #4 @ 16" C.C. 5'–2" EACH	9"	5.08
8'–0"	20 #5 @ 12" C.C. 8'–11" EACH	28 #4 @ 15" C.C. 5'–2" EACH	9"	5.61
9'–0"	20 #5 @ 12" C.C. 9'–11" EACH	28 #4 @ 17" C.C. 5'–2" EACH	9"	6.14

STEEL IN TOP SLAB 16 #6 5'–2" EACH
4 #6 5'–0" EACH
STEEL IN BOTTOM 14 #4 5'–2" EACH
SEE DRAWINGS FOR STEEL PLACEMENT



SECTION AA

1. DIAGONAL BARS IN TOP SLAB PLACED NEAR BOTTOM OF SLAB.
2. REINFORCING BARS SHALL BE CUT OR BENT AT PIPE OPENINGS.
3. ALL PIPES SHALL FIT FLUSH WITH INSIDE FACE OF BOX.
4. MAXIMUM PIPE SIZE FOR BOX IS 42". FOR LARGER PIPES INCREASE INSIDE BOX DIMENSIONS TO THE INSIDE PIPE DIAMETER PLUS 6". USE GIVEN BAR SPACING FOR LARGER BOXES. MAXIMUM ALLOWABLE BOX SIZE IS 72".
5. BOTTOM OF BOX TO BE FILLED WITH CONCRETE TO MID–DEPTH OF PIPE FORMING CHANNELS TOWARD OUTLET PIPE FROM ALL INLET PIPES.
6. ALL CONCRETE SHALL HAVE 28 DAY COMPRESSIVE STRENGTH OF 3000 PSI
7. ALL REINFORCING BARS TO BE DEFORMED BARS AND MEET REQUIREMENTS OF ASTM A–615 MIN. GRADE 40.
8. 4" BEDDING MATERIAL TO BE USED UNDER BOX.
9. IF BOX IS GREATER THAN 9', MUST BE SPECIAL DESIGN.

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	STANDARD JUNCTION BOX	ADOPTED: SS-18

FULL FLOW DATA FOR CIRCULAR PIPE

D Pipe Diameter (inches)	A Area (Square feet)	R Hydraulic Radius (feet)	Value of $C_1 = \frac{1.486}{n} \times A \times R^{2/3}$	
			n=0.013	n=0.024
4	0.0873	0.083	1.9	---
6	0.196	0.125	5.6	---
8	0.349	0.167	12.1	---
10	0.545	0.208	21.8	---
12	0.785	0.250	35.7	26.3
15	1.227	0.312	64.7	35.0
18	1.767	0.375	105	56.9
21	2.405	0.437	158	85.6
24	3.142	0.500	226	122
27	3.976	0.562	310	167
30	4.909	0.625	410	222
36	7.069	0.750	666	360
42	9.621	0.875	1006	545
48	12.566	1.000	1436	778
54	15.904	1.125	1967	1065
60	19.635	1.250	2604	1414
66	23.758	1.375	3357	1818
72	28.274	1.500	4234	2293
84	38.485	1.750	6388	3460
96	50.266	2.000	9119	4439

FROM: American Concrete Pipe Association, 1985
"Concrete Pipe Design Manual"

TABLE 4

FULL FLOW COEFFICIENT VALUES
ELLIPTICAL CONCRETE PIPE

Pipe Size R x S (HE) S x R (VE) (Inches)	Approximate Equivalent Circular Diameter (Inches)	A Area (Square Feet)	R Hydraulic Radius (Feet)	Value of $C_1 = \frac{1.486}{n} \times A \times R^{2/3}$			
				n = 0.010	n = 0.011	n = 0.012	n = 0.013
14 x 23	18	1.8	0.367	138	125	116	108
19 x 30	24	3.3	0.490	301	274	252	232
22 x 34	27	4.1	0.546	405	368	339	313
24 x 38	30	5.1	0.613	547	497	456	421
27 x 42	33	6.3	0.686	728	662	607	560
29 x 45	36	7.4	0.736	891	810	746	686
32 x 49	39	8.8	0.812	1140	1036	948	875
34 x 53	42	10.2	0.875	1386	1260	1156	1067
38 x 60	48	12.9	0.969	1878	1707	1565	1445
43 x 68	54	16.6	1.106	2635	2395	2196	2027
48 x 76	60	20.5	1.229	3491	3174	2910	2686
53 x 83	66	24.8	1.352	4503	4094	3753	3464
58 x 91	72	29.5	1.475	5680	5164	4734	4370
63 x 98	78	34.6	1.598	7027	6388	5856	5406
68 x 106	84	40.1	1.721	8560	7790	7140	6590
72 x 113	90	46.1	1.845	10300	9365	8584	7925
77 x 121	96	52.4	1.967	12220	11110	10190	9403
82 x 128	102	59.2	2.091	14380	13070	11980	11060
87 x 136	108	66.4	2.215	16770	15240	13970	12900
92 x 143	114	74.0	2.340	19380	17620	16150	14910
97 x 151	120	82.0	2.461	22190	20180	18490	17070
106 x 166	132	99.2	2.707	28630	26020	23860	22020
116 x 180	144	118.6	2.968	36400	33100	30340	28000

TABLE 5

FULL FLOW COEFFICIENT VALUES
CONCRETE ARCH PIPE

Pipe Size R x S (Inches)	Approximate Equivalent Circular Diameter (Inches)	A Area (Square Feet)	R Hydraulic Radius (Feet)	Value of C_1 $\frac{1.486}{n} \times A \times R^{2/3}$			
				n 0.010	n - 0.011	n . 0.012	n . 0.013
11 x 18	15	1.1	0.25	65	59	54	50
13½ x 22	18	1.6	0.30	110	100	91	84
15½ x 26	21	2.2	0.36	165	150	137	127
18 x 28½	24	2.8	0.45	243	221	203	187
22½ x 36¼	30	4.4	0.56	441	401	368	339
26⅝ x 43¾	36	6.4	0.68	736	669	613	566
31⁵⁄₁₆ x 51⅛	42	8.8	0.80	1125	1023	938	866
36 x 58½	48	11.4	0.90	1579	1435	1315	1214
40 x 65	54	14.3	1.01	2140	1945	1783	1646
45 x 73	60	17.7	1.13	2851	2592	2376	2193
54 x 88	72	25.6	1.35	4641	4219	3867	3569
62 x 102	84	34.6	1.57	6941	6310	5784	5339
72 x 115	90	44.5	1.77	9668	8789	8056	7436
77¼ x 122	96	51.7	1.92	11850	10770	9872	9112
87⅛ x 138	108	66.0	2.17	16430	14940	13690	12640
96⅞ x 154	120	81.8	2.42	21975	19977	18312	16904
106½ x 168¾	132	99.1	2.65	28292	25720	23577	21763

FROM:

American Iron and Steel Institute, 1994

"Handbook of Steel Drainage & Highway Construction Products"

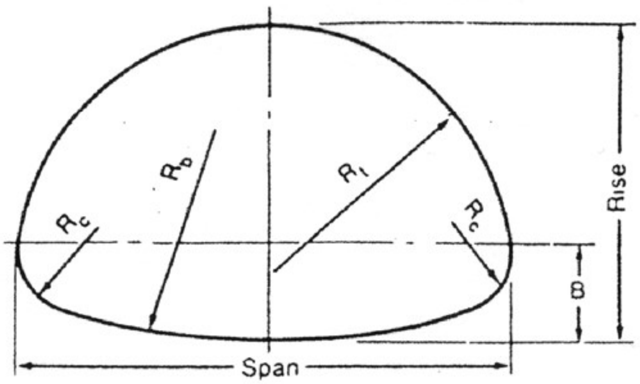


***Table 2.18 Sizes and Layout Details—CSP Pipe Arch.**
2 2/3 x 1/2 in. Corrugation

Equiv. Diameter, in.	Span, in.	Rise, in.	Waterway Area, ft²	Layout Dimensions B in.	R_c in.	R_t in.	R_b in.
15	17	13	1.1	4 1/8	3 1/2	8 5/8	25 5/8
18	21	15	1.6	4 7/8	4 1/8	10 3/4	33 1/8
21	24	18	2.2	5 5/8	4 7/8	11 7/8	34 5/8
24	28	20	2.9	6 1/2	5 1/2	14	42 1/4
30	35	24	4.5	8 1/8	6 7/8	17 7/8	55 1/8
36	42	29	6.5	9 3/4	8 1/4	21 1/2	66 1/8
42	49	33	8.9	11 3/8	9 5/8	25 1/8	77 1/4
48	57	38	11.6	13	11	28 5/8	88 1/4
54	64	43	14.7	14 5/8	12 3/8	32 1/4	99 1/4
60	71	47	18.1	16 1/4	13 3/4	35 3/4	110 1/4
66	77	52	21.9	17 7/8	15 1/8	39 3/8	121 1/4
72	83	57	26.0	19 1/2	16 1/2	43	132 1/4

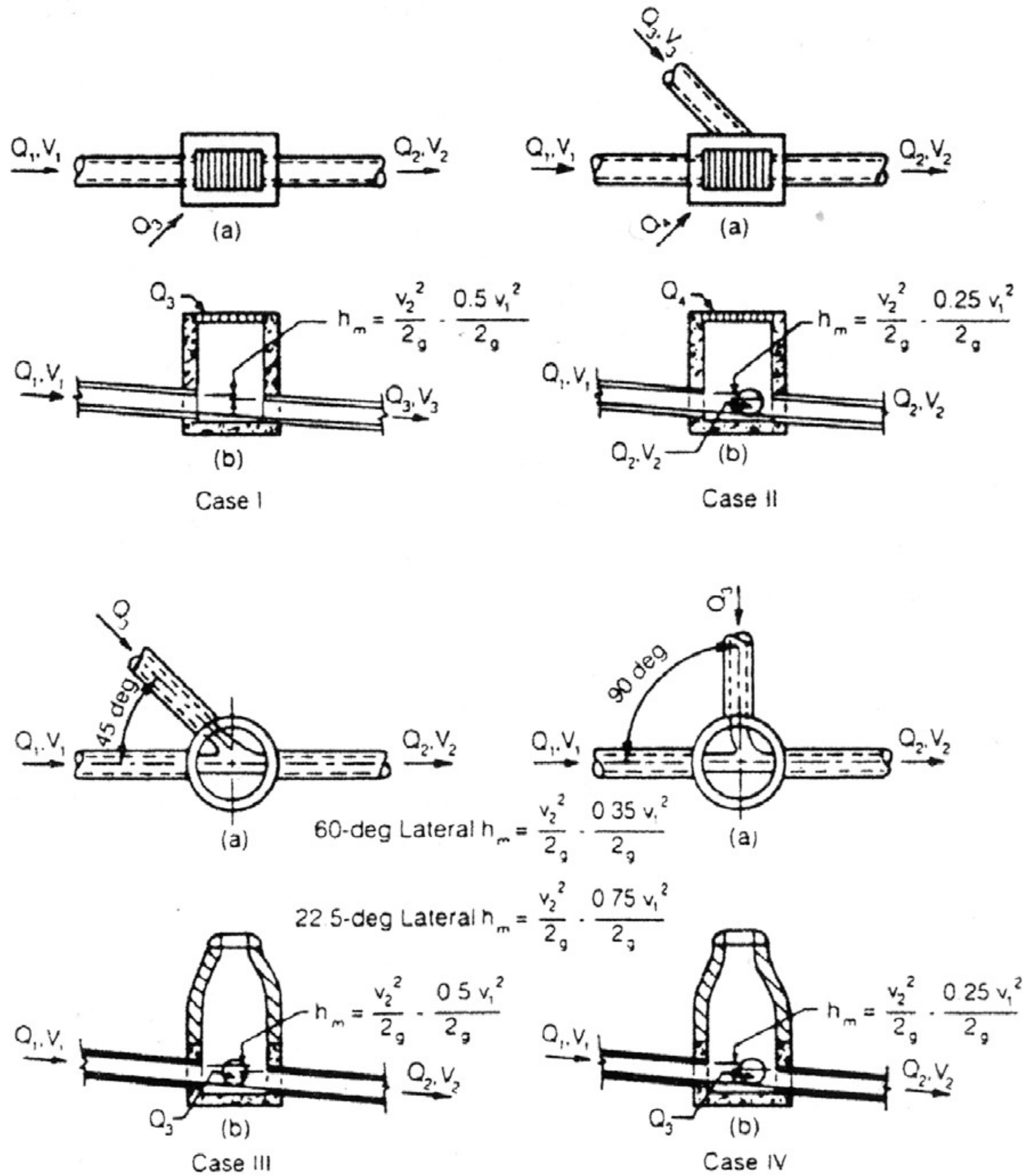
***Table 2.19 Sizes and Layout Details—CSP Pipe-Arch**
3 x 1 or 5 x 1 in. Corrugation

Equiv. Diameter, in.	Nominal Size, in.	Design Span, in.	Design Rise, in.	Waterway Area, ft²	Layout Dimensions B in.	R_c in.	R_t in.	R_b in.
48	53 x 41	53	41	11.7	15 1/4	10 3/16	28 11/16	73 11/16
54	60 x 46	58 1/2	48 1/2	15.6	20 1/2	18 3/4	29 3/8	51 1/8
60	66 x 51	65	54	19.3	22 3/4	20 3/4	32 5/8	56 1/4
66	73 x 55	72 1/2	58 1/4	23.2	25 1/8	22 7/8	36 3/4	63 3/4
72	81 x 59	79	62 1/2	27.4	23 3/4	20 7/8	39 1/2	82 5/8
78	87 x 63	86 1/2	67 1/4	32.1	25 3/4	22 5/8	43 3/8	92 1/4
84	95 x 67	93 1/2	71 3/4	37.0	27 3/4	24 3/8	47	100 1/4
90	103 x 71	101 1/2	76	42.4	29 3/4	26 1/8	51 1/4	111 5/8
96	112 x 75	108 1/2	80 1/2	48.0	31 5/8	27 3/4	54 1/8	120 1/4
102	117 x 79	116 1/2	84 3/4	54.2	33 5/8	29 1/2	59 3/8	131 3/4
108	128 x 83	123 1/2	89 1/4	60.5	35 5/8	31 1/4	63 1/4	139 3/4
114	137 x 87	131	93 3/4	67.4	37 5/8	33	67 3/8	149 1/2
120	142 x 91	138 1/2	98	74.5	39 1/2	34 3/4	71 5/8	162 3/8
126	150 x 96	146	102	81	41	36	76	172
132	157 x 101	153	107	89	43	38	80	180
138	164 x 105	159	113	98	45	40	82	184
144	171 x 110	165	118 1/2	107	47	41	85	190

*Dimensions shown not for specification purposes, subject to manufacturing tolerances.

FROM:

American Society of Civil Engineers
ASCE Manuals and Reports of Engineering Practice No. 77
"Design and Construction of Urban Stormwater Management Systems"



Case I: $h_m = \frac{v_2^2}{2g} - \frac{0.5\, v_1^2}{2g}$

Case II: $h_m = \frac{v_2^2}{2g} - \frac{0.25\, v_1^2}{2g}$

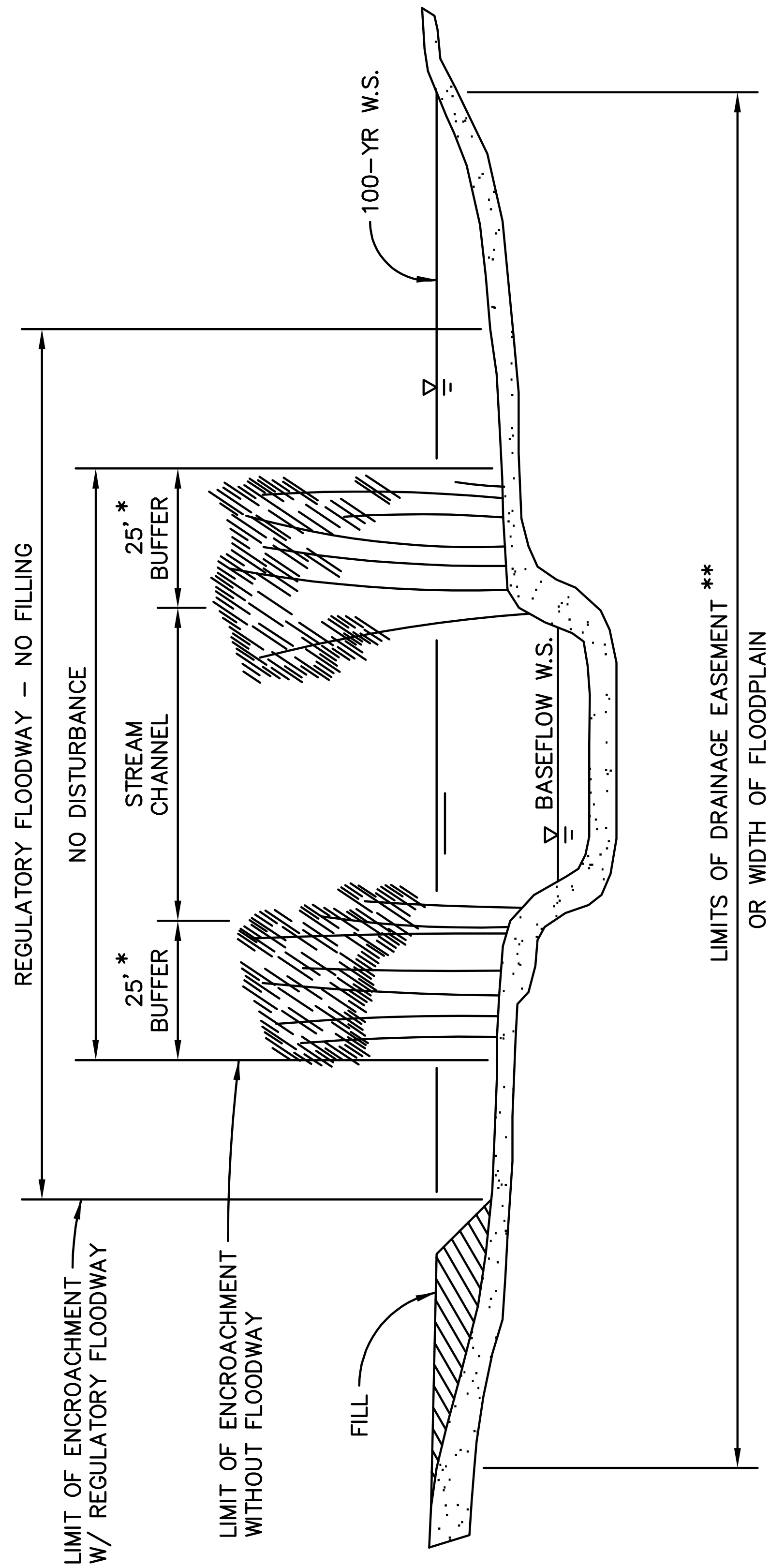
60-deg Lateral $h_m = \frac{v_2^2}{2g} - \frac{0.35\, v_1^2}{2g}$

22.5-deg Lateral $h_m = \frac{v_2^2}{2g} - \frac{0.75\, v_1^2}{2g}$

Case III: $h_m = \frac{v_2^2}{2g} - \frac{0.5\, v_1^2}{2g}$

Case IV: $h_m = \frac{v_2^2}{2g} - \frac{0.25\, v_1^2}{2g}$

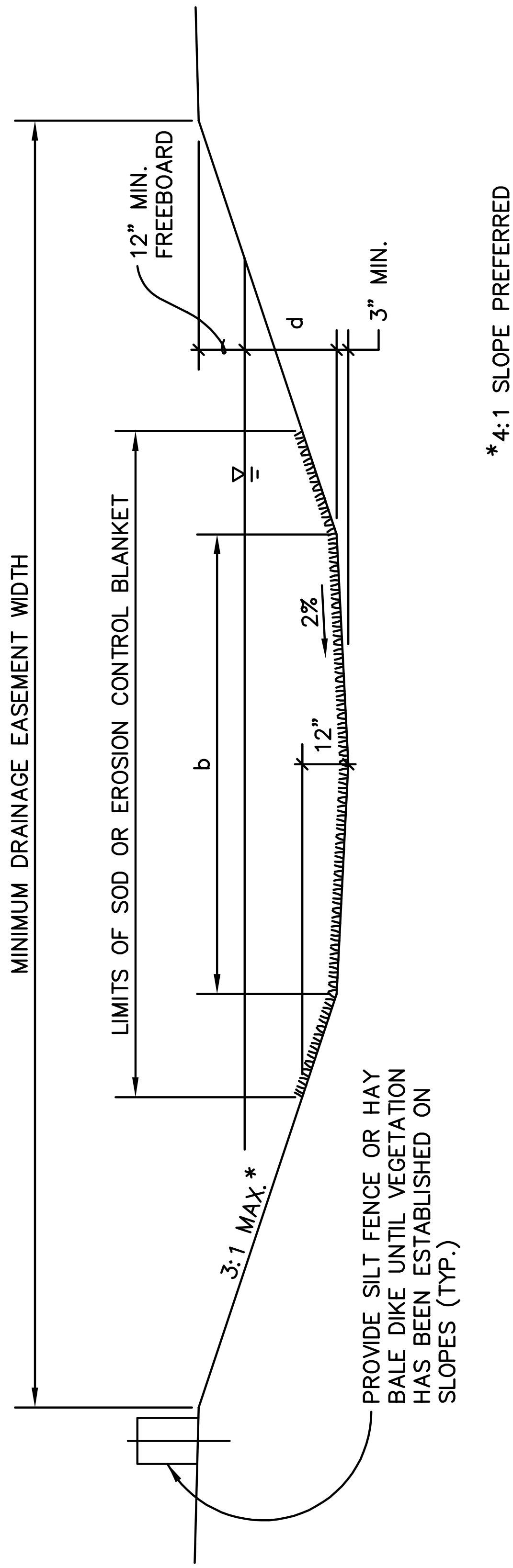
Figure 6.14—Minor head losses due to turbulence at structures: case I—inlet on main line (a) plan and (b) section, case II—inlet on main line with branch lateral (a) plan and (b) section, case III—manhole on main line with 45-deg branch lateral (a) plan and (b) section, and case IV—manhole on main line with 90-deg branch lateral (a) plan and (b) section (City of Austin, 1987).



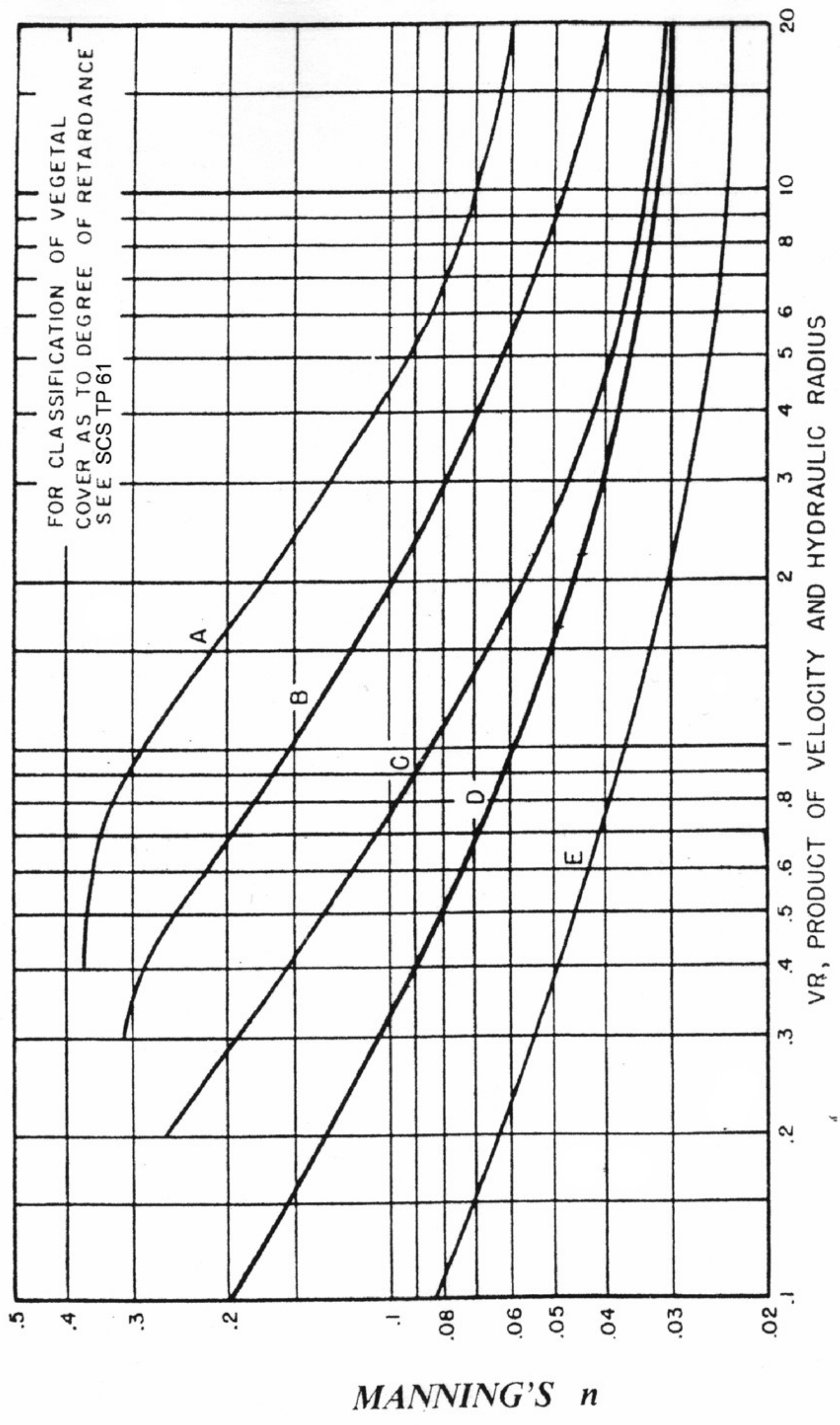
* EXISTING VEGETATION TO REMAIN. 100' WIDTH PREFERRED.

** USE FULLY URBANIZED CONDITIONS FOR PEAK FLOW RATE.

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	TYPICAL NATURAL CHANNEL	ADOPTED: SS-23

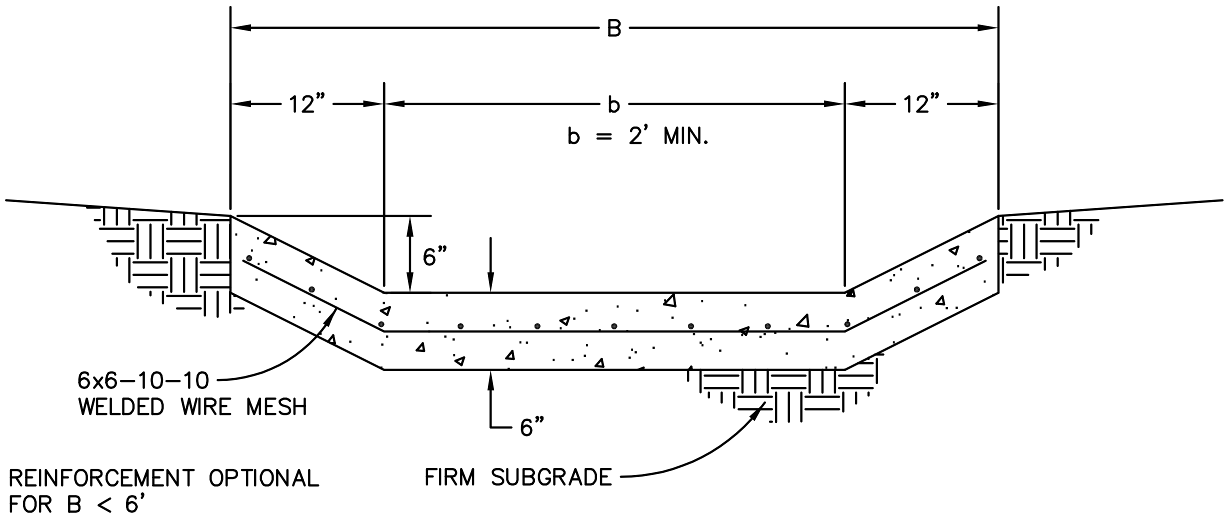


CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	TYPICAL GRASS–LINED CHANNEL	ADOPTED: SS-24



Manning n for vegetal-lined channels (from handbook of channel design for soil and water conservation SCS-TP-61 revised June 1964).

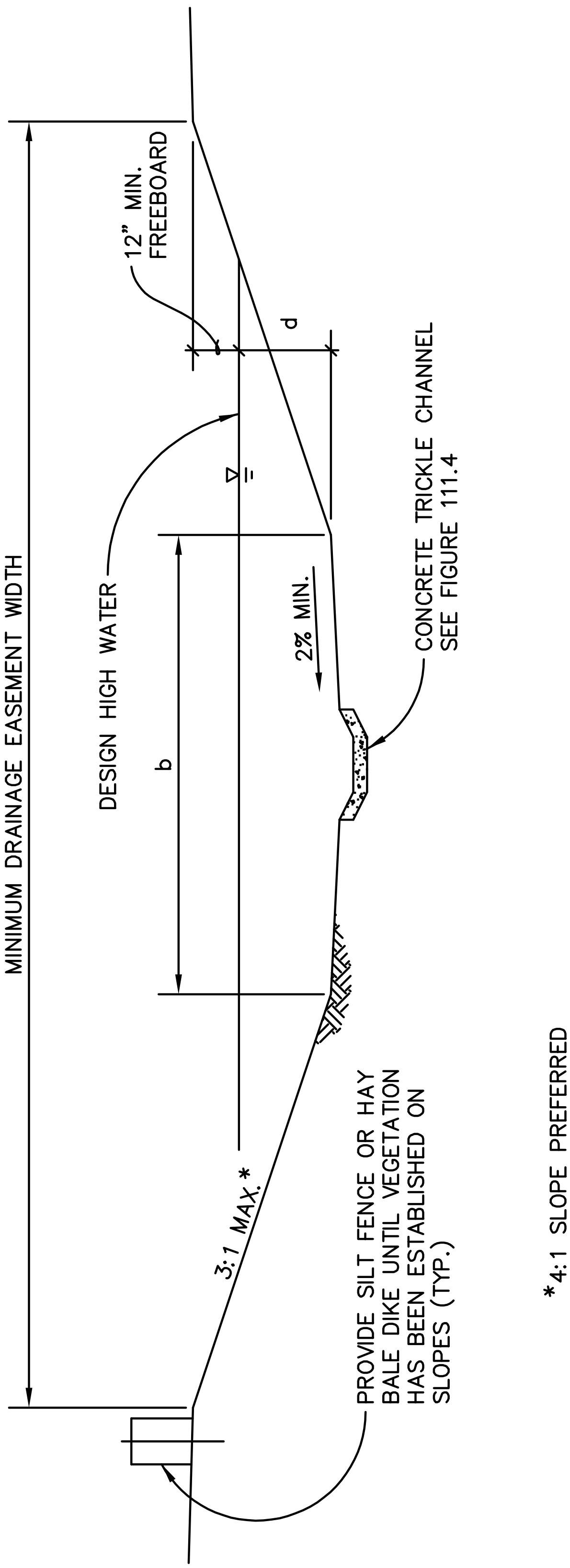
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	MANNING'S n FOR GRASS-LINED CHANNELS	ADOPTED: SS-25



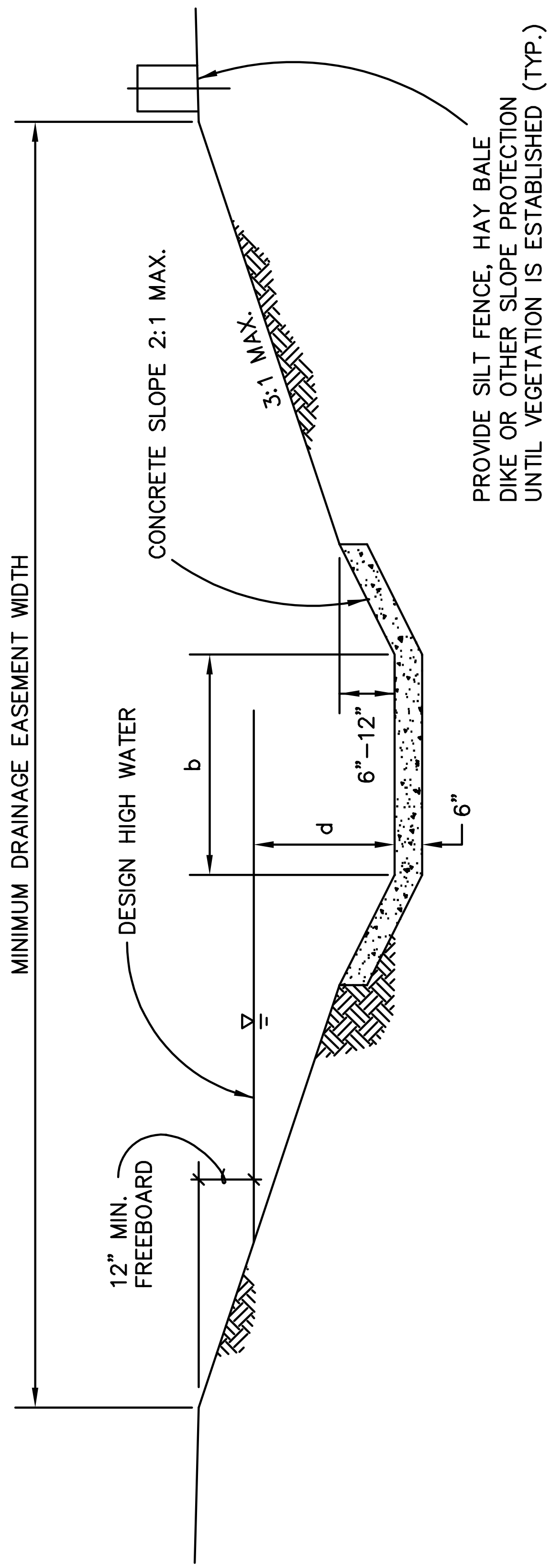
NOTE: CONCRETE WORK SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER VII OF THE CITY OF SPRINGFIELD TECHNICAL SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION.

DESIGN FLOW RATE (cfs)	RECOMMENDED TRICKLE CHANNEL WIDTH, b (ft)
< 150	2'
150 – 200	3'
200 – 250	4'
250 – 350	5'
> 350	DETERMINE ON CASE BY CASE BASIS

CONCRETE TRICKLE CHANNEL



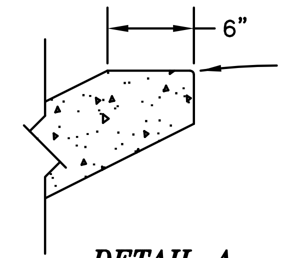
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	GRASS-LINED CHANNEL W/ CONC TRICKLE	ADOPTED: SS-27



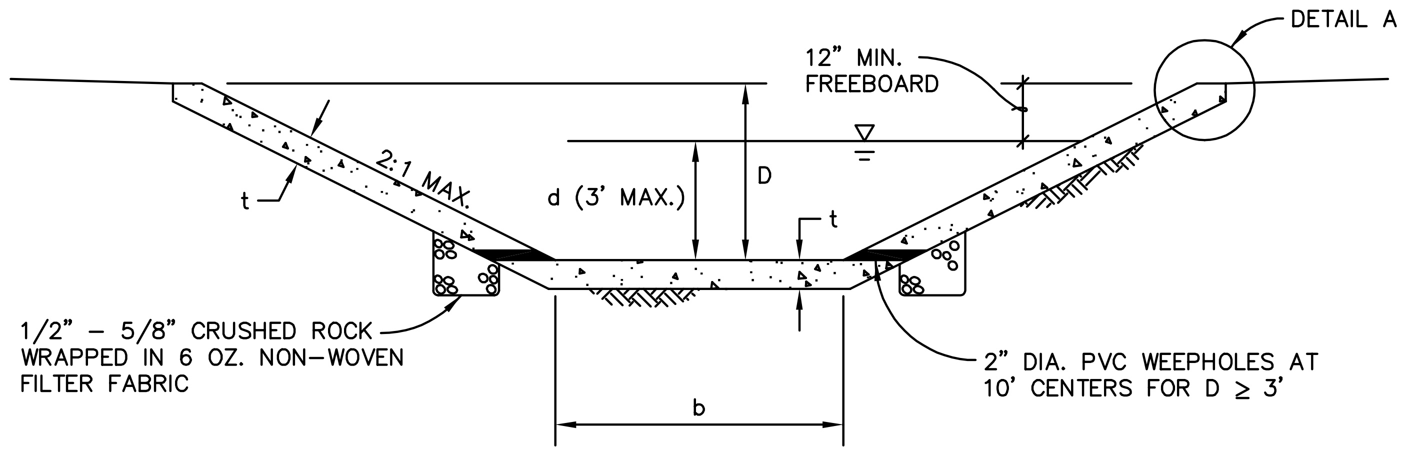
NOTES:

1. CONCRETE WORK SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER VII OF THE CITY OF SPRINGFIELD TECHNICAL SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION.
2. PROVIDE 6x6–10–10 WELDED WIRE MESH OR EQUIVALENT REINFORCEMENT FOR b > 4 FEET.

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	CHANNEL W CONC INVERT & GRASS SIDE SLOPES	ADOPTED: SS-28



DETAIL A

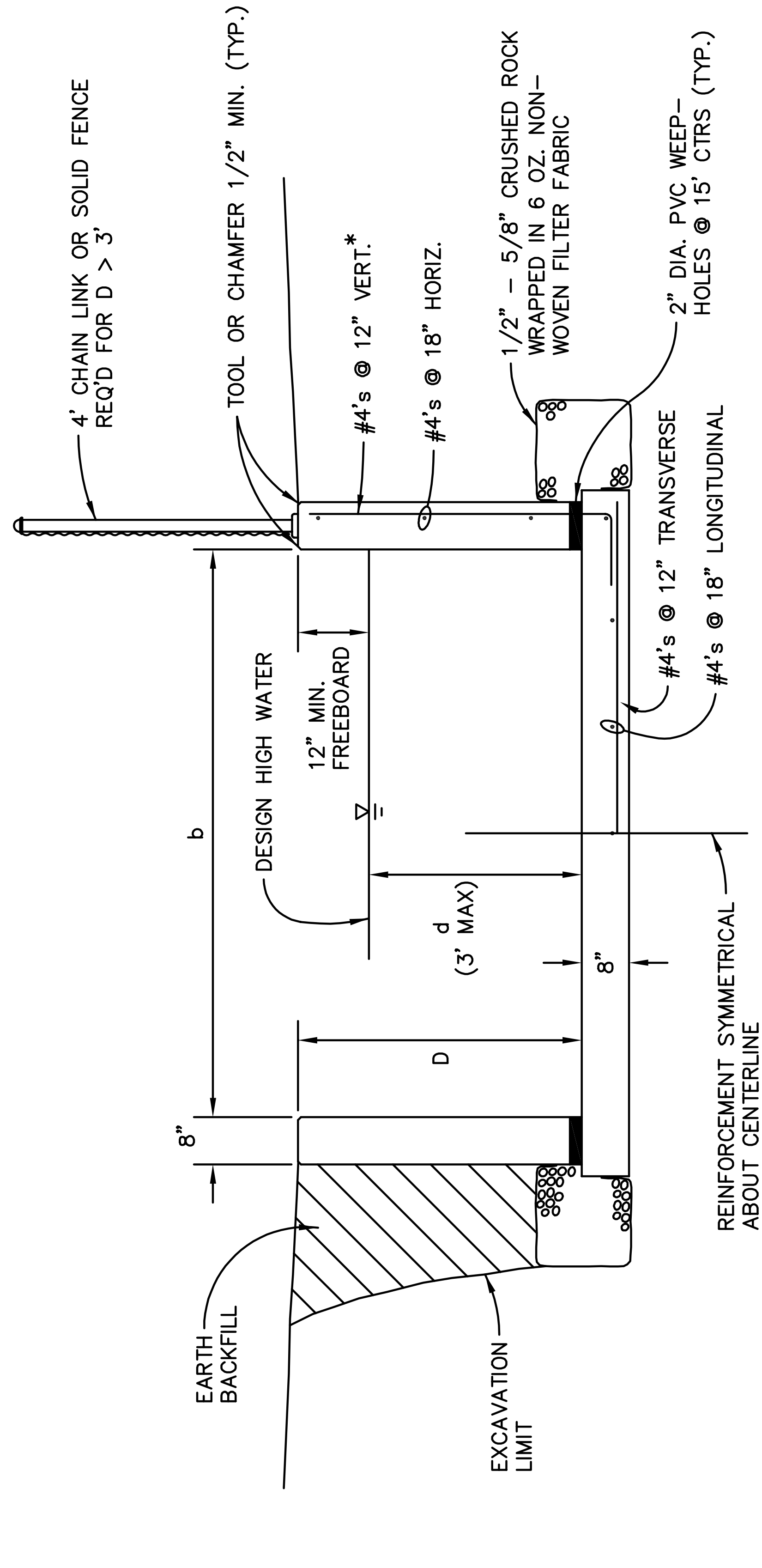


NOTES:

1. B ≤ 5', t = 6" REINFORCE WITH 6x6–10–10 WWM
   B > 5', t = 8" REINFORCE WITH #4's @ 12" TRANSVERSE, #4's @ 18" LONGITUDINAL

2. CONCRETE WORK SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER VII OF THE CITY OF SPRINGFIELD TECHNICAL SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION.

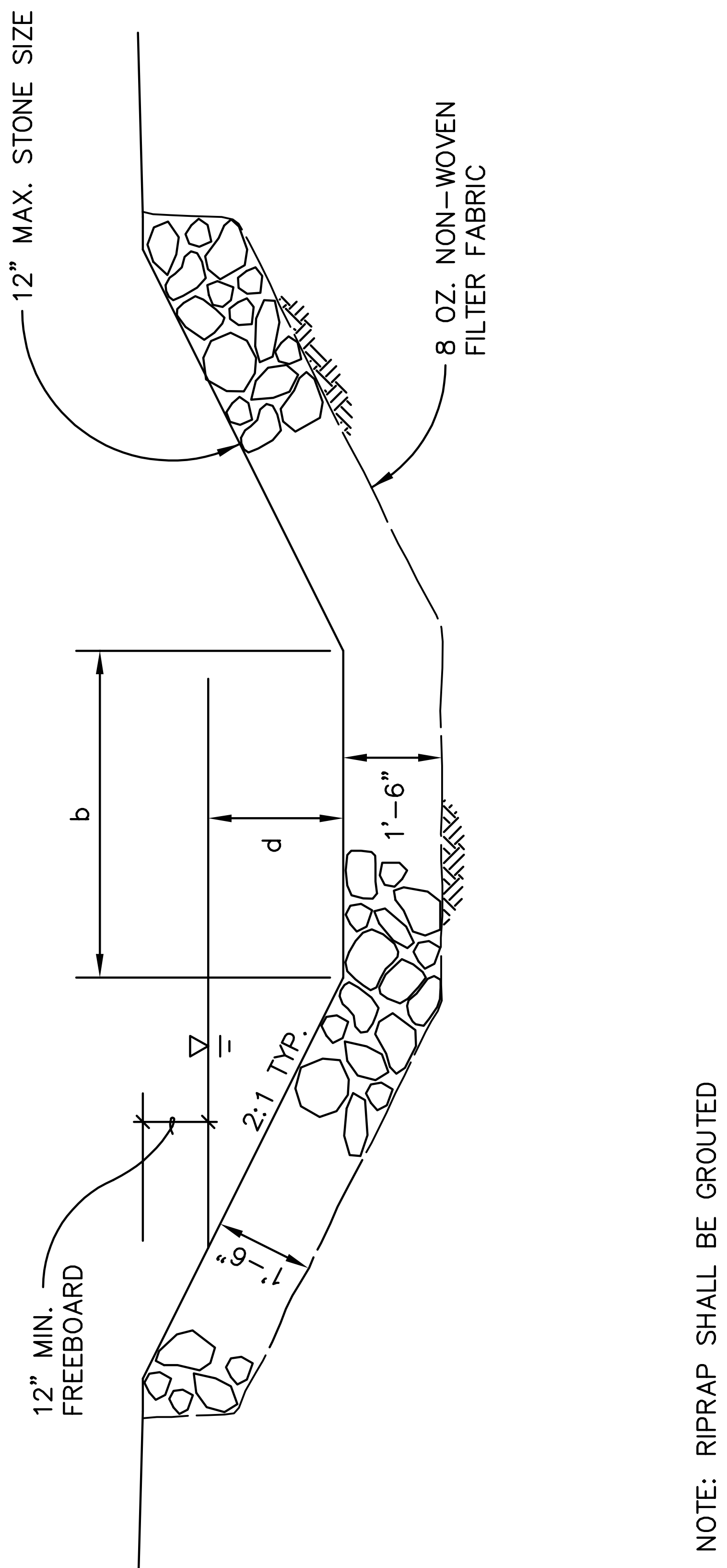
TRAPEZOIDAL CONCRETE CHANNEL



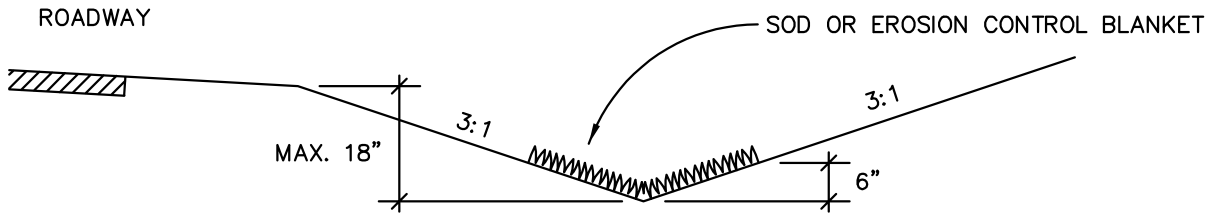
* FOR D ≤ 5'. DESIGNER MUST SPECIFY WHEN D > 5'.

NOTE: CONCRETE SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER VII OF THE CITY OF SPRINGFIELD TECHNICAL SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION.

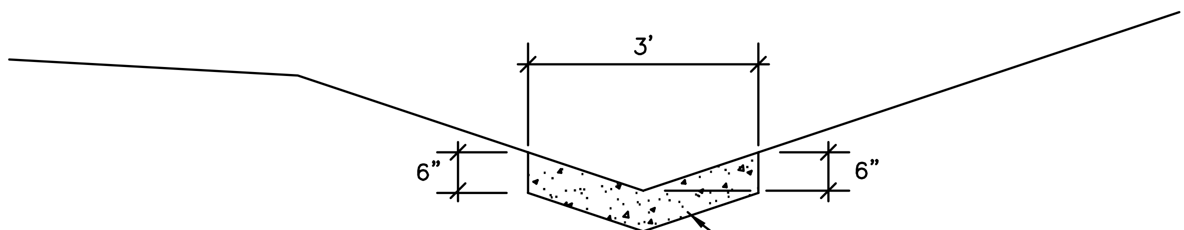
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	RECTANGULAR CONCRETE CHANNEL	ADOPTED: SS-30



CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	TYPICAL RIPRAP LINED CHANNEL	ADOPTED: SS-31



GRASS LINING

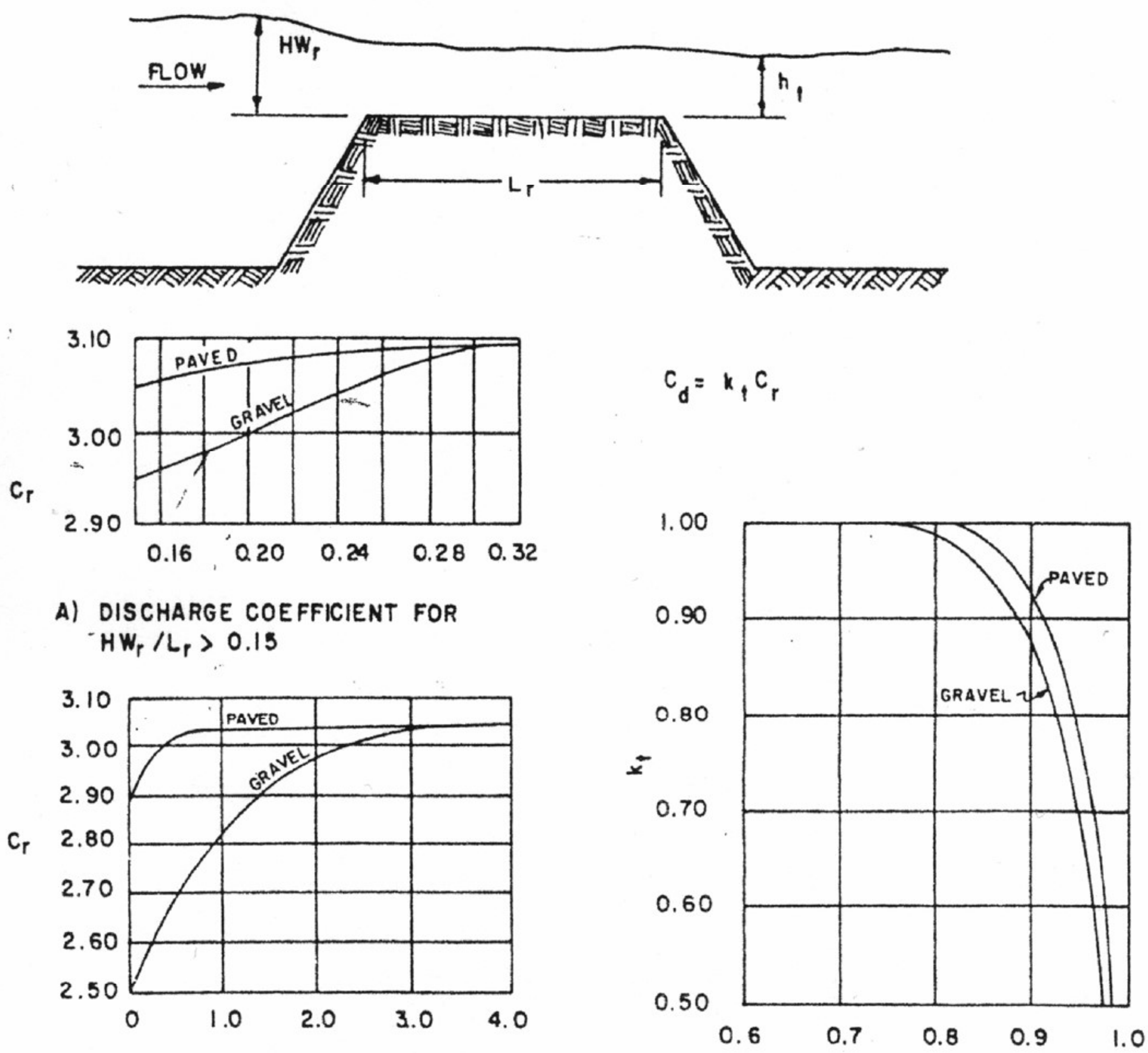


NOTES

1. PROVIDE TOOLED OR SAWCUT CONTRACTION JOINTS AT MAXIMUM 10' SPACING.
2. PROVIDE EXPANSION JOINT WITH 1/2" EXPANSION MATERIAL AT MAXIMUM 50' SPACING.

CONCRETE LINING

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	ROADSIDE DITCHES	ADOPTED: SS-32



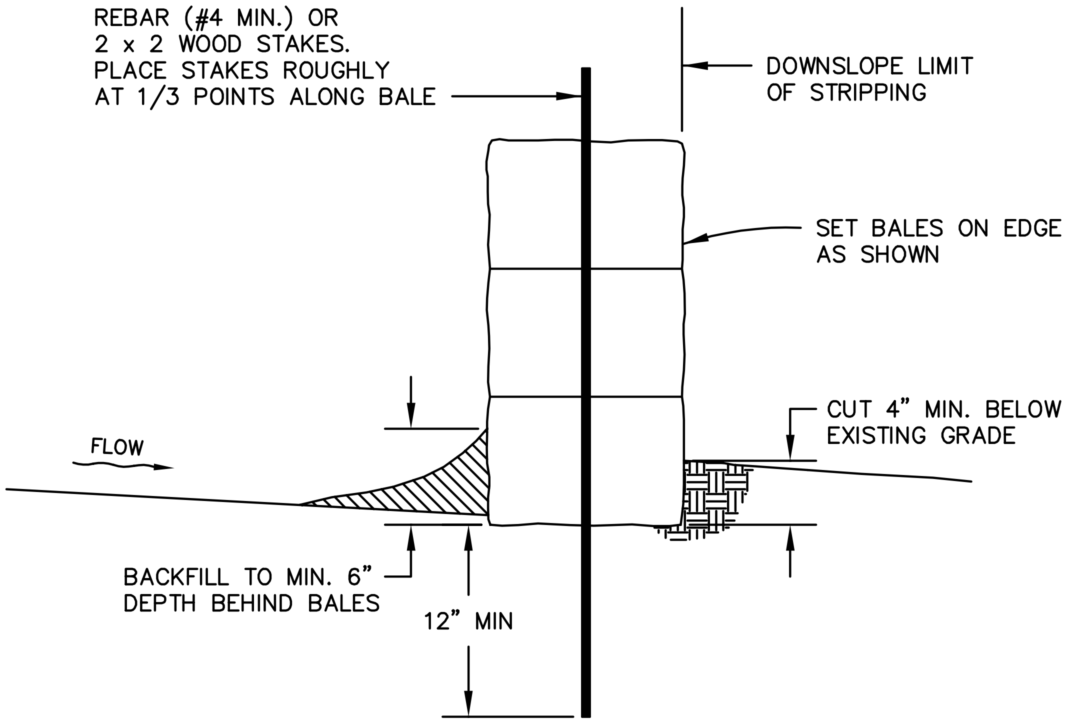
A) DISCHARGE COEFFICIENT FOR $HW_r / L_r > 0.15$

B) DISCHARGE COEFFICIENT FOR $HW_r / L_r \leq 0.15$

C) SUBMERGENCE FACTOR

From "Hydraulic Design of Highway Culverts," HDS-5, Federal Highway Administration, 1985.

DISCHARGE COEFF. FOR FLOW OVER WIDE EMB

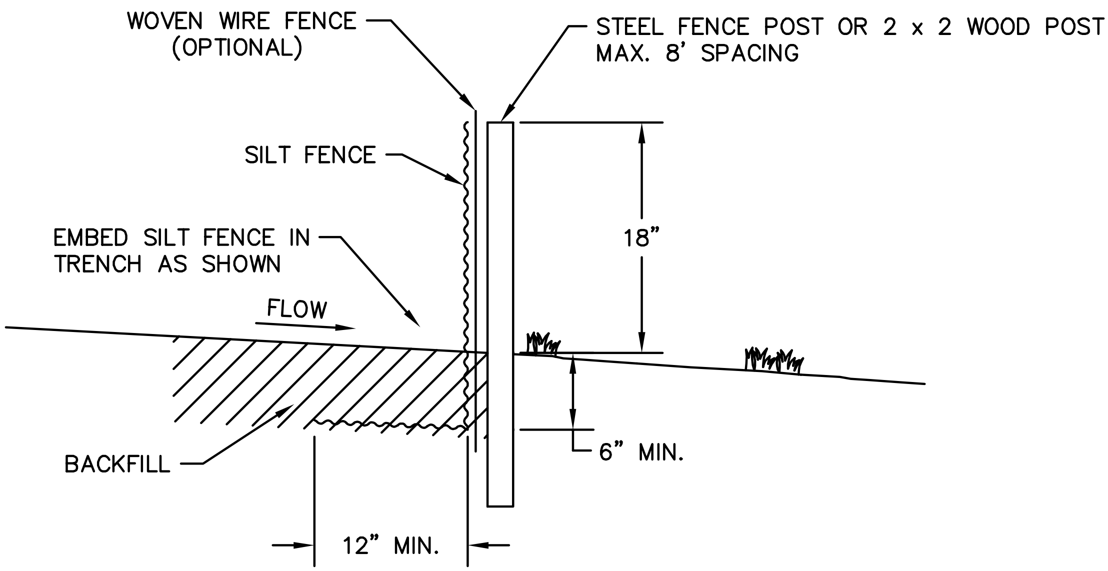


NOTES:

1. PLACE HAY BALE DIKE AT DOWNSLOPE LIMIT OF AREA TO BE GRADED.
2. BALES SHALL BE PLACED IN A ROW WITH ENDS TIGHTLY ABUTTING THE ADJACENT BALES.
3. BALES SHALL BE PLACED ALONG A LEVEL CONTOUR WITH AN ALLOWANCE OF ±4 INCHES.
4. SEDIMENT TRAPPED SHALL BE DISPOSED IN AN APPROVED LOCATION IN A MANNER WHICH WILL NOT CONTRIBUTE ADDITIONAL SILTATION.
5. EACH BALE SHALL BE EMBEDDED IN THE SOIL A MINIMUM OF FOUR INCHES.
6. BALES SHALL BE SECURELY ANCHORED IN PLACE BY STAKES OR RE-BARS DRIVEN THROUGH THE BALES. THE FIRST STAKE IN EACH BALE SHALL BE ANGLED TOWARD PREVIOUSLY LAID BALE TO FORCE BALES TOGETHER.
7. INSPECTION SHALL BE FREQUENT AND REPAIR OR REPLACEMENT SHALL BE MADE PROMPTLY AS NEEDED BY CONTRACTOR.
8. BALES SHALL BE REMOVED WHEN THEY HAVE SERVED THEIR USEFULNESS SO AS NOT TO BLOCK OR IMPEDE STORM FLOW OR DRAINAGE.
9. ACCUMULATED SILT SHALL BE REMOVED WHEN IT REACHES A DEPTH OF 6 INCHES.
10. AT EACH END OF DIKE, TURN DIKE UPSLOPE AND EXTEND UNTIL GROUND SURFACE RISES 18 INCHES.

REFERENCE: Adapted from City of Austin & City of Tulsa Erosion and Sedimentation Control Manuals

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	HAY BALE DIKE	ADOPTED: SS-34

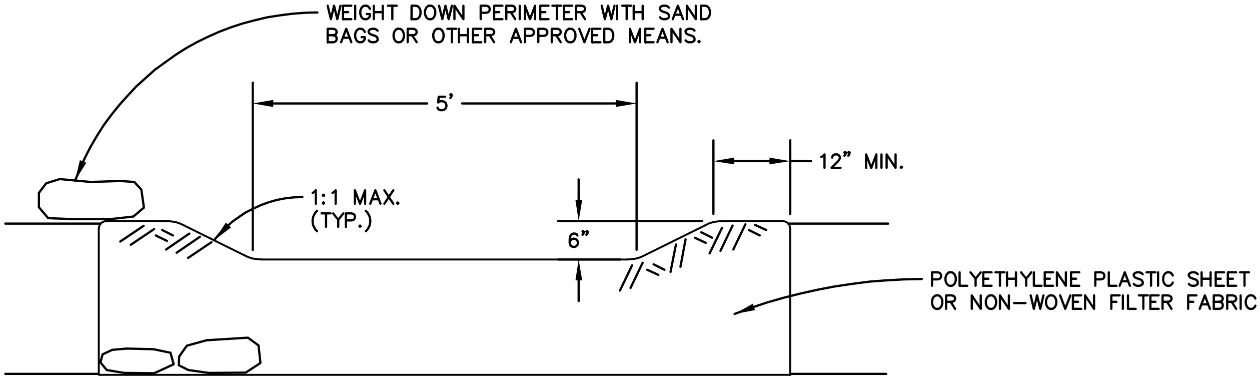


NOTES:

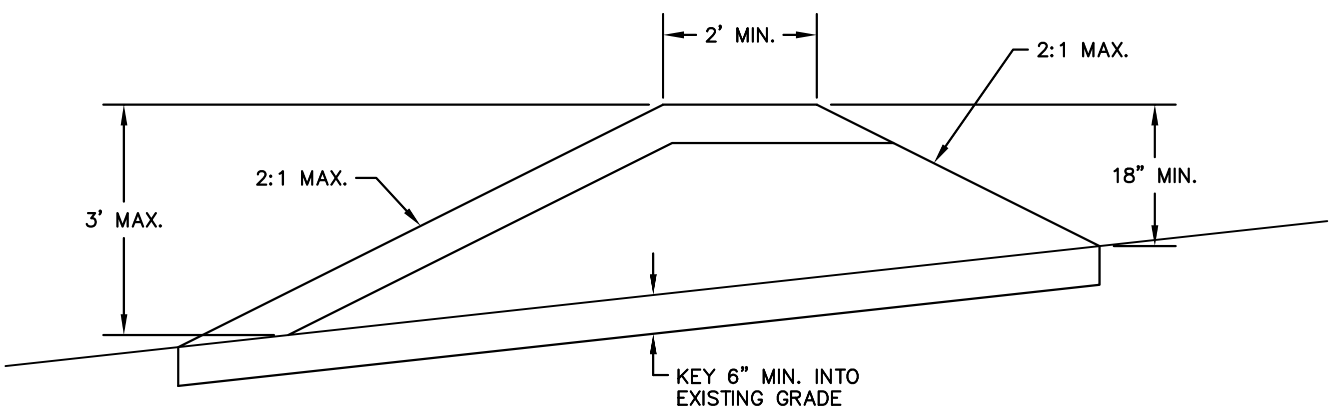
1. PLACE SILT FENCE AT DOWNSLOPE LIMIT OF AREA TO BE GRADED.
2. SILT FENCE SHALL BE PLACED ALONG A LEVEL CONTOUR WITH AN ALLOWANCE OF ± 4 INCHES.
3. SEDIMENT TRAPPED BY THIS PRACTICE SHALL BE DISPOSED OF IN AN APPROVED SITE IN A MANNER THAT WILL NOT CONTRIBUTE TO ADDITIONAL SILTATION.
4. SILT FENCE SHOULD BE SECURELY FASTENED TO EACH SUPPORT POST OR TO WOVEN WIRE, WHICH IS IN TURN ATTACHED TO THE STEEL FENCE POSTS.
5. INSPECTION SHALL BE FREQUENT AND REPAIR OR REPLACEMENT SHALL BE MADE PROMPTLY AS NEEDED.
6. SILT FENCE SHALL BE REMOVED WHEN IT HAS SERVED ITS USEFULNESS SO AS NOT TO BLOCK OR IMPEDE STORM FLOW OR DRAINAGE.
7. ACCUMULATED SILT SHALL BE REMOVED WHEN IT REACHES A DEPTH OF 6 INCHES.
8. AT EACH END OF SILT FENCE, TURN FENCE UPSLOPE AND EXTEND UNTIL GROUND SURFACE RISES 18 INCHES.

REFERENCE: Adapted from City of Austin & City of Tulsa Erosion and Sedimentation Control Manuals

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	SILT FENCE	ADOPTED: SS-35



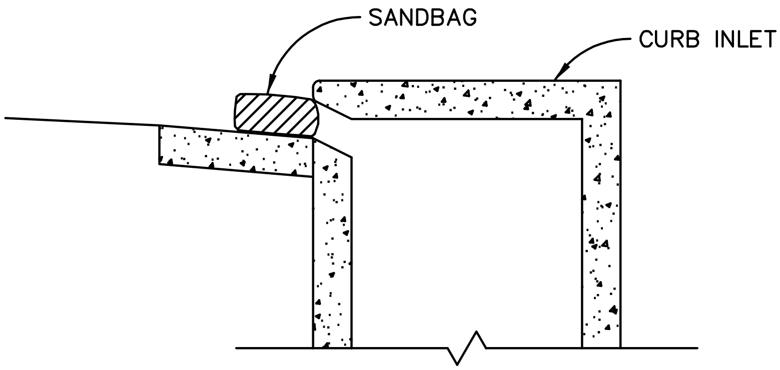
OVERFLOW AREA



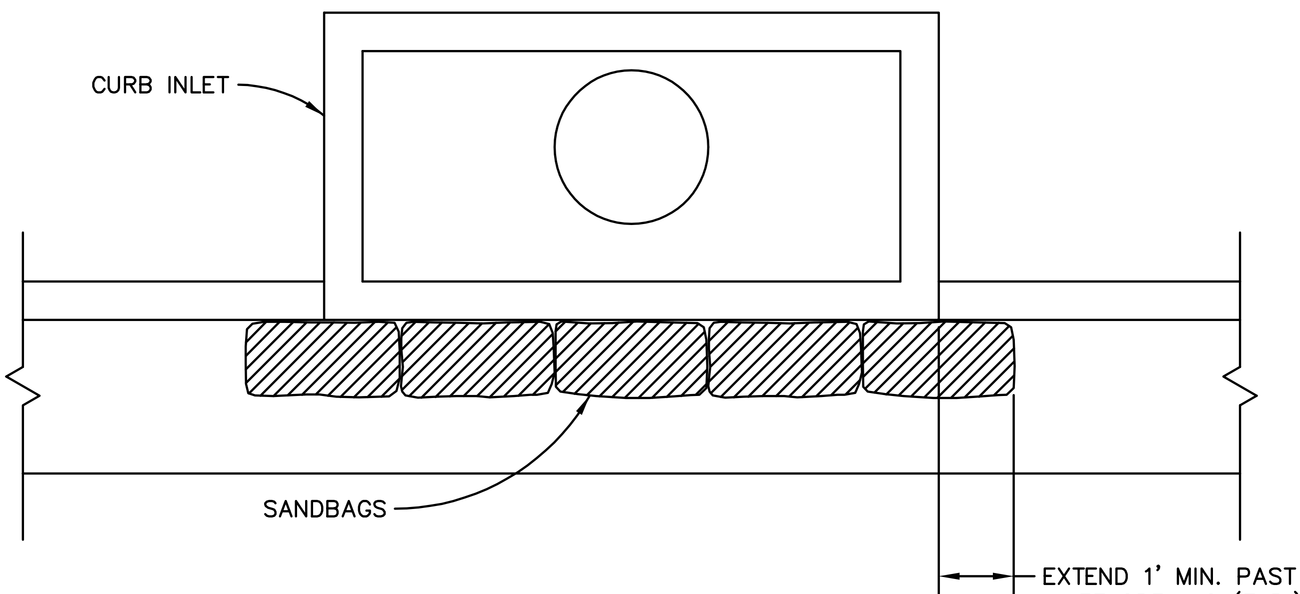
NOTES:

1. SOIL IN BERM SHALL BE FIRMLY COMPACTED.
2. AT EACH END OF BERM, TURN BERM UPSLOPE AND EXTEND UNTIL GROUND SURFACE RISES TO TOP OF BERM ELEVATION.
3. PROVIDE OVERFLOW AREAS AT 200 FT. MAX. INTERVALS.

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	TEMPORARY SILT CONTAINMENT BERM	ADOPTED: SS-36



CROSS–SECTION

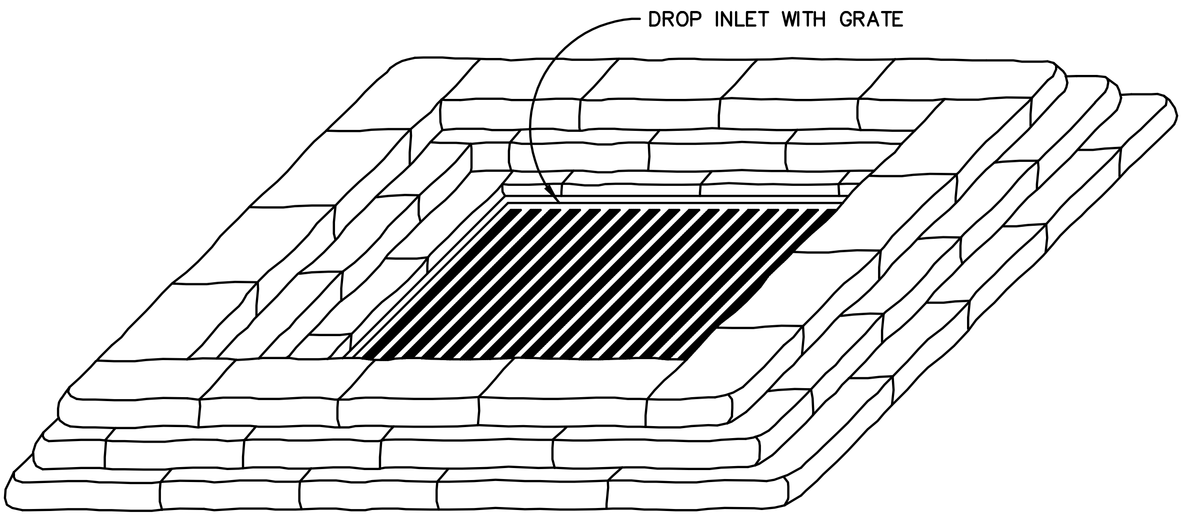


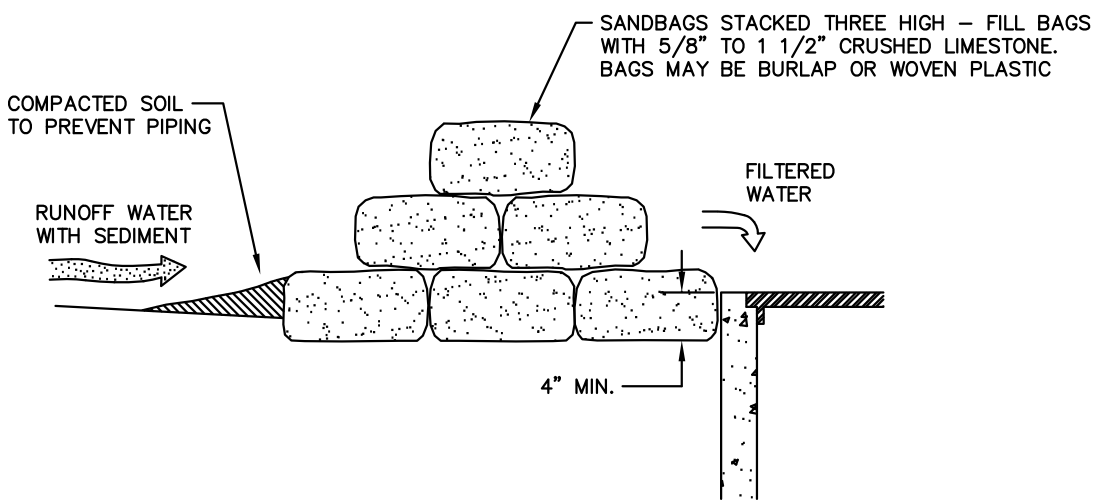
PLAN

NOTES:

1. FILL BAGS WITH 5/8" CRUSHED LIMESTONE.
2. BAGS SHALL BE BURLAP OR BIODEGRADABLE PLASTIC.
3. BAGS SHALL BE INSPECTED AND REPLACED AS NEEDED.

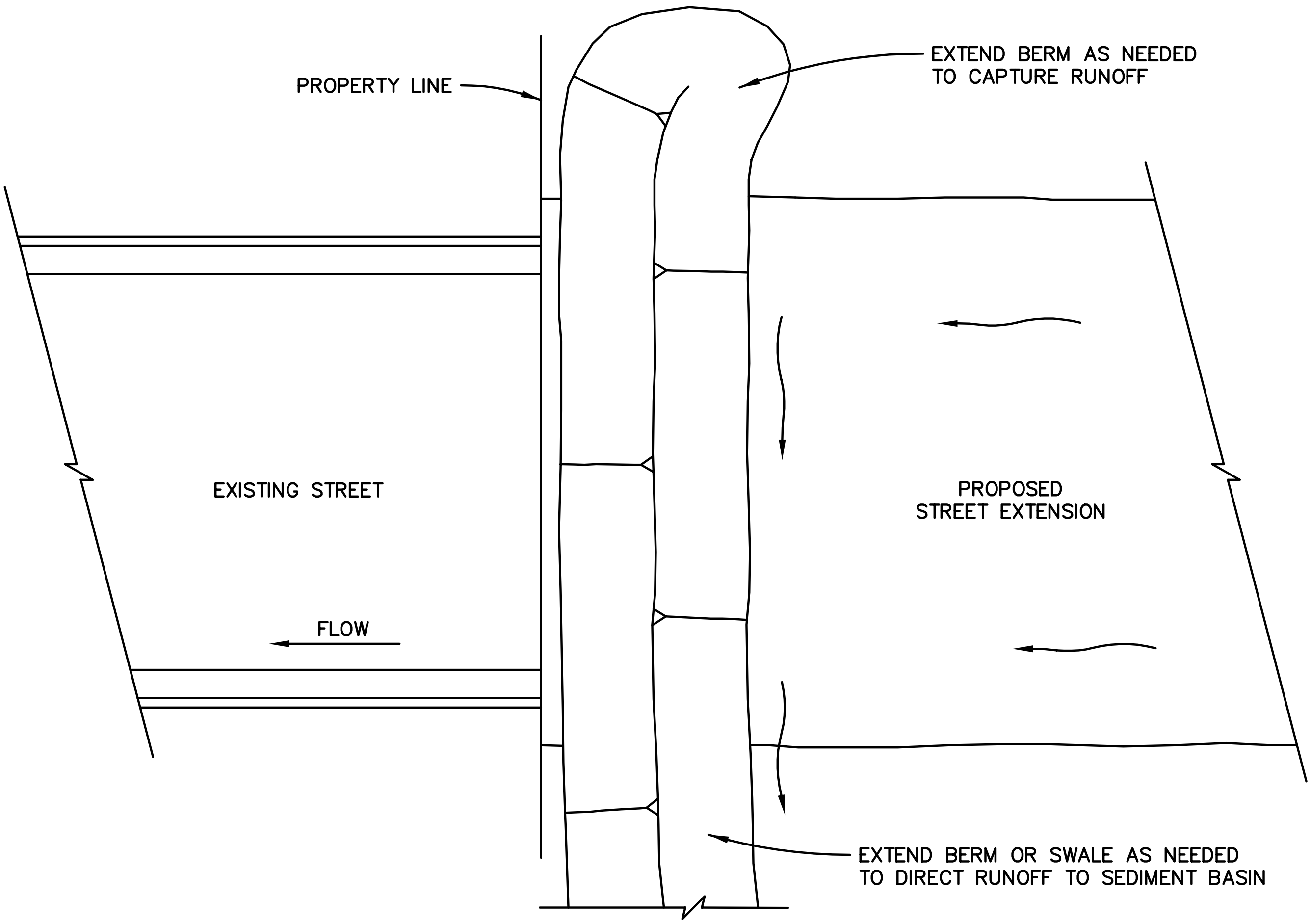
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	SAND BAG SEDIMENT TRAP FOR CURB INLETS	ADOPTED: SS-37



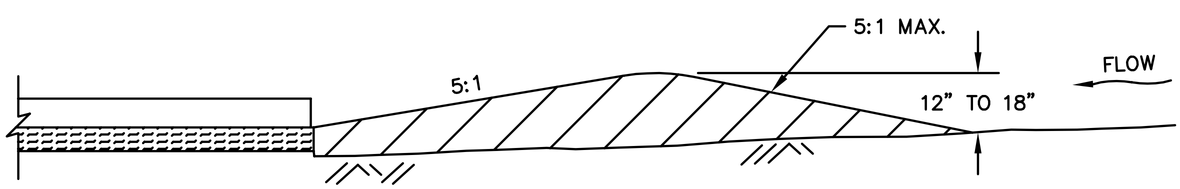


DROP INLET SEDIMENT FILTER

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	AREA INLET PROTECTION	ADOPTED: SS-38



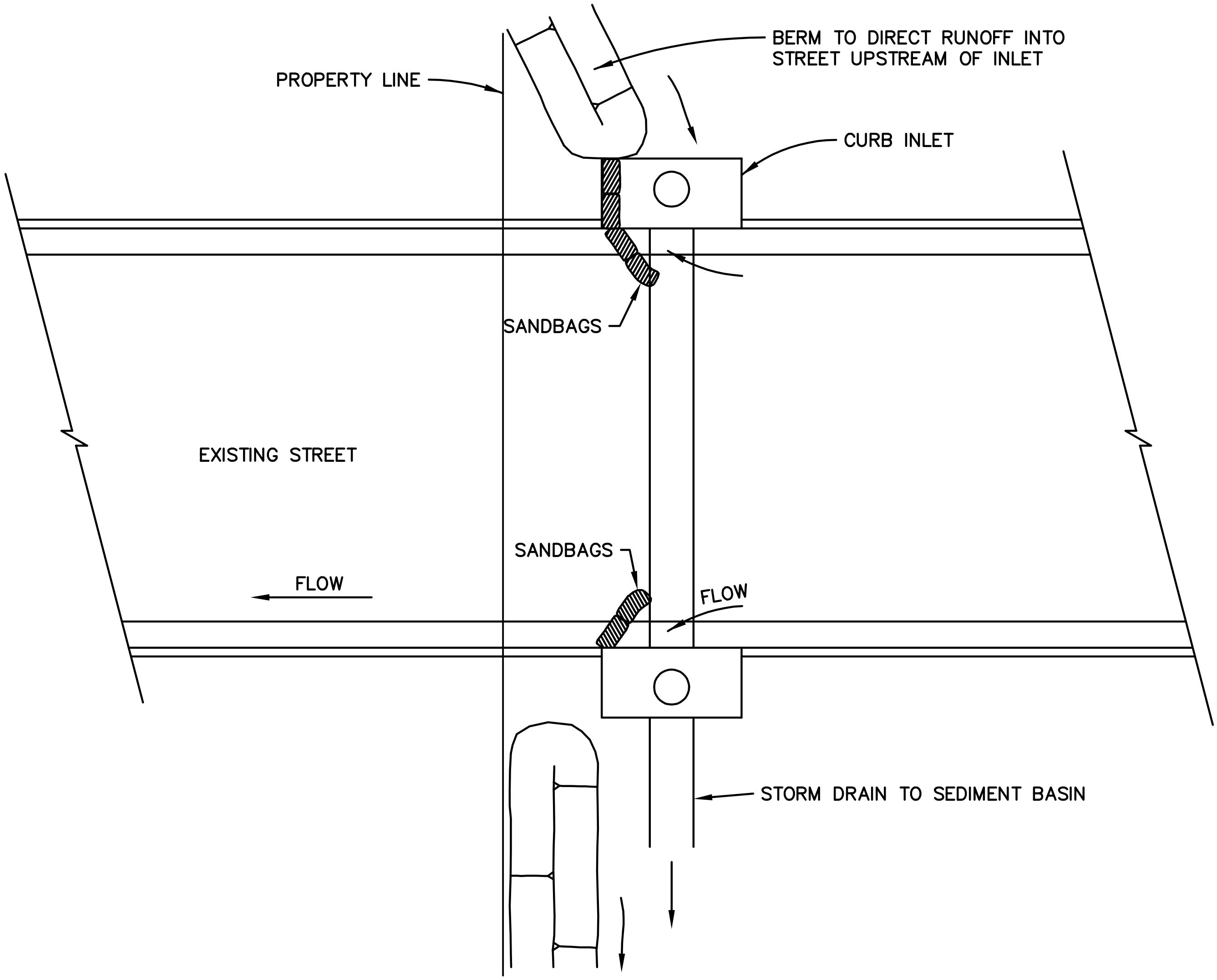
PLAN



CROSS–SECTION

CASE 1 – AFTER INITIAL EXCAVATION OF SUBGRADE

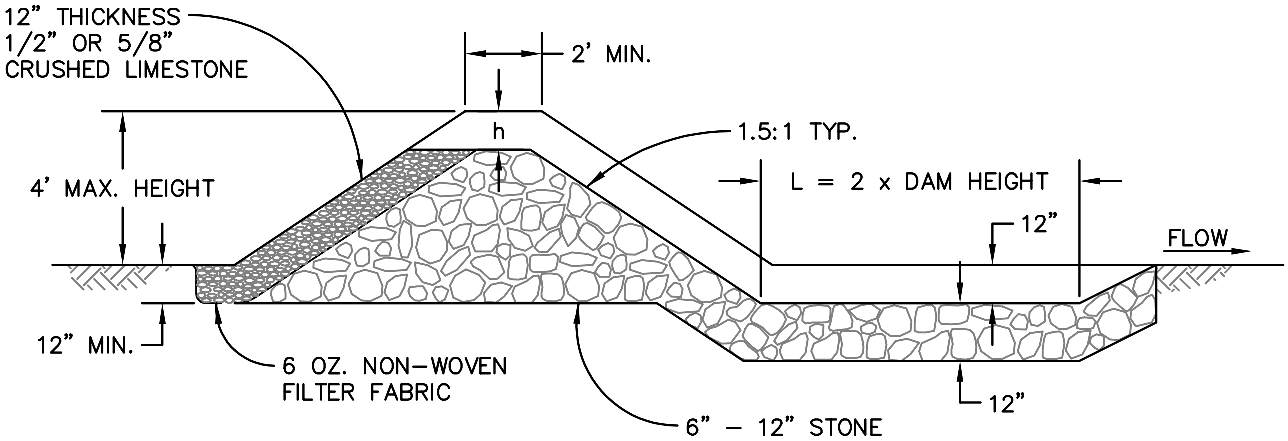
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	DIVERSION OF RUNOFF FOR CURBED STREET	ADOPTED: SS-39



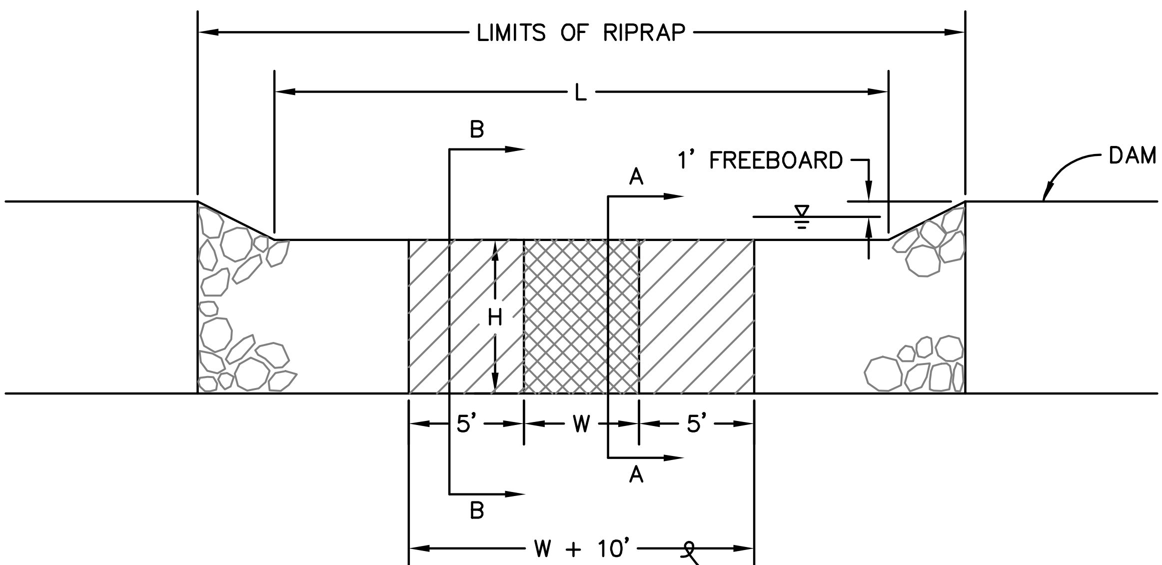
NOTE: FILL SANDBAGS WITH CHAT OR LIMESTONE SAND

CASE 2 – AFTER PAVEMENT AND INLETS COMPLETED

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	DIVERSION OF RUNOFF FOR CURBED STREET	ADOPTED: SS-40



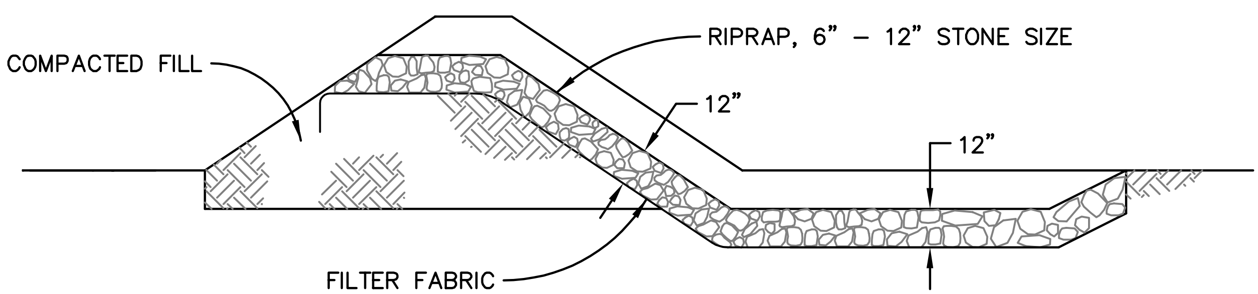
SECTION A – A (THRU GRAVEL FILTER)



L = LENGTH REQUIRED TO PASS Q_{10} WHILE MAINTAINING 1 FT. OF FREEBOARD

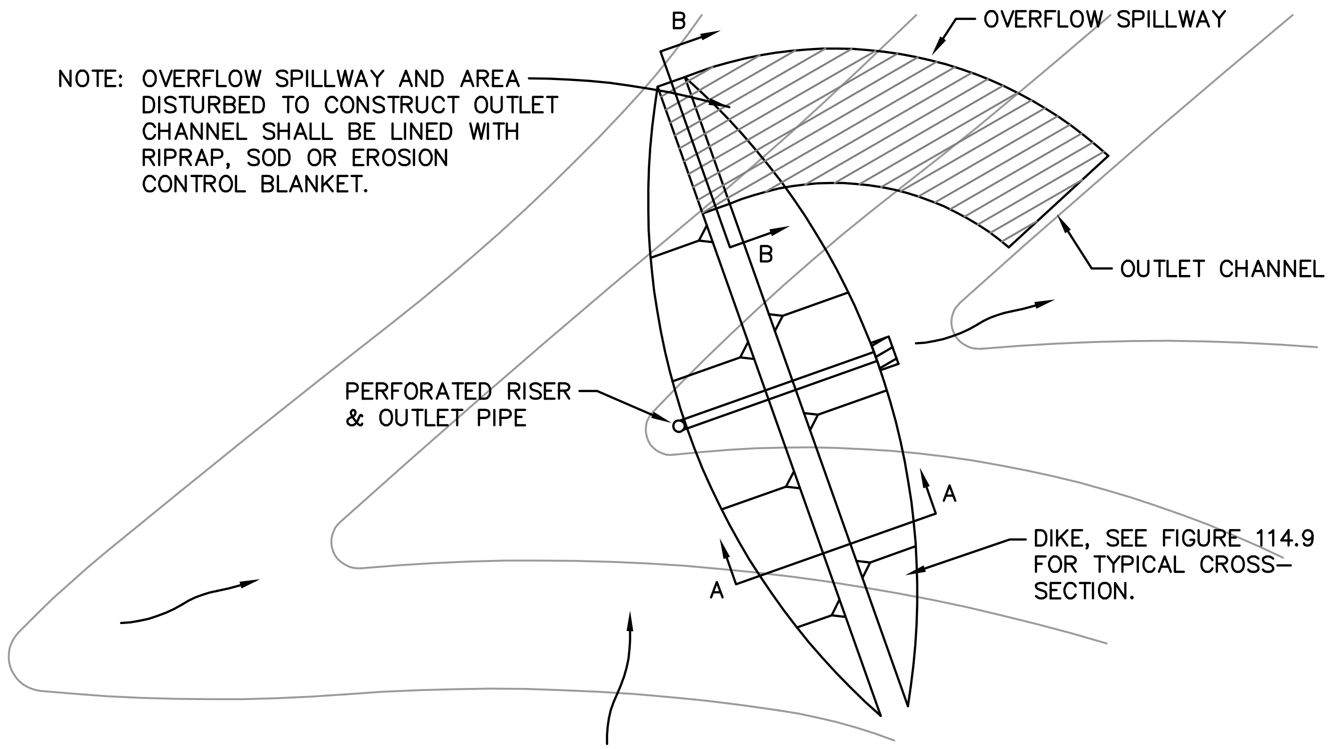
W = WIDTH OF ROCK FILTER AREA

	GRAVEL FILTER DAM	ADOPTED:
		SS-41



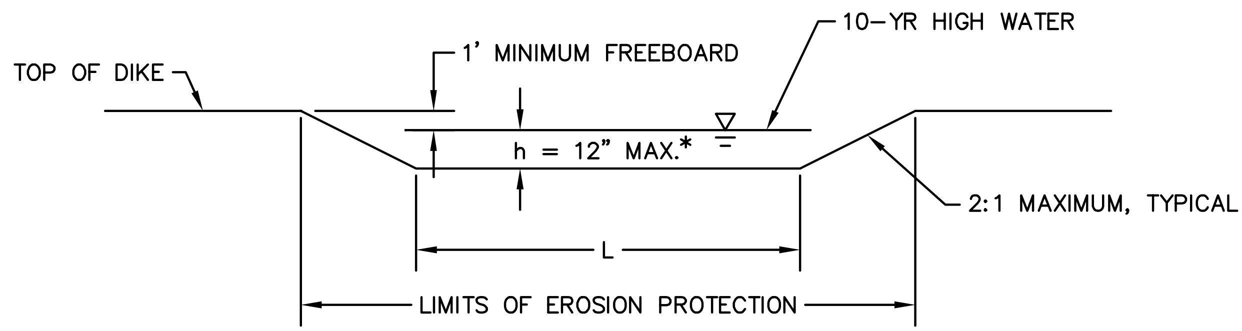
SECTION B – B

(FIGURE 1.7a)



TYPICAL COMPONENTS OF TEMPORARY SEDIMENT BASIN PLAN

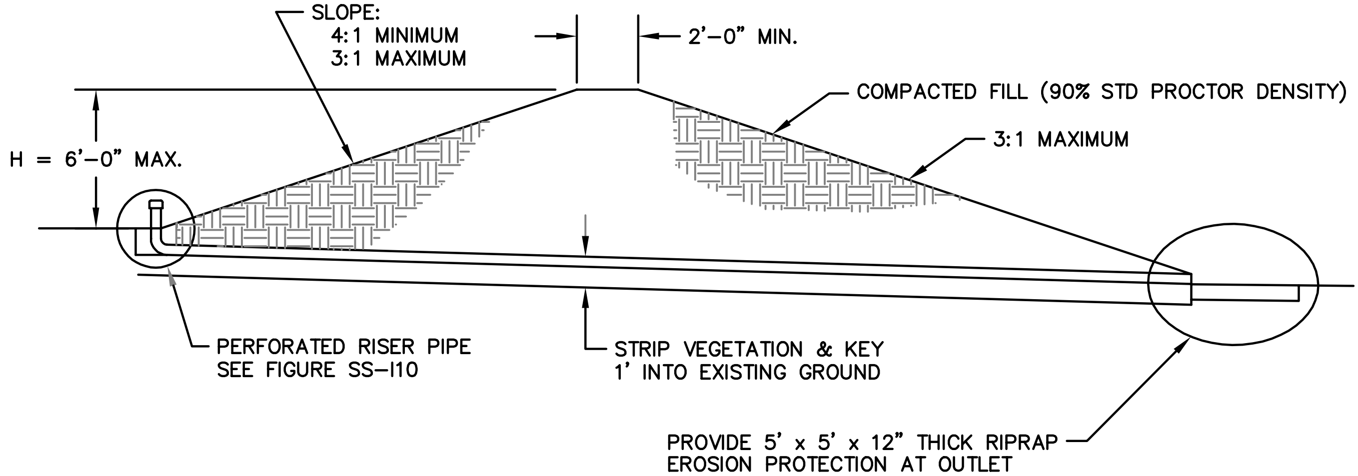
(PERFORATED RISER PIPE AND OVERFLOW SPILLWAY SHOWN. GRAVEL FILTER DAM AND RIPRAP OVERFLOW SPILLWAY AS SHOWN IN FIGURES 114.7A AND 114.7B MAY ALSO BE USED.)



*h = 6" MAX. IF SOD LINING USED

SECTION B -B
TYPICAL OVERFLOW SPILLWAY CROSS-SECTION

	TEMPORARY SEDIMENT BASIN	ADOPTED:
		SS-43



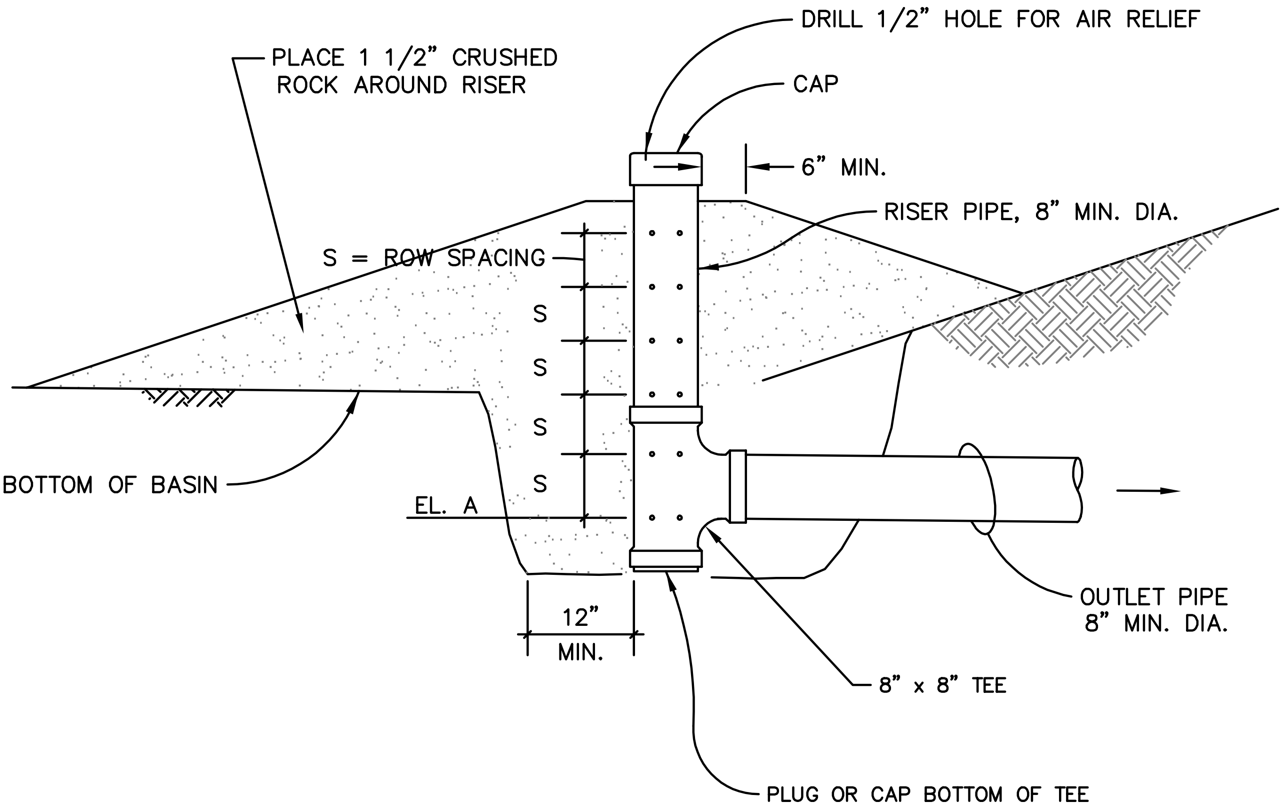
SECTION A – A

(FIGURE SS–I8)

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	TEMP SEDIMENT BASIN BERM & OUTLET	ADOPTED: SS-44

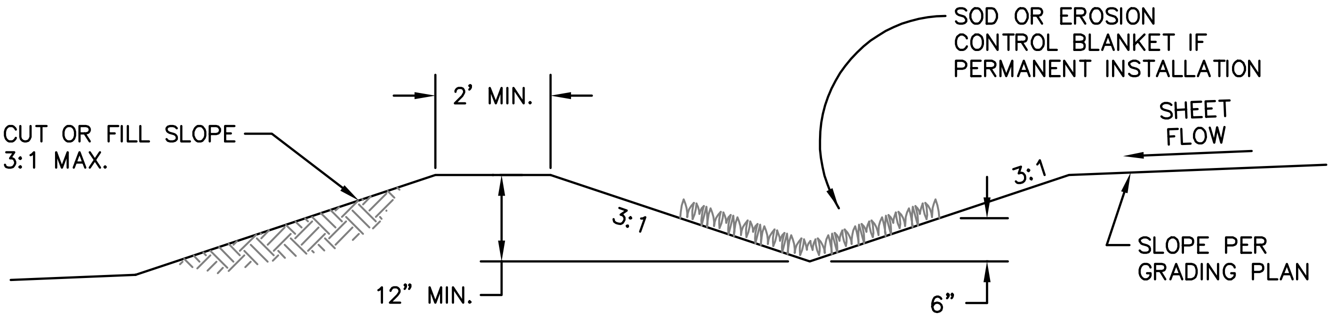
n = NUMBER OF HOLES PER ROW

d = HOLE DIAMETER

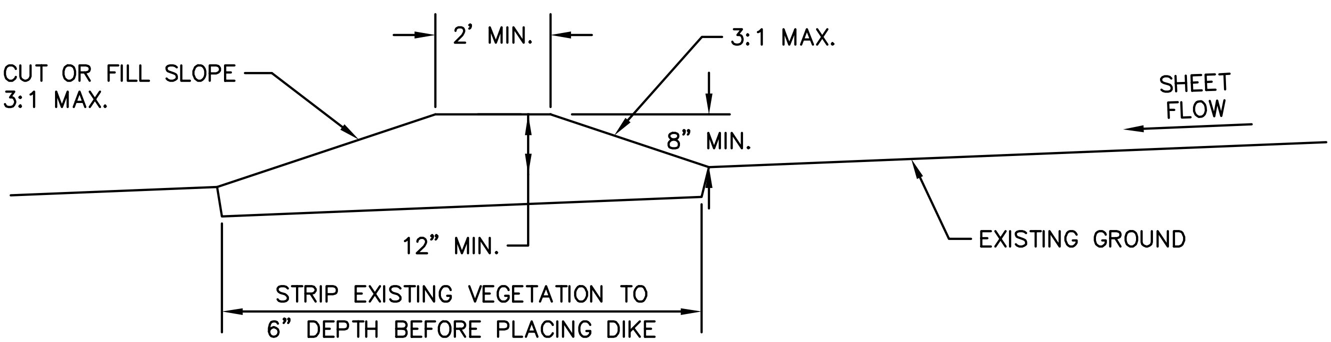


NOTE: BOTTOM ROW OF HOLES SHALL BE SET NO HIGHER THAN BOTTOM OF BASIN. ELEVATION OF BOTTOM ROW OF HOLES SHALL BE SET EQUAL TO INVERT ELEVATION OF OUTLET PIPE (EL. A). THIS ELEVATION MUST BE SPECIFIED ON THE DRAWING.

	TEMP SEDIMENT BASIN PERFORATED RISER PIPE	ADOPTED:
		SS-45



SWALE



DIKE

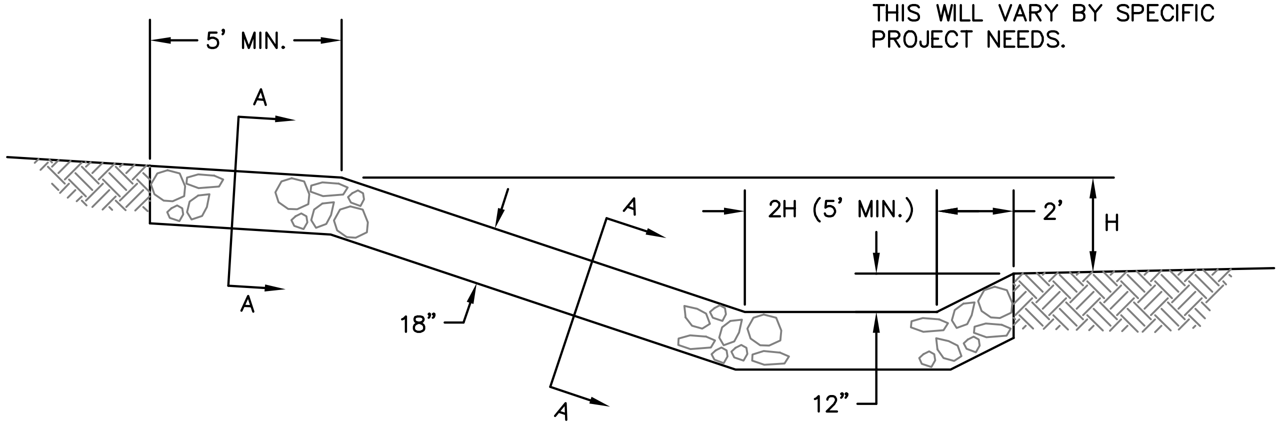
NOTES:

1. DIKE SHALL BE COMPACTED TO DENSITY EQUAL TO THAT SPECIFIED FOR ADJOINING AREA (90% STANDARD PROCTOR DENSITY, MINIMUM).
2. MINIMUM 1% GRADE MUST BE PROVIDED FOR SWALE OR ALONG UPSLOPE SIDE OF DIKE FOR PROPER DRAINAGE.

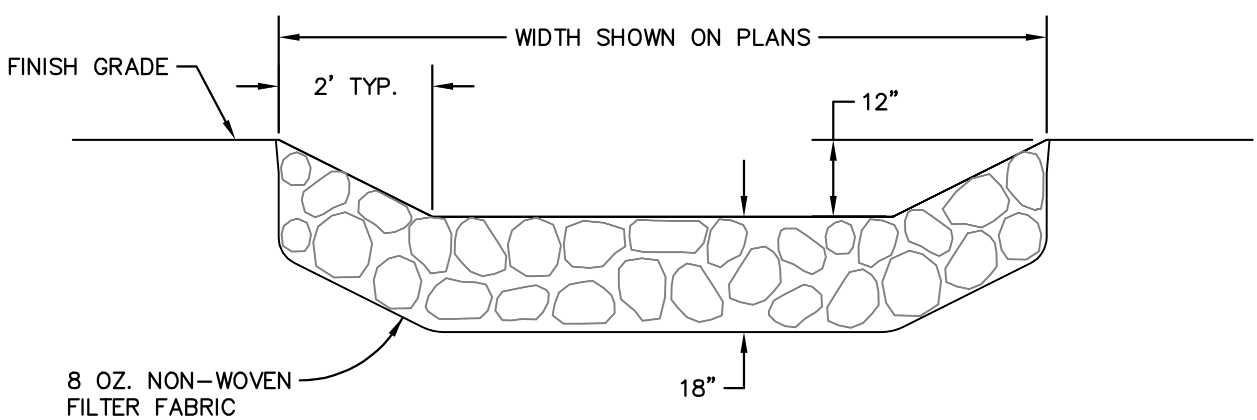
REFERENCE: Adapted from City of Austin & City of Tulsa Erosion and Sedimentation Control Manuals

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	DIVERSION DIKES & SWALES	ADOPTED: SS-46

PLANS TO SPECIFY WHETHER RIPRAP IS LOOSE OR GROUTED. THIS WILL VARY BY SPECIFIC PROJECT NEEDS.

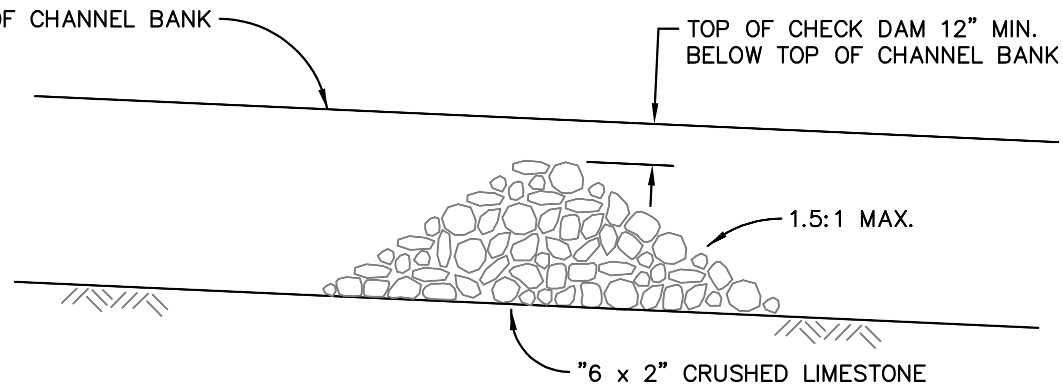


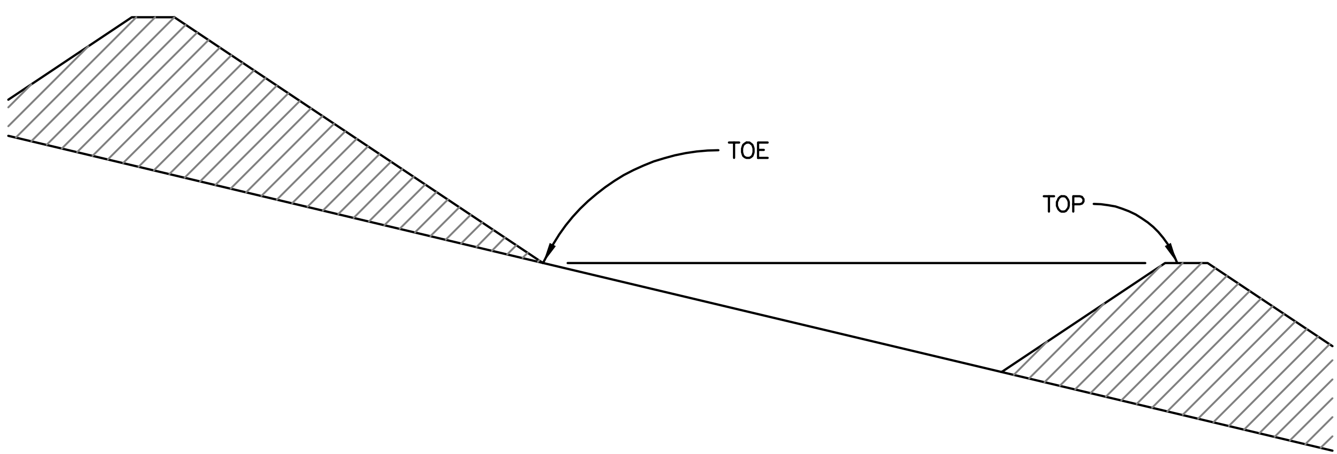
TYPICAL SECTION



SECTION A – A

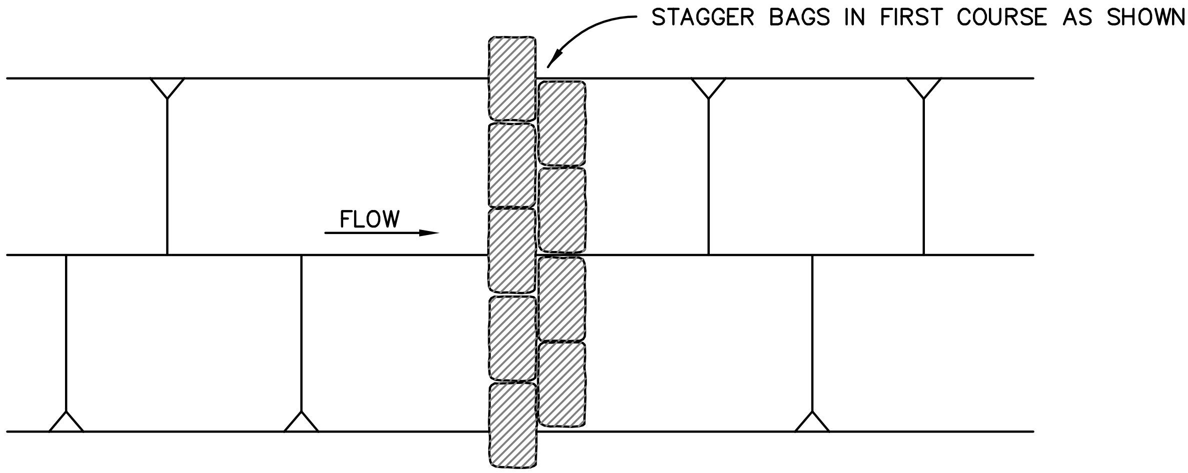
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	RIPRAP CHUTE CROSS–SECTION	ADOPTED: SS-47



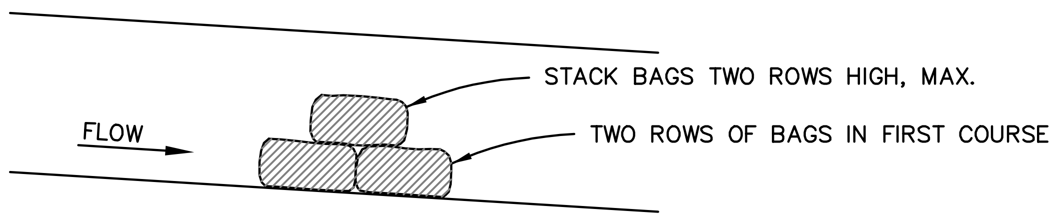


TYPICAL CHECK DAM SPACING

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	ROCK CHECK DAM	ADOPTED: SS-48



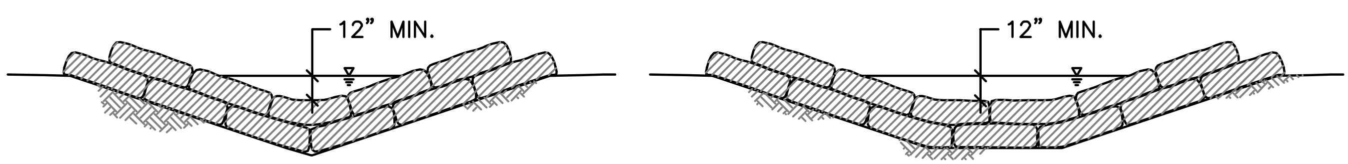
PLAN



PROFILE

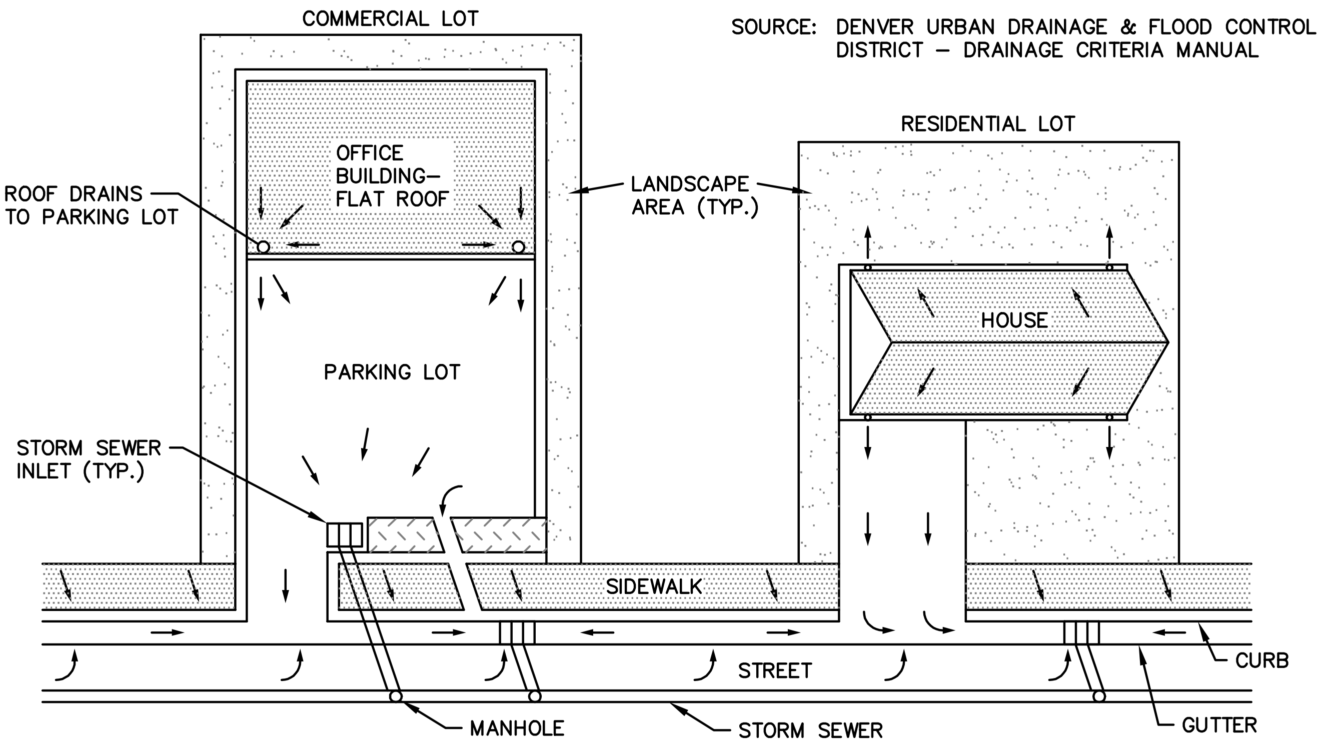
NOTES:

FILL BAGS WITH 5/8" TO 1 1/2" CRUSHED LIMESTONE.
BAGS MAY BE BURLAP OR WOVEN PLASTIC.
SPACE CHECK DAMS AS SHOWN IN FIG. SS-I13, OR AS SPECIFIED ON SEDIMENT & EROSION CONTROL PLAN.

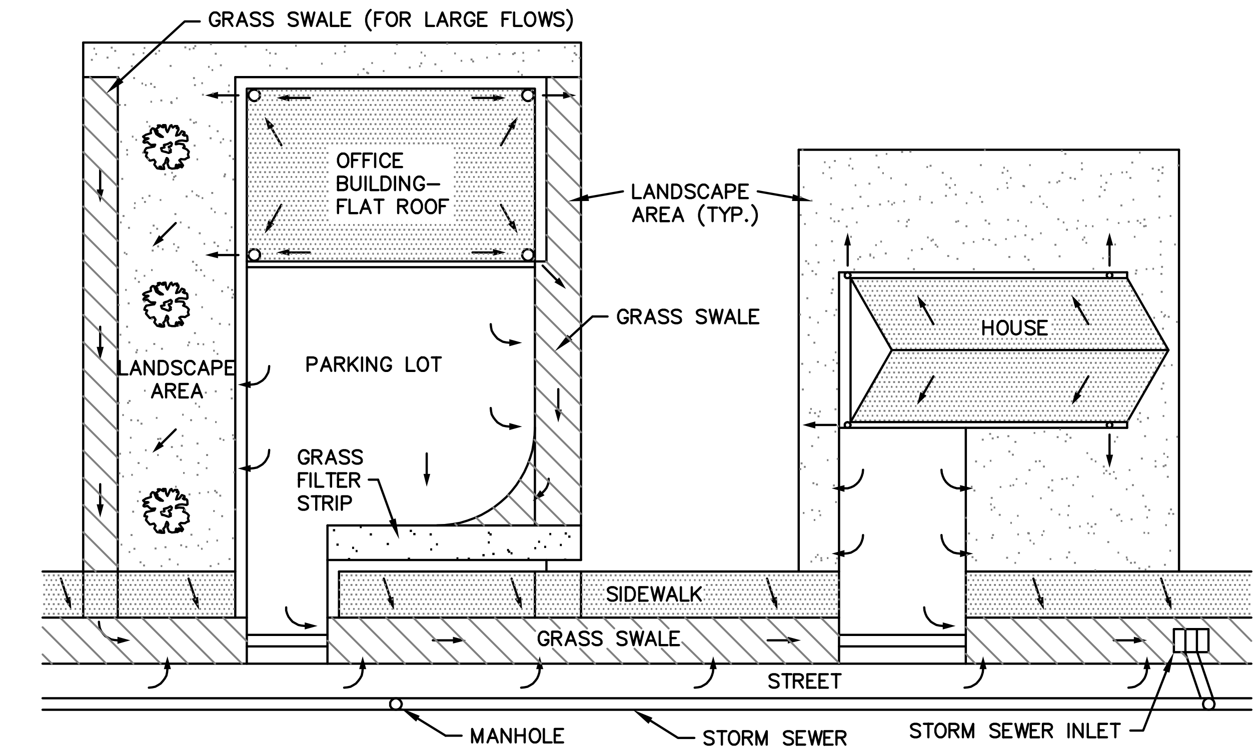


TYPICAL CROSS-SECTIONS

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	SANDBAG CHECK DAM	ADOPTED: SS-49

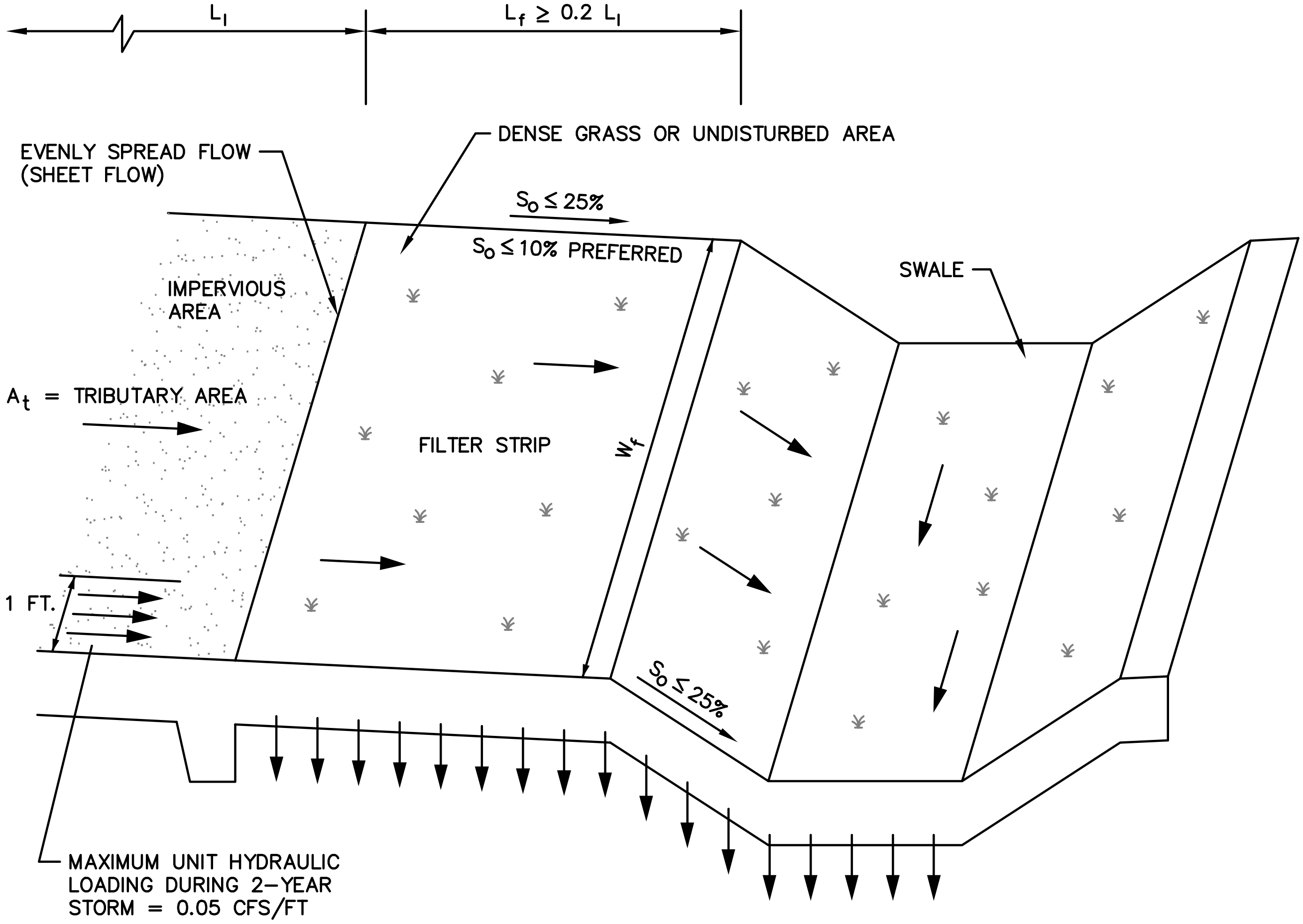


TRADITIONAL SITE & STREET DRAINAGE DESIGN



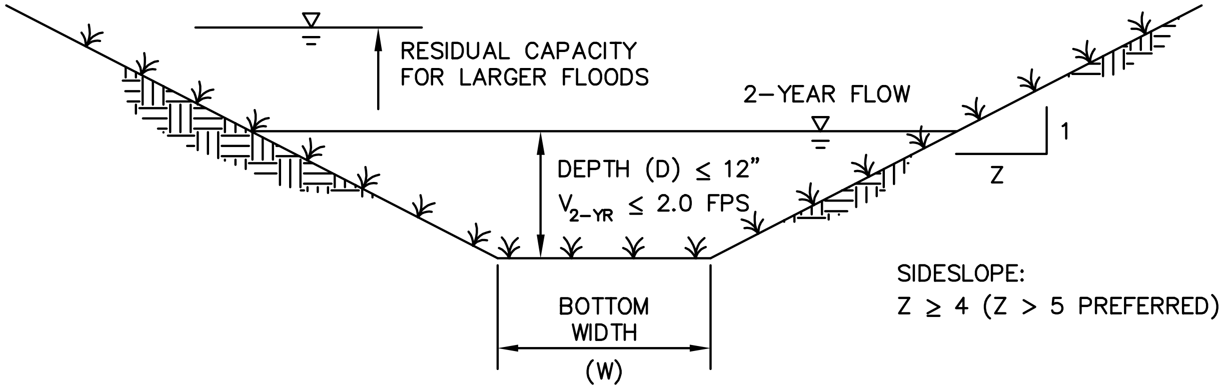
MINIMIZING DIRECTLY CONNECTED IMPERVIOUS AREAS

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	MINIMIZING DIRECTLY CONNECTED IMP AREAS	ADOPTED: SS-50

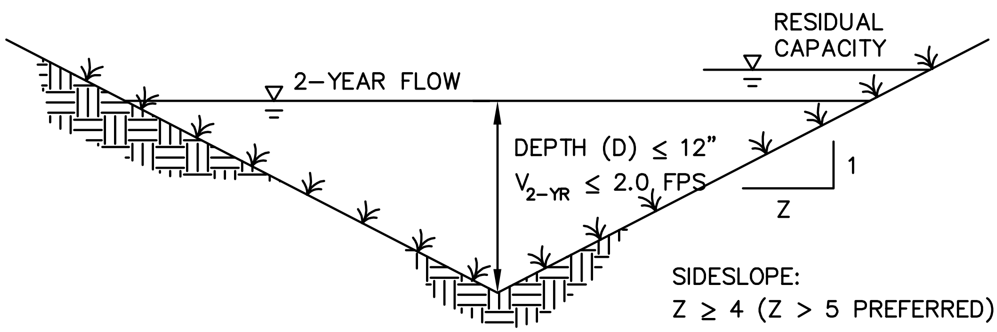


ADAPTED FROM DENVER URBAN DRAINAGE & FLOOD CONTROL DISTRICT – DRAINAGE CRITERIA MANUAL

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	VEGETATIVE FILTER STRIP WATER QUALITY BMP	ADOPTED: SS-51



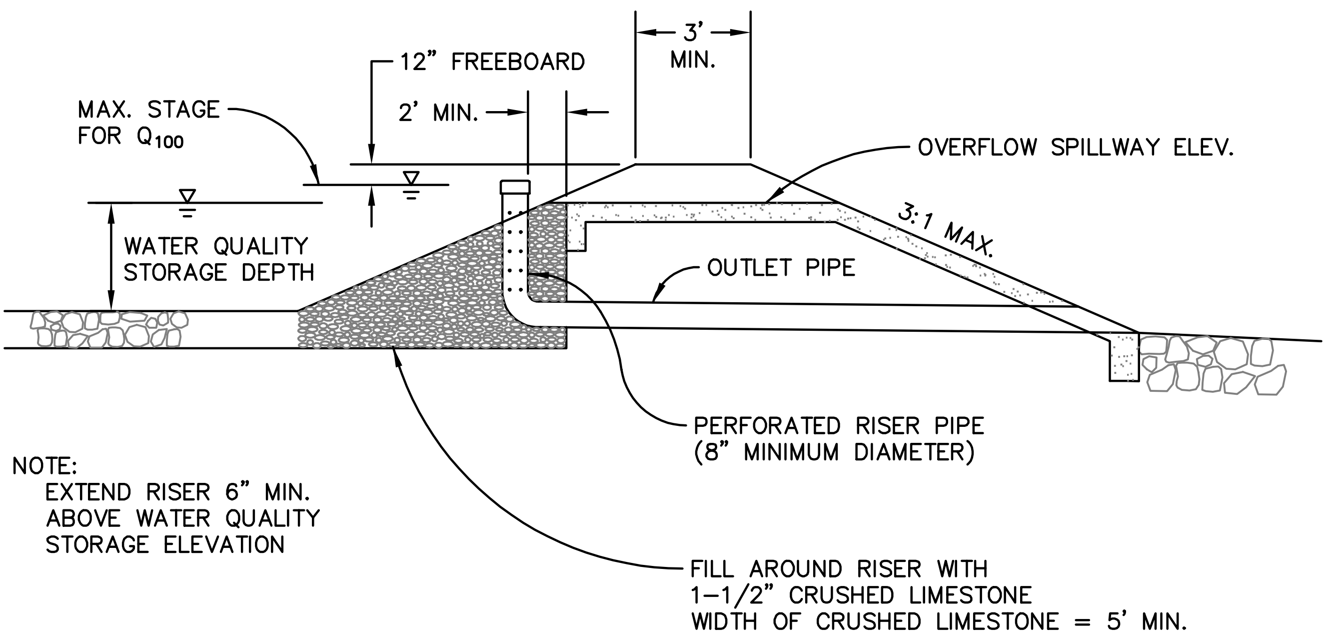
TRAPEZOIDAL GRASS–LINED SWALE SECTION



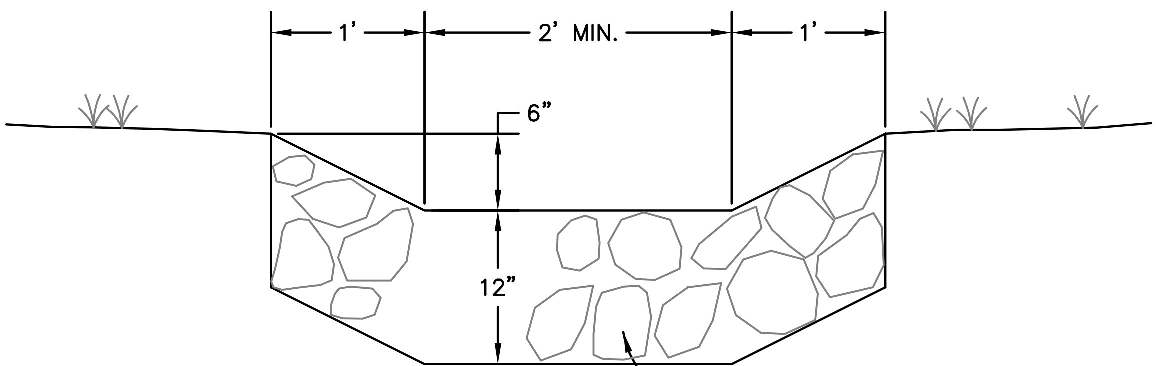
TRIANGULAR GRASS–LINED SWALE SECTION

ADAPTED FROM DENVER URBAN DRAINAGE & FLOOD CONTROL DISTRICT – DRAINAGE CRITERIA MANUAL

CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	GRASS SWALE WATER QUALITY BMP	ADOPTED: SS-52

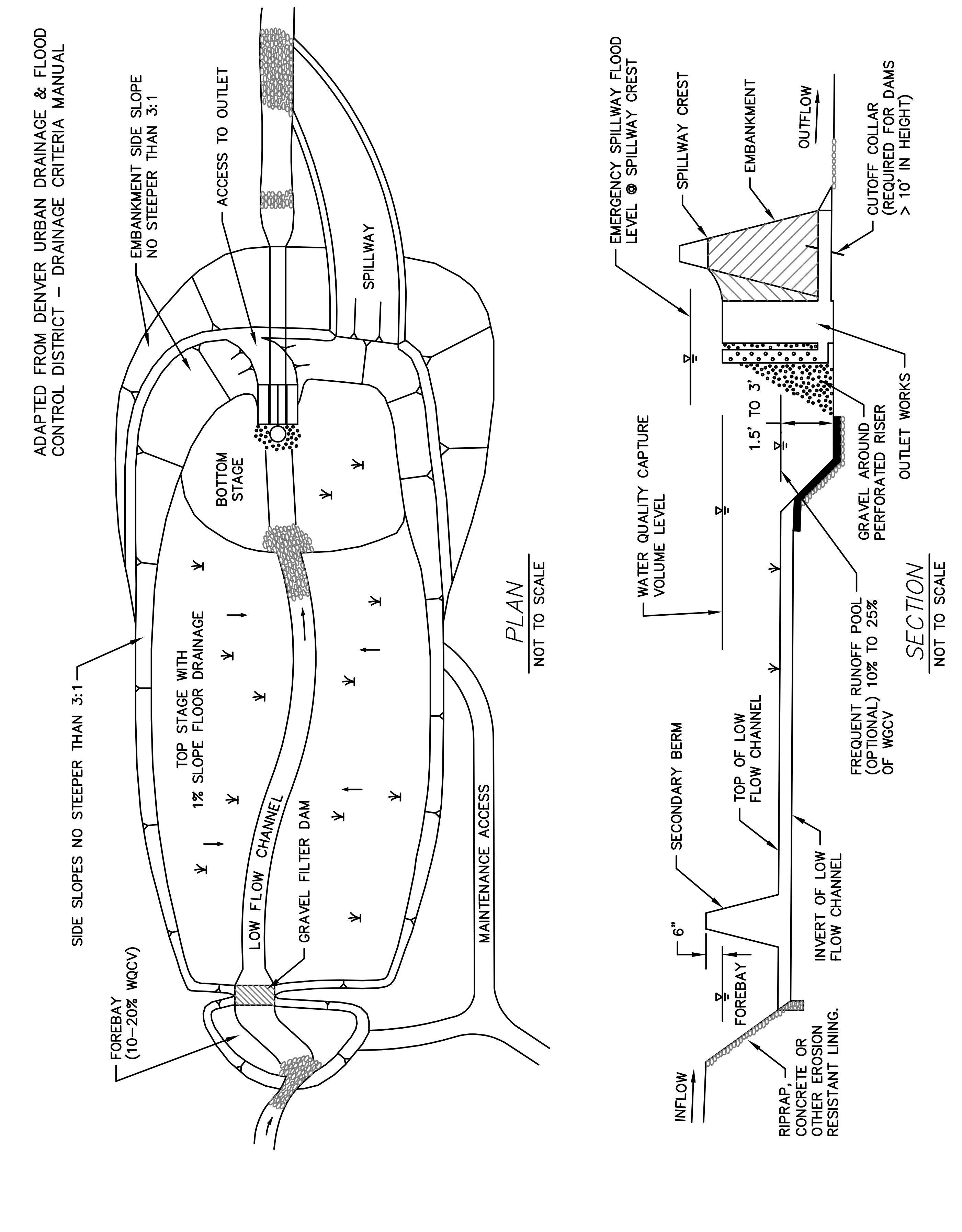


CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	EXT DRY DETENTION DAM & OUTLET	ADOPTED: SS-53

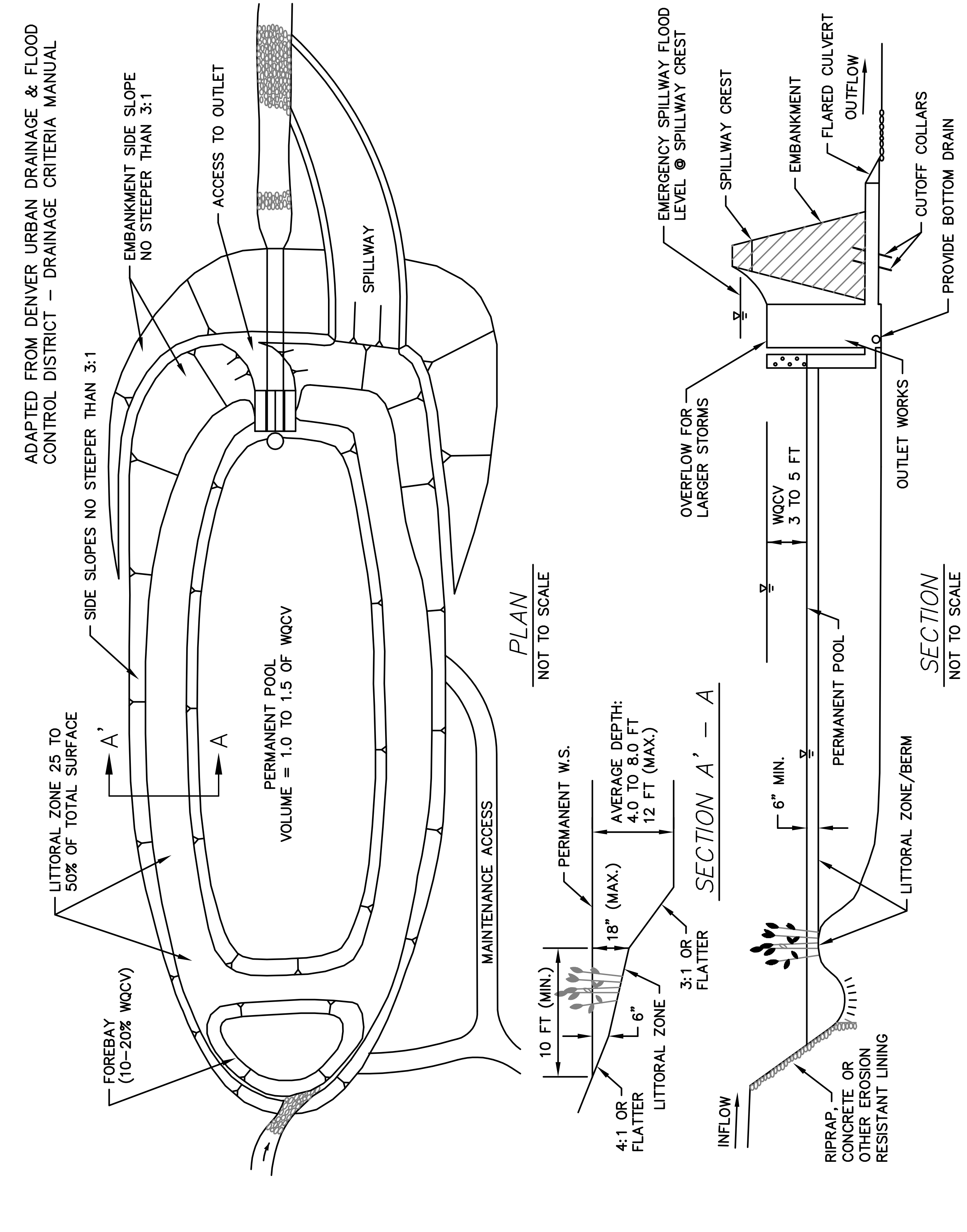


TRICKLE CHANNEL FOR EXTENDED DRY BASINS

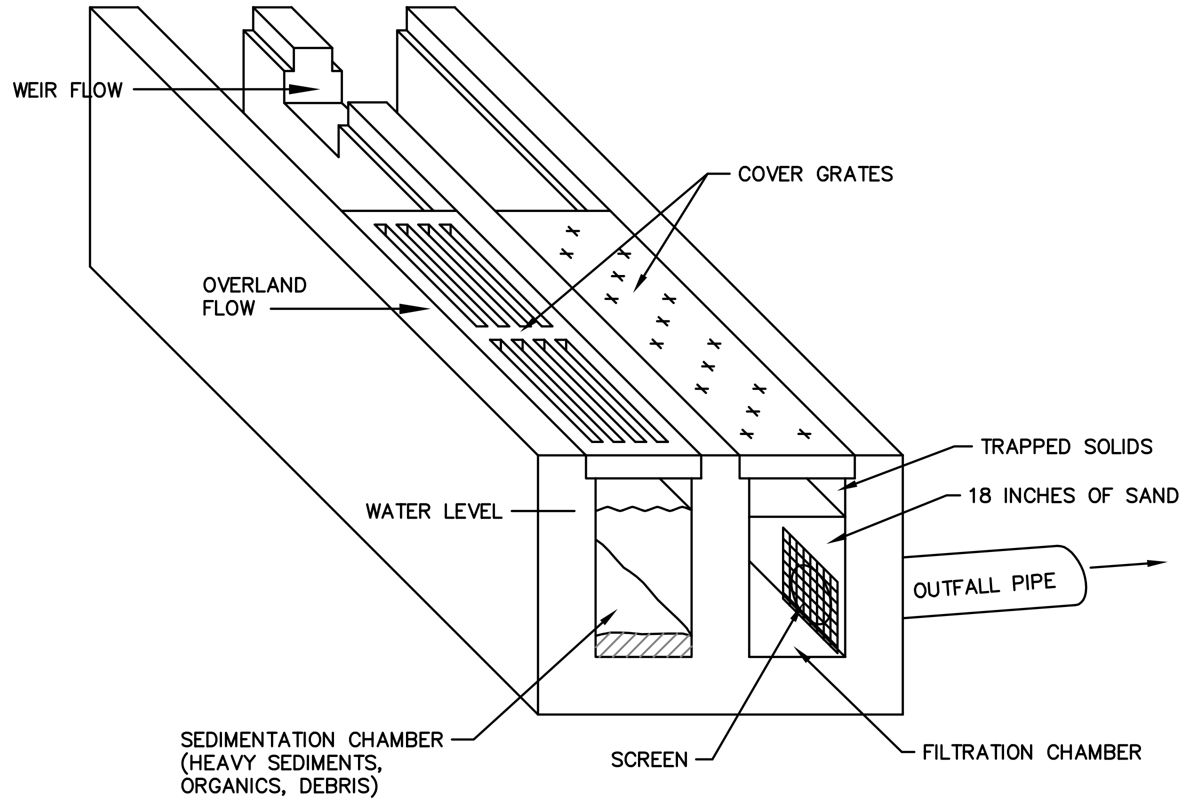
ADOPTED:

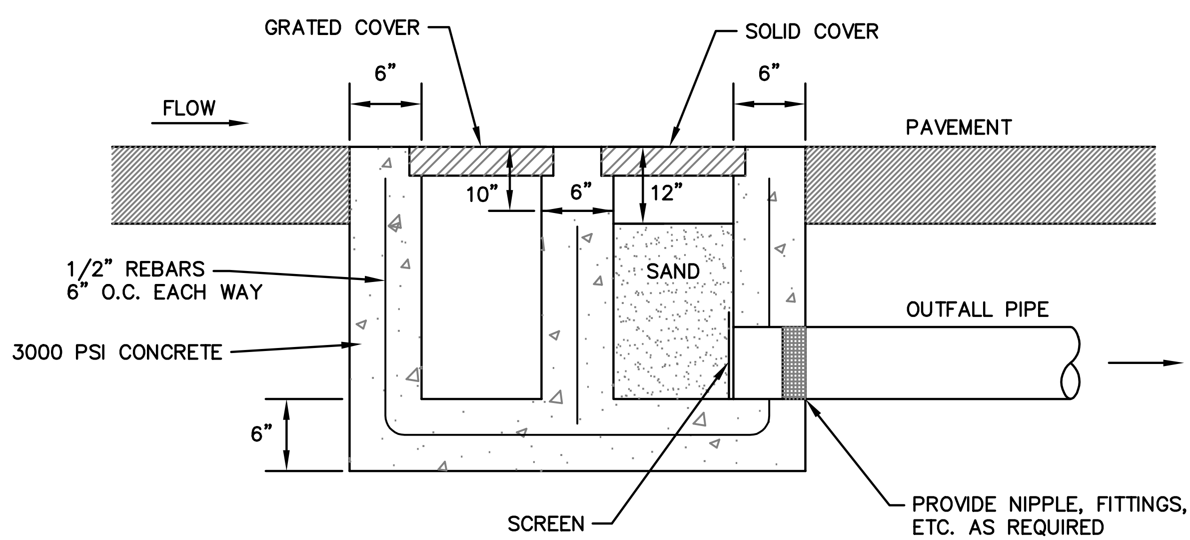


CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	SCHEMATIC PLAN OF A EXTD DRY DETENTION	ADOPTED: SS-55



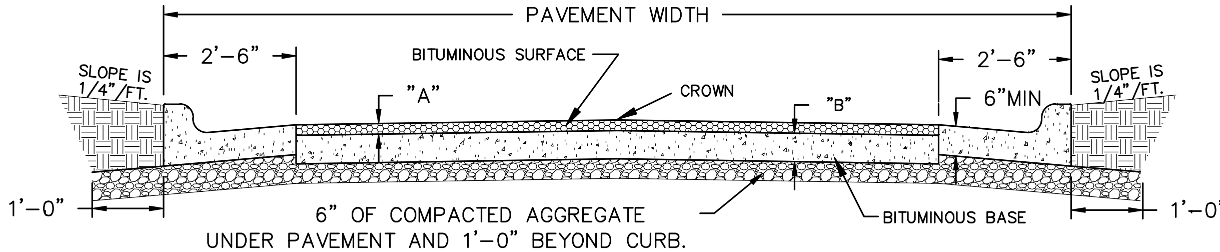
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	SCHEMATIC PLAN OF A EXTD WET DETENTION	ADOPTED: SS-56



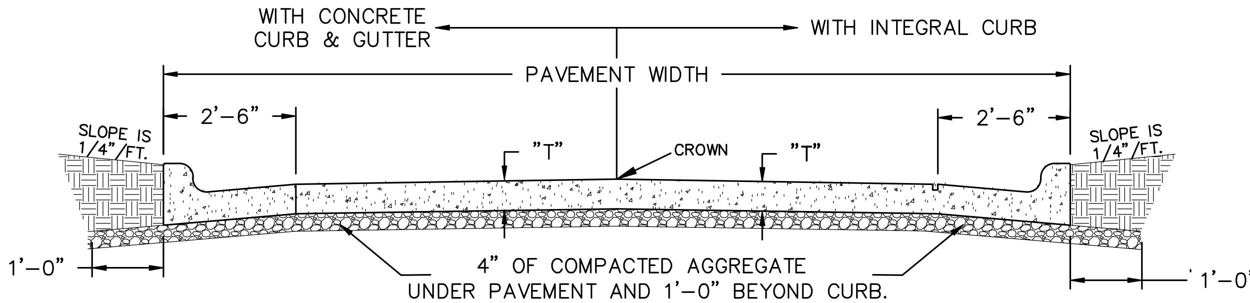


FROM: EPA 1992

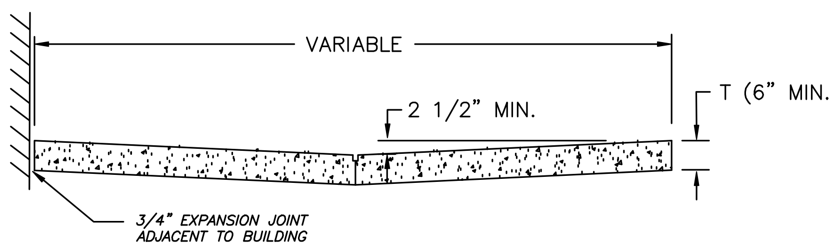
CITY OF BATTLEFIELD STANDARD DRAWINGS AND FIGURES	SAND FILTER SCHEMATIC	ADOPTED: SS-57



BITUMINOUS PAVEMENT WITH CONCRETE CURB & GUTTER



PORTLAND CEMENT CONCRETE PAVEMENT



TYPICAL ALLEY SECTION

NOTE: SEE ST–03 & ST–04 FOR JOINT DETAILS

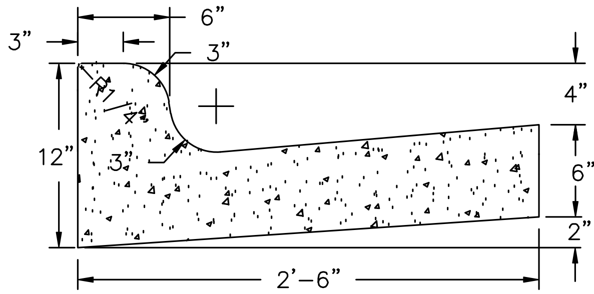
STANDARD PAVEMENT WIDTH AND THICKNESS			
STREET TYPE	"T"	"A"	"B"
ALLEY/LOCAL	6"	2"	5"
COLLECTOR	6"	2"	6"
ARTERIAL	8"	2"	9"

NOTES: CROSS SLOPE SHALL BE 1/4"/FT. ON ALL PAVEMENTS EXCEPT ALLEYS,

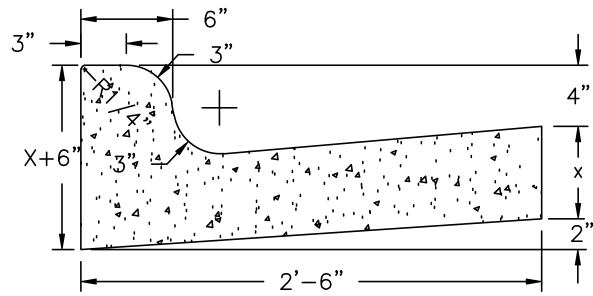
WIDTH OF PAVEMENT IS SUBJECT TO REQUIREMENTS OF THE PLANNING DEPARTMENT AND MAY VARY FROM THE STANDARDS.

TO CREATE A GUTTER SECTION THE CONTRACTOR SHALL FORM A 2" RISE 2' FROM THE INSIDE OF THE CURB. PAVEMENT WIDTH WILL BE MEASURED FROM BACK OF CURBS ON IMPROVED STREETS. PAVEMENT CROWN SHOULD BE CENTERED IN RIGHT OF WAY.

CITY OF BATTLEFIELD, MO	TYPICAL STREET SECTIONS	ADOPTED: XX/XX/2023
		ST–1

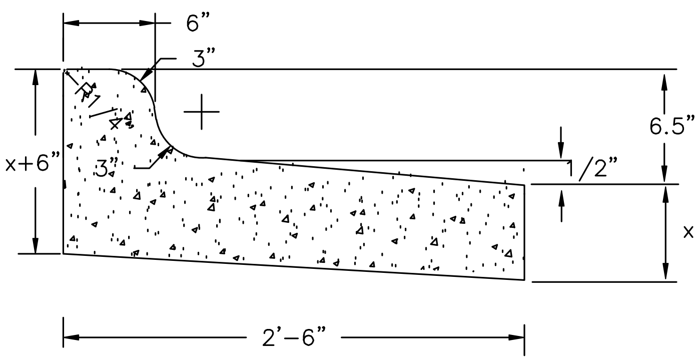


ALLEYS AND LOCAL STREETS



COLLECTOR, 2ND ARTERIAL & HIGHER
X TO MATCH PAVEMENT THICKNESS;
8" MAX FOR ASPHALT PAVEMENT

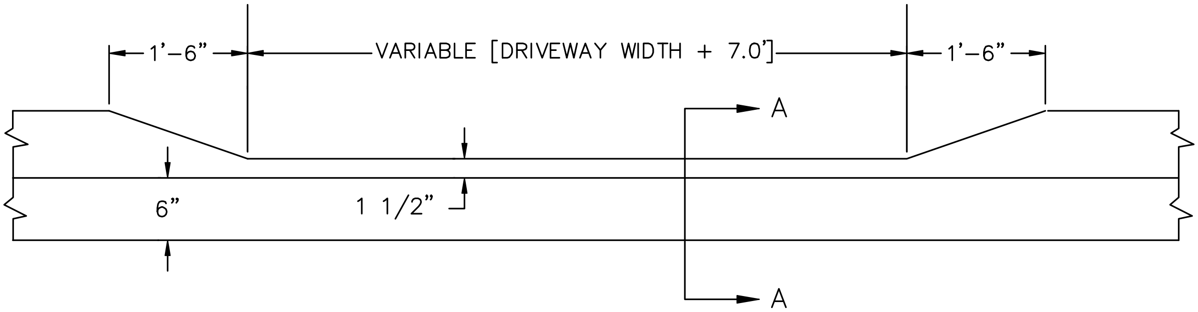
NOTE: #5 REBAR @ 2'6" O.C. TO BE USED ON ALL CONCRETE PAVEMENT. WHEN CONCRETE PAVEMENT IS 8" OR MORE A KEYWAY MAY BE USED IN PLACE OF REBAR. ASPHALT PAVEMENT – DOWELL AND KEYWAY SHALL BE OMITTED.

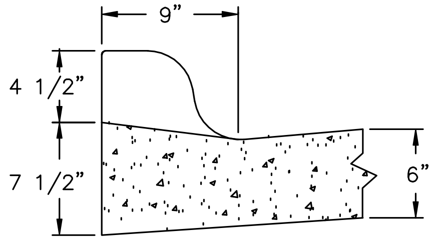


NOTE: TRANSITION LENGTH FOR SPILL CURB SHOULD BE A MINIMUM OF 5'

SPILL CURB

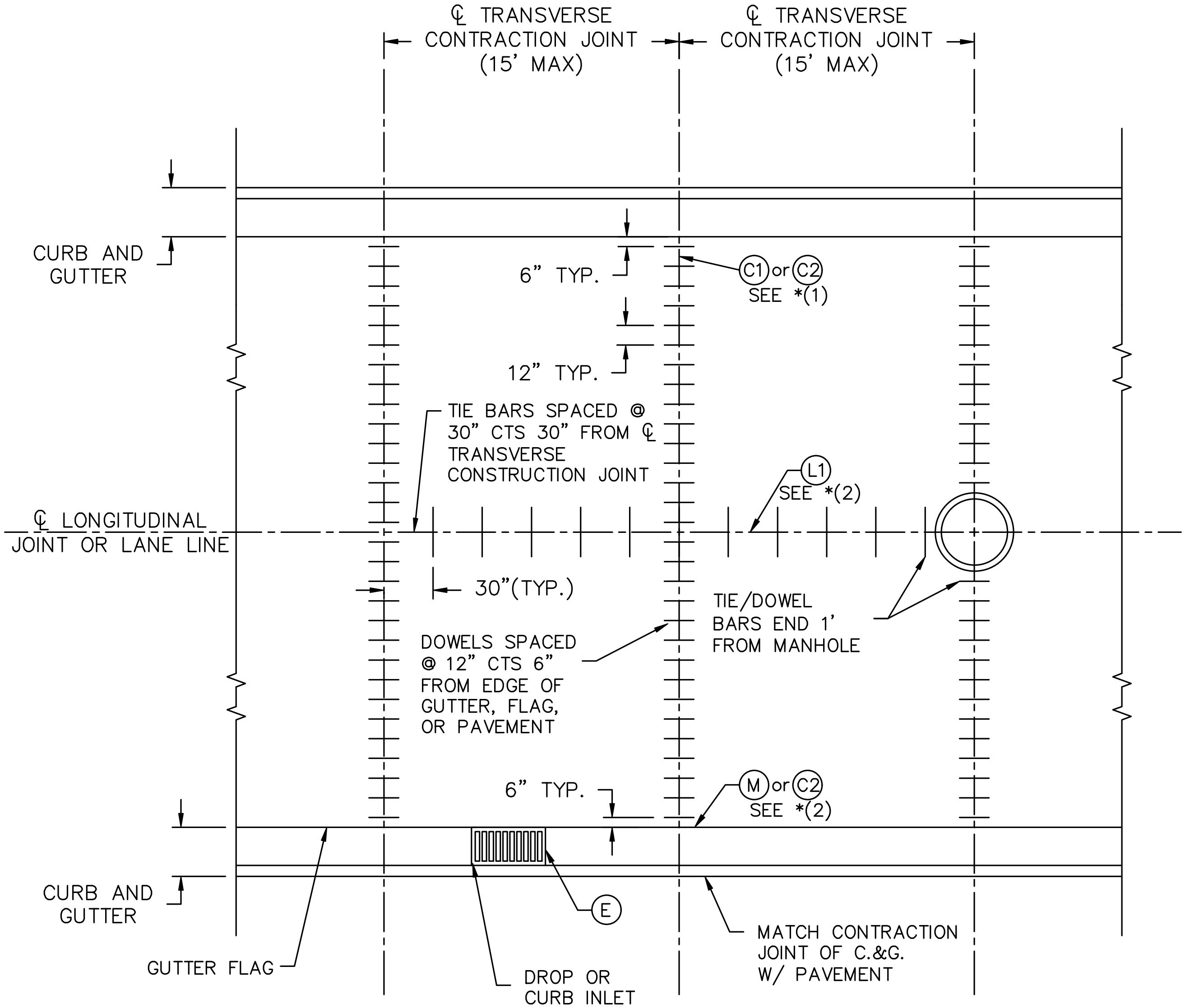
STANDARD RESIDENTIAL DRIVEWAY OPENING





SECTION A–A

CITY OF BATTLEFIELD, MO	CURB & GUTTER / DRIVEWAY OPENING	ADOPTED: XX/XX/2023
		ST–2



NOTES:

TRANSVERSE JOINTS

*(1) – C1 JOINT WITH DOWELS REQUIRED ON ALL PAVEMENTS 7" OR GREATER IN THICKNESS AND AT HEADER LOCATIONS DURING CONSTRUCTION
C2 JOINT REQUIRED ON ALL PAVEMENTS LESS THAN 7" IN THICKNESS

LONGITUDINAL JOINTS

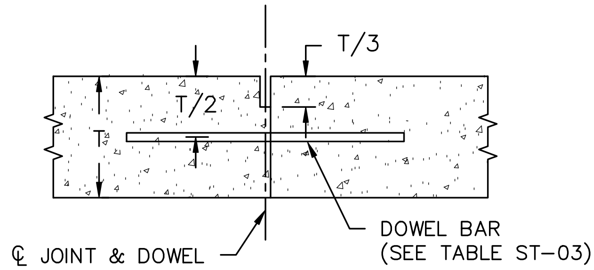
*(2) – L1 JOINT REQUIRED ON ALL PAVEMENTS AT ℄ JOINT OR LANE LINES FOR MULTIPLE LANE CONSTRUCTION
M JOINT REQUIRED ON ALL JOINTS FOR GUTTER FLAG/EDGE OF PAVEMENT LONGITUDINAL JOINT
L1 JOINT MAY BE USED IN LIEU OF M JOINT AND SHALL BE USED FOR ALL REHAB WORK WHERE CURB AND GUTTER IS REPLACED
C2 JOINT SHALL BE USED FOR ALL INTEGRAL CURBS AT PROJECTED GUTTER FLAG LONGITUDINAL JOINT

SEE ST–4 FOR JOINT DETAILS

TIE BAR AND DOWEL TABLE

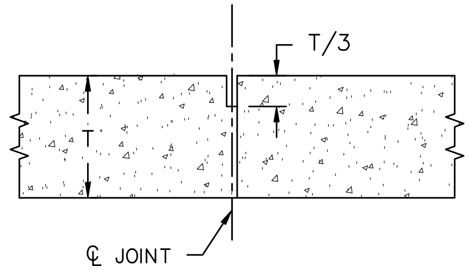
PCCP (T) THICKNESS	DOWEL SIZE	TIE BAR SIZE	DOWEL SPACING	TIE BAR SPACING
LESS THAN 7"	NONE	#5X30"	NONE	30" CTR–CTR
7" TO 10"	1 1/4"X18"	#5X30"	12" CTR–CTR	30" CTR–CTR

CITY OF BATTLEFIELD, MO	JOINT LOCATION – CONCRETE PAVEMENT	ADOPTED: XX/XX/2023 ST–3

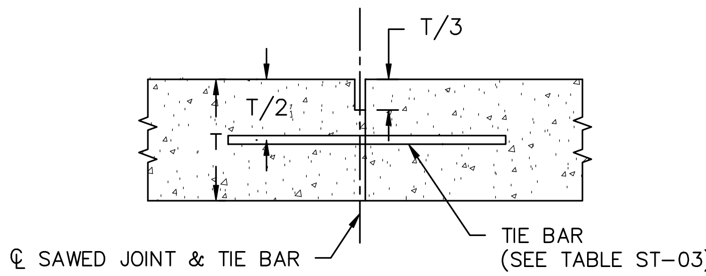


TRANSVERSE CONTRACTION JOINT C1

NOTES:
- TRANSVERSE CONTRACTION JOINTS FOR CONCRETE PAVEMENT OR BASE WIDENING SHALL MATCH EXISTING JOINTS.
- FOR PAVEMENTS HAVING THICKNESS IN $\frac{1}{2}$" INCREMENTS, DOWEL BASKETS SHALL BE T/2" – $\frac{1}{2}$".

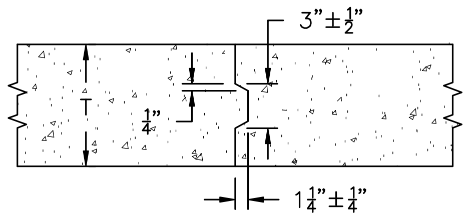


CONTRACTION JOINT C2



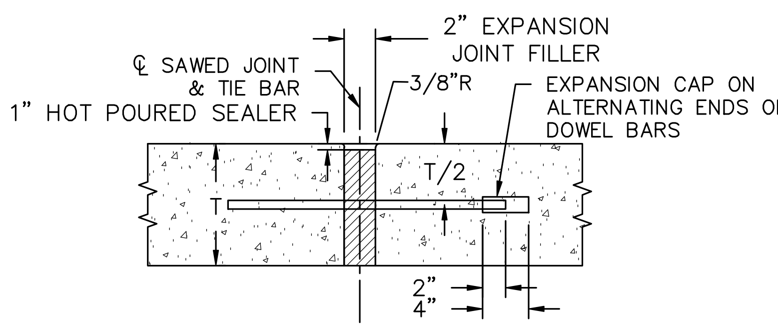
LONGITUDINAL JOINT L1

NOTES:
- IF PLACED AS COLD JOINT (NEW OR EXISTING PAVEMENT) NO SAWING IS REQUIRED.
- FOR DRILLING CONNECTION CONNECTION TO EXISTING PAVEMENT, DIA. OF HOLE SHALL BE TIE BAR + $\frac{1}{8}$"



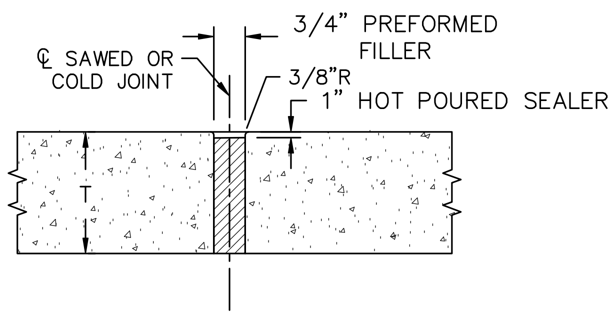
TONGUE AND GROOVE JOINT M

NOTES:
- IF METAL IS USED TO FORM KEY DISCONTINUE STRIP FOR DISTANCE OF APPROX. 3" EACH SIDE OF THE TRANSVERSE JOINT.
- JOINT SHALL NOT BE SAWED.



EXPANSION JOINT F

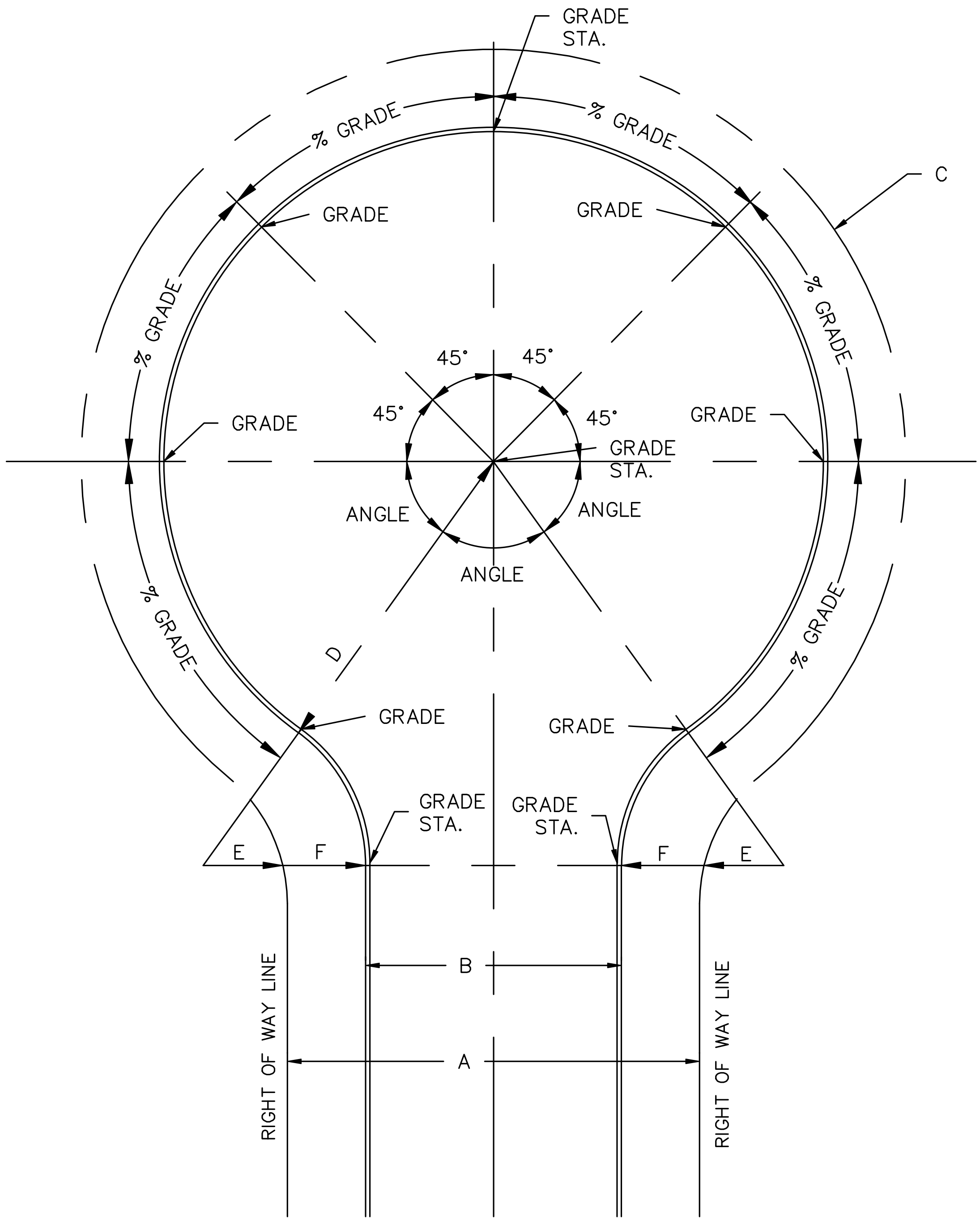
DOWELED EXPANSION JOINT
18" DOWEL BAR AT 12" O.C.



EXPANSION JOINT E

GENERAL NOTES:
- TIE BARS SHALL BE EPOXY COATED. DEFORMED REINFORCING BARS MEETING THE REQUIREMENTS OF THE SPECIFICATIONS.
- BONDING FOR TIE BARS SHALL BE EPOXY BONDING AGENTS AS SPECIFIED.
- TIE BAR SIZE AND LENGTH SHALL BE BASED ON THE THICKNESS OF THE THINNER PAVEMENT TO BE TIED TOGETHER.

CITY OF BATTLEFIELD, MO	JOINT DETAILS – CONCRETE PAVEMENT	ADOPTED: XX/XX/2023
		ST-4



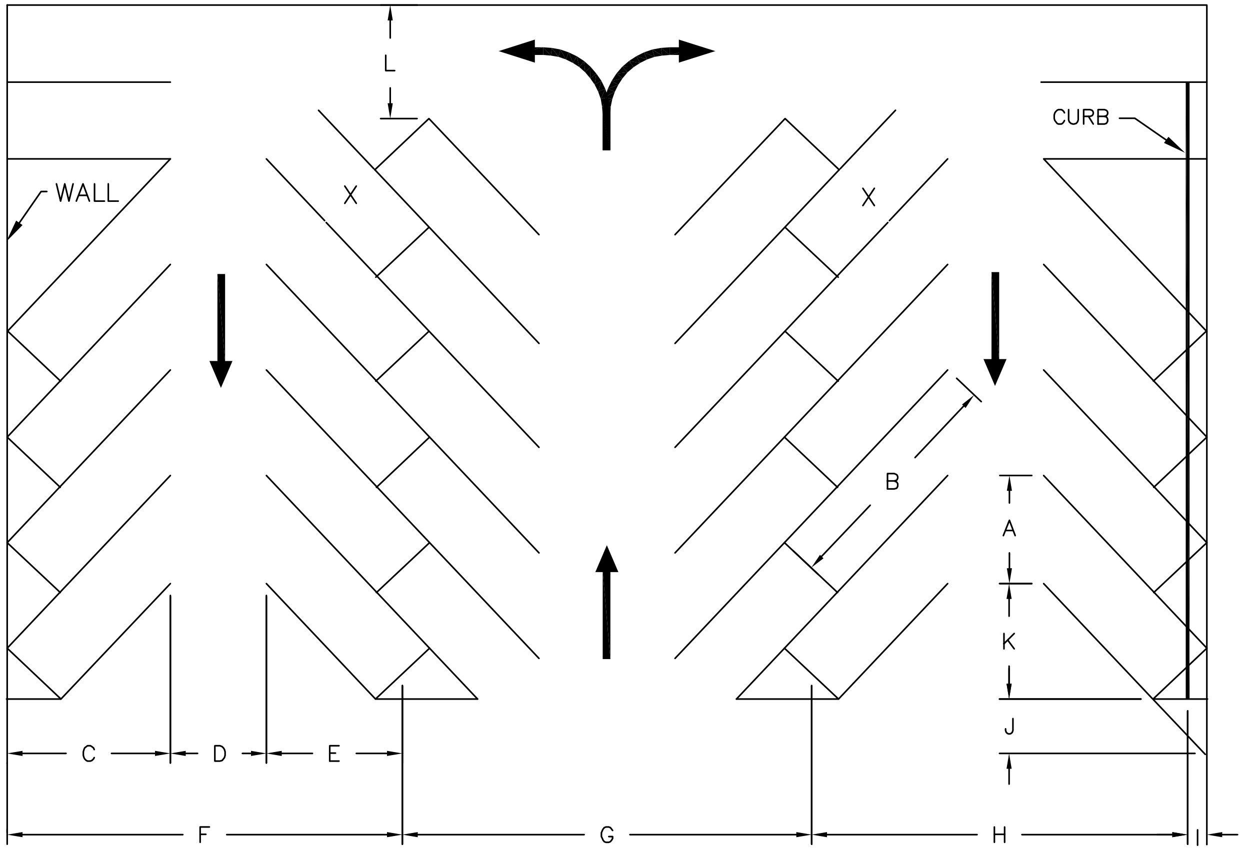
MINIMUM DIMENSIONS (FEET)			
DESCRIPTION	**KEY**	**STANDARD**	**INDUSTRIAL**
STREET RIGHT-OF-WAY WIDTH	A	50	60
STREET PAVEMENT WIDTH TO BACK OF CURB	B	27	37
CUL-DE-SAC RIGHT-OF-WAY RADIUS	C	60	75
CUL-DE-SAC PAVEMENT RADIUS TO BACK OF CURB	D	48.5	63.5
INTERNAL CURVE, RIGHT-OF-WAY RADIUS	E	20	20
INTERNAL CURVE, BACK OF CURB RADIUS	F	31.5	31.5

NOTE: MAXIMUM LENGTH OF CUL-DE-SAC SHALL BE 800 FEET.

CITY OF BATTLEFIELD, MO	STANDARD CUL-DE-SAC	ADOPTED: XX/XX/2023 ST-5

MINIMUM REQUIREMENTS FOR LAYOUT ELEMENTS

X DENOTES THAT STALL NOT ACCESSIBLE IN CERTAIN LAYOUTS

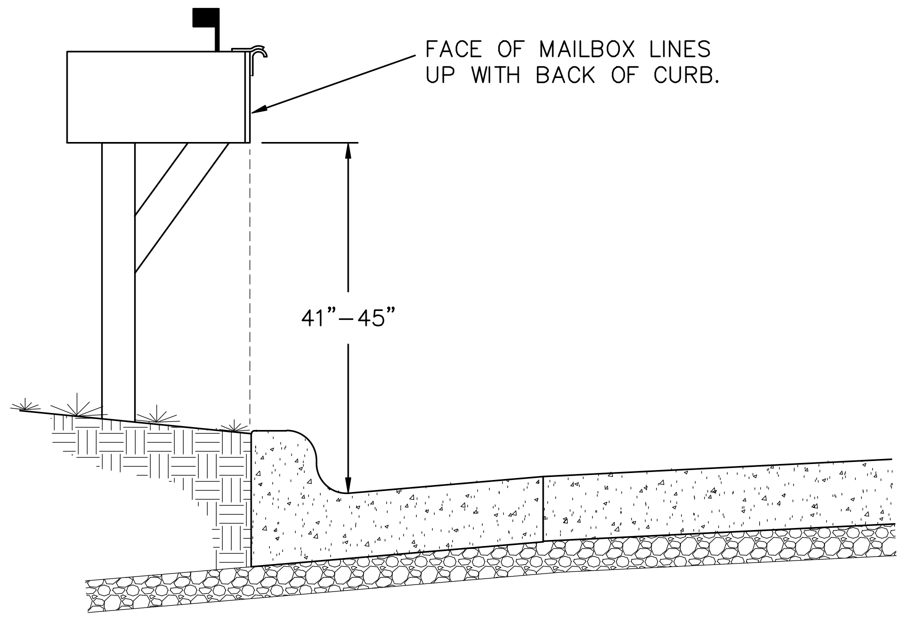


PARKING LAYOUT DIMENSIONS (IN FEET) FOR 9 FT. STALLS AT VARIOUS ANGLES

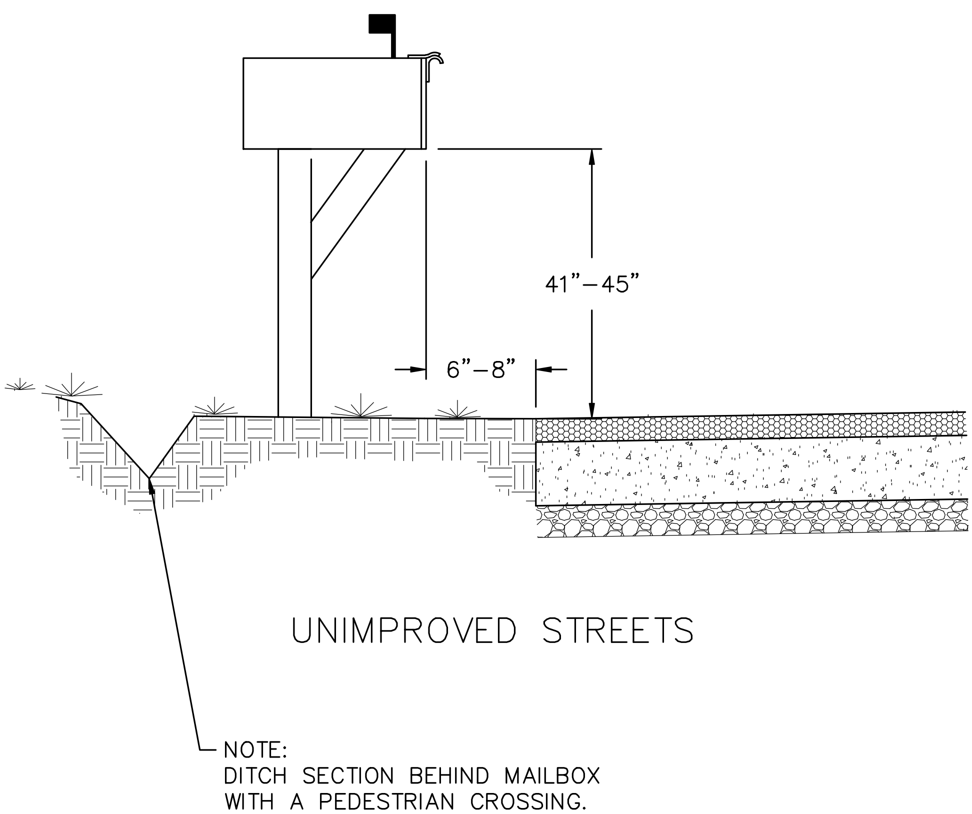
DIMENSION	SYMBOL	90°	75°	60°	45°	30°
STALL WIDTH, PARALLEL TO AISLE	A	9.0	9.3	10.4	12.7	18.0
STALL LENGTH OF LINE	B	18.5	20.0	22.0	25.0	34.1
STALL DEPTH TO WALL	C	18.5	19.5	19.0	17.5	17.1
AISLE WIDTH BETWEEN STALL LINES	D	26.0	23.0	16.0	12.0	10.0
STALL DEPTH, INTERLOCK	E	18.5	18.8	17.5	15.3	13.2
MODULE, WALL TO INTERLOCK	F	63.0	61.3	52.5	44.8	40.3
MODULE, INTERLOCKING	G	63.0	61.0	51.0	42.6	36.4
MODULE, INTERLOCK TO CURB FACE	H	60.5	58.8	50.2	42.8	38.8
BUMPER OVERHANG (TYPICAL)	I	2.5	2.5	2.3	2.0	1.5
OFFSET	J	0.0	0.5	2.7	6.3	13.5
SETBACK	K	0.0	5.0	8.3	11.0	16.0
CROSS AISLE, ONE-WAY	L	14.0	14.0	14.0	14.0	14.0
CROSS AISLE, TWO-WAY	–	24.0	24.0	24.0	24.0	24.0

NOTE: ANY PARKING LAYOUT OTHER THAN SHOWN MUST BE APPROVED BY THE CITY BUILDING INSPECTOR.

CITY OF BATTLEFIELD, MO	PARKING STALL LAYOUT ELEMENTS	ADOPTED: XX/XX/2023
		ST-6

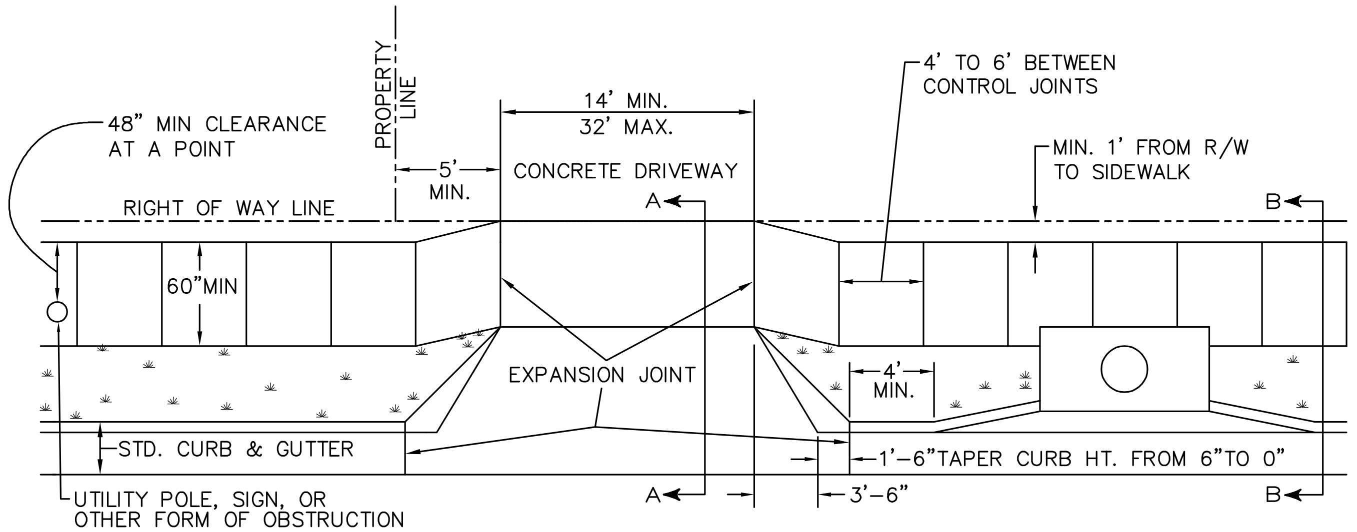


IMPROVED STREETS



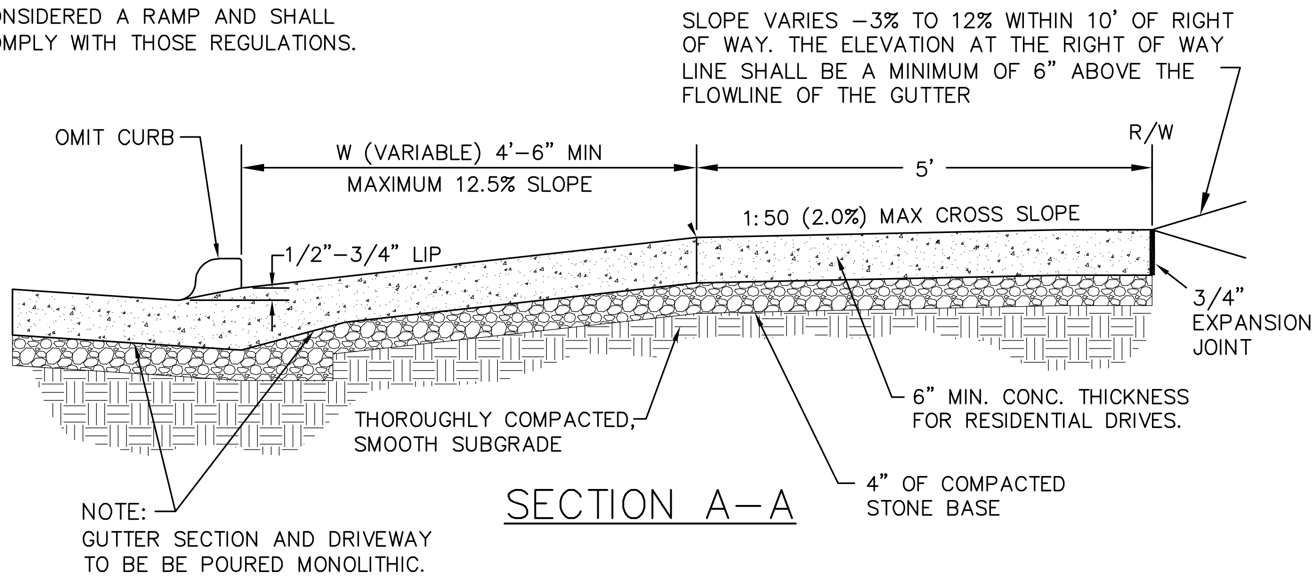
UNIMPROVED STREETS

CITY OF BATTLEFIELD, MO	MAILBOX REPLACEMENT	ADOPTED: XX/XX/2023
		ST–7

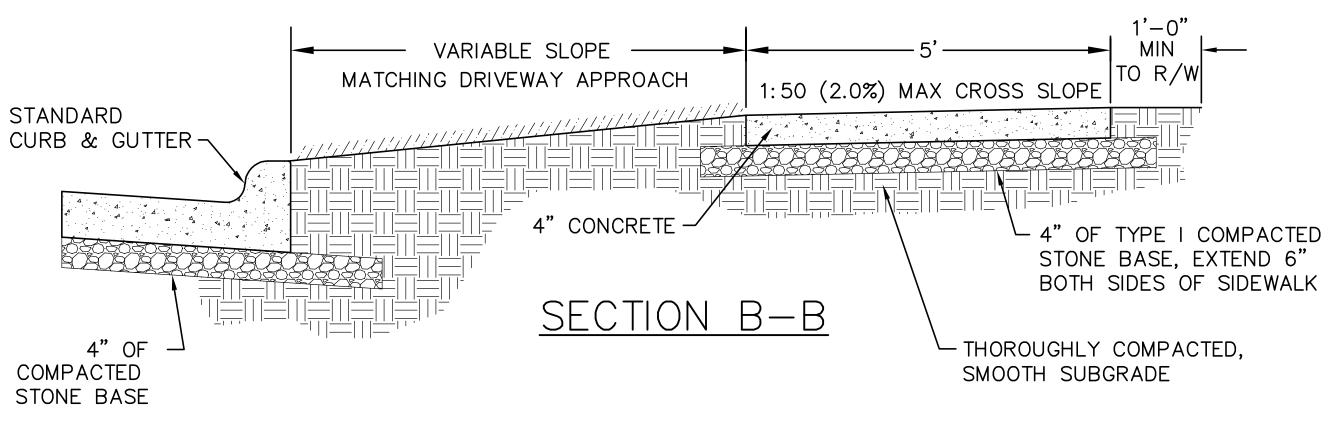


TYPICAL DRIVEWAY PLAN VIEW

NOTE:
ANY PART OF AN ACCESSIBLE ROUTE WITH A RUNNING SLOPE GREATER THAN 1:20 SHALL BE CONSIDERED A RAMP AND SHALL COMPLY WITH THOSE REGULATIONS.

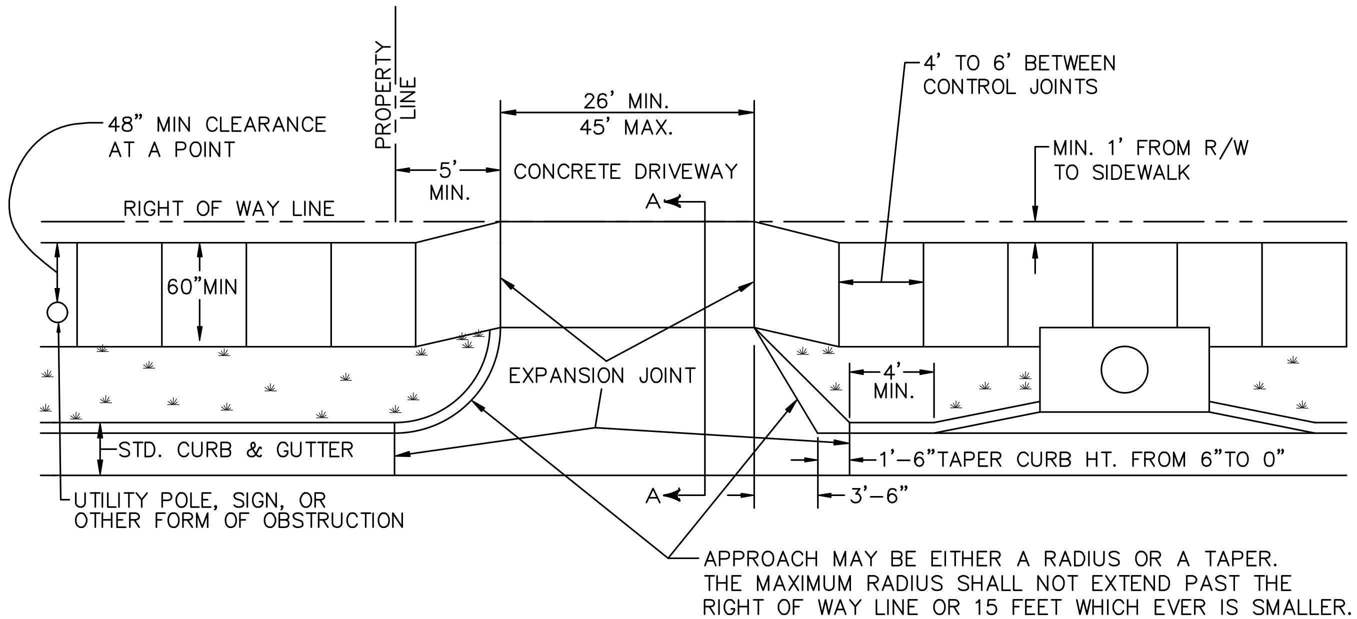


SECTION A-A



SECTION B-B

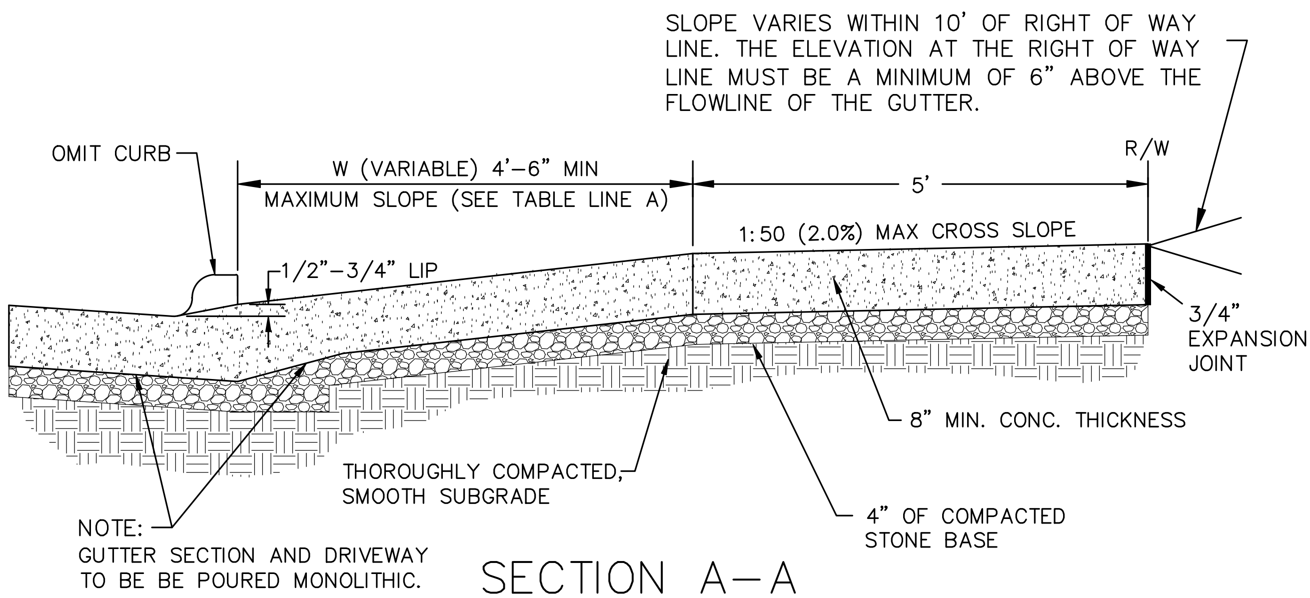
CITY OF BATTLEFIELD, MO	TYPICAL RESIDENTIAL DRIVEWAY & SIDEWALK	ADOPTED: XX/XX/2023 ST-8



TYPICAL DRIVEWAY PLAN VIEW

NOTE:
ANY PART OF AN ACCESSIBLE ROUTE WITH A RUNNING SLOPE GREATER THAN 1:20 SHALL BE CONSIDERED A RAMP AND SHALL COMPLY WITH THOSE REGULATIONS.

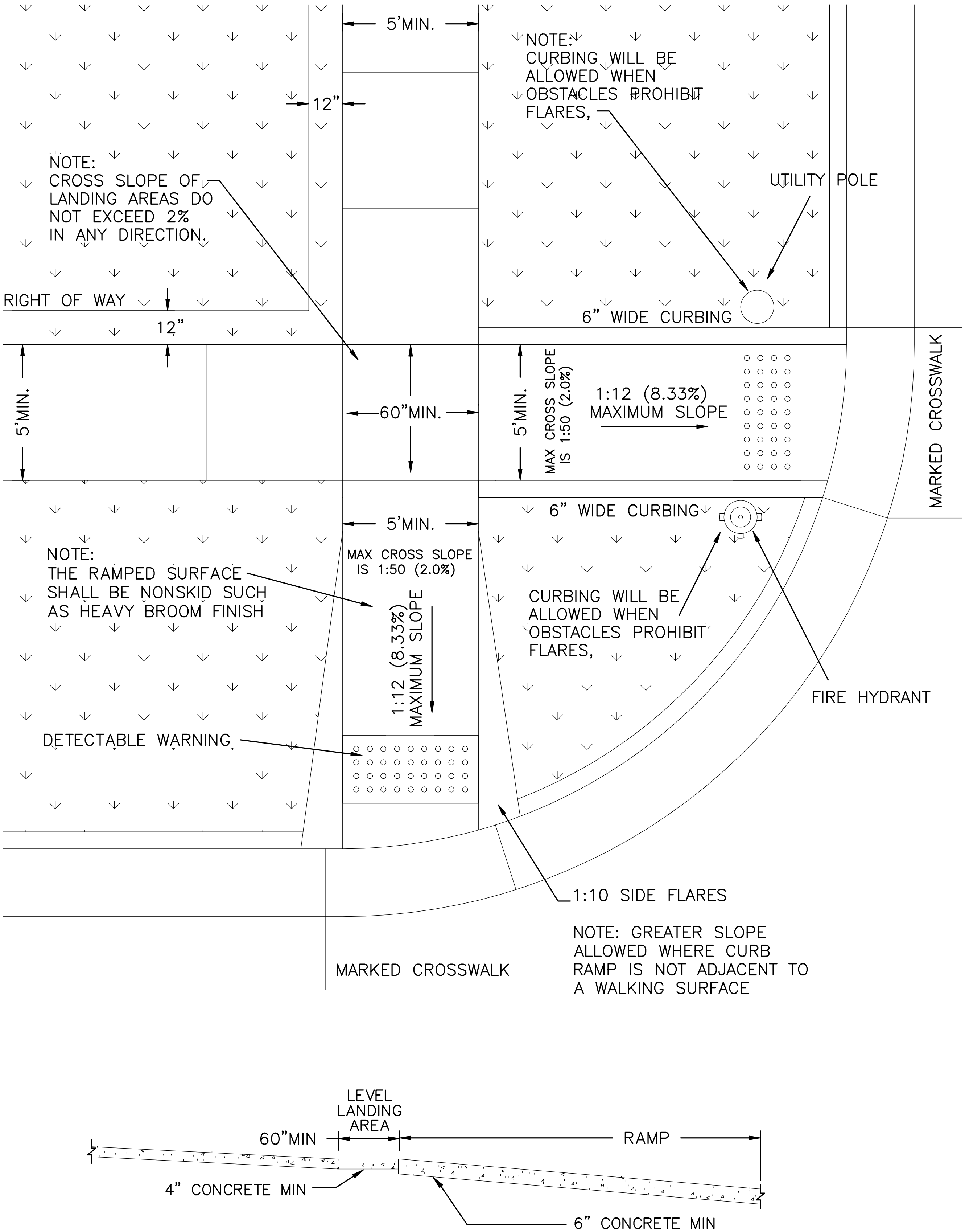
REQUIRED DRIVEWAY GRADES				
	MAJOR ARTERIAL	SECONDARY ARTERIAL	COLLECTOR	NON-RESIDENTIAL LOCAL
A. DRIVEWAY APPROACH GRADE	1/4in/ft to 1/2in/ft	1/4in/ft to 5/8in/ft	1/4in/ft to 3/4in/ft	1/4in/ft to 1in/ft
B. MAXIMUM CHANGE OF GRADE AT BACK OF SIDEWALK	4%	5%	6%	8%
C. SLOPE WITHIN 10 FEET OF RIGHT-OF-WAY LINE	-2% to 6% 1/4in/ft to 3/4in/ft	-3% to 7% -3/8in/ft to 7/8in/ft	-4% to 8% -1/2in/ft to 1in/ft	-6% to 10% -3/4in/ft to 1-1/4in/ft



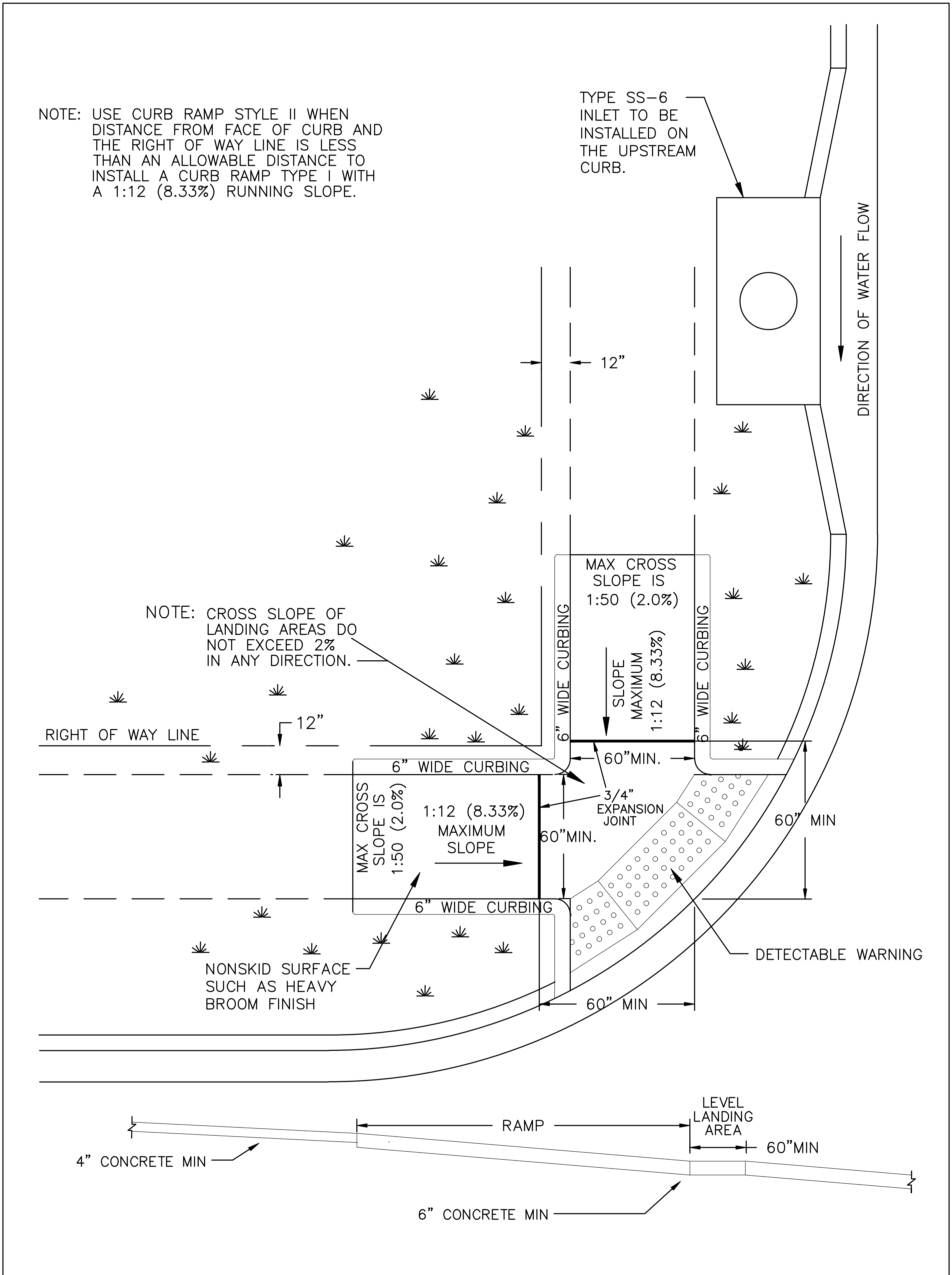
SECTION A-A

REVISED: 10-17-05; REMOVED REINFOREMENT REQUIREMENTS.

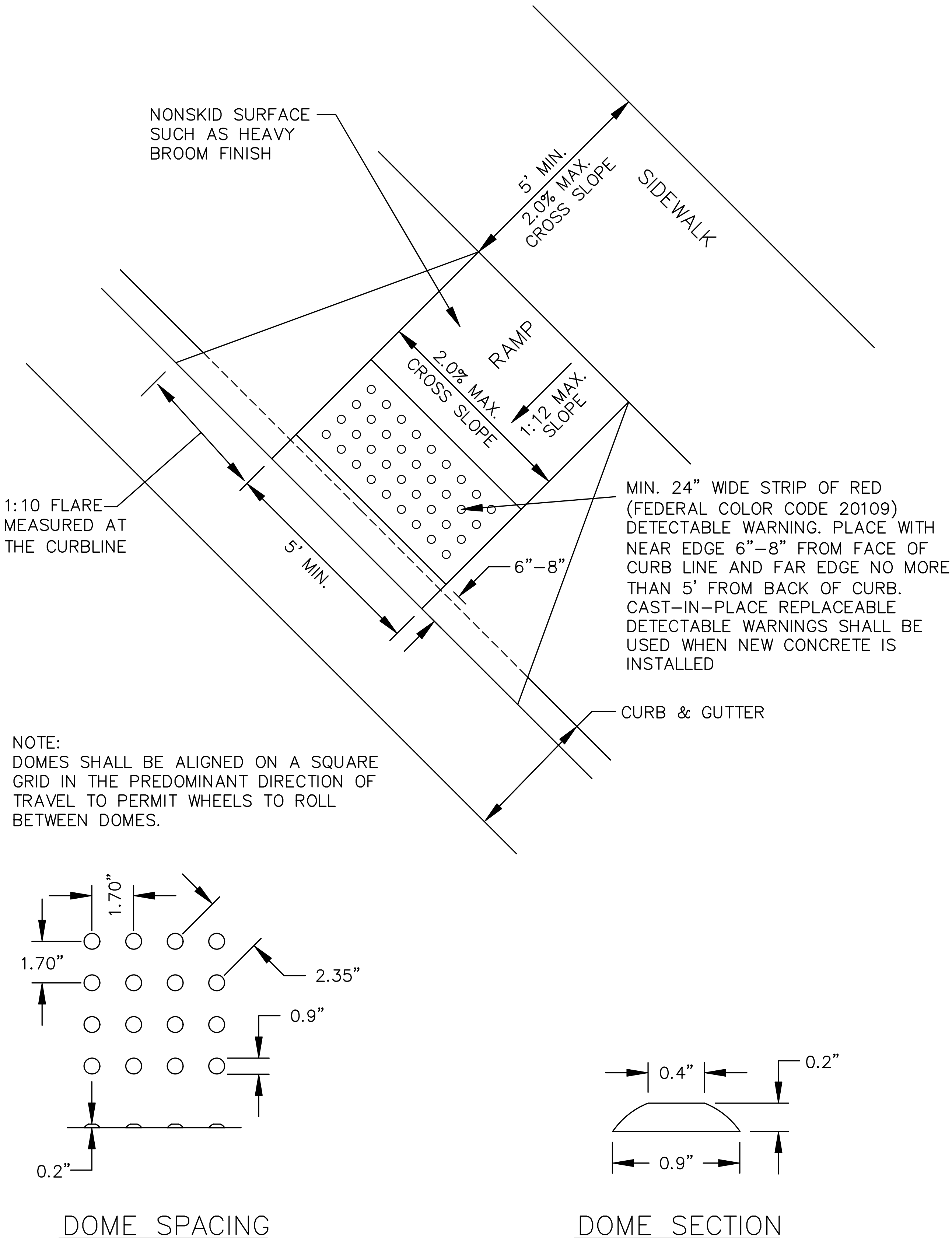
CITY OF BATTLEFIELD, MO	TYPICAL COMMERCIAL DRIVEWAY & SIDEWALK	ADOPTED: XX/XX/2023 ST-9



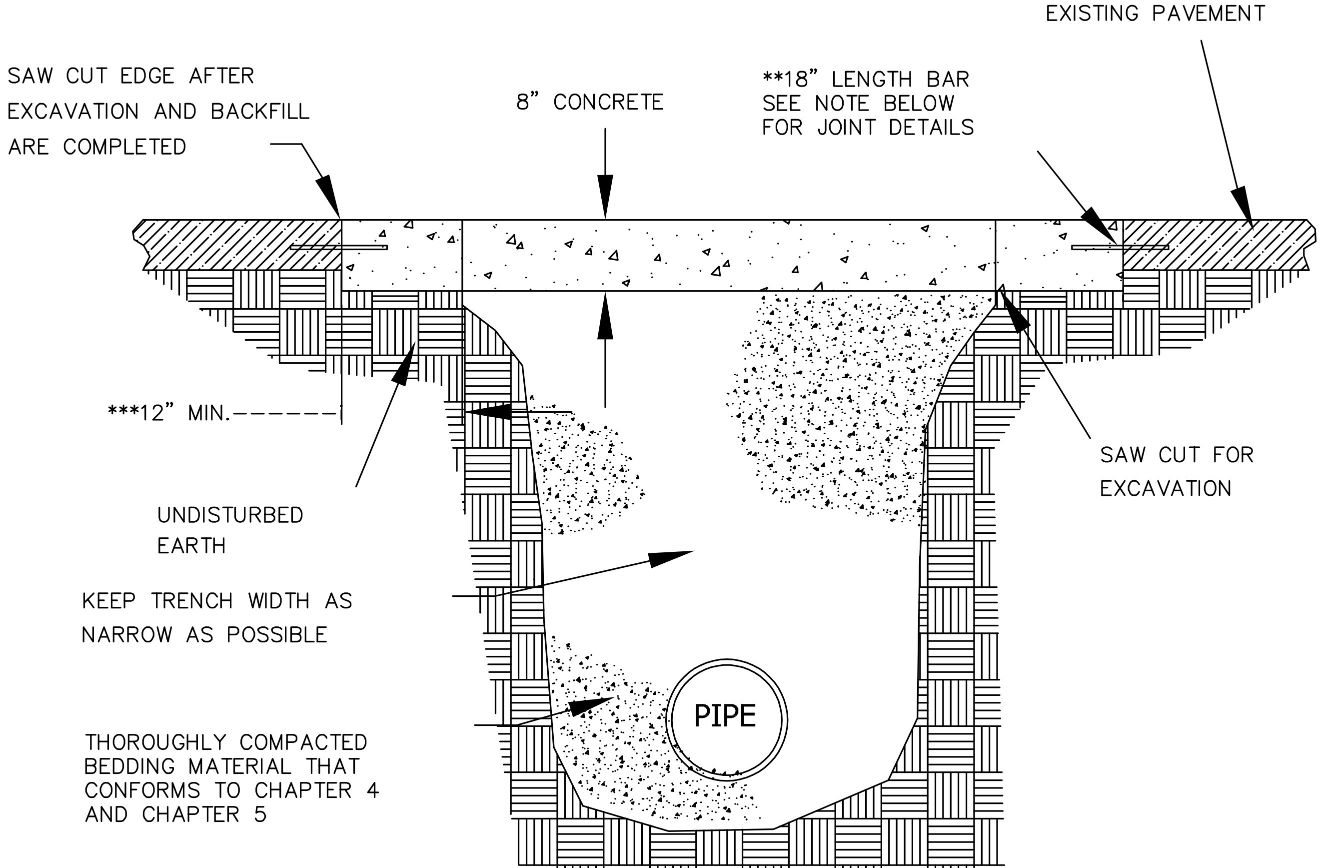
CITY OF BATTLEFIELD, MO	CURB RAMP TYPE 1	ADOPTED: XX/XX/2023
		ST-10



CITY OF BATTLEFIELD, MO	CURB RAMP TYPE II	ADOPTED: XX/XX/2023 ST-11



CITY OF BATTLEFIELD, MO	CURB RAMP WITH DETECTABLE WARNING	ADOPTED: XX/XX/2023
		ST-12



NOTES:

* OMIT DOWEL BARS WHEN REPAIRING ASPHALT PAVEMENT

** JOINTS IN CONCRETE PAVEMENT:

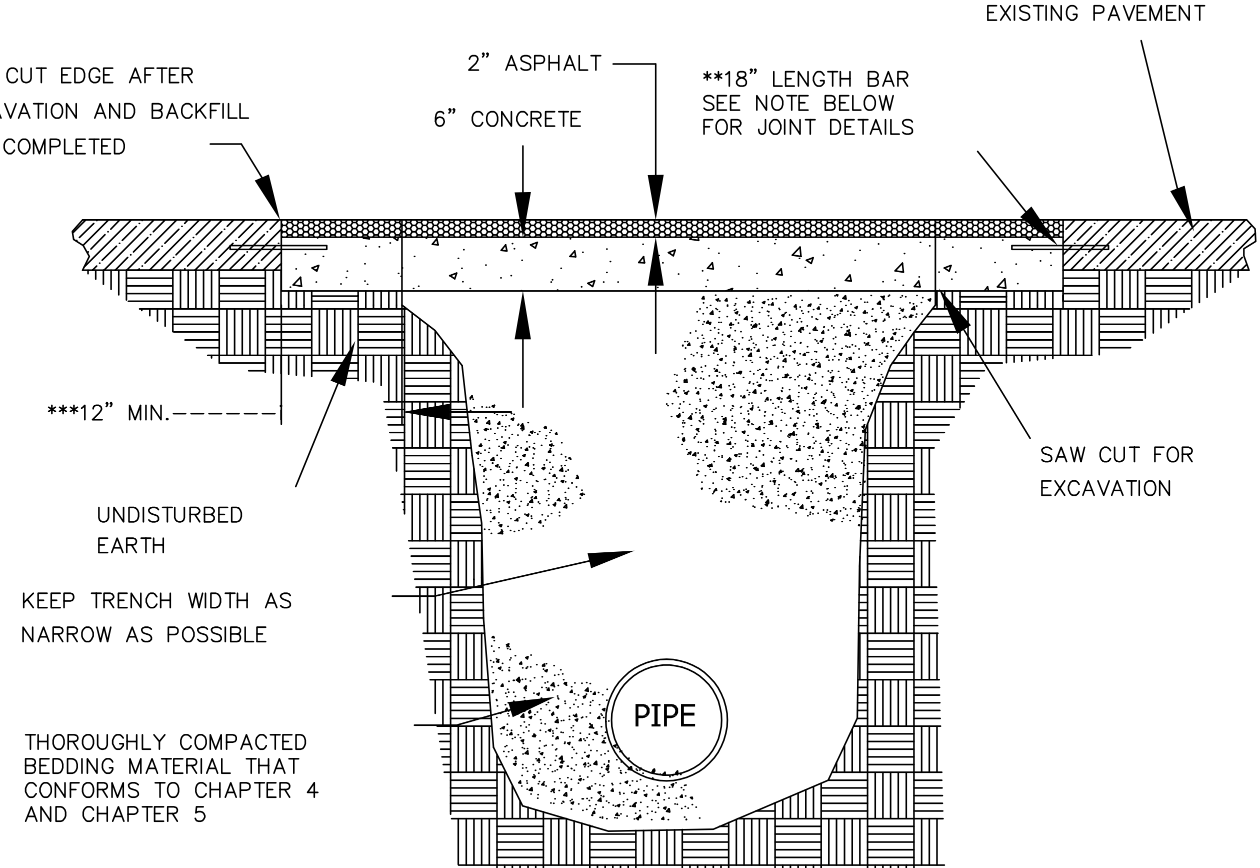
TRANSVERSE JOINTS: ALL TRANSVERSE JOINTS SHALL COMPLY TO ST-3 AND ST-4 WITH THE EXCEPTION THAT AN L 1 JOINT SHALL BE USED ON TRANSVERSE JOINTS FOR PAVEMENTS LESS THAN 6" IN THICKNESS.

LONGITUDINAL JOINTS: ALL LONGITUDINAL JOINTS SHALL COMPLY TO ST-3 AND ST-4. ALL PAVEMENT REPAIRS SHALL BE REMOVED TO EXISTING LANE LINES OR CENTERLINE OF THE ROADWAY AND NO PARTIAL LANE WIDTH REPAIRS WILL BE ALLOWED TO REMAIN IN PLACE.

*** IF TRANSVERSE JOINT FALLS WITHIN 5' OF EXISTING TRANSVERSE JOINT IN CONCRETE PAVEMENT, PAVEMENT SHALL BE REMOVED AND REPLACED TO EXISTING TRANSVERSE JOINT.

REPAIRS AND/OR REPLACEMENT OF DRIVEWAYS SHALL BE TO CURRENT STANDARDS AND SPECIFICATION UNLESS APPROVED BY THE DIRECTOR OF PUBLIC WORKS. NO PARTIAL REPAIRS OF DRIVEWAYS LESS THAN LIMITS OF EXPANSION JOINTS AS SHOWN IN THE STANDARD DRAWINGS FOR NEW DRIVEWAYS WILL BE ALLOWED. IF NO EXPANSION JOINTS EXIST OR THE DRIVE IS ASPHALT AND /OR AGGREGATE MATERIAL, THE REPAIR SHALL REPLACE THE DRIVE FROM THE ADJACENT STREET TO THE RIGHT OF WAY LINE OF EQUAL OR BETTER MATERIAL AS THE EXISTING DRIVE.

CITY OF BATTLEFIELD, MO	EXIST. CONCRETE PAVEMENT REPAIR DETAIL	ADOPTED: XX/XX/2023
		ST-13



NOTES:

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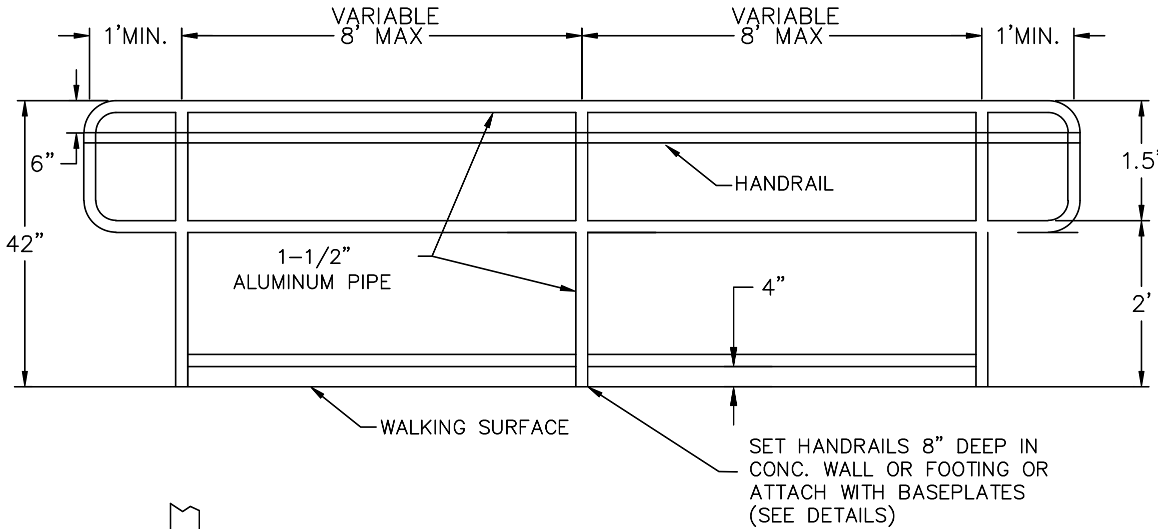
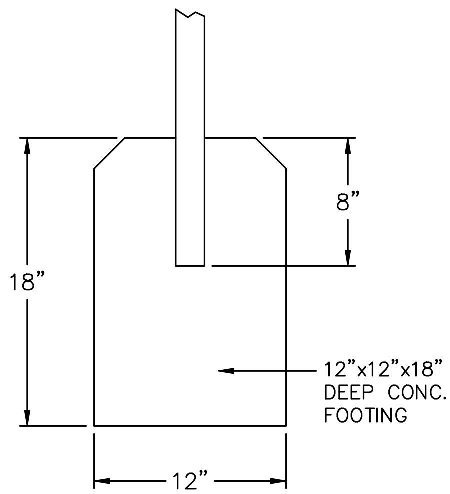
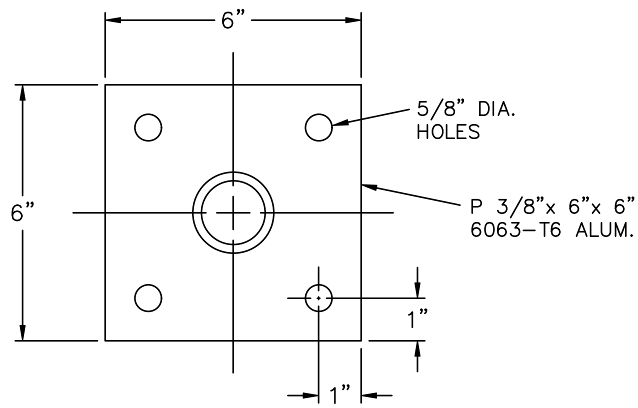
CITY OF BATTLEFIELD, MO	EXIST. ASPHALT PAVEMENT REPAIR DETAIL	ADOPTED: XX/XX/2023
		ST–13A

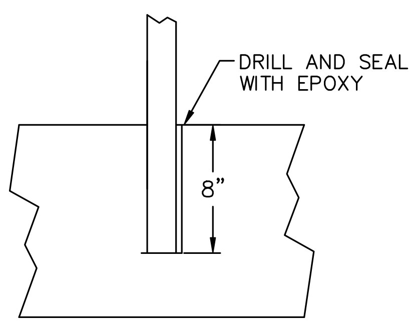




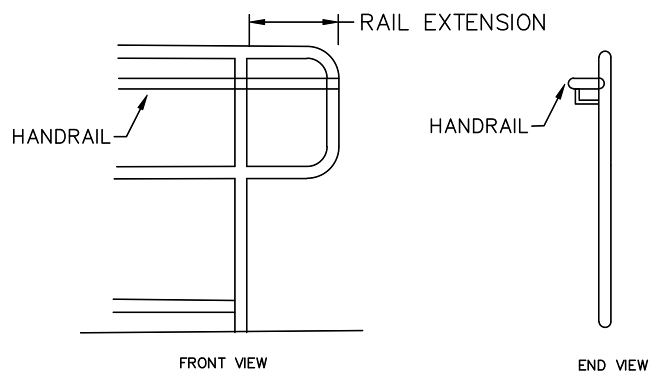
CONC. FOOTING DETAIL



BASEPLATE DETAIL



HEADWALL DETAIL



HANDRAIL DETAIL

RAILING & POST SPECIFICATIONS		
TYPE	SIZE (DIA.)	WEIGHT (LBS./FT.)
ROUND	1-1/2"	ALUMINUM 0.940

GENERAL NOTES:

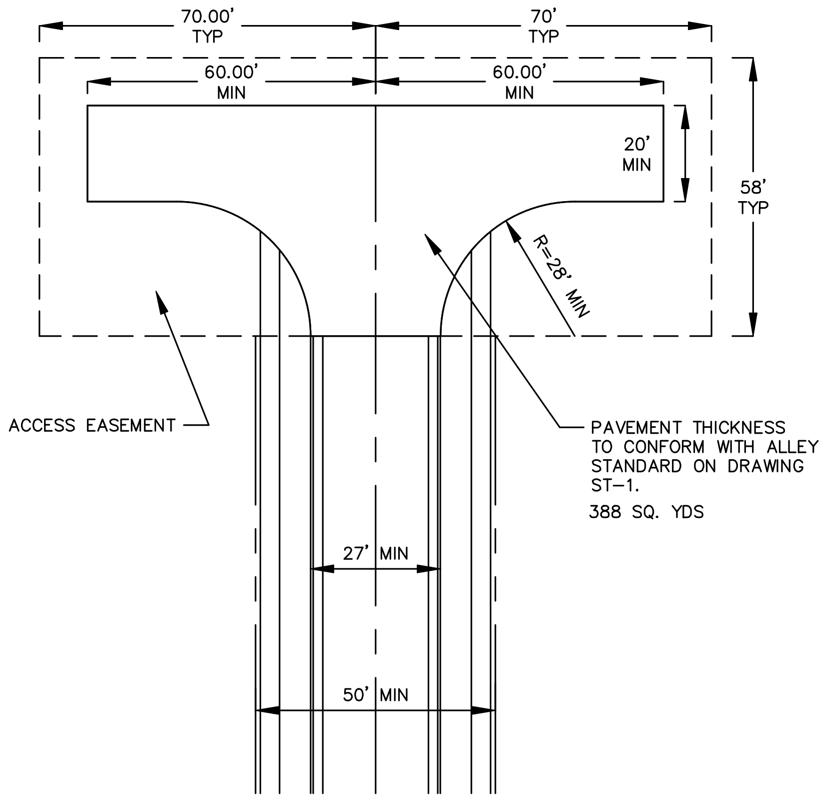
RAILINGS, POSTS, AND BASEPLATES SHALL BE ALUMINUM ALLOY 6061-T6 OR 6063-T6.

IF PRE-MANUFACTURED HANDRAIL COMPONENTS ARE TO BE USED, PRIOR APPROVAL IS REQUIRED.

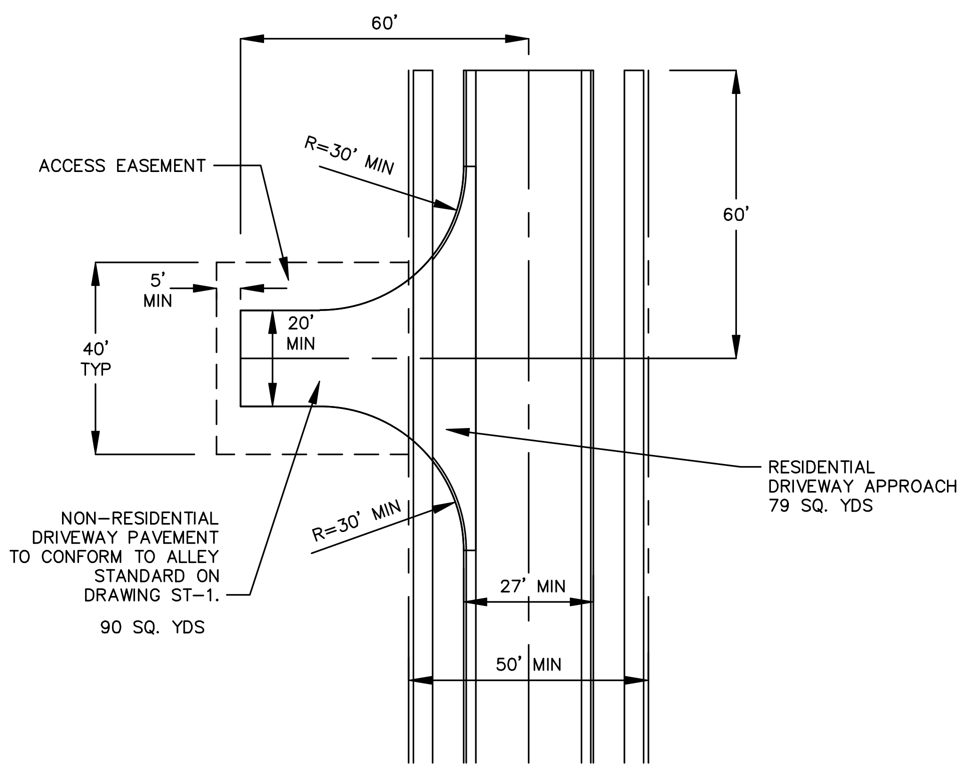
ALL JOINTS SHALL BE CONTINUOUS WELDED.

NOTE: IF THERE IS A DROPOFF OF 30" OR MORE WITHIN 36" OF THE EDGE OF THE SIDEWALK, HANDRAIL IS REQUIRED

CITY OF BATTLEFIELD, MO	HANDRAIL	ADOPTED: XX/XX/2023
		ST-18

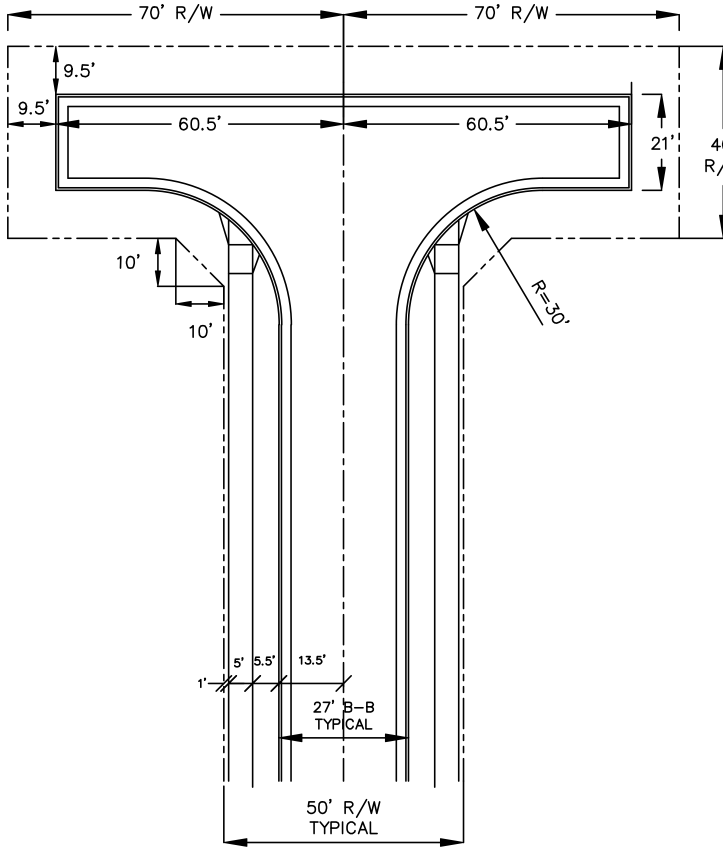


"T" TYPE



"BRANCH" TYPE

CITY OF BATTLEFIELD, MO	TEMPORARY DEAD END STREET TURNAROUND	ADOPTED: XX/XX/2023
		ST-19



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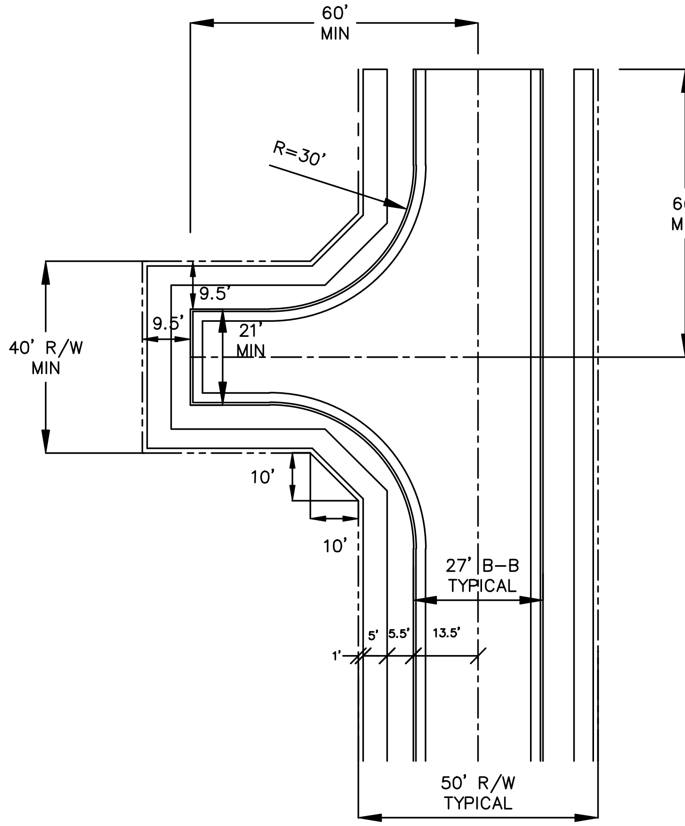

" BRANCH " TYPE

CITY OF BATTLEFIELD, MO	PERMANENT DEAD END STREET TURNAROUND	ADOPTED: XX/XX/2023 ST-20