2023-2026 Review Cycle

Infrastructure Design Manual

Redlines

March 2026

City of Houston

Design Manual

Chapter 1

GENERAL REQUIREMENTS

Chapter 1
Table of Contents

General Requirements

SECTIONS PAGE

Chapter 1

GENERAL REQUIREMENTS

SECTION 1 - GE~~R~~NERAL REQUIREMENTS OVERVIEW

1.1.01 CHAPTER INCLUDES

1.1.01.A Research and submittal requirements for projects inside the city limits of Houston or within Houston's Extraterritorial Jurisdiction (ETJ).

1.1.01.B Tree protection requirements.

1.1.02 REFERENCES

The following references should be reviewed in conjunction with this manual:

1.1.02.A Latest revision of the following City of Houston Code of Ordinances:

1. Chapter 33 - Planning and Development, Article IV - City Surveys.
2. Chapter 33 – Planning and Development, Article V – Trees, Shrubs, and Screening Fences.
3. Chapter 33 – Planning and Development, Article VI – Protection of Certain Trees.
4. Chapter 40 – Streets and Sidewalks, Article V - Excavation in Public Way
5. Chapter 42 - Subdivisions, Developments and Platting.
6. Chapter 47 – Water and Sewers, Article V - Industrial Wastewater.

1.1.02.B Texas Accessibility Standards (TAS) of the Architectural Barriers Act, Article 9102, Texas Civil Statutes.

1.1.02.C City of Houston Standard Specifications and Standard Details, latest revision.

1.1.02.D Rules and Regulations published by Texas Commission on Environmental Quality (TCEQ).

1. Texas Administrative Code Title 30, Part 1, Chapter 290 Public Water Drinking, latest revision.
2. Texas Administrative Code Title 30, Part 1, Chapter 217 Design Criteria for Domestic Wastewater Systems, latest revision.

1.1.02.E Texas Board of Professional Engineers and Land Surveyors (TBPELS) Practice Acts and Rules Concerning Practice and Licensure.

1. Texas Statute, Occupations Code, Title 6, Subtitle A, Chapter 1001 Texas Board of Professional Engineers and Land Surveyors.

2. Texas Statute, Occupations Code, Title 6, Subtitle C, Chapter 1071 Land Surveyors.

3. Texas Administrative Code, Title 22, Part 6 Texas Board of Professional Engineers and Land Surveyors.

1.1.02.F Texas Local Government Code, Title 2, Subtitle C, Chapter 42 Extraterritorial Jurisdiction of Municipalities.

1.1.02.G Storm Water Management Handbook for Construction Activities, Latest Edition as Prepared by Harris County, Harris County Flood Control District (HCFCD), and City of Houston.

1.1.02.H Harris County Public Infrastructure Department's Rules and Regulations.

1.1.02.I City of Houston IDM Chapter 13, Geospatial Data Deliverables.

1.1.02.J American Standard for Nursery Stock (ANSI Z60.1).

1.1.03 DEFINITIONS

1.1.03.A As-Built Drawings - Final revised Drawings at completion of the project, submitted by the contractor to the Engineer of Record and City, that captures all changes in work during the construction process shown as revisions on the as-bid Drawings.

1.1.03.B City Engineer - The authorized representative of the City, or the City’s designee, having approval authority for Publicly-Funded Projects, Privately-Funded Projects, or having authority for administration of design and construction contracts for the City.

1.1.03.C Conflict Verification - For capital improvement projects requiring the acquisition of fee or easement interest in real property, verification that all existing easements that lie across, along, under, over, through and within the parcel to be acquired will not prevent the construction of the utility or infrastructure or the intended use of the easement.

1.1.03.D Drawings - Plan, profile, details, and other graphic sheets to be used in a construction contract which define character and scope of the project.

1.1.03.E Drip Line - Imaginary circle drawn around a Tree, extending to the Tree's branching limit.

1.1.03.F Engineer of Record - A Professional Engineer who seals Drawings, reports or documents for a project.

1.1.03.G Extraterritorial Jurisdiction (ETJ) - The unincorporated territory extending beyond the corporate boundaries of the City established pursuant to Chapter 42 of the Texas Local Government Code, as may be amended from time to time.

1.1.03.H Parkway - Area lying between the street curb or edge of roadway paving and the adjacent property line.

1.1.03.I Privately-Funded Projects - Projects that are funded by an individual or private entity and do not have a design contract with the City.

1.1.03.J Publicly-Funded Projects - Projects that are funded by a public entity, but do not have a design contract with the City.

1.1.03.K Professional Engineer - An engineer currently licensed and in good standing with the Texas Board of Professional Engineers and Land Surveyors (TBPELS).

1.1.03.L Project Manager - An authorized representative of the City of Houston who manages the project or the Engineer of Record for private development.

1.1.03.M Protected Tree - Corridor Tree, designated Tree, green corridor Tree or Parkway Tree as defined by Chapter 33 of the City of Houston Code of Ordinances.

1.1.03.N Record Drawings - Final revised Drawings prepared by the Engineer of Record on the original as-bid Drawings documenting significant changes in work based solely upon the marked-up As-Built Drawings, addenda, revisions, change orders and other data furnished by the contractor.

1.1.03.O Registered Professional Land Surveyor (RPLS) - A surveyor currently registered and in good standing with State of Texas Board of Professional Engineers and Land Surveyors (TBPELS).

1.1.03.P Review Authorities - The authorized representatives of City departments, divisions, branches or sections responsible for reviewing and approving calculations and Drawings for Publicly-Funded Projects, Privately-Funded Projects and for design and construction contracts with the City.

1.1.03.Q Specifications - City of Houston Standard Specifications plus project-specific narrative descriptions of procedures, requirements, and materials for a particular project.

1.1.03.R Tree - Any evergreen or deciduous Tree which at the time of planting has a caliper equal to or greater than 1 1/2 inches as measured six inches above the root collar, which is not less than six feet in height as measured from the root collar, and which meets the Standard for Nursery Stock Specifications.

1.1.04 PLAT AND CONSTRUCTION DRAWING REVIEW PROCESS

1.1.04.A Review of plat and construction Drawings by Houston Public Works is a required part of the overall platting process under purview of the City Planning Commission and the Planning and Development Department of the City of Houston.[1]

1.1.04.B The process to be followed in submitting documents for review and approval of water, wastewater, storm drainage, and street paving is described by the flowchart depicted in Figure 4.1, Class III Preliminary Plat.

1.1.04.C For projects requiring a subdivision plat, construction of utilities and paving is not permitted until the plat has been recorded.

1.1.04.D For projects not requiring a subdivision plat, construction of utilities and paving is not permitted until final design Drawings are approved and signed by the Director of Houston Public Works, or the Director's designee.

1.1.04.E Signature of the Director of Houston Public Works, or the Director's designee, on final design Drawings for utilities which are intended to remain private, does not indicate acceptance of the City for ownership or maintenance or operation of facilities indicated on the Drawings.

[1] Refer to weblink for City requirements: http://www.houstontx.gov/planning/Commissions/commiss_plan.html

SECTION 2 - GE~~R~~NERAL DESIGN REQUIREMENTS

1.2.01 DESIGN REQUIREMENTS

1.2.01.A Preliminary Design.

1. Publicly/Privately-Funded Projects:

    a. Prior to preliminary design submittal, City reviewers are available to discuss alternate solutions for project elements where alternate designs may be considered.

    b. Provide the Office of City Engineer with Drawings in sufficient detail to describe the proposed improvements. Include proposed materials, if different from materials approved by the City. Identify any problems or conflicts associated with the project. Information furnished must be in sufficient detail for the City Engineer to assess whether the design meets current City design standards.

    c. Provide rights-of-way and easement requirements for the project.

2. Design Contracts with the City:

    a. Participate in preliminary conferences with the City's Project Manager outlining the scope of work and extent of the preliminary report.

    b. Prepare preliminary engineering studies and designs based upon the scope of work and as outlined in the professional engineering services contract with the City.

    c. Prepare the contractually specified number of copies of preliminary layouts, sketches, reports, and calculations supporting the preliminary layouts. Prepare alternate solutions, where applicable to the project, and include the engineer's specific recommendations.

    d. Prepare preliminary cost estimates for primary and alternate solutions of the proposed construction.

    e. Participate in conferences with the City to determine final design.

    f. When required by the professional services contract, provide detailed soils and geotechnical investigations and environmental investigations to support proposed construction of utilities and paving.

1.2.01.A.2 continued

g. Provide required real estate, rights-of-way, and easement requirements for the project.

1.2.01.B Final Design.

1. Publicly/Privately-Funded Projects:

   a. Revise design to reflect comments of the City Engineer and Review Authorities. Include design calculations to support proposed improvements.

   b. Provide electronic Drawings to the City Engineer and Review Authorities for verification and compliance with prior review comments.

   c. Obtain required signatures from governmental agencies (other than the City of Houston) and private utility companies prior to requesting signature by the City.

   d. Include the following note on construction Drawings - "Contractor shall notify the City of Houston, Houston Public Works (832-394-9098), 48 hours before starting work on this project."

2. Design Contracts with the City:

   a. Furnish the City, where applicable, engineering data necessary for applications for routine permits required by local, state, and federal authorities.

   b. Prepare detailed final design Drawings and Specifications in compliance with comments received from the City subsequent to the review of the preliminary design.

   c. Prepare detailed cost estimates and proposal forms for the authorized project.

   d. Provide estimated construction duration. Include all back up calculations and assumptions. Provide assumed number of holidays, weekends, severe weather and other non-working days as applicable.

1.2.02 SUBMITTALS

1.2.02.A Submittal Procedures.

1. For Publicly/Privately-Funded Projects:

1.2.02.A.1 continued

a. To obtain review of final design Drawings for both Publicly-Funded and Privately-Funded Projects, first submit Drawings to the Houston Public Works, Office of the City Engineer for assignment of a project number before review will commence. The project number will remain in effect for one year.

b. Once a project number is assigned, reference the number in all correspondence relating to that project.

c. Obtain and complete electronic plan review assigned tasks for each phase of the review process. The same project number will be used for all review phases of each project unless review of a subsequent phase is delayed by over one year.

d. Office of the City Engineer personnel will process reviews through appropriate review teams in Houston Public Works.

e. ~~If a project has begun the review process but becomes inactive for a period of 12 months from the date of the last correspondence, the project will be considered stopped and the project number inactivated.~~ Once a project has begun the review process, it will become expired and the project number inactivated if the project meets all the following:

(1) Gone over the one-year initial project number lifetime since the first plan review submittal.

(2) Has no activity within 30 days of the previous review.

~~(1)~~(3) Has no exceptions granted by the Office of City Engineer for items required of City or other government agencies.

~~e.~~f. The City has a weekly one-day walk-through procedure for the signature of revisions and updates of plans approved through the hard copy review. Instruction sheets for this procedure may be obtained from the Office of the City Engineer.

~~f.~~g. Projects involving construction of privately owned facilities require review and approval of any connection to a public water line, sanitary sewer, or storm sewer or to a public street, using the process defined in this manual.

2. For Design Contracts with the City:

a. Submit documents in accordance with requirements of the professional engineering services contract.

1.2.02.B Preliminary Design.

1. Publicly-Funded and Privately-Funded Projects: Submit set of the design Drawings and supporting documents through the electronic plan review system. Provide supporting evidence as described in Article 1.2.01 and Article 1.2.04. All Drawings submitted through the electronic plan review system to the Office of the City Engineer are considered to be in the final design stage and ready for signature.

2. Design contracts with the City: Submit documents in accordance with requirements of the professional engineering services contract.

1.2.02.C Final Design.

1. Publicly/Privately-Funded Projects:

   a. Plans submitted through the electronic plan review system to the Office of the City Engineer must comply with Article 1.2.02.B.1.

2. Design Contracts with the City:

   a. Submit documents in accordance with requirements of the professional engineering services contract.

   b. Submit a copy of the City review comments on the preliminary Drawings.

1.2.02.D Signature Stage.

1. Publicly/ Privately-Funded Projects:

   a. This stage is only applicable for submittals that comply with Article 1.2.02.A1.f. Submit previously approved Drawings for signatures.

   b. Plans submitted through the electronic plan review system to the Office of the City Engineer must comply with Article 1.2.02.B.1.

2. Design Contracts with the City:

   a. Submit original tracings with prints containing previous review comments.

   b. Specification submittals: Submit final design Specifications for review.

1.2.02.B continued

c. Submit final computer-generated drawing files in acceptable electronic media including vicinity maps, right-of-way Drawings, construction Drawings, or other information pertinent to the project.

d. Submit surveyor's field book and electronic data in accordance with Chapter 2, Survey Requirements.

1.2.02.E Construction.

1. For design contracts with the City, refer to construction submittal requirements in the professional engineering services contract.

2. Record Drawings:

   a. Provide Record Drawings in the format requested by the City.

   b. For design contracts with the City, submit Record Drawings in accordance with requirements of the professional engineering services contract.

   c. For Publicly-Funded and Privately-Funded Projects, submit Record Drawings to the Office of the City Engineer no later than two weeks following final acceptance of the project.

   d. For projects involving waterlines, refer to Chapter 7 for specific requirements.

3. Geospatial Data Deliverables: Provide GIS datasets in accordance with Chapter 13 – Geospatial Data Deliverables for projects that are proposing or modifying assets identified in Chapter 13 that are or will be operated and/or maintained by the City. In addition, provide GIS datasets in accordance with Chapter 13 – Geospatial Data Deliverables for projects that are proposing or modifying the privately owned and operated telecommunications assets described in Chapter 13.

1.2.02.F Provide additional submittals as required in applicable chapters of the City of Houston Infrastructure Design Manual (IDM).

1.2.03 QUALITY ASSURANCE

1.2.03.A Have surveying and platting accomplished under direction of a RPLS.

1.2.03.B Have recording documents sealed, signed, and dated by a RPLS.

1.2.03.C Have calculations prepared by or under the direct supervision of a Professional Engineer trained and licensed in disciplines required by the project scope.

1.2.03.D Have final design Drawings sealed, signed, and dated by the Professional Engineer responsible for development of the Drawings.

1.2.04 RESEARCH REQUIREMENTS

1.2.04.A Research existing utility and right-of-way information with the City departments listed below. Present and discuss the concept of the project with these same departments.

1. Houston Airport System
2. Houston Public Works
   a. Capital Projects
   b. Customer Account Services
   c. Financial Management Services
   d. Houston Permitting Center
   e. Houston Water
   f. Transportation & Drainage Operations
3. Planning and Development Department
4. Parks and Recreation Department
5. Finance Department, Franchise Administration

1.2.04.B Research existing utilities and rights-of-way or easements for conflicts with the following public and private organizations:

1. Texas Department of Transportation
2. Harris County Public Infrastructure Department
3. Harris County Toll Road Authority
4. Metropolitan Transit Authority of Harris County
5. Harris County Flood Control District
6. Other City and County Governments
7. Franchise Holders:

1.2.04.B.7 continued

a. CenterPoint Energy - Gas

b. AT & T Company

c. CenterPoint Energy - Electric

8. Cable television and data communications companies

9. Other utility companies:

a. Utility districts

b. Private utilities/franchises

c. Railroad companies

d. Pipeline companies

1.2.04.C Verify that no restrictions or conflicts exist that will prevent approval and permitting of the project.

1. For capital improvement projects requiring the acquisition of real property, a Conflict Verification is required.

1.2.05 APPROVED DRAWINGS

1.2.05.A Approved Drawings for projects within the city limits and within the ETJ will be assigned a City drawing number and will be filed by the City prior to release back to the Engineer of Record. Record files for facilities within public rights-of-way will be available to the public. Record files associated with plants, buildings and other facilities outside public rights-of-way will be restricted pended security constraints.

SECTION 3 - TREE PROTECTION

1.3.01 TREE PROTECTION

1.3.01.A Tree Protection Requirements

1. Tree protection requirements are designed to protect Trees during any construction activity within the Drip Line circle area of any Protected Tree that is not to be removed. Construction includes, but is not limited to, the following:

    a. Construction or repair of buildings or other structures;

    b. Installation or repair of utilities;

    c. Installation or repair of streets or sidewalks.

2. Tree protection must comply with the following requirements as applicable:

    a. City of Houston Code of Ordinances, Chapter 33, Article V "Trees, Shrubs, and Screening Fences." and Article VI "Protection of Certain Trees."

    b. Trees to be preserved must be clearly tagged in the field with ribbon.

    c. Protection barrier shall be composed of wood, wire, snow fence and braces of similar non injurious material.

    d. Tree wells shall be made of a durable material and set a minimum of four feet from any Tree they are designed to protect.

    e. Retaining walls of a durable material, i.e., stone, or treated lumber, are to be constructed around each Tree immediately after the grade is lowered. A retaining wall must be at least four feet from the Tree it is designed to preserve.

    f. Any under story clearing within six feet of existing Tree trunks shall be done by hand.

    g. No building materials are to be stacked or stockpiled within the Drip Line or within six feet of any Tree to be preserved, whichever is greater.

    h. Topsoil shall not be stockpiled within the Drip Line or within six feet of any Tree to be preserved, whichever is greater.

1.3.01.A.2 continued

i. Selective thinning of dead or dying vegetation, Tree stumps and other undesired growth is required in buffer areas. Supplemental vegetation shall comply with the landscape buffer requirements.

j. Tree boarding shall be used if work is required within construction fencing.

k. Where possible, utility lines shall be tunneled beneath Tree roots in order to protect feeder roots, rather than trenched or open cut.

3. Tree Root Barriers

a. Tree root barriers will be used for planting of new Trees, to prevent the uncontrollable spread of Tree roots, following root pruning, to protect land and hardscapes from root damage.

b. Tree root barriers can be designed and configured to surround the Tree or for linear application.

c. Tree root barrier configuration depends on the hardscape to be protected, distance from surrounding Trees, aggressiveness of the Tree, and rooting depth of the Tree(s).

4. Holes for the Tree shall be excavated two feet greater in width than the diameter of the soil ball.

5. The size of root barriers shall be three times the diameter of the root ball.

END OF CHAPTER

City of Houston

Design Manual

Chapter 3

GRAPHIC REQUIREMENTS

Chapter 3
Table of Contents

Graphic Requirements

SECTION PAGE

List of Tables

List of Figures

Chapter 3

GRAPHIC REQUIREMENTS

SECTION 1 - OVERVIEW

3.1.01 CHAPTER INCLUDES

3.1.01.A Graphic requirements are provided for a consistent uniform appearance for engineering drawings. It is not the intent of this manual to be a training guide for AutoCAD, ArcGIS or other software products.

3.1.01.B This chapter is to be used for all new projects. For projects already underway, coordinate with the City Project Manager to assess the appropriateness of implementation. It is not the intent of this update to cause existing projects to incur additional time or cost, and measure should be taken to avoid such.

3.1.02 REFERENCES

3.1.02.A City of Houston, Code of Ordinances, Chapter 33, Article IV - City Surveys.

3.1.02.B City of Houston, Standard Details, current edition.

3.1.02.C City of Houston, Standard Specifications, current edition.

3.1.02.D National Institute of Building Sciences, U.S. National CAD Standard (NCS).

3.1.02.E Texas Board of Professional Engineers and Land Surveyors (TBPELS), Practice Acts and Rules Concerning Practice and Licensure.

3.1.03 DEFINITIONS

3.1.03.A AutoCAD - CAD software platform for two and three-dimensional design and drafting. The file format of AutoCAD is DWG. AutoCAD has included file format support for DXF and DWF.

3.1.03.B ArcGIS – Provides an infrastructure for making maps and geographic information.

3.1.03.C City Project Manager - An authorized representative of the City of Houston who manages the project.

3.1.03.D Computer Aided Design (CAD) - Preparation of Drawings, plans, prints, and other related documents through the use of computer equipment and software programs.

3.1.03.E Control Point – A point used as a reference for surveying in which horizontal and vertical location/position is known.

3.1.03.F Drawings - Plan, profile, detail, and other graphic sheets to be used in a construction contract which define character and scope of the project.

3.1.03.G Engineer of Record - A Professional Engineer who seals Drawings, reports, and documents for a project.

3.1.03.H Geographic Information System (GIS) – A system designed to capture, store, manipulate, analyze, manage, and present geographic data.

3.1.03.I Layout Space - Commonly known as "Paper Space", is the area designated for producing printed deliverables.

3.1.03.J Model Space – A limitless 3-D drawing area that is the default in AutoCAD software used for the beginning of a design.

3.1.03.K Professional Engineer - An engineer currently licensed and in good standing with the Texas Board of Professional Engineers and Land Surveyors (TBPELS).

3.1.03.L Registered Professional Land Surveyor (RPLS) - A surveyor currently registered and in good standing with the Texas Board of Professional Engineers and Land Surveyors (TBPELS).

3.1.03.M Right-of-Way - Any real estate that the City currently has an interest in or will be acquiring an interest in.

3.1.03.N Special Structures – Structures not covered by approved standard details, such as stream or gully crossings, special manholes, and junction boxes.

3.1.03.O Temporary Benchmark - A semi-permanent man-made object, bearing a marked point, whose elevation above or below an adopted datum is known.

3.1.03.P U.S. National CAD Standard (NCS) – Standards created to encourage a more rational construction regulatory environment. The U.S. National CAD Standard is published by the National Institute of Building Sciences. https://www.nationalcadstandard.org/ncs6/

3.1.04 SOFTWARE AND DATA FORMAT

3.1.04.A All CAD files, both references and sheet file deliverables, shall be provided in .DWG file extension format compatible with the most recent version of AutoCAD. However, the use of other software with the ability to convert files into the proper .DWG format, will also be acceptable.

3.1.04.B Electronic .PDF drawings submitted to the City of Houston are to be devoid of AutoCAD SHX comments or .PDF comments automatically generated during the .PDF conversion process, and shall have a minimum of 400 dpi resolution. Annotations and form fields are to be flattened prior to submittal.

3.1.05 IMPORTING STANDARD DETAILS

3.1.05.A Standard details shall be imported onto the sheet files when applicable. City standard details shall not be cropped and must be included in the Drawings as the City provides them. The standard detail's entire border and title block must remain visible. For visibility each sheet shall only have up to:

1. Six 8 ½" x 11" standard details oriented portrait.
2. Four 8 ½" x 11" standard details oriented landscape.
3. Two 11"x17" standard details oriented landscape.
4. One 22"x34" standard detail oriented landscape.

3.1.05.B The current standard details can be found here: https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.1.06 MODIFICATIONS TO STANDARD DETAILS

3.1.06.A Modifications to standard details are allowed. Any modifications to a City standard detail during the project's design phase, however minor, must follow the requirements in 3.1.06.B.

3.1.06.B Modification Process:

1. CAD files to be used for creating modified standard details are posted online. These CAD files have been modified to remove the City Engineer and Houston Public Works Director's signature. City signatures will not be allowed on modified standard details.
2. All changes in each sheet that are pertinent to each modification shall be enclosed in revision "clouds".
3. The letter of the modification, beginning with "A", shall be placed inside of a triangle, commonly known as a "delta". The letter is meant to indicate the engineer who modified the standard detail. If multiple engineers modify details on the same sheet, they shall use different revision letters. Letters shall only be used for modifications to standard details during the design phase. For modifications during the construction phase follow SECTION 5 of this chapter.
4. Each modification delta shall be placed adjacent to the corresponding modification cloud(s) and next to the corresponding engineer's seal. Modification deltas and clouds shall not be removed from the sheet at any time.

3.1.06.B continued

5. It is acceptable to have multiple clouds with the same modification delta on a sheet if all changes are approved by the same Engineer of Record.

6. The designation "MOD" must be appended to the standard detail title, the sheet title (if different than standard detail title) and must be reflected in the sheet index.

7. Each modification must be documented on the title block area of each sheet.

8. All modification information must be filled out, including the letter of the modification, date, a brief description that explains each item changed, and approver.

SECTION 2 - GENERAL SHEET CONTENT

3.2.01 GENERAL SHEET CONTENT

3.2.01.A Plan sets for typical projects shall be produced to scale on 22” x 34”, ANSI D sheet sizes.

3.2.01.B Final Drawings Submittal.

1. Physical Drawings shall be India ink on mylar or produced by CAD on mylar using non-water based ink. Do not use adhesive-backed material on final Drawings.

2. Electronic Drawings must be submitted according to SECTION 4 of this chapter.

3.2.01.C The seal, date, and original signature of the Professional Engineer responsible for the Drawings is required on each sheet developed by the design engineer. The design engineer may use stamped seal or embossed imprint; however, the embossed imprint must be shaded so that it will reproduce on prints. Use of an electronic seal for plan submittal needs to be in accordance with the Texas Board of Professional Engineers and Land Surveyors (TBPELS) Practice Act and Rules Concerning Practice and Licensure. Survey control sheets require seal and signature of Registered Professional Land Surveyor (RPLS).

3.2.01.D Applicable City standards shall be included in the engineering plan set.

3.2.01.E Develop Drawings to accurate scale showing proposed pavement, typical cross sections, details, lines and grades, existing topography within street Right-of-Way, and any easement contiguous with the Right-of-Way. At the intersection, the cross-street details shall be shown at sufficient distance (20-foot minimum distance outside the existing roadway Right-of-Way or 25-foot minimum distance outside the proposed roadway Right-of-Way, of which the wider Right-of-Way shall govern) in each direction along cross street for designing adequate street crossings.

3.2.01.F If a roadway exists where Drawings are being prepared to improve or construct new pavement or a utility, label the existing roadway width, surfacing type, and thickness.

3.2.01.G Show all street and road alignments on Drawings refer to Chapter 2, Section 2.2.01.F, Construction Drawings.

3.2.01.H Existing utilities shall be plotted in color according to Article 3.3.03 - LINE WEIGHTS.

~~3.2.01.H~~3.2.01.I On the cover sheet, the major utilities and overall scope of work proposed in the plan and profile drawings shall be listed as part of the project title.

3.2.02 DRAWING FILE ASSEMBLY

3.2.02.A To ensure consistency, the same drawing file assembly convention must be followed. This section describes the use of reference files, sheet files, Model and Layout Space.

1. Reference Files.

    a. Contain the subset of design elements and geometric components, with all content drawn and placed in Model Space. All reference files are to be drawn full scale 1’ = 1’ with pertinent annotation, text, and dimensions.

2. Sheet Files.

    a. Reference file attachments shall be included in Model Space except for the title block. The title block shall be attached in Layout Space.

3. Model Space.

    a. Annotation, text, and dimensions that are directly related to the elements in the reference files shall be placed in Model Space. Reference files are to be attached in Model Space.

4. Layout Space.

    a. Typical sheet items include north arrow, bar scales, match lines, benchmarks, revision clouds and deltas, sheet and project text, title block information, specific notes, profile street names, profile stationing, and any other annotation unique to each sheet.

3.2.03 DRAWING SCALE

3.2.03.A Draw key overall layouts to a minimum scale of 1" = 200'.

3.2.03.B Standard scales for plan and profile sheets are required on construction Drawings are as follows:

1. Major thoroughfares, streets with esplanades over 400 feet in length, or special intersections/situations.

    a. 1" = 20' Horizontal, 1" = 2' Vertical

2. Minimum standard scales for minor or residential single-family streets.

    a. 1" = 20' Horizontal, 1" = 2' Vertical

    b. 1" = 40' Horizontal, 1" = 4' Vertical

3.2.03.B.2 continued

c. 1" = 50' Horizontal, 1" = 5' Vertical

3. Larger scales may be used to show details of construction.

4. Single-banked plan and profile sheets are acceptable; double-banked plan and profile sheets are allowed such as off-site utility lines in undeveloped areas.

5. Details of Special Structures shall be drawn with vertical and horizontal scales equal to each other.

3.2.04 TITLE BLOCK

3.2.04.A Use latest edition of the title block issued by Capital Projects for private and City projects.

3.2.05 NORTH ARROW

3.2.05.A The approved City north arrow is on the symbols sheet found here: https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.2.05.B A north arrow is required on all sheets and should be oriented either toward the top or to the right.

3.2.05.C The requirement in 3.2.05.B is waived under the following conditions:

1. A storm water sewer, sanitary sewer, or large diameter water line with flow from east to west or from north to south.

2. A primary outfall drainage ditch with flow from east to west or from north to south.

3. Stationing is intended to start from the cardinal points of the compass and proceed in the direction of construction.

4. The north arrow can be down or to the left on a loop street.

3.2.06 GENERAL NOTES

3.2.06.A Privately Funded Projects.

1. General notes for privately funded projects can be found in the "CAD Tools and Templates" section located here: https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

2. These notes are not intended to be used on City funded projects.

3.2.06.B City Funded Projects.

1. General notes for City funded projects can be found in the “Capital Projects” section located here: https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

2. These notes shall only include third party notes. Any direction given to a contractor shall be handled through the use of construction specification to be accompanied by a unit price item if appropriate.

3.2.07 STATIONING

3.2.07.A Plan stationing must run from left to right, except for short streets or lines originating from a major intersection, where the full length can be shown on one sheet. Tic symbols shall be used to mark stations.

3.2.07.B Never commence stationing at 0+00. Acceptable start stations are 1+00 or 10+00.

3.2.07.C Every even X+00 station shall be annotated with station text and a tic mark.

3.2.07.D Every X+50 station shall only contain a tic mark.

3.2.08 MATCH LINES

3.2.08.A Match lines shall be located at each end of plan view, perpendicular to the design centerline and shall be labeled as to station, and matching sheet number.

3.2.08.B Match lines between plan and profile sheets shall not be placed or shown within cross street intersections including cross street Right-of-Way.

3.2.09 SURVEY REQUIREMENTS

3.2.09.A Show times on survey control or swing tie Drawings to City monuments, Control Points and Temporary Benchmarks. All construction Drawings shall be prepared in accordance with Chapter 2, Section 2.2.01.F, Construction Drawings.

3.2.09.B Monument ties must comply with the City of Houston Code of Ordinances Chapter 33, Article IV – City Surveys.

3.2.10 PLAN AND PROFILE

3.2.10.A Basic plan and profile sheets shall contain the following information:

3.2.10.A continued

1. Identify and label all existing and proposed lines in plan and profile view regardless of line type, including lot lines, property lines, plat record numbers, easements, Rights-of-Way, and Harris County Flood Control District outfalls.

2. Label each plan sheet as to street/easement widths, pavement widths, pavement thickness where applicable, type of roadway materials, curbs, intersection radii, curve data, stationing, existing utilities (type and location), and any other pertinent feature affecting design.

3. Easement labels must clearly identify the type of easement (i.e., dedicated water, dedicated wastewater, combined storm and wastewater easement, etc.). Label will identify the private utility easement owner if the information is obtainable.

4. Show utility lines 4 inches in diameter or larger within the Right-of-Way or construction easement in profile view. Show utility lines, regardless of size, in the plan view, including communication and fiber optic cables.

5. List on plans the typical aerial utility owners for power, telecommunication and other utility lines. List the name of the owner by location of the line on the pole, with the line closest to the top of the pole as the first listed, followed by the other aerial lines listed from highest to lowest.

6. Graphically show flow line elevations and direction of flow for existing ditches.

7. Label proposed top of curb grades except at railroad crossings. Centerline grades are acceptable only for paving without curb and gutters.

8. Show curb return elevations for turnouts in profile view.

9. Gutter elevations are required for vertical curves, where a railroad track is crossed.

10. For street reconstruction projects, show in profile the centerline elevation at the property line of existing driveways.

11. Show both existing and proposed station esplanade noses or the centerline of esplanade openings, including esplanade width.

12. The design of both roadways is required on paving sections with an esplanade.

13. Show in plan view station points of curvature (PCs), points of tangency (PTs), and radius returns. Show station radius returns and grade change points of inflection (PIs) with their respective elevations in profile view.

3.2.10.A continued

14. All existing and proposed utilities and pavement shall be on the same plan and profile sheet for a given section.

15. Plan view and profile view shall be on the same sheet as long as the entire proposed design within the scope of the project can be shown clearly and legibly (i.e., depth of all utilities can be graphically viewed).

16. Each plan and profile sheet shall have a benchmark elevation and description defined. Refer to Chapter 2 for further specification.

17. Show natural ground profiles as follows:

    a. For privately funded projects, centerline profiles are satisfactory except where a difference of 0.50 feet or more exists from one Right-of-Way or easement line to the other, in which case, dual profiles are required.

    b. For City funded projects, provide natural ground profiles for each Right-of-Way line. For projects with existing (and/or proposed) roadside ditches, provide ditch flowline in profile view. Also show and label all driveway culverts.

3.2.11 TELECOMMUNICATION REQUIREMENTS

3.2.11.A To ensure identification of utility conflicts, all utilities within the public Right-of-Way shall be shown on the Drawings when any on-ground or underground telecommunication facilities are proposed. For exceptions see article 3.2.11.B.

1. On-ground and underground telecommunication facilities include, but are not limited to, underground telecommunication lines, ground supported utility boxes, telecommunication facility support structures (e.g. utility poles, service poles, and cabinets) and foundations.

2. All utility lines located on both sides of the roadway must be shown regardless of the location of the proposed telecommunication line relative to the roadway.

3.2.11.B For projects where aerial telecommunication facilities are proposed exclusively on existing poles and are supported off-ground (e.g. utility boxes on existing poles, network nodes on existing poles):

1. It is not required to show existing underground utilities and their above grade features (e.g. fire hydrants, cabinets, etc.) on the plan view.

2. Profile view is not required.

3.2.11.C Aerial telecommunication lines, along with other aerial lines must be listed on Drawings according to 3.2.10.A. 5~~3.2.10.A.5~~.

3.2.11.D Drawings must conform to additional labeling requirements as defined in other chapters of this manual. This includes, but is not limited to, Chapter 6 and Chapter 7 requirements.

3.2.12 BORE HOLE REQUIREMENTS

3.2.12.A See Chapter 11 for project types that require geotechnical bore hole information in the Drawings, boring spacing and depth requirements. A bore hole layout along with the corresponding bore hole logs is to be included as part of the Drawings.

3.2.12.B The bore hole layout sheets shall contain the following information:

1. Project bore holes at the correct location and providing: bore hole number, station, offset, northing and easting. Station and offset provided should be determined from the project's design base line.
2. Bore hole number or identifier matching the geotechnical report.
3. Topographic survey and surveyed benchmark.
4. Design baseline.

3.2.12.C The bore hole log sheets shall contain the following information:

1. Project bore logs, arranged on sheet from left to right, in order of ascending stationing with 6 bore hole logs per sheet. Bore logs should match the project geotechnical report.

SECTION 3 - LEADERS AND DIMENSIONS

3.3.01 LEADERS AND DIMENSIONS

3.3.01.A Leaders shall use straight leader lines and closed, filled arrows.

3.3.01.B The leader style shall attach the leader landing to the top of the multi-line text.

3.3.01.C Leader lines shall be placed as close as possible to the object being identified.

3.3.01.D Leader lines in the same area shall be parallel whenever possible.

3.3.01.E Leader lines shall be avoided that are: horizontal or vertical. At the same angle as cross-hatching, at very small angles to the terminating surface, parallel to extension or dimension lines, curved, or crossed.

Table 3.1 - DIMENSION SETTINGS[1]

Dimension Setting	Value for Proposed	Value for Existing
Associative Dimensions	2”	2”
Extension line beyond dimension line	0.05”	0.05”
Extension line offset from object	0.05”	0.05”
Arrow Size	0.10”	0.08”
Dimension Text Style	RomanS	RomanS
Dimension Text Height	0.10”	0.08”
Dimension Primary Units	2 (Decimal)	2 (Decimal)
Dimension Precision	0.00	0.00

Note:
1. Dimension settings can be used as a general guide.

3.3.02 LETTERING

3.3.02.A Standard text height is 0.10” for most drawing annotations. A minimum height of 0.05” is acceptable when used for special purposes such as for symbols or stacked fractions. The standard text style shall use the upper-case RomanS font. Table 3.2 can be used as a general text property guide.

1. Text shall be in designated Model Space.

2. Text shall be placed readable from the bottom or right side of the page.

3. Text shall be justified top left, top right, or middle center as best applicable for each case.

4. Text strings shall not overlap one another.

3.3.02.A continued

5. Where necessary, place text strings away from the features and use a leader.

Table 3.2 – TEXT PROPERTIES

Existing/Proposed	**Text Style**	**Printed Height**	**Printed Width**
Proposed text and dimensions	RomanS	0.10”	1.0
Existing text and dimensions	RomanS	0.08”	1.0
Major title block text	RomanS	0.30”	1.0
Survey spot elevations	RomanS	0.08”	1.0
Sheet numbers, detail titles, section or detail call outs, match line labels, table and location map sub-titles, and column headings	RomanS	0.20”	1.0
Stacked fractions, symbols, small detail annotation	RomanS	0.05”	1.0
Cover sheet title	COH CIP Cover	0.70”	1.0
Cover sheet sub-titles	COH CIP Cover	0.40”	1.0

3.3.03 LINE WEIGHTS

3.3.03.A The “COH.ctb” plot configuration file included with the City drawings specifies plotted line weights. No modifications are to be made to this file.

1. Colors 1-9 and 20 have been reserved for unscreened elements such as proposed objects, annotations, text and dimensions in the “COH.ctb” file. The basic colors and corresponding weights can be located in Table 3.3.

2. With exception to colors reserved for color plotting for existing utilities, colors 11-248 can be used as needed for the described typical use and each designated weight is represented by various colors within this color rage.

3. Colors 249-254 have been reserved for screening, ranging from 80-30%, in descending value in the “COH.ctb” file

4. Refer to “COH Std Line Weights.pdf” for a visual representation of available colors and corresponding line weights. See SECTION 7 of this chapter for description and weblink to design aids.

5. Table 3.3 is based on the U.S. National CAD Standard (NCS) – V6, 2.0 line width guide and corresponds with colors 1-10 in the “COH.ctb” file.

6. Existing utilities shall be plotted in color according to “COH Std Line Weights.pdf”.

3.3.03.B The line weights shown in Table 3.3 are shown as a general guide. Some objects will need to be shown in a different line weight for clarity.

3.3.03.B continued

Table 3.3 – LINE WEIGHTS

Colors[1]	Thickness	MM	IN.	Typical Use
1	Fine	0.18	0.007	Hatch patterns, sheet trim lines
2, 3, 4	Thin	0.25	0.010	Table and section grid lines, construction details
8	Thin	0.25	0.010	Existing object lines and text
7, 9	Medium	0.35	0.0138	Proposed medium object lines, proposed text, existing Right-of-Way
5	Wide	0.50	0.020	Sheet and title block borders, sheet dividers, major title text, match line text, outlines, location map outlines, section lines, proposed object lines requiring special emphasis, proposed design lines and elements
6	Extra Wide	0.70	0.028	Proposed Right-of-Way
20	XX Wide	1.20	0.048	Drainage areas

Notes:
1. Basic colors are shown. Other pen table colors may be used to satisfy these requirements.

3.3.04 LINE TYPE

3.3.04.A Use Standard line types shown in the “COH Line Type.pdf”. See SECTION 7 of this chapter for description and weblink to design aids.

3.3.04.B Standard line type definitions are located in the “COH.lin” file provided by the City and can be downloaded at the following link: https://www.houstonpermittingcenter.org/media/3696/download.

3.3.05 LAYERS

3.3.05.A The layer standard is based on the drawing layer format by the U.S. National CAD Standard (NCS). The NCS format consists of four data fields (Discipline Designator, Major Group, and two Minor Groups), and a status field. Each field is separated by a dash for clarity. The Discipline Designator and Major Group fields are mandatory. The Minor Groups and Status field are optional.

	C	-	A	L	G	N	-	C	N	T	R	-	A	N	N	O	-	1

Discipline Designator (1-2 Letters) | Major Group (4 Letters) | Minor Group (4 Letters) | Minor Group (4 Letters) | Status Field (1 Letter)

Figure 3.1 – LAYER NAMING DIAGRAM

3.3.05.B Table 3.4, Table 3.5, and Table 3.6 are lists of common layer fields. Not all field codes are represented. Refer to the U.S. National CAD Standards (NCS)[1] for layer field codes of disciplines not defined in this section. Layers may be created to provide additional clarity to the data placed in a drawing. The guidelines above shall be observed when creating layers not listed in the NCS. Layer names shall not exceed 18 characters.

Table 3.4 – DISCIPLINE DESIGNATORS

Designator:	**Description of Discipline Designator:**
G	General
GR	General Record Drawings
V	Survey
VA	Aerial Survey
VF	Construction Field Survey
C	Civil
CD	Civil Demolition
CU	Civil Utilities
CP	Civil Paving
CT	Civil Transportation

Table 3.5 – MAJOR GROUP

Major Field:	**Description of Major Layer Field:**
ALGN	Alignments
ANNO	Sheet annotation
BLDG	Buildings and primary structures
BLIN	Baseline
BORE	Test borings
BRDG	Bridge
CABL	Cable
COMM	Communications
CTRL	Control Points
DETL	Details
DRIV	Driveways
ESMT	Easements
NGAS	Natural gas
PIPE	Pipes
PROP	Property
PVMT	Pavement
RAIL	Railway
ROAD	Roadways
RWAY	Right-of-Way
SIGL	Traffic signals
SSWR	Sanitary sewer
STRM	Storm sewer
WATR	Water supply
WETL	Wetlands

[1] https://www.nationalcadstandard.org/ncs6/

3.3.05.B
continued

Table 3.6 – MINOR GROUP

Minor Field:	Description of Minor Layer Field:
ANNO	Annotation
ASPH	Pavement: asphalt
CNTR	All: center lines
CONC	Pavement: concrete
DATM	Datum notes
DIMS	Dimensions
EDGE	Channels, major water bodies, ponds, creeks and rivers
FDPL	Flood plain
FIBR	Fiber optic
LABL	Annotation: labels
LEGN	Sheets: legends, symbols keys
NOTE	Sheets: notes
NRTH	Sheets: north arrows
POLE	Utilities: boxes / poles
ROAD	Pavement: roadways
SECT	Sections
TTLB	Sheets: border and title blocks
UTIL	Utilities

Table 3.7 – STATUS GROUP

Status Field:	Description of Status Field:
1	Phase 1
2	Phase 2
3	Phase 3
H	Horizontal (for profile grids)
V	Vertical (for profile grids)
F	Future work

SECTION 4 - ELECTRONIC DRAWINGS

3.4.01 ELECTRONIC PLAN REVIEW

3.4.01.A The process for registering the engineering firm with the iPermits Customer Portal for the Office of the City Engineer Plan Review, and the electronic plan review system is called ProjectDox. The electronic plan review process is broken down into 10 key steps. The process utilizes two systems: iPermits and ProjectDox. The iPermits Customer Portal is used to submit applications and to make payments. ProjectDox is used to upload Drawings, receive comments, and receive approvals. The step-by-step user guide can be found here:

~~https://www.houstonpermittingcenter.org/media/2296/download~~https://bit.ly/4cWK6yT

3.4.02 ELECTRONIC PLAN FILE NAMING

3.4.02.A File names are limited to 70 characters. Documents should be submitted in PDF format per the COH I-Permits and ProjectDox system requirements. File names should contain the sheet number, dash, and corresponding sheet title the following format: “### - XXXXXXX” add “00” to single digit page numbers to avoid the page jumping from 1, 11,12, etc. See Table 3.8 below for some examples of common sheet files and corresponding file name to be used.

Table 3.8 – FILE NAMING

Sheet Title	Sheet Number	File Name
Cover Sheet	01	001 – Cover Sheet
Sheet Index	02	002 – Sheet Index
Abbreviations	03	003 – Abbreviations
Symbols	04	004 – Symbols
General Notes	05	005 – General Notes
Overall Project Layout(s)	06	006 – Overall Project Layout(s)

SECTION 5 - REVISION PROCESS

3.5.01 REVISION PROCEEDURES

3.5.01.A Revisions required during the construction phase shall follow the revision process in this section. Revisions on plans are to be annotated and documented with the following guidelines:

1. First Revision Procedures.

   a. All changes in each sheet that are pertinent to each revision shall be enclosed in revision “clouds”.

   b. The number of the revision shall be placed inside of a triangle, commonly known as a “delta”.

   c. Each revision delta shall be placed adjacent to the corresponding revision cloud(s).

   d. It is acceptable to have multiple clouds with the same revision delta on a sheet if all changes apply to that revision.

   e. It is acceptable to cloud an entire plan view area with a single revision cloud and delta, when a significant portion within the cloud has been revised or when clouding each revised item becomes impractical.

   f. If an entire sheet is added to a plan set as a part of a revision, the sheet title and sheet number shall be clouded along with a delta.

   g. The sheet index for each plan set shall also reflect revisions with the outlined procedures.

2. Second (and Subsequent) Revisions Procedures.

   a. The revision cloud(s) from any previous revision(s) shall be removed from each sheet.

   b. The revision delta(s) from any previous revisions(s) shall remain in their original location on each sheet.

   c. All of the new changes to each sheet shall follow the revision procedures outlines in the above narrative.

3. Title Block / Cover Sheet Annotation Procedures.

   a. Each revision is to be documented on the title block area of each plan sheet or cover sheet, see Figure 3.2 for examples.

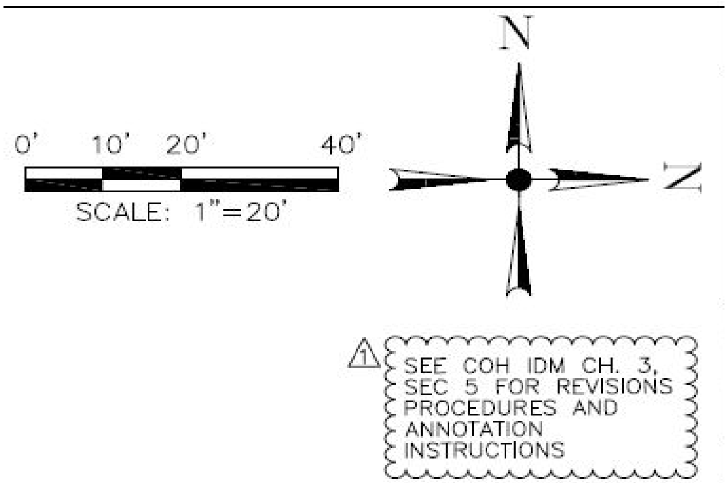
3.5.01.A.3 continued

b. All information is to be filled out, to include a brief description of the revision, starting from bottom to top or right to left.

c. Once the maximum amount of revision lines is completed, the oldest revision annotation will be removed to accommodate the newest current revision information.

d. The oldest revision information will be located at the bottom or right, with the current information located at the top or left.

3	MM/DD/YY	BRIEF DESCRIPTION	XXX
2	MM/DD/YY	BRIEF DESCRIPTION	XXX
1	MM/DD/YY	BRIEF DESCRIPTION	XXX
NO.	DATE	REVISION	APP.



3	2	1	NO.
MM/DD/YY	MM/DD/YY	MM/DD/YY	DATE
BRIEF DESCRIPTION	BRIEF DESCRIPTION	BRIEF DESCRIPTION	REVISION
XXX	XXX	XXX	APP.

Figure 3.2 – REVISION BLOCK EXAMPLES

SECTION 6 - EXAMPLE PLAN SET SHEETS

3.6.01 CAD STANDARDS APPLICABLE TO CITY AND PRIVATELY FUNDED PROJECTS

3.6.01.A Provide a cover sheet for projects involving three or more design Drawings (excluding City of Houston standard detail sheets).

3.6.01.B The example sheets in the following figures are to give the user an overall feel of how specific plans should appear and how they differ from each other. A few basic sample sheets are listed below and shown in this section:

1. Figure 3.3 - ABBREVIATONS~~Figure 3.3 - ABBREVIATONS~~

2. Figure 3.4 – LINETYPES, CELLS & STANDARD SYMBOLS~~Figure 3.4 – LINETYPES, CELLS & STANDARD SYMBOLS~~

3. Figure 3.5 – COH SHEET INDEX

4. Figure 3.6 – CAPITAL PROJECTS COVER SHEET

5. Figure 3.7 – NON- CAPITAL / PRIVATE PROJECTS COVER SHEET

6. Figure 3.8 – TELECOMMUNICATION COVER SHEET

7. Figure 3.9 – GENERAL NOTES

~~7.~~ Figure 3.10 – PLAN AND PROFILE

8. ~~Figure 3.10 – PLAN AND PROFILE~~

9. Figure 3.11 – BORE HOLE LAYOUT

10. Figure 3.12 – BORE HOLE LOGS

3.6.01.B
continued

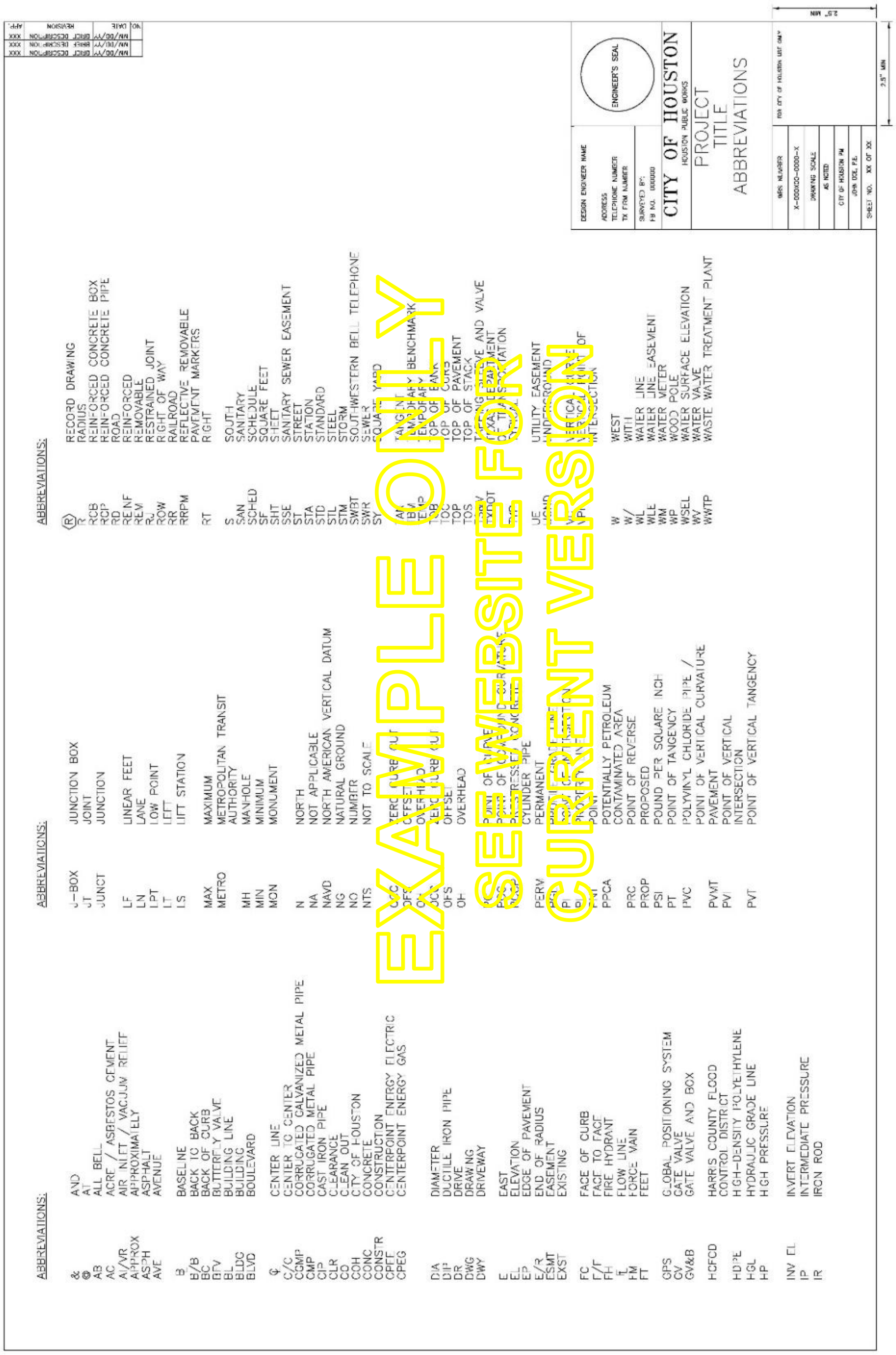


Figure 3.3 - ABBREVIATONS[2]

[2] For the most up to date sheet go to:
https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.6.01.B
continued

Figure 3.4 – LINETYPES, CELLS & STANDARD SYMBOLS[3]

[3] For the most up to date sheet go to:
https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.6.01.B
continued

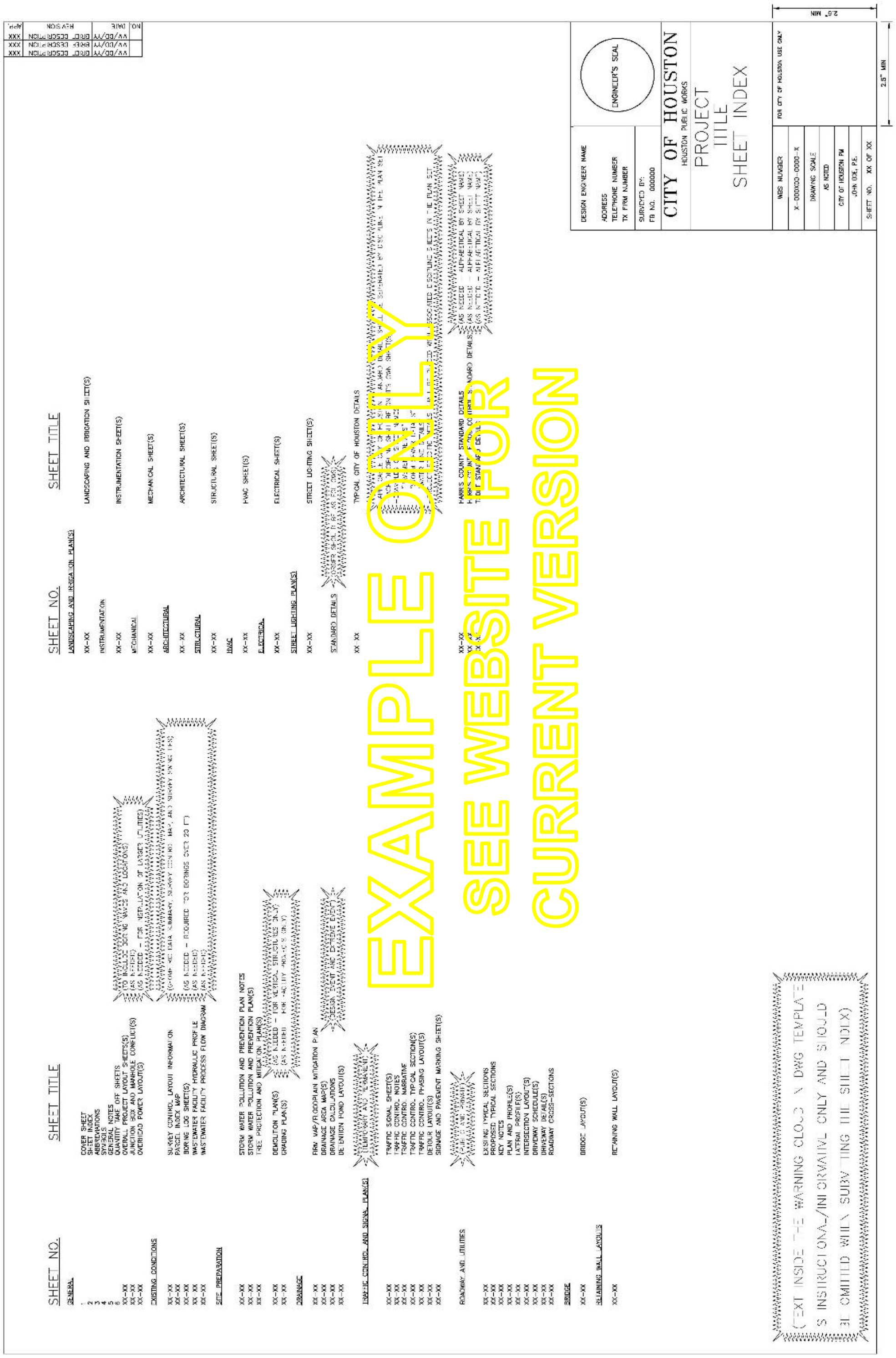


Figure 3.5 – COH SHEET INDEX[4]

[4] For the most up to date sheet go to: https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.6.01.B
continued

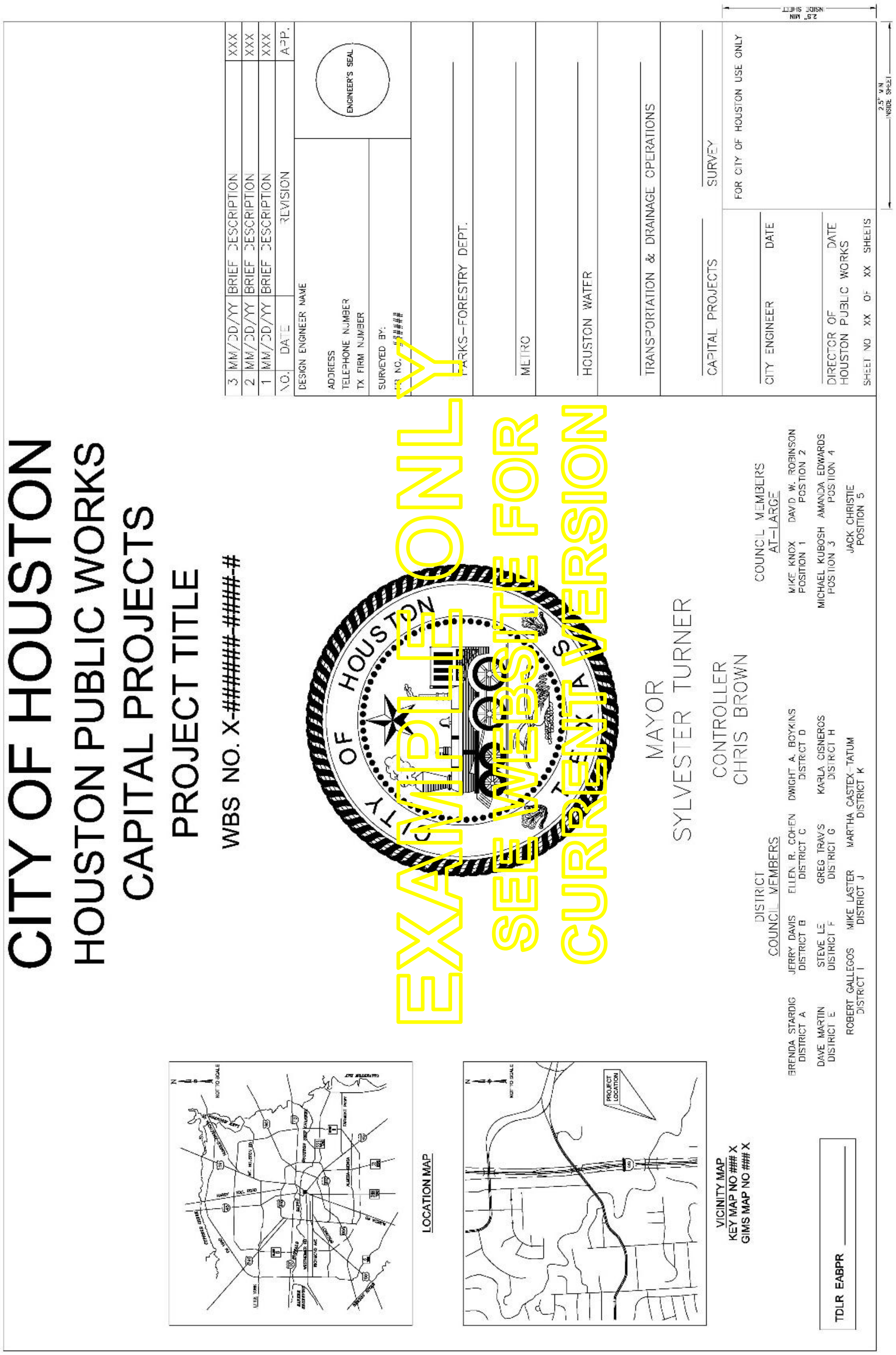


Figure 3.6 – CAPITAL PROJECTS COVER SHEET[5]

5 For the most up to date sheet go to https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.6.01.B
continued

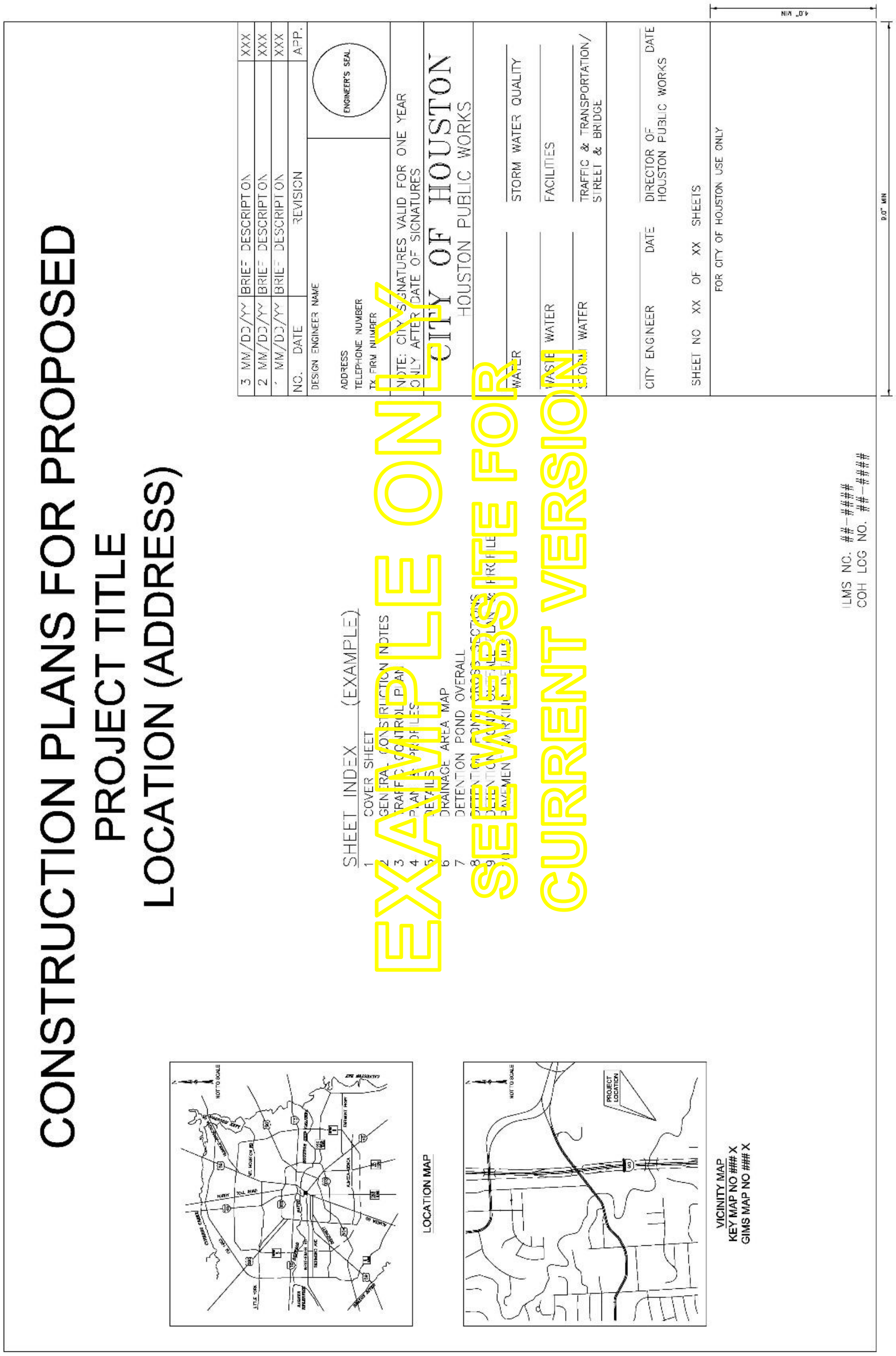


Figure 3.7 – NON- CAPITAL / PRIVATE PROJECTS COVER SHEET[6]

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[6] For the most up to date sheet go to:
https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.6.01.B
continued

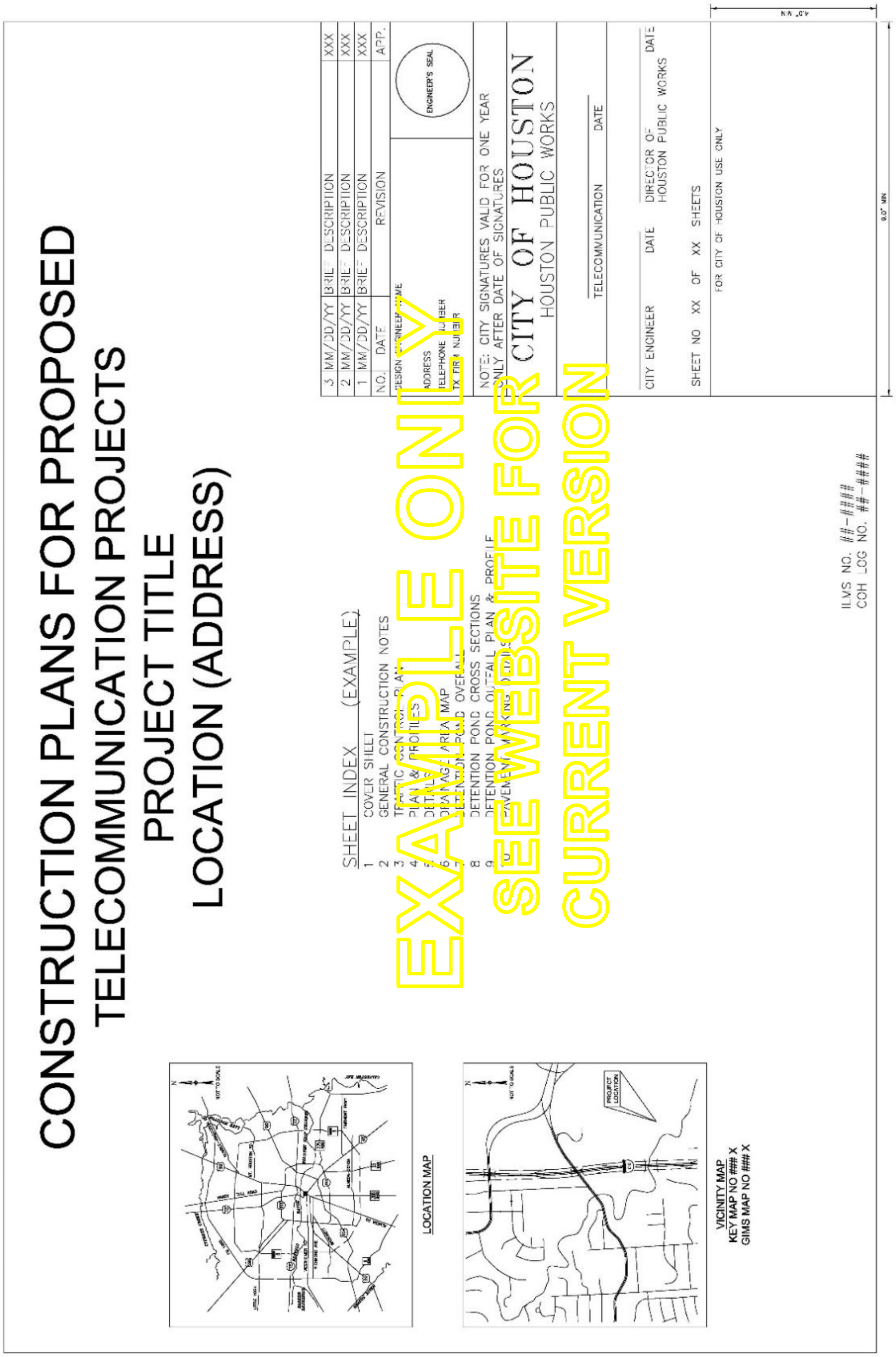


Figure 3.8 – TELECOMMUNICATION COVER SHEET[7]

[7] For the most up to date sheet go to:
https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.6.01.B
continued

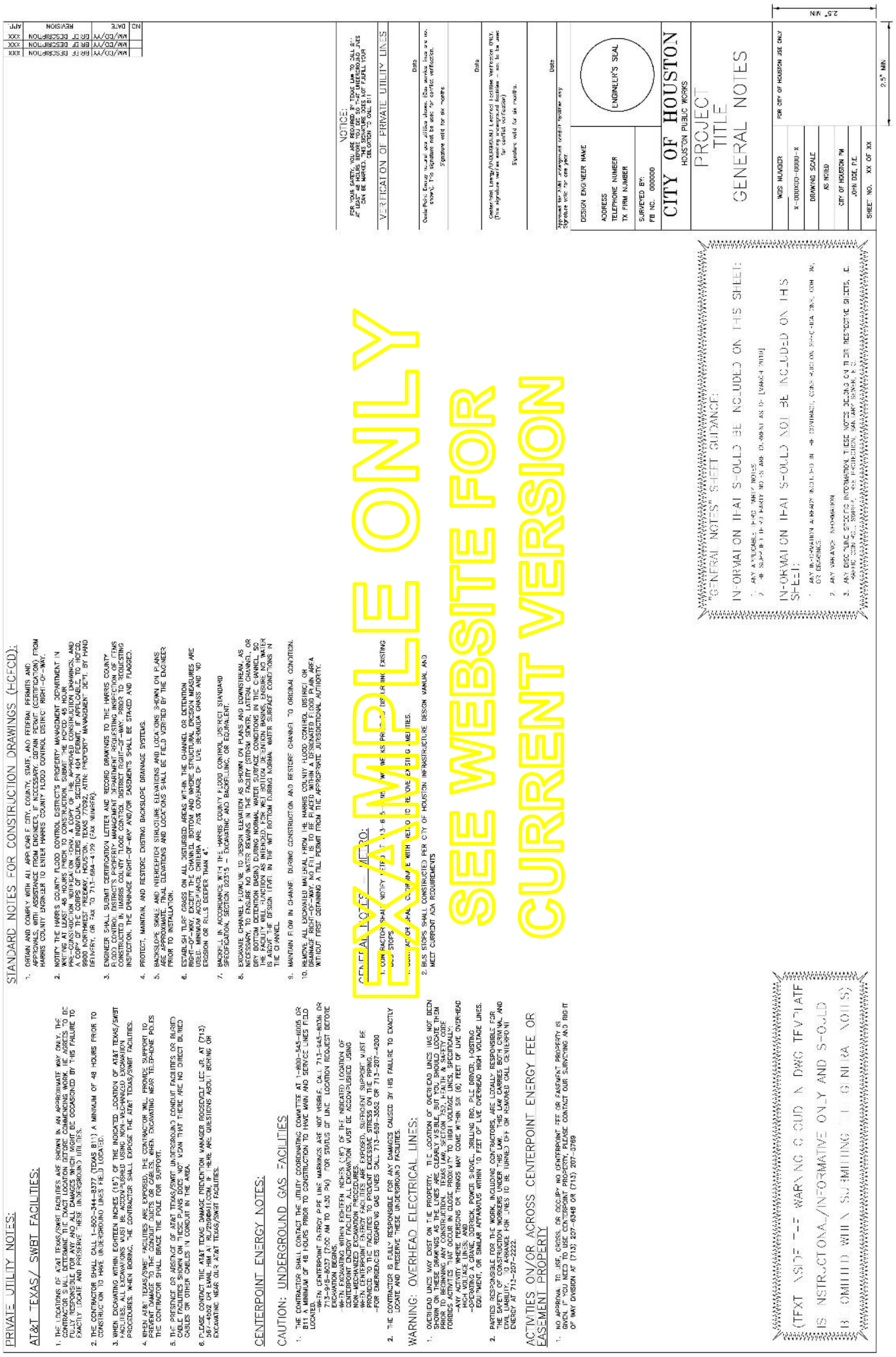


Figure 3.9 – GENERAL NOTES[8]

[8] For the most up to date sheet go to: https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.6.01.B
continued

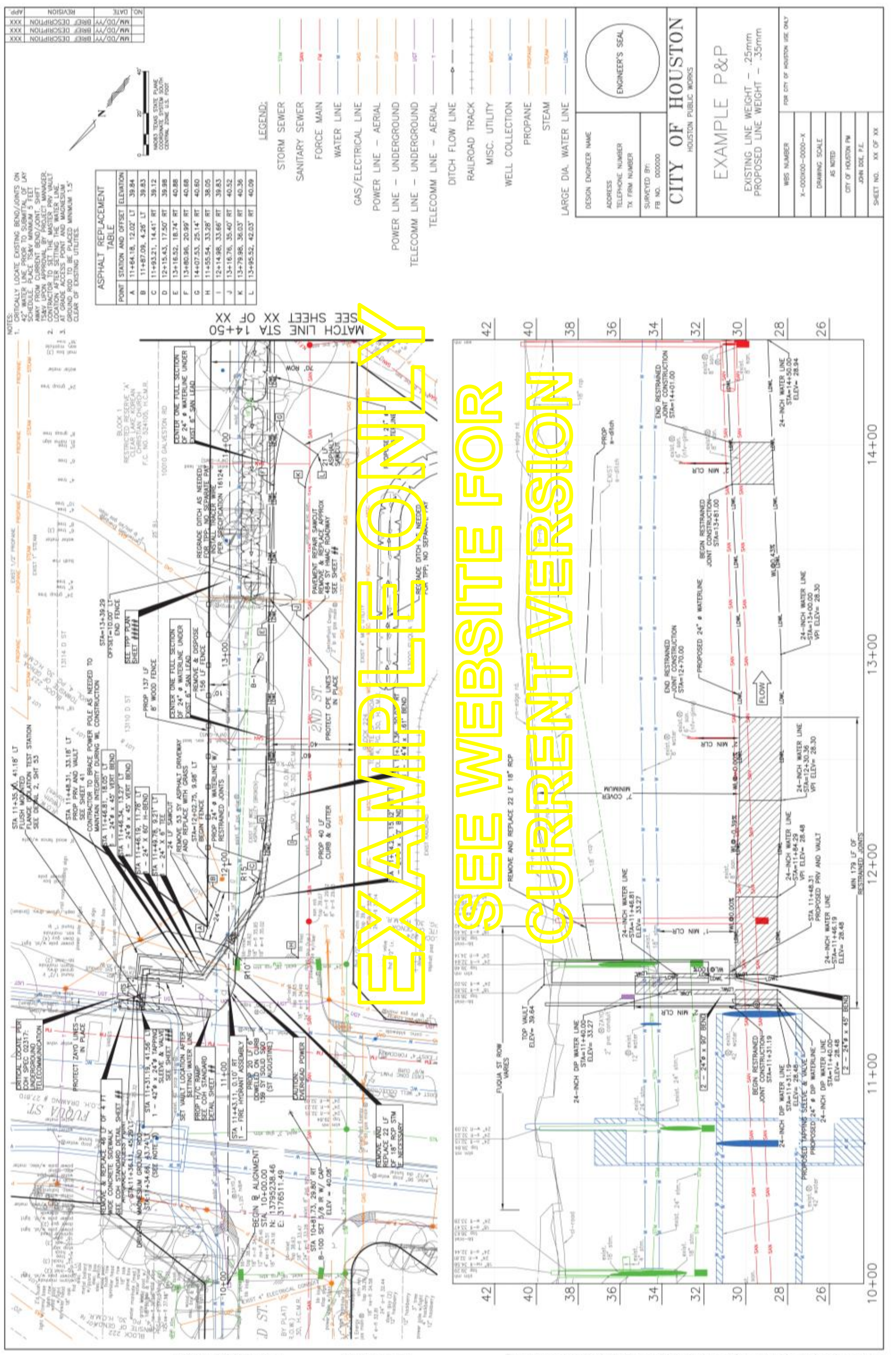


Figure 3.10 – PLAN AND PROFILE[9]

[9] For the most up to date sheet go to: https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

3.6.01.B
continued

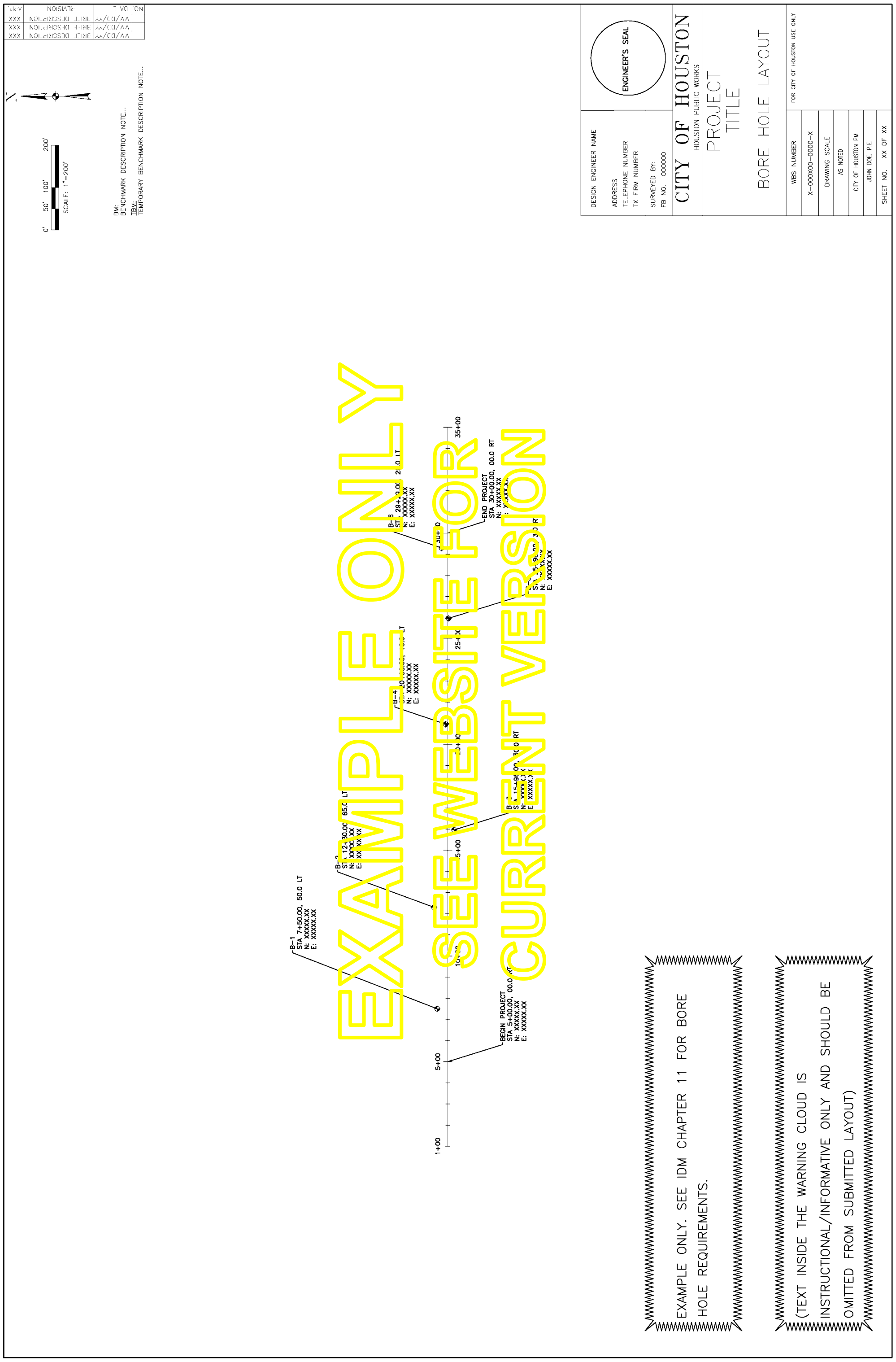


Figure 3.11 – BORE HOLE LAYOUT

3.6.01.B
continued

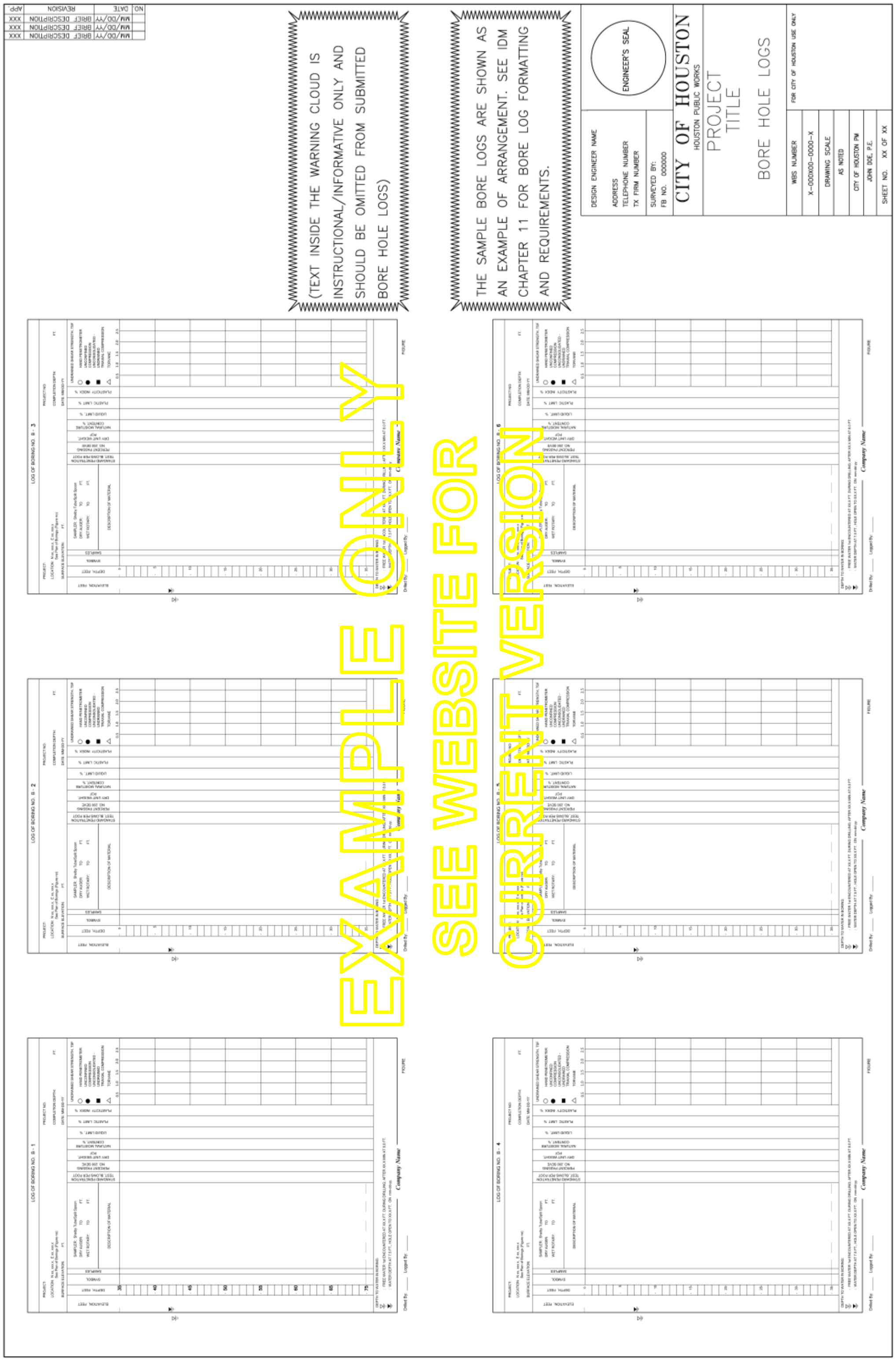


Figure 3.12 – BORE HOLE LOGS

SECTION 7 - RESOURCES

3.7.01 CAD TOOLS

3.7.01.A Listed below are the files that are provided by the City for use along with all the sections of Chapter 3. The files can be found here: https://www.houstonpermittingcenter.org/office-city-engineer/design-and-construction-standards

File Name	Description	File Type
1. COH	COH line types	.LIN
2. COH Line Types	COH line types	.PDF
3. COH	COH plot table	.CTB
4. COH Std Line Weights	COH standard line weights	.PDF
5. COH Drawing Template	COH drawing template	.DWT/PDF
6. COH Symbols	COH standard symbols	.DWG/PDF

3.7.01.B HELPFUL TEMPLATES

File Name	Description	File Type
1. coh_cp_title_block	COH standard title block	.DWG / .PDF
2. coh_cp_cover_sheet	COH standard Capital Projects cover sheet	.DWG / .PDF
3. coh_sheet_index	COH standard sheet index	.DWG / .PDF
4. coh_abbreviations	COH standard abbreviations	.DWG / .PDF
5. coh_symbol	COH standard symbols	.DWG / .PDF
6. coh_cp_general_notes	COH standard general notes	.DWG / .PDF
7. coh_non_cp_cover_sheet	Non-CP/private cover sheet	.DWG / .PDF
8. coh_non_cp_title_block	Non-CP/private title block	.DWG / .PDF
9. coh_telecomm_cover_sheet	Telecommunication cover sheet	.DWG / .PDF

END OF CHAPTER

City of Houston

Design Manual

Chapter 6

UTILITY LOCATIONS

Chapter 6
Table of Contents

Utility Locations

SECTIONS PAGE

Utility Locations List of Figures

Chapter 6

UTILITY LOCATIONS

SECTION 1 - UTLITY LOCATIONS OVERVIEW

6.1.01 CHAPTER INCLUDES

6.1.01.A Location of utilities in rights-of-way and easements.

6.1.02 REFERENCES

6.1.02.A Typical utility location in 10-foot-wide and 14-foot-wide easements in back-to-back lots and perimeter lots as detailed in the most current drawing prepared by the Uniform Color Code (UCC).

6.1.02.B Typical utility locations within City rights-of-way.

6.1.02.C ASCE. (2002, October). Standard guidelines for the collection and depiction of existing subsurface utility data. American Society of Civil Engineers.

6.1.03 DEFINITIONS

6.1.03.A Easements - Areas set aside for installation and maintenance of utilities by public and private utility companies.

6.1.03.B Private Utilities - Utilities belonging to, operated, and maintained by private entities.

6.1.03.C Public Utilities - Utilities belonging to, operated, and maintained by public entities

6.1.03.D Right-of-Way - Public property dedicated or deeded to a municipality for the purpose of public use.

6.1.03.E Storm Sewer Lines - Closed gravity (non-pressure) conduits designed to collect and transport storm water from inlet locations to an open conduit outfall, ditch, creek, stream, bayou, river, holding pond, or bay. Inlets are surface mounted basins designed to collect and funnel storm water to the collection system. Storm sewers from the inlets to the collection system are usually defined as inlet leads.

6.1.03.F Subsurface Utility Engineering (SUE) – A branch of engineering practice that involves managing certain risks associated with utility mapping at appropriate quality levels, utility coordination, utility relocation design and coordination, utility condition assessment, communication of utility data to concerned parties, utility relocation cost estimates, implementation of utility accommodation policies, and utility design[1].

6.1.03.G Type 1 Permanent Access Easement - A permanent access easement at least 50 - feet in width that is designed and constructed like a public street in accordance with the design manual and contains one or more public utilities in an unpaved portion of the easement. Refer to Chapter 42 of the Code of Ordinances.

6.1.03.H Water Lines - Closed conduits designed to distribute potable water for human consumption and to provide fire protection. Line size and fire protection accessory locations are dependent on distance from primary source and quantity demand.

6.1.03.I Wastewater Sewer Lines - Closed conduits designed to collect and transport wastewater from residential, commercial, and industrial sites to plants for treatment prior to discharge into open conduits. Wastewater lines may be designed as gravity (non-pressure) flow lines or force (pressure) mains. Gravity flow lines usually fall into three categories in ascending size from service line to lateral line to main line. Service lines (source of wastewater) may discharge into a lateral line or main line.

[1] Refer to paragraph 6.1.02.C (ASCE, 2002)

SECTION 2 - UTLITY LOCATION DESIGN REQUIREMENTS

6.2.01 DESIGN REQUIREMENTS

6.2.01.A Whenever practical, locate public storm sewer, wastewater collection lines, water mains, and appurtenances within public rights-of-way in the manner described by this and corresponding subject-specific chapters in this manual, as well as related details and specifications.

6.2.01.B Research and resolve known conflicts of proposed utilities with existing utilities according to subject-specific criteria developed by the utility owner(s).

6.2.01.C Locate back lot utilities in compliance with UCC recommendations.

6.2.01.D Identify all existing and proposed utilities and related appurtenances in the manner established by the subject-specific chapters in this manual.

6.2.01.E Conduct where appropriate, a subsurface utility exploration (SUE) to definitively locate potential utilities (public and private) that are in conflict with the project. Located utilities shall be shown on the plans as “location verified” with the quality level of SUE listed.

1. Levels of SUE as defined by ASCE 38-02[2]

   a. Utility quality level A:

      1) Precise horizontal and vertical location of utilities obtained by the actual exposure (or verification of previously explored and surveyed utilities) and subsequent measurement of subsurface utilities, usually at a specific point.

      2) Minimally intrusive excavation equipment, such as vacuum excavation, is typically used to minimize the potential for utility damage.

      3) A precise horizontal and vertical location, as well as other utility attributes, are shown on plan documents.

      4) Accuracy is typically set to 15-mm vertical, and to applicable horizontal survey and mapping accuracy as defined or expected by the project owner.

[2] Refer to paragraph 6.1.02.C (ASCE,2002)

6.2.01.E.1 continued

b. Utility quality level B – Information obtained through the application of appropriate surface geophysical methods, such as pipe and cable locators, terrain conductivity methods, metal detectors, and ground-penetrating radar, to determine the existence and approximate horizontal position of subsurface utilities. Quality level B data should be reproducible by surface geophysics at any point of their depiction. This information is surveyed to applicable tolerances defined by the project and reduced onto plan documents.

c. Utility quality level C – Information obtained by surveying and plotting visible above-ground utility features and by using professional judgment in correlation with this information to quality level D information.

d. Utility quality level D – Information derived from existing records or as-builts.

2. Level of SUE Required

a. ~~For private projects, if a quality level B, C, or D SUE indicates that the proposed utility has a horizontal or vertical clearance that is less than what is required in this manual, a quality level A SUE is required to confirm location of the existing utility. In the case that the proposed utility is parallel to the existing utility, then a quality level A SUE is required at intervals of every 500 feet within the limits where there is less than sufficient horizontal clearance as indicated by the quality level B, C or D SUE. A quality level A SUE must be provided in order to be granted a variance for utility clearance.~~For private projects, if a quality level C or D SUE indicates that the proposed utility has a horizontal or vertical clearance that is less than what is required in this manual for water lines or sanitary sewer force mains, a quality level B SUE is required to confirm location of the existing water line or force main. If a quality level B SUE cannot provide an accurate horizontal and/or vertical location of the water line or force main, a quality level A SUE is required. If a quality level A SUE is required and the proposed utility is parallel to the existing water line or force main, the quality level A SUE is required at intervals of every 500 feet within the limits where there is less than sufficient horizontal clearance as indicated by the quality level B, C or D SUE. A quality level A or B SUE must be provided in order to be granted a variance for utility clearance.

~~a.~~b. ~~For private projects in which underground trenchless construction will be performed, if a quality level C or D SUE indicates that the proposed utility will cross (above or below) an existing public utility with less than 10 feet of vertical clearance from exterior of the existing public utility to exterior of the proposed utility, a quality level A or B SUE is required to confirm the location of the existing public utility. If minimum clearances cannot be maintained, see article 6.2.01.E.2.a.~~For private projects in which underground trenchless construction will be performed, if a quality level C or D SUE indicates that the proposed utility will cross (above or below) an existing water line or sanitary sewer force main with less than 10 feet of vertical clearance from exterior of the existing water line or force main to exterior of the proposed utility, a quality level A or B SUE is required to confirm the location of the existing water line or force main. If minimum clearances cannot be maintained, see article 6.2.01.E.2.a.

~~b.~~c. At a minimum, a topographical survey equivalent to a quality level C SUE is required for every project in which excavation equal to or deeper than three (3) feet is performed and any other project in which the City requests a quality level C SUE. Driveway projects do not require a quality level C SUE.

6.2.02 SUBMITTALS

6.2.02.A Submittals are to be made according to the criteria established by the utility owner(s)

6.2.03 QUALITY ASSURANCE

6.2.03.A All existing utilities must be shown on project drawings. Sources of data include survey, record drawings, graphical information systems, and field visits. Field visits must be made to verify the project drawings accurately portray the existing conditions.

6.2.04 DESIGN

6.2.04.A Back Lot Utilities: Identify type of electrical service and select the appropriate width of the easement. For mixed overhead and underground service select the 14-foot-wide easement to provide versatility.

6.2.04.B Water Lines

6.2.04.C. continued

1. Water lines may be located within a public right-of-way, within a Type 1 permanent access easement with overlapping public utility easements, within a dedicated easement adjacent to and contiguous with the right-of-way, or within separate dedicated water line easements, to meet the requirements of this manual. Water lines and related appurtenances shall be as specified in the subject-specific chapter(s) in this manual, as well as related details and specifications.

2. Water lines shall not be located in combination easements without approval of Houston Public Works. Water line easements shall not be combined with wastewater sewer easements.

3. Water lines, with the exception of transmission lines, shall be located within the right-of-way between the property line and back of curb or in a dedicated easement adjacent to and contiguous with the right-of-way.

4. Water lines and fire hydrants shall not be located in State rights-of-way. Water lines and fire hydrants should be located outside of the right-of-way in a separate contiguous easement. Width of easements shall be as provided in Paragraph 5.2.04.C.1.e & 5.2.04.C.2 Existing interagency utility agreements between the City and the State within State rights-of-way may supersede this requirement. Agreements shall be provided upon request for review and applicability.

6.2.04.C Wastewater Lines

1. Wastewater lines shall be located in a public right-of-way, within a Type 1 permanent access easement with overlapping public utility easements or within a dedicated easement adjacent to the public right-of-way. Side lot easements may be used when required. Backlot easements shall not be utilized except in cases of pre-existing conditions and with approval of the City. Wastewater, force mains, and related appurtenances shall be as specified in the chapter (7, 8, and 9) in this manual, as well as related details and specifications.

2. Wastewater trunk or collector mains shall not be located inside lot easements without approval of the City.

3. Wastewater gravity sewer trunks, collector mains, and force mains shall be generally located on the opposite side of the right-of-way from the water main.

4. Wastewater force mains are generally located within the right-of-way between the property line and the back of curb, or in a dedicated easement adjacent and contiguous with the right-of-way.

5. When wastewater or force mains are parallel to the storm sewer, they shall not be constructed in the same theoretical trench widths.

6. Wastewater Sewer Lines shall not be located in State rights-of-way. Wastewater Sewer Lines should be located outside of the right-of-way in a separate contiguous easement. Width of easements shall be as provided in Paragraph 5.2.04.D.2 & 5.2.04.D.3 Existing interagency utility agreements between the City and the State within State rights-of-way may supersede this requirement. Agreements shall be provided upon request for review and applicability.

6.2.04.D Storm Water Lines

1. Storm water lines shall be located within public rights-of-way, within a Type 1 permanent access easement with overlapping public utility easements or approved easements. Approval of the location for storm water lines should be obtained from Houston Public Works prior to plan preparation.

2. Coordinate the proposed storm sewer alignment with water line location and future pavement widening.

6.2.04.E Private Utility Lines/Underground Structures

1. Proposed work, location, and placement of utilities shall be submitted to the Office of the City Engineer for review and permitting. A minimum separation distance of either three feet (or more as stated in other portions of this design manual and/or related specifications, standards, or details) of horizontal clearance when parallel, and two feet (or more as stated in other portions of this design manual and/or related specifications, standards, or details) vertical clearance when crossing, shall be maintained between the exterior of all private utilities and public utilities.

2. For other underground structures (e.g. foundations, footings, piers, posts, poles, etc.) that are greater than 3 feet deep, a minimum horizontal clearance of 5-feet shall be maintained between the exterior of private underground structures and public utilities.

~~2.~~3. Structures shall not be imbedded within sidewalks.

~~3.~~4. All proposed work must be coordinated with the City of Houston Capital Improvement Program.

6.2.04.E continued

~~4.~~5. Above-ground utility structures and appurtenances shall have a minimum of three feet of horizontal clearance from the right-of-way, unless approved by the City Engineer. Utility poles should be placed within two feet of the ROW line, unless approved by the City Engineer. These clearances do not apply to wireless service facilities: See Chapter 16. In no case shall above ground utility infrastructure from one utility entity be located within a clear distance of other infrastructure (retaining wall, exterior wall, trees, planters, light poles, traffic signals, other utility entity's infrastructure, etc.) that prevents use /
travel along the sidewalk's path by persons in wheelchairs.

SECTION 3 - UTILITY LINES ON CITY OF HOUSTON BRIDGES AND OTHER STRUCTURES

Utilities mounted to bridges that go over waterways that fall under the jurisdiction of the Army Corp of Engineers, must meet their requirements and are subject to their approval.

6.3.01 UTILITY LINES ON CITY BRIDGES OVERVIEW

6.3.01.A These criteria are not applicable when removing and replacing a utility in kind on a bridge structure.

6.3.01.B The following information is adapted from the Texas Department of Transportation Bridge Project Development Manual, Chapter 4: Advanced Planning, Section 4: Utility Attachments; March 2018 Edition.

6.3.01.C To every extent possible, do not attach utility lines to bridges and separation structures because the proliferation of such lines and their maintenance constitutes a hazard to traffic and complicates widening or repair. Attaching utility lines to a bridge structure can materially affect the structure, the safe operation of traffic, the efficiency of maintenance, and the overall appearance.

6.3.01.D Where other arrangements for a utility line to span an obstruction are not feasible, Houston Public Works may consider the attachment of such line to a bridge structure. Any exceptions that are permitted will be handled in accordance with the conditions set forth in Title 43 TAC, Section 21.35 and 21.37 (relating to utility structures) and other pertinent requirements contained therein. Each such attachment will be considered on an individual basis and permission to attach will not be considered as establishing a precedent for granting of subsequent requests for attachment.

6.3.01.E Written permission is required from TxDOT's Bridge Division Office for any utility attachments to on-system bridges. On-system bridges are Federal-Aid highway/roadway bridges. In addition, written permission is also required from the City of Houston (Houston Public Works – Street and Bridge Maintenance) for these any utility attachments to on-system bridges. The reason is that the City of Houston is a stakeholder in terms of taking over maintenance of the bridges, and these bridges, because they cross City of Houston water bodies, watersheds, roads, paths, etc. Permit requests to perform the attachment work to on-system bridges shall be submitted to Office of the City Engineer (see paragraph 6.3.06) as well as any other regulatory agency with jurisdiction.

6.3.01.F Written permission is required from Houston Public Works - Street and Bridge Maintenance for any utility attachments to off-system bridges within the City of Houston's jurisdiction. Off-system bridges are non-Federal-aid roadway bridges.

6.3.01.G Permit requests to perform the attachment work to off-system bridges shall be submitted to Office of the City Engineer (see paragraph 6.3.06).

6.3.01.H Considerations for allowing or rejecting attachment of utilities to bridges include, but are not limited to the following:

1. Painting of Steel Bridges: Utility attachments may limit the ability of Bridge Maintenance crews to sandblast (prep) and paint steel bridge components. Panting is critical in maintaining steel bridges and extending their useful service life.

2. Hazardous Liquid or Gas Utility Lines: Requests for such lines will be reviewed on a case by case basis. Shut off valves may be required on either side of the bridge.

3. Bridge Maintenance / Repair: Some bridge maintenance / repair work may require vertical displacement of the bridge deck. This work includes replacing bearing pads, repairing bridge columns, or other bridge repair work. Such displacements may damage rigid pipe utilities, used for transporting liquids or gas, or utility conduits, used for carrying cable utilities.

4. Added Cost: There may be added cost for incorporating utility attachment to a bridge. This cost may be comprised of design costs, material costs, construction costs, change orders, schedule delays, etc.

5. Proposed attachment details submitted by the utility owner and the impacts the details may have on the bridge/structure.

6.3.02 DECISION AND NOTIFICATION TO ALLOW ATTACHMENT

6.3.02.A If it is decided to allow utility attachment to a bridge, written permission (Letters of Decision or Issuance of No Objection) will be issued. The following terms and conditions are associated with allowing a utility line to be attached to a bridge or other structure: These terms are not an all-inclusive list, and additional site-specific additions may be required.

1. Maintenance of utility, including all conduit and attachment material for supporting the utility on the bridge (or other structure) shall be the responsibility and at the cost of the utility owner.

2. The City of Houston is not responsible for any damage or out-of-service losses associated with the utility, its conduit (if applicable), coatings, or attachment hardware resulting from any event, including but not limited to bridge repair and maintenance work, such as sand-blasting and painting, raising the deck to replace bearing pads, and any other bridge repair or maintenance activities.

6.3.02.A continued

3. Utility owner shall remove its utility line, conduit, and attachments at the request of the City of Houston at any time. This includes, but is not limited to, shut down, disruption of service, de-inventory / evacuating of a liquid or gas utility pipeline, inerting a flammable liquid or gas utility pipeline, swabbing / cleaning a hazardous liquid pipeline, and traffic control for work areas and potential dropped object zones above roadways. Timing may be immediate if required to protect public safety or the environment. Timing may be urgent for bridge maintenance work. Removal shall be at the expense of the utility owner.

4. The utility owner shall reimburse (pay) the City of Houston Public Works all costs realized by the city to review and facilitate the supported utility on a bridge. The costs may include engineering / design services costs, material costs, and construction costs for new bridges/structures in the design process (not yet existing or being reconstructed) or for a third-party engineering contractor(s) or supplier(s) to review attachment details for existing bridges. The utility owner will still be responsible for reimbursement (payment) of costs realized by the city to review and facilitate the utility attachment if the utility owner ultimately decides not to attach its utility to the bridge for any reason.

5. Utility owner will be responsible for all costs associated with installation and attachment of the utility. This includes, but is not limited to, installation of the utility into pre-existing or pre-installed conduits if available, condition assessment of pre-existing conduits, attachment hardware for supporting the utility, tie-ins, materials not pre-installed by the City of Houston, electrical isolation and grounding of the utility as applicable, removal of existing conduit and attachments that may be inadequate, damaged, or corroded, work to install new conduit and attachment hardware, development and implementation of traffic control plans for the work, and installation execution plans.

6. Permits are required for performing the actual work of attaching the utility. Permit requests for the work shall be submitted to Office of the City Engineer (see paragraph 6.3.06).

6.3.03 OVERALL DESIGN GUIDELINES

6.3.03.A All requests for attachments to an existing City of Houston bridge/structure must be submitted to the City's Bridge Maintenance Office.

6.3.03.B All requests for attachments to a new City of Houston bridge/structure in the design process (not yet existing or being reconstructed) must be submitted to Houston Public Works – Street and Bridge Maintenance, / Interagency Coordinator in consultation with the Bridge Maintenance Office. Requests should be submitted (and addressed) as early as possible in the design process to minimize the cost to the City of Houston in the form of design changes, schedule delay, and change orders.

6.3.03.C All new bridge structures should include conduit for future utilities, per TxDOT's current design standards.

6.3.03.D Attachment Locations

1. Recommended attachment locations are on the overhang, as close as possible to the outside beam, or behind the outside beam. Behind the outside beam is preferred.

2. Hanging lines on the outside of the beams is not aesthetically pleasing and may be subject to vandalism. Attachments to water crossing structures should be placed on the downstream side where exposure to high water is less likely.

3. Bridge attachments shall not be made to any bridge rail or rail hardware, including anchor bolts. Bridge rails are the most susceptible to damage caused by motor vehicles, and hence are not a suitable location for utility placement. This will reduce the risk of damage to the utility, and it will reduce the need to get the utility owner involved when bridge rail repair is performed.

4. Do not hang lines from the bottom of beams. This decreases freeboard (water crossings) and clearance (road crossings), and hence increases the likelihood of damage.

5. It may be beneficial to carry lines across an obstruction using a separate utility structure rather than an attachment to a City of Houston Public Works bridge / structure.

6.3.04 DESIGN GUIDELINES PER TYPE OF UTILITY

6.3.04.A Communication Lines

1. When it is impractical to carry a self-supporting communication line across a stream or other obstruction, Houston Public Works may permit the attachment of the line to its bridges. On existing bridges, Houston Public Works generally requires that the line be enclosed in conduits and located on structures such that it does not interfere with stream flow, traffic, or routine maintenance operations. When a request is made prior to construction of a bridge, suitable conduits will be provided in the structure if the utility company bears the cost of all additional work and materials involved.

6.3.04.B Gas or Fuel Utility Lines

1. No gas or liquid fuel lines may be attached to a bridge or grade separation structure without the specific permission from Houston Public Works. Note that attachment of US Department of Transportation (49 CFR 192 and 49 CFR 195) transmission pipelines and attachment of oil and gas production flowlines/pipelines to City of Houston bridges and other structures are strictly prohibited. Transmission pipelines and production flowlines/pipelines require their separate and dedicated ROW and bridge/crossing. The only exception is that consideration may be given to temporary water or saltwater pipelines (Paragraph 6.3.04.E). See paragraph 6.3.04.D regarding costs.

6.3.04.C Power Lines

1. Power lines are not permitted on bridges under any condition with the exception of low-voltage distribution lines where the cost of independent facilities to carry these lines would be prohibitive. For this requirement, low-voltage lines must carry 600 volts or less.

6.3.04.D Utility Pipelines

1. When a utility company requests permission to attach a pipeline to a proposed bridge prior to construction, and the added load is sufficient to require an increase in the strength of the structure or use of more costly materials or type of construction, the utility owner is required to pay for the increase in cost.

6.3.04.E Temporary Water Lines or Saltwater Pipelines

1. Temporary water lines are sometimes requested to be attached to bridges by companies in the oil and gas industry. If considered, special review and procedures will be required to assure that leaks during operation and an approved de-inventory, swabbing/cleaning/pigging, air-drying, and containment procedure(s) does not cause accelerated corrosion of the bridge/structure when a line is removed. See paragraph 6.3.04.D regarding costs.

6.3.05 REQUESTS TO ATTACH A UTILITY TO AN EXISTING BRIDGE

6.3.05.A All requests shall be sent to the Bridge Maintenance Office and each request may include the following as determined applicable by Bridge Maintenance Office:

1. Alternatives Study
2. Hydraulic Impact Analysis (stream analysis and/or scour analysis)
3. Stress analysis showing the effect of the added load on the structure.

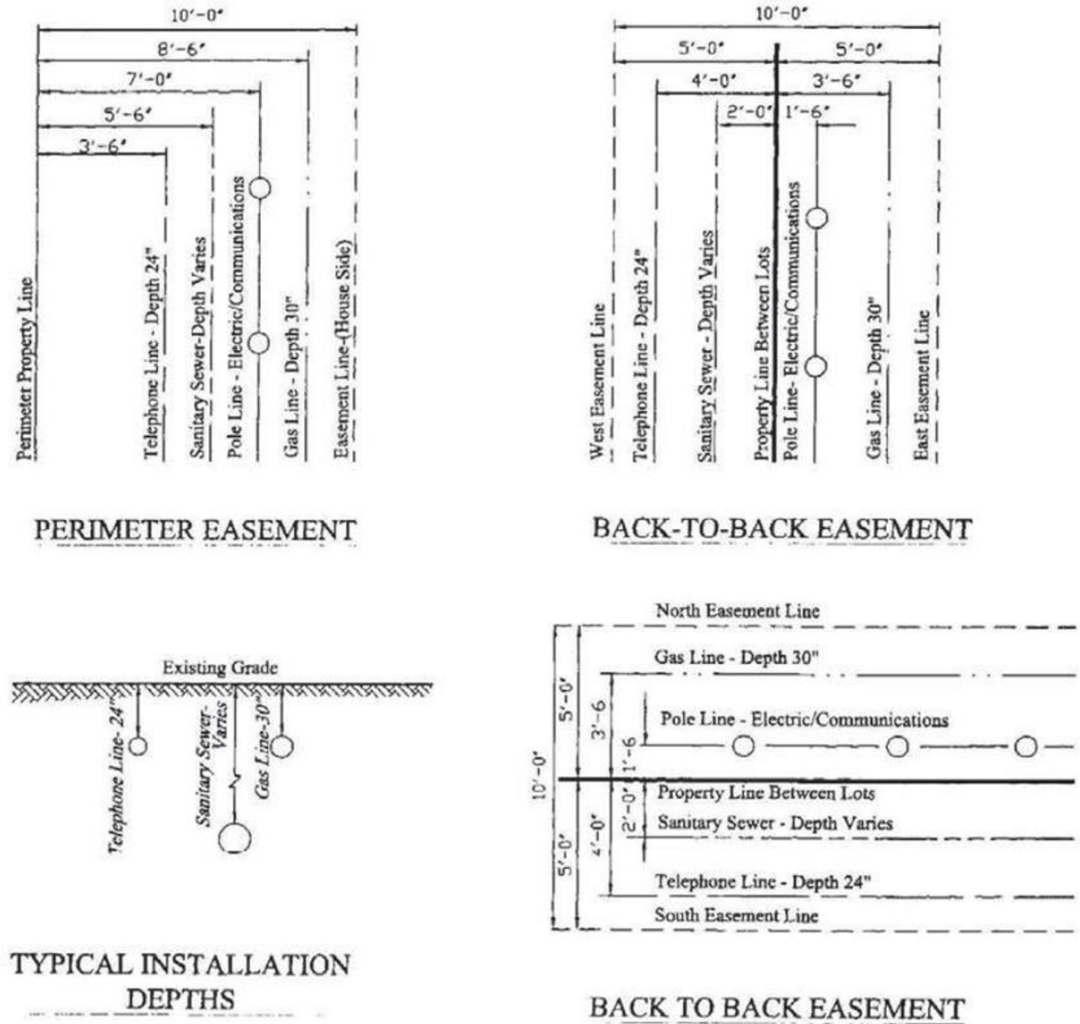
6.3.06 PERMITTING OF UTILITY WORK ON THE CITY OF HOUSTON BRIDGES

6.3.06.A All third-party utility work shall be submitted to the Office of the City Engineer for reviews and permitting.

6.3.06.B Plans shall:

1. Show proposed location of attachment
2. Show specific detail for the attachment
3. Identify materials
4. Traffic Control Plans, including staging, for all work areas
5. Traffic Control Plans, including staging for all dropped object zones for roads being crossed by a bridge on which utility attachment work is being conducted.
6. Installation execution plans
7. Provide Letters of Decision/Issuance of No Objection from the Bridge Maintenance Office for off-system bridges and written permission from TxDOT, with additional written permission from City of Houston Public Works for flammable or hazardous liquid utility pipelines, for on-system bridges.

END OF CHAPTER



NOTES:
(1) Utilities are normally installed as shown but depth may vary due to fill or cut by others.
(2) Maintain minimum 4" clearance between utility lines extending from easement to house/building.
(3) Flexible base shall be 8" minimum hot mix asphaltic concrete (hmac).

Figure 6.1 - TYPICAL UTILITY LOCATIONS IN 10-FOOT WIDE RESIDENTIAL EASEMENT

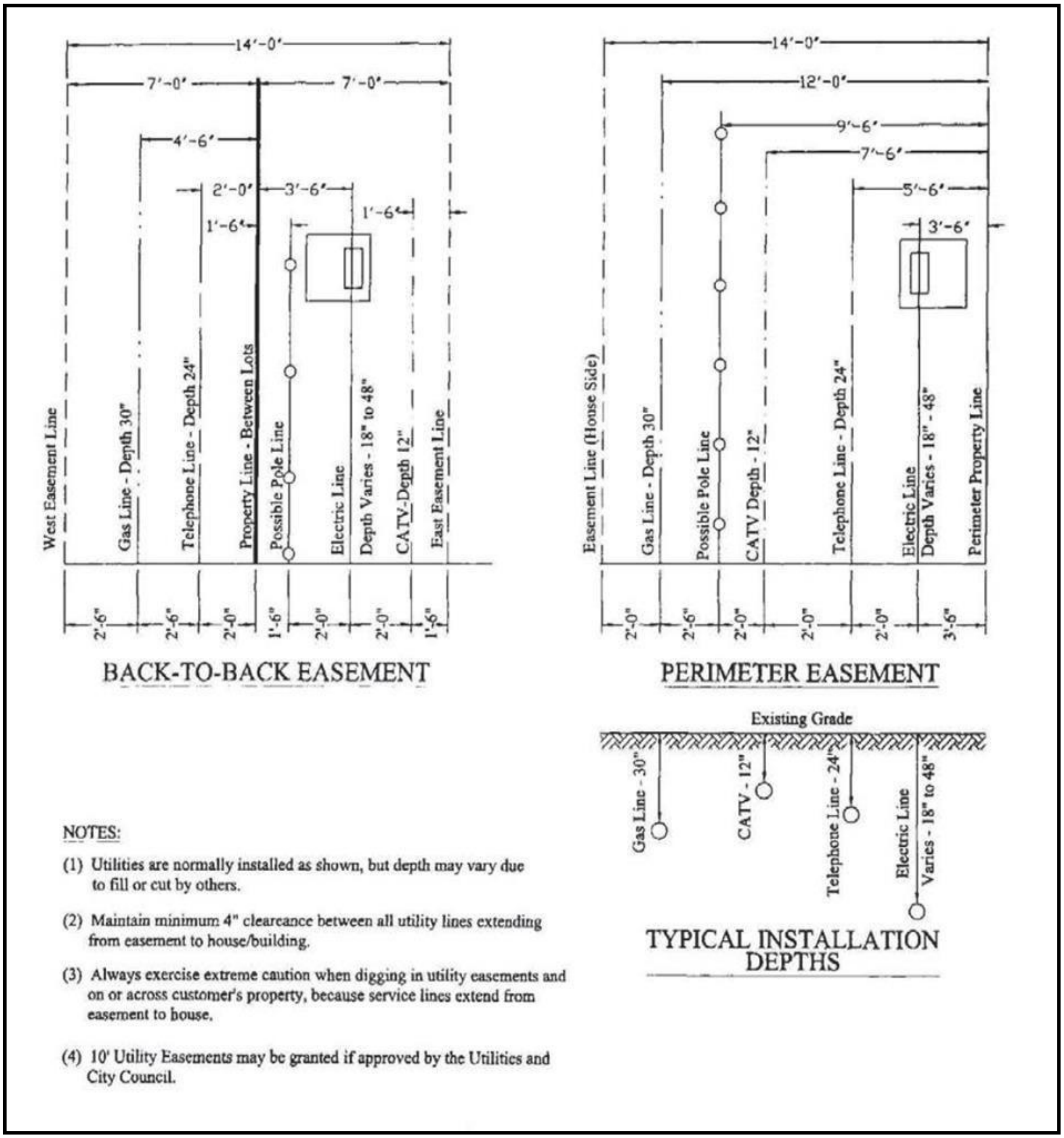


Figure 6.2 - TYPICAL UTILITY LOCATIONS IN 14-FOOT WIDE RESIDENTIAL EASEMENT (NO BACKLOT SEWER)

City of Houston

Design Manual

Chapter 9

STORMWATER DESIGN ~~AND WATER QUALITY~~ REQUIREMENTS

Chapter 9
Table of Contents

Stormwater Design Requirements

~~Stormwater~~ List of Tables

~~Stormwater~~ List of Figures

Chapter 9

STORMWATER DESIGN REQUIREMENTS

SECTION 1 – STORMWATER DESIGN OVERVIEW

9.1.01 CHAPTER INCLUDES

9.1.01.A Criteria for the design of storm drainage improvements.

9.1.01.B Criteria for the design of ~~S~~stormwater pollution prevention procedures and controls for construction activities.

9.1.01.C Criteria for the design of permanent ~~S~~stormwater pollution prevention facilities and controls to minimize impacts for ~~n~~New ~~d~~Development and decrease impacts for ~~r~~Redevelopment on tracts of land within the City of Houston ~~of one acre or more~~.

9.1.02 POLICY

9.1.02.A Design Requirements:

1. Drainage criteria administered by the City of Houston and complemented by Harris County and the Harris County Flood Control District (HCFCD) for newly designed areas provide~~s~~ protection from Structural Flooding from a 100-~~y~~Year storm event. This is accomplished through application of various drainage enhancements, such as storm sewers, roadside ditches, open channels, ~~d~~Detention and overland (sheet) run-off. The combined system is intended to prevent Structural Flooding from extreme events up to a 100-~~y~~Year storm.

2. Recognizing that each site has unique differences that can enhance the opportunity to provide proper drainage, the intent of these criteria is to specify minimum requirements that can be modified provided that the objective for drainage standards is maintained. For projects which require a site-specific approach and where unique engineering solutions will achieve drainage objective, a request for consideration of alternative standards (pipe flow, overland ~~s~~Sheet ~~f~~Flow, and ~~d~~Detention storage) shall be submitted to the City of Houston, Houston Public Works, Office of the City Engineer (1002 Washington), for review and approval.

9.1.02.B Ponding in streets and roadside ditches ~~of~~for short duration is anticipated and designed to contribute to the overall drainage capacity of the system. Storm sewers and roadside ditch ~~c~~Conduits should be designed considering a balance of capacity and economics. These ~~c~~Conduits should be designed to convey less intense, more frequent rainfalls with the intent of allowing for traffic movement during these events. When rainfall events exceed the capacity of the storm sewer system, the additional runoff is intended to be conveyed or stored overland in a manner that reduces the threat of ~~s~~Structural ~~f~~Flooding.

9.1.02.C Sheet Flow

1. All proposed New Development, Redevelopment, or Site Modifications shall not alter existing or natural ~~o~~Overland ~~f~~Flow patterns and shall not increase or redirect existing ~~s~~Sheet ~~f~~Flow to adjacent private or public property[1].

2. Where the existing ~~s~~Sheet F~~f~~low pattern is blocked by construction (i.e. raising the site elevation) of the ~~D~~development, the ~~s~~Sheet ~~f~~Flow shall be re-routed within the developed property to return flow to original configuration or to the public R.O.W.

~~1.~~3. Except under special circumstances dictated by natural or existing drainage patterns, no ~~s~~Sheet ~~f~~Flow from the developed property will be allowed to drain onto adjacent private property. No impact will be allowed onto adjacent property. The estimated volume of displaced ~~s~~Sheet ~~f~~Flow shall be calculated, and the rerouted flow pattern shall have adequate volume to provide that adjacent property is not impacted by the development.

4. Sheet Flow from the developed property will be allowed to drain (via Sheet Flow) into the adjacent R.O.W. for Single Family Residential (SFR) developments for cases defined in Articles 9.2.01.C.4.b.(2).(a) and 9.2.01.C.4.b.(3).(a).[1], and meet the other requirements in 9.1.02.C.

~~2.~~5. With exception to article 9.1.02.C.4, ~~N~~no ~~s~~Sheet ~~f~~Flow from the developed property will be allowed to drain (via ~~s~~Sheet ~~f~~Flow) ~~o~~into the adjacent R.O.W. Any increased quantity discharge should only be discharged to the R.O.W. at the approved point of connection (which have enough capacity to handle the discharged) via a subsurface internal

[1] Texas Water Code 11.086 – Overflow Caused by Diversion of Water
(a) No person may divert or impound the natural flow of surface waters in this state, or permit a diversion or impounding by him to continue, in a manner that damages the property of another by the overflow of the water diverted or impounded.

drainage system.

9.1.02.D The City is a participant in the National Flood Insurance Program (NFIP). The flood insurance program makes insurance available at low cost where the municipal entity implements measures that reduce the likelihood of ~~s~~Structural ~~f~~Flooding. The design criteria in this chapter are provided to support the NFIP. All development located within the City limits shall comply with Chapter 19, Floodplain, of the Code of Ordinances.

9.1.02.E Approval of storm drainage is a part of the review process for planning and platting of a New Development, site plan review process for Redevelopments, and the permitting process for Site Modifications. Review and approval of plats is conducted by the Department of Planning and Development. Review of storm drainage is conducted by Houston Public Works.

9.1.02.F Joint Project Funding

1. The City will consider joint project funding with a private entity for construction of drainage systems that improve existing drainage infrastructure. The City's first priority will be to fund those projects included in the Capital Improvement Plan (CIP).

2. Where feasible, City funding will be leveraged with other funding sources including private entities, civic organizations, and other public agencies (Harris County, HCFCD, Corps of Engineers, Housing and Community Development, and other funding sources).

3. For drainage systems that have been identified as deficient and are not scheduled to receive funding in the current CIP, the City will consider authorizing improvements performed by the private entity which comply with the City's objectives and may be a candidate for a Developer Participation Contract (DPC)[2] contract as described in Code of Ordinances, Article IV - Section 47-164.

[2] Refer to City of Houston Infrastructure Development Services, Developers Participation Contract webpage for more information: https://www.houstonpermittingcenter.org/infrastructure-development-services/developer-participation-contracts - agency-links-2576

9.1.02.G The criteria in this ~~C~~chapter apply to all projects located in the City limits and to expanding utility districts and new utility districts located in the City's Extraterritorial Jurisdiction (ETJ). ~~If the criteria conflicts with Harris County, HCFCD, Fort Bend County, Montgomery County or other jurisdictions, the criteria of the jurisdiction that is directly receiving the storm water shall govern~~ However for Detention facilities and their Outfalls that directly discharge to other jurisdictions, the criteria of the receiving jurisdiction shall govern. The receiving jurisdiction's review and approval is required.

9.1.02.H Property owners and public agencies are responsible for not adversely impacting the community, neighbors, future property owners, or City facilities in terms of flood risks, erosion, ~~i~~Infiltration and siltation.

9.1.02.I Projects shall meet the standards of this chapter. The Office of the City Engineer (OCE) may grant exceptions or deviations from these requirements on a project-by-project basis.

9.1.02.J Unless an exception or credit is allowed in other articles in this chapter, any proposed impervious area will require Detention. Detention rate is defined in Section 9.2.01.H.

~~9.1.02.F~~9.1.02.K For a Low Impact Development (LID) technique to be considered as pervious, the infiltration rate shall be greater or equal to 0.5 inches per hour and shall be confirmed by an Infiltration test report. See SECTION 6 for LID requirements.

9.1.03 REFERENCES

9.1.03.H continued

9.1.03.A 40 CFR 122 - EPA Administered Permit Programs: The National Pollutant Discharge Elimination System.

~~9.1.03.A~~9.1.03.B AASHTO LRFD Bridge Construction Specifications, 4th Edition, 2017.

9.1.03.C AASHTO LRFD Bridge Design Specifications, 10th Edition, 2024.

9.1.03.D A Guide to Developing and Maintaining Low Impact Development Techniques in Houston, Current Edition.

~~ASCE Manual and Reports of Engineering Practice No. 77, Design and Construction of Urban Stormwater Management Systems, Current Edition~~

9.1.03.E ASCE Standard Reference Number 7, Minimum Design Loads for Buildings and Other Structures.

9.1.03.F ASTM C33 - Standard Specification for Concrete Aggregates.

9.1.03.G Atlas 14 – Refer to 2019 Harris County Flood Control District (HCFCD) Policy Criteria and Procedures Manual (PCPM).

9.1.03.H City of Houston, Code of Ordinances:

1. Chapter 19 – Floodplain.
2. Chapter 42 – Subdivisions, Developments and Platting.
   a. Article I – In General.
   b. Article II – Requirements and Procedures.
3. Chapter 47 – Water and Sewers.
   a. Article IV – Development and Utility System Extensions.
   ~~a.~~b. Article XII ~~of Chapter 47 Water and Sewers of the City of Houston Code of Ordinances~~ – Storm Water Discharges.
   ~~b.~~c. Article XV – Drainage Impact Fees.

9.1.03.I City of Houston, Comprehensive Drainage Plan (CDP) and Houston Stormwater Master Plan (SWMP).

9.1.03.J City of Houston, Infrastructure Design Manual.

~~2.~~1. ~~Refer to the list of references in~~ Chapter 1, General Requirements – Refer to list of references.

2. Chapter 2, Survey Requirements.

3. Chapter 5, Easement Requirements.

4. Chapter 10, Street Paving Design Requirements.

5. Chapter 13, Geospatial Data Deliverables.

~~9.1.03.B~~9.1.03.K City of Houston, Standard Details and Working Drawings.

9.1.03.L City of Houston, Standard Specifications.

9.1.03.M Clean Water Act (CWA) – Refer to City of Houston Ordinance Section 47-601.

~~9.1.03.C~~9.1.03.N FHWA-HIF-13-006, Tech Brief: Pervious Concrete.

9.1.03.O FHWA-HIF-15-009, Tech Brief: Porous Asphalt Pavements with Stone Reservoirs.

9.1.03.P Handbook of Hydraulics, Brater and King.

9.1.03.Q Harris County Flood Control District (HCFCD) Policy, Criteria, and Procedures Manual (~~HCFCD Criteria Manual~~PCPM), ~~C~~current ~~E~~edition[3]. ~~https://www.hcfcd.org/~~

9.1.03.R Harris County Flood Control District (HCFCD), Hydrology and Hydraulics Guidance Manual, current edition.

~~9.1.03.D Hydraulic Engineering Circular No. 22, (HEC-22), Current Edition, "Urban Drainage Design Manual", Federal Highway Administration (FHWA).~~

~~9.1.03.E~~9.1.03.S International Building Code (IBC), edition with local amendments adopted by the City of Houston[4].

[3] https://www.hcfcd.org/Resources/Technical-Manuals/2019-Atlas-14-Policy-Criteria-and-Procedures-Manual-PCPM
[4] Refer to weblink for City requirements: https://www.houstonpermittingcenter.org/building-code-enforcement/code-development - agency-links-416

~~9.1.03.F~~9.1.03.T Minimum Design Criteria (MDC) for Implementation of Certain Best Management Practices for Stormwater Runoff Treatment Options, 2001 edition[5]~~, City of Houston~~.

~~9.1.03.G~~9.1.03.U Minnesota Department of Transportation, Technical Memorandum No, 22-04-B-02, Use of Plastic Pipe for Storm Sewer and Culverts on Trunk Highways, 2022.[6]

~~9.1.03.H~~9.1.03.V National Weather Service Documents:

~~TP-40 Rainfall Frequency Atlas of the United States.~~

~~Hydro-35; 5-to-60-Minute Precipitation Duration for the Eastern and Central United States.~~

~~3.~~1. National Oceanic and Atmospheric Administration (NOAA) - Atlas - Precipitation - Frequency Atlas of the United States (Texas) – ~~C~~current ~~E~~edition.

~~4.~~2. TP-100 Storm Sewer Design Applications.

3. TP-101 Guidelines for Consideration of Overland Flow for the Extreme Event for Improvement Projects in the City of Houston, Harris County, Texas Region.

9.1.03.W ~~HouStorm - The City of Houston's version of The Texas Department of Transportation's (TxDOT) software. The program is available from the City.~~Native Plant Society of Texas Houston Chapter, Native Plant Guide.

9.1.03.X Regulations of Harris County, Texas for the Construction of Driveways and/or Culverts on County Easements and Right-Of-Ways, 2005.

~~9.1.03.I~~9.1.03.Y Stormwater Management Handbook for Construction Activities, City of Houston, Harris County, Harris County Flood Control District, 2006 or ~~C~~current ~~E~~edition.[7]

~~9.1.03.J~~9.1.03.Z Stormwater Quality Management Guidance Manual (SWQGM), City of Houston, Harris County, Harris County Flood Control District, 2001 or current edition.[8]

[5] https://www.eng.hctx.net/Portals/23/Publications/criteria_2001_edition.pdf
[6] https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=17917826
[7] https://www.cleanwaterways.org/Portals/73/downloads/professional/construction_handbook_full.pdf
[8] https://www.cleanwaterways.org/Portals/73/downloads/professional/guidance_manual_full.pdf

9.1.03.AA Texas Department of Transportation ~~. (2011).~~ Hydraulic Design, Manual, current edition.

9.1.03.BB Texas Department of Transportation, Structural Design Considerations for Specifying Thermoplastic Pipe, 2023.[9]

~~9.1.03.K~~9.1.03.CC Texas Pollutant Discharge Elimination System (TPDES) General Permit No. TXR150000 (known as the Construction Stormwater General Permit)

9.1.03.DD Texas Water Code 11.086.

~~9.1.03.L~~9.1.03.EE Uniform Plumbing Code, latest edition with local amendments adopted by the City of Houston[10].

9.1.04 DEFINITIONS AND ACRONYMS

9.1.04.A Aggregate - Materials used to strengthen the overall composite material for constructing stormwater infrastructure. An example would be rounded riverbed gravel.

~~9.1.03.M~~9.1.04.B Applicant - The owner of the land on which the ~~n~~New ~~d~~Development or ~~s~~Significant ~~r~~Redevelopment will occur, or authorized agent.

[9] https://ftp.txdot.gov/pub/txdot/brg/specifying-thermoplastic-pipes.pdf
[10] Refer to weblink for City requirements: https://www.houstonpermittingcenter.org/building-code-enforcement/code-development - agency-links-416

9.1.04.C ~~Best Management Practice (BMP) - Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. Stormwater management BMP to control or abate the discharge of pollutants when authorized under section 402(p) of the Clean Water Act (CWA) for the control of Stormwater discharges. Best Management Practices (BMP) - A number of Stormwater structural and non-structural control strategies that have become the national focus for the mitigation of Stormwater pollution. BMP types include ponds, Bioretention facilities, Infiltration trenches, grass swales, and filter strips (Ref EPA.gov- TMDL 2007).~~Best Management Practices (BMP) – Devices, practices, or methods that are used to manage stormwater runoff by controlling peak runoff rate, improving water quality, and managing runoff volume. BMPs can be categorized into different types such as storage practices, vegetative practices, pollution prevention, and Low Impact Development.[11]

9.1.04.D Bioretention/Biofiltration – Stormwater quality management facility that retains runoff in a shallow basin, usually less than 18 inches in depth and provides Infiltration of runoff through designed soil media to filter pollutants. Bioretention basins can be landscaped to be an attractive site amenity. Rain gardens are a form of Bioretention.

9.1.04.E Blue Roof – Temporary capture and Detention of rainwater on a building roof, capable of accommodating extra rain load. Rainwater can be slowly released, evaporated or used for non-potable activities (irrigation, toilet flushing).

9.1.04.F Central Business District (CBD) - The area of downtown Houston as defined in the City of Houston Code of Ordinances, Chapter 42 - Subdivisions, Developments & Platting, Article I, Sec. 42-1.

~~9.1.03.N~~9.1.04.G Conduit – Any open or closed device for conveying flowing water examples, culverts, ditches, and storm sewers.

[11]International Stormwater Best Management Practices (BMP) Database, www.bmpdatabase.org

9.1.04.H Constructed Wetland Basin – Series of engineered and constructed shallow basins and ponds that are based on the ecological function of natural wetlands. These facilities create growing conditions suitable for wetland and marsh plants while providing runoff storage to provide water quality and flood reduction benefits. Constructed wetlands provide physical, chemical, and biological water quality treatment of stormwater runoff. Natural wetlands are more or less self-maintaining systems; whereas, constructed wetlands for storm water treatment purposes require active management.

~~9.1.03.O~~9.1.04.I Critical Elevation – The maximum ~~h~~Hydraulic ~~g~~Grade ~~l~~Line elevation a system is allowed to exhibit when conveying the design rainfall. This elevation is related to the ~~l~~Level of ~~s~~Service of the primary system.

~~9.1.03.P~~9.1.04.J Design Ponding Depth – The depth of water adjacent to an inlet during the ~~d~~Design ~~r~~Rainfall ~~e~~Event. Depth is measured from the bottom of the inlet opening for curb opening or from the top of the grate openings. This depth is used in inlet capacity calculations.

~~9.1.03.Q~~9.1.04.K Design Rainfall Event – Rainfall intensity upon which the drainage facility will be sized.

9.1.04.L Detention – ~~A feature meant to collect a site's stormwater and slowly release it at a control rate to not significantly impact downstream areas.~~ A technique of temporarily storing stormwater in an area to reduce the stormwater runoff discharge rate from a site.

~~Development - (i) any activity that requires a subdivision plat or development plat pursuant to Code of Ordinances Chapter 42; (ii) the further subdivision of any reserve tract that is part of a subdivision plat approved by the city planning commission or pursuant to Article II of Chapter 42, the Code of Ordinances; or (iii) any activity that requires a construction permit. The term includes New Development and Redevelopment.Development - (i) Any activity that requires a subdivision plat or development plat pursuant to Chapter 42 of this Code; (ii) the further subdivision of any reserve tract that is part of a subdivision plat approved by the city planning commission or pursuant to article II of Chapter 42 of this Code; or (iii) any activity that requires a construction permit.~~

~~Disturbed Area - means the existing surface has been altered by activity including, but not limited to, clearing, grubbing, demolition, grading, excavating and construction related activity (e.g. equipment staging, stockpiling of fill material and material storage areas), and construction support activity. This does not include altering the surface for routine maintenance that is performed to maintain the original line and grade, hydraulic capacity, or original purpose of the site (e.g., the routine grading of existing dirt roads, asphalt overlays of existing roads, the routine clearing of existing right-of- ways, and similar maintenance activities).~~

9.1.04.M Developer Participation Contract (DPC).

9.1.04.N Direct Driveway Access - A driveway that is essentially perpendicular to the street and provides vehicular access from the street to the parking area. Refer to Figure 9.2 for example.

~~9.1.03.S~~9.1.04.O Drainage Area – The surface area determined by topography that contributes rainfall runoff to a point of interception. The drainage area represents the drainage system service area and is not limited by the project boundary or street R.O.W. The possibility of ~~o~~Overland ~~f~~Flow contributions from adjacent ~~d~~Drainage ~~a~~Areas during certain extreme events shall be considered for accurate assurance of ~~l~~Level of ~~s~~Service.

~~9.1.03.T~~9.1.04.P Drainage Area Map – Service area map of the watershed or drainage system presented as specified in ~~9.4.01.A.8~~9.7.01.B.5.

~~9.1.03.U~~9.1.04.Q Dwelling Unit – A structure, or a portion of a structure, that has independent living including provisions for non-transient sleeping, cooking and sanitation.

9.1.04.R Engineer of Record – A Professional Engineer who seals Drawings, reports, and documents for a project.

~~9.1.03.V~~9.1.04.S Engineered Soil – Cement-Based Engineered Soil technology used to stabilize the soil on a work site where it is not solid enough to safely support a building or roadway. Portland cement is blended with soil (sometimes including ~~a~~Aggregate) and water and then compacted. The resulting mix, known as soil cement, provides a secure and stable base for construction. It is also used for flood control structures.

9.1.04.T Engineered Soil Media – Low Impact Design (LID) practice used to reduce storm runoff volume and loading of pollutants in the discharge from its contributing ~~d~~Drainage ~~a~~Area. Engineered ~~s~~Soil incorporates a growing media with the native soil to create a functional soil designed for high infiltration, filtration, and plant sustainability. The layer should be compacted ~~as minimally as possible~~ only with boot compaction or water flooding to allow for surface percolation through the ~~e~~Engineered ~~s~~Soil layer and into the surrounding native soil or ~~u~~Underdrain.

~~9.1.03.W~~9.1.04.U ~~FEMA –~~ Federal Emergency Management Agency (FEMA).

~~9.1.03.X~~9.1.04.V ~~FIS –~~ Flood Insurance Study (FIS) - ~~, t~~The formal document and associated models used to define the floodplain boundaries. An appraisal of the community's flood problems in a narrative that describes: a) the purpose of the study; b) historic floods; c) the area and flooding sources studied; d) the engineering methods employed. FIS serves as the basis for rating flood insurance and for regulating floodplain development and carrying out other floodplain management measures.

9.1.04.W Forebay – A separate deep pool of water at the entrance to a stormwater management facility designed to allow larger particles to settle out. For large facilities, it must include a maintenance ramp to facilitate periodic sediment removal.

9.1.04.X Green Stormwater Infrastructure (GSI) – A resilient approach to managing impacts from wet weather events. GSI reduces and treats stormwater at its source while delivering environmental, social and economic benefits. GSI is a term that is used to describe a range of techniques to manage and filter stormwater.

9.1.04.Y Green Roof – A roofing system that is covered with growing media and vegetation that enable rainfall capture and/or evapotranspiration of stored water.

~~9.1.03.Y~~9.1.04.Z ~~HCFCD –~~ Harris County Flood Control District (HCFCD).

~~9.1.03.Z~~9.1.04.AA ~~HouStorm - The City's version of TxDOT's software. The program is available from the City.~~ Hydraulic Grade Line (HGL) – A line representing the pressure head available at any given point within the drainage system.

9.1.04.BB Impervious Area, Impervious Cover, or Impervious Surface – Impervious Area, Impervious Cover, or Impervious ~~s~~Surface means any area that has been compacted or covered such that it does not readily absorb water or does not allow water to percolate through to undisturbed underlying soil strata. Surface materials considered impervious shall include, but not be limited to, bricks, pavers, concrete, asphalt, compacted oil-dirt, compacted or decomposed shale, oyster shell, gravel, or granite, and other similar materials. Surface features utilizing such materials and considered impervious shall include, but not be limited to, decks (whether on pier and beam or directly over soil), foundations (whether pier and beam or slab), building roofs, parking and driveway areas, sidewalks, compacted or rolled areas, paved recreation areas, swimming pools, dry or wet ~~d~~Detention ponds, shade structures and other features or surfaces that are built or laid on the surface of the land and have the effect of increasing, concentrating, or otherwise altering water runoff so that runoff is not readily absorbed. Infiltration report of soil testing, signed and sealed by a Professional Engineer licensed in the State of Texas, must confirm surface can provide infiltration through underlying soil strata at a rate of 0.5 inches/hour or greater to be considered permeable.

9.1.04.CC Infiltration – The vertical movement of stormwater through the ground, plants and soil in a system without an Under-drain or liner that also recharges groundwater.

9.1.04.DD Infiltration Rate – The downward velocity at which water enters the soil through rainfall or irrigation events, typically expressed in inches per hour.

9.1.04.EE Infiltration Trench – An excavated trench backfilled with stone Aggregate and lined filter fabric. A small portion of the runoff, usually the Water Quality Volume, is diverted to the Infiltration Trench, which is located either underground or at grade. Pollutants are filtered out of the runoff as it infiltrates the surrounding soils.

9.1.04.FF Infrastructure Design Manual (IDM)

9.1.04.GG Level of Service (LOS) Evaluation – A condition assessment to determine the stormwater system's level of performance with respect to site-specific numeric criteria (e.g. assessment of stormwater system capacity for a 2-Year or 100-Year return period of rainfall).

9.1.04.HH Long Run Culvert – A culvert that is 40--feet or longer in length.

9.1.04.KK.1 continued

~~.AA~~9.1.04.II Low Impact Development (LID) – A land planning and engineering design approach to manage ~~S~~stormwater runoff. LID emphasizes conservation and use of on-site natural features to protect water quality. This approach implements engineered small-scale hydrologic controls to replicate the pre-development hydrologic regime of watersheds through infiltrating, filtering, storing, evaporating, and detaining runoff close to its source. LID based practices are used to reduce ~~S~~stormwater runoff volume and pollutant loading from developed sites. LID is interchangeable with GSI.

9.1.04.JJ Maintenance Activity – Any work that is performed to maintain the original line and grade, hydraulic capacity, or original purpose of the site (e.g., the routine grading of existing dirt roads, asphalt overlays of existing roads, the routine clearing of existing right-of-way, and similar Maintenance Activities). These activities do not include any increase in impervious area, and the altered surface to be restored to original condition. For detailed requirements, refer to 9.2.01.H.3.n.

9.1.04.KK Municipal Separate Storm Sewer System (MS4) – A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):

1. Owned or operated by the U.S., a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over the disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under the §208 that discharges to surface water in the State;

2. That is designed or used for collecting or conveying stormwater;

3. That is not a combined sewer; and

4. That is not part of a Publicly Owned Treatment Works (POTW) as defined in 40 CFR §122.2.

9.1.04.LL Multi-Unit Residential (MUR) Development – As defined in the City of Houston Code of Ordinances, Chapter 42 – Subdivisions, Developments and Platting, Section 42-1.

~~9.1.03.BB~~9.1.04.MM No Adverse Impact (NAI)

~~9.1.03.CC~~9.1.04.NN ~~Notice of Intent (NOI) - A written submission to the executive director from an Applicant requesting coverage under general permit, reference definition 9.8.03.G. NPDES –~~National Pollutant Discharge Elimination System (NPDES) – Permit system addressing water pollution by regulating point sources that discharge pollutants to the Waters of the United States (WOTUS). Created in 1972 by the Clean Water Act (CWA), the program is authorized to state governments by EPA to perform many permitting, administrative, and enforcement aspects of the program.[12]

~~9.1.03.DD~~9.1.04.OO New Development – Development of an ~~u~~Undeveloped ~~p~~Parcel of land.

9.1.04.PP Outfall – A point where an MS4 discharges to Waters of the U.S. and does not include open conveyances connecting two municipal separate storm sewers, or pipes, tunnels, or other conveyances that connect segments of the same stream or other waters of the U.S. and are used to convey Waters of the U.S.

~~9.1.03.EE~~9.1.04.QQ Overland Flow – Flow resulting from a rainfall event that is routed along surface streets or surface channels in a defined manner.

~~9.1.03.FF~~9.1.04.RR Professional Engineer – An engineer currently licensed and in good standing with the Texas Board of Professional Engineers and Land Surveyors (TBPELS).

9.1.04.SS Registered Professional Land Surveyor (RPLS) – A surveyor currently registered and in good standing with State of Texas Board of Professional Engineers and Land Surveyors (TBPELS).

~~9.1.03.GG~~9.1.04.TT Rainfall Frequency – Probability of a rainfall event of defined characteristics occurring in any given year at a given location. Information on Rainfall Frequency is published by the National Weather Service. For the purpose of storm drainage design, the following frequencies are applicable:

1. 2-~~y~~Year ~~f~~Frequency – ~~a~~ A rainfall intensity having a 50 percent probability of occurrence in any given year, that occurs on the average every 2 years over a long period of time.

[12] National Pollutant Discharge Elimination System Permit Number TXS001201.

9.1.04.MM.4 continued

2. 3-~~y~~Year ~~f~~Frequency – ~~a~~ A rainfall intensity having a 33 percent probability of occurrence in any given year, that occurs on the average every 3 years over a long period of time.

3. 5-~~y~~Year ~~f~~Frequency – ~~a~~A rainfall intensity having a 20 percent probability of occurrence in any given year, that occurs on the average every 5 years over a long period of time.

4. 10-~~y~~Year ~~f~~Frequency – ~~a~~A rainfall intensity having a 10 percent probability of occurrence in any given year, that occurs on the average every 10 years over a long period of time.

5. 25-~~y~~Year ~~f~~Frequency – ~~a~~A rainfall intensity having a 4 percent probability of occurrence in any given year, that occurs on the average every 25 years over a long period of time.

~~5.~~6. 50-Year Frequency – A rainfall intensity having a 2 percent probability of occurrence in any given year that occurs on the average every 50 years over a long period of time.

~~6.~~7. 100-~~y~~Year ~~f~~Frequency – ~~a~~A rainfall intensity having a 1 percent probability of occurrence in any given year, that occurs on the average every 100 years over a long period of time.

~~7.~~8. 500-~~y~~Year ~~f~~Frequency – ~~a~~A rainfall intensity having a 0.2 percent probability of occurrence in any given year, that occurs on the average of every 500 years over a long period of time.

9.1.04.UU Redevelopment – A change in land use that alters the ~~i~~Impervious ~~s~~Surface from one type of ~~D~~development to either the same type or another type, or green field, and alters the drainage patterns internally or externally to the ~~D~~development.

~~9.1.03.HH~~9.1.04.VV Regulated Construction Activity – Construction activities, including clearing, grading, and excavation that disturb either one acre or more, or less than one acre if the activities are part of a larger plan of development or sale to be in accordance with TPDES General Permit No. TXR150000. For developments that are less than one acre tract, the activities shall be subject to Ordinance Section 47-741.

~~9.1.03.II~~9.1.04.WW Residence Time – The length of time that runoff remains in a pond, which is known as the pond's Hydraulic Residence Time (HRT). Removal efficiency is primarily dependent on the HRT.

~~9.1.03.JJ~~9.1.04.XX Sheet Flow – A shallow depth of runoff on a sloping and/or relatively flat surface that does not have a precisely defined bounding condition.

~~9.1.03.KK~~9.1.04.YY Single Family Residential (SFR) – As defined in the City of Houston Code of Ordinances, Chapter 42 – Subdivisions, Developments and Platting, Section 42-1.

~~9.1.03.LL~~9.1.04.ZZ Significant New Development – Development on a currently ~~u~~Undeveloped ~~p~~Parcel of land one acre or larger without regard to the amount of land that will actually be disturbed, except for development on an existing undeveloped and undivided parcel of one acre or more of one single-family ~~d~~Dwelling ~~u~~Unit and/or the types of non-commercial building(s) typically associated with a single-family ~~d~~Dwelling ~~u~~Unit, including, but not limited to, a garage, carport or barn. If the occupancy for any structure excluded under the foregoing exception at any time changes to a commercial use, the owner of the property will at that time have to comply with all requirements of this program. The term also does not include a ~~S~~stormwater ~~d~~Detention basin that includes a water quality feature. The required Stormwater ~~q~~Quality ~~p~~Permit must include Detention.

~~9.1.03.MM~~9.1.04.AAA Significant Redevelopment – Increase of 0.2 acre or more to the ~~i~~Impervious ~~s~~Surface on one acre or larger developed parcel, but does not include a ~~S~~stormwater ~~d~~Detention basin that includes a water quality feature. The required Stormwater ~~q~~Quality ~~p~~Permit must include Detention.

~~9.1.03.NN~~9.1.04.BBB Site Modifications – A site improvement that alters the area of ~~i~~Impervious ~~s~~Surface (e.g., an addition to an existing structure or creating additional parking), or a change in existing storm water collection, conveyance or runoff conditions for the developed site (e.g., replacing existing parking surface with pervious pavement).

~~9.1.03.OO~~9.1.04.CCC Spread – Calculated only for design rainfall. The width of flow in the gutter, measured laterally from the roadway curb, approaching an inlet. ~~In HouStorm this value is called the ponding width.~~

~~9.1.03.PP~~9.1.04.DDD Storm Sewer Junction Box – Precast or cast-in-place concrete, square or rectangular structure used to merge upstream pipes, accommodate changes in pipe size or direction, or provide service access to the storm sewer system by the addition of a circular manhole structure to the top of the junction box.

~~9.1.03.QQ~~9.1.04.EEE Stormwater Pollution Prevention Plan (SWPPP) – A site-specific, written document that: Identifies potential sources of ~~S~~stormwater pollution at the construction site; describes practices to reduce pollutants in ~~S~~stormwater discharges from the construction site. Reduction of pollutants is often achieved by controlling the volume of ~~S~~stormwater runoff (e.g., taking steps to allow ~~S~~stormwater to infiltrate into the soil). Identifies procedures the operator will implement to comply with the terms and conditions of a construction general permit.

~~9.1.03.RR~~9.1.04.FFF ~~SWQMP –~~ Stormwater Quality Management Plan (SWQMP) – Document describing how flow and water quality are going to be addressed and managed through programs and projects.

9.1.04.GGG Stormwater Quality ~~p~~Permit or SWQ ~~p~~Permit – ~~s~~~~Shall mean a~~ A current, valid permit issued pursuant to Article XII, Chapter 47, Division 2 of the City Code of Ordinances. A SWQ ~~p~~Permit shall be obtained for all ~~n~~New ~~d~~Development and ~~s~~Significant ~~r~~Redevelopment sites that will construct or modify their ~~d~~Detention features. This requirement applies only to the ~~d~~Detention feature if the facility has or will have permit coverage for stormwater discharges from industrial activity issued by the state.

~~9.1.03.SS~~9.1.04.HHH Structural Flooding – The Water Surface Elevation (WSE) from the storm event exceeds the finished slab elevation of the building (for pier and beam construction the top of first floor elevation), resulting in water entering the residential or commercial structure.

~~9.1.03.TT~~9.1.04.III Texas Pollutant Discharge Elimination System (TPDES) – Regulatory program to control discharges of pollutants to surface waters. The TCEQ Texas Pollutant Discharge Elimination System (TPDES) program has federal regulatory authority over discharges of pollutants to Texas surface water, with the exception of dis-charges associated with oil, gas, and geothermal exploration and development activities, which are regulated by the Railroad Commission of Texas.[13,14]

[13]Texas Pollutant Discharge Elimination System (TPDES) Permit No. WQ0004685000 (known as the Municipal Separate Storm Sewer System - MS4 permit)
[14] Texas Pollutant Discharge Elimination System (TPDES) General Permit No. TXR050000 (known as the Industrial Stormwater Multi-Sector General Permit)

9.1.04.JJJ Type 2 Permanent Access Easement – A permanent access easement at least 28-feet in width that is designed and constructed like a private street serving a development that has no public utilities other than a public water line, connected to one or more fire hydrants, that provides no domestic water services.

9.1.04.KKK Underdrain – An underground structure with void spaces and a conveyance to a nearby storm sewer system or similar conveyance. Removes water from under a Bioretention system or porous LID system.

9.1.04.LLL Undeveloped Parcel – ~~a~~A parcel on which there are no structures at the time that a construction permit, subdivision plat or other city approval is applied for or required.

9.1.04.MMM United States Army Corps of Engineers (USACE).

~~9.1.03.UU~~9.1.04.NNN Vegetated Swales – Stormwater quality management channels that convey runoff and remove pollutants by filtering and Infiltration through the soil. Pollutant management is related to the slope, vegetation density, and soil type; thus, an optimum swale would have a shallow slope, dense vegetation, and porous soils to maximize water quality treatment benefits.

9.1.04.OOO Water Quality Volume – Target established by the City of Houston for New Development based on capturing 90% of the rainfall events in a year. This is also known as the 90th percentile storm event. For Redevelopment, the Target Water Quality Volume is based on the 85th percentile storm event.

SECTION 2~~-~~ - STORMWATER DESIGN REQUIREMENTS
~~SECTION 2A STORM WATER DESIGN REQUIREMENTS~~

~~9.2.02~~9.2.01 DESIGN REQUIREMENTS

~~9.2.02.A~~9.2.01.A ~~Construction of d~~Drainage facilities designed per this chapter shall meet requirements of the City of Houston Standard Specifications and Standard Details. ~~HouStorm~~Applicable software (two-dimensional hydraulic modeling) shall be used to perform 2-~~y~~Year and inlet design analysis and design of storm drainage systems as follows:

1. City CIP Projects ~~-~~– In conjunction with design analysis using applicable software (two-dimensional hydraulic modeling)~~HouStorm~~, designs shall comply with guidelines provided in Technical Paper No. 100 (TP-100), Storm Sewer Design Applications for the City of Houston, Texas, CIP Projects, February 2005, or the latest published date.

2. Private ~~P~~projects within City ~~L~~limits which include City funding participation. See article 9.2.01.A.1 City CIP Projects.

3. 100% Privately-funded ~~P~~project located in City ~~L~~limits ~~-~~– ~~HouStorm preferred but~~ alternative equivalent analysis procedures will be accepted.

4. Projects in ~~N~~new or ~~E~~expanding ~~U~~utility ~~D~~districts located in City's ETJ ~~-~~ – ~~HouStorm preferred but~~ alternative equivalent analysis procedures will be accepted.

~~9.2.02.B~~9.2.01.B Determination of Runoff~~.~~

1. Rational Method – A method for calculating the peak runoff for a drainage system using the following equation for runoff:

$$Q = I \times (CA)$$

Where:

	Q	=	runoff (cfs)
	I	=	rainfall intensity (inches per hour)
	C	=	~~watershed~~runoff coefficient
	A	=	area (acres)

~~Design Rainfall Events.~~

~~b.~~a. ~~Coefficients for the Rational Method.~~Calculation of Runoff Coefficient~~.~~

(1) The runoff coefficient C values in the rational method formula will vary based on the land use. Land use types and C values which can be used are as follows:

9.2.01.B.1.a.(1) continued

Land Use Type	Runoff Coefficient (C)
Residential Districts	
Lots more than 1/2 acre	0.35
Lots 1/4 - 1/2 acre	0.45
Lots less than 1/4 acre	0.55
Townhomes	0.60
Multi-Family areas	
Less than 20 Service Units/Acre	0.65
20 Service Units/Acre or Greater	0.80
Business Districts	0.80
Industrial Districts	
Light Areas	0.65
Heavy Areas	0.75
Railroad Yard Areas	0.30
Parks/Open Areas	0.18
Pavement/R.O.W.	0.~~9~~80

(2) Alternatively, the runoff coefficient C in the Rational Method formula can be calculated from the equation:

$$C = 0.6I_a + 0.2$$

Where: C = ~~watershed~~runoff coefficient
I_a~~a~~ = impervious area/total Drainage Area

(3) If the alternate form is to be submitted, the calculation of C shall be provided as part of the drainage calculations.

~~c.~~b. Rainfall Intensity~~:~~

(1) Determination of Time of Concentration~~.~~: Time of concentration can be calculated from the following formula:

$$T_c = 10A^{0.1761}+15$$

Where: T_c~~C~~ = time of concentration (minutes)
A = ~~Subarea~~subdrainage area (acres)

(2) Calculate Intensity ~~: t~~T~~he intensity calculation is based on duration equal to the time of~~-~~ concentration. The intensity is calculated as follows:

$$I = b/(d + T_c)^e$$ ~~; TC = 10 A^0.1761 + 15~~

Where: I = ~~r~~Rainfall intensity (inches per hour)
T_c = Time of concentration (minutes)

9.2.01.B.1.b.(2) continued

Where b, d, and e are coefficients dependent on the rainfall event, as provided in Table 9.1~~Table 9.1~~ below and are based on City depth-~~-~~duration-frequency values.

Table 9.1 – RAINFALL INTENSITY COEFFICIENTS

Rainfall Frequency	b	d (min.)	e
2-~~y~~Year	48.35	9.07	0.7244
5-~~y~~Year	52.32	7.88	0.6900
10-~~y~~Year	54.68	6.96	0.6623
25-~~y~~Year	57.79	5.89	0.6294
50-~~y~~Year	61.00	5.46	0.6096
100-~~y~~Year	60.66	4.44	0.5797
500-~~y~~Year	62.17	2.95	0.5196

Note: The rainfall data presented above is the latest available as of the date of Chapter 9 issuance. The City may adopt revised data not reflected in this table. It is the engineer's responsibility to ensure that current accepted rainfall intensity calculations are being utilized for the analysis.

~~(2)~~(3) Intensity Duration Frequency (IDF) Curves, depict the intensity-duration curves to be used for storm sewer and roadside ditch design in the City and the ETJ. The source of these curves is data from Atlas 14 IDF Curves, assistance with NOAA Atlas 14 Updates to the Harris County Flood Control District (HCFCD) Policy Criteria ~~&~~ and Procedures Manual (PCPM) adopted July 9, 2019. The Atlas 14 IDF Curves report is based upon the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Precipitation-Frequency Atlas of the United States, Volume 11, Version 2.0 Texas (Atlas 14).

(a) Harris County ~~f~~Flood Control District (HCFCD) developed three (3) Hydrologic Regions based on the Atlas 14 rainfall distribution. The City of Houston requires the rainfall intensity for storm sewer design must be determined using the Region 3 data.

(b) The City acknowledges that Harris County and Harris County Flood Control District have adopted new data based on Atlas 14.

2. Application of Runoff Calculation Models~~.~~

9.2.01.B.2 continued

a. Rational Method: The Rational Method will be used to estimate peak flows for individual ~~d~~Drainage ~~a~~Areas up to 200 acres in size, and for project areas up to 640 acres in size. Project areas greater than 200 acres must be broken down into smaller ~~d~~Drainage ~~a~~Areas for analysis, with each ~~d~~Drainage ~~a~~Area being less than 200 acres in size. The Rational Method will be used for design on areas served by storm sewers up to 640 acres in size.

b. Runoff Watershed Modeling: For areas greater than 640 acres, use the methodology specified in the HCFCD ~~H&H~~Hydrology and Hydraulics Guidance Manual.

c. Hydrograph Development Dynamic Conditions – For development of runoff hydrograph for use in dynamic modeling utilize Clark Unit Hydrograph Method.

d. Hydrograph Development Static Conditions – For evaluation of ~~d~~Detention volume the approved methodology for hydrograph development shall be based upon the National Resources Conservation Services Dimensionless Unit Hydrograph or Malcolm's Small Watershed Method.

3. Hydrograph Development~~.~~

a. Where necessary to calculate runoff hydrographs, the peak flow of the hydrograph should match the Rational Method peak flow as calculated above. The hydrograph should be calculated using the entire ~~d~~Drainage ~~a~~Area, the Flood Insurance Study (FIS) rainfall distribution, Green & Ampt loss rates, and the Clark Unit Hydrograph (TC&R) methodology. These methodologies are described in the HCFCD ~~H&H~~Hydrology and Hydraulics Guidance Manual. For design and impact analyses, Green & Ampt parameters as included in the effective hydrologic model for the watershed, rather than using the values from the FIS models. Selection of the Clark Unit Hydrograph parameters will be done as follows: TC will be calculated as described above, with a minimum value of 10 minutes, and the storage coefficient (R) will be selected such that the peak flow matches the rational method peak flow. There will be a different R value for each rainfall event.

~~9.2.02.C~~9.2.01.C Design of Storm Sewers~~.~~

1. General Considerations

a. Continuity Equation:

9.2.01.C.1.a continued

$Q = VA$

Where:
Q = discharge (cfs~~ or cms~~)
V = velocity (ft/sec~~ or m/sec~~)
A = cross sectional area of ~~Conduit~~flow (square feet~~ or square meters~~)

b. Manning's Equation:

~~V~~Q = $(K/n)AR^{2/3}S_f^{1/2}$

Where:
Q = discharge (cfs)
K = 1.49 for English units,~~1.00 for metric units~~
n = ~~0.012 for corrugated profile-wall polyethylene pipe~~
0.013 for thermoplastic and concrete pipes
0.015 for concrete boxes
0.024 for CMP pipes
~~V~~A = ~~velocity (ft./sec or m/sec)~~cross sectional area of flow (square ft)
R = hydraulic radius (ft~~. or m~~) (area/wetted perimeter)
S_f = friction slope (head loss/length) ~~(101)~~

c. Drainage systems for curb-and-gutter pavement shall consist of underground closed ~~c~~Conduits.

d. City CIP Projects or New Development that is anticipated to become City infrastructure and R.O.W.:

(1) The City's Comprehensive Drainage Plan (CDP) and Houston Stormwater Master Plan (SWMP) may indicate that a larger diameter storm sewer is planned in the area proposed for paving improvements. The Transportation and Drainage Operations of HPW has information on proposed improvements and should be consulted for impact on New Development.

e. Private Drainage Systems:

9.2.01.C.2 continued

~~(2)~~(1) Storm sewers for private drainage systems should conform to the ~~City~~ Uniform ~~Building~~Plumbing Code and the International Building Code including City of Houston Amendments[15] for development within the City limits. The City recommends the contents of this chapter as a guideline for best practices for all storm sewers within the City or its ETJ.

2. Design Frequency~~.~~

   a. New Development: The ~~D~~design ~~R~~rainfall ~~E~~event for sizing storm sewers in newly developed areas will be at minimum a 2-~~y~~Year rainfall event. The proposed storm sewers shall also meet requirements of extreme event analysis as detailed in section 9.2.01.D.

   b. Redevelopment: The existing storm drain (sewer, ditch) shall be evaluated using a 2-~~y~~Year rainfall event, assuming no development takes place. The storm drain shall then be evaluated for the 2-~~y~~Year rainfall event design with the ~~D~~development in place.

      (1) If the proposed Redevelopment has an equal or lesser amount of ~~i~~Impervious ~~s~~Surface and the existing storm drain (sewer, ditch) meets 2-~~y~~Year ~~l~~Level of ~~s~~Service, then no modifications to the existing storm drain are required.

      (2) If the proposed Redevelopment results in the ~~hydraulic gradient~~2-Year Hydraulic Grade Line of the existing storm drain below the gutter line, no improvements to the existing storm drain are required.

      (3) If the analysis of the existing conditions finds that the existing storm drain is deficient (i.e. the 2-Year ~~h~~Hydraulic ~~g~~Grade ~~l~~Line is above the gutter line), the ~~a~~Applicant should check with the City to see if a CIP or a DPC project is proposed that will require a capital contribution.

3. Starting Water Surface and Hydraulic Grad~~eient~~ Line~~.~~

   a. Tailwater elevation selections for Hydraulic Grad~~eient~~ Line (HGL) analysis:

      (1) Capital Improvement Plan (CIP) Projects:

[15] https://www.houstonpermittingcenter.org/houston-code-archive

9.2.01.C.3.a.(1).(b) continued

(a) If the ~~receiving channel for the~~ storm system being analyzed is ~~less than 2,000 feet from the project limits~~ part of a Capital Improvements Plan (CIP) project that includes drainage improvements, then the storm system shall be modeled to the receiving channel, and the starting tailwater elevation shall be determined, ~~from outfall at the receiving channel according to criteria~~as noted below.

(b) If the Engineer of Record and the City's project team have determined that modeling to the receiving channel is not necessary (i.e., has minimal impact on the project), then this requirement may be lifted.

[1] For the 2-~~y~~Year ~~d~~Design ~~r~~Rainfall ~~e~~Event with non-submerged ~~o~~Outfall to the receiving channel, the starting tailwater shall be the top of Outfall pipe.

[2] For the 100-~~y~~Year extreme rainfall event, ~~and outfall to the receiving channel,~~ the starting tailwater shall be the greater of the 10-~~y~~Year water surface elevation (WSE) or 2-feet below the top of bank.

(2) Non-Capital Improvement Plan (CIP) Projects:

(a) If the receiving channel is less than 2,000 feet from the project limits, then the storm system shall be modeled to the receiving channel, and the starting tailwater shall be determined, as noted below.

[1] For the 2-Year Design Rainfall Event with non-submerged Outfall to the receiving channel, the starting tailwater elevation shall be the top of Outfall pipe.

[2] For the 100-Year extreme rainfall event, the starting tailwater elevation shall be the greater of the 10-Year water surface elevation (WSE) or 2-feet below the top of bank.

9.2.01.C.3.a.(2).(b) continued

continued

~~(c)~~(b)If the receiving channel for the storm system being analyzed is greater than 2,000-feet from the project limits, then the hydraulic model shall include at least 2,000-feet of trunkline downstream of the project limits. The starting tailwater elevation ~~may~~shall be determined ~~from an outfall point, or~~at the model truncation point, downstream of the project interconnect ~~point~~limit, as noted below.~~:~~

[1] For the 2-~~y~~Year ~~d~~Design ~~r~~Rainfall ~~e~~Event, the starting HGL~~,~~ at the model truncation point shall be the midpoint between the gutter line elevation and the soffit of the receiving pipe (i.e. midpoint elevation).~~top of pipe 2,000-feet downstream of the project interconnect point assuming pipes are connected at soffit. If pipes are connected at flow line, the top of the larger receiving pipe must be used.~~ If a starting tailwater elevation ~~other than~~at the ~~top of pipe~~"midpoint elevation" is ~~chosen,~~not allowed due to agency coordination, the ~~consultant~~engineer shall ~~analyze~~model the storm system ~~from~~to ~~outfall at~~ the receiving channel, as noted below. ~~upstream to the point of interconnect to demonstrate the alternate starting HGL value.~~

[a] For the 2-Year Design Rainfall Event with non-submerged Outfall to the receiving channel, the starting tailwater elevation shall be the top of Outfall pipe.

[2] For the 100-~~y~~Year extreme rainfall event, the starting HGL at the model truncation point shall be ~~2-feet~~1-foot ~~above the top of pipe 2,000-feet downstream of the project interconnect point~~ below the gutter line elevation. If a starting tailwater elevation ~~other than 2-ft~~ at 1-foot~~above the top of pipe~~ below the gutter line elevation is ~~chosen~~ not allowed due to agency coordination, the ~~consultant~~engineer shall ~~analyze~~model the storm system ~~from outfall at~~to the receiving channel ~~upstream to the point of interconnect to demonstrate the alternate starting HGL value~~using the tailwater criterion, as noted below.

9.2.01.C.4 continued

[a] For the 100-Year extreme rainfall event the starting tailwater elevation shall be the greater of the 10-Year water surface elevation (WSE) or 2-feet below the top of bank.

(3) If the Engineer of Record has determined that modeling to the receiving channel or 2,000-feet is not necessary (i.e., a critical location is more representative of tailwater), then this requirement may be lifted subject to approval from Office of The City Engineer's Storm Water Review Group.

~~(2)~~(4) For the hydraulic impact analysis, a variable tailwater at the downstream end of the model may be used (reference to TP-100). A variable tailwater condition is recommended for use for ~~d~~Detention analyses.

b. At drops in pipe invert, where the top of the upstream pipe ~~be~~is higher than the HGL, then the HGL shall be recalculated assuming the starting water surface to be at the top of pipe at that point.

c. For the Design Rainfall Event, the ~~h~~Hydraulic ~~gradient~~Grade Line shall at all times be below the ~~gutter line~~Critical Elevation for all newly developed areas. Critical Elevation for 2-Year rainfall event is gutter line. Critical Elevation for 100-Year rainfall event is maximum ponding elevation.

4. Pipe Sizes, Material, and Placement~~.~~

a. Use storm sewer and inlet leads with at least 24-inches inside diameter or equivalent cross section. Box culverts shall be at least 3-feet by 2-feet. Closed Conduits, circular, elliptical, arch pipe, or box, shall be selected based on hydraulic principles and economy of size and shape.

b. Design of Outfalls: Unless otherwise allowed in the subsections of this article ~~U~~use storm sewer and inlet leads with at least 24-~~-~~inches inside diameter or equivalent cross section. Box culverts shall be at least 3-~~-~~feet by 2-~~-~~feet. Closed ~~c~~Conduits, circular, elliptical, arch pipe, or box, shall be selected based on hydraulic principles and economy of size and shape. Using multiple pipes smaller than 24-inches is not permitted. A separate OCE plan and profile project is required to be submitted. For submittal requirements see SECTION 7.

(1) For private connection to the back of the curb inlet, a minimum 12-inch inside diameter storm sewer can be used.

~~(2)~~ ~~Only s~~Single-family residential projects with Direct Driveway Access~~, without sharing~~ that do not share a storm ~~o~~Outfall with others, shall be permitted to use the point of connection through a curb via a 4-inch schedule 40 pipe or to connect to the roadside ditch ~~with~~ via a 4-inch to 12-inch schedule 40 pipe within the R.O.W. without a plan and profile drawing submittal. This option is only available if curb or ditch is directly fronting the single-family residential lot. (See Table 9.6 - DETENTION CRITERIA 1).

(2)

(a) Single Family Residential projects are allowed to Sheet Flow to a ditch, curb and gutter, or any R.O.W. drainage as long as the tract meets all of the following conditions:

[1] Tract size is less than or equal to 15,000 SF.

[2] Total percent Impervious Area within tract is less than or equal to 65% of tract area.

[3] Tract shall have Direct Driveway Access to the R.O.W.

[4] The site shall have adequate grading in place, the Sheet Flow shall be effectively managed by adequately sloped runoff, and shall promote soil infiltration through gently sloped well drained areas as it flows to the R.O.W.

(3) ~~An alternative outfall option to For~~Single-Family Residential developments ~~that are 15,000 SF or less~~ with Direct Driveway Access~~direct driveway access,~~ joint access, shared access, ~~c~~Courtyard ~~a~~Access ~~d~~Drive, and Multi-Unit Residential (MUR) developments (MUR) (See Table 9.7 - DETENTION CRITERIA 2):

9.2.01.C.4.b.(3) continued

~~(a) Storm outfall analysis to be provided by a state or Texas Licensed Professional Engineer to justify using a~~Developments that are 15,000 SF or less in tract size shall be permitted to use an alternative point of connection through a curb via ~~A~~a 4-inch schedule 40 pipe ~~curb cut~~ or ~~12-inch schedule 40 pipe~~to connect~~ion~~ to the roadside ditch ~~is allowed~~ via a 4-inch to 12-inch schedule 40 pipe within the R.O.W. without a plan and profile drawing submittal. This option is only- allowed ~~only~~ if a curb or ditch is directly fronting the~~se~~ ~~D~~developments. ~~The Professional Engineer shall confirm through storm outfall analysis that there is no negative drainage impact on the City system.~~

(a)

[1] Single Family Residential developments are allowed to Sheet Flow to a ditch, curb and gutter, or any R.O.W. drainage as long as the tract meets all the following conditions:

[a] Tract size is less than or equal to 15,000 SF.

[b] Total percent Impervious Area within tract is less than or equal to 65% of tract area.

[c] Tracts shall conform to configurations shown in Figure 9.2 and as described below:

[i] Tracts with any number of lots that have Direct Driveway Access to the R.O.W.

[ii] Tracts with a maximum of two lots that have shared driveway access to the R.O.W.

[d] The site shall have adequate grading in place, the Sheet Flow shall be effectively managed by adequately sloped runoff, and shall promote soil infiltration through gently sloped well drained areas as it flows to the R.O.W.

(b) Unless allowed by exception for sheet flow according to 9.2.01.C.4.b.(3).(a).[1]~~9.2.01.C4.c(3)(a)[1]~~. Single Family Residential developments with joint access, shared access, Courtyard Access Drive, and Multi-Unit

9.2.01.C.4 continued

Residential developments (MUR) require a subsurface drainage system.

Single Family Residential tracts that Outfall through a pipe to a ditch shall have an Outfall pipe end that is mitered to match the ditch slope.

~~(3)~~(4)

~~b.~~c. Larger pipes upstream should not flow directly (via inlet, junction box, manhole) into smaller pipes downstream unless construction constraints prohibit the use of a larger pipe downstream, or the upstream system is intended for use as ~~d~~Detention. When a larger upstream pipe is proposed, an analysis of the downstream flow capacity is required.

~~c.~~d. Match crowns of pipe at any size change unless severe depth constraints prohibit.

~~d.~~e. Locate public storm sewers in public street R.O.W. or in approved easements.

~~e.~~f. Follow the alignment of the R.O.W. or easement when designing cast-in-place concrete storm sewers.

~~f.~~g. ~~Conduits shall connect to~~For box manholes, junction boxes and inlets~~, preferably on a straight alignment, however angled connections~~ Conduits shall connect at no greater than ~~10~~ 7 degrees normal to the wall~~ will be provided~~. See Figure 9.3.

~~g.~~h. Junction angles: At junctions, acute angles are preferred to reduce head losses and pass debris more easily. See Figure 9.4.

i. ~~Refer to Chapter 5, Section 5.2.04.E for storm sewer culvert location relative to easement boundarys.~~Clearance:

(1) Minimum horizontal clearance ~~between~~from the exterior of any storm pipe or box culvert shall be at least 48-inches ~~from~~to the exterior of the existing or proposed public or private utility and other appurtenances (i.e., inlet or manhole).

(2) Minimum vertical clearance ~~between~~ from the exterior of any storm pipe or box culvert or other appurtenances (i.e., manhole or inlet) shall be at least 24-inches ~~from~~to exterior of the existing or proposed public or private utility and other appurtenances.

~~h.~~j. Siphon design connection shall not be allowed.

~~i.~~k. Conflict manhole shall not be allowed.

~~j.~~l. Any Conduits with bends ~~over 10 degrees~~ shall have a structure such as an inlet, junction box, manhole, or cleanout within 100 ~~-~~feet for maintenance.

9.2.01.C.4 continued

m. Thermoplastic pipe design requirements:

(1) Pipe structural design shall be according to AASHTO LRFD Bridge Design Specifications.

(2) Pipe Cover Requirements:

(a) Do not exceed manufacturer's specifications for maximum cover.

(b) Minimum cover shall not be less than values provided in Table 9.2. In case the values in Table 9.2 are less than the manufacturer's values, the manufacturer's values shall govern.

(3) Engineer of Record shall confirm the project conditions are suitable for use of pipe material and structural adequacy of the pipe system.

(4) When thermoplastic pipes are placed under pavement subject to vehicular traffic loading, interaction between the pavement and pipe shall be a structural design consideration for both pavement and pipe design.

(5) Buoyancy shall be a design consideration when specifying thermoplastic pipes.

(6) For projects where more than one type of backfill is specified, backfill material locations shall be clearly noted in contract documents.

9.2.01.C.4.m continued

Table 9.2 – MINIMUM STORM SEWER AND CULVERT COVER REQUIREMENTS FOR THERMOPLASTIC PIPE

Location	Minimum Cover Based on Pipe Diameter (D) ~~(~~[Note 1]~~)~~		Notes
	D ≤ 36-in.	D > 36-in.	
Under Paved Roadways (Thoroughfares and Major Collectors)	24-in.	24-in.	1, 2, 3, 9
Under Paved Roadways (Minor Collectors, Local Streets)	18-in.	24-in.	1, 2, 3
Driveways on Roadways with Open Ditches (Commercial Driveways)	18-in.	24-in.	1, 2, 3
Driveways on Roadways with Open Ditches (Residential Driveways)	12-in.	18-in.	1, 2, 3
Under Unpaved Non-Roadway Areas with Potential for Rutting	18-in.	24-in.	1, 4, 7, 11
Under Unpaved Areas	12-in.	12-in.	1, 4, 7, 9

Table Notes:

1. Values in this table are provided based on reference data available at time of publication.
2. For rigid pavement, depth of cover is from top of pipe to top of pavement.
3. For flexible pavement, depth of cover is from top of pipe to bottom of pavement.
4. For unpaved areas, depth of cover is from top of pipe to ground surface.
5. Where rutting due to live loading is a design consideration, the amount of rutting shall not be permitted to reduce the cover less than 12-inches (Note 11).
6. Topsoil and erosion control products are not included in minimum cover depth (Note 11).
7. Where groundwater and fully saturated soil conditions are anticipated, the minimum cover shall be 4-feet (Note 10) unless justified by buoyancy calculations.
8. These requirements are not applicable to construction loads. Minimum cover for construction loads shall conform to requirements in 2017 AASHTO LRFD Bridge Construction Specifications: Section 30.6 Minimum Cover, Table 30.6-1-Minimum Cover for Construction Loads.
9. Requirements have been established using the 2024 AASHTO LRFD Bridge Design Specifications: Section 12.6.6.3 Minimum Cover, Table 12.6.6.3-1 Minimum Cover.
10. Requirements have been established using the 2023 TxDOT's "Structural Design Considerations for Specifying Thermoplastic Pipe".

9.2.01.C.4 continued

11. Requirements have been established using the 2022 MnDOT Technical Memorandum No. 22-04-B-02 "Use of Plastic Pipe for Storm Sewer and Culverts on Trunk Highways".

~~k.~~n. Pipe materials and installation shall conform to latest City of Houston Standard Specification 02631. See Table 9.3 for a summary of Conduit materials.

9.2.01.C.4.n continued

Table 9.39. – STORM SEWER CONDUIT MATERIALS

Location(5)	Specification Section	Pipe Material (2)(3)	Restrictions(4)
Storm Sewer Pipe in R.O.W.	02505	High Density Polyethylene (HDPE)	a. Only use for local streets(1). b. Not allowed in augering. c. Multi-barrel installations are not allowed.
	02506	Polyvinyl Chloride (PVC)	a. Not allowed in Potentially Petroleum Contaminated Areas (PPCA). b. Not allowed in augering/jacking c. Not allowed in the City right-of-way and easements, except for the cases outlined in paragraph 9.2.01.C.4.b.(2) & 9.2.01.C.4.b.(3) d. Not allowed on projects handled by Capital Projects Service Line except for the cases outlined in paragraph 9.2.01.C.4.b.(2) & 9.2.01.C.4.b.(3).
	02510	Polypropylene (PP)	a. Not allowed in augering. eb. Multi-barrel installations are not allowed.
	02611	Reinforced Concrete	-
	02612	Precast Reinforced Concrete Box Sewer	-
	02642	Corrugated Metal	a. Only use at railroad crossings (not street crossings).
Driveway Culvert Pipe for Streets with Open Ditches	02505	High Density Polyethylene (HDPE)	a. Single Family Residential (SFR) culverts only. b. Multi-barrel installations are not allowed.
	02506	Polyvinyl Chloride (PVC)	a. Not allowed for driveway culverts.
	02510	Polypropylene (PP)	a. Multi-barrel installations are not allowed.
	02611	Reinforced Concrete	-
	02612	Precast Reinforced Concrete Box Sewer	-

(1) ~~(1)~~ Local street is defined as by the City Code of Ordinances 42-1: Local street shall mean a type 1 permanent access easement and a public street that is not a major thoroughfare or collector street.

(2) ~~(2)~~ Pipe shall meet minimum class, dimension ratio, and other criteria indicated in the specifications.

(3) ~~(3)~~ Pipe material other than listed above should not be specified.

(4) ~~(4)~~ Engineer shall refer to Standard Specifications for any other restrictions that may impact design. If there is a discrepancy between this table and the Standard Specifications, the Standard Specifications shall take precedence.

~~(5)~~ Pipe materials for private developments shall comply with the latest edition of Uniform Plumbing Code and City of Houston amendments[16].

(5)

[16] Refer to weblink for City requirements: https://www.houstonpermittingcenter.org/building-code-enforcement/code-development - agency-links-416

Table 9.4 – ALLOWED STORM SEWER PIPE DIAMETERS IN THE R.O.W.

Pipe Material	Pipe Diameter Limitation [(1)]	Storm Sewers	Driveway Culvert For Streets With Open Ditches
Polyvinyl Chloride (PVC)	4-in SCH. 40 Pipe for SFR Curb Cuts 4-in to 12-in SCH. 40 for SFR Ditch Outfalls	X [(2)]	
High Density Polyethylene (HDPE)	24-in ≤ Pipe Diameter ≤ 48-in	X	X
Polypropylene (PP)	24-in ≤ Pipe Diameter ≤ 48-in	X	X
Reinforced Concrete	Pipe Diameter ≥ 24-in	X	X
Precast Reinforced Concrete Box Sewer	3-ft × 2-ft ≤ W × H ≤ 12-ft × 12-ft	X	X
Corrugated Metal	Pipe Diameter ≥ 24-in	X	

(1) Values provided in this table are approved for design and construction. Where there is a conflict between the IDM and construction specifications, the material specifications in City's Standard Construction Specifications shall govern.

(2) Allowed only for Single Family Residential Outfalls.

5. Manhole Locations~~.~~

   a. Use manholes at the following locations:

      (1) Size or cross section changes.

      (2) Inlet lead and ~~c~~Conduit intersections.

      (3) Changes in pipe grade.

      (4) A maximum spacing of 700~~-~~-feet measured along the ~~c~~Conduit run.

9.2.01.C.5 continued

b. Use manholes for existing monolithic-concrete storm sewers at the same locations as above except for intersections of inlet leads unless a manhole is needed to provide maintenance access at those intersections.

c. Do not place manholes in driveways or in the street in front of or immediately adjacent to a driveway.

6. Inlets~~.~~

a. Locate inlets at low points in the gutter.

b. Valley gutters across intersections are not permitted.

c. Inlet spacing is a function of gutter slope. The minimum gutter slope shall comply with Chapter 10, Street Paving Design Requirements.

(1) For minimum gutter slopes, the maximum spacing of inlets shall result from a gutter run of 700-feet from high point in pavement or the adjacent inlet on a continuously graded street section, with a maximum of 1,400-feet of pavement draining towards any one inlet location.

(2) Inlet location should be spaced to ensure that ~~s~~Spread does not exceed one lane of the roadway for the ~~d~~Design ~~r~~Rainfall ~~e~~Event.

(3) Residential ~~D~~development: Maximum spacing of inlets shall result from a gutter run of 700-feet from high point in pavement to the adjacent inlet on a continuously graded street section, with a maximum of 1,400-feet of pavement draining towards any one inlet location.

(4) Commercial ~~D~~development: Maximum spacing of inlets shall result from a gutter run of 400-feet from high point in pavement to the adjacent inlet on a continuously graded street section with a maximum of 600-feet of pavement draining towards any one inlet location.

9.2.01.C.6.c continued

(5) Spread: Calculate 2-Y~~y~~ear rainfall flow approaching each inlet from each direction. Additional inlets may be required if the Spread exceeds the maximum allowable value. The Spread in a typical prismatic curb-and-gutter street may be calculated using the following relationships:

$$Q = (K_g/n)(S_x^{1.67})(S_o^{0.5})(T^{2.67}), \text{ and}$$
$$T = y/S_x$$

Where: K_g = 0.56 (US Customary Units) ~~or 0.376 (SI Units)~~

n = Manning's roughness coefficient

S_x = Transverse slope (or cross slope) (ft/ft),

S_o = Longitudinal pavement slope (gutter slope) (ft/ft)

T = Spread (ft), and

y = Ponded depth (ft)

(6) Allowable Spread:

(a) On a residential street, the Spread shall be no greater than the distance from the curb to the center crown of the roadway.

(b) For a roadway with two or more lanes in each direction, the Spread shall be no greater than the distance from the curb to the inside edge of the outside lane.

(c) The Spread adjacent to an inlet shall be no greater than the point of intersection of the transverse pavement slope with the top of curb elevation (i.e., the maximum Design Ponding Depth).

d. Use only City of Houston standard inlets (See Table 9.5~~2~~).

9.2.01.C.6.d continued

Table 9.5~~9.2~~ – *STANDARD STORM -SEWER INLETS

INLET	APPLICATION	NOMINAL CAPACITY CFS	DWG. NOS.
Type A	Driveway, parking lots, small areas (curb and gutter system not available area). Please note inlets shall not allowed on travel lanes.	2.50	026323-01
Type B-B (without extensions, with solid plate or grate)	Curb and gutter system within collector streets (major collector, minor collector), transit corridor street, residential and commercial area.	5.00	026323-042
Type B-B (1) (with one extension; with solid plate or grate)	Curb and gutter system within collector streets (major collector, minor collector), transit corridor street, residential and commercial area.	10.00	02633-02
Type B-B (2) (with two extensions; with solid plate or grate)	Curb and gutter system within collector streets (major collector, minor collector), transit corridor street, residential and commercial area.	15.00	02633-02
Modified B-B (with solid plate or grate)	Driveway, parking lots, small areas (with no curb and gutter system). Please note grates shall not allowed on travel lanes.	N/A	
Type C (without extensions)	Curb and gutter system within collector streets (major collector, minor collector), transit corridor street, residential & commercial area.	5.00	026323-063
Type C-1 (with one extension)	Curb and gutter system within major thoroughfare, collector streets (major collector, minor collector), transit corridor street & commercial area.	10.00	026323-063
Type C-2 (with two extensions)	Curb and gutter system within major thoroughfare & commercial area.	15.00	026323-063
~~Type C-2A~~	~~Curb and gutter system within major thoroughfare & commercial area.~~	~~20.00~~	~~02632-06~~
Type D	Driveway, parking lots, small areas (curb and gutter system not available area). Please note inlets shall not be allowed on travel lanes.	2.00	026323-074
~~Type D-1~~	~~Driveway, parking lots, small areas (curb and gutter system not available area). Please note inlets shall not be allowed on travel lanes.~~	~~2.50~~	~~02632.08~~
Type E	Roadside ditch connect with storm sewer system.	20.00	02632-09, -10
Precast Area Zone Drain (PAZD)	Low profile roadside ditch in residential and commercial area	Varies TBD by Engineer	Styles 'RG' and 'FG' on TxDOT detail ~~prestd08~~CD-PAZD-20~~.dgn~~

9.2.01.C.6 continued

* The nominal capacity values provided in Table 9.5 are to be used for initial sizing only. The actual ~~I~~inlet size all shall be based on hydraulic analysis of the required inlet capacity. Inlet capacities are calculated using either orifice and or weir equations depending upon their location and a type of inlet openings with or without plates.

e. Do not use beehive grate inlets or other specialty inlets.

f. Do not use grate top inlets in unlined roadside ditch.

g. Do not place inlets in the circular portion of cul-de-sac streets unless justification based on special conditions can be provided.

h. Place inlets at the end of proposed pavement if drainage will enter or leave pavement.

i. Do not locate inlets adjacent to esplanade openings.

j. For new residential development, locate inlets at the center of lots and drainage system with lot site layout such that inlets are not located within the driveway between the radius end points as defined by the driveway radius intersection with the curb or edge of pavement.

k. Place inlets on side streets intersecting major streets, unless justification based on special conditions can be provided.

l. ~~Only the private development directly behind the inlet shall be permitted to make~~When connecting to a curb inlet, only one connection to that inlet shall be allowed, and that connection (lead) shall be made to the back of the inlet. ~~All other private developments must connect directly to the storm sewer trunkline even if the trunkline must be extended to the front of such development.~~ The connection~~extension~~ is to be designed and constructed in accordance with Section 9.2.01.C.4, Pipe Sizes, Materials and Placement. Connection shall not be made to the front face or to the short sides of the inlet. Design the connection not to exceed the downstream pipe capacity minus either the inlet capacity listed in Table 9.5, Standard Storm Sewer Inlets, or calculated inlet inflow.

m. For all new construction, convey ~~public or private~~ alley~~way~~ drainage to an inlet prior to entering the public street drainage system.

9.2.01.C continued

n. For all new connections, the ~~e~~Engineer shall be required to demonstrate that inlets for design storm events have adequate capacity based on ponding and available opening. For New Development, Redevelopment, or Site Modification or connections to curbside inlets, existing B inlets along or immediately downstream of said development shall be enlarged to BB inlets.

o. For inlet calculations reference the TXDOT Hydraulic Design Manual Chapter 10, Section 5, Storm Drain Inlets. ~~at http://onlinemanuals.txdot.gov/txdotmanuals/hyd/index.htm~~

p. Grate inlets shall not be allowed on travel lanes other than the gutter.

q. Do not use inlets without top manhole lip in major streets (i.e. Type BB inlet).

7. Velocity Considerations~~.~~

a. Storm sewers should be constructed to flow in subcritical hydraulic conditions if possible.

b. Minimum velocities should not be less than 3 feet per second with the pipe flowing full, under the design conditions.

c. Maximum velocities within storm sewers should not exceed 12 ~~-~~feet per second.

d. Maximum velocities at the storm sewer system ~~o~~Outfall should not exceed 8 feet per second without use of energy dissipation at the ~~o~~Outfall.

8. Sample Calculation Forms

a. Figure 9.5~~3~~, City of Houston Storm Sewer Calculation Form, is a sample calculation form for storm sewer systems.

b. Figure 9.6~~4~~, City of Houston Roadside Ditch Worksheet, is a sample calculation form for roadside ditch systems.

~~9.2.02.D~~9.2.01.D Extreme Event Analysis

1. Design Frequency

9.2.01.D.2 continued

a. The design frequency for consideration of overland ~~s~~Sheet ~~f~~Flow will consider extreme storm events (up to 100-~~y~~Year storms). These events, which exceed the capacity of the underground storm sewer system and result in ponding and overland ~~s~~Sheet ~~f~~Flow, shall be routed to drain along street R.O.W. or open areas and through the development to a primary outlet.

2. Overland Flow Analysis

~~b.~~a. An ~~o~~Overland ~~f~~Flow analysis of the proposed drainage system shall be prepared by the design ~~e~~Engineer. The design ~~e~~Engineer shall submit supporting calculations, exhibits, and drawings, which define the conveyance capacity of the roadway, define the flow paths of ~~o~~Overland ~~s~~Sheet ~~f~~Flow and define the ponding depths of ~~o~~Overland ~~s~~Sheet ~~f~~Flow.

~~c.~~b. Three analysis methods as presented in Technical Paper No. 101 (TP-101), Simplified 100-~~y~~Year Event Analyses of Storm Sewers and Resultant Water Surface Elevations for Improvement Projects in the City of Houston, Harris County, Texas Region will be acceptable to the City.

(1) Method 1: Hydraulic Grade Line (HGL) Analysis. A simplified approach to analyze and control the 100-~~y~~Year water surface elevation (WSEL) can be achieved by designing the storm sewer system for the 2-~~y~~Year ~~f~~Frequency rainfall event; imposing a 100-~~y~~Year ~~f~~Frequency storm event on the proposed design; calculating the ~~h~~Hydraulic ~~g~~Grade Line for the 100-~~y~~Year ~~f~~Frequency event for the proposed design; and adjusting the position of the HGL to not exceed the ~~c~~Critical ~~e~~Elevation by increasing the size of the proposed storm sewer for selective reaches.

(2) Method 2: Qt = Qo + Qc

~~w~~Where: Qt is the total flow conveyed~~,~~;
Qo is the ~~o~~Overland F~~f~~low component, and
Qc is the calculated flow in the ~~c~~Conduit for the 2-~~y~~Year design event.

The ~~o~~Overland ~~f~~Flow component (Qo) is computed by applying Manning's Equation to calculate the flow across the critical street cross-section along the R.O.W. This method accounts for flow in the storm sewer and ~~o~~Overland F~~f~~low across the street crest, but does not account for street ponding or storage.

(3) Method 3: Qt = Qo + Qc + ΔS/T

~~w~~Where: Qt, Qo, and Qc are as defined above;~~,~~ and ΔS/T is the change in storage volume relative to time provided in the streets and adjacent area upstream of the point of interest being analyzed.

This method uses a volumetric calculation based on a 100-~~y~~Year ~~f~~Frequency storm event with a duration of 3-hours for developments less than 200 acre and 6-hours duration for developments over 200 acres. The Soil Conservation Service, TR-20 method is used to set a peak triangular hydrograph shape. This method accounts for flow in the storm sewer, ~~o~~Overland ~~f~~Flow across the street crest, and storage within the street and adjacent area.

~~d.~~c. Analysis using the U.S. Environmental Protection Agency's Stormwater Management Model (SWMM) will be acceptable to the City.

3. Design Considerations

~~e.~~a. Relationship of Structures to Street: All structures shall be above the maximum ponding elevation anticipated resulting from the extreme event analysis.

(1) Barring conditions listed in 9.2.01.D.3.a.(1) and 9.2.01.D.3.a.(2), the maximum ponding elevation for the 100-~~y~~Year event at any point along the street shall not be higher than the natural ground elevation at the R.O.W. line.

(2) For City CIP Projects, the maximum ponding elevations shall be no higher than 12~~-~~-inches below the finished slab elevations, or, if the finished slab elevations are less than 12~~-~~-inches above the natural ground elevations at the R.O.W., the ponding elevations shall be no higher than the natural ground elevations at the R.O.W. In instances where the maximum ponding elevation for the 100-~~y~~Year event is not within the natural ground elevation at the R.O.W. line, the ~~e~~Engineer will add a note on the drawings indicating the ~~r~~Rainfall ~~f~~Frequency event is designed to be conveyed within the R.O.W.

9.2.01.D.3 continued

(3) For ~~D~~development or Redevelopment by private entities, the post-project maximum WSE shall be no higher than the pre-project maximum WSE in surrounding areas and proposed finished slab elevation shall be above the post-project maximum WSE. The ~~M~~maximum ~~P~~ponding ~~E~~elevation is determined from the physical characteristics of an area, and may change as a result of the proposed ~~D~~development. Where existing topographic conditions, project location within a special flood hazard area, and/or other site conditions preclude achieving this objective, the City will consider waiver of this requirement upon submittal of documentation and analysis prepared, signed, and sealed by a ~~p~~Professional ~~e~~Engineer, registered in the State of Texas. Analysis shall demonstrate that ~~s~~Structural ~~f~~Flooding will not occur and will identify the ~~r~~Rainfall ~~f~~Frequency event that will be conveyed within the R.O.W. The limiting parameter will depend on project-specific conditions, and the most restrictive condition (the lowest ponded water elevation) shall govern.

~~f.~~b. ~~Design Considerations:~~Streets shall be designed so that consecutive high points in the street will provide for a gravity flow of drainage to the ultimate outlet. If a ~~d~~Detention facility is designed to mitigate peak flows from the extreme event, the ~~o~~Overland ~~f~~Flow path shall carry the extreme event ~~s~~Sheet ~~f~~Flow to the ~~d~~Detention facility. If the extreme event ~~s~~Sheet ~~f~~Flow must enter a receiving channel, the ~~o~~Overland ~~f~~Flow path shall carry the extreme event ~~s~~Sheet ~~f~~Flow to the channel. In the event that there is no ~~o~~Overland ~~f~~Flow path, or the ~~o~~Overland ~~f~~Flow path is insufficient to carry all of the extreme event ~~s~~Sheet ~~f~~Flow, the inlets and storm sewer at the downstream end of the ~~o~~Overland ~~f~~Flow path shall be sized to carry the extreme event ~~s~~Sheet ~~f~~Flow from the end of the ~~o~~Overland ~~f~~Flow path into the ~~d~~Detention facility or receiving channel.

(1) The maximum depth of ponding at high points shall be 6~~-~~ inches above top of curb.

(2) The maximum depth of ponding at low points shall be 18~~-~~ inches above top of curb.

(3) Refer to Article 5.2.04.E.3 for easement requirements for ~~s~~Sheet ~~f~~Flow. Fence lines and other improvements shall not be constructed on or across dedicated drainage easements.

9.2.01.D.3.b continued

(4) A drawing(s) shall be provided to delineate extreme event flow direction through a ~~D~~development and how this flow is discharged to the primary drainage outlet.

(a) The extreme event flow path(s) shall be identified on a plan view drawing(s) such as the ~~d~~Drainage ~~a~~Area ~~m~~Map. There will be multiple extreme event flow paths for most projects. A profile for each path should be shown. Where secondary paths join a primary path, the secondary path profile should extend at least one street high/low point downstream along the major flow path, until the maximum ponding elevation downstream of the confluence is lower than the maximum ponding elevation upstream of the confluence.

(5) The drawing for each path shall show a profile of the roadway (or ~~o~~Overland ~~f~~Flow path) from the upper reach of the ~~d~~Drainage ~~a~~Area to the primary drainage outlet. The drawing(s) shall be exaggerated vertical scale and shall include roadway profile at the gutter, ground profile at the R.O.W., all the parameters used to determine the maximum ponding elevations, the maximum ponding elevations, and the hydraulic gradient for the extreme event, or an alternative equivalent drawing accepted by the City. The drawing(s) should be separate from the plan and profile sheets, and should include the entire ~~o~~Overland ~~f~~Flow path on one sheet, if possible. The drawings are not required to include the storm sewer profile.

~~g.~~c. Evacuation Routes and Emergency Service Routes. This standard applies to routes designated by HPW for emergency evacuation and for routes where access by the emergency service vehicles is a public safety need. Ponding of surface runoff is not allowed in the highest travel lane (each direction) for the 100-~~y~~Year event. Exceptions to this standard based on technical infeasibility or cost limitations will require approval of the Director, Houston Public Works, or the Director's designated representative. This standard may be modified or exempted for locations in the 100-~~y~~Year floodplain.

~~9.2.02.E~~9.2.01.E Design of Roadside Ditches.

1. Design Frequency~~.~~

a. Roadside ditch design is permissible only for single family residential lots or commercial areas equal to or larger than 0.5 acres.

9.2.01.E.2 continued

b. The Design Rainfall Event for the roadside ditches shall be a minimum of 2-~~-y~~Year rainfall.

c. Design capacity for a roadside ditch shall be to a minimum of 0.5~~-~~-feet below the edge of pavement or 0.5~~-~~-feet below the natural ground at R.O.W. line, whichever is lower, including head loss across the culvert. ~~Design Capacity~~Hydraulic calculations shall include head loss calculations for driveway and roadway culverts that are placed along the roadside ditch.

d. The design must include an extreme event analysis to indicate that structures will not be flooded, and that maximum ponding elevation for the extreme event complies with article~~Paragraph~~ 9.2.01.D.3.a.

2. Velocity Considerations~~.~~

a. For grass-lined sections, the maximum design velocity shall be 3.0 feet per second during the design event.

b. Minimum grades for roadside ditches shall be 0.1-foot per 100~~-~~-feet.

c. Calculation of velocity will use ~~a~~ Manning's roughness coefficient (n) of 0.045 for earthen sections and 0.025 for ditches with paved inverts.

d. Use erosion control methods acceptable to the City when design velocities are expected to be greater than 3~~-~~-feet per second.

3. Driveway and Roadway Crossings

a. Culverts will be placed at all driveway and roadway crossings, and other locations where appropriate.

b. Culverts shall be evaluated for inlet and outlet control, as well as normal depth. The highest of the three shall be designated as the computed headwater for design of the culvert section.

c. Roadside culverts are to be sized based on hydraulic analysis. The minimum culvert size shall be 24-inches inside diameter or equivalent ‘cross section’. For example, if the ditch is deeper than or equal to 29~~-~~-inches, the elliptical pipe with inside diameter of 19-inches x 30-inches can be used. Calculations shall be provided for review. In the ETJ, the Regulations for Harris~~,~~ County, Texas for the Construction of Driveways and/or Culverts on County Easements and R.O.W. shall govern.

9.2.01.E.3 continued

d. When spacing of driveways results in a roadside ditch that is less than 8-feet long (e.g., less than 8-feet between culverts), options shall be considered to address maintenance challenges and may include replacement of the short roadside ditch with a Long Run Culvert.

~~c.~~e. For culverts that are 40-feet in length or longer (i.e., Long Run Culverts), provide a grated inlet, junction box or manhole (with grated manhole cover). Engineer to coordinate with the City the spacing of inlets, junction boxes or manholes for Long Run Culverts.

~~d.~~f. Design capacity calculations shall include head loss calculations for driveway and roadway culverts that are placed along the roadside ditch.

~~e.~~g. Stormwater discharging from a ditch into a storm sewer system must be received by an appropriate structure (i.e., stubs with ring grates or Type E inlets).

h. Install appropriate ~~structures~~ measures (~~i~~e.~~g~~g~~e~~., headwalls, safety end treatments, riprap, sloped paving, earthen slope protection, etc.) at both sides of inlet and outlet of a culvert to prevent erosion and increase public safety.

(1) End treatment/appropriate measure details shall be provided in the Drawings.

(2) Headwall or safety end treatment shall be provided for commercial driveways.

(3) Riprap, sloped paving and earthen slope protection are only allowed for single family residential driveway culverts located along Local Streets.

(4) Where earthen slope protection is specified, factors such as erosion control, soil and pipe strength to carry errant vehicle loads shall be design considerations.

~~(1)~~(5) Where earthen slopes are specified, the slope shall not be steeper than 3H:1V. The pipe end shall extend 2-feet minimum beyond the edge of driveway pavement on each side of the driveway culvert.

i. Proposed street parking pads over an existing ditch are not allowed.

j. Partially replacing roadside ditches with a subsurface drainage system is not allowed unless the Engineer can demonstrate that there is no adverse impact to drainage.

4. Invert Protection~~.~~

a. Ditch invert protection shall be used when velocities exceed 3-feet per second.

b. Ditch invert protection will be used at the upstream and downstream ends of all culverts.

5. Depth and Size Limitations (Figure 9.7)~~.~~

a. Maximum depth shall not exceed 4-feet from adjacent edge of pavement.

b. Roadside ditch bottoms shall be at least 2-feet wide, unless design analysis will support a narrower width.

c. Ditches in adjoining and parallel easements shall have top of bank not less than 2-feet from the outside easement line.

d. The top of bank shall not encroach beyond the City R.O.W. or within 2~~-~~-feet of the edge of pavement.

e. A grass-lined or unimproved roadside ditch shall have side slopes no steeper than three horizontal to one vertical (3:1), or as soil conditions will permit.

~~9.2.02.F~~9.2.01.F Design of Open Channels~~.~~

1. Design Requirements and General Criteria.

a. Open channels shall be designed according to methods described in the Harris County Flood Control District Interim PCPM 2019: Policy Criteria and Procedures Manual for approval and acceptance ~~which can be accessed at www.hcfcd.org/dl_manuals.html~~ and shall convey 100~~-~~~~y~~Year event.

b. Design standards for channel construction shall follow the requirements specified in the Harris County Flood Control District Interim PCPM 2019: Policy Criteria and Procedures Manual for approval and acceptance. ~~which can be accessed at www.hcfcd.org/dl_manuals.html.~~

9.2.01.E.5 continued

c. Design standards for ~~o~~Outfalls into channels shall conform to those in the Harris County Flood Control District Interim PCPM 2019: Policy Criteria and Procedures Manual for approval and acceptance. ~~which can be accessed at www.hcfcd.org/dl_manuals.html.~~

2. Determination of Water Surface Elevation (WSE)~~.~~

a. WSE shall be calculated using Manning's Equation and the Continuity Equation.

b. For the Design Rainfall Event, the water surface shall be calculated to remain 1~~2~~-foot below the top of banks.

3. Design of Culverts~~.~~

a. Head losses in culverts shall conform to TxDOT Hydraulics Manual~~, Chapter 8, and Culverts~~.

b. Corrugated metal pipe will be approved only for railroad crossings.

9.2.01.G ~~Design of Outfalls: Outfalls from storm sewers or detention facilities that discharge directly into a channel or other HCFCD facility shall be designed and constructed in accordance with HCFCD criteria. If the criteria conflicts with City of Houston, the drainage criteria of the jurisdiction that is directly receiving the storm water shall govern. .~~Outfalls that directly discharge to other jurisdictions see 9.1.02.G.

~~9.2.02.G~~9.2.01.H Stormwater Detention

1. ~~The intention of Stormwater detention is to mitigate the effect of New Development, Redevelopment, or Site Modifications on an existing drainage system. Stormwater d~~Detention volume requirements are based on the ~~acreage of the Disturbed Area~~proposed Development area. ~~that results in Impervious Surface or alters stormwater runoff. Stormwater d~~Detention volumes are calculated at the minimum rates set forth in ~~Paragraph~~ article 9.2.01.H.3.

2. Application of Detention~~.~~

a. The use of ~~on-site d~~Detention is required for all ~~D~~developments within the City and for new or expanding utility districts within the City's ETJ. Detention may not be required if the City has developed ~~d~~Detention capacity for a drainage watershed, and/or infrastructure improvements, to serve the drainage watershed in compliance with the requirements of this ~~C~~chapter. Under these conditions, the City will consider a funding contribution in lieu of on-site ~~d~~Detention volume constructed by the owner.

~~a.~~b. Drainage and storm designs are still required to collect and convey site run off for projects that are exempt from providing Detention.

c. Stormwater ~~d~~Detention requirements are invoked for New Developments and ~~r~~Redevelopments that ~~include disturbed area resulting in~~contain Impervious ~~Surface~~Areas.

d. Stormwater Detention requirements are not invoked for the following conditions:

(1) Where existing Impervious Cover exists, Detention is not required for the addition of a feature or improvement on top of the existing Impervious Cover. This is only in scenarios where existing Impervious Cover is not redeveloped (e.g. a charging station equipment without proposed pavement is added to an existing parking lot, awnings, canopies, table umbrellas, shade structures, a covered patio added to a deck, etc.).

(2) Addition of floors to existing buildings that do not change the footprint of the building or the storm drainage pattern of the building.

(3) Building roof repair that does not change the storm drainage pattern of the building.

(4) Change in use of existing roof areas that do not change the storm drainage pattern of the building.

~~(1)~~(5) Maintenance Activities as defined in article 9.1.04.JJ.~~If the drainage system outfalls directly into a channel maintained by HCFCD, and the requirements of HCFCD include payment of an impact fee, then no further impact fee will be required by the City.~~

9.2.01.H.2.d continued

~~(2)~~(6) New development or Redevelopment projects that result in an increase in Impervious Area within the Right-of-Way due to construction of sidewalks, monuments, travel/left-turn lanes, among other facilities on the condition that the following can be established:

(a) Provide a hydraulic computations for the 2-Year storm event showing that both:

[1] The proposed total surface flow resulting from the increased Impervious Area will not exceed the allowable capacity of the receiving public storm sewer inlet or open drainage system in the street; and

[2] The proposed additional Impervious Area within the Right-of-Way will not exceed the impervious coverage reflected in the 'C' value for the Right-of-Way area used in the design of the storm sewer draining into the Right-of-way.

(b) If 9.2.01.H.2.d.(6).(a) cannot be met, the conditions in the following article shall apply:

[1] Perform a Hydraulic Grade Line (HGL) analysis for the receiving public drainage system to demonstrate that the 2-Year HGL does not exceed the Critical Elevations (e.g., gutter line) and that the 100-Year HGL remains below the Maximum Ponding Elevation (MPE) or the existing 100-Year HGL.

(7) Developments on parcels immediately adjacent to Lake Houston which outfall directly into Lake Houston. This exemption does not apply to portions of the development that are located outside of the Lake Houston watershed.

(a) However, for developments within the Lake Houston watershed not governed by 9.2.01.H.2.d.(7), provide a hydraulic analysis that shows No Adverse Impact (NAI) to channels, gullies, tributaries, parcels downstream and surrounding developments. The analysis shall extend to Lake Houston.

9.2.01.H.2.d.(8) continued

(8) Proposed underground utility lines that meet both of the following criteria:

(a) Utility line installation does not create new Impervious Areas; and

~~(a)~~(b) Construction site restoration due to utility installation does not alter the site's existing drainage pattern.

e. Existing Impervious Cover Detention Credit for Redevelopment: Applicant must present a valid survey that is signed and sealed by a Registered Professional Land Surveyor licensed in the state of Texas. To claim existing Impervious Area, the survey shall be signed and sealed within five years of the project submittal date and shall include supporting pictures taken within the same period to validate site conditions.

(1) Detention storage credit for Redevelopment shall apply only to developments that are subject to Detention criteria 3.

(2) Detention storage credit is allowed at a rate of 0.4 acre-foot/acre for Redevelopment of existing Impervious Cover area.

(3) The Detention volume required including the credit shall be calculated as follows:

$$\text{Detention Volume Required} = \left(A_p \times r_d\right) - (A_e \times 0.4\ \text{acre-ft/acre})$$

Where:

A_p = Proposed Impervious Area (SF)

A_e = Existing Impervious Area (SF) onsite to be removed with Redevelopment

r_d = Detention rate (acre-foot/acre) required by Table 9.8

(4) When a tract has existing Detention volume provided onsite prior to Redevelopment, the Detention volume determined according to article 9.2.01.H.2.e.(3) shall not be less than the existing Detention volume provided for the tract.

9.2.01.H.2.e continued

(5) If existing Impervious Cover on a Redevelopment site will remain and not be redeveloped, no additional Detention will be required for the area not being redeveloped.

(6) Credit can be applied for all Impervious Cover removed with Redevelopment.

f. Detention credit for dry-grass-lined Detention basins may be considered when justified by Infiltration report of soil testing and by hydraulic analysis.

g. Master Drainage Plan:~~A master drainage plan for the purpose of grandfathering projects regarding drainage and detention plan is as follows:~~

(1) A master drainage plan establishes the current and future drainage plan for a development~~al site~~. A master drainage plan generally consists of drainage, grading, ~~d~~Detention, and other applicable site plans. These site plans contain detailed calculations for ~~i~~Impervious ~~a~~Area, ~~d~~Detention, restrictors, flow rate, etc. All master drainage plans shall follow Detention requirements in Table 9.6, Table 9.7, or Table 9.8 and other applicable criteria in this chapter shall be utilized.

(2) Developments will be recognized as legacy projects where the Detention system and storm sewers have been fully constructed for the entire Development based on a master drainage plan approved after the year 2002. Legacy projects will be allowed to build out the remainder of the project under the approved drainage plan without additional requirements.~~For any master drainage plan with provided detention that is based on the Atlas 14 rainfall data, the City shall allow Development to proceed under the approved master drainage plan for up to five years. If the master drainage plan for provided detention is not based on the Atlas 14 rainfall data, then the delta of the detention requirement must be provided by the property owner.~~

(a) Minimum Requirements for Legacy Projects:

[1] Applicants claiming to be a legacy project shall provide documents that show the proposed design matches the original approved design.

9.2.01.H.2.g.(2).(b) continued

~~[1]~~[2] Impervious Area for proposed tracts should match the total Impervious Area based on the estimated amount in the original design. If this information is not available, the amount shown on the plat should be applied.

~~[0] If a Development results in increased impervious area from what was designed originally, Tables 9.3, 9.4, or 9.5 and other applicable criteria in this chapter shall be utilized.~~

(b) Qualification: Proposed New Development or Redevelopment of tracts do not require Detention when all of the following criteria are met:

[1] Detention has been provided on the master plan (regardless of current Detention rates).

[2] Detention has been permitted and constructed.

[3] Associated public infrastructure has been permitted and constructed.

h. Plat, replat, change the use of, or subdividing any tract to reduce stormwater ~~d~~Detention requirements will not be permitted. Original tract size on plat or replat, change the use of, subdividing, HCAD and survey will be used to determine stormwater ~~d~~Detention requirements. Replating subdivisions that result in increased Impervious Cover and differs from the regional master plan design originally approved does not reduce Detention requirements.

~~b.~~i. Project site that discharges directly into the Harris County, HCFCD, Fort Bend County, Montgomery County or other jurisdictions requires their review and approval prior to City's approval.

~~c.~~j. Detention basins that directly discharge to other jurisdictions see 9.1.02.G.~~(Policy Section)If the Detention criteria conflicts with Harris County, HCFCD, Fort Bend County, Montgomery County or other jurisdictions, the Detention criteria of the jurisdiction that is directly receiving the storm water shall govern.~~

~~d.~~k. City no longer allows timing analysis to avoid ~~d~~Detention requirements.

l. De Minimis Impact Credit:

9.2.01.H.2.i.(3).(a) continued

(1) De minimis impact projects will be considered where the increase in Impervious Area will have minimal impact on the City's drainage system. De minimis impact projects include but are not limited to adding charging stations to existing parking lots (equipment and proposed pavement), adding a deck or pool to a home, and adding additional parking area to an existing parking lot.

(2) Drainage and storm designs are still required even when Detention requirement is not applicable due to de minimis impact.

(3) De minimis impact credit will only apply to existing Single Family Residential developments or existing commercial developments where improvements are added.

(a) For existing single family residential developments that fall under criteria 1 (See article 9.2.01.H.3.b) and criteria 2 (See article 9.2.01.H.3.c) where improvements are added.

[1] Tracts less than 15,000 square feet in size: De minimis credit will be allowed up to 5% of the lot size area for increased Impervious Cover improvements. This credit is for additions that exceed the 65% Impervious Cover allowance for single family residential tracts. Total Impervious Area for the tract shall not exceed 70% of the tract area for this credit allowance.

[2] Tracts greater than 15,000 square feet in size: De minimis credit will be allowed up to 5% of the lot size area for increased Impervious Cover improvements. This credit is for additions that exceed the greater of 9,750 square feet or 40% Impervious Cover allowance for single family residential tracts. Total Impervious Area for the tract shall not exceed 750 square feet for this credit allowance.

[3] Repetitive submittals to claim de minimis impact credit will be accepted as long as the summation of all historical submittals requested for the tract does not exceed the maximum credit allowance.

(b) For existing developments that fall under criteria 3 as defined in article 9.2.01.H.3.d where improvements are added.

[1] Tracts 20 acres and less in size: De minimis impact credit will be given for an improvement of an existing development up to 1% of the total tract area. Credit will only be allowed once. Repetitive submittals to claim de minimis credits will not be accepted and tract will be subject to Detention requirements.

[2] Tracts greater than 20 acres in size: A drainage study will be required to determine the total impact. The City Engineer will determine whether the impact(s) can be considered a de minimis impact.

9.2.01.H continued

3. Calculation of Detention Volume~~.~~

a. Detention volume requirements ~~for redevelopment and new Development areas is calculated on the basis of Disturbed Area~~ are based on the proposed Development area ~~that results in Impervious Surface (defined in 9.1.04.O) or alters stormwater runoff. associated with the project development associated with the project developement.~~

~~a.~~b. Detention ~~Volume for~~ Criteria 1: For a tract containing only one ~~S~~single family residential (SFR) home, follow Table 9.6.

Table 9.6~~9.3~~ - DETENTION ~~VOLUME FOR~~ CRITERIA 1

SFR Tract Size	Percentage/Total Impervious Area[i]	Detention Required (Y/N)	Detention Volume	Notes
One SFR tract ≤ 15,000 SF	~~%~~ Total ~~i~~Impervious ~~a~~Area ≤ 65% of tract	N	N/A	1-3~~2~~
One SFR tract ≤ 15,000 SF	~~%~~ Total ~~i~~Impervious ~~a~~Area > 65% of tract	Y	0.75 ac-ft/ac rate × ~~i~~Impervious ~~a~~Area in excess of 65% of tract	1-3~~2~~
One SFR tract >15,000 SF	Total ~~i~~Impervious ~~a~~Area ≤ the greater of 9,750 SF or 40% of tract	N	N/A	1-3~~2~~
One SFR tract >15,000 SF	Total ~~i~~Impervious ~~a~~Area > the greater of 9,750 SF or 40% of the tract	Y	0.75 ac-ft/ac rate × ~~i~~Impervious ~~a~~Area in excess of the greater of 9,750 SF or 40% of tract	1-3~~2~~

(1) For a tract with multiple lots, the ~~d~~Detention exemption shown in ~~Table 9.3~~ this table is not applicable. Refer to Table 9.7~~4~~ for Detention volume requirements.

(2) No Sheet Flow shall be permitted to an alley~~way~~, neighboring properties,~~or~~ R.O.W. ~~nor~~or ~~to~~ a ditch unless allowed according to 9.2.01.C.4.b.(2).(a). ~~Without sharing storm outfall with others, a point of connection shall be through a curb via a 4-inch schedule 40 pipe or to the roadside ditch with a 12-inch schedule 40 pipe within the ROW.~~The point of connection shall be as described in 9.2.01.C.4.b.(2).

(3) See article 9.2.01.H.2. Application of Detention for criteria for acceptable Detention credits.

i Total impervious area = (existing + proposed) impervious area.

9.2.01.H.3 continued

~~Notes for Table 9.3:~~

~~b.~~c. Detention ~~Volume for~~ Criteria 2: For tracts with SFR ~~D~~developments with ~~d~~Direct ~~d~~Driveway ~~a~~Access, joint access, shared access, ~~c~~Courtyard ~~a~~Access ~~d~~Drive or ~~m~~Multi-~~u~~Unit ~~r~~Residential (MUR) ~~D~~development, follow Table 9.7.

Table 9.7~~9.4~~ - DETENTION ~~VOLUME FOR~~ CRITERIA 2

Tract Size	Percentage/Total Impervious Area[i]	Detention required (Y/N)	Detention Volume	Notes
Tract ≤ 15,000 SF	Total % ~~i~~Impervious ~~a~~Area within tract ≤ 65% of tract	N	N/A	1-~~5~~6
Tract ≤ 15,000 SF	Total % ~~i~~Impervious ~~a~~Area within tract > 65% of tract	Y	0.75 ac-ft/ac rate × ~~i~~Impervious ~~a~~Area in excess of 65% of the tract	1-~~5~~6
15,~~-~~000 SF < Tract < 1 acre	Total ~~i~~Impervious ~~a~~Area within tract ≤ the greater of 9,750 SF or 40% of tract	N	N/A	1-~~5~~6
15,000 SF < Tract < 1 acre	Total ~~i~~Impervious ~~a~~Area within tract > the greater of 9,750 SF or 40% of tract	Y	0.75 ac-ft/ac rate × ~~i~~Impervious ~~a~~Area in excess of the greater of 9,750 SF or 40% of tract	1-~~5~~6
Tract ≥ 1 acre	All proposed ~~i~~Impervious ~~a~~Area	Y	Refer to requirements in Table 9.8	1-~~5~~6

(1) When a tract of one acre or more is divided into multiple lots, ~~d~~Detention is required for all proposed ~~i~~Impervious ~~a~~Area within the lot. No residential exemption will be granted for the individual lot within this subdivision tract.

(2) No Sheet Flow shall be permitted to an alley~~way~~, neighboring properties, R.O.W. or a ditch unless allowed according to 9.2.01.C.4.b.(3).(a).[1]. ~~For projects using Table 9.4, a subsurface drainage system with one shared outfall is required. A~~The point of connection shall be through a ~~minimum 24-inch RCP inside diameter or equivalent~~pipe as ~~cross-section~~ described in 9.2.01.C.4.b.(3).~~A separate project, plan, and profile shall be submitted to OCE for storm outfall approval.~~

(3) The Detention exemption for ~~i~~Impervious ~~a~~Area should be proportionate among all the lots within the tract; this also includes any ~~d~~Direct ~~d~~Driveway ~~a~~Access, shared access, joint access, ~~and~~ ~~c~~Courtyard ~~a~~Access ~~d~~Drive and Multi-Unit Residential (MUR). A ~~state of Texas Licensed Professional Engineer shall~~ breakdown of impervious area calculation for each lot shall be submitted to take the Detention exemption.

(4) An ~~public~~ alley created with recorded plat prior to January 1st, 2023, is exempt from detention requirements.

~~(3)~~(5) Proposed permanent access easement (28' PAE), ~~private~~ alley, ~~public alley,~~ or similar accessway by any other name requires ~~d~~Detention; no ~~d~~Detention exemption will be allowed.

~~9.2.01.H.3 continued~~

~~(5)~~(6) See article 9.2.01.H.2. Application of Detention for criteria for acceptable Detention credits.

i Total ~~i~~Impervious ~~a~~Area = (existing + proposed) ~~i~~Impervious ~~a~~Area also including ~~d~~Direct ~~d~~Driveway ~~a~~Access, joint access, shared access, ~~c~~Courtyard ~~a~~Access ~~d~~Drive or Multi-Unit Residential (MUR) developments.

~~Notes for Table 9.4:~~

~~e.~~d. Detention ~~Volume for~~ Criteria 3: For other projects not subject to 9.2.01.H.3.b or 9.2.01.H.3.c follow Table 9.8.

Table 9.8~~9.~~ - DETENTION ~~VOLUME FOR~~ CRITERIA 3

Tract Size	Proposed ~~Percent~~ Impervious~~i~~ Area	Detention Required (Y/N)	Detention Volume	Notes
~~Tract < 1 acre~~	~~All proposed impervious area~~	~~Y~~	~~0.75 ac-ft/ac rate × proposed impervious area of the tract~~	~~1-2~~
~~1 acre ≤~~ Tract ≤ 20 acre	All proposed ~~i~~Impervious ~~a~~Area	Y	~~Follow Figure9.2/Table 9.6 Minimum Detention Rate chart/table~~ 0.8 ac-ft/ac rate × proposed Impervious Area of the tract	1-~~4~~2
Tract > 20 acre	All proposed ~~i~~Impervious ~~a~~Area	Y	Follow the most current version of the HCFCD PCPM; Minimum rate is 0.75ac-ft/ac	1-~~4~~2

(1) No Sheet Flow shall be permitted to an alley~~way~~, neighboring properties, R.O.W., or a ditch. For projects using ~~Table 9.65~~this table, a subsurface drainage system is required. ~~A~~ The point of connection shall be ~~through a minimum 24-inch RCP inside diameter or equivalent cross-section~~designed as described in article 9.2.01.C.4.b. ~~A separate project, plan and profile shall be submitted to OCE for storm outfall approval.~~

~~(2) For projects within City limits, the minimum detention rate is 0.75-acre feet per acre.~~

(2) Tract size greater than 20 acres: Detention calculation will be per the most current version of the HCFCD Policy, Criteria and Procedures Manual (PCPM). ~~Refer to https://www.hcfcd.org/About/Technical-Manuals/2019-Atlas-14-Policy-Criteria-and-Procedures-Manual-PCPM~~ When project Outfalls within City limits, the maximum Detention credit due to existing impervious area shall be as defined in article 9.2.01.H.2.e.

~~For those properties equal to 20-acres or more, if property is added to become larger than 20 -acres, then the curve/values shown in Figure 9.2 and Table 9.6 must be utilized on the additional property. The percent Impervious Surface will be used to define the Detention rate.~~
~~If the total increase in mpervious urface is less than 0.10acres, the project is exempt from this requiement.~~

(3) See article 9.2.01.H.2. Application of Detention for criteria for other acceptable Detention credits.

~~i Proposed percent impervious = proposed impervious area/Disturbed Area.Notes for Table 9.5:~~

9.2.01.H.3.f continued

~~Table 9.8.6 - MINIMUM DETENTION RATE~~

~~Proposed Percent Impervious (Proposed Impervious Area/ Disturbed Area)~~	~~Minimum Detention Rate acre-foot/acre~~
~~0% - 51%~~	~~0.75~~
~~55%~~	~~0.78~~
~~60%~~	~~0.81~~
~~65%~~	~~0.83~~
~~70%~~	~~0.86~~
~~75%~~	~~0.88~~
~~80%~~	~~0.91~~
~~85%~~	~~0.93~~
~~90%~~	~~0.95~~
~~95%~~	~~0.97~~
~~100%~~	~~0.98~~

~~rr.~~e. In private parking areas, and private streets, provide ~~d~~Detention or portion of ~~d~~Detention utilizing underground system or ~~d~~Detention pond, whenever possible. If the existing conditions do not allow for underground ~~d~~Detention or ~~d~~Detention pond, ~~d~~Detention through ponding in private parking areas, private transport truck only parking areas will be considered. Engineer shall provide calculations and analysis to the Office of the City Engineer for approval of design method prior to plan submittal.

~~ss.~~f. If approved for ~~d~~Detention through ponding in private parking areas, the maximum depth of ponding cannot exceed 9~~-~~ inches directly over the inlet and paved parking areas must provide signage stating that the area is subject to flooding during rainfall events.

If approved for ~~d~~Detention through ponding in private transport truck only parking, the maximum depth of flooding cannot exceed 15~~-~~ inches directly above the inlet, and signage must be provided stating that the area is subject to flooding during rainfall events.

g. All ~~mitigation~~Detention facilities shall be located within or adjacent to the project area except for roadway projects or projects where impacts are mitigated in a regional stormwater ~~d~~Detention facility. Engineer shall provide calculations indicating receiving stormwater system was designed to have conveyance capacity to non-adjacent ~~d~~Detention facilities.

9.2.01.H.3 continued

h. Overflow from the Detention facility shall be directed away from adjacent properties and building structures. Where possible, reroute overflow within the development away from sidewalks and into swales or ditches to return the overflow to the development's Detention basin.

~~tt.~~i. Sheet Flow across sidewalks is allowed in cases where criteria in Article 9.2.01.H.2.d.(6) is met.

j. Low Impact Development (LID) techniques that are considered acceptable for achieving ~~d~~Detention are ~~Bioretention, Infiltration Trenches, Porous Pavement, Vegetative Swales, Green Roof, Hard Roof, and Rain Barrels~~ listed in Table 9.11. See SECTION 6~~9.10.01~~ for LID design guidelines.

(1) Review and approval of engineering calculations demonstrating the volume of ~~d~~Detention achieved for each LID technique~~feature~~ will be required.

(2) If LID techniques are considered for achieving ~~d~~Detention, review and approval of a maintenance and ~~L~~life ~~C~~cycle plan are required per this section and section 9.2.01.~~(~~H~~)~~ of this chapter. Review and approval of engineering calculations demonstrating the volume of ~~d~~Detention achieved for each LID technique~~feature~~ will be required. This plan shall be signed and sealed by a registered ~~p~~Professional ~~registered e~~Engineer and included as part of the review and approval process.

(3) For project implementing GSI (Green Stormwater Infrastructure)/LID technique, refer to Section 9.2.01.H for Detention requirements.

~~uu.~~k. ~~For any new development or any part of an existing development that is still undeveloped, the most recent detention requirements would apply~~Detention requirement for projects dealing with natural disasters (e.g. hurricanes, tornados, flood, and unintentional damages such as fire damages to the structures, chemical leaking, chemical explosion): Detention criteria will be determined on a case-by-case basis. Supporting reports showing proof of damages will be required to be submitted for the projects.

9.2.01.H.3.n continued

l. The Detention requirement for projects within the Central Business District, approved locations within the Medical Center and Lower Buffalo Bayou: In lieu of the required Detention, these developments or Redevelopments shall consider the application of LID techniques to significantly reduce the runoff prior to discharging into the R.O.W. See Table 9.11 for LID techniques. For Buffalo Bayou, this provision is only valid if runoff from the development is routed directly to the bayou. For Central Business District, Texas Medical Center and Buffalo Bayou boundaries, see Figure 9.8, Figure 9.9 and Figure 9.10.

m. Safety should be given careful consideration in Detention basin designs. Embankment slopes, railings, fences, grates, and other features should be incorporated into the design of the facility wherever appropriate. Appropriate warning signs should be placed around the perimeter of the facility.

(1) Vehicular access gate for the Detention fence shall be designed for vehicles of various types and sizes for routine maintenance visits.

~~vv.~~n. Requirements for projects with Maintenance Activity:

(1) For maintenance of existing parking lots, the use of different materials may be permissible while keeping the same grading and drainage pattern.

(2) Maintenance of an existing roof requires the original roof area, slope of the roof, downspout, drainage, and Outfall to be shown in civil plan.

(3) Maintaining or repairing underground utilities/pipe systems is allowed without requiring Detention given the existing condition is maintained.

(4) All Maintenance Activity requires a survey or site plan showing the existing condition to be submitted to the City.

(5) A separate plan and profile permit is required for maintenance projects of a commercial driveway approach that is required to upgrade the culvert size to current standards.

~~(1)~~(6) For SFR projects only, when repairing or replacing driveways, and walkways, the use of different materials may be permissible while keeping the same grading and drainage pattern.

9.2.01.H.4.b continued

4. Underground Detention Requirements: Underground Detention systems are comprised of the use of underground pipes, tanks, vaults, inlets, manholes, and other engineered underground structures for Detention purposes.

~~ww.~~a. Site requirements: Sites that are allowed to use underground Detention are grouped as follows:

(1) All residential projects

(2) Commercial projects up to 10-acres.

(3) Commercial projects above 10-acres may be approved using underground Detention systems on a case-by-case basis.

(4) Public projects where approved by City.

b. Inlet/Outlet and Structural Requirements:

(1) Underground Detention systems require an overflow design for extreme flood events in accordance with section 9.2.01.D. See to article 9.2.01.H.3.h.

(2) Include energy dissipaters (i.e., riprap or plunge pools) at the end of the outlet pipe if the pipe discharges onto a pervious surface.

(3) Provide a storm water quality BMP to remove trash/sediment/debris at all direct inflow points of the storage chamber.

(4) Follow the current maximum drainage rule of 48-hours or less.

(5) Follow pump requirements in the event a pump is being used to discharge stormwater.

(6) A minimum of 12-inches of cover on top of the Detention structure is required.

(7) A cross-section of the underground Detention system with manufacturer's recommendations is required to be submitted with the plans.

9.2.01.H.4.c.(2) continued

~~(1)~~(8) A Texas Licensed Professional Engineer shall be responsible for design of underground Detention systems and shall verify if the underground Detention system is structurally adequate to support any imposed loads (vertical and lateral).

(9) The Drawings shall be signed and sealed by a Texas Licensed Professional Engineer.

(10) Use manufacturer's recommendation for access locations over the inlet pipe and outflow structure. Additional access locations may be needed depending on system size. Access points should be bolted or locked.

(11) Note that confined space entry may be required in certain systems.

~~(2)~~(12) Add notes in the plan stating:

(a) Underground Detention systems shall be installed and maintained based on the manufacturer's recommendation.

c. Maintenance Requirements: Active maintenance is required for all underground Detention systems. Sediment removal and trash collection are necessary to upkeep the Detention system.

(1) The following maintenance requirements supplied by the manufacturer shall be included in plans:

(a) Trash and debris removal schedule.

(b) Sediment removal schedule.

(c) Inspections schedule.

(2) Include the following notes on plans:

(a) Inspections shall include:

[1] Pre-treatment screening, sediment capture devices and outlet control devices.

[2] Investigation of any leaks (sinkholes or other indications of a failing system).

(b) Repair inlets and outlets when damage occurs.

(c) If media is utilized, replace if the drawdown time exceeds 48-hours.

(3) If the system is used as a stormwater quality feature, the design requirements shall be meet article 9.5.01.

d. If the underground system is approved in the R.O.W., an agreement between the private development and the City of Houston must be in place to clearly define ownership and maintenance responsibilities.

~~4.~~5. Calculation of Outlet Size~~.~~

a. Detention pond discharge pipe into an existing storm sewer line or existing City of Houston ditch:

(1) If the maximum pool elevation is at or below the design ~~h~~Hydraulic ~~g~~Grade Line (HGL) at the drainage system ~~o~~Outfall, the discharge line shall be sized for the ~~D~~design ~~R~~rainfall with the discharge pipe flowing full. The pond will float on the drainage system to provide maximum benefit.

(2) If the maximum pool elevation is ~~at or~~ above the design ~~h~~Hydraulic ~~g~~Grade Line (HGL) at the drainage system ~~o~~Outfall, provide a reducer or restrictor pipe to be constructed inside the discharge line. The discharge line shall be sized for the ~~D~~design ~~R~~rainfall with the discharge pipe flowing full.

b. Reducer or ~~R~~restrictor ~~P~~pipes shall be sized as follows:

(1) Allowable Discharge Rate - Use the lowest of the discharge rates described below:

9.2.01.H.5.b.(1) continued

(a) Restrictor pipes will provide a combination of low level and high level controlled release from the ~~d~~Detention basin. The low level restrictor pipe (primary orifice) shall be sized to provide a release rate of 0.5 CFS/acre when the ~~d~~Detention basin water depth is 25% of capacity. The low level restrictor pipe (primary orifice) shall be located at the bottom of the basin to provide complete drainage of the pond. The high level restrictor pipe (secondary orifice) shall be sized to provide a combined release rate (from the primary orifice and secondary orifice) of 2.0 CFS/acre at full basin depth. The high level restrictor secondary orifice) shall begin releasing flow when ~~d~~Detention basin water depth reaches 75% of capacity. The combined rate of 2.0 CFS/acre is the approximate discharge from an undeveloped tract for the 100-~~y~~Year storm. The basin is considered 100% full when it reaches its maximum volume during the 100-~~y~~Year storm. See Figure 9.11.

(b) Flow discharged to the storm drain shall not exceed the proportional amount of pipe capacity allocated to the ~~D~~development. The proportional amount of pipe capacity allocated to the ~~D~~development shall be determined by the ratio of the area (acres) of the ~~D~~development (in storm drain watershed) divided by the total ~~d~~Drainage ~~a~~Area (acres) of the storm drain multiplied by the capacity of the storm drain.

(2) Use the following equations to calculate the required outflow orifice (see Figure 9.12):

$$Q = CA\sqrt{2g}\ \sqrt{h}$$

$$D = Q^{1/2} / (2.25h^{1/4})$$

Where:

Q	=	outflow discharge (cfs)
C	=	coefficient of discharge
	=	0.8 for short segment of pipe
	=	0.6 for opening in plates, standpipes, or concrete walls
A	=	orifice area (square feet)
g	=	gravitational factor (32.2)
h	=	head, water surface differential (feet)
D	=	orifice diameter (feet)

9.2.01.H.5.b continued

(3) For rectangular weir flow calculation (see Figure 9.13):

$$Q = CLH^{3/2}$$

Where:

Q	=	weir discharge (cfs)
C	=	weir coefficient
L	=	horizontal length (ft)
H	=	head on weir (ft)

The value of the weir coefficient, C, depends on the weir shape (i.e., broad crested or sharp crested) and if the weir is submerged or not. See Brater and King's Handbook of Hydraulics or other applicable references.

(4) Restrictor shall be either of the required diameter or of the equivalent cross-sectional area. The orifice diameter D shall be a minimum of 0.5 feet.

c. In addition to a pipe outlet, the ~~d~~Detention basin shall be provided with a gravity spillway that will protect structures from flooding should the ~~d~~Detention basin be overtopped.

~~5.~~6. Ownership and Easements~~.~~

a. Private Facilities:

(1) Pump discharges into a roadside ditch or storm sewer system must comply with the following:

(a) Submittal of pump specifications, including capacity (GPM) of the pump, on the design drawings.

(b) Provide a backup pump in the event of a pump failure.

(c) Provide emergency power from a second source or install a quick connect for a mobile generator.

(d) Provide a stilling basin to dissipate the energy from the pump outlet prior to gravity flow into the ditch or storm sewer.

(e) HCFCD projects with tracts above 20 acres utilizing pumps require pumped volume to be less than 50% of the Detention basin capacity.

9.2.01.H.6.a continued

(2) The City reserves the right to prohibit the use of pump discharges where their use may aggravate flooding in the public R.O.W.

(3) Responsibility for maintenance of the ~~d~~Detention facility must be confirmed by letter submitted to the City as part of the design review and shall also be stated on the drawings.

(4) All private properties being served have drainage access to the pond. Dedicated easements may be required.

(5) No public properties may drain into the ~~d~~Detention area.

(6) A private maintenance agreement must be provided when multiple tracts are being served.

(7) All ~~d~~Detention facilities must completely drain out of property within 48-~~-~~hours with exception to facilities that are intended to maintain a static water level (e.g. wet bottom detention basins). ~~this~~Where applicable Drawings shall state that the facility shall completely drain out of the property within 48-hours.

(8) All inflow pipes to the detention basin cannot be submerged.

(9) For swales and detention ponds, ~~A~~ a minimum of 2-feet ~~grading~~ set-back from ~~of one fifth the vertical height of the cut or 2-feet minimum~~ the property line or boundary is required. Set-back shall be measured from ~~between~~ the top of ~~the cut~~ bank ~~of pond or swale~~whichever is closest to the property line or boundary.

~~(9)~~(10) ~~A grading set-back of one half the height of the slope (H/2) or 2-feet minimum is required between the toe of the slope of pond or swale and the property line or boundary.~~All storm sewer within a Type 2 Permanent Access Easement (PAE) must be designed to public storm standards outlined in this chapter of the Infrastructure Design Manual except when it is indicated that the PAE will not be dedicated to the City. Refer to Chapter 42 of the Code of Ordinances. A separate plan and profile shall be submitted.

b. Public Facilities:

9.2.01.H.6.b continued

(1) Facilities will only be accepted for maintenance by the City within the City limits in cases if public drainage is being provided.

~~(2)~~ The City requires a maintenance work area of 20-foot width surrounding the extent of the ~~d~~Detention area. Public R.O.W. or permanent access easements may be included as a portion of this 20- foot width. See Table 9.9 below from the HCFCD PCPM for minimum berm widths around a ~~d~~Detention basin.

Table 9.99.~~7~~ – MINIMUM BERM WIDTH AROUND A DETENTION BASIN

Detention Basins That Are	The Minimum Berm Width Is
Grass-lined with a depth > 7-~~-~~feet	30-~~-~~feet
Grass-lined with a depth < 7-~~-~~feet	20-~~-~~feet[1]
Grass-lined where side slopes are 8(horizontal):1(vertical) or flatter	10-~~-~~feet[2]
Grass-lined with the 20-f~~oo~~t maintenance access on a bench	10-~~-~~feet
Lined with riprap or articulated concrete blocks or partially concrete-lined	Same as grass-lined channel
Fully concrete-lined	20-~~-~~feet[1]

[1]Backslope swale system not needed.
[2]Maintenance access is on the side slope.

~~(4)~~(3) A dedication of easement shall be provided by plat or by separate instrument.

~~(5)~~(4) Proper dedication of public access to the ~~d~~Detention pond must be shown on the plat or by separate instrument. This includes permanent access easements with overlapping public utility easements.

(5) Backslope drainage systems are required where the natural ground slopes towards the drainage basin. A basin that is within 30-~~-~~feet of a parking lot or roadway with berms that drain away from the basin does not require a backslope swale. Comply with criteria provided in HCFCD Policy Criteria and Procedure Manual (PCPM).

~~9.2.04~~9.2.02 STORM STRUCTURAL DESIGN REQUIREMENTS

~~9.2.04.A~~9.2.02.A Structural Design Requirements

1. The ~~e~~Engineer of ~~r~~Record is responsible for the design of all structural components within the proposed storm water design. This includes but is not limited to pipe, box sewers, manholes and junction boxes.

2. Cast~~-~~-in~~-~~-place and precast structural elements are both allowed given that each design is signed and sealed by a ~~p~~Professional ~~e~~Engineer.

SECTION 3 – EASEMENTS AND RIGHTS-OF-WAY

9.3.01 EASEMENTS AND RIGHTS-OF-WAY

9.3.01.A Storm sewer easement and R.O.W. requirements are described in Chapter 5 Easement Requirements.

SECTION 4 – SURVEY REQUIREMENTS

9.4.01 SURVEY REQUIREMENTS

9.4.01.A Projects shall be tied to National Geodetic Survey (NGS) datum adjustment which matches the Federal Emergency Management Agency (FEMA) rate maps or the most current NGS datum which matches the FEMA rate maps. In the event GPS surveying is used to establish bench-marks, at least two references to bench-marks relating to the rate maps shall be identified. Equations may be used to translate other datum adjustments to the required adjustment.

9.4.01.B Refer to Chapter 2 – Survey Requirements for additional requirements.

SECTION 5 – ~~S~~STORMWATER QUALITY DESIGN REQUIREMENTS
~~**SECTION 8 – STORMWATER QUALITY OVERVIEW**~~

9.5.01 STORMWATER QUALITY DESIGN REQUIREMENTS

9.5.01.A Stormwater quality design requirements shall be integrated to meet the standards in all chapters of the IDM. Stormwater quality measures must work to meet or exceed the drainage requirements of this chapter.

~~9.5.01.A~~9.5.01.B Obtain approval from the Office of the City Engineer (OCE) for exceptions or deviations from these requirements. Exceptions or deviations may be granted on a project-by-project basis.

9.5.01.C For individual BMPs the Water Quality Volume is calculated using the Rational Method runoff coefficients in Section 9.2.01.B.1 and minimum storm depth of 1.00-inches [preferably 1.72–inches (90th percentile) for New Development or 1.39-inches (85th percentile) for Redevelopment]. The BMP shall be preferably designed to remove 80% (minimum of 50%) of TSS and 60 percent of best achievable practice for bacteria removal (i.e. indicated by E. coli and Enterococci). See LID section for additional bacterial removal requirements for LID techniques. For BMPs requiring a flow rate, the calculation shall be based on the rational method using a minimum design intensity of 1.00 inches per hour with the ultimate goal of a design of an Atlas 14, 2-year, 1-hour storm event (See section 9.2.01.B.1).

9.5.01.D Regulated Construction Activity:

1. SWPPPs and BMPs will be developed in accordance with the Stormwater Management Handbook for Construction Activities (9.1.03.Y~~9.8.02 Reference A~~),~~ for sites that are less than one acre~~ for all construction in the City limits. A site-specific SWPPP~~ can be as simple as~~ (e.g., erosion control plan) is required and must include the Stormwater Pollution Prevention Plan Detail (DWG No. 015~~10~~70-01).

2. Construction plans will include a note requiring contractor to comply with the ~~C~~construction ~~S~~stormwater ~~G~~general ~~P~~permit including preparation of a SWPPP and to provide a copy of the Site Notice, NOI, and maintenance checklist to City Engineer or Building Official five (5) workdays prior to commencement of any construction activity.

~~9.5.01.D~~ continued

3. For post-construction permanent BMPs, designs and construction activities should be consistent with the guidance given in the Harris County's "Minimum Design Criteria for Implementation of Certain Best Management Practices for Storm Water Runoff Treatment Options"[17].

~~9.5.01.B~~9.5.01.E New Development and Significant Redevelopment:

1. All designs must be consistent with the Stormwater Quality Guidance Manual[18] (SWQGM) and the Minimum Design Criteria for Certain Stormwater Runoff Treatment Options[19] (MDC), 2001 edition.

2. Pollutants expected from the site (e.g. floatables, sediments, hydrocarbon, bacteria, etc.) must be identified in the SWQMP. BMPs must be designed and selected to remove the pollutants identified.

3. At a minimum, the system must be designed to be in accordance with 9.5.01.C ~~treat the first 1/2 inch of runoff, except as noted in the SWQGM or the MDC~~.

4. BMPs listed in the SWQGM but not in the MDC may be acceptable for implementation pending review of design calculations and site applicability. BMPs not listed in the SWQGM may be considered on a case-~~-~~by-~~-~~case basis. Acceptance of these BMPs will require not only review of design calculations and site applicability, but also review of case studies or other data provided by an uninterested third party indicating the effectiveness of the BMP. All calculations and literature must be provided as part of the plan submittal.

5. In addition to meeting the ~~S~~stormwater quality requirements of this section, the ~~S~~stormwater system must also meet the requirements of the rest of this ~~C~~chapter.

9.5.01.F Demonstration of Soil Permeability

[17] https://www.eng.hctx.net/Portals/23/Publications/criteria_2001_edition.pdf
[18] The Stormwater Quality Management Guidance Manual developed jointly by City of Houston, Harris County, and Harris County Flood Control District can be found at https://www.cleanwaterways.org/Portals/73/downloads/professional/guidance_manual_full.pdf ~~http://www.cleanwaterways.org/downloads/professional/guidance_manual_full.pdf~~
[19] The Minimum Design Criteria (MDC) Manual developed jointly by City of Houston, Harris County, and Harris County Flood Control District can be found at https://www.eng.hctx.net/Portals/23/Publications/criteria_2001_edition.pdf ~~http://www.cleanwaterways.org/downloads/criteria_2001_edition.pdf~~

1. Representative soil sampling of the in-situ soil shall be conducted by qualified personnel to determine if Underdrain system is required, to be in accordance with applicable requirements in 9.6.02.

9.5.01.G The minimum design criteria for conventional SWQ features shall be applied in accordance with Table 9.10.

Table 9.10 – MINIMUM DESIGN CRITERIA FOR CONVENTIONAL TECHNOLOGIES

SWQ Conventional Type	SWQ Treatment Technology	General Design Criteria	SWQ Application Example
Hydrodynamic Separator	Sedimentation and Separation	• Capture 90-micron particles, or an equivalent. • Access for cleaning/accessible to cleaning equipment.	• Small or large development. • For retrofit or existing storm systems.
Inlet Filter Basket	Filtration and sedimentation	• Have coarse and fine filter screens. • Be able to capture floatable and coarse/fine sediments. • Corrosion resistant.	• Small development or # of inlets less than 10. • Retrofits for existing urban areas.
Dry Detention Pond	Sedimentation and Separation	• Vegetated. • Side slope is 3H:1V or flatter. • Have trash rack or perforated riser pipe. • Capture floatables larger than 1.5-in wide and capture settleable materials < 90microns.	• Larger developments • Where other stormwater BMPs do not apply.
Wet Detention Pond	Sedimentation and Separation	• Vegetated. • Side slope is 3H:1V or flatter. • Have trash rack or perforated riser pipe. • Forebay 3-ft min. depth • Capture floatables larger than 1.5-in wide and capture settleable solids < 90micron.	• Larger developments • Where other stormwater BMPs do not apply.

9.5.02 SWQ PERMIT APPLICATION REQUIREMENTS

9.5.02.A Refer to section 9.7.01.E for SWQ Permit application submittal requirements.

SECTION 6 – LOW IMPACT DEVELOPMENT (LID) DESIGN REQUIREMENTS

9.6.01 ~~LOW IMPACT DEVELOPMENT~~LID OVERVIEW

9.6.01.A ~~Design requirements for Low Impact Development techniques are included in section 9.10.01. Only three techniques may be considered to have impact on impervious surface: Hard Roof, Green Roof, and Porous Pavement.~~The City of Houston is promoting GSI, which encourages the use of natural features within a development. See 9.6.02 for design requirements. For additional LID information refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston."

9.6.01.B LID is considered as an alternative to conventional Detention and conveyance systems. All LID projects must provide supporting engineering calculations to prove that the introduction or proposal of GSI or LID in the project will equal or exceed current capacity and the minimum capacity criteria set by SECTION 2. In applicable cases, conventional Detention shall be coupled with LID to meet the Level of Service.

9.6.01.C This section provides an overview of suitable Best Management Practices (BMPs) that are preferred LID techniques to minimize downstream impacts of development and mimic how rainfall behaves when it falls on an undeveloped green landscape.

9.6.01.D LID based practices are used to reduce stormwater runoff volume and pollutant loading from developed sites. For effective Infiltration, Detention, and maintenance, SWQ Permit is required for LID techniques.

9.6.01.E LID practices use natural features to slow and filter stormwater runoff. Project characteristics will define which LID BMPs are applicable. When determining the appropriate LID requirements, Engineers shall consider characteristics such as site location, existing topography and soils, and planning elements. These characteristics and their impacts on design are important because LID BMPs are permanent features that can affect other project elements; therefore, it is critical to conduct thorough site assessments to avoid the need for redesign later. Incorporating LID early in the site design stage can reduce the need for and cost of traditional drainage infrastructure by reducing the amount of stormwater to be conveyed off-site.

9.6.01.F continued

9.6.01.F Siting and selecting appropriate LID practices is an iterative process that requires comprehensive site planning. A site planner, landscape architect, or Engineer can review the existing and proposed site layout when developing final site plans. Consideration to LID practices should be given during all of the design phases of a project (site assessment, preliminary design, and final design).

1. A thorough site assessment is needed initially to identify the development envelope and minimize site alterations. The primary objective of the site assessment process is to identify limitations and development opportunities specific to LID. For example, development opportunities include available space, use of right-of-way as appropriate, and maximizing opportunities for Infiltration through soil and Underdrains. Constraints or limitations that need to be factored into site planning when implementing LID practices include but are not limited to:

   a. Slow-infiltrating soils (typically clays)

   b. Soil contamination

   c. Steep slopes

   d. Adjacent foundations of structures

   e. Wells

   f. High seasonal water table

2. For both New Development and Redevelopment, in the preliminary site plan, the development envelope (site boundary) is delineated. To make the best and most optimal use of LID techniques on a site, a comprehensive site assessment must be completed that includes an evaluation of existing site topography, soils, vegetation, and hydrology (surface water and ground water features). High quality ecological resources (e.g., wildlife habitat, mature trees) should also be identified for conservation or protection. With such considerations, the site assessment phase provides the foundation for consideration of and proper planning around existing natural features and to retain or mimic the site's natural hydrologic functions.

9.6.02 LID DESIGN ~~STANDARDS~~REQUIREMENTS

9.6.02.A When design approaches included in this section are incorporated in designs requiring City Engineer approval, the standards of this section will apply.

9.6.02.B continued

9.6.02.B The minimum design criteria for LID techniques shall be applied in accordance with this section. See Table 9.11 for a list of LID techniques. For applying any LID technique, a SWQMP is required. For facilities requiring a Forebay, see Figure 9.14 and Figure 9.15.

Table 9.11 – LID TECHNIQUES

LID Type	Runoff Reduction/ Detention	SWQ Treatment Feature	Application Example
Bioretention (9.6.02.C.1)	Yes	Filtration, Sorption, Nutrient Uptake	• Residential, commercial • Roadway • Streetscaping projects • Parks and trailways
Tree Box (9.6.02.C.2)	No	Filtration, Sorption, Nutrient Uptake	• Dense urban areas • Residential, commercial and suburban areas • Streetscaping projects
Infiltration Trenches (9.6.02.C.3)	Yes	Filtration	• Urban area • Arid regions (recharging groundwater) • Retrofit • Roadway and R.O.W.
Porous Paver Systems and Porous Pavement (9.6.02.C.4)	Yes	Filtration	• Residential, commercial • Urban areas
Vegetated Swales (9.6.02.C.5)	Yes	Filtration	• Driveways • Parking lot (perimeter, island median) • Along local roads • Highway medians
Green Roof (9.6.02.C.6)	Yes	Filtration	• Commercial, industrial, and residential structures
Blue Roof (9.6.02.C.7)	Yes	Capture	• Commercial, industrial and residential structures
Rain Barrel (9.6.02.C.8)	Yes	Capture, Settling	• Commercial, industrial, and residential structures
Cisterns/Above Ground Systems (9.6.02.C.9)	Yes	Capture, Settling	• Commercial, industrial, and residential structures
Constructed Wetland Basins (9.6.02.C.10)	Yes	Filtration, Settling, Nutrient Uptake	• Parks and trailways • Suburban areas
Underground Storage Tanks (9.6.02.C.11)	Yes	Capture, Settling	• Parking lots • Commercial, industrial, and residential structures

~~9.6.02.A~~9.6.02.C Low Impact Development (LID) Techniques:

1. Bioretention

9.6.02.C.1.a continued

a. Overview

(1) Bioretention is a terrestrial-based (up-land as opposed to wetland), water quality and water quantity control practice using the chemical, biological and physical properties of plants, microbes and soils for removal of pollutants from Stormwater runoff. Some of the processes that may take place in a ~~b~~Bioretention facility include: sedimentation, adsorption, filtration, volatilization, ion exchange, decomposition, phytoremediation, bioremediation, and storage capacity. Bioretention may also be designed to mimic predevelopment hydrology. Native plants are preferred to be used for Bioretention as they are best adapted to the region. A recommended list of plants is available from the Native Plant Society of Texas Houston Chapter Native Plant Guide[20]. Non-native plants shall be reviewed by the Engineer for functionality and applicability.

b. Design Criteria

(1) The ~~cross section~~ design detail for a typical ~~Porous~~ Bioretention basin is shown ~~on~~in Figure 9.16.

(2) Determine volume of ~~b~~Bioretention area below maximum design water surface. Depth of ponding above the Bioretention soil media (BSM) is limited to a maximum of 9-inches in the R.O.W. or where there is public access and 18-inches where access is restricted ~~6 inches~~.

(3) Demonstrate that sufficient area contributes stormwater runoff to the ~~b~~Bioretention area to fill the area to its maximum design water surface for the design storm under consideration. Location of Bioretention systems should be at relative low points in the overall site grading plan. The size (area) of Bioretention system is directly proportional to the contributing Drainage Area flowing to it.

~~(3)~~(4) Protect systems vulnerable to damage from vehicle and pedestrian traffic. Systems are not designed to accommodate any surface loads and compaction from surface loads will harm system function.

[20] https://www.houstontx.gov/police/cpted/planting_information/Houston_native_plant_guide.pdf

9.6.02.C.1.b continued

~~(4)~~(5) Using in-situ, Engineered Soils, or new soils, design the ~~b~~Bioretention area to empty within ~~48~~24 hours to prevent insect breeding and bacteria or algae formation. This may be accomplished through ~~i~~Infiltration, evapotranspiration, and/or the design of a subsurface drainage system. The maximum Infiltration Rate of designed Bioretention media shall be 2-inches per hour.

~~(5)~~(6) Each LID technique shall have a service area of no more than 5 acres~~Mitigating detention volume requirements can be reduced by the volume in the bioretention area below its maximum design water surface~~.

~~(6)~~(7) Runoff from commercial areas and parking lots require pretreatment; grass buffer strip~~ or~~, ~~v~~Vegetated ~~s~~Swales, or other feature to capture sediment and debris prior to draining into ~~b~~Bioretention area.

~~(7)~~(8) For LID techniques without subsurface drainage system, in-situ subsoil shall have a minimum Infiltration Rate of 0.5-inches per hour. Geotechnical testing including one boring per 5,000 square feet or two per project is required to confirm Infiltration Rate. Otherwise, Infiltration Rates less than 0.5-inches per hour or where the project is constructed on fill soils will require a subsurface drainage system. When the capacity of the Bioretention system's reservoir is exceeded, an overflow bypass graded towards existing drainage system to convey the required flow rate from the inlet to a suitable storm sewer, channel, or bayou may be allowed on a case-by-case basis.

~~(8)~~(9) ~~Infiltration rates less than 0.5 inches per hour will require a subsurface drainage system.~~Include an observation port to provide an opening to below grade portions of the system so that water level monitoring can be conducted during drawdown tests. In case of bigger techniques (e.g. multiple techniques in series, large area), observation ports should be typically placed every 300-feet. If the Underdrain system has branches, add ports at the end of every branch lateral.

~~(9)~~(10) Soil media must be a minimum of 24-inches deep~~Geotechnical testing is required to confirm infiltration rates~~.

c. Inspection and Maintenance Requirements

9.6.02.C.1.c continued

(1) Refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston" for inspection and maintenance requirements.

(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.). ~~Verify presence of vegetation considered in design computations (if any) quarterly.~~

~~Verify the bioretention area has adequate volume quarterly by checking whether sedimentation has encroached on design volume. This can be done by comparing actual maximum depth against design maximum depth.~~

~~Verify ability of bioretention area to drain within 48 hours twice yearly after rainfall event.Correct deficiencies related to items 1-3 above as needed.~~

2. Tree Box

a. Overview

(1) Tree boxes are containment systems usually installed along public R.O.W. as a form of Bioretention and beautification. Boxes are usually made with an Engineered Soil mix, an Underdrain, an overflow and may connect to the storm sewer system. The trees act as mini reservoirs to divert, absorb and purify stormwater runoff on site before it enters the stormwater drainage system. Trees help to reduce the amount of stormwater entering the system and increase Infiltration into the soil.

b. Design Criteria

(1) There are a few different strategies for incorporating tree boxes into public R.O.W., along streets, plazas, parking areas and medians.

(a) Engineer tree boxes to accept water and tie into the stormwater management system.

9.6.02.C.2.b.(1) continued

(b) Suspended pavement techniques can be used to extend tree rooting volume under HS-20 load bearing surfaces. This technique suspends pavement above the soil to provide ample room for larger tree roots to grow. The pavement can be suspended using soil cells between the soil and pavement, which reduces compaction on the soil and increases filtration and holding capacity.

(c) Other options are rock-based structural soils that are gap graded Engineered Soils. This technique provides load bearing capacity while also protecting soil in its void spaces from compaction. These types of designs drain very quickly and tree species tolerant of well drained soils should be selected.

(d) Holes for the tree should be excavated two feet greater in width than the diameter of the soil ball. Care should be taken not to compact the soil immediately around the tree as this will restrict root growth.

(e) Tree boxes with Engineered Soils have the capacity for larger shrubs and trees with a radius of around 5-feet.

(f) Tree selection should reference the street trees list in Houston's ordinances and consideration of height is important. For the site, take note of obstructing views and presence of overhead power and utility lines.

(g) Diversity of species is important to reduce risk of disease and pests threatening health of trees. More than one variety of species should be planted in an area.

c. Inspection and Maintenance Requirements

(1) Refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston" for inspection and maintenance requirements.

(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

~~2.~~3. Infiltration Trenches

a. Overview

(1) Trenches or basins that temporarily detain a design ~~w~~Water ~~q~~Quality ~~v~~Volume while allowing ~~i~~Infiltration to occur over a prescribed period of time. Trenches are applicable for both water quality and water quantity control practices. Infiltration Trenches consist of a long, narrow excavation ranging from 3 to 12-feet in depth (depending on stormwater volume, soil and water table conditions) which is backfilled with stone Aggregate, allowing for the temporary storage of stormwater in the voids between the Aggregate material. Stored runoff then infiltrates into the surrounding soil.

9.6.02.C.3 continued

~~c.~~b. Design Criteria

(1) A design detail for a typical Infiltration Trench is shown in Figure 9.17.

(2) For LID techniques without subsurface drainage system, in-situ subsoil shall have a minimum Infiltration Rate of 0.5-inches per hour. Geotechnical testing including one boring per 5,000 square feet or two per project is required to confirm Infiltration Rate. Otherwise, Infiltration Rates less than 0.5-inches per hour or where the project is constructed on fill soils will require a subsurface drainage system. When the capacity of the Infiltration Trench system's reservoir is exceeded, an overflow bypass graded towards existing drainage system to convey the required flow rate from the inlet to a suitable storm sewer, channel, or bayou may be allowed on a case-by-case basis.

~~In-situ subsoil shall have a minimum infiltration rate of 0.5 inches per hour. Geotechnical testing including one boring per 5,000 square feet or two per project is required to confirm infiltration rate.~~

~~(1) Subsurface drainage systems are required where the in-situ subsoil rate is less than 0.5 inches per hour or where the project is constructed on fill soils.~~

~~(2)~~(3) Vegetation tolerant to temporary inundation should be used in the facility. Root penetration and thatch formation maintains and often enhances Infiltration capacity of the basin floor. In addition, vegetation can trap stormwater constituents by growing through accumulated sediments and preventing re-suspension. Vegetation also provides nutrient uptake in the shallow root zone and a substructure for microbial residence.

~~(3)~~(4) The site should be graded to maximize the trench Sheet Flow distance ~~A~~avoiding placement on slopes greater than 15% in fill areas.

(5) Design of the trench area to empty within 48-hours.

~~(4)~~(6) Include energy dissipation in the inlet design for the basins.

~~(5)~~(7) Backfill using ~~clean a~~Aggregate ~~larger than 1.5-inches and smaller than 3-inches~~ made up of ASTM 8 or 89 crushed stone surrounded by nonwoven geotextile ~~engineered~~ filter fabric.

9.6.02.C.3.b continued

~~(6)~~(8) Provide overflow structure, splitter structure, or channel to accommodate larger runoff events.

(9) Provide 4-inches PVC observation well into subgrade.

~~(7)~~(10) Runoff from commercial areas and parking lots require pretreatment; grass buffer strip or ~~v~~Vegetated ~~s~~Swales, or other feature to capture sediment and debris prior to draining into ~~i~~Infiltration ~~t~~Trench.

~~(8)~~(11) Locate bottom of facility at least 4-feet above seasonal high water table elevation to prevent groundwater contamination.

~~(9)~~(12) Locate at least 100-feet from any water supply well.

(13) -Maximum contributing ~~d~~Drainage ~~a~~Area is 5 acres. Runoff contributing to the Drainage Area directed to the LID technique must be completely stabilized before construction to prevent pollutants, debris and sediments to enter the system.

~~(10)~~(14) The volume of the basin should be sized to retain at least the volume of runoff from a 1.5-inch rainfall event. Maximum water depth in the basin should not exceed 2-feet.

~~(11)~~(15) Mitigating ~~d~~Detention volume can be reduced by the amount of ~~i~~Infiltration into the subsoil and the volume of voids within the trench area.~~i~~

c. Inspection and Maintenance Requirements

~~(12)~~(1) Refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston" for inspection and maintenance requirements.

~~(13)~~(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

~~.Inspect observation well for water level and drainage times.Conduct landscaping, mowing, and desilting of facility.~~

4. Porous Paver Systems and Porous Pavement

a. Overview

Porous Pavement consists of a permeable surface course (typically, but not limited to, pavers, asphalt or concrete) that allows ~~i~~Infiltration of stormwater runoff into a permeable layer of uniformly graded stone bed. The underlying permeable layer serves as a storage reservoir for runoff and/or ~~i~~Infiltration. Porous ~~P~~pavement is applicable for both water quality and water quantity control practices.

9.6.02.C.4 continued

~~c.~~b. Design Criteria: Minimum requirements for porous ~~paver~~ system

(1) Design details for Porous Paver Systems are shown in Figure 9.18~~8~~, Figure 9.19, Figure 9.20, and Figure 9.22. ~~and for~~ Porous Pavement Systems are shown in Figure 9.21~~9~~.

~~(2) Restricted to Single Family Residential Construction or Commercial Construction on private property when the system is covered by a Stormwater Quality Permit.~~

~~(3) Residential Porous Pavers Systems without a subsurface drainage system may be determined as pervious for up to 10% of the lot area for a Single Family Residential (SFR) lot: (1) qualifying for exemption from detention under 9.2.01.H.3 and for basis of City Drainage Utility charges.~~

~~(4) Commercial Porous Paver Systems without a subsurface drainage system that have a Stormwater Quality Permit may be determined as pervious for commercial areas designed for heavy traffic volume and/or vehicles.~~

For LID techniques without subsurface drainage system, in-situ subsoil shall have a minimum Infiltration Rate of 0.5-inches per hour. Geotechnical testing including one boring per 5,000 square feet or two per project is required to confirm Infiltration Rate. Otherwise, Infiltration Rates less than 0.5-inches per hour or where the project is constructed on fill soils will require a subsurface drainage system. When the capacity of the Porous Pavement System's reservoir is exceeded, an overflow bypass graded towards existing drainage system to convey the required flow rate from the inlet to a suitable storm sewer, channel, or bayou may be allowed on a case-by-case basis.

(2) ~~In-situ subsoil shall have a minimum iInfiltration rRate of 0.5 inches per hour. Geotechnical testing including one boring per 5,000 square feet or two per project is required to confirm infiltration rate.~~

~~Subsurface drainage systems are required for stormwater detention where the in-situ subsoil rate is less than 0.5 inches per hour or where the project is constructed on fill soils.~~

(3) Subsurface drainage systems are required to be drained in 48 hours.

(4) The top of the in-situ soil within the pavement system should be at least 2--feet above the groundwater table.

(5) ~~If the volume of storage within the voids of the subsurface drainage system's stone bed meets the detention volume rate of 0.5 acre-feet per acre of development or 0.2 acre-feet per acre for tracts less than one acre, the area of the porous pavement is considered undeveloped. Otherwise, the total voids storage volume will be credited toward the required detention volume.If the time of concentration (Tc) from a project site that includes porous pavement and subsurface drainage system, is equal to the undeveloped time of concentration, the development of the project site is considered undeveloped.~~Porous paving systems should be located at a relative high point and should be placed to avoid accepting runoff from adjacent impermeable Drainage Areas. If this is unavoidable, the ratio of contributing Drainage Area to the porous pavement should be less than 2 to 1, to avoid excessive loading and maintenance requirements. The contributing Drainage Area should be 100% impervious and should not include any significant pollutant loadings.

(7) Soft porous pavement area (use of organic materials such as wood chips, crushed seashells or mulch along pathways to help water infiltrate) shall be considered undeveloped.

(8) The cross-section typically consists of four layers, as shown in Figure 9.20~~9~~. A fifth layer is added for an optional stormwater quality component. The ~~a~~Aggregate reservoir can sometimes be avoided or minimized if the sub-grade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without by-passing the ~~w~~Water ~~q~~Quality ~~v~~Volume. Descriptions of each of the layers are presented below:

9.6.02.C.4.b.(8) continued

(a) Porous Pavement Layer - The porous pavement layer consists of an open graded pavement mixture, concrete or asphalt, specifically designed to be porous with binding agents that create a cohesive wearing surface. The thickness of this layer is based on the design of the pavement section and the loading requirements associated with the intended use. It is important to note that porous asphalt is not to be confused with Open Graded Friction Course (OGFC) that is used as a driving surface on highways which should not be used in this particular application except as an overlay wearing course over the porous concrete or asphalt. Porous pavement may be considered to contain 18% voids (typical range is 16% to 22%). Technical reference for porous concrete is FHWA-HIF-13-006. Technical reference for porous asphalt is FHWA-HIF-15-009.

(b) Top ~~Filter~~Stabilization Layer -Consists of ~~a 0.5 inch diameter crushed stone to a depth of 1 to 2 inches~~ Crushed Aggregate. Grading shall comply with ASTM No.8 or No.89 as stated in ASTM C33 to a depth of 2-inches. This layer serves to stabilize the porous pavement~~concrete~~ layer~~.~~ and ~~C~~can be combined with reservoir layer using suitable stone.

(9) Reservoir Layer ~~-~~– The reservoir layer consists of two components. The structural layer and the storage layer. The structural layer consists of ASTM No. 57 stone to a minimum depth of 4-inches. The reservoir gravel base course (storage layer) consists of washed~~, bank-run~~ gravel, 1.5 to 2.5-inches in diameter with a void space of about 40 %. Typically, ASTM No. 2, 3 or 4 stone is used for this layer. The depth of this layer depends on the desired storage volume, which is a function of the soil ~~i~~Infiltration ~~r~~Rate and void spaces, but typically ranges from ~~two~~2 to ~~four~~ 4-feet. The layer must have a minimum depth of nine inches. The layer shall be designed to drain completely in 48-hours. The layer shall be designed to store at a minimum the ~~w~~Water ~~q~~Quality ~~v~~Volume (WQV~~v~~). Aggregate contaminated with soil shall not be used. A void space~~porosity~~ value (void space/total volume) of ~~0.32~~40% shall be used in calculations unless ~~a~~Aggregate specific data exist.

9.6.02.C.4.b continued

(10) Storm Water Quality Layer (Optional) – For designs that are treating stormwater quality, an additional layer is added between the reservoir and bottom stabilization layers. The stormwater quality layer consists of 3-inches of sand on top of 2-inches of choking stone (ASTM No. 8). The choking stone layer helps prevent the sand from infiltrating the bottom layers.

~~(10)~~(11) Bottom Stabilization~~Filter~~ Layer – The surface of the subgrade shall be a 6~~-~~-inch layer of No. 57 stone~~sand (ASTM C33 concrete sand) or a 2 inch thick layer of 0.5 inch crushed stone~~, and be completely flat to promote ~~i~~Infiltration across the entire surface. This layer serves to stabilize the reservoir layer~~,~~ and Underdrain, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.

~~(11)~~(12) Filter Fabric and Liner - It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the ~~a~~Aggregate. The filter fabric serves as a very important function by inhibiting soil from migrating into the reservoir layer and reducing storage capacity. Fabric shall be MIRAFI ~~#-~~140 N or equivalent. Above the filter fabric, a liner may be required for conditions where Infiltration Rates are too low, or Infiltration will cause damage to surrounding infrastructure. The liner should be overlapped and seamed and shall be 30 mil PVC or HDPE. The fabric and liner help prevent punctures during construction and improve performance of the system.

(13) Underlying Soil - The underlying soil shall have an ~~i~~Infiltration capacity of at least 0.5 inches ~~/~~per hour, but preferably greater than 0.50 inches per ~~/~~hour. as initially determined from Natural Resources Conservation Services (NRCS) soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5,000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration ~~t~~Trenches cannot be used in fill soils. Soils at the lower end of this range may not be suited for a full ~~i~~Infiltration system. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability. Often a double-ring infiltrometer test is done at subgrade elevation to determine the impermeable layer, and for safety, one-half the measured value is allowed for ~~i~~Infiltration calculations.

9.10.01.B.3.c continued

9.6.02.C.4.c continued

c. Inspection and Maintenance Requirements

(1) Refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston" for inspection and maintenance requirements. ~~Initial inspection of porous pavement shall be monthly for the first three months post construction.~~

~~(1)~~(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

~~Semi-annual inspection to ensure pavement surface is free of sediment.~~

~~Vacuum sweep hard porous pavement followed by high pressure hosing to keep voids free of sediment quarterly.~~

~~Annually inspect pavement surface and subsurface drainage system (if any) for deterioration, spalling or malfunctioning.~~

~~Additional provisions regarding use as a pervious cover. Approval of plans considering the SFR exemption in cases including porous pavement will include the following condition:~~

~~Approval of the proposed development is based in-part on capacity for proposed porous pavement to mitigate increased stormwater runoff.~~

~~As condition of approval, applicant is required to provide notice to the owner/buyer of the property of the stormwater quality permit and that maintenance of porous paver system or porous pavement is necessary for continued functionality, that requirements for routine maintenance have been published by Houston Public Works and may be revised in the future, and that failure to fulfill maintenance actions and reporting may result in citations or an increase of drainage utility charges for the property pursuant to City of Houston Ordinance Chapter 47 Water and Sewers, Article XV Drainage Impact Fees.~~

~~11.~~5. Vegetated Swales

9.6.02.C.5.b continued

a. Overview

(1) Vegetated Swales (dry or wet) are earthen, planted stormwater conveyances designed to filter a shallow depth of runoff (<4~~-~~ inches) for water quality improvement and to infiltrate stormwater. There are two types, dry or wet. Dry swales include an ~~u~~Underdrain system. Wet swales do not. Swales are typically designed to convey runoff from larger storm events~~,~~; however, treatment and ~~i~~Infiltration is reduced during high flows. Infiltrative soils or an engineered porous subgrade is required for ~~i~~Infiltration use. Vegetated Swales are applicable for both water quality and water quantity control practices.

b. Design Criteria for Dry Swale

(1) A ~~D~~design detail~~s~~ for a typical dry swale ~~are~~is shown in Figure 9.23.

~~(1)~~(2) Soil ~~i~~Infiltration ~~r~~Rate of 0.27 to 0.50 inches per~~/~~ hour.

~~(2)~~(3) Trapezoidal or parabolic cross section.

~~(3)~~(4) Bottom width shall be 2~~-~~ feet wide minimum or 6~~-~~ feet wide max.

~~(4)~~(5) Longitudinal slope shall range from 1% to 6%.

~~(5)~~(6) Flow depth shall be less than 4~~-~~ inches for water quality treatment.

~~(6)~~(7) Flow velocity shall be less than 1 foot per second for water quality, less than 5 feet per second for 2-~~y~~Year storm (non-erosive velocities for grass and soils).

~~(7)~~(8) Length shall yield a 10-minute ~~r~~Residence ~~t~~Time.

~~(8)~~(9) Side slopes shall be flatter than 3H:1V.

~~(9)~~(10) Maximum ponding time shall be 48~~-~~ hours.

~~(10)~~(11) Use proper vegetation (grass or wetland plants) consistent with climate, ecoregion, soils, and hydric conditions.

~~(11)~~(12) Provide at least 3~~-~~ inches of free-board during design storm.

(13) Provide pretreatment of runoff into the swale.

9.6.02.C.5.c continued

~~(12)~~(14) Swale outlet or Outfall shall be designed to protect bed and banks receiving channel or bayou considering tailwater conditions during hydrology and hydraulic analysis.

c. Design Criteria for Wet Swale

(1) Design details are shown in Figure 9.24 and Figure 9.25.

~~(13)~~(2) Soil ~~i~~Infiltration ~~r~~Rate of 0.27 to 0.50 inches ~~/~~per hour.

~~(14)~~(3) Trapezoidal or parabolic cross section.

~~(15)~~(4) Bottom width shall be 2 feet wide minimum or 8-feet wide max,~~.~~ to avoid gullying or channel braiding.

~~(16)~~(5) Longitudinal slope shall range from 1% to 6%.

~~(17)~~(6) Flow depth shall be less than 4~~-~~-inches for water quality treatment.

~~(18)~~(7) Flow velocity shall be less than 1 foot per second for water quality, less than 5 feet per second for 2-~~y~~Year storm (non-erosive velocities for grass and soils).

~~(19)~~(8) Length shall yield a 10-minute ~~r~~Residence ~~t~~Time.

~~(20)~~(9) S~~l~~ide slopes shall be flatter than 3H:1V.

~~(21)~~(10) Maximum ponding time shall be < 48-hours.

~~(22)~~(11) Use proper vegetation (grass or wetland plants) consistent with climate, ecoregion, soils, and hydric conditions.

~~(23)~~(12) Provide at least 3-inches of free-board during design storm.

(13) Provide pretreatment of runoff into the swale.

~~(24)~~(14) Swale outlet or Outfall shall be designed to protect bed and banks receiving channel or bayou considering tailwater conditions during hydrology and hydraulic analysis.

~~e.~~d. Inspection and Maintenance Requirements

(1) Refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston" for inspection and maintenance requirements.

(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

~~Mow dry swales as required during growing season to maintain grass heights in the 4 to 6 -inch range. Wet swales, employing wetland vegetation or other low maintenance ground cover do not require frequent mowing. Remove sediment when 25% of the original water quality volume has been exceeded.~~

~~13.~~6. Green Roof

a. Overview

(1) ~~A green roof, i~~In the simplest terms, a Green Roof is a vegetated roof. The vegetation varies, but must be suitable to the local climate and be drought tolerant unless a method of irrigation is also installed.

(2) Green Roofs have been shown to effectively retain pollutants. Green Roofs with a lightweight media should be connected in a treatment train with a downstream BMP that can treat the runoff for pollutants especially bacteria and hydrocarbons (from roofing materials).

(3) If a modular system is selected, the drainage system may already be incorporated into the design, along with the soil and vegetation, depending on the manufacturer.

(4) The substrate material and depth are also factors that influence the efficiency of the ~~g~~Green ~~r~~Roof to store and/or treat stormwater.

(5) There are three basic categories of Green Roof infrastructure, extensive, semi-intensive, and intensive. Roofs consisting of relatively thin soil layers, called extensive roofs, are not as heavy as the intensive roofs, which are covered with thicker soil layers that provide better water quality benefits.

9.6.02.C.6.a continued

~~(1)~~(6) Additional considerations of a Green Roof are how they may: offset the need for an underground storm water Detention vault, how it may reduce the size of the receiving drainage system, and how the growing media can be used to filter contaminants to improve the water quality coming off the roof.

b. Design Criteria

(1) A design detail for typical Green Roof is shown in Figure 9.26.

(2) ~~Vegetation~~Plants suitable to the roof micro-climate ~~and preferably a species that is drought tolerant, unless a method of irrigation is provided,~~ shall be installed. Plants should be selected to remain healthy and minimize maintenance for the long term. The following factors should be considered:

(a) Roofs are typically hotter and drier than the surrounding city, thus drought tolerant plants are necessary, unless a method of irrigation is provided.

(b) Wind velocities are typically higher on rooftops. The effect of wind on the vegetation shall also be considered when selecting the plants.~~roof foliage, as wind velocities are typically higher at rooftop elevations.~~

~~(a)~~(c) Roof shading or heat/solar reflection from surrounding buildings should be considered when selecting plants.

(3) The design must consider the additional structural loads (gravity and lateral) that the system will impose on the building structure. The additional loading includes, but is not limited to, the water weight, soil weight and the weight of the other elements of the system such as pipes, drainage mats, modular systems, and any dead and live loads that may be on the roof for recreational use or routine maintenance of the system.

~~(b)~~(a) Structural calculations shall be submitted that demonstrate the structure's ability to sustain the additional loading of the ~~g~~Green ~~r~~Roof appurtenances plus the maximum water weight that could be stored.

(4) The roof must consist of a medium designed as a filter to remove the anticipated contaminants identified in the Stormwater Quality Permit such as bacteria, wind borne contaminants, fertilizers, etc.

9.6.02.C.6.b.(5) continued

(5) The functional part of a Green Roof will typically contain four sections.

~~(c)~~(a) Vegetation Layer: The vegetation layer is the plant material on the exposed surface of the Green Roof.

(b) Growing Medium: The vegetation layer and the soil growing medium work together to filter and remove contaminants from the stormwater runoff. There are two types of growing medium depths shown in Table 9.12.

Table 9.12~~9.~~ – GROWING MEDIUM

Roof Type	Minimum Growing Medium Depth	Purpose
Extensive	6"	Vegetation
Intensive	12"	Vegetation and Water Quality Control

(c) Filter Layer: The filter layer is below the growing medium to hold the growing medium in place and let the water pass through to the drainage layer.

(d) Drainage Layer: The drainage layer captures the water and routes it to the roof drain.

(6) When used as Detention, the vegetation layer, the growing medium, the filter fabric and the drainage layer all contribute to the attenuation of flow of the rainfall through the system and provide the storage of water. Further attenuation may be required through a restrictor at the roof drain depending on the design of the system.

(7) Attenuation approach with the calculated hydrograph is required to mitigate proposed runoff (Detention) from the proposed building roof.

(a) Captured Drainage Area is only for the Green Roof.

(b) Underdrain system is required to capture water draining through the growing and drainage layers. In addition, an emergency outflow is required to provide the emergency overflow required by plumbing code.

(c) Develop inflow and outflow hydrograph to calculate Detention volume as stated below:

9.6.02.C.6.b.(7).(c) continued

[1] Since the time of concentration on a building roof will be nearly instantaneous, and the land use can be assumed to be impervious, it may be assumed that the runoff hydrograph will follow the typical design rainfall pattern.

[2] If the design storm is assumed, for example, to be a 24-hour 100-Year Atlas 14 for City of Houston rainfall (16.9 inches), the rainfall pattern would be multiplied by the area of the roof (for this example, a typical downtown roof might be 250-feet x 250-feet, or 1.43 acres).

[3] If the design storm is broken into hourly increments, the conversion of the rainfall in inches per hour is a direct conversion to cubic feet per second (the factor is actually 1.000 acre-in/hour = 1.008 cfs).

[4] Once the outflow is determined from the above analysis, evaporation can be separated out to determine the remaining detained/attenuated outflow from the medium.

[5] This entire routing procedure can be set up in a spreadsheet to simplify the analysis.

~~(2)~~(8) The ~~amount of~~ credit value given for the stored rainfall ~~amount stored~~volume shall be as prescribed by the manufacturer for a modular system.

(9) The ~~amount of~~ credit value given for the stored rainfall ~~amount stored~~volume for non-modular systems shall be calculated for the ~~e~~Engineered ~~s~~Soil ~~m~~Media.

(a) The rate shall be derived by in-situ porosity testing. The porosity test shall be performed four times with the first time results being discarded and the three remaining results averaged.

(b) The test shall require the first sample remain wet a minimum of 1-hour.

(c) The subsequent porosity tests shall be performed the same day.

9.6.02.C.6.b.(9) continued

~~(a)~~(d) In no case shall the storage volume be credited more than 33% of total volume, as that is the assumed volume of clean graded washed gravel.

~~(3)~~(10) The roof membrane must be sufficiently designed and installed to pond a minimum of 1 inch of water at the most shallow point on the roof for 24-hours without leaks. This shall be tested in the same manner as shower pans are tested under the building code. Additionally, special consideration shall be given for the plant root structure and prevention of soil migration during membrane selection. A root barrier may also be required to protect the waterproof membrane integrity.

~~(4)~~(11) The under~~-~~drain drainage system shall be designed for the selected plant's tolerance for drought and varying soil moisture contents by maintaining the proper balance of moisture and aerobic conditions within the soil media for optimum vegetation sustainability. Design provisions shall address higher volume rainfall events to keep excessive amounts of water from ponding on top of the soil, to prevent erosion, and to prevent soil media saturation for extended periods.

~~(5)~~(12) Installation generally consists of a waterproof membrane installed over a suitably constructed roof deck.

~~(6)~~(13) For in-situ installations, an under-drain drainage system is installed over the membrane. A lightweight ~~e~~Engineered ~~s~~Soil is installed on top of the under~~-~~drain, as fill dirt or topsoil is typically too heavy to use in rooftop applications. The ~~e~~Engineered ~~s~~Soil is then planted with select vegetation.

c. Inspection and Maintenance Requirements

(1) Refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston" for inspection and maintenance requirements.

(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

9.10.01.B.5.c.(2) continued

~~(0) A maintenance plan for the green roof system shall be developed in accordance with the membrane manufacturer's instructions and plant species selected. At a minimum, maintenance inspections shall be performed at least four times per year. The maintenance plan shall include provisions for vegetation maintenance and replacement as needed to maintain a minimum 80% coverage/survival rate in order to sustain Stormwater quality and/or detention credits. Irrigation may be required initially in order to establish the roof vegetation and to supply water under severe drought conditions. Any requirements for initial or intermittent use of fertilizer and pesticides for disease or insect control shall be identified in the plan. Plant species shall be carefully selected to minimize intermittent fertilizer and pesticide applications.~~

~~(0) Each green roof installation shall be inspected by the agency responsible for issuing the Stormwater quality or detention credits to check compliance with the approved drawings before final acceptance is issued and the proper credits are approved. At a minimum, the following items shall be checked during the inspection:~~

~~( ) Results from porosity testing (for non-modular installations).~~

~~( ) Certification from a registered Professional Engineer or registered Architect that the green roof, including membrane, drain system and engineered soil media system, was installed per the approved (permitted) drawings and operates as designed.~~

~~( ) Drawings of the green roof installation.~~

~~(0) Once the green roof is installed and established, additional inspections will be required in order to properly maintain the vegetation, drainage system and roof membrane. Routine inspections shall be conducted and associated maintenance activities performed on the following:~~

~~( ) Joints at adjoining walls, roof penetrations for vents, electrical and air conditioning conduits shall be inspected regularly for leaks. The ceilings located directly below the green roof installation shall also be visually inspected for signs of water staining or leaking.~~

9.6.02.C continued

~~( ) Designated drainage paths and drainage system components shall be inspected to ensure proper surface drainage is maintained and that the soil layer is drained to prevent excessively saturated soils. Vegetation selected to tolerate drought conditions may rot or die if the soil is allowed to become saturated for extended periods.~~

~~( ) Vegetation shall be visually inspected to identify weeds, accumulated trash or debris, dead or dying vegetation, disease or other infestation problems requiring maintenance attention. Weeds and dead vegetation shall be removed on a regular basis, especially right after the roof is planted. If a certain plant or grass species continues to die, that plant or grass shall be removed and replaced with a more tolerant species. Certified professionals shall only be used to apply chemical applications for the control of disease or insects at trouble spot locations.~~

~~( ) Trimming and pruning shall be done in accordance with horticulture practices to keep vegetation aesthetically groomed.~~

~~24.~~7. ~~Hard~~Blue Roof

a. Overview

(1) Horizontal roof surfaces can be used to attenuate peak runoff associated with rainfall and effectively detain flow resulting from smaller rain events. The ~~d~~Detention volume can be controlled in several ways, but typically a simple drain ring is placed around the roof drains. As stormwater begins to pond on the roof, flow into the roof drains is controlled by orifices or slits in the drain ring. Extreme flows can be designed to overflow the ring and drain directly to the roof drains or be directed to openings in the parapet walls to prevent structural and flood damage to the roof. The roof deck must be designed to withstand the live load and be properly waterproofed.

b. Design Criteria

(1) A design detail for typical Blue Roof is shown on Figure 9.27.

9.6.02.C.7.b continued

(2) The structural capability of the roof system must be considered when designing a temporary rooftop storage system. For example, a 3-inch water depth is equivalent to a load of 15.6 ~~lbs~~pounds per~~/~~ square~~.~~ foot~~.~~, which is less than most current building code requirements for live loads. The design must consider the additional structural loads (gravity and lateral) that the system will impose on the building structure. The additional loading includes, but is not limited to, the water weight, the weight of the other elements of the system such as pipes, drainage mats, modular systems, and any dead and live loads that may be on the roof for recreational use or routine maintenance of the system.

~~(1)~~(3) Consideration must be given to the placement of electrical devices on the roof, such as air conditioning or ventilation systems and lights, and proper measures shall be taken to protect the electrical devices from the collected water.

~~(2)~~(4) Overflow mechanisms shall be provided so that there is no danger of overloading the roof storage system during major storms. Additionally, roof slopes shall be designed to drain positively toward the roof drains to help minimize localized roof ponding or ‘bird bath’ formation after the detained water volume is released.

~~(3)~~(5) ~~It is recommended that~~Refer to Chapter 16 of the International Building Code, Current Edition ~~be used~~ for additional structural criteria along with ASCE Standard Reference Number 7, Minimum Design Loads for Buildings and Other Structures.

(6) The amount of credit given for ~~d~~Detention volume for rooftop storage shall take into account that many flat roofs already pond significant amounts of water, although not by design. Therefore, when measuring credit given for ~~hard~~Blue ~~r~~Roof ~~d~~Detention volume, it is recommended that only credit be given for the total rooftop storage volume less the rooftop storage volume associated with the first inch of rain. Typically, rooftop storage volumes are only effective during the smaller, more frequent rainfall events as the larger, less frequent storms typically exceed the rooftop storage capacity.

c. Inspection and Maintenance Requirements

(1) Refer to “A Guide to Developing and Maintaining Low Impact Development Techniques in Houston” for inspection and maintenance requirements.

~~(4)~~(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ ~~p~~Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

~~Each hard roof installation shall be inspected by the agency responsible for issuing the detention credits to check compliance with the approved drawings before final acceptance is issued and the proper credits are approved. At a minimum, the following items shall be checked during the inspection:~~

~~Roof penetrations for ventilation, electrical or plumbing connections to verify proper sealing against leaks.~~

~~The overflow system that drains excessive rainfall off of thehard roof once the maximum storage volume is captured.~~

~~Certification from a registered Professional Engineer or registered Architect that he hard roof, drain system and appurtenances have been installed and operate as designed.~~

~~Drawings of the hard roof installation.~~

~~Once the hard roof is installed, additional inspections will be required in order to properly maintain the drainage system and roof membrane. Routine inspections shall be conducted and associated maintenance activities performed on the following:~~

~~Designated drainage paths and drainage system components shall be inspected to ensure proper surface drainage is maintained and that the roof is draining properly after the collected stormwater volume is released from a rainfall event.~~

~~Routine inspections to collect and remove any trash or debris from the roof shall be conducted to prevent clogging of the roof drains and overflow drainage system.~~

9.6.02.C.8.b continued

~~Visible cracks in the roof surface shall be identified and repaired in accordance with the roof manufacturer's recommendations in order to maintain roof integrity.~~

~~34.~~8. Rain Barrels ~~/ Cisterns~~

a. Overview

(1) A ~~cistern (“~~rain barrel~~”)~~, ranging from 55-gallons to several hundred gallons in capacity, is placed near the down spout of a house and is used to collect rain~~-~~water runoff from the roof of the house. The captured water is then typically used as a pure water source for plants and lawns.

b. Design Criteria

(1) Gutters and downspouts carry water from the rooftops to rain barrels as shown on Figure 9.28~~12~~ and/or connect directly to subsurface drainage system.

(2) Screens are required on gutters to prevent clogging.

(3) Rain barrels shall be equipped with a restrictor (ex. Valve) or low-flow outlet~~drain spigot~~.

(4) Overflow outlet must be provided to bypass rain barrel from large rainfall events.

(5) Rain barrel must be designed with removable, child resistant covers marked “Danger-Confined Space” and mosquito screening.

(6) Minimum rain barrel capacity equal to 1 inch of runoff from roof top surface area.

c. Inspection and Maintenance Requirements

(1) Refer to “A Guide to Developing and Maintaining Low Impact Development Techniques in Houston” for inspection and maintenance requirements.

9.6.02.C.9.b continued

(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

~~As condition of approval, applicant is required to provide notice to the owner/buyer of the property that the stormwater quality permit and the maintenance of rain barrel / cistern is necessary for continued functionality. The requirements for routine maintenance have been published by Houston Public Works and may be revised in the future. Failure to fulfill maintenance actions and reporting may result in citations or an increase of drainage utility charges for the property pursuant to City of Houston Ordinance Chapter 47 Water and Sewers, Article XV Drainage Impact Fees.~~

~~Owner/Buyer of Property shall maintain and inspect Rain Barrels and Cisterns according to the following:~~

~~Empty rain barrel after each rainfall event.~~

~~Rain barrel shall be inspected annually.~~

9. Cisterns/Above Ground Systems

a. Overview

(1) A cistern/above-ground system is placed near the down spout of a building structure and is used to collect rainwater runoff from the roof of the building structure. The captured water is to be released to the subsurface drainage system onsite. When used for Detention, this feature should be used in conjunction with other subsurface Detention system for proper flood mitigation.

b. Design Criteria

(1) Gutters and downspouts carry water from the rooftops to cisterns as shown on Figure 9.29 and/or connect directly to the subsurface drainage system.

(2) Screens are required on gutters to prevent clogging. All inlets, overflows, and other openings should be protected with mosquito screens.

(3) Cisterns/above-ground systems must be designed with removable, child-resistant covers marked “Danger-Confined Space”.

(4) Overflow outlet must be provided to bypass the cisterns/above-ground systems from large rainfall events. Overflow pipe should convey overflow to point of discharge.

(5) Low flow outlet should be always clear.

(6) Restrictor should be placed at the connection of cisterns/above-ground systems to the subsurface drainage system. Cisterns shall have a drainage valve to empty within 24 to 48 hours after each rain event.

~~(1)~~(7) Cisterns/above-ground systems shall be designed by a State of Texas Professional Engineer.

c. Inspection and Maintenance Requirements

(1) Refer to “A Guide to Developing and Maintaining Low Impact Development Techniques in Houston” for inspection and maintenance requirements.

(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

10. Constructed Wetlands Basins

~~b.~~a. Overview

9.6.02.C.10.a continued

(1) Storm water treatment wetlands are constructed shallow ponds designed often based on the ecological function of natural wetlands. Natural wetlands are more or less self-maintaining systems; whereas, constructed wetlands for storm water treatment purposes require active management. Wetlands are constructed in development and Redevelopment activity for two main purposes.- The first purpose is to mitigate lost, impacted or filled wetlands due to development or construction activity, and the second purpose is to treat storm water runoff (storm water treatment wetlands). Newly Constructed Wetland Basins should be evaluated for exemption listed in 40 CFR 122.2 that provides an exemption to classification as "Waters of the U.S." for treatment pond systems or lagoons designed to meet the requirements of the Clean Water Act. However, if a Constructed Wetland Basin is exempted by being defined as a treatment facility, it cannot be used for wetlands mitigation for losses due to construction. Modification of an existing wetland area to serve for storm water treatment function is potentially subject to 404 permitting. The need for section 404 permits should be evaluated on a case-by-case basis.

b. Design Criteria

(1) A design detail for a typical Constructed Wetland Basin is shown in Figure 9.30.

(2) Constructed Wetland Basins should be designed with an armored sediment Forebay that captures initial sediment depositions and reduces stormwater inflow velocities that will lengthen the life of the project and reduce erosion.

(3) They should be designed to maximize the hydraulic retention time to store water and slowly release it, reducing risk of flooding.

(4) Reduce hydraulic short-circuiting to avoid creating dead zones in the system and giving sediment time to filter out.

(5) Water quality treatment volume and permanent pool volume should be calculated based on requirements in 9.5.01.C for runoff from the Drainage Area.

(6) Depth of sediment Forebay (Pre-treatment) is 4 to 6-feet.

9.6.02.C.10.b continued

(7) Volume of pre-settling basin or Forebay should be 20% of permanent pool volume with inlets that convey stormwater runoff entering the Forebay first or pre-treatment before wetland.

(8) Length to width ratio is 3:1 or more. Design of layout should avoid dead storage area and minimize short-circuiting.

(9) Side slope is 3H:1V or flatter.

(10) Surface-area-to-pool-depth relationship:

(a) 50% area: 0.5-feet deep

(b) 15% of the area: 0.5 to 2-feet deep

(c) 15% of the area: 3 to 4-feet deep

(d) 20% of the area: greater than 3-feet deep with max of 6-feet in Forebay section.

~~(1)~~(11) Wetland Vegetation should be a mix of floating, emergent, and submergent plants that are native to the SE region of Texas. Depending on location in the city, wetland plants may need to be salt tolerant. Consult a wetland specialist for specific species. The site should be frequently monitored for invasive species.

c. Inspection and Maintenance Requirements

(1) Refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston" for inspection and maintenance requirements.

(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

9.6.02.C continued

11. Underground Storage Tanks

a. Overview

(1) Underground Storage Tanks (UST) are containment systems that are installed under the ground to hold and slow down stormwater runoff and mitigate risk of flooding. USTs are buried under parking lots or open green spaces, and help to collect runoff from shopping malls, medical centers, universities, or other similar type development. The storage tank will be connected to runoff through the stormwater piping system and have specially designed valves so it can temporarily hold and slowly release water into the groundwater after a major rain event. The goal is to reduce the amount of runoff on the roads and in the built environment while also encouraging Infiltration. The soil medium surrounding the tank needs to have permeability for the water to release back into the groundwater. Underground Storage Tanks are ideal for urban areas with high population densities and limited space.

b. Design Criteria

(1) Water storage structures (vaults) or large diameter, rigid pipes or arches with capped ends and made of metal, reinforced concrete, plastic, steel, or aluminum.

(2) Pipes and floors of vaults should be designed with a maximum of two percent slopes to facilitate drainage of water.

(3) Consider incorporating sufficient number of access points (manholes) for personnel to facilitate easy maintenance.

(4) This type of BMP can be combined with other techniques such as porous pavers above or installing filtration devices at inlets and outlets to enhance water quality.

(5) Stone backfill around perimeter and a layer of crushed stone between the surface and the stormwater storage systems.

(6) When any storage volume of USTs are proposed to be used for Detention, USTs shall meet the underground Detention requirements in 9.2.01.H.3.

(7) When storage volume of USTS is used primarily for any purpose other than Detention:

9.6.02.C.11.b.(7) continued

(a) In-situ subsoil shall have a minimum Infiltration Rate of 0.5--inches per hour. Geotechnical testing including one boring per 5,000 square feet or two per project is required to confirm Infiltration Rate. Otherwise, Infiltration Rates less than 0.5--inches per hour or where the project is constructed on fill soils will require a subsurface drainage system. When the capacity of the UST is exceeded, an overflow bypass graded towards existing drainage system to convey the required flow rate from the inlet to a suitable storm sewer, channel, or bayou may be allowed on a case-by-case basis.

c. Inspection and Maintenance Requirements

(1) Refer to "A Guide to Developing and Maintaining Low Impact Development Techniques in Houston" for inspection and maintenance requirements.

~~(1)~~(2) For any LID technique that requires a SWQ Permit, the Engineer shall provide a checklist for required inspection and maintenance and include it in the SWQMP that will be submitted as a part of the package for obtaining SWQ Permit for LID. The inspection and Maintenance Activities shall be scheduled as per SWQMP (after any heavy rains, annually, etc.).

9.6.03 ~~QUALITY ASSURANCE~~ LID INCENTIVES

9.6.03.A Detention Reduction

1. A preliminary meeting is required to demonstrate a conceptual design to show the pre-development and post-development Hydrology-and-Hydraulic of the stormwater runoff for the proposed LID techniques.

9.6.03.B Plan Review

1. To expedite the plan review, the Applicant shall label the plan set as "Green Stormwater Infrastructure."

9.6.03.C Incentives for using LID techniques as a part of the stormwater Detention system can be applied (Table 9.11):

1. Per the GSI initiative, projects utilizing one or more of the LID techniques can receive a detention reduction of up to a maximum of 0.15 acre-foot per acre from the required Detention rate, as applicable. The minimum Detention requirement will be reduced as long as calculations are provided to justify that the detention supplied by LID techniques sufficiently mitigate storm runoff.

2. Tax Abatement: Qualified Applicants are also encouraged to apply for the City's Green Stormwater Infrastructure Tax Abatement program that will provide an abatement to offset the incremental cost of constructing GSI as an incentive to increase green infrastructure within the city. For more information, please refer to https://www.houstontx.gov/ecodev/tax_abatements.html.

SECTION 7 – SUBMITTALS

9.7.01 SUBMITTALS

9.7.01.A ~~Submittal for review and comments~~ For Building Code Enforcement (BCE) projects inside property, submit the following:

1. Stormwater Information Form and supporting documents (survey and recorded plat, tax account information, and recorded deed/title in owner's name) See Figure 9.31~~9~~[21].

2. Comments and responses sheet is required for resubmittal projects only. A narrative is required for revision projects.

3. Grading Permit for Excavation and Fill Worksheet (not required where there will be no excavation or fill proposed).

4. Floodplain information, including floodplain boundary, if any; FEMA map number, effective map date and zone.

5. Copies of any documents which show approval of exceptions/variances to the City design criteria.

6. Where applicable, copies of any documents which show approval of other jurisdictions where approval is required (i.e., TXDOT, HCFCD, USACE, etc.).

7. Site plan showing all surveying and topographic data including property legal description, lot, block, subdivision name, property lines, building lines, and utility easements (i.e., surface and underground utility easements).

8. Grading plan with elevations across lot and within 2-feet of adjoining lots along subject property lines, showing no Sheet Flow to unapproved locations.

[21] https://www.houstonpermittingcenter.org/media/7636/download?inline

9.7.01.A continued

9. Drainage Area Map ~~with the following information:~~ showing the ~~E~~existing contour map, ~~E~~existing and proposed ~~d~~Drainage ~~a~~Area and sub-~~d~~Drainage ~~a~~Area boundaries, ~~E~~existing and proposed ~~d~~Drainage ~~a~~Area (acres) and flow quantity (cfs) draining to each inlet and each pipe segment from storm structure (i.e., manhole, inlet, catch basin, etc.) to storm structure; and the ~~E~~extreme event (100-~~y~~Year) Sheet Flow direction, ~~E~~existing condition, and proposed condition Sheet Flow direction for the surrounding properties.

10. Drainage Plan showing all internal site drainage. Also provide the following using current Atlas 14 rainfall intensity:

    a. Design calculations for time of concentration, storm line sizes and grades, and for Detention facilities, if any.

    b. Design calculations for the Hydraulic Grade Line of each storm line or ditch, and for Detention facilities, if any, for 2-Year and 100-Year rainfall events.

~~10.~~11. Where applicable, Detention plan with calculations for required volume and designed volume, restrictor calculations and detail(s), calculations and details for all storage areas and overflow structure design~~Calculation for proportional amount of pipe capacity allocated to the Development along with the drainage area map used for these calculations~~. See Figure 9.11.

12. If ~~the~~off-site ~~d~~Detention has been provided by other projects, a ~~M~~memorandum should be provided to explain how the existing ~~d~~Detention facility serves this proposed project. Include a Detention breakdown, see Figure 9.32 as an example.

~~11.~~13. Where applicable, a Stormwater Quality (SWQ) Permit will be required per article 9.1.04.GGG or when any Low Impact Development (LID) technique is proposed. Submit copies of approved SWQ Permit and SWQ ILMS number to be called out in the Drainage plan.

9.7.01.B For Office of the City Engineer (OCE) plan and profiles, submit the following:

1. Approximate definition of lots and street patterns.

2. Stormwater Information Form. See Figure 9.31[22].

[22] https://www.houstonpermittingcenter.org/media/7636/download?inline

9.7.01.B.4 continued

3. Show ~~A~~any existing and proposed drainage easements on drawings and provide recorded easement documents.

4. Floodplain information, including floodplain boundary, if any, FEMA map number, effective map date and zone. Projects located within a floodplain boundary or within a floodplain management area shall:

   a. Show the floodplain boundary or floodplain area, as appropriate, on the Drainage Area Map.

   b. Comply with all applicable submittal requirements of Chapter 19, Code of Ordinances.

   c. Be ~~R~~reviewed and obtain approval ~~of this project by~~from the City of Houston Floodplain Management Office (FMO)~~ is required~~.

5. Drainage Area Map with the following information:

   a. Existing contour map.

   b. Existing and ~~P~~proposed ~~d~~Drainage ~~a~~Area and sub-~~d~~Drainage ~~a~~Area boundaries.

   c. Existing and ~~P~~proposed ~~d~~Drainage ~~a~~Area (acres) and flow quantity (cfs) draining to each inlet and each pipe segment from storm structure (i.e. manhole, inlet, catch basin, etc.) to storm structure.

   d. Extreme event (100-~~y~~Year) Sheet Flow direction.

   e. Existing ~~condition~~ and proposed ~~condition~~ Sheet Flow direction for the proposed and surrounding properties.

   f. A note referencing the BCE project number for proposed Detention and restrictor calculations on site, if applicable.

6. Design calculations for time of concentration, rainfall intensity, stormwater runoff, flow capacity and velocity in both existing and proposed conditions for each proposed storm sewer line or ditch. Refer to Figure 9.5, Figure 9.6 and Figure 9.7.

7. If replacing roadside ditch with culverts, show the flow capacity and storage volume of both existing and proposed condition.

8. Design calculations for Detention facilities providing Detention for public infrastructure, if applicable.

9.7.01.B.10 continued

9. If the off-site ~~d~~Detention has been provided by other projects, a ~~M~~memorandum should be provided to explain how the existing ~~d~~Detention facility serves this proposed project. Include a Detention breakdown, See Figure 9.32 as an example.

10. Cover sheet

    ~~e.~~a. Provide Stormwater Information Form log number on the cover sheet.

    ~~f. Provide all information requested in section 9.4.01A.~~

    b. Provide reference note for FEMA map number, effective map date and zone.

    c. Reference BCE project number for private onsite development, if applicable.

11. Plan and profile sheets showing proposed public ~~S~~stormwater infrastructure design ~~(public facilities only)~~ with 2-Year and 100-Year Hydraulic Grade Lines.

~~6.~~12. Profile drawing of roadway (or ~~o~~Overland ~~f~~Flow path) with exaggerated vertical scale from the upper reach of ~~d~~Drainage ~~a~~Area to the primary drainage outlet. Show roadway profile at gutter, ground profile at the public R.O.W., and ~~h~~Hydraulic ~~g~~Grad~~e~~~~ient~~ ~~l~~Lines for the 2-~~y~~Year and 100-~~y~~Year extreme event; or an alternative equivalent drawing accepted by the City.

13. Conditions for approval.

    a. All comments are addressed according to requirements listed in SECTION 7.

    ~~Original drawings~~

    ~~e.~~b. Stormwater ~~d~~Detention maintenance agreement letters, if any.

    c. All required permits from other agencies ~~or departments~~ (i.e., HCFCD approval, ~~Floodplain Management Office (FMO)~~ TXDOT approval, USACE approval, etc.)

    d. Copies of any documents which show approval of exceptions to the City design criteria (i.e. approved variances, etc.).

    e. Stormwater Quality Permit, if applicable. See article 9.1.04.GGG for requirements.

9.7.01.C continued

14. Revisions

    a. For approved projects that require revisions:

        (1) Provide a separate narrative describing the scope of proposed revisions.

        (2) Cloud and label changes with a numbered triangle corresponding to the iteration of revision per Chapter 3 – Graphic Requirements.

9.7.01.C For Capital Projects, submit the following:

1. Approximate definition of lots and street patterns.

2. Show ~~A~~any existing and proposed drainage easements with dimensions on drawings.

~~2.~~3. Floodplain information, including floodplain boundary, if any, FEMA map number, effective map date and zone. Projects located within a floodplain boundary or within a floodplain management area shall:

    a. Show the floodplain boundary or floodplain area, as appropriate, on the Drainage Area Map.

    b. Comply with all applicable submittal requirements of Chapter 19, Code of Ordinances.

    c. Be ~~R~~reviewed and obtain approval ~~of this project~~ ~~by~~from the City of Houston Floodplain Management Office (FMO)~~ is required~~.

4. Engineer of Record to coordinate with Office of the City Engineer Stormwater Quality group for review and approval of plans that requires a SWQ Permit.

~~3.~~5. Drainage Area Map with the following information:

    a. Existing contour map.

    b. Existing and ~~P~~proposed ~~d~~Drainage ~~a~~Area and sub-~~d~~Drainage ~~a~~Area boundaries.

    c. Existing and ~~P~~proposed ~~d~~Drainage ~~a~~Area (acres) and flow quantity (cfs) draining to each inlet and each pipe segment from storm structure (i.e. manhole, inlet, catch basin, etc.) to storm structure.

    d. Extreme event (100-~~y~~Year) Sheet Flow direction.

9.7.01.C continued

e. Existing ~~condition~~ and proposed ~~condition~~ Sheet Flow direction for the proposed and surrounding properties.

~~4.~~6. Design calculations for time of concentration, ~~storm line sizes and grades,~~rainfall intensity, stormwater runoff, flow capacity and ~~for detention facilities, if any~~velocity in both existing and proposed conditions for each proposed storm sewer line or ditch. Refer to Figure 9.5, Figure 9.6 and Figure 9.7.

7. Design calculations for Detention facilities providing Detention for public infrastructure. If the ~~d~~Detention has been provided by other projects, a ~~M~~memorandum with supporting documents shall be provided to explain how the existing ~~d~~Detention facility serves the proposed project.

8. Plan and profile sheets showing proposed public ~~S~~storm~~water~~ infrastructure design ~~(public facilities only)~~ with 2-Year and 100-Year Hydraulic Grade Lines.

9. Profile drawing of roadway (or ~~o~~Overland ~~f~~Flow path) with exaggerated vertical scale from the upper reach of ~~d~~Drainage ~~a~~Area to the primary drainage outlet. Show roadway profile at gutter, ground profile at the public R.O.W., and ~~h~~Hydraulic ~~g~~Grade ~~l~~Lines for the 2-~~y~~Year and 100-~~y~~Year extreme event; or an alternative equivalent drawing accepted by the City.

~~5.~~10. Calculation for proportional amount of pipe capacity allocated to the ~~D~~development along with the Drainage Area Map used for these calculations.

~~6.~~11. Signature Stage - Submit the following for approval:

a. Review ~~prints~~ files with all comments.

b. Original drawings: Provide all information requested in section 9.7.01.C~~9.4.01.A~~.

c. Stormwater ~~d~~Detention maintenance agreement letters.

~~a.~~d. All required permits/approvals from other agencies or departments (i.e., HCFCD approval, Floodplain Management Office (FMO) approval, TXDOT approval, USACE approval, etc.).

e. Copies of any documents which show approval of exceptions to the City design criteria (i.e. approved variances, etc.).

9.7.01.D For drainage impact analysis, submit the following:

9.7.01.D continued

1. Submit an electronic copy of the completed analysis that follows City issued Drainage Impact Analysis Guidelines.

2. The desired format is an indexed Portable Document Format (PDF) with a minimum of 400 dpi. If drawings are included, flatten the PDF as required in article 3.1.04.B of Chapter 3 – Graphic Requirements.

3. Large files shall be sent through a City of Houston approved downloadable link.

4. The analysis must be completed, sealed, signed, and dated by the licensed Professional Engineer in the State of Texas responsible for its completion.

5. Do not attach any information unrelated to the analysis (i.e. storm water quality plans, etc.).

6. Provide a summary of any model export files; do not send full exported file, unless requested by the City.

7. Provide a separate response sheet describing changes made to the analysis in response to review comments.

8. Incomplete submittals will not be accepted and will be rejected immediately.

9. Provide all required approvals from other agencies (i.e., HCFCD, FBCDD, etc.).

10. Plan submittal requirements:

    a. Reference approved drainage impact analysis on the coversheet. This should include the name of the analysis, the engineering firm and the responsible Professional Engineer.

    b. A drainage memo should be provided for each section. For drainage memo guidelines, contact the Office of the City Engineer's Stormwater Section.

    c. Provide an overall Drainage Area Map for entire development.

    d. Provide a Drainage Area Map for proposed section.

    e. Provide design calculations for time of concentration, rainfall intensity and stormwater runoff for proposed conditions.

    f. Provide design calculations for the flow capacity, velocity and Hydraulic Grade Line of each proposed storm sewer line or ditch.

9.7.01.E.1 continued

g. Provide plan and profile sheets showing proposed public storm infrastructure design with Hydraulic Grade Lines based on design storm event.

h. Provide a table summarizing the applied Detention for developed sections of the development. See Figure 9.32 as an example.

9.7.01.E For Storm Water Quality (SWQ) application, submit the following:

1. Administrative documents:

a. Owner's Affidavit must be signed by the owner.

b. Engineer's Certification certified by a Professional Engineer stating that the prepared Stormwater Quality Management Plan (SWQMP) complies with the City's requirements.

c. Notice of Stormwater Quality Requirements and its Exhibit A (Metes and Bounds Legal Description or Survey). The notice must be signed and notarized, then the notice and Exhibit A (preferably property boundary survey) must be recorded at the county courthouse. The submittal shall be official (i.e., no unofficial watermark on the document) and legible.

d. Cost estimate for the stormwater quality feature and its installation. The estimate is to determine the amount of the SWQ Structural Control Bond that is required. The bond does not have to be submitted with the SWQMP; the owner can attach a letter stating that the bond will be provided prior to construction.

2. The SWQ Management Plan (SWQMP).

~~9.7.01.D~~9.7.01.F Geospatial Data Deliverables: Provide GIS datasets in accordance with Chapter 13 – Geospatial Data Deliverables for projects that are proposing or modifying assets identified in Chapter 13 that are or will be operated and/or maintained by the City.

SECTION 8 - QUALITY ASSURANCE

9.8.01 QUALITY ASSURANCE

9.8.01.A Prepare calculations ~~and~~, design drawings, and SWQMPs under the supervision of a Professional Engineer trained and licensed under the disciplines required by the project scope. The final design drawings, ~~and~~ all design calculations, and SWQMPs must be sealed, signed, and dated by the Professional Engineer responsible for the development of the drawings.

~~Final design drawings, BMPs, SWPPPs, and SWQMPs shall be sealed, signed, and dated by the Professional Engineer registered in the State of Texas responsible for their Development.~~

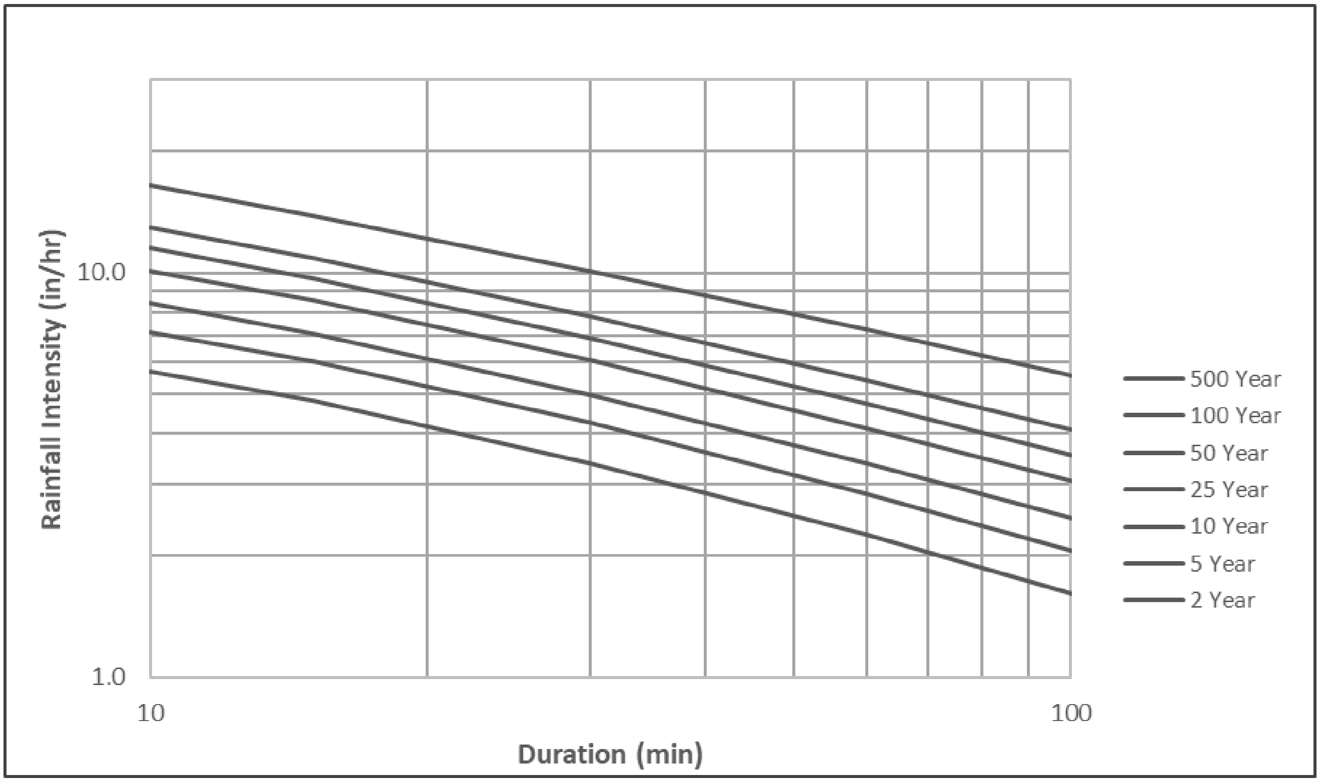


Figure 9.1 – IDF CURVES
Intensity vs Time of Concentration vs Rainfall Frequency
Source: Atlas 14

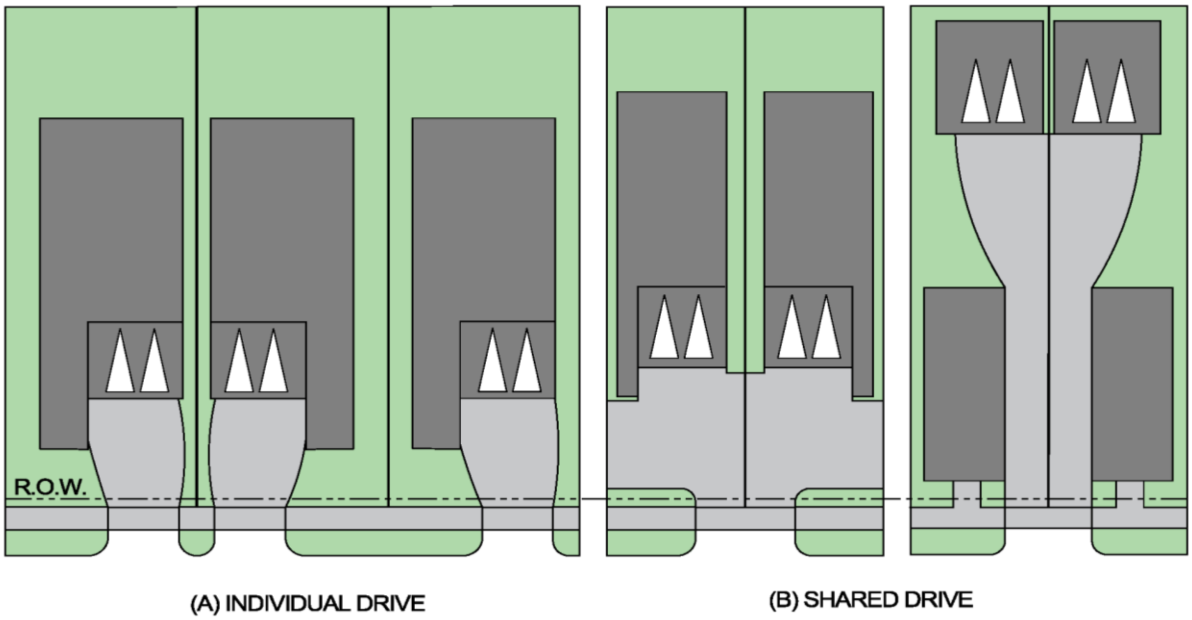
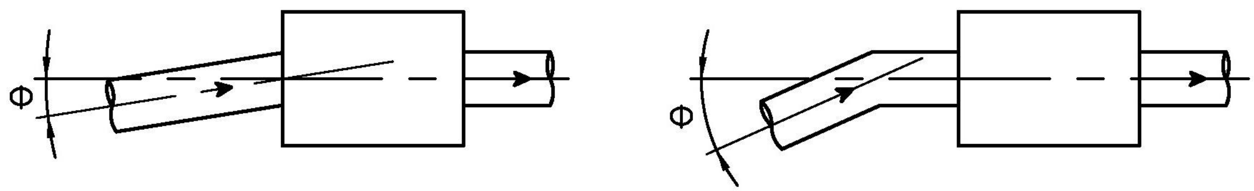


Figure 9.2 – INDIVIDUAL DRIVE AND SHARED DRIVE PROPERTIES



(A) ANGLE OF ENTRY IS LESS THAN OR EQUAL TO 7°

(B) ANGLE OF ENTRY IS GREATER THAN 7°

CONNECT PIPES WITHIN 7° OF NORMAL TO PRECAST BASE WALL. IF NECESSARY, USE PIPE ELBOW OR CURVED APPROACH ALIGNMENT TO STAY WITHIN THIS LIMIT.

Figure 9.3 – PIPE CONNECTION TO BOX STRUCTURES

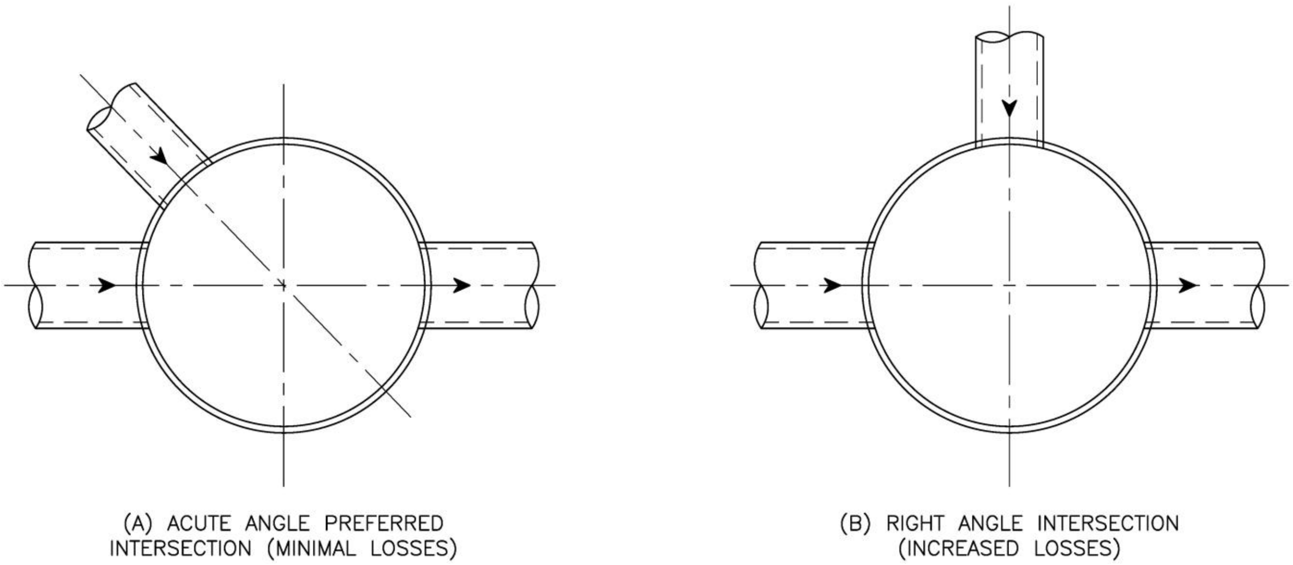


Figure 9.4 – ANGLES AT JUNCTIONS

City of Houston Storm Sewer Calculation Form

Project:

Job No:

System:

By: Date:

Checked By: Date:

HGL Starting Elevation =

Design Storm =

b =

d =

e =

MH From	HM To	Area (acres)	Cumulative Area	Runoff Coefficient, C	Sum of C*A	Time of Conc. (min)	Intensity, I (in/hr)	Sum of Flows (cfs)	Reach Length (ft)	Dia. or Rise (in)	Span (ft)	Slope (%)	Manning's "n"	Design Capacity (cfs)	Design Velocity, V (fps)	Fall (ft)	Manhole Drop (ft)	Flowline Elevation Upstream (ft)	Flowline Elevation Downstream (ft)	Actual Velocity, V (fps)	Hydraulic Grade (%)	Change in Head (ft)	Elevation of Hyd. Grade Upstream (ft)	Elevation of Hyd. Grade Downstream (ft)	Natural Ground Upstream (ft)	Natural Ground Downstream (ft)	Maximum Ponding Elevation (ft)
-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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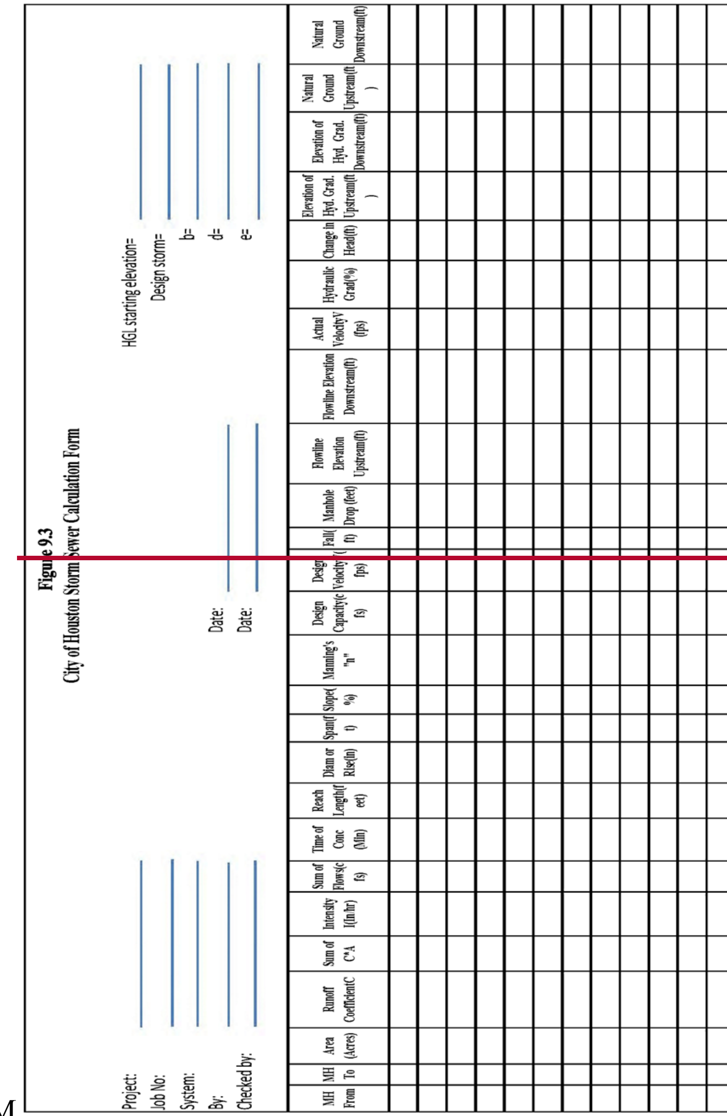


Figure 9.3
City of Houston Storm Sewer Calculation Form

Project:
Job No:
System:
By: Date:
Checked by: Date:

HGL starting elevation=
Design storm=
b=
d=
e=

MH From	MH To	Area (Acres)	Runoff CoefficientC	Sum of C*A	Intensity I(in/hr)	Sum of Flows(cfs)	Time of Conc (Min)	Reach Length(feet)	Diam or Rise(in)	Span(ft)	Slope(%)	Manning's "n"	Design Capacity(cfs)	Design Velocity(fps)	Fall(ft)	Manhole Drop (feet)	Flowline Elevation Upstream(ft)	Flowline Elevation Downstream(ft)	Actual VelocityV (fps)	Hydraulic Grad(%)	Change in Head(ft)	Elevation of Hyd. Grad. Upstream(ft)	Elevation of Hyd. Grad. Downstream(ft)	Natural Ground Upstream(ft)	Natural Ground Downstream(ft)

Figure 9.5 – STORM SEWER CALCULATION FORM

City of Houston Roadside Ditch Worksheet

Project: ______________
Job No: ______________
System: ______________
By: ______________ Date: ________
Checked By: ______________ Date: ________

HGL Starting Elevation = ________
Design Storm = ________
b = ________
d = ________
e = ________

STATION TO STATION	SIDE	SLOPE, %	DRAINAGE AREA	"C"	T_C (minutes)	I (inches/hr)	Q (CFS)	DITCH SECT FS	DITCH SECT BW	DITCH SECT BS	"n"	"d"	VELOCITY (fps)	DITCH LINING	SIDE DRAIN PIPE DIA	REMARKS

Figure 9.64 – ROADSIDE DITCH WORKSHEET

Figure 9.4
City of Houston Roadside Ditch Worksheet

Project: ____________________
Job No: ____________________
System: ____________________
By: ____________________ Date: __________
Checked by: ____________________ Date: __________

HGL starting elevation= ____________________
Design Storm= ____________________
b= ____________________
d= ____________________
e= ____________________

STATION TO STATION	SIDE	SLOPE %	DRAINAGE AREA	"C"	Tc (minutes)	I (inches/hr)	Q (CFS)	DITCH SECT			"n"	"d"	VELOCITY (fps)	DITCH LINING	SIDE DRAIN PIPE DIA	REMARKS
								FS	BW	BS						

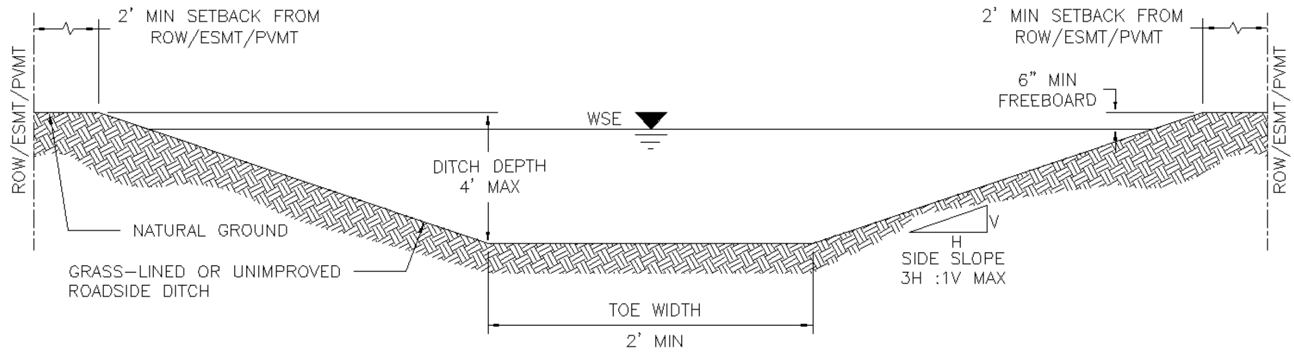
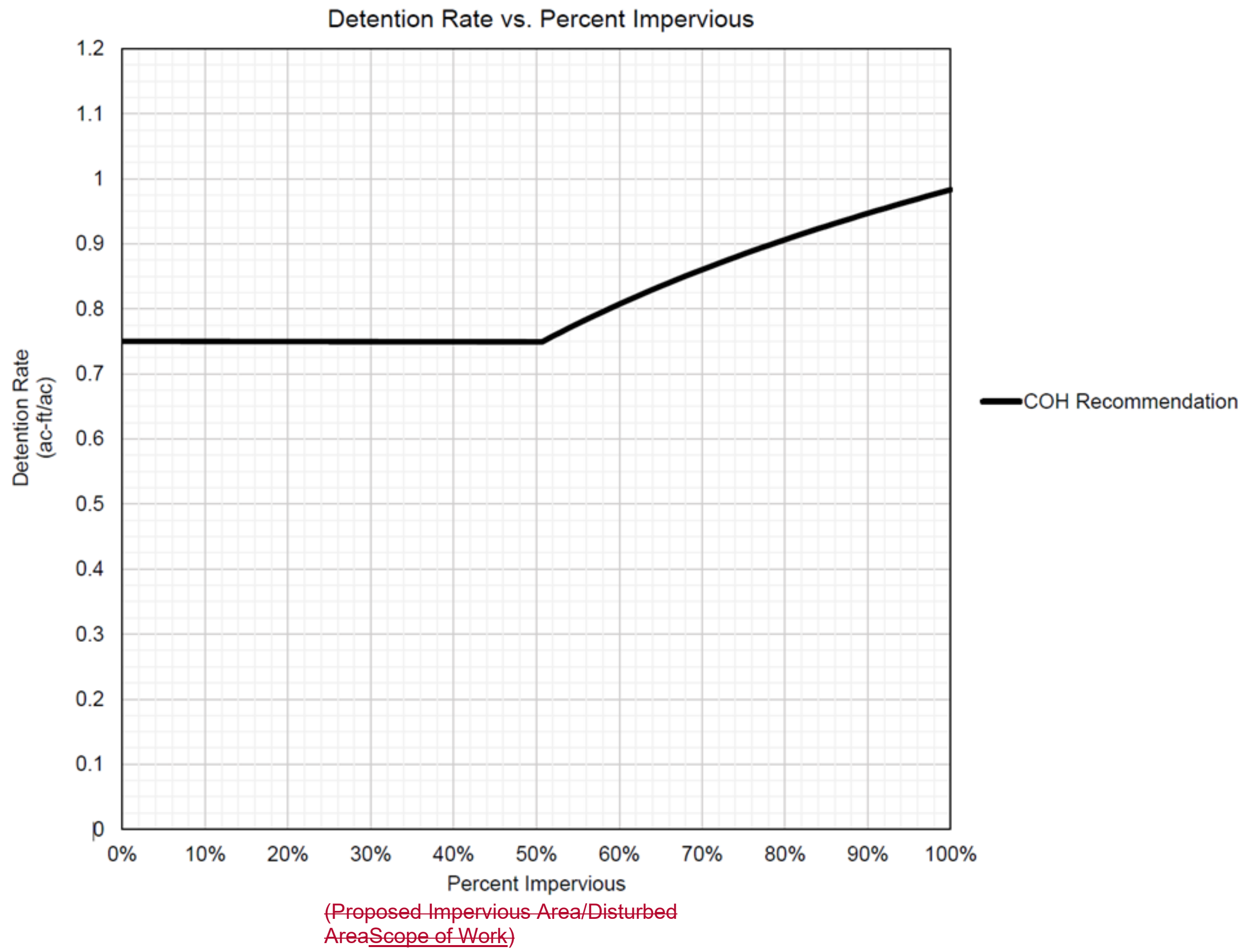


Figure 9.7 – GRASS-LINED/UNIMPROVED ROADSIDE DITCH CROSS SECTION



~~Figure 2 – MINIMUM DETENTION RATE CHART~~

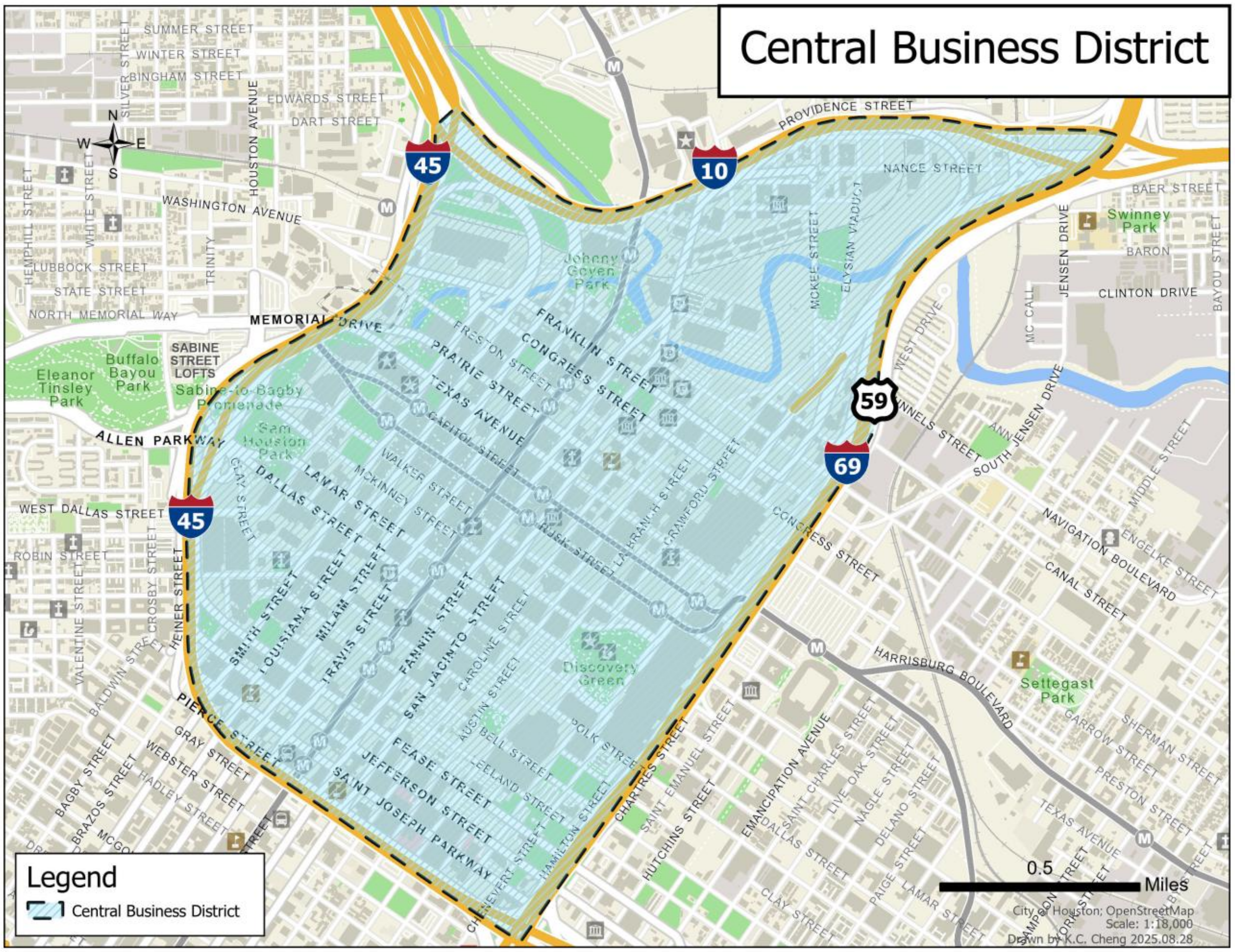


Figure 9.8 – CENTRAL BUSINESS DISTRICT

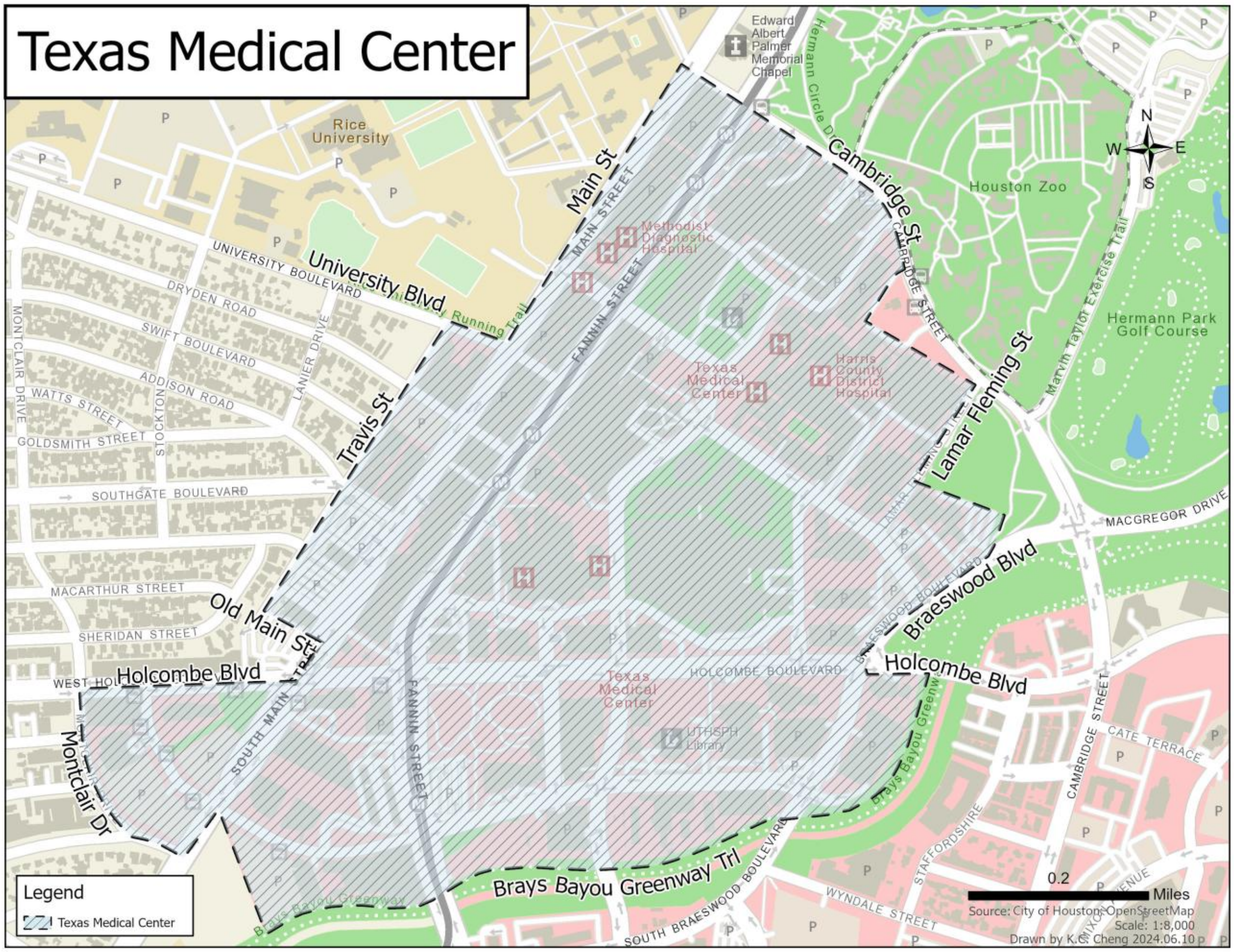


Figure 9.9 – TEXAS MEDICAL CENTER

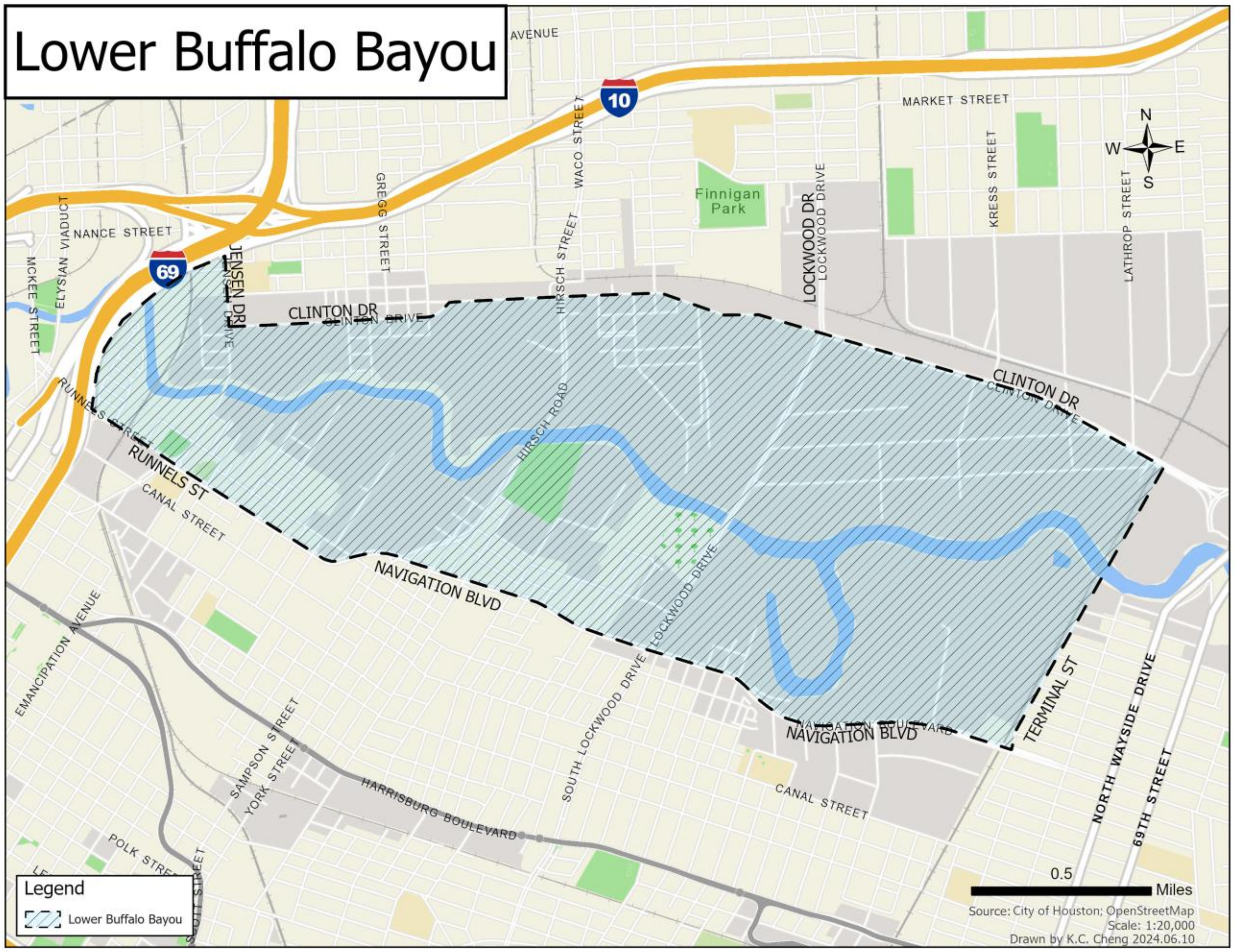


Figure 9.10 – LOWER BUFFALO BAYOU

~~DETENTION:~~

~~Tract size =…………..……………………………………………………………………..acres~~
~~Disturbed area =………………………………….........................acres to four decimal places or SF~~
~~Proposed (final) Impervious area =………….………….................acres to four decimal places or SF~~
~~Please provide your calculations:~~
~~Required Detention Volume =…………………........acre-feet (Show calculations, refer to 9.2.01.H)~~
~~Provided Detention Volume =……………………………..…… acre-feet (must show calculations)~~

RESTRICTORS:

Low Level Restrictor (25% flow):
Total Drainage Area =…………………………………………...acres
Outflow Rate Allowed for Low Flow QL1 =……………………… ……cfs (based on 0.5 cfs/ac)
Head HL1 (water surface differential based on 25% water surface and centroid of the primary restrictor) for Low Flow =…...……………………………………………………………………ft
Calculated Low Level Restrictor Size DL =……………………....................................... inches
Provided/Designed Low Level Restrictor Size DL1 =………..........…...inches (min. 6 inches)

High Level Restrictor (75% flow):
(Secondary restrictor should be placed at the 75% WSE, if any)
Total Drainage Area =…………………………………………...acres
Total Outflow Rate Allowed (100%) Q =………………………………..cfs (based on 2 cfs/ac)
Re-calculated Head HL2 (water surface differential based on 100% water surface and centroid of the primary restrictor) for Low Level Restrictor =……………………………………………….ft
Re-calculated Low Flow Q L2 for Low Level Restrictor =………..cfs (based on DL1 and HL2)

Outflow Rate Allowed for High Flow Qh1 (75%) =………………………cfs (based Q and Q L2)
Head Hh2 (water surface differential based on 100% water surface and centroid of the secondary restrictor) for High Level Restrictor =……………………...............ft
Calculated High Level Restrictor Size Dh =……………………………………………...inches
Provided/Designed High Level Restrictor Size Dh1 (75%) =………………………………inches
Outflow Rate Provided for High Flow Qh2 =……………………cfs (based on Dh1, must < Qh1)

To explain your design above, please provide information below to the plan:

The location of the restrictor(s) on the plan(s)
~~The cross section for the restrictor(s) with the water surface elevations for 25%, 75%, and full~~ detention capacity.
The location and elevation of the overflow structure (should be placed at 100% WSE).
HL1: Low-level Head

HL2: Low-level Head
HH2: High-level Head
WSE: Water Surface Elevation
FL: Flow Line
CL: Center Line

Figure 9.11 – RESTRICTOR CALCULATION SAMPLE

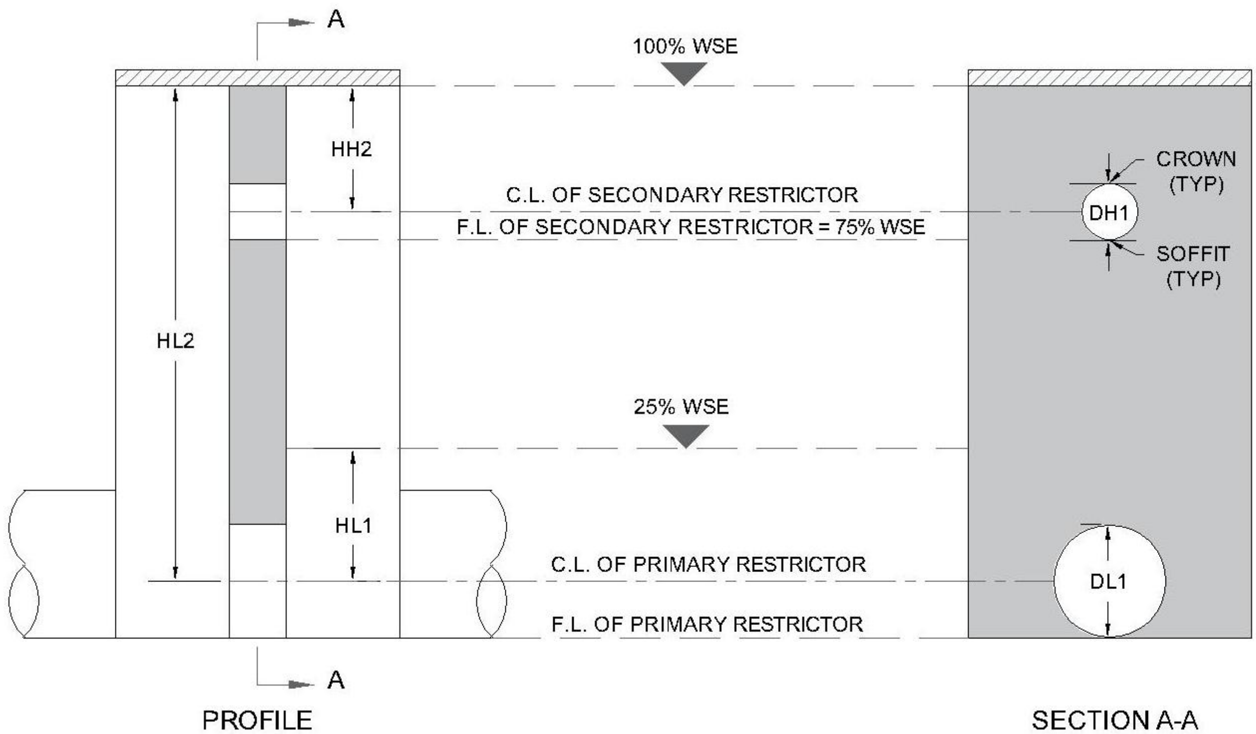


Figure 9.12 – ORIFICE RESTRICTOR SAMPLE

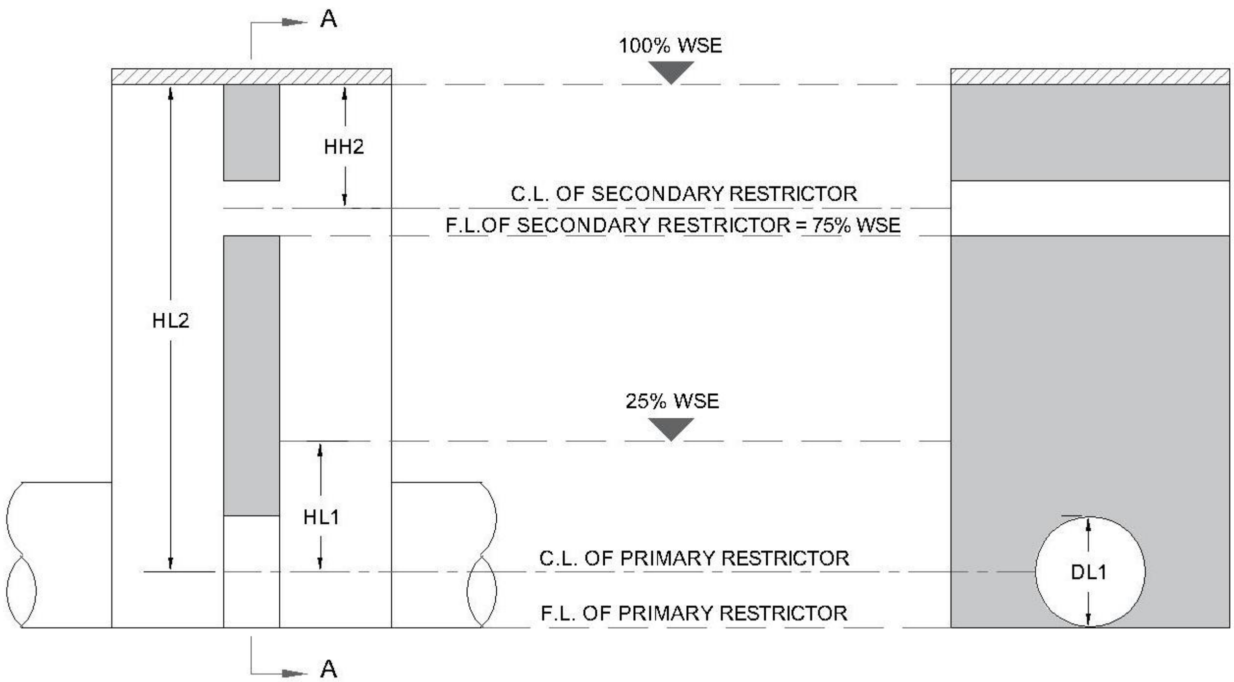


Figure 9.13 – WEIR RESTRICTOR SAMPLE

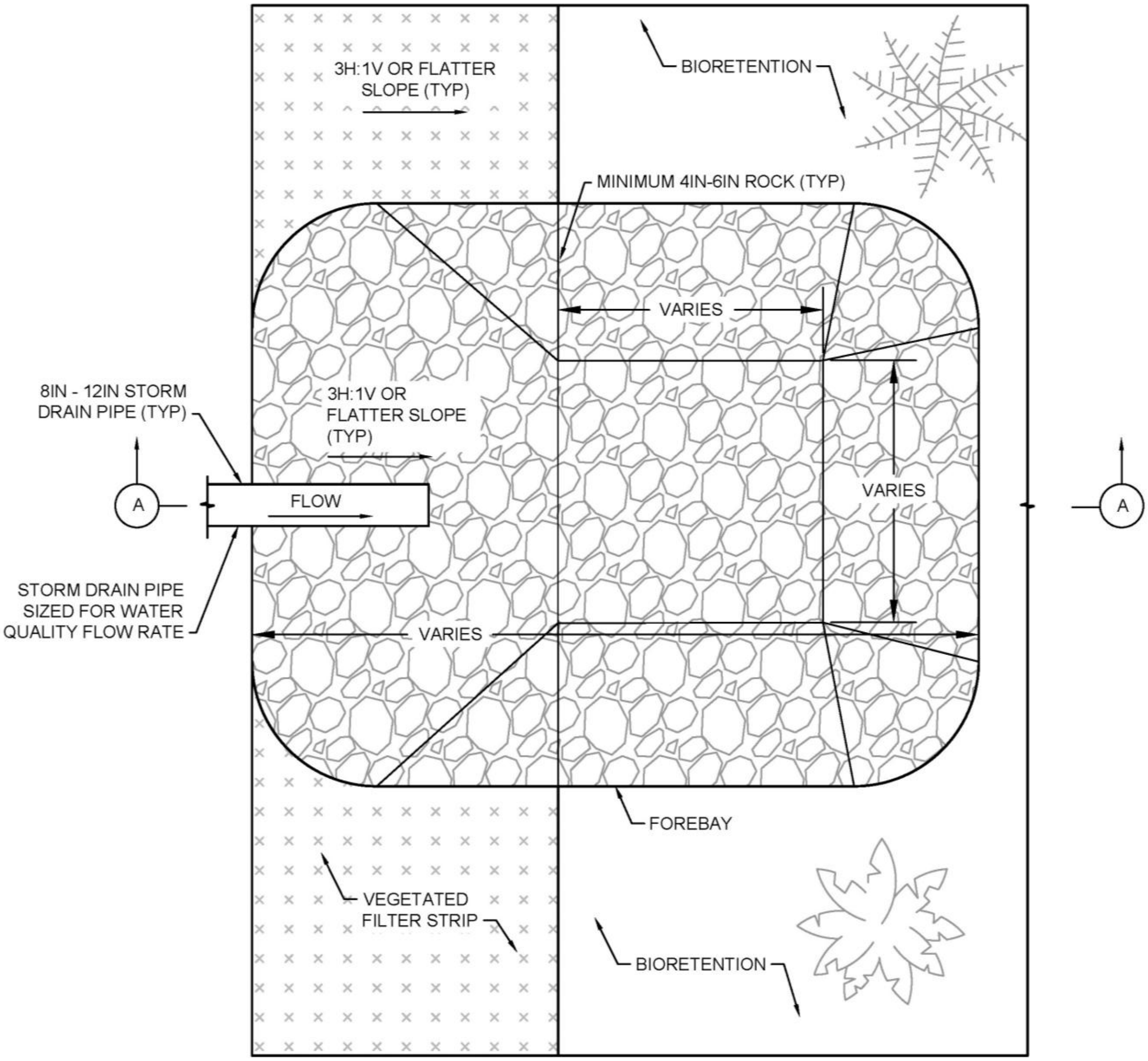


Figure 9.14 – BIORETENTION WITH FOREBAY PLAN VIEW

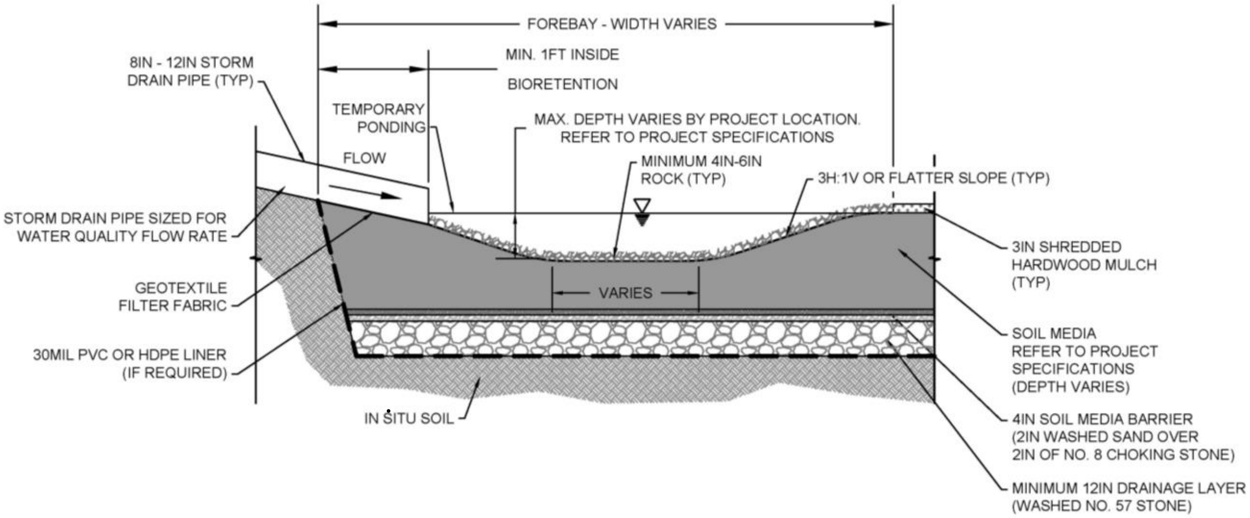


Figure 9.15 – BIORETENTION WITH FOREBAY SECTION A

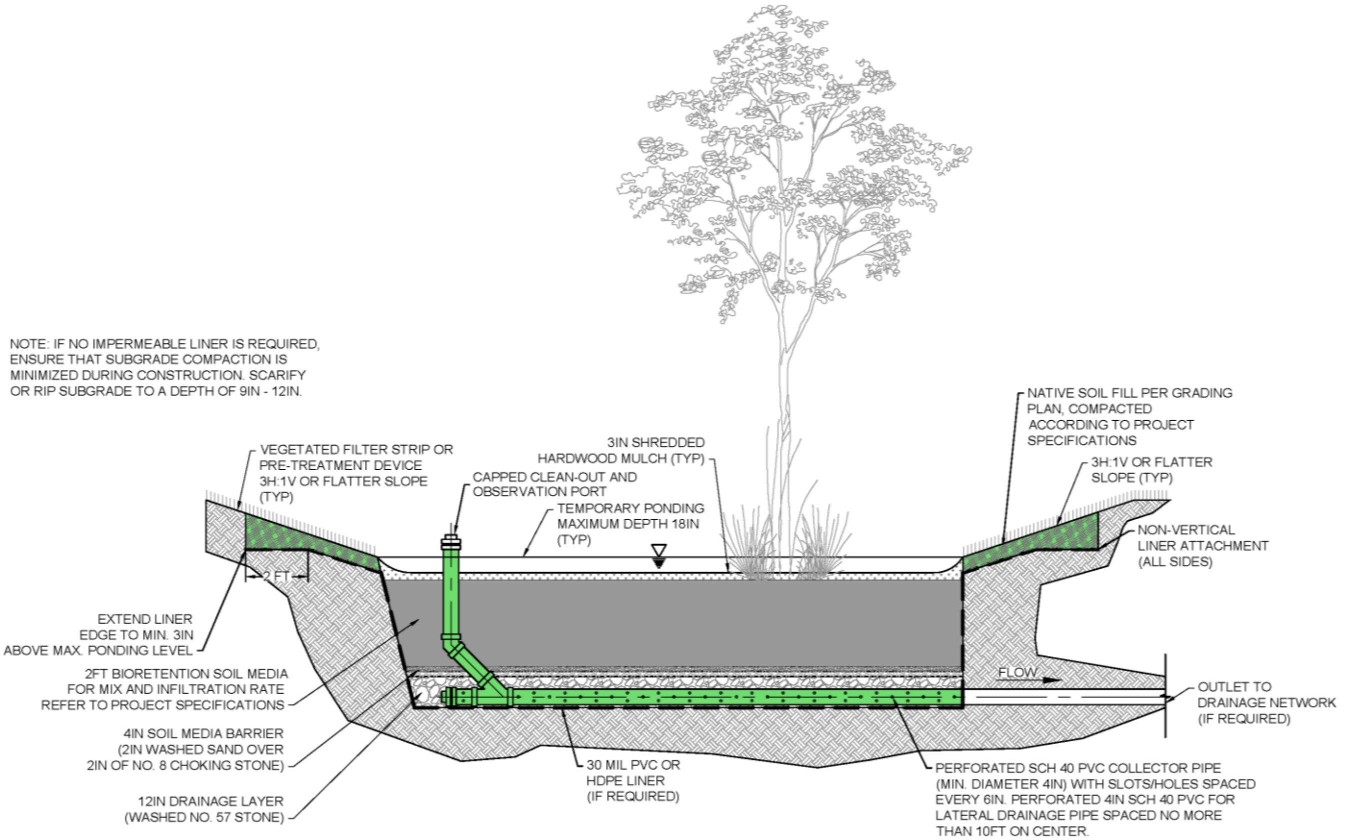


Figure 9.16~~7~~ – ~~POROUS~~BIORETENTION BASIN

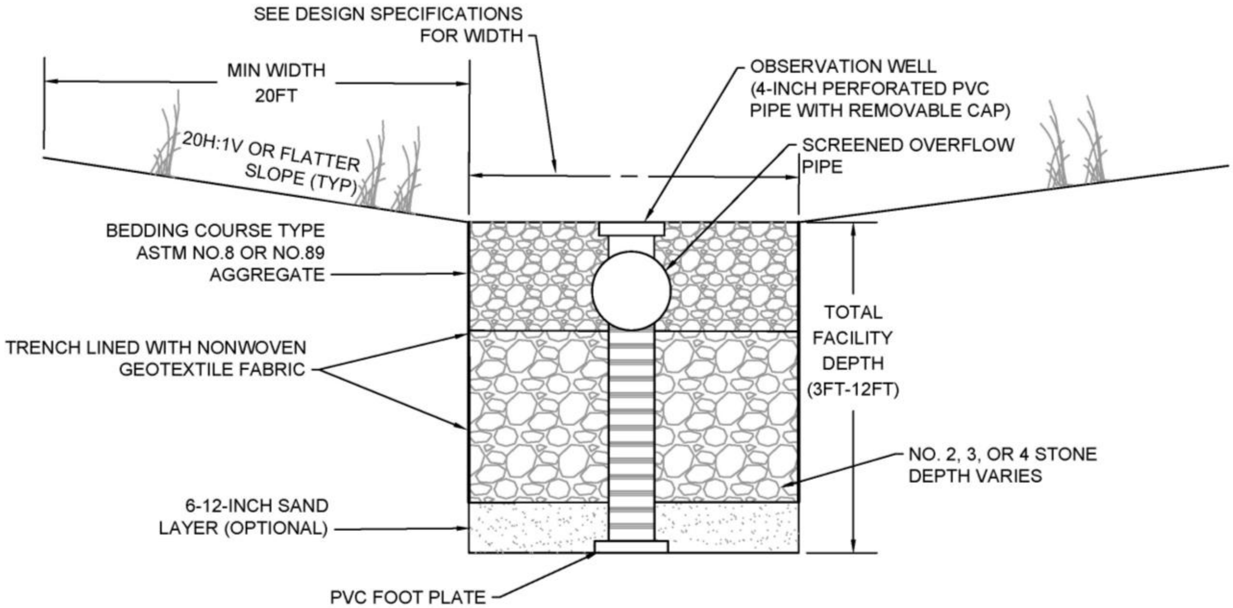
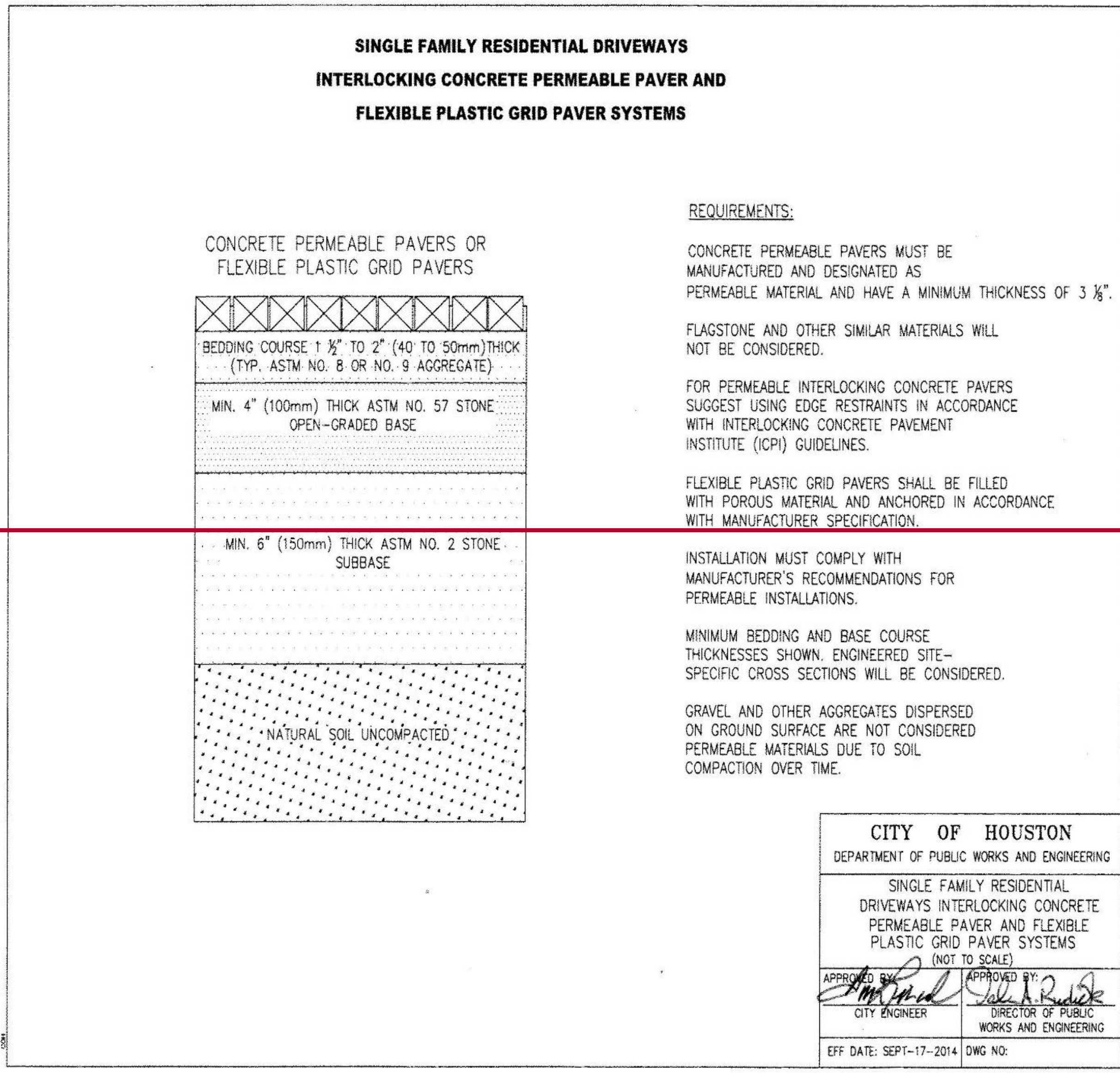
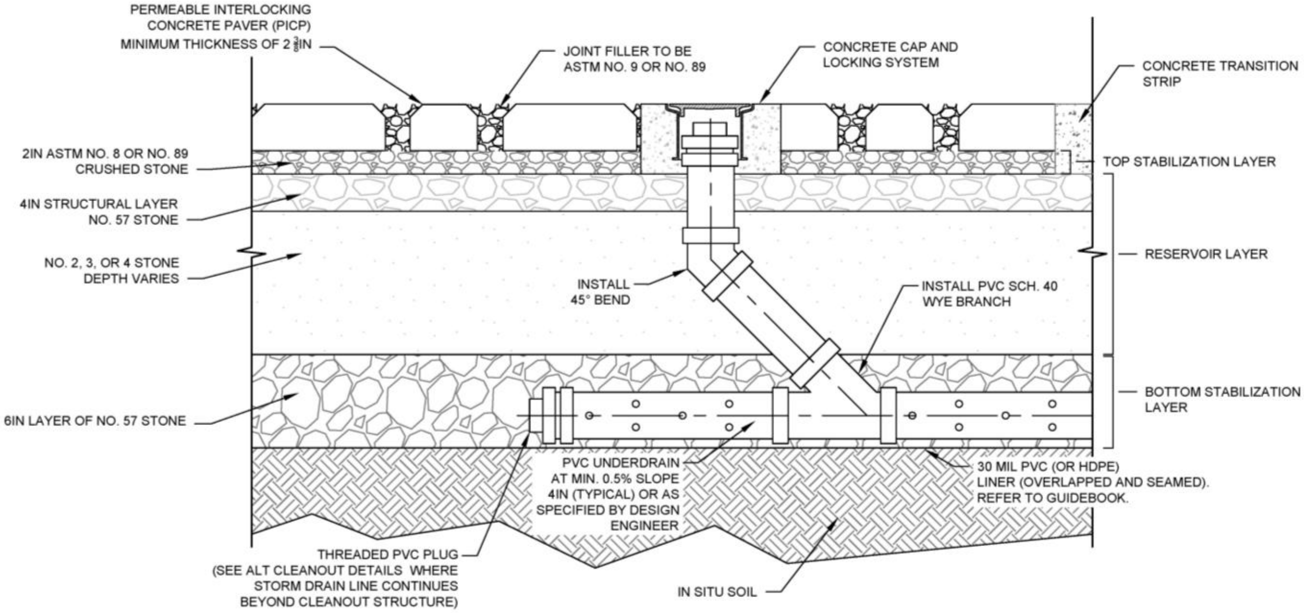


Figure 9.17 – INFILTRATION TRENCH

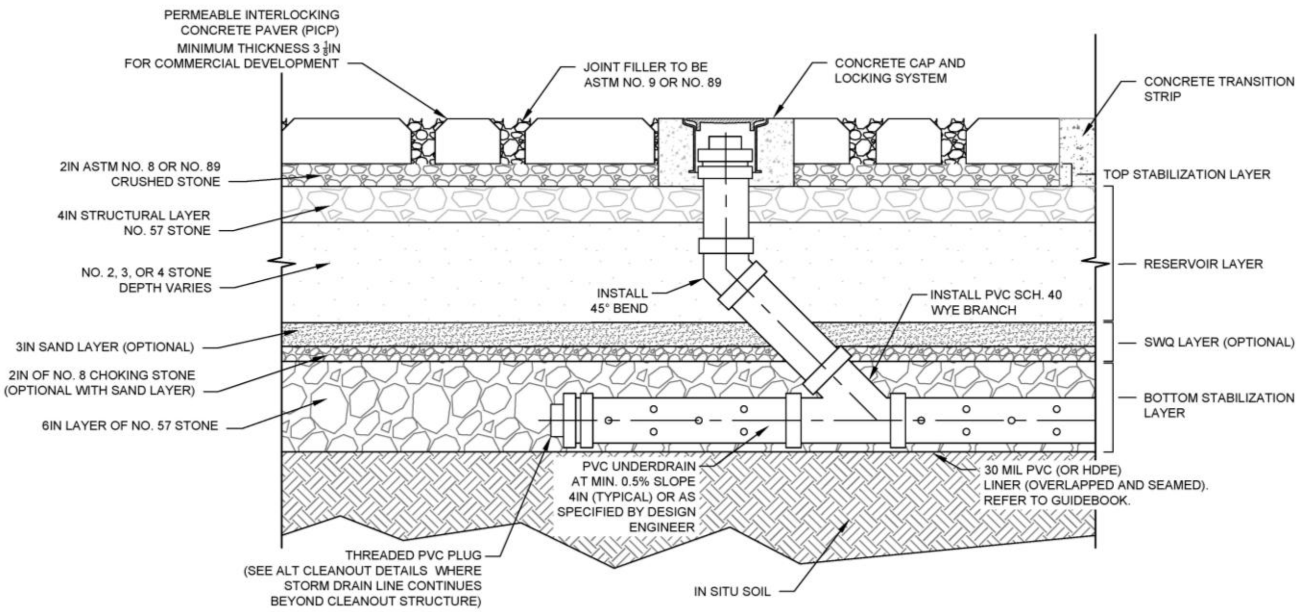


~~Figure 9.16 – SINGLE FAMILY RESIDENTIAL DRIVEWAYS INTERLOCKING CONCRETE PERMEABLE PAVER AND FLEXIBLE PLASTIC GRID PAVER SYSTEMS~~



NOTE:
PIPES AND FITTINGS SHALL BE PROPERLY ALIGNED AND MAINTAINED WHILE CONCRETE IS BEING PLACE AND ALLOWED TO HARDEN. JOINTS FOR PIPES AND FITTINGS SHALL BE MADE PRIOR TO PLACING CONCRETE. CONCRETE FOR BEDDING, ENCASEMENT, AND WALL SUPPORT FOR PIPES AND FITTINGS SHALL BE PLACED UNIFORMLY AROUND THE PIPE AND FITTINGS AS SHOWN HEREON TO MAINTAIN PROPER ALIGNMENT, AND SHALL BE CLASS B.

Figure 9.18 – SINGLE FAMILY POROUS PAVER TYPICAL SECTION (WITH UNDERDRAIN)



NOTE:
PIPES AND FITTINGS SHALL BE PROPERLY ALIGNED AND MAINTAINED WHILE CONCRETE IS BEING PLACE AND ALLOWED TO HARDEN. JOINTS FOR PIPES AND FITTINGS SHALL BE MADE PRIOR TO PLACING CONCRETE. CONCRETE FOR BEDDING, ENCASEMENT, AND WALL SUPPORT FOR PIPES AND FITTINGS SHALL BE PLACED UNIFORMLY AROUND THE PIPE AND FITTINGS AS SHOWN HEREON TO MAINTAIN PROPER ALIGNMENT, AND SHALL BE CLASS B.

Figure 9.19 – COMMERCIAL/MULTI-FAMILY POROUS PAVER TYPICAL SECTION (WITH UNDERDRAIN)

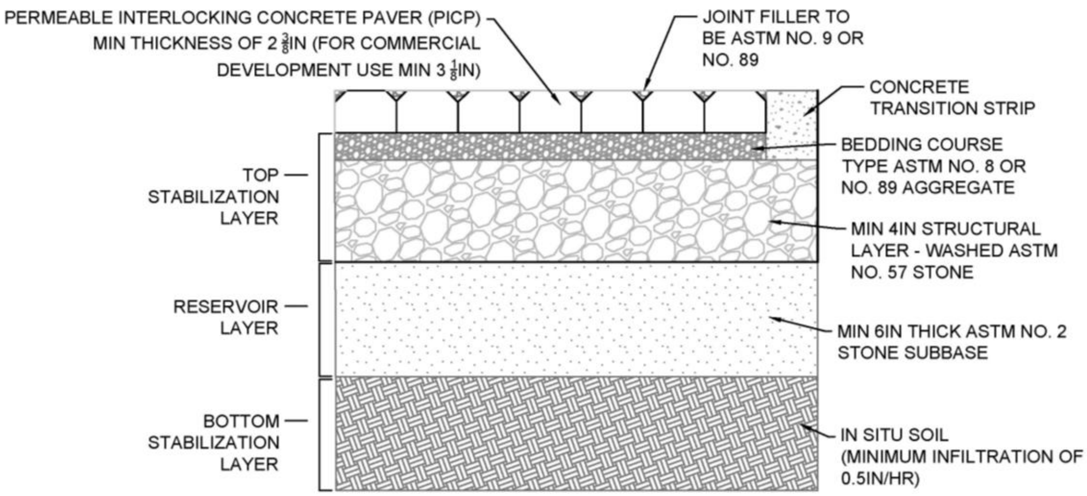
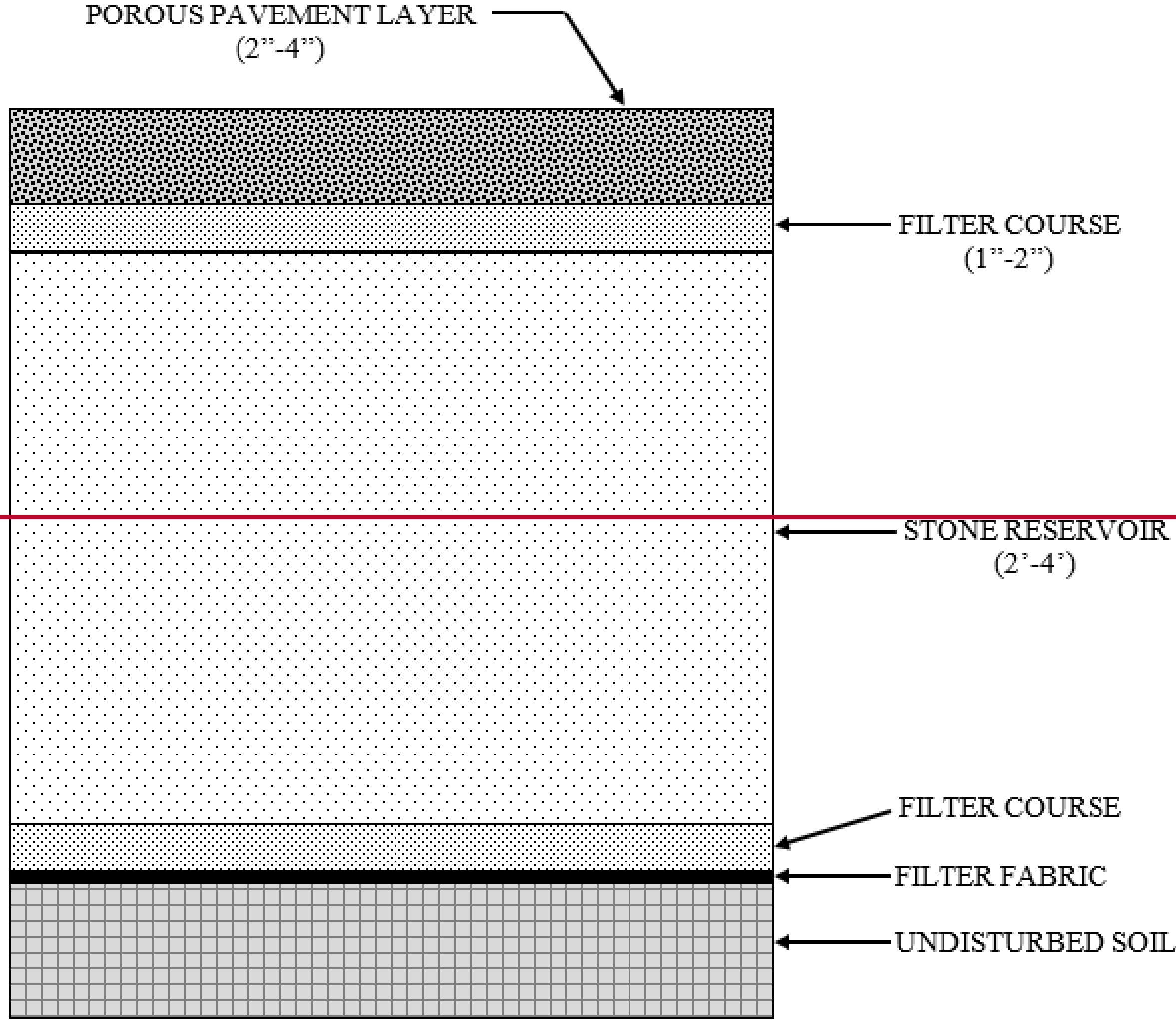
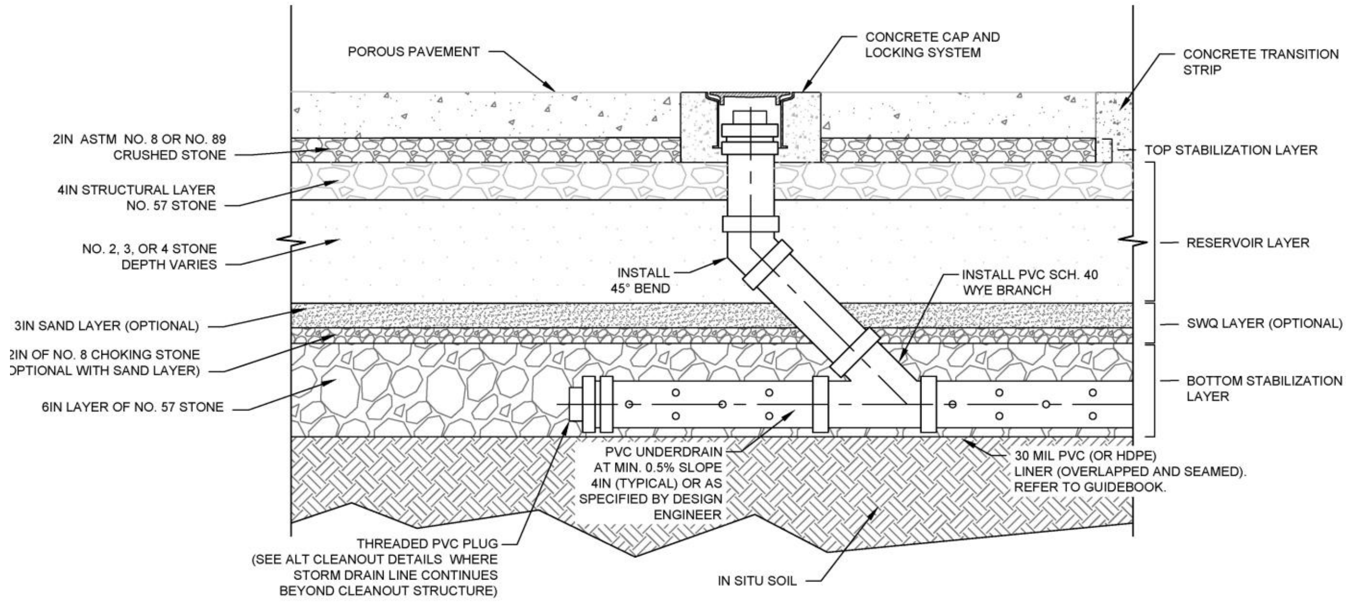


Figure 9.20 – POROUS ~~PAVEMENT~~PAVER TYPICAL SECTION



~~Figure 9.17 – POROUS PAVEMENT TYPICAL SECTION~~



NOTE:
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Figure 9.21 – POROUS PAVEMENT TYPICAL SECTION (WITH UNDERDRAIN)

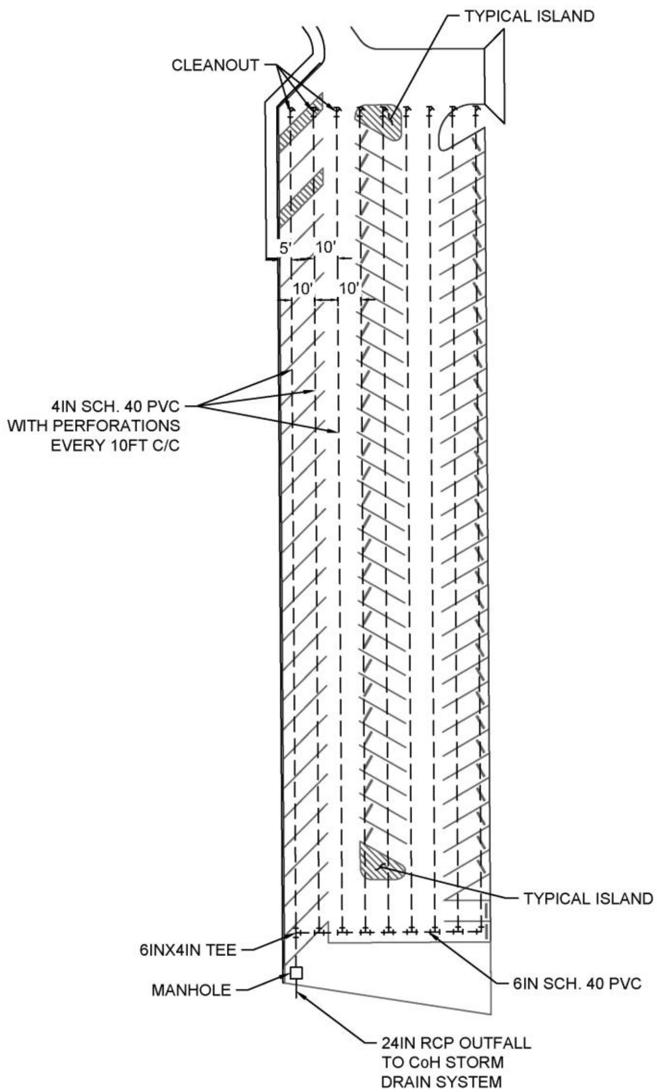
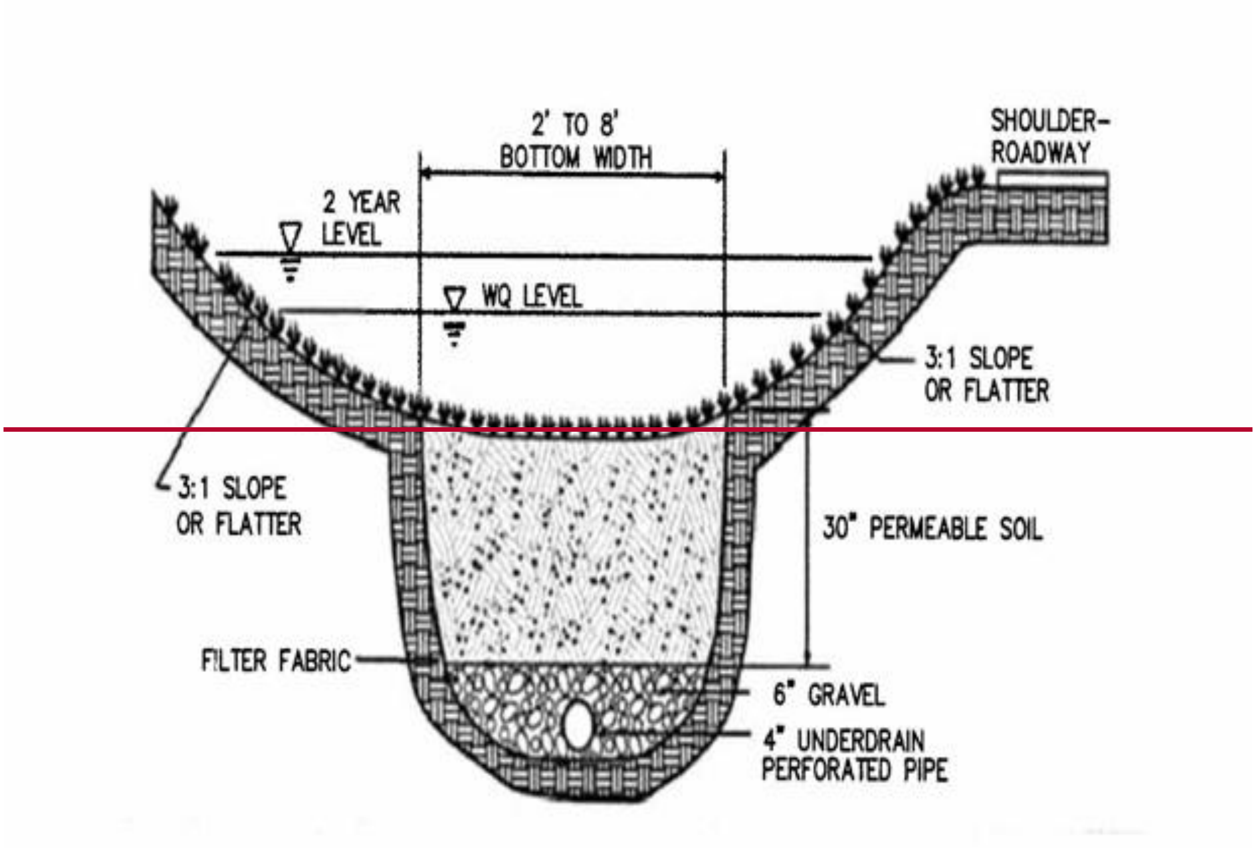


Figure 9.22 – POROUS PAVER PLAN VIEW



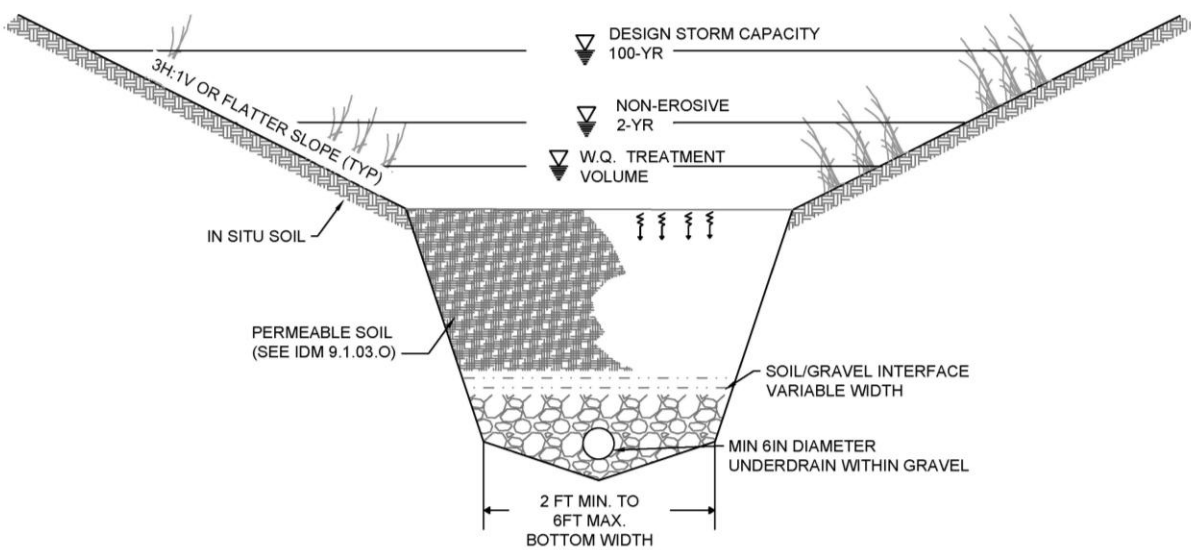
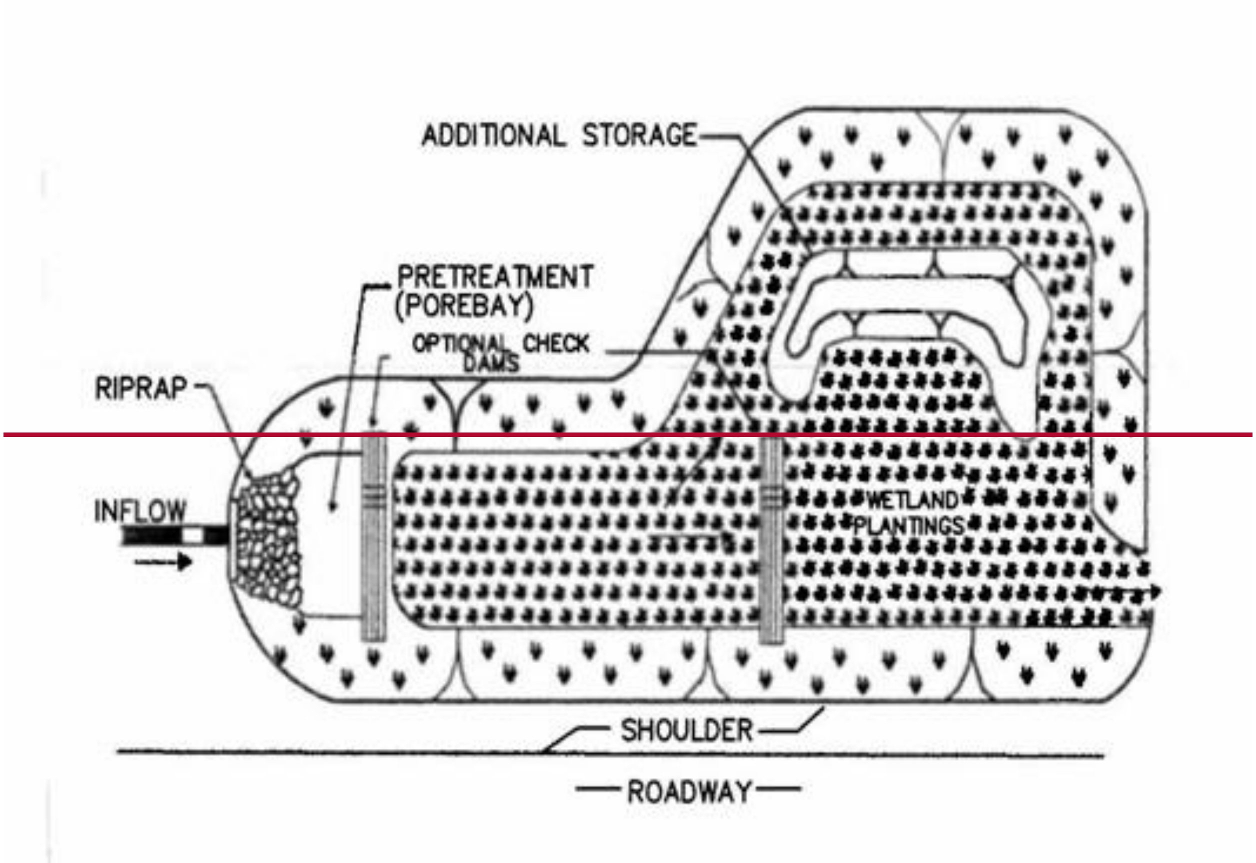


Figure 9.23 – DRY SWALE SECTION


ADDITIONAL STORAGE
PRETREATMENT (POREBAY)
OPTIONAL CHECK DAMS
RIPRAP
INFLOW
WETLAND PLANTINGS
SHOULDER
ROADWAY

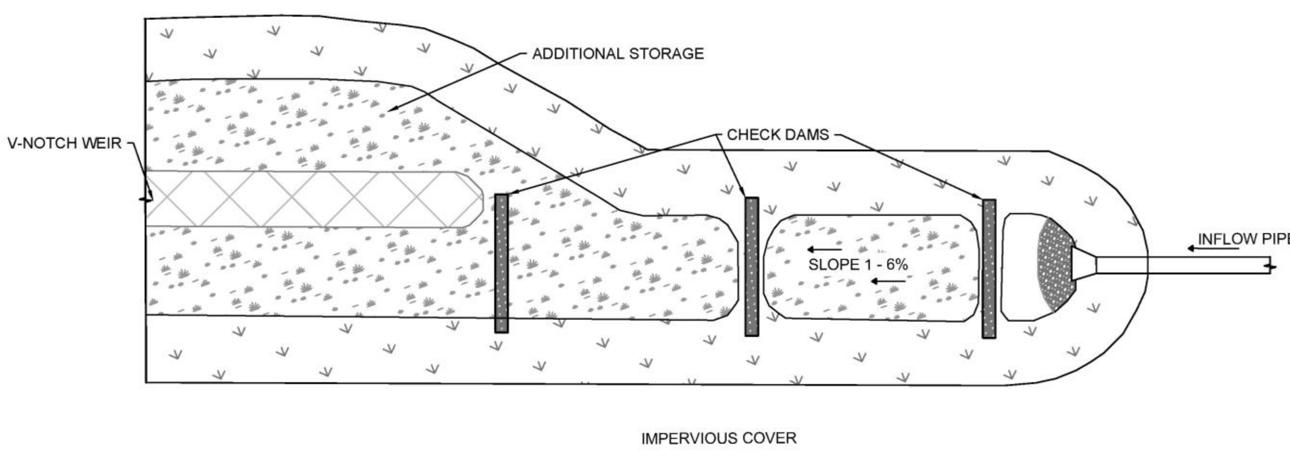

ADDITIONAL STORAGE
V-NOTCH WEIR
CHECK DAMS
SLOPE 1 - 6%
INFLOW PIPE
IMPERVIOUS COVER

Figure 9.24 – WET SWALE PLAN VIEW

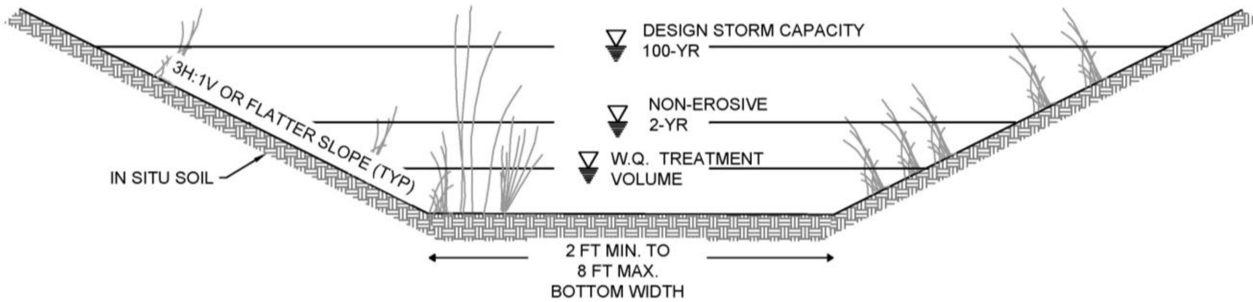


Figure 9.25 – WET SWALE CROSS SECTION

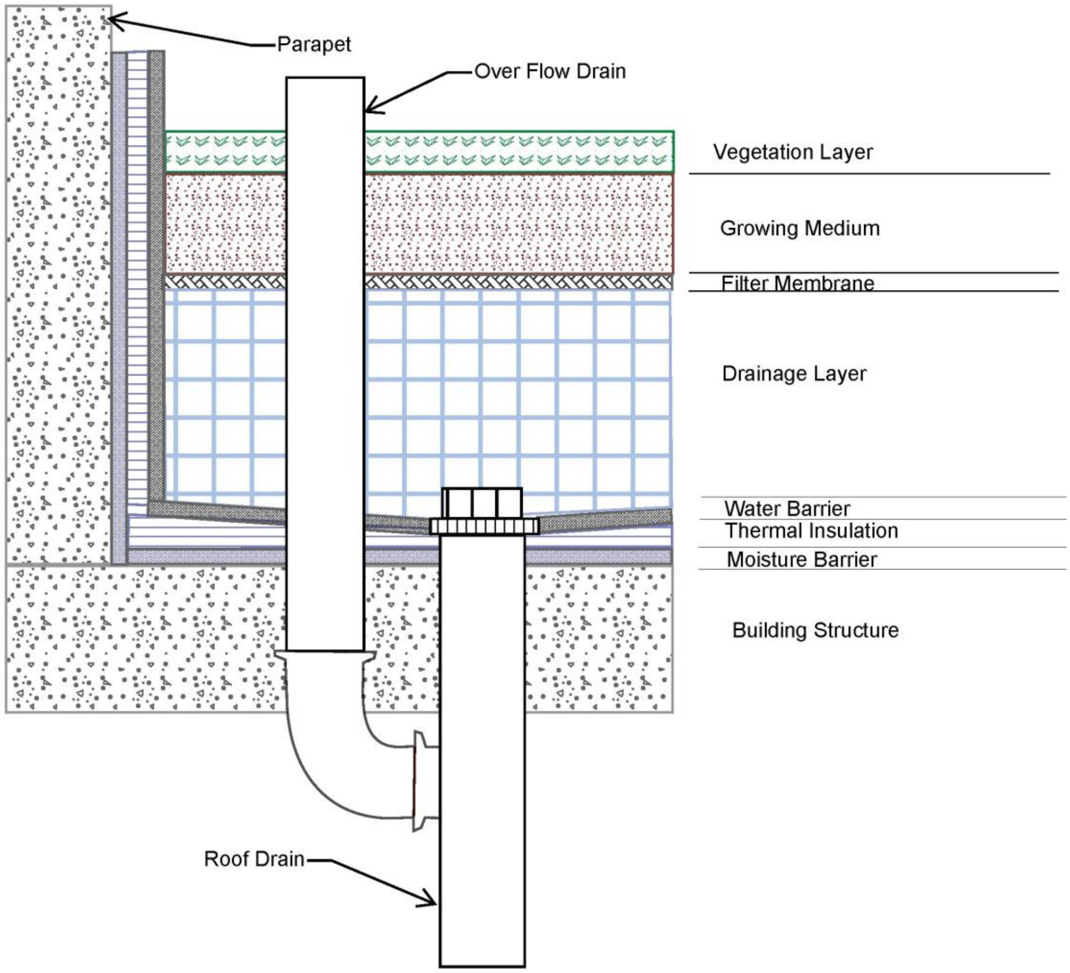


Figure 9.26 – GREEN ROOF CROSS SECTION

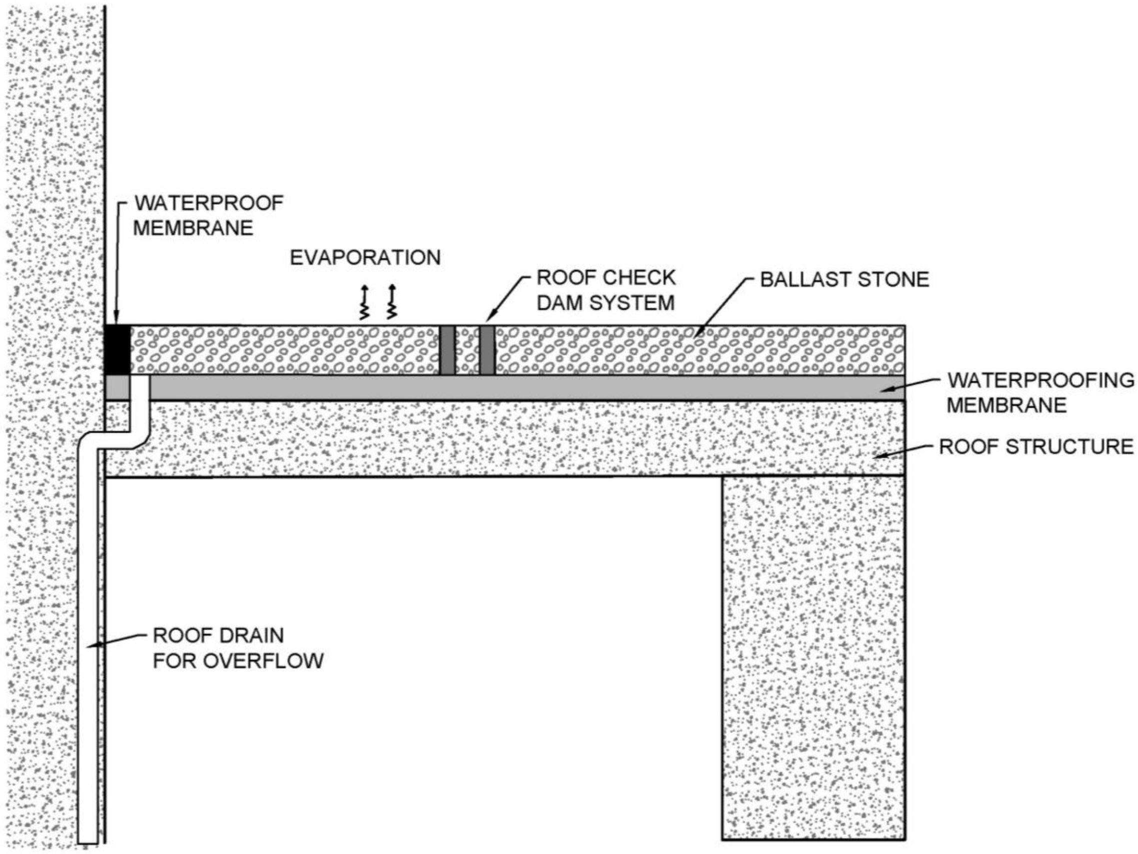


Figure 9.27 – BLUE ROOF CROSS SECTION

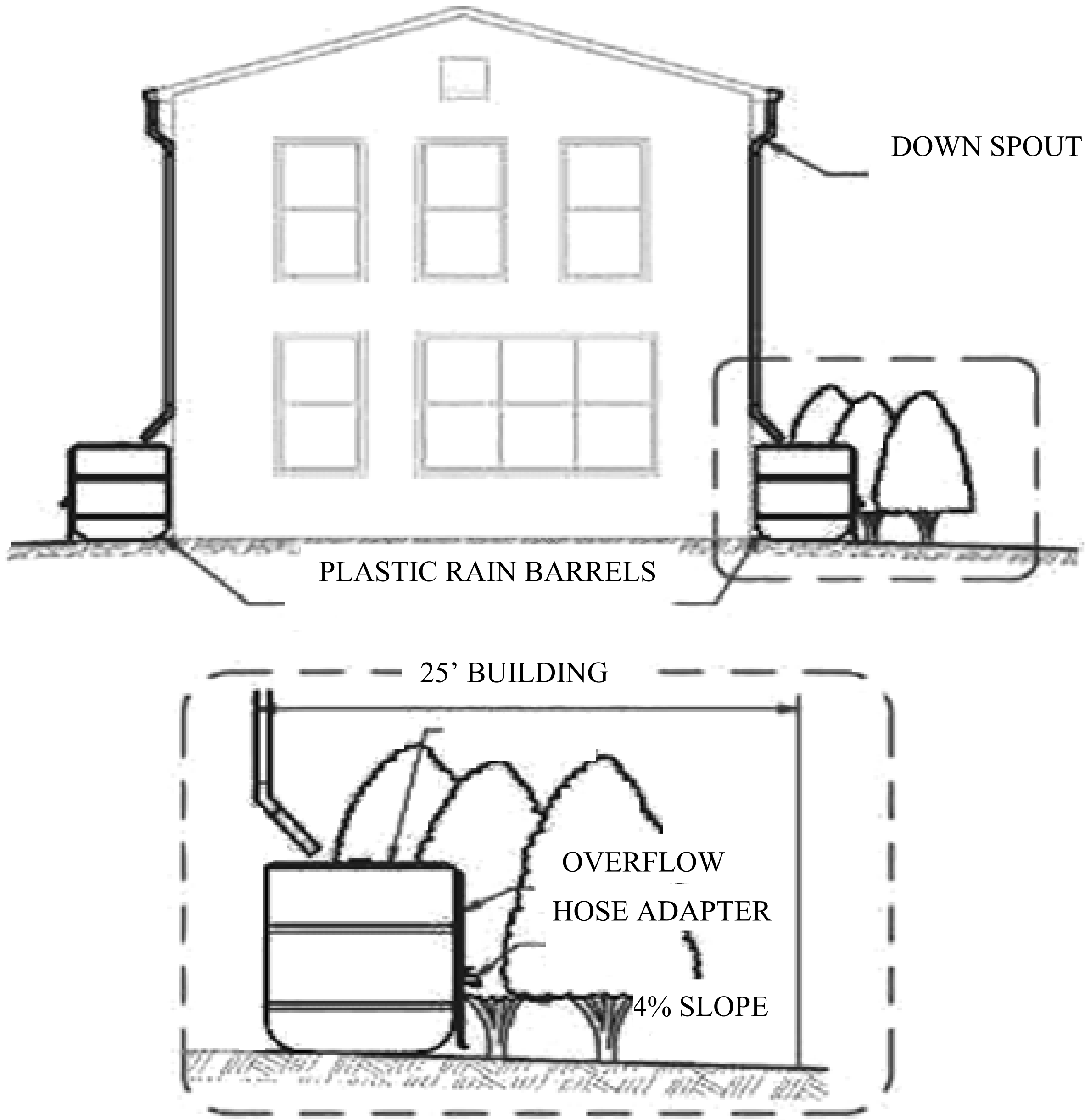


Figure 9.28 – TYPICAL RAIN BARREL

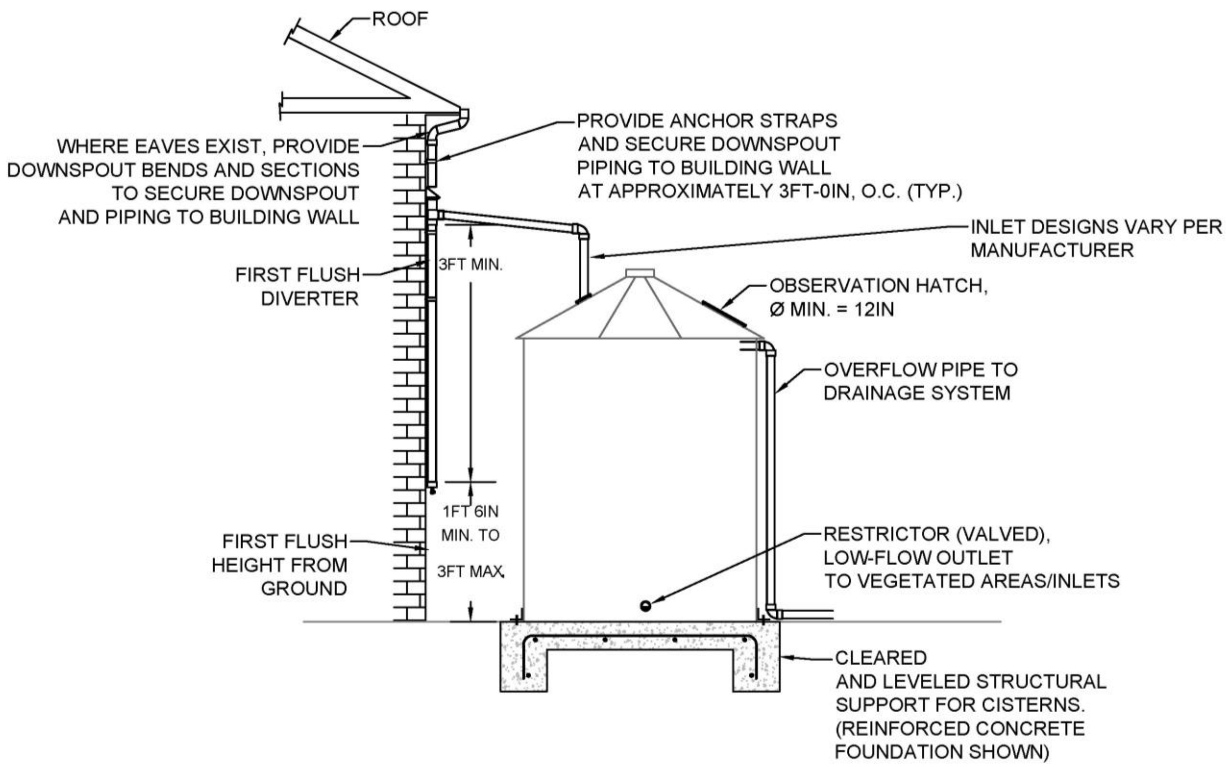


Figure 9.29 – TYPICAL CISTERN

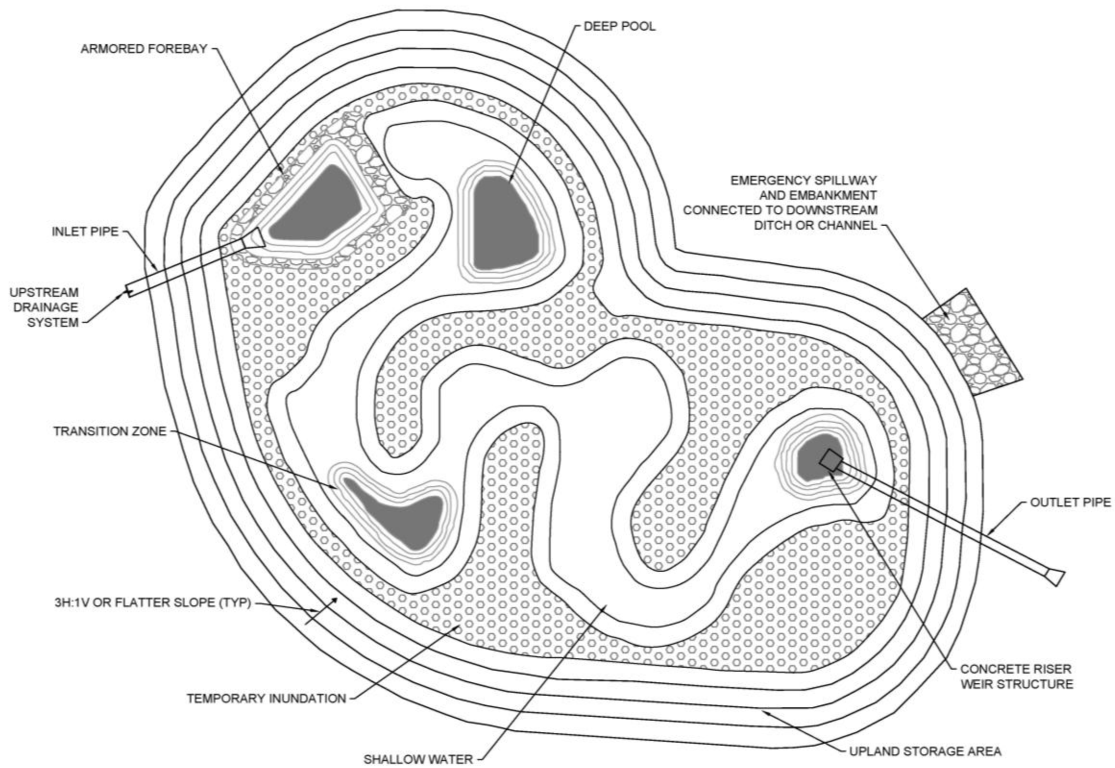


Figure 9.30 – CONSTRUCTED WETLAND BASIN

HOUSTON PUBLIC WORKS

OFFICE OF THE CITY ENGINEER
STORMWATER INFORMATION FORM

FOR OFFICE USE ONLY							
Log Number:		Private Building ILMS Project #:		Public Plan ILMS Project #:		PW Record Drawing #:	

The Office of the City Engineer reviews and approves development plans to ensure the proper design and construction of storm sewer utilities in addition to enforcing private storm design criteria and parameters as stated in City of Houston Code of Ordinances and the current City of Houston Infrastructure Design Manual. When a property owner proposes new development or redevelopment of property, the applicant must submit this form with their plans. *Completion of this form does not represent an approval or commitment by the City of Houston. This form is informational only to assist in the review and approval of your plans.*

Fee Simple Title Owner Information		Authorized Representative Information	
Name		Name	
Company		Company	
Address		Address	
City, State ZIP		City, State ZIP	
Phone		Phone	
Email		Email	
Signature*		Signature	

** As the fee simple owner of the property referenced in this form, I hereby authorize the referenced representative on this form (if applicable) to submit this form on my behalf. My authorized representative is also approved to make changes or corrections.*

Property Information					
~~Service Address~~					
City		State		ZIP Code	
Property Tax Account Number(s)					
Lot(s)		Block		Reserve	
Subdivision		Section			

Development Information
Provide description of development with associated footprint (in square feet).

	Single Family Residential Development		Multiple Family Residential Development		Commercial Development		Other
Existing Development:							
Development to be Removed:							
Proposed Development:							

Flood Plain Information											
FIRM Panel Number:											
Property is located within the following FEMA Flood Zone:											
	X (shaded)		X (unshaded)		AE		A		AO		Other:

HoustonPermittingCenter.org
832-394-9579

1

revised: May 20, 2020
Form OCE-0004

HOUSTON PUBLIC WORKS

OFFICE OF THE CITY ENGINEER
STORMWATER SECTION
STORMWATER INFORMATION FORMS

The Office of the City Engineer reviews and approves development plans to ensure the proper design and construction of storm sewer utilities in addition to enforcing private storm design criteria and parameters as stated in the City of Houston Code of Ordinances and the current City of Houston Infrastructure Design Manual.

- When a property owner proposes new development or redevelopment of property, the applicant must submit this form with their plans.
- Completion of this form does not represent an approval or commitment by the City of Houston.
- This form is informational only to assist in the review and approval of your plans.

Fee Simple Title Owner Information:	Authorized Representative Information:
Name:	Name:
Company:	Company:
Address:	Address:
City, State ZIP:	City, State ZIP:
Phone:	Phone:
Email:	Email:
*Signature:	Signature:

* As the fee simple owner of the property referenced in this form, I hereby authorize the referenced representative on this form (if applicable) to submit this form on my behalf. My authorized representative is also approved to make changes or corrections.

Property Information					
Service Address					
City, State ZIP Code:					
Property Tax Account Number(s):					
Lot(s):		Block:		Reserve:	
Subdivision:			Section:		

Flood Plain Information:

FIRM Panel Number: __________

Property Is Located Within the Following FEMA Flood Zone:

☐ X (shaded) ☐ X (unshaded) ☐ AE ☐ A ☐ AO ☐ Other:

FOR OFFICE USE ONLY

Log Number:	Private Building ILMS Project #
Public Plan ILMS Project #:	PW Record Drawing #:

StormPlanReview@houstontx.gov Coming Soon https://bit.ly/OCESWPRO

Page 1 of 3 revised: April 2024 OCE - 1001

HOUSTON PUBLIC WORKS

OFFICE OF THE CITY ENGINEER
STORMWATER SECTION
STORMWATER INFORMATION FORMS

Development Information

Provide description of development with associated footprint (in square feet):

☐ Single Family Residential Development ☐ Multiple Family Residential Development ☐ Commercial Development
☐ Other:

Existing Development:	
Proposed Development:	

Impervious Cover Information:

Improvements	Area of Existing Impervious Cover (Sq Ft.)	Area of Final Impervious Cover (Sq Ft.)
Building		
Parking Lot/Driveway		
Sidewalk/Patio		
Detention Pond		
Pool		
Other(s)		
Total Area		

Tract Size (Square Feet)		**Total Impervious Cover (Square Feet)**		**Percentage of Impervious Cover (%)**	

Storm Sewer Information:

Storm Infrastructure Is Maintained By:
NOTE: Any infrastructure maintained by outside agencies will require their respective approval prior to final City plan approval.

☐ City of Houston ☐ HCFCD ☐ TXDOT
☐ Clear Lake City Water Authority ☐ Fort Bend County ☐ Montgomery County
☐ Other:

Detention Criteria:

Stormwater detention volume was determined utilizing City of Houston Infrastructure Design Manual:

☐ 9.2.01.H.3 (b) Criteria 1 ☐ 9.2.01.H.3 (c) Criteria 2 ☐ 9.2.01.H.3 (d) Criteria 3

HOUSTON PUBLIC WORKS

OFFICE OF THE CITY ENGINEER
STORMWATER SECTION
STORMWATER INFORMATION FORMS

Proposed Storm Connection Development Will Be Connected To:

☐ Existing on-site storm sewer system that outfalls to: ____________________
(Street Name / Pipe Size)

☐ Public storm sewer located in: ____________________
(Street Name and Pipe Size)

☐ Public roadside ditch located in: ____________________
(Street Name)

☐ Off-road ditch/watershed: ____________________

Documentation

This form Must be accompanied with:

☐ A recorded deed / title report in the owner's name ☐ HCAD printout ☐ Recorded Plat/Replat ☐ Survey

The Applicant Can Also Provide the Following Documentation If Applicable to Their Project:

☐ Previous Stormwater Letter of Availability ☐ Copy of outside agency approval

☐ Storm Water Quality Permit:
Per Section 47-631 of the City of Houston Ordinance, SWQ permit is required when the development is meeting the definition of "new development" or "significant redevelopment".

☐ Drainage study/hydraulic analysis is required for developments larger than 20 acres

Developer Drainage Impact Fee Rate Information:

Service Area Rate is per service unit (1 service unit = 1,000 sf of impervious area) of increased impervious area.
Please Select One:

☐ Brays Bayou $25.00/SU ☐ Clear Creek $25.00/SU ☐ Hunting Bayou $25.00/SU ☐ Sims Bayou $25.00/SU
☐ Buffalo/White Oak Bayou(1) $25.00/SU ☐ Greens Bayou $25.00/SU ☐ San Jacinto $25.00/SU ☐ Vince Bayou $25.00/SU

(1) Now incorporates Addicks Reservoir, Barker Reservoir, and Ship Channel Service Areas

FOR OFFICE USE ONLY

Employee:		Comments:	

Figure 9.31~~6~~ – STORMWATER INFORMATION FORMS

Detention Volume Breakdown Table

Project Name
Project Address
Project Number Date
Number of Lots

	Lot #	Total Area (SF)	Total Impervious Area* (SF)	Percentage of Lot Improvement Area	Detention Rate (acre-ft/acre)	Detention Volume Required (cu-ft)	Detention Volume Provided (cu-ft)	Detention Volume Excess (cu-ft)	Detention Credit Volume Credit (cu-ft)**
Total (SF)									

Note	* Total impervious area should include any shared driveway impervious area present as part of the lot as well as house, driveway, sidewalk, patio, pool, etc.
	** If applicable, otherwise leave empty

Figure 9.32 – DETENTION VOLUME BREAKDOWN TABLE

City of Houston

Design Manual

Chapter 17

PEDESTRIAN, BICYCLE, AND TRANSIT DESIGN REQUIREMENTS

Chapter 17
Table of Contents

Pedestrian, Bicycle, and Transit Design Requirements

List of Tables

List of Figures

Chapter 17

PEDESTRIAN, BICYCLE, AND TRANSIT DESIGN REQUIREMENTS

SECTION 1 - PEDESTRIAN, BICYCLE, AND TRANSIT OVERVIEW

17.1.01 CHAPTER INCLUDES

17.1.01.A Standards and guidelines for the design of complete streets that are safe, accessible and enjoyable for Vulnerable Road Users who walk, use a mobility aid, bike, and take transit. By improving the street for its most Vulnerable Road Users, we improve safety for everyone.

17.1.01.B Standards and guidelines for pedestrian, bicycle and transit infrastructure including but not limited to new streets/ full street reconstruction, Retrofit projects, and street rehabilitation.

17.1.02 POLICY

17.1.02.A Designing complete streets with space for pedestrians, bicyclists, transit users, and other Vulnerable Road Users is necessary to meet the goals and commitments established by the City of Houston in the Houston Vision Zero Action Plan, Houston Bike Plan, Houston Climate Action Plan, and Resilient Houston strategy. Combined, these plans aim to fulfill a need for Houston to be a safe, resilient city for everyone.

17.1.02.B Roadway projects are an opportunity to increase the overall resilience of our streets to serve multimodal needs, adapt to climate change, and improve safety, accessibility, and equity.

1. New streets or fully reconstructed streets provide the opportunity to reimagine the right-of-way and implement infrastructure that provides space for multiple uses and functions, such as pedestrian, bicycle, and transit facilities for people of all ages and abilities; Green Infrastructure to manage stormwater, shade structures to decrease urban heat island effects; and Placemaking that incorporates universal design principles.

2. Retrofit projects provide the opportunity to reconfigure existing roadways using a range of temporary or permanent solutions to meet multimodal transportation needs of the most Vulnerable Road Users and mitigate the impact and rate of future climate change.

17.1.02.C The City of Houston will approve pedestrian, bicycle, and transit facilities that are safe and accessible for people of all ages and abilities. This means that street design must meet the needs of children, who have less ability to detect risks or negotiate conflicts; older adults who have lower visual acuity and slower riding and walking speeds; and people who may use mobility aids or adaptive bicycles which are wider, lower to the ground, and operate at lower speeds. The standards in the following sections aim to establish all ages and abilities design criteria.

17.1.03 REFERENCES

17.1.03.A References listed are the latest edition, version, amendments, and recodifications unless otherwise noted.

1. AASHTO Guide for the Development of Bicycle Facilities
2. Americans with Disabilities Act (ADA, Standards for Transportation Facilities)
3. City of Houston Code of Ordinances [1]:
    a. Chapter 40 – Streets and Sidewalks
    b. Chapter 42 – Subdivisions, Developments and Platting
4. FHWA Separated Bike Lane Planning and Design Guide
5. Highway Capacity Manual
6. Houston Bike Plan and Houston Bike Plan Network [2]
7. Houston Climate Action Plan [3]
8. Houston Vision Zero Action Plan [4]
9. Major Thoroughfare Freeway Plan (MTFP) [5]
10. NACTO, Urban Street Design, Urban Bikeway Design, and Transit Street Design Guide

Refer to the weblink for reference:
[1] https://www.houstontx.gov/codes/
[2] https://houstonbikeplan.org/
[3] http://greenhoustontx.gov/
[4] https://www.houstontx.gov/visionzero/
[5] https://www.houstontx.gov/planning/transportation/MTFP.html

17.1.03.A continued

11. Resilient Houston [6]

12. Texas Accessibility Standards (TAS)

13. Texas Manual on Uniform Traffic Control Devices (TMUTCD), TXDOT

14. Texas Transportation Code, Chapter 552 - Pedestrians

17.1.04 DEFINITIONS

17.1.04.A Bicycle Corral – A group of bike racks installed adjacent to the curb in the parking lane of the roadway or in the area of Curb Extensions. They are often sited near the intersection in areas where space behind the curb is limited. See Figure 17.17 for a conceptual design of Bicycle Corrals.

17.1.04.B Bicycle Facility - A portion of the right-of-way for bicyclists that is either off-street and adjacent to the Sidewalk (Dedicated Bike Path), shared with pedestrians (Shared Use Path), on-street and separated from vehicle traffic with striping, physical delineation (Protected Bike Lane), above-grade features (Raised Bike Lane) or shared with motorists (Neighborhood Bikeway).

17.1.04.C Bike Boxes - A designated area at the head of a traffic lane at a signalized intersection that provides bicyclists with a safe and visible way to be ahead of queuing traffic during the red signal phase.

17.1.04.D Corridor Crossing Analysis – Identifies safe and convenient locations for Vulnerable Road Users to cross streets. Any crossing that provides a type of treatment as recommended by this analysis will be known as an Enhanced Crossing.

17.1.04.E Crossing Treatments – Traffic control proposed at unsignalized crossings for Vulnerable Road Users. Crossing Treatments are based on traffic data and context and may include a variety of design elements to facilitate safe crossings, either as standalone treatments or grouped together.

17.1.04.F Curb Extensions – Also known as bulb-outs. Tools that add space for pedestrians along a roadway by extending the Pedestrian Realm from the Sidewalk into the street. This narrows the roadway width, which can improve pedestrian safety by increasing visibility, shortening the crossing distance, and reducing exposure time to traffic.

[6] https://www.houstontx.gov/policies/executive_orders.html

17.1.04.G Curb Management – Proactively determining the function of curbside street space for a variety of specified uses such as transit, municipal services, commercial loading zones, parklets, non-vehicular transportation, or parking based on the priorities for the corridor. These uses may change over time to improve safety, accessibility, or other needs defined for the location.

17.1.04.H Daylighting – A design strategy to increase visibility and sight distance at intersections, typically achieved by removing parking near the intersection.

17.1.04.I Dedicated Bicycle Facility - A portion of the right-of-way dedicated exclusively for bicyclists (e.g. Dedicated Bike Path, Raised Bike Lane, and Protected Bike Lane).

17.1.04.J Dedicated Bike Paths – Bicycle Facilities that run alongside a roadway behind the curb within the right-of-way. Dedicated Bike Paths are at the same grade as the Sidewalk and increase safety by grade-separating bicyclists and people driving and provide a physical buffer or detectable warning surface to separate pedestrian traffic in the Sidewalk.

17.1.04.K Desire Lines - Also known as a desire path or goat path. An unplanned route, typically in a grassy area, created by human or animal traffic in preference to or in the absence of a designated alternative, such as a paved Walkway. The desire line usually represents the shortest or most easily navigated route between an origin and destination.

17.1.04.L Enhanced Crossing – Any crossing that provides a type of treatment as recommended by the Corridor Crossing Analysis.

17.1.04.M Floating Bus Stop –Floating Bus Stops have a layout that allows pedestrian and Bicycle Facilities to locate behind the bus boarding pad, safely separating different modes of transportation while reducing bus delays by remaining in-lane.

17.1.04.N Frontage Buffer – The area between the outermost edge of the Sidewalk and the edge of the right-of-way or easement that is designed to improve visibility and reduce potential conflicts between Vulnerable Road Users and motorists.

17.1.04.O Green Infrastructure – The range of measures that use plant or soil systems; permeable pavement or other permeable surfaces or substrates; and stormwater harvest and reuse, or landscaping to store, infiltrate, or evaportranspirate stormwater and reduce flows to sewer systems or to surface waters.

17.1.04.P High-Comfort (HC) Bicycle Facility – A Bicycle Facility that provides comfortable, low stress bicycling conditions for people of all ages and abilities based on contextual factors like vehicle speeds and volumes, operational uses, and observed sources of bicycling stress.

17.1.04.Q High-Visibility Crosswalk – Use patterns (bar pairs, continental, ladder) that are visible to both the driver and pedestrian from farther away compared to traditional transverse line crosswalks.

17.1.04.R Houston Bike Plan – Establishes the vision and goals for the City of Houston to be a safer, more accessible, bike-friendly city. The Houston Bike Plan will change over time.

17.1.04.S Houston Bike Plan Network – A map developed as part of the Houston Bike Plan and establishes where neighborhood, on-street, and off-street bicycle facilities are existing, programmed, and planned. Streets indicated as planned are intended to be a guide for future Bicycle Facilities. The Houston Bike Plan Network will change over time.

17.1.04.T Median Refuge Islands – Protected spaces located in the center of the roadway to allow for safe crossings at midblock locations. They enable bicyclists and pedestrians to cross a single direction of traffic at a time, thereby limiting pedestrian and bicyclist exposure to traffic. May also be called pedestrian refuge islands. A crosswalk across a full median on a median-divided roadway is not considered a Median Refuge Island.

17.1.04.U Micromobility – Transportation that includes small, lightweight vehicles operating at slow speeds. It may include bicycles, e-bikes, electric scooters, and skateboards.

17.1.04.V Neighborhood Bikeways – Also known as bicycle boulevards. Low speed, typically residential streets shared by motorists and bicyclists.

17.1.04.W Off-Street Bicycle Facility - Dedicated space for bicyclists that is separate from vehicle traffic outside of the roadway. Off-Street Bicycle Facilities may be outside of street right-of-way like trails in Harris County Flood Control District; within the street right-of-way but outside the roadway and shared with pedestrians (Shared Use Path); or adjacent to the sidewalk (Dedicated Bike Path).

17.1.04.X Off-Street Bicycle Facility Bus Stop – Allows for a bus stop at the standard location on the curb of the vehicular travel lane while the Bicycle Facility travels at Sidewalk grade adjacent to, and behind, the bus pad.

17.1.04.Y On-Street Bicycle Facility – Dedicated space for bicyclists that is separate from vehicle traffic within the roadway. Separation may be created with striping, physical delineation (Protected Bike Lane), or above-grade features (Raised Bike Lane).

17.1.04.Z On-Street Shared Bus Stop – A shared space between buses and road-grade Dedicated Bicycle Facilities.

17.1.04.AA Pedestrian Hybrid Beacons (PHBs or HAWKS) – Special type of traffic control device used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk. PHBs are made up of a signal head in three sections, consisting of two horizontally arranged circular red sections over a single circular yellow section that is centered between the red lights.

17.1.04.BB Pedestrian Realm - Area within a public right-of-way or easement between the back of curb (or Curb Extension) or edge of the roadway and outermost edge of the public right-of-way or easement. The Pedestrian Realm provides the necessary space for safe, comfortable, and accessible pedestrian activity, and may accommodate other approved public amenities, infrastructure, or uses. It consists of a Frontage Buffer, Sidewalk and Safety Buffer.

17.1.04.CC Placemaking – Participatory process for shaping public space that harnesses the ideas and assets of the people who use it. An effective Placemaking process capitalizes on a local community’s assets, inspiration, and potential and it results in the creation of quality public spaces that contribute to people’s health, happiness and well-being.

17.1.04.DD Protected Bike Lanes – On-Street Bicycle Facilities between curb faces with physical delineation between the vehicle lane and bike lane. In Retrofit projects where a Dedicated Bike Path is not feasible, Protected Bike Lanes provide enhanced safety for bicyclists.

17.1.04.EE Protected Intersections – Reduce conflicts at intersections by providing safe, separated bikeways that set the bikeway back from parallel motor vehicle traffic so that bicyclists are not forced to merge into mixed traffic. Bicyclists can safely move straight and make two-stage turns through a Protected Intersection.

17.1.04.FF Raised Bike Lanes – Grade-separated Bicycle Facilities that are at a level between the Sidewalk and the roadway.

17.1.04.GG Raised Crosswalks – Provide a crossing that brings the level of the roadway up to the level of the Sidewalk. Raised Crosswalks increase visibility of Vulnerable Road Users, which can improve safety for all road users.

17.1.04.HH Retrofit – In the context of streets, any reconfiguration of the street and/or components in the right-of-way that is not part of a full street reconstruction. Typically, Retrofits use low-cost measures to improve existing infrastructure.

17.1.04.II “S” Dimensions – Defines the total space in the public right-of-way behind the face of curb on a roadway.

17.1.04.JJ Safety Buffer – Area between the back-of-curb or the edge of roadway and the edge of the Sidewalk nearest the back-of-curb or the edge of roadway.

17.1.04.KK Seamless Curb Extensions – Also known as seamless curb. A continuation of the Pedestrian Realm or median such that the grade, concrete, sodding and other components are consistent.

17.1.04.LL Shared Raised Bus Stop – Allows for a bus stop to be in line with a Dedicated Bicycle Facility without altering the Pedestrian Realm and allows for bus boarding at the Sidewalk level by ramping up the Dedicated Bicycle Facility to the curb.

17.1.04.MM Shared Use Paths – Combined bicycle and pedestrian facilities that run alongside a roadway behind the curb within the right-of-way.

17.1.04.NN Sidewalk – Publicly accessible firm-and-stable path as defined in the City of Houston Code of Ordinances, Chapter 40 – Streets and Sidewalks, Article XXII, Section 40-551.

17.1.04.OO Sidewalk Easement – Grants to the public a perpetual, non-exclusive right to cross or otherwise use someone else's land for a specified purpose as defined in the City of Houston Code of Ordinances, Chapter 40 – Streets and Sidewalks, Article XXII, Section 40-551.

17.1.04.PP Traffic Calming – Range of visual and physical elements used to slow vehicle speeds. Traffic Calming methods may include devices, roadway geometry adjustments, and/or other physical elements. Methods may be implemented temporarily or permanently to mitigate speeding.

17.1.04.QQ Transit-Oriented Development (TOD) Street – Public street designated as a primary TOD street or secondary TOD street on the transit-oriented development plan.

17.1.04.RR Two-Stage Turn Queue Boxes – Offer bicyclists a designated way to make left turns at multi-lane signalized intersections from a right-side Dedicated Bicycle Facility, or right turns from a left-side Designated Bicycle Facility. Two-Stage Turn Queue Boxes may also be used at unsignalized intersections to simplify turns from a Dedicated Bicycle Facility onto a Neighborhood Bikeway.

17.1.04.SS Vulnerable Road Users – Those most at risk in traffic. Vulnerable Road Users are mainly those unprotected by an outside shield, namely pedestrians, bicyclists, and people with disabilities, as they sustain a greater risk of injury in any collision against a vehicle and are therefore highly in need of protection against such collisions.

17.1.04.TT Walkable Places (WP) Street – Public street designated as a primary WP street or secondary WP street on the Walkable Places plan.

17.1.04.UU Walkway – Also known as “walkable surface”. Portion of the right-of-way or easement that is for pedestrian traffic. A Walkway may not include a clearly defined Sidewalk.

SECTION 2 - GENERAL REQUIREMENTS FOR PEDESTRIAN, BICYCLE, AND TRANSIT DESIGN

17.2.01 APPLICABILITY OF CHAPTER 17 DESIGN REQUIREMENTS

17.2.01.A Design requirements of Chapter 17 apply to any project that builds or impacts pedestrian, bicyclist, and transit infrastructure in the public right-of-way. All pedestrian, bicyclist, and transit infrastructure shall satisfy the requirements of this chapter.

17.2.01.B All street projects shall submit all required reports as defined in Chapter 15, Section 15.2.02 – Traffic and Design Studies and comply with all applicable Multimodal Service Standards (MMSSs) as defined in Chapter 15, Section 15.2.01 - Multimodal Service Standards.

17.2.01.C Design of pedestrian, bicycle, and transit facilities must consider the users perceived safety, also known as subjective safety. Using minimum values without consideration of facility context may result in ineffective facility use. The dimensional values in this chapter fall under two categories and should be used as follows:

1. In general, preferred values should be used to maximize the safety and comfort benefits for pedestrians, bicyclists and other users. Alternative values should only be used in locations where it is not possible to use preferred values due to social, economic, and environmental impacts. Where the Pedestrian Realm is wide enough to accommodate preferred values, preferred values shall be used.

2. Minimum values should not automatically be considered a default for pedestrian, bicycle, and transit elements due to the inherent vulnerability of its users.

3. Where ranges are presented within the chapter, the most conservative value is considered the preferred value, while the least conservative value in the range is considered the minimum value.

17.2.01.D All street projects shall ensure that all new or modified pedestrian, bicyclist, and transit elements are designed to minimize conflict with motorists, maximize safety for all road users, and meet the all ages and abilities design criteria established in the following sections.

17.2.02 SHADE AND GREEN INFRASTRUCTURE

17.2.02.A Shade, either from trees and vegetation or from structures, is important for pedestrian, bicyclists, and transit users and should be included wherever possible in infrastructure built for those users. Although street trees are desirable, this section does not specifically require their planting.

17.2.02.B Trees shall be selected and planted so that they:

1. Maximize shade for pedestrian Walkways and bicycle infrastructure;

2. Maximize the health of the tree;

3. Minimize damage to infrastructure including Sidewalks, curbs, pavement, foundations, and underground utilities. Tree selections and plans shall be reviewed and approved by the Houston Parks and Recreation Department and City Engineer;

4. Maintain all required clear zones from overhead utilities when trees achieve mature tree height; and

5. Will not cause damage to buses or other vehicles at any stage of the tree lifecycle.

17.2.02.C Trees and plants shall be selected and planted such that they ensure proper clearance for vehicular and infrastructure safety and ensure they do not interfere with visibility and sight line requirements at any stage of their lifecycles. Visibility obstructions from both the foliage of individual plants as well as clumping of multiple plants, including trees, can create safety concerns and shall be avoided.

17.2.02.D Root barriers shall be used whenever the health of the tree and impact to adjacent infrastructure cannot otherwise be mitigated. Refer to City Standard Details 02912-01 and 02912-02.

17.2.02.E For additional information regarding allowed installations and planting in the Safety Buffer between the Sidewalk and the roadway, see section 17.3.01.D.6.

17.2.02.F Pedestrian, bicycle, and transit infrastructure provides an opportunity for Green Infrastructure for stormwater management. This may include permeable surfaces, which are encouraged to be used on pedestrian and bicycle paths to promote water infiltration and reduce ponding and general street runoff.

17.2.03 PEDESTRIAN AND BICYCLE TEMPORARY TRAFFIC CONTROL

17.2.03.A Temporary traffic control must be provided for all pedestrian and bicyclists that are impacted or obstructed.

17.2.03.B Justification for type of temporary traffic control for pedestrian and bicyclists shall be provided to the City for review and approval. Temporary traffic control must follow the requirements listed in the order provided in this section.

17.2.03.C Options for Pedestrian and Bicycle Traffic Control (Ordered from Most to Least Preferred)

17.2.03.C continued

1. Option 1: Provide protection for pedestrians and bicyclists from debris in their present-day path using scaffolding, fencing or other barriers.

2. Option 2: Temporary Pedestrian and Bicyclist Traffic Diversions.

   a. Diversion may be provided on-street depending on local conditions to be determined by Houston Public Works. If on-street space is used for a diversion, barriers shall delineate vehicle travel lanes from pedestrians and/or bicyclists. See Chapter 15 requirements for type of barriers allowed.

   b. ADA compliant temporary curb transition ramps shall be provided for pedestrian or bicycle diversions that include a movement over a curb or other vertical barrier.

   c. Clear pedestrian and bicycle diversion signage shall indicate a diversion ahead, and along diversion route at all changes in direction and at regular intervals as necessary to highlight the diversion.

   d. Pedestrians and bicyclists may share the same diversion if approved by Houston Public Works.

3. Option 3: Pedestrian and Bicycle Detours

   a. Pedestrian and bicycle detours shall satisfy all design requirements for pedestrian and bicycle infrastructure as defined in this chapter.

   b. Pedestrian and Bicycle Facility detours shall provide the most direct route possible.

   c. Any closure of a pedestrian or Bicycle Facility shall require the shortest detour that maintains the safety of pedestrians and/or bicyclists.

   d. If detour users must cross the street, an existing safe crossing shall be used or a temporary safe crossing shall be provided.

   e. ADA compliant temporary curb transition ramps shall be provided for pedestrian or bicycle detours that include a movement over a curb or other vertical barrier.

   f. Clear pedestrian and bicycle detour signage shall indicate a detour ahead, and along detour route at all changes in direction and at regular intervals as necessary to highlight the detour.

   g. Pedestrians and bicyclists may share the same detour if approved by Houston Public Works.

17.2.04 BRIDGE CROSSINGS AND TUNNELS

17.2.04.A All new bridges and tunnels shall accommodate multimodal transportation usage by implementing the following requirements.

1. When the approach roadway to the bridge/tunnel has an existing or planned Bicycle Facility, the bridge/tunnel shall provide a Bicycle Facility that satisfies all current IDM requirements.

2. When the approach roadway to the bridge/tunnel does not have either an existing or planned Bicycle Facility, a 10-ft or greater Sidewalk that is accessible to bicyclists shall be provided. This ensures that, at a minimum, a Shared Use Path will be available if a Bicycle Facility is ever planned for the corridor.

3. Bridge Sidewalks and Shared Use Paths shall be physically separated from the vehicle pavement, either by a grade difference or physical delineation.

17.2.04.B Exterior bridge railings adjacent to a pedestrian/Bicycle Facility shall meet the following standards:

1. Maintain a minimum height of 42-inches. A height of 48-inches shall be used in the following cases:

    a. Speed of adjacent traffic exceeds 35 mph.

    b. Width of pedestrian/Bicycle Facility is less than 10-ft.

2. The railing design shall minimize opportunities for bicycle handlebars to get caught in the railing.

3. A railing or delineator may be used to separate bicycle traffic from pedestrian traffic to improve bicycle/pedestrian safety and comfort where appropriate.

SECTION 3 - PEDESTRIAN ELEMENTS REQUIREMENTS

17.3.01 PEDESTRIAN REALM

17.3.01.A For Pedestrian Realm components see Figure 17.1.

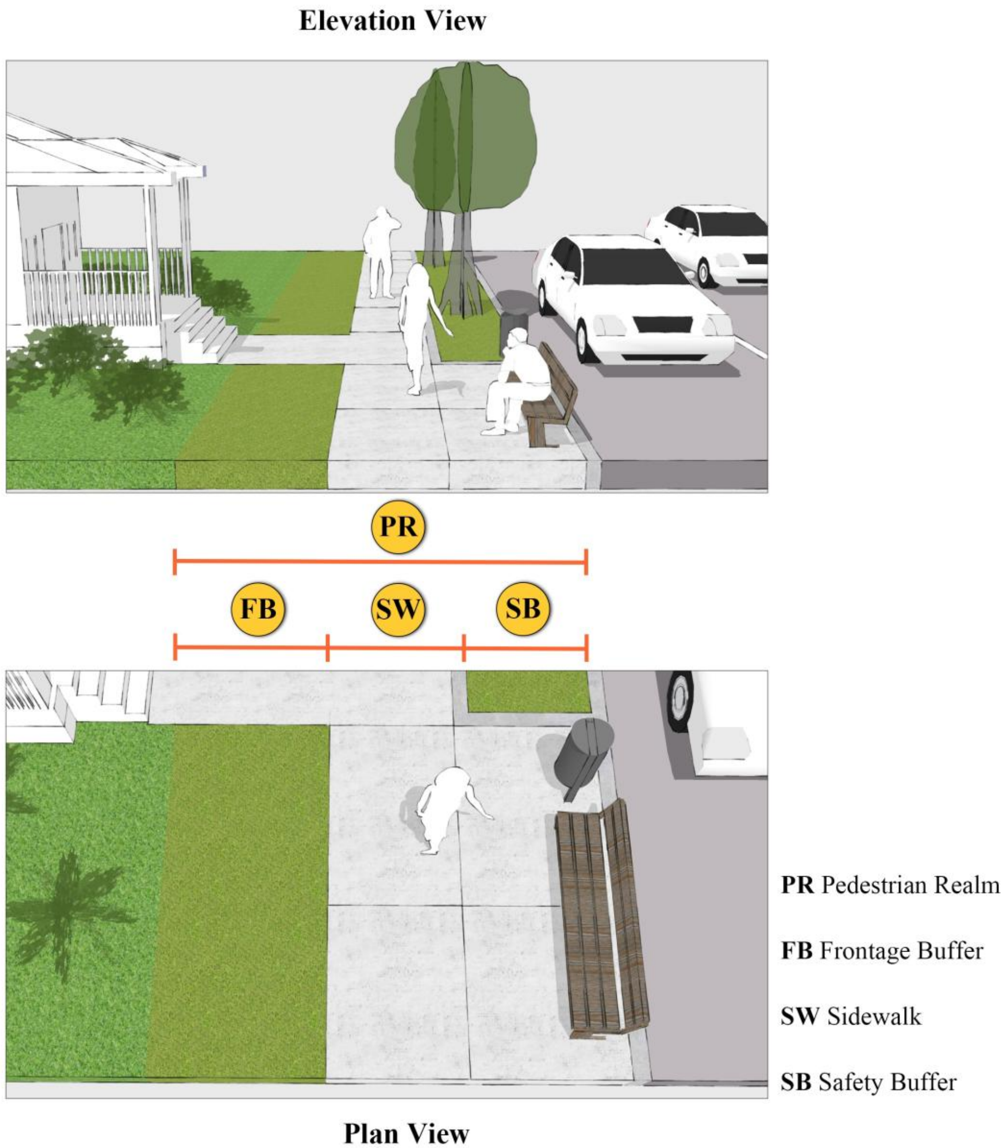


Figure 17.1 – PEDESTRIAN REALM COMPONENTS

17.3.01.B Frontage Buffer

1. The Frontage Buffer is the area between the outermost edge of the Sidewalk and the edge of the right-of-way or easement that is designed to improve visibility and reduce potential conflicts between Vulnerable Road Users and motorists.

2. The Frontage Buffer preferred width is three (3) feet. The Frontage Buffer shall maintain a minimum width of one (1) foot. See Table 17.2.

3. The Frontage Buffer shall be kept free from visual obstructions in the space above twenty four (24) inches and below eight (8) feet in height as measured vertically from the surface of the adjacent Sidewalk.

4. The Frontage Buffer may be paved or unpaved. If paved, it will be indistinguishable from the Sidewalk. Alternative materials of Frontage Buffer construction, such as permeable materials, may be used to support resiliency goals. All alternatives shall meet minimum Frontage Buffer requirements and shall be coordinated and approved by the City Engineer.

5. The intersection of the Pedestrian Realm with a driveway is subject to a pedestrian safety and visibility buffer in accordance with Chapter 40, Article I of the Code of Ordinances and illustrated in Figure 17.2 and Figure 17.3. The Frontage Buffer of the Pedestrian Realm as defined in this chapter may be used to satisfy the pedestrian safety and visibility buffer requirements.

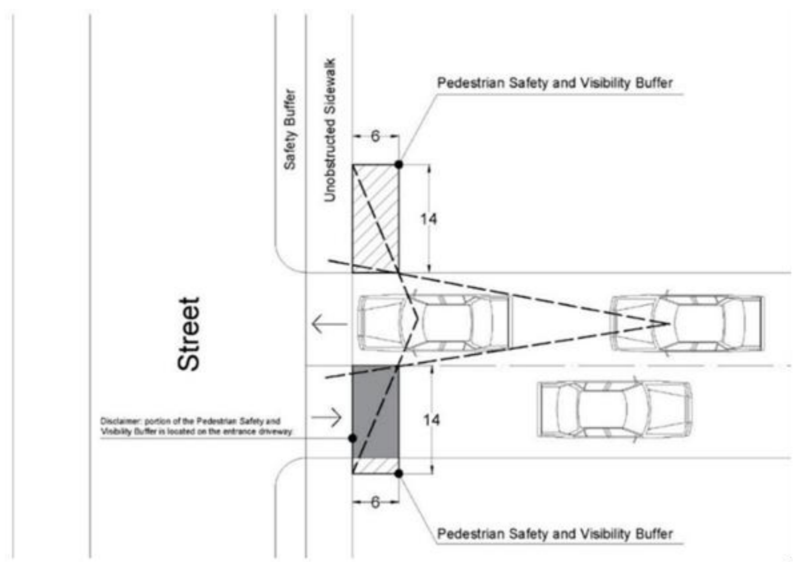


Figure 17.2 – PEDESTRIAN SAFETY AND VISIBILITY BUFFER (TWO-WAY DRIVEWAY) [7]

[7] City of Houston Code of Ordinances Section 40-32

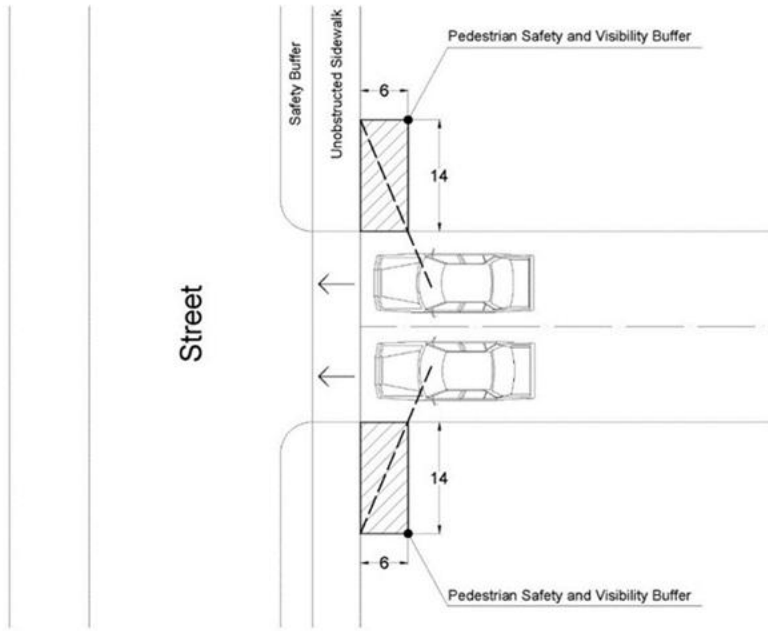


Figure 17.3 – PEDESTRIAN SAFETY AND VISIBILITY BUFFER (ONE-WAY DRIVEWAY) [8]

17.3.01.C Sidewalk

1. The Sidewalk is a publicly accessible path designed to ensure that a person has a safe and comfortable place to walk or use a mobility aid. The Sidewalk must be free of obstructions and encroachments and shall be designed as a continuous, obstacle-free space that maintains adequate drainage. Sidewalks shall adhere to standards in Table 17.1.

2. The Sidewalk cross slope shall be 2% to maintain ADA access and ensure that water flows across the Sidewalk without pooling in the Walkway.

3. The Sidewalk must be constructed in accordance with Houston Public Works standards, Texas Accessibility Standards (TAS), and Americans with Disabilities Act (ADA) requirements. If there is a conflict in the requirements, the strictest requirement(s) shall govern.

[8] City of Houston Code of Ordinances Section 40-32

17.3.01.C continued

4. The minimum unobstructed vertical clearance of a Sidewalk is eight (8) feet as measured vertically from the surface of the Sidewalk. Additional vertical clearance requirements apply for certain improvements constructed over a Sidewalk along a designated WP Street or TOD Street in accordance with the Enhanced Pedestrian Realm Standards of Chapter 42, Article IV of the Code of Ordinances.

5. The design of a Sidewalk near an approved bus or transit stop must meet the requirements in this section, Chapter 10 subsection 10.3.03.B.2 and be coordinated with METRO or other transit operators.

6. Sidewalks should be continuous and follow Desire Lines. When a Sidewalk must deviate to circumnavigate obstructions, transition curves should avoid sharp turns and be as long as necessary to ensure the highest comfort pathway.

7. The placement of a new above-grade feature within the minimum required Sidewalk width or within an existing substandard Sidewalk is prohibited unless a modification is granted under the Modification of Standards process detailed in Chapter 40, Article XXII of the Code of Ordinances or otherwise expressly authorized by law.

8. Sidewalks Traversing Driveways:

   a. Sidewalks should maintain Sidewalk grade across driveways.

   b. Sidewalks should be differentiated from driveways through pavement materials or Sidewalk edge delineation.

9. Sidewalks traversing a railroad track must be at 0% slope for a distance of five (5) feet from the centerline of the track in each direction. The Sidewalk should cross the railroad track as close to 90-degrees as possible.

10. Sidewalk Materials

    a. Sidewalks should typically be concrete.

    b. Alternative methods of Sidewalk construction may be used in places where tree preservation is of concern.

    c. Alternative materials for Sidewalk construction, such as permeable materials, may be used to support resiliency goals.

    d. If alternative material is selected by the Engineer, the Engineer shall create and submit an alternative material Sidewalk construction specification as a part of the design submittal. The specification shall include measurement and payment, material requirements, and instructions on execution.

17.3.01.C.10 continued

e. All alternatives shall meet minimum Sidewalk requirements and shall be coordinated and approved by Houston Public Works.

11. Sidewalks may be paired or combined with off-street bike paths. These Sidewalks shall comply with all requirements of this section and Section 17.4.02, High-Comfort Facility Type Standards.

Table 17.1 – MINIMUM SIDEWALK WIDTH STANDARDS

Street Type	Type	Minimum Width
Within Central Business District [9]	All	8 feet
Major Thoroughfare	WP Street	As designated by the Walkable Places Plan
	TOD Street	8 feet
	All Others	6 feet
All Other Public Streets	WP Street	As designated by the Walkable Places Plan
	TOD Street	6 feet
	All Others	6 feet preferred / 5 feet minimum

17.3.01.D Safety Buffer

1. The Safety Buffer is the area between the back-of-curb or the edge of roadway, and the edge of the Sidewalk nearest the back-of-curb or the edge of roadway. [10]

   a. The Safety Buffer creates a safe and comfortable distance between a person using the Sidewalk and vehicles on the adjacent roadway.

   b. The Safety Buffer also provides the opportunity to use Green Infrastructure to manage stormwater and reduce the urban heat island effect through the use of shade trees.

   c. The Safety Buffer may be utilized to accommodate different utilities; pedestrian, bicycle or transit amenities; or other approved uses.

[9] "Central Business District" is defined in Chapter 42, Article I of the Code of Ordinances.
[10] City of Houston Code of Ordinances: Section 40-551

17.3.01.D.1 continued

d. The Safety Buffer shall not be used for vehicle purposes including but not limited to parking, loading/unloading, valet zones, and ride share zones.

2. Safety Buffers shall adhere to the width standards in Table 17.2.

3. Safety Buffers greater than 2-feet wide may be paved or unpaved, unless otherwise stated in Chapter 15, Table 15.7.

   a. If paved, it may be indistinguishable from the Sidewalk.

4. Safety Buffers less than or equal to 2-feet wide shall be paved, unless otherwise stated in Chapter 15, Table 15.7.

   a. Pavement may be indistinguishable from the Sidewalk.

5. Alternative methods of Safety Buffer construction, such as permeable materials, may be used to support resiliency goals. All alternatives shall meet minimum Safety Buffer requirements and shall be coordinated and approved by the City Engineer.

6. Where the Safety Buffer width is at least four (4)-ft or greater, trees should be planted to provide Sidewalk shade. Trees shall not be planted in a Safety Buffer that is narrower than four (4)-ft. The selected tree variety shall be chosen to maximize shade coverage for pedestrians while also maximizing tree health and minimizing impact to infrastructure. For more information on providing shade and trees, see Section 17.2.02 - Shade and Green Infrastructure.

7. A combination Sidewalk and paved Safety Buffer is acceptable adjacent to dedicated on-street parking or valet zones. The entire Pedestrian Realm must still satisfy all requirements of this chapter.

   a. The resulting combined width of the Sidewalk and paved Safety Buffer in this scenario must be at least ten (10) feet.

   b. Subject to approval by both the Traffic Engineer and City Engineer, the minimum width of the Safety Buffer may be reduced or eliminated adjacent to the section of the Sidewalk designed to create a continuous path of travel to connect to an existing Sidewalk.

8. Approved above-grade features may be placed within the Safety Buffer.

Table 17.2 – FRONTAGE BUFFER AND SAFETY BUFFER WIDTH STANDARDS

Classification	**Preferred**	**Minimum**
Safety Buffer	6 feet or more	4 feet
Frontage Buffer	3 feet or more	1 foot

17.3.01.E Other Pedestrian Realm Requirements

1. The Pedestrian Realm at an intersection corner is formed by the intersection of Pedestrian Realms on the cross streets plus the additional right-of-way for corner cut-back as required by Chapter 10, Section 10.3.02.B. The entire space should be made available for a combination of Safety Buffer, curb ramps, Walkway, and other approved Pedestrian Realm features.

2. New development and certain redevelopment along a designated TOD Street or WP Street must meet additional requirements for the Pedestrian Realm and private property adjacent to the public street. These requirements are detailed in Chapter 42, Article IV of the Code of Ordinances.

3. “S” Dimension, Easements and Pedestrian Realm:

   a. The “S” Dimension may be smaller than or sufficient for the required Pedestrian Realm.

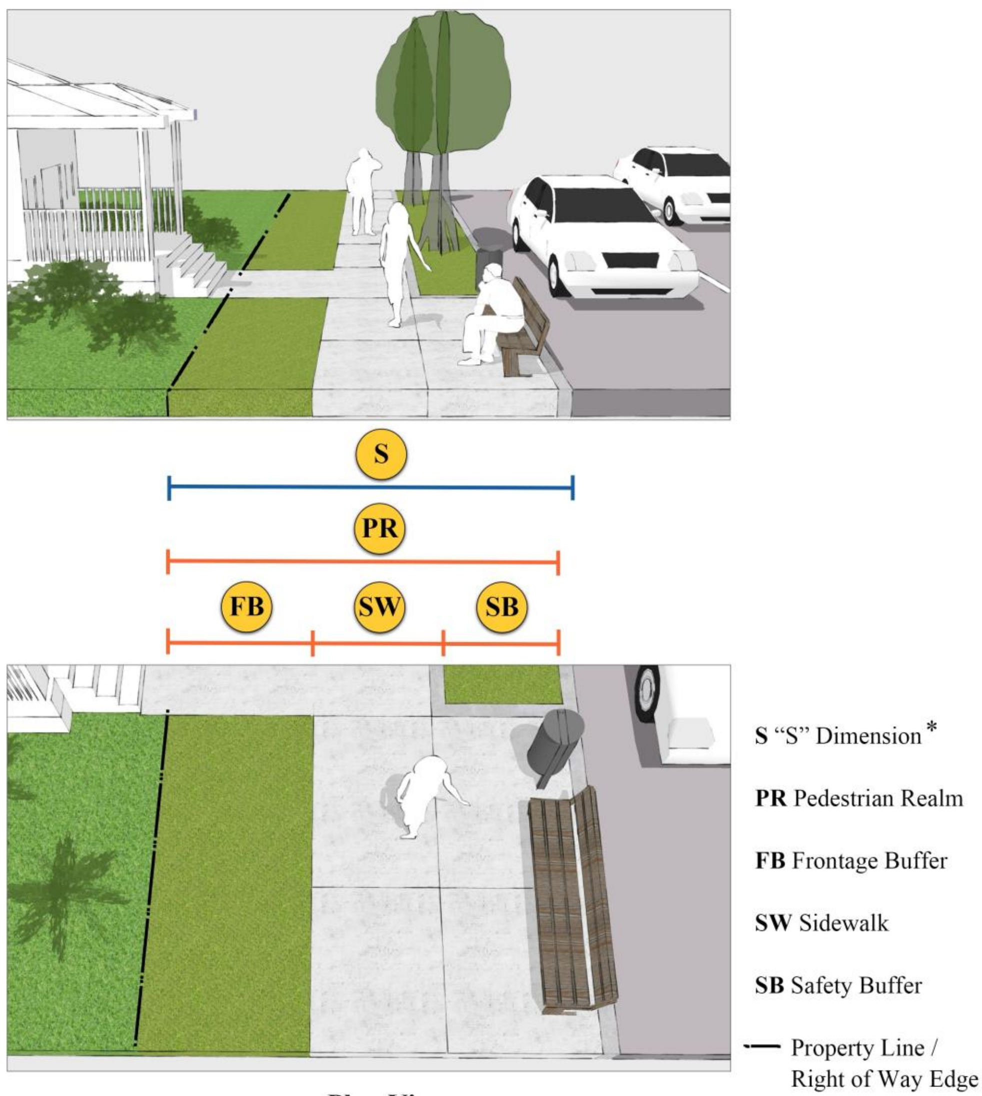
      (1). When the “S” Dimension is wide enough to accommodate the required Pedestrian Realm, the Pedestrian Realm will be located within the public right-of-way. See Figure 17.4.

      (2). When the “S” Dimension is not wide enough to accommodate the required Pedestrian Realm components, part of the Pedestrian Realm will need to be within a public Sidewalk Easement on the private property. See Figure 17.5.

   b. The duly recorded easement must grant the public a perpetual, non-exclusive easement on, over, and across the private land for the construction, maintenance, and use of a Sidewalk.

   c. See Figure 17.4 and Figure 17.5 for conceptual designs of the Pedestrian Realm and “S” Dimensions. All IDM conceptual designs are for reference only and do not constitute design standards.

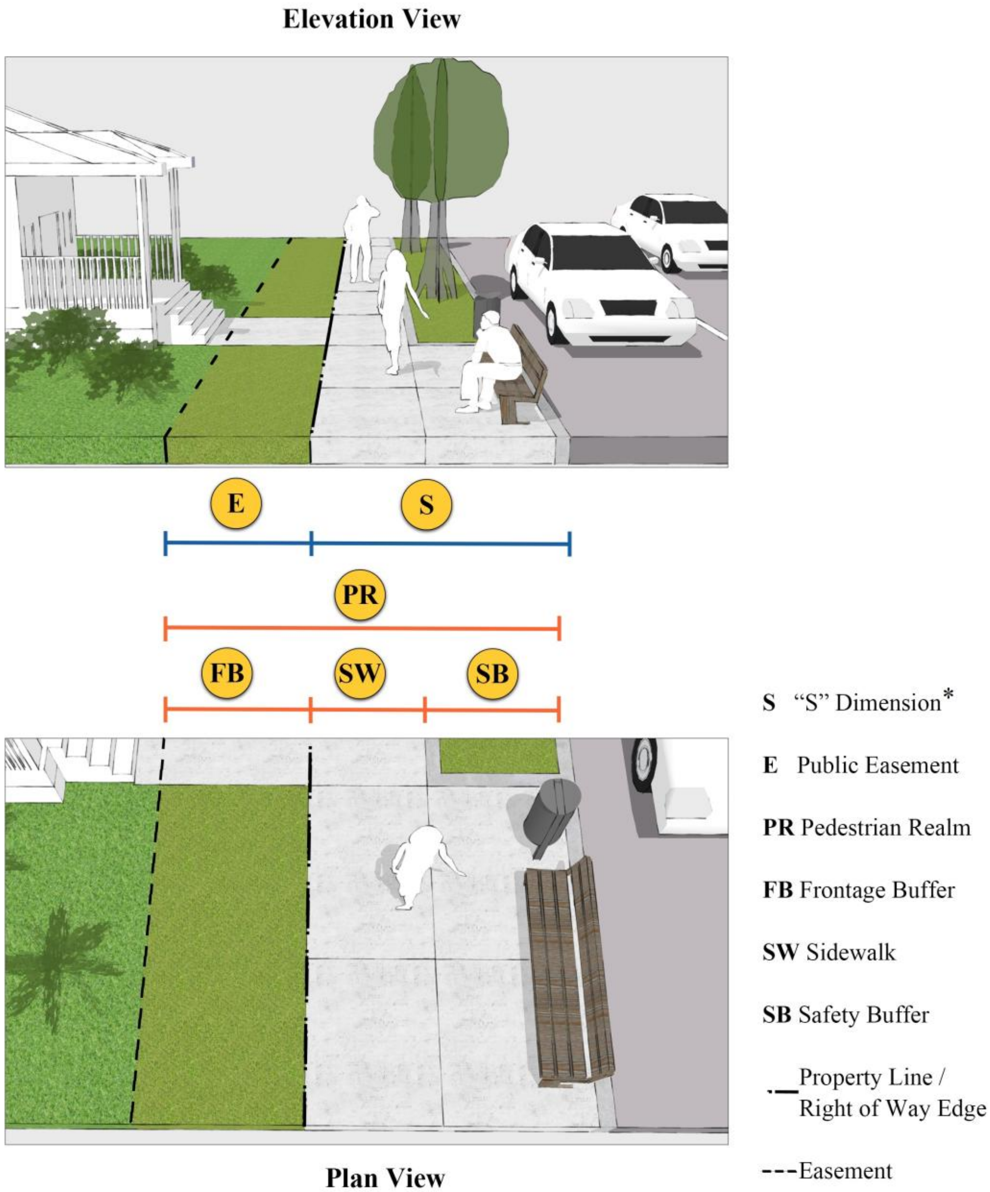
Elevation View



Plan View

Note: "S" Dimension is measured from the face of curb as defined in Chapter 10 of this manual.

Figure 17.4 – ENTIRE PEDESTRIAN REALM LOCATED WITHIN PUBLIC RIGHT-OF-WAY



Note: "S" Dimension is measured from the face of curb as defined in Chapter 10 of this manual.

Figure 17.5 – PORTION OF PEDESTRIAN REALM LOCATED WITHIN PRIVATE PROPERTY

17.3.02 INTERSECTIONS AND MIDBLOCK CROSSINGS

17.3.02.A Curb Ramps and Corner Treatments

1. Curb ramps provide accessible connections across roadways by creating a slope from the Pedestrian Realm to the street. Properly designed curb ramps ensure a high level of comfort and safety for Vulnerable Road Users. Figure 17.6 shows conceptual designs of intersection curb ramps that satisfy the pedestrian elements standards and guidelines defined in this section. This figure is for reference only and does not constitute design standards.

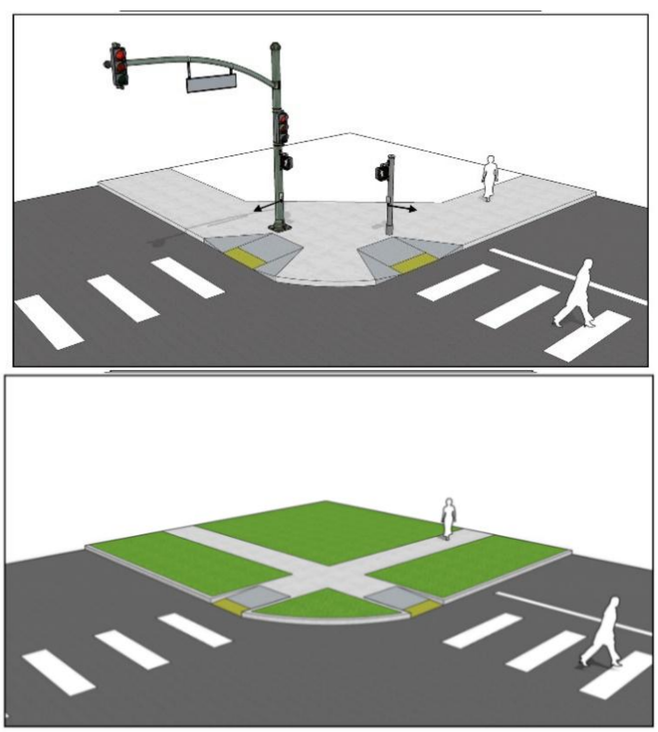


Figure 17.6 – EXAMPLES OF PREFERRED CURB RAMPS TREATMENTS

2. Curb ramps shall be constructed at all intersection corners and midblock crossing locations for any approach that includes a Sidewalk and/or that serves a legal crosswalk. Typically, this means that each corner should have curb ramps serving two crossings, regardless of traffic control.

3. All Curb Ramps shall be constructed in accordance with Houston Public Works standard details, Texas Accessibility Standards (TAS), and Americans with Disabilities Act (ADA) requirements. If there is a conflict in the requirements, the strictest requirements shall govern. At absolute minimum, all curb ramps must comply with all applicable ADA and TAS requirements.

17.3.02.A continued

4. All curb ramps constructed as part of an adjacent development or as part of a capital project with the capacity for right-of-way acquisition must comply with the curb ramp standards and guidelines.

5. Curb Ramp and Corner Treatment Design Standards

   a. For openings that are perpendicular (90 degrees) to the centerline of street, curb ramps shall not point into the center of the intersection.

   b. Minimum width shall be 5-ft, not including curb (see Figure 17.7).

   c. Maximum slope shall be 1:12. Small/flatter slopes are strongly preferred. See Figure 17.7.

   d. Provide a minimum 5-ft by 5-ft clear and level landing space at the top of every curb ramp (see Figure 17.7).

   e. Provide detectable warning strip of 2-ft at the interface with the roadway (see Figure 17.7). Every pedestrian-accessible trail, Walkway, or ramp shall meet this requirement.

   f. Ramps and the 5-ft x 5-ft level landing shall be free of obstructions, utilities, and hardware. Any obstructions, utilities, or hardware installed in an approved area shall maintain a minimum 5-ft clearance zone (see Figure 17.8).

   g. Curb ramp flares shall be provided for any side of a curb ramp that is adjacent to the walkable surface.

   h. The walkable surface shall be maximized at every corner of a signalized location and other pedestrian-dense areas to safely and comfortably accommodate pedestrians waiting to cross the street.

   i. See Figure 17.7 and Figure 17.8 for curb ramp dimensions and clearance zones, respectively.

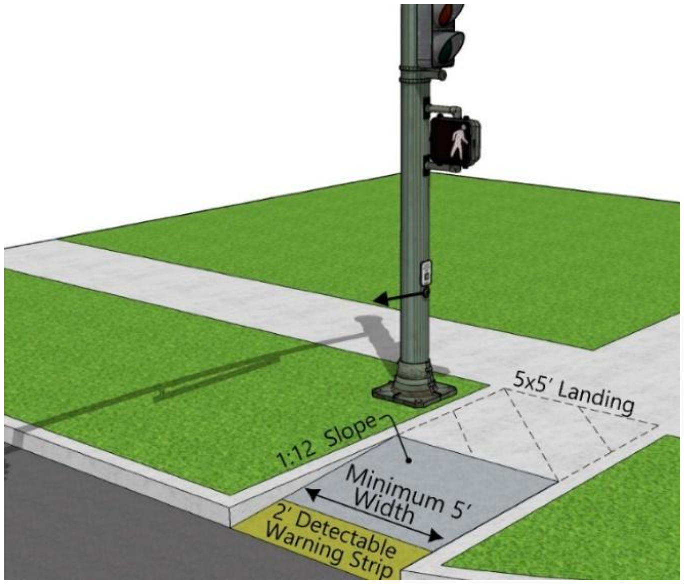


Figure 17.7 – CURB RAMP DIMENSIONS

17.3.02.A continued

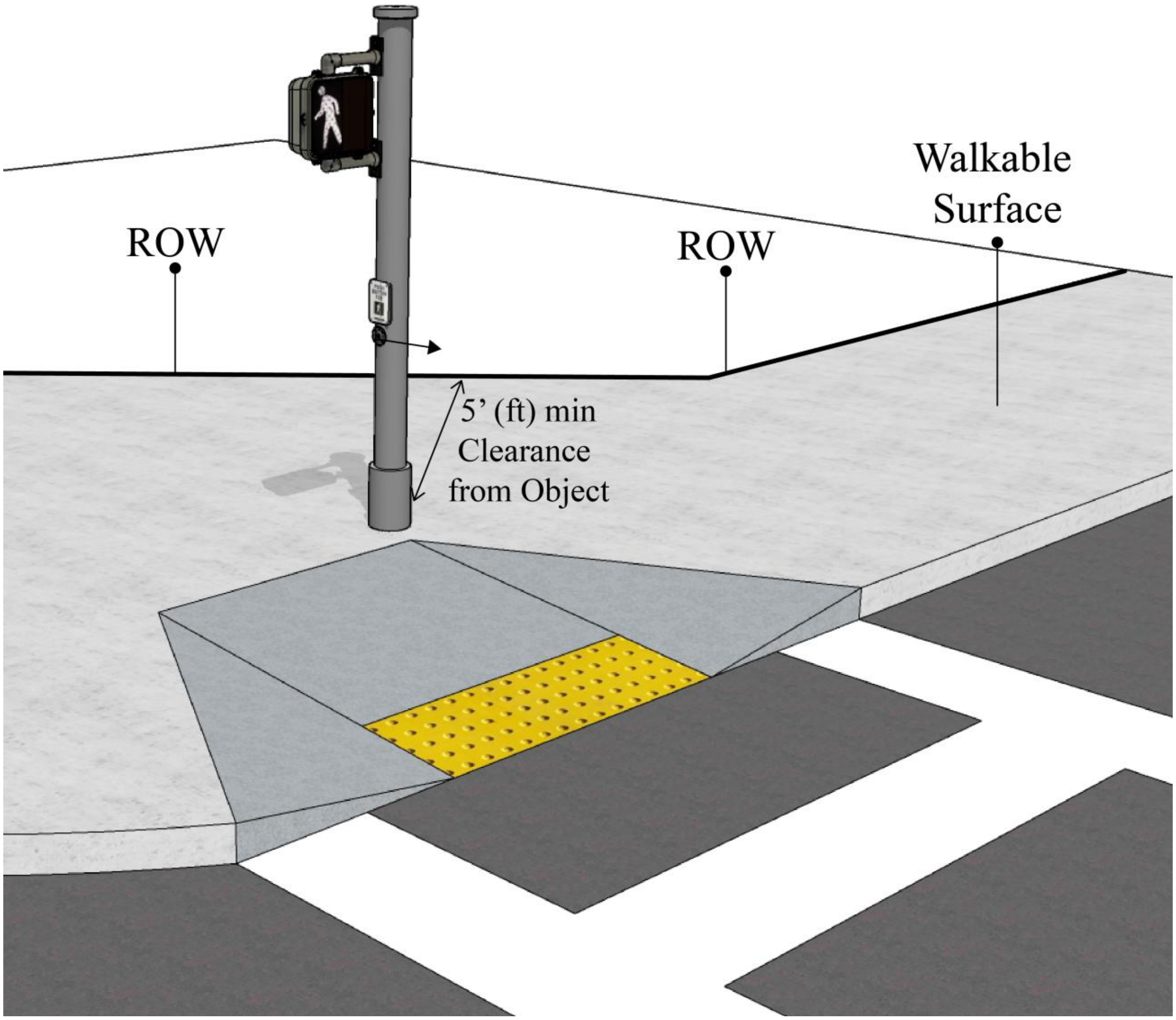


Figure 17.8 – CURB RAMP CLEARANCE ZONE

6. Curb Ramp Design Guidelines

   a. Curb ramps should be directional so that a person traveling down the ramp is directed towards a legal crosswalk and towards a receiving ramp.

   b. Curb ramp construction on an intersection corner should be interconnected to facilitate a walking route around the corner that does not require a pedestrian to utilize a ramp or enter the street.

17.3.02.A.6 continued

c. Where a curb ramp serves a Walkway, Bicycle Facility or trail that is directed toward the ramp, the width of the ramp should generally match the width of the Walkway, Bicycle Facility and/or trail.

d. Curb ramps should be designed so that water does not pool on or at the bottom of the ramp. This may require minor pavement work around the ramp to ensure adequate gutter flow.

e. Presence of a curb ramp does not in and of itself require crosswalk markings. Legal crosswalks exist at most intersections regardless of installation of crosswalk markings.

f. Pedestrian pushbuttons should be placed adjacent to a level Walkway that directs a pedestrian crossing in the direction served by the pushbutton. See Figure 17.9 for a conceptual design of pedestrian pushbuttons. This figure is for reference only and does not constitute design standards.

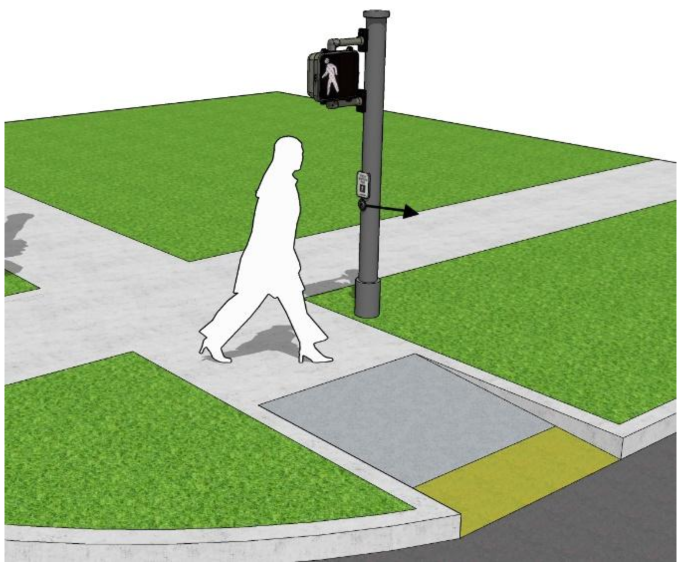


Figure 17.9 – EXAMPLE OF A PEDESTRIAN PUSHBUTTON LOCATED IN THE DIRECTION SERVED BY THE PUSHBUTTON

g. Pedestrian pushbuttons should be located so that they are equally accessible for pedestrians traveling via any Sidewalk and/or crosswalk served by the corner.

h. Signal poles without pedestrian pushbuttons should be installed in a fashion that maximizes the surrounding walkable surface.

i. Signal equipment may be installed in the walkable surface if doing so provides a net gain in space for pedestrians.

17.3.02.B Crosswalk Markings (see Chapter 15.2.06.B.4)

17.3.02.C Curb Extensions

1. Curb extensions (also known as bulb-outs) are tools that add space for pedestrians along a roadway by extending the Pedestrian Realm from the Sidewalk into the street. This narrows the roadway width, which can improve pedestrian safety by increasing visibility, shortening the crossing distance, and reducing exposure time to traffic.

   a. Curb Extensions can achieve Daylighting, which is a safety measure that improves visibility and comfort for all road users at intersections by eliminating visual barriers between motorists and Vulnerable Road Users on the cross street.

2. Curb Extensions can be added at intersections, midblock crossings, and where travel lanes are reduced or reconfigured.

   a. Streets with 24-hour on-street parking shall have Curb Extensions at intersections and midblock crossings. Curb Extensions can be implemented at midblock crossings and intersections where construction would not require obstructing a travel lane.

   b. See Section 17.3.03 - Corridor Crossing Analysis and Treatments for additional guidelines on Curb Extension placement.

3. Curb Extensions should be added at all intersections with excess width where roadway geometry allows. Excess width is present when a roadway cross section meets the following condition:

$$If, x > (y \times 11) + m$$

$$Then, e = x - \left((y \times 11) + m\right)$$

Where: x = face of curb to face of curb width (ft)
y = number of through and turn lanes
m = median width (ft)
e = excess width (ft)

4. Curb Extensions should be a minimum twenty (20)-ft in length from a point beginning at the crosswalk, marked or unmarked. The length may be altered if driveways, bus stops or other uses of the curb-adjacent area are present.

17.3.02.C continued

5. Curb Extensions shall maintain or improve existing crosswalk and curb ramp widths. Curb Extensions shall not impede pedestrian travel paths.

6. Curb Extensions can be made from corner reconstruction and extend the Sidewalk into the roadway, or they may be defined with the use of pavement markings, curbs, bollards, planters, or a combination of the aforementioned.

7. Materials for Curb Extensions:

   a. Seamless Curb Extensions shall be used in new or full street reconstruction projects and may be used in Retrofit projects. Seamless Curb Extensions should be a continuation of the Pedestrian Realm such that the grade, concrete, sodding, and other components are consistent. See Figure 17.10 for a conceptual design of an intersection with Seamless Curb Extensions. This figure is for reference only and does not constitute design standards.

Figure 17.10 – SEAMLESS CURB EXTENSION WITH ON-STREET PARKING

   b. Median concrete (also known as floating curb) can only be used in Retrofit projects.

      (1). On curb and gutter streets, median concrete shall maintain an eighteen (18)-in wide gutter flow area.

      (2). Median concrete may be installed on open ditch streets subject to Houston Public Works review and approval.

   c. Precast or cast-in-place curb can only be used in Retrofit projects. The length and openings of precast and cast-in-place curb will vary depending on context but generally should be placed such that vehicles cannot encroach.

17.3.02.C.7 continued

d. Bollards or flexible posts with pavement markings can only be used in Retrofit projects. Hatched pavement markings (see 17.3.02.C.7.e) shall create a buffer and the bollards or flexible posts shall be placed on the inside edge of the buffer. Spacing between individual bollards or flex-posts will vary depending on context but generally should be placed such that vehicles cannot encroach.

e. Hatched pavement markings alone may only be used where all other Curb Extension treatments are not feasible. Curb Extensions that consist only of hatched pavement markings are subject to approval by City Traffic Engineer.

(1). Hatched pavement markings shall consist of twenty-four (24)-in diagonal white stripes spaced at eight (8)-ft bounded by a six (6)-in solid white line.

f. Other materials may be considered to delineate Curb Extensions, such as planters. Alternative materials are subject to approval by the City Traffic Engineer.

8. Curb Extensions may include street furniture, bike racks/corrals (see section 17.4.01.C), or other amenities to enhance the public realm. The City of Houston will maintain standard Curb Extension delineation (see subsections 17.3.02.C.7.a-d) and bike racks (‘U’ Racks, refer to Standard Detail 02871-01) within Curb Extensions. Other amenities require a maintenance agreement.

9. Where Curb Extensions intersect with Dedicated Bicycle Facilities, see Protected Intersections, Section 17.4.03.A11.

10. Drainage

a. On curb and gutter streets, Curb Extensions should include a new stormwater inlet on the upstream side of the Curb Extensions. If a new inlet is not feasible, the Curb Extensions shall at a minimum maintain the existing gutter flow line. This may be achieved through cuts in median concrete or curb spacing.

b. Curb Extensions on open ditch streets are subject to Houston Public Works review and approval.

17.3.02.D Median Refuge Islands

1. Median Refuge Islands are protected spaces located in the center of the roadway to allow for safe crossings in stages. Median Refuge Islands enable bicyclists and pedestrians to cross a single direction of traffic at a time, thereby limiting pedestrian and bicyclist exposure to traffic.

17.3.02.D continued

2. Median Refuge Islands at unsignalized locations must be recommended as part of a Corridor Crossing Analysis report, as defined in Section 17.3.03.

3. Crossings through an existing median or at an unsignalized intersection with an existing median are not considered Median Refuge Islands for the purpose of these standards; however, many of the standards and guidelines presented here may be utilized as applicable for those crossings.

4. Materials

   a. Median Refuge Islands shall be constructed with a suitable material to discourage driver encroachment.

   b. The preferred treatment is standard concrete curb with a fill of sod or other Green Infrastructure. Concrete fill may be used.

5. Geometry

   a. Median Refuge Island dimensions shall meet the minimums established in Table 17.3.

   b. The front edge of the Median Refuge Island shall be rounded to discourage the accumulation of roadway debris.

   c. The Walkway through the Median Refuge Island may be either cut-through or ramped:

      (1). For Median Refuge Islands less than 20-ft width, a cut-through design is required.

      (2). For Median Refuge Islands greater than 20-ft width, a Walkway with ramps shall be used to keep debris from accumulating and to increase the height of pedestrians to make them more visible to drivers.

   d. Detectable warning surfaces shall be provided at the entrance and exit of the Median Refuge Island and at both roadway edges as part of accessible curb ramps.

6. See Figure 17.11 for a conceptual design of a Median Refuge Island. This figure is for reference only and does not constitute design standards.

17.3.02.D continued

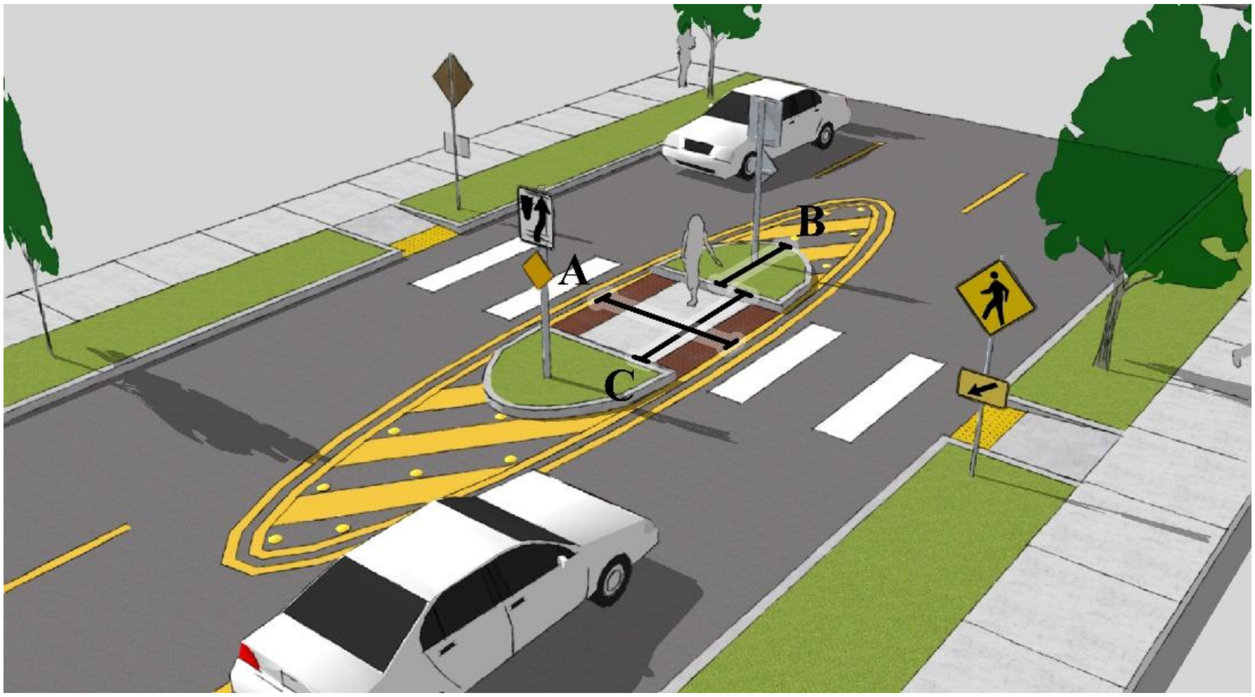


Figure 17.11 – MEDIAN REFUGE ISLAND WITH WIDTH (A), LENGTH (B) AND WALKWAY WIDTH (C)

Table 17.3 – MINIMUM DIMENSIONS FOR MEDIAN REFUGE ISLANDS

Design Element[2]	Label	Minimum (ft) [1]
Median Refuge Width	A	8
Median Refuge Length	B	6
Walkway Width	C	6

Notes:

(1) Dimensions measured from face of curb to face of curb.

(2) See Figure 17.11 for an example of design elements

7. Signage and Pavement Markings

17.3.02.D.7 continued

a. Median Refuge Islands installed on undivided roadways will be treated as a roadway obstruction and shall follow all TMUTCD requirements for markings and signage.

b. The approach edge of the Median Refuge Island shall utilize retroreflective treatments. If it is a curb, the curb shall be painted with retroreflective paint. Yellow paint shall be used when the Median Refuge Island is located between opposing directions of traffic. White paint shall be used when the Median Refuge Island is located between lanes in the same direction.

c. A Keep Right sign (R4-7) shall be installed in the center of the Median Refuge Island near the approach edge.

d. Signing and striping for the crosswalks shall comply with Section 17.3.03.C - Crossing Treatments.

8. Street lighting shall be installed in the vicinity of the Median Refuge Island. See Chapter 15, Section 15.2.13 - Streetlight Design Requirements.

9. The height of any Median Refuge Island features, such as landscaping, that could restrict visibility of road users shall be no greater than four (4)-ft from the roadway surface.

10. All Median Refuge Islands must comply with all requirements defined in 17.3.02 - Intersections and Midblock Crossings and with Standard Details 02760-10, 02760-11 and 02760-12.

11. Guidelines

a. Median Refuge Islands can be located at intersections or midblock.

b. Z-style Walkways within the Median Refuge Islands are preferred to increase the chance that a pedestrian can see a conflicting vehicle before entering the road and to slow movements by bicyclists and other higher-speed users.

c. When extra visibility is required, such as when site conditions make street lighting challenging, reflective bollards should be installed along the approach edge of the Median Refuge Island.

d. A Median Refuge Island should not be placed in front of or near a driveway unless access control into or out of the driveway is specifically desired. Coordination with Houston Public Works will be required whenever access to a driveway is impacted.

17.3.02.D continued

12. Sod or other LID features may be preferable in the median if adequate drainage is provided and with Houston Parks and Recreation Department approval. Additional landscaping shall require an approved maintenance agreement.

17.3.02.E Raised Crosswalks

1. Raised Crosswalks provide a crossing that brings the level of the roadway up to the level of the Sidewalk. Raised Crosswalks increase visibility of Vulnerable Road Users, which can improve safety for all road users. Figure 17.12 and Figure 17.13 show conceptual designs of Raised Crosswalks. These figures are for reference only and do not constitute design standards.

Figure 17.12 - RAISED CROSSWALK ON A TWO-WAY, UNDIVIDED ROADWAY

17.3.02.E continued

Figure 17.13 - RAISED CROSSWALK ON A ONE-WAY ROADWAY WITH A Z-STYLE CROSSING

2. Raised Crosswalks may be installed at intersections, midblock, as part of trail crossings, pedestrian and bicyclist crossings at roundabouts, or other locations where approved by City Traffic Engineer or designated approver.

3. Raised Crosswalks at unsignalized locations, shall only be installed where determined by Corridor Crossing Analysis report and approved by City Traffic Engineer, as defined in 17.3.03.B.

4. Geometry

   a. Raised Crosswalks shall follow the design standards established in Table 17.4.

   b. Figure 17.14 demonstrates the platform width (W), approach slope (S_a) and departure slope (S_d) and Figure 17.15 demonstrates the height (H).

   c. Raised Crosswalks on undivided roadways shall have an identical approach and departure slope. On divided and one-way roadways, the approach and departure slopes shall vary according to Table 17.4.

Table 17.4 – RAISED CROSSWALK DIMENSIONS AND SLOPE

Classification & Speed (85th % or posted)	Platform Width W (ft)	Height H (in)	Undivided	Divided/ 1-Way	
			Approach & Departure Slope S_a & S_d	Approach Slope S_a	Departure Slope S_d
Unclassified 30 MPH or less	10	6	1:15	1:15	1:35
Classified 30 MPH	20	4	1:20	1:15	1:35
Classified 35 MPH	20	4	1:25	1:20	1:35
Classified 40 MPH	20	4	1:25	1:25	1:35

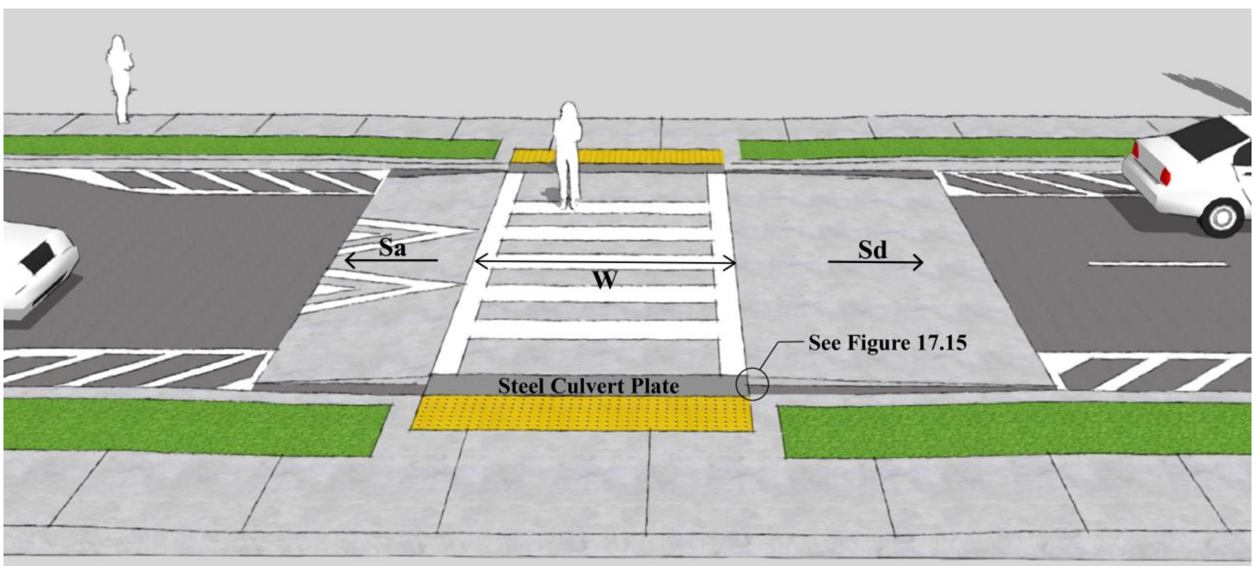


Figure 17.14 – RAISED CROSSWALK ON A ONE-WAY ROADWAY WITH THE APPROACH SLOPE (S_a), DEPARTURE SLOPE (S_d) AND PLATFORM WIDTH (W)

17.3.02.E continued

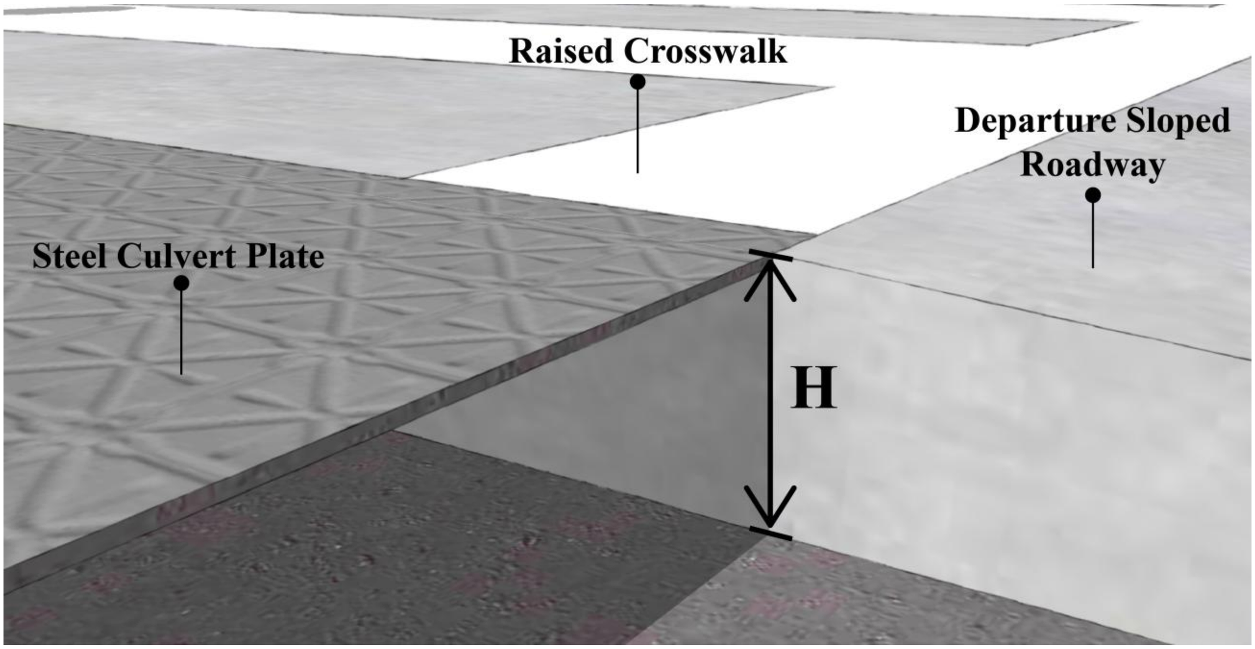


Figure 17.15 – DEMONSTRATION OF RAISED CROSSWALK HEIGHT (H)

5. Signage and Pavement Markings

   a. All Raised Crosswalks shall provide High-Visibility Crosswalk or dual-use crossing markings.

   b. White retroreflective chevron markings, consistent with those shown on Standard Detail 13501-01, shall be installed on the sloped part of the Raised Crosswalk on the approach section.

   c. Whenever a drainage gap is approved, drivers shall be guided away from the gap. At a minimum, pavement markings shall be provided consisting of retroreflective edge lines and white hatched tapers compliant with lane narrowing requirements in the Texas Manual on Uniform Traffic Control Devices.

   d. Signing and striping for the crosswalks shall comply with Chapter 15, Section 15.2.06.B.4 - Crosswalks and Section 17.3.03.C - Crossing Treatments.

6. Drainage

   a. Raised Crosswalk design shall fully accommodate drainage. A Raised Crosswalk shall not create new ponding of stormwater.

17.3.02.E.6 continued

b. For classified collector and major thoroughfare streets and any street with a posted speed of 35 mph or higher:

(1). Raised Crosswalks shall be installed on a high point of the gutter flow line or a new storm inlet with appropriate connections installed on the upstream side of the Raised Crosswalk.

c. For Local Streets:

(1). Raised Crosswalks should be installed on a high point of the gutter flow line or a new storm inlet with appropriate connections installed on the upstream side of the Raised Crosswalk.

d. Roundabouts with Raised Crosswalks shall include inlets upstream on the legs of the roundabout to avoid ponding in the inscribed circle.

e. A minimum eighteen (18)-in gap shall be provided to preserve the gutter flow. An easily removable steel plate shall be provided over the drainage gap at the level of the Raised Crosswalk. Retroreflective edge lines and hatch markings shall be provided to guide drivers away from the gap.

7. Street lighting shall be installed in the vicinity of the Raised Crossing. See Chapter 15, Section 15.2.13 – Streetlight Design Requirements.

8. Guidelines

a. Raised Crosswalks can be located at intersections or midblock.

b. Raised Crosswalks may be placed on median-divided roadways such that a Z-style Walkway is created within the median (see Figure 17.13). Z-style crossings are preferred to increase the chance that a pedestrian can see a conflicting vehicle before entering the road and to slow movements by bicyclists and other higher-speed users.

c. A Raised Crosswalk shall not be placed in front of a driveway unless access control into or out of the driveway is specifically desired. Coordination with Houston Public Works will be required whenever access to a driveway is impacted.

17.3.02.F For safe crossings at Roundabouts see Chapter 10, Section 10.3.02.F - Roundabout Intersections.

17.3.03 CORRIDOR CROSSING ANALYSIS AND TREATMENTS

17.3.03.A General

1. Legal crosswalks exist at most intersections, regardless of presence of signage or striping (Texas Transportation Code Chapter 552.003). Most crosswalks across minor streets do not require any special treatment.

2. New crossings or modifications to existing crossings for Vulnerable Road Users at unsignalized locations must be recommended as part of a Corridor Crossing Analysis as defined in 17.3.03.B and require approval by Houston Public Works.

3. Trail crossings at classified roadways (MTFP) shall follow the general crossing analysis methodology described below. Trail crossings at local streets should follow the criteria in Section 17.3.03.D - Special Case: Midblock Trail Crossing at Local Streets.

17.3.03.B Corridor Crossing Analysis

1. Applicability and Scope

   a. All new marked crosswalks at unsignalized locations must be recommended as part of a Corridor Crossing Analysis. All enhancements to an existing marked crosswalk shall also require a Corridor Crossing Analysis to justify the enhancements.

   b. The requirements of this section apply to improvements to a single location and to a corridor with multiple crossing locations. Both situations require an assessment of corridor conditions between existing crossing locations that meet the requirements of this section. A full corridor assessment assures that new crossing locations do not preclude other high-demand crossing locations.

   c. Special cases may be appropriate for the assessment of a single crossing location instead of a corridor assessment. Such cases may include a trail crossing location that is dictated by the geometric constraints of the trail corridor. Any Crossing Analysis of a single site instead of a full corridor requires Transportation and Drainage Operations approval.

   d. Note: This section does not provide requirements for the installation timeline of any crossing improvement. It only provides the requirements for acceptable locations for crossings and infrastructure treatments.

2. Corridor Crossing Analysis Report

17.3.03.B.2 continued

a. A Corridor Crossing Analysis report shall summarize all data, analysis, and recommendations required by this section. The report must be signed/sealed by a registered Professional Engineer and submitted to Houston Public Works for approval by the City Traffic Engineer or designated approver.

b. Corridor Crossing Analysis Reports shall recommend locations for crossings using the methodology in this section and shall recommend treatments for each crossing using the methodology in Section 17.3.03.C - Crossing Treatments.

3. Siting of Enhanced Crossings

a. Crossing enhancements may be provided midblock or at an unsignalized intersection. New midblock crossings shall be at least 100-ft from an intersection.

b. A Corridor Crossing Analysis shall result in safe, convenient crossings for Vulnerable Road Users spaced approximately every 500-720 feet. This distance ensures that no Vulnerable Road User must travel more than 360 feet (approximately two (2) minutes at three (3) ft/s walking speed) out of their way to reach an established crossing location. Closer spacing may be appropriate depending on land use and context.

(1). Note: Traffic signals, all-way stops, and modern roundabouts may be considered roadway treatments with acceptable crossings.

c. The locations of Enhanced Crossings recommended by a Corridor Crossing Analysis shall:

(1). Maintain spacing standards for the next adjacent designated crossing on either side of the proposed crossing location.

(2). Ensure that future, potentially desirable crossing locations can be installed according to the spacing standards.

(3). Use the following criteria to identify and prioritize crossing locations:

(a). Trail crossings

(b). Bus/transit stops

(c). Houston Bike Plan

17.3.03.B.3.c.(3) continued

(d). Schools, especially where students are expected to cross at the location

(e). Adjacent parks

(f). Adjacent churches

(g). Other significant pedestrian generators

(h). High-crash location along the corridor

(i). Desire Lines or other indications of existing pedestrian activity.

17.3.03.C Crossing Treatments

1. General Considerations for Crossing Treatments

   a. Crossing Treatments define the details of traffic control associated with various types of unsignalized crossings for Vulnerable Road Users. Specific Crossing Treatment requirements are included in Section 17.3.03.C.3.

   b. All new or enhanced marked crossings at unsignalized locations shall comply with these standards. The type of crossing and specific location of an Enhanced Crossing shall be defined by a Corridor Crossing Analysis (see Section 17.3.03.B).

   c. All Enhanced Crossings must be recommended by a Corridor Crossing Analysis or required by another section of this manual. All other Enhanced Crossings require approval by Transportation and Drainage Operations.

   d. Street lighting shall be provided at Enhanced Crossings to illuminate the crosswalk where approved by Houston Public Works.

   e. Pavement markings shall be used to define all midblock crossing locations.

   f. All Enhanced Crossings shall be fully ADA-compliant and provide curb ramps that meet design requirements of Section 17.3.02.A.

2. Selection of Appropriate Crossing Treatments:

   a. An existing or proposed treatment shall satisfy all applicable City standards for that treatment before it may be considered an Enhanced Crossing.

17.3.03.C.2 continued

b. New crossings shall provide a pedestrian Level of Service (LOS) E or better and have a calculated pedestrian delay less than 30 seconds based on the Pedestrian Mode methodology in the Two-Way STOP-Controlled Intersections chapter of the Highway Capacity Manual (latest edition). This methodology applies to Two-Way STOP-Controlled intersections and midblock crossings.

c. The simplest option that would achieve the required pedestrian LOS shall be used.

d. Prior to choosing a Crossing Treatment, alternatives shall be considered for reducing the crossing distance for the Vulnerable Road User, which impacts the pedestrian LOS. This reduction can be achieved with lane narrowing, lane repurposing, and curb extensions.

e. Crossings at existing medians shall be considered a two-stage crossing for the analysis if the crossing satisfies or will be retrofitted to satisfy all applicable requirements for a Median Refuge Island.

f. A combination of Crossing Treatments may be utilized; the highest yield rate of the combination should be used for the analysis unless a justifiable combined yield rate is available.

g. Other treatments may be acceptable; however, it will be the responsibility of the requestor to present justifiable yield rates.

h. Satisfaction of these requirements shall constitute an acceptable Corridor Crossing Analysis for the approved toolset defined above. The Corridor Crossing Analysis must be approved by Houston Public Works before the treatment may be installed.

3. Enhanced Crossing Treatments

a. High-Visibility Signs and Markings. See Section 17.3.03.C.4 - High-Visibility Signs and Markings.

b. Raised Crossing. See Section 17.3.02.E - Raised Crosswalks.

c. Curb Extensions. See Section 17.3.02.C - Curb Extensions.

d. Median Refuge Islands. See Section 17.3.02.D - Median Refuge Islands.

e. Rectangular Rapid Flashing Beacons (RRFBs)

17.3.03.C.3.e continued

(1). RRFBs are pedestrian-actuated enhancements used in combination with a pedestrian, school, or trail crossing warning sign to improve safety at uncontrolled, marked crosswalks. The device includes two rectangular-shaped yellow indications, each with an LED-array-based light source, that flash with high frequency when activated.

(2). RRFBs shall include Level B or C high-visibility signs and markings, as defined in Section 17.3.03.C.4 - High-Visibility Signs and Markings.

(3). RRFB indicators shall be provided on both sides of the road for each approach, to ensure that drivers are aware that pedestrians may begin crossing from either side. This applies to both divided roads and undivided roads.

f. Pedestrian Hybrid Beacons (PHBs or HAWKS) are a special type of traffic control device used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk. PHBs are made up of a signal head in three sections, consisting of two horizontally arranged circular red sections over a single circular yellow section that is centered between the red lights.

4. High-Visibility Signs and Markings

a. Where a Corridor Crossing Analysis recommends high-visibility signs and markings, or where another kind of Crossing Treatment requires high-visibility signs and markings, the signs and markings shall follow the requirements of this section.

b. General Signage and Pavement Marking Requirements:

(1). For pedestrian-only crossings, white High-Visibility Crosswalk markings shall be used.

(2). For shared use midblock crossings, dual use markings shall be used, consisting of a series of white strips flanked by square bicycle-green pavement markings (refer to Standard Detail 02760-10).

(3). For median-divided roadways, all signs required by this standard shall be mirrored on either side of a direction of travel.

17.3.03.C.4.b continued

(4). Roadways with more than one lane in each direction, require R1-5b “Stop Here to Pedestrians” (pedestrian-only crossing) or R1-5PBb “Stop Here to Pedestrians and Bicyclists” (shared-use crossing) signage and stop bars (refer to Standard Detail 02760-10).

Table 17.5 – LEVEL OF TREATMENT CRITERIA SUMMARY

ADT	Speed Limit	4 Lanes with Median	2 Lanes without Median	4 Lanes without Median
≤5,000	≤ 30 mph	A	A	A
	> 30 mph	A	B	C
5,000 – 15,000	≤ 30 mph	B	B	B
	> 30 mph	C	C	C*
>15,000	≤ 30 mph	C	C*	C*
	> 30 mph	C*	C*	C*

* Indicates that high-visibility signs and markings may not be sufficient for these crossings and should be combined with higher level treatments.

c. The following levels of treatment are specified for pavement markings and signage at locations with characteristics specified by Table 17.5.

(1). Level A = Crossing pavement markings only

(a). Install, as appropriate, white High-Visibility Crosswalk markings (pedestrian-only crossing) or dual use crossings (shared-use crossing).

(2). Level B = Advance warning signage + Level A

(a). Install, as appropriate, white High-Visibility Crosswalk markings (pedestrian-only crossing) or dual use crossings (shared-use crossing).

(b). Install W11-2 pedestrian warning sign (pedestrian-only crossing) or W11-15 pedestrian/bicycle warning sign (shared-use crossing) with W16-9P AHEAD (plaque) mounted on the side of the roadway in advance of the crossing.

17.3.03.C.4.c.(2) continued

(c). Install W11-2 pedestrian warning sign (pedestrian-only crossing) or W11-15 pedestrian/bicycle warning sign (shared-use crossing) with W16-7PL diagonal downward arrow plaque mounted on the side of the roadway at the crossing.

(3). Level C = Additional pavement markings + Level B

(a). Install, as appropriate, white High-Visibility Crosswalk markings (pedestrian-only crossing) or dual use crossings (shared-use crossing).

(b). Install W11-2 pedestrian warning sign (pedestrian-only crossing) or W11-15 pedestrian/bicycle warning sign (shared-use crossing) with W16-9P AHEAD (plaque) mounted on the side of the roadway in advance of the crossing.

(c). Install W11-2 pedestrian warning sign (pedestrian-only crossing) or W11-15 pedestrian/bicycle warning sign (shared-use crossing) with W16-7PL diagonal downward arrow (plaque) mounted on the side of the roadway at the crossing.

(d). Install “PED XING” (pedestrian-only crossing) or “BIKE XING” (shared-use crossing) advanced pavement marking.

17.3.03.D Special Case: Midblock Trail Crossings at Local Streets

1. Trails that cross classified roadways (MTFP) shall follow the Corridor Crossing Analysis methodology described above. Trails that cross midblock on local streets (i.e. not on the MTFP) shall follow the below criteria.

2. Trails that cross local streets should first determine whether the trail, street, or both are stop-controlled.

a. If the street ADT is greater than 1,000, then the general crossing analysis methodology should be used to determine appropriate Crossing Treatments.

b. If the street ADT is less than or equal to 1,000, then the road shall be stop-controlled and the trail shall be free-flow, unless there is an identified visibility concern, in which case the trail should also be stop-controlled.

17.3.03.D.2 continued

c. If the street is proposed to be stop-controlled, stop bars, stop ahead signage, and pedestrian/bicycle warning signage shall be provided on the street approaches.

d. Install dual use crossings (shared-use crossing) for the trail crossing.

SECTION 4 - BIKEWAY FACILITY REQUIREMENTS

17.4.01 GENERAL BIKEWAY FACILITY REQUIREMENTS

17.4.01.A Guides and Standards

1. The City of Houston uses the Houston Bike Plan as a guide to determine type and location of Bicycle Facilities. Street design should incorporate the Houston Bike Plan Network. Any street can include safe Bicycle Facilities even if not on the Houston Bike Plan Network.

2. The City of Houston encourages Bicycle Facility design standards that exceed the requirements in this section. The following standards should be utilized when designing Bicycle Facilities: AASHTO Guide for the Development of Bicycle Facilities, FHWA Separated Bike Lane Planning and Design Guide, and NACTO Urban Bikeway Design Guide.

3. The type of Bicycle Facility shall be determined using the Bicycle Facility Type Decision Matrix (see Figure 17.16).

4. Bicycle Facilities that change the number/type/width of existing lanes shall require a Traffic and Design Study as defined in Chapter 15, Section 15.2.02.

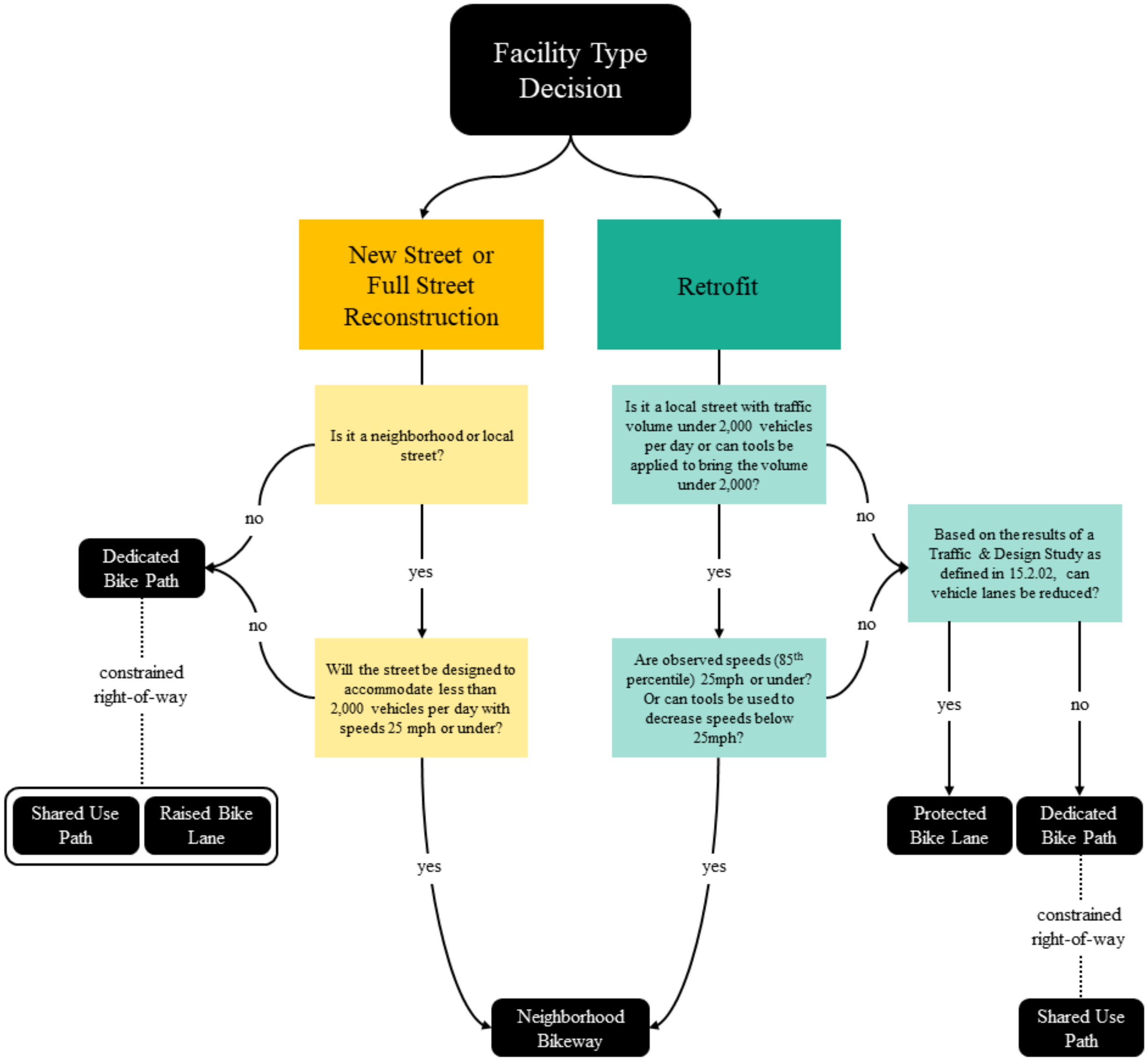


Figure 17.16 - BICYCLE FACILITY TYPE DECISION MATRIX

17.4.01.B Curb Management

1. Curb Management shall be incorporated in all Bicycle Facility designs.

2. Curb Management may consist of solid waste, recycling, and heavy trash services, school queues, parcel and mail delivery, and loading zones.

17.4.01.C Bicycle Parking

1. Bicycle parking includes bike racks, Bicycle Corrals and any other designated space to store bicycles.

17.4.01.C.1 continued

a. Bike Rack: A fixture upon which one or more bicycles may be parked.

b. Bicycle Corral – A group of bike racks installed adjacent to the curb in the parking lane of the roadway or in the area of Curb Extensions (see Section 17.3.02.C). Bicycle Corrals are often sited near the intersection in areas where space behind the curb is limited.

2. Bicycle parking shall be included in the design of all Bicycle Facilities where feasible. Bicycle parking may be added to existing Bicycle Facilities.

3. Bicycle parking may be provided in many configurations subject to City of Houston approval. The City of Houston preference is a ‘U’ rack (refer to Standard Detail 02871-01). The guidelines for spacing of multiple ‘U’ racks is available in Table 17.6 – ‘U’ Rack Spacing Standards and Standard Detail 02871-01.

Table 17.6– ‘U’ RACK SPACING STANDARDS

Location	Orientation	Minimum	Preferred
Between Racks	Side-by-Side	3’-0”	4’-0”
	End-to-end	6’-0”	8’-0”
From Back of Curb	Perpendicular	2’-0”	3’-0”
	Parallel	2’-0”	3’-0”
From Wall	Perpendicular	4’-0”	-
	Parallel	3’-0”	-
From Obstruction*	All	3’-0”	4-0”
From Crosswalk	Perpendicular	5’-0”	-

* Streetlights, trees, sidewalk furniture, traffic signs or posts, parking meters, utility facilities/covers, etc.

4. Bicycle Parking Siting Guidelines

a. Land Use: Sites along a Bicycle Facility should be prioritized based on nearby land uses. These land uses include commercial, retail, libraries, parks, community centers, other public institutions, medical centers and sports facilities.

17.4.01.C.4 continued

b. Transportation: Locations that allow for connections to additional transportation opportunities should be prioritized, such as METRO bus; Bus Rapid Transit (BRT) or Light Rail Transit (LRT) stations; Houston Bicycle stations; a high density of Micromobility options; or car sharing locations.

c. Existing Conditions: Avoid locating bike racks in areas where public utilities or emergency services are present or in locations that are prone to flooding.

d. Bicycle Facility Type: Bike racks may be installed off-street (see 17.4.01.C.5) or on-street (see 17.4.01.C.6).

e. Lighting is an important component of safe and secure bicycle parking. If good nighttime lighting does not already exist, then nighttime lighting shall be provided wherever bike parking is installed.

5. Off-Street Bicycle Parking

   a. Bike racks shall not impede the minimum Sidewalk width and shall have a clearance zone of 4-ft x 6-ft (refer to Standard Detail 02871-01).

   b. Racks must be oriented so that users can safely enter and exit without conflicting with motorists or pedestrians.

   c. Bicycle parking should have a minimum of two (2) 'U' racks installed per bicycle parking location.

   d. Bicycle parking installed by any entity besides the City of Houston or an entity with an established maintenance agreement shall apply for a bike rack encroachment permit with the Office of the City Engineer.

   e. Custom elements, such as non-standard racks or bicycle parking shelters, are subject to approval by the City of Houston and require a maintenance agreement.

6. On-Street Bicycle Parking (aka "Bicycle Corrals")

   a. Bicycle Corrals will consist of bike racks located within the public right-of-way at street grade. See Figure 17.17 for a conceptual design of Bicycle Corrals. This Figure is for reference only and does not constitute design standards.

17.4.01.C.6 continued

Figure 17.17 – ON-STREET BICYCLE PARKING

b. All proposed Bicycle Corrals require approval by the City Traffic Engineer.

c. Bicycle Corrals should be installed near intersections or driveways to create necessary sight distance clearances for motorists (see subsection 17.3.02.C - Curb Extensions). Bicycle Corrals may be installed in place of on-street parking, including midblock locations.

d. Bicycle Corrals must be oriented so that bicyclists can safely enter and exit without conflicting with motor vehicles or pedestrians.

e. Bicycle Corrals should provide six (6) or more 'U' racks for bicycle parking. The minimum number of 'U' racks installed at a Bicycle Corral shall be three (3).

f. Bicycle Corrals must include delineation that complies with the delineation requirements of Curb Extensions. See Section 17.3.02.C - Curb Extensions.

g. Custom elements, such as non-standard racks or bicycle parking shelters, are subject to approval by the City of Houston. Custom elements require a maintenance agreement.

17.4.01.D Wayfinding

17.4.01.D continued

1. Wayfinding is made up of directional signage, confirmational signage, decision signage and pavement markings that guide bicyclists along High-Comfort Bicycle Facilities and to certain destinations such as neighborhoods, parks, and trail entry points.

   a. Directional signs indicate to bicyclists the direction in which a Bicycle Facility continues.

   b. Confirmational signs indicate to bicyclists that they are on a Bicycle Facility and make motorists aware of the Bicycle Facility.

   c. Decision signs mark the junction of two or more bikeways and inform bicyclists of the designated bike route to access key destinations.

2. Wayfinding signage and pavement markings shall be provided for all Bicycle Facilities in addition to regulatory signage and standard bike facility pavement markings.

3. This section applies generally to all Bicycle Facility types. Individual Bicycle Facilities may have additional wayfinding requirements. See Bicycle Facility design standards for more details.

4. General requirements for usage of Houston Bikeways signage:

   a. The Houston Bikeways Bike Route, Bike Route Ahead and Bike Route Ends signs shall only be used along High-Comfort Bicycle Facilities.

   b. The Houston Bikeways Bike Route sign (D11-1 MOD HB) shall be used along all High-Comfort Bicycle Facilities as a confirmational, directional, and decision sign and shall be placed at regular intervals no more than ½ mile apart and directly preceding all intersections with other High-Comfort Bicycle Facilities.

   c. A Houston Bikeways Bike Route Ahead (D11-1 MOD HB-A) confirmational and directional sign shall be included at the beginning of all High-Comfort Bicycle Facilities. This shall be substituted with a Bike Lane Ahead sign on Raised or Protected Bike Lanes.

   d. A Houston Bikeways Bike Route Ends (D11-1 MOD HB-E) sign shall be included at the end of all High-Comfort Bicycle Facilities. This shall be substituted with a Bike Lane Ends sign on Raised or Protected Bike Lanes.

5. At all intersections of multiple High-Comfort Bicycle Facilities:

17.4.01.D.5 continued

a. Include Houston Bikeways Bike Route sign on all bicycle approaches to the intersection.

b. A modified Houston Bikeways Bike Route directional sign shall indicate with arrows the direction of all High-Comfort Bicycle Facilities (e.g. left, right and forward arrows).

c. Destination placards (D1-1c, 2c, 3c) shall be added underneath the Houston Bikeways Bike Route sign as decision signs to indicate the direction and distance of destinations.

(1). Destinations should generally be neighborhoods; public parks; nearby streets; trail entrances; Bus Rapid Transit (BRT) or Light Rail Transit (LRT) stations; or other locations of community importance; and be accessible via High-Comfort Bicycle Facilities from the sign location.

(2). Other destination types shall require approval by Houston Public Works.

17.4.01.E Railroad Crossings

1. Where Bicycle Facilities cross a street-surface rail track, bicyclists should be directed to cross tracks at a safe angle (90 degrees preferred, 60 degrees minimum) so that bicycle tires do not become stuck in rail flanges.

2. If preferred crossing angle is not possible, a warning sign (W10-1 or W10-12) shall be placed in advance of the rail crossing alerting the bicyclist of skewed railroad crossing.

3. In the presence of uneven railroad tracks, a warning sign (W10-6) should be installed.

4. Where Bicycle Facilities cross Light Rail Transit (LRT) tracks, a warning sign (W10-1) shall be placed in advance of the rail crossing alerting the bicyclist of the railroad crossing.

17.4.02 HIGH-COMFORT FACILITY TYPE STANDARDS

17.4.02.A Figure 17.18 shows a summary of the types of bicycle facilities as defined by the City and their level of roadway separation. See the following section for a detailed description of each type of facility.

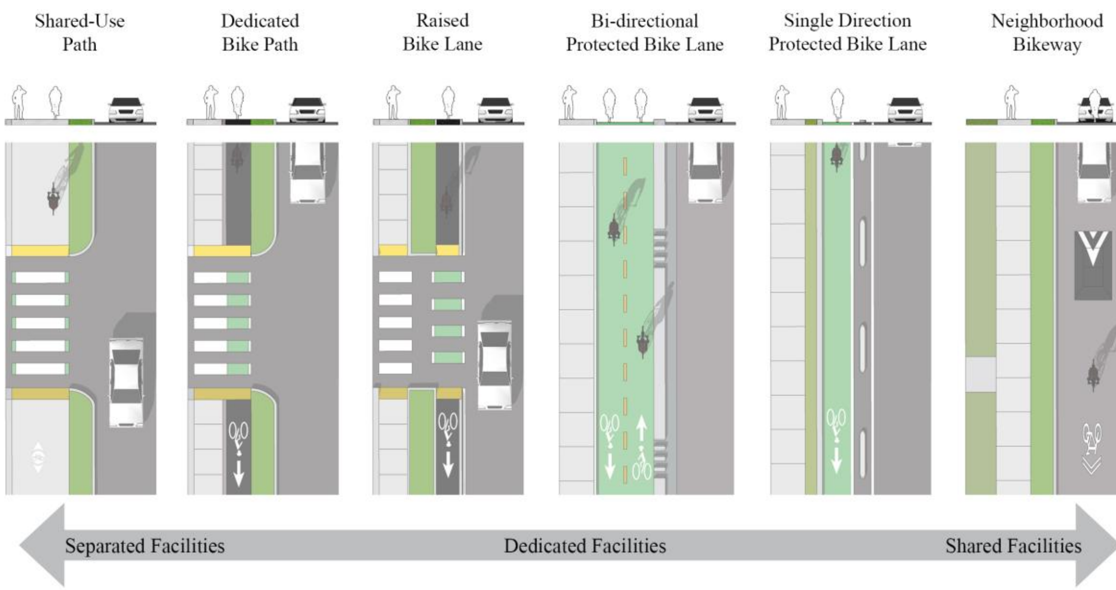


Figure 17.18 – BICYCLE FACILITY TYPES BY LEVEL OF SEPARATION

17.4.02.B Dedicated Bike Path

1. Dedicated Bike Paths are Bicycle Facilities that run alongside a roadway behind the curb within the right-of-way. See Figure 17.19 for a conceptual design of a Dedicated Bike Path. This figure is for reference only and does not constitute design standards.

17.4.02.B continued

Figure 17.19 – DEDICATED BIKE PATH

2. Dedicated Bike Paths must be at the same grade as the Sidewalk and increase safety by grade-separating bicyclists and people driving.

3. Dedicated Bike Paths must be separated from pedestrian traffic with a physical buffer or with a detectable warning surface.

4. Dedicated Bike Paths may provide single or bidirectional bicycle traffic flow.

5. A Dedicated Bike Path shall maintain a minimum width of six (6)-ft for a single directional bicycle traffic flow and a twelve (12)-ft preferred, ten (10) ft minimum width for bidirectional traffic flow. This is in addition to the width of the pedestrian travel area.

6. A Safety Buffer of at least four (4)-ft shall be provided between the side path and the adjacent motor vehicle lane.

17.4.02.B continued

7. Driveways: Dedicated Bike Paths shall maintain bikeway facility grade at driveways. Dedicated Bike Path pavement materials and striping shall continue across driveways. Warning signage may be placed facing driveways depending on width, traffic volume, and visibility. Refer to Figure 17.2 and Figure 17.3 for pedestrian safety and visibility buffer requirements.

8. Signage:

    a. A Dedicated Bike Path may include signage to indicate separation between the bicyclist and pedestrian facility.

    b. A Bicycle Warning sign (W11-1) shall be implemented at all intersecting streets along the corridor preceding the intersection with the Dedicated Bike Path.

9. General Pavement Markings

    a. Pavement Marking (Symbols): A bicycle symbol and arrow markings shall be used to define Dedicated Bike Paths. Alternative pavement marking symbols are subject to the approval of Houston Public Works. Symbols shall be placed at the beginning of a Bicycle Facility and the start of every block or at regular intervals as necessary to reinforce the intended use. Refer to Standard Detail 02760-04.

    b. Longitudinal Pavement Markings: A dashed yellow line may be used to separate two-way bicycle traffic.

10. Ramps: See Section 17.3.02.A - Curb Ramps and Corner Treatments.

11. Wayfinding:

    a. Signage: See Section 17.4.01.D.

    b. The Pavement Markings required in Section 17.4.02.B.9 are sufficient for Wayfinding.

12. For Dedicated Bike Path design criteria, refer to City of Houston Standard Detail 02760-09.

13. See Section 17.4.01 - General Bikeway Facility Requirements and Section 17.4.03 - Bikeways at Intersections for General Facility Requirements that apply to all bikeway facility types.

17.4.02.C Shared Use Path

1. Shared Use Paths are combined bicycle and pedestrian facilities that run alongside a roadway behind the curb within the right-of-way. See Figure 17.20 for a conceptual design of a Shared Use Path. This figure is for reference only and does not constitute design standards.

Figure 17.20 – SHARED USE PATH

2. Shared Use Paths may provide single or bidirectional bicycle traffic flow.

3. A Shared Use Path shall maintain a minimum width of ten (10)-ft. A width of fourteen (14)-ft in contexts with high pedestrian or bicyclist traffic is preferred.

4. A Safety Buffer of at least four (4)-ft shall be provided between the Shared Use Path and the adjacent motor vehicle lane.

5. Driveways: Shared Use Paths shall maintain bikeway facility grade at driveways. Shared Use Path pavement materials and striping shall continue across driveways. Warning signage may be placed facing driveways depending on width, traffic volume, and visibility.

17.4.02.C continued

6. Signage: A Bicycle Warning sign (W11-1) shall be implemented at all intersecting streets along the corridor preceding the intersection with the Shared Use Path.

7. General Pavement Markings

    a. Pavement Marking (Symbols): A bicycle dot shall be used to define Shared Use Paths. The arrows on the bicycle dot shall be used to guide bicyclists in the direction of the facility. Symbols shall be placed at the beginning of a bike facility and the start of every block or at regular intervals as necessary to reinforce the intended use. Refer to Standard Detail 02760-04.

    b. In a bidirectional Shared Use Path, a bike dot with arrows in both directions of travel is required.

    c. In a single direction Shared Use Path, a bike dot with one or more arrows pointing in the direction of bicycle traffic shall be used.

    d. Alternative pavement marking symbols for single direction Shared Use Paths and/or where there may be opportunities for Placemaking are subject to approval by Houston Public Works.

8. Wayfinding:

    a. Signage: See Section 17.4.01.D.

    b. The Pavement Markings required in Section 17.4.02.C.7 are sufficient for Wayfinding.

9. Ramps: See Section 17.3.02.A - Curb Ramps and Corner Treatments.

10. See Section 17.4.01 - General Bikeway Facility Requirements and Section 17.4.03 - Bikeways at Intersections for General Facility Requirements that apply to all bikeway facility types.

17.4.02.D Raised Bike Lane

1. Raised Bike Lanes are grade-separated Bicycle Facilities that shall be at a level between the Sidewalk and the roadway with a minimum three (3)-in and maximum six (6)-in grade separation from the roadway surface. See Figure 17.21 for a conceptual design of a Raised Bike Lane. This figure is for reference only and does not constitute design standards.

17.4.02.D continued

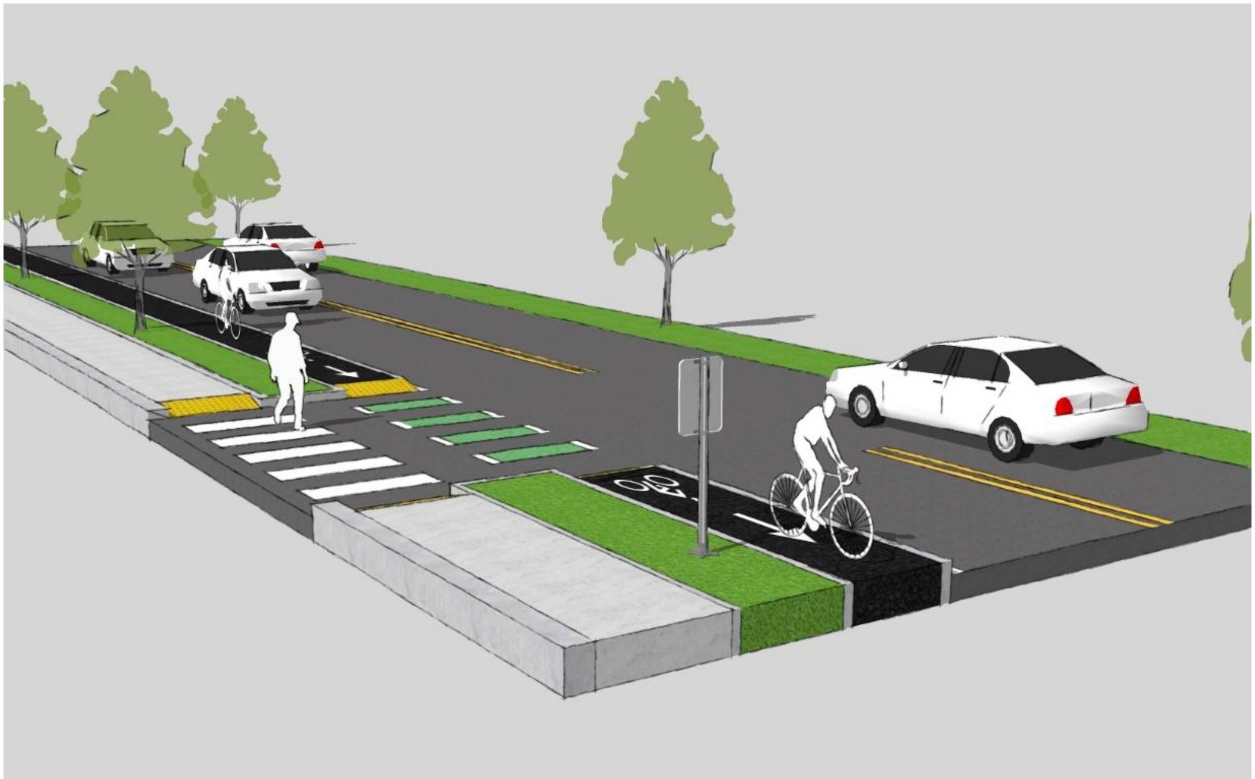


Figure 17.21 – RAISED BIKE LANE

2. Raised Bike Lanes shall be placed immediately adjacent to the vehicle lane.

3. Parking shall be prohibited along Raised Bike Lanes.

4. Raised Bike Lanes shall provide single direction bicycle traffic flow (one-way) only.

5. Raised Bike Lanes should maintain a standard width of six (6)-ft. Raised Bike Lanes cannot be narrower than five (5)-ft. The effective width of the bike lane shall not include the mountable curb.

6. General Pavement Markings

   a. Pavement Markings (Buffer): A six (6)-in solid white line is required between the Raised Bike Lane and the vehicle lane.

17.4.02.D.6 continued

b. Pavement Marking (Symbols): A bicycle symbol and arrow markings shall be used to define bicycle lanes and shall be placed at the beginning of a Bicycle Facility and at the start of every block and at regular intervals as necessary to reinforce the intended use. Refer to Standard Detail 02760-04 for pavement marking details.

c. Pavement Markings (Driveways): Conflict markings shall be used at driveways with high traffic uses, with a width greater than thirty-five (35)-ft, or where consecutive adjacent driveway openings are greater than fifty (50)-ft.

7. Signage:

a. A Bicycle Warning sign (W11-1) shall be implemented at all intersecting streets along the corridor preceding the intersection with the raised bikeway.

b. No Parking in Bike Lane signs (R7-9) should be placed on every block and at regular intervals no more than ½ mile apart.

8. Wayfinding

a. Signage: See Section 17.4.01.D.

b. Pavement Markings: The Pavement Markings required in Section 17.4.02.D.6 are sufficient for Wayfinding.

9. See Section 17.4.01 - General Bikeway Facility Requirements and Section 17.4.03 - Bikeways at Intersections for General Facility Requirements that apply to all Bicycle Facility types.

17.4.02.E Protected Bike Lane (Retrofit)

1. Protected Bike Lanes are On-Street Bicycle Facilities between curb faces with physical delineation between the vehicle lane and bike lane. In Retrofit projects where a Dedicated Bike Path is not feasible, Protected Bike Lanes provide enhanced safety for bicyclists. See Figure 17.22 and Figure 17.23 for conceptual designs of Protected Bike Lanes. These figures are for reference only and do not constitute design standards.

17.4.02.E continued

Figure 17.22 – SINGLE DIRECTION PROTECTED BIKE LANE WITH PRE-CAST CURB

Figure 17.23 – BIDIRECTIONAL PROTECTED BIKE LANE WITH CAST-IN-PLACE CURB

2. Protected Bike Lanes may provide single or bidirectional (two-way) bicycle traffic flow.

3. A bidirectional Protected Bike Lane shall maintain a standard width of ten (10)-ft. A one-way Protected Bike Lane shall maintain a standard width of six (6)-ft.

17.4.02.E continued

4. Delineator: A vertical barrier shall be provided to physically separate the bike lane and vehicle lane. Delineators are generally placed in the center of the striped buffer.

   a. The vertical barrier may be discrete elements, such as curb stops or bollards, or a continuous element, such as a concrete median. Delineator selection shall require approval from Houston Public Works.

   b. Delineators shall maintain existing stormwater flow or include improvements to the stormwater drainage system where necessary per Chapter 9. Delineators shall accommodate stormwater runoff at all drainage inlets.

   c. A continuous delineator shall have ten (10)-ft wide openings at least every two hundred fifty (250)-ft to enable bicyclists to exit the bike lane.

      (1). Openings at driveways, intersections and inlets can be used to satisfy this requirement.

   d. Breaks in delineation shall be provided at all driveways. Refer to detail 02760-11 for requirements on placement.

   e. Delineator placement should consider Curb Management such as driveways, solid waste and recycle collection, bus stops, and mail delivery. Use of mountable curb may be desirable to accommodate heavy trash pick-up.

5. General Pavement Markings

   a. Pavement Markings (Buffer): The buffer shall be designed to accommodate and complement the selected delineator device and shall typically be at least three (3)-ft.

      (1). For delineators that are discrete elements, a striped buffer shall be utilized and shall consist of two six (6)-in solid white lines, with six (6)-in diagonal white hatching of three (3)-ft in width or wider. Spacing of hatching should be between ten (10) and forty (40)-ft.

      (2). For delineators that are continuous elements, a six (6)-in solid white line shall be striped on either side.

17.4.02.E.5 continued

b. Pavement Marking (Symbols): A bicycle symbol and arrow markings shall be used to define bicycle lanes and shall be placed at the beginning of a Bicycle Facility and at the start of every block and at regular intervals as necessary to reinforce the intended use. Refer to Standard Detail 02760-04 for pavement marking details.

c. Pavement Markings (Driveways): Conflict markings shall be used at driveways with high traffic uses, with a width greater than thirty-five (35)-ft, or where consecutive adjacent driveways cause a gap in protection greater than fifty (50)-ft.

d. Pavement Markings (Longitudinal): For bidirectional Protected Bike Lanes, a dashed yellow line shall be used to separate two-way bicycle traffic.

6. Signage: Bike Lane signs (R3-17 series) are required at the start, end, and throughout a Bicycle Facility in the direction of travel.

   a. Bike Lane signs (R3-17) are required and should be spaced at the start of every block and at regular intervals as necessary to reinforce the intended use.

   b. Bike Lane signs (R3-17) and plaques (R3-17aP) are required preceding the Bicycle Facility.

   c. Bike Lane signs (R3-17) and plaques (R3- 17bP) are required at the end of a Bicycle Facility.

   d. A Bicycle Warning sign (W11-1) shall be implemented at all intersecting streets along the corridor preceding the intersection with the protected/separated bikeway.

7. Wayfinding:

   a. Signage: See Section 17.4.01.D.

   b. Pavement Markings: The Pavement Markings required in Section 17.4.02.E.5 are sufficient for Wayfinding.

8. For Protected Bike Lane design criteria, refer to City of Houston Standard Detail 02760-09.

9. See Section 17.4.01 - General Bikeway Facility Requirements and Section 17.4.03 - Bikeways at Intersections for General Facility Requirements that apply to all Bicycle Facility types.

17.4.02.F Neighborhood Bikeway (Local Streets Only)

17.4.02.F continued

1. Neighborhood Bikeways, also known as bicycle boulevards, are low speed, typically residential streets shared by motorists and bicyclists. See Figure 17.24 for a conceptual design of a Neighborhood Bikeway. This figure is for reference only and does not constitute design standards.

Figure 17.24 – NEIGHBORHOOD BIKEWAY

2. Neighborhood Bikeways should only be installed on local/unclassified streets without marked lanes.

3. Neighborhood Bikeways should include measures to improve bicycle safety along streets and intersections as recommended in a traffic engineering report. Such measures include:

   a. Curb Extensions (see section 17.3.02.C)

   b. Median Refuge Islands (see section 17.3.02.D)

   c. Raised Crosswalks (see section 17.3.02.E)

   d. Median Closures (see section 17.4.03.F)

   e. Mini Roundabouts

   f. Traffic Calming (see Chapter 15, Section 15.2.11 for suggested tools). Traffic Calming elements require specific approval by Houston Public Works.

4. General Pavement Markings

17.4.02.F.4 continued

a. Pavement Markings: Shared lane markings shall be placed at the beginning of a Neighborhood Bikeway and at the start and end of every block and at regular intervals as necessary to reinforce the intended use. Refer to Standard Detail 02760-04.

5. Signage:

a. May Use Full Lane signs (R4-11) shall be placed on every other block and at regular intervals to reinforce the intended use.

b. A majority of stop signs on the Neighborhood Bikeway shall provide priority to the bikeway over intersecting local streets to minimize bicycle stops.

c. A Bicycle Warning sign (W11-1) shall be implemented at all intersecting streets along the corridor preceding the intersection with the Neighborhood Bikeway.

6. Wayfinding:

a. Signage: See Section 17.4.01.D.

b. Shared lane markings (refer to Standard Detail 02760-04) shall be included on every block and no more than ½ mile apart in the direction of the Bicycle Facility.

c. Additional shared lane markings may be necessary where there are many driveways or large traffic generators present.

d. The arrows in the shared lane marking shall generally indicate the forward direction of bicycle movement. At turning locations, the arrow shall indicate the forward direction of all bicycle routes.

7. See Section 17.4.01 - General Bikeway Facility Requirements and Section 17.4.03 - Bikeways at Intersections for General Facility Requirements that apply to all bikeway facility types.

17.4.03 BIKEWAYS AT INTERSECTIONS

17.4.03.A General

1. Intersections present significant challenges to bicyclists, and specific design features should be provided to ensure bicyclist safety and comfort through an intersection. These design features shall also increase pedestrian safety.

17.4.03.A continued

2. Design features shall include roadway geometry alterations, signing, striping, signal modifications, and deliberate transitions from one type of Bicycle Facility to another.

3. At all approaches to a signalized intersection with a cross street with a Dedicated or Off-Street Bicycle Facility, a No Turn on Red sign (R10-11A) shall be mounted on the signal assembly directed towards the motorists on the cross street.

4. Signalized intersections where Bicycle Facilities intersect one another shall be designed to facilitate bicyclist left turns.

   a. Protected Intersections shall be implemented to facilitate safe two-stage left turns.

   b. At intersections with Bicycle Facilities where Protected Intersections cannot be included in the design due to roadway geometry, right-of-way width or other factors, Bike Boxes should be included.

   c. Two-Stage Turn Queue Boxes may be added in certain contexts where additional guidance and space for bicyclists turning movements are needed. Two-Stage Turn Queue Boxes must be approved by Transportation and Drainage Operations.

5. For Protected Bike Lanes, barriers and/or delineators shall extend as close to the intersection without impeding vehicle turning movements or pedestrian crossings. Refer to City of Houston Standard Detail 02760-11 for typical delineator layout.

6. For Raised Bike Lanes, the bike lane shall return to road grade prior to the intersection. Barriers and/or delineators shall extend as close to the intersection without impeding vehicle turning movements or pedestrian crossings. Refer to City of Houston Standard Detail 02760-11 for typical delineator layout.

7. Green bicycle pavement markings shall be used at intersections to increase Bicycle Facility visibility and identify potential conflict areas between motorists and bicyclists. Green bicycle pavement markings should not be used in lieu of but in addition to white pavement markings. Refer to City of Houston Standard Detail No. 02760-10 and 02760-11.

8. Bicycle Facility crossings where the cross street is free flow shall follow the Enhanced Crossing requirements in Section 17.3.03.C - Crossing Treatments.

9. Where a Bicycle Facility includes physical delineation, delineation shall continue to the approach edge of the intersecting pedestrian crosswalk or bicycle box, whichever comes first.

17.4.03.A continued

10. Bicycle Facilities should not terminate at intersections.

    a. At intersections where On-Street Bicycle Facilities cannot be extended to the intersection because of geometric or right-of-way constraints, Off-Street Bicycle Facility transitions should be explored.

    b. Where On-Street Bicycle Facilities end at an intersection, and Off-Street Bicycle Facility transitions are not feasible, at a minimum, Bike Lane Ends signage (R3-17, R3-17b) shall be placed preceding the intersection.

11. Wayfinding signage is required at intersections. See Section 17.4.01.D.

17.4.03.B Protected Intersections

1. Protected Intersections reduce conflicts between motorists, bicyclists, and pedestrians by providing safe, separated waiting areas for each mode. See Figure 17.25 and Figure 17.26 for conceptual designs of Protected Intersections. These figures are for reference only and do not constitute design standards.

Figure 17.25 - PROTECTED INTERSECTION

17.4.03.B continued

Figure 17.26 - PROTECTED INTERSECTION (RETROFIT)

2. Protected Intersections are an intersection improvement that sets the bikeway back from parallel motor vehicle traffic so that bicyclists are not forced to merge into mixed traffic.

3. Protected Intersections allow bicyclists to safely move straight and make two-stage turns through an intersection. They are given a dedicated path through the intersection and have the right-of-way over motorists making turns.

4. For siting requirements, see Section 17.4.03.A - General Bikeways at Intersections.

5. Design

   a. Protected Intersections shall consist of pavement markings and concrete median or other physical delineation.

   b. Protected Intersections shall include green bicycle pavement markings with an approved material that provides adequate surface traction.

17.4.03.B.5 continued

c. Protected Intersections shall include Curb Extensions. See Section 17.3.02.C - Curb Extensions.

(1). Protected Intersections shall have barrier-protected bicycle queue areas on all corners of the intersection where there will be a designated two-stage turn onto a Bicycle Facility.

(2). Protected Intersections shall include barrier-protected pedestrian islands on all corners of the intersection where a barrier-protected bicycle queue area is present.

(3). Barriers at Protected Intersections may be made up of concrete curb, vertical flex posts, bollards, or other delineation.

(4). Barriers at Protected Intersections may contain mountable elements so that smaller curb radii can accommodate large vehicles.

d. Protected Intersections shall include crosswalk markings adjacent to the bikeway crossing markings. See Section 17.3.03.C - Crossing Treatments.

e. Protected Intersections may include bicycle symbols and turn arrow pavement markings to assist in bicyclist navigation through the intersection.

6. Protected Intersection materials and design are subject to approval by Houston Public Works.

17.4.03.C Two-Stage Turn Queue Boxes

1. Two-Stage Turn Queue Boxes are an intersection improvement consisting of pavement markings and signage that accommodate a safe left turn for bicyclists by providing space for crossing in two stages.

2. Two-Stage Turn Queue Boxes allow bicyclists to make the turn in two movements: first, proceeding through the intersection in the bike lane, then turning ninety degrees within the queue box to face in the desired direction in front of motorists on the cross street.

3. For siting recommendations, see Section 17.4.03.A - General Bikeways at Intersections.

4. Design

a. Two-Stage Turn Queue Boxes shall be placed in a protected zone that will not be encroached upon by motorists or bicyclists along the origin street.

17.4.03.C.4.a continued

(1). Depending on the intersection geometry, this zone may be located between the lateral extension of the Bicycle Facility and the adjacent travel lane on the origin street when a buffer exists or between the pedestrian crosswalk and the lateral extension of the bicycle facility.

b. Two-Stage Turn Queue Boxes shall be green bicycle pavement markings with an approved material that provides adequate surface traction.

c. Two-Stage Turn Queue Boxes shall include a bicycle symbol and turn arrow pavement markings to designate the space for turning bicycle use only. Refer to City of Houston Standard Detail No. 02760-04.

5. Two-Stage Turn Queue Boxes shall include a No Turn on Red (R10-11A) sign mounted on the signal assembly directed towards the motorists on the cross street that would stop behind the queue box.

6. Two-Stage Turn Queue Boxes should be positioned to orient the bicyclist towards the receiving Bicycle Facility on the cross street.

17.4.03.D Bike Boxes

1. Bike Boxes are an intersection improvement consisting of pavement markings and signage that safely positions bicyclists in front of vehicular traffic.

2. Bike Boxes consist of pavement markings that enable bicyclists to queue at a red light in front of stopped vehicles in adjacent lanes. Bicycle Boxes facilitate bicyclists moving forward or turning left.

3. For siting recommendations, see Section 17.4.03.A - General Bikeways at Intersections.

   a. Bike Boxes shall be allowed only at signalized intersections.

   b. Bike Boxes shall only be used in conjunction with On-Street Bicycle Facilities.

4. Design

   a. Bike Boxes shall be located between the pedestrian crosswalk and the vehicular stop bar.

   b. Bike Boxes shall be filled with bicycle-green pavement markings that provide adequate surface traction.

17.4.03.D.4 continued

c. Bike Boxes shall include a bicycle symbol pavement marker to designate the space for bicycle use only and WAIT HERE pavement marking beneath the stop bar. Refer to Standard Detail 02760-10 for design details.

d. Bike Boxes shall include a No Turn on Red sign (R10-11A) mounted on the signal assembly when those movements would be otherwise allowed across the Bike Box.

e. Bike Boxes shall only be approved across a single direction of general-purpose lanes. A single Bike Box will not be approved across bidirectional travel lanes.

f. A Bike Box may extend across multiple adjacent lanes to facilitate bicyclist left-turn movements.

g. A Bicycle Facility should implement physical delineation devices along the approach to the Bike Box. For physical delineation devices see Section 17.4.02.E.4 - Protected Bike Lane Delineator.

17.4.03.E Bicycle Crossing Pavement Markings

1. Crossing pavement markings for dedicated bicycle lanes and paths shall continue in line with the Bicycle Facility through the intersection with the combination hatched bicycle green and white pavement markings (refer to City of Houston Standard Detail No. 02760-10 Detail “A”).

   a. Bidirectional dedicated bicycle lanes and paths shall include a dashed yellow line to separate the lanes.

   b. Bidirectional dedicated bicycle lanes and paths shall be the greater of ten (10)-ft or the width of the approach facility.

   c. Single direction dedicated bicycle lanes and paths shall be the greater of six (6)-ft or the width of the approaching facility.

2. Crossing pavement markings for Shared Use Paths shall continue in line with the Bicycle Facility through the intersection with the combination enhanced crosswalk and bicycle green pavement markings (refer to City of Houston Standard Detail No. 02760-10 Detail “B”).

   a. Crossing pavement markings for Shared Use Paths shall be the greater of ten (10)-ft or the width of the approach facility.

17.4.03.E continued

3. Bicycle crossing pavement markings shall be included in conflict zones between bicyclists and motorists and shall not be included through crosswalks or in bicycle or pedestrian waiting areas. Bicycle crossing pavement markings may be set back from or adjacent to parallel crosswalk markings.

17.4.03.F Median Closures

1. Median closures prevent motorists from through and left turn movements and maintain pedestrian and bicyclist crossings. Median closures may be included in any Bicycle Facility design to improve safety of pedestrians and bicyclists.

2. Median closures shall only be included on roadways with a median width of eight (8)-ft or greater. Median closures shall match the width of the existing median.

3. Median closures shall be made up of Seamless Curb median extensions that are a continuation of the existing median such that the grade, concrete, sodding, and other components are consistent.

   a. The Seamless Curb median should include permeable treatments where feasible.

   b. For Retrofit roadway construction projects, alternative treatments may be considered. Alternative materials are subject to approval by the City of Houston.

4. Median closures shall include median openings for pedestrians and bicyclists where a pedestrian or bicyclist crossing is located.

   a. The median openings shall be the same width as the approaching pedestrian or Bicycle Facility.

   b. Median opening widths greater than or equal to eight (8)-ft should install a bollard or flex post in the center at both approaches to discourage driver encroachment.

5. Pavement Markings

   a. Pedestrian crosswalk pavement markings shall be included in median closures. See Chapter 15, Section 15.2.06.B.4.

   b. Bicyclist crossing pavement markings shall be included in median closures. See Section 17.4.03.E for bicycle crossing pavement markings.

17.4.03.F continued

6. Signage: A Right Turn Only (R3-5) sign with an Except Bicycle plaque shall be implemented.

17.4.03.G Bicycle Facilities at Roundabouts

1. Bicycle Facilities shall not be provided within the circulatory roadway.
2. Where Bicycle Facilities or shoulders are used on approach roadways, they should be terminated at least one hundred (100)-ft from the edge of the circulatory roadway.
3. A ramp should be provided to allow bicyclists to exit the roadway onto an Off-Street Bicycle Facility and to re-enter the roadway after the roundabout.
4. If a ramp is provided for bicyclists to access the Sidewalk, the slope shall not exceed 1:7.
5. Street lighting should be considered for increased facility safety at transition points.
6. See Section 17.4.03.E for bicycle crossing pavement markings.
7. See Chapter 10 regarding general roundabout considerations for all roadway users.

17.4.03.H Bicycle Facilities Traffic Signals

1. General standards for signalized intersections are defined in Chapter 15 and include signal phasing for Bicycle Facilities. Bicycle-related signal options are summarized below.
2. Bicycle signal heads shall be installed at signalized intersections with On-Street or Off-Street Bicycle Facilities.
3. Bicycle-specific signal strategies (e.g. bicycle-pedestrian leading interval) shall be employed where there are bicycle signal heads at intersections.
4. Bicycle detection shall be used at all Bicycle Facility intersections with actuated traffic signals to alert the signal controller of bicyclist demand.
5. Where bicycle detection is present, a Bicycle Signal Actuation Sign (R10-22) shall be used, and a bicycle detection marking (Standard Detail 02760-10) shall be placed on the pavement indicating the optimal position for a bicyclist to actuate the signal.

17.4.03.H.5 continued

a. Where Bike Boxes are present, utilize bicycle detection that will detect within the entire Bike Box. If bicycle detection is not feasible for the entire Bike Box, indicate bicycle detection location with the bicycle signal actuation sign and bicycle detection marking.

6. Visibility-limited signal faces shall be adjusted to ensure bicyclists can see the signal indications. If the visibility-limited signal faces cannot be aimed to serve the bicyclist, then separate signal faces shall be provided for bicyclists.

SECTION 5 - TRANSIT FACILITY REQUIREMENTS

17.5.01 TRANSIT OVERVIEW

17.5.01.A In coordination with Metropolitan Transit Authority of Harris County (METRO), the City of Houston works to design safe streets that prioritize transit, improve transit service quality, and support other goals related to transit so that everyone may have safe and accessible multimodal transportation options.

17.5.01.B The City of Houston requires designs for city streets and multimodal transportation facilities that meet IDM standards and improve safety for all road users. The City uses other design standards and guidelines to achieve safe streets, including but not limited to, METRO transit design guidelines.

17.5.01.C The METRO transit design guidelines are referenced in the sections below and serve to work in tandem with the City of Houston's design standards, guidelines, and references.

1. The Street-Side Guidelines and Curb-Side Guidelines should be referenced when impacting the City right-of-way.

2. The whole of METRO transit design guidelines should be referenced for any project impacting an existing or future transit facility.

17.5.01.D All projects impacting an existing or future transit facility shall coordinate with METRO and meet design criteria and guidelines that improve safety for all road users.

17.5.02 TRANSIT STOP TYPOLOGIES, CONFIGURATIONS, AND STANDARD DIMENSIONS

17.5.02.A Refer to METRO transit design guidelines for all transit stop typologies, configurations, and standard dimensions.

17.5.02.B Bus Stops on High-Comfort Bicycle Facilities

1. All bus stop locations shall prioritize the safety of pedestrians and bicyclists in the design of High-Comfort Bicycle Facilities.

2. Floating Bus Stops

    a. Floating Bus Stops have a layout that allows pedestrian and Bicycle Facilities to locate behind the bus boarding pad, safely separating different modes of transportation while reducing bus delays by remaining in-lane.

17.5.02.B.2 continued

b. Floating Bus Stops shall be included along Raised Bike Lanes and Protected Bike Lanes (Retrofit). Refer to Figure 17.27 below.

(1). Floating Bus Stop A (see Figure 17.28) is the default, unless conditions in article 17.5.02.B.2.b.(2) or article 17.5.02.B.2.b.(3) apply.

(2). Floating Bus Stop B shall be used where on-street parking or excess pavement width is present. Refer to Figure 17.29 below.

(3). A Shared Raised Bus Stop may be used in right-of-way-constrained settings, subject to approval by Transportation and Drainage Operations.

3. Dedicated Bike Path bus stops shall be included along all Off-Street Bicycle Facilities.

a. A Seamless Curb version of Floating Bus Stop A may be included on Off-Street Bicycle Facilities.

4. Typically, corridors with proposed Neighborhood Bikeways will not have bus stops along them. Houston Public Works will work with METRO for the design of bus stops on these corridors.

5. All METRO bus stop design and location requirements must be met.

a. METRO will review and approve all bus stop locations and design.

b. Planned METRO bus stop improvements and/or optimization shall be incorporated into the Bicycle Facility design.

c. With METRO's approval, new or reconstructed bus stops should be located near safe pedestrian and bicycle crossings, typically intersections.

17.5.02.C Off-Street Bicycle Facility Bus Stop

1. An Off-Street Bicycle Facility Bus Stop allows for a bus stop at the standard location on the curb of the vehicular travel lane. See Figure 17.27 for a conceptual design of Off-Street Bicycle Facility Bus Stop concept. This figure is for reference only and does not constitute design standards.

17.5.02.C continued

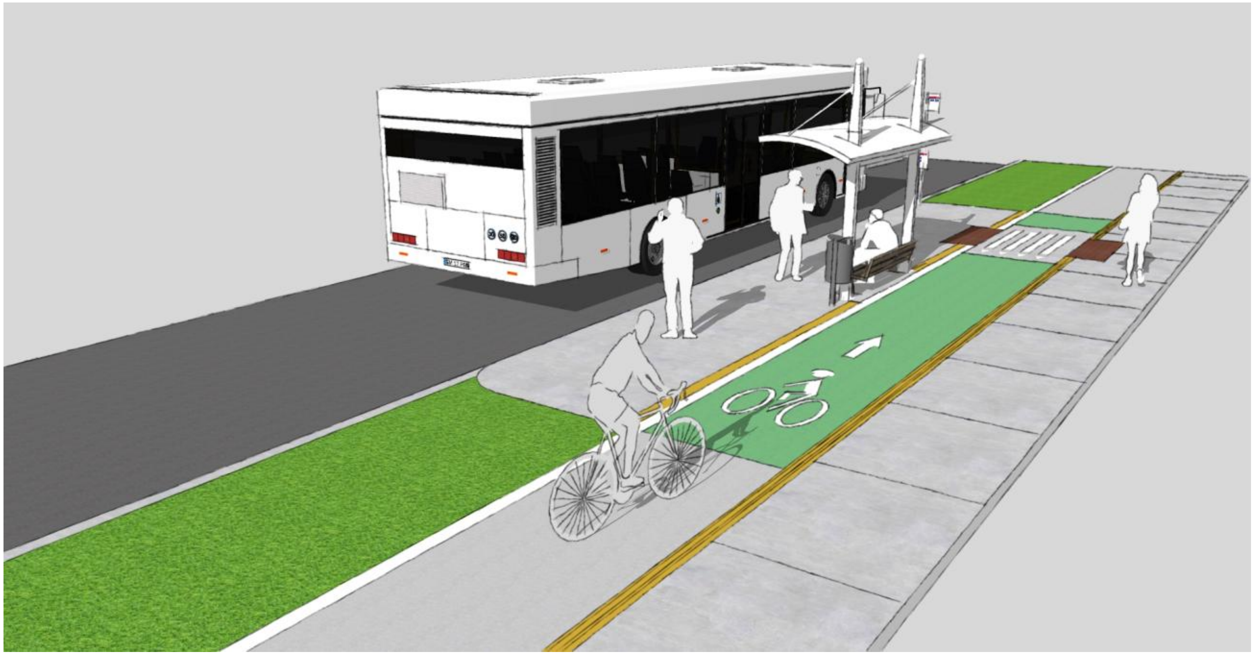


Figure 17.27 – OFF-STREET BICYCLE FACILITY BUS STOP

2. Where an Off-Street Bicycle Facility Bus Stop is present, the Off-Street Bicycle Facility will travel at Sidewalk grade adjacent to the bus pad.

3. Pedestrian Crossings

    a. Off-Street Bicycle Facility Bus Stops adjacent to Shared Use Paths do not require pedestrian crossings.

    b. Off-Street Bicycle Facility Bus Stops adjacent to Dedicated Bike Paths shall have at least one marked pedestrian crossing from the Sidewalk to the bus boarding pad.

        (1). Pedestrian crossings shall be level between the bus boarding pad and the Sidewalk.

        (2). Pedestrian crossings shall be clearly indicated with crosswalks made up of four (4) six (6)-in wide, minimum five (5)-ft long white stripes perpendicular to the Bicycle Facility. Additional stripes may be necessary for wider bicycle paths.

        (3). Yield lines made up of white yield triangles shall be placed in advance of the pedestrian crossing. YIELD TO PEDS pavement markings may be included.

17.5.02.C.3.b continued

(4). Two (2)-ft wide detectable warning surfaces shall be placed on either side of the pedestrian crossing.

4. Pavement Markings

a. Dedicated Bike Paths

(1). Solid bicycle green pavement markings shall be placed over the entire width of the bicycle lane adjacent to the bus boarding pad with breaks provided for pedestrian crossings.

(2). A bicycle symbol and arrow marking shall be included in the segment of the bicycle path adjacent to the bus boarding pad, not conflicting with pedestrian crosswalk pavement markings.

b. In constrained right-of-way settings where an Off-Street Bicycle Facility travels through a bus boarding pad, crosswalk and yield pavement markings shall be included that indicate the conflict zones between pedestrians and bicyclists.

5. Drainage: Off-Street Bicycle Facility Bus Stops shall maintain the existing gutter flow line.

17.5.02.D Floating Bus Stop A

1. Floating Bus Stop A is constructed in line with the Bicycle Facility so that the bicycle lane, and the Sidewalk if necessary, are shifted away from the roadway to accommodate the bus boarding pad. See Figure 17.28 for a conceptual design of Floating Bus Stop A. This figure is for reference only and does not constitute design standards.

17.5.02.D continued

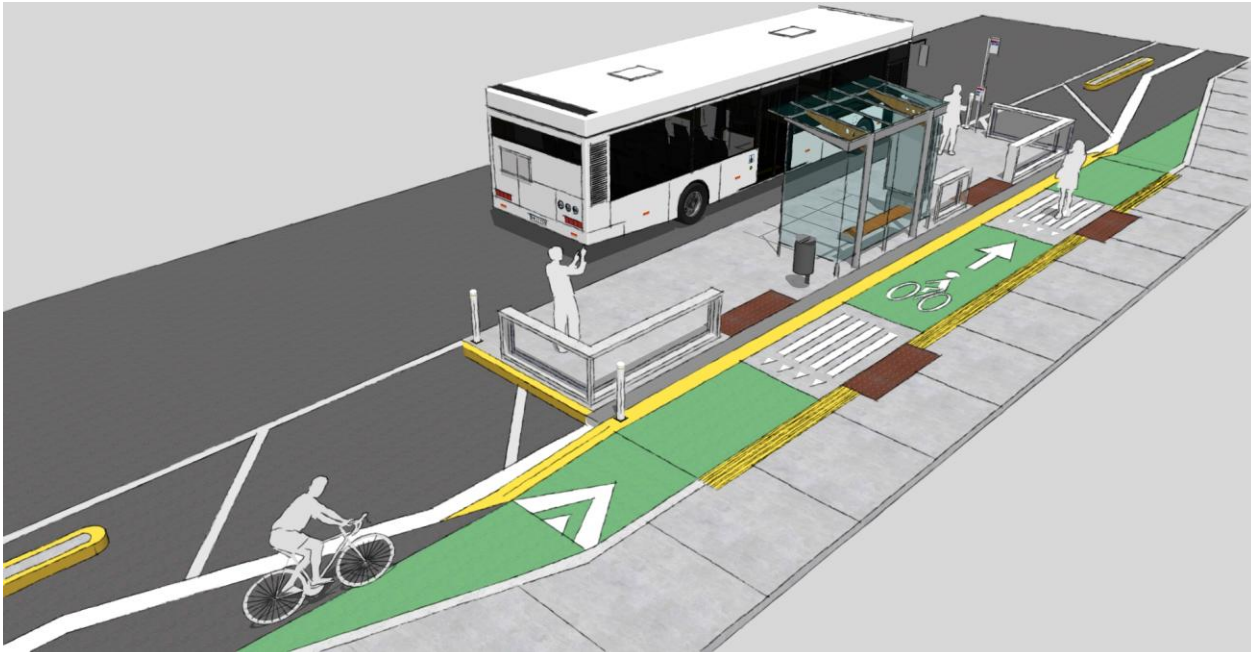


Figure 17.28 – FLOATING BUS STOP A

2. The bicycle lane shall shift away from the roadway to travel between the Pedestrian Realm and the bus boarding pad with transition curves as long as necessary to ensure the highest comfort bicycle movement.

3. For level pedestrian access to the bus pad, the Bicycle Facility shall transition before and after the pedestrian crossings at a maximum slope of 1:7 and a preferred slope of 1:15. The minimum length of the Sidewalk level Bicycle Facility should be twenty-five (25)-ft.

4. Any curb that could be struck by bicyclists because of a deviation of normal path of travel shall be painted yellow.

5. Vertical delineation should be implemented where there may be limited visibility of the curb.

6. Pedestrian Crossings

   a. There shall be at least one marked pedestrian crossing from the Pedestrian Realm to the bus boarding pad.

   b. Pedestrian crossings shall maintain the height of the Sidewalk and curb and have a cross slope of 2%.

17.5.02.D.6 continued

c. Pedestrian crossings shall be clearly indicated with crosswalks made up of four (4) six (6)-in wide, minimum five (5)-ft long white stripes perpendicular to the Bicycle Facility. Additional stripes may be necessary for wider bicycle lanes.

d. Yield lines made up of white yield triangles shall be placed in advance of the pedestrian crossing. YIELD TO PEDS pavement markings may be included.

e. Two (2)-ft wide detectable warning surfaces shall be placed on either side of the pedestrian crossing.

f. A longitudinal detectable warning strip should be placed adjacent to the Sidewalk-grade segment of the bicycle lane.

7. Pavement Markings

a. Solid bicycle green pavement markings shall be placed over the entire width of the bicycle lane behind the bus boarding pad with breaks provided for pedestrian crossings. Bicycle green pavement markings shall extend to include all bicycle lane area behind the gutter line.

b. A bicycle symbol and arrow marking shall be included in the Sidewalk-grade segment of the bicycle lane, not conflicting with pedestrian crosswalk pavement markings.

c. A six (6)-in solid white striped buffer shall delineate the area between the Bicycle Facility and the vehicular lane and shall provide bicycle lane alignment behind the bus boarding pad.

8. Drainage

a. Drainage shall be fully accommodated by the design of Floating Bus Stop A. Implementation of Floating Bus Stop A shall not create new ponding of stormwater.

b. Floating Bus Stop A should be installed on a high point of the gutter flow line.

(1). If it is not feasible to install Floating Bus Stop A on a high point of the gutter flow line, a new storm inlet with appropriate connections should be installed on the upstream side of the bus platform.

17.5.02.D.8.b continued

(2). If article 17.5.02.D.8.b.(1) is not feasible, an eighteen (18)-in gap between the curb and the bus boarding pad shall be provided to preserve the gutter flow. An easily removable steel plate shall be provided over the drainage gap along any walkable surface.

17.5.02.E Floating Bus Stop B

1. Floating Bus Stop B is constructed on-street in line with on-street parking or where a road segment has excess width that allows the bus boarding pad to be constructed on-street. See Figure 17.29 for a conceptual design of Floating Bus Stop B. This figure is for reference only and does not constitute design standards.

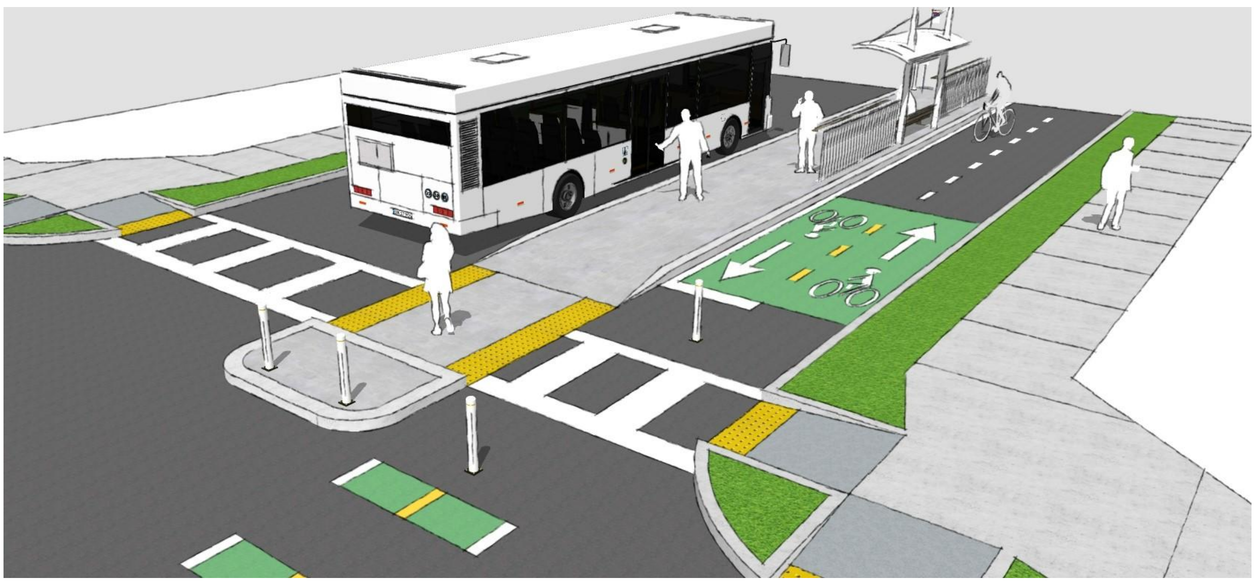


Figure 17.29 – FLOATING BUS STOP B

2. Floating Bus Stop B allows the bicycle lane to continue at roadway grade without shifting significantly around the bus boarding pad.

3. Any curb that could be struck by bicyclists because of a deviation of normal path of travel shall be painted yellow.

4. Vertical delineation should be implemented where there may be limited visibility of the curb.

5. When a Floating Bus Stop B is placed at a marked crosswalk, the existing pedestrian crosswalk and pedestrian ramps should be used as access to the bus boarding pad.

17.5.02.E.5 continued

a. All pedestrian ramps shall meet the requirements in Section 17.3.02.A – Curb Ramps and Corner Treatments.

b. A Median Refuge Island shall be included where the bus boarding pad intersects with the crosswalk. The Median Refuge Island shall meet the requirements in Section 17.3.02.D – Median Refuge Islands.

6. When a Floating Bus Stop B is not placed at a marked crosswalk, accessible pedestrian ramps and pedestrian crosswalk markings shall be provided at Sidewalk grade or at road grade.

   a. If a Sidewalk grade pedestrian crossing is provided, use Floating Bus Stop A pedestrian crossing and drainage requirements.

   b. If a Sidewalk grade pedestrian crossing is provided, the Bicycle Facility shall transition before and after the pedestrian crossings at a maximum slope of 1:7 and a preferred slope of 1:15. The minimum length of the Sidewalk level Bicycle Facility should be twenty-five (25)-ft.

7. Drainage

   a. Drainage shall be fully accommodated by the design of Floating Bus Stop B. Implementation of Floating Bus Stop B shall not create new ponding of stormwater.

17.5.02.F Floating Bus Stop B shall maintain the existing gutter flow line. Shared Raised Bus Stop

1. A Shared Raised Bus Stop allows for a bus stop to be in line with the Bicycle Facility without altering the Pedestrian Realm and allows for bus boarding at the Sidewalk level by ramping up the bicycle lane to the curb. See Figure 17.30 for a conceptual design of a Shared Raised Bus Stop. This figure is for reference only and does not constitute design standards.

17.5.02.F continued

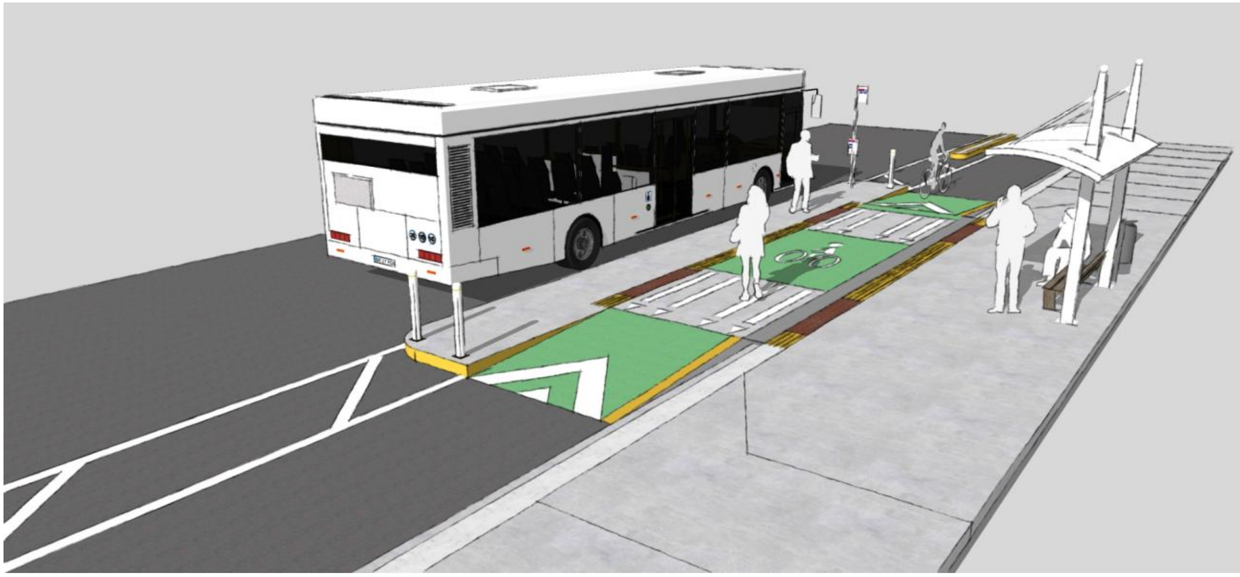


Figure 17.30 - SHARED RAISED BUS STOP

2. Shared Raised Bus Stops should only be used on right-of-way-constrained roadways where the Off-Street Bicycle Facility Bus Stop, Floating Bus Stop A or Floating Bus Stop B is not feasible.

3. Any curb that could be struck by bicyclists because of a deviation of normal path of travel shall be painted yellow.

4. Vertical delineation should be implemented where there may be limited visibility of the curb.

5. Bicycle Facilities shall transition before and after the pedestrian crossings at a maximum slope of 1:7 and a preferred slope of 1:15.

6. Pedestrian Crossings

   a. There shall be at least one marked pedestrian crossing across the Bicycle Facility.

   b. Pedestrian crossings shall maintain the height of the Sidewalk and curb and have a cross slope of 2%.

   c. Pedestrian crossings shall be clearly indicated with crosswalks made up of four (4) six (6)-in wide, minimum five (5)-ft long white stripes perpendicular to the Bicycle Facility. Additional stripes may be necessary for wider bicycle lanes.

17.5.02.F.6 continued

d. Yield lines made up of white yield triangles shall be placed in advance of the pedestrian crossing. YIELD TO PEDS pavement markings may be included.

e. Two (2)-ft-wide detectable warning surfaces shall be placed on either side of the pedestrian crossing.

f. A longitudinal detectable warning strip should be placed on both sides of the Sidewalk-grade segment of the Bicycle Facility.

7. Pavement Markings

a. Solid bicycle green pavement markings shall be placed over the entire width of the Bicycle Facility adjacent to the bus stop. Breaks shall be provided for pedestrian crossings.

b. A bicycle symbol and arrow marking shall be included in the Bicycle Facility adjacent to the bus stop, not conflicting with pedestrian crosswalk pavement markings.

c. A six (6)-in solid white striped buffer shall delineate the area between the Bicycle Facility and the vehicular lane and shall provide bicycle lane alignment behind the bus boarding pad.

d. A six (6)-in solid yellow stripe shall be included on the gutter side of Bicycle Facility ramps.

8. Drainage

a. Drainage shall be fully accommodated by the design of the Shared Raised Bus Stop. Implementation of the Shared Raised Bus Stop shall not create new ponding of stormwater.

b. Shared Raised Bus Stops should be installed on a high point of the gutter flow line.

(1). If it is not feasible to install the Shared Raised Bus Stops on a high point of the gutter flow line, a new storm inlet with appropriate connections should be installed on the upstream side of the bus platform.

(2). If article 17.5.02.F.8.b.(1) is not feasible, an eighteen (18)-in gap between the curb and the Bicycle Facility shall be provided to preserve the gutter flow. An easily removable steel plate shall be provided over the drainage gap along any walkable surface.

17.5.02.G On-Street Shared Bus Stop

17.5.02.G continued

1. On-Street Shared Bus Stops are bus stops where buses share space with road-grade Bicycle Facilities. See Figure 17.31 for a conceptual design of an On-Street Shared Bus Stop. This figure is for reference only and does not constitute design standards.

Figure 17.31 – ON-STREET SHARED BUS STOP

2. Where right-of-way is constrained, bus frequency is greater than or equal to 60 minutes, and the scope of the project does not allow for Shared Raised Bus Stops, On-Street Shared Bus Stops may be used.

3. On-Street Shared Bus stops should be placed on the far side of intersections. Where they are placed at the near side of intersections, they should be placed such that motorists cannot use the bicycle lane to make a right turn.

4. Pavement Markings

   a. On-Street Shared Bus Stops are made up of bicycle green pavement markings adjacent to the bus stop.

   b. There shall be bicycle green pavement markings combined with a bicycle symbol, an arrow and BUS pavement markings preceding the bus stop (refer to Standard Detail 02760-04).

   c. Dashed, white six (6)-in guideline pavement markings shall be placed adjacent to the bus stop area and in advance of the bus stop to allow for bus access to the curb.

5. Delineation

17.5.02.G.5 continued

a. On-street bike lane delineation shall end in advance of the bus stop area. The area without delineation can include driveways.

(1). For near side bus stops, delineation should be placed such that motorists cannot use the bicycle lane to make a right turn.

(2). For far side bus stops, delineation should only be placed following the stop.

17.5.03 TRANSIT STOP PLACEMENT (REFER TO METRO TRANSIT DESIGN GUIDELINES)

17.5.04 PAVEMENT MARKINGS/SIGNAGE (REFER TO METRO TRANSIT DESIGN GUIDELINES)

END OF CHAPTER