Sec. 35-803. – Historic and Design Review Commission.

* * * * *

(c) **Composition and Qualifications.** In appointing members of the commission, the city council shall make appointments that are sensitive to the preservation and development goals of the city and will enable the city to retain compliance as a certified local government under the rules incorporating the provisions of the U.S. Historic Preservation Act of 1966, as amended, and Title 13, Texas Historic Commission, chapter 15, ~~specifically 13 TAC 15.6(f)(3)(C),~~ so that all members shall have a demonstrated "interest, competence, or knowledge in historic preservation."

* * * * *

(j) **Quorum.**

(1) A quorum of the commission shall require six (6) members present. The affirmative votes of a majority of the members present is required for action, except in the case of an application for demolition which shall require a two-thirds (2/3) majority of the members present for a recommendation of approval.

(2) Except when considering an application for demolition or a question of procedure or qualification, when a motion to approve, deny, or approve with conditions fails to pass with the requisite number of five votes, such outcome shall be deemed to be the approval of a motion to reconsider the question, and an automatic continuance to the next regularly scheduled meeting of the commission. If the commission has continued an item at two (2) consecutive meetings, such action, at the option of the applicant, shall be deemed to be a negative recommendation.

(3) Subpart (2) shall apply only when an application has been heard and the chair calls for motions, and so long as no subsequent motions on the application are made.

(k) **Conflicts of Interest.** No member of the commission shall vote or participate as a member in any matter that materially affects the property, income, or business interest of that member or in which the member holds a substantial interest. Such member shall refrain from all discussions of the matter with other commissioners, not be present when the matter is considered, not vote on the matter, and file all required written recusal documents prior to consideration of the item. ~~give notice of abstention from voting prior to the taking of a vote.~~

* * * * *

Sec. 35-451. Certificate of Appropriateness.

* * * * *

(d) **Decision.**

(1) **Commission Review.** The commission shall make its written final recommendation to either approve, deny, or approve with stipulations the application within sixty (60) days after the historic preservation officer's receipt of the completed application. Applications forwarded to the commission shall include all required materials and documents from the applicant. If the commission does not make its final recommendation within a sixty-day period, the application shall be deemed recommended by the commission for approval and the city manager or her designee shall either approve, deny or approve with conditions the application within five (5) days of the applicant's demand. The sixty-day time period may be extended up to three additional times, with each time not exceeding thirty (30) days, with the concurrence of the applicant if additional time is required for the preparation of information or for research required by the commission. In cases involving demolition applications, the Historic Preservation Officer may extend this timeline consistent with Section 35-455(d).

(2) **City Manager Review.** Upon receipt of the recommendation by the commission, or on their own initiative, the city manager or designee may implement such recommendation by notifying the applicant within ten (10) business days from receipt of such recommendation that the application has been approved, conditionally approved, or disapproved. The city manager designee for this purpose shall be the historic preservation officer, unless the city manager chooses to designate otherwise. The city manager or designee shall also submit a copy of the decision to the commission for its information, to the department of planning and development services for issuance of permits, and to other departments, as applicable. The city manager or designee shall assure the decision is based on the criteria established by the Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation, and was considered by the commission in the determination as to issuance or denial of any certificate.

* * * * *

Sec. 35-B121. - Subdivision Plat Applications.

* * * * *

(c) **Contents.**

(22) All notes placed on the proposed plat shall be approved by ~~a certifying and/or reviewing agency and the planning and~~ the director of development services ~~director~~ for form and content.

* * * * *

(24) All easements known to the applicant, in effect at the time of platting, and created prior to the subdivision or development of any tract of land shall be shown on the subdivision plat or development plat with appropriate notations indicating the name of the holder of the easement, the purpose of the easement, the dimensions of the easement tied to all adjacent lot lines, street rights-of-way and plat boundary lines and the recording reference of the instruments creating and establishing the easement.

If an easement has not been defined by accurate survey dimensions, such as an "over and across" easement, the city's preference is that the easement be defined as to the limits and location of the easement through the property within the plat boundaries, and all easements shall be noted on the plat, including the name of the easement owner, the nature or type of easement, the location and width if described in the instrument creating the easement, and the Deed and Plat Records recording information of the appropriate county, if applicable. Failure to define the easement area by survey dimensions shall not be a basis for rejection of the plat.

Additionally, for all undefined utility easements, the applicant shall accurately depict the centerline location of all existing pipelines or other utility facilities placed in conformance with the easement owners' rights on the subdivision or development plat.

* * * * *

Sec. 35-B121. - Subdivision Plat Applications.

* * * * *

(f) **Certification and Forms.**

* * * * *

(23) FORM X

City of San Antonio
Development Services
Department
Land Entitlements Section

FORM X
LEGAL DECLARATION:
SUBDIVISION COMMON AREAS
AND FACILITIES

For: _____ Subdivision Plat #: _____

THE STATE OF TEXAS §
§
COUNTY OF BEXAR §

BEFORE ME, the undersigned authority, on this day personally appeared _____ who, being duly sworn by me, deposes and says:

(1) That my name is _____and that I am _____ of _____ the entity that owns the real property described below, hereinafter referred to as the "Property".

(2) That the property is identified by the following legal description (which should match the plat filing):

_____
_____
_____

(3) That _____ is the "Declarant" of the Property and declares that the Property shall be held, sold and conveyed subject to restrictions, covenants, and conditions which shall be deemed to be covenants with the land and imposed to benefit and burden each lot and other portion of the Property in order to maintain within the Property a planned community of high standards. Such covenants will be binding on all parties having heirs, personal representatives, successors, and assigns, and shall inure to the benefit of each owner thereof.

(4) That the Declarant and every Owner of a lot by virtue of ownership of such lots shall be a member of the _____ Homeowner Association hereinafter referred to as the "Association".

(5) That the Association shall establish a maintenance fund and shall use the proceeds of such funds in providing for normal, recurring maintenance charges for the common areas/facilities for the use and benefit of all members of the Association. The Association shall, in addition, establish and maintain an adequate reserve fund for periodic maintenance, repair and replacement of improvements to the common maintenance areas/facilities. The fund shall be established and maintained out of regular annual assessments.

(6) That Declarant hereby assigns its right of ingress and egress across and over the property to the City of San Antonio for purposes of conducting official City business; which may include removal of obstructions during emergency situations in which case the City shall not be held liable for its repair, replacement, or any future maintenance.

For: _____

By: _____

_____

_____

LANDOWNER – APPLICANT

THE STATE OF TEXAS §
COUNTY OF BEXAR §

BEFORE ME, the undersigned authority, on this day personally appeared _____, known to me to be the person whose name is subscribed to the foregoing instrument, and acknowledged to me that (s)he executed same for the purpose and consideration therein expressed.

GIVEN under my hand and seal of office this _____ day of _____, 20_____.

_____
NOTARY PUBLIC

_____
Typed or Printed Name of Notary

MY COMMISSION EXPIRES: _____

Upon Recordation, Please Return to:

_____

_____

* * * * *

Sec. 35-305. – Zoning District Boundaries.

* * * * *

(h) In order to correct survey errors in courses or distances, scrivener errors, or clerical errors, if a parcel is rezoned and a remainder strip of less than fifty (50) feet is inadvertently not included in the rezoning, the entire parcel will be considered rezoned.

* * * * *

Section 35-412– Master Development Plan

*** * * * ***

(i) **Scope of Approval**

(1) An approved master development plan shall remain valid in accordance with the following time frame:

A. **Initial Validation**. A MDP shall expire unless ~~the~~ a plat within the MDP boundary is approved and recorded within five (5) years ~~twenty-four (24) months~~ of the acceptance date, or unless there is at least five hundred thousand dollars ($500,000.00) in project expenses if the MDP is one thousand (1,000) acres or less, or at least one million dollars ($1,000,000.00) in project expenses if the MDP is more than one thousand (1,000) acres. Project expenses shall be spent during the first ~~twenty-four (24) months~~ five (5) years from the MDP approval ~~acceptance~~ date.

B. Maintaining Validity. An MDP shall expire following initial validation unless at least one plat within the MDP boundary is recorded every five (5) years from the last recorded plat. ~~and the plat used to validate the MDP shall be recorded within thirty-six (36) months of the plat approval date. The minimum platted area must be at least twenty (20) acres or eight (8) percent of the net area of the MDP, or a MDP shall expire unless there is at least five hundred thousand dollars ($500,000.00) in project expenses if the MDP is one thousand (1,000) acres or less or at least one million dollars ($1,000,000.00) in project expenses if the MDP is more than one thousand (1,000) acres.~~ Project expenses may be used in lieu of recording a plat every five (5) years and may be used every five (5) years from the last validated expenditure; however, the expenses for a recorded validated plat may not be used in subsequent validations. The expenses must be for a tract of land within the MDP boundary that has not been platted and recorded.

Project expenses shall be defined to include "infrastructure expenses" as provided in Appendix A of the UDC. It is noted that this section uses the word "paid" in the past tense.

Project expenses shall also be defined to include the Local Government Code definition of progress toward completion as defined in § 245.005(c). It is noted that this section speaks in the past tense when referencing actions that were part of progress toward completion.

This Section is applicable to any MDP that is valid as of the effective date of this Section. These previously validated MDPs shall expire unless the ongoing platting or project expense requirements of 412(i)(1)(B) are satisfied, provided that the initial five (5) years shall start as of the effective date of this Section. This Section does not allow an MDP that expired prior to the adoption of this code to become valid.

~~B.~~

~~Further, an approved master development plan shall expire unless fifty (50) percent of the net area within the approved master development plan is the subject of final plats or development within ten (10) years from the date of approval of the master development plan, or an MDP shall expire unless there is at least five million dollars ($5,000,000.00) in project expenses within ten (10) years from the date of approval of the master development plan. The remaining fifty (50) percent must obtain final plat approval or be developed within ten (10) years after the initial fifty (50) percent of the net area within the master development plan has been platted or developed. Unless specific provisions to the contrary exist in an individual ordinance or city municipal code provision, the filing of a minor amendment to a master development plan (see subsection 35-412(gh)(2), plat, or replat will not result in a loss of permit rights and abandonment of the original master development plan provided that the required area of acreage within the master development plan platted or value of infrastructure expenses do not fall below the amounts indicated above as a result of the amendment or replat.~~

* * * * *

Section 35-712– Recognition of Rights Derived from Texas Local Government Code Chapter 245.

*** * * * ***

(b) **Recognition of Statutory Rights**

* * * * *

(3) **Basis for Statutory Rights**

* * * * *

A. **Master Development Plan (MDP)** ~~/ Preliminary overall area development plan (POADP).~~ Rights under Chapter 245 will be recognized for the project that is the subject of a MDP~~/POADP~~ that has been approved by the city and maintains validity in accordance with 35-412(i) ~~by the city~~. ~~A property owner or developer may elect to continue a project under the City Code provisions in effect on September 1, 1997 or to take advantage of changes to this chapter that enhance or protect the project without forfeiting any rights under this chapter provided that information describing the project giving fair notice of the project to the city is provided with a MDP/POADP application in accordance with this chapter or by requesting recognition of rights for an existing and valid MDP/POADP and providing information describing the project to provide fair notice of the project to the city in accordance with this chapter. The rights recognized for projects located within an approved MDP/POADP will expire unless a final plat is approved within two (2) years from the approval of the MDP/POADP that plats, at least eight (8) percent of the net area of the POADP area or an expenditure of at least five hundred thousand dollars ($500,000.00) in project expenses has been made if the master development plan is one thousand (1,000) acres or less or an expenditure of at least one million dollars ($1,000,000.00) has been made if the master development plan is more than one thousand (1,000) acres.~~

B. Preliminary overall area development plan (POADP). A property owner or developer may elect to continue a project under the City Code provisions in effect on September 1, 1997 or to take advantage of changes to this chapter that enhance or protect the project without forfeiting any rights under this chapter ~~provided that information describing the project giving fair notice of the project to the city is provided with a MDP/POADP application in accordance with this chapter or~~ by requesting recognition of rights for an existing and valid ~~MDP/~~POADP ~~and providing information describing the project to provide fair notice of the project to the city in accordance with this chapter.~~ The rights recognized for projects located within an approved ~~MDP/~~POADP will expire unless a final plat is approved within two (2) years from the approval of the ~~MDP/~~POADP that plats, at least eight (8) percent of the net area of the POADP area or an expenditure of at least five hundred thousand dollars ($500,000.00) in project expenses has been made if the ~~master development plan~~ POADP

is one thousand (1,000) acres or less or an expenditure of at least one million dollars ($1,000,000.00) has been made if the ~~master development plan~~ POADP is more than one thousand (1,000) acres.

Further, the rights for projects within an approved ~~MDP/~~POADP will expire unless fifty (50) percent of the net area within the approved ~~MDP/~~POADP is the subject of final plats or development within ten (10) years from the date of approval of the ~~MDP/~~POADP. For a POADP existing prior to September 1, 1997 that meets the requirements of subsection 35-1027(j) of the 1987 UDC, the rights for projects will expire ten (10) years from the date of approval of the ~~MDP/~~POADP or September 25, 2007, whichever is later. ~~The remaining fifty (50) percent must obtain final plat approval or be developed within ten (10) years after the initial fifty (50) percent of the net area within the MDP/POADP has been platted or developed unless specific provisions to the contrary exist in an individual ordinance or City Code provision.~~ Rights may continue to be recognized once the aforementioned criteria have been fulfilled provided a plat is recorded every five years thereafter. The filing of a minor amendment to a ~~MDP/~~POADP, a plat, or a replat will not result in a loss of rights to the entire ~~MDP/~~POADP provided that the required area of acreage within the ~~MDP/~~POADP platted or the value of project expenses do not fall below the amounts indicated above as a result of the minor amendment, plat, or replat. A plat or replat that changes the project within a particular area of an ~~MDP/~~POADP will cause rights for that area to terminate. An expired or invalid ~~MDP/~~POADP may not be the basis for accrual of statutory rights under V.T.C.A. Local Government Code Ch. 245 or any other right of claim based on common law. Neither shall any endeavor of project that does not meet the requirements of section 35-1027 of the 1987 UDC as amended nor any permit that has expired in accordance with the dormancy provisions of any state statute or provision of the City Code be used as a basis for approval of permit rights, development rights, or statutory rights.

POADP is defined as a preliminary overall development plan that was submitted to the City prior to June 4, 2001

~~B.~~C. **Plat Applications.** Rights under Chapter 245 will be recognized for the project that is the subject of an application for a plat identification number/letters of certification that has been filed with the department of development services, provided all necessary fees have been paid. The rights recognized for a project located within such a plat application will expire unless the plat application is heard by and approved by the director of development services or the planning commission within two (2) years from the date the initial application and information describing the project giving fair notice of the project to the city is provided with the plat application in accordance with this chapter. Neither an expired nor a withdrawn plat application may be relied upon as a permit application for the assertion of statutory rights under Chapter 245 or any other right or claim based on common law. If after the expiration or the withdrawal of a plat application the applicant wishes future plat approval of the subject property, a new plat application shall be filed, new application fees shall be required and a new plat number shall be assigned.

~~C.~~D. **Plats**. Rights under Chapter 245 will be recognized for projects associated with the property which is the subject of a plat that has been approved by the city planning commission or director of development services if information describing the project giving fair notice of the project to the city is provided with the plat application in accordance with this chapter. The rights recognized for a project located within an approved plat will expire unless the plat is recorded in the Bexar County Deed Records within three (3) years from the date of approval by the city planning commission or director of development services.

~~D.~~E. **Building Permits.** A building permit may be relied on as a basis for rights under Chapter 245 for projects identified in the site plan submitted to the city as part of the building permit application provided that information describing the project giving fair notice of the project to the city is provided with the permit application in accordance with this chapter. However, rights that are based on a building permit will expire unless construction authorized by the building permit is begun within six (6) months from the date the building permit is issued.

~~E.~~F. **Rights under Chapter 245.** Rights accrued under this section shall not extend beyond the time periods prescribed herein except by the granting of a variance from the time limits as provided herein. Under no circumstances shall the extension of a time limit extend the rights conferred herein except through the variance provision of this section.

* * * * *

Sec. 35-506. - Transportation and Street Design.

* * * * *

(d) **Cross-Section and Construction Standards.**

* * * * *

(9) **Substandard Existing Streets.**

* * * * *

B. **Sidewalks, Curbs and Pavement Construction.** For purposes of this section, pavement cross-section includes the following: width of ROW, sidewalks, curbs, bicycle facilities, and the pavement structural section.

1. Where platted property or property meeting a plat exception under 35-430(c) is adjacent or contiguous to an existing publicly maintained street and the pavement cross-section of the existing street is less than the minimum required by this chapter for the development accessing the existing street, no ~~building~~ permit for the property shall be issued or any utility connected until the pavement cross-section has been improved to the minimum pavement cross-section required by this chapter. If the property does not access the street and the minimum street cross-section is only lacking sidewalk, refer to 35-506(q) to determine if sidewalk is required.

2. Where property is being platted adjacent or contiguous to an existing publicly maintained street and is using the street for access and the pavement cross-section of the existing street is less than the minimum required by this chapter, no plat shall be recorded until the pavement cross-section has been improved to the minimum pavement cross-section required by this chapter, or a guarantee of performance has been executed and filed as provided in section 35-437. If the minimum pavement cross-section is only lacking sidewalk, refer to 35-506(q) to determine if sidewalk is required.

3. If a property is being platted adjacent or contiguous to an existing privately maintained street or paper street and is using the street for access, the property owner must coordinate with the entity responsible for maintaining the street to access the street for daily access. A note on the plat shall be added to the plat informing the public that the development has access to a street that is privately maintained or not maintained.

4. Minimum Construction Required. Where the roughly proportionate determination (determination study under section 35-502) has

determined that the applicant's development would not generate enough traffic to require mitigation for right-of way dedication or improvements to the pavement cross section, the provisions of this subsection shall not apply. In such cases, the safety lane requirements of 35-506(d)(11) shall be met.

C. **Exceptions.**

1. In cases where an existing fence and landscaping is present, the planning and development services director shall require dedication of the additional right-of-way but may allow existing landscaping and fences to remain until such time as construction is required in accordance with subsection B. The director shall evaluate the condition of the existing fencing and the character of the landscaping and may direct additional reconstruction of the fence or new plantings. In such cases the landscaping required by the director shall not be greater than that required by this chapter for new projects.

2. The provisions of this subsection shall not apply within the infill development zone "IDZ" as stated in subsection 35-343(e) provided that ADA standards are met.

~~3. Paper Streets. Where subdivisions are adjacent or contiguous to platted rights-of-way and no street exists, (including paper streets) no building permit shall be granted or any utility connected until one-half (½) of the road is constructed adjacent to the proposed development.~~

~~4. Minimum Construction Required. Where the roughly proportionate determination (determination study under section 35-502) has determined that the applicant's development would not generate enough traffic to require mitigation for right-of way dedication or improvements to the pavement cross section, the provisions of this subsection shall not apply. In such cases, sidewalk ADA standards and a minimum fourteen-feet clear pavement width within the street for emergency access are required and no building permit shall be issued for properties adjacent to paper streets until Exception 3 listed above is met.~~

~~5~~3. CRAG Area. Right-of-way and pavement width requirements in established neighborhoods within the CRAG area may be reduced by the director of development services based on existing encroachments.

Sec. 35-506. - Transportation and Street Design.

* * * * *

(d) **Cross-Section and Construction Standards.**

* * * * *

(10) **Curbs and ~~Pavement~~Parkways.** ~~Curbs shall be required on both sides of all interior streets. Curbs and pavement are required on the development side of all adjacent streets except:~~

A. Curb and Gutter. Concrete curbs or monolithic curbs and gutters shall be constructed on both sides of a street in accordance with the City of San Antonio standard details where indicated in Table 506-3 or Table 506-4 except:

~~A~~1. When the director of ~~planning and~~ development services or County Engineer in consultation with the director of ~~public works~~ transportation and capital improvements determines that the curbs will interfere with or disrupt drainage.

~~B~~2. When the director of ~~planning and~~ development services or County Engineer in consultation with the director of ~~public works~~ transportation and capital improvements determines that public construction that would require curb replacement will take place on the street within three (3) years.

~~C. On local type A streets in single-family or two-family residential subdivisions within the "RP" and "RE" zoning districts.~~

~~D~~3. On streets in residential subdivisions where no ~~adjacent lots are platted if approved by the director of planning and development services, such as streets adjacent to walls~~ sidewalk is required under 35-506(q) ~~or drainage ways~~.

~~E~~4. Where the director of ~~planning and~~ development services determines that preservation of trees warrants the elimination, reduction in width, or modification to the curb requirements in accordance with the tree preservation standards.

~~F~~5. ~~When densities of less than two (2) units per acre exist and a county section for local streets~~On streets utilizing a county road section as allowed in 35-506(b)(1) is proposed in the ETJ.

6. When one-half of an arterial section is proposed to be constructed, one side of the curb may not be constructed if the proposed pavement width is less than 36 feet.

B. Medians and Dividers.

1. Medians and dividers having curbs shall be constructed in accordance with the approved cross section. The parkway slope requirements of C below shall be met.

2. For streets without curb, slopes shall meet the preferred requirements specified in the latest version of the "TxDOT Roadside Design Manual" at a minimum.

C. Parkways.

1. Landscaping, walls or fences placed in the parkway for aesthetic purposes shall not obstruct sight distance. ROW permits from the appropriate permitting authority must be obtained before adding any of these improvements in the ROW.

2. Parkway slopes between a curb and back of sidewalk for standard parkways–shall have a slope of one-quarter (0.25) inch per foot toward the street.

3. Parkway slopes outside of the area noted above, shall continue a slope of one-quarter (0.25) inch per foot toward the street except in heavy cuts. In heavy cuts, a slope of one (1) inch per foot toward the street outside of the area mentioned above is preferred; however, the slope shall not exceed a slope of four (4) inches per foot toward the street.

4. Parkway slopes inside a curbed median shall meet the requirement of subsection C3 above.

5. For streets without curb, slopes shall meet the preferred requirements specified in the latest version of the "TxDOT Roadside Design Manual" at a minimum.

6. Deviations from this section are considered an exception and not a variance.

* * * * *

(p) **Pavement Standards.**

* * * * *

~~(8) Curb and Gutter. Concrete curbs or monolithic curbs and gutters constructed in accordance with the City of San Antonio standard details shall be provided where indicated on the typical cross sections provided in subsection (d) of this section.~~

~~(9) Medians and Dividers. Medians and dividers having curbs shall be constructed in accordance with the approved cross section. Where divider strips on primary and secondary streets are constructed without curbs, they shall be graded to a slope of one-quarter (0.25) inch per foot from the center of the divider strip to a point seven (7) inches from above the edge of pavement and from that point to the edge of pavement.~~

~~(10) Parkways. Parkway slopes shall be one-quarter (0.25) inch per foot toward the street except in heavy cuts, where a maximum of one (1) inch per foot shall be permitted. Landscaping, walls or fences placed in the parkway for aesthetic purposes shall not obstruct sight distance.~~

* * * * *

Sec. 35-506. - Transportation and Street Design.

*** * * * ***

(j) **Private Streets.**

(1) **Applicability.**

A. Private streets are permitted within planned unit developments, the business park "BP" zoning district, and manufactured home/recreational vehicle parks subject to the design criteria and standards of this section.

B. Private streets are only allowed within an enclave subdivision subject to being designed and constructed to the standards of a public street.

C. Private streets shall be located within a private street lot identified as "Lot 999."

D. The subdivision plat name shall prominently indicate the type of private street development (e.g., "planned unit development", "PUD" "Enclave).

(2) **Design Standards**. With the exception of enclave subdivisions, ~~T~~the design standards and construction specifications of private streets shall be the same as for public streets except as noted below:

A. A right-of-way of fifty (50) feet for a local type A streets and sixty (60) feet for local type B streets shall not be required.

i. Private street lot should extend a minimum of two (2) feet outside of the face of curb.

ii. Regulatory sign easements shall be provided if regulatory and warning signs cannot be located within the private street lot.

B. The paved street width, exclusive of curb exposures, shall be a minimum of twenty-seven (27) feet for local type A streets and thirty (30) feet for local type B streets.

(3) **Certification.** Upon completion of construction, the director of ~~planning and~~ development services and county in the ETJ shall be provided with a written certification signed by a licensed professional engineer certifying that the private streets and sidewalks (as applicable) were designed and installed as required by the provisions of this chapter.

(4) **Maintenance.** Private streets and sidewalks shall be owned and maintained by a corporation, community association, or other legal entity established for this purpose.

A. The applicant shall record a dedicatory instrument covering the establishment, maintenance, and operation of a residential subdivision subsequent to the recordation of the subdivision plat. The applicant shall include with the homeowners' association (HOA) dedicatory instrument a plan for the use and permanent maintenance of the common areas/facilities and demonstrate that

the property owners' association is self-perpetuating and adequately funded by regular assessment and/or special assessment to accomplish its purpose. The dedicatory instrument(s) shall include provisions that provide the city or county with permission for access at any time without liability when on official business, and further, to permit the city or county to remove obstructions if necessary for emergency vehicle access and assess the cost of removal to the owner of the obstruction.

B. Any HOA requesting that the city acquire their private streets shall produce documentation that the maintenance schedule set forth in the HOA's original pavement management plan as part of the HOA documents has been followed.

* * * * *

(6) **Parking on Private Streets.** Parking shall be ~~prohibited~~ limited to one designated side of the street on any private street with pavement less than twenty-eight (28) feet in width in accordance with Table 506-4a of this Chapter. ~~and, if utilized on streets thirty (30) feet wide or wider, it must be clearly distinguishable from the movement lanes.~~ The HOA documents may require the HOAs to identify and enforce a no parking restriction in fire lanes throughout the community.

(7) **Gated Subdivision Streets.** When a gate will be installed on a private street, the following provisions shall be met:

A. Master Key Security System. An access security system shall be provided on all gates. The security system shall include the following for the specified type of gate:

i. Electric Operated Gates:

1. In the ETJ, a siren operated sensor in conformance with the "Bexar County Rules for the Regulation of Electric-Operated Gates" is required; and

2. A gate override in case of power failure; or

3. Inside the city limits,

a. An access provided to the school district, and police department; and

b. A Knox box for the fire department.

ii. Non-electric Operated Gates:

1. A Knox box. In the ETJ, provide key or code of the knox box to Bexar County Office of Emergency Management.

B. Queuing. At gated entrances where traffic can queue into public streets, the gate and entrance design must provide for sufficient storage capacity so that no

vehicles will queue into the public street. Queuing at a gated entrance shall be designed as follows:

i. The Poisson distributed probability model shows that no vehicles will queue into the public street with a ninety-five (95) percent confidence level. The minimum entryway vehicle storage length shall be forty (40) feet measured from the call box to the public right-of-way as shown in Figure 506-11.

ii. The subdivider shall provide for vehicle turnaround capability based on the single unit design (SU-30) vehicle as provided in the 2011 AASHTO Green Book or latest revision thereof or be able to make a three-point turning movement to prevent a motorist from backing on to the public street.

* * * * *

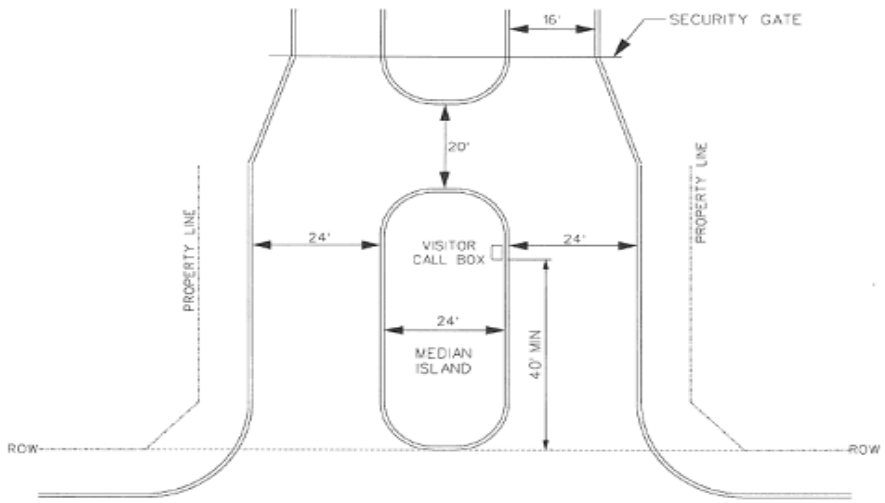


Figure 506-11. Standard Entryway Detail

C. Connectivity. The street system shall comply with the connectivity standards (subsection (e) of this section).

(s) ~~Gated Subdivision Streets.~~ Reserved

~~(1) Pavement Management. The applicant shall include with the homeowners' association (HOA) documents a forecast and schedule of street maintenance costs prepared by a licensed professional engineer, licensed as such by the State of Texas. A maintenance account with seed money shall be established by the developer to enable the HOA to meet the maintenance schedule until the HOA is self-sufficient. Any HOA requesting that the city acquire their private streets shall produce documentation that the~~

~~maintenance schedule set forth in the HOA's original pavement management plan as part of the HOA documents has been followed.~~

~~(2) Fire Lanes. The HOA documents shall require the HOAs to identify and enforce a no parking restriction in fire lanes throughout the community.~~

~~(3) Master Key Security System. A master key security system shall be provided on all gates. The security system shall include the following for the specified type of gate:~~

~~A. Electric Operated Gates:~~

~~(1) A gate override in case of power failure; and~~

~~(2) A siren operated sensor in conformance with the "Bexar County Rules for the Regulation of Electric-Operated Gates"; or~~

~~(3) Inside the city limits,~~

~~(i) A master key provided to the fire department, the school district, and police department; or~~

~~(ii) A Knox box.~~

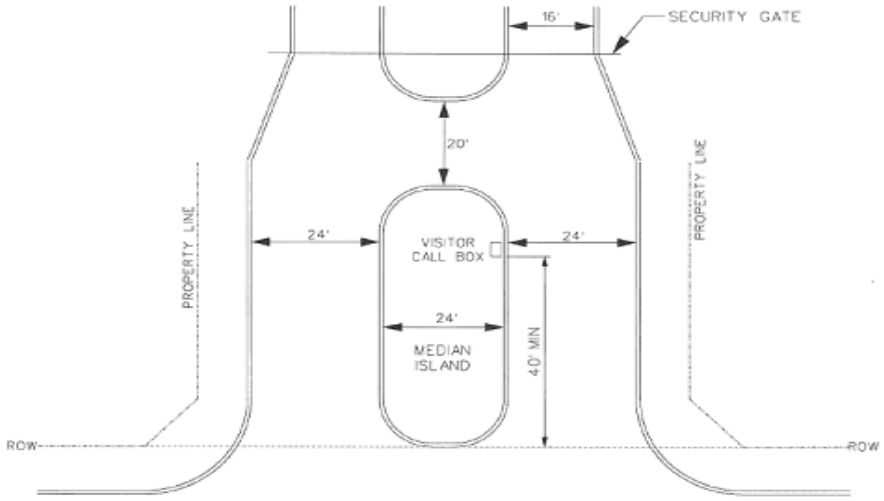
~~B. Non-electric Operated Gates:~~

~~(1) A Knox box.~~

~~(4) Queuing. At gated entrances where traffic can queue into public streets, the gate and entrance design must provide for sufficient storage capacity so that no vehicles will queue into the public street. Queuing at a gated entrance shall be designed as follows:~~

~~A. The Poisson distributed probability model shows that no vehicles will queue into the public street with a ninety-five (95) percent confidence level. The minimum entryway vehicle storage length shall be forty (40) feet measured from the call box to the public right-of-way as shown in Figure 506-11.~~

~~B. The subdivider shall provide for vehicle turnaround capability based on the single unit design vehicle as provided in the 2004 AASHTO Green Book or latest revision thereof or be able to make a three-point turning movement.~~



~~(5) Connectivity. The street system shall comply with the connectivity standards (subsection (e) of this section).~~

(t) **Traffic Calming.** The purpose of this section, is to protect the public health, safety and general welfare by ensuring that speeds on local streets are suitable for their intended purpose. The city hereby finds and determines that long blocks, wide street cross sections and uninterrupted traffic flows can encourage speeding on local streets. Accordingly, these design standards will slow traffic on local streets while allowing flexibility in design and offering applicants the choice of treatment that works best for the streets in a proposed development.

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Sec. 35-506. - Transportation and Street Design.

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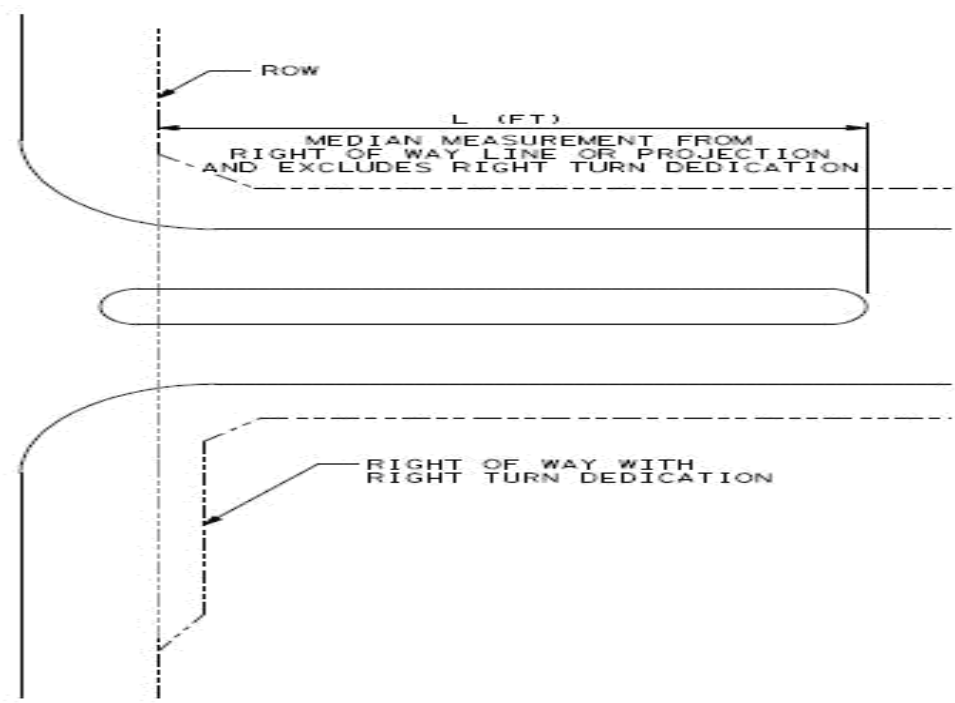
(n) **Medians.**

(1) **Openings.** Medians shall be continuous. Openings in the median may be provided for public streets or major driveways (having one hundred (100) peak hour trips (PHT) or more) provided the spacing between median openings is in accordance with table 506-5.1, will not obstruct an intersection clear vision easement or stopping sight line distance, meets the minimum spacing requirements, and will not impact an existing intersection as specified in 35-502(d). When medians are open, left turn bays and median radii shall be provided in accordance with subsection 35-502(e)(2) ~~and curbed~~. Existing medians shall be modified to conform to these requirements where necessitated by the traffic generated by the proposed development, as set forth in the traffic impact analysis (see subsection 35-502(e)(2) of this chapter). Where existing streets are improved, dual left turn lanes can be approved if supported by a TIA (see section 35-502).

In determining if a median opening request should be approved, the city will require a traffic engineering analysis by a licensed professional engineer. The median opening analysis shall be at the expense of the requestor.

Figure 506-6.1 Methodology to Measure Median Opening Distance from a Projected Right-of-way Line of an Intersecting Freeway or Arterial:



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(2) **Special Purpose Medians**. Dividers constructed for aesthetic purposes such as entrances for subdivisions or landscaping shall be permitted. The minimum width for such dividers is fourteen (14) feet with minimum twenty (20) feet of pavement width on either side of the median. The divider shall maintain the full width for a minimum twenty-five (25) feet but not more than fifty (50) feet after which an appropriate transition shall be provided in accordance with standards for pavement and median transition (subsection (m), above). The ~~twenty-five (25) feet~~length of the median shall be measured from the edge of pavement of the ultimate width of the intersecting roadway. The nose or rounded portion of the divider shall be placed a minimum of two (2) feet off the edge of the traveled roadway of the intersecting street unless the turning radius of vehicular traffic or conflicts with an ADA street crossing indicates other modifications to the median nose are required. No signs, walls or fences, trees, shrubs or other ground cover shall be placed in the median which will obstruct the driver's sight distance (See Figure 506-7). The median design and exceptions to pavement width adjacent to median must be approved by the director of ~~planning and~~ development services in consultation with the director of public works. In addition, the director shall seek concurrence from the applicable county authority for all proposed medians located in the ETJ.

Landscaping shall be in accordance with current landscaping standards (section 35-511) design standards. In addition, appropriate maintenance agreements shall be made with the director of ~~planning and~~ development services.

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Sec. 35-506. - Transportation and Street Design.
*** * * * ***

(q) **Sidewalk Standards.**

*** * * * ***

(1) **Applicability.**

A. Sidewalks shall be required on both sides of all internal streets and the subdivision side of all adjacent or perimeter streets except as specified in subsection (2) below.

B. All nonresidential, residential corner and reverse residential street lots shall have sidewalks provided on both street frontages.

C. Sidewalks shall be required as part of the street improvements ~~only on one (1) side of subdivision entry streets unless residential lots are platted or planned to be platted on both sides of the street~~. at the following locations:

i. along the entry street of a gated private street subdivision where a pedestrian access gate is provided;

ii. the rear of a reverse residential street lot;

iii. drain crossings; and/or

iv. along the street frontage of existing developed lots when streets are extended.

~~C~~D. Sidewalks located in the right-of-way in place at the time of platting or permitting that meets the criteria under 506(a)(1)C2 for sidewalks to be evaluated, ~~that~~ which do not meet minimum standards of this chapter, Americans with Disabilities Act and Texas Accessibility ~~s~~Standards requirements shall be reconstructed to meet the most stringent minimum ~~ADA~~ standards.

~~D~~E. All sidewalk construction shall conform to the latest most stringent criteria of the Americans with Disabilities Act (ADA) and the Texas Accessibility Standards (TAS) (see subsection 35-501(~~e~~g) herein).

(2) **Sidewalk Exceptions.** Sidewalks shall not be required in the following situations:

A. When the director of ~~planning and~~ development services or County Engineer, in consultation with the director of ~~public works~~ transportation and capital improvements, determines that the sidewalks will interfere with or disrupt existing drainage.

B. When the director of ~~planning and~~ development services or County Engineer, in consultation with the director of ~~public works~~ transportation and capital improvements, determines that public construction which would require sidewalk replacement will take place on the street within three (3) years.

C. On local type A streets in single- or two-family residential subdivisions with a density less than one (1.~~0~~) residential unit per acre.

D. ~~On streets in residential subdivisions where no adjacent lots are platted, if approved by the director of planning and development services, such as streets adjacent to walls or drainage ways.~~On streets utilizing the county road cross section as allowed in 35-506(b)(1).

E. Where the director of ~~planning and~~ development services determines that preservation of trees warrants the elimination, reduction in width, or modification to the sidewalk and curb requirements in accordance with the tree preservation standards.

~~F. In developed blocks, where the area is residentially zoned for single-family detached dwellings, and where both of the following conditions exist:~~

~~a. Seventy (70) percent or more of the improved lots fronting the street in any one (1) block face do not have sidewalks; and~~

~~b. A connecting sidewalk does not exist on both sides of the subject property for which construction permits are being sought.~~

(3) **Planting Strips or Sidewalk Buffer.** When required by Table 506-3 or 506-4 above or identified in construction plans, sidewalks shall be defined by placing a ~~planted~~ planting strip or sidewalk buffer ~~of not less than three (3) feet~~ between the back of the curb (BOC) and the street edge of the sidewalk in accordance with the minimum planting strip required by Table 506-3 or 506-4.

(4) **Performance Agreement and Time of Construction.** All sidewalks noted in subsection (1)(C) above shall be included as part of the performance agreement required by section 35-437 of this chapter ~~with exception to sidewalks along street frontage of lots within the city limits for which building permits will be required. All sidewalks within a subdivision must be completed when ninety-five (95) percent of the lots within the subdivision are built out, excluding lots for which a building permit is pending.~~

(5) **Width.** Except as otherwise specified in Americans with Disabilities Act (ADA) or Texas Accessibility Standards (see subsection 35-501(g) herein), sidewalks shall have a minimum unobstructed width as follows:

A. In residential areas within the city limits and ETJ the minimum width of sidewalks adjoining a planting strip shall be four (4) feet. In nonresidential areas the minimum width of sidewalks shall be six (6) feet. Sidewalk width does not include curb width.

B. The minimum width of sidewalks located within the boundaries of the "D" downtown district shall be not less than six (6) feet.

(6) **Location.** Changes in the sidewalk location for a maximum linear distance of two hundred (200) feet are permitted to be approved by the field inspector without amending the street plan or utility layout provided such plans are annotated with a note stating that intent and does not relocate an ADA access ramp. If a

pedestrian access easement is required, the easement shall be recorded prior to final acceptance. During the plat review process, reviewing agencies may designate areas where prior approval of the agency is necessary for any alteration to the sidewalk location. No other changes shall be allowed without the approval of all agencies that approved the original utility layout.

(7) **Continuity.** Sidewalks shall not be installed in such a manner that they conflict with or are obstructed by power lines, telephone poles, fire hydrants, traffic/street signs, mail boxes, trees, buildings, barriers, light poles, or any other structure. The grades of sidewalks shall be such that changes of grades greater than ten (10) percent are not encountered within blocks. When there is an existing or anticipated obstruction, the sidewalk shall be installed around the object with a one (1) foot buffer around the object and shall provide the required sidewalk width. When utility layouts are required as part of a plat, the location and extent of sidewalks within the subdivision shall be shown on the utility layout and shall be subject to the approval of the director of ~~planning and~~ development services in consultation with the director of ~~public works~~ transportation and capital improvements and the utility agencies. In the ETJ, all sidewalk along a publicly maintained street or a street proposed to be publicly maintained must be contained within the ROW.

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Sec. 35-506. - Transportation and Street Design.

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(r) **Access and Driveways.**

(1) **Applicability.** The provisions of this section shall apply to all driveways. A lot which is a part of an approved plat which does not otherwise limit access and which was approved by the city and filed for record as of the effective date of this section, and which does not have sufficient frontage to meet the driveway approach spacing requirements in this section, shall be allowed one (1) driveway approach.

(2) **Single-Family Residential Subdivisions.**

A. **Frontage and Access off a Collector or Major Thoroughfare.** ~~Where a subdivision abuts a collector or major thoroughfare, lots for single-family residential use in the ETJ or in residential zoning districts shall not have direct access. The sole exception shall be lots~~ Residential lots having direct access on a Collector or Major Thoroughfare may be platted only if:

i. All lots are greater than one (1) acre in size, have a minimum lot frontage of one hundred (100) feet and ~~which~~ provide for permanent vehicular turn around on the lot to prevent backing onto the roadway. ~~and this restriction should be~~ A note~~d~~ shall be on the plat stating a permanent vehicular turn around shall be provided on each lot to prevent a vehicle from backing onto the roadway.

ii. Access points which would permit vehicular access to ~~existing~~ lots less than one acre in size from the thoroughfare or collector ~~shall~~ may be ~~prohibited~~allowed if~~.~~ ~~However, if conditions are such that vehicular access to such lots cannot be provided other than from the roadway, the director of planning and development services may permit the creation of~~ a marginal access street or easement to serve two (2) or more lots spaced a minimum of two hundred (200) feet apart or 200 feet from an existing driveway or street is constructed. The marginal access street or easement shall be designed to permit entry to the roadway without requiring a motorist to execute a backing maneuver. Marginal access streets or easements shall be included on the subdivision plat and shall be constructed or bonded in accordance with Section 35-437 before recordation of the plat.

B. **Marginal Access Streets**. Where the subdivider furnishes a marginal access street on the subdivision side of an existing, improved primary or secondary arterial, the subdivider shall not be required to furnish any pavement, curbs, or sidewalks for the primary or secondary arterial. (see also: subsection 35-506(q)(5))

~~(~~C~~)~~ ~~Collector sections are required for a minimum of forty (40) feet off of an arterial to prevent construction of residential driveways closer than~~

~~forty (40) feet from the arterial's end of property line return, or if a local type B section is designed, a~~ A residential lot shall ~~not side the arterial for~~be located a minimum of forty (40) feet from an arterial right-of-way.

(3) **Commercial, Industrial and Medium or High Density Residential Developments.** Lots ~~in~~ proposed for commercial, industrial and ~~medium or high-density~~multi-family residential developments in the ETJ or in the "MF," "NC," "O," "C," "I-1," or "I-2" zoning districts may have vehicular access from a thoroughfare or collector. However, the number of access points permitted will be based on the following criteria and following the driveway spacing requirements in subsection (7) below, if applicable.~~:~~

~~(~~A~~)~~ For lots with less than two hundred (200) feet of unrestricted frontage, one (1) access point may be permitted;

~~(~~B~~)~~ ~~f~~For lots with ~~a frontage of~~ two hundred (200) feet or more of unrestricted frontage, one (1) access point for every two hundred (200) feet of unrestricted frontage ~~will~~ may be permitted.

C ~~Driveway spacing will be in accordance with subsection (7) below, if applicable~~. All lots proposed for commercial, development in the ETJ or in "NC," "O," and "C" zoning districts with less than four hundred (400) feet fronting an arterial street shall provide for shared cross access with adjacent lots fronting the arterial, by means of platted common access easement across the lot or recorded deed covenant providing common access across the lot with adjacent lot(s).

(4) **Additional Access Points.** The director of ~~planning and~~ development services (or the Texas Department of Transportation, or county authority, if appropriate) is authorized to permit additional access points under the following conditions:

(A) The additional land; and access points are necessary to ensure the property owner beneficial use of the land; and

(B) The resulting additional ingress and egress of vehicles will not seriously disrupt the flow of traffic on the thoroughfare.

(5) **Location of Access Points**. The specific location of access points will be determined by the director of ~~planning and~~ development services (or by the Texas Department of Transportation or county authority, if appropriate) at such time as a site plan is reviewed prior to the issuance of a building permit. The location shall be based on the following criteria:

(A) The location shall minimize conflicts with vehicle turning movements;

(B) The location shall be located as far as practicable from intersections; and

(C) The location shall be not less than fifty (50) feet from another driveway location.

If this standard is not possible, based upon the frontage of the property, the location shall be directed as far as practicable from the other driveway locations. Driveways along an arterial within four hundred (400) feet of a major intersection, such as the intersection of two (2) arterial streets or the intersection of a collector and an arterial street, may be restricted to right turn movements.

(D) Not located within an auxiliary lane.

(6) **Driveway Throat or Vehicle Storage Length.** For purposes of this subsection, "throat length" means the length of extending from the entry into the site at the property line, to the first conflict or intersection with a parking aisle. Vehicle storage length means the length of a driveway, service lane, bay, or other passageway for motor vehicles which is designed to minimize queuing onto surrounding streets. Throat length shall be designed in accordance with the anticipated storage length for entering and exiting vehicles to prevent vehicles from backing into the flow of traffic on the public street or causing unsafe conflicts with on-site circulation. Throat length and vehicle storage length shall not be less than the standards set forth in Table 506-7 unless approved by the director of development services. These measures generally are acceptable for the principal and secondary access to a property and are not intended for minor driveways such as residential driveways serving less than four (4) homes, or a commercial/industrial driveway with less than four hundred (400) ADT, or forty (40) average peak hour volume of vehicles, not located on a major roadway (see note under Table 506-7) or thoroughfare. The throat length may be reduced to no less than twenty (20) feet measured from the outside of the right-of-way by the director of development services by administrative exception. Throat lengths of less than twenty (20) feet from the outside of the right-of-way may be only be approved in accordance with section 35-482.

Table 506-7
Minimum Driveway Throat Lengths for Collectors and Arterials*

Land Use	*Throat Length or Vehicle Storage Length*
Shopping Centers > 200,000 GLA or nonresidential developments > 400 PHT per driveway	Throat length two hundred (200) feet or as required by the TIA
Nonresidential development between 200 and 400 PHT per driveway	Throat length seventy-five (75) feet or as required by the TIA

Nonresidential development less than 200 PHT per driveway or other major driveways not otherwise enumerated in this table	Throat length forty-foot minimum
Residential subdivision entryway (Private, gated entries)	Poisson distributed probability model at a ninety-five (95) percent confidence level. In addition, the subdivider shall provide for vehicle turnaround capability based on the single unit design vehicle as provided in the AASHTO Green Book, or latest revision thereof. The minimum entryway vehicle storage length shall be forty (40) feet measured from the call box to the public right-of-way. See Figure 506-11
Single-lane drive-in banks	Sufficient to accommodate minimum queue of six (6) vehicles
Drive-in banks with more than one (1) lane	Sufficient to accommodate minimum queue of four (4) vehicles per service lane
Single-lane drive-through car washes	Sufficient to accommodate minimum queue of twelve (12) vehicles
Automatic or self-serve car washes with more than one (1) bay	Vehicle storage of sixty (60) feet per bay
Fast-food restaurants with drive-through window service	Sufficient to accommodate minimum queue of eight (8) vehicles per service lane
Gasoline service stations with pump islands perpendicular to the pavement edge	Minimum thirty-five (35) feet between pump islands and right-of-way
Dry-cleaning establishments with drive-through window service	Sufficient to accommodate minimum queue of three (3) vehicles

* Note: May include local B roadways with traffic volumes above eight thousand (8,000) vpd where a major driveway (over 40 PHT) is being proposed that would affect exterior traffic.

Commentary: The throat lengths in Table 506-7 are provided to assure adequate stacking space within driveways for general land use intensities. This helps prevent vehicles from stacking into the thoroughfare as they attempt to access the site. High traffic generators, such as large shopping plazas, need much greater throat length than smaller developments or those with unsignalized driveways. These standards refer to the primary access drive.

(7) **Spacing and Location on Major Thoroughfares.** This subsection applies to driveway approach spacing and location along or adjacent to major thoroughfares.

A. Where a traffic impact analysis is required, driveways shall be spaced in such a manner as to avoid reducing the traffic LOS below that established in the section 35-502 traffic impact analysis. A subdivision of land into two (2) or more lots fronting a major thoroughfare may not automatically increase the number of driveway approaches allowed over those allowed prior to the subdivision.

B. Along either side of any corner commercial or industrial property ~~the~~ a driveway approach~~es~~ when allowed shall be located so as to maintain a minimum distance from the corner of the intersecting roadways. The minimum distance from the corner to the intersecting roadway is referred to as corner clearance. Corner clearance is measured along the property line from the property line return or flare. Corner clearance shall be established on a plat by providing a one (1) foot vehicular non-access easement. The easement shall extend a minimum of:

i. one hundred twenty-five (125) feet; or

ii. ~~equal to~~ ninety (90) percent of the length of the property along the roadway upon which the proposed driveway approach is to be located and restricted to a right in/out driveway and cannot be located within the limits of the right turn deceleration or acceleration lanes~~, or one hundred twenty-five (125) feet, whichever distance is less. Corner clearance is measured along the property line from the property line return or flare~~.

iii. The corner clearance may be reduced by the director of development services to allow a driveway for development where a driveway may not otherwise be allowed.

(8) **Alignment.** Major driveway approaches, with peak hour trips greater than one hundred (100) pht, accessing major thoroughfares shall attempt to meet the following guidelines:

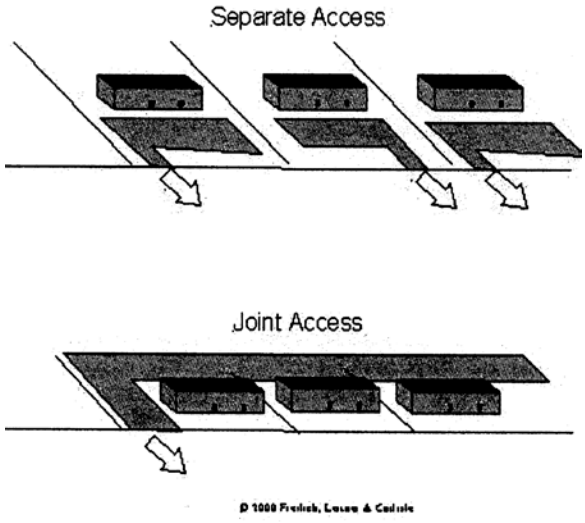

Figure 506-10

A. Align with opposing driveway approaches if any, or shall be offset by one hundred seventy-five (175) feet or more to provide adequate left turn storage capacity in advance of each driveway approach and to avoid the overlap of left turn lanes.

B. Shared among different property owners or users when necessary to maintain minimum spacing requirements.

C. Planned, when possible, to match existing openings in medians. In addition, no cuts through the left turn reservoir of a median shall be permitted in order to provide left turn movements for driveway approaches accessing major thoroughfares or median divided roadways.

(9) **Parking Approaches**. For minor driveways, parking aisles shall be located a minimum of twenty (20) feet from the intersection of the driveway approach and the thoroughfare property line.

(10) **Driveway Approaches.** Driveway approach materials may be asphalt, concrete or other materials as approved by the development services director. Inside the city limits or when a curb is provided in the ETJ, ~~R~~residential driveway approaches materials shall be concrete. Both residential and commercial driveway approaches shall conform to the latest edition of the City of San Antonio Sidewalk and Driveway Design and Construction Guidelines compiled by the department of public works. Commercial two-way driveways and residential driveway approaches may have a width greater than that specified by the guideline if approved by the development services director.

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Sec. 35-350. – "QD" Quarry District.

*** * * * ***

(c) **Operating Standards.** It is the intent of these regulations to allow the existence of quarrying and processing operations which are sensitive to surrounding land uses and cognizant of the concerns of neighborhood interest and environmental interest with respect to protecting quality of life and ensuring protection of the environment. As such, the following operating standards are established to allow the quarry and processing operations to be carried out in a manner that is as compatible as possible with the surrounding land uses. All quarrying, processing, and related operations that are not the subject of nonconforming rights and that are performed in a quarry district "QD" shall be done and shall operate in conformance with the standards set forth in each applicable subsection below.

(1) **Frontage Requirements.** All property within a "QD" shall have a minimum of sixty (60) feet of frontage on an adjacent public right-of-way or recorded easement, at least sixty (60) feet in width, which provides ingress or egress to public roads. Regardless of the frontage provided onto a public road a district shall comply with the provision of subsection (7), clear vision and queuing, below.

(2) **Natural Buffer.** A natural area shall be maintained around the perimeter of the property within the district and no grading, removal, or disturbance of native plant material shall be allowed within fifty-five (55) feet of any perimeter property line of the property within the district or public right-of-way, except that such natural area shall not be required where the property owner adjacent to the perimeter of the property within the district grants a recorded irrevocable easement for non-development on such adjacent property equal to the buffer area that would otherwise be required. ~~except~~ Such easements may contain, as required, ~~for establishing required~~ berms and fencing and ~~for~~ an eighteen-foot-wide access road for the purpose of establishing and maintaining fencing, landscaping, access and/or security patrol.

(3) **Screening Requirements.** Notwithstanding subsection (2) above, visual screening shall be required at any point where the active quarry pit is located within one hundred (100) feet of a public right-of-way carrying pedestrian or vehicular traffic. The visual screen in such areas shall not be less than six (6) feet in height at or near the property line and shall be made up of any combination of the following materials: existing native plant materials, supplementary plant materials, existing grading, berming, and/or fencing.

(4) **Fencing Requirements.** A fence shall be provided around the perimeter of the property or not less than twenty-five (25) feet from the outer edge of any excavation that is ten (10) feet or greater in depth.

(5) **Excavation Setbacks.** No excavation or extraction of material, other than is required for the installation and maintenance of fences, landscape screen, access points, crossings, or clear vision zones at entry points, shall be permitted closer than fifty-five (55) feet from the property line of any property adjoining the property located in the district that has been zoned for single-family residential use at the time such excavation or extraction has begun, or closer than fifty-five (55) feet from any public right-of-way, unless and except for any point at which a quarry or quarrying operations cross said public right-of-way. Such crossing shall not exceed the width limitations established by the governmental authority having jurisdiction of the applicable right-of-way. Due to the unique nature of quarries and their related operations, article V, division 3 of this chapter shall not apply within a "QD."

(6) **Facility Setbacks.** All facilities for the production of finished products that are made from excavated materials (i.e., ready-mix concrete batch plants, lime plants, cement plants, concrete block plants, cement packaging plants, precast and prestressed yards, concrete pipe plants, and other similar facilities), which are constructed or installed after the effective date of this section, shall be located at least one hundred (100) feet from the property line of any adjoining property that is developed and/or zoned for residential uses at the time the facilities are constructed or installed, and at least fifty-five (55) feet from any public right-of-way on which pedestrian or vehicular access is allowed except for at points of crossing said right-of-way.

(7) **Clear Vision and Queuing Requirements.** A triangular clear vision zone shall be provided at the intersection of all access points with public roads to provide an area of clear vision for vehicles. The zone shall be defined by a triangle consisting of three hundred (300) feet parallel with the public road and fifty (50) feet along the access road or drive measured from the intersection point of the two (2) rights-of-way. A queuing area sufficient to accommodate four (4) or more trucks of no less than two thousand four hundred (2,400) square feet shall be provided between the edge of the public right-of-way and the access point or gate station, whichever is nearest the public right-of-way.

(8) **Floodplain Protection.** No building may be placed or excavation be conducted within one hundred fifty (150) feet from the outer limit of a 100-year floodplain. All NPDES and TEQC requirements must be met any time the quarry operations come within one hundred fifty (150) feet of a 100-year floodplain to prohibit silt or sediment from entering the creek or stream. These restrictions will not apply in any case where the floodplain is located more than one hundred fifty (150) feet inside the property line of the "QD." The buffer required by this provision shall in no case be wider than one hundred fifty (150) feet from the boundary line of the "QD."

(9) **Water Quality Protection.** Operations within a "QD" shall comply with applicable water quality standards set forth in chapter 34 of the City Code.

(10) **Industrial Waste Monitoring.** Upon request of the city fire department and/or solid waste management department, any person operating an activity within a "QD" shall provide, to the requesting agency's satisfaction, documentation evidencing the characterization, handling, and disposal of any industrial waste generated within the "QD." Documentation which will satisfy the characterization inquiry includes process knowledge literature and/or waste analysis records.

(11) **Material Safety Data.** Upon request of the city fire department, independent of the Federal Emergency Planning and Community Right to Know Act (EPCRA), any person operating an activity within a "QD" shall provide copies of material safety data sheets (MSDS) for material maintained, stored, or used within the "QD." The materials, subject of this section, are those materials whose properties for volatility, flammability, explosive potential, corrosiveness, radioactivity, or other toxic or hazardous property allow them to be listed in the North American Emergency Response Guidebook, current edition and as amended.

(12) **Blasting Setback.** Blasting shall not be allowed within three hundred (300) feet of a residential structure under construction or completed at the time the "QD" is established. This requirement shall not apply in any case were the owner of such a residential structure has consented in writing to blasting occurring within less than three hundred (300) feet of the structure.

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Sec. 35-506. – Transportation and Street Design

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(d) **Cross-Section and Construction Standards.**

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Table 506-3
Conventional Street Design Standards

Street Type	Marginal Access	Alley	Access to Conservation Subdivision	Local Type A	Local Type B	Collector	Secondary Arterial[1]	Primary Arterial[2]
****								
Planting Strips or Sidewalk Buffer[12]	NR	NR	NR	NR	3' Min.	3' Min.	3' Min.	3' Min.

Notes and Rules of Interpretation:

* * * * *

[12] Stamped concrete, painted buffer, or other permeable material as shown on the approved city detail, may be used to satisfy the sidewalk buffer width requirement. Alternative materials may be approved by the Director of TCI.

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Table 506-4
Traditional Street Design Standards

Street Type	Trail	Alley	Lane	Local	Avenue	Main Street	Boulevard	Parkway
****								
Planting Strips or Sidewalk Buffer[8]	NR	NR	6'	6'	6'	City Option	6—11'	7—20'

Notes and Rules of Interpretation:

* * * * *

[8] Stamped concrete, painted buffer, or other permeable material as shown on the approved city detail, may be used to satisfy the sidewalk buffer width requirement. Alternative materials may be approved by the Director of TCI.

* * * * *

(4) **Bicycle Facilities**. Bike ~~paths~~ facilities, when required within the city limits, may be constructed with development of the abutting property at the time building permit acquired.

When identified on the city council approved bike ~~facilities~~ master plan roadways requiring bicycle facilities shall be constructed in accordance with the American Association of State Highway and Transportation Officials "Guide for the Development of Bicycle Facilities~~.~~" with additional guidance from the National Association of City Transportation Officials (NACTO) Urban Bikeway Design Guide.

* * * * *

(i) **Street Lights.**

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(2) In subdivisions ~~within the "RP" or "RE"~~ in residential zoning districts, which do not exceed ~~two (2)~~ one (1) dwelling unit~~s~~ per acre, the director of ~~planning and~~ development services may waive the requirement for streetlights for public street intersections or mid-block areas where he finds that the area does not require such lighting for safe pedestrian or vehicular traffic.

* * * * *

(q) **Sidewalk Standards**

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(3) **Planting Strips** or Sidewalk Buffer**.** When required by Table 506-3 or 506-4 above sidewalks shall be defined by placing a planted strip or sidewalk buffer of not less than three (3) feet between the back of the curb (BOC) and the street edge of the sidewalk.

(4) **Performance Agreement and Time of Construction.**

A. All sidewalks shall be included as part of the performance agreement required by section 35-437 of this chapter with exception to sidewalks along Local A type street frontage of single family residential lots within the city limits for which building permits will be required. All sidewalks within a single family residential subdivision must be completed when ninety-five (95) percent of the lots within the subdivision are built out, excluding lots for which a building permit is pending.

B. Sidewalks shall be constructed within five years of the abutting roadway construction except as specified in section A above. If roadway construction is not required prior to the issuance of building permits for lots within the City and prior to building construction for lots located outside the City, then the sidewalks shall be constructed prior to building occupancy.

* * * * *

(t) **Traffic Calming.** The purpose of this section, is to protect the public health, safety and general welfare by ensuring that speeds on local streets are suitable for their intended purpose. The city hereby finds and determines that long blocks, wide street cross sections and uninterrupted traffic flows can encourage speeding on local and collector streets. Accordingly, these design standards will slow traffic on local streets while allowing flexibility in design and offering applicants the choice of treatment that works best for the streets in a proposed development.

(1) **Applicability**. The provisions of this subsection shall apply to local and collector streets when any traffic control devices are proposed and shall be approved by both the city and the county when located in the ETJ.

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Sec. 35-506. - Transportation and Street Design.

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(a) **Applicability.**

* * * * *

(3) **Variance.** A variance to the requirements of this section may be granted by the planning commission if the commission finds that there are special circumstances or conditions, unique to the land involved, such that strict application of these requirements would be unreasonable and the granting of the variance would not be detrimental to the public health, safety, or welfare. No variance shall be granted that reduces the number of traffic lanes or waives the construction of any traffic lane required by the major thoroughfare plan unless constructing the lanes exceeds the Roughly Proportionate Determination amount established under 35-501(b). Application for a variance shall be submitted in writing to the development services director accompanied by the variance fee specified in Appendix "C" to this chapter and an eight and one-half by eleven (8½ × 11) inch site plan indicating the location of the variance request and the location of existing sidewalks and curbs within a two thousand-foot radius.

(b) **Improvements Required.**

* * * * *

(2) **Street Layout.** The arrangement, character, extent, width, grade and location of all streets shall conform to the master plan and the major thoroughfare plan and shall be considered in their relation to existing and planned streets, to topographical conditions, to public safety and convenience, and in their appropriate relation to the proposed uses of the land to be served by such streets. The street layout shall be devised for the most advantageous development of the entire neighborhood or regional development.

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Sec. 35-506. - Transportation and Street Design.

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(d) Cross-Section and Construction Standards.

(1) **Streets.**

A. Tables 506-3 and 506-4 provide the standards for all existing and future streets.

B. The subdivider shall dedicate and construct all interior streets within the subdivision plat and shall provide dedication and construction for exterior streets based upon tables 506-3 and 506-4.

C. The director of ~~planning and~~ development services shall include the dedication and construction of rights-of-way for exterior streets in the roughly proportionate determination as described in subsection 35-501(b).

Table 506-3
Conventional Street Design Standards

Street Type	Marginal Access	Alley	Access to Conservation Subdivision	Local Type A	Local Type B	Collector	Secondary Arterial[1]	Primary Arterial[2]
R.O.W. (min.)[1, 2, 10]	36'	24'	34'	50'	60'	70—90'	86—110'	120'[11]
Pavement Width	26'	18—24'	24'[7]	28' -34'	40'	44—55'	48—81'	48—81'
Design Speed (mph)	30	20	30	30	30—35	40—45	45	45
Grade (max.)[3] ICL	12%	12%	12%	12%	12%	7%	5%	5%
Grade (max.)[3] ETJ	10%	10%	10%	10%	10%	7%	5%	5%
Grade (min.)[4]	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Centerline Radius (min.)	100'	50'	100'	100'	100'	400'	700'	1,200'
Curb	NR	NR	NR	Yes	Yes	Yes	Yes	Yes

Median	NR	NR	NR	NR	NR	NR	16' min.	16' min.
Sidewalk Width (see subsection (q)(5))[5]	NR	NR	4/6[8] one side only	4'[8]	4[8] /6[9]	4[8] /6[9]	4[8] /6[9]	4[8] /6[9]
Bicycle Facilities[5, 6]	NR	NR	NR	NR	NR	Yes[5]	Yes [5]	Yes [5]
Streetscape Planting	NR	NR	NR	NR	NR	Yes	Yes	Yes
Planting Strips[9, 12]	NR	NR	NR	NR	3' Min.	3' Min.	3' Min	3' Min.

Notes and Rules of Interpretation:

NR designates the item is "not required."

ICL designates inside city limits.

ETJ designates within the extraterritorial jurisdiction Table 506-3 is required for conventional option subdivisions (see section 35-202) or subdivisions not subject to Table 506-4, below, except for access to conservation subdivision (section 35-203).

[1]For secondary arterial type B streets the minimum width of right-of-way shall be 70 feet and at intersections with other major arterials on the major thoroughfare plan 86 feet to 110 feet as determined by the director of development services.

[2]For primary arterial type B streets the minimum width of right-of-way shall be 70 feet and at intersections with other major arterials illustrated on the major thoroughfare plan the right-of way shall be 86 feet to 120 feet subject to the findings of the TIA as determined by the director of ~~planning and~~ development services.

[3]Refer to 35-506(d)(3) for grades exceeding maximum values specified in the table.

[4]0.4% Optional with concrete curb and gutter.

[5]Bicycle path and sidewalks can be combined. See subsection 35-506(d)(4).

[6]When designated on bicycle master plan as approved by city council.

[7]Entry portion without parking.

[8]In residential areas sidewalks shall be located to provide improved safety, to improve walkway intersection alignment and to reduce sidewalk conflicts with utility poles and mail boxes.

[9]Sidewalks shall be four (4) foot in width with a planting strip or six (6) foot in width without a planting strip. Sidewalks may be four (4) foot in width without a planting strip when houses are fronting on a Local Type B street.

[10]R.O.W. width and construction design of state maintained streets and certain inner-city streets and certain primary arterials (approved by city council ordinance) pertaining to R.O.W. dedication and design standards within the CRAG area boundary shall take precedence over the standard UDC street R.O.W. and design provisions outlined in Table 506-3 above.

[11]120 feet is the maximum right-of-way width but may be varied in accordance with the adopted major thoroughfare plan.

[12]Meandering sidewalks may have up to twenty five percent (25%) of the total block length of the sidewalk within the minimum planting strip area. This does not apply to multi-use or bicycle facilities.

Sec. 35-506. - Transportation and Street Design.

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(d) Cross-Section and Construction Standards.

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Table 506-4
Traditional Street Design Standards

Street Type	Trail	Alley	Lane	Local	Avenue	Main Street	Boulevard	Parkway
R.O.W. (min.)	14'	20'	38'	48'	82'	58'	124'	86'
Pavement Width[1]	8'—14'	10'—12'	16'—18'	22'—27'	27'—48'	28'—36'	44'—70'	44'+
Design Speed (mph)	N/A	20	30	30	35	40	45	45
Grade (max.) Grade (min.)[4]	Follow AAS HTO	10% 0.5%	10% 0.5%	10% 0.5%	7% 0.5%	7% 0.5%	5% 0.5%	5% 0.5%
Curb Radius	N/A	15'	15'	15'	25'	25'	25'	25'
Centerline Radius[2]	95'	50'	90'	90'	250'	300'	500'	1,000'
Curb	NR	NR	Yes	Yes	Yes	Yes	Yes	NR
Median	NR	NR	NR	NR	16' min.	NR	16' min.	16' min.
Sidewalk Width (see subsection (q)(5))[5]	NR	NR	4'[7]/6'[7]	4'[7]/6'[7]	4'[7]/6'[7]	4'[7]/6'[7]	4'[7]/6'[7]	4'[7]/6'[7]
Bicycle facilities[3, 6]	NR	NR	NR	NR	Yes	Yes	Yes	Yes Path
Streetscape Planting	Yes	NR	Yes	Yes	Yes	Yes	Yes	Yes
Planting Strips	NR	NR	6'	6'	6'	City	6—11'	7—20'

						Option		

Notes and Rules of Interpretation:

NR designates the item is "not required."

R.O.W. width and construction design of state maintained streets and certain inner-city streets and certain primary arterials (approved by city council ordinance) pertaining to R.O.W. dedication and design standards within the CRAG area boundary shall take precedence over the standard UDC street R.O.W. and design provisions outlined in Table 506-4 above.

Table 506-4 applies only to the following development options: Commercial Center (section 35-204), Commercial Retrofit (section 35-206), Traditional Neighborhood development (section 35-207), and Transit-oriented development (section 35-208), except as provided in footnote 5, below.

[1]~~See Table 506-4A below. The smaller street width with on-street parking prohibited, or the larger street width coupled with on-street parking on one (1) or both sides of the street, may be provided if the adjoining buildings are provided with (1) an NFPA 13D fire sprinkler system for Single-Family Dwelling Units, One Family Attached Dwelling Units, Two Family (Duplex) Dwelling Units, Two Family Attached Dwelling Units; (2) an NFPA 13R fire sprinkler system for Multi-Family buildings; or (3) an NFPA 13 fire sprinkler system for Commercial Building.~~

[2]Lesser radius can be approved by the director of development services.

[3]Bike path and sidewalks can be combined. See subsection 35-506(d)(4).

[4]Optional 0.4% with concrete curb and gutter.

[5]Any provision in Table 506-3 (entitled "conventional street design standards") notwithstanding, interior streets in a subdivision that would otherwise be required to comply with the provisions of Table 506-3 may instead comply with the provisions of Table 506-4 (entitled "traditional street design standards"), regarding pavement width requirements only, provided that the connectivity ratio (see subsection (e), below and subsection 35-207(g) of this chapter) shall comply with the requirements for a Traditional Neighborhood development. The proposed development shall comply with footnote 1 hereto. Pursuant hereto, street types in such subdivisions shall comply with Table 506-4 as follows: An Alley shall be required to meet the street width standards for an Alley as provided in Table 506-4; a Conservation Access street shall be required to meet the street width standards for a Lane; a Local Type A street shall be required to meet the street width standards for a street; a Local Type B street shall be required to meet the street width standards for an Avenue; a Collector street shall be required to meet the street width standards for a Main street; a Secondary Arterial shall be required to meet the street width standards for a Boulevard; and Primary Arterial shall be required to meet the street width standards for a Parkway.

[6]When designated on bicycle master plan as approved by city council.

[7]Sidewalks shall be four (4) foot in width with a three (3) foot planting strip or six (6) foot in width without a planting strip. Sidewalks may be four (4) foot in width without a planting strip when houses are fronting on an Avenue.

Table 506-4A
Street Width Options for Traditional Street Design Standards

Street Type	A	B	C	D~~E~~	E~~F~~	F~~G~~	G~~H~~
	Street Width	Parking	Directional	Alleys	Max. Block	Connections	Turning Radius
Lane	18'	None	1-Way	No	300'	27'	25—50'
Local	24'	1 Side	2-Way	Yes	35-207(f)	NR	25—50'
Local	27'	Both Sides	2-Way	No	35-207(f)	NR	25—50'
Lane	16'	None	1-Way	Yes	35-207(f)	NR	25—50'
Lane	18'	None	2-Way	Yes	35-207(f)	NR	25—50'
Lane	18'	1-Side	1-Way	Yes	35-207(f)	NR	25—50'
Local	22'	None	2-Way	Yes	35-207(f)	NR	25—50'
Local	22'	1-Side	2-Way	Yes	35-207(f)	NR	25—50'
Local	25'	Both Sides	2-Way	Yes	35-207(f)	NR	25—50'
Local	26'	Both Sides	2-Way	Yes	35-207(f)	NR	25—50'

Notes and rules of interpretation:

R.O.W. width and construction design of state maintained streets and certain inner-city streets and certain primary arterials (approved by city council ordinance) pertaining to R.O.W. dedication and design standards within the CRAG area boundary shall take precedence over the standard UDC street R.O.W. and design provisions outlined in Table 506-4A above.

Column A (Street Width) refers to the width of the street from curb face to curb face.

Column B (Parking) indicates whether on-street parking is permitted, whether on both sides or only one (1) side of the street.

Column C (Directional) refers to the directional flow of traffic.

~~Column D (Fire Sprinklers) refers to whether fire sprinklers are required. See footnote 1 of Table 506-4, above~~.

Column D~~E~~ (Alleys) indicates whether alleys are required. Alleys are permitted for any street classification.

Column E~~F~~ (Max. Block) refers to the maximum block length. Maximum block length is not subject to an administrative exception (see subsections 35-501(b) and 35-207(f) of this chapter).

Column F~~G~~ (Connections) indicates the width of streets connecting to the street from intersection to intersection. The connecting street must be located at each end of the block. "NR" means that a connecting street of minimum width is not required.

Column G~~H~~ (Turning Radius) refers to the minimum inside and outside turning radii (see "Figure 506-1 Turning Radius Design," below).

This diagram below provides the minimum turning radius for a pumper truck. The minimum inside radius is 25' and the minimum outside radius is 50'.

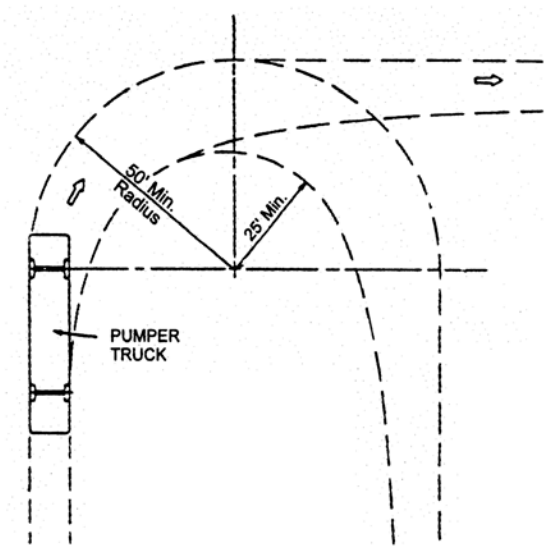

Figure 506-1

Turning Radius Design

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Sec. 35-506. - Transportation and Street Design.

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(d) Cross-Section and Construction Standards.

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Table 506-4A.1
Enhanced Street Design Standards

	Enhanced Local B	Modified Collector	Rural Roadway	Enhanced Secondary Arterial	Enhanced Primary Arterial	Super Arterial Type A	Super Arterial Type B
R.O.W. (min.)	60'	86' – 110'	120'	120'—142'	144'—166'	200—250'	200'—250'
Pavement Width	44'	48'	24'—36'	48'—84'	72'—120'	44'—136'	48'—136'
Design Speed (mph)	40	45	40'—45'	45'	45'	45'—55'	45'—55'
Grade (max) [3]	7%	7%	5%	5%	5%	5%	5%
Grade (min.)	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Centerline Radius (min.)	700'	700'	700'	700'	1200'	1200'	1200'
Curb	Yes	Yes	NR	Yes	Yes	Yes	Yes
Shoulder Width (min.)	NR	NR	8' on each side	NR	NR	10' on each side for outside lanes, 4' on each side for inside lane (without curb)	10' on each side for outside lanes, 4' on each side for inside lane

							(without curb)
Median Width (min.)	16’	16’	NR	6'—18'	6'—28'	48'	48'
Sidewalk Width, min. (see subsection (q)(5))[5]	4[8] /6[9]	4[8] /6[9]	NR	10'	10'	NR	NR
Bicycle facilities[5,6]	NR	Yes	NR	Yes	Yes	NR	NR
Streetscape Planting	NR	Yes	NR	Yes	Yes	NR	NR
Planting strips width (min.)[9, 12]	3’	3’	NR	~~4~~3'	~~4~~3'	NR	NR
Drainage & clear zone	NR	NR	68'—80'	NR	NR	NR	NR

Notes and Rules of Interpretation:
See notes and rules of interpretation for Table 506-3

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Sec. 35-506. - Transportation and Street Design.

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(d) **Cross-Section and Construction Standards.**

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(12) **Design Speed.**

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B. **Special Considerations.** The following minimum design speeds shall be used for the following street types or specified condition:

1. Local Type B:

   i. If houses are fronting this street, the design speed shall be thirty (30) miles per hour.

   ii. If no houses are fronting this street, the design speed shall be thirty-five (35) miles per hour.

   iii. If street has a median, the design speed shall be forty (40) miles per hour.

2. Collector:

   i. If street has a ~~raised~~ median, the design speed shall be forty-five (45) miles per hour.

   ii. If street does not have a ~~raised~~ median, the design speed shall be forty (40) miles per hour.

3. Turn bay design. Turn bays shall be designed in accordance with the TxDOT design manual for the minimum taper and storage lengths. The deceleration length shall be determined using one of the following:

   i. Using a differential speed of twenty (20) miles per hour from the street's design speed if using the TxDOT Design Manual tables; or

   ii. Using a differential speed of ten (10) miles per hour from the street's design speed if the stopping sight distance is calculated based on the design topographic conditions.

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Sec. 35-515. - Lot Layout Regulations.

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(b) **Blocks.**

* * * * *

(3) **Block and Street Length.**

A. **Block Length.** The length of a block where homes front a street within a subdivision or site plan shall be measured from the edge of the property line of the street siding the furthest lot of the block width or to the center of a cul-de-sac, 90° Elbow, or 90° Knuckle.

(i) A street's block length shall not exceed seven hundred (700) feet when the street is a:

- Local type B (with houses fronting),
- Local type A which serves as an entrance street to the proposed neighborhood, or
- Part of a TND use pattern (see subsection 35-207(f)).

(ii) A street's block length shall not exceed one thousand two hundred (1,200) feet when the street is a:

- Block that ends with a cul-de-sac
- Local type A

(iii) Block lengths do not apply to the following unless they transition into a street with houses fronting:

- Local type B
- Collectors or avenues
- Secondary arterials or main streets
- Primary arterials or boulevards
- Freeways or parkways

(iv) In the ETJ, dead end streets or streets with no outlet exceeding seven hundred fifty (750) feet shall provide a fire apparatus turnaround with a spacing not to exceed 750 feet. This provision shall also apply to phased street construction when a street outlet has not been constructed.

B. **Street Length.** The maximum overall length of streets with homes fronting shall not exceed three thousand (3,000) feet. The overall street length shall be measured from the center of the two furthest intersecting streets or from its intersection with a higher tier street whichever is less. There is no limit to the street length of a street without home fronting.

C. Maximum street or block lengths, except subsection 35-515(b)(3)(A)(i), may be exceeded in accordance with subsection 35-506(~~t~~s) of this chapter.

(c) **Lots.**

* * * * *

(4) **Frontage**. All lots shall front on a public or private street or platted irrevocable ingress/egress easement and shall have a minimum frontage width as indicated in section 35-310. ~~Where a platted irrevocable ingress/egress easement is utilized for frontage, the private street provisions of section 35-506 for street name and design standards shall be met. Neither the use of an irrevocable ingress/egress easement nor use of a private street shall be allowed to satisfy the major thoroughfare plan requirements.~~ Frontage of a lot shall be determined by the property line of the lot adjacent to the right-of-way of the street upon which the property's address is based. Single-family residential lots shall not front on a collector street, arterial street, or parkway except as specified under subsection 35-506(r)(2). On irregular shaped lots, a minimum street frontage of fifteen (15) feet shall be required. ~~Single-family residential lots shall not front on a collector street, arterial street, or parkway except as specified under subsection 35-506(r)(2).~~ An "irregular shaped lot" includes any lot located on a cul-de-sac or adjoining a curved section of a roadway with a centerline radius of less than two hundred (200) feet. Where a platted irrevocable ingress/egress easement is utilized for frontage, the private street provisions of section 35-506 for street name and design standards shall be met. When a platted irrevocable ingress/egress easement is utilized for frontage, the following plat note shall be prominently displayed: "No structure, fences, walls, or other obstructions shall be placed within the limits of the ingress/egress easement shown on this plat." Neither the use of an irrevocable ingress/egress easement nor use of a private street shall be allowed to satisfy the major thoroughfare plan requirements.

* * * * *

(h) **Flag Lots.**

(1) Not more than the following number of flag lots may be authorized to allow for the more efficient use of irregularly shaped parcels of land, or where the integrated nature of multiple buildings on a site dictates the need for such lots. Flag lots may be used to better use irregularly shaped properties or sites with physical limitations. Flag lots shall not be permitted where they will increase the number of lots that take their access from collector or arterial streets. Table 310-1 and/or section 35-

353 are superseded by the development standards of this section when applied to flag lots as follows:

Table 515-2
Maximum Number of Flag Lots

Size of Subdivision	Maximum Number or Percentage (%) of Flag Lots
10 or fewer lots	2 lots
11—50	20%
51 or more	20%

(2) The minimum driveway width shall be ten (10) feet.

(3) Notwithstanding the provisions above, access to not more than four (4) lots may be provided by a shared driveway.

(4) The minimum frontage at the right-of-way line for any flag lot shall be ~~equal to the minimum required driveway width plus four (4)~~fifteen (15) feet. The flag pole portion of the lot shall not be considered in determining the area of the lot related to on-site sewage facility suitability.

(5) On flag lots the maximum front setback line shall be measured from the nearest point at which the lot meets the minimum width (as required in Table 35-310-1) parallel to the street on which the lot fronts.

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Sec. 35-B101. - Specifications for Documents to be Submitted.

* * * * *

(c) Information Required. No application for development approval shall be accepted unless the following information and data required is included. The required information and data is set forth in Table B-1, below, and any specific regulations set forth in section 35-B102 et seq. An asterisk (*) indicates that the item listed in the row heading is required for the item listed in the column heading.

TABLE B101-1

	A	B	C	D	E	F	G
	(A) Material/Information	Master Development Plan	PUD Plan	Major Plat Application	Minor Plat Application	Development Plat Application	Specific Use Authorization
E.	PROPERTY SURVEY AND TOPOGRAPHIC						
	(6) Existing topography with maximum contour interval of ten (10) feet when ground slope exceeds ten (10) percent; two (2) feet for slopes between five (5) percent and up to ten (10) percent, ~~except~~ and where existing ground is on a slope of less than five (5) percent then either one (1) foot contours or spot elevations shall be provided where necessary.		*	*	*		
F.	PLANNING						
	(28) An exhibit indicating the area of			*	*		

	each lot in square feet for all single-family lots (gross and net (excluding easements, flag poles)) using on-site sewage (septic tank) disposal						
G.	DESIGN						
	(17) Location and size in acres of school sites, amenity center areas, or non-single family lots as applicable.	*	*	*	*		
	(20) Signage, Pavement Markings, Street, alley and cross walkway plans (section 35-B120)			*			

*1. Specific use permits shall only require a stormwater management plan when the site is located over the Edwards Recharge Zone (ERZD).

* * * * *

Sec. 35-B120. – Signage, Pavement Markings, Street, Alley, and Cross Walkway Plans.

(a) **Number of Copies**. The applicant shall provide three (3) sets of construction plans and two (2) sets of the pavement design report.

(b) **Format**. Construction plans shall be twenty-four by thirty-six (24 x 36) inches with a margin of two and one-half (2½) inches on the left side of the sheet, and appropriate margins on the other three (3) sides. Construction plans shall be drawn at a scale of one (1) inch equal to fifty (50) feet.

Where more than one (1) sheet is necessary to accommodate the entire area to be subdivided, an index sheet showing the entire subdivision at an appropriate scale shall be attached to the plat.

(c) **Contents**. The plans and profiles for street, alley, cross walkway and drainage easement improvements submitted shall include the following information:

(1) Typical sections showing the proposed pavement width, type, thickness and crown; the proposed curb and gutter type, location in relation to center line and exposure; the

proposed parkway grading slopes; the proposed locations and type of wheelchair ramps; location of traffic signal conduit; and construction details of all drainage including dimensions, reinforcing and components such as grates and manhole covers. The information shall be given for each different type of streets and alleys in the subdivision.

(2) Alignment of each street, alley, cross walkway and drainage easement showing a beginning and ending station; each deflection angle of the center line and the station of the point of intersection; the station of the point of curvature and the point of tangency of each curve; the station and angle of intersection of each intersection with another street, alley or drainage easement; the station and radius of each curb return; the location of adjacent right-of-way lines; location and station of city limit or county lines; the location and limits of sidewalks and curbs of each street; the location and size of existing trees to remain in ROW; the location of each drainage structure; the location and size of all storm sewers; and the length, width, and thickness of cement stabilized base.

(3) The top of curb grade at each curb end, each fifty-foot station and each end of each curb return; the center line grade at each end and at each fifty-foot station of alleys and drainage ditches; the gradient of each tangent grade and the location and length of each vertical curve; the direction of storm drainage flow at each intersection; the flow line elevations of each drainage structure; the flow line elevation of each storm sewer at each point of change of grade, each end, and the intervening gradients. The profiles of streets, alleys and drainage ditches shall show the natural ground at adjacent property lines and the proposed center line.

(4) Scale, north arrow, date and plat number of the associated plat. Plans and profiles shall be drawn to scales of one (1) inch equals fifty (50) feet horizontally and one (1) inch equals five (5) feet vertically, unless different scales are approved by the director of planning and development services.

(5) Signage and pavement marking plans shall show the locations of street signs, warning, and regulatory signs, pavement markings and raised pavement markers and provide a summary table listing sign types, pavement markings types, and pavement marker types using TMUTCD designations with quantities.

(6) All signage, pavement markings, street and alley plans and profiles shall bear the seal of a licensed professional engineer.

Sec. 35-B122. – Traffic Impact Analysis

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(b) Study level TIAs shall consist of the following:

* * * * *

(7) **Conclusions and Recommendations.**

A. A summary of the conclusions and recommendations for the transportation network required to serve the proposed development.

B. Identification of peak hour trip (PHT) levels that will trigger mitigation actions identified.

C. A statement that each subsequent TIA submitted for the proposed development will be compared to the results of the Study Level TIA to determine if the overall roadway network remains adequate to serve the proposed development.

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Sec. 35-B131. - Application for Plat Identification Number/Letters of Certification.

*** * * * ***

(b) **Data Required for Letters of Certification.** To obtain the required letters of certification, an applicant for plat approval shall submit the following data to the certifying agencies/departments. All data shall be annotated with the plat number of the associated plat.

* * * * *

(6) **Bexar County.**

A. Digital copy of plat.

B. Two (2) sets of storm water management plans.

C. Two (2) copies of TIA and disk of analysis.

D. Address plat.

E. If applicable, the following item(s):

1. Two (2) sets of utility plans.
2. One (1) copy of approved POADP, MDP, PUD.
3. Final Geotech report.
4. Three (3) sets of streets and drainage plans.
5. Two (2) copies of cost estimates streets and drainage.
6. One (1) digital copy of construction plans.
7. Site evaluation form with required soil analysis.
8. Water purveyor documentation/letter.
9. Plan showing the proposed on-site sewage facility (OSSF) on the property and supporting documents required under 30 TAC §285.4(c) detailing the site's suitability for on-site sewage facility systems.

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35-A101. Definitions and Rules of Interpretation.

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Comprehensive land use category. Land use categories designated in the comprehensive/master planning process. The following shall be the designated comprehensive land use categories for neighborhood, community and perimeter plans:

Low density residential estate - includes large lot singe-family detached houses on individual estate-sized lots or in conservation subdivisions. This form of development should be located away from major arterials, and can include certain nonresidential uses such as schools, places of worship, and parks that are centrally located for convenient neighborhood access. Permitted zoning districts: R-20, RE, RP and RD, as well as IDZ with uses and density permitted in R-20, RE, RP, and RD.

Low density residential - includes single-family detached houses on individual lots at typical suburban densities. This form of development should be located away from major arterials, and can include certain nonresidential uses such as schools, places of worship, and parks that are centrally located for convenient neighborhood access. Permitted zoning districts: R-5, R-6, NP-8, NP-10, NP-15, and UD, as well as IDZ with uses and density permitted in R-5, R-6, NP-8, NP-10, NP-15, and UD.

Medium density residential - accommodates a range of housing types including single-family attached and detached houses on individual lots, duplexes, triplexes, fourplexes, and low-rise, garden-style apartments with more than four (4) dwelling units per building. Cottage homes and very small lot single-family houses are also appropriate within this land use category. Detached and attached accessory dwelling units such as granny flats and garage apartments are allowed when located on the same lot as the principal residence. Certain nonresidential uses, such as schools, places of worship and parks, are appropriate within these areas and should be centrally located to provide easy accessibility. Permitted zoning districts: R-3, R-4, RM-4, RM-5, RM-6, MF-18 and UD, as well as IDZ with uses and density permitted in R-3, R-4, RM-4, RM-5, RM-6, MF-18 and UD.

High density residential - includes low-rise to mid-rise apartments with more than four (4) dwelling units per building. High density residential provides for compact development including apartments, condominiums and assisted living facilities. This form of development is typically located along or near major arterials or collectors. Certain nonresidential uses, such as schools, places of worship and parks, are appropriate within these areas and should be centrally located to provide easy accessibility. This classification may be used as a transitional buffer between lower density residential uses and nonresidential uses. High density residential uses should be located in a manner that does not route traffic through other, lower-density residential uses. Permitted zoning districts: MF-25, MF-33 and UD, as well as IDZ with density permitted in MF-25, MF-33, and UD.

Very high density residential - includes mid-rise to high-rise apartments with more than four dwelling units per building. Very high density residential provides for apartments, condominiums and assisted living facilities at urban densities. This form of development is typically located along or near high capacity roadways including major arterials and collectors. Parking areas should be contained in structured parking garages beneath apartments, wrapped by apartments, or placed to the rear of the lot. Very high density residential development should be located in close proximity to compact, pedestrian-oriented retail and service uses. This classification may be used as a transitional buffer between lower density residential uses and nonresidential uses. Very high density residential uses should be located in a manner that does not route traffic through other, lower density residential uses. Permitted zoning districts: MF-40, MF-50, and MF-65, as well as IDZ with density permitted in MF-40, MF-50 and MF-65.

Sec. 35-310.07. – "MF-18", "MF-25", "MF-33" , "MF-40", "MF-50" and "MF-65" Multi-Family"

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STATEMENT OF PURPOSE

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General Provisions. See subsection 35-517(d) relating to additional setback for building height increases. An increase of up to ten (10) percent of the allowable gross units per acre shall be permitted in the MF-40, MF-50 and MF-65 districts where ~~all~~ the minimum required on-site visitor and resident parking is provided in a structured parking garage in accordance with section35-384(c). When utilizing the provisions of this section for structured and non-structured parking, structured parking is not subject to the maximum parking requirements per Section 35-526(b)(5). Non-structured parking spaces are permitted but shall not exceed 20% of the minimum number of parking spaces.

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Sec. 35-421. - Zoning Amendments.

STATEMENT OF PURPOSE

The purpose of this section is to provide uniform procedures for the amendment of this chapter or the official zoning map by the city council whenever the public necessity, convenience, general welfare or good zoning practice so requires.

(a)

Applicability. The provisions of this section apply to any application for zoning of a tract, parcel or land area from one zoning district to another.

(b)

Initiation. All petitions, applications, recommendations or proposals for changes in the zoning district of property (referred to as a "rezoning") or for changes in the textual provisions of this chapter shall be filed with the zoning commission, and a pre-application conference is required for all applications prior to submittal of said applications. This conference must take place between the applicant and the zoning section of the development services department. Text amendments may be proposed by any person. A proposed rezoning may be initiated by:

(1)

The city council by resolution; or

(2)

An application properly signed and filed by the owner or, with the owner's specific written consent, a contract purchaser or owner's agent of a property included within the boundaries of a proposed rezoning, unless otherwise provided for by this chapter.[3][1] When an amendment is initiated, an application for such amendment shall be submitted to the director. The applicant may file an application for subdivision plat approval concurrent with an application for a rezoning.

(3)

The director of development services pursuant to an annexation service plan or to correct an administrative error in the rezoning of a tract of land pursuant to this chapter.

(c)

Completeness Review. The director of development services shall conduct a completeness review as set forth in section 35-402 of this chapter within two (2) working days of application submittal. The appellate agency for purposes of completeness review (see subsection 35-402(c) of this chapter) shall be the zoning commission.

(d)

Consistency. For all applications for rezoning, the development services department, based on the information provided by the applicant, shall make a determination regarding consistency with the policies contained in the master plan of the city or if applicable the land use element of a neighborhood, community, or perimeter plan adopted pursuant to section 35-420 of this chapter, within five (5) working days.

(1)

If the development services department makes a determination that the requested rezoning is inconsistent with the master plan policies or the land use element of the applicable neighborhood, community or perimeter plan, then the application for rezoning shall not be deemed complete until a completed application for a master plan amendment is filed with the planning and community development department. The requested rezoning shall not be considered by the ~~zoning commission~~ City Council until the planning commission has considered the master plan amendment request.

(2)

If the development services department determines that the requested change is consistent with the master plan policies or the land use element of the applicable neighborhood, community or perimeter plan, then the zoning case may be deemed complete without an amendment to the master plan of the city.

(3)

The appellate agency for purposes of consistency determination shall be the planning commission.

Commentary: The master plan is the comprehensive plan for the physical development of the city, as prescribed in the City Charter. The master plan includes any unit or part of such plan separately adopted and any amendment to such plan or part thereof. Neighborhood, community and perimeter plans are components of the master plan.

Sec. 35-209. - Form Based Development.

GOALS AND OBJECTIVES

The purpose of these regulations is to enable, encourage and qualify the implementation of the following goals and objectives:

(1) The Regional Scale and Sector Principles.

A. That natural infrastructure and visual character derived from topography, woodlands, farmlands, riparian corridors and shorelines be retained.

B. That development non-contiguous to urban areas should be organized in the pattern of hamlets, villages, and regional centers.

C. That affordable housing shall be distributed throughout the region to match job opportunities and to avoid concentrations of poverty.

D. That transportation corridors shall be planned and reserved in coordination with land use.

E. That green corridors shall be used to define and connect the urbanized areas.

F. That the region shall include a framework of transit, pedestrian, and bicycle systems that provide alternatives to the automobile.

G. That the region will not allow gated communities.

(2) The Development Pattern Plan.

A. That hamlets, villages, and regional centers shall be compact, pedestrian-oriented and mixed-use.

B. That the simultaneous planning of adjacent parcels is a preferred development practice.

C. That villages and regional centers shall be the preferred pattern of development and that districts specializing in single-use should be the exception.

D. That ordinary activities of daily living shall occur within walking distance of most dwellings, allowing independence to those who do not drive.

E. That interconnected networks of thoroughfares shall be designed to disperse and reduce the length of automobile trips.

F. That within villages, a range of housing types and price levels shall be provided to accommodate diverse ages and incomes.

G. That building densities and land uses supportive of transit shall be provided within walking distance of transit stops and, similarly, appropriate transit options shall be available to support the intensity of land uses.

H. That civic, institutional, and commercial activity shall be mixed, not isolated in remote single-use complexes.

I. That schools shall be sized and located to enable children to walk or bicycle to them.

J. That a range of open space including parks, squares, and playgrounds shall be distributed within neighborhoods and urban center zones.

(3) The Block and the Building.

A. That buildings and landscaping shall contribute to the physical definition of thoroughfares as civic places.

B. That development shall adequately accommodate automobiles while respecting the pedestrian and the spatial form of public space.

C. That the design of streets and buildings shall reinforce safe environments, but not at the expense of accessibility.

D. That architecture and landscape design shall grow from local climate, topography, history, and building practice.

E. That buildings shall provide their inhabitants with a clear sense of geography and climate through energy efficient methods.

F. That civic buildings and public gathering places shall be provided at locations that reinforce community identity and support self-government.

G. That civic buildings shall be distinctive and appropriate to a role more important than the other buildings that constitute the fabric of the city.

H. That the preservation and renewal of historic buildings shall be facilitated to affirm the continuity and evolution of society.

(a) General to All Plans.

(1) Applicability.

A. This section shall be applicable to any zoning district boundary designated as Form Based Zoning (FBZ) within the city or to any master development pattern plan (MDPP) in the ETJ.

B. FBZ districts are FBZ-T1, FBZ-T2, FBZ-T3, FBZ-T4, FBZ-T5, and FBZ-T6, and are generally referred to as transect zones in this chapter.

C. Adopted form based master plans and associated transect zoning districts are referenced herein as follows:

1. Verano FBZD, December 6, 2007.

2. River North FBZD, April 1, 2010.

D. The Unified Development Code continues to be applicable to issues not covered by these regulations except where these would conflict with the form based use pattern, in which case the conflict shall be resolved in favor of the form based use pattern. The exceptions shall be that the FBZD and use pattern shall not supersede the requirements of the following districts:

1. Edwards Recharge Zone District (ERZD).

2. The River Improvement Overlay (RIO) District standards with the exception of the following sections: 35-338(c), 35-672(b)(1), 35-672(b)(2), 35-672(b)(3), 35-672(b)(4), 35-673(f)(3), 35-673(m), 35-674(b)(6), and 35-674(c). Maximum height standards are superseded by the form based use pattern standards provided that the project is in conformance with the RIO solar access requirements of subsection 35-673(a).
3. Military Airport Overlay Zone Districts (MAOZ).
4. Viewshed Protection Districts (VP).
5. Airport Hazard Overlay Districts (AHOD).

E. Terms used throughout these regulations shall take their commonly accepted meanings or as defined for the FBZD in the definitions subsection 35-209(g). In the event of conflicts between these definitions and Appendix A of the Unified Development Code, subsection 35-209(g) shall take precedence.

F. The definitions of terms contain regulatory language that is integral to these regulations.

G. Unless otherwise indicated, all section references in these regulations pertain to chapter 35 of the Code of Ordinances for San Antonio, Texas.

(2) Process.

A. Sectors [defined geographically in subsection 35-209(b)] permit development patterns [defined by extent and intensity in subsection 35-209(c)], which are composed of transect zones [defined by the elements appropriate to them in subsection 35-209(e)].

B. The City of San Antonio Department of Planning and Community Development shall include a consolidated review committee (CRC) comprised of a representative from each of the various regulatory agencies and departments that have jurisdiction over the permitting of a project. The CRC shall provide a single interface between the applicant and the agencies. The CRC coordinator shall schedule meetings as needed, but no later than ten (10) working days after a request of an applicant unless additional time is requested by an applicant.

C. The CRC shall be comprised of, but not limited to, one (1) representative from each of the following:

1. Public Works (Stormwater, Transportation);
2. Development Services (Engineering, Trees, Land Entitlements, Zoning, and Building Review Division);
3. SAWS;
4. CPS Energy;
5. Parks and Recreation;

6. Bexar County (if applicable);
7. VIA Metropolitan Transit;
8. Fire Department;
9. School Districts;
10. Office of Environmental Policy (Bicycle Coordinator).

D. The CRC shall issue a recommendation for approval or denial of master development pattern plans, zoning site plans, ~~plats, and~~ building plans, and, if requested, plats to the approval authority for the respective application.

E. An applicant may appeal a decision of the CRC to the director of planning and community development. Decisions of the director of planning and community development may be appealed to the board of adjustment when concerning subsection 35-209(e)], or to planning commission when concerning subsection 35-209(c)] and shall follow the procedures set forth in chapter 35, article IV, subsections 35-412 and 35-481.

F. Should a violation of an approved plan occur during construction, the development services director has the right to require the owner or applicant to stop, remove, and/or mitigate the violation, or to require the owner or applicant to secure a variance to cover the violation.

(3) Variances and Special Exceptions.

A. Variances shall be granted only by the board of adjustment or planning commission. Variances to subsections 35-209(b), 35-209(c)(1)(F), 35-209(c)(6), 35-209(c)(7), and 35-209(c)(8) shall be heard by the planning commission. All other variances shall be heard by the board of adjustment. Notwithstanding the preceding or anything else herein to the contrary, exceptions to subsection 35-209(e) will be considered "special exceptions" to be heard by the board of adjustment.

B. The request for a variance shall not subject the entire application to public hearing, but only that portion necessary to rule on the issue under consideration.

C. The board of adjustment may approve an adjustment of ten (10) percent or less to any dimensional standard contained in subsections 35-209(c) and 35-209(e) and in the tables referenced [therein] [in subsections 35-209(c) and 35-209(e)] as a special exception pursuant to subsection 35-801(k), provided that the board of adjustment shall not increase the overall density, intensity, or height permitted by subsections 35-209(c) and 35-209(e). Such special exception shall only be approved after the board of adjustment makes specific findings as required in subsection 35-801(k).

(4) Incentives. The following incentives may be utilized in the application of these regulations:

A. The application may qualify for fee relief under the city's incentive scorecard system.

B. Through utilization of the transfer of development rights option or qualification under the sustainable design option, density shall be increased to the levels indicated in table 209-18. The transfer of development rights option shall follow the procedures set forth in section 35-361 of the Unified Development Code. Receiving areas and density bonus shall follow the standards set forth in the FBZD and use pattern.

(5) Traffic Study.

A. A traffic study for the master development pattern plan shall be required that indicates trip generation (daily and peak-hour volumes), trip distribution (daily and peak-hour volumes), and capacity and level of service analysis based on the latest methodologies of the Highway Capacity Manual (HCM). A trip generation worksheet is required at the time of zoning, and the remaining requirements are due with the submittal of the master development pattern plan.

B. Mitigation shall not be required for level of service indicators reported within the boundaries of the MDPP by the traffic study.

1. Street cross sections, intersection control, and intersection configurations will be determined based on the results of the traffic study.

2. Intersection configurations will be determined based on the overall volume to capacity (v/c) ratio of the intersection, with a required v/c ratio <= 1.0.

3. Mitigation shall be required for other traffic engineering safety related indicators including, but not limited to: parking, pedestrian facilities, bicycle facilities, vehicular safety, and general traffic circulation.

C. Mitigation shall be required for level of service indicators reported outside the boundaries of the MDPP by the traffic study in accordance with section 35-502.

(b) Sector Analysis Report.

(1) Instructions. The form based development use pattern is based on regional planning principles that incorporate six (6) sectors. These sectors are based on geographic characteristics (including but not limited to topography and transportation networks) of the planning area. The sectors determine the development pattern(s) that are allowed (as illustrated in table 209-1).

The first two (2) sectors are planned for little or no development and include Sector 1 (S1) Preserved Open Space, Sector 2 (S2) Reserved Open Space. The next three (3) sectors are intended for varying intensity of development in greenfield areas. They include Sector 3 (S3) Restricted Growth, Sector 4 (S4) Controlled Growth, and Sector 5 (S5) Intended Growth. The last sector, Sector 6 (S6) Infill addresses infill conditions.

A sector analysis report shall be required and utilized as one (1) criteria for the approval of an FBZD rezoning application. The sector analysis shall be prepared by the planning and community development director in coordination with the CRC prior to presentation to the zoning commission.

The sector analysis report shall utilize the sector principles set forth in subsections 35-209(b)(3) through (b)(9).

The sector analysis shall factor existing conditions (including, but not limited to, existing land use, location, lot size, physical geography, and the major thoroughfare plan) with respect to the development pattern requested.

The sector analysis report shall be presented to the zoning commission with the application for rezoning to the FBZD.

(2) Transfer of Development Rights. Development rights may be transferred from the S2 and S3 sectors to development patterns in the S3, S4, and S5 Sectors in accordance with the provisions of this chapter. Development patterns receiving transferred development rights may use the density bonus option as listed in table 209-18. Areas sending development rights thereby become part of the preserved open space sector.

(3) (S1) Preserved Open Space Sector.

A. The preserved open space sector shall consist of open space that is protected from development by law or standard, as well as land acquired for conservation through purchase, by easement, or by transferred development rights.

B. The preserved open space sector shall consist of, but not be limited to, one (1) or more of the following categories:

1. Surface waterbodies.
2. Protected wetlands.
3. Protected habitat.
4. Riparian corridors.
5. Acquired or dedicated open space.
6. Conservation easements.

C. No building shall be placed or excavation shall be conducted within the preserved open space sector except for rights-of-way for trails, any streets needed to provide access to the property, and the minimum dedication requirement for easements of utilities (including, but not limited to water, sewer, electric, or cable) may be cleared. The preserved open space sector may be used for passive recreation.

(4) (S2) Reserved Open Space Sector.

A. The reserved open space sector shall consist of open space that may have qualities worthy of preservation (for environmental, topographical, or geological reasons or to preserve the rural character of a community), but is not yet fully protected from development by law or standard.

B. The reserved open space sector shall consist of, but not be limited to, one (1) or more of the following categories:

1. Floodplain and existing buffers.
2. Steep slopes.
3. Land over aquifer transitional, contributing, or recharge zones.
4. Wildlife habitat and corridors.
5. Woodland.
6. Viewsheds

(5) (S3) Restricted Growth Sector.

A. The restricted growth sector shall be appropriate to those areas that have physical conditions suitable to agricultural and agriculturally related uses. Development within these areas shall be compatible with the viability of adjacent agriculture and agriculturally related uses.

B. Only hamlets are permitted within the restricted growth sector. Hamlets consist of no more than one (1) standard (¼-mile radius) pedestrian shed with that portion of its site assigned to the T1 natural or T2 rural zones as specified in subsection 35-209(c)(3)(A).

(6) (S4) Controlled Growth Sector.

A. The controlled growth sector shall be appropriate to those locations where development is encouraged, as it can support mixed-use by virtue of proximity to a thoroughfare.

B. Villages and hamlets are permitted within the controlled growth sector. Villages consist of one (1) or several standard pedestrian sheds as specified in subsection 35-209(c)(3)(B).

(7) (S5) Intended Growth Sector.

A. The intended growth sector shall be appropriate to those locations planned for high-capacity thoroughfares (or high capacity transit corridor) that can thereby support a substantial commercial program.

B. Regional centers and villages are permitted within the intended growth sector. Regional centers consist of one long pedestrian shed as specified in subsection 35-209(c)(3)(C). Villages may be freestanding or may adjoin a regional center without buffer requirements.

(8) (S6) Infill Sector.

A. The infill sector shall be appropriate for existing developed areas that contain opportunities for infill of vacant lots, redevelopment of existing buildings, and/or a change in the predominant pattern of development.

B. The infill sector shall be analyzed within a larger context of the immediate pedestrian shed as well as the larger regional environment in which it exists.

C. Within the infill sector, there are two (2) development pattern options: the infill village and the infill regional center. A pedestrian shed analysis shall be conducted by the applicant to determine which pattern is most appropriate. Details for the submittal is outlined in (d) Infill Development.

D. An infill village shall be assessed within the context of a standard pedestrian shed (¼-mile radius). An infill regional center shall be assessed within the context of a long pedestrian shed (½-mile radius).

(c) Development Patterns.

(1) General.

A. Development patterns shall correspond to sectors and be planned according to the provisions of these regulations.

B. The design of the development pattern shall connect and continue thoroughfares; bicycle facilities; green corridors; and historic/archeological surveys on adjacent developments, master plans, and plats as determined by the CRC.

C. Each development pattern, according to its type, and to existing conditions, shall be structured as one (1) or several pedestrian sheds as specified in subsection 35-209(c)(3). The pedestrian shed(s) shall determine the approximate boundaries and centers of the development pattern.

D. Transect zones and densities shall be allocated as specified in table 209-18, while accommodating the environmental requirements as specified in subsection 35-209(d)(6).

E. Remnants of the site outside the pedestrian sheds and within the development pattern shall be allocated as natural zones (T1), rural zones (T2), or sub-urban zones (T3). Remnants assigned T3 shall not constitute more than thirty (30) percent of the size of the pedestrian shed within the development pattern. Sites that can not be designed to meet these requirements shall instead be designed as multiple development patterns.

F. The thoroughfare network shall be laid out according to the provisions of subsection 35-209(c)(8) and table 209-6.

G. Civic requirements shall be provided according to subsection 35-209(c)(9).

H. Specific designations described in subsection 35-209(c)(10) may be designated on the master development pattern plan by the applicant.

I. Overhead utility lines are not permitted within hamlets, villages and regional centers, unless located in the rear of lots. Infill development patterns are exempt from this clause.

(2) Transect Zones.

A. Transect zones shall be constituted of the elements in tables 209-3, 209-4 and 209-18. Each development pattern requires a minimum of three (3) transects, with the exception of infill development patterns.

B. Transect zones in infill development patterns may be calibrated to infill context according to the requirements in subsection 35-209(d).

C. Transect zones in non-infill development patterns may be calibrated according to the following requirements:

1. A calibrated transect zone may only be developed from a non-calibrated transect zone. Non-calibrated transect zones are T1, T2, T3, T4, T5, and T6 as defined in table 209-18. Only transect zones appropriate to the development pattern in accordance with table 209-18 may be calibrated for that development pattern. Calibrated transect zoning district boundaries shall be designated by adding a numeric designation following the base transect designation, e.g., FBZ T4 (T4-1).

2. A calibrated transect zone shall be based on a single non-calibrated transect zone, and shall not establish standards that are outside the parameters set by that non-calibrated transect zone in table 209-18(C)—(L), subsection 35-209(e)(3)(E), subsection 35-209(e)(4)(E), subsection 35-209(e)(5)(E), and/or subsection 35-209(e)(6)(E). For instance, a calibrated T5 shall not establish principal building heights that are taller than the principal building heights prescribed by the non-calibrated T5 in table 209-18. A calibrated transect zone overlay district may restrict standards that are permitted in the non-calibrated transect zone, but shall not permit standards that are not permitted in the non-calibrated transect zone.

3. Calibrated transect zone standards shall be in accordance with table 209-18A.

D. Separate rezoning actions are required to designate each calibration of the "FBZ" District, per requirements of sections 35-357 and 35-209.

(3) Development Patterns.

A. Hamlets.

1. Hamlets are development patterns of at least twenty (20) contiguous acres and no more than eighty (80) contiguous acres, including rights-of-way, within the S3 restricted growth sector and S4 controlled growth sector.

2. A hamlet shall consist of no more than one (1) standard pedestrian shed (¼-mile radius) including T1 and/or T2, T3, and T4 zones as specified in table 209-18. A minimum of fifty (50) percent of the development pattern

shall be allocated to a natural or rural zone (T1 and T2), shall not be further subdivided, and shall be protected through a conservation easement held by the city, a land trust or conservancy.

B. Villages.

1. Villages are development patterns of at least eighty (80) contiguous acres and no more than one hundred sixty (160) contiguous acres, including rights-of-way, within the S4 controlled growth sector and S5 intended growth sector.

2. A village shall consist of one (1) standard pedestrian shed (¼-mile radius) including T3, T4 and T5 zones as specified in table 209-18. Larger sites shall be designed and developed as multiple pedestrian sheds, each with the individual transect zone requirements of a village as specified in table 209-18.

3. Villages shall be designated as transit-oriented if they are planned for, or have access to, a high capacity transit corridor within ¼ mile as measured from the geographic center of pedestrian shed. Transit-oriented villages shall reduce parking requirements by thirty (30) percent.

C. Regional Centers.

1. Regional centers are development patterns appropriate within S5, the intended growth sector.

2. The minimum developable area of a site to be planned as a regional center shall be at least one hundred sixty (160) contiguous acres and no more than six hundred forty (640) contiguous acres, including rights-of-way.

3. A Regional center shall be limited to one (1) long pedestrian shed (½-mile radius) including T4, T5 and T6 zones as specified in table 209-18, and may be adjoined without buffers by one (1) or several standard pedestrian sheds with the individual transect zone requirements of a village as specified in table 209-18.

4. Regional centers shall be designated as transit-oriented if they are planned for, or have access to, a high capacity transit corridor within ¼ mile measured from the geographic center of the pedestrian shed. Transit-oriented regional centers shall reduce parking requirements by thirty (30) percent.

D. Infill Development Patterns.

1. The infill village and infill regional center are development patterns appropriate within the S6, infill sector. Infill development patterns are subject to the requirements in subsection 35-209(d).

2. The infill village shall be limited to one (1) standard pedestrian shed. The minimum site that may be designated an infill village shall be ten (10) acres, including rights-of-way.

3. The infill regional center shall be limited to one (1) long pedestrian shed. The minimum site that may be designated an infill regional center shall be twenty (20) acres, including rights-of-way.

4. Infill villages and infill regional centers shall be designated as transit-oriented if they are planned for, or have access to, a high capacity transit corridor within ¼ mile. Once this designation has been made, the parking requirements shall be reduced by thirty (30) percent.

   Proof of high capacity transit corridor may be submitted in the form of an adopted plan by VIA or other public transit agency.

(4) Density Calculations.

A. Density shall be calculated per transect zone for all areas of a development pattern plan that are classified as T3, T4, T5, or T6. Infill development patterns are not required to calculate density according to this section, but instead shall refer to the requirements of subsection 35-209(d).

1. Gross developable area. For each transect zone, the gross developable area shall be determined by calculating the acreage classified as the specified transect zone, including thoroughfares, but excepting land allocated to civic functions and thoroughfares within civic spaces.

2. Gross development units. Gross development units shall be calculated for the gross developable area of each transect zone as specified by table 209-18(B).

   a. With density bonus. When a density bonus is utilized, the minimum densities listed in the row labeled "By Density Bonus" in table 209-18(B) shall be used to calculate gross development units. For instance, four (4) units/acre for T3, eight (8) units/acre for T4, twelve (12) units/acre for T5, and sixteen (16) units/acre for T6. Note that while no minimum density is generally prescribed for T6, a density of sixteen (16) units/acre is used to calculate gross development units.

   b. Without density bonus. When a density bonus is not utilized, the maximum densities listed in the row labeled "By Right" in table 209-18(B) shall be used to calculate gross development units.

3. Allocation of gross development units among functions. A percentage of each transect zone's gross development units shall be allocated to nonresidential functions in accordance with the percentage ranges in the row labeled "Other Functions". The remaining balance of gross development units shall be allocated to residential functions.

   a. Nonresidential functions. Gross development units allocated to nonresidential functions shall be distributed among one (1) or both of the nonresidential categories listed here:

      i. For lodging: 1—3 bedrooms for each gross development unit.

ii. For office or retail: 750—1,500 square feet for each gross development unit.

b. Residential functions. Gross development units allocated to residential functions shall be calculated as one (1) residential unit for each gross development unit.

(5) Density Bonus Options.

A. The overall density of the master development pattern plan may be increased by the transfer of development rights or by the exercise of the sustainable design option. When a density bonus option is used, a minimum density is established per transect zone, and maximum densities are not prescribed. If density bonus options are pursued for an adopted MDPP, such a change shall be considered a major amendment to that MDPP.

B. Transfer of Development Rights. When development rights are transferred the density bonus shall apply to the receiving area.

C. Sustainable Design Option.

1. The sustainable design option requires compliance with two (2) components:

a. Housing mix requirement (table 209-5B), and

b. Sustainable design option point system (table 209-5A).

2. When the sustainable design option is utilized the density bonus applies to the entire development pattern.

3. Housing mix requirement.

a. From the list of residential types [table 209-5B], for each development pattern the following residential housing mix shall be required for each applicable transect:

i. T1—Not applicable.

ii. T2—Not applicable.

iii. T3—At least three (3) residential types (each must be at least five (5) percent of total units of the transect).

iv. T4—At least four (4) residential types (each must be at least five (5) percent of total units of the transect).

v. T5—At least four (4) residential types (each must be at least five (5) percent of total units of the transect).

vi. T6—No minimum mix required.

b. Phasing. Each submittal of the project shall include a calculation of the overall housing mix required and the percent of this requirement met by the specific submittal or phase. The information shall be

shown in table format and the location of each type utilized to meet the requirement shall be illustrated on the plan submitted.

i. Projects exercising the sustainable design option shall commence construction of the mixed housing types according to the phase or acreage indicated below. Building permits shall not be issued for projects that do not meet the thresholds below. Phases of construction shall correspond with the phasing of the master development pattern plan and plat approvals.

ii. In T3, the second of three (3) residential types shall be commenced by the second phase of construction, or when building permits for structures have been issued for more than twenty (20) acres under any transect zone within the development pattern, whichever occurs first. The third residential type shall be commenced by the third phase of construction, or when building permits for structures have been issued for more than forty (40) acres under any transect zone within the development pattern, whichever comes first.

iii. In T4 and T5, the second of four (4) residential types shall be commenced by the second phase of construction, or when building permits for structures have been issued for more than twenty (20) acres under any transect zone within the development pattern, whichever occurs first. The third and fourth residential type shall be commenced by the third phase of construction, or when building permits for structures have been issued for more than forty (40) acres under any transect zone within the development pattern, whichever comes first.

4. Sustainable development option point system. To qualify for the density bonus, a minimum number of points as defined in table 209-5A is required. The CRC shall review a development pattern for compliance with standards of tables 209-5A and 5B.

(6) Environmental and Stormwater Requirements.

A. General.

1. Transect zones manifest a range of natural and urban conditions. In case of conflict, the natural environment shall have priority in the more rural zones (T1—T3); the built environment shall have priority in the more urban zones (T4—T6).

2. The regulations in section 25-209 shall be utilized for stormwater and environmental issues. In the case of conflict with Appendix F: Floodplains, Appendix F shall apply.

3. There shall be three (3) classes of waterways classified according to the size of their contributing drainage area (DA). The drainage area for class I is greater than five (5) square miles (DA > 5 mi^2); class II is between 1.5

and five (5) square miles (1.5 mi^2 < DA < 5 mi^2); and class III is less than 1.5 square miles (DA < 1.5 mi^2). Each waterway classification generates a streamside corridor subject to a standard for crossing and protection of its riparian condition as specified below for each transect zone.

4. Wetlands shall be subject to a standard of restoration, retention and mitigation as specified below in subsections 35-209(c)(6)(B) through (F) for each transect zone.

5. The technical guidance manual, "Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices" (RG-348), or the latest version of the document shall be the governing document for implementation of the recommended BMPs over the Edwards Aquifer Recharge Zone.

B. Specific to Natural and Rural Zones (T1—T2).

1. Within T1 and T2 zones the encroachment and modification of natural conditions listed in subsections 35-209(b)(3)(B) and (b)(4)(B) shall be limited according to local, state and federal guidelines.

2. The riparian corridors shall extend a specific distance from each side of the centerline of the watercourse, or the limits of one hundred (100) year City of San Antonio (CoSA) ultimate floodplain, whichever is greater. Class I waterways shall extend at one hundred fifty (150) feet from the centerline; class II shall extend one hundred (100) feet; and class III shall extend fifty (50) feet. Riparian corridors shall be maintained free of structures or other modifications to the natural landscape, including agriculture. Thoroughfare crossings shall be allowed by variance only.

3. Wetlands shall be retained and restored if in degraded condition. Additional buffers shall be maintained at one hundred (100) feet for class I and II. Wetland buffers shall be free of structures or other modifications to the natural landscape, including agriculture. Thoroughfare crossings shall be allowed by variance only.

4. Stormwater management on thoroughfares shall be primarily through retention and percolation, channeled by curbside swales.

C. Specific to Sub-Urban Zones (T3).

1. Within T3 zones the continuity of the urbanized areas shall be subject to the precedence of the natural environmental conditions listed in subsections 35-209(b)(3)(B) and (b)(4)(B). The alteration of such conditions shall be limited according to local, state and federal guidelines.

2. The riparian corridors shall extend a specific distance from each side of the centerline of the watercourse, or the limits of one hundred (100) year City of San Antonio (CoSA) ultimate floodplain, whichever is greater. Class I waterways shall extend one hundred fifty (150) feet from the centerline; class II shall extend one hundred (100) feet, class III has no additional extension. These riparian corridors shall be maintained free of

structures, except that thoroughfare crossings may be allowed over class I and II waterways and class III waterways may be modified upon review and approval of the floodplain administrator.

3. Wetlands in degraded condition shall be retained and restored. Buffers shall be maintained at fifty (50) feet. Buffers shall be free of structures or other modifications to the natural landscape. Thoroughfare crossings may be allowed by variance.

4. Stormwater management on thoroughfares shall be primarily through retention and percolation, channeled by curbside swales.

D. Specific to General Urban Zones (T4).

1. Within T4 zones the continuity of the urbanized areas should take precedence over the natural environmental conditions listed in subsections 35-209(b)(3)(B) and (b)(4)(B). The alteration of such conditions, where necessary, shall be mitigated on or off-site utilizing the best management practice suggestions from the light imprint storm drainage (table 209-20). The determination for modification and mitigation shall be made upon review and approval of the floodplain administrator.

2. Riparian corridors of all classes of waterways may be crossed by thoroughfares as required by the thoroughfare network and approved on the master development pattern plan.

3. Wetlands shall be retained and maintained free of structures or other modifications to the natural landscape. Thoroughfare crossings may be allowed upon review and approval of the floodplain administrator.

4. Stormwater management on thoroughfares and lots shall be primarily through underground storm drainage channeled by raised curbs. Retention or detention shall not be required on the individual lots. Detention may be required as part of the overall development.

E. Specific to Urban Center Zones (T5).

1. Within T5 zones the continuity of the urbanized areas shall take precedence over natural environmental conditions listed in subsections 35-209(b)(3)(B) and (b)(4)(B). The alteration of such conditions, where necessary, shall be mitigated off-site. The determination shall be made upon review and approval of the floodplain administrator.

2. The riparian corridors of all classes or waterways may be embanked and crossed by thoroughfares as required by the thoroughfare network.

3. Class I and II wetlands may be modified if mitigated on- or off-site utilizing the best management practice suggestions from the light imprint storm drainage (table 209-20). Thoroughfare crossings shall be allowed by right.

4. Stormwater management shall be primarily through underground storm drainage channeled by raised curbs. There shall be no retention or

detention required on the individual lot. Detention may be required as part of the overall development.

F. Specific to Urban Core Zones (T6).

1. Within T6 zones the continuity of the urbanized areas shall take precedence over the natural environmental conditions listed in subsections 35-209(b)(3)(B) and (b)(4)(B). The alteration of such conditions, where necessary, shall not require off-site mitigation. The determination shall be made upon review and approval of the floodplain administrator.

2. The riparian corridors of all classes of waterways may be embanked and crossed by right or enclosed by thoroughfares as required by the thoroughfare network.

3. Class I and II wetlands may be altered by right not requiring off-site mitigation. Thoroughfare crossings shall be allowed by right.

4. Stormwater management shall be primarily through underground storm drainage channeled by raised curbs. There shall be no retention and detention required on the individual lot. Detention may be required as part of the overall development.

(7) Tree Preservation. Tree preservation shall follow the regulations in section 35-523 and shall be applied to the entire master development pattern plan.

(8) Thoroughfare Requirements.

A. General.

1. All thoroughfares shall be accessible to the public including pedestrians, bicycles and automobiles as accommodated by the thoroughfare type.

2. Thoroughfares shall be designed in context with the urban form and desired design speed of the transect zones through which they pass. Thoroughfares that pass from one transect zone to another shall adjust their public frontages accordingly or, alternatively, the transect zone may follow the trajectory of the thoroughfare to the depth of one (1) lot, retaining a single public frontage throughout its trajectory.

3. Within the more rural zones (T1 through T3) pedestrian comfort shall be a secondary consideration of the thoroughfare. Design conflict between vehicular and pedestrian movement shall be generally decided in favor of vehicular mobility.

4. Within the more urban transect zones (T4 through T6) pedestrian comfort shall be a primary consideration of the thoroughfare. Design conflict between vehicular and pedestrian movement shall be decided in favor of the pedestrian.

5. Streetscape trees shall be provided in the public right-of-way as indicated in subsections 35-209(c)(8)(D) and 35-209(c)(8)(E).

B. Thoroughfares.

1. Thoroughfares shall be assembled according to design speed, parking lane widths, and curb radius (table 209-6A), effective turning radius (table 209-6B), turning radius (table 209-6C), travel lanes and parking provisions (table 209-6D), and public frontages (table 209-6E and 209-6F). Examples of complete thoroughfare assemblies are illustrated in table 209-6G.
2. Block Size. The thoroughfare network shall be designed to define blocks not exceeding the maximum size prescribed in table 209-18. The size shall be measured as the sum of lot frontage lines.
3. Connectivity. All thoroughfares shall terminate at other thoroughfares, forming a network. Internal thoroughfares shall connect wherever possible to those on adjacent sites. Cul-de-sacs may be permitted only by variance and shall be justified by natural site conditions.
4. B-Grid. Thoroughfares along a designated B-Grid may be exempted from one (1) or more of the specified public or private frontage requirements as indicated in subsection 35-209(c)(10)(A)(1).
5. Bicycle Network. A bicycle network consisting of lanes, routes and multi-use paths shall be provided throughout the master development pattern plan as defined in table 209-7 and subsection 35-209(c)(8)(C). The community bicycle network shall be connected to existing or proposed sector networks in accordance with the San Antonio-Bexar County Regional Bicycle Master Plan.
6. Transit. The street network shall be designed to facilitate the movement of transit vehicles between centers of activity. Boulevards with a dedicated transit lane may be utilized to connect high traffic areas.
7. School Bus. Transit routes and/or facilities shall be coordinated with school bus routes.
8. Alleys.
    a. All lots in T5 and T6 (other than T5-1, T6-1, and T6-2) shall be accessed from an alley. Exemptions shall be made for lots in an infill development pattern that do not abut a pre-existing alley, if lots meet at least one (1) of the following conditions:
        1. Lot size is less than forty thousand (40,000) square feet.
        2. Lot has river frontage and lot size is less than ninety thousand (90,000) square feet.
        3. Lot size is less than one-quarter (¼) of its block.
        4. Lot has vehicular access to two (2) or more streets.
        5. One (1) or more lots on the block are exempt.
        6. Pre-existing alley has been closed and vacated by official city council action.

b. Temporary driveways may be constructed through the first and second lot layers to provide access to the third lot layer prior to alley construction. Upon construction of alley, temporary driveway shall be closed to vehicular traffic.

c. Alleys designated for emergency access must comply with additional standards set forth in the International Fire Code as amended and adopted by the City of San Antonio. Alleys designated for garbage collection must comply with additional standards set forth by the City of San Antonio Solid Waste Management Department.

d. Alleys designated to provide access to industrial functions shall be built to the standards listed in subsection 35-506(4)(B)(p). Pavement standards based on the expected 18-kip ESAL loading on the alley.

e. In order to accommodate existing right-of-way and building conditions in infill contexts, narrower alley dimensions than those listed in tables 209-6A and 209-6D may be approved upon review of an emergency access plan and finding by the fire department that an additional access road extends to within one hundred fifty (150) feet of all buildings, as described in section 503.1.1 of the International Fire Code.

f. Where lots in an infill development pattern abut pre-existing alleys, alleys shall be used to provide vehicular access to the side or rear of property, including parking, utilities, solid waste disposal, and/or emergency access unless one (1) or more of the following conditions is present:

1. Width of pre-existing alley right-of-way is less than width required by tables 209-6A and 209-6D.

2. Pre-existing alley right-of-way does not extend through the entire block.

3. Pre-existing alley does not meet the minimum standards set forth in the International Fire Code as amended and adopted by the City of San Antonio and/ or the minimum standards set forth by the City of San Antonio Solid Waste Management Department.

4. Pre-existing alley has been closed and vacated by official city council action.

C. Bicycle and Pedestrian Path Connectivity.

1. An overall integrated bicycle network must be established on the master development pattern plan and shall consist of bicycle lanes (permitted on standard streets, commercial streets, boulevards, and avenues); bicycle routes (permitted on rural roads and parkways); and multi-use paths on roadways where adequate separation from vehicle lanes is possible or through parks and linear creekways. The placement of bicycle facilities shall be coordinated at the master development pattern plan level with the

CRC and the bicycle coordinator to provide connection to neighborhoods, schools, universities, retail, community centers, civic spaces, and existing bicycle facilities. Bicycle facilities shall be designed and construction in accordance with the AASHTO (American Association of State Highway and Transportation Officials) Guide for the Development of Bicycle Facilities and the Texas MUTCD (Manual on Uniform Traffic Control Devices).

D. Public Frontages.

1. Public frontages shall be designed as shown in tables (tables 209-6E, 209-6F and 209-18) and allocated within transect zones as specified in table 209-18.

2. Within the public frontages, the prescribed type of streetscape trees and street lights shall be as shown in table 209-6 (public frontage), 209-8 (street lights), 209-21 (street trees and streetscape trees) and 209-18 (summary).

~~3. Public frontage streetscape trees shall avoid placement within utility easements.~~

E. Public Frontages by Transect.

1. The public frontage in T1 and T2 (tables 209-6E, 209-6F and 209-18) shall include trees of various species as listed in table 209-21, naturalistically clustered, as well as understory. The introduced landscape shall consist primarily of native species requiring minimal irrigation, fertilization and maintenance (table 209-21).

2. The public frontage in T3 (tables 209-6E, 209-6F and 209-18) shall include trees of various species as listed in table 209-21, (no more than twenty-five (25) percent of any single species), naturalistically clustered, as well as low maintenance understory. The overall number of trees shall be determined by the ratio of one (1) tree per thirty (30) linear feet lot frontage. The introduced landscape shall consist primarily of native species and shall be established by drip irrigation (table 209-21). ~~Single trees shall require a tree well of at least one hundred (100) square feet (e.g. five (5) feet by twenty (20) feet); c~~Clustered tree wells shall be approved on a site by site basis. Parts of the tree well may be capped with pervious or impervious materials as permitted by approval of the city arborist.

3. The public frontage in T4 (tables 209-6E, 209-6F and 209-18) shall include trees of various species as listed in table 209-21, (no more than twenty-five (25) percent of any single species), naturalistically clustered, or regularly spaced in allee pattern with shade canopies of a height that, at maturity, clears first floor owning but remains predominantly clear of building frontages. The overall number of trees shall be determined by the ratio of one (1) tree per thirty (30) linear feet lot frontage. The introduced

landscape shall consist primarily of durable species tolerant of soil compaction (table 209-21). ~~Single trees shall require a tree well of at least one hundred (100) square feet (e.g. five (5) feet by twenty (20) feet); c~~Clustered tree wells are also an option and shall be approved on a site by site basis. The number of trees required shall be reduced by twenty (20) percent if understory is provided. Parts of the tree well may be capped with pervious or impervious materials as permitted by approval of the city arborist.

4. The public frontage in T5 (tables 209-6E, 209-6F and 209-18) shall include trees of various species as listed in table 209-21, (no more than twenty-five (25) percent of any single species), naturalistically clustered, or regularly spaced in allee pattern with shade canopies of a height that, at maturity, clears first floor, but remains predominantly clear of building frontages. The overall number of trees shall be determined by the ratio of one (1) tree per thirty (30) linear feet lot frontage. The introduced landscape shall consist primarily of durable species tolerant of soil compaction (table 209-21). ~~Single trees shall require a tree well of at least one hundred (100) square feet (e.g. five (5) feet by twenty (20) feet); c~~Clustered tree wells shall be approved on a site by site basis. Parts of the tree well may be capped with pervious or impervious materials as permitted by approval of the city arborist.

5. The public frontage in T6 (tables 209-6E, 209-6F and 209-18) shall include trees of various species as listed in table 209-21, (no more than twenty-five (25) percent of any single species), naturalistically clustered, or regularly spaced in allee pattern with shade canopies of a height that, at maturity, clears ~~three (3) stories~~ the first floor (unless such height conflicts with government rule, law, ordinance or other policy) but remains predominantly clear of building frontages. The overall number of trees shall be determined by the ratio of one (1) tree per thirty (30) linear feet lot frontage. The new landscape shall consist primarily of durable species tolerant of soil compaction (table 209-21). ~~Single trees shall require a tree well of at least one hundred (100) square feet (e.g. five (5) feet by twenty (20) feet); c~~Clustered tree wells shall be approved on a site by site basis. Parts of the tree well may be capped with pervious or impervious materials as permitted by approval of the city arborist.

F. Specific to Specialized Districts. The standards for thoroughfares and public frontages within specialized districts shall be indicated on the zoning site plan. When the boundaries of a specialized district and a transect zone meet within a thoroughfare right-of-way, the thoroughfare and public frontage standards for the abutting transect zone shall apply to the portion of the thoroughfare and the public frontage in the specialized district.

(9) Civic Requirements.

A. General.

1. The master development pattern plan shall designate civic spaces (CS), civic buildings (CB), and civic transit zones (CT).
2. Civic spaces are publicly or privately owned, pedestrian oriented, outdoor spaces that are accessible to and designed for the use of the general public. Civic space types are prescribed in table 209-9A. Civic spaces shall not be dedicated to the City of San Antonio parks and recreation department unless specifically permitted by the director of parks and recreation.
3. The ongoing construction and improvement of the required civic spaces and buildings shall be supported by an annual assessment dedicated to this purpose and administered by a mandatory property owners association or other maintenance entity established for this purpose by the developer under the Texas Property Code.
4. Civic transit zones are sites dedicated for transit amenities including transit shelters, park and ride facilities, and transit centers.

B. Civic Spaces (CS) Specific to T3—T6 Zones.

1. Each pedestrian shed shall assign at least five (5) percent of its urbanized area (T3 through T6) to civic spaces. The calculation shall include rights-of-way.
2. Civic spaces may not occupy more than a total of twenty (20) percent of the area of each pedestrian shed. A civic space requiring more than twenty (20) percent of the pedestrian shed shall be subject to the creation of a specialized district. [See subsection 35-209(c)(11)].
3. Civic spaces shall be designed in accordance with table 209-9A and approved by the consolidated review committee and allocated to zones in accordance with table 209-18.
4. Main Civic Space. Each pedestrian shed shall contain at least one (1) main civic space. The main civic space shall be within eight hundred (800) feet of the geographic center of each pedestrian shed, unless topographic conditions, pre-existing thoroughfare alignments or other circumstances justify it.
5. Playgrounds. Within eight hundred (800) feet of every lot in residential use, a civic space designed as a playground shall be provided.
6. Each civic space shall have a minimum of fifty (50) percent of its perimeter fronting a thoroughfare, except greens which may have a minimum of twenty-five (25) percent of its perimeter fronting a thoroughfare.

C. Civic Buildings (CB) Specific to T3—T6 Zones.

1. Meeting Hall. The developer shall covenant to construct a meeting hall in proximity to the main civic space of each pedestrian shed. Its corresponding public frontage shall be equipped with a shelter and seating for a transit stop.

2. Elementary School.

   a. Each development pattern shall reserve a site for an elementary school. Hamlets shall be exempt from this requirement. Each elementary school should follow the guidelines set forth in subsection 35-209(f). If a master development pattern plan includes more than one (1) development pattern, a shared site that serves both development patterns is permissible. A plat may not be approved for a development pattern that does not include a designated school site or reference a shared school site on an approved master development pattern plan. Although the school site may be used for civic space, it does not count toward the minimum five (5) percent per pedestrian shed.

   b. Prior to approval of the master development pattern plan, the applicant shall provide documentation outlining discussions with the school district regarding the location of the site reserved for an elementary school. After the master development pattern plan is approved, if a school district decides not to locate at the designated site, the applicant shall provide a letter from the school district indicating the proximity of the school that shall serve the development. The reserved site may then be converted to other uses through amendment of the master development pattern plan.

3. Child Care. One (1) civic building lot suitable for a childcare building shall be reserved within each pedestrian shed.

4. Civic building sites shall not occupy more than twenty (20) percent of the area of each pedestrian shed. A civic building requiring more than twenty (20) percent of the pedestrian shed shall be subject to the creation of a specialized district. [See subsection 35-209(c)(11)]

5. Civic building sites shall be located within or adjacent to civic spaces, or at the axial termination of significant thoroughfares.

6. Civic buildings shall be subject to the standards of subsection 35-209(e). The particulars of the design of civic buildings shall be subject to approval by the director of planning and community development upon review by the historic design and review commission and recommendation to issue or deny a certificate of appropriateness [in accordance with guidelines of section 35-803].

7. Parking for civic functions shall be calculated per the standards of table 526-3a and 3b of the Unified Development Code. On-street parking available along the frontage lines that correspond to each lot shall be counted toward the parking requirement of the building on the lot. The required parking may also be provided within one-quarter mile of the site that it serves. Civic parking lots may be of pervious cover if they follow the standards in subsection 35-526(j) and are landscaped.

8. Civic buildings do not count toward the minimum five (5) percent of civic space per pedestrian shed.

D. Civic Transit Zones (CT) Specific to T3—T6 Zones.

1. Transit. A site shall be dedicated for at least one (1) "Park and Ride", transit center, or transit shelter within each pedestrian shed. Park and ride facilities are permitted in T3 and T4. Transit centers are permitted in T5 and T6. Bus shelters are permitted in T3, T4, T5, and T6. Transit shelters shall be located within close proximity to commercial and mixed use areas. Sites for transit do not count toward the minimum five (5) percent of civic space per pedestrian shed.

2. The guidelines for transit routes and facilities can be found in subsection 35-209(f). Transit locations and facilities are subject to approval by VIA as part of the CRC approval process.

E. Civic Spaces Specific to T1 and T2 Zones.

1. Those portions of the T1 natural and T2 rural zones that occur within a village or regional center development pattern may be classified as civic space in accordance with table 209-9A. If classified as civic space, the property shall be considered urbanized for the purposes of subsection 35-209(c)(9)(B)(1) and shall count toward the requirement for civic space for the development pattern.

2. The T1 natural and T2 rural zone acreage within a hamlet, per subsection 35-209(c)(3)(A)(2), shall not apply toward the civic space requirement for a hamlet.

(10) Specific Designations.

A. A zoning site plan and master development pattern plan may designate one (1) or more of the following designations:

1. Differentiation of specific thoroughfares as B-Grid.

a. The frontages assigned to the B-Grid shall not exceed twenty (20) percent of the total length all frontages within a pedestrian shed.

b. Property fronting B-Grid streets are allowed the following exemptions to accommodate automobile-oriented uses:

i. Parking lots and garages are allowed in the first or second lot layer. Street screens and liner buildings are not required to mask parking facilities. Parking lot shading and screening requirements of the Unified Development Code [subsections 35-511(c)(7) and (e)(3) shall apply].

ii. Drive-thru facilities are permitted in certain transect zones as indicated in table 209-13B. The front building setback may be increased up to fifteen (15) feet by-right to allow for the safe flow of traffic.

iii. To allow for safe ingress and egress for gas stations, gas pump canopies may be used to calculate compliance with the maximum front setback requirement. The front building setback may be increased up to fifteen (15) feet by-right to accommodate the safe flow of traffic.

iv. Single functions may occupy an area exceeding ninety thousand (90,000) square feet on the ground floor of a building without conforming to conditions set by subsection (e)(4)(c)(2)(a) or subsection (e)(5)(c)(3)(a) or subsection (e)(6)(c)(4)(a).

2. Retail frontage designation of mandatory retail frontage requiring that buildings provide a shopfront and awning, gallery, or arcade frontage type at sidewalk level along the entire length of the frontage. The facade shall be glazed no less than seventy (70) percent on the sidewalk-level story.

3. Sidewalk Cover. Designation of mandatory gallery or arcade frontage, requiring that buildings provide a permanent cover over the sidewalk, either cantilevered or supported by columns. The gallery or arcade frontage may be combined with a retail frontage as shown in table 209-12 (private frontage).

4. Common Lawn. Designation of mandatory common lawn frontage requiring that individual private lawns at frontages not be delineated with fences or hedges and thus read as a continuous lawn.

5. Coordinated Public and Private Frontage. Designation of mandatory coordinated streetscape frontage, requiring that the public and private frontages be coordinated as a single, coherent landscape and paving design.

6. Terminated Vista. Designation of mandatory terminated vista locations, requiring that buildings in these locations be provided with architectural articulation that emphasizes the building's axial location at the terminus of a vista or viewshed by creating a distinctive point of interest to a viewer stationed along the vista or viewshed corridor.

7. Cross Block Passage. Designation of mandatory locations for pedestrian or non-motorized vehicle paths between buildings. Paths must be a minimum of eight (8) feet wide.

8. Stepback Frontage/Cornice Line. A designation of mandatory stepback frontage requiring that building heights not exceed a specific height along the entire length of the frontage and through a specific depth of the building. Such designation may permit a Cornice Line in lieu of a stepback.

9. River Frontage. Designation of mandatory river frontage requiring that lots that abut the San Antonio River meet the following standards:

   a. Lots shall designate one of the rear or side lot lines that abuts the river as the river frontage lot line.

b. A river lot layer shall be identified on each lot. The river lot layer shall extend from the river frontage lot line to the nearest façade of the principal building or outbuilding. For lots with river lot layers, the third lot layer shall be defined as the area between the second lot layer and the river lot layer.

c. Buildings shall provide a principal entrance toward the primary frontage, and a river entrance toward the river frontage.

d. River setbacks shall be established as prescribed by table 18 or its specific calibration.

e. Stoops, lightwells, balconies, bay windows, awnings, arcades, galleries and terraces may encroach fifty (50) percent of the depth of the river lot layer.

f. Parking, loading docks, service entrances, and service yards shall be located and accessed as specified per transect zone, unless the lot is a mid-block lot without access to street or alley. In such cases, access to the interior of the lot may be provided through the First Lot Layer.

10. Specific Architectural Standards. Designation of one (1) or more of the following architectural standards as mandatory for new construction:

a. Principal elevation features. Identification of principal elevation features.

b. Roof design. Identification of roof design elements such as materials, pitch, and HVAC screening.

c. Window/door design. Identification of window and door sizes, proportions, and elements.

d. Specific frontage features. Identification of detailed private frontage elements. These elements shall conform to the frontage types in table 209-12 and shall not override the standards for those types as listed in that table.

e. Streetscreen and fence design. Identification of detailed streetscreen and/or fence features, such as height, materials, permeability. These elements shall be more restrictive than the requirements of subsection 35-209(e)(2)(E).

(11) Specialized Districts.

A. Specialized district designations shall be appropriate to areas within a development pattern plan that, by their intrinsic function, cannot conform to one of the development patterns specified in this section.

B. The boundaries of each specialized district shall be identified on the zoning site plan.

C. The development standards for each specialized district shall be enumerated on the zoning site plan.

1. Such standards shall be drawn from table 209-18, column "SD", and shall not establish standards that are outside the parameters set by that column.

2. Table 209-18(J) (private frontages) shall not apply to specialized districts.

D. A specialized district may be approved for any function as enumerated in table 209-13B, column "SD".

E. Each individual function must be identified on the zoning site plan which shall be filed with the application for rezoning and be incorporated into the ordinance designating FBZD as the base zoning district and the specialized district as a sub-district. The site plan shall be reviewed by the zoning commission and approved by the city council concurrent with the approval of the zoning case.

(d) Infill Development.

(1) General.

A. Intent.

1. Subsection 35-209(d) shall be appropriate for use in infill contexts where large, contiguous lots are to be developed; or to implement large-scale city initiatives in an infill context. The FBZD is not designed for individual small vacant lots within an actively used urban fabric.

2. Subsection 35-209(d) includes requirements and calibration procedures that are specific to infill development and shall be applied exclusively to infill development. Requirements that are applicable to both infill and greenfield development are prescribed by all other sections of 35-209 and 35-357.

B. Definition of Infill. To be considered infill for subsection 35-209(d), the area to be rezoned to FBZD shall meet any one (1) of the following four (4) conditions. For the purpose of this analysis, a street does not constitute previously developed land; instead the status of property on the other side of the street is considered. Any fraction of the perimeter that borders waterfront other than a stream is excluded from the calculation.

1. At least seventy-five (75) percent of the boundary of the area to be rezoned to FBZD borders lots that individually are at least fifty (50) percent previously developed, and that in aggregate are at least seventy-five (75) percent previously developed.

2. The area to be rezoned to FBZD, in combination with bordering lots, forms an aggregate parcel whose boundary is seventy-five (75) percent bounded by lots that individually are at least fifty (50) percent previously developed, and that in aggregate are at least seventy-five (75) percent previously developed.

3. At least seventy-five (75) percent of the land area, exclusive of rights-of-way, within a ½-mile distance from the boundary of the area to be rezoned to FBZD is previously developed.

4. The lands within a ½-mile distance from the boundary of the area to be rezoned to FBZD have a pre-project connectivity of at least one hundred forty (140) intersections per square mile.

C. Requirements. The following analyses and plans must be completed to apply the FBZD in an infill situation:

1. Pedestrian shed analysis.
2. Zoning site plan.
3. Master development pattern plan.

(2) Pedestrian Shed Analysis.

A. The purpose of the pedestrian shed analysis is to ensure that infill development responds appropriately to its urban context. The pedestrian shed analysis provides a snapshot of existing conditions in the vicinity of the area to be zoned FBZD, and provides for community input on proposed development.

B. A pedestrian shed analysis shall be prepared and submitted as a report to the zoning commission with the application for rezoning to the FBZD. The pedestrian shed analysis shall be prepared by the applicant and shall be prepared in a process of public consultation.

C. The pedestrian shed analysis shall:

1. Describe existing conditions within a certain distance from the site being considered for rezoning. Infill villages shall describe existing conditions within one standard pedestrian shed which is defined as a geographic area with a ¼-mile radius. Infill regional centers shall describe conditions within one long pedestrian shed which is defined as a geographic area with ½-mile radius.
2. Identify the appropriate infill development pattern based on existing conditions, size of site being considered for rezoning, and vision for the pedestrian shed area.
3. Map transect zones appropriate to existing conditions over the entirety of the analysis area.
4. For the area to be rezoned, map the proposed transect zones.
5. For the area to be rezoned, provide the proposed calibration of transect zone-regulated elements.

D. The public consultation process shall include the following:

1. A minimum of two (2) public meetings.
2. Meeting notifications shall be sent to all property owners and registered neighborhood associations within the pedestrian shed(s) and within two hundred (200) feet of the pedestrian shed(s) analyzed, and to all owners of property to be rezoned to FBZD.

3. For areas with an adopted community, neighborhood, or perimeter plan, notification shall also be sent to planning team members.
4. Meeting notifications shall also be published in an official newspaper of general circulation before the fifteenth day before the date of the meeting.
5. One meeting shall present a draft of the pedestrian shed analysis and the zoning site plan. A subsequent meeting shall present a final draft of the pedestrian shed analysis and zoning site plan that takes into account public comment provided at the previous meeting.
6. The pedestrian shed analysis shall include information regarding the public consultation process including but not limited to:
   a. A map of the pedestrian shed(s).
   b. List with addresses of property owners and neighborhood associations to whom notices were sent.
   c. Copy of meeting announcements mailed to property owners and neighborhood associations.
   d. Copy of meeting announcements published in newspaper.
   e. Sign-in sheets from meetings.
   f. Copies of other documents distributed at the meeting.
   g. Copies of public comments received or submitted.

F. The CRC will provide a review of the pedestrian shed analysis submitted by the applicant to ensure consistency with the sector analysis and any community or neighborhood plans adopted for the area. The review shall occur within ten (10) days of request to the planning and community development department by the applicant and shall be submitted to the zoning case manager for inclusion in the staff recommendation to the zoning commission.

(3) Zoning Site Plan.

A. A zoning site plan based on the pedestrian shed analysis shall be required for the infill village and infill regional center master development pattern plans.

B. The zoning site plan for infill shall include those items identified in subsection 35-357(f)(2) including, but not limited to: location of pedestrian sheds, location of development patterns, location of transect zones, and location of street network.

(4) Master Development Pattern Plan.

A. A master development pattern plan (MDPP) shall be submitted and approved for property rezoned to FBZD before any building permits shall be issued.

B. The MDPP shall follow the standards set forth in subsections 35-209(c), 35-209(d), 35-209(e), and 35-209(f) and shall be in accordance with the provisions of subsection 35-357(h).

C. Thoroughfare requirements for infill conditions. If specific existing ROW is narrower than the minimum standards for thoroughfares as prescribed by tables 209-6A, 209-6D, 209-6E and 209-6F, then narrower standards for public frontage elements, travel lanes, parking lanes, and/or other thoroughfare elements shall be permitted for those specific infill conditions.

D. In an infill context, one (1) of the following development patterns shall be required:

1. Infill Village.

   a. Context. An infill village shall be appropriate to neighborhood areas that are predominantly residential with one (1) or more mixed use corridors or centers.

   b. Structure. An infill village shall be mapped as at least one (1) complete standard pedestrian shed oriented around and preferably centered on the lots to be rezoned to FBZD. An infill village pedestrian shed analysis shall include all applicable transect zones as prescribed in table 209-18(A). The edges of an infill village should blend into adjacent neighborhoods and/or a downtown without buffers.

   c. Area to be rezoned. The minimum acreage for rezoning shall be ten (10) acres. The area to be rezoned FBZD shall include one (1) or more transect zones. The appropriateness of transect zones included shall be based upon the pedestrian shed analysis of the existing and proposed mix of density and intensity of uses.

   d. Calibration of infill transect zones. Within the infill village area to be rezoned, subcategories of one (1) or more transect zones may be calibrated as specified in subsection 35-209(d)(5).

2. Infill Regional Center.

   a. Context. An infill regional center shall be appropriate to areas that include significant office and retail uses as well as government and other civic institutions of regional importance.

   b. Structure. An infill regional center shall be mapped as at least one (1) complete long pedestrian shed oriented around and preferably centered on the lots to be rezoned to FBZD. An infill regional center pedestrian shed analysis shall include all applicable transect zones as prescribed in table 209-18(A). The edges of an infill regional center should blend into adjacent neighborhoods without buffers.

   c. Area to be rezoned. The minimum acreage for rezoning shall be twenty (20) acres. The area to be rezoned FBZD shall include one (1) or more transect zones. The appropriateness of transect zones included shall be based upon the pedestrian shed analysis of the existing and proposed mix of density and intensity of uses.

d. Calibration of infill transect zones. Within the infill regional center area to be rezoned, subcategories of one (1) or more transect zones may be calibrated as specified in subsection 35-209(d)(5).

(5) Transect Zone Calibration.

A. The area within an infill village or infill regional center to be rezoned shall use one (1) or more of the six (6) standard transect zones listed in table 209-18 as the base zoning district. In order to preserve and establish the goals of form based zoning through sustainable patterns of development within infill areas and accommodate the unique characteristics of individual neighborhoods one (1) or more calibrated transect zoning district boundaries, or combination of transect zoning district boundaries and calibrated transect zoning district boundaries may be designated in a FBZD. Calibrated transect zoning district boundaries shall be designated by adding a numeric designation following the base transect designation, e.g., FBZ T4 (T4-1).

B. A calibrated transect zone shall be based on a single standard transect zone, and shall not establish standards that are outside the parameters set by that standard transect zone in table 209-18(C) through (L), subsection 35-209(e)(3)(E), subsection 35-209(e)(4)(E), subsection 35-209(e)(5)(E), and/or subsection 35-209(e)(6)(E). For example, a calibrated T5 district shall not establish principal building heights that are taller than the principal building height prescribed by the standard T5 district in table 209-18. A calibrated transect zone district may restrict standards that are permitted in the standard transect zone, but shall not permit standards that are not permitted in the base transect zone district.

C. No other sections or tables other than those listed in subsection 35-209(d)(5)(B) shall be calibrated.

D. The density of the area to be rezoned within an infill village or infill regional center shall be controlled by the row labeled "Infill Option" in table 209-18.

E. The calibrated transect zone standards shall be derived by means of a survey of exemplary existing and intended conditions, as identified in a process of public consultation prescribed in subsection 25-209(d)(2).

F. The calibrated transect zone standards shall be documented, attached, and approved as part of the rezoning ordinance.

G. Calibrated transect zone districts shall be designated by adding a numeric suffix to the base transect zone designation, e.g., a T-6 base zoning, if calibrated, would become a T-6-1, T-6-2, T-6-3, etc. calibrated transect zone district in accordance with table 209-18A.

H. For structures designated as historic landmarks or for structures identified as having high historic integrity by the office of historic preservation, the existing front setback of the designated or identified structure shall establish the minimum required front setback for that lot.

(6) Civic Requirements.

A. General.

1. Master development pattern plans for infill shall designate civic spaces (CS), civic buildings (CB), and civic transit zones (CT) within each development pattern. A minimum allocation of five (5) percent of the development pattern's urbanized area (T-3 through T-6, or the calibrated equivalents) is required. Existing civic spaces may count toward this requirement if designated as such in the MDPP.

2. A civic space, civic building, or civic transect zone shall be permitted if it does not occupy more than twenty (20) percent of a pedestrian shed; otherwise it is subject to the creation of a specialized district [See subsection 35-209(c)(11)].

3. Parking for civic functions shall be provided in accordance with the parking standards set forth in subsection 35-209(c)(9)(c)(7).

B. Civic Spaces (CS). Civic spaces shall be permitted in accordance with table 209-9.

C. Civic Buildings (CB). Civic buildings shall be approved in accordance with the standards of subsection 35-209(c)(9)(c)(6).

(e) Building-Scale Plans.

(1) Instructions.

A. The requirements in subsection 35-209(e) and in the tables in subsection 35-209(h) shall control the disposition, configuration and function of buildings, as well as their architectural, landscape, parking, and sign standards. Specific designations that are identified or listed on the master development pattern plan shall be mandatory.

B. Plan submittals for the MDPP, plats, and building permits shall show adequate information to determine that each development pattern is in compliance with these regulations at each stage of permitting. The specific submittal requirements are outlined in section 35-357.

(2) General to T2—T6 and SD.

A. Building Disposition.

1. Newly platted lots shall be dimensioned as shown graphically on the master development pattern plan or on an addendum per subsection 35-357(h)(3) and shall be platted or re-platted according to the standards of table 209-18.

2. One (1) principal building, one (1) back building, and one (1) outbuilding may be built on each lot as shown in table 209-10B.

3. Rear setbacks for outbuildings shall be as indicated on table 209-18.

4. Buildings shall be disposed in relation to the boundaries of their lots according to table 209-11 and table 209-18.

5. Lot coverage by building shall not exceed that shown in table 209-18.

6. Facades shall be built parallel to a rectilinear primary frontage line or tangent to a curved primary frontage line. Facades in an infill development pattern may instead be built parallel to adjacent building facades to create a uniform street wall. Facades shall be built along a minimum percentage of the primary frontage width between the minimum and maximum setback as prescribed by the Primary Frontage Buildout standard in Table 209-18 or 209-18A1. For lots having two (2) frontages, one (1) shall be designated the primary frontage. The other shall be designated the secondary frontage.

7. Buildings shall have their principal entrance facing the primary frontage.

8. Setbacks for principal buildings shall be as shown in table 209-18. Notwithstanding the preceeding, if ~~Maximum setbacks for principal buildings shall be increased in~~ one (1) or more of the following conditions is present, then the Maximum setbacks for principal buildings shall be increased to the extent necessary to accommodate such existing easement(s) or to comply with such conflicting governmental law(s), rule(s), ordinance(s) or policy:~~.accordance with the following provisions:~~

   ~~a. A maximum setback for a principal building shall be increased by fifty (50) percent if one (1) or more of the following conditions is present:~~

   i. Recorded easement held by the City of San Antonio, Bexar County, Texas Department of Transportation, City Public Service Energy, San Antonio Water System or other utility provider (including telephone or cable television) is present and would prevent compliance with the setback requirements hereunder. ~~between the minimum and maximum setbacks and the easement holder has provided written verification that the easement cannot be relocated or removed,~~

   ii. A governmental law, rule, ordinance, or policy would prevent compliance with the setback requirements hereunder.

   ~~ii.~~iii. Structure designated as a City of San Antonio historic landmark, National Register landmark, state historic landmark, or state archaeological landmark is present between the minimum and maximum setbacks and will be preserved,

   ~~iii.~~iv. An existing slope exceeding ten (10) percent is present between the minimum and maximum setbacks and will be maintained, or

   ~~iv.~~v. An existing pedestrian connection to the river is present and will be retained or a new pedestrian connection to the river will be constructed between the minimum and maximum setbacks.

~~v.~~vi. If a significant or heritage tree is present between the minimum and maximum setbacks and will be preserved.

9. In a parking structure or garage, each level above grade counts as a single-story.

10. Lot Orientation to Street. Lots shall front a vehicular thoroughfare (with the exception of alleys), except that twenty-five (25) percent of the lots within each development pattern transect zone may front a pedestrian path, green civic space, or conservation area.

11. Sideyard (Zero Lot Line) Type Buildings. Buildings with sideyard dispositions are permitted in certain transect zones by table 209-18. Such buildings are characterized by occupying at most one hundred (100) percent of one lot line (the "zero lot line").

    a. On corner lots, the zero lot line may be either a secondary frontage line or a lot line.

    b. In the case of sideyard type buildings, the side setbacks prescribed in table 18 refer only to the non-zero lot line setback.

12. Porte-cochères are allowed in the first lot layer for passenger drop-off and pick-up.

B. Building Configuration.

1. Private frontage types shall be as prescribed in table 209-12 and allocated in table 209-18.

2. Building heights shall be as prescribed in table 209-18.

3. Where minimum stories of two (2) or more are prescribed by table 209-18, single-story buildings are permitted if they conform to all of the following requirements:

    a. The single-story buildings are no more than forty (40) percent of a linear block face

    b. The single-story buildings are not located within sixty (60) feet from a street intersection

    c. The building is replacing a single story building that is being demolished in connection with the development of the new building.

C. Building Function.

1. Buildings in each transect zone shall be dedicated to the functions listed in tables 209-13A and 209-13B.

2. Intensity of building functions shall be limited by the requirements in table 209-13A.

3. Primary functions masked by liner buildings shall provide access by emergency vehicles as required by the latest adopted version of the International Fire Code.

4. Manufacturing, production, warehousing, wholesale, storage, processing, assembly, and extraction functions shall be determined to be light or heavy within the context of FBZD based on the following performance criteria. If a function conforms with all of the criteria listed in subsection (e)(2)(c)(4)(a) through (m), it shall be determined to be light industrial. If it does not conform to one (1) or more of the criteria, it shall be determined to be heavy industrial.

   a. The use of vehicles with two (2) or more rear axles and/or vehicles that require a Texas commercial drivers license is limited to:

      i. The hours between 6:00 a.m. and 6:00 p.m.

      ii. Fifteen (15) trips per day.

   b. The commercial use of vehicles with one (1) rear axle, excluding employees' personal vehicles, is limited to:

      i. The hours between 4:00 a.m. and 10:00 p.m.

      ii. Fifteen (15) trips between 4:00 a.m. and 10:00 p.m. per day.

   c. No outdoor storage, outdoor disposal containers (unless located in a rear alley and adequately screened), outdoor operations, or outdoor loading docks.

   d. ~~Between the hours of 6:00 a.m. and 6:00 p.m., noise levels measured at the property line do not exceed:~~

      ~~i. The existing background broadband sound pressure level by more than seven (7) dBA.~~

      ~~ii. A broadband sound pressure level greater than sixty (60) dBA.~~

   ~~e. Between the hours of 6:01 p.m. and 5:59 a.m., noise levels measured at the property line do not exceed:~~

      ~~i. The existing background broadband sound pressure level by more than three (3) dBA.~~

      ~~ii. A broadband sound pressure level greater than forty-five (45) dBA.~~

   ~~f.~~e. Exterior lighting conforms to the following criteria:

      i. Lighting fixtures are shielded with a cutoff of less than ninety (90) degrees. All structural parts of the fixture providing the ninety (90) degree cutoff angle are permanently affixed to the general light structure.

      ii. Fixtures with a lamp or lamps rated at a total of more than one thousand eight hundred (1,800) lumens, and flood lamps rated at a total of more than nine hundred (900) lumens, do not emit any direct light above a horizontal plane through the lowest direct-light-emitting part of the fixture.

iii. All lighting is aimed, located, designed, shielded, fitted and maintained so as not to project light into a neighboring use or property.

~~iv. Flood lamps and the light source they emit are not visible from the thoroughfare.~~

~~v. All exterior lighting and all lighting or glare resulting from industrial processes are installed and/or shielded in such a manner that the light source is obscured to prevent glare on thoroughfares and other properties.~~

~~g.~~f. At any time and at any point on the property line, ground vibrations do not exceed the limits of displacement prescribed in table 209-16.

~~h.~~g. No air contaminants (such as, but not limited to, dust, ash, vapor, carbon, pollen, or other air pollutants) are discharged into the air.

~~i.~~h. No smoke is discharged into the atmosphere.

~~j.~~i. No refuse is incinerated.

~~k.~~j. No liquids are disposed onto the site or into adjacent drainage systems, except for sanitary waste.

~~l.~~k. At the property line, odor does not exceed toxic odor thresholds established by ASTM International E679-04.

~~m.~~l. The following materials are prohibited:

i. Radioactive or fissionable materials.

ii. Forbidden materials as defined in 49 CFR Ch. 1, § 173.21.

iii. Forbidden explosives as defined in 49 CFR Ch. 1, § 173.54.

iv. Materials classified as 1.1 Explosives (with a mass explosion hazard) as defined in 49 CFR Ch. 1, § 173.50.

v. Materials classified as 1.2 Explosives (with a mass projection hazard) as defined in 49 CFR Ch. 1, § 173.50.

vi. Materials classified as 4.2 Spontaneously combustible material as defined in 49 CFR Ch. 1, § 173.124.

D. Parking Standards.

1. Vehicular parking shall be provided as required by the minimum and maximum parking requirements in tables 209-14A and 209-14B. Table 209-14A establishes minimum parking requirements for all parking types (surface, structured, underground). Table 209-14B establishes maximum parking standards for surface parking only. The quantity of required parking spaces shall be adjusted for sharing in accordance with table 209-14C.

2. On-street parking immediately adjacent to the frontage lines of a lot shall count toward the minimum (not maximum) parking requirement of the building on the lot.

3. The required parking may be provided within one-quarter mile of the site that it serves. A form based parking plan for the area must be provided to exercise this option.

    a. A form based parking plan shall include the location of public or private surface or structured parking facilities. The number of automobile and bicycle spaces provided by the facility shall be indicated.

    b. A form based parking plan shall be submitted with the master development pattern plan. The form based parking plan must be approved and the parking facilities built prior to issuance of building permits or certificates of occupancy for uses that intend to utilize the facilities to meet parking requirements.

4. Parking lots shall be masked at the frontage(s) by a building or streetscreen. In lieu of a building or streetscreen, parking lots ~~in T2, T3, and T4~~ may be masked at the frontage(s) by dense native landscaping that will achieve a minimum height of three (3) feet and form an opaque visual barrier at maturity.

5. Exemptions from required parking.

    a. Nonresidential. The first one thousand five hundred (1,500) square feet of nonresidential space shall be exempt from required parking calculation.

    b. Rehabilitated building. Building that has been rehabilitated or retrofitted by an investment greater than fifty (50) percent of the building's value prior to rehabilitation or retrofit. Only the rehabilitated or retrofitted square footage is eligible for the parking exemption.

    c. Small properties. Lots under ten thousand (10,000) square feet in size are exempt from required parking.

6. Bicycle Parking.

    a. May be shared within the pedestrian shed if demonstrated in a form based parking plan.

    b. Shall be required in T3, T4, T5 and T6.

    c. Shall be convenient, secure and visible.

    d. Shall consist of short term and long term parking as specified in tables 209-14D and 209-14E.

7. Underground Parking. Underground structured parking is allowed in all lot layers.

8. Primary use parking lots may be permitted on A-Grid streets with a Specific Use Authorization in accordance with table 209-13B if the primary use parking lot would facilitate the development of surrounding lots where parking placement is limited due to lot size, shape, configuration, location, or access. Primary use parking lots permitted by a specific use authorization shall comply with the following requirements as well as any standards, conditions, or requirements imposed by city council in the zoning ordinance or required by this chapter to protect the public interest and welfare.

    a. Parking areas shall not be located within ten (10) feet of the primary frontage or within the minimum front building setback, whichever is greater.

    b. Primary use parking lots shall be masked along the primary, secondary, and river frontages by a streetscreen.

    c. Parking lot shading and screening shall be required and shall be installed in accordance with the standards outlined in 35-511(c)(7) and (e)(3).

    d. Exterior lighting shall conform to the following criteria:

        i. Lighting fixtures are shielded with a cutoff of less than ninety (90) degrees. All structural parts of the fixture providing the ninety (90) degree cutoff angle are permanently affixed to the general light structure.

        ii. Fixtures with a lamp or lamps rated at a total of more than one thousand eight hundred (1,800) lumens, and flood lamps rated at a total of more than nine hundred (900) lumens, do not emit any direct light above a horizontal plane through the lowest direct-light-emitting part of the fixture.

        iii. All lighting is aimed, located, designed, shielded, fitted and maintained so as not to project light into a neighboring use or property.

        ~~iv. Flood lamps and the light source they emit are not visible from the thoroughfare.~~

E. Architectural Standards.

1. Streetscreens shall be made of brick, stucco, ~~or~~ masonry or other material that complements ~~to match~~ the facade of the principal building.

2. Openings above the first story shall not exceed fifty (50) percent of the total building wall area, with each facade being calculated independently.

3. Fences, if provided in the private frontage, shall be constructed at the frontage lines as illustrated in table 209-10C. Fences at lot lines shall be of painted wood board, ironwork, stone, block, tile, stucco, tubular steel, welded wire, or a combination of masonry and metal, cedar posts and

welded wire or garden loop. Chain link may be used only in the second and third lot layers. Chain link shall not be installed on street frontage. Fences shall not exceed four (4) feet in height in the first lot layer and six (6) feet in height in the second and third lot layers. Solid fencing is not allowed in the first lot layer.

F. Landscape Standards.

1. Mandatory Criteria. See Section 35-511(c).

2. Streetscape trees shall be provided in accordance with the public frontage requirements in Section 35-209(c)(8)E. Street and streetscape trees shall be of a type illustrated in table 209-21.

3. Landscaped areas shall be prepared to no more than fifty (50) percent compaction, must include no less than one (1) percent organic material, and shall be a minimum depth of twenty-four (24) inches (two (2) feet).

G. Sign Standards.

1. One (1) address number no more than six (6) inches vertically shall be attached to the building in proximity to the principal entrance or at a mailbox.

2. One (1) blade sign for each business may be permanently installed perpendicular to the facade. Such a sign shall not exceed a total of four (4) square feet unless otherwise specified.

3. Encroachment. Freestanding signs including monument signs shall have a minimum five-foot setback from frontage lines or a fifteen-foot setback from lot lines (see table 209-10C) and shall not exceed six (6) feet in height.

4. Address Numbers. Numbers (not letters spelling numbers) shall be placed near the front door or front porch steps. Numbers shall be mounted to the door, the wall beside the door, the entablature, a porch column or the top riser.

5. Directional Signs. Parking directional signs shall not exceed four (4) square feet in area per side and three (3) feet in height.

6. Lighting.

a. In T1, T2, and T3, signs shall not be illuminated.

b. In T4, T5, and T6, signs may be illuminated. If illuminated, signs shall only be illuminated by an internal or external lighting source that is shielded and positioned in a manner that illuminates only the sign and prevents any glare or spillover onto adjacent properties.

7. Configuration. The following sign configurations are allowed in all transect zones except T3 and T4:

a. Band Signs. Band signs consist of a band of lettering across the width of the building, building wall plane, or tenant space. Band signs may

include stylized fonts and logos affixed directly to the exterior façade of the building. Band signs shall be a maximum of thirty-six (36) inches tall and shall be installed between the top of the first story openings and the top of the exterior wall for a single story building or between the top of the first story openings and the bottom of the second story openings for a multi-story building. Band signs may be installed directly above the openings of an upper story of a multi-story building if there are tenants with exterior entries on the upper story.

b. Plaque Signs. A plaque sign is a signboard attached flush with a building wall or streetwall adjacent to an entry. Plaque signs shall be a maximum size of six (6) square feet.

c. Window Signs. Window signs may be neon behind the glass, or, paint or vinyl applied directly to the glass. Neither shall be mounted on opaque sign boards. The area of any window sign is limited to one-third (1/3) of the glass in the sash where the sign is installed, excluding muntins.

d. Painted Wall Signs. Painted wall signs shall be rectangular, oriented horizontally or vertically, and no larger in area than twenty-five (25) percent of the area of the building façade on which the sign is located.

e. Home-Based Business Signs. Signs advertising a home-based business shall be wood, painted, and a maximum size of four (4) square feet. Signs may have engraved, gold leaf letters and symbols. Signs may be mounted to a freestanding post, hung below a porch roof, or mounted to a building wall. Alternately, brass may be used for signs mounted to masonry building walls. One (1) sign advertising a home-based business is permitted at each frontage.

f. Real Estate Sign. One (1) real estate sign advertising a property for sale or rent may be displayed at each frontage, not to exceed six (6) square feet.

g. Monument Signs. Monument signs are permanent freestanding signs mounted on a solid base with no more than two (2) sign faces, and are limited to a landscaped area. Signs shall not exceed four (4) feet in height, including the base, four (4) feet in width, and eight (8) square feet per sign face.

8. Exceptions. The following signs shall be exempt from the sign standards:

a. Transit Stops. Signs or markers installed by a public transit agency to designate transit stops.

b. Government Signs. Public signs erected by or on behalf of a governmental agency to convey public information, identify public property, post legal notices, or direct or regulate pedestrian or vehicular traffic.

c. Noncommercial or Political Speech Signs. Must not exceed fifteen (15) square feet of facing composed of durable material, situated wholly upon private property and securely affixed to a building, fence, or wall, and having a frame or trim not more than three (3) inches wide. Noncommercial or political speech signs may be used for a maximum of ninety (90) days.

d. Public Utility Signs. Informational signs of a public utility regarding its lines, pipes, poles, or other facilities.

e. Temporary Signs. Temporary signs shall include: cloth banners extending over public right-of-way; A-boards and other portable sidewalk signs; emergency warning signs erected by a government agency, a public utility company or a contractor doing authorized work within the public right-of-way; and balloons less than one (1) foot in diameter. Temporary signs may be used for a maximum duration of thirty (30) days each six (6) months.

9. Prohibited Signs.

a. Inflatable Figures/Devices. Three-dimensional wind powered or air-filled figures other than balloons one (1) foot in diameter or less.

b. Off-Premises Signs. A sign which is a primary use and advertises businesses, commodities, activities, services or persons which are not usually available or present upon the premises upon which such sign is located, or which directs persons to any location not on the premises. Any sign with more than ten (10) percent of the sign devoted to such use shall be deemed to be an off-premises sign.

c. Pole Signs. Freestanding pole signs, not including flag poles.

d. Roof Signs. Signs painted on or mounted on a building roof.

e. Signs that simulate in color, size, or design, any traffic control sign or signal or that make use of words, symbols, or characters in a manner that interferes with, misleads, or confuses pedestrian or vehicular traffic.

10. All signs shall comply with chapter 28 if not expressly addressed in this section and the standards of any overlay zone and the standards of chapter 35.

11. No sign shall be placed in a manner that disfigures, damages, or conceals any window opening, door, or architectural feature or detail.

(3) Specific to Sub-Urban Zones (T3).

A. (T3) Building Disposition.

1. Porches may encroach up to fifty (50) percent of the depth of the first lot layer.

2. Balconies and bay windows may encroach up to twenty-five (25) percent of the depth of the first lot layer.

B. (T3) Building Configuration. [See subsection 35-209(e)(2)(B).

C. (T3) Building Function. Ancillary functions to lodging, office, retail, and civic functions shall be permitted within an outbuilding and/or backbuilding.

D. (T3) Parking Standards.

1. All parking areas shall be located in the second and/or third lot layers.

2. Garages shall be located in the third lot layer as illustrated in table 209-10D and table 209-10E.

3. Parking areas in the second lot layer are only allowed at mid-block locations (not corner lots), shall be a minimum of sixty (60) feet from either street intersection, and shall be masked from the public frontage by a streetscreen.

4. Parking may be accessed from the primary or secondary frontage by means of a driveway.

E. (T3) Architectural Standards.

1. The facades on retail frontages shall be detailed as shopfronts.

2. The exterior finish material on all facades shall be limited to brick, masonry, stone, wood siding, cement fiber siding, corrugated metal, composite aluminum panels and/or stucco with the exception of cast and molded metal which can be used for detailing on shopfronts.

3. Balconies and porches shall be made of the same material as the primary structure, or made of painted wood/wood fiber composite.

4. Principal buildings shall have sloped roofs.

5. Disposal receptacles shall be stored in the second or third lot layer and shall not be visible from the thoroughfare.

6. Disposal receptacles that serve nonresidential functions shall be screened completely from public view at ground level.

a. Screening shall be a minimum of six (6) feet in height or a height sufficient to obscure the area or equipment requiring the screening, whichever is less.

b. Screening shall be provided by plants, a solid screen fence or wall, or a combination thereof.

c. Materials for walls shall conform to transect zone standards as prescribed in subsection 35-209(e)(3)(E)(2).

d. Fences shall consist of painted wood board.

e. Screening provided by plants shall follow the standards in subsection 35-511(c).

F. (T3) Landscape Standards.

1. A minimum of one (1) street tree shall be planted within the first lot layer for each thirty (30) feet of primary frontage line.

2. The first lot layer as shown in table 209-10D and table 209-10E shall consist of trees of various species, naturalistically clustered, as well as low maintenance understory.

3. The landscape installed shall consist primarily of native species (eighty (80) percent) and established by drip irrigation.

G. (T3) Sign Standards.

1. Signs may not be illuminated.

2. Sign Materials. Signs shall be constructed of wood, synthetic wood or metal, or they may be painted on building walls or windows.

3. Address Numbers. Numbers shall be metal, ceramic or paint.

4. Configuration.

Blade Signs. Blade signs hung from an architectural element shall be centered on that element. Blade signs projecting from the wall may project a maximum of five (5) feet. The top of the blade sign shall be between nine (9) and twelve (12) feet above the sidewalk. The blade sign shall be thirty-two (32) inches tall maximum. Blade signs shall be no more than four (4) feet wide nor project more than five (5) feet from the wall. Brackets and other suspension devices shall match the sign style and shall not be computed as part of the allowable size of the sign.

5. There shall be no signs permitted in T3 other than as specified in this subsection 35-209(e)(3)(G).

(4) Specific to General Urban Zones (T4).

A. (T4) Building Disposition.

1. Balconies, porches, bay windows, stoops, shopfront awnings, and galleries may encroach up to fifty (50) percent of the depth of the first lot layer.

2. Loading docks, service entrances, and service yards shall be permitted on side and rear yards.

B. (T4) Building Configuration.

1. Any building with a ground-floor area larger than ninety thousand (90,000) square feet shall meet at least one (1) of the following conditions:

a. The building shall be enclosed by a liner building.

b. Each building facade shall provide at least one (1) public entrance at the ground-floor level every seventy-five (75) linear feet. If a facade is narrower than seventy-five (75) linear feet, one (1) entrance, which

may be either a public entrance or a tenant/resident entrance, shall be provided along that facade. Corner entrances count for both facades.

C. (T4) Building Function.

1. Ancillary functions to lodging, office, retail, and civic functions shall be permitted within an outbuilding and/or backbuilding.

D. (T4) Parking Standards.

1. All parking areas shall be located in the second and/or third lot layers.

2. Parking areas in the second lot layer are only allowed as follows:

~~a. At mid-block location. Mid-block locations shall be a minimum of sixty (60) feet from either street intersection and shall be masked at the frontage by a liner building or streetscreen~~

~~b. In parking structures above the first story.~~

a. As Primary Use Parking Lots.

b. As Parking Structures that are masked with a Streetscreen; or

c. Above the first floor of Parking Structures that are masked with a Liner Building.

~~3. Garages shall be located in the third lot layer as illustrated by table 209-10D and table 209-10E.~~

~~4.~~3. Parking may be accessed from the primary frontage by means of a driveway.

4. Parking structures shall have either of the following along the primary frontage and (to the extent the property has river frontage) along the river frontage: (i) a Liner Building, or (ii) a Streetscreen.

For river frontage only, if a Streetscreen is used to mask a Parking Structure, the Streetscreen must be the full height of the Parking Structure. Additionally, for the river frontage only, if a Liner Building is used to mask a Parking Structure, then: (i) the Liner Building must be the full height of the Parking Structure, or (ii) a full height Streetscreen must be installed above the Liner Building to mask any parking above the height of the Liner Building

In the event a Streetscreen or Liner Building is used to mask a Parking Structure on the Primary Frontage, the height of such Liner Building or Streetscreen shall be as otherwise provided herein.

~~5. Parking structures shall have a liner building of at least two (2) stories in height and twenty-five (25) feet in depth on the primary and secondary frontages, or the primary and river frontages for properties with river frontage. In lieu of a liner building, at least the first and second stories of a parking structure shall be enclosed. The first story shall be enclosed to a minimum depth of twenty-five (25) feet and the façade detailed as a~~

~~shopfront. The second story shall be enclosed and the façade detailed in accordance with the (T4) Architectural Standards.~~

E. (T4) Architectural Standards.

1. The facades on retail frontages shall be detailed as shopfronts.
2. The exterior finish materials on all facades shall be limited to brick, masonry, stone, clapboard, cement fiber siding, corrugated metal, composite aluminum panels, and/or stucco. For accent, external insulation finishing system (EIFS), river rock, glass block, ironwork and/or tile may be used on no more than twenty-five (25) percent of each elevation.
3. Balconies and porches shall be made of the same material as the primary structure, or made of painted wood/wood composite or metal.
4. Principal buildings shall have sloped roofs.
5. Disposal receptacles shall be stored in the second or third lot layer and shall not be visible from the thoroughfare.
6. Disposal receptacles that serve nonresidential functions shall be screened completely from public view at ground level.
    a. Screening shall be a minimum of six (6) feet in height or a height sufficient to obscure the area or equipment requiring the screening, whichever is less.
    b. Screening shall be provided by plants, a solid screen fence or wall, or a combination thereof.
    c. Materials for walls shall conform to transect zone standards as prescribed in subsection 35-209(e)(4)(E)(2).
    d. Fences shall consist of painted wood board.
    e. Screening provided by plants shall follow the standards in subsection 35-511(c).
7. The maximum length of an individual wall plane that faces a street shall be fifty (50) feet, except under the following conditions:
    a. If a building wall plane facing a street exceeds fifty (50) feet in length, at least two (2) of the following techniques shall be employed to reduce the perceived mass:
        i. Change materials with each building module to reduce its perceived mass; or
        ii. Change the height with each building module of a wall plane. The change in height shall be at least ten (10) percent of the vertical height; or

iii. Change the roof form of each building module to help express the different modules of the building mass; or

iv. Change the arrangement of windows and other facade articulation features, such as, columns, pilasters or strap work, which divides large planes into smaller components.

b. If a building wall plane facing a street exceeds one hundred fifty (150) feet in length, then massing breaks shall be employed. Massing breaks shall:

i. Be employed at intervals of no more than one hundred fifty (150) feet.

ii. Take the form of a forecourt [see table 209-12 D] or a passage connecting to an internal courtyard.

iii. Extend into the third lot layer and measure at least twenty-five (25) feet in width.

F. (T4) Landscape Standards.

1. A minimum of one (1) street tree shall be planted within the first lot layer for each thirty (30) feet of primary frontage line.

2. The first lot layer as shown in table 209-10D and table 209-10E shall be planted with trees. Lawn shall be permitted.

3. The landscape installed shall consist of eighty (80) percent native species that are drought tolerant and established by drip irrigation.

G. (T4) Sign Standards.

1. Address Numbers. Numbers shall be metal, ceramic or paint.

2. Configuration.

Blade Signs. Blade signs hung from an architectural element shall be centered on that element. Blade signs projecting from the wall may project a maximum of five (5) feet. The top of the blade sign shall be between nine (9) feet and twelve (12) feet above the sidewalk. The blade sign shall be thirty-two (32) inches tall maximum. Blade signs shall be no more than four (4) feet wide nor project more than five (5) feet from the wall. Brackets and other suspension devices shall match the sign style and shall not be computed as part of the allowable size of the sign.

3. There shall be no signs permitted in T4 other than as specified in this section 35-209(e)(4)(G).

(5) Specific to Urban Center Zones (T5).

A. (T5) Building Disposition.

1. Stoops, lightwells, balconies, bay windows and terraces may encroach one hundred (100) percent of the depth of the first lot layer.

2. Awnings, arcades, and galleries may encroach the sidewalk to within two (2) feet of the curb but must clear the sidewalk vertically by at least eight (8) feet.

3. Loading docks, service entrances, and service yards shall be located in the third lot layer and shall only be accessed through the alley when an abutting alley is provided on the MDPP. If an alley is not provided on the MDPP or if the subject property is exempt from the requirement of alley access per 35-209(c)(8)B8, ~~the alley is pre-existing and meets one (1) or more of the conditions in 35-209(c)(8)B.8f.,~~ loading docks, service entrances, and service yards may be accessed from the primary or secondary frontage by means of a driveway.

B. (T5) Building Configuration.

1. A first level residential function shall be raised a minimum of two (2) feet from average sidewalk grade. Site design shall factor access issues to the public right-of-way. Site design shall provide an accessible pedestrian access route (PAR) and a minimum of one (1) no-step entrance as required by applicable local, state, and federal requirements.

2. Any building with a ground-floor area larger than ninety thousand (90,000) square feet shall meet at least one (1) of the following conditions:

a. The building shall be enclosed by a liner building.

b. Each building facade shall provide at least one (1) public entrance at the ground-floor level every seventy-five (75) linear feet. If a facade is narrower than seventy-five (75) linear feet, one (1) entrance, which may be either a public entrance or a tenant/resident entrance, shall be provided along that facade. Corner entrances count for both facades.

C. (T5) Building Function.

1. Ancillary functions to lodging, office, retail, and civic functions shall be permitted within an outbuilding and/or backbuilding.

2. First story retail shall be permitted in all buildings.

D. (T5) Parking Standards.

1. All parking areas shall be located in the second and/or third lot layer as illustrated in table 209-10D and table 209-10E.

2. Parking areas in the second lot layer are only allowed as follows:

~~a. At mid-block location. Mid-block locations shall be a minimum of sixty (60) feet from either street intersection and shall be masked at the frontage by a liner building or streetscreen~~

~~b. In parking structures above the first story.~~

a. As Primary Use Parking Lots;

b. As Parking Structures that are masked with a Streetscreen; or

c. Above the first floor of Parking Structures that are masked with a Liner Building.

~~3. Garages shall be located in the third lot layer~~

~~4.~~3. Parking shall be accessed from an alley when an abutting alley is provided on the MDPP. If an alley is not provided on the MDPP or ~~the alley is pre existing and meets one (1) or more of the conditions in 35-209(c)(8)B.8.f.~~ if the subject property is exempt from the requirement of alley access per 35-209(c)(8)B.8., parking may be accessed from the primary or secondary frontages by means of a driveway.

~~5.~~4. Primary pedestrian entrances to all parking lots and parking structures shall be directly from a frontage line. Parking structures may also be entered by pedestrians directly from a principal building.

~~6.~~5. The vehicular entrance, exit, or entrance/exit of a parking lot or garage shall be no wider than thirty (30) feet at the frontage line; provided, however, the preceding restriction shall not apply to commercial garages available to the general public for parking.

~~7.~~6. When a form based parking plan is provided within the long pedestrian shed of a regional center, the effective parking available for calculating the intensity on each lot may be increased by a multiplier of thirty (30) percent without increasing parking requirements cited in table 209-14.

~~8. Parking structures shall have a liner building of at least two (2) stories in height and twenty-five (25) feet in depth on the primary and secondary frontages, or the primary and river frontages for properties with river frontage. In lieu of a liner building, at least the first and second stories of a parking structure shall be enclosed. The first story shall be enclosed to a minimum depth of twenty-five (25) feet and the façade detailed as a shopfront. The second story shall be enclosed and the façade detailed in accordance with the (T5) Architectural Standards.~~

7. Parking Structures shall have either of the following along the primary frontage and (to the extent the property has river frontage) along the river frontage: (i) a Liner Building, or (ii) a Streetscreen.

For river frontage only, if a Streetscreen is used to mask a Parking Structure, the Streetscreen must be the full height of the Parking Structure. Additionally, for the river frontage only, if a Liner Building is used to mask a Parking Structure, then: (i) the Liner Building must be the full height of the Parking Structure, or (ii) a full height Streetscreen must be installed above the Liner Building to mask any parking above the height of the Liner Building.

In the event a Streetscreen or Liner Building is used to mask a Parking Structure on the Primary Frontage, the height of such Liner Building or Streetscreen shall be as otherwise provided herein.

E. (T5) Architectural Standards.

1. The facades on retail frontages shall be detailed as shopfronts.

2. The exterior finish materials on all facades shall be limited to stone, brick, masonry, corrugated metal, composite aluminum panel, and/or stucco. Clapboard and cement fiber siding may be used, but are not permitted on the first story of the primary facade. For accent, external insulation finishing system (EIFS), river rock, glass block, ironwork and/or tile may be used on no more than twenty-five (25) percent of each elevation.

3. Balconies, galleries and arcades shall be made of concrete, painted wood/wood composite or metal.

4. Buildings may have flat roofs enclosed by parapets or sloped roofs.

5. Streetscreens shall be located parallel to a frontage line as shown in table 209-10D.

~~6. Disposal receptacles shall be stored in the second or third lot layer.~~

~~7.~~6. Disposal receptacles shall be screened completely from public view at ground level.

   a. Screening shall consist of a solid wall and be a minimum of six (6) feet in height, or a height sufficient to obscure the area or equipment requiring the screening, whichever is less.

   b. Screening materials shall conform to transect zone standards as prescribed in subsection 35-209(e)(5)(E)(2).

~~8.~~7. The maximum length of an individual wall plane that faces a street shall be fifty (50) feet, except under the following conditions:

   a. If a building wall plane facing a street exceeds fifty (50) feet in length, at least two (2) of the following techniques shall be employed to reduce the perceived mass:

      i. Change materials with each building module to reduce its perceived mass; or

      ii. Change the height with each building module of a wall plane. The change in height shall be at least ten (10) percent of the vertical height; or

      iii. Change the roof form of each building module to help express the different modules of the building mass; or

      iv. Change the arrangement of windows and other facade articulation features, such as, columns, pilasters or strap work, which divides large planes into smaller components.

   b. If a building wall plane facing a street exceeds one hundred fifty (150) feet in length, then massing breaks shall be employed. Massing breaks shall:

i. Be employed at intervals of no more than one hundred fifty (150) feet; or

ii. Take the form of a forecourt (see table 209-12(d)) or a passage connecting to an internal courtyard; or

iii. Extend into the third lot layer and measure at least twenty-five (25) feet in width.

F. (T5) Landscape Standards.

1. The first lot layer shall be landscaped or paved to match the adjacent public frontage as shown in tables 209-6E and 209-6F.

2. Trees shall be a species with shade canopies that, at maturity, remain clear of building frontages.

3. The landscape installed shall consist of eighty (80) percent native species that are drought tolerant and established by drip irrigation.

G. (T5) Sign Standards.

1. Address Numbers. Numbers shall be metal, ceramic or paint.

2. Configuration. The following configurations are allowed in T5 in addition to the configurations allowed in subsection (e)(3)(G)(6).

a. Blade Signs. Blade signs hung from an architectural element shall be centered on that element. Blade signs projecting from the wall may project a maximum of five (5) feet. The top of the blade sign shall be between nine (9) feet and twelve (12) feet above the sidewalk. The blade sign shall be thirty-two (32) inches tall maximum. Blade signs shall be no more than four (4) feet wide nor project more than five (5) feet from the wall. No blade sign shall exceed six (6) feet square feet. Brackets and other suspension devices shall match the sign style and shall not be computed as part of the allowable size of the sign.

i. Parking garages that provide publicly-usable parking spaces may have a blade illuminated blade sign not exceeding twenty four (24) square feet.

b. Vertical Corner Signs. Vertical corner signs are permitted at the corners of blocks. They may project perpendicular from one (1) side of the building or at a forty-five (45) degree angle to the corner. Vertical corner signs shall be constructed of either signboards or metal, and they may be lit either with gooseneck lights ~~or~~ with surface neon, reversed halo letters, or internally illuminated with push-though clear acrylic letters minimum of ¾ inch deep. Internally illuminated signs must have opaque boxes with only the sign text and/or logo illuminated. Vertical corner signs shall be mounted a minimum of twelve (12) feet from the sidewalk, measured to the bottom of the sign. The height of the sign shall not exceed ~~ten (10)~~ fifteen (15) feet in height. Vertical corner signs shall be mounted twelve (12) feet

maximum away from the exterior wall of the building and shall be a maximum of three (3) feet wide.

c. Cornice Signs. Buildings may have one sign consisting of the building's name integrated into the architecture of one façade as part of a cornice, parapet, or immediately below the building's roof. The maximum height of any letter in the cornice sign may not exceed thirty (24) inches in buildings from 2 to 4 stories in height and thirty (36) inches buildings over 4 stories. Buildings with cornice signs may have only one blade sign in addition to a sign designating a publicly usable parking garage.

(6) Specific to Urban Core Zones (T6).

A. (T6) Building Disposition.

1. Stoops, lightwells, balconies, and bay windows may encroach one hundred (100) percent of the depth of the first lot layer.

2. Awnings, arcades, and galleries may encroach the sidewalk to within two (2) feet of the curb but must clear the sidewalk vertically by at least eight (8) feet.

3. Loading docks, service entrances, and service yards shall be located in the third lot layer and shall only be accessed through the alley when an abutting alley is provided on the MDPP. If an alley is not provided on the MDPP or ~~the alley is pre-existing and meets one (1) or more of the conditions in 35-209(c)(8)B.8.f.~~ if the subject property is exempt from the requirement of alley access per 35-209(c)(8)B8, loading docks, service entrances, and service yards may be accessed from the primary or secondary frontage by means of a driveway.

B. (T6) Building Configuration.

1. Any building with a ground-floor area larger than ninety thousand (90,000) square feet shall meet at least one (1) of the following conditions:

a. The building shall be enclosed by a liner building.

b. Each building facade shall provide at least one (1) public entrance at the ground-floor level every seventy-five (75) linear feet. If a facade is narrower than seventy-five (75) linear feet, one (1) entrance, which may be either a public entrance or a tenant/resident entrance, shall be provided along that facade. Corner entrances count for both facades.

C. (T6) Building Function.

1. Ancillary functions to lodging, office, retail, and civic functions shall be permitted within an outbuilding and/or backbuilding.

2. First story retail shall be permitted in all buildings.

D. (T6) Parking Standards.

1. All parking areas shall be located in the second and/or third lot layer as illustrated in table 209-10D and table 209-10E.
2. Parking areas in the second lot layer are only allowed as follows:

   ~~a. At mid-block location. Mid-block locations shall be a minimum of sixty (60) feet from either street intersection and shall be masked at the frontage by a liner building or streetscreen~~

   ~~b. In parking structures above the first story.~~

   a. As Primary Use Parking Lots;

   b. As Parking Structures that are masked with a Streetscreen; or

   c. Above the first floor of Parking Structures that are masked with a Liner Building.
3. Parking shall be accessed from an alley when an abutting alley is provided on the MDPP. If an alley is not provided on the MDPP or ~~the alley is pre existing and meets one (1) or more of the conditions in 35-209(c)(8)B.8.f.~~ if the subject property is exempt from the requirement of alley access per 35-209(c)(8)B.8., parking may be accessed from the primary or secondary frontages by means of a driveway.
4. Primary pedestrian entrances to all parking lots and parking structures shall be directly accessed from a frontage line. Parking structures may also be entered by pedestrians directly from a principal building.
5. The vehicular entrance, exit, or entrance/ exit of a parking lot or garage shall be no wider than thirty (30) feet at the frontage line; provided, however, the preceding restriction shall not apply to commercial garages available to the general public for parking.
6. When a form based parking plan is provided within the long pedestrian shed of a regional center, the effective parking available for calculating the intensity on each lot may be increased by a multiplier of thirty (30) percent without increasing parking requirements cited in table 209-14.

~~7. Parking structures shall have a liner building of at least two (2) stories in height and twenty-five (25) feet in depth on the primary and secondary frontages, or the primary and river frontages for properties with river frontage. In lieu of a liner building, at least the first and second stories of a parking structure shall be enclosed. The first story shall be enclosed to a minimum depth of twenty-five (25) feet and the façade detailed as a shopfront. The second story shall be enclosed and the façade detailed in accordance with the (T5) Architectural Standards.~~

7. Parking Structures shall have either of the following along the primary frontage and (to the extent the property has river frontage) along the river frontage: (i) a Liner Building, or (ii) a Streetscreen.

For river frontage only, if a Streetscreen is used to mask a Parking Structure, the Streetscreen must be the full height of the Parking Structure. Additionally, for river frontage only, if a Liner Building is used to mask a Parking Structure, then: (i) the Liner Building must be the full height of the Parking Structure, or (ii) a full height Streetscreen must be installed above the Liner Building to mask any parking above the height of the Liner Building.

In the event a Streetscreen or Liner Building is used to mask a Parking Structure on the Primary Frontage, the height of such Liner Building or Streetscreen shall be as otherwise provided herein.

E. (T6) Architectural Standards.

1. The facades on retail frontages shall be detailed as shopfronts.
2. The exterior finish materials on all facades shall be limited to stone, brick, masonry, composite aluminum panel, and/or stucco. Clapboard and cement fiber siding may be used, but are not permitted on the first story of the primary facade. For accent, external insulation finishing system (EIFS), river rock, glass block, ironwork and/or tile may be used on no more than twenty-five (25) percent of each elevation.
3. Balconies, galleries and arcades shall be made of concrete, painted wood/wood composite or metal.
4. Buildings may have flat roofs enclosed by parapets, or sloped roofs.
5. Streetscreens shall be located parallel to a frontage line as shown in table 209-10D.

~~6. Disposal receptacles shall be stored in the second or third lot layer.~~

~~7.~~6. Disposal receptacles shall be screened completely from public view at ground level.

   a. Screening shall consist of a solid wall and be a minimum of six (6) feet in height, or a height sufficient to obscure the area or equipment requiring the screening, whichever is less.

   b. Screening materials shall conform to transect zone standards as prescribed in subsection 35-209(e)(6)(E)(2).

~~8.~~7. The maximum length of an individual wall plane that faces a street shall be fifty (50) feet, except under the following conditions:

   a. If a building wall plane facing a street exceeds fifty (50) feet in length, at least two (2) of the following techniques shall be employed to reduce the perceived mass:

      i. Change materials with each building module to reduce its perceived mass; or

ii. Change the height with each building module of a wall plane. The change in height shall be at least ten (10) percent of the vertical height; or

iii. Change the roof form of each building module to help express the different modules of the building mass; or

iv. Change the arrangement of windows and other facade articulation features, such as, columns, pilasters or strap work, which divides large planes into smaller components.

b. If a building wall plane facing a street exceeds one hundred fifty (150) feet in length, then massing breaks shall be employed. Massing breaks shall:

i. Be employed at intervals of no more than one hundred fifty (150) feet; or

ii. Take the form of a forecourt (see table 209-12(d)) or a passage connecting to an internal courtyard; or

iii. Extend into the third lot layer and measure at least twenty-five (25) feet in width.

F. (T6) Landscape Standards.

1. The first lot layer shall be landscaped or paved to match the public frontage as shown in tables 209-6E and 6F.

2. Trees shall be species with shade canopies that, at maturity, remain clear of building frontages.

3. Trees shall not be required in the first lot layer.

4. The species of landscape installed shall consist of eighty (80) percent native species that are drought tolerant and established by drip irrigation.

G. (T6) Sign Standards.

1. Address Numbers. Numbers shall be metal, ceramic or paint.

2. Configuration. The following configurations are allowed in T5 in addition to the configurations allowed in subsection 35-209(e)(3)(G)(6):

a. Blade Signs. Blade signs hung from an architectural element shall be centered on that element. Blade signs projecting from the wall may project a maximum of five (5) feet. The top of the blade sign shall be between nine (9) feet and twelve (12) feet above the sidewalk. The blade sign shall be thirty-two (32) inches tall maximum. Blade signs shall be no more than four (4) feet wide nor project more than five (5) feet from the wall. No blade sign shall exceed eight (8) square feet. Brackets and other suspension devices shall match the sign style and shall not be computed as part of the allowable size of the sign.

i. Parking garages that provide publicly-usable parking spaces may have a blade illuminated blade sign not exceeding twenty four (24) square feet.

b. Vertical Corner Signs. Vertical corner signs are permitted at the corners of blocks. They may project perpendicular from one (1) side of the building or at a forty-five (45) degree angle to the corner. Vertical corner signs shall be constructed of either signboards or metal, and they may be lit either with gooseneck lights ~~or~~ with surface neon, reversed halo letters, or internally illuminated with push-though clear acrylic letters minimum of ¾ inch deep. Internally illuminated signs must have opaque boxes with only the sign text and/or logo illuminated. Vertical corner signs shall be mounted a minimum of twelve (12) feet from the sidewalk, measured to the bottom of the sign. The height of the sign shall not exceed ~~ten (10)~~ fifteen (15) feet in height. Vertical corner signs shall be mounted twelve (12) feet maximum away from the exterior wall of the building and shall be a maximum of three (3) feet wide.

c. Cornice Signs. Buildings may have one sign consisting of the building's name integrated into the architecture of one façade as part of a cornice, parapet, or immediately below the building's roof. The maximum height of any letter in the cornice sign may not exceed thirty (24) inches in buildings from 2 to 4 stories in height and thirty (36) inches buildings over 4 stories. Buildings with cornice signs may have only one blade sign in addition to a sign designating a publicly usable parking garage.

(f) Guidelines for Transit Facilities, Bicycle Parking, and Schools.

(1) Transit Guidelines.

A. Transit amenities shall be provided as indicated in table 209-9B.

B. Bus service to suburban and rural areas shall not create street networks that prohibit the feasibility of future transit options.

C. Where suburban or rural bus routes pass through nonresidential areas or areas of limited development for a distance of a mile or longer, the distance standard may be altered or waived for these areas only, at the discretion of bus operations. Where the sum of boardings and lightings is less than four (4) per vehicle mile in the peak hour for a distance of one (1) mile or longer, a courtesy stop zone may be created by the bus operations.

D. No more than six (6) and no less than four (4) bus stops per route mile will be provided along all line service routes, except express and limited stop routes outside the downtown business district.

E. The application of this standard is subject to the availability of suitable sites that provide safe access for passengers. The location of bus stops should also consider the future placement of passenger shelters or benches, and compliance

with ADA regulations. A bus stop should be provided at all sites where transfers are possible.

F. Park and ride facilities may be provided at any suitable location which can be shown to attract two hundred (200) autos per day within three (3) years, if express service is offered, and one hundred fifty (150) automobiles per day within three (3) years, if limited stop service is offered.

G. Transit facilities designed to facilitate transfer activity and support primary origin-destination trip service can be provided by exception. Transit facilities may vary in form from an on-street transit stop with a shelter to an elaborate multi-modal facility. Limited automobile parking or waiting areas for passenger pick-ups may be provided. Selection of a site will be based on an evaluation of the impact on traffic and pedestrian operations in the area, the ability of the site to accommodate a design that provides good circulation, and access for transit vehicles and transit patrons and the potential for joint development.

(2) Bicycle Parking Guidelines.

A. Short term bicycle parking shall be free, prevalent, visible, well lit, and convenient to building entrances. This type of parking is intended for customers, visitors and messengers who generally park for two (2) hours or less, and is typically in the form of a bicycle rack.

B. Long term bicycle parking provides a secure and weather-protected place to park bicycles. Parking shall be covered or indoors, and may be located in space such as under stairways, at the end of hallways, basements, or in unused areas of parking structures. This type of parking is intended for employees, students, residents and commuters who generally stay at a site for several hours and may be access controlled by the user. Bicycle lockers or enclosed cages are typical.

C. Bicycle parking requirements are referenced in tables 209-14C and 14D.

(3) Elementary School Guidelines.

A. It shall be anticipated that each public school shall require between ten (10) and sixteen (16) acres of land. Each public school shall be expected to serve between six hundred (600) and eight hundred (800) students. Smaller public and private schools that are compatible with an urban environment are permissible.

B. Per subsection 35-209(c)(8)(B)(7) transit routes and/or facilities shall be coordinated with school bus routes.

(g) Definitions. The definitions in this subsection 35-209(g) are specific to subsections 35-209 and 35-357.

A-Grid Street: a primary street that by virtue of its pre-existing pedestrian-supportive qualities, or its future importance to pedestrian connectivity, is held to the highest standards prescribed by this section.

Acquired or Dedicated Open Space: open space that is protected from development by law or standard, as well as land acquired for conservation through purchase, by easement, or by transferred development rights.

Allee: a regularly spaced and aligned row of trees usually planted along a thoroughfare or pedestrian path.

Alley: a public or private thoroughfare dedicated to providing vehicular access to the side or rear of property, including access to parking, utilities solid waste disposal, and/or emergency access.

Alley Apron: the portion of the alley within the public right-of-way, from the curb line of the roadway to the front edge of the property line that provides ingress and egress between private property and the public right-of-way.

Alley - Fire Access: any alleyway designated as the primary access point for the fire department in case of emergency. Additional standards apply, see the International Fire Code Sections 503.2.1 through 503.2.7, Appendix D and any other applicable sections.

Alley - Garbage Collection: any alleyway designated and designed for garbage and recycling collection.

Accessory Unit: an apartment not greater than six hundred (600) square feet sharing ownership and utility connections with a principal building. An accessory unit may or may not be within an outbuilding. Accessory units do not count toward maximum density calculations.

Ancillary Function: a function that is incidental and subordinate to the principal function of a lot or the main building thereon and located on the same lot as the principal function or building.

Apartment: a dwelling unit sharing a building and a lot with other dwellings and/or uses. Apartments may be for rent or for sale as condominiums.

Arcade: a private frontage wherein the facade is a colonnade supporting habitable space that overlaps the sidewalk, while the facade at sidewalk level remains at the frontage line.

Artisan/Craft Manufacturing: an establishment for the preparation, display and sale of individually crafted, visual forms of artwork including but not limited to: sculpture, painting, jewelry, furniture and hand woven articles.

B-Grid Street: a secondary street usually located on the periphery of a development where non-pedestrian-oriented uses are allowed and where vehicular traffic, not pedestrian traffic, takes precedence.

Backbuilding: a single-story structure connecting a principal building to an outbuilding (see table 209-10B).

Bicycle Facility: Reference table 209-7.

Bicycle Parking: See subsections (e)(3)(D) and (f)(2).

Blade Sign: a sign located below a marquee or awning and attached to a wall, marquee, or awning with the exposed face of the sign in a plane perpendicular to the plane of the building wall.

Block: the aggregate of private lots, passages, and alleys, circumscribed by thoroughfares.

Block Face: one (1) side of a block. A "block face" includes the portion of a block that abuts a street up to the nearest intersecting street.

Brownfield: an area previously used primarily as an industrial site as defined by the U.S. Environmental Protection Agency.

Building Disposition: the placement of a building on its lot (see table 209-11).

Building Function: the uses accommodated by a building and its lot. Functions are categorized as restricted, limited, or open, according to the intensity of the use (see table 209-13).

Building Height: the vertical extent of a building measured in stories, not including a raised basement or a habitable attic. Height limits do not apply to masts, belfries, clock towers, chimney flues, water tanks, elevator bulkheads and similar structures. Building Height shall be measured from the average grade of the enfronting thoroughfare.

Building Type: a structure category determined by function, disposition on the lot, and configuration, including frontage and height. For example, a rowhouse is a type, not a style.

Bungalow Court: a group of three (3) or more detached one-story, one-family or two-family dwellings located on a single lot arranged around one (1), two (2) or three (3) sides of a courtyard that opens to a street. Each dwelling unit has a separate entrance on the ground floor.

Bus Rapid Transit: a high capacity rubber tire transit system that emulates rail transit modes in speed, frequency, and comfort, serving high capacity transit corridors with limited stops.

Bus Turnouts: a recessed curb area located adjacent to the traffic lanes where buses pull into and out of without impeding traffic.

Civic: the term defining not-for-profit organizations dedicated to arts, culture, education, recreation, government, and transit.

Civic Building: a building owned, leased, maintained, or occupied by an organization that is dedicated to culture, education, or government and is accessible to and for the use of the general public.

Civic Space: a public or privately owned, pedestrian oriented, outdoor space that is accessible to and for the use by the general public. See table 209-9A.

Civic Transit Zone: area reserved for transit facilities.

Commercial: the term collectively defining workplace, office and retail functions.

Common Destination: an area designed for community interaction, usually defining the approximate center of a pedestrian shed. It may include with out limitation one (1) or more of the following: a civic space, a civic building, a commercial center or a transit facility and may act as the social center of a neighborhood.

Context: surroundings made up of the particular combination of elements that create specific habitat.

Cornice Line: horizontal articulation along approximately 85% or more of a building façade accomplished by one or more of the following: (i) a projecting architectural element, (ii) a change in material from the building façade below the Cornice Line and/or the building façade above the Cornice Line, or (iii) a discernable change in the arrangement of windows or other architectural features.

Corridor: a lineal geographic system incorporating transportation and/or greenway trajectories. A transportation corridor may be a lineal urban transect zone.

Cottage: a single-family dwelling, edge yard building type no more than one and one-half (1½) stories tall and between seven hundred (700) and one thousand five hundred (1,500) square feet total floor area.

Courtyard: an open, unoccupied, unobstructed space other than a front-, side-, or rear yard, on the same lot as a building or group of related buildings, used primarily for supplying access, light and air to abutting buildings.

Courtyard Building: a building or group of related buildings on one (1) lot surrounding a courtyard on two (2) or more sides.

Cross Block Passage: a pedestrian passage through one (1) or a group of structures that connects the principal frontage to the rear lot line or alley and is a minimum of eight (8) feet wide.

Curb: the edge of the vehicular pavement detailed as a raised curb or flush to a swale. The curb usually incorporates the drainage system (see table 209-6).

Degraded Wetland: manmade or natural occurring wetlands which are impaired as it relates to size, function (reducing stormwater amount improving water quality, etc.) vegetational diversity, and vegetational composition, as defined by the EPA in accordance with the Clean Water Act (33 US Code Part 1344) and determined by the US Corp of Engineers. A restoration or rehabilitation effort would need to address each of the areas deemed as impaired.

Density: the number of dwelling units within a standard measure of land area, usually given as units per acre [see subsection 35-209(c)(4)].

Design Speed: is the velocity at which a thoroughfare tends to be driven without the constraints of signage or enforcement. There are three (3) ranges of speed: Very low: (below 20 MPH); Low: (20—25 miles per hour); Moderate: (25—35 miles per hour); High: (above 35 miles per hour). Lane width is determined by desired design speed.

Detached House: a dwelling unit not attached to any other primary use structure that is on a forty-five- to one hundred twenty-foot wide lot.

Developable areas: residual to the preserved open space sector.

Developable area of the site: see net developable area or net site area.

Development Pattern: the physical form of a settlement. Variations are due to the particulars of the site, density, spatial definition program, transportation and implementation. Transect-based development patterns are socially and functionally variegated; they are walkable, and they manifest a gradient from urban to rural. (see master development pattern plan.)

District: See specialized district.

Driveway: a vehicular lane within a lot, usually leading to a garage. A driveway in the first lot layer may be used for parking if it is no more than eighteen (18) feet wide, thereby becoming subject to the constraints of a parking lot.

Edgeyard Building: a building that occupies the center of its lot with setbacks on all sides.

Effective Turning Radius: the measurement of the inside turning radius taking into account an on-street parking lane.

Elevation: the exterior walls of a building not along a frontage line. See facade (table 209-10C).

Emergency/Transitional Center: a residential facility for the homeless integrated with food preparation facilities, social services and counseling programs to assist in the transition to self-sufficiency and independent living.

Enfront: to place an element along a frontage line, as in "porches enfront the street."

Entrance, Principal: the main point of access of pedestrians into a building.

Estate House: a single-family dwelling, edge yard building type constructed on a lot at least seven hundred twenty (720) feet wide along the frontage, of rural character, often shared by one (1) or more accessory buildings.

Facade: the exterior wall of a building that is set along a frontage line (see elevation; frontage line).

Farm Land: any land within which agriculture and farming operations occur year-around.

Fence: a barrier enclosing space or separating lots.

Free Movement: vehicular movement on dedicated, striped travel lanes.

Frontage Buildout: the percentage of a building facade that is required to be located between the minimum and maximum setbacks, measured as a proportion of the lot's width. Squares, plazas, forecourts and pedestrian breezeways shall be considered as buildings for the calculation of frontage buildout.

Frontage Line: the lot line that separates the public frontage from the private frontage. (see table 209-10C)

FIPS: Federal Information Processing Standards. A standardized set of numeric or alphabetic codes issued by the National Institute of Standards and Technology (NIST) to ensure uniform identification of geographic entities through all federal government agencies.

Function: the use that is imposed or applied to on or for which land or a building is arranged, designed, or intended, or for which land or a building is or may be occupied, including all accessory uses.

Garage: an outbuilding or back building used as storage of not more than four (4) motor vehicles or boats. No commercial vehicles or vehicles having capacity in excess of one (1) ton shall be stored in the space nor shall any spaces be rented out.

Gallery: a private frontage wherein the facade is aligned close to the frontage line with an attached cantilevered shed or lightweight colonnade overlapping the sidewalk.

GIS (Geographic Information System): a computerized program in widespread municipal use that organizes data on maps. Various municipal departments can input information including the location of wetlands, thoroughfares, water/sewer lines, boundaries, building footprints, schools, zoning, land-use, etc. GIS makes information available as layered databases. The protocol for preparing sectors should be based on GIS information.

Glazing: transparent glass with a reflectance of no more than twenty (20) percent.

Greenfield: a project planned for an undeveloped area outside the existing urban fabric. See Infill.

Greenway: an open space corridor in largely natural conditions which may include trails for bicycles and pedestrians.

Greyfield: an area previously used primarily as a parking lot. Shopping centers and shopping malls are typical Greyfield sites.

Gross Acres: the total amount of acres within a specified area.

Hamlet: an incomplete village, standing free in the countryside. Because of a location away from transportation, a hamlet has a weak commercial center.

High Capacity Thoroughfare: a major street with vehicular traffic levels above twenty thousand (20,000) vehicles per day.

High Capacity Transit Corridor: corridor with the potential to serve a total of at least eight thousand (8,000) daily riders. Determination of the appropriate mode or modes is done through a formal alternatives analysis on a corridor-by-corridor basis.

Home Occupation: any activity carried out for gain by a resident conducted as an accessory use on the resident's dwelling unit. The work quarters should be invisible from the frontage, located either within the house or in an outbuilding. For additional regulations, see section 35-378 of the UDC.

Independent Building: a building designed by a different architect from the adjacent buildings.

Industrial, Heavy: a medium- to large-scale industrial use that is capable of producing byproducts discernable from outside the building and property. The function should not be located near civic, lodging, residential, service, or retail functions due to its inability to blend into the surrounding functions and its capacity to cause detrimental consequences to nearby properties.

Industrial, Light: a small-scale industrial use that can be located adjacent to civic, lodging, residential, service, and retail functions without disturbing its neighbors or causing detrimental effects.

Infill: development within existing urban fabric. See subsection 35-209 (d)(1)(b).

Inside Turning Radius: the curved edge of a thoroughfare at an intersection, measured at the inside edge of the vehicular tracking. The smaller the turning radius, the smaller the pedestrian crossing distance and the more slowly the vehicle is forced to make the turn. (See table 209-6)

Light Court: a private frontage parallel to the sidewalk that provides direct access to levels below grade in patio or walkway form.

Liner Building: a functional ancillary building with a minimum depth of twenty-five (25) feet, specifically designed to mask the primary use of a single function over ninety thousand (90,000) square feet on the ground floor, a primary function parking lot, or a ~~p~~Parking ~~s~~Structure from a frontage using a mix of residential, office and/or commercial functions. The building shall cover the entirety of the frontage line(s). Pedestrian and vehicular access shall be allowed as stated in subsection 35-209(f). For clarification, if the Liner Building is being used in connection with a Parking Structure, the Liner Building may be recessed within the Parking Structure.

Linear Corridor: a civic space, park, green, square or plaza, minimum two (2) blocks in length, that is longer than it is wide and follows the trajectories of natural corridors or the built environment.

Live/Work: a dwelling unit that contains a commercial component. A live/work unit is a fee-simple unit on a lot with the commercial component anywhere within the unit.

Lodging: premises available for daily and weekly renting of bedrooms. The area allocated for food service shall be calculated and provided with parking according to retail use.

Lot Layer: a range of depth of a lot within which certain elements are permitted (see table 209-10D and table 209-10E). The first lot layer is measured from the primary frontage line to the front building facade. The second layer extends twenty (20) feet behind the first layer. The third layer extends from the rear of the second layer to the rear lot line.

Lot Line: the line demarcating the division between one property and another.

Lot Width: the length of the primary frontage line of a lot.

Low Maintenance Understory: mostly native, drought tolerant, disease and pest free plant material requiring no mowing and minimal irrigation.

Mandatory Streets: for zoning site plan, includes avenues, boulevards, commercial streets, and standard streets that provide connectivity between development patterns and/or provide connectivity to major regional arterials.

Manufacturing: premises available for the creation, assemblage and/or repair of artifacts, using table-mounted electrical machinery and including their retail sale.

Massing Break: an architectural technique to create the perception that an individual building mass is broken into smaller units.

Master development pattern plan: master development plan submittal that contains one (1) or more development patterns per the requirements of section 35-357.

Media Production: the creation and manufacturing of any form of communication, including newspaper, television, radio and/or magazine.

Meeting Hall: a building available for gatherings, including conferences. It should accommodate at least one (1) room equivalent to a minimum of ten (10) square feet per projected dwelling unit within the pedestrian shed in which the meeting hall is located.

Mezzanine: a small story between two (2) main floors, usually the ground and first floors.

Mixed Use Building: a building containing a mixture of residential and commercial activities, planned as a unified complementary whole, and functionally integrated into the use of shared access points from the street level.

Mixed Use Corridor: the integration of two (2) or more dissimilar but compatible functions within a specific corridor.

Monument Sign: a permanent, freestanding sign mounted on a solid base with no more than two (2) sign faces and located in a landscaped area.

Muntins: a strip of wood or metal separating and holding panes of glass in a window.

NAD: North American Datum: the official reference ellipsoid used for the primary geodetic network in North America to define spatial relations in Geographic Information Systems.

Neighborhood Market: an establishment primarily engaged in the provision of frequently or recurrently needed goods for household consumption. Does not include fuel pumps or the selling of fuel for motor vehicles.

Net Developable Area, Net Site Area: the developable areas of a site. The net site area shall be allocated to the various transect zones according to the parameters in table 209-18.

Non-Native Invasive Tree Species: includes Chinese Pistache (Pistacia chinesis), Chinaberry (Melia azedarach), Chinese Tallow (Sapium sebiferum), Tree of Heaven (Ailanthus Altissima), and Salt Cedar (Tamerix species). Non-native invasive tree species are not protected and will be omitted from the tree survey.

Office: a function where the primary activities are administrative, executive, professional and where no merchandise is on the premises.

Open-Market Building: a business that sells, stores, and displays merchandise outdoors, other than automobiles, tractors, trailers, logging equipment, or other agricultural equipment.

Outbuilding: a building, usually located towards the rear of the same lot as a principal building. It is sometimes connected to the principal building by a backbuilding. Outbuildings shall not exceed six hundred (600) square feet of habitable space, excluding parking areas (see table 209-10B).

Park and Ride Facility (Transit): a facility used for parking by transit riders while they use transit agency services. Park-and-ride facilities are generally established as collector sites for transit service. Park-and-ride facilities may also serve as collector sites for vanpools and carpools, and as transit facilities. The facility may have limited passenger amenities such as shelters, seating and posted route and schedule information.

Parking Lot: a lot or portion thereof used for the temporary storage of motorized or non-motorized vehicles.

Parking Structure: a structure used for the temporary storage of motor vehicles.

Passage (PS): a pedestrian connector passing between buildings, providing shortcuts through long blocks and connecting rear parking areas to frontages. Passages may be roofed over.

Path (PT): a pedestrian way traversing a park or rural area, with landscape matching the contiguous open space. Paths should connect directly with the urban sidewalk network.

Pedestrian Shed: an area defined by the average distance that may be traversed at an easy walking pace from its edge to its center. This distance is applied to determine the size of a development pattern. A standard pedestrian shed is one-quarter (¼) of a mile radius or one thousand three hundred twenty (1,320) feet. With transit available or proposed, a long pedestrian shed has an average walking distance of a half-mile (½) or two thousand six hundred forty (2,640) feet. Pedestrian sheds are oriented toward a central destination containing one (1) or more important intersections, meeting places, civic spaces, civic buildings.

Personal Services: an establishment primarily engaged in providing individual services generally related to non-medical personal needs such as a tailor, beauty shop, or photographic studio. These uses may also include accessory retail sales of products related to the services provided.

Planter: the element of the public frontage that which accommodates street trees and other landscaping.

Planting Strip: a vegetated area with dimensions no less than twenty (20) inches in length. Planting strips are located at grade of walkway areas and may accommodate some pedestrian access through the vegetated area.

Potable Water: water suitable for drinking or cooking purposes.

Primary Frontage: the frontage designated to bear the street address, along which minimum lot width is measured, and containing the principal entrance to the building.

Primary Use Parking Lot: an off-street, at grade, open area for the temporary storage of motorized and non-motorized vehicles. A "primary use parking lot" does not include an area used exclusively for the display of motor vehicles for sale as part of an automobile dealership.

Principal Building: the main building on a lot, usually located toward the frontage (See table 209-10B).

Principal Entrance: the primary entrance to a structure that determines the addressing.

Private Dormitory: a privately owned and operated residential structure specifically designed for students of a college, university or non-profit organization for the purpose of providing rooms for sleeping purposes. Common kitchens and common rooms may also be provided.

Private Frontage: the privately held layer between the frontage line and the principal building facade. The structures and landscaping within the private frontage may be held to specific standards. The variables of private frontage are the depth of the setback and the combination of architectural elements such as fences, stoops, porches and galleries (See tables 209-10A and 209-12).

Protected Wetlands: wetland ecosystems regulated by the United States Army Corps of Engineers (USACE), as outlined in Section 404 of the Clean Water Act.

Protected Habitat: geographic areas within which rare or endangered flora and fauna exist as listed by the United States Fish and Wildlife Service.

Public Frontage: the area between the curb of the vehicular lanes of a thoroughfare, (excluding alleys), and the frontage line. Elements of the public frontage include the type of curb, walk, planter, streetscape tree and streetlight (see table 209-6 209-10D).

Public Utility Structure or Facility: buildings, structures and facilities that provide a public utility service deemed necessary for the public health, safety and welfare of the city.

Rear Alley (AL): a vehicular driveway located to the rear of lots providing access to service areas and parking, and containing utility easements. Alleys should be paved from building face to building face, with drainage by inverted crown at the center or with roll curbs at the edges.

Rearyard Building: a building that occupies the full frontage line, leaving the rear of the lot as the sole yard. This is a more urban type, as the continuous facade spatially defines the public thoroughfare. In its residential form, this type yields a rowhouse. For its commercial form, the rear yard can accommodate substantial parking.

Recess Line: a line prescribed for the full width of a facade, above which there is a stepback of a minimum distance, such that the height to this line (not the overall building height) effectively defines the enclosure of the enfronting public space.

Regional Center: a development pattern consisting of one long pedestrian shed with a strong retail core.

Remnant: the amount of land within a development pattern that is outside the pedestrian shed.

Research and Development: applied and developmental research, where product testing, environmental analysis, evaluation, and marketing research is permitted. No hazardous materials or on-site manufacturing shall be permitted.

Residential: includes single-family and multifamily.

Residential Care Facility: a residential complex containing multifamily dwellings designed for and principally occupied by senior citizens and physically and mentally disabled persons. Such a structure focuses on providing medical and social support services for the residents.

Retail: premises available for the sale of merchandise and food service.

Riparian Corridors: area that includes the waterway and floodplain, as well as the fertile soils on either side. Riparian corridors are typically capable of supporting a greater diversity of vegetation and wildlife than the drier uplands.

Road (RD): a local, rural and suburban thoroughfare of low vehicular speed and capacity. Its public frontage consists of swales drained by percolation and a walking path or bicycle trail along one (1) or both sides. The landscaping consists of multiple species composed in naturalistic clusters. This type is allocated to the more rural transect zones (T1—T3).

Secondary Frontage Line: only found on corner lots, the frontage facing a right-of-way that does not bear the address of the property and is not used to measure the lot width. Also known as a reverse frontage (see table 209-10C).

Sector: a neutral term for a geographic area. In the form-based development use pattern there are six (6) specific sectors that establish the boundaries for several kinds of development. Two (2) sectors represent unbuildable open space (preserve and reserve) and the other four (4) are urban growth sectors of varying intensity (restricted, controlled, and intended growth sectors, and the infill sector). Sectors address the regional scale while transect zones address the physical character of communities. Sectors contain development patterns (hamlet, village, and regional center) which contain prescribed transect zones, which contain design standards appropriate to those T-zones.

Service: labor which does not in itself produce a tangible commodity.

Setback: the area of a lot measured from the lot line to a building facade or elevation. This area must be maintained clear of permanent structures with the exception of: galleries, fences, garden walls, arcades, porches, stoops, balconies, bay windows, terraces and decks (that align with the first story level) which are permitted to encroach into the setback as permitted by each transect. (See subsection (e)(3) and table 209-18G).

Shared Parking Policy: an accounting for parking spaces that are available to more than one function. The requirement is reduced by a factor, shown as a calculation. The

shared parking ratio varies according to multiple functions in close proximity which are unlikely to require the spaces at the same time (See table 209-14C).

Shopfront: a retail frontage with seventy (70) percent of the primary facade glazed no less than seventy (70) percent in clear glass on the sidewalk-level story and an awning overlapping the sidewalk.

Shopping Center: a structure with one (1) owner that is strictly retail and includes three (3) or more businesses within the same building.

Sidewalk: the paved layer of the public frontage dedicated to pedestrian activity.

Sideyard Building: a residential building where the structure occupies at most one hundred (100) percent of one (1) lot line.

Sloped Roof: a roof with a rise (height) to span (width) ratio of at least 5:12.

Slow Movement: vehicular movement on roadway that does not include striped, dedicated lanes of travel but includes enough width for cars to pass each other comfortably at a slow speed.

Specialized Building: a building that is not subject to residential, commercial, or lodging classification. Most specialized buildings are dedicated to manufacturing and transportation, and are distorted by the trajectories of machinery.

Specialized District (SD): specialized district shall be assigned to areas that, by their intrinsic function, disposition, or configuration, cannot conform to one of the normative transect zones or development patterns. Typical districts may include large parks, institutional campuses, refinery sites, airports, etc.

Story: a habitable level within a building of no more than fourteen (14) feet in height from finished floor to finished ceiling; with the exception of a first story commercial function which shall be a minimum of eleven (11) feet and maximum of twenty-five (25) feet. A single commercial story that exceeds fourteen (14) feet shall be counted as two (2) stories. A mezzanine that extends beyond thirty-three (33) percent of the floor area shall be counted as an additional story. Attics and raised basements are not considered stories for the purposes of determining building height.

Streamside Corridor: the zone within which a waterway flows, its width to be variably interpreted according to the transect zone.

Streetscape: the urban element that establishes the major part of the public realm. The streetscape is composed of thoroughfares (travel lanes for vehicles and bicycles, parking lanes for cars, and sidewalks or paths for pedestrians) as well as the visible private frontages (building facades and elevations, porches, yards, fences, awnings, etc.), and the amenities of the public frontages (streetscape trees and plantings, benches, streetlights, etc.).

Streetscape Tree: required tree in public frontage.

Street Tree: tree on private frontage.

Streetscreen: a ~~freestanding~~ wall (whether freestanding or part of a façade) built along the frontage line, or parallel to a frontage line, often for the purpose of masking a

parking lot or parking structure from the thoroughfare. Unless otherwise provided herein, Streetscreens should be between three and one-half (3.5) and eight (8) feet in height and constructed of a material complementing ~~matching~~ the adjacent building façade, if present. Streetscreens shall have openings no larger than is necessary to allow automobile and pedestrian access. In addition, all Streetscreens over four (4) feet high should be thirty (30) percent permeable or otherwise articulated to avoid blank walls.

Substantial Modification: alterations to a building that are valued at more than fifty (50) percent of the replacement cost of the entire building, if new.

Surface Waterbodies: lakes, bays, ponds, impounding reservoirs, springs, rivers, streams, creeks, estuaries, marshes, inlets, canals, the Gulf of Mexico inside the territorial limits of the state, and all other bodies of surface water, natural or artificial, inland or coastal, fresh or salt, navigable or non-navigable, and including the beds and banks of all watercourses and bodies of surface water, that are wholly or partially inside or bordering the state or inside the jurisdiction of the state (from TCEQ).

TDR (Transfer of Development Rights): a method of relocating existing zoning rights from areas to be preserved as open space to areas to be more densely urbanized.

TDR Receiving Area: an area intended for development that may be made more dense by the purchase of development rights from TDR sending areas.

TDR Sending Area: an area previously zoned for development within the designated reserve shed (S2). The development rights assigned to this land may be purchased for TDR receiving areas. The sending areas, voided of their development rights, are re-allocated to the preserve shed (S1).

Terminated Vista: a location at the axial conclusion of a thoroughfare. A building located at a terminated vista designated on a master development pattern plan is required to be designed in response to the axis.

Terrace: a private frontage wherein the facade is set back from the primary frontage line by an elevated, level, landscaped and/or surfaced area directly adjacent to a principal building uncovered by a permanent roof.

Thoroughfare: thoroughfares describe all of the elements required within the transportation right-of-way. This includes, but is not limited to, vehicular lanes, parking lanes, curbs, plantings, and sidewalks.

Tower on Podium: a multi-level building organized around a central core with the first five (5) floors expressed as a podium building.

Transect: a system of ordering human habitats in a range from the most natural to the most urban. The form-based development use pattern is based upon six (6) transect zones which describe the physical character of place at any scale, according to the density and intensity of land use and urbanism.

Transect Zone: transect zones are similar to the land-use zones in conventional codes, except that in addition to the usual building use, density, height, and setback requirements, other elements of the intended habitat are integrated, including those of the private lot and building and the enfronting public streetscape. The elements are

determined by their location on the transect scale. The T-Zones are: T1 Natural, T2 Rural, T3 Sub-Urban, T4 General Urban, T5 Urban Center, and T6 Urban Core. (See tables 209-3 and 209-4)

Transit: a mass transportation system available to the general public.

Transit Boulevard: a multi-functional and multi-modal arterial designed to match the mixed-use centers it supports. Like traditional boulevards, it has a central area for through traffic and transit, along with small-scale parallel access roads, similar to frontage roads, to support local activities and pedestrian environment at the edges. It is a place where cafes, small businesses, apartments, transit, parking, and through traffic safely mingle.

Transit Center: a fixed location where passengers transfer from one (1) transit route to another. A transit center often includes a waiting room, seating areas, restrooms, sales outlet, ticket or pass vending machines, and/or waiting areas for passenger pick-ups.

Transit Oriented Infill Village: an infill village with a transit oriented development overlay.

Transit Oriented Infill Regional Center: an infill regional center with a transit oriented development overlay.

Transit Park-and-Ride Facility: a facility used for parking by transit riders, while they use transit agency services. Park-and-ride facilities are generally established as collector sites for transit service. Park-and-ride facilities may also serve as collector sites for vanpools and carpools, and as transit facilities. The facility may have limited passenger amenities such as shelters and seating.

Transit Shelter: a roofed structure located on or adjacent to the right-of-way of a street, designed to be used primarily for the protection and convenience of waiting transit passengers.

Transition Line: a horizontal line spanning the full width of a facade, expressed by a material change or by a continuous horizontal articulation such as a cornice or a balcony.

Transportation Corridor: a combination of discrete, adjacent surface transportation networks (e.g., freeway, arterial, rail networks) that link the same major origins and destinations.

Tree Well: area, below post development grade, that is created for the preservation of existing and newly planted trees and vegetation consisting of drainage and a root aeration system around the tree and root zone. The area is created at existing grade before grade changes (fill) is completed.

Village: a development pattern structured by a short pedestrian shed (¼-mile radius) containing a mixed use center and having a minimum developable area of eighty (80) acres.

Wildlife corridors: a continuous strip of habitat connecting wildlife populations separated by human activities (such as roads, development, or logging).

Yield Movement: two-way vehicular movement on a single, shared travel lane.

(h) Standards and Tables.

Overview:

Table 209-1 Relationship Between Sectors and Development Patterns

Development Patterns:

Table 209-2 Sector Analysis

Table 209-3 Transect System Illustration

Table 209-4 Transect Zone Descriptions

Table 209-5A Sustainable Design Option Point System

Table 209-5B Residential Types For Sustainable Design Option

Table 209-6A Thoroughfare Design: Design Speed, Parking Lane Widths and Curb Radius

Table 209-6B Thoroughfare Design: Effective Turning Radius

Table 209-6C Thoroughfare Design: Turning Radius

Table 209-6D Thoroughfare Design: Travel Lanes and Parking Provisions

Table 209-6E Thoroughfare Design: Public Frontages - General

Table 209-6F Thoroughfare Design: Public Frontages - Specific

Table 209-6G Thoroughfare Design: Complete Assemblies

Table 209-7 Bicycle Facility Design Guide

Table 209-8 Street Lighting Design Requirements

Table 209-9A Civic Space Types

Table 209-9B Allowable Public Transit Facilities

Table 209-10A Thoroughfare & Frontage

Table 209-10B Building Disposition

Table 209-10C Frontage & Lot Lines

Table 209-10D & 209-10E Lot Layers

Building-Scale Plans:

Table 209-11 Building Disposition

Table 209-12 Private Frontages

Table 209-13A Intensity of Function

Table 209-13B Specific Function by Transect

Table 209-14A Parking Standards: Minimum Required Parking

Table 209-14B Parking Standards: Maximum Allowable Parking

Table 209-14C Parking Standards: Sharing Factor

Table 209-14D Parking Standards: Minimum Required Bicycle Parking

Table 209-15 Residential Building Types

Table 209-16 Vibration Levels for Industrial Functions

(Table—209-17 Reserved)

Summary:

Table 209-18 Transect Zone Summary

Table 209-18A1 Transect Zone Summary: River North Calibration

Table 209-19 Reserved

Table 209-20 Light Imprint Storm Drainage Summary

Table 209-21 Street Tree and Streetscape Tree Illustrations

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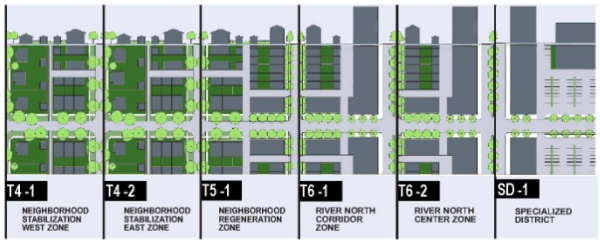
Table 209-18A1 Transect Zone Summary: River North Calibration

TABLE 209-18A1 TRANSECT ZONE SUMMARY
RIVER NORTH CALIBRATION



	T4 -1	T4 -2	T5 -1	T6 -1	T6 -2	SD -1
A. ALLOCATION OF ZONES see section 35-209(c)						
Infill Regional Center						
B. OVERALL DENSITY see section 35-209(c)						
Infill Option						
C. BLOCK SIZE						
Block Perimeter	1600 ft. max	1600 ft. max	1600 ft. max	1600 ft. max	2000 ft. max	3400 ft. max
Block Face Length	400 ft. max	400 ft. max	400 ft. max	400 ft. max	600 ft. max	850 ft. max
D. PUBLIC FRONTAGES (see Table 209-6E and 209-6F)						
PW	not permitted	not permitted	not permitted	not permitted	not permitted	permitted
BV	permitted	permitted	permitted	permitted	permitted	permitted
RR	not permitted	not permitted	not permitted	not permitted	not permitted	permitted
RS	permitted	permitted	not permitted	not permitted	not permitted	permitted
SS & AV	permitted	permitted	permitted	permitted	permitted	permitted
CS & AV	not permitted	not permitted	permitted	permitted	permitted	permitted
Alley	permitted	permitted	required*	required*	required*	permitted
E. CIVIC SPACE (see Table 209-9A)						
Park	not permitted	not permitted	not permitted	not permitted	not permitted	permitted
Green	permitted	permitted	permitted	not permitted	not permitted	permitted
Square	permitted	permitted	permitted	permitted	permitted	permitted
Plaza	not permitted	not permitted	permitted	permitted	permitted	permitted
Playground	permitted	permitted	permitted	permitted	permitted	permitted
F. LOT OCCUPATION						
Primary Frontage Width	25 ft. min 200 ft. max	25 ft. min. 200 ft. max	18 ft. min. 300 ft. max	no min - no max	no min - no max	50 ft. - 850 ft.
Lot Coverage [1]	70% max	70% max	80% max	85% max	90% max	90% max
G. SETBACKS - PRINCIPAL BUILDING						
Front Setback (Primary)	10 ft. min 15 ft. max.	10 ft. min 15 ft. max.	5 ft. min 12 ft. max.	0 ft. min 12 ft. max.	0 ft. min. 12 ft. max.	0 ft min.
River Setback	see 35-672(d)	see 35-672(d)	see 35-672(d)	see 35-672(d)	see 35-672(d)	see 35-672(d)
Front Setback (Secondary)	6 ft. min. 10 ft. max	6 ft. min. 10 ft. max	5 ft. min. 12 ft. max	0 ft. min. 12 ft. max	0 ft. min. 10 ft. max	0 ft min.
Side Setback [2]	0 ft. min. 7 ft. max	0 ft. min. 7 ft. max	0 ft. min. 12 ft. max	0 ft. min. 12 ft. max	0 ft. min. 10 ft. max	0 ft min.
Rear	3 ft. min.	3 ft. min.	3 ft. min.	3 ft. min.	3 ft. min.	0 ft min.
Primary Frontage Buildout	60% min.	60% min.	80 %min.	80%min	80%min	40%min
H. SETBACKS - OUTBUILDING						
Front Setback	24 ft. min. +bldg setback	24 ft. min. +bldg setback	40 ft. max from rear prop line	3rd lot layer	3rd lot layer	20-30 ft + bldg setback
Side Setback	0 ft or 3 ft.	0 ft or 3 ft.	0 ft. min	no max, no min.	no max, no min.	0 ft. - 10 ft.
Rear Setback [3]	3 ft. min.	3 ft. min.	3 ft. max	no max, no min.	no max, no min.	3 ft. min.
I. BUILDING DISPOSITION (see Table 209-11)						
Edge Yard	permitted	permitted	not permitted	not permitted	not permitted	permitted
Side Yard	permitted	permitted	permitted	not permitted	not permitted	permitted
Rear Yard	permitted	permitted	permitted	permitted	permitted	permitted
Court Yard	permitted	permitted	permitted	permitted	permitted	permitted
J. PRIVATE FRONTAGES (see Table 209-12)						
Common Yard	not permitted	not permitted	not permitted	not permitted	not permitted	not applicable.
Porch & Fence	permitted	permitted	not permitted	not permitted	not permitted	not applicable
Terrace or L.C.	permitted	permitted	permitted	not permitted	not permitted	not applicable
Forecourt	permitted	permitted	permitted	permitted	permitted	not applicable
Stoop	permitted	permitted	permitted	permitted	permitted	not applicable
Shopfront & Awning	permitted	permitted	permitted	permitted	permitted	not applicable
Gallery	permitted	permitted	permitted	permitted	permitted	not applicable
Arcade	not permitted	not permitted	permitted	permitted	permitted	not applicable
K. BUILDING HEIGHT						
Principal Building	3 stories max.	4 stories max.	2 stories min., 4 max.[4]	2 stories min., 15 8 max.*	2 stories min., 15 10 max.	3 stories max
Outbuilding	2 stories max.	2 stories max.	2 stories max.	3 stories max	3 stories max	2 stories max
L. FUNCTION (see Tables 209-13A & 209-13B)**						
Residential	limited use	limited use	open use	open use	open use	see table 209-13B
Lodging	limited use	limited use	open use	open use	open use	see table 209-13B
Office / Service	limited use	limited use	open use	open use	open use	see table 209-13B
Retail	limited use	limited use	open use	open use	open use	see table 209-13B

DISPOSITION

CONFIGURATION

FUNCTION

SECTION (e)

SECTION (b) & (c)

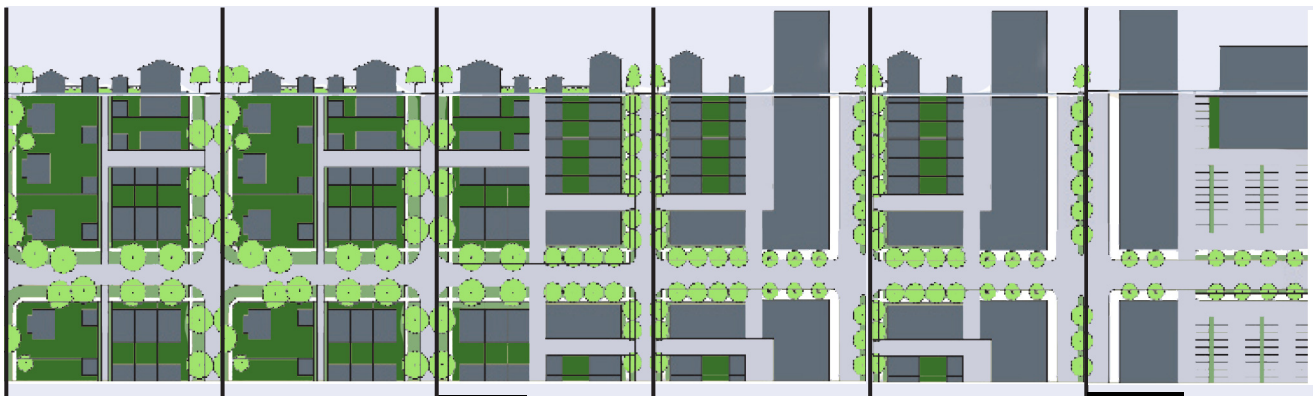
1. Refers to the percentage of the lot that can be covered by the structure
2. For sideyard buildings, see section 209(e)(2)(A)(11)
3. The rear setback shall be measured from the rear lot line as defined on table 209-10C
4. Single story buildings are permitted if they follow all of the following requirements:
   a. the buildings are no more than 40% of a linear block face
   b. the buildings are not located on street corners

* See Section 209(c)(5)(B)(b)
** For specific function, see table 209-13B

FORM BASED DEVELOPMENT
Use Pattern

* * * * *

TABLE 209-18A1 TRANSECT ZONE SUMMARY
RIVER NORTH CALIBRATION



T4 -1	T4 -2	T5 -1	T6 -1	T6 -2	SD -1
NEIGHBORHOOD STABILIZATION WEST ZONE	NEIGHBORHOOD STABILIZATION EAST ZONE	NEIGHBORHOOD REGENERATION ZONE	RIVER NORTH CORRIDOR ZONE	RIVER NORTH CENTER ZONE	SPECIALIZED DISTRICT

A. ALLOCATION OF ZONES see section 35-209(c)

Infill Regional Center						

B. OVERALL DENSITY see section 35-209(c)

Infill Option						

C. BLOCK SIZE

Block Perimeter	1600 ft. max	1600 ft. max	1600 ft. max	1600 ft. max	2000 ft. max	3400 ft. max
Block Face Length	400 ft. max	400 ft. max	400 ft. max	400 ft. max	600 ft. max	850 ft. max

D. PUBLIC FRONTAGES (see Table 209-6E and 209-6F)

PW	not permitted	not permitted	not permitted	not permitted	not permitted	permitted
BV	permitted	permitted	permitted	permitted	permitted	permitted
RR	not permitted	not permitted	not permitted	not permitted	not permitted	permitted
RS	permitted	permitted	not permitted	not permitted	not permitted	permitted
SS & AV	permitted	permitted	permitted	permitted	permitted	permitted
CS & AV	not permitted	not permitted	permitted	permitted	permitted	permitted
Alley	permitted	permitted	required*	required*	required*	permitted

E. CIVIC SPACE (see Table 209-9A)

Park	not permitted	not permitted	not permitted	not permitted	not permitted	permitted
Green	permitted	permitted	permitted	not permitted	not permitted	permitted
Square	permitted	permitted	permitted	permitted	permitted	permitted
Plaza	not permitted	not permitted	permitted	permitted	permitted	permitted
Playground	permitted	permitted	permitted	permitted	permitted	permitted

F. LOT OCCUPATION

Primary Frontage Width	25 ft. min 200 ft. max	25 ft. min. 200 ft. max	18 ft. min. 300 ft. max	no min - no max	no min - no max	50 ft. - 850 ft.
Lot Coverage [1]	70% max	70% max	80% max	85% max	90% max	90% max

G. SETBACKS - PRINCIPAL BUILDING

Front Setback (Primary)	10 ft. min 15 ft. max.	10 ft. min 15 ft. max.	5 ft. min 12 ft. max.	0 ft. min 12 ft. max.	0 ft. min. 12 ft. max.	0 ft min.
River Setback	see 35-672(d)	see 35-672(d)	see 35-672(d)	see 35-672(d)	see 35-672(d)	see 35-672(d)
Front Setback (Secondary)	6 ft. min. 10 ft. max	6 ft. min. 10 ft. max	5 ft. min. 12 ft. max	0 ft. min. 12 ft. max	0 ft. min. 10 ft. max	0 ft min.
Side Setback [2]	0 ft. min. 7 ft. max	0 ft. min. 7 ft. max	0 ft. min. 12 ft. max	0 ft. min. 12 ft. max	0 ft. min. 10 ft. max	0 ft min.
Rear	3 ft. min.	3 ft. min.	3 ft. min.	3 ft. min.	3 ft. min.	0 ft min.
Primary Frontage Buildout	60%. min.	60%. min.	80 % min.	80% min	80% min	40% min

H. SETBACKS - OUTBUILDING

Front Setback	24 ft. min. +bldg setback	24 ft. min. +bldg setback	40 ft. max from rear prop line	3rd lot layer	3rd lot layer	20-30 ft + bldg setback
Side Setback	0 ft or 3 ft..	0 ft or 3 ft..	0 ft. min	no max, no min.	no max, no min.	0 ft. - 10 ft.
Rear Setback [3]	3 ft. min.	3 ft. min.	3 ft. max	no max, no min.	no max, no min.	3 ft. min.

I. BUILDING DISPOSITION (see Table 209-11)

Edge Yard	permitted	permitted	not permitted	not permitted	not permitted	permitted
Side Yard	permitted	permitted	permitted	not permitted	not permitted	permitted
Rear Yard	permitted	permitted	permitted	permitted	permitted	permitted
Court Yard	permitted	permitted	permitted	permitted	permitted	permitted

DISPOSITION

J. PRIVATE FRONTAGES (see Table 209-12)

Common Yard	not permitted	not permitted	not permitted	not permitted	not permitted	not applicable
Porch & Fence	permitted	permitted	not permitted	not permitted	not permitted	not applicable
Terrace or L.C.	permitted	permitted	permitted	not permitted	not permitted	not applicable
Forecourt	permitted	permitted	permitted	permitted	permitted	not applicable
Stoop	permitted	permitted	permitted	permitted	permitted	not applicable
Shopfront & Awning	permitted	permitted	permitted	permitted	permitted	not applicable
Gallery	permitted	permitted	permitted	permitted	permitted	not applicable
Arcade	not permitted	not permitted	permitted	permitted	permitted	not applicable

K. BUILDING HEIGHT

Principal Building	3 stories max.	4 stories max.	2 stories min., 4 max.[4].	2 stories min., 15 ~~8~~ max.[4]	2 stories min., 15 ~~10~~ max.[4]	3 stories max
Outbuilding	2 stories max.	2 stories max.	2 stories max.	3 stories max	3 stories max	2 stories max

CONFIGURATION

L. FUNCTION (see Tables 209-13A & 209-13B)**

Residential	limited use	limited use	open use	open use	open use	see table 209-13B
Lodging	limited use	limited use	open use	open use	open use	see table 209-13B
Office / Service	limited use	limited use	open use	open use	open use	see table 209-13B
Retail	limited use	limited use	open use	open use	open use	see table 209-13B

FUNCTION

SECTION (e)

SECTION (b) & (c)

1. Refers to the percentage of the lot that can be covered by the structure
2. For sideyard buildings, see section 209(e)(2)(A)(11)
3. The rear setback shall be measured from the rear lot line as defined on table 209-10C
4. Single story buildings are permitted if they follow all of the following requirements:
   a. the buildings are no more than 40% of a linear block face
   b. the buildings are not located on street corners

* See Section 209(c)(8)(B)(8)

** For specific function, see table 209-13B

FORM BASED DEVELOPMENT
Use Pattern

+Sec. 35-430.- Applicability and General Rules.

*** * * * ***

(f) **Performance Agreements.**

* * * * *

(2) **Performance Agreement and Site Improvement Time Extension Granted by the dDirector ~~of Development Services~~ or Planning Commission.**

(1) Application Requirements.

A. Site improvement construction must have begun.

B. A proper application must be submitted in writing, including the justification for such extension, to the director of development services at least thirty (30) days prior to the time limit in the performance agreement.

C. A Performance Guarantee Extension must be provided, if applicable. Whether an extension agreement is approved by the director or the planning commission, for:

i. Recorded Plats. An applicant must file a guarantee extension within thirty (30) days of the granting of an agreement extension or the agreement extension becomes null and void.

ii. Unrecorded Plats. If the plat is unrecorded and no performance guarantee previously provided, no guarantee extension is required.

(2) Procedure.

A. The city attorney's office shall have ten (10) working days for review of the guarantee as to form, and

B. The director shall have five (5) working days for review and approval/denial of the guarantee.

C. Any re-submittal of a revised guarantee for shall have the same review periods as under subsections A and B, above.

D. The applicant and the city may agree to an extension of such time periods.

(3) Fees. A subdivider shall pay any fees associated with time extensions to the director.

(4) Approval of Extensions.

A. May be granted by the director after consultation with all affected departments and utilities for:

i. Sidewalk Improvements. Unless subject to subsection 35-506(q)(4), a time extension of three (3) years from the

expiration of a performance agreement may be granted upon submission to and approval by the director of:

(a) Plan showing uncompleted sidewalks; and,

(b) Time schedule for completion; and,

(c) Updated cost estimate to complete.

ii. Other Site Improvements. A time extension of one (1) year from the expiration of a performance agreement may be granted upon completion of at least seventy-five (75) percent of the required site improvements and approval by the director.

B. May be granted by the planning commission if an applicant is unsuccessful or ineligible for approval under A, above, and the planning commission decision to approve/deny is made at least thirty (30) days prior to the expiration of any current performance agreement or guarantee, however such extension shall not exceed three (3) years.

(5) Effect. Notwithstanding any extensions approved or required hereunder, approved plats shall expire if not recorded within seven (7) years of approval.

~~An applicant may request a performance agreement time extension provided that site improvement construction has started and is submitted with a written request and justification to the director of development services at least thirty (30) days prior to the time limit set out in the performance agreement. Any applicant requesting a performance agreement time extension for a recorded plat shall provide a performance guarantee extension in order for an extension to be granted, unless the plat has not been recorded. Such guarantee must be filed within thirty (30) days of the granting of the extension or the extension shall become null and void. Once filed, the city attorney's office shall have fifteen (15) working days to review the guarantee as to form. Within the same fifteen (15) working days' period, the director of development services shall review the guarantee for approval or denial. If denied, the applicant may at his/her option revise any nonconforming aspects. However, if the guarantee is revised and resubmitted, the director of development services and city attorney's office shall have an additional fifteen (15) working days from the latest date of submission to review and approve or deny the revised guarantee. Such time periods shall not prevent the applicant and the city from agreeing to extend the city's response time contained in this subsection. Any fees associated with time extensions granted under this subsection shall be paid by the subdivider to the director of development services. The director of development services is authorized to approve time extensions which meet the following criteria after consultation with all affected departments and utilities:~~

~~A. Sidewalk improvements. Except for sidewalks subject to subsection 35-506(q)(4), a three-year time extension from the expiration of the performance agreement may be granted provided a plan indicating the uncompleted sidewalks, a time schedule for completion, and an~~

~~updated cost estimate for completion is submitted and approved by the director of development services.~~

~~B. Other site improvements. A one-year time extension from the expiration of the performance agreement may be granted provided at least seventy-five (75) percent of the required site improvements are completed and approved by the director of development services.~~

~~C. Time extension requests that are not eligible for approval or are not approved by the director of development services may be considered by the planning commission provided that:~~

~~1. A decision to either approve or disapprove the extension is made by the planning commission at least thirty (30) days prior to the expiration of any current performance agreement or guarantee;~~

~~2. Any extension approved by the planning commission shall not exceed three years;~~

~~3. Any plat not recorded within six (6) years from the date of plat approval, including any time extensions, shall expire; and~~

~~4. A guarantee of performance in an amount sufficient to cover the cost of remaining site improvements shall be required in order for an extension to be approved. Such guarantee must be filed and approved within thirty (30) days of the approval of the extension or the extension shall become null and void.~~

* * * * *

Sec. 35-437. Performance Agreement.

When site improvements, other than gas and electric lines, are required in conjunction with a plat, a performance agreement to ensure construction of the site improvements shall be executed by the applicant and filed with the planning commission together with the plat. Such instrument shall be substantially the same as form "F" in Appendix "B," section 35-121 and shall be filed with the City of San Antonio when a guarantee of performance is required. A request for an extension of time for plat recordation shall include a request for an extension of the performance agreement.

(a) **Guarantee of Performance.** As is provided for in subsection 35-432(i), an approved plat may be filed for record before the required site improvements are completed if one (1) of the following guarantees of performance is approved and filed with the City of San Antonio within three (3) years after ~~(i)~~ the plat has been approved by the planning commission ~~or (ii) the application for Subdivision plat approval has been filed by the applicant and accepted as complete by the director of development services~~: a performance bond, an irrevocable trust agreement, ~~a or~~ an irrevocable standby letter of credit, or a cash or cashier's check. A guarantee of performance may be submitted before plat approval however, for plat recordation the plat must meet the requirements of this section. In no event shall an applicant self-insure, notwithstanding that the applicant is a surety company, trust institution, or bank. All site

improvement estimates submitted to the director of development services shall detail the specific improvements needed, and shall bear the official seal and signature of a professional engineer attesting to the accuracy of the dollar amounts contained in the estimate. Any guarantee submitted shall clearly state the procedure and complete contact information for collection should a claim or draw be necessary, and shall cover the time period from submittal and approval to three (3) years, or three (3) years and ninety (90) days in the case of a letter of credit, from the date of plat approval.

* * * * *

Sec. 35-504. - Stormwater Management. (Moved to Appendix H)

~~STATEMENT OF PURPOSE~~

~~*The purpose of this section is to provide adequate measures for the retention, detention and distribution of stormwater in a manner that minimizes the possibility of adverse impacts on both water quantity and water quality during development. Innovative runoff management practices designed to meet the provisions of this chapter, enhance the recharge of groundwater, and maintain the function of critical environmental features are encouraged. The city recognizes that watercourses and their associated watersheds within the City of San Antonio's jurisdiction represent significant and irreplaceable recreational and aesthetic resources and contribute to the economic and environmental health of the city. In addition, all of the watersheds within the city are vulnerable to concentrated surface water runoff, disturbance of wildlife habitat, non-point source pollution and sedimentation resulting from development activities and should be developed in a sensitive and innovative manner.*~~

~~*This section implements the following policies of the master plan:*~~

~~*• Natural Resources, Policy 1d: Encourage retention of the 100-year floodplains as natural drainageways without permanent construction, unnecessary straightening, bank clearing or channeling.*~~

~~*• Natural Resources, Policy 1d: Adopt strong stormwater management practices throughout the drainage area which include site specific measures such as:*~~

~~*On-site stormwater retention and detention;*~~

~~*Reduction in impervious cover;*~~

~~*Natural bank contouring;*~~

~~*Floodplain preservation and buffering;*~~

~~*Preservation of riparian habitat;*~~

~~*Stormwater harvesting sites for reuse purposes.*~~

~~*• Urban Design, Policy 1g: Prepare design and construction policies and standards for utility and transportation infrastructure, capital improvement projects, public facilities and development projects that reinforce neighborhood centers and provide diverse, pedestrian-friendly neighborhoods.*~~

~~(a) Applicability. The provisions of this section shall apply to any application for subdivision plat, master development plan, or building permit approval except as otherwise provided by this chapter. A stormwater management plan shall be provided as set forth in Appendix "B," section 35-B119 of this chapter.~~

~~(b) Stormwater Management Program.~~

~~(1) Regional Stormwater Management Program (RSWMP).~~

~~A. The City of San Antonio has determined that regional stormwater management is preferable to site specific stormwater mitigation. The regional stormwater management program provides for the administration, planning, design, construction, and operational management of regional stormwater facilities (RSWF). Regional stormwater management uses a watershed-wide approach to analyze potential flooding problems, identify appropriate mitigation measures and select site locations and design criteria for RSWF. These RSWF include, but are not limited to, regional detention and retention ponds, watershed protection, land purchase, waterway enlargement, channelization, and improved conveyance structures. The regional~~

~~stormwater management program allows developers to participate in the program rather than constructing the on-site detention controls required by this section, where the resulting use of a RSWF will not produce a significant adverse impact to other properties due to the increased runoff from the proposed development.~~

~~B. All developers shall participate in the RSWMP in one (1) of three (3) ways:~~

~~1. Payment of a fee in lieu of on-site detention (except in areas designated by the director of public works as "mandatory detention areas"). The fee schedule is included in Appendix "C," section 35C-109.~~

~~2. Construction of on-site or off-site measures (typically stormwater detention facilities) to mitigate increases in runoff resulting from the proposed development.~~

~~3. Construction or participation in the construction of an off-site RSWF to mitigate increased stormwater runoff anticipated from ultimate development of the watershed.~~

~~C. To determine a significant adverse impact for the purposes of this section, the following criteria will be used to analyze the receiving stormwater facilities within two thousand (2,000) linear feet of the project, to the nearest downstream RSWF, or to the nearest floodplain with an ultimate analysis accepted by the city, whichever is less. For lots less than three (3) acres in size, adverse impact analyses need only extend to where tributary drainage areas equal one hundred (100) or more acres.~~

~~1. The stormwater surface elevation (WSE) in receiving facility [natural or improved] drainage systems within two thousand (2,000) linear feet of the proposed development may not be increased by the proposed development unless the increased WSE is contained within easements or rights-of-way or the receiving systems have sufficient capacity to contain the increased WSE without increasing flooding to habitable structures.~~

~~2. Ultimate development runoff at low water crossings during regulatory (five-year, twenty-five-year and 100-year frequency) storm events must not classify the low water crossing as "Dangerous to Cross" based on Figure 504-2. If the ultimate WSE exceeds this criterion, the crossings may be improved to the standards of this chapter in lieu of providing onsite stormwater control measures or paying a fee.~~

~~3. Three (3) development conditions shall be analyzed with each adverse impact analysis.~~

~~Existing Conditions. This refers to current development conditions in the watershed and on site. This shall be used as the baseline for determining the impact of the development of the site, or the watershed, to other properties or drainage systems.~~

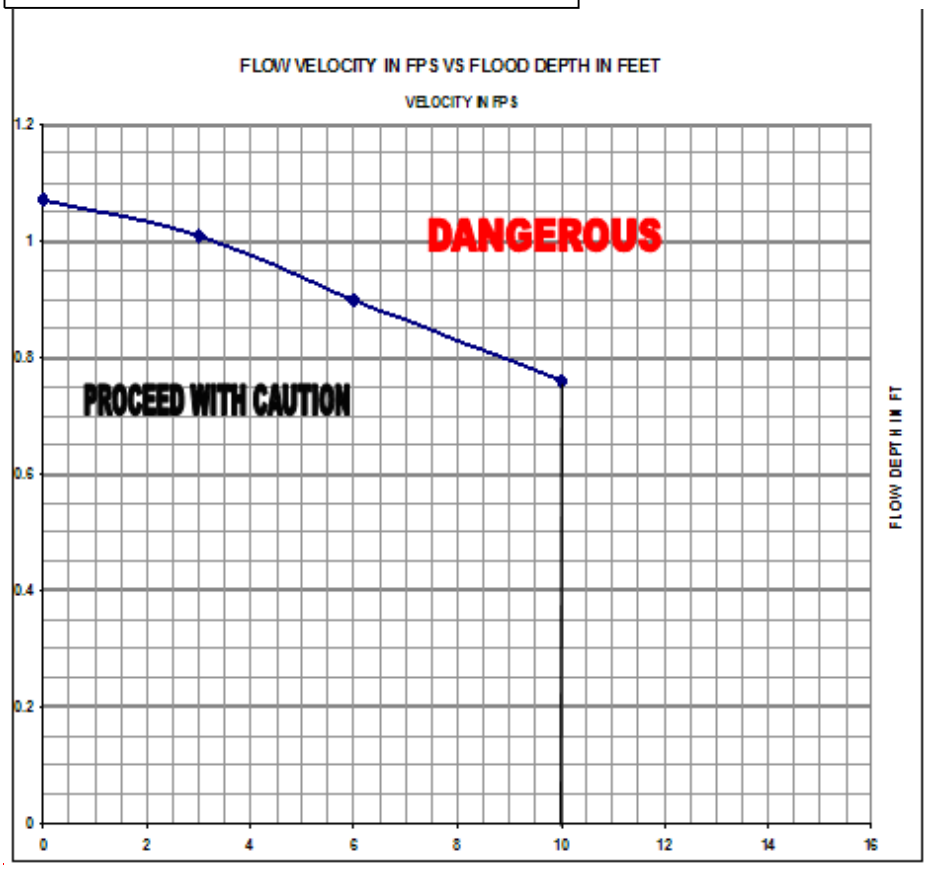
~~Proposed Conditions. This refers to existing conditions with the proposed development added. This shall be used to determine if the increased runoff from the proposed development results in an adverse impact to other properties or drainage systems.~~

~~Ultimate Conditions. This refers to ultimate development conditions within the watershed. In addition to being used to design proposed drainage facilities (subsection "(2) System Criteria," below), this condition shall also be used to determine if the increased runoff from the ultimate development of the watershed results in an adverse impact to other properties or drainage systems.~~

~~In addition to verifying low water crossing capacity (item 2, above), this analysis shall be used to assist the city in identifying watershed wide stormwater management issues.~~

~~4. Minimum standards for identifying Dangerous Roadway conditions are identified in figure 504-2.~~

~~Note: The City of San Antonio contends that any runoff crossing a roadway creates a potentially dangerous condition. Figure 504-2 represents the maximum flow over roadways that the city will accept in adverse impact analyses signed and sealed by the licensed professional engineers.~~



~~Figure 504-2 Dangerous Roadway Conditions During Flood Events~~

~~5. The City of San Antonio may reject a developer's request to participate in the RSWMP by payment or mitigation and require on-site detention. The city's decision will be based on the knowledge of significant adverse impacts that would be created by ultimate development of the watershed regardless of the distance from the development to the area of concern. The city may also reject a request for participation when it is not in the best interests of the RSWMP. The developer is recommended to meet with the stormwater engineering division of the department of public works to discuss participation options prior to commencing design of a project. This preliminary meeting in no way relieves the developer of his responsibility to prepare the necessary engineering documentation to support his request for participation.~~

~~D. The stormwater development fee in lieu of on-site detention must be paid prior to a plat being released for recordation by the City of San Antonio or the issuance of a building permit. The fee shall be determined in accordance with the provisions of section 35-C109, stormwater management fees.~~

~~(2) System Criteria. All stormwater management facilities, or combination of facilities, shall be designed for ultimate development. Facilities with drainage areas under one hundred (100) acres shall be designed for a twenty-five-year storm. Facilities with drainage areas over one hundred (100) acres or areas within a FEMA designated floodplain shall be designed for a 100-year storm or a twenty-five-year storm plus freeboard (based on Table 504-9) if that elevation is higher. Detention facilities and streets are exceptions to the frequency criteria cited above. Detention facility outflows will be designed for five-year, twenty-five-year and 100-year frequency storms. Refer to subsection 35-504(g) for specific drainage design criteria for streets.~~

~~(3) Responsibility to Accept Stormwater. The owner or developer of property to be developed shall be responsible for the conveyance of all stormwater flowing through the property. This responsibility includes the stormwater flowing onto the property by any other developed property as well as the drainage naturally flowing through the property by reason of topography. Future upstream development shall be accounted for by assuming ultimate development when sizing drainage systems as specified in this section.~~

~~(4) Positive Overflow Pathways. Stormwater management facilities for local drainage systems will be designed to ensure that a positive overflow pathway is provided to the nearest 100-year conveyance facility. The overflow pathway must be delineated on a plan that shows all existing structures in the vicinity impacted by the overflow pathway.~~

~~(5) Maintenance.~~

~~A. Maintenance of publicly owned facilities will be the responsibility of the city. Maintenance of private facilities is the responsibility of the property owner or the community association and must be specified in the maintenance schedule submitted to the city. A maintenance schedule for both publicly owned and privately owned facilities must be approved by the director of public works prior to the approval of construction drawings.~~

~~B. Authorized personnel from the City of San Antonio shall conduct periodic inspections of these facilities and structures. Any required repairs will be consistent with current construction standards. Maintenance issues identified by the city or state during inspections shall be the responsibility of the current owner.~~

~~(6) New Development. Peak stormwater runoff rates from all new development shall be less than or equal to the peak runoff rates from the site's predevelopment conditions for the five-year, twenty-five-year and 100-year design storm events, except as provided in subsection 35-504(b)(1), above.~~

~~(7) Redevelopment. Peak stormwater runoff rates from an area of redevelopment due to zoning or replatting shall be less than or equal to the peak runoff rates produced by existing development conditions for the five-year, twenty-five-year and 100-year design storm events, except as provided in subsection 35-504(b)(1), above.~~

~~(8) The City of San Antonio (COSA) encourages the installation of low impact development (LID) features such as engineered swales, engineered infiltration storm sewer systems, bioretention, and engineered wetlands. For all developments proposed within the COSA jurisdictional boundaries, these features may be considered on-site detention features to the extent that they reduce the stormwater runoff expected downstream as a result of such developments. It shall be the developer's responsibility to demonstrate that said LID features provide such benefit. Credit toward RSWMP fees will be considered and approved on a case by case basis by the department of public works.~~

~~(c) Method of Computing Runoff.~~

~~(1) Calculation Methods.~~

~~A. For drainage areas less than six hundred forty (640) acres, the basis for computing runoff shall be the rational formula or some other method provided it is acceptable to the director of public works. Hydraulic calculations shall be performed by using the U.S. Army Corps of Engineers HEC-2 "Water Surface Profiles" or HEC-RAS "River Analysis System" computer models. Normal depth channel calculations are permissible for constructed open channels with a uniform geometric cross section where 1) there is no potential for the water surface elevations to be controlled by backwater and 2) the channel is not in a FEMA floodplain.~~

~~B. For drainage areas six hundred forty (640) acres or greater, the basis for computing runoff shall be a unit hydrograph method, preferably the Soil Conservation Service (SCS) Dimensionless Unitgraph method as contained in the U.S. Army Corps of Engineers Hydrologic Engineering Center HEC-1 "Flood Hydrograph Package," which document shall be maintained on file with the director of public works and is hereby incorporated by this reference. For the SCS method, antecedent moisture condition II shall be used in the runoff model. Design rainfall values listed in Table 504-4 shall be used for hydrograph calculations.~~

~~C. Open channel hydraulic calculations shall be performed by using the U.S. Army Corps of engineers HEC-2 "Water Surface Profiles" or HEC-RAS "River Analysis System" computer models, which documents shall be maintained on file with the director of public works and is hereby incorporated by this reference.~~

~~D. Certain watersheds have hydrologic and hydraulic models that are available through and maintained by the City of San Antonio. Developments proposed within the limits of these watersheds must have the models updated by the consultant to reflect changes in flow, channel configuration (including alterations to vegetation) and channel structures. The consultants' models must use the same computer program that was used in the existing model e.g. HEC-RAS models will not be accepted where the original model used HEC-2. The updated models shall be submitted to the director of public works for incorporation into the master models. The City of San Antonio will periodically update the master models to reflect current watershed development conditions. The updated models will be made available for use and distribution as the latest existing condition models for the watershed.~~

~~(2) Time of Concentration.~~

~~A. Overland (sheet) flow, shallow concentrated flow and channel flows are components that need to be considered in the calculation of time of concentration. The following methods are recommended for time of concentration calculation.~~

B. Overland flow - flow over plane surfaces: Maximum allowable time is twenty (20) minutes. Minimum is five (5) minutes. The overland flow time chart from "Design" by Elwyn E. Seelye may be used to calculate overland flow times. Note that the minimum time has been reduced to five (5) minutes.

C. Shallow concentrated flow - overland flow usually becomes shallow concentrated flow after a maximum of three hundred (300) feet: Use Manning's equation to estimate travel time for defined swales, bar ditches and street sections, etc. Figure 3-1 from TR-55 "Urban Hydrology for Small Watersheds," SCS 1986, may be used where a geometric section has not been defined.

D. Channel flow: Use existing computer models where available or Manning's equation if data is not available. Non-floodplain channel velocities for ultimate watershed development should not be less than six (6) fps when estimating time of concentration.

(3) Runoff Coefficients. Runoff coefficients (C value) for use in the rational formula shall not be less than the values shown in Tables 504-1A or 504-1B, as appropriate.

Table 504-1A
Runoff Coefficients (C) - Percentage

Character of Area	SLOPE			
	Up to 1%	Over 1% up to 3%	Over 3% up to 5%	Flow over 5%
Business or commercial areas (90% or more impervious), Existing Pavement / Buildings or Zoning Districts O, C, I-1, I-2	95	96	97	97
Densely developed areas (80% to 90% impervious) or Zoning Districts D, MX, NC, TOD, Use Pattern TND	85	88	91	95
Closely built residential areas and school sites or Zoning Districts MF, R-4	75	77	80	84
Undeveloped areas * - Present land is undeveloped and ultimate land use is unknown. C values for use in ultimate development calculations.	68	70	72	75
Large lot residential area or Zoning Districts R20, RE	55	57	62	64
Undeveloped areas * - Existing conditions. See Table 504- 1(b)				
Average residential area or Zoning Districts R-5, R-6	65	67	69	72

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~~Table 504-1B~~
~~Runoff Coefficients (C) - Percentage~~

~~Character of Area~~	~~SLOPE~~			
	~~Up to 1%~~	~~Over 1% up to 3%~~	~~Over 3% up to 5%~~	~~Flow over 5%~~
~~Cultivated or Range (Grass Cover < 50% of Area)~~	~~44~~	~~47~~	~~53~~	~~55~~
~~Range (Grass Cover 50—75% of Area)~~	~~37~~	~~41~~	~~49~~	~~53~~
~~Forest or Range (Grass Cover > 75% of Area)~~	~~35~~	~~39~~	~~47~~	~~52~~

-

~~* Areas included within parks, green belts or regulatory floodplains shall be considered to remain undeveloped per Table 504-1B.~~

~~(4) Rainfall Intensity. Use Figure 504-1 or Table 504-2 to determine rainfall intensity.~~

~~Table 504-2 Rainfall Intensities (inches/hour)~~

~~TIME~~	~~FREQUENCY~~						
~~MINUTES~~	~~2-YEAR~~	~~5-YEAR~~	~~10-YEAR~~	~~25-YEAR~~	~~50-YEAR~~	~~100-YEAR~~	~~500-YEAR~~
~~5~~	~~7.2~~	~~8.4~~	~~9.413~~	~~11.1~~	~~12.432~~	~~13.542~~	~~18.204~~
~~6~~	~~6.684~~	~~7.836~~	~~8.83~~	~~10.331~~	~~11.648~~	~~12.877~~	~~17.258~~
~~7~~	~~6.277~~	~~7.381~~	~~8.365~~	~~9.722~~	~~11.025~~	~~12.341~~	~~16.497~~
~~8~~	~~5.944~~	~~7.009~~	~~7.982~~	~~9.224~~	~~10.512~~	~~11.894~~	~~15.864~~
~~9~~	~~5.666~~	~~6.696~~	~~7.658~~	~~8.806~~	~~10.079~~	~~11.514~~	~~15.327~~
~~10~~	~~5.427~~	~~6.427~~	~~7.38~~	~~8.447~~	~~9.707~~	~~11.184~~	~~14.862~~

~~11~~	~~5.22~~	~~6.194~~	~~7.137~~	~~8.136~~	~~9.382~~	~~10.893~~	~~14.453~~
~~12~~	~~5.038~~	~~5.988~~	~~6.923~~	~~7.862~~	~~9.095~~	~~10.635~~	~~14.09~~
~~13~~	~~4.877~~	~~5.805~~	~~6.731~~	~~7.618~~	~~8.839~~	~~10.403~~	~~13.763~~
~~14~~	~~4.731~~	~~5.641~~	~~6.558~~	~~7.399~~	~~8.608~~	~~10.192~~	~~13.468~~
~~15~~	~~4.6~~	~~5.48~~	~~6.4~~	~~7.2~~	~~8.4~~	~~10~~	~~13.2~~
~~16~~	~~4.458~~	~~5.296~~	~~6.159~~	~~6.959~~	~~8.088~~	~~9.551~~	~~12.765~~
~~17~~	~~4.328~~	~~5.129~~	~~5.942~~	~~6.741~~	~~7.806~~	~~9.147~~	~~12.368~~
~~18~~	~~4.209~~	~~4.977~~	~~5.743~~	~~6.541~~	~~7.549~~	~~8.781~~	~~12.005~~
~~19~~	~~4.099~~	~~4.836~~	~~5.562~~	~~6.357~~	~~7.314~~	~~8.449~~	~~11.672~~
~~20~~	~~3.998~~	~~4.707~~	~~5.395~~	~~6.188~~	~~7.098~~	~~8.146~~	~~11.364~~
~~21~~	~~3.904~~	~~4.587~~	~~5.241~~	~~6.031~~	~~6.898~~	~~7.867~~	~~11.079~~
~~22~~	~~3.816~~	~~4.476~~	~~5.098~~	~~5.886~~	~~6.713~~	~~7.61~~	~~10.814~~
~~23~~	~~3.734~~	~~4.372~~	~~4.965~~	~~5.749~~	~~6.541~~	~~7.373~~	~~10.566~~
~~24~~	~~3.658~~	~~4.275~~	~~4.841~~	~~5.622~~	~~6.38~~	~~7.153~~	~~10.335~~
~~25~~	~~3.586~~	~~4.184~~	~~4.725~~	~~5.503~~	~~6.229~~	~~6.947~~	~~10.117~~
~~26~~	~~3.518~~	~~4.098~~	~~4.616~~	~~5.39~~	~~6.088~~	~~6.756~~	~~9.913~~
~~27~~	~~3.453~~	~~4.017~~	~~4.514~~	~~5.284~~	~~5.955~~	~~6.576~~	~~9.72~~
~~28~~	~~3.393~~	~~3.941~~	~~4.417~~	~~5.184~~	~~5.83~~	~~6.408~~	~~9.538~~
~~29~~	~~3.335~~	~~3.868~~	~~4.326~~	~~5.089~~	~~5.711~~	~~6.25~~	~~9.365~~
~~30~~	~~3.28~~	~~3.8~~	~~4.24~~	~~5~~	~~5.6~~	~~6.1~~	~~9.2~~

~~31~~	~~3.209~~	~~3.723~~	~~4.155~~	~~4.905~~	~~5.501~~	~~6.003~~	~~9.025~~
~~32~~	~~3.142~~	~~3.65~~	~~4.074~~	~~4.814~~	~~5.407~~	~~5.911~~	~~8.87~~
~~33~~	~~3.078~~	~~3.58~~	~~3.997~~	~~4.727~~	~~5.318~~	~~5.823~~	~~8.722~~
~~34~~	~~3.018~~	~~3.514~~	~~3.924~~	~~4.644~~	~~5.233~~	~~5.739~~	~~8.581~~
~~35~~	~~2.96~~	~~3.45~~	~~3.854~~	~~4.565~~	~~5.152~~	~~5.658~~	~~8.446~~
~~36~~	~~2.906~~	~~3.39~~	~~3.787~~	~~4.49~~	~~5.074~~	~~5.581~~	~~8.317~~
~~37~~	~~2.853~~	~~3.332~~	~~3.723~~	~~4.418~~	~~4.999~~	~~5.507~~	~~8.194~~
~~38~~	~~2.803~~	~~3.277~~	~~3.662~~	~~4.349~~	~~4.928~~	~~5.435~~	~~8.075~~
~~39~~	~~2.755~~	~~3.224~~	~~3.604~~	~~4.283~~	~~4.859~~	~~5.367~~	~~7.961~~
~~40~~	~~2.709~~	~~3.173~~	~~3.548~~	~~4.219~~	~~4.793~~	~~5.301~~	~~7.852~~
~~41~~	~~2.665~~	~~3.124~~	~~3.494~~	~~4.158~~	~~4.729~~	~~5.238~~	~~7.747~~
~~42~~	~~2.623~~	~~3.077~~	~~3.442~~	~~4.099~~	~~4.668~~	~~5.176~~	~~7.646~~
~~43~~	~~2.582~~	~~3.032~~	~~3.392~~	~~4.043~~	~~4.609~~	~~5.117~~	~~7.548~~
~~44~~	~~2.543~~	~~2.989~~	~~3.345~~	~~3.988~~	~~4.552~~	~~5.06~~	~~7.454~~
~~45~~	~~2.505~~	~~2.947~~	~~3.298~~	~~3.936~~	~~4.497~~	~~5.005~~	~~7.363~~
~~46~~	~~2.469~~	~~2.907~~	~~3.254~~	~~3.885~~	~~4.444~~	~~4.952~~	~~7.275~~
~~47~~	~~2.434~~	~~2.868~~	~~3.211~~	~~3.836~~	~~4.393~~	~~4.9~~	~~7.19~~
~~48~~	~~2.4~~	~~2.83~~	~~3.169~~	~~3.788~~	~~4.343~~	~~4.85~~	~~7.108~~
~~49~~	~~2.368~~	~~2.794~~	~~3.129~~	~~3.743~~	~~4.295~~	~~4.802~~	~~7.028~~
~~50~~	~~2.336~~	~~2.759~~	~~3.09~~	~~3.698~~	~~4.248~~	~~4.754~~	~~6.951~~

~~51~~	~~2.306~~	~~2.724~~	~~3.052~~	~~3.655~~	~~4.203~~	~~4.709~~	~~6.876~~
~~52~~	~~2.276~~	~~2.691~~	~~3.016~~	~~3.613~~	~~4.159~~	~~4.664~~	~~6.804~~
~~53~~	~~2.247~~	~~2.659~~	~~2.98~~	~~3.573~~	~~4.117~~	~~4.621~~	~~6.733~~
~~54~~	~~2.22~~	~~2.628~~	~~2.946~~	~~3.534~~	~~4.075~~	~~4.579~~	~~6.665~~
~~55~~	~~2.193~~	~~2.598~~	~~2.913~~	~~3.496~~	~~4.035~~	~~4.538~~	~~6.598~~
~~56~~	~~2.167~~	~~2.569~~	~~2.88~~	~~3.459~~	~~3.996~~	~~4.499~~	~~6.534~~
~~57~~	~~2.141~~	~~2.541~~	~~2.849~~	~~3.423~~	~~3.958~~	~~4.46~~	~~6.471~~
~~58~~	~~2.117~~	~~2.513~~	~~2.819~~	~~3.388~~	~~3.921~~	~~4.422~~	~~6.41~~
~~59~~	~~2.093~~	~~2.486~~	~~2.789~~	~~3.354~~	~~3.885~~	~~4.386~~	~~6.35~~
~~60~~	~~2.07~~	~~2.46~~	~~2.76~~	~~3.32~~	~~3.85~~	~~4.35~~	~~6.3~~
~~120~~	~~1.285~~	~~1.555~~	~~1.775~~	~~2.175~~	~~2.55~~	~~2.9~~	~~4.05~~
~~180~~	~~0.933~~	~~1.14~~	~~1.317~~	~~1.633~~	~~1.9~~	~~2.2~~	~~3.133~~
~~360~~	~~0.552~~	~~0.668~~	~~0.767~~	~~0.95~~	~~1.083~~	~~1.25~~	~~1.767~~
~~720~~	~~0.315~~	~~0.383~~	~~0.45~~	~~0.533~~	~~0.625~~	~~0.733~~	~~1.033~~
~~1440~~	~~0.185~~	~~0.223~~	~~0.25~~	~~0.313~~	~~0.375~~	~~0.417~~	~~0.571~~

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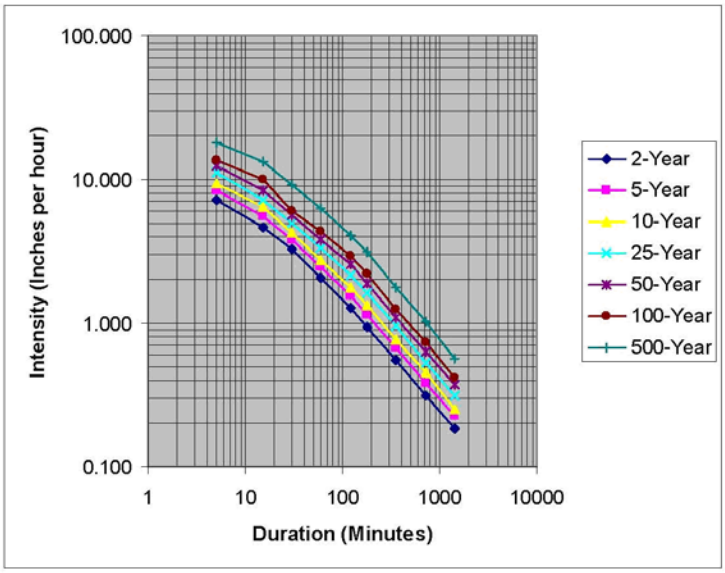

Figure 1. Rainfall Intensities plotted against Duration on Log-Log scale.

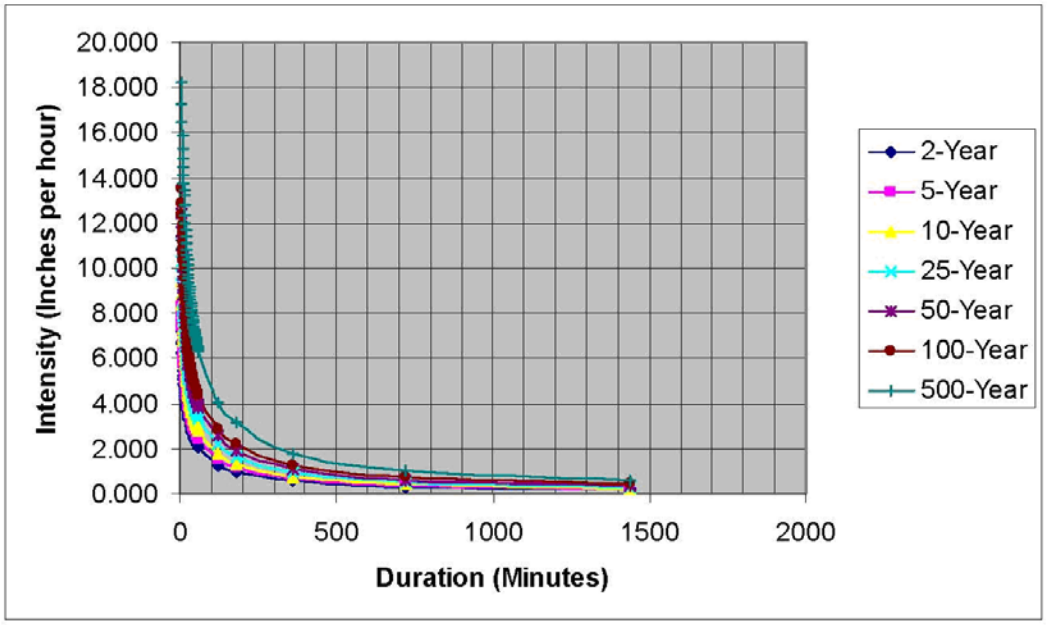

Figure 2. IDF Curves for Bexar County

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~~(5) SCS Curve Numbers. The SCS curve numbers adopted for use by the City of San Antonio are shown in Table 504-3. The hydrologic soil groups are listed in the latest version of the United States Natural Resources Conservation Service [formerly the Soil Conservation Service], "Urban Hydrology for Small Watersheds," Technical Release No. 55 (TR-55), which document is hereby incorporated by this reference. Soil types that relate to the hydrologic soil group may be found in the latest version of the United States Natural Resources Conservation Service "Soil Survey-Bexar County, Texas" which document is hereby incorporated by this reference. Soil types may also be based on a Geotechnical Engineering Report.~~

~~Table 504-3~~
~~SCS Curve Number by Soil Type~~

~~Hydrologic Soil Group~~	~~Description~~	~~SCS Curve Number~~
~~A~~	~~Soils having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well drained sand and gravels.~~	~~25~~
~~B~~	~~Soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.~~	~~55~~
~~C~~	~~Soils having moderately high runoff potential due to slow infiltration rates. These soils consist primarily of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.~~	~~70~~
~~D~~	~~Soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high water tables, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.~~	~~77~~

~~(6) Percent Impervious Cover. The percent impervious cover for typical land use types in San Antonio are presented in Table 504-4.~~

~~Table 504-4~~
~~Percent Impervious Cover by Land Use~~

~~Land Use Category~~		~~Average Percent Impervious Cover~~
~~Residential~~	~~1/8 acre Residential Lots, or Garden or townhouse apartments, or Zoning Districts R-4, R-5, RM-4, RM-5; TND/TOD Use Patterns~~	~~65—85%~~

	~~¼ acre Residential Lots or Zoning District R-6, RM-6~~	~~38%~~
	~~1/3 acre Residential Lots or Zoning District R-15~~	~~30%~~
	~~½ acre Residential Lots or Zoning Districts R-20~~	~~25%~~
	~~1 acre Residential Lots or Zoning Districts RP, RE~~	~~20%~~
~~Industrial or Zoning Districts L, I-1, I-2~~		~~72—85%~~
~~Business or Commercial, or Zoning Districts NC, O, C~~		~~85—95%~~
~~Densely developed (apartments), or Zoning Districts MF~~		~~65—85%~~
~~Streets, Roads, and Parking Areas~~		~~98%~~

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~~(7) Design Rainfall and Areal Reduction.~~

~~1. Design Rainfall. A twenty-four-hour rainfall distribution shall be applied for runoff calculations. Rainfall intensities as adopted for the City of San Antonio are given in Table 504-5. The lag value for a sub-area shall be calculated as 0.6 times the time of concentration.~~

~~Table 504-5~~
~~Design Rainfall Values (inches)~~

~~USGS Adjusted Rainfall Values (pre-areal reduction)~~						
~~Frequency of Storm~~	~~5-year~~	~~10-year~~	~~25-year~~	~~50-year~~	~~100-year~~	~~500-year~~
~~Exceedance probability~~	~~0.2~~	~~0.1~~	~~0.04~~	~~0.02~~	~~0.01~~	~~0.002~~
~~Storm Duration~~						
~~Duration~~	~~Frequency~~					
	~~5-year~~	~~10-year~~	~~25-year~~	~~50-year~~	~~100-year~~	~~500-year~~
~~5-minute~~	~~0.68~~	~~0.78~~	~~0.93~~	~~1.04~~	~~1.13~~	~~1.52~~

~~15 minute~~	~~1.40~~	~~1.60~~	~~1.80~~	~~2.10~~	~~2.50~~	~~3.30~~
~~1 hour~~	~~1.85~~	~~2.76~~	~~3.32~~	~~3.85~~	~~4.35~~	~~5.80~~
~~2 hour~~	~~2.37~~	~~3.55~~	~~4.35~~	~~5.10~~	~~5.80~~	~~8.10~~
~~3 hour~~	~~3.26~~	~~3.95~~	~~4.90~~	~~5.70~~	~~6.60~~	~~9.40~~
~~6 hour~~	~~3.80~~	~~4.60~~	~~5.70~~	~~6.50~~	~~7.50~~	~~10.60~~
~~12 hour~~	~~4.40~~	~~5.40~~	~~6.40~~	~~7.50~~	~~8.80~~	~~12.40~~
~~24 hour~~	~~5.00~~	~~6.00~~	~~7.50~~	~~9.00~~	~~10.00~~	~~13.70~~

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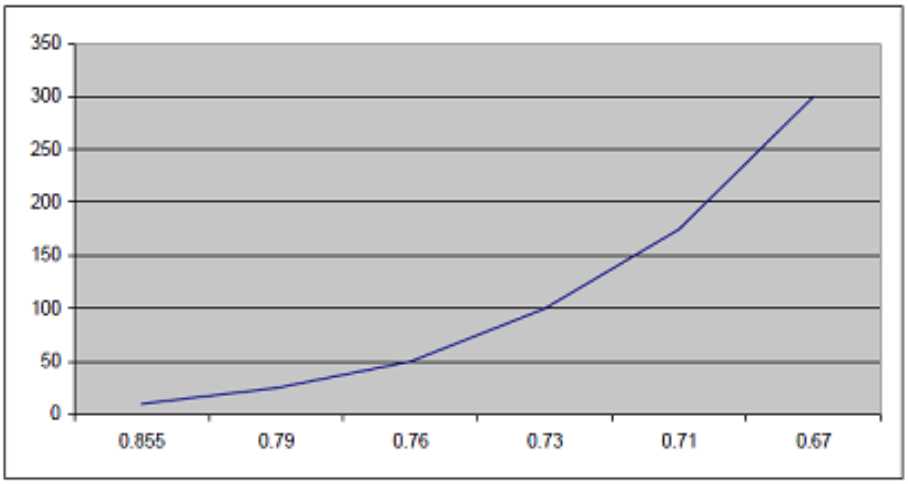
~~2. Areal Reduction. Calculated stormwater runoff at a given point may be reduced by the factors shown in Table 504-5.1 based upon the tributary area (in square miles) draining to said point.~~

Areal Reduction Factors **

(for use in calculating Point Rainfall for Bexar County)

Area (sq mi)	Base ARF for Area
10	0.855
25	0.79
50	0.76
100	0.73
175	0.71
300	0.67



** Source: 2007 Watershed "Hydrology Technical Support Data Notebooks" on file with the San Antonio River Authority

~~(8) Routing of Runoff. Routing of the runoff hydrograph through the channel from one (1) subarea calculation point to the next in the HEC-1 shall be computed using one (1) of the following methods:~~

~~A. Overbank/channel storage not significant: Use normal depth channel routing.~~

B. Overbank/channel storage is significant: use the Muskingum method where a hydraulic model is not available. Use Modified Puls Storage method where a hydraulic model is available to develop storage/out flow relationship.

C. Kinematic wave method for channel reaches where inflow from overbank runoff or multiple point sources (Example: storm sewer outfalls) is significant and where hydrograph attenuation is insignificant.

Channel routing methodologies currently being applied in the existing HEC-1 model of the watershed shall not be replaced with a different methodology without approval or direction from the director of public works.

(9) Manning's Roughness Coefficient. Manning's roughness coefficients ("N" values) for use in routing methods or in hydraulic calculations shall be consistent with the values listed in Table 504-6.

Table 504-6
Manning's Roughness Coefficient

Channel Description	Manning's "N" Value
Concrete Lined Channel	0.015
Grass Lined Channel with regular maintenance	0.035
Grass Lined Channel without recent maintenance	0.050
Vegetated Channel with trees, little or no underbrush	0.055
Natural Channel with trees, moderate underbrush	0.075
Natural Channel with trees, dense underbrush	0.090
Natural Channel with dense trees and dense underbrush	0.100

-

Overbank Description	Manning's "N" Value
Pasture	0.035—0.055
Trees, little or no underbrush, scattered structures	0.060—0.075
Dense vegetation, multiple fences and structures	0.075—0.090

The "N" value to be used in Manning's Formula shall conform to the following for design purposes:

A. Earth channels—0.035

B. Concrete lined channels—0.015

C. Reinforced concrete pipe—0.013

D. Concrete box culverts—0.013

E. Corrugated metal pipe:

i. Unpaved ½" corrugated—0.024

ii. Unpaved one (1) inch corrugated—0.027

F. Asphaltic concrete—0.018

Any other "N" value shall be based on generally accepted engineering principles.

(d) Drainage Easements/Rights-of-Way.

(1) Applicability. Where a subdivision is traversed by a watercourse, drainageway, natural channel or stream, there shall be provided an easement or right-of-way conforming substantially to the limit of such watercourse, plus additional width as outlined below.

(2) Requirements. Easement or right-of-way requirements are specified in the following subsections of this section for particular stormwater management facilities:

A. Subsection (d)(3) Natural Watercourses or Floodplains;

B. Subsection (f)(3) Regional Detention Facilities;

C. Subsection (h)(6)(e) Concrete Lined Channels;

D. Subsection (h)(7)(c) and (d) Vegetated Earth Channels;

E. Subsection (i)(c) Storm Sewers.

(3) Natural Watercourses or Floodplains. Easements for natural watercourses shall be the 100-year floodplain or the twenty-five-year plus freeboard (see Table 504-9 of this section) whichever is less. In floodplain areas where ongoing maintenance is required or the floodplain will be reserved for use by the public, the drainage easements shall be maintained by a public entity and the property will be dedicated to the city as a multi-use drainage easement. A drivable access way shall be provided in floodplain easements for the length of the easement when regular maintenance of the floodplain is required. Diversion of stormwater away from the natural watercourse will not be allowed except within the boundaries of the property controlled by the developer, provided that the diverted water is returned to the watercourse within which it would naturally have been flowing prior to leaving the developer's property. An analysis of the timing of the diverted hydrograph on watersheds greater than twenty (20) acres, as it reenters the receiving watercourse, must be performed to show that the peak flowrate in the receiving watercourse has not been increased as a result of the diversion.

(4) Maintenance Access Right-of-Way. An unobstructed access right-of-way connecting the drainage easement with an alley or roadway parallel to or near the easement shall be provided at a minimum spacing of one (1) access right-of-way at approximately one thousand-foot intervals. The access right-of-way shall be a minimum of fifteen (15) feet in width and shall be maintained clear of obstructions that would limit maintenance vehicular access. If the flow line of the designed channel incorporates grade control structures or

~~vehicular bridges that would prevent maintenance equipment from accessing that portion of the channel, additional access points may be required. Channel design, earthen or concrete, shall have ramps in the side slopes near the access points that would allow maintenance equipment to descend to the floor level of the channel. The maximum allowable ramp slope for vehicular access is seven to 1 (7:1). Access points adjacent to roadways or alleys shall be provided with a post and cable feature with padlock to prevent unauthorized use.~~

~~(5) Lot and Property Line Crossings. In those cases where drainage easements cross lot and property lines, a statement shall be added to the plat that no fencing or structures that will interfere with adequate drainage flow will be allowed on or across such lines. Fencing may be allowed across drainage easements only in accordance with the following restrictions:~~

~~A. Bottom of fence shall be a minimum of the flow depth, plus freeboard (see Table 504-9 of this section) above design flow line of channel or drain.~~

~~B. A hinged gate will be placed across the entire width of the drainage easement. Access must be provided to stormwater operations staff at all times to allow access to the easement for the city crews to perform maintenance.~~

~~C. Fence posts located within the easement must be structurally designed to resist damage from the stormwater flows and impact from debris.~~

~~D. A floodplain development permit will be required to construct a fence within an easement within the 100-year floodplain.~~

~~(6) Interceptor Easements. Drainage easements for proper conveyance of upstream stormwater runoff shall be required on all subdivision plats where upstream contributing area exceeds the criteria indicated below. Interceptor drains shall be constructed prior to the issuing of building permits on any lot that would intercept natural drainage.~~

~~A. Interceptor drainage easements and channels shall be provided for residential subdivisions where the drainage area to the back of platted lots exceeds the depth of two (2) average residential lots with equivalent zoning.~~

~~B. Interceptor drainage easements shall be required on nonresidential subdivision plats where the off-site drainage area contributing to the proposed development exceeds three (3) acres. If necessary, an amending plat may be used to correct drainage easements in conjunction with building permits.~~

~~(7) Lower Elevation of Site. All developments shall provide for adequate drainage outfall at the lower end of the site into an existing street, alley, drainage, easements or right-of-way, or to the centerline of an existing natural drain. Where proposed street, storm sewer, or open channel does not discharge into a natural low or into an existing adequate drainage easement then facilities and drainage easements of adequate width to contain the design discharge shall be constructed and dedicated to the centerline of an existing natural low within the same watershed. However, where the natural low lies within the developer's property, the developer will be required only to plat an easement to the centerline of the natural low, provided that the easement is adequate to accommodate the facilities that will be built in conjunction with the future development of that property.~~

~~(e) Site Design and Grading.~~

~~(1) All land disturbing or land filling activities or soil storage shall be undertaken in a manner designed to minimize surface runoff, erosion and sedimentation, and to safeguard life, limb, property and the public welfare in accordance with the NPDES (TPDES) construction site regulation ordinance, Ordinance No. 94002, as amended, and the document entitled "Complying with the Edwards Aquifer Rules; Technical Guidance on Best Management Practices, " by Michael E. Barrett, Ph.D., P.E. Center for Research in Water Resources, Bureau of Engineering Research, University of Texas at Austin, (RG-348, June 1999), which documents are hereby incorporated by this reference.~~

(2) Erosion and sedimentation controls in accordance with the specifications established by the director of public works in compliance with the National Pollution Discharge Elimination System (NPDES) permitting requirements for the city are required.

(3) Projects shall not be considered complete until restoration has been made in accordance with NPDES requirements.

(4) Where possible, multiple uses of drainage facilities and open space shall be incorporated by the owner or developer of a new subdivision. Alternative uses such as public recreation, horse/bike/hiking trails, walking paths, nature preserves, wildlife habitat areas, etc. are encouraged subject to the approval of the director of public works.

(5) A note must be placed on the plat for residential lots, which states that finished floor elevations must be a minimum of eight (8) inches above final adjacent grade. A grading plan shall be prepared and submitted to the City of San Antonio, which indicates typical lot grading for all lots in the subdivision using typical FHA lot grading types (A, B and C). A more detailed grading plan is also acceptable. No more than two (2) average residential lots may drain onto another lot unless a drainage easement is dedicated to contain the runoff.

(f) Stormwater Detention and Other Stormwater Management Facilities. For projects with an increased impervious area of greater than 0.1 acres that elect not to participate or are not eligible to participate in the regional stormwater management program as described in subsection 35-504(b)(1), then stormwater detention shall be required for all new developments or redevelopment of individual parcels of property to mitigate peak flow rates to predevelopment or existing development conditions as stated in subsections (b)(6) and (b)(7) of this section.

(1) Maximum Outflow Rate. The maximum allowable outflow rate from the detention facility must be restricted to the flow rate from the undeveloped or existing development tract for the five-year, twenty-five-year and 100-year frequency. Best management practices shall be used in the design of detention facilities in accordance with this section. The timing of the hydrograph released from the detention facility must be checked against the timing of the flow rate in the first open watercourse to prevent any increase in the peak flow rate in the receiving watercourse. For detention basins constructed in-line on an existing watercourse, the creation of the basin shall not increase flood elevations in the channel upstream of the new development boundaries.

(2) On-Site Detention and Water Quality (including Low Impact Development) Features.

(i) On-site stormwater management features must be privately owned and shall be maintained by the community association or property owner. A maintenance schedule shall be submitted to the public works department and approved by the director of public works prior to approval of construction plans. The City of San Antonio will have the right to do periodic inspections of privately owned and maintained detention facilities to ensure that the maintenance schedule is being implemented.

(ii) Where a detention facility accepts flows from public facilities such as city rights-of-way the detention facility will be considered a detention facility serving a public purpose and will be dedicated to the city upon completion and a drainage easement will be dedicated to provide for access to the facility. When a regional detention facility accepts flow from an area exceeding three hundred (300) acres, the facility shall be considered serving a public purpose and shall be dedicated to the city.

(3) Regional Detention Facilities. General locations and sizes of regional detention facilities have been identified in the master drainage plan for the major watersheds in the city's jurisdiction. The ownership of regional detention facilities may either be public or private. The creation of regional detention facilities designed to service one (1) or several developments is encouraged, but not required. In watersheds where public regional detention facilities exist, mitigation of increased stormwater runoff from new construction may utilize these facilities if the new construction is eligible to participate in the RSWMP.

~~Temporary detention may be required for the development until sufficient capacity in the outfall channel is provided to accommodate increased flows. Maintenance of publicly owned facilities will be the responsibility of the city. Maintenance of private facilities is the responsibility of the property owner or the community association and must be specified in the maintenance schedule submitted to the city. A maintenance schedule for both publicly owned and privately owned facilities must be approved by the director of public works prior to approval of construction drawings.~~

~~Drainage easements will be provided for all regional detention facilities. The easement will encompass the 100-year pool elevation plus all structural improvements (levees, dykes, berms, outfall structures etc.) necessary to contain the pool. The easement will extend, at a minimum, to the toe of the downstream embankment. Maintenance access (fifteen-foot minimum) will be provided around the facility, outside the limits of the 100-year pool elevation. Ramps, as necessary, with a maximum slope of seven to one (7:1) will be provided for access to the flow line of the facility.~~

~~(4) Easement Requirements.~~

~~A. Drainage easements will be required for all stormwater management facilities accepting runoff from properties other than the lot on which the facility exists or will be constructed. Maintenance of the detention facility shall be the responsibility of the property owner or the property owner's association.~~

~~B. Full detention basin design may be deferred until the building permit stage IF the property owner submits a "request for detention deferral" demonstrating an understanding of the implications of such design deferral AND the following notes are placed on the subdivision plat AND supporting documentation is provided.~~

~~1. "Stormwater detention is required for this property. The engineer of record for this subdivision plat has estimated that an area of approximately _____ acres and a volume of approximately _____ acre feet will be required for this use. This is an estimate only and detailed analysis may reveal different requirements."~~

~~2. "No building permit shall be issued for this platted property until a stormwater detention system design has been approved by the City of San Antonio or Bexar County for commercial properties within the ETJ."~~

~~C. For regional detention facilities, the easement will encompass the 100-year pool elevation plus all structural improvements (levees, dykes, berms, outfall structures etc.) necessary to contain the pool. The easement will extend, at a minimum, to the toe of the downstream embankment. The easement shall also extend to a minimum of fifteen feet outside both the 100-year pool and the structural improvements to facilitate maintenance as well as public safety.~~

~~(5) Access Ramps. Ramps, as necessary, with a maximum slope of seven to one (7:1) will be provided for access to the flow line of all public detention facilities.~~

~~(6) Multi-Use Facilities. Multi-use facilities are encouraged, but not required (multi-use facilities allows for water quality, satisfy NPDES requirements, enhance around water recharge, provide open space, provide recreation or other amenities, and/or provide habitat) and may be utilized so long as the facility meets the standards set forth in subsection (a) of this section and does not increase the rate or volume of erosion above that which would result from the use of a facility without multiple uses. The use of multi-use detention facilities to alleviate existing flooding problems, enhance and provide amenities for older neighborhoods, and support the revitalization of economically depressed areas is encouraged in public and private redevelopment initiatives.~~

~~(7) Permanent Wet Pool or Pumped Detention Systems. Stormwater retention with permanent wet pool or pumped detention systems will not be acceptable methods of stormwater~~

~~mitigation unless the facility will remain privately owned, operated, and maintained. The city will approve the use of a pumped facility for private use under the following conditions:~~

~~A. A gravity system is not feasible from an engineering and economic standpoint.~~

~~B. At least two (2) pumps are provided each of which is sized to pump the design flow rate.~~

~~C. The selected design outflow rate must not aggravate downstream flooding.~~

~~D. Controls and pumps shall be designed to prevent unauthorized operation and vandalism.~~

~~E. Adequate assurance is provided that the system will be operated and maintained on a continuous basis.~~

~~(8) Location of Detention Facilities and Surrounding Development. Stormwater detention facilities shall be located in topographically depressed areas where possible. When necessary, dams may be constructed to detain flows. All proposed dams shall conform to the following items:~~

~~A. All dams over six (6) feet above existing natural around shall be approved by the Dam Safety Team of the TNRCC for safety. All other new dams shall be designed in accordance with acceptable design criteria as approved by the director of public works, or his authorized representative.~~

~~B. All hydrology and hydraulic properties of a dam will be reviewed by the department of public works with regard to spillway design, freeboard hydraulics, backwater curves and downstream effects due to the dam site.~~

~~C. The spillway section of any earthen dam with a height greater than six (6) feet shall be large enough to pass a PMP (probable maximum precipitation) flood, as defined by the NRCS, without overtopping the crest of the dam in accordance with TNRCC regulations.~~

~~D. A 100-year frequency flood shall be routed through the proposed dam and all land subject to flooding shall be dedicated as drainage easement or right-of-way. An unobstructed fifteen-foot access easement around the periphery of the flooded area shall be dedicated as drainage easement for facilities that require regular mowing or other ongoing maintenance, at the discretion of the director of public works. An unobstructed fifteen-foot access right-of-way shall be established which connects the drainage easement adjacent to the dam structure to a road or alley.~~

~~E. Development below existing dams will take into account the original design conditions of the existing dam. Dam breach analysis checks will be required, dependent upon location of development with respect to dam site.~~

~~F. All spillway discharges shall be adequately routed to the centerline of the natural low below the dam site. The adequate routing of spillway discharges pertains to the hydraulic routing of the 100-year frequency flood for dedication of drainage easement limits. Probable maximum precipitation (PMP) defined PMP on definition section flood routing or breaches will only be considered for safety considerations (that is, the placement of building and the setting of minimum floor slab elevations below the dams). Any proposed concrete dam structure need not have spillway capable of routing a PMP flood, however, it shall be shown to be structurally capable of withstanding any range of flood conditions with regard to possible failure due to sliding, overturning, and structural integrity, up to and including the PMP flood.~~

~~(g) Streets.~~

~~(1) Generally.~~

A. Design of streets shall consider public safety and limit potential conflicts between stormwater conveyance, traffic, parking, pedestrian access, ADA requirements, and bicycle traffic.

B. Streets draining a watershed greater than one hundred (100) acres must be designed for the 100-year frequency storm.

C. Streets may be used for stormwater drainage only if the calculated stormwater flow does not exceed the flows outlined in Table 504-7 or the velocity does not exceed ten (10) feet per second.

D. Where streets are not capable of carrying stormwater, as outlined above, inlets or curb openings discharging to drainage channels or storm sewers shall be provided. Partial flow past the inlet will be allowed when the capacity of all downstream street systems can accommodate the flow.

E. Street width shall not be widened beyond the width as determined by the street classification for drainage purposes.

F. Stormwater conveyance on streets shall be designed to account for the cumulative impact of peak flows and runoff volumes on the system as the stormwater progresses downgrade.

G. Curb cuts for driveways on all streets shall be designed for compatibility with the stormwater conveyance function of streets.

H. Potential flooding problems or conflicts at the connection points where new or modified drainage systems (including streets, storm sewers, etc.) and the existing portions of the downstream street system and stormwater conveyance system shall be identified and resolved either in the design of the new or modified drainage system or in modifications to the existing system.

I. Dwelling units located on the downhill side of a T-intersection with a street or drainage channel discharging onto the intersection shall be sited so as to avoid obstruction of the drainage patterns.

(2) Primary and Secondary Arterial Streets. An arterial street is a street so designated on the current major thoroughfare plan. One (1) lane in each direction on arterial streets shall remain passable with a flow depth not to exceed 0.30 feet during a twenty-five-year storm event. The maximum depth of water in the street section must not exceed seven (7) inches (the height of a standard city curb).

(3) Local "B" and Collector Streets. A maximum flow depth to the top of curb on a standard local "B" and collector street section will be allowed during a twenty-five-year storm event. A collector street is a street with a width of forty-four (44) feet or more and not shown as an arterial street on the current major thoroughfare plan.

(4) Local "A" Streets. Local "A" streets shall be designed on a basis of a five-year frequency. A twenty-five-year frequency storm must be contained within the street right-of-way.

(5) Alleys. Alleys shall be designed for five-year frequency within the limits of the alley pavement/curbs and twenty-five-year frequency within the right-of-way/easement to carry stormwater.

(6) Traditional Street Design. Traditional street design shall conform to the storm frequency requirements of the standard street designs listed above as follows:

A. Trails, Alleys and Lanes - Use alley design criteria.

B. Local Street or Avenue - Use local "A" street design criteria.

~~C. Main Street - Use local "A," local "B" or collector street design criteria depending on the pavement widths. Use local "A" criteria where pavement width is less than thirty-four (34) feet.~~

~~D. Boulevard or Parkway - Use arterial street design criteria.~~

~~No flow capacity tables are provided for the traditional street designs due the variety of geometric properties associated with these streets. Drainage calculations specific to a proposed traditional street design must be submitted for approval with every project where a traditional street design is proposed.~~

~~(7) All-Weather Crossings.~~

~~A. Where proposed streets cross existing or proposed watercourses, all-weather crossings shall be required. Culverts or bridges shall be adequate to allow passage of the design storm identified in subsection 35-504(b)(1).~~

~~B. All crossings, culverts and bridges shall be designed for an H-20-44 or HS-20 loading.~~

~~(8) Unflooded Public Road Access.~~

~~A. During a design storm event (see "subsection 35-504(b)(2) System Criteria") unflooded access (within the "Proceed with Caution" range per figure 504-2) shall be available from each proposed new development to an adjacent public street during a regulatory flood event.~~

~~B. Additionally, unflooded access shall be accessible to an arterial street that is not adjacent to the development or to a distance of one-quarter-mile, whichever is less, during a future conditions twenty (20) percent annual chance (five-year) flood event.~~

~~C. The director of public works may waive criterion b of this requirement for developments under three (3) acres in size.~~

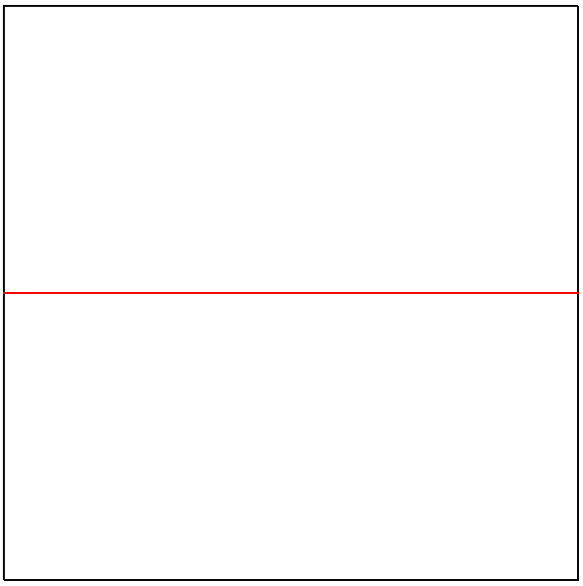
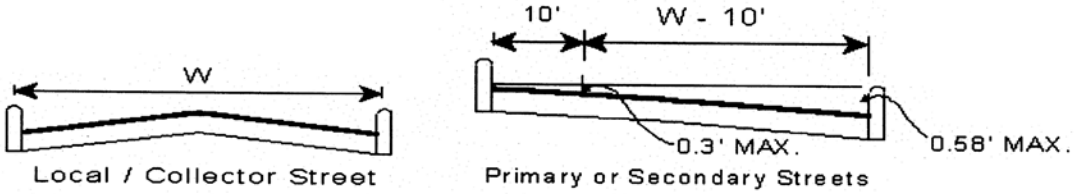


Figure 504-2 Table 504 - 7 Storm Drainage, street Velocities & Capacities, Manning's N=0.018



STORM DRAINAGE
STREET VELOCITIES AND CAPACITIES
Manning's n=0.018

Slope %	LOCAL TYPE "A" W= 30'		LOCAL TYPE "B" W=40'		COLLECTOR W=44'		SECONDARY (W/MEDIAN) Maximum Water Depth = 7" W=24' Min. and 29' Max.		PRIMARY & Secondary (W/O MEDIAN) Maximum Water Depth = 7" W=24' Min. and 29' Max.	
	Q cfs	V f/s	Q cfs	V f/s	Q cfs	V f/s	Q cfs	V f/s	Q cfs	V f/s
0.40	35.4	2.8	47.8	2.9	44.1	2.7	20.6	2.5	19.2	2.3
0.45	37.5	3.0	50.7	3.0	46.8	2.8	21.9	2.7	20.4	2.4
0.50	39.6	3.2	53.4	3.2	49.3	3.0	23.1	2.8	21.5	2.5
0.55	41.5	3.3	56.0	3.4	51.7	3.1	24.2	2.9	22.5	2.7
0.60	43.3	3.5	58.5	3.5	54.0	3.3	25.3	3.1	23.6	2.8
0.65	45.1	3.6	60.9	3.7	56.2	3.4	26.3	3.2	24.5	2.9
0.70	46.8	3.8	63.2	3.8	58.4	3.5	27.3	3.3	25.4	3.0
0.75	48.5	3.9	65.4	3.9	60.4	3.7	28.3	3.4	26.3	3.1
0.80	50.0	4.0	67.6	4.1	62.4	3.8	29.2	3.5	27.2	3.2
0.85	51.6	4.1	69.6	4.2	64.3	3.9	30.1	3.7	28.0	3.3
0.90	53.1	4.3	71.7	4.3	66.2	4.0	30.9	3.8	28.8	3.4
0.95	54.5	4.4	73.6	4.4	68.0	4.1	31.8	3.9	29.6	3.5
1.00	55.9	4.5	75.5	4.5	69.8	4.2	32.6	4.0	30.4	3.6
1.50	68.5	5.5	92.5	5.5	85.4	5.2	40.0	4.9	37.2	4.4
2.00	79.1	6.4	106.8	6.4	98.6	6.0	46.1	5.6	43.0	5.1
2.50	88.5	7.1	119.4	7.2	110.3	6.7	51.6	6.3	48.1	5.7
3.00	96.9	7.8	130.8	7.8	120.8	7.3	56.5	6.9	52.7	6.2
3.50	104.7	8.4	141.3	8.5	130.5	7.9	61.0	7.4	56.9	6.7
4.00	111.9	9.0	151.1	9.1	139.5	8.5	65.2	7.9	60.8	7.2
4.50	118.7	9.5	160.2	9.6	148.0	9.0	69.2	8.4	64.5	7.6
5.00	125.1	10.0	168.9	10.0	156.0	9.5	72.9	8.9	68.0	8.0
5.50	116.0	10.0	153.0	10.0	163.6	9.9	76.5	9.3	71.3	8.4
6.00	108.0	10.0	143.0	10.0	157.0	10.0	79.9	9.7	74.5	8.8
6.50	102.0	10.0	134.0	10.0	148.0	10.0	81.0	10.0	77.5	9.1
7.00	96.0	10.0	127.0	10.0	140.0	10.0	76.0	10.0	80.4	9.5
7.50	91.0	10.0	120.0	10.0	132.0	10.0				
8.00	87.0	10.0	115.0	10.0	126.0	10.0				
8.50	83.0	10.0	110.0	10.0	120.0	10.0				
9.00	79.0	10.0	105.0	10.0	115.0	10.0				
9.5	76.0	10.0	101.0	10.0	111.0	10.0				
10	73.0	10.0	97.0	10.0	106.0	10.0				

~~(h) Drainage Channels and Watercourses. This section addresses proposed improvements or modifications to drainage channels and watercourses required to convey stormwater runoff from or through the proposed development. Refer to subsection 35-504(b)(1) for storm frequency design criteria.~~

(1) Watercourses to Remain Unobstructed. Except as authorized by a development plan approved by the director of public works or his designee, no person shall place or cause to be placed any obstruction of any kind in any watercourse within the city and its ETJ. The owner of any property within the city, through which any watercourse may pass, shall keep the watercourse free from any obstruction not authorized by a development plan.

(2) Channel Modifications.

A. Modifications to existing watercourses or newly created open channels may be designed as earth channels, sod channels or as concrete lined channels. Liners other than sod or concrete which enhance the aesthetics or habitat value of the watercourse and which reduce future maintenance requirements are encouraged. Preliminary planning for the applicability of other channel liners shall be reviewed with the director of public works or his representative prior to the submittal of construction plans for approval.

B. Natural Unimproved Waterways. Runoff that results from upstream development and is discharged to an unimproved waterway can cause flood damage to properties adjacent to the waterway. Natural undeveloped waterways do not receive regular maintenance. Design of natural waterways shall take into consideration fluvial geomorphologic principals and practices and other erosion control measures. Consulting engineers and development review officials shall work to resolve potential downstream impact issues.

(3) Maintenance. Design of new channels or alterations to existing channels shall consider future maintenance requirements. A maintenance schedule for any private channel shall be submitted to and approved by the director of public works prior to approval of construction plans. Maintenance requirements of concrete channels consist of de-silting activities, prevention of vegetation establishment in construction joints, and repair of concrete as necessary. Maintenance of earthen channels includes regular observation and repair, as necessary, of erosion, scouring, and removal of silt deposits, as necessary to maintain design parameters. Developers shall be responsible for maintaining newly planted channels until coverage is established throughout eighty-five (85) percent of the area. This area shall include slopes, floor, and any attendant maintenance easement. New earthen channels shall be planted with drought resistant, low growth, native species grasses, which will allow unobstructed passage of floodwaters. Johnson grass, giant tagweed and other invasive species shall not be allowed to promulgate in channels. Suggested species shall include, but not be limited to, common bermuda, coastal bermuda, buffalo grass, sideoats grama, seep muhly, little bluestem, and indian grass. Mowing frequencies vary with the vegetation growth rates, but is required when the grass exceeds the design roughness coefficient of the channel.

(4) Multiple Uses. Planned multiple-use of a watercourse is allowed (e.g. bike paths or greenbelt). If multiple use of the watercourse is to be incorporated, the applicant shall form a property owners' association that shall assume maintenance responsibility for private amenities. The appropriate government agency will be responsible for maintenance of public amenities. The applicant shall provide overlay easements for public or private use.

(5) Velocity Criteria. Table 504-8 shall be used to determine maximum permissible channel velocity.

Table 504-8 Velocity Control

Velocity (fps)	Type of Facility Required	Hydraulic Radius (ft.)	Correction Factor	Maximum Permissible Velocity

				~~(fps)~~
~~1 to 6 (Maximum Average Velocity = 6 fps)~~	~~Vegetated Earthen Channel~~	~~0—1~~ ~~1—3~~ ~~3—5~~ ~~5—8~~ ~~8—10~~ ~~Over 10~~	~~0.8~~ ~~0.9~~ ~~1.05~~ ~~1.15~~ ~~1.225~~ ~~1.25~~	~~5~~ ~~5.5~~ ~~6.3~~ ~~6.9~~ ~~7.35~~ ~~7.5~~
~~*6 to 12~~	~~Turf Reinforcement Mat (TRM)~~	~~NA~~	~~NA~~	~~12~~
~~6 to 8~~	~~Concrete Retards~~	~~NA~~	~~NA~~	~~NA~~
~~> 8~~	~~Concrete Lining or Drop Structures~~	~~NA~~	~~NA~~	~~NA~~

~~* If Turf Reinforcement Mat (TRM) is proposed, please see City of San Antonio Standard Specifications for Construction Item 554 for submittal requirements. The improvement plan sheets should include the location of placement, details, and manufacturer's installation instructions.~~

~~A. Where velocities are in the supercritical range, allowance shall be made in the design for the proper handling of the water.~~

~~B. Ensure that the channel will contain the hydraulic jump (sequent depth) throughout the extent of the supercritical profile. An exception to this criteria is where concrete lined lateral channels discharge down the side slopes of channels. These channels may be designed for normal depth plus freeboard provided velocity controls are established at the main channel flow line.~~

~~C. Ensure that the energy grade of the channel will not result in upstream flooding at existing or proposed lateral facility connections.~~

~~(6) Retard Spacing. Retard spacing shall be computed as follows when using the city standard retard section Figure 504-3 and the following equations:~~

35-504(h) continued

RETARD SPACING CRITERIA

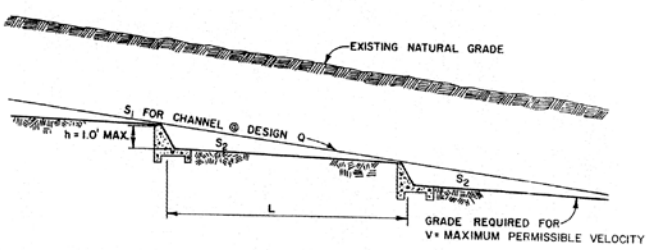


Figure 504-3

~~L = 1.0' ÷ (S1 - S2)~~

~~Where: L = Distance required between retards in feet.~~
~~S1 = Actual slope of channel in ft./ft.~~
~~S2 = Slope of proposed channel for maximum permissible velocity established from Table 504-8, i.e.:~~

~~and~~

~~$S2 = [(NV) \div (1.486R^{2/3})]^2$~~

~~Where: V = maximum permissible velocity established from Table 504-8~~
~~N = .035~~
~~R = area/wetted perimeter~~

~~(7) Concrete Lined Channels. The design of concrete lined channels shall comply with the following general requirements:~~

~~A. Freeboard consistent with Table 504-9 will be applied to the twenty five year design.~~

~~B. From the top of the concrete lining to the top of the ditch, a side slope not steeper than three (3) horizontal to one (1) vertical shall be required; nor shall the slope be less than twelve to one (12:1). The minimum slope of concrete lined channels shall be~~

~~0.4 percent, or 0.1 percent with a minimum "cleaning" velocity of two (2) feet per second (2 fps) during an existing conditions two-year storm event.~~

~~C. For normal conditions, the concrete lining shall be a minimum of five (5) inches thick and reinforced with No. 3 round bars at twelve (12) inches on center each way. Where surcharge, nature of ground, height and steepness of slope, etc., become critical, design shall be in accordance with latest structural standards. All concrete lining shall develop a minimum compressive strength of not less than three thousand (3,000) pounds per square inch in twenty-eight (28) days. The depth of all toe downs shall be thirty-six (36) inches upstream, twenty-four (24) inches downstream, and eighteen (18) inches for side slopes. The city's construction inspector may permit an eighteen-inch toe down in rock subgrade in lieu of the above toe down requirements. The horizontal dimensions of toe downs shall not be less than six (6) inches.~~

~~D. Maximum concrete riprap side slopes shall be one and one-half (1½) horizontal to one (1) vertical, unless soil tests made by a geotechnical engineer show that a greater slope, or a special design, will be stable. Where vehicular traffic may travel within a horizontal distance equal to one-half (½) the vertical rise of the slope, a two-foot surcharge load shall be included in the design.~~

~~E. Fencing will be required adjacent to the channel where channel vertical wall heights exceed two (2) feet. Fencing will also be required adjacent to the channel where channel side slopes exceed two to one (2:1) and the channel depth is greater than two (2) feet. The fencing must not cause sight distance problems for motorists.~~

~~F. Vertical walls will not be permissible for depths greater than two (2) feet unless properly fenced or enclosed. Walls will have a minimum thickness of six (6) inches.~~

~~G. Easements or rights-of-way for concrete lined channels shall extend a minimum of two (2) feet on both sides of the extreme limits of the channel. "Extreme limits" of the channel shall mean the side slope intercept with the natural ground or proposed finished ground elevation.~~

~~H. A minimum "n" value of roughness coefficient of 0.015 shall be used for a wood float type surface finish. This "n" value is as used in Manning's formula.~~

~~Table 504-9~~
~~Drainage Freeboard for Concrete~~
~~Lined and Earth Channels for Twenty-Five-Year Storm~~

~~Design Depth of Flow~~	~~Required Freeboard~~
~~0 to feet 5 feet~~	~~0.5 foot~~
~~5 to 10 feet~~	~~10% of design depth~~
~~10 feet and over~~	~~1.0 foot~~

-

~~(8) Vegetated Earth Channels.~~

~~A. Freeboard consistent with Table 504-9 will be applied to the twenty-five-year design.~~

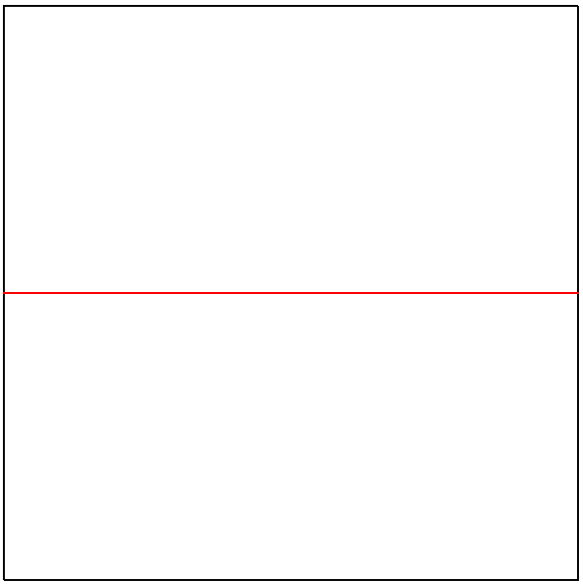
~~B. The side slope shall not be steeper than three (3) horizontal to one (1) vertical.~~

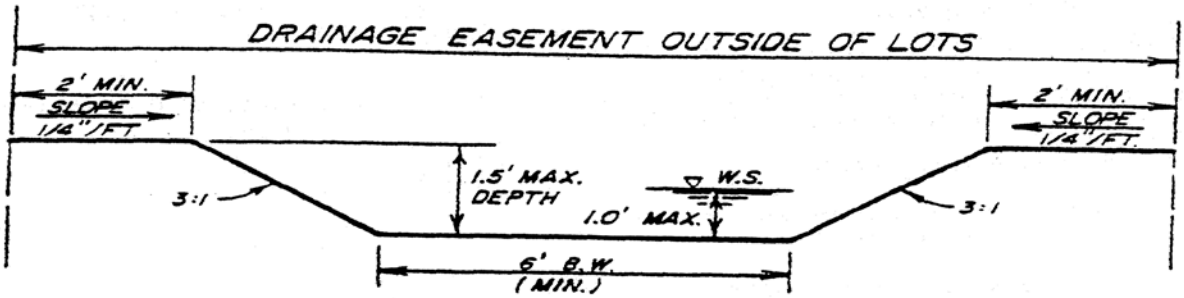
~~C. Easements or rights-of-way for improved earth channels shall conform to the requirements stated in subsection (d) of this section and shall extend a minimum of two (2) feet on one (1) side and fifteen (15) feet for an access road on the opposite side of the extreme limits of the channels when such channels do not parallel and adjoin an alley or roadway. When such channels do parallel and adjoin an alley or roadway, the easement or right-of-way shall extend a minimum of two (2) feet on both sides of the extreme limits of the channel. Where utilities are installed in the access road of the drainage right-of-way, the right-of-way shall extend two (2) feet on one (1) side and seventeen (17) feet on the opposite side of the design limits of the channel. These seventeen (17) feet are to provide an access way along the channel with a maximum cross slope of one (1) inch per foot toward the channel. Where designed channel bottoms exceed one hundred (100) feet in width, the fifteen-foot extra width shall be provided on both sides of the channel.~~

~~D. Interceptor drainage easements shall extend a minimum of two (2) feet on both sides of the extreme limits of the channel. Refer to Figure 504-4.~~

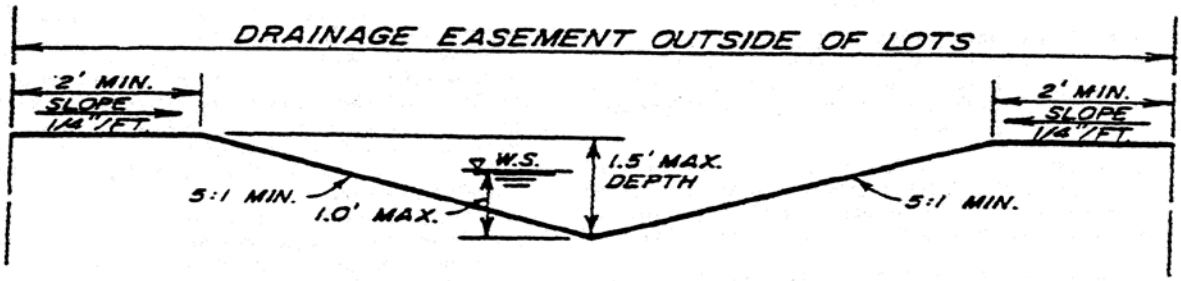
~~E. Improved earthen channels will be vegetated by seeding or sodding. Eighty-five (85) percent of the channel surface area must have established vegetation before the City of San Antonio will accept the channel for maintenance.~~

~~F. For vegetated earthen channels with slopes less than 0.5 percent or bottom widths greater than thirty (30) feet, concrete pilot channels shall be provided. The minimum bottom width of the pilot channel shall be four (4) foot. The minimum [earthen] slope draining toward the pilot channel shall be one (1) percent.~~





TRAPEZOIDAL CHANNEL



"V"- SHAPED CHANNEL

NO RETARDS
VEL. CONTROL

STANDARDS FOR
INTERCEPTOR DRAINS
FOR INTERCEPTING SHEET FLOW
(WITHOUT ACCESS EASEMENT REQ'D)

Figure 504-4

35-504(h)(8) continued

~~(9) Channel Bends and Turns - Freeboard. Allowance for extra freeboard shall be made when the centerline radius of the channel is less than three (3) times the bottom width. Where sharp bends or high velocities are involved and the flow regime is sub-critical, the applicant shall use the following formula for computing the extra freeboard:~~

~~$d_2 - d_1 = V^2(T + B) \div 2gR$~~

~~Where: d_1 = depth of flow at the inside of the bend in feet.~~
~~d_2 = depth of flow at the outside of the bend in feet.~~
~~B = bottom width of the channel in feet.~~
~~V = the average approach velocity in the channel in feet per second.~~
~~T = width of flow at the water surface in feet.~~
~~g = 32.2 feet/second squared.~~
~~R = the center line radius of the turn or bend in feet.~~

A. The quantity d_2-d_1 divided by two (2) shall be added to the normal depth of flow before adding the required freeboard in calculating required right-of-way widths.

B. Where sharp turns are used without curved sections, the depth required shall be large enough to provide for all head losses. Allowance shall be made for any backwater head that may result.

C. For normal design conditions no extra freeboard is required where centerline radius of channel should be at least three (3) times the bottom width. For critical and super-critical flow regimes, the extra freeboard calculated with the above formula shall be doubled.

(i) Storm Sewers.

(1) For all ordinary conditions, storm sewers shall be designed on the assumption that they will flow full under the design discharge; however, whenever there are constrictions, turns, submerged or inadequate outfall, etc., the hydraulic and energy grade lines shall be computed and plotted in profile. The energy grade line (EGL) shall be below the top of curb and the hydraulic grade line (HGL) shall be below the gutter elevation of the drainage structure. In all cases adequate outfalls shall be provided.

(2) No storm sewers shall be less than twenty-four (24) inches in diameter.

(3) Minimum easement widths for storm sewers will be the greater of fifteen (15) feet or six (6) feet on both sides of the extreme limits of the storm sewer width (e.g. the easement width for a three (3) barrel ten-foot wide box culvert with six-inch walls would be (3 x 10')+(4 x 0.5')+(2 x 6') = 44').

(j) Inlets and Openings.

(1) Drop Curb Openings - Sidewalk Does Not Abut Opening. Where drop curb openings are used to take stormwater off the streets and into drains, the length of the curb opening can be calculated from the weir formula using the coefficient of 3.087 in the following formula:

$L = Q \div Ch^{3/2}$

Where: L = the length of drop curb opening required in feet.
Q = amount of flow in CFS based on twenty-five-year design frequency.
C = 3.087.
h = head of weir in feet.

Gutter line depressions will be permitted where such depressions will not hamper the flow of traffic. For amount of curb exposure, conform to City of San Antonio inlet standards.

(2) Curb or Drop Inlets. Where drop inlets are use, the city standard inlets with adequate reinforcing steel may be used. All other types or designs shall be subject to the approval of the director of public works in consultation with the director of planning and development services. The following formulas for inlet capacity are based on drop inlets in sag points. Inlet capacities on grades will be considered less, the amount of which depends on street grades, deflections, cross slopes, depressions, etc.

(3) Grate Inlets. The flow of water through grate openings may be treated as the flow of water through a rectangular orifice. The following formula may be used for determining grate capacity:

$Q = CA\,(2gh)^{1/2}$

Where: Q = discharge in cubic feet per second.
C = orifice coefficient of discharge (taken as 0.70).
g = acceleration due to gravity (32.2 ft./sec.^{2})

~~h = head on the grate in feet.~~
~~A = net area of the openings in the grate in square feet.~~

~~This formula gives the theoretical capacity of the grate inlet. Since grate inlets are subject to considerable clogging, capacity of the grate inlet will be taken as one-half (½) on the value given by this formula.~~

~~(4) Curb Opening Inlets. The capacity of curb opening inlets will depend on whether or not the opening is running partially full or submerged. If the depth of flow at the curb opening inlet is such as to cause a partially full opening, a weir effect will develop and the following formula will apply:~~

$$Q = C_w L(h)^{3/2}$$

~~Where: Q = the discharge of capacity in cubic feet per second.~~
~~C_w = the weir coefficient of discharge (3.087).~~
~~L = the length of curb opening in feet.~~
~~h = the head or depth of water at the opening in feet.~~

~~If the depth of flow at the curb opening is such as to fully submerge the opening, the orifice effect will develop and the formula used shall be identical to that given under grate inlets with the exception that the head, h, on the curb opening orifice shall be taken as the depth from the top of the water surface to the center of orifice or opening; one hundred (100) percent efficiency will be allowed for curb opening inlets.~~

~~(Ord. No. 97568 § 2) (Ord. No. 98697 § 1 and 6) (Ord. No. 2006-11-30-1333, § 2, 11-30-06) (Ord. No. 2009-01-15-0001, § 2, 1-15-09) (Ord. No. 2009-08-20-0661, § 3, 8-20-09) (Ord. No. 2010-11-18-0985, § 2, 11-18-10) (Ord. No. 2012-10-18-0829, § 2, 10-18-12)~~

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CHAPTER 1
INTRODUCTION

1.1 PREFACE

The purpose of this Storm Water Design Criteria Manual (SWDCM) is to provide the design engineer with the criteria necessary to design drainage facilities in and around the San Antonio area. This SWDCM establishes the standard principles and practices for the planning, design, construction, maintenance, and management of drainage facilities. It is not the intent of this SWDCM to limit the design capabilities or engineering judgment of the design engineer.

Should an error be found within the manual or changes are needed within a section of the manual, please submit these errors and changes to Director of TCI for consideration and inclusion into the next manual update.

1.2 ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway Officials
AC	Asphalt Concrete
ACPA	American Concrete Pipe Association
ADA	Americans with Disabilities Act
AEP	Annual Exceedance Probability
ASTM	American Society for Texting Materials
BFE	Base Flood Elevation
BMP	Best Management Practice
CFR	Code of Federal Regulations
cfs	cubic feet per second
CIP	Capital Improvements Program
CIPP	Cast-in-Place Pipe
City	City of San Antonio
CLOMR	Conditional Letter of Map Revision
CLOMR-F	Conditional Letter of Map Revision – Fill
CMP	Corrugated Metal Pipe
CoSA	City of San Antonio
CRS	Community Rating System
CWA	Clean Water Act
DSD	Development Services Department
EARZ	Edwards Aquifer Recharge Zone
EGL	Energy Grade Line
EPA	Environmental Protection Agency

FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
fps	feet per second
Fr	Froude Number
GIS	Geographic Information System
gpm	gallons per minute
HDPE	High Density Polyethylene
HEC-RAS	Hydraulic Engineering Center, River Analysis System
HGL	Hydraulic Grade Line
hp	horsepower
ICL	Inside City Limits
ID	Inside Diameter
ITS	Intelligent Transportation System
Inv.	Invert
JD	Jurisdictional Delineation
LID	Low Impact Development
LOMA	Letter of Map Amendment
LOMR	Letter of Map Revision
LOMR-F	Letter of Map Revision – Fill
MBC	Multi Box Culvert
MDP	Master Development Plan
MCC	Motor Control Center
NFIP	National Flood Insurance Program
NOI	Notice of Intent
NOT	Notice of Termination
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
OD	Outside Diameter
OSHA	Occupational Safety and Health Administration
PCCP	Portland Cement Concrete Pavement
pcf	pounds per cubic foot
PLC	Programmable Logic Controller
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PMR	Physical Map Revision
PUD	Planned Unit Development
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe

ROW	Right of Way
RSWF	Regional Storm Water Facilities
RSWMP	Regional Storm Water Management Program
SARA	San Antonio River Authority
SAWS	San Antonio Water System
SCS	Soil Conservation Service (changed to NRCS)
SFHA	Special Flood Hazard Area
SWMP	Storm Water Management Plan
TAS	Texas Accessibility Standards
TCI	Transportation & Capital Improvements
TCEQ	Texas Commission on Environmental Quality
TPDES	Texas Pollutant Discharge Elimination System
Typ.	Typical
TxDOT	Texas Department of Transportation
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDOT	United States Department of Transportation
USFW	United States Fish & Wildlife Agency
USGS	United States Geological Survey
VFD	Variable Frequency Drives
V.T.C.A.	Vernon's Texas Codes Annotated
WOUS	Waters of the United States

1.3 ACKNOWLEDGEMENTS

To be completed after project

CHAPTER 2
DRAINAGE POLICY

2.1 INTRODUCTION

The drainage policy for the City of San Antonio has changed over the years to provide for the orderly development of drainage improvements to enhance the health, safety, and welfare of its citizens, their property, and the environment. The City has implemented a comprehensive storm water management program through guidance provided by the Drainage Regulation Review Committee in February 1996 with a regional approach to meet the policies of the City Master Plan.

2.2 STATEMENT OF POLICY

~~Sec. 35-504. Stormwater Management.~~

~~STATEMENT OF PURPOSE~~

The purpose of this manual ~~section~~ is to provide adequate measures for the retention, detention, and distribution of storm water ~~stormwater~~ in a manner that minimizes the possibility of adverse impacts on both water quantity and water quality during development. Innovative runoff management practices designed to meet the provisions of this manual ~~chapter,~~ ~~that~~ enhance the recharge of groundwater, and maintain the function of critical environmental features are encouraged. The city recognizes that watercourses, and their associated watersheds, within the City of San Antonio's jurisdiction represent significant, ~~and~~ irreplaceable, recreational, and aesthetic resources and contribute to the economic and environmental health of the city. ~~In addition,~~ As all of the these watersheds ~~within the city~~ are susceptible ~~vulnerable~~ to concentrated surface water runoff, disturbance of wildlife habitat, non-point source pollution, and sedimentation ~~resulting~~ from development activities ~~and~~ they should be developed in a sensitive and innovative manner.

This manual ~~section~~ implements the following policies of the master plan (Section 121 of City Charter, Resolution 97-05-01 approved May 14, 1997, Ordinance 86100 approved May 29, 1997):

- Natural Resources, Policy 1d: Encourage retention of the 100-year floodplains as natural drainage ways without permanent construction, unnecessary straightening, bank clearing, or channeling.
- Natural Resources, Policy 1d: 2. Adopt strong storm water ~~stormwater~~ management practices throughout the drainage area which include site specific measures such as:
  - On-site storm water ~~stormwater~~ retention and detention;
  - Reduction in impervious cover;

- Natural bank contouring;
- Floodplain preservation and buffering;
- Preservation of riparian habitat;
- Storm water ~~stormwater~~ harvesting sites for reuse purposes.

Urban Design, Policy 1g: Prepare design and construction policies and standards for utility and transportation infrastructure, capital improvement projects, public facilities, and development projects that reinforce neighborhood centers and provide diverse, pedestrian-friendly neighborhoods.

If principles cannot be met, please visit with the Director of TCI or his authorized representative.

2.3 PRINCIPLES

Listed below are a few guiding principles to consider while developing drainage for the project site:

- Preserve floodplain and riparian buffers.
- Enhance the health, safety, and welfare of its citizens with multi-use facilities.
- Develop cost effective solutions.
- Develop drainage facilities for easier or reduced maintenance.
- Enhance recharge.
- Minimize impacts to existing drainage facilities.

2.4 BASIC KNOWLEDGE

Prior to designing any project, the design engineer should gather and examine existing information of the project area within the watershed under consideration. From this information the design engineer can then determine if the upstream area will impact the project site or if the proposed development will impact existing downstream drainage systems or structures.

2.5 PLANNING

The planning of a project should consider the guiding principles stated above. There are many other guiding principles to consider during the planning of a development or a capital improvement project, including integrated planning by engineer, architect, landscape architect, and other applicable professionals to maximize multi-use features and on-site storm water management performance.

2.6 TECHNICAL CRITERIA

The storm drainage planning and design should follow the criteria within this manual.

The following two items should be considered during the design process.

1)

~~(d)(3)~~

~~Natural Watercourses or Floodplains. Easements for natural watercourses shall be the 100-year floodplain or the twenty-five-year plus freeboard (see Table 504-9 of this section) whichever is less. In floodplain areas where ongoing maintenance is required or the floodplain will be reserved for use by the public, the drainage easements shall be maintained by a public entity and the property will be dedicated to the city as a multi-use drainage easement. A drivable access way shall be provided in floodplain easements for the length of the easement when regular maintenance of the floodplain is required.~~ Diversion of storm water ~~stormwater~~ away from the natural watercourse will not be allowed, except within the property boundaries ~~of the property~~ controlled by the developer~~,~~ under the following conditions: a) The storm water ~~provided that the diverted water~~ is returned to ~~the~~ its natural flowing watercourse ~~within which it would naturally have been flowing~~ prior to leaving the developer's property~~.~~, b) For ~~An analysis of the timing of the diverted hydrograph on~~ watersheds greater than twenty (20) acres, a timing analysis of the existing and diverted hydrograph ~~as it reenters the receiving watercourse,~~ must be performed to confirm ~~show~~ that the peak flowrate ~~in the receiving watercourse~~ has not been increased at the point that it reenters the watercourse, as a result of the diversion.

2)

~~(d)(7)~~
~~Lower Elevation of Site.~~ All developments shall provide ~~for~~ adequate drainage outfall at the lower end of the site into an existing street, alley, drainage, easements or right-of-way, or to the centerline of an existing natural drain. Where a proposed street, storm drain, or open channel does not discharge into a natural low or into an existing adequate drainage easement, then facilities and drainage easements of adequate width — to contain the design discharge — shall be constructed and dedicated to the centerline of an existing natural low within the same watershed. However, ~~where~~ when the natural low lies within the developer's property, the developer will only be required ~~only~~ to plat an easement to the centerline of the natural low;~~,~~ provided that the easement is ~~adequate~~ able to accommodate the facilities that will be built in conjunction with ~~the~~ future development of that property.

2.7 FLOODPLAIN MANAGEMENT

Floodplain management has changed over the years due to the National Flood Insurance Act of 1968. Changes from the program~~,~~ included USGS maps being used with the delineation of floodplains, HUD issuing flood insurance maps in the late 1970's~~.~~, and the founding of FEMA in 1979. The National Flood Insurance Program was ultimately placed under FEMA. As the City began participating in this action in the late 1970's, flood insurance can be purchased through insurance carriers for buildings in Bexar County.

Floodplain management is used to minimize flooding of buildings, reduce flood losses, and improve the quality of life — and safety of the citizens of Bexar County.

2.8 IMPLEMENTATION

~~(a)~~

~~Applicability.~~ The provisions of this manual ~~section~~ shall apply to any application for subdivision plat, master development plan, capital improvement project, or building permit approval except as otherwise provided by Chapter 35 of the UDC ~~this chapter~~. A storm water ~~stormwater~~ management plan shall be provided as set forth in Appendix "A" of this manual ~~"B,"~~ ~~section 35-B119 of Chapter 35 of the UDC this chapter~~.

2.9 REFERENCES

- City of San Antonio. *Master Plan Policies*. Department of Planning & Community Development, City of San Antonio, San Antonio, Texas, Adopted: May 29, 1997. Retrieved from http://www.sanantonio.gov/Portals/0/Files/Planning/NPUD/master_plan.pdf

CHAPTER 3
DRAINAGE LAW

3.1 INTRODUCTION

This chapter briefly references the laws and related policies that affect hydrologic and hydraulic designs for all public and private projects within the City of San Antonio and its Extraterritorial Jurisdiction (ETJ). These laws and policies include Federal, State, and Local Codes and regulations. Not all laws, statues, codes, or regulations are included.

3.2 FEDERAL LAWS AND REGULATIONS

3.2.1 The Code of Federal Regulations

The Code of Federal Regulations (CFR) is the codification of the general and permanent rules and regulations.

3.2.2 National Flood Insurance Program

The NFIP was established under the National Flood Insurance Act (NFIA) in 1968 to reduce future flood losses through local floodplain management. NFIP requires participating cities, counties, or states, to adopt floodplain management ordinances containing certain minimum requirements intended to reduce future flood losses.

3.2.3 NATIONAL ENVIRONMENTAL POLICY ACT

NEPA was passed in 1969, 42 United States Code (U.S.C.) 4321-4347, to establish a national policy to prevent or eliminate damage to the environment and improve the understanding of the ecological systems and natural resources that are important to the Nation.

3.2.4 RIVERS AND HARBORS ACT

Rivers and Harbors Act of 1899 – Allows the US Army Corps of Engineers (USACE) to regulate the navigable waters of the United States (WOUS). Section 9 (33 USC 401) prohibits the construction of any dam or dike across any navigable WOUS without a permit from the USACE. Section 10 (33 USC 403) prohibits the unauthorized obstruction, alteration, work affecting the course, location, condition, or physical capacity of any WOUS is unlawful unless the work has been reviewed and approved by the USACE.

3.2.5 The Federal Water Pollution Control Act

The Federal Water Pollution Control Act, 33 USC 1251-1387, was adopted in 1948 and, after amendments in 1972 and 1977, became known as the Clean Water Act (CWA). This act was enacted for the regulation of pollutants in the WOUS with the objective of restoring and maintaining the chemical, physical, and biological integrity of the nations' waters. This Act operates by authorizing water quality standards for surface water, requiring permits for point discharges of pollutants into WOUS. The EPA is the primary agency tasked with enforcing the CWA, although it also works in conjunction with State Environmental Agencies and the USACE.

3.2.6 Section 402 of the CWA

National Pollutants Discharge Elimination System - NPDES was established by the EPA in 1990 and contains regulations for point source Storm Water Discharge. The purpose of this legislation is to improve the quality of the nation's rivers, lakes, and streams by setting limits for point source discharging pollutants into waters of the United States and establishes monitoring and reporting requirements.

3.2.7 Section 404 of the CWA

Section 404 makes it unlawful to discharge dredged or fill material into WOUS without first receiving authorization from the USACE. The types of 404 Permits include Nationwide Permits, General Permits, and Individual Permits.

3.2.8 Endangered Species Act (ESA)

The ESA was passed by congress in 1973, its purpose was to protect and recover imperiled species and the ecosystem upon which they depend. It is administered by the U.S. Fish and Wildlife Service.

3.3 STATE STATUTES AND RULES

3.3.1 Texas Water Code – Section 11.086

Texas Statutes – Section 11.086(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. (b) A person whose property is injured by an overflow of water caused by an unlawful diversion or impounding has remedies at law and in equity and may recover damages occasioned by the overflow. (c) The prohibition of Subsection (a) of this section does not in any way affect the construction and maintenance of levees and other improvements to control floods, overflows, and freshets in rivers, creeks, and streams or the construction of canals for conveying water for irrigation or other purposes authorized by this code. However, this subsection does not authorize any person to construct a canal, lateral

canal, or ditch that obstructs a river, creek, bayou, gully, slough, ditch, or other well-defined natural drainage. (d) Where gullies or sloughs have cut away or intersected the banks of a river or creek to allow floodwaters from the river or creek to overflow the land nearby, the owner of the flooded land may fill the mouth of the gullies or sloughs up to the height of the adjoining banks of the river or creek without liability to other property owners. Amended by Acts 1977, 65th Leg., p. 2207, ch. 870, Sec. 1, eff. Sept. 1, 1977.

3.3.2 Texas Water Code – Section 16.236

Texas Statutes – Section 16.236 – Construction of Levee Without Approval of Plans; The commission shall make and enforce rules and orders and shall perform all other acts necessary to provide for the safe construction, maintenance, repair, and removal of levees located in this state.

3.3.3 Texas Commission on Environmental Quality – Chapter 213

Title 30 of the Texas Administrative Code Chapter 213 Edwards Aquifer Subchapter A. TAC Chapter 213 became effective on April 24, 2008 and its purpose was to regulate activities having the potential for polluting the Edwards Aquifer and hydrologically connected surface streams in order to protect existing and potential uses of groundwater and maintain Texas Surface Water Quality Standards. The activities addressed are those that pose a threat to water quality. Consistent with Texas Water Code, Section 26.401, the goal of this chapter is that the existing quality of groundwater not be degraded.

3.3.4 Texas Commission on Environmental Quality – Chapter 299

Title 30 of the Texas Administrative Code Chapter 299 for Dams and Reservoirs. This chapter applies to design, review, and approval of construction plans and specifications; and construction, operation and maintenance, repair, removal, emergency management, site security, and enforcement of dams that (1) have a height greater than or equal to 25 feet and a maximum storage capacity greater than or equal to 15 acre-feet, as described in paragraph (2) of this subsection; (2) have a height greater than six feet and a maximum storage capacity greater than or equal to 50 acre-feet.

3.4 LOCAL CODES/ORDINANCES/COURT ORDERS

3.4.1 City of San Antonio Texas Unified Development Code

3.4.2 City of San Antonio Flood Plain Ordinance 57969

3.4.3 Bexar County Flood Damage Prevention

Court Order was approved by Commissioners. Court sometime in the 1980's and it includes the minimum standards deemed necessary to minimize or eliminate flood damage to the areas within Bexar County and outside of incorporated cities.

3.4.4 Aquifer Protection Ordinance 81491

Approved on January 12, 1995, by the San Antonio City Council amending Chapter 34, Article VI, of the City Code by adding a new Division 6 thereunder tilted "Aquifer Recharge Zone and Watershed Protection". This ordinance requires that for all projects in the Edwards Aquifer Transition or Recharge Zone submit to the SAWS Resource Protection Division an Aquifer Protection Plan for approval prior to development.

3.4.5 (Ord. No. 97568 § 2) Storm Water Management Plan Checklist

3.4.6 (Ord. No. 2006-11-30-1333, § 2, 11-30-06) Maintenance

Maintenance of Sidewalks, parkways, curbs, downspouts, and driveways by abutting owners.

3.4.7 (Ord. No. 2009-08-20-0661, § 3, 8-20-09) Amendments to Chapter 19 and 35

Amendments of the City Code for further technical amendments to Chapter 35 Unified Development Code.

3.4.8 Ordinance No. 2010-11-18-0985

Requires that developers provide a one year warranty bond for public streets and public drainage improvements. The one year warranty period shall begin on the date the plat is recorded or the date of preliminary field approval of the improvements, whichever is later in time.

3.4.9 (Ord. No. 2013-01-31-0074) Amending FILO Ordinance of 1997

This Ordinance amends the methodology for calculating the fee-in-lieu-of onsite detention; increasing fees to all land use categories; and amending Article V, Chapter 35 of the Unified Development Code.

3.4.10 (Ord. No. 2014-06-19-0472) Amendments to Chapter 34

This Ordinance amends chapter 34 for the purpose of updating program requirements to reduce or eliminate the discharge of harmful pollutants into the SAWS Sanitary Sewer System and the City's Storm Water System in compliance with current State and Federal regulations.

CHAPTER 4
PLANNING

4.1 INTRODUCTION

This chapter will touch on the aspects of planning in regard to drainage.

Planning for different components of a project is crucial to the success of the project, whether the project is a residential subdivision, commercial development, or a capital improvement project. The Design Engineer must consider the impacts to the existing drainage systems as well as the aesthetics of the planned improvements.

The City of San Antonio had commissioned a study in the 1950's to determine drainage improvement needs throughout the City of San Antonio (City Drainage Master Plan). These improvements cost hundreds of millions of dollars and a number of the improvements were funded over the years through bond programs and other funding sources. In more recent years, following the development of the Digital Flood Insurance Rate Maps (DFIRM) for Bexar County, a number of additional flooding issues were realized throughout Bexar County. These flooding issues were studied and a Regional Drainage Master Plan was developed to address these issues.

The following should be considered during the development of the project:

~~(f)(6)~~
~~Multi-Use Facilities.~~ Multi-use facilities are encouraged, but not required. ~~(multi~~ Multi-use facilities allow ~~allows~~ for water quality, satisfy National Pollutant Discharge Elimination System (NPDES) requirements, enhance ground ~~around~~ water recharge, provide open space, provide recreation or other amenities, and/or provide habitat. ~~) and~~ Multi-use facilities may be utilized so long as the facility meets the standards set forth in ~~subsection~~ Chapter 2.8 ~~(a)~~ of this manual ~~section~~ and does not increase the rate or volume of erosion above that which would result from the use of a facility without multiple uses. ~~The use~~ Utilization of multi-use detention facilities to alleviate existing flooding problems, enhance and provide amenities for older neighborhoods, and support the revitalization of economically depressed areas is encouraged in public and private redevelopment initiatives.

4.2 REGIONAL DRAINAGE MASTER PLAN (WATERSHED MASTER PLAN)

The Bexar Regional Watershed Management (BRWM) is a partnership among Bexar County, the City of San Antonio, the San Antonio River Authority and 20 suburban cities to address flood management and water quality concerns on a regional basis.

An Inter Local Agreement for Bexar Regional Watershed Management program was approved in May 2003 and amended in April 2010 between the managing partners (Bexar County, the City of San Antonio, and the San Antonio River Authority). The oversight and implementation process for this program includes elected officials, entity staff at all levels, and most importantly, a citizens' advisory process. The program was set up to develop and implement, efficient and economic flood control throughout Bexar County.

A number of potential Capital Improvement Projects have been identified through the BRWM Watershed Master Plans. A number of these projects within the Watershed Master Plan have been funded and constructed.

4.3 REGIONAL STORM WATER MANAGEMENT PROGRAM (RSWMP)

This section represents the policies of the RSWMP and understanding this section will enable the design engineer to provide utility and transportation infrastructure, capital improvement projects, public facilities, and development projects meeting the policies of the UDC.
~~(b)~~
~~Storm water stormwater Management Program.~~
~~(1)~~
~~Regional Storm Water stormwater Management Program (RSWMP).~~
~~(b)(1)A~~.

4.3.1A RSWMP Overview

The City of San Antonio ~~has~~ determined that regional storm water ~~stormwater~~ management is preferable to site specific storm water ~~stormwater~~ mitigation. The regional storm water ~~stormwater~~ management program provides for the administration, planning, design, construction, and operational management of regional storm water ~~stormwater~~ facilities (RSWF). Regional storm water ~~stormwater~~ management uses a watershed-wide approach to analyze potential flooding problems, identify appropriate mitigation measures and select site locations and design criteria for RSWF. These RSWF include, but are not limited to, regional detention and retention ponds, watershed protection, land purchase, waterway enlargement, channelization, and improved conveyance structures. The regional storm water ~~stormwater~~ management program allows developers to participate in the program rather than constructing the on-site detention controls required by this section, ~~where the resulting use of a RSWF~~ when the City has determined that the increased runoff from the proposed development will not produce a significant adverse impact to other properties. ~~due to the increased runoff from the proposed development.~~

~~(b)(1)B.~~

4.3.1B RSWMP Participation

All developers shall participate in the RSWMP in one (1) of three (3) ways:

1. Payment of a fee in lieu of on-site detention (except in areas designated by the Director of TCI ~~director of public works~~ as "mandatory detention areas"). The fee schedule is included in UDC Appendix "C," section 35C-109.
2. Construction of on-site or off-site measures (typically storm water ~~stormwater~~ detention facilities) to mitigate increases in runoff resulting from the proposed development.
3. Construction or participation in the construction of an off-site RSWF to mitigate increased storm water ~~stormwater~~ runoff anticipated from ultimate development of the watershed.

~~(b)(1)C.~~

4.3.1C Adverse Impact

To determine a significant adverse impact for the purposes of this section, the following criteria will be used to analyze the receiving storm water ~~stormwater~~ facilities within two thousand (2,000) linear feet of the project, to the nearest downstream RSWF, or to the nearest floodplain with an ultimate analysis accepted by the city, whichever is less. For lots less than three (3) acres in size, adverse impact analyses need only extend to where tributary drainage areas equal one hundred (100) or more acres.

1. The storm water ~~stormwater~~ surface elevation (WSE) in receiving facility [natural or improved] drainage systems within two thousand (2,000) linear feet of the proposed development may not be increased by the proposed development unless the increased WSE is contained within easements or rights-of-way or the receiving systems have sufficient capacity to contain the increased WSE without increasing flooding to habitable structures.
2. Ultimate development runoff at low water crossings during regulatory (five (5)~~year~~, twenty-five (25)~~-year~~, and one hundred (100~~-~~) year frequency) storm events must not classify the low water crossing as "Dangerous to Cross" based on Figure 4.3.1.C ~~504-2~~. If the ultimate WSE exceeds this criterion, the crossings may be improved to the standards of this chapter in lieu of providing onsite storm water ~~stormwater~~ control measures or paying a fee.
3. Three (3) development conditions shall be analyzed with each adverse impact analysis.

Existing Conditions. This refers to current development conditions in the watershed and on site. This shall be used as the baseline for determining the impact of the development of the site, or the watershed, to other properties or drainage systems.

Proposed Conditions. This refers to existing conditions with the proposed development added. This shall be used to determine if the increased runoff from the proposed development results in an adverse impact to other properties or drainage systems.

Ultimate Conditions. This refers to ultimate development conditions within the watershed. In addition to being used to design proposed drainage facilities (subsection "4.3.2 ~~(2)~~ System Criteria," below), this condition shall also be used to determine if the increased runoff from the ultimate development of the watershed results in an adverse impact to other properties or drainage systems.

In addition to verifying low water crossing capacity (item 2, above), this analysis shall be used to assist the city in identifying watershed wide storm water ~~stormwater~~ management issues.

4. Minimum standards for identifying Dangerous Roadway conditions are identified in Figure 4.3.1C ~~504-2~~ below.

Note: The City of San Antonio contends that any runoff crossing a roadway creates a potentially dangerous condition. Figure 4.3.1C ~~504-2~~ represents the maximum flow depth over roadways that the City will accept in adverse impact analyses signed and sealed by the licensed professional engineers.

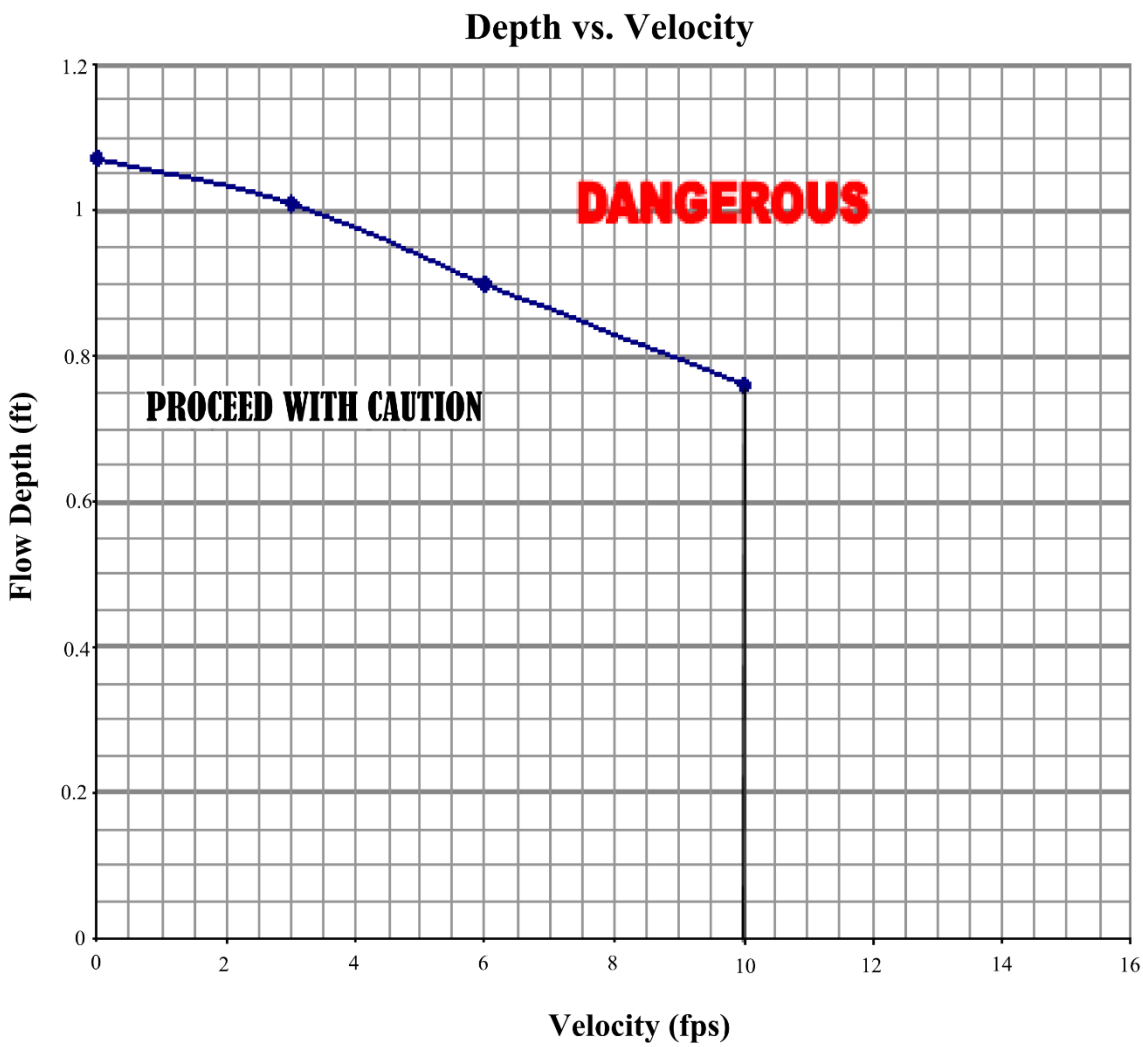


Figure 4.3.1C 1 – Roadway Flow Depth vs. Velocity

5. The City of San Antonio may reject a developer's request to participate in the RSWMP by payment or mitigation and require on-site detention. The City's decision will be based on the knowledge of significant adverse impacts that would be created by ultimate development of the watershed regardless of the distance from the development to the area of concern. The City may also reject a request for participation when it is not in the best interests of the RSWMP. The developer is recommended to meet with ~~the stormwater engineering division of the department of public works~~TCI Storm Water Division to discuss participation options prior to commencing design of a project. This preliminary

meeting in no way relieves the developer of his responsibility to prepare the necessary engineering documentation to support his request for participation.

~~(b)(1)D.~~

4.3.1D Fee In Lieu Of

The storm water ~~stormwater~~ development fee in lieu of on-site detention must be paid prior to a plat being released for recordation by the City of San Antonio or the issuance of a building permit. The fee shall be determined in accordance with the provisions of UDC S~~s~~ection 35-C109, storm water ~~stormwater~~ management fees.
~~(b)(2)~~

4.3.2 System Criteria

~~System Criteria~~. All storm water ~~stormwater~~ management facilities, or combination of facilities, shall be designed for ultimate development. Facilities with drainage areas ~~under~~ less than one hundred (100) acres shall be designed for a twenty-five (25) year storm. Facilities with drainage areas over one hundred (100) acres or areas within a FEMA designated floodplain shall be designed for a one hundred (100~~-~~) year storm or a twenty-five (25~~-~~) year storm plus freeboard (based on Table 9.3.14 ~~504-9~~) if that elevation is higher. Detention facilities and streets are exceptions to the frequency criteria cited above. Detention facility outflows will be designed for five (5) year, twenty-five (25) year and one hundred (100~~-~~) year frequency storms. Refer to subsection 6.2 ~~35-504(g)~~ for specific drainage design criteria for streets.

~~(b)(3)~~

4.3.3 Responsibility to Accept Storm Water

~~Responsibility to Accept Storm Water~~ ~~stormwater~~. The owner or developer of property to be developed shall be responsible for the conveyance of all storm water ~~stormwater~~ flowing through the property. This responsibility includes the storm water ~~stormwater~~ flowing onto the property by any other developed property as well as the drainage naturally flowing through the property by reason of topography. Future upstream development shall be accounted for by assuming ultimate development when sizing drainage systems as specified in this section. Existing detention facilities may be accounted for in the ultimate analysis and shall be incorporated in the models if included.

4.3.4 Positive Overflow Pathways

~~Positive Overflow Pathways~~. ~~(b)(4)~~ Storm water ~~stormwater~~ management facilities for local drainage systems will be designed to ensure that a positive overflow pathway is provided to the nearest one hundred (100~~-~~) year conveyance facility. The overflow pathway must be

delineated on a plan that shows all existing structures in the vicinity impacted by the overflow pathway.
~~(b)(5)~~

4.3.5 Maintenance

~~(b)(5)A.~~

Maintenance of publicly owned facilities will be the responsibility of the City. Maintenance of private facilities is the responsibility of the property owner or the community association and must be specified in the maintenance schedule submitted to the City. A maintenance schedule for both publicly owned and privately owned facilities must be approved by the Director of TCI ~~director of public works~~ prior to the approval of construction drawings.

4.3.6 Inspection

~~(b)(5)B.~~

Authorized personnel from the City of San Antonio or Bexar County within the ETJ shall conduct periodic inspections of these facilities and structures. Any required repairs will be consistent with current construction standards. Maintenance issues identified by the City, County, or State during inspections shall be the responsibility of the current owner.

4.3.7 New Development

~~(b)(5)B.~~

~~New Development.~~ Peak storm water ~~stormwater~~ runoff rates from all new development shall be less than or equal to the peak runoff rates from the site's predevelopment conditions for the five (5)~~year~~, twenty-five (25)~~year~~ and one hundred (100~~-~~) year design storm events, except as provided in section 4.3.1 ~~subsection 35-504(b)(1),~~ above.

4.3.8 Redevelopment

~~(b) (7)~~

Peak storm water ~~stormwater~~ runoff rates from an area of redevelopment due to zoning or replatting shall be less than or equal to the peak runoff rates produced by existing development conditions for the five (5)~~year~~, twenty-five (25)~~year~~ and one hundred (100~~-~~) year design storm events, except as provided in section 4.3.1 ~~subsection 35-504(b)(1),~~ above.

4.3.9 Low Impact Development

~~(b)(8)~~

The City of San Antonio ~~(COSA)~~ encourages the installation of low impact development (LID) features such as bioretention, permeable pavement with storage, engineered swales, engineered infiltration storm drain systems, ~~bioretention,~~ and engineered wetlands. For all developments proposed within the City of San Antonio ~~COSA~~ jurisdictional boundaries, these features may be considered on-site detention features to the extent that they reduce the storm water ~~stormwater~~ runoff expected downstream as a result of such developments. It shall be the developer's responsibility to demonstrate that said LID features provide such benefit. Credit toward RSWMP fees will be considered and approved on a case by case basis by the Director of TCI ~~director of public works~~.

4.4 SUBDIVISION/DEVELOPMENT

This section represents the policies of the City of San Antonio Unified Development Code as it relates to drainage and is included as a reference for the design engineer.

4.4.1 Major Plat

A Major Plat is a subdivision of property into five (5) or more lots or has infrastructure that is required to facilitate the development of the property. If there is an alteration of an existing floodplain or any drainage facility or other infrastructure is required, then the platting of property will fall under a Major Plat. A Storm Water Management Plan Report is required for the plat. Should the Storm Water Management Plan Report show no adverse impact within the reach downstream of the proposed development per section 4.3.1C and the City has reviewed and concurs with the findings; the developer may participate in the RSWMP by payment of the “Fee in Lieu of” (FILO) instead of providing detention.

4.4.2 Minor Plat

A Minor Plat is a subdivision of property into four (4) or less lots and no infrastructure is required to facilitate the development of the property. A Storm Water Management Plan Report is required for the plat. Should the Storm Water Management Plan Report show no adverse impact within the reach downstream of the proposed development per section 4.3.1C and the City has reviewed and concurs with the findings; the developer may participate in the RSWMP by payment of the “Fee in Lieu of” (FILO) instead of providing detention.

4.4.3 Replat

A replat is for property that was previously platted and the property will be reconfigured or further subdivided. A Storm Water Management Plan Report is required for the replat. If the previous plat had paid a fee to participate in the FILO and the Storm Water Management Plan Report show no adverse impact within the reach downstream of the proposed replat per section 4.3.1C and the City has reviewed and concur with the findings, the developer may continue to participate in the FILO, by paying any additional fees if required.

4.4.4 Amending Plat

An Amending Plat is for correcting an error on a previously approved or recorded plat. There should be no changes to drainage facilities or infrastructure. A letter will be required with the plat submittal that there are not changes to drainage facilities or infrastructure.

4.4.5 Master Development Plan (MDP)

The Master Development Plan is a conceptual long range development plan that provides an overall view for residential or commercial development. The MDP requires a Storm Water Management Plan Report to show what impacts the development might have on existing infrastructure and floodplains. The SWMP Report may require updating if the report is referenced during plat reviews. In addition, if the MDP SWMP Report is submitted with a plat review, a letter identifying what pages of the report are relevant to the plat area along with an exhibit identifying where the platted area is in relation to the overall MDP area will be required.

4.4.6 Planned Unit Development (PUD)

The Planned Unit Development is considered under the Master Development Plan. The streets within a PUD may be public or private. Drainage facilities shall conform to storm water management standards. A Storm Water Management Plan Report is required for the PUD.

4.4.7 Enclave

An Enclave subdivision will have private streets. The private streets are design and constructed to public street standards. Drainage facilities shall conform to storm water management standards. A Storm Water Management Plan Report is required for the Enclave subdivision.

4.4.8 Master Plan Community District (MPCD)

The Master Plan Community District is considered under the Master Development Plan. The streets within a MPCD may be public or private. Drainage facilities shall conform to storm water management standards. A Storm Water Management Plan Report is required for the MPCD.

4.4.9 Master Development Pattern Plan (MDPP)

The Master Development Pattern Plan is considered under the Master Development Plan. Drainage facilities shall conform to storm water management standards. A Storm Water Management Plan Report is required for the MDPP.

4.4.10 Inner City Reinvestment/Infill Policy (ICRIP)

A development within the ICRIP target area and fit into one of the following two categories; Residential, Mixed use Development; or Commercial/Industrial Development with drainage facilities shall conform to storm water management standards. A Storm Water Management

Plan Report is required for the development. The development may qualify for Waivers of City and SAWS fees. If the development within the ICRIP area is less than twenty thousand (20,000) square feet then the development is exempt from the FILO fee. If the development within the ICRIP area is greater than twenty thousand (20,000) square feet then the development is subject to fifty percent (50%) of the FILO fee.

4.4.11 Infill Development Zone (IDZ)

A development within the IDZ area shall comply with the storm water management standards with the following exception. The reuse of an existing building or the development of an existing parcel or lot of less than ten thousand (10,000) square feet. The development within an IDZ area is exempt from the FILO fee.

4.4.12 Redevelopment Projects

A development project that redevelops an existing site shall conform to storm water management standards. A Storm Water Management Plan Report is required for the redevelopment. If the existing site included some impervious cover prior to 1997 and the development is eligible for the FILO, then the fee would be paid on additional impervious cover. The exception to the FILO fee would be if the redevelopment is within an ICRIP or IDZ areas.

4.5 PLANNING FOR THE FLOODPLAIN

There are a number of floodplains across the county that may impact a development or the development may impact the floodplain. The engineer should consider, during the planning of the development, to minimize the impacts to the floodplain.

Where the floodplain is part of the development, and where

~~(e)(4)~~

~~Where~~ possible, multiple uses of drainage facilities and open space shall be incorporated by the owner or developer of a new subdivision. Alternative uses such as:

~~public recreation, horse/bike/hiking trails, walking paths, nature preserves, wildlife habitat areas, etc~~

- public recreation
- horse/bike/hiking trails
- walking paths
- nature preserves
- wildlife habitat areas, etc.

are encouraged subject to the approval of the Director of TCI ~~director of public works~~.

The above alternative uses should enhance the floodplain and provide a benefit to the development.

4.6 PLANNING FOR DRAINAGE SYSTEMS

There are many components that may make up the drainage system within a development. These components should work together to provide an economical solution for the conveyance of storm water to an outfall location.

Should the conveyance of the storm water require the alteration of the natural water course, the following will apply.

~~(d)(3)~~
~~Natural Watercourses or Floodplains. Easements for natural watercourses shall be the 100-year floodplain or the twenty-five year plus freeboard (see Table 504-9 of this section) whichever is less. In floodplain areas where ongoing maintenance is required or the floodplain will be reserved for use by the public, the drainage easements shall be maintained by a public entity and the property will be dedicated to the city as a multi-use drainage easement. A drivable access way shall be provided in floodplain easements for the length of the easement when regular maintenance of the floodplain is required.~~ Diversion of storm water ~~stormwater~~ away from the natural watercourse will not be allowed, except within the property boundaries ~~of the property~~ controlled by the developer~~,~~ provided that the diverted water is returned to ~~the~~ its natural flowing watercourse ~~within which it would naturally have been flowing~~ prior to leaving the developer's property. A~~n~~ timing analysis ~~of the timing~~ of the diverted hydrograph on watersheds greater than twenty (20) acres, as it reenters the receiving watercourse, must be performed to show that the peak flowrate ~~in the receiving watercourse~~ has not been increased as a result of the diversion.

~~(e)(4)~~
Where possible, multiple uses of drainage facilities and open space shall be incorporated by the owner or developer of a new subdivision. Alternative uses such as: ~~public recreation, horse/bike/hiking trails, walking paths, nature preserves, wildlife habitat areas, etc.~~

- public recreation
- horse/bike/hiking trails
- walking paths
- nature preserves
- wildlife habitat areas, etc.

are encouraged subject to the approval of the Director of TCI ~~director of public works~~.

The above alternative uses should enhance the drainage facilities and provide a benefit to the development.

4.6.1 Storm Water Management Plan Checklist

The Storm Water Management Plan Checklist is provided in Appendix A as a reference.

4.7 PLANNING FOR STORAGE

Storage of storm water may be needed for a proposed development or for the mitigation of an existing flooding problem. There are different storage solutions available to the design engineer. These may include regional storage facility, surface or underground storage facilities, or natural surface areas.

Some of the items that need to be considered during the planning process are:

- Is the development/site within a mandatory detention area?
- Is there a regional detention close to the development/site?
- What are the downstream drainage system capacities/restrictions?
- Is the storage facility private or public?
- Who will maintain the facility? (property owner, homeowners association, or public agency)
- What permits are required?

The following should be considered during the planning process for surface storage facilities.

~~(e)(4)~~
Where possible, multiple uses of drainage facilities and open space shall be incorporated by the owner or developer of a new subdivision. Alternative uses such as public recreation, horse/bike/hiking trails, walking paths, nature preserves, wildlife habitat areas, etc. are encouraged subject to the approval of the Director of TCI ~~director of public works~~.

~~(f)(8)~~
~~Location of Detention Facilities and Surrounding Development.~~ Storm water ~~stormwater~~ detention facilities shall be located in topographically depressed areas where possible. When necessary, dams may be constructed to detain flows. ~~All proposed dams shall conform to the following items:~~

For developments that require a subdivision plat and a storage facility is required/needed, the following deferral may be considered with the approval of Director of TCI. The deferral is for the final design and construction of the storage facility to be completed before any additional development occurs on the property.
~~(f)(4)B.~~
Full detention basin design may be deferred until the building permit stage IF the property owner submits a "request for detention deferral" demonstrating an understanding of the implications of such design deferral AND the following notes are placed on the subdivision plat AND supporting documentation is provided.

1. " Storm water ~~stormwater~~ detention is required for this property. The engineer of record for this subdivision plat has estimated that an area of approximately _____ acres and a volume of approximately _____ acre feet will be required for this use. This is an estimate only and detailed analysis may reveal different requirements."
2. "No building permit shall be issued for this platted property until a storm water ~~stormwater~~ detention system design has been approved by the City of San Antonio or Bexar County for commercial properties within the ETJ."

4.8 PLANNING FOR TRANSPORTATION

The streets and highways within the San Antonio area provide the connections for private and public transportation. The streets are used for different modes of transportation, but are also used for the collection and conveyance of storm water. Arterial streets shall remain passable during a storm event as described in Chapter 6.2.1.1. All culvert and bridge crossings shall be "all weather crossings" to allow safe passage of all modes of transportation during a storm event as described in Chapters 10.1 and 11.1 respectively.

4.9 PLANNING FOR OPEN SPACE

A viable system of natural open space that serves to protect and conserve cultural resources, riparian areas, significant natural features, and preserve floodplains will help reduce erosion, provide recharge, improve water quality, and help reduce impacts of development.

These open space areas shall be covered by some form of easement and deed restrictions for allowed uses. These uses shall be compatible with the open space and may provide some low-impact forms of recreation such as walking, bicycling and nature watching are encouraged.

Should a drainage facility traverse or be adjacent to an open space, every effort should be made to make sure that the facility is compatible with the open space.

4.10 PLANNING FOR LID

Low Impact Development is a land development approach which manages storm water runoff close to its source. It can be a cost effective tool for managing storm water while meeting multiple goals and enhancing the site. Technical guidance for the overall site and specific BMP design is found in the San Antonio River Basin Low Impact Development Technical Design Guidance Manual.

4.11 PLANNING FOR DAMS

Dams are used for the capture of storm water, which may contain an outlet structure.

The storm water impounded by a dam may impact upstream or adjacent property owners. A drainage easement as described in Chapter 15.5, shall be required to cover the storm water impoundment area.

An overflow structure should be considered for storms greater than the design storm and to eliminate the overtopping of the dam.

Upstream of an existing or proposed dam, the elevations of structures should be placed such that the finished floor is at a minimum of one foot above the top elevation of the dam and above the backwater elevation.

Downstream of an existing or proposed dam, placement of structures immediately downstream should be avoided and elevation of structures should be placed such that the finished floor is at a minimum of one foot above the backwater or breach water surface elevation.

If a dam is proposed, impacts to development and infrastructure, both upstream and downstream shall be evaluated.

4.12 MAINTENANCE STANDARDS

~~**Maintenance.**~~

The following section is intended to provide guidance on general maintenance responsibilities and designation for Public and Private Drainage Easements. It is not meant to address rights or responsibilities associated with emergency situations.

An easement is a grant of one or more property rights by a property owner to another person or entity. Private drainage easements are typically necessary when storm water is to be conveyed across private property from a separate private property up to a contributing drainage area of 100 acres. Public drainage easements are typically necessary when the off-site contributing drainage area exceeds 100 acres or if the contributing area is a FEMA designated floodplain. Additionally, public drainage easements are typically necessary when storm water is to be conveyed across private property from public property, public rights-of-way and easements, or public infrastructure to an established channel, creek, or other public drainage system.

Drainage easements are a form of utility easement and per the Unified Development Code are required to be labeled or designated “public” or “private”. Maintenance is action taken to restore or preserve the design functionality of any facility or system. The granting and acceptance of an easement does not confer ownership but rather confers the right to use a landowner’s property in some specific way. Per the Unified Development Code, the City of San Antonio assumes no responsibility for the maintenance, installation or improvement of pipes or storm water systems within an enclave or planned unit development. There is also a

general duty under state law for property owners to keep their property free from nuisance and in a reasonably safe condition.

Drainage easements allow the City of San Antonio to perform certain maintenance and make repairs to drainage structures, at its option and as necessary, so that the overall safety and health of the city related to drainage can be maintained. The property owner retains ownership of the property and, similar to other utility easements on private property, also retains responsibility for normal care and maintenance.

For example, the City of San Antonio will remove a blockage in a channel within a public drainage easement, but will not remove a standing tree on a channel bank outside of the conveyance area. Additionally, the City of San Antonio may not remove a blockage in the conveyance area until that blockage has the potential to significantly affect water flow. Other examples of normal care and routine maintenance for owners includes, but is not limited to, litter collection, nuisance mowing, or other items that do not impede drainage. Examples of typical storm water conveyance maintenance undertaken by the City of San Antonio are managing significant overgrowth of vegetation (greater than 24-inches to 36-inches depending on grass species type), debris removal, channel restoration, and removal of downed trees in the conveyance area.

A. Maintenance of publicly owned facilities will be the responsibility of the city. Maintenance of private facilities is the responsibility of the property owner or the community association and must be specified in the maintenance schedule submitted to the city. A maintenance schedule for both publicly owned and privately owned facilities must be approved by the Director of TCI ~~public works~~ prior to the approval of construction drawings.
B. Authorized personnel from the City of San Antonio shall conduct periodic inspections of these facilities and structures. Any required repairs will be consistent with current construction standards. Maintenance issues identified by the city or state during inspections shall be the responsibility of the current owner.
C. ~~**(4) Maintenance Access Right-of-Way.**~~ An unobstructed access right-of-way connecting the drainage easement with an alley or roadway, parallel to or near the easement, shall be provided at a minimum spacing of one (1) access right-of-way at approximately one thousand (1,000) ~~-~~foot intervals. The access right-of-way shall be a minimum of fifteen (15) feet in width and shall be ~~maintained~~ kept clear of obstructions that would limit maintenance vehicular access. ~~If the flow line of the designed channel incorporates grade control structures or vehicular bridges that would prevent maintenance equipment from accessing that portion of the channel, additional access points may be required.~~ Additional access points may be required if the flow line of the designed channel incorporates grade control structures of vehicular bridges that may block channel access to maintenance equipment. Channel design, earthen or concrete, shall have ramps

in the side slopes near the access points that ~~would~~ allow maintenance equipment to descend to the floor level of the channel. The maximum allowable ramp slope for vehicular access is seven to ~~1~~ one (7:1). Access points adjacent to roadways or alleys shall be provided with a post and cable feature with padlock to prevent unauthorized use.

D. ~~**Maintenance**~~. Design of new channels or alterations to existing channels shall consider future maintenance requirements. A maintenance schedule for any private channel shall be submitted to and approved by the Director of ~~public works~~ TCI prior to approval of construction plans. Maintenance requirements of concrete channels consist of de-silting activities, prevention of vegetation establishment in construction joints, and repair of concrete as necessary. Maintenance of earthen channels includes regular observation and repair, as necessary, of erosion, scouring, and removal of silt deposits, as necessary to maintain design parameters. Developers shall be responsible for maintaining newly planted channels until coverage is established throughout eighty-five ~~(85)~~ percent (85%) of the area. This area shall include slopes, floor, and any attendant maintenance easement. New earthen channels shall be planted with drought resistant, low growth, native species grasses, which will allow unobstructed passage of floodwaters. Johnson grass, giant ragweed ~~tagweed~~ and other invasive species shall not be allowed to promulgate in channels. Suggested species shall include, but are not ~~be~~ limited to, common bermuda, coastal bermuda, buffalo grass, sideoats grama, seep muhly, little bluestem, and indian grass. Mowing frequencies vary with the vegetation growth rates, but is required when the grass exceeds the design roughness coefficient of the channel.

4.13 REFERENCES

- City of San Antonio Development Services. *Interactive Development Process Manual*. City of San Antonio, San Antonio, Texas. Retrieved from http://www.sanantonio.gov/dsd/pdf/DPM/0_Coversheet_Intro.pdf
- City of San Antonio Department of Public Works. *Fee In-Lieu-Of (FILO) Program*. City of San Antonio, San Antonio, Texas, April 2013. Retrieved from http://www.sanantonio.gov/dsd/pdf/FILO_Final.pdf

CHAPTER 5
HYDROLOGY

5.1 INTRODUCTION

Hydrology is the study of water, its source, distribution, quantity, quality, and movement. For the purpose of this Storm Water Design Criteria Manual (SWDCM), the hydrology guidance will be limited to surface hydrology; the portion of the hydrologic cycle that deals specifically with precipitation, infiltration, and surface runoff.

This chapter describes the specific precipitation data which has been defined by federal and state agencies and regionalized to Bexar County. This chapter will also address infiltration and surface runoff by providing guidance on Methods of Analysis (Chapter 5.3) that range from small local analysis (i.e. Rational Method) to the hydrograph methods as well as guidance on probable maximum precipitation, with equation parameters specific for this region. The selection of these methods will be determined by drainage area size and purpose of the study. The proper application of these methods will generate discharge values that may be used for planning, design, mitigation, or regulation. Other methods of proven engineering use may be used with approval from the Director of TCI or his authorized representative.

5.2 METHOD OF ANALYSIS

5.2.1 Basin Delineation

A watershed or drainage basin is an area that drains storm water runoff to a designated point. Drainage basins are defined by its geographical terrain. The basin delineation is one of the most important parameters in the hydrologic model. When defining the basin boundary the design engineer should use the most recent topography data. In San Antonio and its ETJ, this may include:

- High accuracy LiDAR based contours, as generated by public or private agencies
- On-the-ground topographic survey data
- Historical topography maps, including USGS Quad. maps for pre-developed conditions
- Roadway construction plans
- Aerial Photos
- Underground infrastructure plans

The design engineer should follow standard engineering practice when delineating basin boundaries.

All basin delineation should consider previously defined drainage basins as found by the regions DFIRM data sets, Master Development Plans, or previous approved drainage studies. While the DFIRM data set was defined for the regions FEMA re-study, errors that may be

found should be corrected. These basins can be accessed on-line at the San Antonio River Authority's Digital Data & Modeling Repository website (D2MR, website link may change, please refer to SARA staff for access to system).

Basin delineations defined by computer software should be reviewed carefully. Software including ~~such as,~~ AutoCAD, Microstation, ESRI – GIS, and others have the capability to define basins. These basins are created by source data such as a Digital Elevation Model (DEM), a Triangular Irregular Network (TIN) or Raster grid files. The data set should be detailed enough to define the basin; it may require the use of break lines or fault lines to create certain features. Generally when DEM or Raster is used to generate basin delineation the resulting basin will create jagged or zigzagged basin boundary. The design engineer should verify that this resulting basin has the correct level of accuracy for the individual study.

5.2.2 Selection of Rational or Hydrograph Method

For drainage areas less than ~~six hundred forty (640)~~ ~~one~~ 200 hundred (~~100~~200) acres, the basis for computing runoff shall be the rational formula (as defined in Section 5.3) or some other method provided it is acceptable to the Director of TCI.

For drainage areas ~~six hundred forty (640)~~ ~~one~~ 200 hundred (~~100~~200) acres or greater, the basis for computing runoff shall be a unit hydrograph method (as defined in Section 5.6), preferably the Soil Conservation Service (SCS) Dimensionless Unit Hydrograph method as contained in the U.S. Army Corps of Engineers Hydrologic Engineering Center HEC-HMS "Hydrologic Modeling Systems". ~~For the SCS method, antecedent moisture condition II shall be used in the runoff model. Design rainfall values listed in Table 5.2.2.1 shall be used for hydrograph calculations.~~

~~Certain watersheds have hydrologic and hydraulic models that are available through and maintained by the City of San Antonio and local partners. Developments proposed within the limits of these watersheds must have the models updated by the Design Engineer to reflect changes in flow, channel configuration (including alterations to vegetation), and channel structures. The Design Engineer's models must use the same computer program that was used in the existing model (e.g. HEC-RAS models will not be accepted where the original model used HEC-2). The updated models shall be submitted to the Director of TCI or his designee for incorporation into the master models. The City of San Antonio will periodically update the master models to reflect current watershed development conditions. The updated models will be made available for use and distribution as the latest existing condition models for the watershed~~.

5.2.3 Selection of Method for Detention Ponds

For detention ponds with drainage areas of twenty (20) acres or less, the basis for computing runoff shall be the modified rational method. When the drainage area of a detention pond is greater than twenty (20) acres the unit hydrograph method shall be used.

5.3 RATIONAL METHOD

The Rational Method is appropriate for estimating peak discharge for small areas up to (~~100~~ 200) acres with no significant flood storage. This method provides a peak discharge value but no time-series of flow or flow volume

(Equation 5.3.1)

$$Q = C\ I\ A$$

Q = Peak Discharge (cfs)
C = Runoff coefficient
I = Average rainfall intensity (in./hr.)
A = Drainage area (acres)

Runoff coefficients (C) may need to be calculated as a weighted runoff coefficient where multiple values are present in one drainage area.

To determine the intensity (I) it is necessary to calculate the Time of Concentration (Tc). This value is used to identify the rainfall intensity found in Figure 5.5.1A of this manual.

5.4 TIME OF CONCENTRATION

~~Overland (sheet) flow, shallow concentrated flow and channel flows are components that need to be considered in the calculation of time of concentration.~~ The following methods are recommended for time of concentration calculation:

(Equation 5.4)

$$T_c = T_t + T_{sc} + T_{ch}$$

T_c = Time of Concentration
T_t = Sheet flow over plane surface
T_{sc} = Shallow Concentrated Flow
T_{ch} = Open Channel Flow

5.4.1 Overland Flow

Flow over plane surfaces: Maximum allowable time is twenty (20) minutes. Minimum is five (5) minutes.

- The overland flow time chart from "Design" by Elwyn E. Seelye may be used to calculate overland flow times. Note that the minimum time has been reduced to five (5) minutes.

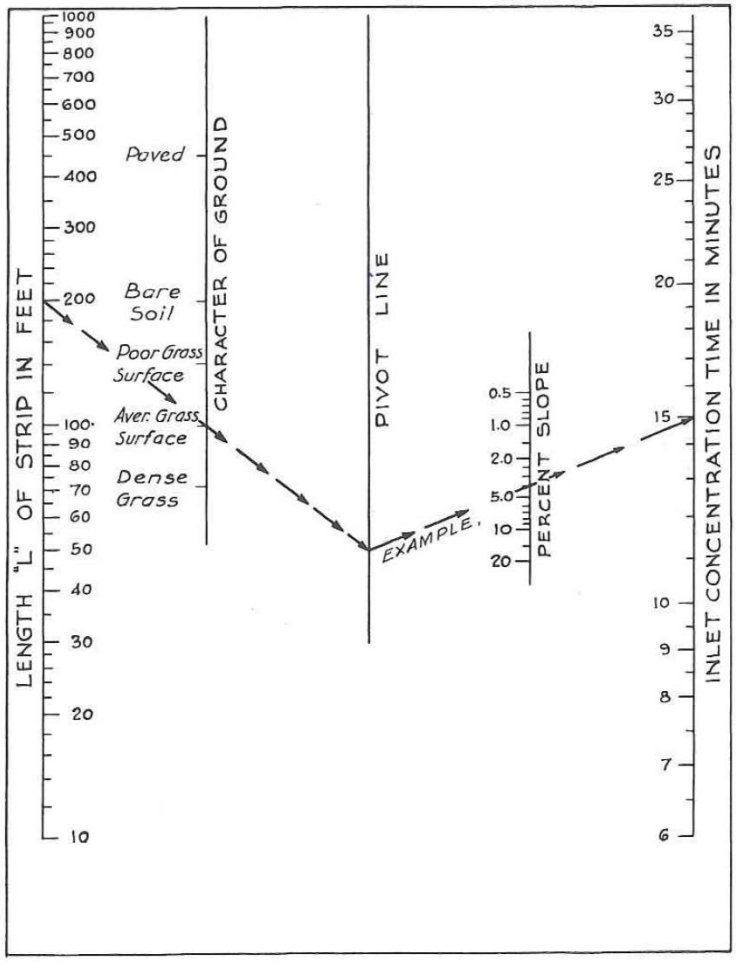


Figure 5.4.1 – Overland Flow Time *(Source: "DESIGN" by Elwyn Seelys Figure. H)*

- TR-55 "Urban Hydrology for Small Watersheds," SCS 1986 may be used, please consider the maximum (20 min.) and minimum (5 min.) when defining the flow length (L).

(Equation 5.4.1)

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} s^{0.4}}$$

T_t = travel time (hr.)
n = Manning's roughness coefficient
L = flow length (ft.)
P_2 = 2-year, 24-hour rainfall*
s = slope of hydraulic grade line (land slope, ft/ft)
*in San Antonio and its ETJ please use 4.44 inches for the two (2) -year, twenty-four (24)-hour rainfall value

Table 5.4.1 - Roughness Values for sheet flow

Roughness Coefficient (Manning's n) for sheet flow	
Surface Description	n[1]
Smooth surface (concrete, asphalt, gravel or baresoil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods[3]:	
Light underbrush	0.40
Dense underbrush	0.80

1. The n values are composite of information compiled by Engman (1968)
2. Included species such as weeping lovegrass, bluegrass, bufallo grass, blue gamma grass, and native grass mixtures
3. When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

5.4.2 Shallow Concentrated Flow

Overland flow usually becomes shallow concentrated flow after a maximum of three hundred (300) feet: Use Manning's equation to estimate travel time for defined swales, bar ditches, ~~and~~ street sections, etc. ~~Figure 3-1~~ or Figure 5.4.2 from TR-55 "Urban Hydrology for Small Watersheds," SCS 1986, may be used where a geometric section has not been defined.

(Equation: 5.4.2)

$$\mathbf{T}_{sc} = \frac{L_{sc}}{3600\ K\ S_{sc}^{0.5}}$$

$\mathbf{T}_{sc}$ = shallow concentrated flow time (hr.)
$\mathbf{L}_{sc}$ = shallow concentrated flow length (ft.)
K = 16.13 for unpaved surface; 20.32 for paved surface
$\mathbf{S}_{sc}$ = shallow concentrated flow slope (ft./ft.)

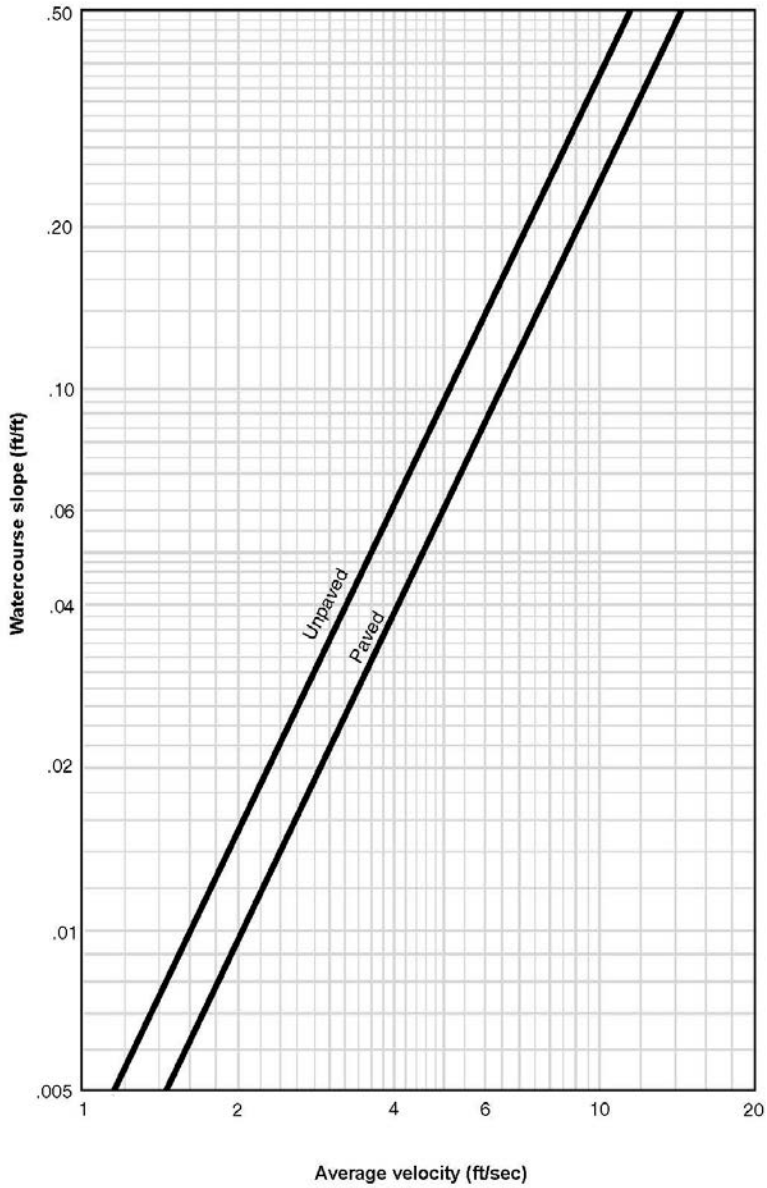


Figure 5.4.2 - Average Velocities for Estimating Travel Time for Shallow Concentrated Flow (Source: NRCS Technical Release 55 – Figure 3-1)

5.4.3 Channel Flow

Use existing computer models where available or Manning's equation if the data is not available. When estimating the time of concentration, non-floodplain ~~Non-floodplain~~ channel velocities for ultimate watershed development should not be less than six (6) fps~~ when estimating time of concentration~~.

(Equation 5.4.3)

$$\mathbf{T}_{ch} = \frac{L_{ch}}{3600\ 1.49/n\ R^{2/3}\ S_{ch}^{1/2}}$$

$\mathbf{T}_{ch}$ = channel flow time (hr.)
$\mathbf{L}_{ch}$ = channel flow length (ft.)
$\mathbf{S}_{ch}$ = channel flow slope (ft. /ft.)
n = Manning's roughness coefficient
R = channel hydraulic radius (ft.) and is equal to a/P_w
a = cross sectional area ($ft.^2$)
$\mathbf{P}_w$ = wetted perimeter (ft.)

5.5 RAINFALL DATA

5.5.1 Rainfall Intensity-Duration

Use Table 5.5.1A to determine rainfall intensity.

Table 5.5.1.A – Rainfall Intensity Duration

TIME MINUTES	FREQUENCY						
	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR
5	7.200	8.400	9.413	11.100	12.432	13.542	18.204
6	6.684	7.836	8.830	10.331	11.648	12.877	17.258
7	6.277	7.381	8.365	9.722	11.025	12.341	16.497
8	5.944	7.009	7.982	9.224	10.512	11.894	15.864
9	5.666	6.696	7.658	8.806	10.079	11.514	15.327
10	5.427	6.427	7.380	8.447	9.707	11.184	14.862
11	5.220	6.194	7.137	8.136	9.382	10.893	14.453
12	5.038	5.988	6.923	7.862	9.095	10.635	14.090
13	4.877	5.805	6.731	7.618	8.839	10.403	13.763
14	4.731	5.641	6.558	7.399	8.608	10.192	13.468
15	4.600	5.480	6.400	7.200	8.400	10.000	13.200
16	4.458	5.296	6.159	6.959	8.088	9.551	12.765
17	4.328	5.129	5.942	6.741	7.806	9.147	12.368
18	4.209	4.977	5.743	6.541	7.549	8.781	12.005
19	4.099	4.836	5.562	6.357	7.314	8.449	11.672
20	3.998	4.707	5.395	6.188	7.098	8.146	11.364
21	3.904	4.587	5.241	6.031	6.898	7.867	11.079
22	3.816	4.476	5.098	5.886	6.713	7.610	10.814
23	3.734	4.372	4.965	5.749	6.541	7.373	10.566
24	3.658	4.275	4.841	5.622	6.380	7.153	10.335
25	3.586	4.184	4.725	5.503	6.229	6.947	10.117
26	3.518	4.098	4.616	5.390	6.088	6.756	9.913
27	3.453	4.017	4.514	5.284	5.955	6.576	9.720
28	3.393	3.941	4.417	5.184	5.830	6.408	9.538
29	3.335	3.868	4.326	5.089	5.711	6.250	9.365
30	3.280	3.800	4.240	5.000	5.600	6.100	9.200
31	3.209	3.723	4.155	4.905	5.501	6.003	9.025
32	3.142	3.650	4.074	4.814	5.407	5.911	8.870
33	3.078	3.580	3.997	4.727	5.318	5.823	8.722
34	3.018	3.514	3.924	4.644	5.233	5.739	8.581
35	2.960	3.450	3.854	4.565	5.152	5.658	8.446
36	2.906	3.390	3.787	4.490	5.074	5.581	8.317
37	2.853	3.332	3.723	4.418	4.999	5.507	8.194
38	2.803	3.277	3.662	4.349	4.928	5.435	8.075
39	2.755	3.224	3.604	4.283	4.859	5.367	7.961
40	2.709	3.173	3.548	4.219	4.793	5.301	7.852
41	2.665	3.124	3.494	4.158	4.729	5.238	7.747
42	2.623	3.077	3.442	4.099	4.668	5.176	7.646
43	2.582	3.032	3.392	4.043	4.609	5.117	7.548
44	2.543	2.989	3.345	3.988	4.552	5.060	7.454
45	2.505	2.947	3.298	3.936	4.497	5.005	7.363
46	2.469	2.907	3.254	3.885	4.444	4.952	7.275
47	2.434	2.868	3.211	3.836	4.393	4.900	7.190
48	2.400	2.830	3.169	3.788	4.343	4.850	7.108
49	2.368	2.794	3.129	3.743	4.295	4.802	7.028
50	2.336	2.759	3.090	3.698	4.248	4.754	6.951
51	2.306	2.724	3.052	3.655	4.203	4.709	6.876
52	2.276	2.691	3.016	3.613	4.159	4.664	6.804
53	2.247	2.659	2.980	3.573	4.117	4.621	6.733
54	2.220	2.628	2.946	3.534	4.075	4.579	6.665
55	2.193	2.598	2.913	3.496	4.035	4.538	6.598
56	2.167	2.569	2.880	3.459	3.996	4.499	6.534
57	2.141	2.541	2.849	3.423	3.958	4.460	6.471
58	2.117	2.513	2.819	3.388	3.921	4.422	6.410
59	2.093	2.486	2.789	3.354	3.885	4.386	6.350
60	2.070	2.460	2.760	3.320	3.850	4.350	6.300
120	1.285	1.555	1.775	2.175	2.550	2.900	4.050
180	0.933	1.140	1.317	1.633	1.900	2.200	3.133
360	0.552	0.668	0.767	0.950	1.083	1.250	1.767
720	0.315	0.383	0.450	0.533	0.625	0.733	1.033
1440	0.185	0.223	0.250	0.313	0.375	0.417	0.571

5.5.2 Rainfall Depth-Duration-Frequency

5.5.2.1 Design Rainfall

For the Design Rainfall, a twenty-four (24) hour rainfall distribution shall be applied for hydrograph based runoff calculations. Rainfall intensities as adopted for the City of San Antonio are given in Table 5.5.2.1.

Table 5.5.2.1 - Design Rainfall Values (inches)

USGS Adjusted Rainfall Values (pre-areal reduction)								
Frequency of Storm	**1-year**	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**	**500-year**
Exceedance probability	1	0.5	0.2	0.1	0.04	0.02	0.01	0.002
Storm Duration								
Duration	**Frequency**							
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	500-year
5 minute	0.54	0.61	~~0.68~~ 0.70	0.78	0.93	1.04	1.13	1.52
15 minute	1.00	1.15	~~1.40~~ 1.37	1.60	1.80	2.10	2.50	3.30
30 minute	1.46	1.64	1.90	2.12	2.50	2.80	3.05	4.60
1 hour	1.81	2.07	~~1.85~~ 2.46	2.76	3.32	3.85	4.35	~~5.80~~ 6.30
2 hour	2.22	2.57	~~2.37~~ 3.11	3.55	4.35	5.10	5.80	8.10
3 hour	2.41	2.80	~~3.26~~ 3.42	3.95	4.90	5.70	6.60	9.40
6 hour	2.86	3.31	~~3.80~~ 4.01	4.60	5.70	6.50	7.50	10.60
12 hour	3.26	3.78	~~4.40~~ 4.60	5.40	6.40	7.50	8.80	12.40
24 hour	3.85	4.44	~~5.00~~ 5.36	6.00	7.50	9.00	10.00	13.70

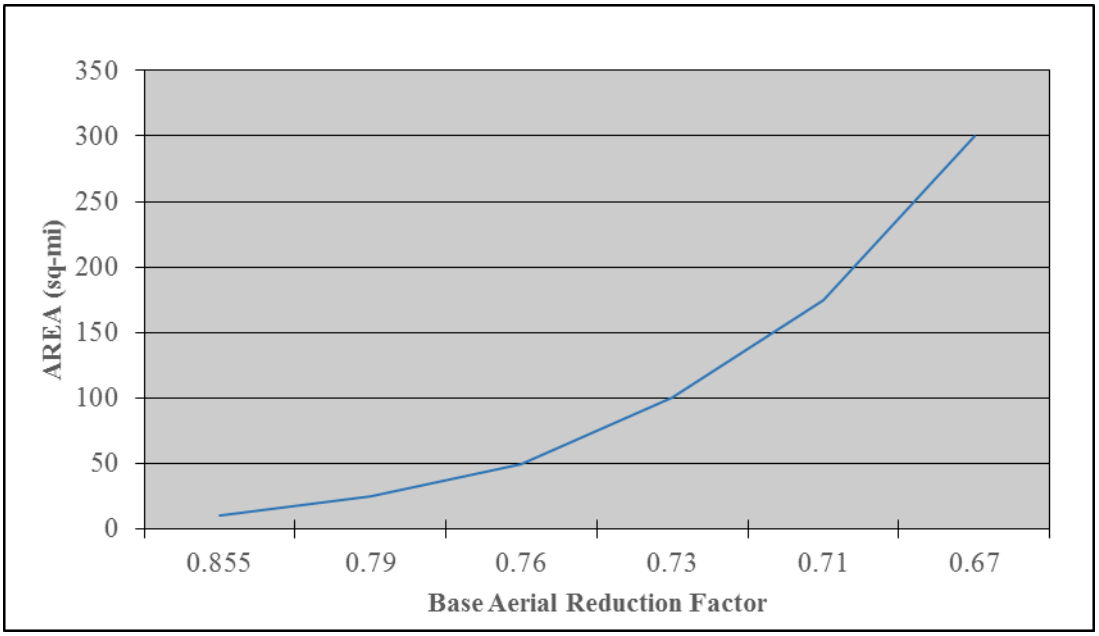
5.5.2.2 Areal Reduction Factor

Calculated storm water runoff at a given point may be reduced by ~~the~~ factors shown in Table 5.5.2.2 based ~~upon~~ on the tributary area (in square miles) draining to said point.

Table 5.2.2.2 - Areal Reduction Factors

Areal Reduction Factors** (for use in calculating Point Rainfall for Bexar County)	
Area (sq mi)	Base ARF for Area
10	0.855

25	0.79
50	0.76
100	0.73
175	0.71
300	0.67
***Source: 2007 Watershed Hydrology Technical Support Data Notebooks on file with San Antonio River Authority*	



5.5.3 Runoff Coefficient

Runoff coefficients (C value) for use in the rational formula shall not be less than the values shown in Table 5.5.3A, as appropriate

Table 5.5.3A - Runoff Coefficient (C value) - percentage

Character of Area	SLOPE			
	Up to 1%	Over 1% up to 3%	Over 3% up to 5%	~~Flow~~ over 5%
Business or commercial areas (90% or more impervious), Existing Pavement / Buildings or Zoning Districts O, C, I-1, I-2	95	96	97	97
Densely developed areas (80% to 90% impervious) or Zoning Districts D, MX, NC, TOD, Use Pattern TND	85	88	91	95
Closely built residential areas and school sites or Zoning Districts MF, R-4	75	77	80	84
Undeveloped areas * - Present land is undeveloped and ultimate land use is unknown. C values for use in ultimate development calculations.	68	70	72	75

Large lot residential area or Zoning Districts R20, RE	55	57	62	64
Undeveloped areas * - Existing conditions. ~~See Table 504-1(b)~~				
Average residential area or Zoning Districts R-5, R-6	65	67	69	72
Cultivated or Range (Grass Cover < 50% of Area)	44	47	53	55
Range (Grass Cover 50—75% of Area)	37	41	49	53
Forest or Range (Grass Cover > 75% of Area)	35	39	47	52

**Areas included within parks, green belts, or regulatory floodplains shall be considered to remain undeveloped per this table*

5.6 HYDROGRAPH METHOD

5.6.1 Sub-Basin

5.6.1.1 Loss Method

5.6.1.1.1 SCS Curve Number Loss

The SCS curve numbers adopted for use by the City of San Antonio are shown in Table 5.6.1.1.1.1 ~~504-3~~. The hydrologic soil groups are listed in the latest version of the United States Natural Resources Conservation Service [formerly the Soil Conservation Service], "Urban Hydrology for Small Watersheds," Technical Release No. 55 (TR 55)~~,~~; ~~which~~ this document is hereby incorporated by this reference. Soil types that relate to the hydrologic soil group may be found in the latest version of the United States Natural Resources Conservation Service "Soil Survey-Bexar County, Texas;" ~~which~~ this document is hereby incorporated by this reference. Soil types may also be based on a Geotechnical Engineering Report.

Table 5.6.1.1.1.1 - SCS Curve Number by Soil Type

~~Hydrologic Soil Group~~	~~Description~~	~~SCS Curve Number~~
~~A~~	~~Soils having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well drained sand and gravels.~~	~~25~~
~~B~~	~~Soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.~~	~~55~~
~~C~~	~~Soils having moderately high runoff potential due to slow infiltration rates. These soils consist primarily of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.~~	~~70~~

~~D~~	~~Soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high water tables, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.~~	~~77~~

Cover Description	Hydrologic Condition	Curve Number (CN) for Hydrologic Soil Group			
		A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.)	Good	39	61	74	80
Meadow (continuous grass, protected from grazing and generally mowed for hay)		30	58	71	78
Brush (brush-weed-grass mixture with brush the major element)	Good	30	48	65	73
Woods	Good	30	55	70	77

Table 5.6.1.1.1.2 - Percent Impervious Cover by Land Use

Land Use Category		Average Percent Impervious Cover
Residential	1/8 acre Residential Lots, or Garden or townhouse apartments, or Zoning Districts R-4, R-5, RM-4, RM-5; TND/TOD Use Patterns	65—85
	¼ acre Residential Lots or Zoning District R-6, RM-6	38
	1/3 acre Residential Lots or Zoning District R-15	30
	½ acre Residential Lots or Zoning Districts R-20	25
	1 acre Residential Lots or Zoning Districts RP, RE	20
Industrial or Zoning Districts L, I-1, I-2		72—85
Business or Commercial, or Zoning Districts NC, O, C		85—95
Densely developed (apartments), or Zoning Districts MF		65—85
Streets, Roads, and Parking Areas		98

5.6.1.2 Transform Method

5.6.1.2.1 SCS Unit Hydrograph

A method developed by the Natural Resource Conservation Service (formally known as the Soil Conservation Service) for constructing unit hydrographs. This method is based on empirical data from small agriculture watersheds across the United States. For the SCS method, antecedent moisture condition II shall be used in the runoff model. Design rainfall values listed in Table 5.5.2.1 shall be used for hydrograph calculations. The method requires the determination of the SCS lag time and time to peak, the peak discharge is calculated by the following equation:

(Equation 5.6.1.2a)

$$\mathbf{Q}_p = \frac{484\ A}{t_p}$$

$\mathbf{Q}_p$ = peak discharge (cfs.)
A = drainage area (mi.^{2})
$\mathbf{t_p}$ = time to peak (hr.)

(Equation 5.6.1.2b)

$\mathbf{t_p}$ = time to peak (hr.)
$\Delta\mathbf{t}$ = the duration of rainfall (hr.) = 0.133 $\mathbf{t_c}$
$\mathbf{t_{lag}}$ = lag time from the centroid of rainfall to peak discharge, estimated at 0.6 $\mathbf{t_c}$ (hr.)

Table 5.6.1.2.1 – SCS Dimensionless Unit Coordinates

Coordinates of SCS Dimensionless unit hydrograph			
t/t_p	Q/Q_p	t/t_p	Q/Q_p
0	0	1.4	0.750
0.1	0.015	1.5	0.660
0.2	0.075	1.6	0.560
0.3	0.160	1.8	0.420
0.4	0.280	2.0	0.320
0.5	0.430	2.2	0.240

$$\mathbf{t}_p = \frac{\Delta\mathbf{t}}{2} + \mathbf{t}_{lag}$$

0.6	0.600	2.4	0.180
0.7	0.770	2.6	0.130
0.8	0.890	2.8	0.098
0.9	0.970	3.0	0.075
1.0	1.000	3.5	0.036
1.1	0.980	4.0	0.018
1.2	0.920	4.5	0.009
1.3	0.840	5.0	0.004

5.6.1.2.2 Snyder Unit Hydrograph

The Synder Unit Hydrograph is a method developed from analysis of ungauged watersheds in the Appalachian Highlands in the United States. Required parameters are the standard lag (hr.) and the peaking coefficient. ~~The San Antonio River Basin – Regional Modeling Standards for Hydrology and Hydraulics modeling states the following equation:~~

(Equation 5.6.1.2.2a)

$$\mathbf{Q}_p = \frac{640\ C_p\ A}{t_{lag}}$$

Q_p = Snyder peak discharge (cfs.)
C_p = peaking coefficient; range from 0.5 – 0.9
A = Drainage Area (mi.^{2})
t_{lag} = Snyder lag time (hr.)

(Equation 5.6.1.2.2b)

$$T_{lag} = C_t \left(\frac{LL_{ca}}{\sqrt{S}}\right)^{0.33}$$

T_{lag} = Snyder lag time (hr.)
C_t = basin coefficient based on the level of development in the watershed
L = length of the main stream from the outlet to the watershed divide
L_{ca} = length of the centroid along the flow path
S = Slope of the longest path (L)

(Equation 5.6.1.2.2c)

$$C_t = 1.4224e^{-0.0088x}$$

x = the percentage of development

Note:Typically C_t range for this area is 1.1 to 1.4.

5.6.1.2.3 Clark Unit Hydrograph

The Clark Unit Hydrograph is derived by two major parameters; the translation or movement of runoff and the attenuation or reduction of runoff as it moves through the watershed. These two parameters are defined at its basis with the following equation:

(Equation: 5.6.1.2.3)

$$\frac{dS}{dt} = I_t - O_t$$

$\frac{dS}{dt}$ = time rate of change in storage at time ($_t$)
$\mathbf{I_t}$ = average inflow at time ($_t$)
$\mathbf{O_t}$ = outflow from storage at time ($_t$)

To use this method in HEC-HMS the parameters of translation and attenuation are defined by the watersheds time of concentration (t_c) and Basin Storage coefficient (R).

- **The Translation** is derived by the time of concentration (t_c), and is defined by Equation 5.4 in this manual, the TR-55 method of calculation. The t_c is provided as a unit of time in hours (hr.)
- **The Attenuation** is the Basin Storage coefficient (R), a measure of the storage within the individual watershed. The larger the R value, the larger the attenuation. This value can be defined by calibration. R is given as a unit of time (hrs.)

5.6.1.3 Baseflow Method

5.6.1.3.1 None

For a majority of the perennial streams in San Antonio and its ETJ, the hydrology models will not account for any base flow condition. It is recommended that the design engineer visit the study stream to observe average conditions.

5.6.1.3.2 Constant Monthly Baseflow

As defined in the HEC-HMS technical Manual of March 2000 "[the base flow parameter is] best estimated empirically, with measurements of channel flow when storm runoff is not

occurring. In the absence of such records, field observation may help establish the average flow…for most urban channels and for smaller streams in the western and southwestern US, the baseflow contribution may be negligible."

5.6.2 Reach – Routing

Routing of the runoff hydrograph through the channel from one (1) subarea calculation point to the next in the HEC-HMS shall be computed using one (1) of the ~~following~~ methods listed below.

Channel routing methodologies that are currently being applied in the existing HEC-HMS model of the watershed shall not be replaced with a different methodology without approval or direction from the Director of TCI.

For use in routing methods, Manning's roughness coefficients ("N" values) ~~for use in routing methods~~ shall be consistent with the values listed in Table 9.2.4.1

(Equation: 5.6.2)

$$I - O = \frac{dS}{dt}$$

$\frac{dS}{dt}$ = time rate of change in storage at time t
I = average inflow
O = outflow from storage

5.6.2.1 Muskingum

If ~~O~~overbank/channel storage not significant~~: Use~~, use Muskingum/normal depth channel routing.

5.6.2.2 Muskingum-Cunge 8 Point Cross Section

If ~~O~~overbank/channel storage is not significant~~:~~ and a hydraulic model is not available, use the Muskingum-Cunge eight (8) point cross section Method. ~~where a hydraulic model is not available~~

5.6.2.3 Modified Puls

Use the Modified Puls Storage Method where a hydraulic model is available to develop storage/out flow relationship.

5.6.2.4 Kinematic Wave

The Kinematic Wave Method for channel reaches where inflow from overbank runoff or multiple point sources (Example: storm drain outfalls) is significant and where hydrograph attenuation is insignificant.

5.7 PROBABLE MAXIMUM FLOOD

For information on calculating the Probable Maximum Flood (PMF), please refer to the National Oceanic and Atmospheric Administration (NOAA) Hydro-meteorological Report (HMR) 51 & 52 and the various USGS report for the probable maximum flood peak discharges in Texas. When defining the PMF please contact the City of San Antonio TCI staff and also refer to the Texas Commission on Environmental Quality (TCEQ) Dam Safety program for additional guidance.

5.8 REFERENCES

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- Snyder, Franklin F., 1938, *Synthetic unit-graphs*: Am Geophys. Union Trans., Pt. I, p. 447-454.
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- Seelye, Elwyn E. (1960) *Data Book for Civil Engineers: Design Vol. 1* (3rd ed.). New York, NY: John Wiley and Sons, Inc.
- San Antonio River Authority. (September 2013) *San Antonio River Basin Regional Modeling Standards for Hydrology and Hydraulic Modeling.*

CHAPTER 6
PAVEMENT DRAINAGE

6.1 INTRODUCTION

~~(g)(1)A.~~

The design of new streets and the improvement of existing streets shall consider public safety and limit potential conflicts between storm water ~~stormwater~~ conveyance, vehicular traffic, parking, pedestrian access, ADA requirements, and bicycle traffic. ~~(g) (1) F.~~ Storm water ~~Stormwater~~ conveyance on streets shall be designed to account for the cumulative impact of peak flows and runoff volumes on the system as the storm water ~~stormwater~~ progresses downgrade.

~~(g)(1)H.~~ Potential flooding problems or conflicts at ~~the~~ connection points where new or modified drainage systems (including streets, storm drains, etc.) and ~~the~~ existing portions of the downstream street system and storm water ~~stormwater~~ conveyance system shall be identified and resolved, either in the design of the new or modified drainage system or in modifications to the existing system. Appropriate longitudinal ~~slope~~ and cross slope serve to move any accumulated water off the roadway as quickly and effectively as possible.

~~(g)(7)A.~~

Where proposed streets cross existing or proposed watercourses, all-weather crossings shall be required. Culverts or bridges shall be adequate to allow passage of the design storm identified in Chapters 10.3.1 and 11.3.1~~subsection 35-504(b)(1).~~

6.2 DESIGN GUIDELINES

6.2.1 Design Frequency and Spread

~~(g)(1)B.~~

Streets draining a watershed greater than one hundred (100) acres must be designed for the 100-year ultimate design frequency storm. ~~(g)(1)E.~~ Street width shall not be widened beyond the width as determined by the street classification for drainage purposes. The width of pavement, maximum and minimal longitudinal street grades, and maximum and minimum pavement cross slopes shall follow UDC 35-506 Transportation and Street Design based on their street classifications.

6.2.1.1 Street Classification – Primary and Secondary Arterial Streets

~~(g)(2)~~

~~Primary and Secondary Arterial Streets.~~ An A~~a~~rterial S~~s~~treet is a street ~~so~~ designated on the current major thoroughfare plan. One (1) lane in each direction on arterial streets shall remain passable with a flow depth not to exceed 0.30 feet in the passable lane during a twenty-five (25)-year ultimate storm event or the one hundred (100) year ultimate if the street drains a

watershed greater than one hundred (100) acres. The maximum depth of water in the street section must not exceed seven (7) inches (the height of a standard city curb).

The Roadway Spread, also known as ponding width, is dependent on the depth of water at the curb, longitudinal slope, cross slope, and roadway pavement material.

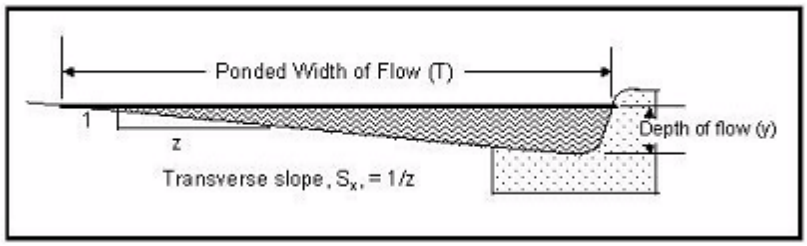


Figure 6.2.1.1 - Gutter Flow (Source TxDOT, 2000)

The depth of flow in a gutter section with a longitudinal slope (S) is taken as the uniform (normal) depth of flow. Manning's Equation is used as a basis for this determination. Ordinarily, it would not be possible to solve for uniform depth of flow directly from Manning's Equation. For Equation 6.2, the portion of wetted perimeter represented by the vertical (or near-vertical) face of the curb is ignored. This is a justifiable expedient which does not appreciably alter the resulting estimate of depth of flow in the curb section.

(Equation 6.2)

$$y=1.243(QnS_x / S^{1/2})^{3/8}$$

y = depth of water in the curb section (ft.)
Q = gutter flow rate (cfs.)
n = Manning's roughness coefficient
S = longitudinal slope (ft./ft.)
S_x = pavement cross slope (ft./ft.)

6.2.1.2 Street Classification – Local "B" and Collector Streets

~~(g)(3)~~

~~Local "B" and Collector Streets.~~ A maximum flow depth to the top of curb on a standard L~~l~~ocal "B" and C~~c~~ollector S~~s~~treet section will be allowed during a twenty-five (25)-year ultimate storm event. A C~~c~~ollector S~~s~~treet is a street with a width of forty-four (44) feet or more and not shown as an A~~a~~rterial S~~s~~treet on the current major thoroughfare plan.

6.2.1.3 Street Classification – Local "A" Streets

~~(g)(4)~~

~~Local "A" Streets.~~ Local "A" streets shall be designed on a basis of a five-year ultimate frequency. A twenty-five-year ultimate frequency storm must be contained within the street right-of-way.

6.2.1.4 Street Classification – Alleys

~~(g)(5)~~

~~Alleys.~~ Alleys shall be designed for five (5)-year ultimate frequency within the limits of the alley pavement/curbs, and twenty-five (25)-year ultimate frequency within the right-of-way or ~~/~~easement to carry storm water ~~stormwater~~.

6.2.1.5 Street Classification – Traditional Street Design

~~(g)(6)~~

~~Traditional Street Design.~~ Traditional street design shall conform to the storm frequency requirements of the standard street designs listed above as follows:

- Trails, Alleys, and Lanes - Use alley design criteria.
- Local Street or Avenue - Use L~~l~~ocal "A" street design criteria.
- Main Street - Use L~~l~~ocal "A," L~~l~~ocal "B," or C~~c~~ollector S~~s~~treet design criteria depending on the pavement width. Use L~~l~~ocal "A" criteria where pavement width is less than thirty-four (34) feet.
- Boulevard or Parkway - Use A~~a~~rterial S~~s~~treet design criteria.
- A County section with no curbs and with bar ditches - Design street section to contain the twenty five (25)-year ultimate frequency storm within the right-of-way.

~~No flow capacity tables are provided for the traditional street designs due the variety of geometric properties associated with these streets. Drainage calculations specific to a proposed traditional street design must be submitted for approval with every project where a traditional street design is proposed.~~

6.2.2 Street Capacity

~~(g)(1)C.~~

Streets may be used for storm water ~~stormwater~~ drainage only if the calculated storm water ~~stormwater~~ flow does not exceed the maximum flow depth and velocity allowable for the streets roadway classification as outlined above.~~or the velocity does not exceed ten (10) feet per second.~~

~~(g)(1)D.~~

Where streets are not capable of carrying their design criteria storm water discharge ~~stormwater, as outlined above,~~ inlets or curb openings ~~discharging to drainage channels or storm drains shall be provided.~~ are then required. The inlets or openings will discharge into a drainage channel or storm drain system. If there is not one available, one shall be provided. Partial flow past the inlet will be allowed when the capacity of all downstream street systems

can accommodate the flow. The Inlets and Storm Drain System design criteria requirements are outlined in Chapters 7 and 8.

~~(g)(1)G.~~

Curb cuts for driveways on all streets shall be designed for compatibility with the storm water ~~stormwater~~ conveyance function of streets. The design criteria maximum frequency must be contained within the right-of-way. Considerations will be given to cross streets as well as drive ways draining to streets

~~(g)(1)I.~~

Where Dwelling units are located on the downhill side of a T-intersection, Cul-de-sac, or knuckle with a street or drainage channel discharging onto it, the street ~~the~~ intersection shall be graded ~~sited~~ so ~~as~~ to avoid water flowing over the curb and out of the right-of-way. ~~obstruction of the drainage patterns.~~ Detailed calculations will be required at these locations to show that the discharges are contained within the right-of-way.

~~(g)(6)~~

~~Traditional Street Design. Traditional street design shall conform to the storm frequency requirements of the standard street designs listed above as follows:~~

~~A.~~

~~Trails, Alleys and Lanes - Use alley design criteria.~~

~~B.~~

~~Local Street or Avenue - Use local "A" street design criteria.~~

~~C.~~

~~Main Street - Use local "A," local "B" or collector street design criteria depending on the pavement widths. Use local "A" criteria where pavement width is less than thirty-four (34) feet.~~

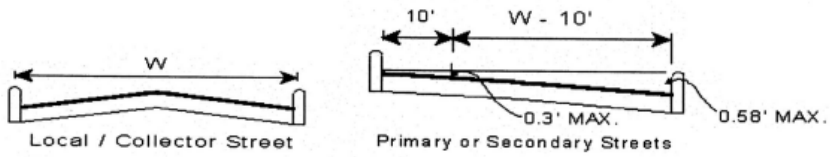
~~D.~~

~~Boulevard or Parkway - Use arterial street design criteria.~~

No flow capacity tables are provided for the traditional street designs due the variety of geometric properties associated with these streets. When proposing street designs, drainage ~~Drainage~~ calculations specific to a proposed ~~traditional~~ street design must be submitted for approval ~~with every project where a traditional street design is proposed~~.

Table 6.2.2.1 - ~~504-6~~Manning's Roughness Coefficient

Pavement Description	Manning's "n" Value
Concrete Pavement (wood float type surface finish)	0.015
Asphalt Pavement	0.018



Slope	28' Pvm't Width c=.28' wp=29.16 A=12.32 r=0.42		30' Pvm't Width c=0.3' wp=31.16 A=12.9 r=0.41		40' Pvm't Width c=0.4' wp=41.16 A=15.2 r=0.37		44' Pvm't Width c=0.44' wp=45.16 A=15.84 r=0.35		Secondary with Median 24' Pvm't wp=24.68 A=8.16 r=0.33		Primary (w/o & w/) Median 36' Pvm't wp=29.58 A=8.41 r=0.28	
	Q(cfs)	Vel.	Q(cfs)	Vel.	Q(cfs)	Vel.	Q(cfs)	Vel.	Q(cfs)	Vel.	Q(cfs)	Vel.
0.40	36.22	2.94	37.41	2.90	40.85	2.69	41.13	2.60	20.37	2.50	18.99	2.26
0.45	38.42	3.12	39.68	3.08	43.33	2.85	43.63	2.75	21.61	2.65	20.14	2.39
0.50	31.07	2.52	41.83	3.24	45.67	3.00	45.99	2.90	22.78	2.79	21.23	2.52
0.55	42.47	3.45	43.87	3.40	47.90	3.15	48.23	3.05	23.89	2.93	22.26	2.65
0.60	44.36	3.60	45.82	3.55	50.03	3.29	50.38	3.18	24.95	3.06	23.25	2.76
0.65	46.17	3.75	47.69	3.70	52.07	3.43	52.44	3.31	25.97	3.18	24.20	2.88
0.70	47.91	3.89	49.49	3.84	54.04	3.56	54.41	3.44	26.95	3.30	25.12	2.99
0.75	49.59	4.03	51.23	3.97	55.94	3.68	56.32	3.56	27.90	3.42	26.00	3.09
0.80	51.22	4.16	52.91	4.10	57.77	3.80	58.17	3.67	28.81	3.53	26.85	3.19
0.85	52.80	4.29	54.54	4.23	59.55	3.92	59.96	3.79	29.70	3.64	27.68	3.29
0.90	54.33	4.41	56.12	4.35	61.28	4.03	61.70	3.90	30.56	3.74	28.48	3.39
0.95	55.82	4.53	57.66	4.47	62.96	4.14	63.39	4.00	31.40	3.85	29.26	3.48
1.00	57.27	4.65	59.16	4.59	64.59	4.25	65.04	4.11	32.21	3.95	30.02	3.57
1.50	70.14	5.69	72.45	5.62	79.11	5.20	79.66	5.03	39.45	4.83	36.77	4.37
2.00	80.99	6.57	83.66	6.49	91.34	6.01	91.98	5.81	45.55	5.58	42.45	5.05
2.50	90.55	7.35	93.53	7.25	102.13	6.72	102.83	6.49	50.93	6.24	47.47	5.64
3.00	99.19	8.05	102.46	7.94	111.87	7.36	112.65	7.11	55.79	6.84	52.00	6.18
3.50	107.14	8.70	110.67	8.58	120.84	7.95	121.68	7.68	60.26	7.38	56.16	6.68
4.00	114.53	9.30	118.31	9.17	129.18	8.50	130.08	8.21	64.42	7.89	60.04	7.14
4.50	121.48	9.86	125.49	9.73	137.02	9.01	137.97	8.71	68.33	8.37	63.68	7.57
5.00	116.06	10.00	124.11	10.00	144.43	9.50	145.43	9.18	72.03	8.83	67.13	7.98
5.50	107.83	10.00	115.33	10.00	151.48	9.97	152.53	9.63	75.54	9.26	70.40	8.37
6.00	100.85	10.00	107.87	10.00	142.98	10.00	157.02	10.00	78.90	9.67	73.53	8.74
6.50	94.83	10.00	101.44	10.00	134.51	10.00	147.73	10.00	80.80	10.00	76.54	9.10
7.00	89.59	10.00	95.84	10.00	127.12	10.00	139.63	10.00	76.32	10.00	79.42	9.44
7.50	84.97	10.00	90.91	10.00	120.61	10.00	132.50	10.00	72.37	10.00	82.21	9.78
8.00	80.88	10.00	86.54	10.00	114.83	10.00	126.16	10.00	68.87	10.00	81.72	10.00
8.50	77.21	10.00	82.62	10.00	109.66	10.00	120.48	10.00	65.74	10.00	74.62	10.00
9.00	73.91	10.00	79.09	10.00	105.00	10.00	115.36	10.00	62.92	10.00	68.49	10.00
9.50	70.92	10.00	75.90	10.00	100.77	10.00	110.73	10.00	60.37	10.00	63.15	10.00
10.00	68.20	10.00	72.99	10.00	96.93	10.00	106.50	10.00	58.04	10.00	58.47	10.00

Figure 6.2.2.1 - Storm Drainage, Flow Velocities & Capacities for Typical Conventional Street Sections

6.2.3 High Velocity Flow

~~(g)(1)C.~~

Streets may be used for storm water ~~stormwater~~ drainage only if the calculated storm water ~~stormwater~~ flow does not exceed ~~the flows outlined in Table 504-7 or the velocity does not exceed~~ ten (10) feet per second.

6.2.4 Longitudinal Slope

~~(d)(1)Streets~~

~~(A) Tables 506-3 and 506-4 provide the standards for all existing and future streets.~~

Longitudinal slopes of a roadway are determined by its street classification as described in Sections 6.2.1. Table 506-3 and Table 506-4 contained in the UDC under Section 35-506 shall be used as the latest design standards.

6.2.4.1 Minimum

All proposed streets, both inside the City Limits and in the Extraterritorial Jurisdiction, shall have a minimum Longitudinal Slope of 0.5%. An optional 0.4% longitudinal slope can used with a concrete curb and gutter.

6.2.4.2 Maximum

The maximum Longitudinal Slope for Primary and Secondary Arterial Streets will be 5% both ICL and within the ETJ. The maximum slope for Collector Streets will be 7% both ICL and within the ETJ. The maximum slope for Local 'A', Local 'B', and alleys will be 12% ICL. The maximum slope for Local 'A', Local 'B', and alleys will be 10% in the ETJ. The maximum slope for a Traditional Street Parkway or Boulevard will be 5%. The maximum slope for a Traditional Street Main Street or Avenue will be 7%. The maximum slope for a Traditional Street Local, Lane, Alley, and County Section will be 10%. Grades over ten (10) percent in the extra-territorial jurisdiction shall be approved by the county fire marshal.

6.2.5 Cross Slope

The minimum and maximum street cross slopes are as described below. If not found below, then the cross slope will follow the latest version of AASHTO's guidelines for "A Policy on Geometric Design of Highways and Streets".

6.2.5.1 Minimum

All proposed streets must have a minimum cross slope of 2%. A slope less than 2% may be used to re-direct storm water runoff at street intersections, Cul-de-sacs, or into receiving drainage structures.

6.2.5.2 Maximum

All proposed streets should have a maximum cross slope of 4%. Cross slope at intersections may exceed 4% depending on the slope of the intersecting streets. Streets with super elevation should follow the latest version of AASHTO's guidelines for "A Policy on Geometric Design of Highways and Streets," and meet all the requirements identified in

Section 6.2.1 (depth of flow at curb, one passable lane in each direction, flow contained within right-of-way - all that apply).

6.2.6 Inverted Crown

Streets with inverted crowns will be acceptable if approved by the Director of TCI.

6.2.6.1 Maximum Flow Depth

Streets with a proposed inverted crown section will meet the same maximum depth based on their street classification as described above.

6.2.8 Flow In Sag – Vertical Curves

When street flow approaches a low point in the roadway the maximum depth design criteria(s) above should be checked to provide that the design runoff remains within the allowable limits (depth of flow at curb, one passable lane in each direction, flow contained within right-of-way, and all others that apply). If the maximum design criteria exceed any of the design parameters, additional inlets or curb openings are required to reduce the flow upstream of the low point.

6.2.9 Unflooded Public Road Access

~~(g)(8)(A)~~ During a design storm event ~~(see "subsection 35-504(b)(2) System Criteria")~~ unflooded access (within the "Proceed with Caution" range per Figure 4.3.1C ~~504-2~~) shall be available from each proposed new development to an adjacent public street during a regulatory flood event. ~~(g)(8)(B)~~ Additionally, unflooded access shall be accessible to an arterial street that is not adjacent to the development or to a distance of one-quarter (1/4)~~-~~ mile, whichever is less, during a future conditions ~~twenty (20)~~ four percent (4%) annual chance (twenty five (25) ~~five~~ -year ultimate) flood event. ~~(g)(8)(C)~~ The director of ~~public works~~ TCI may waive ~~criterion~~ the design criteria above ~~b of this requirement~~ for developments under three (3) acres in size.

6.3 REFERENCES

- AASHTO. *A Policy on Geometric Design of Highways and Streets - 1994*. American Association of State Highway and Transportation Officials, Washington, DC, 1995.
- TxDOT. *Roadway Design Manual*. Texas Department of Transportation, Revised October 2002.

CHAPTER 7
STORM DRAIN SYSTEMS

7.1 INTRODUCTION

The street system, roadside ditch, swale or channel may direct flow into an inlet, grate, or other collection structure into the storm drain system. This storm drain system will be comprised of inlets, pipes, junction boxes, bends, outlets, and other appurtenances. These systems may include water quality devices to meet state and federal water quality standards. This chapter describes the general guidelines needed to provide an adequate storm drain system and minimize impacts to both upstream and downstream properties.

The following shall be considered during the design of the storm drain systems.

~~(i)(1)~~
For all ordinary conditions, storm drains ~~sewer~~ shall be designed on the assumption that they will flow full under the design discharge; however, when~~ever~~ there are constrictions, turns, submerged, or inadequate outfall, etc., the hydraulic and energy grade lines shall be computed and plotted in profile. The Energy Grade Line (EGL) shall be below the top of curb and the Hydraulic Grade Line (HGL) shall be below the gutter elevation of the drainage structure. In all cases adequate outfalls shall be provided, including review of point source discharges.

The EGL and HGL will be required on all storm drain systems.

7.2 HYDRAULICS OF STORM DRAINAGE SYSTEMS

7.2.1 Flow Type Assumptions

The design procedures assume that the flow within each segment of the underground drainage system is steady and uniform. Also the average velocity within each segment is considered to be constant.

7.2.2 Partial Flow vs. Pressure Flow

There are two types of considerations for sizing storm drain lines under steady uniform flow assumption. The first is referred to as partial or open channel flow design. The flow depth within the conduit is less than the height of the conduit; so the HGL will be within the conduit. The second is referred to as pressure flow design or full flow. The conduit is fully flowing, and the HGL may be at the soffit or above the soffit of the conduit. See Figure 7.2.4.

For partial flow the design engineer should check for possible hydraulic jumps within the system if the flow is supercritical. If a hydraulic jump occurs within the system, the upper

conduits could change to pressure flow or the hydraulic jump could move downstream within the conduit to another design point.

The design may have both partial and pressure flow segments within the same drainage system.

The drainage system should be designed for full flow as this will increase the efficiency of the storm drain system.

7.2.3 Hydraulic Capacity

The hydraulic capacity is controlled by the conduits size, shape, and frictional resistance. Use Manning's Formula for the design of all conduits.

(Equation 7.2.3a)

$$\mathbf{Q = AV}$$

Q = flow (cfs.)
A = cross section area (sq. ft.)
V = velocity of flow (ft./sec.)

(Equation 7.2.3b)

$$\mathbf{Q = \frac{1.49}{n} AR^{0.67} S_f^{0.5}}$$

Q = flow (cfs.)
A = cross section area (sq. ft.)
n = roughness coefficient of conduit
R = hydraulic radius = A/**WP** (ft.)
WP = wetted perimeter (ft.)
S_f = frictional slope of conduit (ft./ft.)

~~(c)(9)~~

The "~~N~~n" value to be used in Manning's Formula shall conform to Table 7.2.3 ~~the following~~ for design purposes.~~:~~
~~A.~~
~~Earth channels – 0.035~~
~~B.~~
~~Concrete lined channels – 0.015~~
~~C.~~
~~Reinforced concrete pipe – 0.013~~
~~D.~~

~~Concrete box culverts – 0.013~~

~~E.~~

~~Corrugated metal pipe:~~

~~i.~~

~~Unpaved ½" corrugated – 0.024~~

~~ii.~~

~~Unpaved one (1) inch corrugated – 0.027~~

~~F.~~

~~Asphaltic concrete – 0.018~~

Any other "~~N~~n" value shall be based on generally accepted engineering principles.

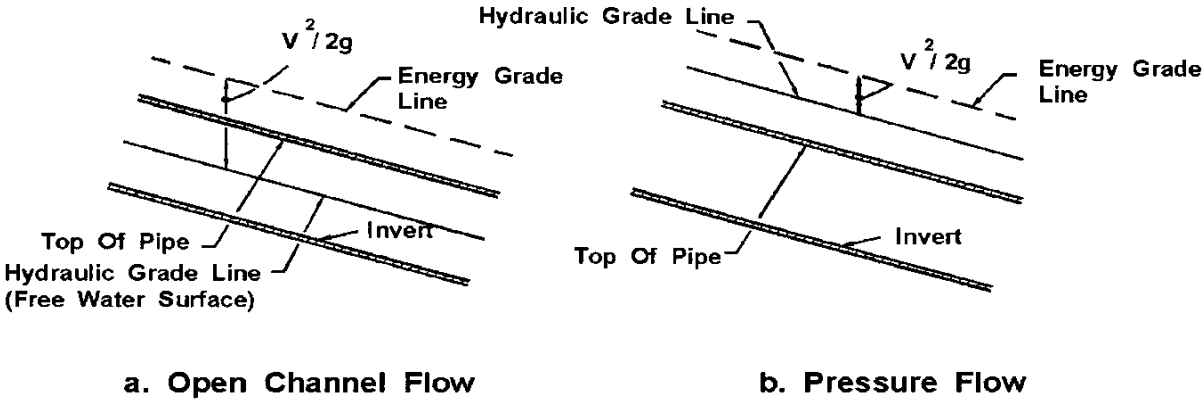
Table 7.2.3 - Manning's Roughness Coefficient

Type of Culvert	Roughness or Corrugation	Manning's n
Concrete Pipe	Smooth	0.013
Concrete Box	Smooth	0.013
Corrugated Metal Pipe, Pipe-Arch - Unpaved	2-2/3 by 1/2 inch Annular	0.024
Corrugated Metal Pipe, Pipe-Arch - Unpaved	3 by 1 inch Annular	0.027

7.2.4 Hydraulic Grade Line and Energy Grade Line

The HGL is the water surface of an open channel or the water surface of a conduit with partial flow. For a conduit with pressure flow, the HGL would be the level of water surface that would rise within a vertical tube at any point along the conduit.

The EGL is an imaginary line that is the measure of total energy along the open channel or conduit carrying water. This total energy includes elevation head, velocity head, and pressure head. The EGL is a velocity head ($V^2/2g$) above the HGL. The EGL is always increasing in the upstream conduit. The EGL should not be above the finished grade, or top of curb, at any point along the conduit.



a. Open Channel Flow b. Pressure Flow

Figure 7.2.4 - Hydraulic and Energy Grade Line in a conduit *(Source FHWA HEC No. 22)*

7.2.5 Storm Dain Inlets and Outfalls

7.2.5.1 Inlets

The drainage system will include inlets on streets, parking areas, and other areas to direct flow into the underground system. For inlets on streets, the HGL at the inlet should be below the gutter and the EGL not be above the top of curb or ponding depth. For area inlets the EGL should not be higher than the ponding depth.

An inlet could also be a pickup structure that channelizes flow from an upstream channel into the underground system. Careful analysis of the junction between the downstream underground system and the upstream channel should be performed to check both the HGL and EGL.

7.2.5.2 Outfalls

The outfall for the storm drain system should discharge into a natural low, existing storm drainage system, or a channel. The start of the EGL for the storm drain system begins at the outfall. The design engineer should determine the tail water for the downstream drain to find the impact on the proposed outfall. There are two conditions for determining the starting point for the HGL at the outfall. The tail water may be above the critical depth of the outfall conduit or between the critical depth and invert of the outfall conduit. The starting point for the HGL should be either the tail water elevation or the average of critical depth plus the height of the storm drain conduit, whichever is greater. The design engineer will consider an exit loss at the outlet.

If the outfall of the storm drain system is into a river, stream, or creek, the design engineer should consider the coincidental probability of the peaks of both systems occurring at the same time. The tail water for the receiving stream should be checked with the peak of the storm drain system.

7.2.6 Energy Losses

The energy losses for the storm drain system include frictional, exit, entrance, bend, and manhole and junction losses. These losses add to the hydraulic gradient along the storm drain system.

7.2.6.1 Pipe Friction Losses

The frictional loss from the conduit is one of the losses. The head loss due to friction is determined by the following formulas:

(Equation 7.2.6.1a, Friction Loss Formula)

$$H_f = S_f L$$

H_f = Friction loss (ft.)
S_f = Friction slope (ft./ft.)
L = Length of pipe (ft.)

Should the conduit have partial flow, then the frictional slope will match the pipe slope. For pressure flow or full flow of the conduit, the formula below can be used to determine the frictional slope of the conduit:

(Equation 7.2.6.1b, Pressure Flow Formula)

$$S_f = \left[Q\left(\frac{n}{1.49}\right) / \left(AR^{2/3}\right)\right]^2$$

S_f = Friction slope (ft./ft.)
Q = flow (cfs.)
n = roughness coefficient of conduit
A = cross section area (sq. ft.)
R = hydraulic radius = A/WP (ft.)
WP = wetted perimeter (ft.

7.2.6.2 Exit Losses

The exit loss from the storm drain outlet should be determined by the following formula:

(Equation 7.2.6.2, Exit Loss Formula)

$$H_o = 1.0\left[\left(\frac{V_o^2}{2g}\right) - \left(\frac{V_d^2}{2g}\right)\right]$$

H_o = Exit loss (ft.)
V_o = Velocity of outfall conduit (fps)
g = Acceleration due to gravity (ft./s^2 (32.2 ft./s^2))
V_d = Velocity of downstream channel (fps)

7.2.6.3 Bend Losses

This loss is for a bend located in the conduit run and not at a junction or manhole structure. Use the following formula to determine the bend loss:

(Equation 7.2.6.3, Bend Loss Formula)

$$H_b = 0.0033(\Delta)\left(\frac{V^2}{2g}\right)$$

H_b = Bend loss (ft.)
Δ = Angle of curvature in degrees
V = Velocity of the conduit (fps)
g = Acceleration due to gravity (ft./s^2 (32.2 ft./s^2))

7.2.6.4 Transition Losses

These losses are used where box culverts have a transition in width, height, or both width and height. The energy loss for expansions or contraction in open channel or partial flow must use the following formulas:

(Equation 7.2.6.4a)

$$H_c = K_c\left[\left(V_2^2/2g\right) - \left(V_1^2/2g\right)\right]$$

$$H_e = K_e\left[\left(V_1^2/2g\right) - \left(V_2^2/2g\right)\right]$$

H_c = Contraction loss (ft.)
H_e = Expansion loss (ft.)
K_c = Contraction coefficient (0.5 K_e)
K_e = Expansion coefficient
V_1= Velocity upstream of transition (fps)
V_2= Velocity downstream of transition (fps)
g = Acceleration due to gravity (ft./s^2 (32.2 ft./s^2))

Energy loss for expansions or contraction in pressure flow conditions will use the following formulas:

(Equation 7.2.6.4b)

$$H_c = K_c\left(V_2^2/2g\right)$$

$$H_e = K_e\left(V_1^2/2g\right)$$

H_c = Contraction loss (ft.)
H_e = Expansion loss (ft.)
K_c = Contraction coefficient (Tables 7.2.E)
K_e = Expansion coefficient (Tables 7.2.C and 7.2.D)
V_1 = Velocity upstream of transition (fps)

V_2 = Velocity downstream of transition (fps)
g = Acceleration due to gravity (ft./s^2 (32.2 ft./s^2))

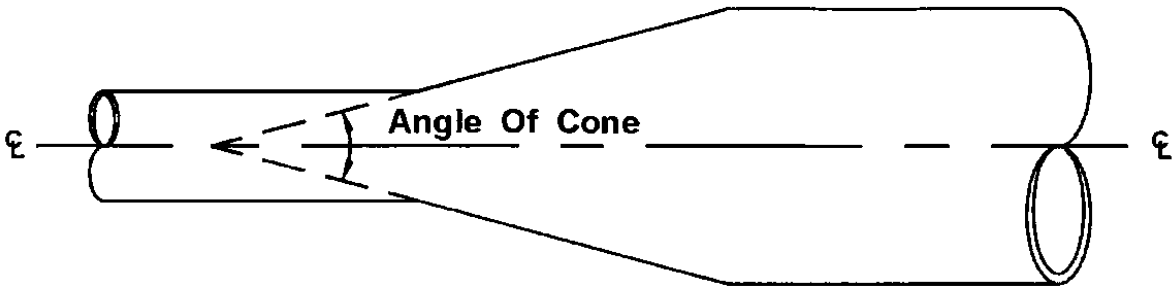


Figure 7.2.6.4 - Angle of Cone for change in pipe diameter *(Source FHWA HEC 22)*

Table 7.2.6.4A - *(Source FHWA HEC 22)*

Typical Values for K_e for Gradual Enlargement of Pipes in Non-Pressure Flow							
D_2/D_1	Angle of Cone						
	10°	20°	45°	60°	90°	120°	180°
1.5	0.17	0.40	1.06	1.21	1.14	1.07	1.00
3	0.17	0.40	0.86	1.02	1.06	1.04	1.00

Table 7.2.6.4B - *(Source ASCE Manuals and Reports of Engineering Practice No. 77)*

Typical Values of K_c for Sudden Pipe Contractions	
D_2/D_1	K_c
0.2	0.5
0.4	0.4
0.6	0.3
0.8	0.1
1.0	0.0
D_2/D_1 = Ratio of diameter of smaller pipe to larger pipe.	

Table 7.2.6.4C - *(Source ASCE Manuals and Reports of Engineering Practice No. 77)*

Values of K_e for Determining Loss of Head due to Sudden Enlargement in Pipes.													
D_2/D_1	Velocity, V_1, in feet Per Second												
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	10.0	12.0	15.0	20.0	30.0	40.0
1.2	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.08
1.4	0.26	0.26	0.25	0.24	0.24	0.24	0.24	0.23	0.23	0.22	0.22	0.21	0.20
1.6	0.40	0.39	0.38	0.37	0.37	0.36	0.36	0.35	0.35	0.34	0.33	0.32	0.32
1.8	0.51	0.49	0.48	0.47	0.47	0.46	0.46	0.45	0.44	0.43	0.42	0.41	0.40
2.0	0.60	0.58	0.56	0.55	0.55	0.54	0.53	0.52	0.52	0.51	0.50	0.48	0.47
2.5	0.74	0.72	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.60	0.58
3.0	0.83	0.80	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.70	0.69	0.67	0.65
4.0	0.92	0.89	0.87	0.85	0.84	0.83	0.82	0.80	0.79	0.78	0.76	0.74	0.72
5.0	0.96	0.93	0.91	0.89	0.88	0.87	0.86	0.84	0.83	0.82	0.80	0.77	0.75
10.0	1.00	0.99	0.96	0.95	0.93	0.92	0.91	0.89	0.88	0.86	0.84	0.82	0.80
∞	1.00	1.00	0.98	0.96	0.95	0.94	0.93	0.91	0.90	0.88	0.86	0.83	0.81

D_2/D_1 = ratio of diameter of larger pipe to smaller pipe
V_1 = Velocity in smaller pipe (upstream of transition)

Table 7.2.6.4D - *(Source ASCE Manuals and Reports of Engineering Practice No. 77)*

Values of K_e for Determining Loss of Head due to Gradual Enlargement in Pipes.											
D_2/D_1	Angle of Cone										
	2°	6°	10°	15°	20°	25°	30°	35°	40°	50°	60°
1.1	0.01	0.01	0.03	0.05	0.10	0.13	0.16	0.18	0.19	0.21	0.23
1.2	0.02	0.02	0.04	0.09	0.16	0.21	0.25	0.29	0.31	0.35	0.37
1.4	0.02	0.03	0.06	0.12	0.23	0.30	0.36	0.41	0.44	0.50	0.53
1.6	0.03	0.04	0.07	0.14	0.26	0.35	0.42	0.47	0.51	0.57	0.61
1.8	0.03	0.04	0.07	0.15	0.28	0.37	0.44	0.50	0.54	0.61	0.65
2.0	0.03	0.04	0.07	0.16	0.29	0.38	0.46	0.52	0.56	0.63	0.68
2.5	0.03	0.04	0.08	0.16	0.30	0.39	0.48	0.54	0.58	0.65	0.70
3.0	0.03	0.04	0.08	0.16	0.31	0.40	0.48	0.55	0.59	0.66	0.71
∞	0.03	0.05	0.08	0.16	0.31	0.40	0.49	0.46	0.60	0.67	0.72

D_2/D_1 = ratio of diameter of larger pipe to smaller pipe
Angle of cone is the angle in degrees between the sides of the tapering section

Table 7.2.6.4E - *(Source ASCE Manuals and Reports of Engineering Practice No. 77)*

Values of K_e for Determining Loss of Head due to Sudden Contraction.													
D_2/D_1	Velocity, V_1, in feet Per Second												
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	10.0	12.0	15.0	20.0	30.0	40.0
1.1	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.60
1.2	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.10	0.11
1.4	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.19	0.20
1.6	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.24

1.8	0.34	0.34	0.34	0.34	0.34	0.34	0.33	0.33	0.32	0.32	0.32	0.29	0.27
2.0	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.35	0.34	0.33	0.31	0.29
2.2	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.38	0.37	0.37	0.35	0.33	0.30
2.5	0.42	0.42	0.42	0.41	0.41	0.41	0.40	0.40	0.39	0.38	0.37	0.34	0.31
3.0	0.44	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.41	0.40	0.39	0.36	0.33
4.0	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.44	0.43	0.42	0.41	0.37	0.34
5.0	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.45	0.45	0.44	0.42	0.38	0.35
10.0	0.49	0.48	0.48	0.48	0.48	0.47	0.47	0.46	0.46	0.45	0.43	0.40	0.36
∞	0.49	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.45	0.44	0.41	0.38
D_2/D_1 = ratio of diameter of larger pipe to smaller pipe *V_1 = Velocity in smaller pipe (downstream of transition)*													

7.2.6.5 Junction Losses

For junction losses the design engineer can use the losses found in the University of Missouri Engineering Bulletin No. 41 "Pressure Changes at Storm Drain Junctions." The bulletin was a result of flume model testing.

The conduit junction losses within this section is for the connection of a lateral pipe to a larger storm drain trunk line without an access manhole. The following formula is a form of the momentum equation.

(Equation 7.2.6.5)

$$\mathbf{H_j = \{[(Q_o V_o) - (Q_i V_i) - (Q_l V_l \cos\theta_j)]/[0.5g(A_o + A_i)]\} + h_i - h_o}$$

$\mathbf{H_j}$ = Junction loss (ft.)
$\mathbf{Q_o, Q_i, Q_l}$ = Outlet, inlet, and lateral flows (cfs)
$\mathbf{V_o, V_i, V_l}$ = Outlet, inlet, and lateral velocity
$\mathbf{h_o, h_i}$ = Outlet and inlet velocity head (ft.)
$\mathbf{A_o, A_i}$ = Outlet and inlet cross sectional area (ft.^{2})
$\boldsymbol{\theta_j}$ = Angle between the inflow trunk line and lateral pipe

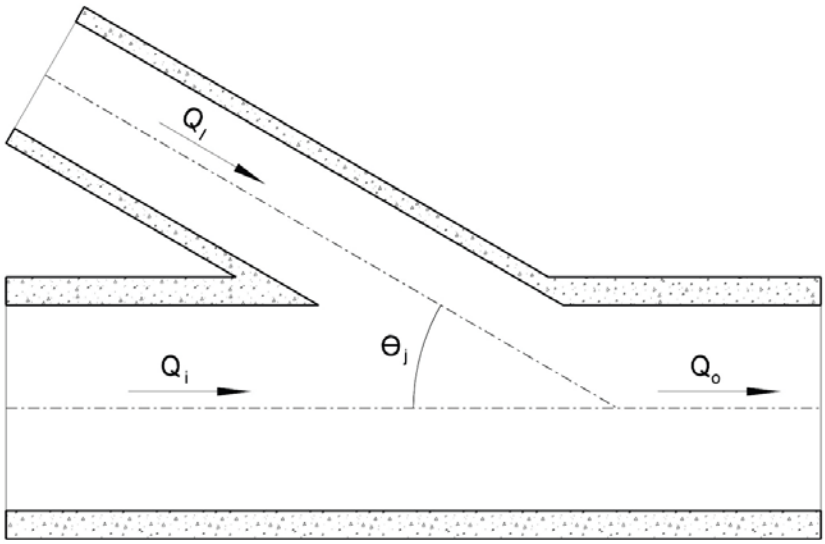


Figure 7.2.6.5 - Interior angle for pipe junction without manhole (Source FHWA HEC 22)

7.2.6.6 Inlet and Manhole Losses

The conduit junction losses within this section are for the connection of a lateral pipe(s) to a larger storm drain trunk line with an access manhole or junction box.

There are a number of ways to determine the losses within a junction. It is up to the design engineer to determine the appropriate loss method.

7.2.6.6.1 Missouri Charts

The instructions and charts from the University of Missouri Engineering Bulletin No. 41 "Pressure Changes at Storm Drain Junctions" is provided in the Appendix B of this manual as a reference for the design engineer should there be special configuration of manholes and junction boxes within the storm drain system. The University of Missouri Engineering Bulletin No. 41 "Pressure Changes at Storm Drain Junctions" was the results of flume model testing.

7.2.6.6.2 FHWA Inlet and Access Hole Energy Loss

FHWA has been developing and refining the methods to determine the energy losses within an access manholes (junction box) and inlets. The effort has been supported by research and laboratory analysis to improve the methodologies. These methodologies calculate the energy level through the manhole.

The FHWA method follows the following three steps. For more information on this method see reference FHWA HEC-22 Urban Drainage Design Manual.

STEP 1: Determine an initial access hole energy level (E_{ai}) based on inlet control (weir and orifice) or outlet control (partial and full flow) equations.
STEP 2: Adjust the initial access hole energy level based on benching, inflow angle(s), and plunging flows to compute the final calculated energy level (E_a).
STEP 3: Calculate the exit loss from each inflow pipe and estimate the energy gradeline (EGL_o), which will then be used to continue calculations upstream.

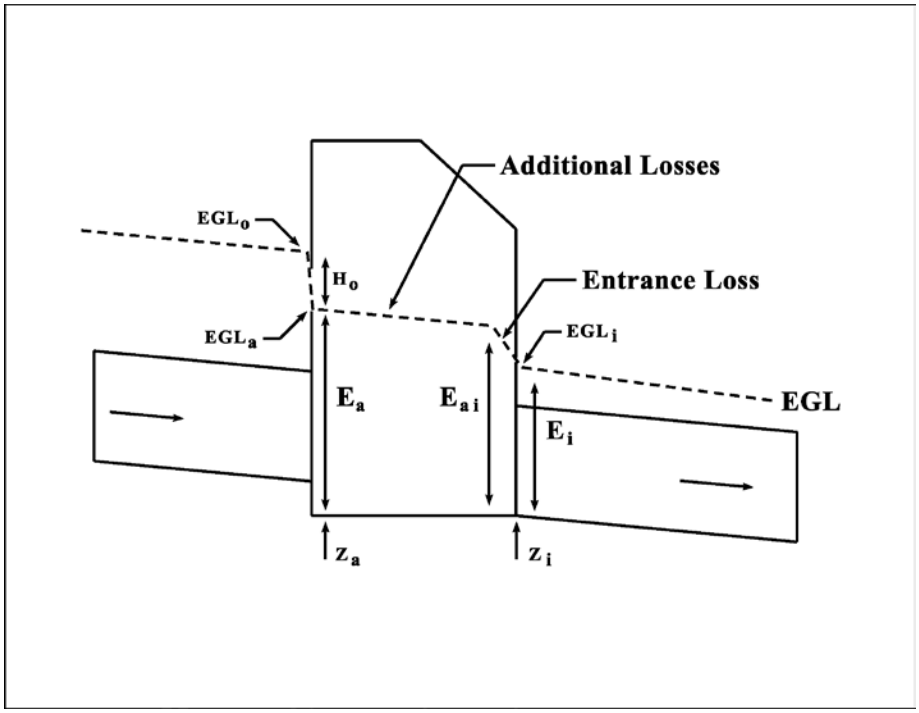


Figure 7.2.6.6.2 Sketch of FHWA access hole method *(Source FHWA HEC-22, 3rd Edition)*

7.2.6.6.3 Energy Loss Method (FHWA HEC-22, 2nd Edition)

A number of modeling programs use this method to calculate the energy loss for a junction.

When the inflow conduit invert is above the water surface elevation in the manhole, then the energy loss method does not apply to this upstream conduit.

(Equation: 7.2.6.6.3a)

$$H_{ah} = K\left(\frac{V_o^2}{2g}\right)$$

$$K = K_o C_D C_d C_Q C_p C_B$$

H_{ah} = Energy loss head
K = adjusted loss coefficient
K_o = initial head loss coefficient based on relative access hole size
C_D = correction factor for pipe diameter (pressure Flow only)
C_d = correction factor for Flow depth
C_Q = correction factor for relative Flow
C_p = correction factor for plunging Flow
C_B = correction factor for benching
V_o = velocity of outlet pipe
K_o: The initial head loss coefficient is based on the relative access hole size and the angle of deflection between the inflow and outflow conduits.

(Equation: 7.2.6.6.3b)

$$K_o = 0.1\left(\frac{b}{D_o}\right)(1 - \sin\theta) + 1.4\left(\frac{b}{D_o}\right)^{0.15}\sin\theta$$

K_o = initial head loss coefficient based on relative access hole size
θ = angle between the inflow and outflow pipes (figure 7.2.6.6.3A)
b = access hole or junction diameter
D_o = outlet pipe diameter

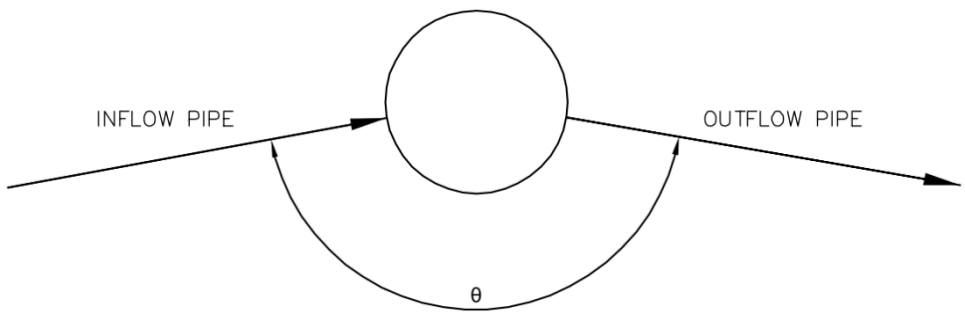


Figure 7.2.6.6.3.A - Deflection angle

C_D: When the depth of flow within the manhole relative to the diameter of the outlet conduit ratio, d_{aho}/D_o, is greater than 3.2, the correction factor for the **conduit diameter** is as follows.

(Equation: 7.2.6.6.3c)

$$C_D = \left(\frac{D_o}{D_i}\right)^3$$

C_D = correction factor for pipe diameter (pressure Flow only)
D_o = outgoing pipe diameter
D_i = inflowing pipe diameter

C_d: The correction factor for **flow depth** is used when the depth of flow within the manhole relative to the diameter of the outlet conduit ratio, d_{aho}/D_o, is less than 3.2. If the ratio is greater than 3.2, then the value of C_d is set to 1. The correction factor for **flow depth** is as follows.

(Equation: 7.2.6.6.3d)

$$C_d = 0.5\left(\frac{d_{aho}}{D_o}\right)^{0.6}$$

C_d = correction factor for Flow depth
d_{aho} = water depth in access hole above the outlet pipe invert
D_o = outlet pipe diameter

C_Q: The correction factor for **relative flow** is a function of the angle of the incoming flow and the percentage of flow coming in throught the conduit of intrest. The correction factor will be different for each upstream conduit. The correction factor for **relative flow** is applicable where the conduits are approximately the same elevation, otherwise the value of C_Q is equal to 1.

(Equation: 7.2.6.6.3e)

$$C_Q = (1 - 2\sin\theta)\left(1 - \frac{Q_i}{Q_o}\right)^{0.75} + 1$$

C_Q = correction factor for relative Flow
θ = the angle between the inflow and outflow pipes (figure 72.6.6.3.B)
Q_i = Flow in the inflow pipe
Q_o = Flow in the outflow pipe

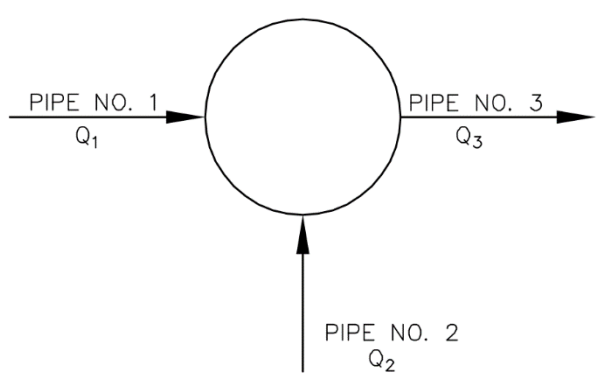


Figure 7.2.6.6.3.B - Relative flow effect

C_p: The correction factor for **plunging flow** is where the inflow one of the conduits plunges into the water surface within the manhole. This correction factor is applied to the inflow conduit and the outflow are at the bottom of the manhole and when $h>d_{aho}$. Flows from a grate inlet or curb opening are considered **plunging flow**. If there are no plunging flow within the manhole, the correction factor is set to 1.

(Equation: 7.2.6.6.3f)

$$C_p = 1 + 0.2\left(\frac{h}{D_o}\right)\left(\frac{h - d_{aho}}{D_o}\right)$$

C_p = correction for plunging Flow
h = vertical distance of plunging Flow from the Flow line of the higher elevation inlet pipe to the center of the outflow pipe
D_o = outlet pipe diameter
d_{aho} = water depth in access hole relative to the outlet pipe invert

C_B: The correction factor for **benching** in the manhole is obtained from Table 7.2.6.6.3. The benching directs flow through the manhole. See Figure 7.2.6.6.3C

Table 7.2.6.6.3 - Correction for Benching

Bench Type	Correction Factors, C_B	
	Submerged*	Unsubmerged**
Flat or Depressed Floor	1.00	1.00
Half Bench	0.95	0.15
Full Bench	0.75	0.07

**pressure Flow, $d_{aho}/D_o \geq 3.2$*
***free surface Flow, $d_{aho}/D_o \leq 1.0$*

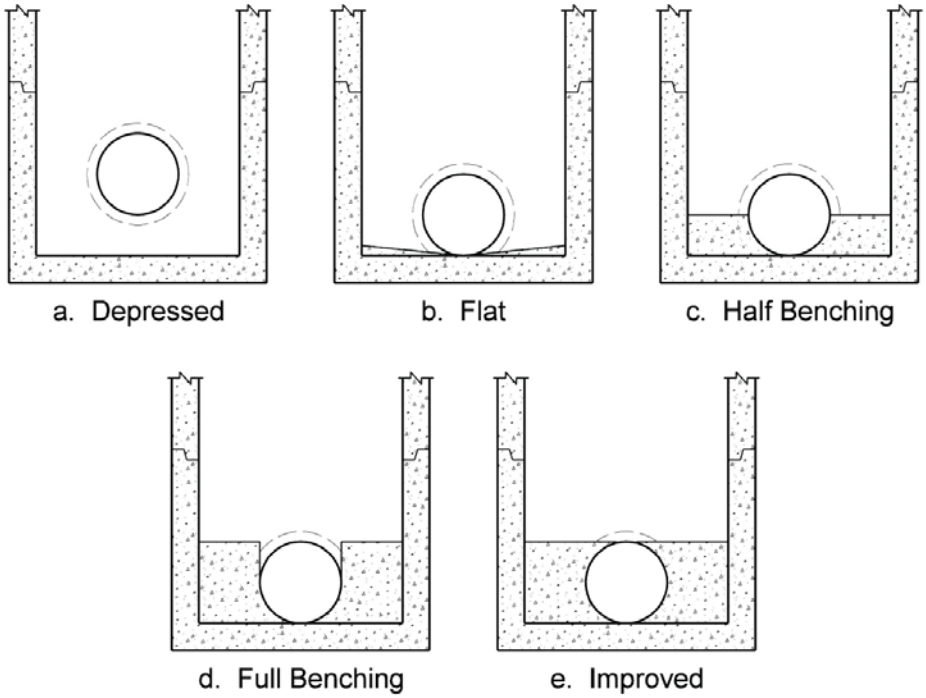


Figure 7.2.6.6.3.C - Manhole benching methods *(Source FHWA HEC-22, 3rd Edition)*

7.3 DESIGN GUIDELINES

7.3.1 Design Frequency

The system must be designed for the ultimate twenty-five (25)-year storm if the cumulative drainage area within the system is less than one hundred (100) acres. If the cumulative drainage area within the system is more than one hundred (100) acres, the system should be designed for the ultimate one hundred (100)-year storm.

7.3.2 Time of Concentration and Discharge

The rational formula should be used to determine the discharges through the storm drain system. The time of concentration is the time required for water to travel from the most hydraulically distant point in the watershed to the point under consideration. The time of concentration is comprised of overland flow, sheet flow, and gutter flow to the first inlet. Then from the first inlet there is additional time in the underground drainage system to the design points which should be considered. With the total time of concentration to the point of interest in the storm drain system the designer can select the intensity value for use in the rational formula.

7.3.3 Velocity and Grade Considerations

The minimum cleaning velocity for a storm drain line is three (3) fps for a 5 year event is recommended. Use the following formula to determine the minimum slope required for a velocity of three (3) fps.

(Equation: 7.3.3)

$$S = K_u\left[(nV)/D^{0.67}\right]^2$$

S = pipe slope (ft./ft.)
K_u = 2.87
n = Manning's N
V = Cleaning velocity (ft./sec.)
D = diameter of conduit (ft.)

The maximum velocity for a storm drain line in a twenty-five (25)-year event should follow Table 7.3 below. Velocities above the maximum shall be approved by the Director of TCI.

Table 7.3 - Maximum Velocity

Type	Maximum Permissible Velocity
Laterals	No limit
Main trunk lines	15 fps

The minimum slope for the storm drain line is 0.3% or as approved by the Director of TCI.

7.3.4 Pipe/Box Size and Placement

~~(i)(2)~~

No storm drains ~~sewer~~ shall be less than twenty-four (24) inches in diameter. For laterals and at driveway and roadway crossings, the minimum pipe/culvert size shall be twenty-four (24) inches in diameter unless the option for multiple smaller sized culverts is approved by the Director of TCI. A minimum (15) inches in diameter culvert pipe may be used for driveways accessing a county road section when required within the city limits or by the County Engineer in the County or ETJ.

If a storm drain accepts storm water from offsite area, the storm drain should not be placed below/underneath buildings or structures unless approved by the Director of TCI. If a proposed building or structure is over an existing storm drain, the storm drain should be relocated around the exterior of the building or structure.

Minimum cover over pipes and boxes should be maintained to make sure the structural stability of the conduit under live and impact loads. Pipes shall have a minimum cover per the manufactures design requirements.

7.3.5 Multiple Conduits Spacing and Placement

Should multiple parallel precast box culverts be used for a storm drain line, the spacing between adjacent boxes shall be six (6) inches. An increase in this dimension will require additional consideration of the fill material between the boxes.

Should multiple conduits, other than multiple parallel precast box culverts mentioned above, be used, the minimum spacing between conduits should be one (1) foot to allow for the compaction of backfill around the conduits.

Flow equalizers may be needed between multiple conduits to equalize the HGL where laterals or other conduits tie into the drainage system. The equalizer opening should have the same area as the incoming conduit.

7.3.6 Access Spacing

The maximum distance between access points in a storm drain line shall be five hundred (500) feet.

7.3.7 Manholes

Manholes to be used on box culvert storm drain lines shall have a manhole ring with a locking or bolted cover and with an inside diameter of thirty (30) inches for maintenance access.

7.3.8 Junction Boxes

Junction boxes shall be constructed at locations of laterals, changes in grade or alignment of pipes. The riser should have a manhole ring with a locking or bolted cover and with an inside diameter of thirty (30) inches for maintenance access. At the spring line of the pipe, the inside wall of the junction box must be a minimum of the outside diameter of the pipe, plus six (6) inches on each side of the pipe. If the pipe is at a skew to the junction box wall, additional distance is required. When an upstream conduit is smaller than the downstream conduit, it is preferable to match conduit soffits, unless the upstream conduit needs to miss a conflict such as a utility or minimum conduit cover.

7.3.9 Materials and Specifications

7.3.9.1 Pipe Material

The pipe material must have a minimum service life of fifty (50) years.

Reinforced concrete pipe is preferred. The use of HDPE or PVC, or corrugated metal pipe will not be allowed crossing under public streets or within public street ROW unless

approved by the Director of TCI. If use is allowed by the Director of TCI, corrugated metal pipe must be checked for corrosion resistance. Asphalt lining or bituminous interior coated corrugated metal pipe will not be allowed.

7.3.9.2 Minimum Structural Loads

The minimum live load should be HS 20 for streets and E 80 for railways. Heavier live load may be needed in special cases, and the design engineer should determine the required live load.

7.3.9.3 Mud Slab

A mud slab is a base slab of low strength concrete used to level up or stabilize the bottom of an excavation for the placement of multiple inlets, multiple boxes, or other structures. The mud slab is from two (2) to six (6) inches thick, but may be thicker if needed.

7.3.10 Outfalls

The outfall of a storm drain system should be to an existing low or proposed channel. The discharge velocity from the outfall should not cause erosion to the existing low or proposed channel. Velocity controls should be used when erosion is possible of the existing low or proposed channel. The outfall of the storm drain should be positioned in the existing low or proposed channel in the downstream direction to reduce the turbulence and erosion. The design engineer should meet with TCI Storm Water Division to discuss a solution, if a defined low does not exist for the discharge of the outfall. Should the discharge from an outfall cross a sidewalk area, discharge will not be allowed over the sidewalk. A channel section will be provided under the sidewalk.

7.3.10.1 Velocity Controls

Energy dissipation at the outlet may be required to prevent erosion of the channel bottom and banks. The use of baffle blocks, USBR Type VI impact basin, Contra Costa Basin, rock riprap basin, and rock riprap aprons may be used to reduce the velocity of the discharge from the storm drain conduit. See Chapter 10.4.3 for use of different energy dissipators.

The velocity at the end of the outlet structure should be a maximum of six (6) ft/sec. Sandy soils may require a discharge velocity less than six (6) ft/sec. The design engineer should be aware of the types of soils at the outfall location and design accordingly.

7.3.11 French Drains

French drains are used to control ground water or surface water. The French drain consists of a perforated pipe with a fabric sock around the exterior of the pipe to keep soil particles from entering the pipe. The pipe is installed in a trench filled with gravel.

A project may encounter a perched water table that will impact the street design section. A French drain may be needed to intercept the ground water that will impact the street section. The French drain should be placed in the parkway between the curb and property line, and

should outfall into a drainage inlet, pipe, or channel. The outfall should not drain onto the street, as this could cause street failure or cause an unsafe condition.

7.4 MAINTENANCE CONSIDERATIONS

A few items to consider during the design of a storm drain system would be the minimum cleaning velocity to keep sediment in suspension during a storm, access points along the trunk line for ease of maintenance personnel to clean and inspect the system, and access to outfall or intake structures for cleaning and inspection. See Chapter 4.12 for additional guidance on maintenance standards.

7.5 REFERENCES

- FHWA. *Hydraulic Design of Energy Dissipators for Culverts and Channels*. Hydraulic Engineering Circular No. 14. 3rd edition. FHWA-NHI-06-086. Federal Highway Administration, Department of Transportation, Washington, DC, July 2006.
- FHWA. *Urban Drainage Design Manual*. Hydraulic Engineering Circular No. 22, 3rd edition, FHWA-NHI-10-009. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, Sept. 2009.
- ASCE. *Design and Construction of Urban Storm Water Management Systems*. ASCE Manuals and Reports of Engineering Practice No. 77, WEF Manual of Practice FD-20. American Society of Civil Engineers, New York, NY, 1992.
- University of Missouri. *Pressure Changes at Storm Drain Junctions - Engineering Bulletin No. 41*. University of Missouri, Columbia, MO, 1958.
- FHWA. *Hydraulic Design of Highway Culverts*. Hydraulic Design Series No. 5, FHWA-IP-85-15. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1985.

CHAPTER 8
INLETS

8.1 INTRODUCTION

~~(j)(2)~~
~~Curb or Drop Inlets.~~ Where ~~drop~~ inlets are proposed ~~use~~, the ~~city~~ City of San Antonio standard inlets with adequate reinforcing steel ~~may~~ shall be used. All other types or designs shall be subject to the approval of the Director ~~director~~ of ~~Public Works~~ TCI ~~in consultation with the director of planning and development services.~~ This Chapter describes the considerations and design criteria for different types of storm water inlets.

8.2 INLET TYPES

Inlets may be incorporated into LID design per Section 4.3.9.

8.2.1 Curb Inlet

A Curb Inlet is a vertical opening in the curb covered by a top slab or the upper unit. The City of San Antonio standard details shall be used.

8.2.2 Grate Inlet

A Grate Inlet is a concrete box with a metal grate on the top that sits on the box. Use of the materials and following the dimensions that are called out in the City of San Antonio Standard Detail is recommended. Any modifications to the standard details will need to be approved by the Director of TCI. Additionally, where bicycle traffic occurs, grates should be bicycle safe.

8.2.3 4-Way Inlet

A 4-Way Inlet has four sides with normal six (6) inch high rectangular openings, with a 6 inch concrete top slab and a minimum 5 foot Concrete Apron around the inlet. Use of the materials and following the dimensions that are called out in the City of San Antonio Standard Detail is recommended. The maximum height of opening for the inlet is nine (9) inches, unless approved by the Director of TCI.

8.2.4 Combination Curb Inlet and Grate Inlet

A Combination Curb Inlet and Grate is an Inlet that has a curb opening with a concrete slab and a metal grate in the gutter portion of the section. These inlets are very useful in sag conditions because if clogged by debris the curb openings act as relief valves for the clogged grates.

8.2.5 Combination Grate and 4-Way Inlet

A Combination Grate and 4-Way inlet is the combination of the inlet described in part 8.2.3 with a grate in place of the top slab. These inlets are very useful in sag conditions where flow approaches a low spot from multiple directions.

8.2.6 Drop Curb Opening

A Drop Curb Opening is a cut in the curb in order to allow water to drain off the roadway and into a drainage swale. The Curb Openings are located where there is no cover over the opening and the sidewalk does not abut the curb. These inlets are also known as over-side drains or curb slots. The openings come in a variety of forms from metal curb lines to concrete saw tooth openings. In most cases, an opening in the curb connects to a scour-resistant channel or concrete chute to prevent erosion.

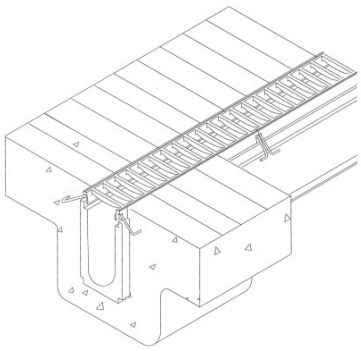
8.2.7 Sidewalk Drains

A Sidewalk Drain is a rectangular opening across a pathway typically made of concrete with a steel cover to convey runoff from one side to the other of the pathway. These types of inlets are typically used across sidewalks in the downtown area to capture the roof runoff from downspouts and discharge them onto the roadways. They can be used in other situations, a typical detail can be found on the City of San Antonio Standard Miscellaneous Details I in the Roadway Standards.

8.2.8 Slotted Drain

A Slotted Drain Inlet is composed of a length of usually circular pipe with a slot cut in the top on which a metal grate opening is mounted on (see figure below). The grate is flush with the pavement at the surface and the throat is reinforced for structural integrity. The designer should ensure structural integrity if used along a roadway.

Slotted Drain Figure



8.3 DESIGN GUIDELINES

~~35-504 (j) Inlets and Openings – Sidewalk Does Not Abut Opening.~~ The minimum design frequency for storm drain inlets is based on the maximum design frequency of the infrastructure that is being conveyed to the inlet or opening. Inlets and openings will be located and sized to meet the design criteria of the roadways they service, the ponds they drain to and from, and other drainage system conveyance features that they are a part of. ~~(j)(2)~~The following formulas for inlet capacit~~y~~ies and design guidelines are based on drop inlets ~~in~~ on grade and at sag points. Inlet capacities for on grade~~s will~~ inlets are less than that of inlets in sump. The capacity of on grade inlets ~~be considered less, the amount of which~~ depends on street grades, deflections, cross slopes, depressions, etc. The capacity of inlets in a sag are dependent on the water depth at the curb opening and the height of the curb opening.

8.3.1 Curb Inlets on Grade

~~(j)(4)~~The capacity ~~of curb opening inlets~~ of inlets on grade will depend on interception capacity and the amount of carry over that is allowed. ~~whether or not the opening is running partially full or submerged~~. If curb inlet extensions are used with the curb inlet, they shall be place on the up gradient end of the curb inlet. If more than one extension is proposed then verification of the hydraulic capacity of the block out openings will be required to verify that the extensions have sufficient capacity to convey the required design storm to the primary curb inlet. The minimum length of curb inlet opening is 5 feet.

The following procedure is used to design curb inlets on-grade:

1. Compute depth of flow and ponded width (T) in the gutter section at the inlet.
2. Determine the ratio of the width of flow in the depressed section (W) to the width of total gutter flow (T) using Equation 8.3.1.a. Figure 8.3.1 shows the gutter cross section at an inlet.

(Equation 8.3.1a)

$$E_O = \frac{K_W}{K_W + K_O}$$

E_0 = ratio of depression flow to total flow

K_W = conveyance of the depressed gutter section (cfs)

K_0 = conveyance of the gutter section beyond the depression (cfs).

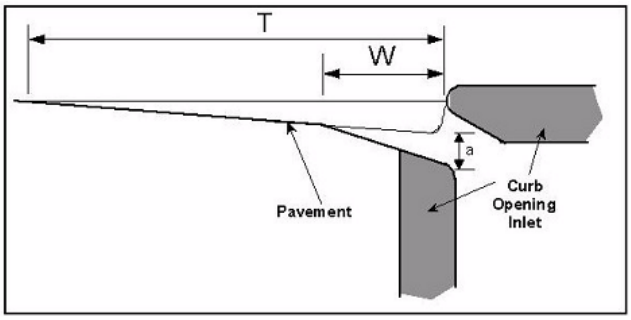


Figure 8.3.1 - Gutter Cross-Section Diagram

Use Equation 8.3.1.b to calculate conveyance, K_W and K_0.

(Equation 8.3.1.b)

$$K = \frac{zA^{5/3}}{nP^{2/3}}$$

K = conveyance of cross section (cfs)
z = 1.486
A = area of cross section (sq.ft.)
n = Manning's roughness coefficient
P = wetted perimeter (ft.).

Use Equation 8.3.1.c to calculate the area of cross section in the depressed gutter section.

(Equation 8.3.1.c)

$$A_W = WS_x\left(T - \frac{W}{2}\right) + \frac{1}{2}aW$$

A_W = area of depressed gutter section (sq.ft)
W = depression width for an on-grade curb inlet (ft.)
Sx = cross slope (ft./ft.)
T = calculated ponded width (ft.)
a = curb opening depression depth (ft.).

Use Equation 8.3.1.d to calculate the wetted perimeter in the depressed gutter section.

(Equation 8.3.1.d)

$$P_W = \sqrt{(WS_x + a)^2 + W^2}$$

P_W = wetted perimeter of depressed gutter section (ft.)
W = depression width for an on-grade curb inlet (ft.)
Sx = cross slope (ft./ft.)
a = curb opening depression depth (ft.).

Use Equation 8.3.1.e to calculate the area of cross section of the gutter section beyond the depression.

(Equation 8.3.1.e)

$$A_O = \frac{S_X}{2}(T - W)^2$$

A_0 = area of gutter/road section beyond the depression width (ft^2)
Sx = cross slope (ft./ft.)
W = depression width for an on-grade curb inlet (ft.)
T = calculated ponded width (ft.)

Use Equation 8.3.1.f to calculate the wetted perimeter of the gutter section beyond the depression.

(Equation 8.3.1.f)

$$P_O = T - W$$

P_0 = wetted perimeter of the depressed gutter section (ft.)
T = calculated ponded width (ft.)
W = depression width for an on-grade curb inlet (ft.).

Use Equation 8.3.1.g to determine the equivalent cross slope (S_e) for a depressed curb opening inlet.

(Equation8.3.1.g)

$$S_e = S_X + \frac{a}{W} E_O$$

Se = equivalent cross slope (ft./ft.)
Sx = cross slope of the road (ft./ft.)
a = gutter depression depth (ft.)
W = gutter depression width (ft.)
Eo = ratio of depression flow to total flow.

Calculate the length of curb inlet required for total interception using Equation 8.3.1.h.

(Equation 8.3.1.h)

$$L_r = zQ^{0.42}S^{0.3}\left(\frac{1}{nS_e}\right)^{0.6}$$

Lr = length of curb inlet required (ft.)
z = 0.6
Q = flow rate in gutter (cfs)
S = longitudinal slope (ft./ft.)
n = Manning's roughness coefficient
Se = equivalent cross slope (ft./ft.).

If no bypass flow is allowed, the inlet length is assigned a nominal dimension of at least L_r, which should be an available (nominal) standard curb opening length. The exact value of L_r should not be used if doing so requires special details, special drawings, structural design, and costly construction.

If bypass flow is allowed, the inlet length is rounded down to the next available standard (nominal) curb opening length.

Determine bypass flow. In bypass flow computations, efficiency of flow interception varies with the ratio of actual length of curb opening inlet supplied (L_a) to required length (L_r) and with the depression to depth of flow ratio. Use Equation 8.3.1.i to calculate bypass flow.

(Equation 8.3.1.i)

$$Q_{co} = Q\left(1 - \frac{L_a}{L_r}\right)^{1.8}$$

Qco = carryover discharge (cfs)
Q = total discharge (cfs)
La = design length of the curb opening inlet (ft.)
Lr = length of curb opening inlet required to intercept the total flow (ft.).

In all cases, the bypass flow must be accommodated at some other specified point in the storm drain system.

Calculate the intercepted flow as the original discharge in the approach curb and gutter minus the amount of bypass flow.

8.3.2 Curb Inlets in Sump

~~(j)(4) The capacity of curb opening inlets will depend on whether or not the opening is running partially full or submerged.~~ To calculate the capacity of a Curb Inlet you must first calculate if the inlet is fully submerged or partially full. This will depend on the depth of flow at the curb. If the depth of flow at the curb opening inlet is such as to cause a partially full opening, a weir effect will develop and the following formula will apply. The minimum length of curb inlet opening is 5 feet.

(Equation 8.3.2.a)

$$Q = CL(h)^{3/2}$$

Q = amount of flow in CFS ~~based on twenty-five year design.frequency~~
C = the weir coefficient 3.087
L = the length of drop curb opening required in feet.
h = the head or depth of water at the opening in feet (should include inlet depression 'a').

If the depth of flow at the Curb Inlet ~~opening~~ is such as to fully submerge the opening, the orifice effect will develop and the formula used shall be identical to that given under grate inlets with the exception that the head, h, on the curb opening orifice shall be taken as the depth from the top of the water surface to the center of orifice or opening; one hundred (100) percent efficiency will be allowed for curb opening inlets.

(Equation 8.3.2.b)

$$\mathbf{Q = CA(2gh)^{1/2}}$$

Q = discharge in cubic feet per second.
C = orifice coefficient of discharge (taken as 0.70).
g = acceleration due to gravity (32.2 ft./sec.^{2})
h = head on the ~~grate~~ opening in feet from top of water surface to the center of opening
A = net area of the openings ~~in the grate~~ in square feet.

Curb Inlet Extensions are not allowed in sump conditions. The Hydraulic Grade Line shall be designed below the gutter elevation of the drainage structure with the Energy Grade Line below the top of curb.

8.3.3 Grate Inlets on Grade

The interception capacity of Grate Inlets on grade depends on the cross slope, longitudinal slope, depth of flow, Manning's Roughness coefficient, and the net area of grate opening. The depth of water over the grate shall be calculated based on the cross section. A clogging factor will be applied to Grate Inlets on grade based on equation 8.3.3.h below.

Use the following procedure for grate inlets on-grade:

1. Compute the ponded width of flow (T).
2. Choose a grate type and size.
3. Find the ratio of frontal flow to total gutter flow (E_O) for a straight cross-slope using Equation 8.3.1.a. No depression is applied to a grate on-grade inlet.
4. Find the ratio of frontal flow intercepted to total frontal flow, R_f, using Equations 8.3.3.a, 8.3.3.b, and 8.3.3.c.

If $v > v_O$, use the Equation below (8.3)

(Equation 8.3.3.a)

$$\mathbf{R_f = 1 - K_u(v - v_O)}$$

If $v < v_O$, use Equation below (8.4)

(Equation 8.3.3.b)

$$R_f = 1.0$$

R_f = ratio of frontal flow intercepted to total frontal flow
K_u = 0.09
v = approach velocity of flow in gutter (ft./s)
v_o = minimum velocity that will cause splash over grate (ft./s)

For triangular sections, calculate the approach velocity of flow in gutter (v) using the Equation below.

(Equation 8.3.3c)

$$v = \frac{2Q}{Ty} = \frac{2Q}{T^2 S_X}$$

v = approach velocity of flow in gutter (ft./s)
Q = flow rate in gutter (cfs)
S_x = cross slope of the road (ft./ft.)
T = calculated ponded width (ft.)
T_y = max ponded depth (ft.)

Otherwise, compute the section flow area of flow (A) and calculate the velocity using Equation 8.3.3.d.

(Equation 8.3.3.d)

$$v = \frac{Q}{A}$$

v = approach velocity of flow in gutter (ft./s)
Q = flow rate in gutter (cfs)

A = the section flow area of flow (ft^2)

Calculate the minimum velocity (v_O) that will cause splash over the grate using the appropriate equation in Table 10-2 below.

Table 8.3.3 - Splash-Over Velocity Calculation Equations (English)

Grate Configuration	Typical Bar Spacing (in.)	Splash-over Velocity Equation
Parallel Bars	2	$vo = 2.218+4.031L-0.649L^2+0.056L^3$
Parallel Bars	1.2	$vo = 1.762+3.11L-0.451L^2+0.033L^3$
Parallel bars w/ transverse rods	2 parallel / 4 transverse	$vo = 0.735+2.437L-0.265L^2+0.018L^3$

$\mathbf{v_O}$ = splash-over velocity (ft./s or m/s)
L = length of grate (ft.)

5. Find the ratio of side flow intercepted to total side flow, R_S.

(Equation: 8.3.3.e)

$$R_S = \left[1 + \frac{zv^{1.8}}{S_X L^{2.3}}\right]^{-1}$$

$\mathbf{R_S}$ = ratio of side flow intercepted to total flow
z = 0.15
$\mathbf{S_x}$ = transverse slope
v = approach velocity of flow in gutter (ft./s)
L = length of grate (ft.).

6. Determine the efficiency of grate, E_f.

(Equation 8.3.3.f)

$$E_f = [R_f E_O + R_s(1 - E_O)]$$

$\mathbf{R_f}$ = ratio of frontal flow intercepted to total frontal flow

E_o = ratio of depression flow to total flow.

R_S = ratio of side flow intercepted to total flow

7. When calculating the interception capacity of the grate, Q_i a reduction factor (C) due to clogging should be included. If the interception capacity is greater than the design discharge, skip step 9.

(Equation 8.3.3.g)

$$Q_i = CE_fQ = CQ[R_fE_O + R_s(1 - E_O)]$$

C= *Clogging Factor (see equation 8.3.3.h)*
E_f = ratio of grate efficiency
R_f = ratio of frontal flow intercepted to total frontal flow
E_O = ratio of depression flow to total flow.
R_S = ratio of side flow intercepted to total flow

8. Calculate the clogging factor for grate inlets on grade with multiple units using the equation below.

(Equation 8.3.3.h)

$$C = \frac{KCo}{N}$$

C= *Multiple Unit Clogging Factor for an inlet with multiple units*

C_o = single unit clogging factor (50%)

e = decay ratio (0.5 for grate inlets)

N= number of units

K= *clogging coefficient from Table 8.3 below*

Table 8.3.a - Clogging Coefficients for Multiple Units

N =	1	2	3	4	5	6	7	8	>8
Grate Inlet (K)	1.0	1.5	1.8	1.9	1.9	2.0	2.0	2.0	2.0

9. Determine the bypass flow (CO) using this Equation. Remember to include the varying clogging factor for grate inlets in series.

(Equation 8.3.3.i)

$$CO = Q - Q_i$$

10. Depending on the bypass flow, select a larger or smaller inlet as needed. If the bypass flow is excessive, select a larger configuration of inlet and return to step 3. If the interception capacity far exceeds the design discharge, consider using a smaller inlet and return to step 3.

8.3.4 Grate Inlets In Sump

Grates should be designed assuming a clogging factor of 50%. When calculating the capacity of a grate inlet the net area of opening should be used, minus 50% for the clogging assumed above when calculating its capacity. ~~(j)(3)~~ The flow of water through grate openings may be treated as the flow of water through a rectangular orifice. Use equation 8.3.2.b to calculate the inlet capacity.

(Equation 8.3.2.b)

$$Q = CA(2gh)^{1/2}$$

Q = discharge in cubic feet per second.
C = orifice coefficient of discharge (taken as 0.70).
g = acceleration due to gravity (32.2 ft./sec.^{2})
h = head on the grate in feet.
A = 50% of net area of the openings in the grate in square feet.

8.3.5 4-Way Inlet

4-Way Inlets are typically proposed in sump situations. If they are fully submerged then use equation 8.3.2 to calculate the inlet capacity ~~the orifice formula below shall be used to calculate their capacity~~. The head, h, on the inlet ~~curb~~ opening orifice shall be taken as the depth from the top of the water surface to the center of orifice or opening.

8.3.6 Combination Curb Inlet and Grate Inlet

The capacity of the grate portion should be calculated based on whether the inlet is fully submerged or it is partially submerged. If the grate portion of the inlet is fully submerged then the capacity will be calculated using the orifice equation (assuming 50% clogging). If the grate portion of the inlet is not partially submerged then it should be calculated as a weir. The capacity of the curb inlet opening portion will also be calculated using the orifice equation if it is fully submerged or by using the weir equation if is not. The depth of flow along the curb needs to be calculated prior to making the determination of partially submerged or fully submerged. The minimum length of curb inlet is 5 feet.

8.3.7 Combination Grate and 4-Way Inlet

The capacity of the grate portion should be calculated based on whether the inlet is fully submerged or it is partially submerged. If the grate portion of the inlet is fully submerged then the capacity will be calculated using the orifice equation (assuming 50% clogging). If the grate portion of the inlet is not partially submerged then it should be calculated as a weir. The capacity of the curb inlet openings should also be calculated using the orifice equation if they are fully submerged or by using the weir equation if they are not. The depth of flow approaching the combination inlet needs to be calculated prior to making the determination of partially submerged or fully submerged.

8.3.8 Drop Curb Opening on Grade

~~(j)(1)~~

A drop curb opening is a curb opening where there is no cover over the opening and the sidewalk does not abut the curb opening. ~~Drop Curb Openings - Sidewalk Does Not Abut Opening~~. Where drop curb openings are used to take storm water ~~stormwater~~ off the streets and into drains, the length of the curb opening can be calculated following the steps in Section 8.3.1 above. The minimum length of curb opening is 5 feet.

8.3.9 Drop Curb Opening in Sump

~~(j)(1)~~

A drop curb opening is a curb opening where there is no cover over the opening and the sidewalk does not abut the curb opening. ~~Drop Curb Openings - Sidewalk Does Not Abut Opening~~. Where drop curb openings are used to take storm water ~~stormwater~~ off the streets and into drains, the length of the curb opening can be calculated from the weir formula using the coefficient of 3.087 using equation 8.3.2.a. ~~in the following formula:~~ The minimum length of curb opening is 5 feet.

Gutter line depressions will be permitted where such depressions will not hamper the flow of traffic. For amount of curb exposure, conform to City of San Antonio inlet standards.

8.3.10 Sidewalk Drains

Slope of a Sidewalk Drain should match the slope of the sidewalk that it crosses. The capacity of the opening will be determined by using Manning's Equation.

8.3.11 Slotted Drain

The throat of a slotted drain should be reinforced. The amount of reinforcement will be dependent on the anticipated loads that it will be subject to. Slotted drains should be oriented parallel to the flow so as to maximize the hydraulic efficiency. Slotted drains will only be allowed within public right-of-ways with the approval of the Director of TCI. The capacity of slotted drains will be calculated using the orifice.

8.4 MATERIALS AND SPECIFICATIONS

8.4.1 Cast In Place

Cast in Place Inlets shall meet all the requirements found in latest version of the City of San Antonio Standard Specifications' Item 307 "Concrete Structures".

8.4.2 Pre Cast

Pre-Cast Inlets shall meet all the requirements found in latest version of the City of San Antonio Standard Specifications' Item 403 "Storm Drain Junction Boxes and Inlets" or ASTM C478.

8.4.3 Minimum Structural Loads

The minimum live load should be HS 20 for streets and E 80 for railways. Heaver live load may be needed in special cases, and the designer should determine the required live load.

8.4.4 Grate

All Grates should meet all the requirements found in the latest version of the City of San Antonio Standard Specifications' Item 407 "Cast Iron Castings". Steel Grates and Frames need to be galvanized with hold down bolts.

8.4.5 Sidewalk plates

Sidewalk plates can be found on the City of San Antonio Standard Roadway Details "Miscellaneous Construction Standards 1".

8.4.6 Sidewalk Pipe Railing

All Sidewalk Pipe Railing shall be made of Galvanized Steel Pipe and shall conform to the requirements of the Standard Specifications for Steel for Bridges and Buildings, ASTM A 36, or approved equal. Additional specifications can be found in the latest version of the City of San Antonio Standard Specifications' Item 522 "Sidewalk Pipe Railing".

8.4.7 Mud Slab

A mud slab is a base slab of low strength concrete used to level up or stabilize the bottom of an excavation for the placement of multiple inlets, multiple boxes or other structures. The mud slab is from two (2) to six (6) inches thick, or thicker if needed. The mud slab shall be wide enough and long enough to encompass all proposed inlet bottoms.

8.5 REFERENCES

- TXDOT. Storm Drains. Chapter 10 in *Hydraulic Design Manual*. Texas Department of Transportation, Revised May 2014. Retrieved from http://onlinemanuals.txdot.gov/txdotmanuals/hyd/index.htm

- City of San Antonio. *Standard Specifications for Construction*. City of San Antonio, San Antonio, Texas, June 2008. Retrieved from http://www.sanantonio.gov/TCI/CurrentVendorResources/StandardSpecificationsandDetails.aspx
- City of San Antonio Capital Improvements Management Services. *Design Guidance Manual*. City of San Antonio, San Antonio, Texas, February 2012. Retrieved from http://www.sanantonio.gov/TCI/CurrentVendorResources/DesignGuidanceManualandForms.aspx
- UDFCD. *Urban Storm Drainage Criteria Manual Volume 1*. Urban Drainage and Flood Control District, Denver, Colorado, April 2008.
- FHWA. *Urban Drainage Design Manual*. Hydraulic Engineering Circular No. 22, 3rd edition, FHWA-NHI-10-009. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, Sept. 2009.1

CHAPTER 9
OPEN CHANNELS

9.1 INTRODUCTION

~~(h)~~
~~Drainage Channels and Watercourses.~~ This chapter ~~section~~ addresses proposed improvements or modifications to drainage channels and watercourses required to convey storm water ~~stormwater~~ runoff from or through the proposed development. Refer to section 9.3.1 ~~subsection 35-504(b)(1)~~ for storm frequency design criteria.

~~(h)(1)~~
~~Watercourses to Remain Unobstructed.~~ Except as authorized by a development plan approved by the Director ~~director~~ of TCI ~~public works~~ or his designee, no person shall place or cause to be placed any obstruction of any kind in any watercourse within the City and its ETJ. The owner of any property within the City, through which any watercourse may pass, shall keep the watercourse free from any obstruction not authorized by a development plan.

~~(h)(4)~~
~~Multiple Uses.~~ Planned multiple-use of a watercourse is allowed (e.g. bike paths or greenbelt). If multiple use of the watercourse is to be incorporated, the applicant shall form a property owners' association that shall assume maintenance responsibility for private amenities. The appropriate government agency will be responsible for maintenance of public amenities. ~~The applicant shall provide overlay easements for public or private use.~~

9.2 HYDRAULICS OF OPEN CHANNEL FLOW

~~(c)(1)A.~~
~~For drainage areas less than six hundred forty (640) acres, the basis for computing runoff shall be the rational formula or some other method provided it is acceptable to the director of public works.~~ Hydraulic calculations shall be performed by using the U.S. Army Corps of Engineers ~~HEC-2 "Water Surface Profiles" or~~ HEC-RAS "River Analysis System" computer models. Normal depth channel calculations are permissible for constructed open channels with a uniform geometric cross section where 1) there is no potential for the water surface elevations to be controlled by backwater and 2) the channel is not in a FEMA floodplain.
~~(c)(1)C.~~
~~Open channel hydraulic calculations shall be performed by using the U.S. Army Corps of Engineers HEC-2 "Water Surface Profiles" or HEC-RAS "River Analysis System" computer models, which documents shall be maintained on file with the Director of TCI director of public works and is hereby incorporated by this reference.~~
~~(c)(1)D.~~

Certain watersheds have hydrologic and hydraulic models that are available through the San Antonio River Authority website, Digital Data & Modeling Repository (D2MR) ~~and maintained by the City of San Antonio~~. Developments proposed within the limits of these watersheds must have the models updated by the ~~consultant~~ design engineer to reflect changes in flow, channel configuration (including alterations to vegetation) and channel structures. The ~~consultants'~~ design engineer's models must use the same computer program that was used in the existing model e.g. HEC-RAS or FEMA latest accepted models ~~will not be accepted where the original model used HEC 2~~. The updated models shall be submitted to the Director of TCI ~~director of public works for incorporation into the master models. The City of San Antonio will periodically update the master models to reflect current watershed development conditions. The updated models will be made available for use and distribution as the latest existing condition models for the watershed~~.

The influence of gravity on fluid motion in an open channel flow can be expressed in a dimensionless quantity called a Froude Number (Fr). The Froude Number is expressed in the following equation.

(Equation 9.2)

$$\mathbf{Fr} = \frac{\mathbf{V}}{\sqrt{\mathbf{gd}}}$$

V = Mean velocity (fps)
g = Acceleration of gravity = 32.2 ft/s^2
d = Hydraulic depth (ft.)

The hydraulic depth is defined as the cross sectional area of the channel perpendicular to the flow divided by the free water surface.

9.2.1 Energy

Conservation of energy is a basic principal in open channel flow. As shown in Figure 9.2.1, the total energy at a given location in an open channel is expressed as the sum of the potential energy head (elevation), pressure head, and kinetic energy head (velocity head). The total energy at given channel cross section can be represented as: (A)

(Equation 9.2.1.a)

$$\mathbf{E_t = Z + y + \left(\frac{V^2}{2g}\right)}$$

E_t = Total energy (ft.)
Z = Elevation above a given datum (ft.)
y = Flow depth (ft.)
V = Mean velocity (ft.)

g = Gravitational acceleration = 32.2 ft/s^2

Written between an upstream cross section designated 1 and a downstream cross section designated 2, the energy equation becomes the following:(A)

(Equation 9.2.1.b)

$$Z_1 + y_1 + \frac{V_1^2}{2g} = Z_2 + y_2 + \frac{V_2^2}{2g} + h_L$$

h_L = Head or energy loss between Section 1 and 2 (ft.)

The terms in the energy equation are illustrated in Figure 9.2.1. The energy equation states that the total energy head at an upstream cross section is equal to the total energy head at a downstream section plus the energy head loss between the two sections. (A)

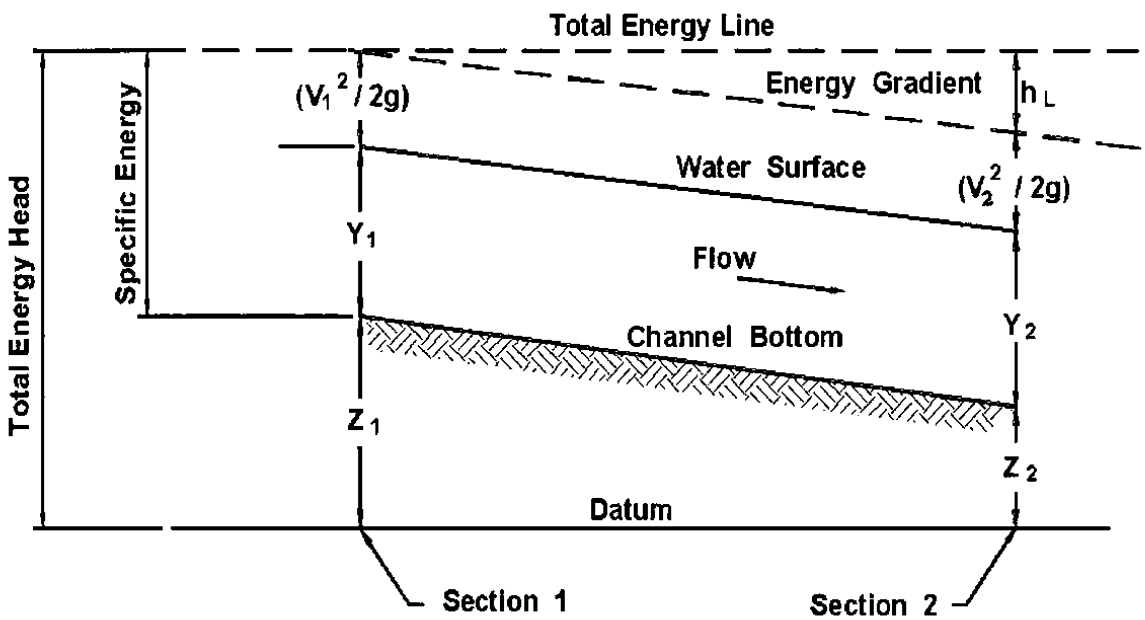


Figure 9.2.1 Total energy in open channels
(Source FHWA, HEC-22 Urban Drainage Design Manual, 3ed)

9.2.2 Specific Energy

The *specific energy* of flow in a channel section is defined as the energy per pound of water measured with respect to the channel bottom. Specific energy, *E* (expressed as head in feet), is given by the following: (B)

(Equation 9.2.2.a)

$$\mathbf{E = y + \frac{V^2}{2g} = y + \left(\frac{Q^2}{2gA^2}\right)}$$

y = depth (ft)
V = mean velocity (ft/sec)
g = acceleration of gravity = 32.2 ft/sec2
Q = discharge (cfs)
A = area of channel cross section (ft^2)

9.2.3 Flow Classification

9.2.3.1 Types of Flow in Open Channels

Open channel flow can be characterized in many ways. Types of flow are commonly characterized by variability with respect to time and space. The following terms are used to identify types of open channel flow: (B)

Steady flow—conditions at any point in a stream remain constant with respect to time (Daugherty and Franzini 1977). (B)

Unsteady flow—flow conditions (e.g., depth) vary with time. (B)

Uniform flow—the magnitude and direction of velocity in a stream are the same at all points in the stream at a given time (Daugherty and Franzini 1977). If a channel is uniform and resistance and gravity forces are in exact balance, the water surface will be parallel to the bottom of the channel for uniform flow. (B)

Varied flow—discharge, depth, or other characteristics of the flow change along the course of the stream. For a steady flow condition, flow is termed *rapidly varied* if these characteristics change over a short distance. If characteristics change over a longer stretch of the channel for steady flow conditions, flow is termed *gradually varied*. (B)

9.2.3.2 Critical Flow

Critical flow in an open channel or covered conduit with a free water surface is characterized by the following conditions (Fletcher and Grace 1972)

1. The specific energy is a minimum for a given discharge. (B)
2. The discharge is a maximum for a given specific energy. (B)
3. The specific force is a minimum for a given discharge. (B)
4. The velocity head is equal to half the hydraulic depth in a channel of small slope. (B)
5. The Froude number is equal to 1.0 (see Equation 9.2.) (B)
6. The velocity of flow in a channel of small slope is equal to the celerity of small gravity waves in shallow water. (B)

If the critical state of flow exists throughout an entire reach, the channel flow is critical flow, and the channel slope is at critical slope, *Scr*. A slope less than *Scr* will cause subcritical flow, and a slope greater than *Scr* will cause supercritical flow. A flow at or near the critical state may not be stable. In design, if the depth is found to be at or near critical, the shape or slope should be changed to achieve greater hydraulic stability. (B)

To simplify the computation of critical flow, dimensionless curves have been given for rectangular, trapezoidal, and circular channels in Figure 9.2.3.2. Critical velocity, *Vc*, can be calculated from the critical hydraulic depth, *dc*. For a rectangular channel, the flow depth is equal to hydraulic depth, (*yc* = *dc*), and the critical flow velocity is: (B)

(Equation 9.2.3.2)

$$\mathbf{V = \left(gYc^{1/2}\right)}$$

V = mean velocity (ft/sec)
g = acceleration of gravity = 32.2 ft/sec2
Yc = Critical Depth

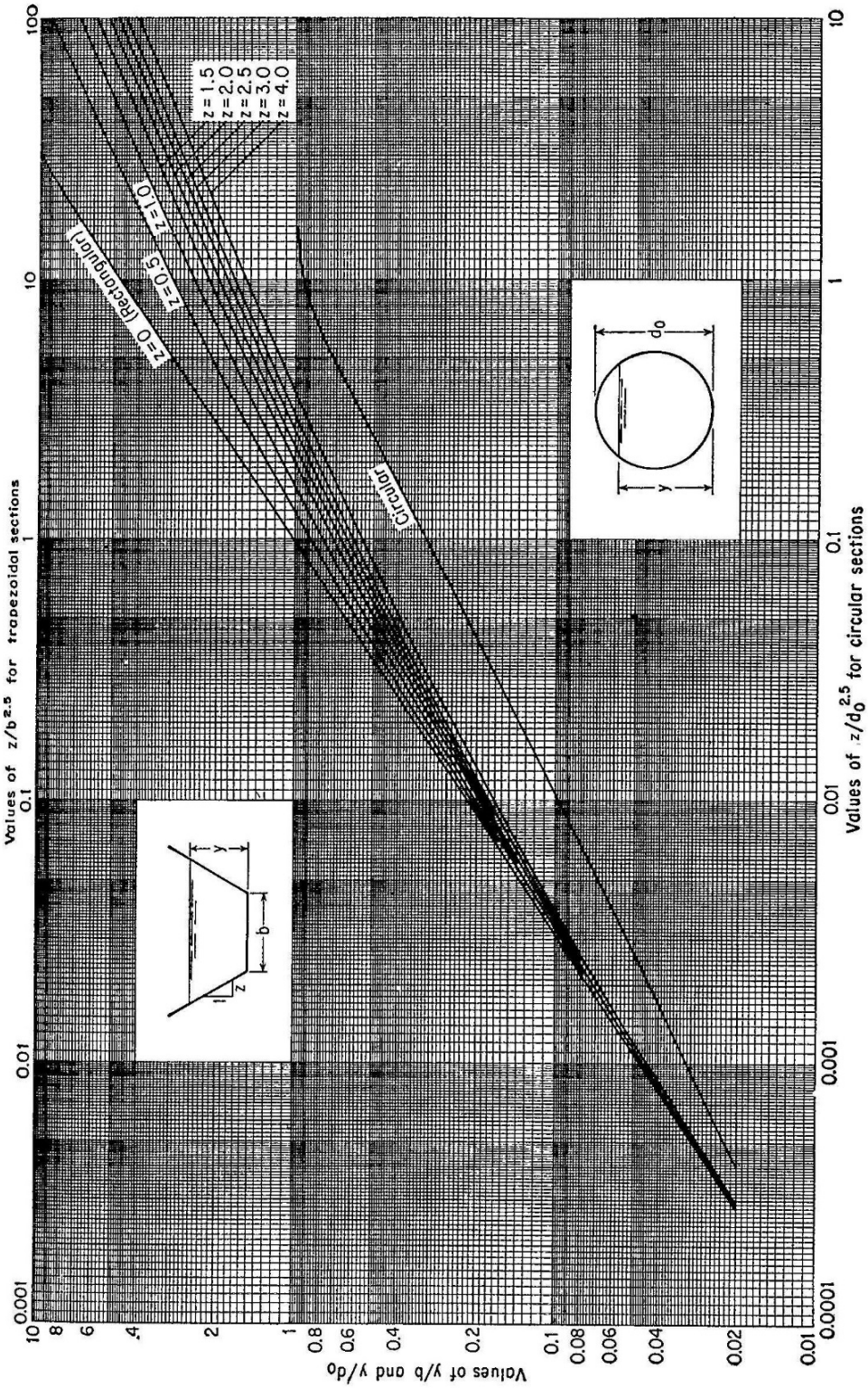


Figure 9.2.3.2 - Curves for Determining the Critical Depth in Open Channels

9.2.3.3 Subcritical Flow

Flows with a Froude number less than 1.0 are *subcritical* flows and have the following characteristics relative to critical flows : (B)

1. Flow velocity is lower. (B)
2. Flow depth is greater. (B)
3. Hydraulic losses are lower. (B)
4. Erosive power is less. (B)
5. Behavior is easily described by relatively simple mathematical equations. (B)
6. Surface waves can propagate upstream. (B)

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

9.2.3.4 Supercritical Flow

Flows with a Froude number greater than 1.0 are supercritical flows and have the following characteristics relative to critical flows: (B)

1. Flows have higher velocities. (B)
2. Depth of flow is shallower. (B)
3. Hydraulic losses are higher. (B)
4. Erosive power is greater.-(B)
5. Surface waves propagate downstream only. (B)

Supercritical flow in an open channel in an urban area creates hazards that the designer must consider. The minimum design depth of a channel shall be the frictional depth plus freeboard, or sequent depth without freeboard, whichever is greater. (B)

9.2.4 Uniform Flow

9.2.4.1 Manning's Equation

Manning's Equation describes the relationship between channel geometry, slope, roughness, and discharge for uniform flow:

(Equation 9.2.4.1.a)

$$\mathbf{Q = \left(\frac{1.486}{n}\right) A R^{2/3} S^{1/2}}$$

Q = discharge (cfs)
n = roughness coefficient
A = area of channel cross section (ft^2)
P = wetted perimeter (ft.)

R = hydraulic radius = A/P (ft.)
S = channel bottom slope (ft./ft.)

Manning's Equation can also be expressed in terms of velocity by employing the continuity equation, *Q* = *VA*, as a substitution in Equation 9.2.4.1.a, where *V* is velocity (ft/sec).

For wide channels of uniform depth, where the width, *b*, is at least twenty-five (25) times the depth, the hydraulic radius can be assumed to be equal to the depth, *y*, expressed in feet, and, therefore:

(Equation 9.2.4.1.b)

$$\mathbf{Q = \left(\frac{1.486}{n}\right) b y^{5/3} S^{1/2}}$$

(Equation 9.2.4.1.c)

$$\mathbf{y = \frac{Q^{0.6} n^{0.6}}{1.27 b^{0.6} S^{0.3}}}$$

(Equation 9.2.4.1.d)

$$\mathbf{S = \frac{((Qn)^2)}{(2.2 b^2 y^{3.33})}}$$

~~(c)(9)~~
~~Manning's Roughness Coefficient.~~ Manning's roughness coefficients ("~~N~~n" values) for use in ~~routing methods or in~~ hydraulic calculations shall be consistent with the values listed in Table 9.2.4.1 ~~504-6~~.

Table 9.2.4.1 - ~~504-6~~Manning's Roughness Coefficient

Channel Description	Manning's "n" Value
Concrete Lined Channel (wood float type surface finish)	0.015
Grass Lined Channel with regular maintenance	0.035
Grass Lined Channel without recent maintenance	0.050
Vegetated Channel with trees, little or no underbrush	0.055
Natural Channel with trees, moderate underbrush	0.075
Natural Channel with trees, dense underbrush	0.090
Natural Channel with dense trees and dense underbrush	0.100
Overbank Description	**Manning's "n" Value**
Pasture	0.035-0.055
Trees, little or no underbrush, scattered structures	0.060-0.075
Dense vegetation, multiple fences and structures	0.075-0.090

9.2.5 Gradually Varied Flow

When not flowing full, water surface profiles within a culvert are generally calculated using equations that describe Gradually Varied Flow (GVF) conditions. The GVF equations account for gravitational and frictional forces acting on the water, and are used to calculate water depths throughout the culvert. A GVF profile is also known as a water depth profile and applies to steady-state, or constant flow, conditions.

Limitations of Gradually Varied Flow equation:

1. Steady State Flow
2. One Dimensional (can only calculate average cross sectional water velocity)

Steady flow—conditions at any point in a stream remain constant with respect to time *(Daugherty and Franzini 1977).*

9.2.6 Rapidly Varied Flow

If water depth or velocity change abruptly over a short distance and the pressure distribution is not hydrostatic, the water surface profile is characterized as Rapidly Varying Flow (RVF). The occurrence of RVF is usually a local phenomenon. RVF can often be observed near the inlet and outlet of culverts, and wherever hydraulic jumps occur.

9.2.7 Hydraulic Jump

The hydraulic jump is a natural phenomenon that occurs when supercritical flow is forced to change to subcritical flow by an obstruction to the flow. This abrupt change in flow condition is accompanied by considerable turbulence and loss of energy. The hydraulic jump can be illustrated by use of a specific energy diagram as shown in Figure 9.2.7. The flow enters the jump at supercritical velocity, V_1, and depth, y_1, that has a specific energy of $E = y_1 +$

$V_1^2/(2g)$. The kinetic energy term, $V^2/(2g)$, is predominant. As the depth of flow increases through the jump, the specific energy decreases. Flow leaves the jump area at subcritical velocity with the potential energy, y, predominant. (C)

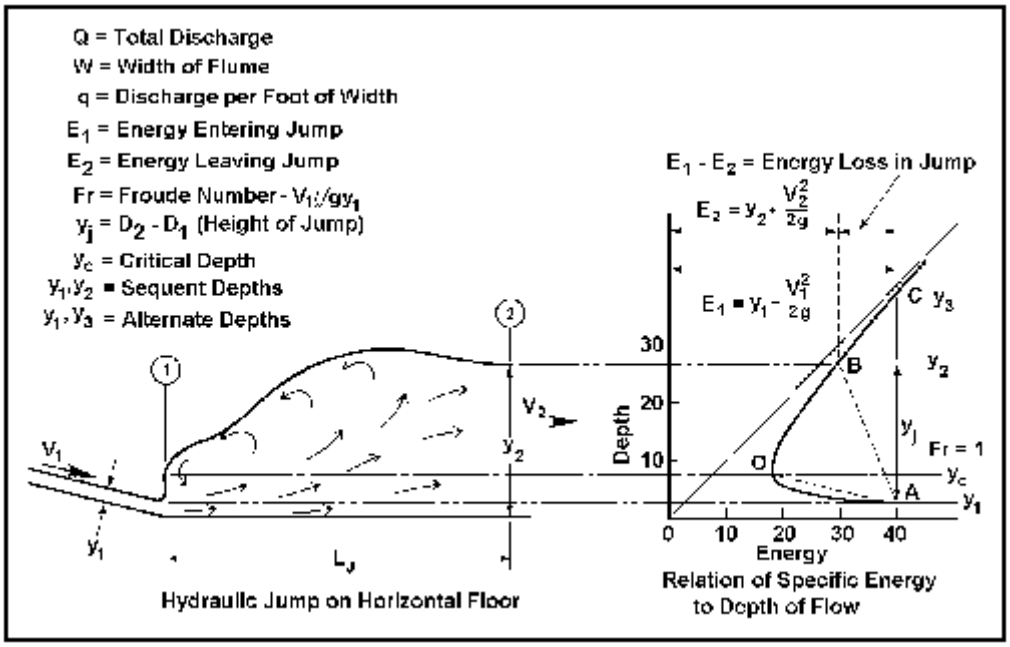


Figure 9.2.7 - Hydraulic Jump *(Source FHWA, HEC-14 Hydraulic Design of Energy Dissipators, 3ed)*

9.2.7.2 Types of Hydraulic Jump

When the upstream Froude number, Fr, is 1.0, the flow is at critical and a jump cannot form. For Froude numbers greater than 1.0, but less than 1.7, the upstream flow is only slightly below critical depth and the change from supercritical to subcritical flow will result in only a slight disturbance of the water surface. On the high end of this range, Fr approaching 1.7, the downstream depth will be about twice the incoming depth and the exit velocity about half the upstream velocity. (C)

The Bureau of Reclamation (USBR, 1987) has related the jump form and flow characteristics to the Froude number for Froude numbers greater than 1.7, as shown in Figure 9.2.7.2. When the upstream Froude number is between 1.7 and 2.5, a roller begins to appear, becoming more intense as the Froude number increases. This is the prejump range with very low energy loss. The water surface is quite smooth, the velocity throughout the cross section uniform, and the energy loss in the range of 20 percent. (C)

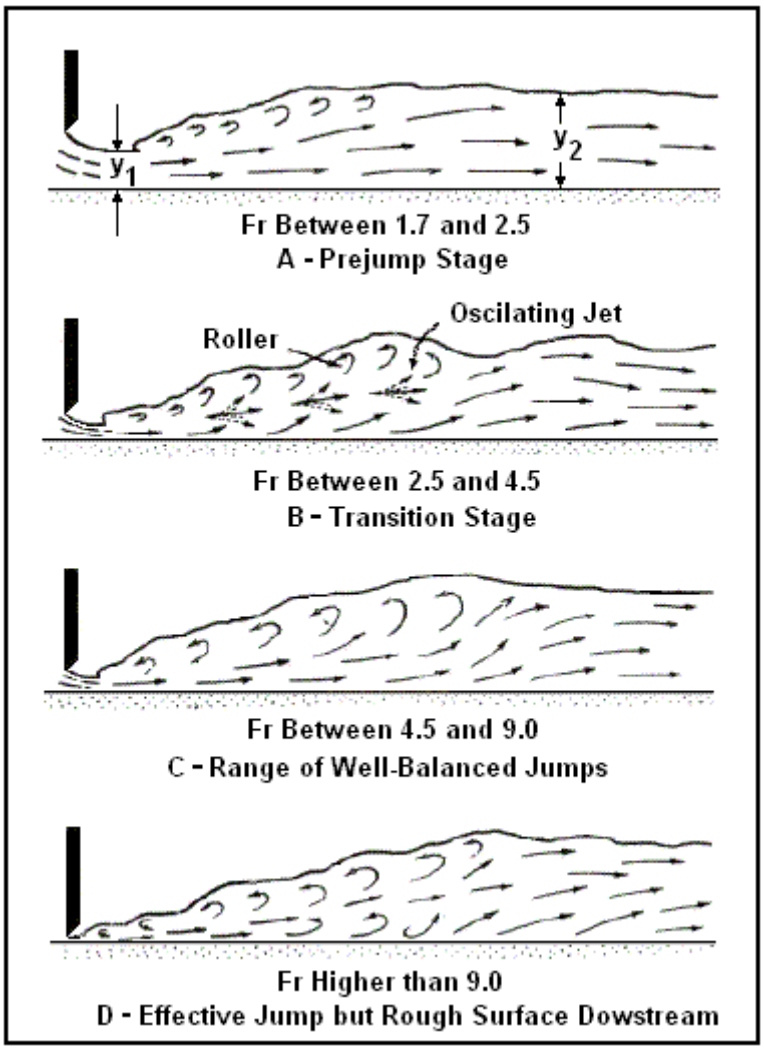


Figure 9.2.7.2 - Jump Forms Related to Froude Number (USBR, 1987)
(Source FHWA, HEC-14 Hydraulic Design of Energy Dissipators, 3ed)

An oscillating form of jump occurs for Froude numbers between 2.5 and 4.5. The incoming jet alternately flows near the bottom and then along the surface. This results in objectionable surface waves that can cause erosion problems downstream from the jump. (C)

A well balanced and stable jump occurs where the incoming flow Froude number is greater than 4.5. Fluid turbulence is mostly confined to the jump, and for Froude numbers up to 9.0 the downstream water surface is comparatively smooth. Jump energy loss of 45 to 70 percent can be expected. (C)

With Froude numbers greater than 9.0, a highly efficient jump results but the rough water surface may cause downstream erosion problems. (C)

The hydraulic jump commonly occurs with natural flow conditions and with proper design can be an effective means of dissipating energy at hydraulic structures. Expressions for computing the before and after jump depth ratio (conjugate depths) and the length of jump are needed to design energy dissipators that induce a hydraulic jump. These expressions are related to culvert outlet Froude number, which for many culverts falls within the range 1.5 to 4.5. (C)

9.2.7.3 Hydraulic Jump In Horizontal Channels

The hydraulic jump in any shape of horizontal channel is relatively simple to analyze (Sylvester, 1964). Figure 9.2.7.3 indicates the control volume used and the forces involved. Control section 1 is before the jump where the flow is undisturbed, and control section 2 is after the jump, far enough downstream for the flow to be again taken as parallel. Distribution of pressure in both sections is assumed hydrostatic. The change in momentum of the entering and exiting stream is balanced by the resultant of the forces acting on the control volume, i.e., pressure and boundary frictional forces. Since the length of the jump is relatively short, the external energy losses (boundary frictional forces) may be ignored without introducing serious error. Also, a channel may be considered horizontal up to a slope of 18 percent (10 degree angle with the horizontal) without introducing serious error. The momentum equation provides for solution of the sequent depth, y_2, and downstream velocity, V_2. Once these are known, the internal energy losses and jump efficiency can be determined by application of the energy equation. (C)

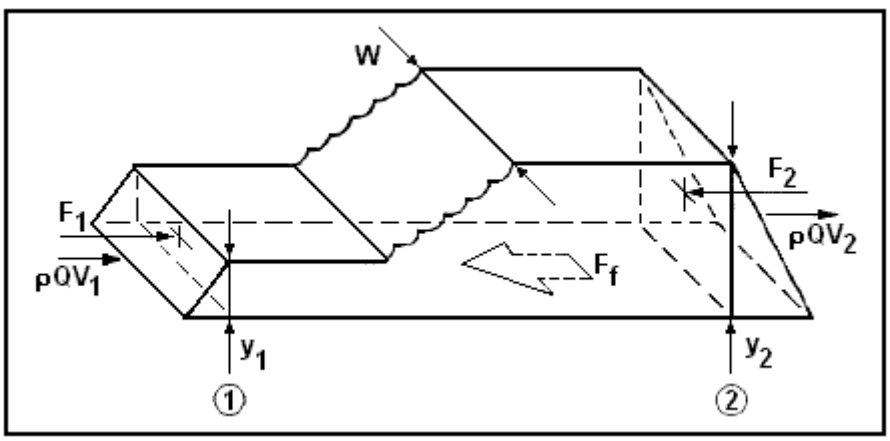


Figure 9.2.7.3. Hydraulic Jump in a Horizontal Channel
(Source FHWA, HEC-14 Hydraulic Design of Energy Dissipators, 3ed)

The general form of the momentum equation can be used for the solution of the hydraulic jump sequent-depth relationship in any shape of channel with a horizontal floor. Defining a momentum quantity as, $M = Q^2/(gA) + AY$ and recognizing that momentum is conserved through a hydraulic jump, the following can be written: (C)

(Equation 9.2.7.3)

$$\frac{Q^2}{(gA_1)} + A_1Y_1 = \frac{Q^2}{(gA_2)} + A_2Y_2$$

Q = channel discharge (ft^3/s)
A_1, A_2 = cross-sectional flow areas in sections 1 and 2, respectively (ft^2)
Y_1,Y_2 = depth from water surface to centroid of cross-section area (ft)

9.3 DESIGN GUIDELINES

9.3.1 Design Frequency

The channel(s) shall be designed for the ultimate twenty-five (25) year storm with freeboard if the drainage area to the channel is less than one hundred (100) acres. For freeboard requirements see 9.3.14. If the drainage area to the channel is more than one hundred (100) acres, the channel shall be designed for the ultimate one hundred (100) year storm.

9.3.2 Natural Channels

~~(h)(2)B.~~

~~Natural Unimproved Waterways.~~ Runoff that results from upstream development and is discharged to an unimproved waterway can cause flood damage to properties adjacent to the waterway. Natural undeveloped waterways do not receive regular maintenance. Design of natural waterways shall take into consideration fluvial geomorphologic principals and practices and other erosion control measures. ~~Consulting~~ Design engineers and development review officials shall work to resolve potential downstream impact issues.

~~(d)(3) Natural Watercourses or Floodplains.~~

~~Easements for natural watercourses shall be the 100-year floodplain or the twenty-five year plus freeboard (see Table 504-9 of this section) whichever is less. In floodplain areas where ongoing maintenance is required or the floodplain will be reserved for use by the public, the drainage easements shall be maintained by a public entity and the property will be dedicated to the city as a multi-use drainage easement.~~ A drivable access way shall be provided in floodplain easements for the length of the easement when regular maintenance of the floodplain is required.

9.3.3 Constructed Channels

~~(h)(2)A.~~

Modifications to existing watercourses or newly created open channels may be designed as earthen ~~earth channels, sod~~ channels or as concrete lined channels. Liners other than grass ~~sod~~ or concrete which enhance the aesthetics or habitat value of the watercourse and which reduce future maintenance requirements are encouraged. Preliminary planning for the

applicability of other channel liners shall be reviewed with the Director ~~director~~ of TCI ~~public works~~ or his representative prior to the submittal of construction plans for approval.

9.3.3.1 Earthen

The design of earthen channels shall comply with the following general requirements:

~~(h)(8)A.~~

A. Freeboard consistent with Table 9.3.14 ~~504-9~~ will be applied to the twenty-five~~-~~ (25) year design.

B. ~~(h)(8)B.~~The side slope shall not be steeper than three (3) horizontal to one (1) vertical.

C. ~~(h)(8)C.~~A ~~Easements or rights-of-way for improved earth channels shall conform to the requirements stated in subsection (d) of this section and shall extend a minimum of two (2) feet on one (1) side and~~ fifteen (15) foot ~~feet for an~~ access road on one ~~the opposite~~ side of the extreme limits of the channels is required when channels do not parallel and adjoin an alley or roadway. ~~When such channels do parallel and adjoin an alley or roadway, the easement or right-of-way shall extend a minimum of two (2) feet on both sides of the extreme limits of the channel.~~ Where utilities are installed in the access road of the channel, the access road will be widen to ~~drainage right-of-way, the right-of-way shall extend two (2) feet on one (1) side and~~ seventeen (17) feet. ~~on the opposite side of the design limits of the channel.~~ "Extreme Limits" of the channel shall mean the side slope intercept with the natural ground or proposed finished ground elevation. ~~These seventeen (17) feet are to provide an access way along the channel with a maximum cross slope of one (1) inch per foot toward the channel.~~ Where designed channel bottoms exceed one hundred (100) feet in width, the fifteen-foot access road ~~extra width~~ shall be provided on both sides of the channel. The access road will slope toward the channel with a maximum cross slope of one (1) inch per foot. Additionally, the top of utility manholes within the access road to match the finish ground surface.

D. Earthen interceptor drains are for proper conveyance of upstream storm water sheet flow only. See Section 9.3.10.

E. Earthen channels shall be vegetated. See Section 16.2.1.

F. ~~(h)(8)F.~~Channels ~~For vegetated earthen channels~~ with longitudinal slopes less than 0.5 percent or bottom widths greater than thirty (30) feet, concrete pilot channels shall be provided. The minimum bottom width of the pilot channel shall be six (6) feet ~~four (4) foot~~. The minimum [earthen] slope draining toward the pilot channel shall be one (1) percent.

G. ~~(h)(5)B.~~Ensure that the channel will contain the hydraulic jump (sequent depth) throughout the extent of the supercritical profile. An exception to this criteria is where concrete lined lateral channels discharge down the side slopes of channels. These channels may be designed for normal depth plus freeboard provided velocity controls are established at the main channel flow line.

H. ~~(h)(5)C.~~Ensure that the energy grade of the channel will not result in upstream flooding at existing or proposed lateral facility connections.

Example: Improved channel through the proposed development with a channel flare to accept upstream storm water should be checked with a backwater model to ensure that the hydraulic grade line and energy grade line match the pre-project conditions on the adjoining/upstream property.

9.3.3.2 Concrete

~~(h)(7)~~

~~Concrete Lined Channels.~~ The design of concrete lined channels shall comply with the following general requirements:

A. ~~(h)(7)A.~~Freeboard consistent with Table 9.3.14 ~~504-9~~ will be applied to the twenty-five~~-~~ (25) year design.

B. ~~(h)(7)B.~~From the top of the concrete lining to the top of the ditch, a side slope not steeper than three (3) horizontal to one (1) vertical shall be required; nor shall the slope be less than twelve to one (12:1). The minimum longitudinal slope ~~of concrete lined channels~~ shall be 0.4 percent, or 0.1 percent with a minimum "cleaning" velocity of ~~two (2)~~ three (3) feet per second (~~2~~3 fps) during an existing conditions ~~two~~ five (5) year storm event.

C. ~~(h)(7)C.For normal conditions, the concrete lining shall be a minimum of five (5) inches thick and reinforced with No. 3 round bars at twelve (12) inches on center each way. Where surcharge, nature of ground, height and steepness of slope, etc., become critical, design shall be in accordance with latest structural standards. All concrete lining shall develop a minimum compressive strength of not less than three thousand (3,000) pounds per square inch in twenty-eight (28) days.~~ The depth of all toe downs shall be thirty-six (36) inches upstream, twenty-four (24) inches downstream, and eighteen (18) inches for side slopes. The City's construction inspector may permit an eighteen-inch toe down in rock subgrade in lieu of the above toe down requirements. The horizontal dimensions (thickness) of toe downs shall not be less than six (6) inches.

D. ~~(h)(7)D.~~Riprap ~~Maximum concrete riprap~~ side slopes shall not be steeper than one and one-half (1½) horizontal to one (1) vertical, unless soil tests made by a geotechnical engineer show that a greater slope, or a special design, will be stable. Where vehicular traffic may travel within a horizontal distance equal to one-half (½) the vertical rise of the slope, a two-foot surcharge load shall be included in the design.

E. ~~(h)(7)E.~~Fencing will be required adjacent to the channel where channel vertical wall heights exceed two (2) feet. Fencing will also be required adjacent to the channel where channel side slopes exceed two to one (2:1) and the channel depth is greater than two (2) feet. The fencing must not cause sight distance problems for motorists.

F. ~~(h)(7)F.~~Vertical walls will not be permissible for depths greater than two (2) feet unless properly fenced or enclosed. Walls will have a minimum thickness of six (6) inches.

~~(h)(7)H.A minimum "n" value of roughness coefficient of 0.015 shall be used for a wood float type surface finish. This "n" value is as used in Manning's formula.~~

G. ~~(h)(5)B.~~Ensure that the channel will contain the hydraulic jump (sequent depth) throughout the extent of the supercritical profile. An exception to this criteria is where concrete lined lateral channels discharge down the side slopes of channels. These channels may be designed for normal depth plus freeboard provided velocity controls are established at the main channel flow line.

H. ~~(h)(5)C.~~Ensure that the energy grade of the channel will not result in upstream flooding at existing or proposed lateral facility connections.

Example: Improved channel through the proposed development with a channel flare to accept upstream storm water should be checked with a backwater model to ensure that the hydraulic grade line and energy grade line match the pre-project conditions on the adjoining/upstream property.

I. A fifteen (15) foot access road on one side of the extreme limits of the channels is required when channels do not parallel and adjoin an alley or roadway. Where utilities are installed in the access road of the channel, the access road will be widen to seventeen (17) feet. The access road will slope toward the channel with a maximum cross slope of one (1) inch per foot.

J. The top of utility manholes within the access road to match the finish ground surface

9.3.4 Channel Geometry

The constructed channel geometry may be triangular, rectangular or trapezoidal in shape. The side slopes should not exceed the requirements in 9.3.3.1 or 9.3.3.2. In areas where traffic safety may be of concern, the channel side slope should be 4H:1V or flatter or other vehicular protection devices may be required.

For natural channels, the channel geometry may be irregular in shape. The channel sections should be checked for areas of erosion and provide corrective measures with the natural channel design.

9.3.5 Channel Slope

The channel slope for constructed earthen channels shall meet the requirements of 9.3.3.1.F. The design engineer should consider the channel stability of the design slope to determine if additional protection will be needed to protect the bottom and side slopes.

For concrete channels, the channel slope shall meet the requirements of 9.3.3.2.B. For steep channel slopes, the flow maybe supercritical and the total depth of the channel should contain the sequent depth.

9.3.6 Channel Drops

9.3.6.1 Earthen Channels with Drops.

~~(h)(6) Retard Spacing.~~

Retard spacing shall be computed as follows when using the City standard retard section. See Figure 9.3.6.1 ~~504-3~~ and the following equations for spacing criteria:

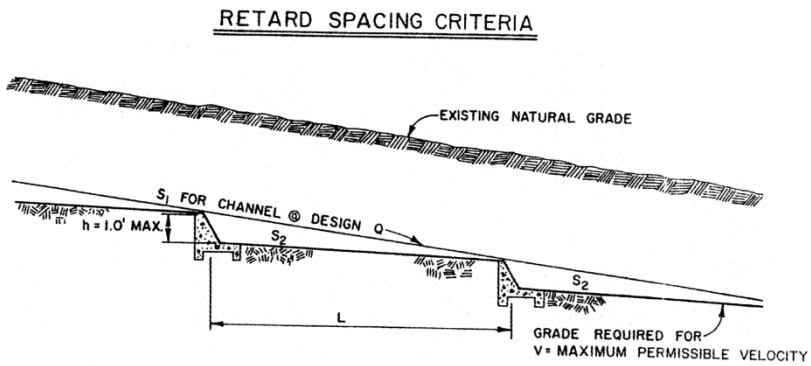


Figure 9.3.6.1 - Retard Spacing Criteria

(Equation 9.3.6.1.a)

~~*L = 1.0' / (S1 - S2)*~~

$$L = \frac{1.0'}{S_1 - S_2}$$

L = Distance required between retards in feet.

S_1~~*S1*~~ = Actual slope of channel in ft./ft.

S_2~~*S2*~~ = Slope of proposed channel for maximum permissible velocity established from Table 9.3.8 ~~504-8, i.e.:~~

And

(Equation 9.3.6.1.b)

~~$S2 = [(NV) / (1.486R^{2/3})]^2$~~

$$S_2 = \frac{NV^2}{(1.486R^{2/3})^2}$$

V = maximum permissible velocity established from Table 9.3.8 ~~504-8~~
N = channel n-value – normally 0.035 ~~.035~~
R = area/wetted perimeter

9.3.6.2 Concrete Channels with Drops

The design engineer should analyze channel drops to determine if the flow is or will become super critical along the channel. If the channel becomes super critical, the depth of the channel should contain the sequent depth.

9.3.7 Baffle Chutes

For concrete chutes on earthen side slopes, the following should be used for the design of the baffle blocks on the chute drop. The approach velocity to the chute should be less than critical velocity. The chute slope should fall between 2H:1V to 4H:1V. The maximum flow should be 60 cfs per foot of chute width.

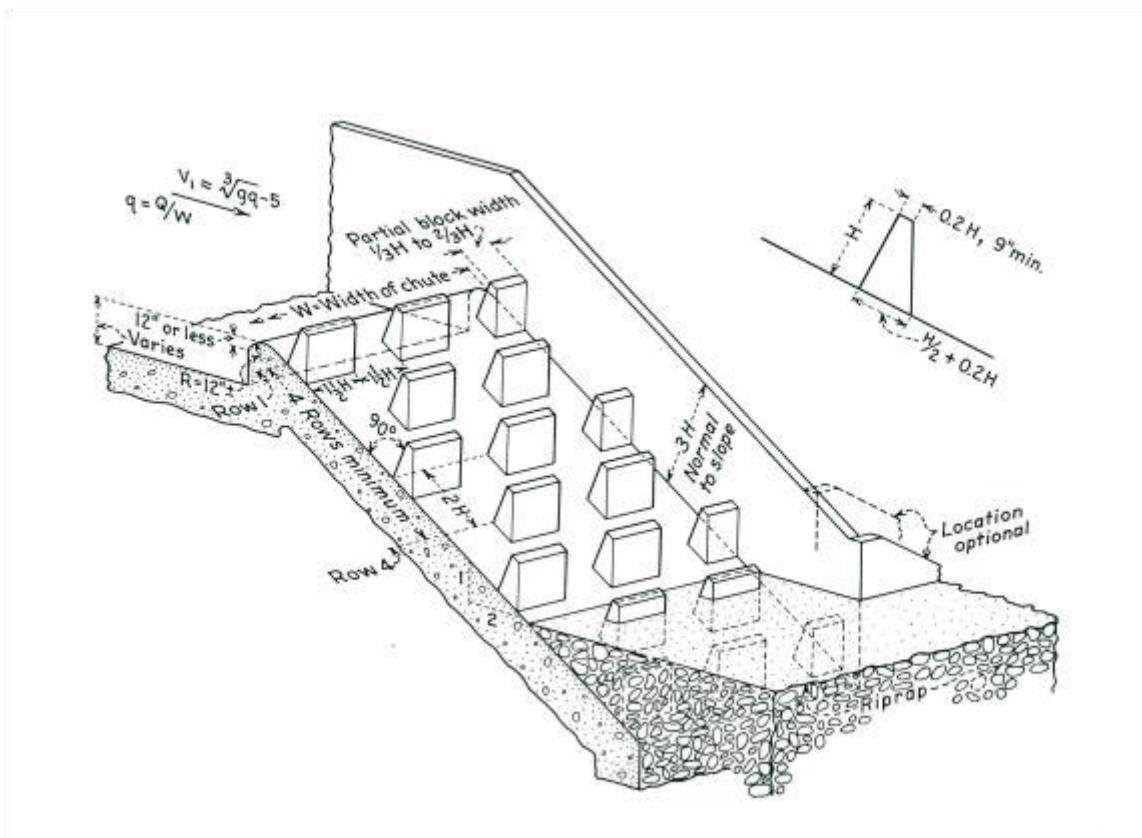


Figure 9.3.7 USBR Type IX Baffled Apron Peterka, 1978,
(Source FHWA, HEC-14 Hydraulic Design of Energy Dissipators)

The height of the blocks, H should range from 0.8 times the critical depth to 0.9 times critical depth. The width and spacing of the baffle block should be 1.5H, but not less than H. The chute blocks are to extend across the total width of the chute. The subsequent rows of blocks should be offset so the blocks lines up with the spacing of the upstream block. The spacing of the row of blocks should be 2H.

9.3.8 Channel Velocity

~~(h)(5)~~

The following ~~Velocity Criteria.~~ Table 9.3.8 ~~504-8~~ shall be used to determine maximum permissible channel velocity.

~~(h)(5)A.~~

Where velocities are in the supercritical range, allowance shall be made in the design for the proper handling of the storm water.

Table 9.3.8 ~~504-8~~ - Velocity Control

Velocity (fps)	Type of Facility Required	Hydraulic Radius (ft.)	Correction Factor	Maximum Permissible Velocity (fps)
1 to 6 (Maximum Average Velocity = 6 fps)	Vegetated Earthen Channel	0-1 1-3 3-5 5-8 8-10 Over 10	0.8 0.9 1.05 1.15 1.225 1.25	5 5.5 6.3 6.9 7.35 7.5
***6 to 12**	Turf Reinforcement Mat (TRM)	N/A	N/A	12
6 to 8	Concrete Retards	N/A	N/A	N/A
>8	Concrete Lining or Drop Structures	N/A	N/A	N/A
**If Turf Reinforcement Mat (TMR) is proposed, please see City of San Antonio Standard Specifications for Construction Item 554 for submittal requirements. The improvement plan sheets should include the location of the placement, details, and manufacturer's installation instructions.*				

* If Turf Reinforcement Mat (TRM) is proposed, please see City of San Antonio Standard Specifications for Construction Item 554 for submittal requirements. The improvement plan sheets should include the location of placement, details, and manufacturer's installation instructions. The use of velocity protection devices other than TRM shall be submitted to and approved by the Director of TCI prior to approval of construction plans.

9.3.9 Low Flow Channels

~~(h)(8)F.~~

Earthen channels ~~For vegetated earthen channels~~ with longitudinal slopes less than 0.5 percent or bottom widths greater than thirty (30) feet, concrete pilot channels shall be provided. The minimum bottom width of the pilot channel shall be six (6) feet ~~four (4) foot~~. The minimum [earthen] slope draining toward the pilot channel shall be one (1) percent.

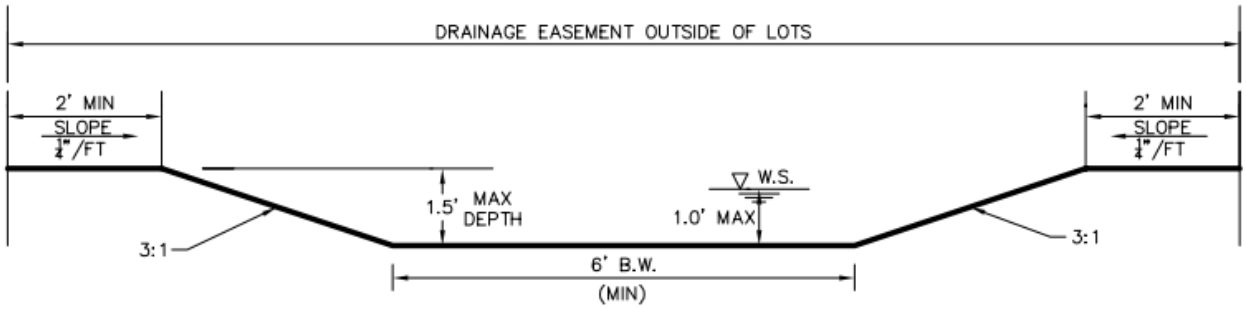
9.3.10 Interceptor Channel

~~(d)(6) Interceptor Easements.~~

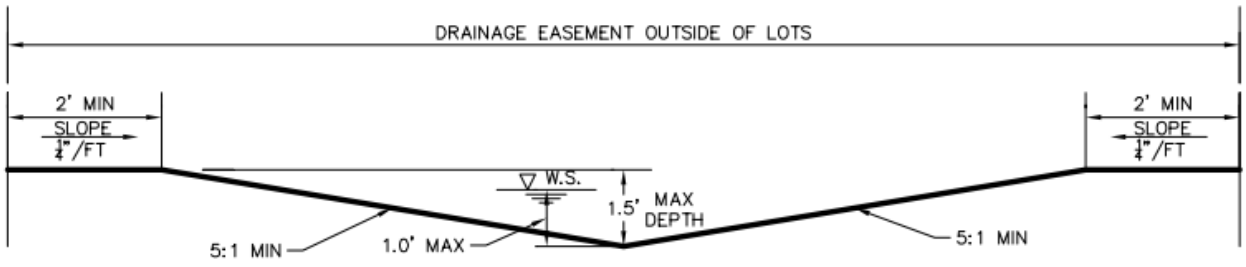
Interceptor channels ~~Drainage easements~~ for proper conveyance of upstream storm water ~~stormwater~~ sheet flow ~~runoff~~ shall be required on all subdivision plats where upstream contributing area exceeds the criteria indicated below. Interceptor channels ~~drains~~ shall be constructed prior to the issuing of building permits on any lot that would intercept natural drainage.

A. Interceptor ~~drainage easements and~~ channels shall be provided for residential subdivisions where the drainage area to the back of platted lots exceeds the depth of two (2) average residential lots with equivalent zoning.

B. Interceptor channels ~~drainage easements~~ shall be required on nonresidential subdivision plats where the off-site drainage area contributing to the proposed development exceeds three (3) acres. ~~If necessary, an amending plat may be used to correct drainage easements in conjunction with building permits.~~



TRAPEZOIDAL CHANNEL



"V"–SHAPED CHANNEL

Figure 9.3.10 - Standard for interceptor drains for intercepting sheet flow

9.3.11 Channel Transitions

Channel transitions can occur upstream and downstream of a culvert or bridge, with the contraction and expansion of the flow. The expansion and contraction coefficients at these transitions should be increased to account the energy loss. An analysis of the water surface through a channel transition should be modeled if the flow is subcritical or supercritical to determine any increase in water surface that may exceed the top of channel or impact to adjoining properties.

Another channel transition to be analyzed is a drop curb opening discharging into the downstream channel. The modeling of the transition is necessary to determine if the hydraulic grade line at the property line is below the gutter and the energy line at the property line is below the top of curb.

9.3.12 Channel Linings

The design of flexible linings described in sections 9.3.12.1, 9.3.12.2, 9.3.12.3, and 9.3.12.4 can be found in FHWA HEC-15, Design of Roadside Channels with Flexible Linings.

9.3.12.1 Grass

The grass lined channel should have grasses as described in 17.2.1 and with good, deep root structure to stabilize the soil from erosive velocities.

9.3.12.2 Turf Reinforcement

There are a number of turf reinforcement mats (TRM) and high performance turf reinforcement mats (HPTRM) that is available to the design engineer. Selection and installation of the TRM or HPTRM is critical to the stability of the earthen channel. The TRM will provide scour protection and enhance the vegetative root and stem development.

9.3.12.3 Rubble Rip Rap

Rock rip rap or rubble rip rap can be used to protect against erosion downstream of energy dissipaters or at other locations along the channel bottom or side slopes. The rock rip rap is placed on a filter blanket and should be hard, durable, and angular. The filter blanket is to keep the subgrade soil from migrating into the rock rip rap. The thickness of the rip rap section should be between 1.5 to 3 times the mean rip rap diameter and no less than the largest rock size. The rip rap should have a proper distribution of sizes in the gradation so that the smaller stones will fill the voids of the larger stones.

9.3.12.4 Gabions

Gabions are rock filled wire baskets or mattresses. The gabions can be used similar to rock rip rap, but usually the size of rocks are of a smaller diameter. A filter blanket below the basket or mattress is required to keep the subgrade soil from migrating into the gabions. The

gabions shall be installed per the manufactures instructions and proper anchoring and toe downs are required.

9.3.12.5 Concrete

The lining of a channel with concrete may be necessary for erosive velocities, or confined channel areas.

~~(h)(7)C.~~

For normal conditions, the concrete lining shall be a minimum of five (5) inches thick and reinforced with No. 3 round bars at twelve (12) inches on center each way. Where surcharge, nature of ground, height and steepness of slope, etc., become critical, design shall be in accordance with latest structural standards. All concrete lining shall develop a minimum compressive strength of not less than three thousand (3,000) pounds per square inch in twenty-eight (28) days. ~~The depth of all toe downs shall be thirty six (36) inches upstream, twenty four (24) inches downstream, and eighteen (18) inches for side slopes. The city's construction inspector may permit an eighteen-inch toe down in rock subgrade in lieu of the above toe down requirements. The horizontal dimensions (thickness) of toe downs shall not be less than six (6) inches.~~

9.3.13 Channel Stability

A stable earthen channel is essential for low maintenance. The velocities shown in table 9.3.8 should not be exceeded without additional surface treatment.

There are areas within Bexar County that have non-cohesive soils and are susceptible to erosion. These non-cohesive soils may need additional surface treatment. To increase the soil stability within these soil types, a lesser velocity or different channel geometry may be needed.

9.3.14 Freeboard

~~(h)(7)~~

Table 9.3.14 ~~504-9~~ - Drainage Freeboard for Concrete Lined and Earth Channels for Twenty-Five-Year Storm

Design Depth of Flow	Required Freeboard
0 to 5 feet	0.5 foot
5 to 10 feet	10% of design depth
10 feet and over	1.0 foot

~~(h)(8)A.~~

Freeboard for earthen channels consistent with Table 9.3.14 ~~504-9~~ will be applied to the twenty-five-year design.

See section 9.3.15 for additional freeboard required at channel bends and turns.

9.3.15 Super Elevation

~~(h)(9)~~

Channel Bends and Turns - Freeboard. Allowance for extra freeboard shall be made when the centerline radius of the channel is less than three (3) times the bottom width or for super-critical flow regime. Where ~~sharp~~ bends or high velocities are involved and the flow regime is sub-critical, the applicant shall use the following formula for computing the extra freeboard:

(Equation 9.3.15)

$$d_2 - d_1 = V^2(T + B) / 2gR$$

d1 = depth of flow at the inside of the bend in feet.
d2 = depth of flow at the outside of the bend in feet.
B = bottom width of the channel in feet.
V = the average approach velocity in the channel in feet per second.
T = width of flow at the water surface in feet.
g = 32.2 feet/second squared.
R = the center line radius of the turn or bend in feet.

A. The quantity d_2-d_1 divided by two (2) shall be added to the normal depth of flow before adding the required freeboard in calculating required right-of-way widths.
B. Where sharp turns are used without curved sections, the depth required shall be large enough to provide for all head losses. Allowance shall be made for any backwater head that may result.
C. ~~For normal design conditions no extra freeboard is required where centerline radius of channel should be at least three (3) times the bottom width.~~ For critical and super-critical flow regimes, the extra freeboard calculated with the above formula shall be doubled.

9.3.16 Utilities – Scour And Buoyancy

Utilities should be checked for scour depth and buoyancy of conduits that are within a floodplain or drainage channel.

9.3.16.1 Scour

The scour analysis for the underground utility line will determine the maximum probable depth of bed scour that could expose or undercut the line. Should the analysis show the depth

of scour to impact the utility line, concrete encasement or other measures may be needed to mitigate the scour.

(Equation 9.3.16.1)

$$d_s = d_m\left(\frac{V_m}{V_c} - 1\right)$$

d_s = Scour Depth below stream bed (ft.)

d_m = Mean Depth (ft.) - depth of flow in channel

V_m = Mean velocity (fps) – velocity of flow in channel

V_c = Shear velocity (fps) – competent velocity

Table 9.3.16.1 - Tentative guide to competent velocities for erosion of cohesive materials*
(after Neill, 1973, Source USBR "Computing Degradation and Local Scour", 1984)

Depth of flow (ft)	Competent mean velocity		
	Low values - easily erodible material (ft/s)	Average values (ft/s)	High values - resistant material (ft/s)
5	1.9	3.4	5.9
10	2.1	3.9	6.6
20	2.3	4.3	7.4
50	2.7	5.0	8.6

* Notes: (1) This table is to be regarded as a rough guide only, in the absence of data based on local experience. Account must be taken of the expected condition of the material after exposure to weathering and saturation. (2) It is not considered advisable to relate the suggested low, average, and high values to soil shear strength or other conventional indices, because of the predominating effects of weathering and saturation on the erodibility of many cohesive soils. (D)

9.3.16.2 Buoyancy

The buoyancy analysis will determine the stability of the conduit in the stream bed to resist floatation. If the analysis shows possible floatation of the conduit, additional anchorage should be added.

(Equation 9.3.16.2)

$$\frac{\pi}{4}\left(B_c^2 - d^2\right)w_p + H(B_c)\left(1 - \frac{1}{g_e}\right)w_e \geq SF\left(\frac{\pi}{4}B_c^2 w_w\right)$$

Bc = outside pipe diameter (ft)
d = inside pipe diameter (ft)
wp = unit weight of pipe material in air (lb/ft^3)
H = soil cover over pipe (ft)
ge = specific gravity of backfill particles
we = bulk unit weight of dry backfill (lb/ft^3)
SF = safety factor
ww = unit weight of water (lb/ft^3)

The following design values are suggested:
wp = 150 lb/ft^3
ge = 2.65
we = 110 lb/ft^3
SF = 1.5 if overburden is used to offset buoyancy
ww = 62.4 lb/ft^3

9.4 MAINTENANCE CONSIDERATIONS

See Chapter 4.12 for additional guidance on maintenance standards.

9.4.1 Access

~~(d)(3) Natural Watercourses or Floodplains.~~
~~Easements for natural watercourses shall be the 100-year floodplain or the twenty-five-year plus freeboard (see Table 504-9 of this section) whichever is less. In floodplain areas where ongoing maintenance is required or the floodplain will be reserved for use by the public, the drainage easements shall be maintained by a public entity and the property will be dedicated to the city as a multi-use drainage easement.~~ A drivable access way shall be provided in ~~floodplain~~ drainage easements for the length of the easement when regular maintenance of the floodplain is required.

~~(d)(4)~~
Maintenance Access Right-of-Way. An unobstructed access right-of-way connecting the drainage easement with an alley or roadway parallel to or near the easement shall be provided at a minimum spacing of one (1) access right-of-way at approximately one thousand-foot intervals. The access right-of-way shall be a minimum of fifteen (15) feet in width and shall be maintained clear of obstructions that would limit maintenance vehicular access. If the flow line of the designed channel incorporates grade control structures or vehicular bridges that would prevent maintenance equipment from accessing that portion of the channel, additional access points may be required. Channel design, earthen or concrete, shall have ramps in the side slopes near the access points that would allow maintenance equipment to descend to the floor level of the channel. The maximum allowable ramp slope for vehicular access is seven

to one ~~1~~ (H7:V1). Access points adjacent to roadways or alleys shall be provided with a post and cable feature with padlock to prevent unauthorized use.

9.4.2 Schedule

~~(h)(3)~~

~~Maintenance.~~ Design of new channels or alterations to existing channels shall consider future maintenance requirements. A maintenance schedule for any private channel shall be submitted to and approved by the Director director of TCI ~~public works~~ prior to approval of construction plans. Maintenance requirements of concrete channels consist of de-silting activities, prevention of vegetation establishment in construction joints, and repair of concrete as necessary. Maintenance of earthen channels includes regular observation and repair, as necessary, of erosion, scouring, and removal of silt deposits, as necessary to maintain design parameters. Developers shall be responsible for maintaining newly planted channels until coverage is established throughout eighty-five (85) percent of the area. This area shall include slopes, floor, and any attendant maintenance easement. New earthen channels shall be planted with grass species per section 17.2.1. ~~drought resistant, low growth, native species grasses, which will allow unobstructed passage of floodwaters. Johnson grass, giant tagweed and other invasive species shall not be allowed to promulgate in channels. Suggested species shall include, but not be limited to, common bermuda, coastal bermuda, buffalo grass, sideoats grama, seep muhly, little bluestem, and indian grass.~~ Mowing frequencies vary with the vegetation growth rates, but is required when the grass exceeds the design roughness coefficient of the channel.

9.5 REFERENCES

9.5.1 Reference Citations

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B. UDFCD. Major Drainage in *Urban Storm Drainage Criteria Manual Volume 1*. Urban Drainage and Flood Control District, Denver, Colorado, April 2008.
C. FHWA. *Hydraulic Design of Energy Dissipators for Culverts and Channels*. Hydraulic Engineering Circular No. 14. 3rd edition. FHWA-NHI-06-086. Federal Highway Administration, Department of Transportation, Washington, DC, July 2006.
D. US Bureau of Reclamation. *Computing Degradation and Local Scour – Technical Guideline for Bureau of Reclamation*. Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado, Jan. 1984.

9.5.2 References

- FHWA. *Design of Roadside Channels with Flexible Linings*. Hydraulic Engineering Circular No. 15, 3rd edition, FHWA-NHI-05-114. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, Sept. 2005.

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CHAPTER 10
CULVERTS

10.1 INTRODUCTION

The function of a culvert is to convey surface water under a highway, railroad, or other embankment. In addition to the hydraulic function, the culvert must carry construction, highway, railroad, or other traffic and earth loads. This chapter describes the hydraulic aspects of culvert design, construction and operation of culverts, and references structural aspects as they are related to the hydraulic design.

Any culvert with a clear opening of more than twenty (20) feet, measured along the center of the roadway between inside of end walls, is considered a bridge by FHWA and is designated as a bridge class culvert.

Culverts are available in a variety of sizes, shapes, and materials. These factors, along with several others, affect their capacity and overall performance. Sizes and shapes may vary from small circular pipes to extremely large box culvert sections that are sometimes used in place of bridges.

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

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

A careful approach to culvert design is essential, both in new land development and retrofit situations, because culverts often significantly influence upstream and downstream flood risks, floodplain management, and public safety.

~~(g)(7)A.~~
~~Where proposed streets cross existing or proposed watercourses, all-weather crossings shall be required.~~ All-weather crossings will be required where proposed streets cross existing or proposed water courses. Culverts ~~or bridges~~ ~~shall be adequate to allow~~ should be capable of allowing passage of the design storm identified in Chapter 10.3.1. ~~subsection 35-504(b)(1).~~

10.2 HYDRAULICS OF CULVERTS

The placement of a culvert within a stream, creek, or channel should be such that the centerline of the culvert closely aligns with the center line of the stream; while this will

minimize the impact to the stream it may also skew the culvert to the roadway centerline. The placement of culvert(s) should be modeled with an appropriate hydraulic model to determine impacts both upstream and downstream of the crossing.

Existing culverts downstream of a site must be analyzed for project impacts if the culvert is within the reach downstream of the proposed development per section 4.3.1C.

10.3 DESIGN GUIDELINES

10.3.1 Design Frequency

The culvert(s) should be designed for the ultimate twenty-five (25) year storm if the drainage area to the culvert crossing is less than one hundred (100) acres. If the drainage area to the culvert(s) is more than one hundred (100) acres, the system should be designed for the ultimate one hundred (100) year storm. Channels upstream and downstream of culverts must contain the design storm and freeboard.

10.3.2 Inlet Control

Inlet or entrance control occurs when a culvert is capable of carrying more flow than the inlet will accept and the culvert is hydraulically steep (critical depth is greater than normal depth).

When the culvert is under inlet control, the control section is just inside the entrance of the culvert. If the flow of the culvert is a free surface flow, then critical depth will occur at or near the control section. Downstream of the control section and a free surface flow, the flow will be supercritical and a hydraulic jump may occur within the culvert.

Inlet control can become outlet control when the tail water depth is above the soffit or crown of the culvert entrance and a full flow condition exists in the culvert.

TxDOT uses a fifth-degree polynomial equation based on regression analysis to define the inlet control headwater for a give flow. This equation is used for the ratio of HWi/D greater than one-half (0.5) and less than three (3). The following equations from TxDOT are provided as a reference.

(Equation 10.3.2.a)

$$\mathbf{HW_{ic} = [a + bF + cF^2 + dF^3 + eF^4 + fF^5]D - 0.5DS_o}$$

HW_{ic} = inlet control headwater (ft.)
D = rise of the culvert (ft.)
a to f = regression coefficients for each type of culvert, see TxDOT manual for coefficients
S_o = culvert slope (ft./ft.)
F = function of average outflow discharge, culvert rise and width

(Equation 10.3.2.b)

$$F = 1.8113\frac{Q}{WD^{1.5}}$$

W = width of the culvert (ft.)

For the ratio of HW_i/D greater than three (3), use Equations 10.3.2.c and 10.3.2.d on the following page to estimate the headwater. Equation 10.3.2.c is an orifice equation.

(Equation 10.3.2.c)

$$HW_i = \left[\frac{Q}{k}\right]^2 + \frac{D}{2}$$

$\mathbf{HW_i}$ = inlet control headwater (ft.)
Q = design discharge (cfs)
k = orifice equation constant
D = culver rise (ft.)

(Equation 10.3.2.d)

$$k = 0.6325\frac{Q_{3.0}}{D^{0.5}}$$

$\mathbf{Q_{3.0}}$ = discharge (cfs)

10.3.3 Outlet Control

Outlet or exit control occurs when a culvert is not capable of carrying as much flow as the inlet will accept and the culvert is hydraulically mild slope (normal depth is greater than critical depth).

When the culvert is under outlet control, the hydraulic grade line inside the culvert at the entrance exceeds critical depth. The headwater of a culvert with outlet control is determined by the frictional slope, entrance and exit geometry, and tail water level.

(Equation 10.3.3.a)

$$HW_{oc} = h_e + h_{vi} + \sum h_f - S_o L + H_o - h_{va}$$

$\mathbf{HW_{oc}}$ = headwater depth due to outlet control (ft.)
$\mathbf{h_{va}}$ = velocity head of flow approaching the culvert entrance (ft.)
$\mathbf{h_{vi}}$ = velocity head in the entrance (ft.)

h_e = entrance head loss (ft.)
h_f = frictional head losses (ft.)
S_o = culvert slope (ft./ft.)
L = culvert length (ft.)
H_o = depth of hydraulic grade line just inside the culvert at outlet (ft.)

(Equation 10.3.3.b)

$$h_v = \left[\frac{v^2}{2g}\right]$$

h_v = velocity head (ft.)
v = velocity (fps)
g = gravitational acceleration (32.2 ft./s^2)

When tail water controls, the following formula includes the exit loss.

(Equation 10.3.3.c)

$$H_o = TW + h_{TW} + h_o - h_{vo}$$

H_o = water surface at outlet
h_{vo} = velocity head inside culvert at outlet (ft.)
h_{TW} = velocity head in tail water (ft.)
h_o = exit head loss (ft.)

The outlet depth, H_o is the hydraulic grade line inside the culvert outlet. The conditions in Table 10.3.3 will determine the outlet depth.

Table 10.3.3 - Outlet Depth Conditions
(Source TxDOT, Hydraulic Design Manual, 2011)

If	And	Then
Tailwater depth (TW) exceeds critical depth (d_c) in the culvert at outlet	Slope is hydraulically mild	Set H_o using Equation 10.3.3.c, using the tailwater as the basis.
Tailwater depth (TW) is lower than critical depth (dc) in the culvert at outlet	Slope is hydraulically mild	Set Ho as critical depth.
Uniform depth is higher than top of the barrel	Slope is hydraulically steep	Set H_o as the higher of the barrel depth (D) and depth using Equation 10.3.3.c.
Uniform depth is lower than top of barrel and tail-water exceeds critical depth	Slope is hydraulically steep	Set Ho using Equation 10.3.3.c.
Uniform depth is lower than top of barrel and tail-water is below critical depth	Slope is hydraulically steep	Ignore, as outlet control is not likely.

10.3.4 Energy Losses through Culvert

There are four (4) different flow conditions that are considered occurring within the culvert, free surface flow, full flow in conduit, full flow at outlet and free surface flow at inlet, and free surface at outlet and full flow at inlet. These conditions are further explained on the following pages.

10.3.4.1 Free Surface Flow – Type A

With a free surface flow occurring in the culvert a standard step backwater can be used to calculate the water surface through the culvert to the entrance. With this condition the backwater profile is based on the outlet depth. Normal depth is within the culvert.

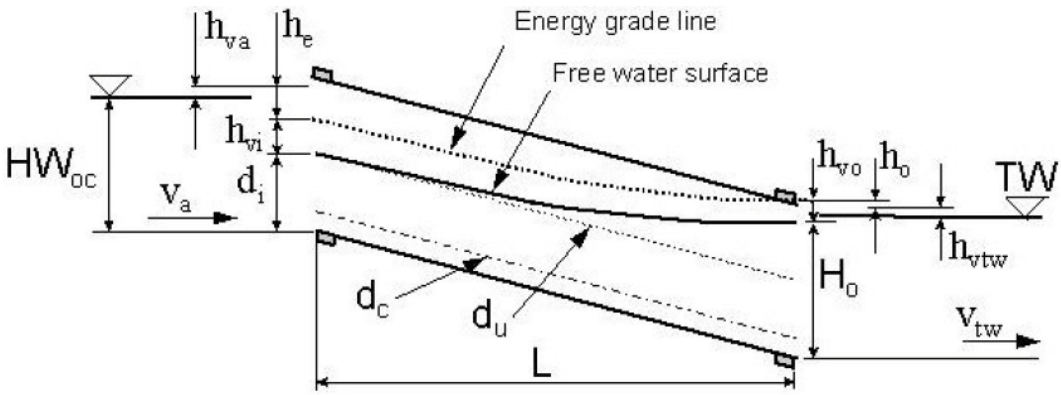


Figure 10.3.4.1 - Outlet Control Headwater for Culvert with Free Surface
(Source TxDOT, Hydraulic Design Manual, 2011)

The headwater may be affected only when the culvert is in subcritical flow, backwater from the culvert outlet is present, and if the culvert is on a steep slope with a tail water higher than critical depth and lower than the soffit of the culvert outlet.

10.3.4.2 Full Flow in Conduit – Type B

If the full flow condition exists within the length of the culvert then the hydraulic grade line will be at above the soffit. The hydraulic grade line at the culvert outlet is based on the outlet depth (H_o) being at or above the soffit at the outlet.

Use the Equation 10.3.4.2.c on the following page to calculate the frictional slope of the culvert. If the frictional slope is less than the culvert slope, the hydraulic grade line may drop below the soffit of the culvert. If this condition exists then the culvert flow may be Type BA.

The frictional loss through the culvert is determined by Equation 10.3.4.2.a.

To determine the hydraulic grade line at the upstream end of the culvert, at the inlet use Equation 10.3.4.2.b. To obtain the headwater elevation the entrance loss will need to be calculated. See Energy Balance at Inlet section.

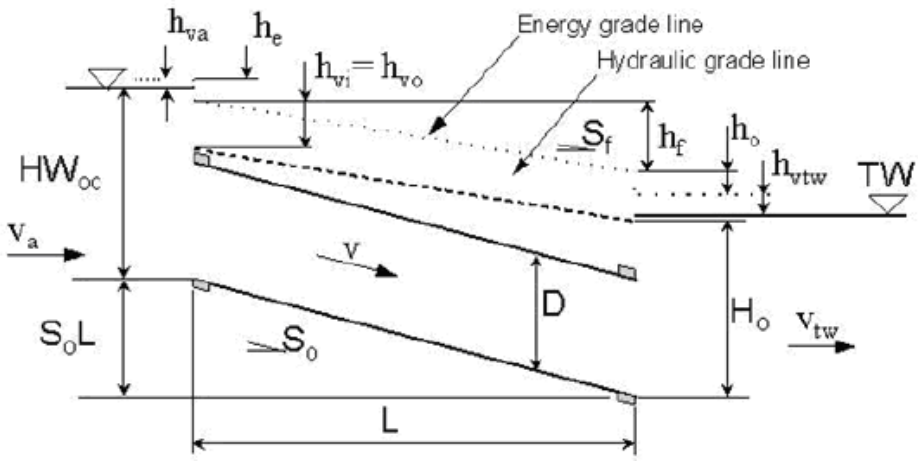


Figure 10.3.4.2 - Outlet Control, Fully Submerged Flow
(Source TxDOT, Hydraulic Design Manual, 2011)

(Equation 10.3.4.2.a)

$$h_f = S_f L$$

h_f = head loss due to friction in the culvert barrel, ft.
S_f = friction slope, ft. (See Equation 10.3.2.2.3)
L = length of culvert containing full flow, ft.

(Equation 10.3.4.2.b)

$$H_i = H_o + h_f - S_o L$$

H_i = depth of hydraulic grade line at inlet (ft.)
Hf = friction head losses (ft.) (calculated using Equation 10.3.2.2.1)
So = culvert slope (ft./ft.)
L = culvert length (ft.)
Ho = outlet depth (ft.)

(Equation 10.3.4.2.c)

$$S_f = \left(\frac{Qn}{1.486R^{2/3}A}\right)^2$$

S_f = friction slope (ft./ft.)
Q = flow in pipe (cfs)
n = Manning's 'n'-value
A= Area of the pipe (ft^2)
R= Hydraulic Radius (A/P_W) (ft.)

10.3.4.3 Full Flow at Outlet and Free Surface Flow at Inlet – Type BA

If the frictional slope is less than the culvert slope and the outlet depth (H_o) is greater than the soffit of the culvert at the outlet then the culvert may flow full for a portion of its length.

First determine the length of full flow using Equation 10.3.4.3.a.

(Equation 10.3.4.3.a)

$$L_f = \frac{H_o - D}{S_o - S_f}$$

L_f = length over which full flow occurs (ft.)
S_o = culvert slope (ft./ft.)
S_f = friction slope (ft./ft.)
H_o = outlet depth (ft.)
D = Conduit barrel height (ft.)

Should the length L_f be greater than the culvert length, the culvert is flowing full for its entire length, see Type B calculations on the previous page. If the length of L_f is less than the culvert length, a free surface flow begins a point along the culvert at a distance of L_f from the culvert outlet. From this point up to the culvert inlet the water surface can be calculated using the standard step backwater method.
With the water surface (H_i) or d_i (shown on Figure 10.3.4.3 below) at the culvert inlet, the headwater elevation at the entrance can be calculated. See Energy Balance at Inlet section 10.3.5 on following page.

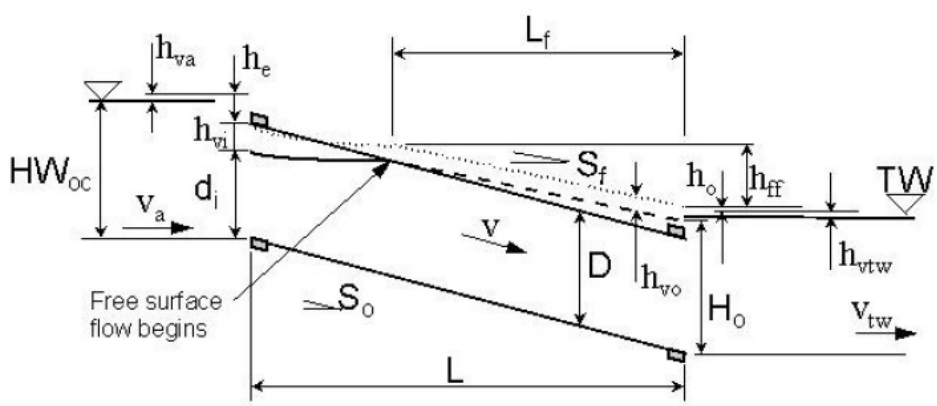


Figure 10.3.4.3 - Point at Which Free Surface Flow Begins
(Source TxDOT, Hydraulic Design Manual, 2011)

10.3.4.4 Free Surface at Outlet and Full Flow at Inlet – Type AB

If the frictional slope is greater than the culvert slope and the outlet water surface H_o is less than the culvert soffit at the outlet, calculate the H_i using the following steps.

Step 1 – Start with the outlet depth H_o and
Step 2 – Use a standard step backwater to determine the point along the conduit where the water surface will intersect the soffit.
Step 3 – At this point along the culvert length, the remaining culvert length L_f is substituted for L in the Equation 10.3.4.2.b to determine h_{ff} in Figure 10.3.4.4.
Step 4 – With the hydraulic grade line at the culvert inlet, the headwater elevation at the entrance can be calculated. See Energy Balance at Inlet section for further calculations.

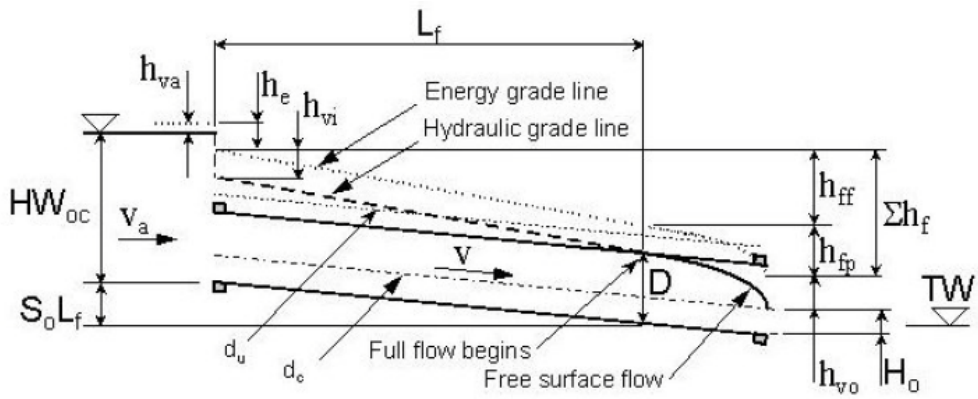


Figure 10.3.4.4 - Headwater due to Full Flow at Inlet and Free surface at Outlet
(Source TxDOT, Hydraulic Design Manual, 2011)

10.3.5 Energy Balance at Inlet

The culvert inlet headwater (HW_{oc}) can be calculated using the energy Equation 10.3.5.a below. With the hydraulic grade line at the culvert entrance (calculated from section 10.3.4)- the velocity head at the entrance (h_{vi}) can be calculated.

(Equation 10.3.5.a)

$$HW_{oc} = H_i + h_{vi} + h_e - h_{va}$$

HW_{oc} = headwater depth due to outlet control (ft.)
h_{va} = velocity head of flow approaching the culvert entrance (ft.)
h_{vi} = velocity head in the entrance (ft.) (calculated using Equation 10.3.3.b)
h_e = entrance head loss (ft.) (calculated using Equation 10.3.5.b)
H_i = depth of hydraulic grade line just inside the culvert at inlet (ft.)

Generally the approach velocity of the upstream channel to the culvert inlet can be assumed to be zero (0), thus the headwater and energy grade line are equal. This is a conservative approach for a headwater depth. The design engineer can calculate the approach velocity and determine the appropriate headwater.

The entrance loss should be calculated using Equation 10.3.5.b on the following page.

(Equation 10.3.5.b)

$$h_e = C_e \left[\frac{V_i^2}{2g}\right]$$

h_e = entrance loss
C_e = entrance loss coefficient
V_i = flow velocity inside culvert inlet (fps)

The values of C_e are shown below on Table 10.3.5.

Table 10.3.5 - Entrance Loss Coefficients (C_e)
(Source FHWA "Hydraulic Design of Highway Culverts",3rd ed.)

Type of Structure and Design of Entrance	Coefficient C_e
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = D/12)	0.2
Mitered to conform to fill slope	0.7
End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Pipe or Pipe-Arch Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of D/12 or B/12	
or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of D/12 or beveled top edge	0.2
Wingwall at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

10.3.6 Determination of Outlet Velocity

The outlet velocity is based on the discharge and the cross sectional area at the outlet. See Equation 10.3.6.

(Equation 10.3.6)

$$v_o = \frac{Q}{A_o}$$

v_o = outlet velocity (ft/s)
Q = culvert discharge (cfs)
A_o = cross-sectional area of flow at outlet (ft^2)

There are a few conditions to consider for determining the depth (d_o) at the outlet.

If the tail water at the outlet is above the culvert outlet soffit or the culvert is flowing full due to the culvert capacity is less than the discharge, then the depth (d_o) is equal to the barrel rise (D) and the full cross sectional area of the culvert is used. See Figure 10.3.6.B on the following page.

If the tail water at the outlet is below the culvert outlet soffit, determine the critical depth of the culvert. Set the depth (d_o), to the higher of tail water or critical depth.

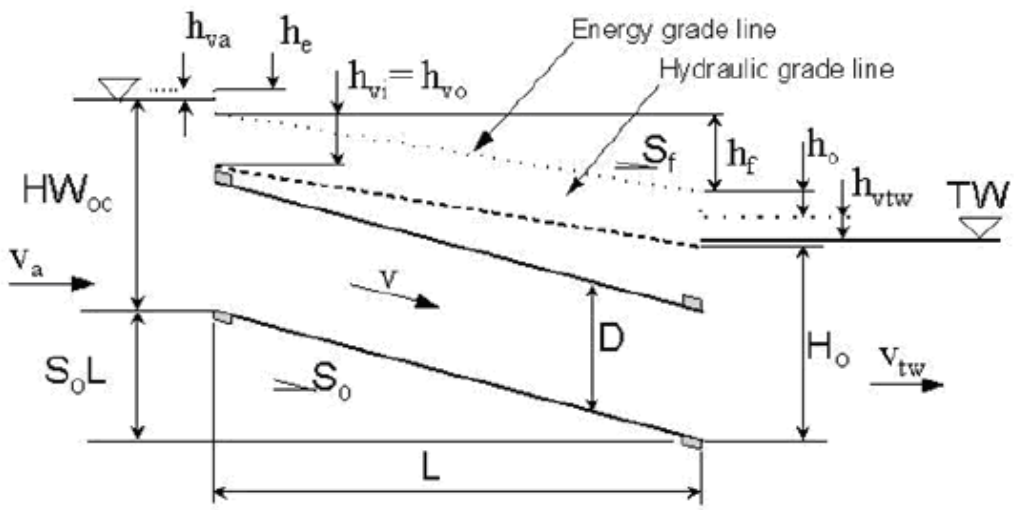


Figure 10.3.6.A - Cross Sectional Area based on the Higher of Critical Depth and Tailwater
(Source TxDOT, Hydraulic Design Manual, 2011)

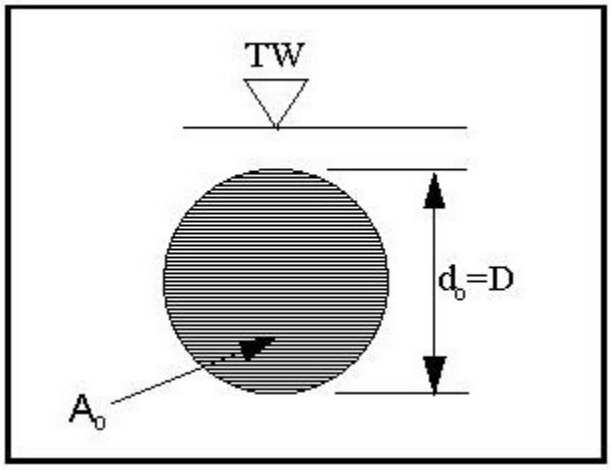


Figure 10.3.6.B - Cross Sectional Area Based on Full Flow
(Source TxDOT, Hydraulic Design Manual, 2011)

10.3.7 Depth Estimation Approaches

For inlet control under steep slope conditions, estimate the depth at the outlet using one of the following approaches: (A)

- Use a step backwater method starting from critical depth (d_c) at the inlet and proceed down-stream to the outlet. If the tail water is lower than critical depth at the outlet, calculate the velocity resulting from the computed depth at the outlet. If the tail water is higher than critical depth, a hydraulic jump within the culvert is possible. Section 10.3.11, Hydraulic Jump in Culverts, below discusses a means of estimating whether the hydraulic jump occurs within the culvert. If the hydraulic jump does occur within the culvert, determine the outlet velocity based on the outlet depth, $d_o = H_o$.
- Assume uniform depth at the outlet. If the culvert is long enough and tail water is lower than uniform depth, uniform depth will be reached at the outlet of a steep slope culvert. For a short, steep culvert with tail water lower than uniform depth, the actual depth will be higher than uniform depth but lower than critical depth. This assumption will be conservative; the estimate of velocity will be somewhat higher than the actual velocity. If the tail water is higher than critical depth, a hydraulic jump is possible and the outlet velocity could be significantly lower than the velocity at uniform depth.

10.3.8 Direct Step Backwater Method

The free flow water surface water within a culvert can be determined with the Direct Step Method describe in TxDOT "Hydraulic Design Manual". An increment (or decrement) of water depth (δd) is chosen and the corresponding distance over which the depth of change is computed. This method can be used for either supercritical or subcritical flow within a culvert.

10.3.9 Subcritical Flow and Steep Slope

If the culvert has a free water surface with a subcritical flow at the outlet and the culvert has a steep slope, then the water depth δd is negative in the computation (decrement). If the depth of flow reaches critical depth before reaching the culvert entrance, then the culvert is under inlet control. A hydraulic jump may occur in the culvert. If the depth of flow calculated at the culvert entrance is higher than the culvert critical depth, use Equation 10.3.5.a

10.3.10 Supercritical Flow and Steep Slope

If the culvert has supercritical flow and a steep slope, then begin the computation starting at the culvert entrance with critical depth and proceed downstream for the water surface computation. Use a decrement water depth δd in the computation. If the tail water is higher than the culvert critical depth a backwater may occur within the culvert.

10.3.11 Hydraulic Jump in Culverts

An example of a momentum and energy plot is shown in Figure 10.3.11 on the following page. For a given discharge there are two possible depths; the first is **less than critical depth** (supercritical flow) and the other is **greater than critical depth** (subcritical flow), a sequent (or conjugate) depth. Both depths will have the same momentum with different specific energy. If you have a supercritical flow in a culvert, the possibility of hydraulic jump can occur with the proper configuration. There will be a loss in energy, ΔE as a result of the hydraulic jump.

(Equation 10.3.11)

$$\mathbf{M} = \frac{\mathbf{Q}^2}{\mathbf{gA}} + \mathbf{A}\bar{\mathbf{d}}$$

M = momentum function
Q = discharge (cfs)
g = gravitational constant (32 ft./sec^2)
A = section area of flow (sq. ft.)
$\bar{\mathbf{d}}$ = distance from water surface to centroid of flow area (ft.)

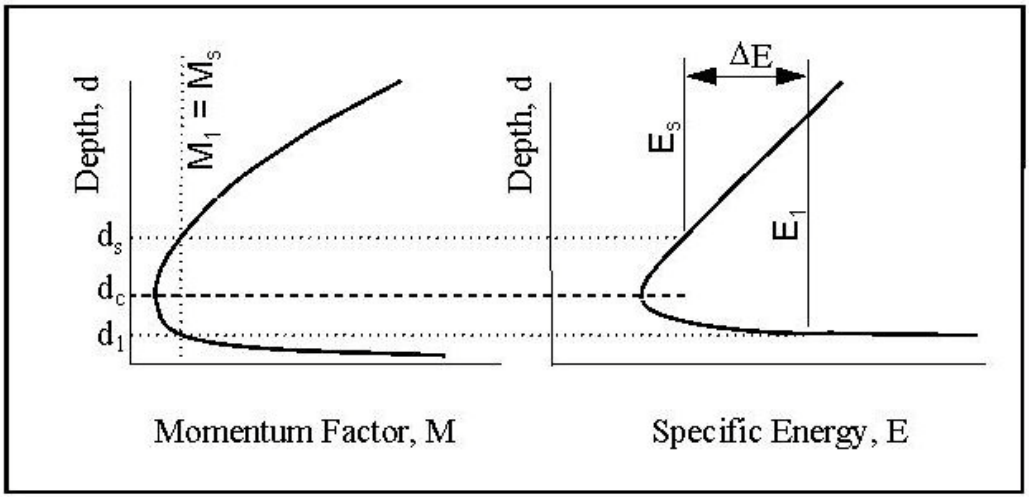


Figure 10.3.11 - Momentum Function and Specific Energy
(Source TxDOT, Hydraulic Design Manual, 2011)

10.3.12 Sequent Depth

If the culvert has a free surface flow and is supercritical, sequent depth can be calculated. For slopes greater than ten percent (10%) a more complex solution is required and is provide in FHWA HEC-14 "Hydraulic Design of Energy Dissipators".

To determine sequent depth within a rectangular culvert, use Equation 10.3.12.a below.

(Equation 10.3.12.a)

$$\mathbf{d_s = 0.5d_1\left(\sqrt{1 + \frac{8v_1^{\,2}}{gd_1}} - 1\right)}$$

$\mathbf{d_s}$ = sequent depth (ft.)
$\mathbf{d_1}$ = depth of flow (supercritical) (ft.)
$\mathbf{v_1}$ = velocity of flow at depth d (fps)

For a circular culvert the calculation to determine sequent depth is not a direct solution. An iterative solution of Equation 10.3.12.b, shown below, is used to calculate a discharge that will equal the design discharge.

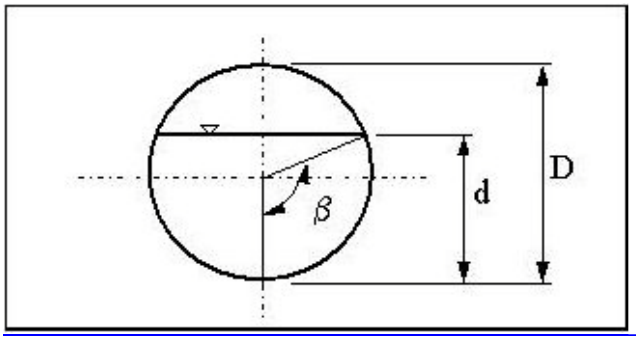


Figure 10.3.12 - Determination of Angle β *(Source TxDOT, Hydraulic Design Manual, 2011)*

(Equation 10.3.12.b)

$$Q^2 = \frac{g\left(A_s\bar{d}_s - A_1\bar{d}_1\right)}{1/A_1 - 1/A_s}$$

Q = discharge (cfs)
A_s = area of flow at sequent depth (sq.ft.)
$A_s\bar{d}_s$ = first moment of area about surface at sequent depth (cu.ft.)
$A_1\bar{d}_1$ = first moment of area about surface at supercritical flow depth (cu.ft.)

(Equation 10.3.12.c)

$$A\bar{d} = \frac{D^3}{24}\left(3\sin\beta - \sin\beta^3 - 3\beta\cos\beta\right)$$

$A\bar{d}$ = first moment of area about water surface (cu.ft.)
D = conduit diameter (ft.)
β = angle shown in Figure 10.3.12 and calculated using Equation 10.3.12.d.

(Equation 10.3.12.d)

$$\beta = \cos^{-1}\left(1 - \frac{2d}{D}\right)$$

(Equation 10.3.12.e)

$$A = \frac{D^2}{8}\left[2\cos^{-1}\left(1 - \frac{2d}{D}\right) - \sin\left(2\cos^{-1}\left(1 - \frac{2d}{D}\right)\right)\right]$$

10.3.13 Roadway Overtopping

When roadway overtopping occurs on an existing roadway, the design engineer should check the depth of flow over the roadway for the design storm and compare the depth to Figure 4.3.1C. A new development should not increase the depth of flow from the "Proceed with

Caution" to "Dangerous" conditions. If this condition occurs then some culvert or other drainage improvements may be needed to mitigate this "Dangerous" condition.

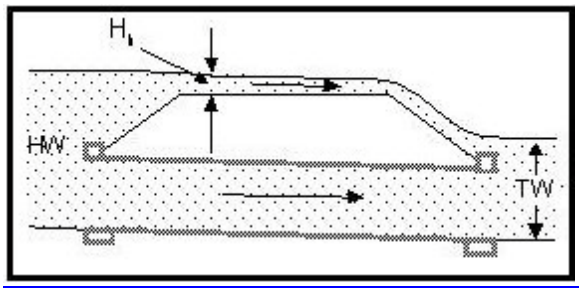


Figure 10.3.13.A - Culvert with Overtopping Flow
(Source TxDOT, Hydraulic Design Manual, 2011)

When the calculation of the culvert headwater, assuming the total discharge is going through the culverts, is above the low point of the roadway, a weir condition will develop. The calculation of the amount of flow that passes through the culvert and the remaining portion of flow that overtops the roadway is an iterative process.

Use the Weir Equation 10.3.13 to determine the average depth between headwater and low roadway elevation (H_h) for the roadway. The normal discharge coefficient for roadways should be 2.9.

(Equation 10.3.13)

$$Q = k_t C L H_h^{1.5}$$

Q = discharge (cfs)
k_t = over-embankment flow adjustment factor (see Figure 10.3.11.B)
C = discharge coefficient
L = horizontal length of overflow, ft. This length should be perpendicular to the over-flow direction.
H_h = average depth between headwater and low roadway elevation (ft.)

If the tail water is sufficiently high, the adjustment factor k_t would reduce the discharge over the roadway. For values of H_t/H_h below 0.8, the adjustment factor k_t is one (1). For roadway embankments as shown in Figure 10.3.13.D may need to be broken down into segments for the computation of the weir flow.

The use of HEC-RAS or other approved model can be used to determine the flow through the culvert and over the roadway.

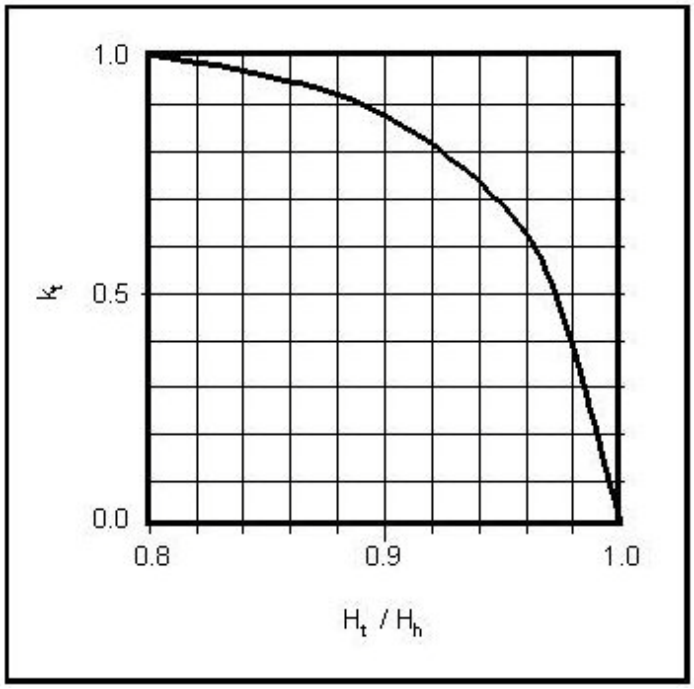


Figure 10.3.13.B - Over-Embankment Flow Adjustment Factor
(Source TxDOT, Hydraulic Design Manual, 2011)

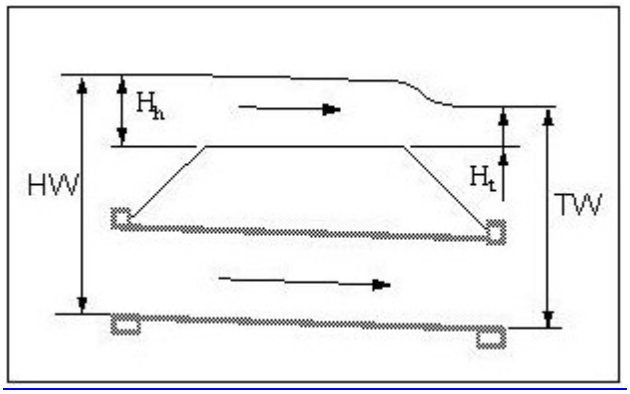


Figure 10.3.13.C - Roadway Overtopping with High Tailwater
(Source TxDOT, Hydraulic Design Manual, 2011)

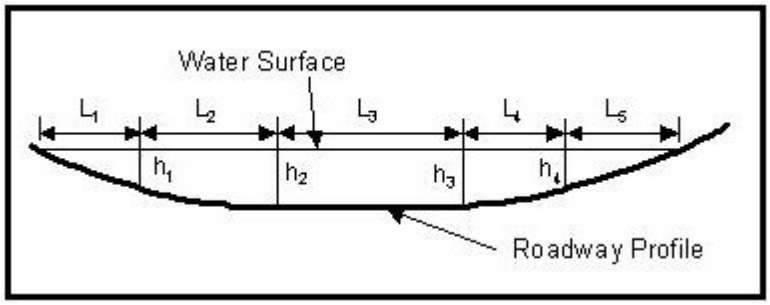


Figure 10.3.13.D - Cross Section of Flow over Embankment
(Source TxDOT, Hydraulic Design Manual, 2011)

10.3.14 Performance Curves

The performance curve is a combination of inlet and outlet control that will vary with the discharge.

A sample plot of the headwater versus discharge for inlet and outlet control of a culvert is shown in Figure 10.3.14 below. With varying discharge the culvert system may change from inlet control to outlet control. This information is useful for a risk assessment or routing a hydrograph through a detention basin with a culvert outlet.

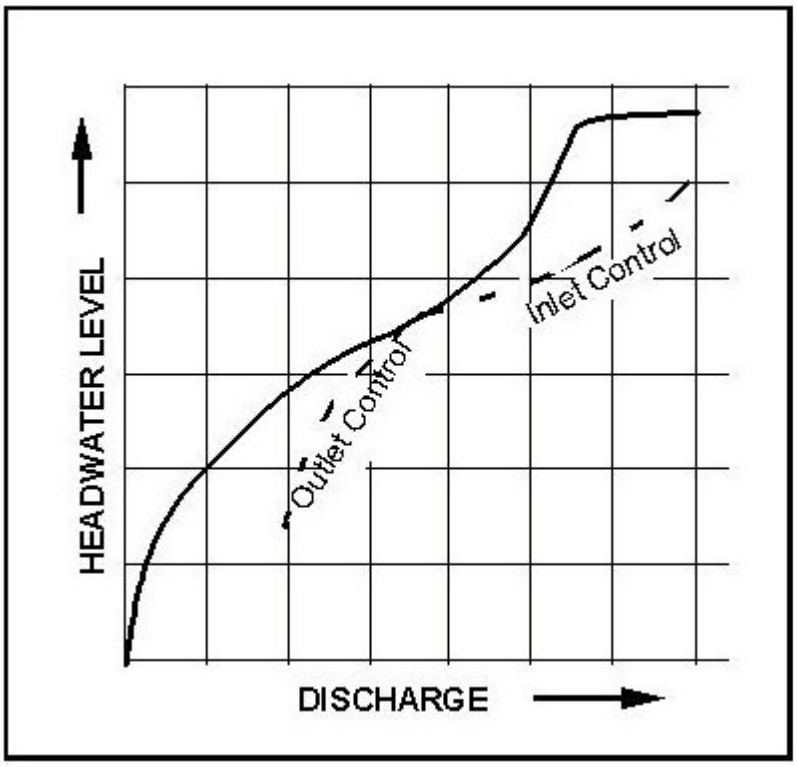


Figure 10.3.14 - Typical Performance Curve
(Source TxDOT, Hydraulic Design Manual, 2011)

10.3.15 Exit Loss Considerations

An exit loss should be considered at the hydraulic interface between the tail water and the culvert outlet. The exit loss coefficient varies from one-half (0.5) to one (1). The starting hydraulic grade line (H_o) at the interface between the outside and inside of the culvert outlet is based on Equation 10.3.15.a below.

(Equation 10.3.15.a)

$$\mathbf{H_o = TW + \frac{v_{TW}^2}{2g} + h_o - \frac{v_o^2}{2g}}$$

H_o = outlet depth - depth from the culvert flow line to the hydraulic grade line inside the culvert at the outlet (ft.)
v_o = culvert outlet velocity (fps)
v_{TW} = velocity in outfall (tail water velocity) (fps)
h_o = exit loss (ft.)

(Equation 10.3.15.b)

$$\mathbf{h_o = K\frac{v_o^2 - v_{TW}^2}{2g}}$$

K = loss coefficient which typically varies from 0.5 to 1

10.3.16 Materials and Specifications

10.3.16.1 Pipe Material

The pipe material selected must meet all the requirements found in the latest version of the City of San Antonio Standard Specifications. The use of HDPE pipe or PVC will not be allowed crossing under City streets or within street ROW unless approved by the Director of TCI.

Corrugated metal pipe must be checked for corrosion resistance. The use of corrugated metal pipe will not be allowed crossing under City streets or within street ROW unless approval of the Director of TCI. Asphalt lining or bituminous interior coated corrugated metal pipe will not be allowed.

10.3.16.2 Minimum Structural Loads

~~(g)(7)B.~~

All roadway crossings, culverts, and bridges shall be designed for an H-20-44 or HS-20 loading. All train crossings, culverts, and bridges shall be designed for a minimum of E80 or as designated by the railroad.

10.3.16.3 Mud Slab

A mud slab is a base slab of low strength concrete used to level up or stabilize the bottom of an excavation for the placement of multiple boxes or other structures. The mud slab is from two (2) to six (6) inches thick, or thicker if needed.

10.3.17 Railing

The design engineer should determine the railing needed for the culvert inlet or outlet. The railing should meet applicable AASHTO, ADA or TAS design standards.

10.3.17.1 Hand Rail

A hand rail should be used on culvert headwalls and wingwalls if the lateral drop-off is more than two (2) feet. If a traffic rail is used on top of the culvert headwall, a hand rail may still be needed on top of the traffic rail where the sidewalk abuts the culvert headwall.

10.3.17.2 Traffic Rail

A traffic rail may be needed if the roadway is not curbed.

If overtopping of the culvert from a design storm is possible, the traffic railing should be design to minimize obstruction to the storm overtopping.

10.3.17.3 Guard Rail

If there are no curb or traffic railing on the culvert headwall, the placement of guard rail should be used to keep vehicular traffic from encountering the lateral drop-offs at the edge of pavement. A guard rail may still be needed if a traffic railing is attached to the culvert headwall due to other conditions at the headwall location.

10.4 VELOCITY PROTECTION AND CONTROL DEVICES

10.4.1 Excess Velocity

Excess velocity discharge from a culvert to earthen channel or in some instances in concrete lined channel should be minimized with the use of protection or control devices.

10.4.2 Velocity Protection Devices

The velocity protection device used in an earthen channel should not take the place of a velocity control device but may complement a velocity control device.

There are a number of products available to the design engineer to stabilize an earthen channel, including soil retention blankets, articulated concrete blocks, and revetment mattresses. The use of these stabilizing products should be based on the velocity from the culvert outlet structure and the soil erodibility.

10.4.3 Velocity Control Devices

The velocity control device is used to reduce excessive velocity of the culvert outlet to six (6) feet per second or less for earthen channels.

There are a number of control devices that the design engineer can select from. Table 10.4.3 is a list of possible energy dissipators to use on a project. The table has appropriate control device for super critical or subcritical flow. For dissipators not contained within the manual, refer to FHWA Hydraulic Engineering Circular No. 14 for design computations.

Table 10.4.3 Energy Dissipators and Limitations

HEC-14 Chapter	Dissipator Type	Froude Number[a] (Fr)	Allowable Debris[b]			Tailwater (TW)
			Silt/ Sand	Boulders	Floating	
4	Flow transitions	N/A	H	H	H	Desirable
5	Scour hole	N/A	H	H	H	Desirable
6	Hydraulic jump	>1	H	H	H	Required
7	Tumbling flow[c]	>1	M	L	L	Not needed
7	Increased resistance[d]	N/A	M	L	L	Not needed
7	USBR Type IX baffled apron	<1	M	L	L	Not needed
7	Broken-back culvert[d]	>1	M	L	L	Desirable
7	Outlet weir	2–7	M	L	M	Not needed
7	Outlet drop/weir	3.5–6	M	L	M	Not needed
8	USBR Type III stilling basin	4.5–17	M	L	M	Required
8	USBR Type IV stilling basin	2.5–4.5	M	L	M	Required
8	SAF stilling basin	1.7–17	M	L	M	Required
9	CSU rigid boundary basin	<3	M	L	M	Not needed
9	Contra Costa basin	<3	H	M	M	<0.5D
9	Hook basin	1.8–3	H	M	M	Not needed
9	USBR Type VI impact basin[e]	N/A	M	L	L	Desirable
10	Rip-rap basin	<3	H	H	H	Not needed
10	Rip-rap apron	N/A	H	H	H	Not needed
11	Straight drop structure[f]	<1	H	L	M	Required
11	Box inlet drop structure[g]	<1	H	L	M	Required
12	USACE stilling well	N/A	M	L	N	Desirable

[a] *At release point from culvert or channel*

[b] *Debris notes: N = None, L = Low, M = Moderate, H = Heavy*
[c] *Internal: Bed slope must be in the range of 4% <S_o < 25%*
[d] *Internal: Check headwater for outlet control*
[e] *Discharge, Q < 400 ft^3/s and Velocity, V < 50 ft/s*
[f] *Drop <15 ft*
[g] *Drop <12 ft*
N/A = not applicable
Source: FHWA - Hydraulic Design of Energy Dissipators for Culverts and Channels, HEC-14

10.4.3.1 Broken Back Design

TxDOT has a complete design procedure for the use of a broken back culvert. These are used for steep culverts (culvert slope is greater than critical slope) and where the outlet section of the culvert is sufficient length and on a mild slope to make sure that the hydraulic jump occurs within the culvert. See Figures 10.4.3.1.A and 10.4.3.1.B below.

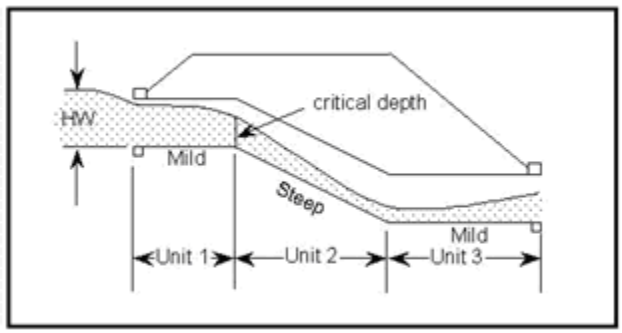


Figure 10.4.3.1.A - Three Unit Broken Back Culvert
(Source TxDOT, Hydraulic Design Manual, 2011)

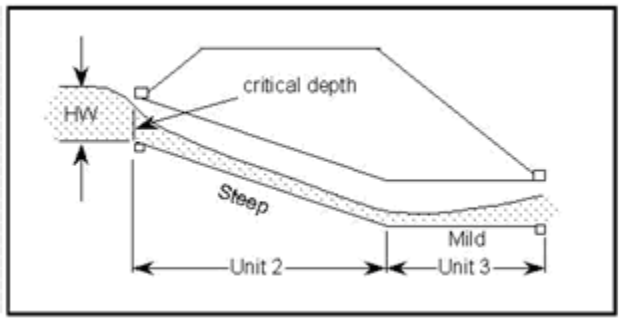


Figure 10.4.3.1.B - Three Unit Broken Back Culvert
(Source TxDOT, Hydraulic Design Manual, 2011)

The maintenance of this design should consider the location of possible silting within the culvert.

10.4.3.2 Stilling Basin

The stilling basin is used as an energy dissipator to trigger a hydraulic jump within the basin. The basin requires a tail water condition. These stilling basins normally operate within Froude numbers from 1.7 to 17. The Saint Anthony Falls (SAF) stilling basin is shown in Figure 10.4.3.2.A on the following page.

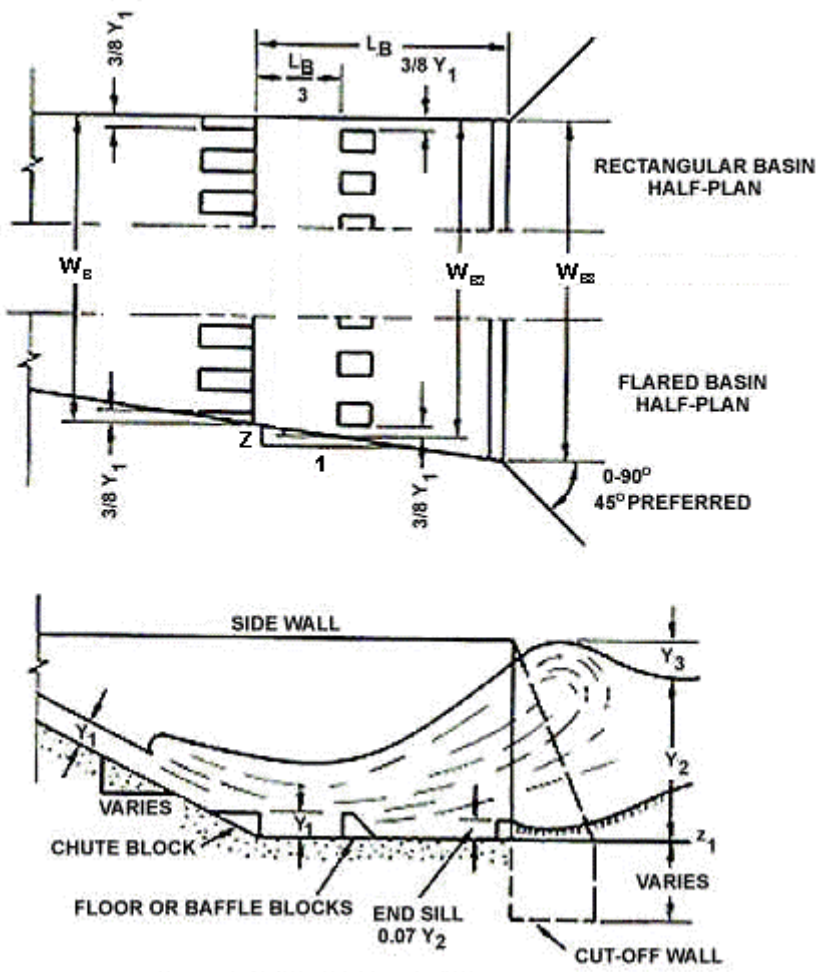


Figure 10.4.3.2.A - SAF Stilling Basin
(Source FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, 2006)

The following is for the design of a SAF stilling basin. For the design of other stilling basins, refer to FHWA HEC14.

The following are seven (7) design steps used for a SAF basin.

Step 1. Determine the velocity and depth at the culvert outlet. For the culvert outlet, calculate culvert brink depth (y_o) velocity (V_o) and (Fr_o.) For subcritical flow, use Figure

10.4.3.2.B or Figure 10.4.3.2.C found on the following pages. For supercritical flow, use normal depth in the culvert for y_o. (See FHWA HDS 5 (Normann, et al., 2001) for additional information on culvert brink depths.) (B)

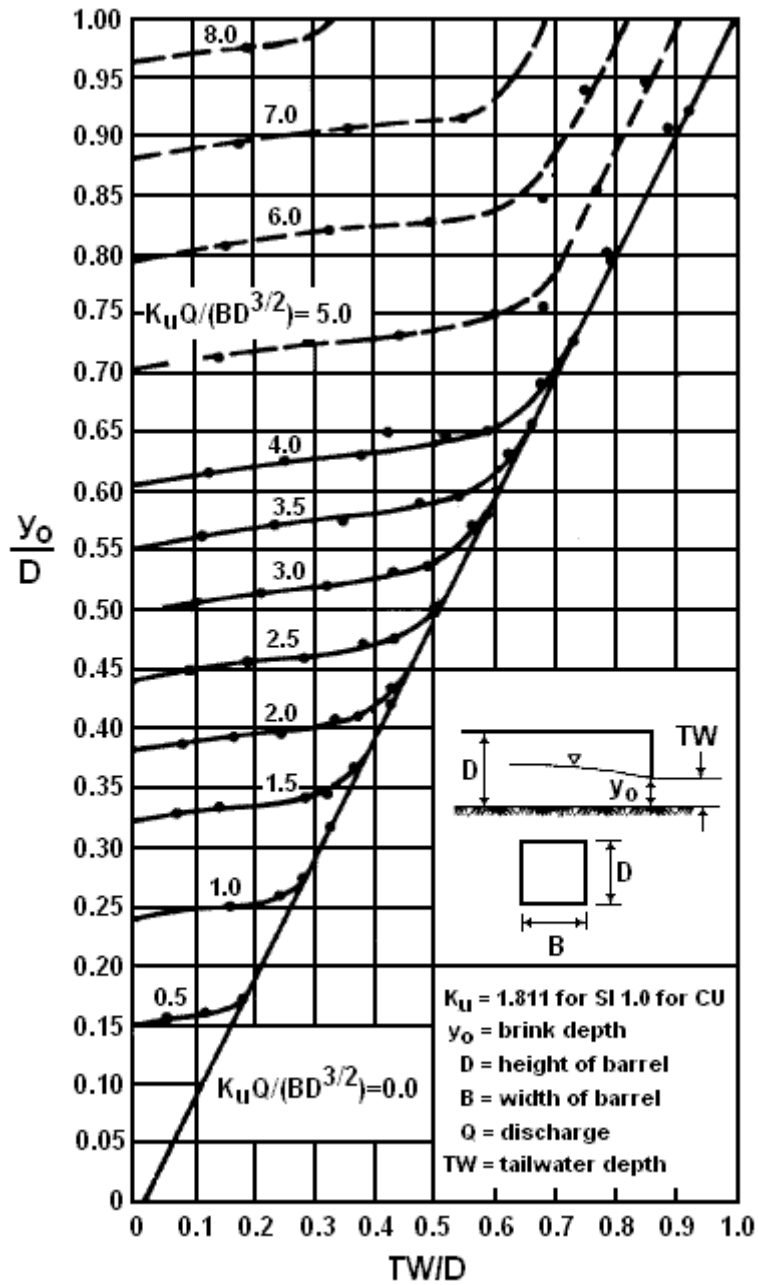


Figure 10.4.3.2.B - Dimensionless Rating Curves for the Outlets of rectangular Culverts on Horizontal and Mild Slopes

(Simnos, 1970, Source FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, 2006)

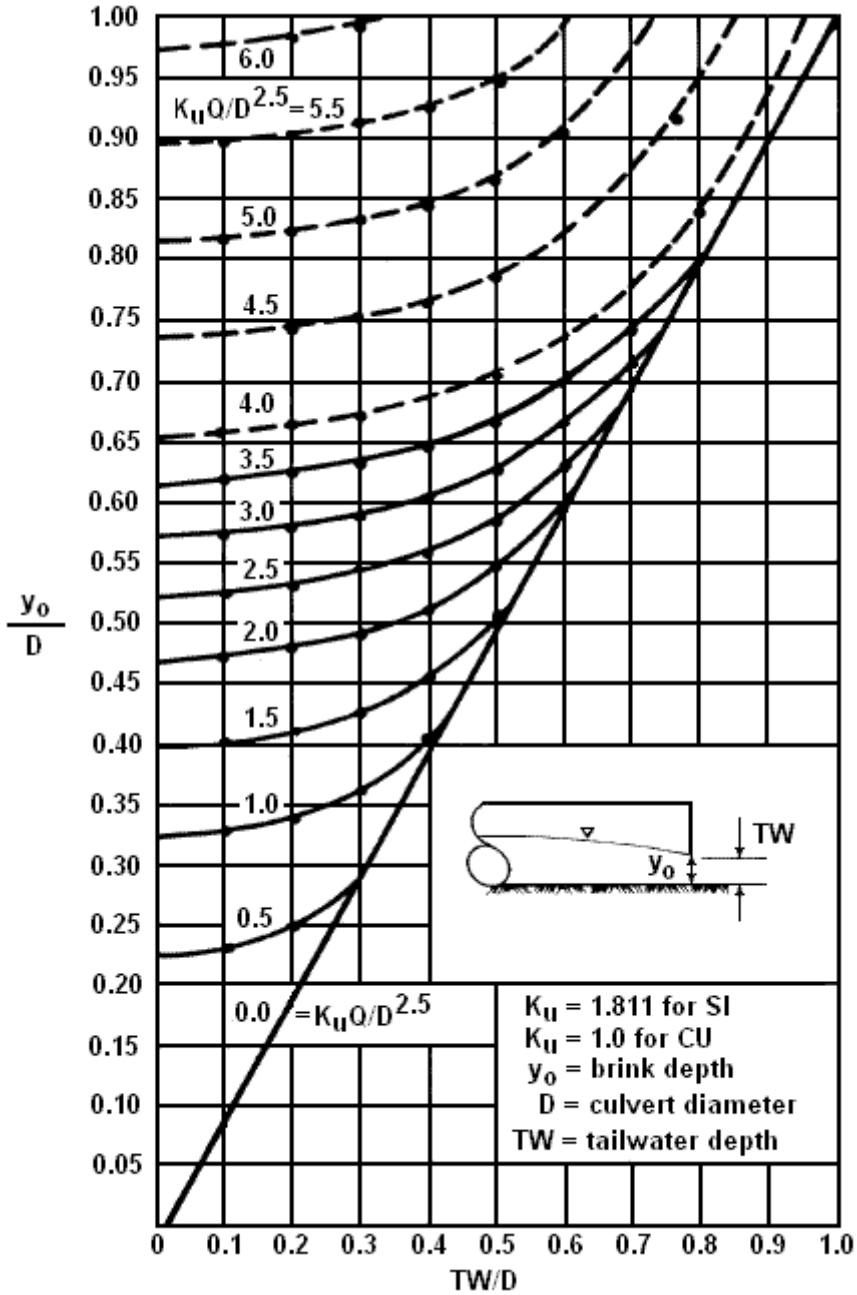


Figure 10.4.3.2.C - Dimensionless Rating Curves for the Outlets of Circular Culverts on Horizontal and Mild Slopes

(Simnos, 1970, Source FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, 2006)

Step 2. Determine the velocity and TW depth in the receiving channel downstream of the basin.

Step 3. Estimate the conjugate depth for the culvert outlet conditions using Equation 10.4.3.2.a to determine if a basin is needed. Substitute y_o and Fr_o for y_1 and Fr_1, respectively. The value of C is dependent, in part, on the type of stilling basin to be designed. However, in this step the occurrence of a free hydraulic jump without a basin is considered so a value of one (1) is used. Compare y2 and TW. If y2 < TW, there is sufficient tail water and a jump will form without a basin. The remaining steps are unnecessary.(B)

(Equation 10.4.3.2.a)

$$y_2 = \frac{C_{TW} y_1}{2}\left(\sqrt{1 + 8Fr_1^2} - 1\right)$$

y_2 = conjugate depth (ft.)
y_1 = depth approaching the jump (ft.)
C_{TW} = ratio of tail water to conjugate depth (TW/y_2)
Fr_1 = approach Froude number

Step 4. The design engineer should select a basin width (W_B). For box culverts, W_B must equal the culvert width (W_o). For circular culverts, the basin width is taken as the larger of the culvert diameter and the value calculated according to the following Equation:(B)

(Equation 10.4.3.2.b)

$$W_B = 1.7 D_o \left(\frac{Q}{g^{0.5} D_o^{2.5}}\right)$$

W_B = basin width (ft.)
Q = design discharge (fps)
D_o = culvert diameter (ft.)

The basin can be flared to fit an existing channel as indicated on Figure 10.4.3.2. The sidewall flare dimension z should not be greater than 0.5, i.e., 0.5:1, 0.33:1, or flatter. (B)

Step 5. Compute conjugate depth (C) is a function of Froude number as given by the following set of equations. Depending on the Froude number, C ranges from 0.64 to 1.08 implying that the SAF basin may operate with less tail water than the USBR basins, though tail water is still required. (B)

(Equation 10.4.3.2.c – When $1.7 < FR_1 < 5.5$**)**

$$C = 1.1 - \frac{Fr_1^2}{120}$$

(Equation 10.4.3.2.d – When $5.5 < FR_1 < 11$**)**

$$C = 0.85$$

(Equation 10.4.3.2.e – When $11 < FR_1 < 17$**)**

$$C = 1.0 - \frac{Fr_1^2}{800}$$

The determination of the basin length, L_B, using Equation 10.4.3.2.f below.

(Equation 10.4.3.2.f)

$$L_B = \frac{4.5y_2}{CFr_1^{0.76}}$$

Step 6. Determine the needed radius of curvature for the slope changes entering the basin using Equation 10.4.3.2.g found below.(B) The design engineer should determine if this step is required for the transition between the channel or culvert at the top of the drop to the transition slope and from the transitions slope to the bottom of the stilling basin floor. The curved slope change would provide improved flow conditions at the top and bottom of the drop.

If the transition slope is 1H:0.5V or steeper, use a circular curve at the transition with a radius defined by Equation 10.4.3.2.g (Meshgin and Moore, 1970). It is also advisable to use the same curved transition going from the transition slope to the stilling basin floor.(B)

(Equation 10.4.3.2.g)

$$r = \frac{y}{e^{\frac{1.5}{Fr^2}} - 1}$$

r = radius of the curved transition (ft.)
Fr = Froude number
y = depth approaching the curvature (ft.)

For the curvature between the culvert outlet and the transition, the Froude number and depth are taken at the culvert outlet. For the curvature between the transition and the stilling basin floor, the Froude number and depth are taken as Fr_1 and y_1.(B)

Step 7. Sizing the basin elements (chute blocks, baffle blocks, and an end sill), the following guidance is recommended. The height of the chute blocks (h_1) is set equal to y_1. The number of chute blocks is determined by Equation 10.4.3.2.h, below, rounded to the nearest integer.(B)

(Equation 10.4.3.2.h)

$$N_c = \frac{W_B}{1.5y_1}$$

N_c = number of chute blocks

Block width and block spacing are determined by the equation on the following page:

(Equation 10.4.3.2.i)

$$W_1 = W_2 = \frac{W_B}{2N_c}$$

W_1 = block width (ft.)
W_2 = block spacing (ft.)

Equations 10.4.3.2.h and 10.4.3.2.i will provide N_c blocks and N_c spaces between those blocks. A one-half block (.05) is placed at the basin wall so there is no space at the wall. The height, width, and spacing of the baffle blocks are shown in Figure 10.4.3.2.A. The height of the baffles (h_3) is set equal to the entering flow depth (y_1). The width and spacing of the baffle blocks must account for any basin flare. If the basin is flared as shown in Figure 10.4.3.2.A, the width of the basin at the baffle row is calculated according to the following equation:(B)

(Equation 10.4.3.2.j)

$$W_{B2} = W_B + \left(\frac{2zL_B}{3}\right)$$

W_{B2} = basin width at the baffle row (ft.)
L_B = basin length (ft.)
z = basin flare, z:1 as defined in Figure 10.4.3.2.A (z=0.0 for no flare)

The top thickness of the baffle blocks should be set at $0.2h_3$ with the back slope of the block on a 1:1 slope. The number of baffles blocks is calculated using the following equation :(B)

(Equation 10.4.3.2.k)

$$N_B = \frac{W_{B2}}{1.5y_1}$$

N_B = number of baffle blocks (rounded to an integer)

Baffle width and spacing are determined using the following equation:

(Equation 10.4.3.2.l)

$$W_3 = W_4 = \frac{W_{2B}}{2N_B}$$

W_3 = baffle width (ft.)
W_4 = baffle spacing (ft.)

Equations 10.4.3.2.k and 10.4.3.2.l will provide N_B baffles and N_B-1 spaces between those baffles. The remaining basin width is divided equally for spaces between the outside baffles and the basin sidewalls. No baffle block should be placed closer to the sidewall than $3y_1/8$. Verify that the percentage of W_{B2} obstructed by baffles is between forty and fifty-five percent (40-55%). The distance from the downstream face of the chute blocks to the upstream face of the baffle block should be LB/3. (B)

The height of the final basin element is calculated using the following equation:

(Equation 10.4.3.2.m)

$$h_4 = \frac{0.07y_2}{C}$$

h_4 = height of the end sill (ft.)

The end sill will extend across the basin.

Wingwalls should be equal in height and length to the stilling basin sidewalls. The top of the wingwall should have a 1H:1V slope. Flaring wingwalls are preferred to perpendicular or parallel wingwalls. The best overall conditions are obtained if the triangular wingwalls are located at an angle of forty-five degrees (45°) to the outlet centerline. (B)

The stilling basin sidewalls may be parallel (rectangular stilling basin) or diverge as an extension of the transition sidewalls (flared stilling basin). The height of the sidewall above the floor of the basin is given by the equation below :(B)

(Equation 10.4.3.2.n)

$$h_5 \geq y_2\left(1 + \frac{1}{3C}\right)$$

h_5 = height of the sidewall (ft.)

A cutoff wall should be used at the end of the stilling basin to prevent undermining. The depth of the cutoff wall must be greater than the maximum depth of anticipated erosion at the end of the stilling basin (B) The cutoff wall, toe down, to be a minimum depth of twenty-four (24) inches.

10.4.3.3 Contra Costa Basin

The Contra Costa Basin could be used for a culvert outlet with some tail water. The Contra Costa Basin was developed at the University of California, Berkeley, in conjunction with the

Contra Costa County, California. This basin is best suited to where the depth of flow at the outlet is equal to one-half (0.5) the culvert height.

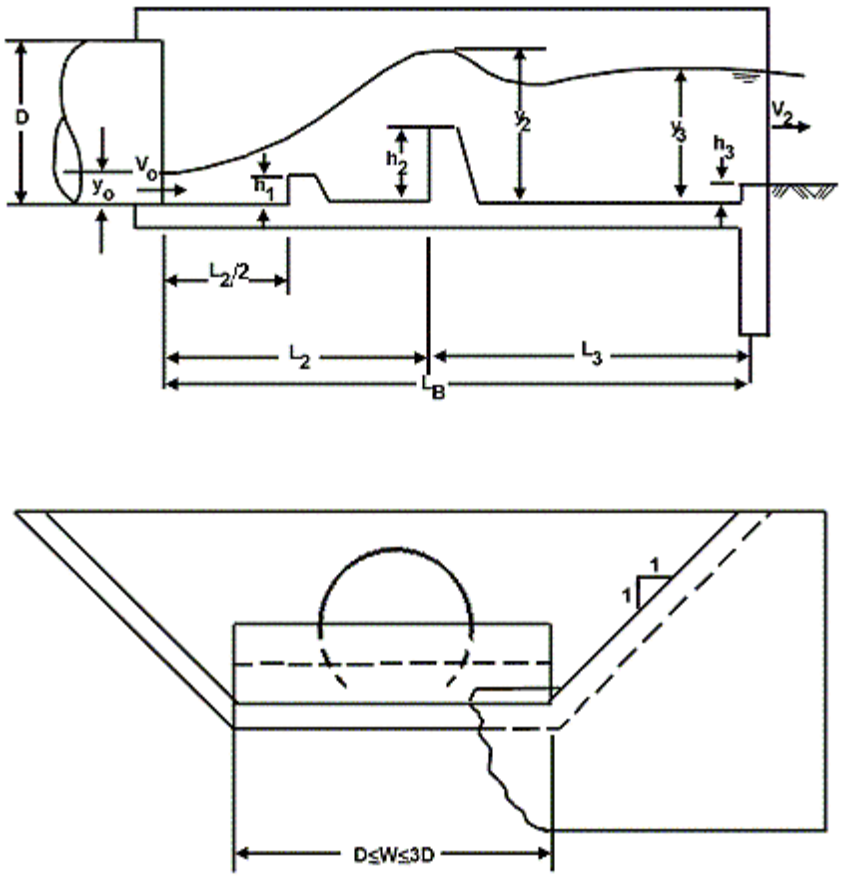


Figure 10.4.3.3.A - Contra Costa Basin (Source FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, 2006)

The following equation was tested with L_2/h_2 ratios from 2.5 to 7, and is in terms of culvert exit velocity (Vo) and depth (yo) for a circular culvert.

(Equation 10.4.3.3.1)

$$\frac{L_2}{h_2} = 1.2Fr^2\left(\frac{h_2}{y_o}\right)^{-1.83}$$

y_o = outlet depth (ft.)
V_o = outlet velocity (ft/s)
Fr = $Vo/(g\ y_o)^{1/2}$

h_2 = height of large baffle (ft.)
L_2 = length from culvert exit to large baffle (ft.)

The following are steps for designing a Contra Costa basin:

Step 1. Determine the flow conditions at the outfall of the culvert for the design discharge. If the depth of flow at the outlet, y_o, is D/2 or less, the Contra Costa basin is applicable. (B)
Step 2. Compute equivalent depth, y_e, and Froude number, Fr. (B)
$y_e = y_o$ for rectangular culvert
$y_e = (A/2)^{1/2}$ for other shapes
$Fr = V_o / (gy_e)^{1/2}$

Step 3. The width of the basin floor, W_B, is selected to conform to the natural channel, but must be $1W_o$ to $3W_o$. If there is no defined channel, the width should be no greater than 3 times the culvert width. The basin side slopes should be 1:1. (B)
Step 4. Assume a value of L_2/h_2 between 2.5 and 7. If $L_2/h_2 = 3.5$, use Equation 10.4.3.3.3 to determine h_2. Use Equation 10.4.3.3.2-A or Equation 10.4.3.3.2-B for other values. Calculate $L_2 = 3.5\ h_2$. Calculate the first baffle height, $h_1 = 0.5h_2$ and position, $L_1 = 0.5L_2$. (B)

The following equation is generalized from the previous equation for other shapes by substituting y_e (equivalent flow depth) for y_o.

(Equation 10.4.3.3.2-A)

$$\frac{L_2}{h_2} = 1.35Fr^2\left(\frac{h_2}{y_e}\right)^{-1.83}$$

(Equation 10.4.3.3.2-B)

$$\frac{h_2}{y_e} = \left(\frac{1.35Fr^2}{\frac{L_2}{h_2}}\right)^{0.546}$$

y_e = equivalent depth, $(A/2)^{1/2}$ (ft.)
A = outlet flow area (ft^2)
V_o = outlet velocity (ft./s)
Fr = $V_o/ (g\ y_e)^{1/2}$

With use of recommended $L_2/h_2 = 3.5$ value, we get:

(Equation 10.4.3.3.3)

$$\frac{h_2}{y_e} = 0.595Fr^{1.092}$$

Step 5. Determine the length from the large baffle to the end sill (L_3) using Equation 10.4.3.3.4 below. If necessary, repeat the procedure until a dissipator is defined which optimizes the design requirements. (B)

(Equation 10.4.3.3.4)

$$\frac{L_3}{L_2} = 3.75\left(\frac{h_2}{L_2}\right)^{0.68}$$

The height of the small baffle (h_1) is one-half (0.5) the height of the large baffle (h_2). The position of the small baffle is half way between the culvert outlet and the large baffle or $L_2/2$. The height of the end sill (h3) may vary from $0.06y_2$ to $0.10y_2$.

For basins with $W_b/W_o = 2$ (end width is twice the outlet width), an approximate maximum water surface depth (y2) without tail water, can be obtained by using the

(Equation 10.4.3.3.5)

$$\frac{y_2}{h_2} = 1.3\left(\frac{L_2}{h_2}\right)^{0.36}$$

Step 6. Estimate the approximate maximum water surface depth without tail water (y_2) using the above Equation 10.4.3.3.5 which is for $W_B = 2W_o$. Set the end sill height, h_3, between $0.06y_2$ and $0.1y_2$. If the above dimensions are compatible with the topography at the site, the dimensions are final. If not, a different value of L_2/h_2 is selected and the design procedure repeated. (B)

Step 7. Determine the basin exit depth, $y_3 = y_c$ and exit velocity, $V_2 = V_c$. (B) $Q^2/g = (A_c)^3/T_c = [y_c(W_B + y_c)]^3/(W_B + 2y_c)$ (substituting for A_c and T_c using the properties of a trapezoid).

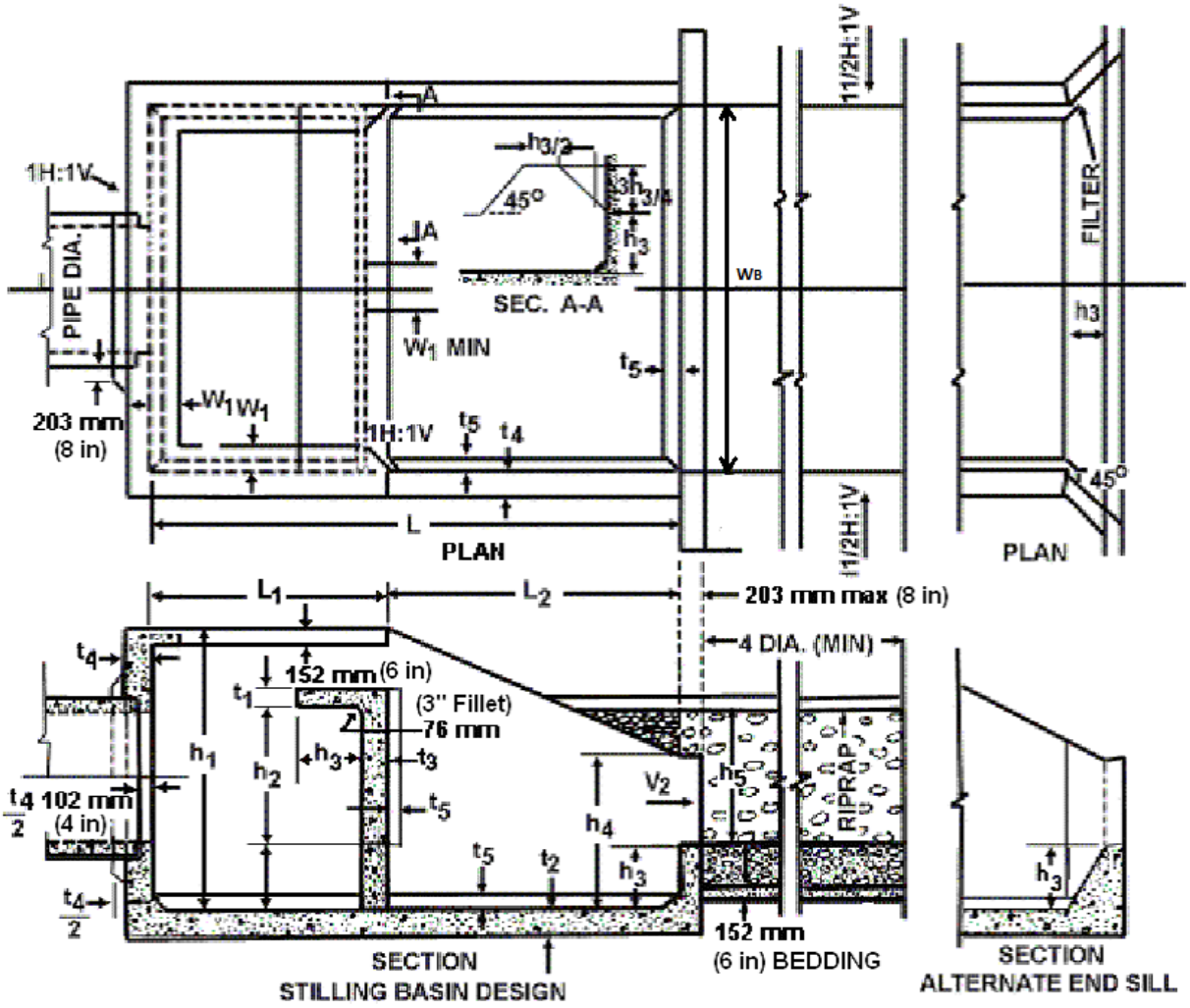
$V_c = Q/A_c$

Step 8. Riprap may be necessary downstream especially for the low tail water cases. (B)Two (2) or three (3) foot toe down is a recommended minimum.

10.4.3.4 USBR Type VI Impact Basin

The U.S. Bureau of Reclamation Type VI impact basin requires no tail water to function. The outflow hits the vertical hanging baffle and provides the necessary energy dissipation.

Figure 10.4.3.4.A - USBR Type VI Impact Basin



(Source FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, 2006)

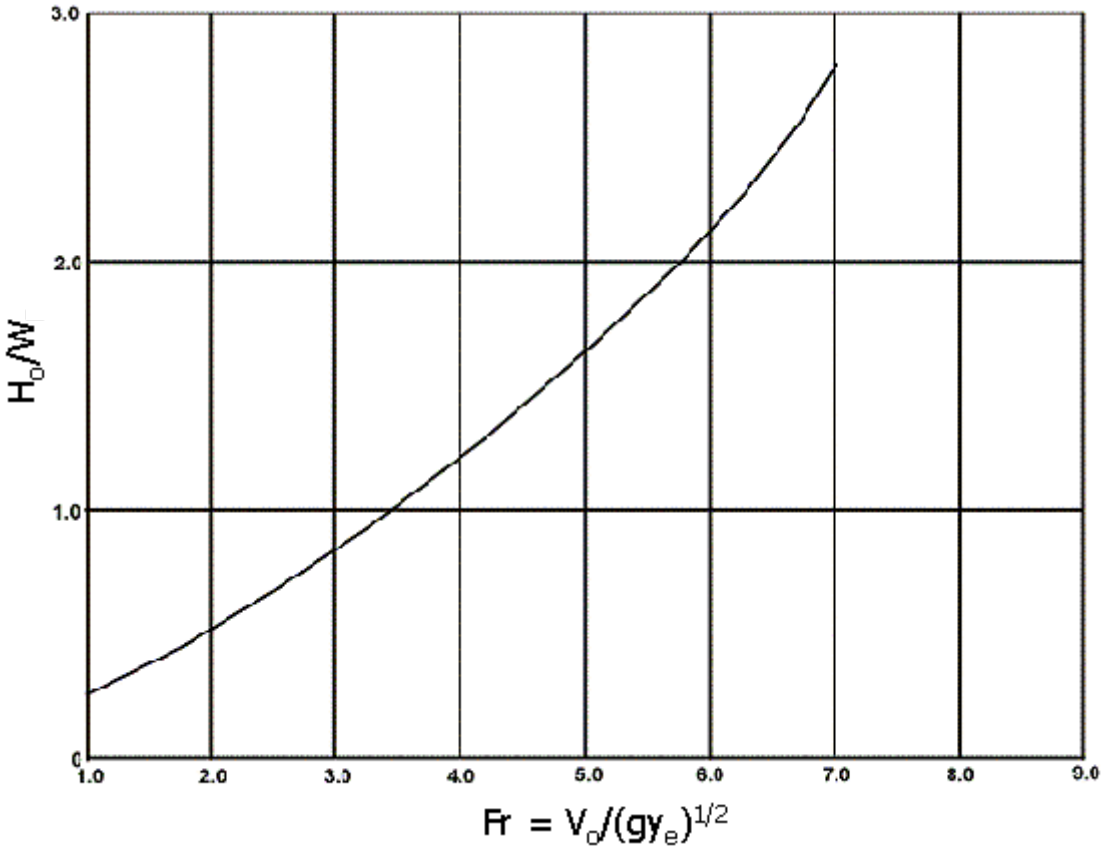


Figure 10.4.3.4.B - Design Curve for USBR Type VI Impact Basin
(Source FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, 2006)

Table 10.4.3.4. - USBR Type VI Impact Basin Dimensions (ft)
(Source FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, 2006)

W_B	h_1	h_2	h_3	h_4	L	L_1	L_2
4	3.08	1.50	0.67	1.67	5.42	2.33	3.08
5	3.83	1.92	0.83	2.08	6.67	2.92	3.83
6	4.58	2.25	1.00	2.50	8.00	3.42	4.58
7	5.42	2.58	1.17	2.92	9.42	4.00	5.42
8	6.17	3.00	1.33	3.33	10.67	4.58	6.17
9	6.92	3.42	1.50	3.75	12.00	5.17	6.92
10	7.58	3.75	1.67	4.17	13.42	5.75	7.58
11	8.42	4.17	1.83	4.58	14.58	6.33	8.42
12	9.17	4.50	2.00	5.00	16.00	6.83	9.17
13	10.17	4.92	2.17	5.42	17.33	7.42	10.17
14	10.75	5.25	2.33	5.83	18.67	8.00	10.75
15	11.50	5.58	2.50	6.25	20.00	8.50	11.50
16	12.25	6.00	2.67	6.67	21.33	9.08	12.25
17	13.00	6.33	2.83	7.08	21.50	9.67	13.00
18	13.75	6.67	3.00	7.50	23.92	10.25	13.75
19	14.58	7.08	3.17	7.92	25.33	10.83	14.58
20	15.33	7.50	3.33	8.33	26.58	11.42	15.33

W_B	W_1	W_2	t_1	t_2	t_3	t_4	t_5
4	0.33	1.08	0.50	0.50	0.50	0.50	0.25
5	0.42	1.42	0.50	0.50	0.50	0.50	0.25
6	0.50	1.67	0.50	0.50	0.50	0.50	0.25
7	0.50	1.92	0.50	0.50	0.50	0.50	0.25
8	0.58	2.17	0.50	0.58	0.58	0.50	0.25
9	0.67	2.50	0.58	0.58	0.67	0.58	0.25
10	0.75	2.75	0.67	0.67	0.75	0.67	0.25
11	0.83	3.00	0.67	0.75	0.75	0.67	0.33
12	0.92	3.00	0.67	0.83	0.83	0.75	0.33
13	1.00	3.00	0.67	0.92	0.83	0.83	0.33
14	1.08	3.00	0.67	1.00	0.92	0.92	0.42
15	1.17	3.00	0.67	1.00	1.00	1.00	0.42
16	1.25	3.00	0.75	1.00	1.00	1.00	0.50
17	1.33	3.00	0.75	1.08	1.00	1.00	0.50
18	1.33	3.00	0.75	1.08	1.08	1.08	0.58
19	1.42	3.00	0.83	1.17	1.08	1.08	0.58
20	1.50	3.00	0.83	1.17	1.17	1.17	0.67

The recommended design procedure for the USBR Type VI impact basin is as follows: (B)

Step 1. Determine the maximum discharge (Q (cfs)) and velocity (V_o (ft./s) and check against design limits. Calculate the flow area at the end of the approach pipe, A (ft^2). Calculate equivalent depth, $y_e = (A/2)^{1/2}$ (ft). (B)

$$A = Q/V_o$$

$$y_e = (A/2)^{1/2}$$

Step 2. Calculate the Froude number (Fr) and the energy at the end of the pipe (H_o (ft)). (B)

$$Fr = V_o / (g y_e)^{1/2}$$

$$H_o = y_e + V_o^2/(2g)$$

Step 3. Determine H_o/W_B from Figure 10.4.3.4.B. Calculate the required width of basin (W_B (ft)). (B)
$W_B = H_o / (H_o/ W_B)$

Step 4. Obtain the remaining dimensions of the USBR Type VI impact basin from Table 10.4.3.4 using W_B obtained from Step 3. (B)

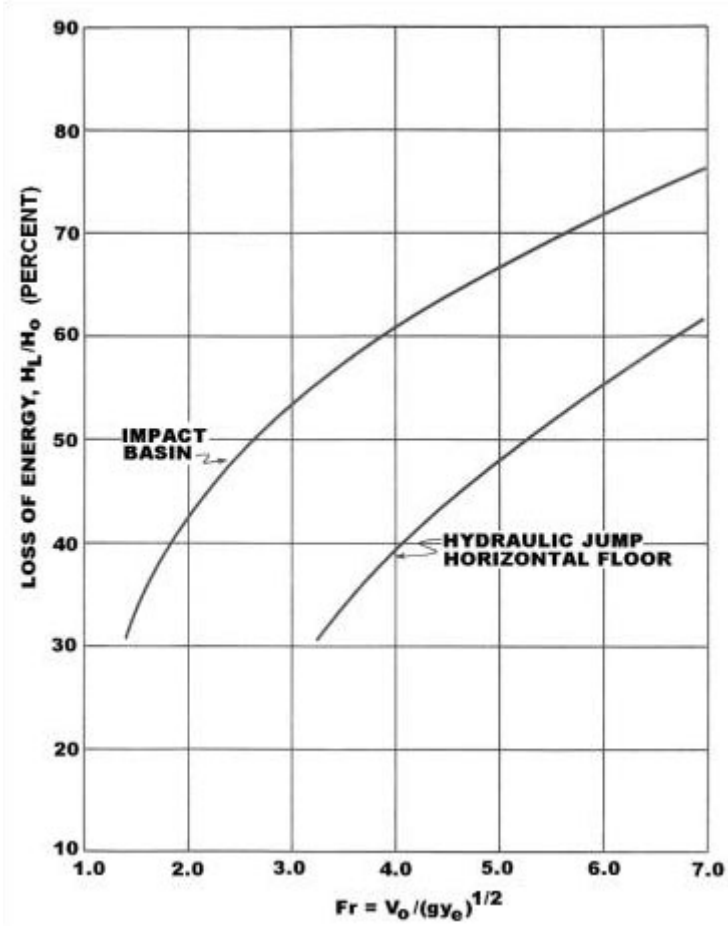


Figure 10.4.3.4.C - Energy Loss of USBR Type VI Impact Basin versus Hydraulic Jump
(Source FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, 2006)

Step 5. Determine exit velocity, $V_B = V_2$, by trial and error using an energy balance between the culvert exit and the basin exit. Determine if this velocity is acceptable and whether or not riprap protection is needed downstream. (B) Use Figure 10.1.3.4.C to determine H_L/H_o percent by using the calculated Fr from Step 2. $H_B = Q/(W_B V_B) + V_B^2/(2g) = H_o(1 - H_L/H_o)$

This equation is a cubic equation yielding three (3) solutions, two (2) positive and one (1) negative. The negative solution is discarded. The two positive roots yield a subcritical and supercritical solution. Where low or no tail water exists, the supercritical solution is taken. Where sufficient tail water exists, the subcritical solution is taken. (B)

10.4.3.5 Baffle Blocks

Baffle blocks should be used to reduce the subcritical velocity to six (6) feet per second or less. A minimum of two (2) rows of block should be used. The distance from the culvert to the first row of blocks should be a minimum of the culvert height. The height of blocks

should be a minimum of one (1) foot or critical depth (d_c). The width of the block and spacing of blocks should match the height of block. The second row of blocks should be offset so the block lines up with the spacing of the first row of blocks. The blocks should extend across the total bottom width of the culvert outlet structure.

10.5 SPECIAL APPLICATIONS - DETOURS

10.5.1 Detour culverts

A detour route may be required during the reconstruction of an existing roadway. The detour route is a temporary relocation of the road during construction. If an existing roadway has a culvert crossing to be reconstructed, the detour roadway culverts should have the same conveyance as the existing crossing as a minimum. The design should also consider soil protection of the embankment to prevent erosion around the culverts and the temporary roadway.

10.5.2 Risk

The detour stream crossing is usually design to a lower frequency storm. The design engineer should consider a number of risk factors for the hydraulic design of the culverts. The risk factors to be considered during the design should include the probability of flooding during the use of the detour, the risk to life and property from backwater and washouts, traffic requirements, school bus routes, and emergency routes.

The following equation relates the probability of occurrence to the flood event.

(Equation 10.5.2)

$$\mathbf{R = 1 - (1 - AEP)^n}$$

R = Risk – probability of occurrence
AEP = Annual Exceedance Probability of the flood event
n = length of time required for the detour (year)

The above equation generated the curves in Figure 10.5.2. The figure represents the risk versus flood event. As an example, if you were to design the detour culverts for a five (5)-year storm (20% AEP) and the project construction length was one (1)-year, the odds are four to one (4:1) against the occurrence, or twenty percent (20%) risk. If you design the detour culverts for a ten (10)-year storm (10% AEP) with the same project length, then the odds are nine to one (9:1) against the occurrence or ten percent (10% risk). Designing to a higher frequency storm will lower the risk of flood occurrence.

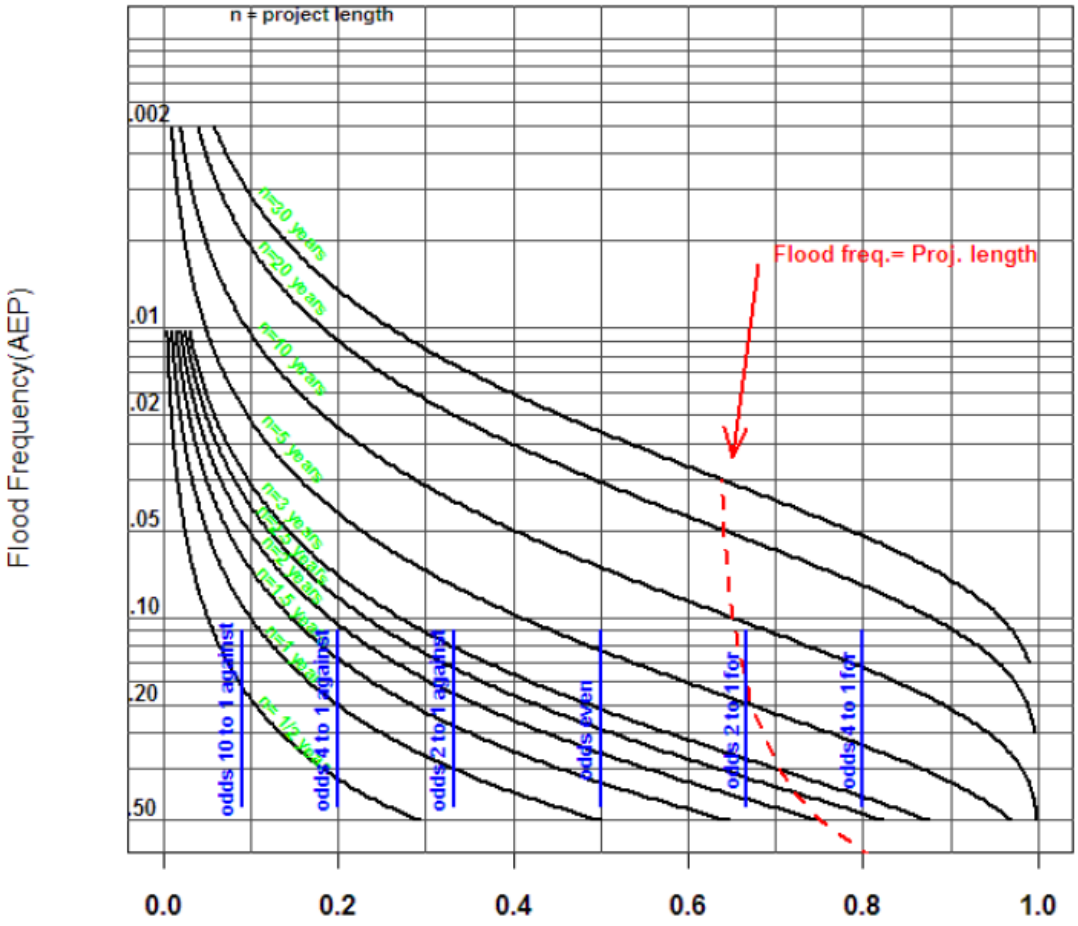


Figure 10.5.2 - Flood Frequency vs. Risk
(Source TxDOT, Hydraulic Design Manual, 2011)

10.5.3 Engineering Requirements

Should a detour road be required for a project and the detour crosses over a low requiring a culvert, the licensed engineer should design the detour road culverts.

10.6 REFERENCES

10.6.1 Reference Citations

A. TXDOT. Culverts. Chapter 8 in *Hydraulic Design Manual*. Texas Department of Transportation, Revised 2011. (Accessed April 2014)
B. FHWA. *Hydraulic Design of Energy Dissipators for Culverts and Channels*. Hydraulic Engineering Circular No. 14. 3rd edition. FHWA-NHI-06-086. Federal Highway Administration, Department of Transportation, Washington, DC, July 2006.

10.6.2 References

- TXDOT. Culverts. Chapter 8 in *Hydraulic Design Manual*. Texas Department of Transportation, Revised 2011. (Accessed April 2014)
- FHWA. *Hydraulic Design of Energy Dissipators for Culverts and Channels*. Hydraulic Engineering Circular No. 14. 3rd edition. FHWA-NHI-06-086. Federal Highway Administration, Department of Transportation, Washington, DC, July 2006.

CHAPTER 11
BRIDGES

11.1 INTRODUCTION

The function of a bridge is similar to a culvert, in that it is to convey surface water under a highway, railroad, or other embankment. This chapter describes the hydraulic aspects of bridge design, construction and operation of bridges, and makes references to structural aspects only as they are related to the hydraulic design. The hydraulic design must consider channel and abutment scour at different bridge components. Also impact from floating debris must be considered for the structural design of the bridge components.

~~(g)(7)A.~~
Where proposed streets cross existing or proposed watercourses, all-weather crossings shall be required. Bridges ~~Culverts or bridges~~ shall be adequate to allow passage of the design storm identified in Section 11.3.1 ~~subsection 35-504(b)(1).~~ of this chapter.

11.2 HYDRAULICS OF BRIDGES

The design engineer will analyze both existing and proposed bridges. The HEC-RAS model is recommended to analyze a bridge. Other models may be used with the approval of the Director of TCI.

A proposed bridge may increase the depth of flow upstream of the encroachment. Modifications of the channel downstream and upstream of the proposed bridge may be needed to reduce the upstream impact. A drainage easement, meeting the requirements of Chapter 15, should encompass any channel improvement needed for the bridge and increase in water surface.

Section 1 should be located downstream of the bridge at a point where the expansion of flow from the bridge is expected to occur. Section 2 should be located a short distance downstream of the bridge. Section 3 should be located a short distance upstream of the bridge. Ineffective flow areas should be placed on section 2 and 3 to represent the roadway embankment. Section 4 should be located upstream of the bridge at a point where the start of contraction is expected to occur.

Typical contraction and expansion values at bridge sections is 0.3 and 0.5 respectively. Abrupt transitions will have higher values. The contraction and expansion values should be used on Sections 2, 3, and 4.

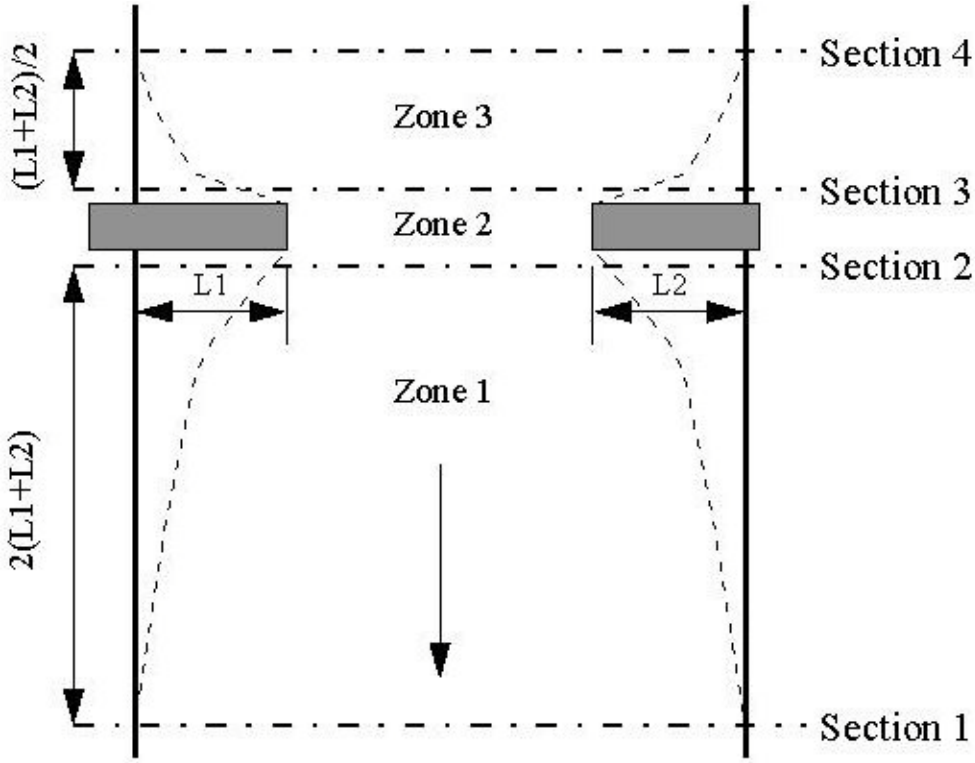


Figure 11.2 - Cross Section Locations at Bridge or Culvert
(Source TxDOT Hydraulic Design Manual)

11.2.1 Low Flow

There are three (3) classes of flow for low flow conditions. Low flow exists when the water surface is below the low chord of the bridge opening. See Figure 11.2.1.

Class A low flow exists when the water surface is subcritical from Sections 1 to 4.

There are four (4) methods available between sections 2 and 3. These methods are energy equation, momentum balance, Yarnell equation, and FHWA WSPRO method.

Class B low flow exists when the water surface passes through critical depth within the bridge constriction between section 2 and 3. The flow upstream and downstream of the bridge can be either subcritical or supercritical.

Class C low flow exists when the water surface is supercritical from section 1 to 4.

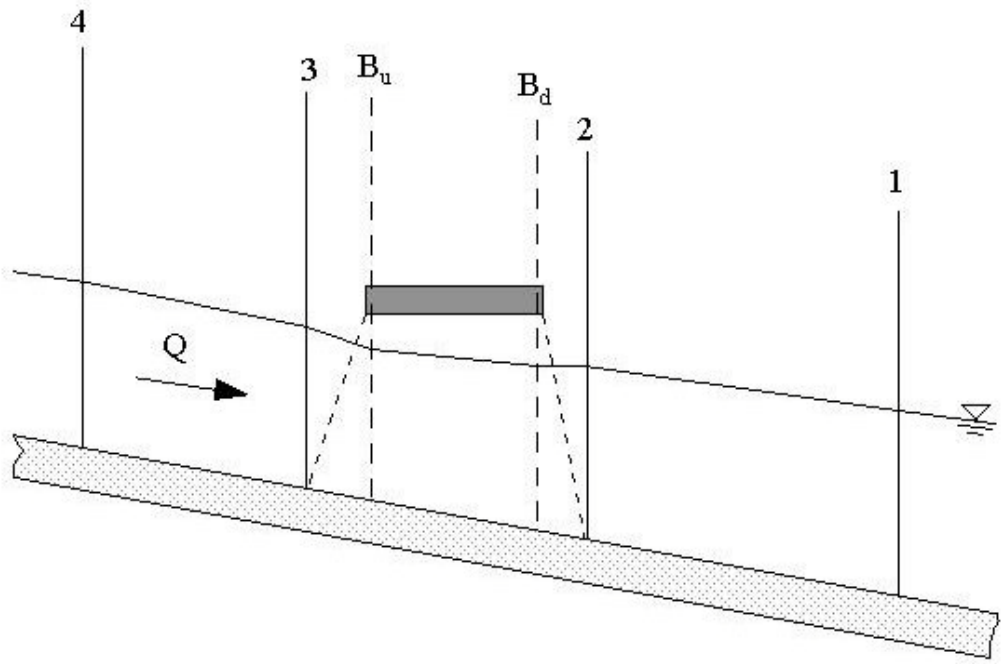


Figure 11.2.1 - Bridge Profile with Cross Section Location
(Source TxDOT Hydraulic Design Manual)

11.2.2 High Flow

High flow exists when the water surface comes into contact with the maximum low chord of the bridge opening. The computation would be by the Energy equation or by hydraulic equations for pressure and or weir flow.

11.2.2.1 Energy Equation

This method is based on balancing the energy equation in three (3) steps through the bridge. These steps are energy losses based on the friction losses along the channel, contraction losses on the upstream side of the bridge, and expansion losses on the downstream side of the bridge.

11.2.2.2 Pressure and Weir Flow

Pressure flow occurs when the upstream water surface comes in contact with the low cord of the bridge and a backwater conditions occur. If the downstream side of the bridge low cord is not in contact with the bridge, then a sluice gate type of equation is used (FHWA, 1978). See Figure and Equation 11.2.2.2A on the following page.

(Equation 11.2.2.2A)

$$Q = CA_b\left[2g\left(y_3 - \frac{D_b}{2} + \alpha_3\frac{v_3^2}{2g}\right)\right]^{0.5}$$

Q = Total discharge through the bridge opening (ft.^{3}/s)
C = Coefficients of discharge for pressure flow
A_b = Net area of the bridge opening at section BU (ft.^{2})
y_3 = Hydraulic depth at section 3
D_b = Vertical distance from maximum bridge low chord to the mean river bed elevation at section BU (ft.)
g = Gravitational acceleration (32.2 ft./s^2)
α_3 = kinetic energy correction coefficient (FHWA HDS-1 1978)
v_3 = Velocity upstream at section 3

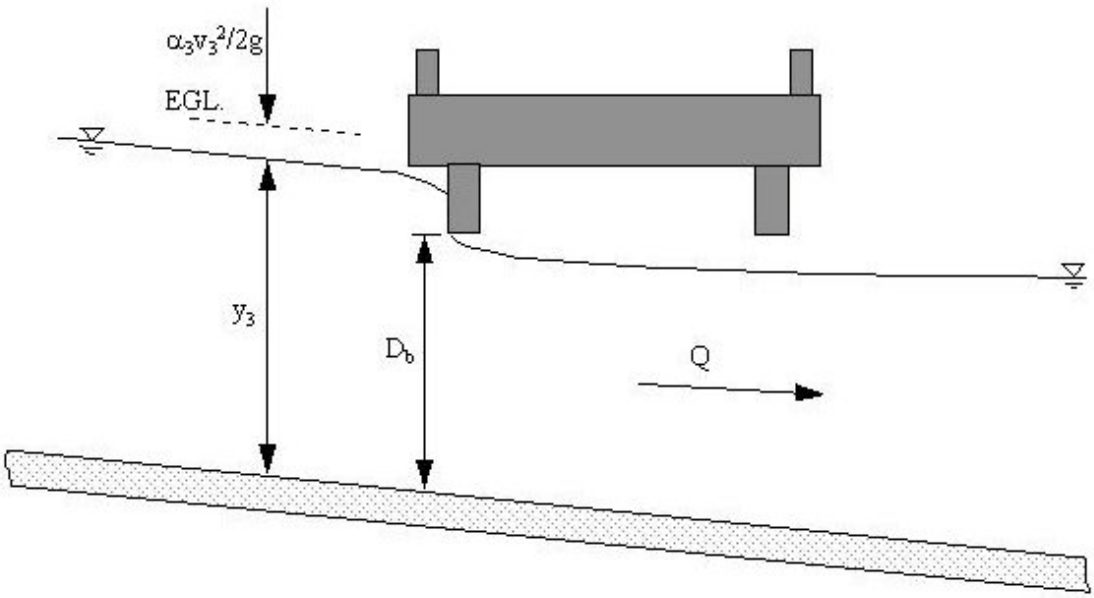


Figure 11.2.2.2.A - Sluice Gate Type Pressure Flow
(Source TxDOT Hydraulic Design Manual)

The orifice equation will be used if both up and downstream of the bridge are submerged. See Figure 11.2.2.2B on the following page.

(Equation 11.2.2.2B)

$$Q = CA(2gH)^{0.5}$$

C = Coefficient of discharge for fully submerged pressure flow. Typical value of C is 0.8
H = The difference between the energy gradient elevation upstream and the water surface elevation downstream (ft.)
A = Net area of the bridge opening (ft^2)

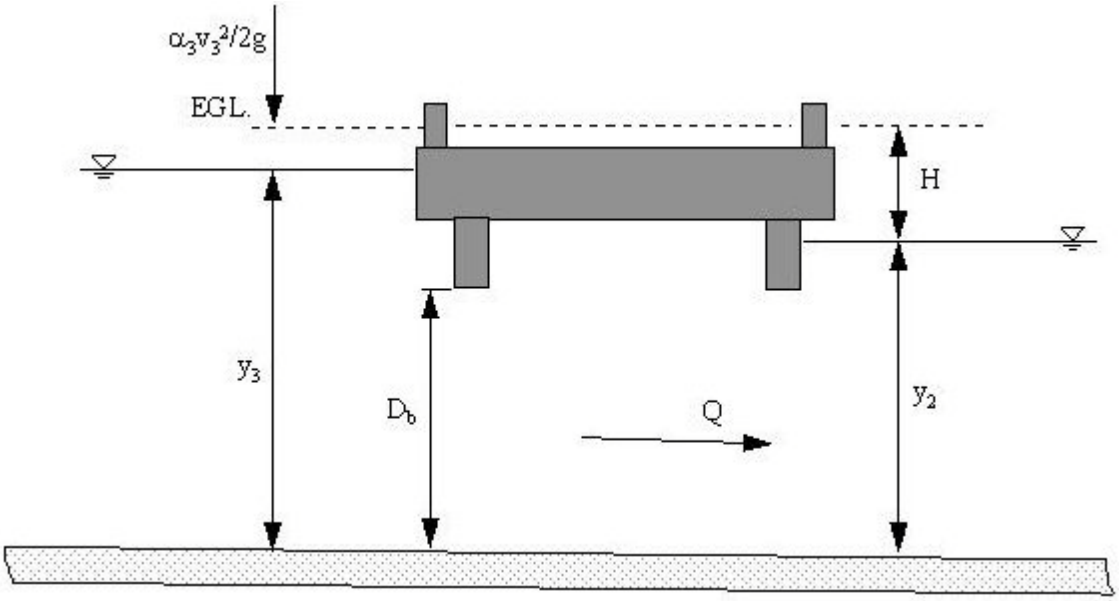


Figure 11.2.2.2.B - Orifice Type Pressure Flow
(Source TxDOT Hydraulic Design Manual)

Should flow be over the bridge and the roadway approaching the bridge, then the standard weir equation is used to calculate flow. See Figure 11.2.2.2.C.

(Equation 11. 2.2.2C)

$$\mathbf{Q = CLH^{3/2}}$$

Q = Total flow over the weir (ft.^{3}/s)
C = Coefficients of discharge for weir flow
L = Effective length of the weir (ft.)
H = Difference between energy upstream and road crest (ft.)

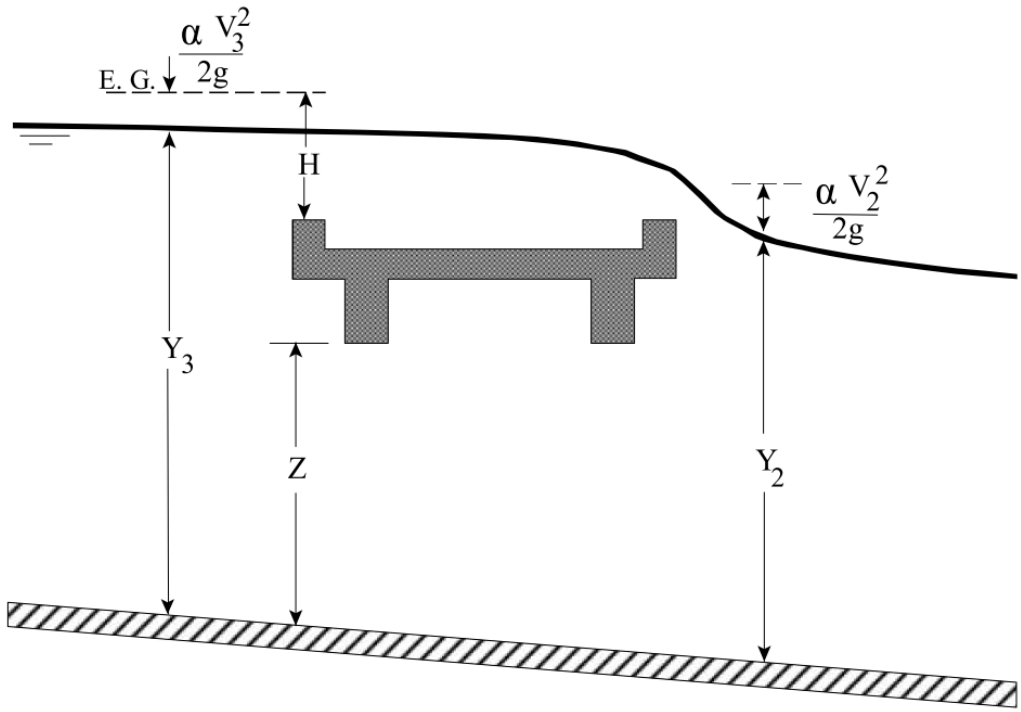


Figure 11.2.2.2.C - Pressure and Weir Flow
(Source USACE HEC-RAS Reference Manual)

For more information regarding hydraulic computations, refer to USACE HEC-RAS Reference Manual.

11.3 DESIGN GUIDELINES

11.3.1 Design Frequency

The design frequency for bridges is the ultimate twenty-five (25) year storm for upstream drainage area less than one hundred (100) acres with a freeboard based on section 11.3.2 or the ultimate one hundred (100) year storm for upstream drainage area greater than one hundred (100) acres.

11.3.2 Freeboard

Freeboard at a bridge is the vertical distance between the design water surface elevation and the low-chord of the bridge. The bridge low-chord is the lowest portion of the bridge deck superstructure. The purpose of freeboard is to provide room for the passage of floating debris, extra area for conveyance in the event that debris build-up on the piers reduces hydraulic capacity of the bridge, and a factor of safety against the occurrence of waves or floods larger than the design flood. (A) The minimum freeboard is one (1) foot for the ultimate one hundred (100) year storm. For drainage areas less than one hundred (100) acres, the ultimate

twenty-five (25) year storm freeboard will range from 6" to 1 ft depending on channel depth please refer to Table 9.3.14.

11.3.3 Supercritical Flow

For supercritical flow conditions in a stream or channel, the design engineer should confirm that the bridge opening is clear of bridge piers or other projections and does not impact the flow. If bridge piers or other projections are within the bridge opening, then hydraulic jumps within the bridge structure should be considered and the impacts should be included in the bridge design.

11.3.4 Scour

Consideration of the scour of soil around a bridge from a storm event(s) is critical to the longevity of the structure. The total scour at a bridge crossing is comprised of three (3) components. These are long term aggradations and degradation, contraction scour, and local scour at piers and abutments. The long term aggradations and degradation should be checked to determine the additional stream bed losses that may impact the bridge scour analysis.

Bridge scour analysis for contraction scour and local scour at piers and abutments must be performed using the HEC-RAS model or other modeling that has been approved by the Director of TCI. Scour analysis will not be needed if the channel is concrete lined.

For slope protection at abutments should be checked, after performing the scour analysis, for slope stability and sliding of the slope protection. The slope protection could impact the stability of the bridge.

11.3.5 Minimum Clear Height

The design engineer should consider the minimum clear height from the channel bottom to the bottom of the bridge beams to be six (6) feet. Additional height should be considered for passage of maintenance vehicles under the bridge to minimize the number of channel access ramps.

11.3.6 Bridge Deck Drains

Bridge deck drains should achieve the following:

- Minimize the spread of water into the traffic lanes
- Prevent the accumulation of significant depth of water to reduce hydroplaning
- Integration of the drain into the structural deck
- Reduce drain~~s~~ hazards to bicyclists
- Maintenance of the deck drains
- Provide sufficient longitudinal grade
- Avoid zero longitudinal grade and sag vertical curves on the bridge
- Intercept all flow from curbed street before it reaches bridge

11.3.6.1 Constant Grade Bridges

The following calculations are for determining possible inlet spacing on a constant- grade bridge. If the slope is less than 0.003 ft./ft., a check should be performed using the calculations for flat bridges. Calculations start from the high end and work downslope. The rest of the bridge specifications are assumed to be known.

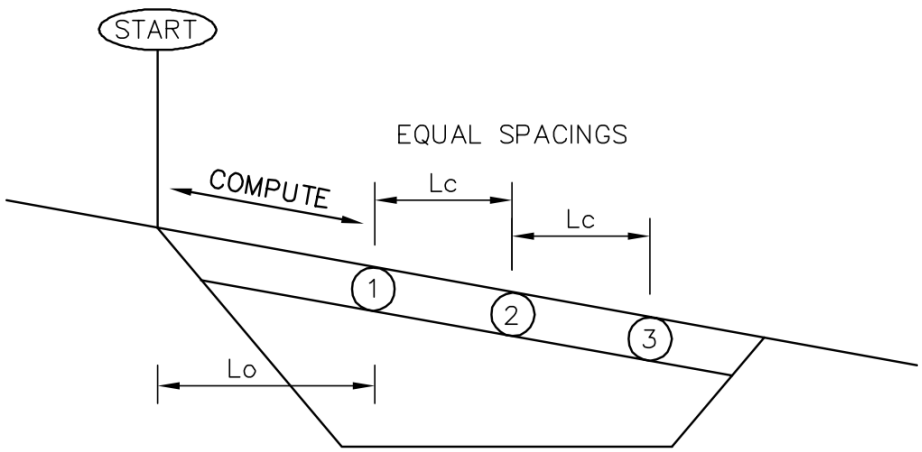


Figure 11.3.6.A Constant Grade Bridge

Flow for initial inlet:

(Equation 11.3.6.1A)

$$L_0 = \frac{43560Q}{CiW_p}$$

i = Design rainfall intensity (in./hr.)
Q = Gutter flow (ft.^{3}/s)
L_0 = Distance to first inlet (ft.)
C = Rational runoff coefficient (usually 0.9 from imperfections in pavement)
W_p = Width of pavement contributing to gutter flow (ft.)

Flow for subsequent inlets:

(Equation 11.3.6.1B)

$$L_c = \frac{43560QE}{CiW_p}$$

L_c = Constant distance between inlets (ft.)
E = Capture efficiency for proposed inlets, which can be found in manufacturers' literature.

If L_0 is greater than the length of the bridge, only end treatment drainage is needed. Caution is needed, as the discharge point for the inlets must be considered in the placement as well. The discharge should not be onto structural elements, over traveled ways, or unprotected ground that has a possibility of erosion.

11.3.6.2 Flat Bridges

The following calculations are for determining possible inlet spacing on flat bridges. Flat bridges are generally discouraged in order to prevent ponding on the bridge surface.

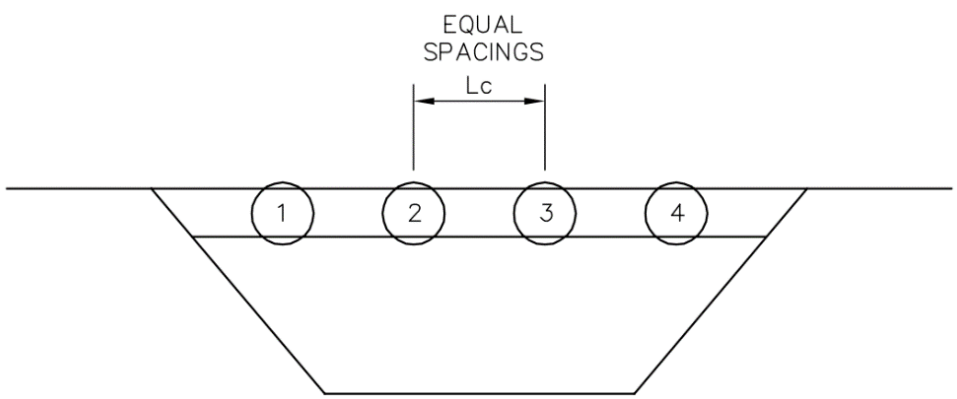


Figure 11.3.6.B - Horizontal Bridge

(Equation 11.3.6.2A)

$$L_c = \frac{1312}{(nCiW_p)^{0.67}} S_x^{1.44} T^{2.11}$$

i = Design rainfall intensity (in./hr.)
L_c = Constant inlet spacing (ft.)
C = Rational runoff coefficient (usually 0.9 from imperfections in pavement)
W_p = Width of pavement contributing to gutter flow (ft.)
n = Manning's N
S_x = Gutter cross-slope (ft.)
T = Design spread (width of gutter flow) (ft.)

If L_c is greater than the length of the bridge, only end treatment drainage is needed. If L_c is less than the bridge length, then compute the total needed inlet perimeter as follows:

(Equation 11.3.2B)

$$P = \frac{(CiW_p)^{0.33} T^{0.61}}{102.5 S_x^{0.06} n^{0.67}}$$

11.3.7 Roadway Overtopping

Avoid overtopping of the bridge deck from a design storm. If overtopping of the bridge is possible, the design engineer should check the bridge for floatation and provide proper anchorage of the deck and super structure components.

11.3.8 Bridge Railing

The bridge railing should be traffic rated.

If overtopping of the bridge from a design storm is possible, the bridge railing should be design to minimize obstruction to the storm overtopping.

Should a bridge railing be on the exterior of the bridge with a sidewalk adjacent to the railing, a hand rail may be needed on top of the bridge railing.

11.3.9 Structural Loads

~~(g)(7)B.~~

All roadway crossings, culverts, and bridges shall be designed for an H-20-44 or HS-20 loading.

All train crossings, culverts and bridges should be designed for a minimum of E80 or as designated by the railroad.

11.3.9.1 Deck

The bridge deck may need to be checked for uplift forces from floatation or from hydraulic jumps in supercritical flow through the bridge.

11.3.9.2 Piers/Columns

The bridge columns should be design for force of the water on the bridge structure and additional impact loading from debris on both the columns and deck.

11.4 REFERENCES

11.4.1 Reference Citation

1) City of El Paso Engineering Department. *Drainage Design Manual*. City of El Paso, El Paso, Texas, June 2008, page 181.

11.4.2 References

- FHWA. *Evaluating Scour at Bridges*, 4th edition. Hydraulic Engineering Circular No. 18, FHWA-NHI-01-001. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, May 2001.
- USACE. *HEC-6 - Scour and Deposition in Rivers and Reservoirs – User's Manual*. U.S. Army Corp of Engineers, Hydrologic Engineering Center, Davis, California, 1991.
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- FHWA. *Design of Bridge Deck Drainage*. Hydraulic Engineering Circular No. 21, FHWA-SA-92-010, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1993.
- USACE. *HEC-RAS River Analysis System – Hydraulic Reference Manual Version 4.1*. U.S. Army Corp of Engineers, Hydrologic Engineering Center, Davis, California, Jan. 2010.
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CHAPTER 12
PUMP STATIONS

12.1 INTRODUCTION

This chapter describes the general guidelines for the design of a pump station.

~~(f)(7)~~
~~Permanent Wet Pool or Pumped Detention Systems. Stormwater retention with permanent wet pool or~~ Pumped detention systems will not be acceptable methods of storm water ~~stormwater~~ mitigation unless the facility will remain privately owned, operated, and maintained. The City of San Antonio ~~city~~ will approve the use of a pumped facility for private use under the following conditions:
Condition 1:
~~A.~~
A gravity system is not feasible from an engineering and economic standpoint.
Condition 2:
~~B.~~
At least two (2) pumps are provided, each of which ~~is~~ are sized to pump the design flow rate.
Condition 3:
~~C.~~
The selected design outflow rate must not aggravate downstream flooding.
Condition 4:
~~D.~~
Controls and pumps ~~shall be~~ are designed to prevent unauthorized operation and vandalism.
Condition 5:
~~E.~~
Adequate ~~assurance~~ verification is provided that the system will be operated and maintained on a continuous basis.

12.1.1 Purpose of a Pump Station

The purpose of a pump station is to lift storm water runoff from a wet well to a receiving stream or outfall. The pump station should be the considered the least desirable method for movement of storm water. The gravity system should be the primary and preferred means of discharging flow from a storm drain system. A pump station may also be used in a water quality basin to discharge treated water into a receiving stream.

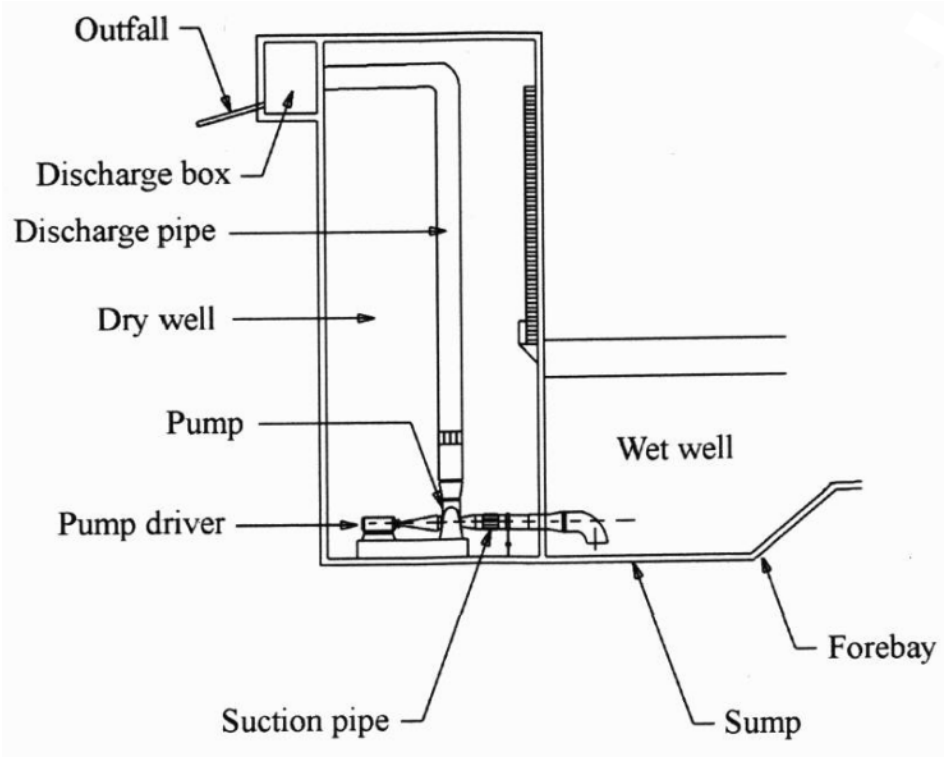


Figure 12.1.1.A - Sump Area with Drywell

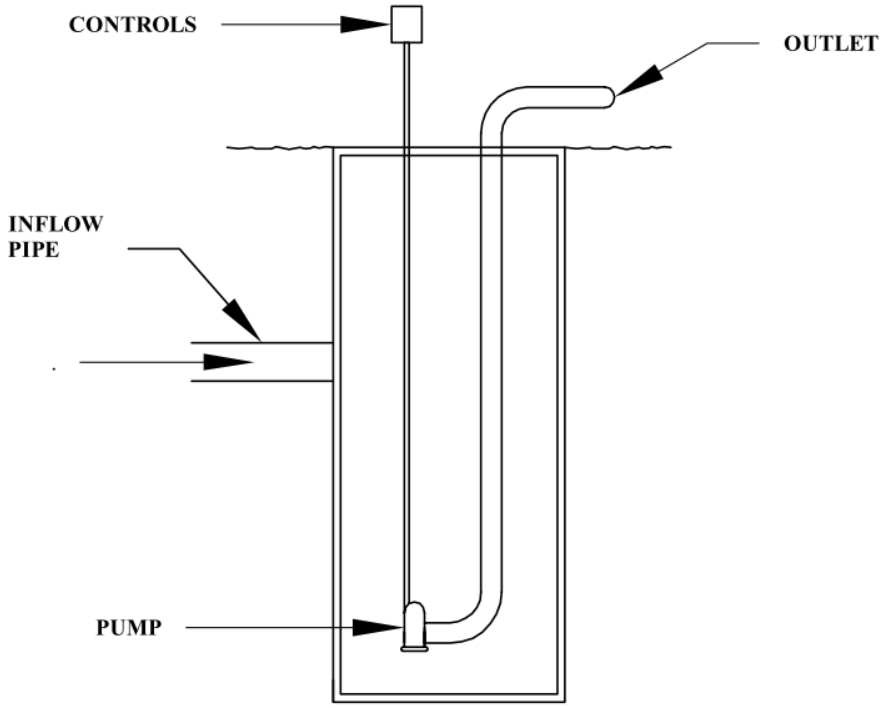


Figure 12.1.1.B - Wet Well

During the pump station planning the design engineer should contact manufacturer representatives for pumps and generators if needed for the site. Contractors who have experience in pump station construction are a good source of information.

12.1.2 Security and Access Considerations

12.1.2.1 Security

The pump station or pump wet well should be protected with fences, gates, and locks to prevent illegal entry.

12.1.2.2 Access

Adequate access must be provided to the pump station or pump wet well. This access should be available for service and maintenance vehicles during a storm event. See Chapter 16.4 Pump Stations for drainage easement requirements.

12.1.3 Safety and Environmental Considerations

12.1.3.1 Safety

Standard OSHA rules and other industrial standards of safety should be followed for installation as well as maintenance of a pump station. Access, lighting, ventilation and traffic control should be considered for all instances dealing with a pump station.

12.1.3.2 Hazardous Spills

Hazardous spills should be handled appropriately according to known safety standards for a spill of that type. Personnel should be able to have access to appropriate materials to contain and/or clean all spills.

12.2 PUMP STATION COMPONENTS

12.2.1 Overview of Components

A full discussion of the design and specifications of a pump station can be had with the use of a common reference for designing pump stations, FHWA Hydraulic Engineering Circular number 24 (HEC-24). Appropriate specialists for the different components should be consulted early in the design process. The following are various necessary components that the design engineer should pay particular attention to.

Property: An entire pump station generally requires more footprint than merely the pumps and wet well or sump. Other necessary parts of the station include the electrical service, system controller, motor control center cabinets - which must be in a separate, dry room - and standby power generation. Other considerations may be on-site storage and parking. A

required consideration is maintenance access to the pumps and the standby generator; not just personnel access, but the ability and room to bring in suitable vehicles and equipment such as a boom crane to lift out pumps, generator, and electrical cabinets for repair or replacement.(A)

- **Arrangement**: The wells and pumps may not need to be in the same place as the control house. An example of this is a set of wells with submerged pumps and discharge conduits located in a wide median of a depressed section of interstate highway. The control house with the electrical service, standby generator, motor control center, and control circuitry is located along the frontage road out of the depressed section and away from buried or overhead utilities.(A)
- **Wet Well**: The wet well receives the inflow of storm water prior to pumping. It must also be designed with a trash collection rack, room for sedimentation collection without diminishing the design capacity, and sump pump to remove the bottom storage below the main pump level.-(A)
- **Electrical**: The appropriate electrical service for a pump station is usually 277/480-volt, three (3-)phase AC. For a typical pump station, the electrical service equipment includes large metal cabinets for the electrical metering, main circuit breaker, a transfer switch to isolate the station from the utility when the standby generator is powering the station, and the electrical distribution panel. The details of the electrical service equipment are the province of the electrical engineer. However, the design engineer must understand that clearances and air space around electrical equipment are not options; they are mandatory safety requirements which may increase the footprint of the pump station, but cannot be ignored.(A)
- **Standby Power**: The normal source of standby power is either a diesel or natural gas engine/generator set. Fuel cells are not suitable for pump stations because of the hours long start-up time they require. Battery technology is improving to the point where solar or wind power may become viable. Natural gas over diesel is preferred, as sitting diesel can possible gel, become contaminated by moisture over the time period of non-use, as well as have interrupted delivery during critical moments.(A)
- **Pumps**: Pump selection depends on station layout, required pump rate, wet well depth, and pump maintenance considerations. Pump selection includes the size, type, and number of pumps. Pump sizes are usually selected to use multiple pumps rather than a single pump of appropriate size. Smaller pumps are usually less expensive to buy and operate, and with multiple pumps the loss of one will not shut down the entire pump station. A single, large pump is more likely to have long term maintenance problems from the frequent start up required to handle flows from smaller events. The sump pump is a much smaller pump, usually designed to handle small amounts of trash or debris loading without failing.(A)
- **Motors**: Pump motors for department pump stations are usually 480-volt, three-phase electric motors. However, the specific voltage selected depends on the power available from the utility and on what pump-motor combinations are commercially available. The size of each motor depends on the pump size, flow rate, pressure head, and duty cycle. The hydraulic engineer specifying the pumps must work together with the electrical engineer specifying the motors and the control system to insure compatibility of components. (A)

- **Control and Communication Systems**: The control system for a pump station is more than the sensor and circuitry to activate the pumps when the water in the wet well reaches a predetermined height. The control system includes a large cabinet for the motor control center (MCC) to operate and protect all the motors in the station, separate cabinets for the variable frequency drives (VFD) for the pump motors or any motor that may be expected to operate at less than full speed, and a separate cabinet for the programmable logic controller (PLC). The PLC monitors all signals and controls the sequence of operations of the pumps, activation of the standby generator when necessary, deactivation when the flood event has passed, and operation of any night security lighting. The PLC may also include automatic communication with the District and/or Maintenance Office to report the station's status regarding water levels, pump readiness, utility electrical power status, standby generator battery status, fuel status, security, and other concerns. The PLC can be integrated with the Intelligent Transportation System (ITS) to warn motorists of water over the roadway in the event of extreme rain events that exceed the capacity of the pump station. The design of the controls and communications is also the province of the electrical designer. However, the design is dependent on the input information from the hydraulic designer such as wet well capacity, allowed pump discharge rate, desired pump discharge rate, and specific communications.(A)
- **Control Board**: The pump station should have a central control board for starting or stopping some processes and verifying the various components' conditions, whether "running", "standby", or "off". In addition, although the station may be operated by a control system (PLC or other), a manual override for each component is highly recommended for maintenance and testing. This must be designed by the electrical engineer with input from maintenance personnel.(A)
- **Structures**: The structure must meet requirements for public safety, safety codes, local extreme weather conditions, site security, and maintenance operations. Maintenance requirements may be oversized doors to move equipment in and out or a movable roof to allow crane access. Aesthetics and the possibility of future expansion should also be considered.(A)
- **Discharge Conduits**: The collected waters are usually discharge to a storm drain system, although sometimes the discharge point is a wetland, mud flat, or creek. The designer must also consider whether the receiving location is suitable for the anticipated pump rate, whether it is available during flood events, and whether flood water discharge from the pump station are allowed.-(A)
- **Acceptance test**: A full run acceptance test should be performed successfully before the pump station is accepted. A full run test procedure consists of running the pumps at maximum capacity for at least 6 hours and testing the control systems. During this procedure, the standby generator should be used to power the full station for at least 6 hours which will test the pumps and generator at full load. The discharge conduits can be arranged with a diverter or bypass to pour the pumped water back into the wet well to maintain the full run test.(A)

- **Scheduled Maintenance**: Pump stations, unlike other hydraulic structures, require scheduled cleaning and maintenance. The trash rack should be cleaned after each storm, while the wet well sump must be cleaned whenever the sediment reaches a set point. The standby generator must be exercised at least once a month for a minimum of 30-minutes run time. The entire system including pumps should be exercised under full load at the same schedule to assure reliability. The discharge diverter or bypass from the acceptance test should be maintained so that it can be used in the scheduled maintenance monthly test.(A)

12.3 PUMP STATION HYDROLOGY

12.3.1 Methods for Design

In order to design a pump station effectively, the inflow hydrology must be known. The hydrology developed for the associated storm drain system usually will not serve as a firm basis for discharge determination into the pump station. A hydrograph is required because the time component is critical in understanding the inflow which governs the sizing of the wet well. The designer needs to know not only the peak inflow, but the timing and volume. The difference between the input and the output hydrographs is the storage requirements of the pump station wet well. The hydrograph should consider the storage abilities of the storm drain system, which may reduce the required size of the wet well. Governmental regulations or the physical limitations of the receiving waters determine the output discharge from the pump station.-(A)

The design frequency for a pump station will be ultimate twenty-five (25) year storm if the drainage area to the pumps is less than one hundred (100) acres. If the drainage area to the pumps is more than one hundred (100) acres, the system should be designed for the ultimate one hundred (100) year storm.

12.3.2 Procedure to Determine Mass Inflow

A mass inflow curve represents the cumulative inflow volume with respect to time. In order to determine a mass inflow curve, the hydraulic designer must first develop an inflow hydrograph based on a design storm.(A) The most typical design method is the NRCS Dimensionless Unit Hydrograph and the procedure can be found in the FHWA Hydraulic Engineering Circular 24 (HEC-24).

12.4 PUMP STATION HYDRAULIC DESIGN GUIDELINES

12.4.1 Storage Design Guidelines

The storage volume of the wet well should be less than the total volume of the wet well because allowances should be made for a sump and for freeboard. The sump is the volume of

the wet well below the required minimum water level, which is the pump cutoff elevation. The wet well must maintain water above the pump inlet to keep the pump from attempting to pump dry or sucking air. The sump must also have room below the pump intake level for sedimentation and heavy trash that wash into the system.

The top of the storage volume determines the maximum water level, the level in the wet well above which the water should not be allowed to exceed. Any freeboard above the maximum water level is not included in the calculated storage volume. Pumping is initiated at or below the maximum water level, and is stopped when the water drops to the minimum water level.

Other spaces outside of the wet well which store storm water before flooding occurs can also be considered part of the available storage volume. These include sumps, pipes, boxes, inlets, manholes, and ditches of the storm drain system. The storm drain system can represent a significant storage capacity.

The pump station schematic shown in figure 12.4.1.A is typical for roadway crossing under a railroad bridge, with the outfall being higher than the low point of the roadway. The typical cross sections shown in figure 12.4.1.B is the drainage system leading to the pump station.

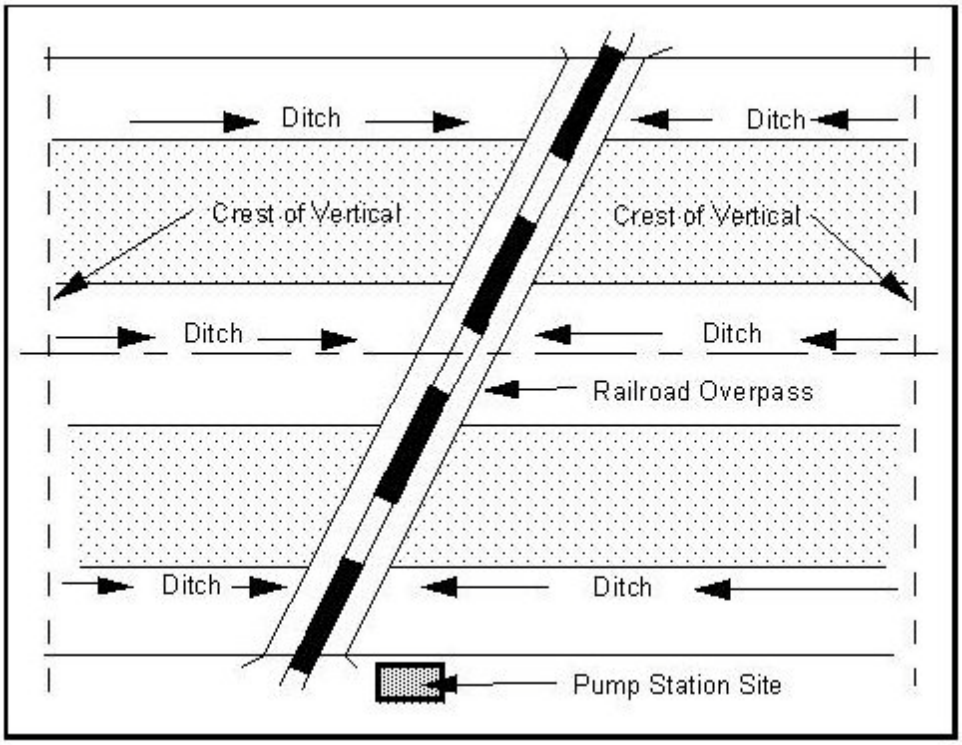


Figure 12.4.1.A - Pump Station Schematic
(Source TxDOT, Hydraulic Design Manual, 2011)

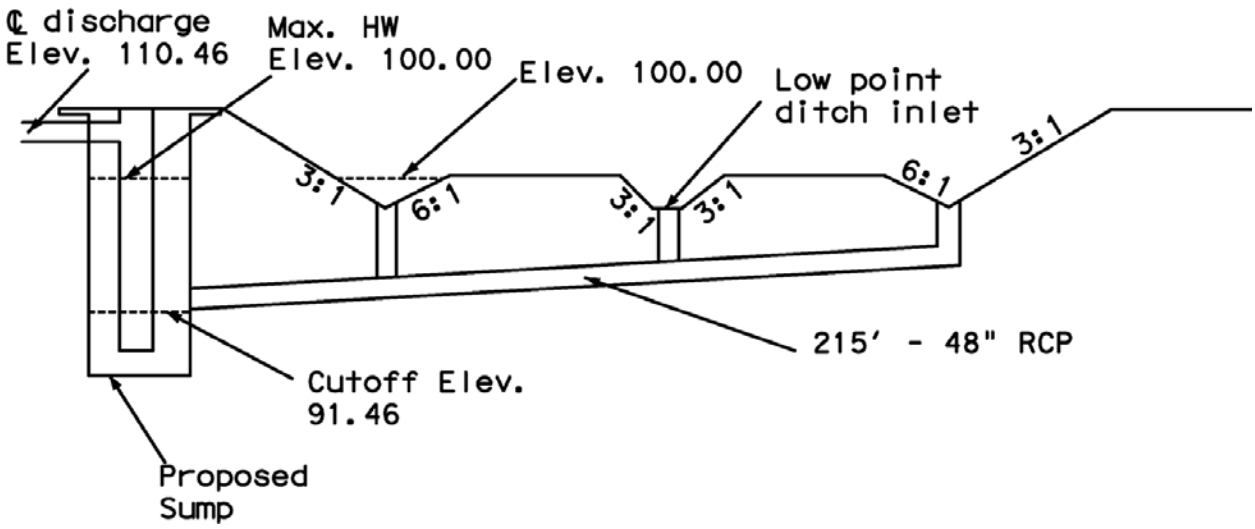


Figure 12.4.1.B - Typical Cross Section
(Source TxDOT, Hydraulic Design Manual, 2011)

12.4.2 Pump Selection

The selected rate of discharge from the pump station determines the number and size of pumps required for the facility. However, pump selection is a matter of economic analysis by the designer. (A) A decision must be made using several manufacturers' technical data and whether a single or number of pumps would be necessary. A backup pump is required, and will be of the same discharge rating. A slightly lower pump rate than the allowable discharge is fine but the lower rate requires a larger wet well volume.

The designer must also consider the cost of construction and physical restrictions for the wet well. Enlarging the wet well and using fewer pumps might be a reasonable alternative to a larger wet well. In situations where one pump may be able to supply the entire discharge necessary, a minimum of two smaller pumps is recommended for reliability and maintenance. Multiple pumps also offer the opportunity for a staggered startup of pumps. Manufacturer's printed technical data and a sales or technical representative can be invaluable sources at this stage of the design in selecting the right pumps. The final design and pump selection must be based on all the considerations together. (A)

12.5 MAINTENANCE CONSIDERATIONS

12.5.1 Operation

During pump station operation, all OSHA and local safety requirements must be adhered to. An entry plan should be developed as part of the operation and maintenance procedures for the pump station. The plan should identify measures to be taken prior to and during any visit to the pump station, including monitoring of environmental conditions, especially air quality.

All semantics, product information, and operational manuals should be provided by the contractor or engineer to the owner upon completion and acceptance of the pump station.

12.5.2 Maintenance Schedule

An operation and maintenance schedule should identify the frequency of inspection in regards to the need for debris and sediment removal, as the build-up may cause a reduction in pump efficiency and possible failure. A provision should be added for future pump maintenance and/or removal due to failure or reduced durability of the pump due to possible unforeseen circumstances. FHWA Hydraulic Engineering Circular No. 24 (HEC-24) has a general list of problems, causes, and solutions available. A full performance test should be periodically performed to check the continued operating efficiency of the pumping station. See Chapter 4.12 for additional guidance on maintenance standards.

12.6 REFERENCES

12.6.1 Reference Citations

(1) TXDOT. Pump Stations. Chapter 11 in *Hydraulic Design Manual*. Texas Department of Transportation, Revised May 2014. Retrieved from http://onlinemanuals.txdot.gov/txdotmanuals/hyd/index.htm

12.6.2 References

- TXDOT. Pump Stations. Chapter 11 in *Hydraulic Design Manual*. Texas Department of Transportation, Revised May 2014. Retrieved from http://onlinemanuals.txdot.gov/txdotmanuals/hyd/index.htm
- FHWA. *Highway Stormwater Pump Station Design*. Hydraulic Engineering Circular No. 24 FHWA-NHI-01-007, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2001.

CHAPTER 13
STORAGE FACILITIES

13.1 INTRODUCTION

For the City of San Antonio, storm water storage facilities cover many different criteria. Storage facilities are used to reduce flood risk and mitigate peak flows to pre-development conditions so downstream water elevations do not increase. Developers should contact the TCI Department for information on whether the property is within the mandatory detention areas prior to starting a project. For properties not located within the mandatory detention areas, any development with an increase in impervious area greater than one hundred (100) square feet has the options of participating in the Regional Storm Water Management Program (RSWMP) per section 4.3.1B. A water quality feature can be incorporated into a storage basin provided it does not interfere with basin functionality. All storage facilities should be designed with public health and safety in mind.

The following should be considered during the design of the storage facility.

~~(f)~~
~~Stormwater Detention and Other Stormwater Management Facilities.~~ For projects with an increased impervious area of greater than ~~0.1 acres~~ one hundred (100) square feet, that elect not to participate or are not eligible to participate in the regional storm water ~~stormwater~~ management program as described in section 4.3 ~~subsection 35-504(b)(1)~~, ~~then~~ storm water ~~stormwater~~ detention shall be required for all new development(s) or redevelopment of individual parcels of property to mitigate peak flow rates to predevelopment or existing development conditions as stated in UDC subsections 4.3.7 ~~(b)(6)~~ and 4.3.8 ~~(b)(7) of this section~~.

~~(f)(1)~~
~~Maximum Outflow Rate. The maximum allowable outflow rate from the detention facility must be restricted to the flow rate from the undeveloped or existing development tract for the five-year, twenty-five-year and 100-year frequency.~~ Best management practices shall be used in the design of detention facilities in accordance with this Chapter ~~section~~. The timing of the hydrograph released from the detention facility must be checked against the timing of the flow rate in the first open watercourse to prevent ~~any~~ increase(s) in the peak flow rate in the receiving watercourse. For detention basins constructed in-line on an existing watercourse, the creation of the basin shall not increase flood elevations in the channel upstream of the new development boundaries.

~~(f)(2)(ii)~~
Where a detention facility accepts flows from public facilities such as City ~~rights-of-way the detention~~ rights-of-way, the facility will be considered ~~a detention facility~~ as serving a public purpose; it ~~and~~ will be dedicated to the City of San Antonio upon completion and a drainage

easement will be ~~dedicated to~~ provided for access to the facility. When a regional detention facility accepts flow from an area exceeding three hundred twenty (320) ~~(300)~~ acres, the facility ~~shall~~ is to be considered as serving a public purpose and shall be dedicated to the City ~~of San Antonio city~~upon completion and a drainage easement will be provided for access to the facility.

13.1.1 Security, Access, and Safety Considerations

13.1.1.1 Security

Due to legal considerations, most storage facilities have gated fencing to keep them in good condition.

13.1.1.2 Access

Easy maintenance access should be considered with easements and access ramps.

~~(f)(8)D.~~

~~A 100-year frequency flood shall be routed through the proposed dam and all land subject to flooding shall be dedicated as drainage easement or right-of-way.~~ An unobstructed fifteen (15)-foot access easement around the periphery of the flooded area shall be dedicated as a drainage easement for facilities that require regular mowing or other ongoing maintenance, at the discretion of the Director of TCI ~~director of public works~~. An unobstructed fifteen (15)-foot access right-of-way shall be established; this will ~~which~~ connect~~s~~ the drainage easement adjacent to the ~~dam structure~~ storage facility to a road or alley.

~~(f)(5)~~

~~Access Ramps. Ramps~~ Access ramps, ~~as necessary~~, with a maximum slope of seven to one (7:1), with a maximum cross slope of 2% ~~percent~~, will be provided for access to the flow line of all storage ~~public detention~~ facilities.

13.1.1.3 Safety

Several considerations can help promote safety. Placing removable and efficient grates or bars on inlet/outlet pipes, fencing, and even lowering flow velocities into/out of the facility can help promote public safety. Even with locating the facility away from busy areas, the design engineer should still maintain easy access.

13.2 SINK HOLES

Sink holes are one of several karst surface expressions that meet the TCEQ definition of a sensitive feature. Several methods are available to deal with sink holes depending on their location, both before and during construction. Due to the possibility of being a recharge feature, an approved geologic assessment of the space and surrounding area by or for TCEQ will be required before any action can be taken. For public safety, a detention basin may replace the function of the sinkhole if no endangered species are impacted. For further information, see TCEQ documents RG-348 and RG-348 Appendix A.

13.3 DETENTION BASINS

The primary function of a detention basin is to store and gradually release storm water runoff by way of a control structure or other release mechanism. The basin can be above or below ground, existing as collection and conveyance facilities, impoundments, and underground tanks. Detention basins are the most common type of storage facility and are usually 'dry-pond' types, which release all of the detained runoff over a short, specified length of time (usually twenty-four (24) or forty-eight (48) hours).

13.3.1 Design types

There are four common types of detention basin: in-line detention storage, off-line detention, on-line detention, and on-site detention.

- **In-line detention**: This type of storage occurs within a channel right-of-way and only near the headwaters of a watershed or sub-area, with only the immediate landowner(s) draining to it. The channel is either oversized and/or changed to elevate the water surface inside it by a control structure or increasing roughness in order to slow the storm water and prevent downstream flooding.
- **Off-line detention**: This type of detention diverts a portion of a hydrograph from a nearby channel only when specific parameters are met. These usually are adjacent to a channel and have a side weir as a control structure, allowing overflow from the open channel.
- **On-line** detention: This type of detention passes the entire hydrograph through itself. This is often used to delay the time-to-peak discharge and is the best at controlling the rising limb of the hydrograph. These can be on-site detention basins as well, with those that are open to a channel being referred to as "flow-through" detention basins.
- **On-site detention**: This type of detention is within the development itself, usually only accepting storm water from the development itself (unless the development is right in the path of the areas' storm water, which makes it on-line) and restricting the outfall to the receiving channel. Mandatory detention areas tend to be this type.

13.3.2 Design Guidelines

The following steps are only guidelines; depending on the size of project, several steps can be removed. (A)

1.) Select a location and prepare a general layout for the detention basin.
2.) Determine the inflow hydrographs and maximum allowable outflow rates.
3.) Establish the maximum allowable water elevation in the basin and determine tail water condition in the outfall channel.
4.) Estimate the detention volume needed and size the outflow structure. Determine the relationship between storage, discharge, and elevation.
5.) Route the design one hundred (100) year ultimate inflow hydrograph through the basin and outflow structure with appropriate tail water condition.

6.) Adjust the detention volume and outflow structure, if necessary, until the allowable one hundred (100) year ultimate is not exceeded and the detention basin fills to or near the design maximum allowable water surface elevation.
7.) Route the other design frequencies through the basin and make appropriate adjustment to the outflow structure. Recheck the one hundred (100) year ultimate after any changes made to the outflow structure.
8.) Verify storm drains, street drainage, and channels entering the basin will function as intended, relative to the design water levels in the detention basin.
9.) Consider an emergency spillway or overflow structure for a rainfall event larger than the design storm or in the event of a blocked outfall pipe.
10.) Investigate potential geotechnical and structural problems and establish an erosion control plan.
11.) Establish the easement limits, including access for maintenance and space for multi-use.

13.3.2.1 Location

The preferred location for a detention basin is the lowest area of the property. However, overland and storm drain flow should also be considered (if the basin will be picking up more than just the local flows), as well as its function in respect to the floodplain (with consideration to timing and backwater elevations; is it receiving all or part of the upstream flows).

13.3.2.2 Design Frequencies

The City of San Antonio restricts the outflow rates to the undeveloped or existing five (5) year, twenty-five (25) year, and one hundred (100) year frequencies, 24 hour storm. The designed basin should not increase flood elevations upstream of the new development. See Chapter 5 "Hydrology" for approved methods of developing flows for the needed frequencies.

13.3.2.3 Features

Several features are necessary for a detention basin. Inflow structure(s), outflow structure(s), layout, outfalls, and the areas' calculated flow (both upstream and downstream of the basin). See this chapter for layouts, inflow, and outflow structures; Chapter 7 for outfalls; and Chapter 5 on calculating required flows.

13.3.2.4 Routing Methods

For most basins, the use of HEC-HMS is preferred as it gives a good look at the outflow hydrograph in relation to the main channel's hydrograph as well as peak timing. HEC-RAS is more difficult, but can give a better idea of where to place control structures for the basin. Solid documentation and calculations will need to be provided to the City by the design engineer, regardless of what routing methods are used.

13.3.2.5 Freeboard

A detention basin should be designed to contain the one hundred (100) year ultimate water surface below the top of basin. The design engineer should determine if additional freeboard is required to mitigate a larger storm event from overtopping the basin.

Should the detention facility or basin meet the TCEQ requirements for a dam under their review, then the design of the dam shall meet the TCEQ freeboard requirements.

13.3.2.6 Layouts

The layout of the basin should consider the location of the inlet to be at the opposite end of the basin from the outlet to minimize the approach velocity at the outlet. The outlet shall drain to a defined low.

For earthen side slopes, the maximum slope should not be steeper than 3H: 1V.

The bottom of a detention basin should be sloped toward the outlet. For detention basins with an earthen bottom, a minimum slope of 0.5 percent should be maintained. A concrete pilot channel should be used for slopes less than 0.5 percent with a minimum width of six (6) feet.

Access ramps into open detention basins should be located for ease of access for maintenance personnel. A maximum slope of seven to one (7H:1V) with a maximum cross slope of 2% will be provided. For underground detention basins, access manholes should be located to allow inspection and maintenance of the underground structure.

The discharge from the outflow structure, overflow structure, and auxiliary/emergency spillway shall not cause adverse downstream impact to adjacent properties and or structures.

13.3.2.7 Overflow

An overflow structure should be provided for a rainfall event larger than the design storm or in the event of a blocked outfall pipe. The overflow discharge shall drain to a defined low.

13.3.2.8 Auxiliary/ Emergency Spillways

The purpose of an auxiliary/emergency spillway is to provide a controlled overflow relief for storm flows in excess of the design discharge for the storage facility. A suitable auxiliary/emergency spillway section for a detention facility is a broad crested weir, cut through the original ground next to the embankment. The transverse cross section of the weir is typically trapezoidal in shape. Please refer to Figure 13.3.2.8a. The invert of the spillway at the outfall should be at an elevation 1 to 2 ft above the maximum design storage elevation.

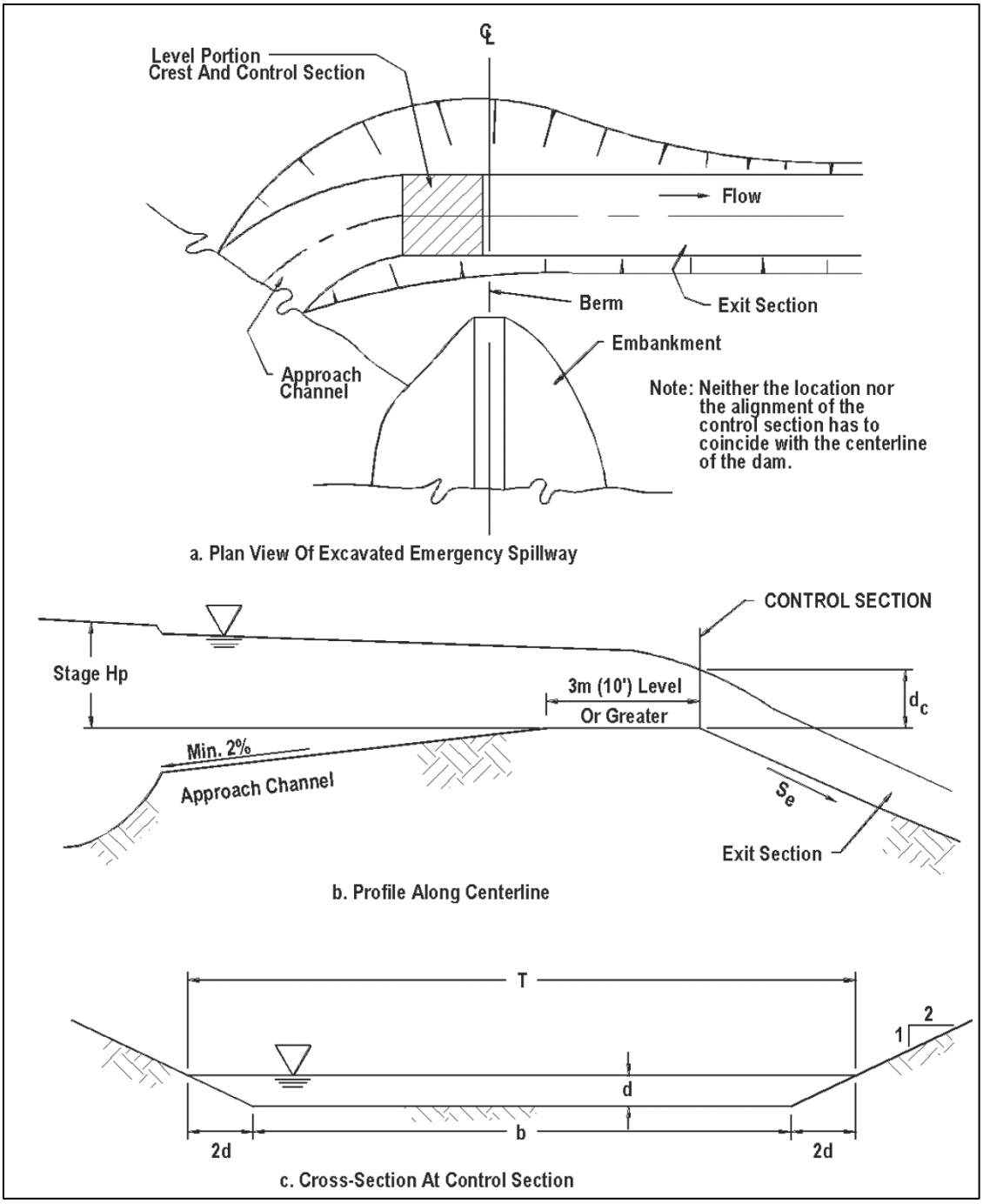


Figure 13.3.2.8a - Auxiliary/Emergency Design Schematic
(Source FWA, Urban Drainage Design Manual, Sept. 2009)

The following equation presents the relationship for computing the flow through a broad-crested auxiliary/emergency spillway.

(Equation 13.3.2.8)

$$Q = C_{sp} b H_p^{1.5}$$

Q = Emergency spillway discharge (cfs)
C_{sp} = Discharge coefficient
b = Width of the emergency spillway (ft.)
H_p = Effective head on the emergency spillway (ft.)

The discharge coefficient, C_{sp}, in equation 13.3.2.8 varies as a function of spillway bottom width and effective head, Figure 13.3.2.8b illustrates this relationship, Table 13.3.2.8 provides a tabulation of auxiliary/emergency spillway design parameters.

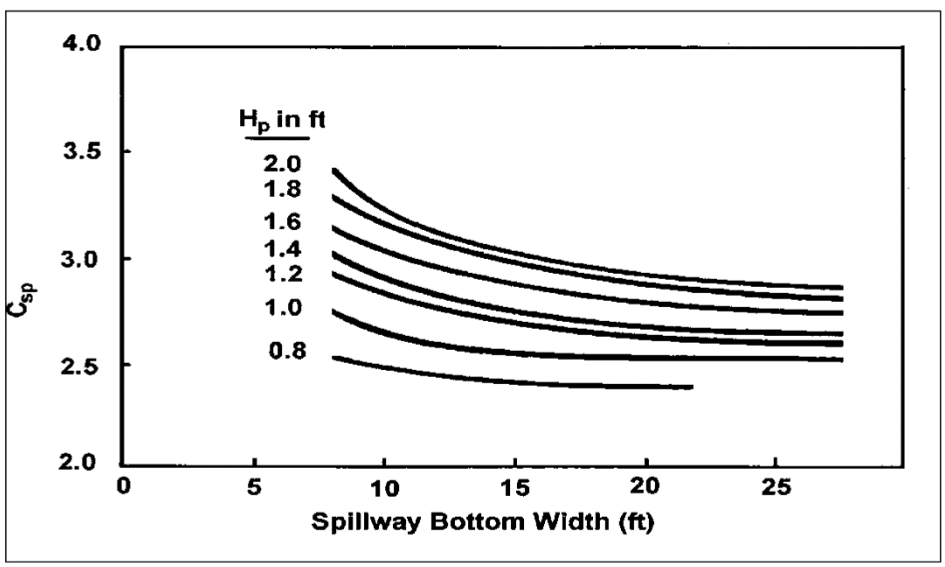


Figure 13.3.2.8b - Discharge coefficients for Spillways
(Source FWA, Urban Drainage Design Manual, Sept. 2009)

Table 13.3.2.8 - Spillway Design Parameters

Emergency Spillway Design Parameters													
H_p (ft)		Spillway Bottom Width, b, feet											
		8	10	12	14	16	18	20	22	24	26	28	30
0.8	Q	14	18	21	24	28	32	35	-	-	-	-	-
	V_c	3.6	3.6	3.6	3.7	3.7	3.7	3.7	-	-	-	-	-
	S_c	3.2	3.2	3.2	3.2	3.1	3.1	3.1	-	-	-	-	-
1.0	Q	22	26	31	36	41	46	51	56	61	66	70	75
	V_c	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.2	4.2
	S_c	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
1.2	Q	31	37	44	50	56	63	70	76	82	88	95	101
	V_c	4.5	4.5	4.5	4.6	4.6	4.6	4.6	4.7	4.6	4.6	4.6	4.6
	S_c	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6
1.4	Q	40	48	56	65	73	81	90	98	105	113	122	131
	V_c	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	S_c	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
1.6	Q	51	62	72	82	92	103	113	123	134	145	155	165
	V_c	5.2	5.2	5.3	5.3	5.3	5.3	5.3	5.4	5.4	5.4	5.4	5.4
	S_c	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4
1.8	Q	64	76	89	102	115	127	140	152	164	176	188	200
	V_c	5.5	5.5	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.7	5.7	5.7
	S_c	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3
2.0	Q	78	91	106	122	137	152	167	181	196	211	225	240
	V_c	5.8	5.8	5.8	5.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	S_c	2.5	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3

NOTE:
1. For a given H_p , decreasing exit slope from S_c decreases spillway discharge, but increasing exit slope from S_c does not increase discharge.
2. If a slope S_e steeper than S_c is used, velocity V_e in the exit channel will increase according to the following relationship:

$$V_e = V_c(S_e/S_c)^{0.3}$$

3. After Maryland SCS

13.4 RETENTION BASINS

The function of true retention basins is to provide storage of storm water runoff, and release via evaporation and infiltration only. Those retention basins that provide for a slow release of storm water over an extended period of several days or more are referred to as extended detention facilities. Retention facilities may also be used for recreation, pollutant removal, groundwater recharge, aesthetics, or even water supply. Like detention basins, they can be above or below ground. Most facilities are designed for both storm water impoundment and quality control.

~~(f)(7)~~

~~Permanent Wet Pool or Pumped Detention Systems.~~ Storm water ~~stormwater~~ retention with or without permanent wet pool ~~or pumped detention systems~~ will not be acceptable methods of storm water ~~stormwater~~ mitigation unless the facility will remain privately owned,

operated, and maintained. ~~The city will approve the use of a pumped facility for private use under the following conditions:~~

13.4.1 Design Guidelines

13.4.1.1 Design Frequencies

The design frequency should be the one hundred (100) year ultimate, 24 hour storm.

13.4.1.2 Routing Methods

The routing method is similar to detention basins, but with a zero discharge.

13.4.1.3 Freeboard

The basin should contain the one hundred (100) year ultimate water surface.

13.4.1.4 Overflow

An overflow structure should be provided for storms greater than the one hundred (100) year ultimate and for multiple storms over a short period of time. The overflow discharge shall drain to a defined low.

13.5 DOWNSTREAM FLOW ANALYSIS

A downstream flow analysis should be performed with the routed storm through the storage facility. The length of reach downstream of the storage facility to be analyzed should be to a point where the drainage area of the stream will be ten times the drainage area to the basin.

13.6 STRUCTURES

13.6.1 Dams

~~(f)(8)B.~~

All hydrology and hydraulic properties of a dam will be reviewed by the TCI Department ~~the department of public works~~ with regard to spillway design, freeboard hydraulics, backwater curves, and downstream effects due to the dam site.

13.6.1.1 Existing Dam

~~(f)(8)E.~~

Development below existing dams will take into account the original design conditions of the existing dam. ~~Dam breach analysis checks will be required, dependent upon location of development with respect to dam site.~~

13.6.1.2 Proposed Dam

~~(f)(8)A.~~

All dams, as defined by section 13.6.1.5 shall be ~~over six (6) feet above existing natural around shall be~~ approved by the Dam Safety Team of the ~~TNRCC~~ TCEQ for safety. All other

new dams shall be designed in accordance with acceptable design criteria as approved by the Director of TCI director of public works, or his authorized representative.

13.6.1.3 Breach Analysis

(f)(8)E.

Development below existing dams will take into account the original design conditions of the existing dam. For Dams defined by the TCEQ, a Dam breach analysis checks will be required, dependent upon location of development with respect to the dam site.

13.6.1.4 Emergency Action Plan

An emergency action plan should be provided if the dam is regulated by TCEQ.

13.6.1.5 Approval of TCEQ Dam Safety Program

The design engineer should determine if the proposed or existing dam or reservoir would be regulated by TCEQ and require their approval.

The following is from the Texas Administrative Code, Title 30 – Environmental Quality, Part 1 – Texas Commission on Environmental Quality, Chapter 299 – Dams and Reservoirs, Subchapter A – General Provisions, Rule §299.1 – Applicability.

(a) This chapter applies to design, review, and approval of construction plans and specifications; and construction, operation and maintenance, inspection, repair, removal, emergency management, site security, and enforcement of dams that:

(1) have a height greater than or equal to 25 feet and a maximum storage capacity greater than or equal to 15 acre-feet, as described in paragraph (2) of this subsection;

(2) have a height greater than six feet and a maximum storage capacity greater than or equal to 50 acre-feet;

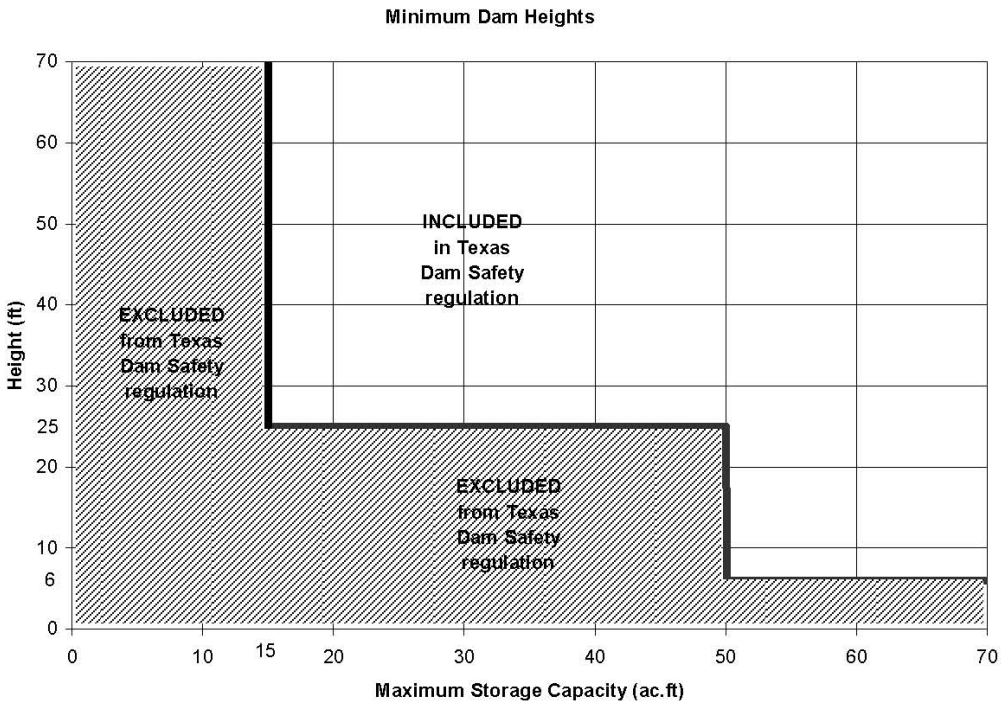


Figure 30 TAC § 299.1(a)(2)

(3) are a high- or significant-hazard dam as defined in §299.14 of this title (relating to Hazard Classification Criteria), regardless of height or maximum storage capacity; or

(4) are used as a pumped storage or terminal storage facility.

(b) This chapter provides the requirements for dams, but does not relieve the owner from meeting the requirements in Texas Water Code (TWC), Chapter 11, and Chapters 213, 295, and 297 of this title (relating to Edwards Aquifer; Water Rights, Procedural; and Water Rights, Substantive; respectively). All applicable requirements in those chapters will still apply.

(c) This chapter does not apply to:

(1) dams designed by, constructed under the supervision of, and owned and maintained by federal agencies such as the Corps of Engineers, International Boundary and Water Commission, and the Bureau of Reclamation;

(2) embankments constructed for roads, highways, and railroads, including low-water crossings, that may temporarily impound floodwater, unless designed to also function as a detention dam;

(3) dikes or levees designed to prevent inundation by floodwater;

(4) off-channel impoundments authorized by the commission under TWC, Chapter 26; and

(5) above-ground water storage tanks (steel, concrete, or plastic).

(d) All dams must meet the requirements in this chapter, including dams that do not require a water right permit, other dams that are exempt from the requirements in Subchapter C of this chapter (relating to Construction Requirements), and dams that are granted an exception as defined in §299.5 of this title (relating to Exception).

13.6.2 Inflow Structure

The inflow structure could be the outlet from a storm drain system, roadway culvert, scupper, chute or channel. The discharge velocity at outlets into an earthen basin should be check for erosion control. The basin hydraulics should be analyzed for the impacts to the inflow structure and upstream drainage system.

13.6.3 Outfall Structure

~~(f)(8)F.~~

All spillway discharges shall be adequately routed to the centerline of the natural low below the dam site. The adequate routing of spillway discharges pertains to the hydraulic routing of the one hundred (100)~~-~~year ~~frequency flood~~ storm event for dedication of drainage easement limits. Probable Maximum Precipitation (PMP) ~~defined PMP on definition section~~ for flood routing or breaches will only be considered for safety considerations (that is, the placement of building and the setting of minimum floor slab elevations below the dams). Any proposed concrete dam structure need not have a spillway capable of routing a PMP flood~~,~~; however, it shall be shown to be structurally capable of withstanding any range of flood conditions with regard to possible failure due to sliding, overturning, and structural integrity, up to and including the PMP flood.

13.6.3.1 Primary Spillway

The primary spillway is the outfall structure for the design storms.

13.6.3.2 Secondary Spillway (Auxiliary Spillway)

~~(f)(8)C.~~

The spillway section of any earthen dam, as defined in section 13.6.1.5 ~~with a height greater than six (6) feet~~ shall be large enough to pass a PMP ~~(probable maximum precipitation)~~ flood, as defined by the NRCS, without overtopping the crest of the dam in accordance with ~~TNRCC~~ TCEQ regulations.

13.6.4 Pumps

~~(f)(7)~~

~~Permanent Wet Pool or Pumped Detention Systems. Stormwater retention with permanent wet pool or~~ Pumped ~~pumped~~ detention systems ~~will~~ are not be acceptable methods of storm water ~~stormwater~~ mitigation, unless the facility ~~will~~ is to remain privately owned, operated, and maintained. The City will approve the use of a pumped facility for private use under the following conditions:

13.6.4.1 Condition 1

~~A.~~

A gravity system is not feasible from an engineering and economic standpoint.

13.6.4.2 Condition 2

~~B.~~

At least two (2) pumps are provided each of which is sized to pump the design flow rate.

13.6.4.3 Condition 3

~~C.~~

The selected design outflow rate must not aggravate downstream flooding.

13.6.4.4 Condition 4

~~D.~~

Controls and pumps ~~shall~~ should be designed to prevent unauthorized operation and vandalism.

13.6.4.5 Condition 5

~~E.~~

Adequate assurance is provided that the system will be operated and maintained on a continuous basis.

13.7 MAINTENANCE CONSIDERATIONS

13.7.1 Operation

Most detention basins will not require an operational plan. The exception is ones that have a pump system or gates to control the discharge. These exceptions will require an operational plan. These plans should be submitted to the City and approved by the Director of TCI.

13.7.2 Maintenance Schedule

13.7.2.1 Regional Detention Facilities

~~(f)(3)~~

~~Regional Detention Facilities. General locations and sizes of regional detention facilities have been identified in the master drainage plan for the major watersheds in the city's jurisdiction. The ownership of regional detention facilities may either be public or private. The creation of regional detention facilities designed to service one (1) or several developments is encouraged, but not required. In watersheds where public regional detention facilities exist, mitigation of increased stormwater runoff from new construction may utilize these facilities if the new construction is eligible to participate in the RSWMP. Temporary detention may be required for the development until sufficient capacity in the outfall channel is provided to accommodate increased flows.~~ Maintenance of publicly owned facilities will be the responsibility of the City. Maintenance of private facilities is the responsibility of the

property owner or the community association and must be specified in the maintenance schedule submitted to the City. A maintenance schedule for both publicly owned and privately owned facilities must be approved by the Director of TCI ~~director of public works~~ prior to approval of construction drawings. See Chapter 4.12 for additional guidance on maintenance standards.

~~Drainage easements will be provided for all regional detention facilities. The easement will encompass the 100-year pool elevation plus all structural improvements (levees, dykes, berms, outfall structures etc.) necessary to contain the pool. The easement will extend, at a minimum, to the toe of the downstream embankment. Maintenance access (fifteen-foot minimum) will be provided around the facility, outside the limits of the 100-year pool elevation. Ramps, as necessary, with a maximum slope of seven to one (7:1) will be provided for access to the flow line of the facility.~~

~~(f)(4) Easement Requirements.~~

~~A.~~

~~Drainage easements will be required for all stormwater management facilities accepting runoff from properties other than the lot on which the facility exists or will be constructed. Maintenance of the detention facility shall be the responsibility of the property owner or the property owner's association.~~

13.7.2.2 On-Site Storm Water Management Features

~~(f)(2)(i)~~

On-site storm water ~~stormwater~~ management features must be privately owned and shall be maintained by the community association or property owner. A maintenance schedule shall be submitted to the ~~public works department~~ Department of TCI and approved by the Director of TCI ~~director of public works~~ prior to approval of construction plans. The City of San Antonio will have the right to do periodic inspections of privately owned and maintained detention facilities to ~~ensure~~ confirm that the maintenance schedule is being implemented.

13.8 CERTIFICATION

13.8.1 Detention Pond Plan Conformance Form

The design engineer should complete a “Detention Pond Plan Conformance” form after the completion of the detention pond and provide the completed form to the City.

13.8.2 As-Built Plans for Dams

As-Built plans should be provided upon completion of the dam and impoundment area if required by the owner or by TCEQ requirements.

13.9 REFERENCES

13.9.1 Reference Citation

A. Harris County Flood Control District. Stormwater Detention Basins. Section 6 in *Policy Criteria & Procedure Manual for Approval and Acceptance of Infrastructure*. Harris County Flood Control District, Houston, Texas, October 2004, updated December 2010. Retrieved from http://www.hcfcd.org/dl_manuals.html

13.9.2 References

- Harris County Flood Control District. *Policy Criteria & Procedure Manual for Approval and Acceptance of Infrastructure*. Harris County Flood Control District, Houston, Texas, October 2004, updated December 2010. Retrieved from http://www.hcfcd.org/dl_manuals.html
- TCEQ. *Complying with the Edwards Aquifer Rules – Technical Guidance on Best Management Practices*. RG-348. Texas Commission on Environmental Quality, Field Operations Division, Austin, Texas, July 2005.
- TCEQ. *Optional Enhanced Measures for the Protection of Water Quality in the Edwards Aquifer (Revised) – Appendix A to RG-348 – Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices*. RG-348A. Texas Commission on Environmental Quality, Chief Engineer's Office, Water Programs, Austin, Texas, September 2007.
- TCEQ. *Hydrologic and Hydraulic Guidelines for Dams in Texas*. GI-364. Texas Commission on Environmental Quality, Field Operations Support Division, Dam Safety Program, Austin, Texas, January 2007.
- TCEQ. *Design and Construction Guidelines for Dams in Texas*. RG-473. Texas Commission on Environmental Quality, Field Operations Support Division, Dam Safety Program, Austin, Texas, August 2009.
- FHWA. *Urban Drainage Design Manual*. Hydraulic Engineering Circular No. 22, 3rd edition, FHWA-NHI-10-009. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, Sept. 2009.

CHAPTER 14
DRAINAGE EASEMENTS

14.1 INTRODUCTION

This chapter provides the general guidelines for easements needed for the storm drainage facilities.

~~(d)(1) Applicability.~~

The dedication or acquisition of drainage easements to cover drainage system components is necessary to allow the orderly development and transfer of storm water across properties. Where a subdivision is traversed by a watercourse, drainageway, natural channel, or stream, ~~there shall be provided~~ an easement conforming substantially to the limit of such watercourse shall be provided, ~~plus~~ including additional width as outlined below.

~~(d)(2) Requirements.~~

Easement ~~or right-of-way~~ requirements are specified in the following subsections of this chapter ~~section~~ for particular storm water ~~stormwater~~ management facilities:

A.
Subsection 14.3.2 Natural Channels ~~(d)(3) Natural Watercourses or Floodplains;~~
B.
Subsection 14.5 Storage Facilities ~~(f)(3) Regional Detention Facilities~~;
C.
Subsection 14.3.1.2 Concrete Channels ~~(h)(6)(e) Concrete Lined Channels;~~
D.
Subsection 14.3.1.1 Improved Earth Channels ~~(h)(7)(c) and (d) Vegetated Earth Channels;~~
E.
Subsection 14.2 Storm Drain Systems ~~(i)(c) Storm Drains.~~
F.
Subsection 14.4 Pump Stations

~~(f)(4) Easement Requirements.~~

~~A.~~

Drainage easements will be required for all storm water ~~stormwater~~ management facilities accepting runoff from properties other than the lot on which the facility exists or will be

constructed. ~~Maintenance of the detention facility shall be the responsibility of the property owner or the property owner's association.~~

Drainage easements may be designated "Public Drainage Easement" or "Private Drainage Easement". A private drainage easement is typically necessary when storm water is to be conveyed across private property from a separate private property up to a contributing drainage area of 100 acres. A Public drainage easement is typically necessary when the off-site contributing drainage area exceeds 100 acres or if the contributing area is a FEMA designated floodplain. Additionally, drainage easements are typically necessary when storm water is to be conveyed across private property from public property, public rights-of-way and easements, or public infrastructure to an established channel, creek, or other public drainage system.

14.2 STORM DRAIN SYSTEMS

~~(i)(3)~~

Minimum easement widths for storm drains will be the greater of fifteen (15) feet or six (6) feet on both sides of the extreme limits ~~(side slope intercept with the natural ground or proposed finished ground elevation)~~ of the width of storm drain ~~width~~ lines or components. See Figure 14.2.

Example: The ~~(e.g. the~~ easement width for a three (3) barrel ten (10)-foot wide box culvert with six (6)-inch walls would be (3 x 10')+(4 x 0.5')+(2 x 6') = 44'~~).~~

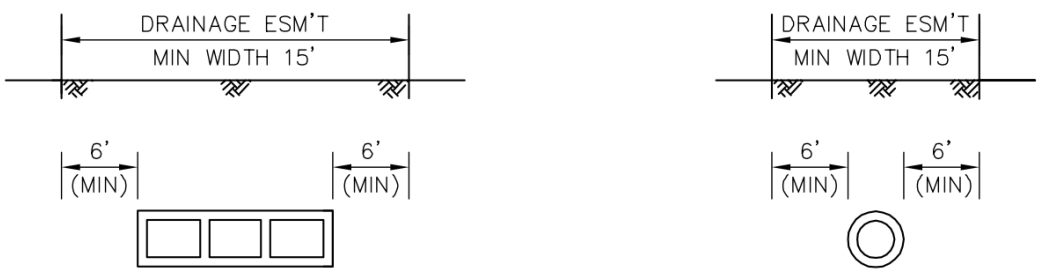


Figure 14.2 - Storm Drain System Easement

14.3 OPEN CHANNELS

14.3.1 Constructed Channels

Constructed channels are created by the movement of earth material by mechanical means and the earth material may be covered by vegetation~~,~~ or other material to minimize erosion.

14.3.1.1 Improved Earth Channels

~~(h)(8)~~

~~C.~~

Easements ~~or rights-of-way~~ for improved earth channels shall ~~conform to the requirements stated in subsection (d) of this section and shall~~ extend a minimum of two (2) feet on one (1) side and fifteen (15) feet for an access road on the opposite side of the extreme limits of the channels do not parallel and adjoin an alley or roadway. When such channels do parallel and adjoin an alley or roadway, the easement ~~easement~~ ~~or right-of-way~~ shall extend a minimum of two (2) feet on both sides of the extreme limits of the channel. Where utilities are installed in the access road of the drainage easement ~~right-of-way~~, the easement ~~right-of-way~~ shall extend two (2) feet on one (1) side and seventeen (17) feet on the opposite side of the extreme limits ~~design limits~~ of the channel. See Figure 14.3.1.1. "Extreme Limits" of the channel shall mean the side slope intercept with the natural ground or proposed finished ground elevation. ~~These seventeen (17) feet are to provide an access way along the channel with a maximum cross slope of one (1) inch per foot toward the channel.~~ Where designed channel bottoms exceed one hundred (100) feet in width, the fifteen (15)-foot extra width shall be provided on both sides of the channel.

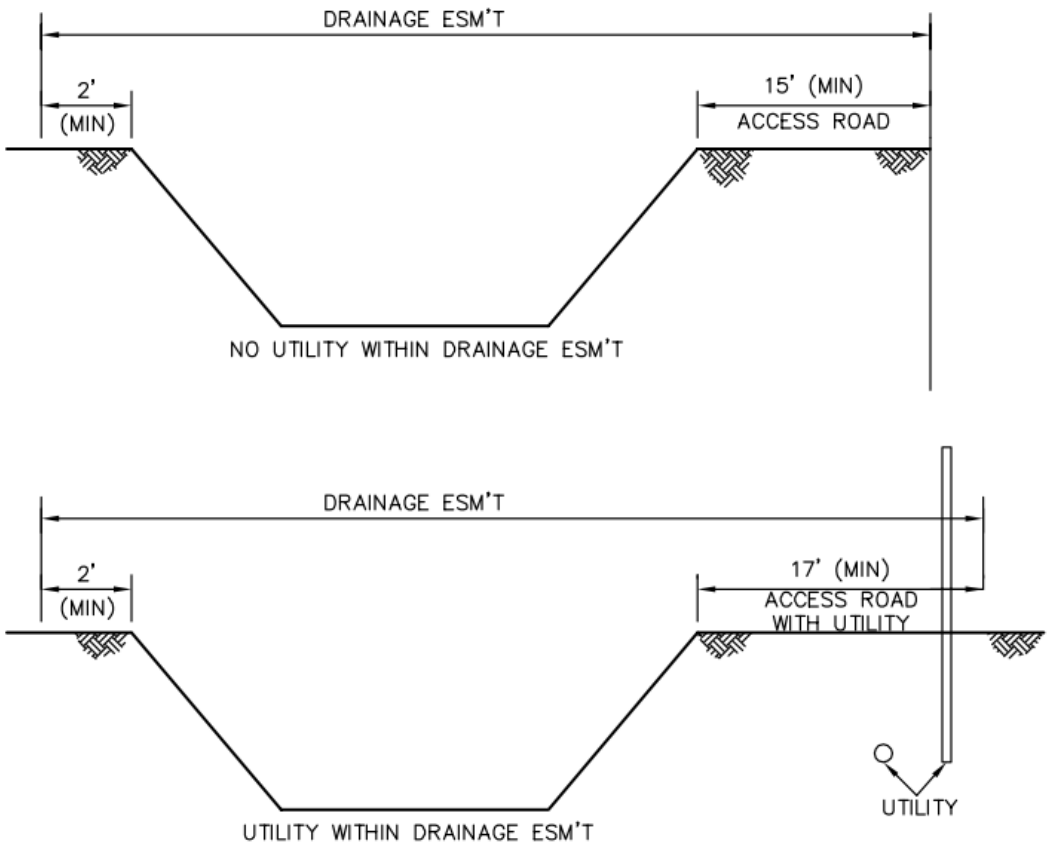


Figure 14.3.1.1 - Earth Channel Easement

14.3.1.2 Concrete Channels

~~(h)(7)~~

~~G.~~

Easements ~~or rights-of-way~~ for concrete lined channels, except for concrete flumes (see Section 14.3.1.4), shall extend a minimum of two (2) feet on one (1) side and fifteen (15) feet for an access on the opposite side of the extreme limits of the channel. When such channels do parallel and adjoin an alley or roadway, the easement shall extend a minimum of two (2) feet on both sides of the extreme limits of the channel. ~~both sides of the extreme limits of the channel. "Extreme Limits" of the channel shall mean the side slope intercept with the natural ground or proposed finished ground elevation.~~ See Figure 14.3.1.2.

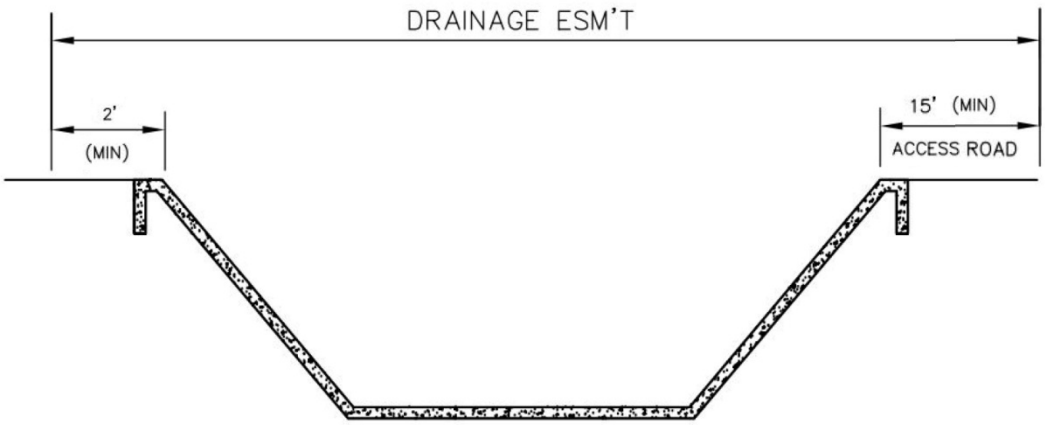


Figure 14.3.1.2 - Concrete Channel Easement

14.3.1.3 Interceptor Channels

~~(d)(6) Interceptor Easements.~~

Drainage easements for proper conveyance of upstream storm water ~~stormwater~~ runoff shall be required on all subdivision plats where upstream contributing area exceeds the criteria indicated below. Interceptor drains shall be constructed prior to the issuing of building permits on any lot that would intercept natural drainage.

A.

Interceptor drainage easements and channels shall be provided for residential subdivisions where the drainage area to the back of platted lots exceeds the depth of two (2) average residential lots with equivalent zoning.

B.

Interceptor drainage easements shall be required on nonresidential subdivision plats where the off-site drainage area contributing to the proposed development exceeds three

(3) acres. ~~If necessary, an amending plat may be used to correct drainage easements in conjunction with building permits.~~

~~(h)(8)~~

~~D.~~

Interceptor drainage easements shall extend a minimum of two (2) feet on both sides of the extreme limits of the channel. See Figure 14.3.1.3 ~~504-4~~.

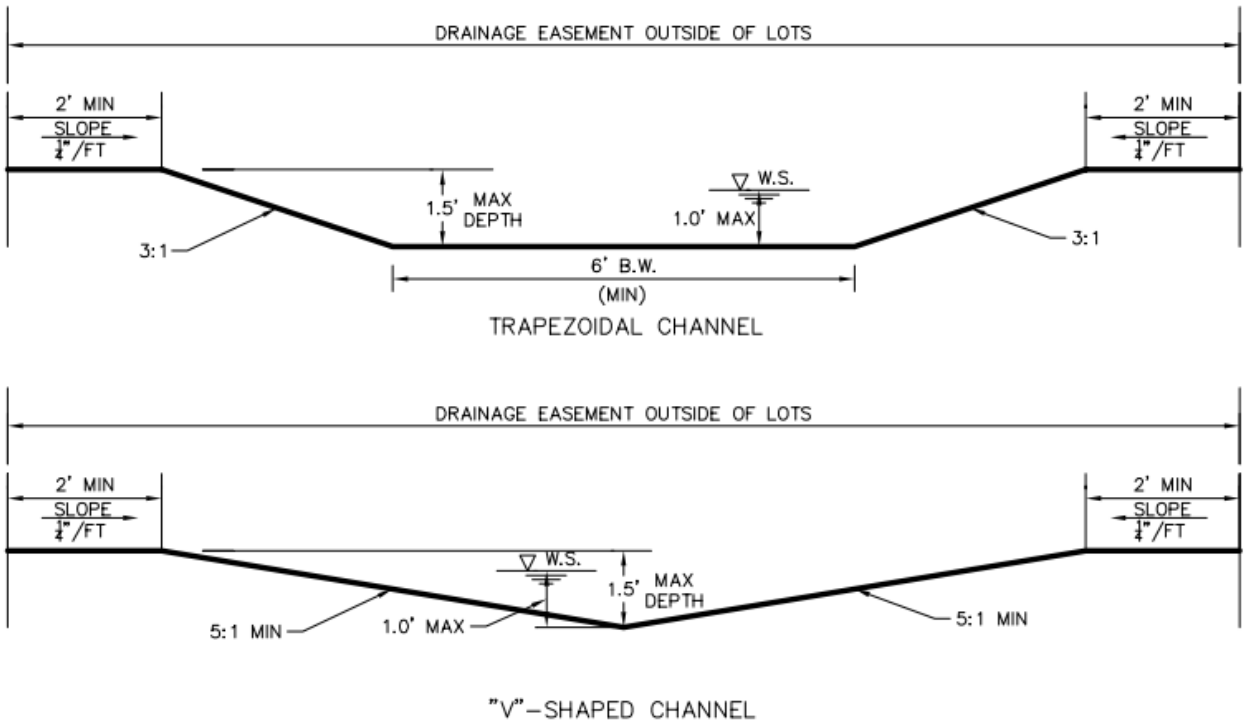


Figure 14.3.1.3 - Interceptor Channel Easement

14.3.1.4 Concrete Flumes

Side-lot flumes are concrete-lined channels that convey storm water runoff between residential lots from street to street or from a street to a storm drain, drainage channel, natural creekway, or floodplain. Easements for side-lot flumes shall extend a minimum of two (2) feet on one (1) side and ten (10) feet for access on the opposite side.

Private side-lot flumes shall have appropriate easement widths as determined by the developer's engineer.

14.3.2 Natural Channels

~~(d)(3) Natural Watercourses or Floodplains.~~

The limits of easements for natural watercourses shall be the ~~(existing or~~ ultimate~~)~~ one hundred (100) ~~-~~year floodplain or the ~~(existing or~~ ultimate~~)~~ twenty-five (25) ~~-~~year plus freeboard ~~(see Table 504-9 of this section)~~ whichever is less. In floodplain areas where ongoing maintenance is required or the floodplain will be reserved for use by the public, the drainage easements shall be maintained by a public entity and the property will be dedicated to the city as a ~~multi-use~~ public drainage easement. See Figure 14.3.2.

14.3.3 ~~(d)(4)~~ Maintenance Access Drainage Easement ~~Right-of-Way~~

An unobstructed access drainage easement ~~right-of-way~~ connecting the channel drainage easement with an alley or roadway, parallel to or near the easement shall be provided at a minimum spacing of one (1) access easement ~~right-of-way~~ at approximately one thousand (1,000)-foot intervals. The access easement ~~right-of-way~~ shall be a minimum of fifteen (15) feet in width and shall be kept ~~maintained~~ clear of obstructions that would limit maintenance ~~vehicular~~ vehicle access. ~~If the flow line of the designed channel incorporates grade control structures or vehicular bridges that would prevent maintenance equipment from accessing that portion of the channel, additional access points may be required.~~ Additional access points may be required if the flow line of the designed channel incorporates grade control structures or vehicular bridges that may block channel access to maintenance equipment.

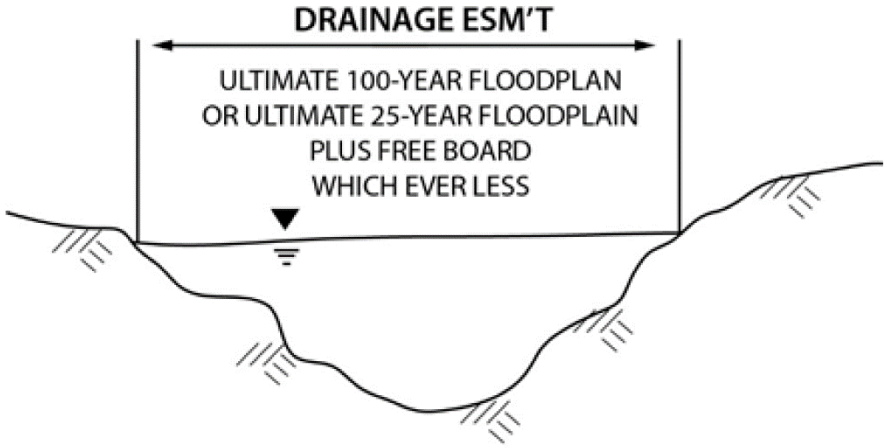


Figure 14.3.2 - Natural Channel Easement

14.4 PUMP STATIONS

A drainage easement will be required for all storm water pump stations. Additional ten (10) foot minimum drainage easement in width shall be required around the pump station for maintenance. All pump stations not included in a street right-of-way or within the storage facilities drainage easement and not adjacent to a public street will require a drainage easement for a fifteen (15) foot width access to the pump station.

14.5 STORAGE FACILITIES

~~(f)(4) Easement Requirements.~~

~~A.~~

Drainage easements will be required for all storm water ~~stormwater~~ management facilities accepting runoff from properties other than the lot on which the facility exists or will be constructed. ~~Maintenance of the detention facility shall be the responsibility of the property owner or the property owner's association.~~

~~(f)(4) Easement Requirements.~~

~~C.~~

For regional detention facilities, the drainage easement will encompass the one hundred (100) ~~-~~year pool elevation ~~plus~~ in addition to all structural improvements (levees, ~~dykes~~dikes, berms, outfall structures, etc.) necessary to contain the pool. The easement will extend, at a minimum, to the toe of the downstream embankment. The easement shall also extend to a minimum of fifteen (15) ~~-~~feet outside both the one-hundred (100) ~~-~~year pool and the structural improvements to facilitate maintenance as well as public safety.

~~(f)(8)D.~~
A one hundred (100) ~~-~~year ~~frequency flood~~ storm event shall be routed through the proposed dam or basin and all land subject to flooding shall be dedicated as drainage easement ~~or right-of-way~~. An unobstructed fifteen (15) ~~-~~foot access easement around the periphery of the flooded area shall be dedicated as drainage easement for facilities that require regular mowing or other ongoing maintenance, at the discretion of the Director of TCI ~~director of public works~~. An unobstructed fifteen (15) ~~-~~foot access ~~right-of-way~~ shall be established, which connects the drainage easement adjacent to the dam structure to a road or alley and the access to be dedicated as a drainage easement.

~~(f)(8)F.~~
~~All spillway discharges shall be adequately routed to the centerline of the natural low below the dam site.~~ The adequate routing of spillway discharges pertains to the hydraulic routing of the one hundred (100) ~~-~~year frequency flood for dedication of drainage easement limits. ~~Probable maximum precipitation (PMP) defined PMP on definition section flood routing or breaches will only be considered for safety considerations (that is, the placement of building and the setting of minimum floor slab elevations below the dams). Any proposed concrete dam structure need not have spillway capable of routing a PMP flood, however, it shall be shown to be structurally capable of withstanding any range of flood conditions with regard to possible failure due to sliding, overturning, and structural integrity, up to and including the PMP flood.~~

CHAPTER 15
LOTS / UNFLOODED ACCESS

15.1 INTRODUCTION

This chapter is for additional drainage criteria for a lot or lots within a development. The proper grading of a lot(s) is necessary so there is no impact to adjoining property or to the proposed development.

15.2 STANDARD LOT GRADING

~~(e)(5)~~

A note ~~must~~ shall be placed on all plats ~~the plat for residential lots, which states~~ stating that residential finished floor elevations must be a minimum of eight (8) inches above final adjacent grade. A grading plan shall be prepared and submitted to the City ~~of San Antonio~~, which indicates typical lot grading for all lots in the subdivision using typical FHA lot grading types (A, B, and C). See Figure 15.2. A more detailed grading plan is also acceptable. No more than two (2) average residential lots may drain onto another lot, unless a drainage easement is dedicated to contain the runoff.

See Section 6.2.2 where Dwelling units are located on the downhill side of a T-intersection, Cul-de-sac, or knuckle.

~~(g)(1)I.~~

~~Dwelling units located on the downhill side of a T-intersection with a street or drainage channel discharging onto the intersection shall be sited so as to avoid obstruction of the drainage patterns.~~

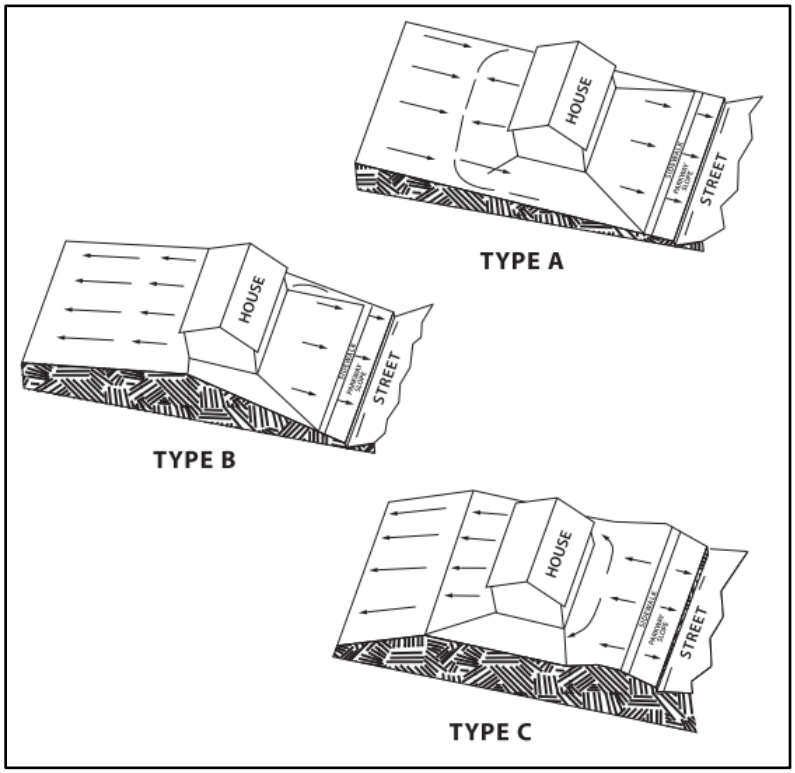


Figure 15.2 - Typical FHA Lot Grading

15.3 UNFLOODED ACCESS

15.3.1 Proposed Development

~~(g)(8) Unflooded Public Road Access.~~

~~A.~~

During a design storm event ~~(see "subsection 35-504(b)(2) System Criteria")~~ unflooded access (within the "Proceed with Caution" range per Figure ~~xxxxx~~4.3.1C ~~504-2~~) shall be available from each proposed new development to an adjacent public street during a regulatory flood event.

15.3.2 Unflooded Access Distance on Existing Public Street

~~(g)(8) Unflooded Public Road Access.~~

~~B.~~

Additionally, unflooded access shall be accessible to an arterial street that is not adjacent to the development or to a distance of one-quarter mile, whichever is less, during a future conditions twenty (20) percent annual chance (five-year) flood event.

15.3.3 Exception

~~(g)(8) Unflooded Public Road Access.~~

~~C.~~

The ~~/~~Director of TCI ~~public works~~ may waive criterion 15.3.2 ~~b~~ of this requirement for developments under three (3) acres in size.

15.4 INTERCEPTOR CHANNELS

~~(d)(6) Interceptor Easements.~~

Interceptor channels ~~Drainage easements~~ for proper conveyance of upstream storm water ~~stormwater~~ sheet flow ~~runoff~~ shall be required on all subdivision plats where upstream contributing area exceeds the criteria indicated ~~below~~ on the following items. (See Figure 9.3.10.) Interceptor channels ~~drains~~ shall be constructed prior to the issuing of building permits on any lot that would intercept natural drainage.

A. Interceptor ~~drainage easements and~~ channels shall be provided for residential subdivisions where the drainage area to the back of platted lots exceeds the depth of two (2) average residential lots with equivalent zoning.
B. Interceptor channels ~~drainage easements~~ shall be required on nonresidential subdivision plats where the off-site drainage area contributing to the proposed development exceeds three (3) acres. ~~If necessary, an amending plat may be used to correct drainage easements in conjunction with building permits.~~

15.5 LOT AND PROPERTY LINE CROSSINGS

~~(d)(5)~~

~~Lot and Property Line Crossings.~~ In ~~those~~ cases where drainage easements cross lot and property lines, a statement shall be added to the plat that no fencing or structures that will interfere with adequate drainage flow will be allowed on or across such lines. Fencing may be allowed across drainage easements only in accordance with the following restrictions:

A. Bottom of fence shall be a minimum of the flow depth, plus freeboard (see Table 9.3.14~~504-9 of this section~~) above design flow line of channel or drain. Any fencing extending below the depth stated above shall be hinged or otherwise designed to allow the design flow to pass. Design details shall be provided.
B. A hinged gate will be placed across the entire width of the drainage easement. Access must be provided to storm water ~~stormwater~~ operations staff at all times to allow access to the easement for the city crews to perform maintenance.
C. Fence posts located within the easement must be structurally designed to resist damage from the storm water ~~stormwater~~ flows and impact from debris.

D. A floodplain development permit will be required to construct a fence within an easement within the one hundred (100) -year floodplain.

CHAPTER 16
VEGETATION

16.1 INTRODUCTION

This chapter provides information on methods and recommendations for plant materials to be used for the vegetation or revegetation of drainage facilities within the San Antonio area. Establishment of a robust vegetative cover is critical to the proper functioning of drainage facilities, such as grass-lined channels, earthen detention basins, earthen retention ponds, and wetlands. Vegetation serves multiple purposes, including stabilization of facilities, prevention or reduction of erosion, removal of pollutants in storm water runoff, and improvement of wildlife habitat. The modified subtropical climate, prevalence of introduced weeds or Johnson Grass, and variety of soil types encountered in the San Antonio area virtually mandate the prompt implementation of a temporary and/or permanent revegetation plan to meet TPDES requirements.

During the design and construction processes and thereafter, existing vegetation should be maintained and preserved intact in order to minimize the effects of construction activities and the changes to the flow characteristics of the existing waterways.

16.2 GENERAL GUIDELINES FOR RECOMMENDED VEGETATION

16.2.1 Grasses

~~(h)(8)E.~~

New or improved earthen channels, earthen retention facilities, and earthen detention facilities will be vegetated by seeding or sodding. Eighty-five ~~(85)~~ percent (85%) of the ~~channel~~ disturbed surface area must ~~have~~ established vegetation before the City ~~of San Antonio~~ will accept the channel for maintenance~~.~~ if the facility is within a public easement. Facilities that are within private easements shall also meet the same seeding and sodding requirements.

New earthen facilities and alterations to existing facilities ~~channels~~ shall be planted with drought resistant, low growth, native species grasses~~,~~ which will allow unobstructed passage of floodwaters. Recommended grasses and groundcover can be found in Appendix E "San Antonio Recommended Plant List - All Suited to Xeriscape Planting Methods" found in the current City of San Antonio Unified Development Code. Johnson grass, giant ragweed and other invasive species shall not be allowed to promulgate in earthen facilities. ~~channels. Mowing frequencies vary with the vegetation growth rates, but is required when the grass exceeds the design roughness coefficient of the channel.~~

16.2.2 Woody Plantings

16.2.2.1 Trees

~~Sec 35-523 Tree Preservation~~While allowing for ~~the~~ reasonable improvement of land within the C~~c~~ity and C~~c~~ity's ETJ, it is stated public policy of the C~~c~~ity to maintain, to the greatest extent possible, existing trees ~~within the city and the ETJ,~~ and to add to the tree population ~~within the city and the ETJ~~ to promote a high tree canopy goal. The planting of additional trees and preservation of existing trees in the C~~c~~ity and the City's ETJ is intended to accomplish a variety of goals~~., where possible, the following objectives:~~ These goals can be found in Sec. 35-523 of the UDC. Recommended trees can be found in Appendix E "San Antonio Recommended Plant List - All Suited to Xeriscape Planting Methods" found in the current City of San Antonio Unified Development Code.

16.2.2.2 Shrubs

Recommended shrubs can be found in Appendix E "San Antonio Recommended Plant List - All Suited to Xeriscape Planting Methods" found in the current City of San Antonio Unified Development Code.

16.3 TREE PRESERVATION REQUIREMENTS

The City of San Antonio Tree Preservation requirements can be found in the latest version of the City of San Antonio UDC.

16.4 PREPARATION OF A PLANTING PLAN

A mitigation plan will be required if the above minimum preservation requirements are not met. See latest version of the City of San Antonio Tree Ordinance for requirements.

16.5 REFERENCES

- City of San Antonio. San Antonio Recommended Plant List—All Suited to Xeriscape Planting Methods. Appendix E in *Unified Development Code*. Retrieved from http://www.sanantonio.gov/dsd/udc.asp
- University of Texas at San Antonio. *Technical and Field Guide: Management Practices for Natural Waterways*. University of Texas at San Antonio, City of San Antonio, San Antonio, Texas, February 2008.
- International Society of Arboriculture
- Texas Parks and Wildlife
- USACE

CHAPTER 17
SOFTWARE

17.1 INTRODUCTION

Hydrology and Hydraulics software is a tool used by engineers to analyze, study, and design water resources features and infrastructure. The software used by engineers is a critical portion of local studies. This chapter will attempt to base line the most available software used by local engineers as well as City of San Antonio staff. Additional and specialized software may be acceptable for use, with the approval of the office of the Director of TCI or his authorized representative.

The following software are acceptable.

- HEC Products
  - HEC-HMS
  - HEC-RAS
- XP Solutions
  - XPSWMM
  - XPSTORM
- Auto Desk
  - AutoCAD - HydraFlow
- Esri
  - ArcGIS
- Bentley
  - MicroStation - Geopak
  - FlowMaster
  - CulvertMaster
  - PondPack
  - STORMCAD
- Misc.
  - HAHNHAUS
  - Hy-8
  - WINSTORM

17.2 REFERENCES

CHAPTER 18
DATA SOURCES

18.1 INTRODUCTION

This chapter will identify commonly used data sources for use in studies. These sources are subject to change and may or may not be a free resource. These include City of San Antonio, Bexar County, SARA, FEMA, etc.

18.2 CITY OF SAN ANTONIO

For general geo-spatial information about San Antonio that include individual shape-file and geodatabase for political boundaries, roadways, special zones and districts, library locations, park boundary, trails and even 2-foot contours. This data can be found in the City of San Antonio GIS department website. Please note the following link may change. http://www.sanantonio.gov/GIS/GISData.aspx

18.3 BEXAR COUNTY

The Bexar County website contains a GIS portal (http://bexar.maps.arcgis.com/home/) to allow users to view and access GIS data. GIS data can be retrieved via the Open Data Portal section (http://www.bexar.org/569/GIS-Open-Data)

18.4 SAN ANTONIO RIVER AUTHORITY

The SARA website contains useful sources of GIS data sets. The first is the Digital Data Model Repository (D2MR) (http://gis.sara-tx.org/D2MR/), used to access Hydrology, Hydraulic and geo-spatial data (GIS and CADD data available). To access data a user will need to create a user name and password.

Additionally SARA hosts 1-foot LiDAR based contours for all of Bexar County, broken into panels a user can access GIS data shape-files from the following link (http://www.sara-tx.org/public_services/gis_information/contours.php)

18.5 FEDERAL EMERGENCY MANAGEMENT AGENCY

For the latest Flood Insurance Rate Map please refer to the FEMA Map Service Center (https://msc.fema.gov/portal) Data found in the Map Service Center includes FIRM maps and the latest Letters of map Changes (LOMC) approved by FEMA.

18.6 U.S. ARMY CORPS OF ENGINEERS

To access the latest hydrology and hydraulic modeling software please refer to the US Army Corps of Engineers Hydrologic Engineering Center website. http://www.hec.usace.army.mil/

18.7 TEXAS NATURAL RESOURCES INFORMATION SYSTEM

To access State wide data set please refer to the Texas Natural Resource Information System (TNRIS) website. http://www.tnris.org/

18.8 U.S. DEPARTMENT OF AGRICULTURE – NATURAL RESOURCES CONSERVATION SERVICE

For information on the NRCS please refer to the following website (http://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/)

18.9 U.S. FISH & WILDLIFE SERVICE

For contact information for the US Fish and Wildlife Serve please refer to the following: http://www.fws.gov/

CHAPTER 19
DEFINITIONS

19.1 INTRODUCTION

The following definitions are used within this manual. A number of definitions were copied from the UDC Appendix A Definitions that relate to drainage and this manual. The UDC definitions are indicated by an asterisk symbol.

1% annual chance floodplain, (formerly 100-year floodplain)*: The land within a community subject to a one (1) percent or greater chance of flooding in any given year. These areas are typically designated as a Federal Emergency Management Agency (FEMA) Zone A, AE, AH, or AO on FEMA Flood Insurance Rate Maps (FIRM Panels).

All weather surface (parking and vehicular access)*: Vehicular "all weather surfaces" shall constitute: poured concrete on prepared subgrade; hot laid asphalt on a prepared base course; single, double, or triple asphalt surface treatment (consisting of applications of asphaltic material, each covered with aggregate) on a prepared base course. Brick/concrete block/tile/flagstone set in mortar or on a prepared base course. The director of planning and development services shall determine if other materials may fit within this category of surface; however, in no case shall a material be considered a "all weather surface" if such surfaces generates or produces any dust or particulate matter that could be airborne to adjacent properties such as occurs with compacted base materials.

All weather surface (pedestrian walkways and access)*: All weather surfaces shall constitute poured concrete, hot laid asphalt, or tile/ flagstone/brick/concrete block. The director of planning and development services shall determine if other materials may fit within this category of surface. For pedestrian application crushed granite, marble and rock slag may be considered an "all weather surface".

All weather surface (temporary access)*: All weather surfaces for temporary construction access or event access such as "homes shows", carnivals, etc., shall be permitted by the director of planning and development services and may be poured concrete, hot or cold laid asphalt or tile/brick/flagstone/concrete block, compacted base material, crushed granite, or gravel for a period not to exceed one hundred twenty (120) days.

Area of flood inundation*: Sites that are subject to flooding as a result of water ponding in the controlled storage areas of dams, detention and retention ponds.

Area of shallow flooding*: A designated AO, AH, or VO zone on a community's flood insurance rate map (FIRM) with a one (1) percent chance or greater annual chance of flooding to an average depth of one (1) to three (3) feet where a clearly defined channel does not exist, where the path of flooding is unpredictable and where velocity flow may be evident. Such flooding is characterized by ponding or sheet flow.

Area of special flood hazard*: The land in the floodplain within a community subject to a one (1) percent or greater chance of flooding in any given year. This area is also known as the 100-year floodplain. The area is designated as a Federal Emergency Management Agency Zone A, AE, AH, AO on the flood insurance rate maps.

Base flood*: The flood having a one (1) percent chance of being equaled or exceeded in any given year. (100-year frequency flood).

Basement*: Any area of the building having its floor subgrade (below ground level) on all sides.

Best management practices (BMP)*: An effective integration of storm water management systems, with appropriate combinations of landscape conservation, enhancement, structural controls, impervious cover, schedules of activities, prohibitions of practices, maintenance procedures and other management practices which provide an optimum way to convey, store and release runoff, so as to reduce peak discharge, remove pollutants, and enhance the environment.

Capital improvements*: Public facilities which have a life expectancy of three (3) or more years that are owned and operated by the city, and are treated as capitalized expenses according to generally accepted accounting principles. This definition does not include costs associated with the operation, administration, maintenance, or replacement of capital improvements.

Capital improvements program*: The list of recommended capital improvements to be constructed during the forthcoming five-year period submitted pursuant to section 118 of the City Charter.

Canopy tree*:A canopy tree is either a medium or large deciduous tree, with a mature height of more than twenty-five (25) feet at maturity.

CLOMR*: A conditional letter of map revision. A CLOMR will be submitted for FEMA approval for all proposed physical changes to the floodplain that will result in a change to the floodplain boundary.

Conservation easement*: A non-possessory interest of a holder in real property that imposes limitations or affirmative obligations designed to:

- Retain or protect natural, scenic, or open-space values of real property or assure its availability for agricultural, forest, recreational, or open-space use;
- Protect natural resources;
- Maintain or enhance air or water quality; or
- Preserve the historical, architectural, archeological, or cultural aspects of real property.

(Source: V.T.A. Natural Resources Code § 183.001).

Dam: Any barrier or barriers, with any appurtenant structure, constructed for the purpose of either permanently or temporarily impounding water.

(Source: TCEQ Chapter §§299.2.(14))

Detention*: The temporary storage of storm runoff, which is used to control the peak discharge rates, and which provides gravity settling of pollutants.

Detention time*: The amount of time a parcel of water actually is present in a storm water basin. Theoretical detention time for a runoff event is the average time a parcel of water resides in the basin over the period of release from the BMP.

Development*: Any manmade change in improved and unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or, drilling operations or storage of equipment or materials.

Development plan*: The proposal for development including such drawings, documents and other information necessary to illustrate completely the proposed development. The development plan shall specifically include such information as required by this chapter.

Drainage system*: All streets, gutters, inlets, swales, storm drains, channels, streams, or other pathways, either naturally occurring or manmade, which carry and convey storm water during rainfall events.

Easement*: A grant of one (1) or more of the property rights by the property owner to and/or for the use by the public, a corporation, or another person or entity.

Easement, utility*: An easement granted for installing and maintaining utilities, across, over or under land together with the right to enter thereon with machinery and other vehicles necessary for the maintenance of utilities.

Edwards Aquifer Recharge Zone (EARZ)*: That area where the stratigraphic units constituting the Edwards Aquifer out crop, and including the outcrops of other formations in proximity to the Edwards Aquifer, where caves, sinkholes, faults, fractures, or other permeable features would create a potential for recharge of surface waters into the Edwards Aquifer. The recharge zone is identified as that area designated as such on official maps located in the offices of the Texas Commission on Environmental Quality (TCEQ) ~~Texas Natural Resource Conservation Commission (TNRCC)~~ and the Edwards Aquifer Authority.

Edwards Aquifer Transition Zone*: That area where geologic formations out crop in proximity to and south and southeast of the recharge zone and where faults, fractures, and other geologic features present a possible avenue for recharge of surface water to the Edwards Aquifer, and including portions of the Del Rio Clay, Buda Limestone, Eagle Ford Group, Austin Chalk, Pecan Gap Chalk, and Anacacho Limestone. The transition zone is identified as that area designated as such on official maps in the offices of the Texas Commission on Environmental Quality (TCEQ) ~~Texas Natural Resource Conservation Commission (TNRCC)~~ and the Edwards Aquifer Authority.

Elevated building*: Elevated building means a non-basement building (i) built, in the case of a building in Zones AE, A, A99, AO, AH, X, and D, to have the top of the elevated floor, elevated above the ground level by means of pilings, columns (posts and piers), or shear walls parallel to the floor of the water and (ii) adequately anchored so as not to impair the structural integrity of the building during a flood of up to the magnitude of the base flood. In the case of Zones AE, A, A99, AO, AH, X, D, "elevated building" also includes a building elevated by means of fill or solid foundation perimeter walls with openings sufficient to facilitate the unimpeded movement of flood waters.

Erodible soils*: Soils rated as Austin Silty Clay, bracket clay loam, Brackett-Austin complex (Austin only), Gullied land, Houston clay, Houston-Sumter clays, Houston Black clay, Houston Black gravelly clay, San Antonio clay loam, Venus loam, Venus clay loam, Webb fine sandy loam, Webb soils in the Soil Survey.

Existing construction*: For the purposes of determining rates, structures for which the "start of construction " commenced before the effective date of the FIRM or before January 1, 1975, for FIRMs effective before the date. "Existing construction" may also be referred to as "existing structures."

Existing manufactured home park or subdivision*: A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before the effective date of the floodplain management regulations adopted by a community.

Filtration basin*: Filtration basins are secondary treatment structures that follow sedimentation basins and release storm water runoff through a filter media to remove additional pollutants.

First flush*: At least the first one-half (½) inch of runoff from a storm event which flushes off and contains a disproportionately large loading of the accumulated pollutants from impervious and non-impervious surfaces.

Flood fringe*: That portion of the floodplain outside of the floodway.

Flood insurance rate map (FIRM)*: Flood rate insurance map (FIRM) means an official map of a community, on which the Federal Emergency Management Agency has delineated both the areas of special flood hazards and the risk premium zones applicable to the community.

Flood insurance study*: The official report provided by the Federal Emergency Management Agency. The report contains flood profiles, water surface elevation or the base flood, as well as the flood boundary map.

Flood or flooding*: Flood or flooding means a general and temporary condition of partial or complete inundation of normally dry land areas from:

1) The overflow of inland or tidal waters.
2) The unusual and rapid accumulation of runoff of surface waters from any source.

Floodplain*: Any land area susceptible to being inundated by water from any source (see definition of flooding). The 100-year floodplain is also known as the area of special flood hazard.

Floodplain, 100-year*: See 1% annual chance floodplain.

Floodplain management*: The operation of an overall program of corrective and preventive measures for reducing flood damage, including but not limited to emergency preparedness plans, flood control works and floodplain management regulations.

Floodplain management regulations*: Zoning ordinances, subdivision regulations, bonding codes, health regulations, special purpose ordinances (such as a floodplain ordinance, grading ordinance and erosion control ordinance) and other applications or police power. The term describes such state or local regulations, in any combination thereof, which provide standards for the purpose of flood damage prevention and reduction.

Floodplain standards or floodplain ordinance*: See Appendix F, Floodplains.

Flood proofing*: Any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents.

Flood protection system*: Those physical structural works for which funds have been authorized, appropriated, and expended and which have been constructed specifically to modify flooding in order to reduce the extent or the areas within a community subject to a "special flood hazard" and the extent or the depths or associated flooding. Such a system typically includes hurricane tidal barriers, dams, reservoirs, levees or dikes. These specialized flood modifying works are those constructed in conformance with sound engineering standards.

Floodway*: The channel or a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood. The floodway is the 100-year floodplain in the City of San Antonio.

Freeboard*: Freeboard is a factor of safety usually expressed in feet above a flood level for purposes of storm water management. "Freeboard" tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, bridge openings, and the hydrological effect of urbanization of the watershed.

Highest adjacent grade*: The highest natural elevation of the ground surface, prior to construction, next to the proposed walls of a structure.

Impervious*: See impervious cover.

Impervious cover*: Roads, parking areas, buildings, pools, patios, sheds, driveways, private sidewalks, and other impermeable construction covering the natural land surface; this shall include, but not [be] limited to, all streets and pavement within the subdivision. "Percent impervious cover" is calculated as the area of impervious cover within a lot, tract, or parcel or within the total site being developed, divided by the total area within the perimeter of such lot, tract, parcel or development. Vegetated water quality basins, vegetated swales, other vegetated conveyances for overland drainage, and public sidewalks shall not be calculated as impervious cover.

Infrastructure*: Any physical system or facility that provides essential services such as transportation, utilities, energy, telecommunications, waste disposal, park lands, sports, buildings, housing facilities and the management and use of resources regarding the same. Infrastructure includes drainage systems, irrigation systems, sidewalks, roadways, drain systems, water systems, driveways, trails, parking lots, and other physical systems or facilities as generally described above that may not be specifically enumerated in this definition.

Intermediate floodplain*: Any channel, creek, stream, branch, or watercourse for surface water drainage that drains an area greater than three hundred twenty (320) acres but less than six hundred forty (640) acres.

Intermittent stream*: A stream that flows only during wet periods of the year (or thirty (30) to ninety (90) percent of the time) and flows in a continuous, well-defined channel.

Levee*: A manmade structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding.

LOMR*: A letter of map revision. A LOMR will be submitted for FEMA approval for all changes to the floodplain boundary that are delineated on the current flood insurance rate maps.

Lot, 900 series*: These lots specifically exclude the construction of all residential and nonresidential structures. The series is designed to allow for designation of permeable or impermeable open space and may include but not be limited to parkland required by section 35-503, storm water management facilities, water quality ponds, driveways, gazebos, playgrounds, private streets, utility easements and private ingress/egress easements.

Lowest floor*: The lowest floor of the lowest enclosed area (including basement). An unfinished or flood resistant enclosure, usable solely for parking or vehicles, building access or storage in an area other than a basement area is not considered a building's lowest floor; provided that such enclosure is not built so as to render the structure in violation of the applicable non-elevation design requirement of Section 60.3 of the National Flood Insurance Program regulations.

Low risk flood area*: Low risk flood area as used in section 35-F145 refers to the River Bend area of the San Antonio Riverwalk. For floodplain management purposes, low risk

flood areas are defined as either the areas outside the one (1) percent annual chance floodplain and inside the 0.2 percent annual chance floodplain or areas of shallow flooding.

Major floodplain*: Any channel, creek, stream, branch, or watercourse for surface water drainage that drains six hundred forty (640) acres or more.

Manufactured home or manufactured housing*: A HUD-Code manufactured home. For purposes of the floodplain ordinance, a "manufactured home" means a structure transportable in one (1) or more sections, which is built on a permanent chassis and is designed for use with or without a permanent foundation when connected to the required utilities. The term "manufactured home" does not include a "recreational vehicle".

Manufactured home park or subdivision*: For purposes of the floodplain ordinance, a parcel (or contiguous parcels) of land divided into two (2) or more manufactured home lots for rent or sale.

Mean sea level*: For purposes of the National Flood Insurance Program, the National Geodetic Vertical Datum (NGVD) of 1929 or other datum, to which base flood elevations shown on a community's flood insurance rate map are referenced.

Minor floodplain*: Any channel, creek, stream, branch, or watercourse for surface water drainage that drains an area greater than one hundred (100) acres but less than three hundred twenty (320) acres.

Natural waterway: A waterway that results from implementation of management practices that allow for adequate conveyance of storm water (stream discharge), optimize plant and wildlife diversity, and maintain high water quality within the waterway while promoting a natural riparian environment.

Net area*: Mean total acreage within a master development plan less the area within the 100-year floodplain and the area dedicated to conservation easement, natural area (such as greenbelt) and parks.

New construction*: For the purpose of determining insurance rates, structures for which the "start of construction" commenced on or after the effective date of an initial FIRM or after December 31, 1974, whichever is later, and includes any subsequent improvements to such structures. For floodplain management purposes, "new construction" means structures for which the "start of construction" commenced on or after the effective date of a floodplain management regulation adopted by a community and includes any subsequent improvements to such structures.

New manufactured home park or subdivision*: A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed on or after the effective date of floodplain management regulations adopted by a community.

Overland flow*: Storm water runoff that is not confined by any natural or manmade channel such as a creek, drainage ditch, storm drain, or the like. Also known as "sheet flow", this involves the movement of runoff in a thin layer (usually less than one (1) inch in depth) over a wide surface, which begins when water ponded on the surface of the land becomes deep enough to overcome surface retention forces.

Pervious pavement*: A pavement system with traditional strength characteristics, but which allows rainfall to percolate through it rather than running off. A permeable pavement system utilizes either porous asphalt, pervious concrete, or plastic pavers interlaid in a running bond pattern and either pinned or interlocked in place. Porous asphalt consists of an open graded course aggregate held together by asphalt with sufficient interconnected voids to provide a high rate of permeability. Pervious concrete is a discontinuous mixture of Portland cement, coarse aggregate, admixtures, and water which allow for passage of runoff and air. Examples of permeable pavement systems include Grasspave2®, Gravelpave2®, Turfstone®, and UNI Eco-stone®. (See Watershed Management Institute, Inc. and U.S. Environmental Protection Agency, Office of Water, Operation, Maintenance and Management of Storm Water Management (Aug. 1997), at 2-32; Booth and Leavitt, Field Evaluation of Permeable Pavement Systems for Improved Storm Water Management, 65 J. Am. Planning Ass'n 314 (Summer 1999), at 314-325.

Public right-of-way*: A strip of land acquired by reservation, dedication, forced dedication, prescription, or condemnation and used or intended to be used, wholly or in part, as a public street, alley, walkway, drain or public utility line.

Public right-of-way (2)*: An area or strip of land, either public or private, occupied or intended to be occupied by a street, walkway, railroad, utility line, drainage channel, or other similar uses.

Redevelopment: Any new development to already developed real estate.

Regional Detention Facility: A detention facility accepting flow from an area exceeding three hundred twenty (320) acres.

Regional storm water improvements (RSI)*: Means regional detention and retention ponds, watershed protection, land purchase, waterway enlargement, channelization, and improved conveyance structures.

Regulatory Flood Event: A flood event that has a one (1) percent or greater chance of flooding in any given year assuming ultimate development has occurred throughout the watershed.

Regulatory floodplain*: The land within the community subject to a one (1) percent or greater chance of flooding in any given year assuming ultimate development has occurred throughout the watershed. For the purposes of this section the regulatory floodplain is limited to the reach of the stream which is designated as an area of special flood hazard on the currently effective FEMA Flood Insurance Rate Maps (FIRM Panels). NOTE: As the city's floodplain ordinance (Appendix F of the Unified Development Code) is approved by FEMA

as a condition of participation in the National Flood Insurance Program (NFIP), the city's regulatory floodplain is considered FEMA's regulatory floodplain. (note: to be consistent with Appendix F, section 106)

Repetitive loss. Flood-related damages sustained by a structure on two (2) separate occasions during a ten-year period for which the cost of repairs at the time of each such flood event, on the average, equals or exceeds twenty-five (25) percent of the market value of the structure before the damage occurred.

Reservation, reserve, or reserve strip*: Any division of property that:

(a) Prohibits or interferes with the orderly extension of streets, bicycle or pedestrian ways, sanitary drain water mains, storm water facilities or other utilities or improvements between two abutting properties; or

(b) Plats an area so as to leave an undevelopable or unmarketable strip of land less than two hundred seventy (270) feet deep off of an arterial right-of-way that could otherwise circumvent construction and dedication requirements.

Right-of-way*: Property that is publicly owned or upon which a governmental entity has an express or implied property interest (e.g. fee title, easement, etc.) held for a public purpose. Examples of such public purpose include, by way of example and not limitation, a highway, a street, sidewalks, drainage facilities, drainage and water facilities.

Sedimentation basins*: Sedimentation basins remove pollutants by creating conditions under which suspended solids can settle out of the water column.

Sheet flow*: See Overland flow.

Shrub, large*. An upright plant growing to a mature height of more than ten (10) feet for use a natural ornamentation or screening.

Shrub, medium*. An upright plant growing to a mature height of five (5) to ten (10) feet.

Shrub, small*. An upright plant growing to a mature height of less than five (5) feet.

Start of construction*: Start of construction means for all new construction and substantial improvements, the date the building permit was issued, provided the actual start of construction, repair, reconstruction, placement, or other improvement was within one hundred eighty (180) days of the permit date. The actual start means either the first placement of permanent construction of a structure on a site, such as the pouring of slab or footings, the installation of piles, the construction of columns, or any work beyond the stage of excavation for a foundation; or the placement of manufactured home on a foundation. Permanent construction includes land preparation, such as clearing, grading and filling; includes the installation of streets and/or walkways; excavation for a basement, footings, piers, or foundations or the erection of temporary forms; the installation on the property of accessory buildings, such as garages or sheds not occupied as dwelling units or not part of the main structure. The start of construction period is valid for one hundred eighty (180) days. Any

delay beyond this period would require resubmission of added data and the permit application.

Storm water drainage fees*: A method or mix of methods for providing adequate, stable and equitable funding for a comprehensive storm water or drainage program. The financing mechanisms included in the method may include, but not be limited to, user fees, new development impact fees, or surcharges on other utility fees.

Streamside management zone (SMZ)*: A streamside management zone (SMZ) includes forested buffers adjacent to streams or bodies of water, including intermittent and perennial streams, river, lake, slough, pond, creek, reservoir, watershed, or wetland (ephemeral streams are excluded). The minimum width of an SMZ on each side and above the head of streams or adjacent to bodies of water shall be fifty (50) feet from each bank. The total SMZ width includes average stream channel width plus buffer width.

Street, private*: Any street not dedicated to the public and to be maintained by a private entity. Informal maintenance or improvements performed by the city, such as the utilization of waste material to temporarily maintain or improve a private street, do not constitute an acceptance of ownership or obligation by the city.

Substantial damage*: Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed fifty (50) percent of the market value of the structure before the damage occurred. Substantial damage also means flood-related damages sustained by a structure on two (2) separate occasions during a ten-year period for which the cost of repairs at the time of each such flood event, on the average, equals or exceeds twenty-five (25) percent of the market value of the structure before the damage occurred.

Substantial improvement*: Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds fifty (50) percent of the market value of the structure before "start of construction" of the improvement. This includes structures which have incurred "repetitive loss" or "substantial damage", regardless of the actual repair work performed. The term does not, however, include either: (1) Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary conditions or (2) Any alteration of a "historic structure", provided that the alteration will not preclude the structure's continued designation as a "historic structure."

Substantial rehabilitation*: Certified improvements to a historic building in which the cost of the project is equal to or greater than fifty (50) percent of the appraised pre-rehabilitation improvement value of the property and which constitutes major work on enhancing existing mechanical or structural systems that preserve the historical integrity, while extending the life of the building.

Swale*: A low lying or depressed stretch of land without a defined channel or tributaries.

Top of bank*: For purposes of determining river improvement overlay riverside setbacks in section 35-673, the point, stage or elevation at which water overflows the natural or man made banks of the river; alternately, the vertical point along the river where an abrupt change in slope is evident, and where the water level is generally able to overflow the natural bank or man made edge and enter adjacent floodplains (if any) during flows at or exceeding the average annual high water stage.

Understory*: Assemblages of natural low level woody, herbaceous and ground cover species.

Unflooded access*: Means that vehicular traffic has safe access to a property from a public street in times of flood (regulatory 100-year flood). A property will be considered to have unflooded access to an existing street if flow depths for access on the street adjacent to the property do not exceed one (1) foot and fall within the safe range on Figure 4.3.1C "Dangerous Conditions on Crossing During Floods."

Violation*: For purposes of the floodplain ordinance, the failure of a structure or other development to be fully compliant with the community's floodplain management regulations. A structure or other development without the elevation certificate, other certifications, or other evidence of compliance required in this chapter is presumed to be in violation until such time as that documentation is provided.

Water surface elevation*: The height, in relation to the National Geodetic Vertical Datum (NGVD) of 1929 (or other datum, where specified), of floods of various magnitudes and frequencies in the floodplains of coastal or riverine areas.

Watercourse*: A natural or manmade channel through which storm water flows.

Watershed*: The area drained by a given stream, river, watercourse, or other body of water.

Wetland*: See Texas Natural Resources Code § 221.001.

[Commentary: this statute presently defines "wetland" as follows: "land that: (A) has a predominance of hydric soil; (B) is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions; and (C) under normal circumstances does support a prevalence of that vegetation.]

APPENDIX

APPENDIX A
CHECKLIST

A.1 STORM WATER MANAGEMENT PLAN CHECKLIST

~~(c) **Contents.**~~

To standardize the review process and minimize the time for approval by the city during review of the plat and construction drawings for a subdivision, a complete submittal regarding the analysis of existing drainage conditions and the design of modifications or new drainage facilities is necessary. The owner of the property to be developed is required by the ~~director of public works~~ Director of TCI to provide, at the owners expense and as a condition of construction plan approval, a storm water ~~stormwater~~ management report for the total development area to be ultimately constructed. The storm water ~~stormwater~~ management report shall contain all of the necessary support data, methodologies used in calculations, and conclusions. The ~~A~~ checklist ~~is~~ below ~~that~~ will be used by the city reviewer as a guide during the evaluation of all storm water ~~stormwater~~ management reports submitted to the city. The purpose of the checklist is to expedite the review process for both the engineer and the city, and to aid the engineer in the preparation of reports for the city's review. The storm water ~~stormwater~~ management report shall be submitted to the Director of TCI ~~director of public works~~ through the director of planning and development services prior to approval of any construction plans.

APPENDIX B
MISSOURI CHARTS

This Appendix presents methods and charts for determining pressure changes at inlets, square and round junction boxes (manholes) on storm drain systems flowing full. The following instructions and charts are from the University of Missouri Engineering Bulletin No. 41 "Pressure Changes at Storm Drain Junctions"

The University of Missouri Engineering Bulletin No. 41 "Pressure Changes at Storm Drain Junctions" was the results of flume model testing.

Figure B.2 Chart 2 through Figure B.7 Chart 7 each dealt with a rectangular inlet box admitting grate flow and having a specific arrangement of pipelines. Figure B.8 Chart 8 through Figure B.10 Chart 10, supplemented by Figure B.3 Chart 3, apply to square and round manholes with various pipeline arrangements but with no flow admitted through the top of the junction structure. Since no one chart presents a complete solution for manholes, the following explanation of methods for the determination of pressure changes is divided into sections relating to the particular configuration instead of into sections relating to each chart, as was done in the case of inlets.

Pressure change coefficients are presented in Figure B.3 Chart 3 for use in determining the elevation of the pressure line of an in-line pipe upstream from a manhole with through flow only. The pressure change coefficient is controlled primarily by the relative diameters of the upstream and outfall pipes, and secondarily by the distance across the open manhole if the outfall pipe entrance is square-edged. Rounding the outfall entrance eliminates the effects of manhole size relative to the pipe and reduces the coefficients to a limited degree. Manhole cross-section shape is not significant. Thus, the values of Figure B.3 Chart 3 apply equally to round, square, or rectangular manholes. Shaping of the bottom of a manhole to continue a portion of the lower sector of the pipe cross-section through from pipe to pipe is ineffective in reducing losses.

The nomenclature used for all manhole types is given in Figure B.1 Chart 1.

B.1 GENERAL INSTRUCTIONS FOR USE OF DESIGN CHARTS

Several operations are common to use of the design charts for various types of junctions. Instructions for performing these recurring procedures are consolidated in the following General Instructions. In the detailed instructions for use of the individual charts, references to these General Instructions are made by number (Gen. Instr. 1, etc.). The General Instructions follow.

1. Determine and tabulate the elevation of the outfall pipe pressure line at the branch point or inlet center (refer to Figure B.1 Chart 1).

This elevation is obtained by adding to the elevation of the pressure line at the preceding structure downstream the pipe friction loss

(Equation B.1a)

$$\mathbf{h_f = LS_f}$$

h_f = friction loss (ft.)
L = length from center to center of structures (ft.)
S_f = friction (or resistance) loss per ft. at the given rate of flow for the given pipe flowing full.

2. Calculate the mean velocity head of the flow in the outfall pipe.

(Equation B.1b)

$$\mathbf{h_v = \frac{V_o^2}{2g} = \frac{1}{2g}\left(\frac{Q}{Area}\right)^2}$$

h_v = velocity head (ft.)
g = acceleration of gravity = 32.2 ft./sec^2.
Q = rate of flow in pipe flowing full (cfs)
Area = Area of pipe = 0.7854 D^2 (ft^2)
D = pipe diameter (ft.)

3. Calculate the required flow rate and size ratios.
   Examples: Q_U/Q_O, Q_L/Q_O, Q_G/Q_O, etc.
   D_U/D_O, D_L/D_O, B/D_O, etc.
4. Estimate the depth of water in a rectangular inlet with flow into the inlet from a top grate, either alone or combining with flow from an upstream pipe.
   d = total depth of water (ft.)
   = (outfall pressure line elevation minus inlet bottom elevation) $+\mathbf{K}\frac{\mathbf{V_o^2}}{\mathbf{2g}}$
   K = the pressure change coefficient for the inlet water depth (This is estimated as detailed for each type of inlet. Such estimates are not necessary for inlets with in-line or off-set opposed laterals.)
5. Use the coefficients K from the charts for inlets and junctions with square-edged entrance to the outfall pipe (entrance flush with box side, with sharp edges).
6. Use reduced coefficients K, where applicable, for a rounded entrance to the outfall pipe (rounded on ¼ circle arc of approximate radius $^1/_8$ D_O) or for an entrance formed by the socket end of a standard tongue-and-groove concrete pipe.
   Figure B.2 Chart 2-insignificant effect; make no reduction.
   Figure B.3 Chart 3-read directly from chart.
   Figure B.4 Chart 4-reduce K_U by 0.1 for usual proportions of grate flow; by 0.2 for Q_G about 0.5 Q_o.

Figure B.5 Chart 5-reduce K_U and K_L in same manner as Chart 4.
Figure B.6 Chart 6-insignificant effect; make no reduction.
Figure B.7 Chart 7-insignificant effect; make no reduction.
Figure B.8 Chart 8 , Figure B.9 Chart 9, and Figure B.10 Chart 10-see specific instructions for each case.

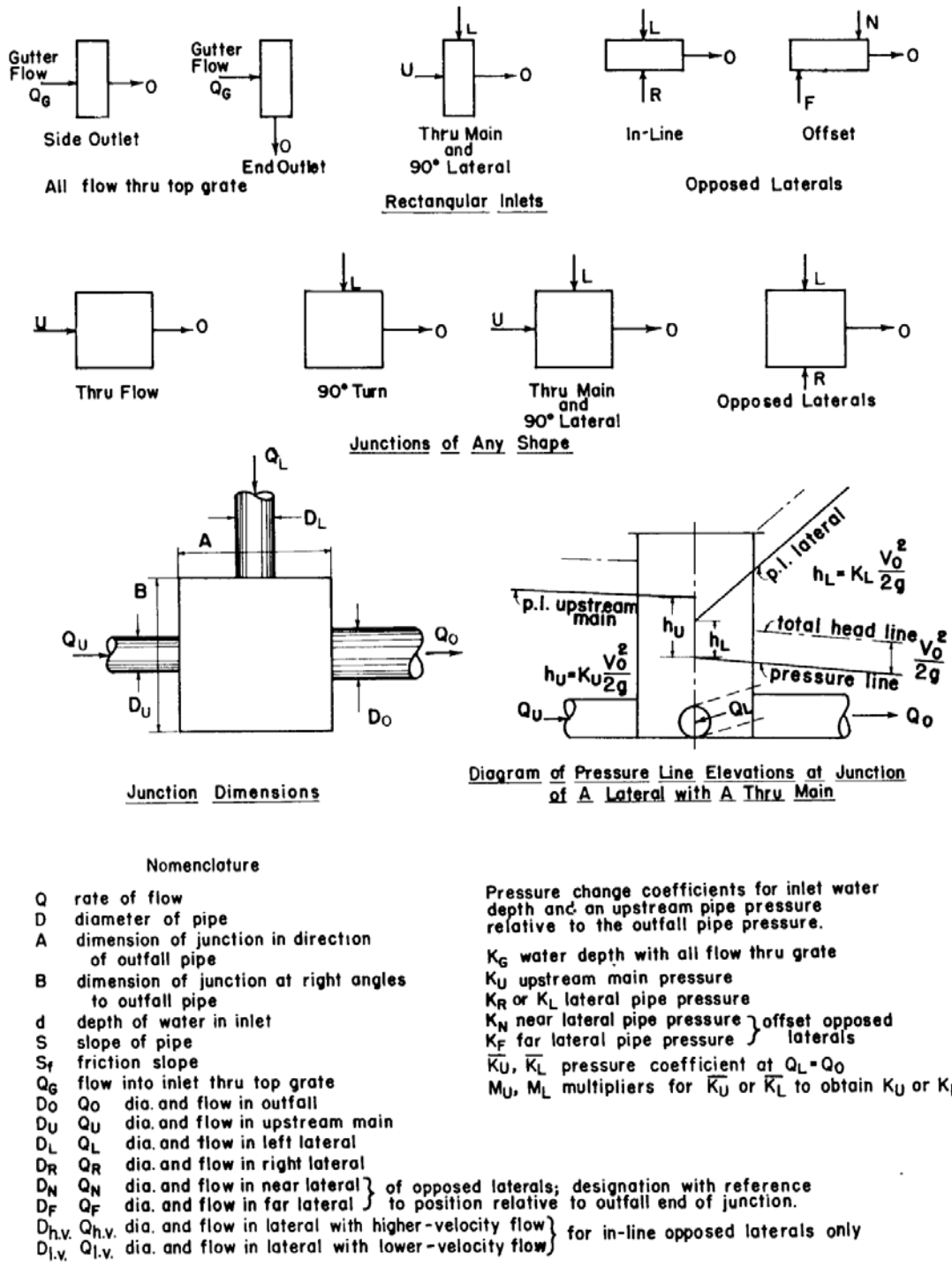
7. Calculate pressure change.
   To calculate the change of pressure at a junction, working upstream from the outfall pipe to an upstream pipe, the design chart applying to the type of junction involved is selected. The pressure change coefficient for a specific upstream pipe is read from the chart for the particular flow rate and size ratios already calculated. The pressure change is calculated from

   (Equation B.1c)

$$\mathbf{h = K\frac{V_o^2}{2g}}$$

   The coefficient is a dimensionless number, and therefore, the change of pressure will be in feet.
8. Apply the pressure change.
   The pressure change, in feet, for each upstream pipe is added to the outfall pipe pressure line elevation at the branch point to obtain the elevation of each pressure line for further calculations upstream along that pipe. In some cases the upstream pressure line at the branch point will be at a lower elevation than the downstream pressure line. Where this less common situation may occur with a particular type of junction, it is mentioned in the instructions for use of the specific chart.
9. Determine the elevation of the water surface.
   The elevation of the water surface in a junction or an inlet (with or without grate flow) receiving flow from a pipe or pipes will correspond to that of the upstream in-line pipe pressure line. At a junction with offset opposed laterals, the water surface will correspond to the elevation of the far lateral pipe pressure line. At a junction with in-line opposed laterals, the water surface will correspond to the elevation of the pressure line of the higher-velocity lateral pipe.

Each of the inlet and junction types for which design charts were derived from the analytical and experimental investigation are now listed separately the chart number appropriate for each is stated, and detailed instructions are given for determination of the change of pressure through use of the chart.



Nomenclature

Q rate of flow
D diameter of pipe
A dimension of junction in direction of outfall pipe
B dimension of junction at right angles to outfall pipe
d depth of water in inlet
S slope of pipe
S_f friction slope
Q_G flow into inlet thru top grate
D_O Q_O dia. and flow in outfall
D_U Q_U dia. and flow in upstream main
D_L Q_L dia. and flow in left lateral
D_R Q_R dia. and flow in right lateral
D_N Q_N dia. and flow in near lateral } of opposed laterals; designation with reference
D_F Q_F dia. and flow in far lateral } to position relative to outfall end of junction.
$D_{h.v.}$ $Q_{h.v.}$ dia. and flow in lateral with higher-velocity flow } for in-line opposed laterals only
$D_{l.v.}$ $Q_{l.v.}$ dia. and flow in lateral with lower-velocity flow }

Pressure change coefficients for inlet water depth and an upstream pipe pressure relative to the outfall pipe pressure.

K_G water depth with all flow thru grate
K_U upstream main pressure
K_R or K_L lateral pipe pressure
K_N near lateral pipe pressure } offset opposed laterals
K_F far lateral pipe pressure }
$\overline{K_U}$, $\overline{K_L}$ pressure coefficient at $Q_L = Q_O$
M_U, M_L multipliers for $\overline{K_U}$ or $\overline{K_L}$ to obtain K_U or K_L

Figure B.1 Chart 1 - Manhole Junction Types & Nomenclature *(Source University of Missouri E.S.B. #41)*

B.2 CHART 2 –RECTANGULAR INLET WITH GRATE FLOW ONLY

Pressure change coefficients are presented in this chart for use in determining the elevation of the water surface in a rectangular inlet with all inflow entering through a top grate. Separate curves are included for the outfall pipe connected at the box end (short dimension) and the box side (long dimension). The coefficient K_G depends on the pipe position and the depth of water in the inlet.

To use the chart:

1. Note whether outlet is at end or side.
2. Determine outfall pipe pressure line elevation – Gen. Instr. 1.
3. Calculate outfall velocity head – Gen. Instr. 2.
4. Estimate a value for water depth d.
   a. Outfall pressure line elevation minus inlet bottom elevation plus $K_G \frac{V_o^2}{2g}$ equals d.
   b. Estimate K_G as follows:
      For pressure line to bottom, not over 2 pipe diameters
      i. 7.0 for end outlet
      ii. 5.0 for side outlet
      For higher pressure lines
      iii. 4.0 for end outlet
      iv. 3.0 for side outlet
5. Calculate the estimated relative water depth d/D_o.
6. Enter Figure B.2 Chart 2 at this depth d/D_O and read K_G from the curve for the particular outfall pipe location.
7. Calculate h_G as indicated on the diagram on the chart and by Gen. Instr. 7.
8. Add h_G to the elevation of the outfall pressure line at the inlet center to obtain the water surface elevation in the inlet.
9. From this water surface elevation subtract the elevation of the inlet bottom to obtain a more precise value for the water depth d.
10. Repeat the above procedure with the improved value of d from step (9), if necessary. Such repetition may not be necessary if the estimated d/D_O of step (5) was reasonable accurate.
11. Check to be sure the inlet water elevation is below the top of the inlet so that inflow may be admitted.

Note: The designer may consider the use of $K_G = 1.5$ and $K_E = 0.5$ for design instead of Chart 2. K_E is the entrance loss. The high values of K_G for curb inlet or grate is questionable.

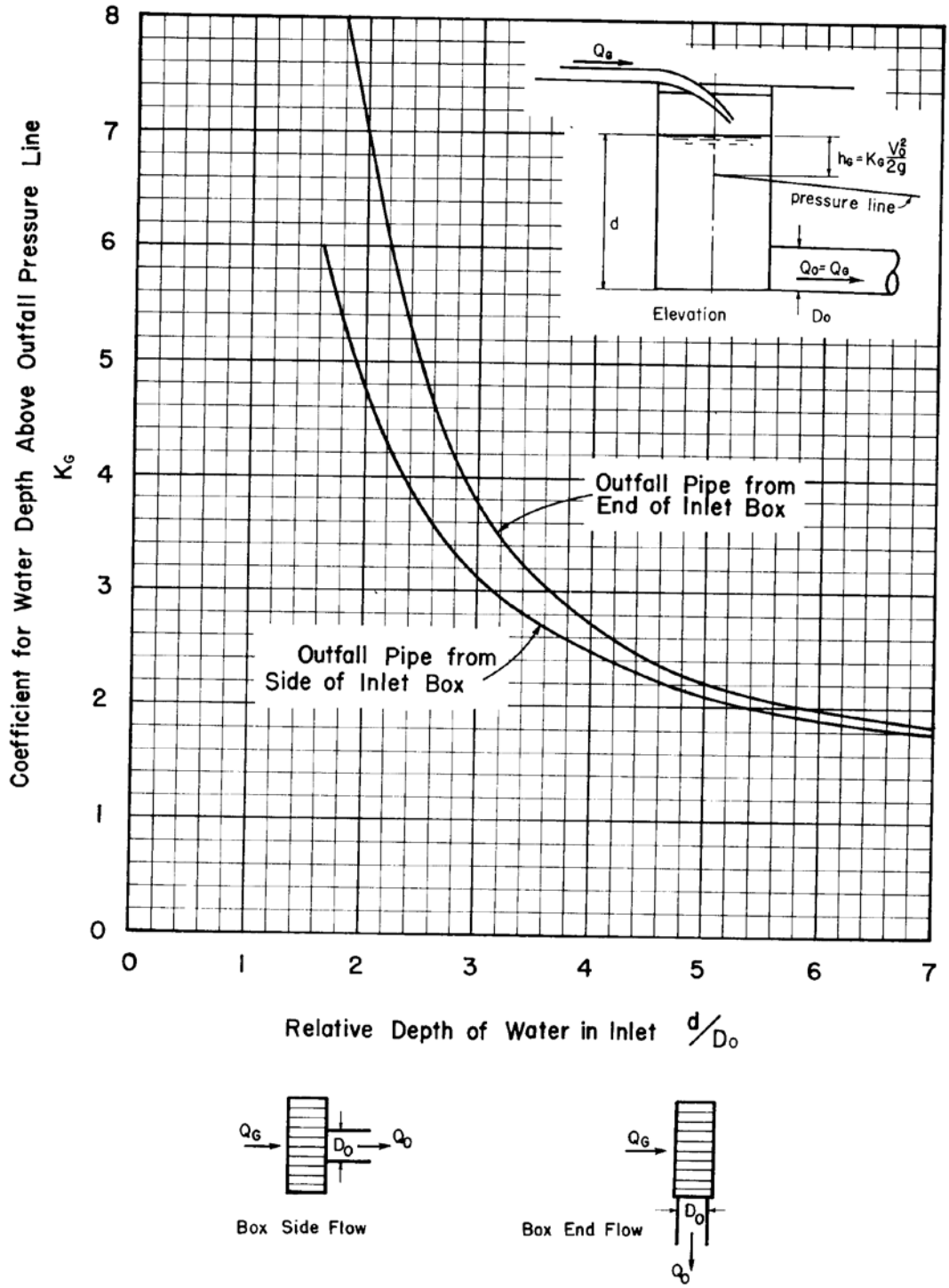


Figure B.2 Chart 2 - Rectangular inlet with grate flow only *(Source University of Missouri E.S.B. #41)*

B.3 CHART 3 – FLOW STRAIGHT THROUGH ANY JUNCTION

Pressure change coefficients are presented in this chart for use in determining the elevation of the pressure line of an upstream in-line pipe relative to that of the outfall. The pipe centerlines must be parallel and not offset more than would permit the area of the smaller pipe to fall entirely within that of the larger if projected across the junction box along the pipe axis. The shape of the junction in plan is not significant in determining the pressure change. The effects of junction size and outfall pipe entrance conditions are included in the chart. Negative pressure changes occur with an upstream pipe smaller than the outfall pipe. That is, at the junction center the upstream pressure line is below the outfall pressure line for this case. No flow other than that from the upstream in-line pipe may be involved where this chart applies.

To use the chart:

1. Determine the outfall pipe pressure line elevation – Gen. Instr. 1
2. Calculate the velocity head in the outfall – Gen. Instr. 2.
3. Calculate the size ratios D_U/D_O and A/D_O – Gen. Instr. 3.
4. Note whether the outfall pipe entrance is to be square-edged or rounded (note Gen. Instr. 6).
5. Enter Figure B.3 Chart 3 at the pipe size ratio D_U/D_O and read K_U at the curve for the proper value of A/D_U for a square-edged entrance condition, or at the dashed curve for a rounded entrance.
6. Calculate h_U (positive or negative) as indicated on the diagrams on the chart and by Gen. Instr. 7.
7. Add a positive h_U to (or subtract a negative h_U from) the elevation of the outfall pressure line at the junction center to obtain the elevation of the upstream pipe pressure line at the same location.
8. The water surface elevation in the junction corresponds to that of the upstream pipe, whether above or below the outfall pressure line.
9. Check to be sure the water surface elevation in the junction is below the top of the junction box so that overflow may not occur.

Comments: For a square-edged entrance to the outfall pipe, values of A/D_U less than 1 do not appreciably reduce the values of K_U shown for $A/D_U = 1$. K_U increases for distances A/D_U greater than 3, but such values are not usual in storm drain construction. For rounded entrances, the curve shown will apply with sufficient accuracy for all values of A/D_U up to 3.

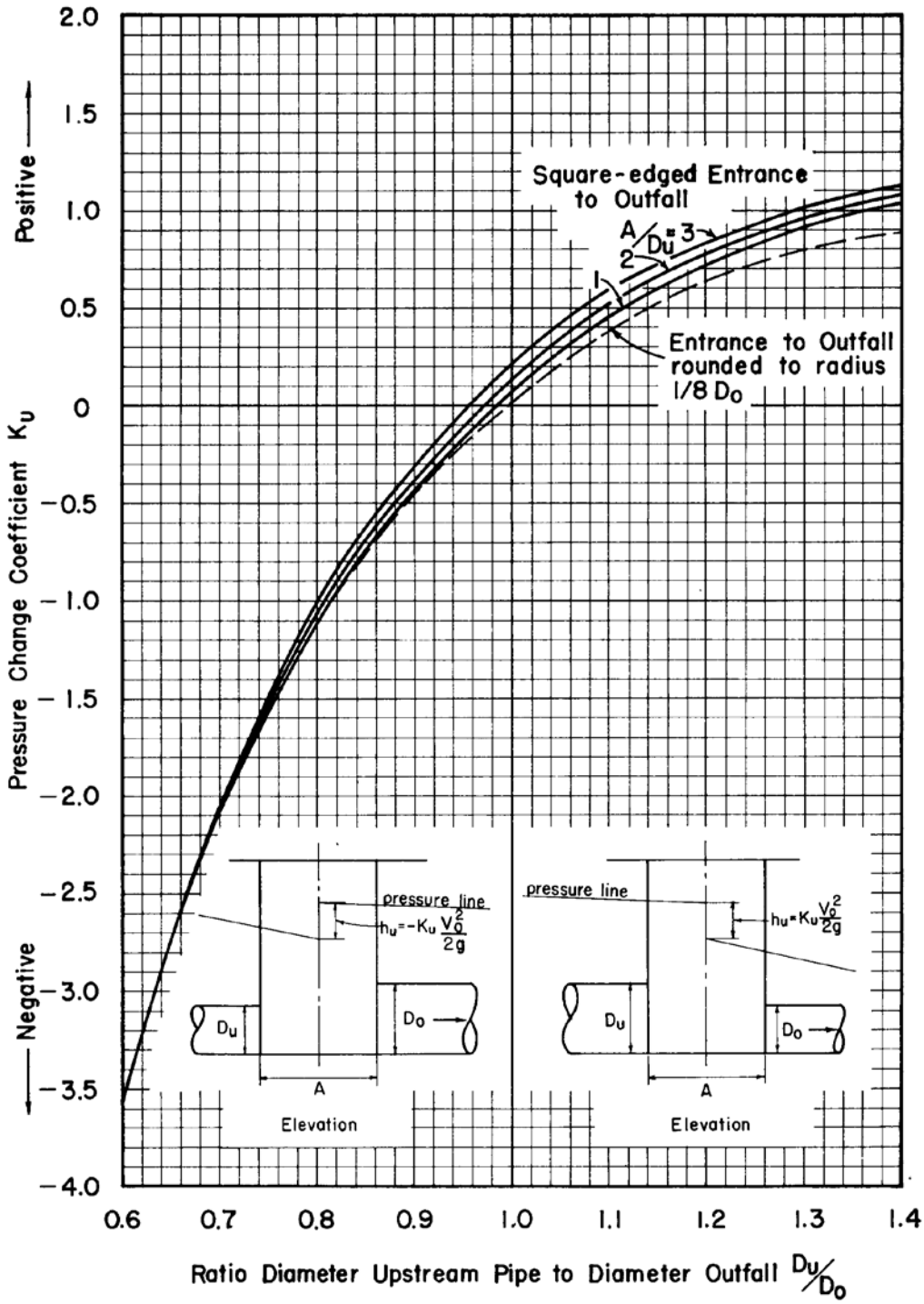


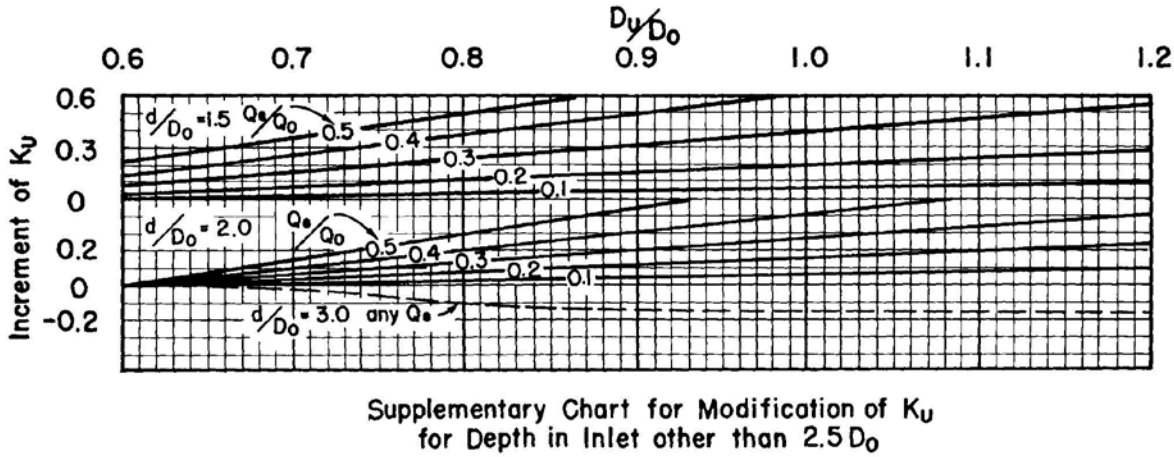
Figure B.3 Chart 3 - Flow Straight Through any Junction
(Source University of Missouri E.S.B. #41)

B.4 CHART 4 – RECTANGULAR INLET WITH THROUGH PIPELINE AND GRATE FLOW

Pressure change coefficients are presented in this chart for use in determining the common elevation of the upstream in-line pipe pressure line and the water surface in the inlet. The in-line pipes connect at the inlet sides (long dimension) and must meet the alignment requirement stated for Figure B.3 Chart 3. As much as half the total flow may enter through a top grate. The main graph of Figure B.4 Chart 4 includes effects of various proportion of grate flow for a relative water depth d/D_O of 2.5. Increments of K_U for other relative depths are shown in the supplemental graphs; positive increments for d/D_O less than 2.5 and negative for greater depths.

To use the chart:

1. Determine the outfall pipe pressure line elevation – Gen. Instr. 1.
2. Calculate velocity head in the outfall – Gen. Instr. 2.
3. Calculate the ratios D_U/D_O and Q_U/Q_O – Gen. Instr. 3. (The grate flow ratio $Q_G/Q_O = 1 - Q_U/Q_O$).
4. Estimate a value for the water depth d.
    a. Follow Gen. Instr. 4.
    b. Estimate $K = 3\ Q_G/Q_O$.
5. Calculate the corresponding relative water depth d/D_O.
6. If the estimated d/D_O is approximately 2.5, enter the lower graph on Figure B.4 Chart 4 at the pipe size ratio D_U/D_O and read K_U at the curve or interpolated curve for Q_U/Q_O; Then proceed as in step (9).
7. If the estimated d/D_O is other than 2.5, follow step (6), then enter the upper graph on Figure B.4 Chart 4 at the given D_U/D_O and determine the increment of Ku required to account for the effects of the estimated relative water depth d/D_O.
8. Add K_U from step (6) and the increment from step (7) to determine the total value of K_U. Note that negative values of K_U, may occur.
9. For a rounded outfall pipe entrance or one consisting of a pipe socket, reduce K_U, according to Gen. Instr. 6.
10. Calculate h_U as indicated on the diagram on the chart and by Gen. Instr. 7.
11. Add h_U, to the elevation of the outfall pressure line at the inlet center to obtain the elevation of the upstream in- line pipe pressure line at the same location. The water surface elevation will correspond.
12. From this water surface elevation subtract the elevation of the inlet bottom to obtain a more precise value for the water depth d.
13. Repeat the above procedure with the improved value of d from (12), if necessary. Such repetition may not be necessary if the original estimated d/D_O of step (5) was reasonably accurate.
14. Check to be sure the inlet water elevation is below the top of the inlet so that inflow may be admitted.



Supplementary Chart for Modification of K_U for Depth in Inlet other than 2.5 D_O

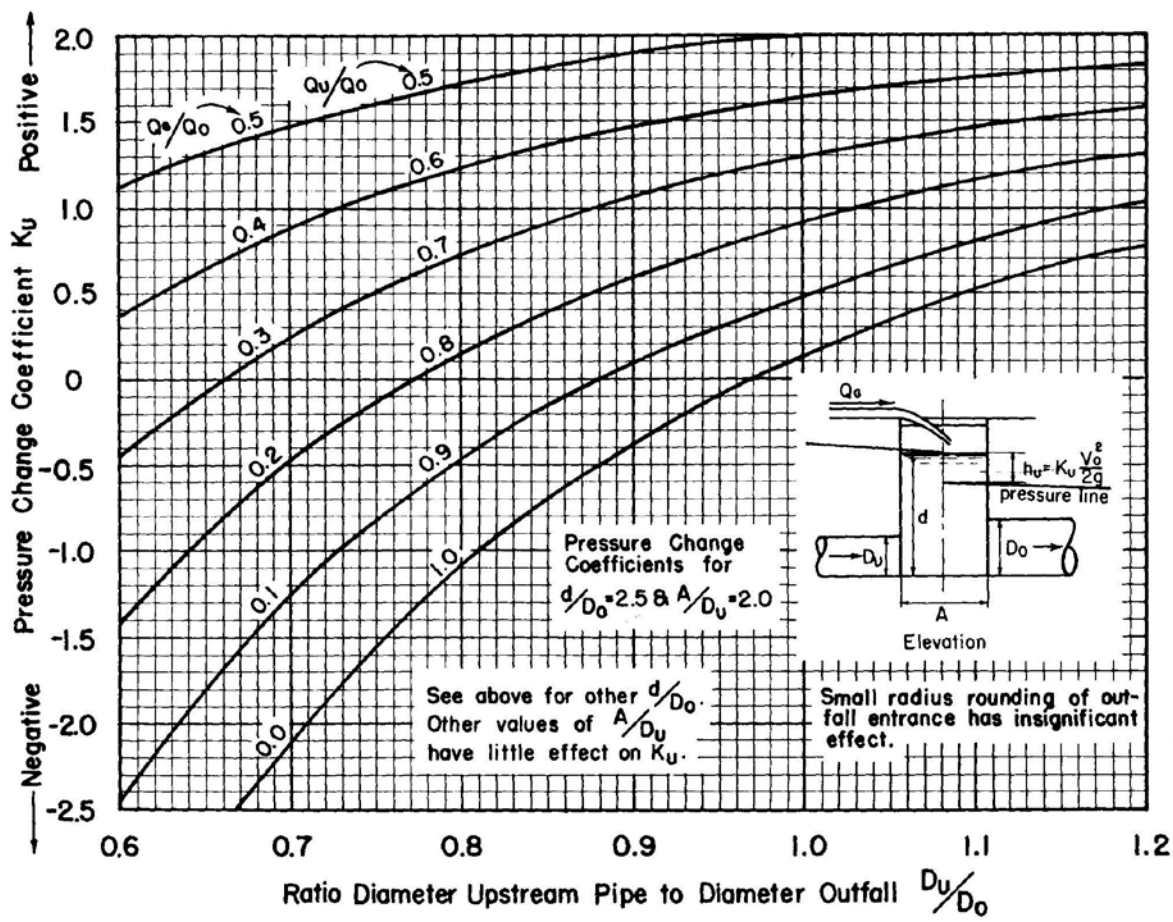


Figure B.4 Chart 4 - Rectangular Inlet With Through Pipeline And Grate Flow
(Source University of Missouri E.S.B. #41)

B.5 CHART 5 – RECTANGULAR INLET WITH IN-LINE UPSTREAM MAIN AND 90° LATERAL PIPE (WITH OR WITHOUT GRATE FLOW)

Pressure change coefficients are presented in this chart for use in determining the common elevation of the two upstream pipe pressure lines and the water surface in the inlet. Flow into the combination inlet and junction box is supplied by an upstream main, in-line with the outfall and flowing through the short dimension of the inlet, and a 90° lateral pipe connected at one end of the inlet box, supplemented by flow through a top grate. The main graph of Figure B.5 Chart 5 applies directly for no flow into the inlet through the grate. Increments of K_U and K_L for grate flow conditions are shown in the supplementary graphs of the upper portion of the chart.

To use the chart:

1. Determine the outfall pipe pressure line elevation - Gen. Instr. 1.
2. Calculate the velocity head in the outfall - Gen. Instr. 2.
3. Calculate the ratios D_U/D_O, Q_U/Q_O, and Q_G/Q_O - Gen. Instr. 3.
4. If no grate flow is involved, enter the lower graph on Figure B.5 Chart 5 at the pipe size ratio D_U/D_O and read K_U (or K_L) at the curve or interpolated curve for Q_U/Q_O; then proceed as in step (10).
5. With grate flow, estimate a value for the water depth d.
    a. Follow Gen. Instr. 4.
    b. Estimate K = 1.5.
6. Calculate the corresponding relative water depth d/D_O.
7. Enter the lower graph and obtain K_U (or K_L) as in step (4), this value applying for Q_G/Q_O = O.
8. Enter the appropriate upper graph on Figure B.5 Chart 5, for the particular d/D_O nearest that estimated in step (6), at the given D_U,/D_O and determine the increment of K_U (or K_L) at the curve for Q_G/Q_O. This increment accounts for the effects of grate flow and is always a positive value, even when K_U of step (7) is negative.
9. Add K_U from step (7) and the increment from step (8) to obtain the total value of K_U. Note that in unusual cases the total value of K_U may be negative.
10. For a rounded outfall pipe entrance or one consisting of a pipe socket, reduce K_U, and K_L according to Gen. Instr. 6.
11. Calculate h_U (also equal to h_L) as indicated by the diagram on the chart and by Gen. Instr. 7.
12. Add h_U to the elevation of the outfall pressure line at the branch point to obtain the elevation of the upstream in-line pipe pressure line at this point. The elevations of the lateral pipe pressure line and the water surface in the inlet will correspond.

13. From this water surface elevation subtract the elevation of the inlet bottom to obtain a more precise value for the water depth d.
14. Repeat the above procedure with the improved value of d from step (13), if necessary. Such repetition may not be necessary if the original estimated d/D_O of step (6) was reasonably accurate.
15. Check to be sure the inlet water surface elevation is below the top of the inlet so that inflow may be admitted.

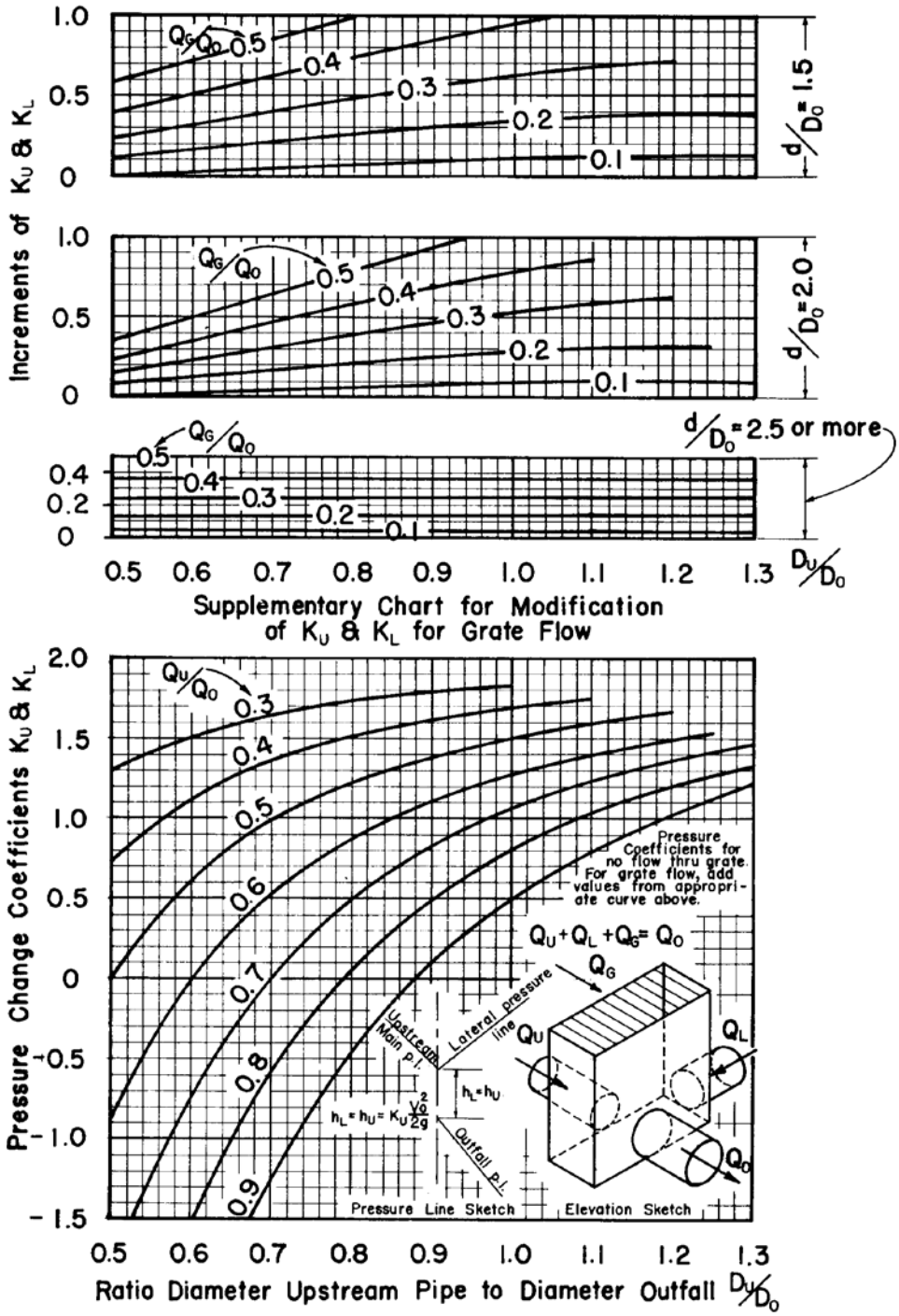


Figure B.5 Chart 5 - Rectangular Inlet With In-line Upstream Main And 90° Lateral Pipe (With or Without Grate Flow) *(Source University of Missouri E.S.B. #41)*

B.6 CHART 6 – RECTANGULAR INLET WITH IN-LINE OPPOSED LATERAL PIPES EACH AT 90° TO OUTFALL (WITH OR WITHOUT GRATE FLOW)

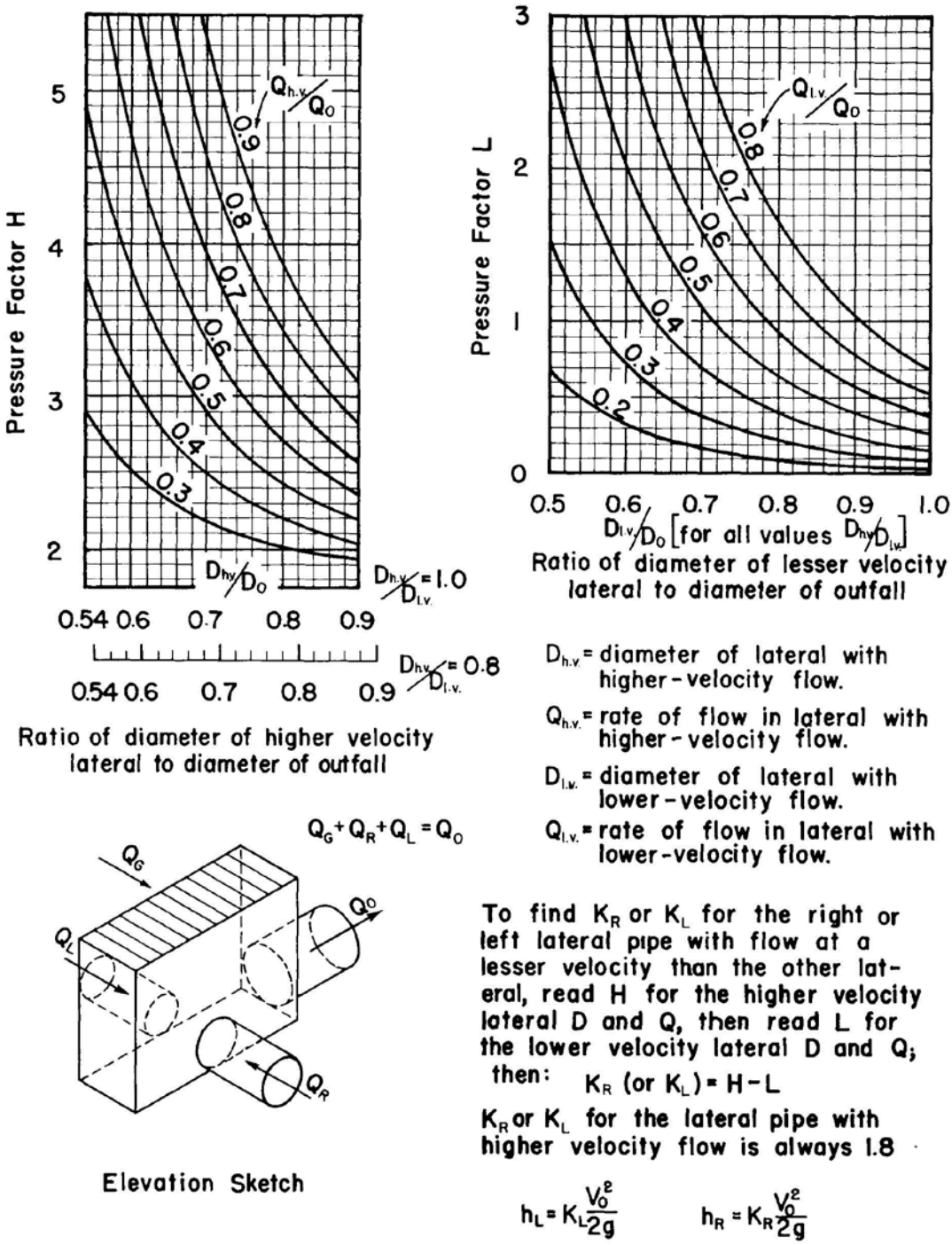
Pressure change coefficients are presented in this chart for use in determining the elevation of the pressure line of the lateral carrying the lower-velocity flow of two in-line opposed lateral pipes supplying a combination junction and inlet box. The pressure change coefficient for the higher-velocity lateral is a constant and so is not read from the chart. An inlet of this type may be used at a low point of street grade where lateral pipes supply flow from up-grade inlets in both directions, and the outfall pipe is located at right angles to the two lateral lines.

The chart may be used for cases with all probable ratios of flow rates in the two laterals, with or without grate flow. For this type of inlet and junction, the pressure changes are not modified by the depth of water in the inlet. The water surface elevation here will correspond to the pressure line of the higher-velocity lateral.

To use the chart:

1. Determine the outfall pipe pressure line elevation - Gen. Instr. 1.
2. Calculate the velocity head in the outfall - Gen. Instr. 2.
3. Calculate the velocities in each of the laterals to determine which is the higher-velocity and which the lower-velocity lateral.
4. Calculate the ratios Q_G/Q_O, Q_{hv}/Q_O, Q_{lv}/Q_O, D_{hv}/D_O, D_{lv}/D_O and D_{hv}/D_{lv} - Gen. Instr. 3.
5. Determine H from the left-hand graph on Figure B.6 Chart 6. Enter the graph at the pipe size ratio D_{hv}/Do (note the two scales) and read H at the curve or interpolated curve for Q_{hv}/Q_O. In entering the graph, note that unequal size laterals (D_{hv}/D_{lv}, not equal to 1.0), effect an offset of the scale for D_{hv}/D_O. Interpolation between the two scales shown is used for intermediate values. Extrapolation beyond the scales is satisfactory.
6. Determine L from the right-hand graph on Figure B.6 Chart 6. Enter the graph at the pipe size ratio D_{lv}/D_O (note only one scale is involved) and read L at the curve or interpolated curve for Q_{lv}/Q_O.
7. Calculate K_{lv} = H - L with grate flow involved. With no grate flow, K_{lv} = (H - L) - 0.2.
8. K_{hv} = 1.8 with grate flow involved. With no grate flow, K_{hv} = 1.6.
9. Calculate $h_{lv} = K_{lv}\frac{V_o^2}{2g}$ and $h_{hv} = K_{hv}\frac{V_o^2}{2g}$
10. Add h_{lv} to the elevation of the outfall pipe pressure line at the branch point to obtain the elevation of the lower-velocity lateral pressure line at this point; similarly, add h_{hv} to the outfall pipe pressure line elevation to obtain the elevation of the higher-velocity lateral pressure line at the branch point.

11. Determine the water surface elevation in the inlet, which is equal to the lower of the two lateral Pressure line elevations (that of the higher-velocity lateral).
12. Check to be sure the inlet water surface elevation is below the top of the inlet so that inflow may be admitted.



$D_{h.v.}$ = diameter of lateral with higher-velocity flow.

$Q_{h.v.}$ = rate of flow in lateral with higher-velocity flow.

$D_{l.v.}$ = diameter of lateral with lower-velocity flow.

$Q_{l.v.}$ = rate of flow in lateral with lower-velocity flow.

To find K_R or K_L for the right or left lateral pipe with flow at a lesser velocity than the other lateral, read H for the higher velocity lateral D and Q, then read L for the lower velocity lateral D and Q; then: K_R (or K_L) = H − L

K_R or K_L for the lateral pipe with higher velocity flow is always 1.8

$$h_L = K_L \frac{V_O^2}{2g} \qquad h_R = K_R \frac{V_O^2}{2g}$$

Figure B.6 Chart 6 - Rectangular Inlet With In-line Opposed Lateral Pipes Each at 90° To Outfall (With or Without Grate Flow) *(Source University of Missouri E.S.B. #41)*

B.7 CHART 7 - RECTANGULAR INLET WITH OFFSET OPPOSED LATERAL PIPES EACH AT 90° TO OUTFALL (WITH OR WITHOUT GRATE FLOW)

Pressure change coefficients are presented in this chart for use in determining the elevations of the pressure lines of each of the two horizontally offset opposed lateral pipes supplying a combination junction and inlet box. The inlet is used in the same situations as those to which Figure B.6 Chart 6 applies, but the pressure rise of the lower velocity lateral is restricted by locating the lateral pipes to enter opposite sides of the inlet box with their centerlines horizontally offset a distance not less than the sum of the two lateral pipe diameters. One lateral enters one side of the box near the outfall pipe end, and one, designated the far lateral, enters the opposite side near the other end.

This chart is used for all probable ratios of flow rates in the two laterals, with or without grate flow. For this type of inlet the pressure changes are not modified by the depth of water in the inlet. The water surface elevation here will correspond to the pressure line of the far lateral.

To use the chart:

1. Determine the horizontal distance between the centerlines of the opposed flow laterals at the inlet; if more than the sum of the pipe diameters, this chart will apply.
2. Determine the outfall pipe pressure line elevation at the branch points - Gen. Instr. 1. An average elevation applicable to both is sufficiently precise.
3. Calculate the velocity head in the outfall - Gen. Instr. 2.
4. Calculate the ratios Q_F/Q_O, Q_N/Q_O, D_F/D_O, and D_N/D_O, observing the nomenclature of Figure B.1 Chart 1- Gen. Instr. l.
5. Calculate the factors $\left(\frac{Q_F}{Q_O}\right)\left(\frac{D_O}{D_F}\right)$ and $\left(\frac{Q_N}{Q_O}\right)\left(\frac{D_O}{D_N}\right)$ noting that the pipe size relations are the reciprocals of the usual ratios.
6. For the far lateral, enter the left-hand graph of Figure B.7 Chart 7 at the abscissa value from step (5) and read K_F at the curve or interpolated curve for D_F/D_O.
7. For the near lateral, obtain K_N, from the right hand graph by a similar procedure.
8. For an inlet with grate flow, calculate h_F and h_N by multiplying the outfall velocity head by the corresponding coefficient K_F or K_N.
9. For a junction without grate flow, calculate h_F and h_N by multiplying the outfall velocity head by the corresponding reduced coefficients (K_F - 0.2) or (K_N - 0.2).
10. Add h_F and h_N to the elevation of the downstream (outfall pipe) pressure line to obtain the elevations of the pressure lines of the two laterals at their branch points.
11. Determine the water surface elevation in the inlet, which is equal to the far lateral pressure line elevation.
12. Check to be sure the inlet water surface elevation is below the top of the inlet so that inflow may be admitted.

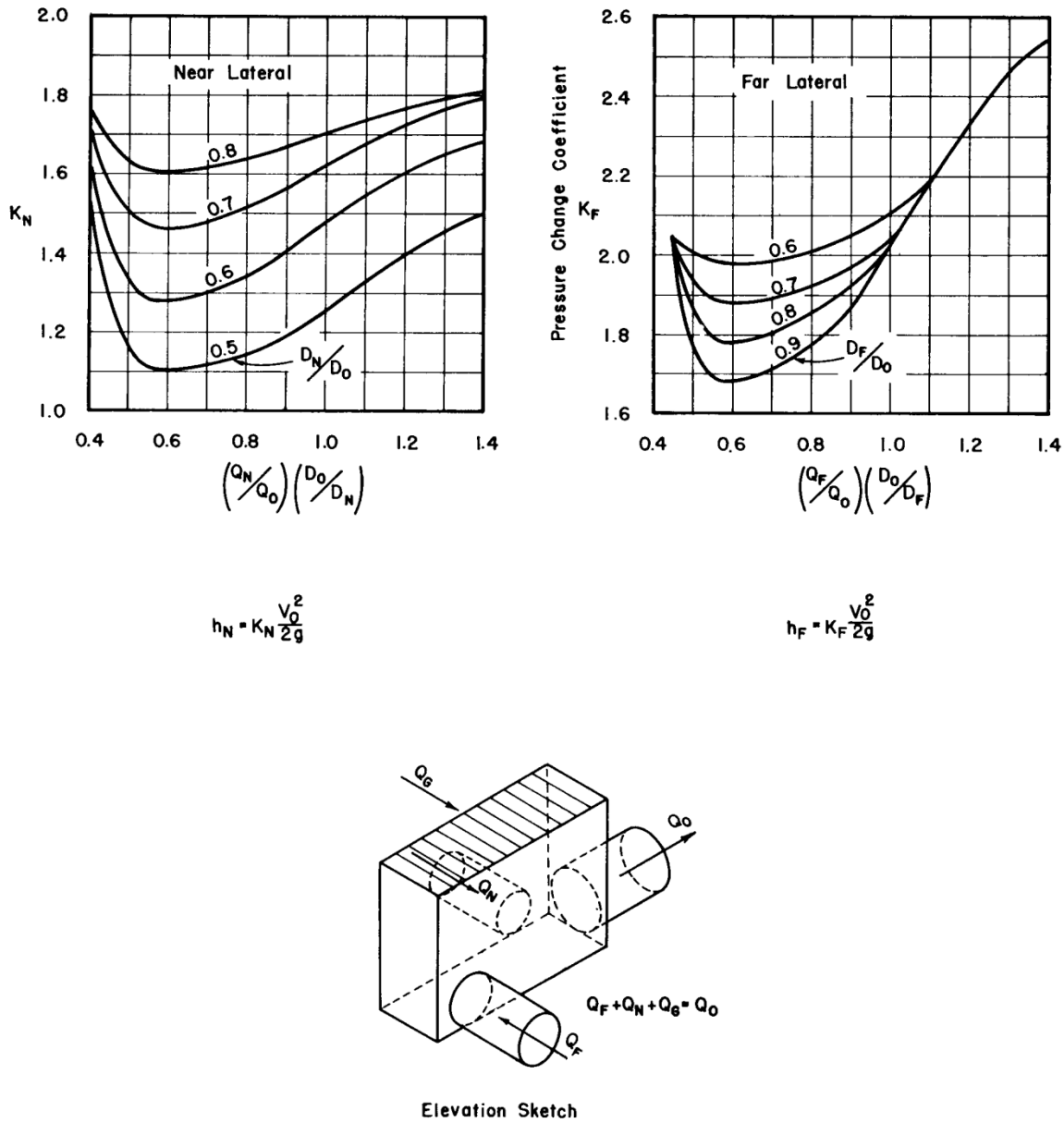


Figure B.7 Chart 7 - Rectangular Inlet With Offset Opposed Lateral Pipes each at 90° To Outfall (With Or Without Grate Flow) *(Source University of Missouri E.S.B. #41)*

B.8 CHART 8 – JUNCTION BOX (MANHOLE) 90° DEFLECTION – LATERAL COEFFICIENT

A. Square Manhole at 90° Deflection - Figure B.8 Chart 8

Pressure change coefficients are presented in this chart for use in determining the elevation of the pressure line of an upstream pipe connected by means of a square manhole to an outfall pipe at a 90° angle. The manhole conditions covered by this chart do not involve an upstream pipe in-line with the outfall pipe. For this and other manhole charts, the lateral pipe is designated by the subscript L irrespective of its right-hand or left-hand position. The coefficients given by the chart apply directly to manholes having a square-edged entrance to the outfall pipe. Coefficients for a rounded entrance are obtained by reduction of the chart values as stated below. The design of manholes with deflector devices is discussed separately.

To use the chart:

1. Determine the outfall pipe pressure line elevation - Gen. Instr. 1.
2. Calculate the velocity head in the outfall - Gen. Instr. 2.
3. Calculate the ratios D_L/D_O and B/D_O - Gen. Instr. 3.
4. Enter the lower graph of Figure B.8 Chart 8 at the pipe size ratio D_L/D_O and read $\overline{K_L}$ at the curve or interpolated curve for the manhole size ratio B/D_O. For all flow from a lateral, $K_L = \overline{K_L}$.
5. For a rounded outfall pipe entrance or one formed by a pipe socket reduce the chart value of $\overline{K_L}$ by 0.3 as defined by Gen. Instr. 6.
6. Calculate the charge of pressure $h_L = K_L\left(\frac{V_O{}^2}{2g}\right)$ (always positive for 90° deflections).
7. Add h_L to the elevation of the outfall pressure line at the branch point to obtain the elevation of the lateral pipe pressure line at this point.
8. The water surface elevation in the manhole will be above the lateral pipe pressure line. To determine the water-surface elevation use Figure B.9 Chart 9 as instructed in steps (12) through (18) of the instructions for a square manhole at the junction of a 90° lateral with a through main.
9. Check to be sure the water surface elevation is above the pipe crowns to justify using these charts and that it is sufficiently below the top of the manhole to indicate safety from overflow.

B. Round Manhole at 90° Deflection - Figure B.8 Chart 8

Pressure change coefficients may also be obtained from this chart for use in determining the elevation of the pressure line of an upstream pipe connected by means of a round manhole to an outfall pipe at a 90° angle.

To use the chart:

1. Proceed as instructed in steps (1) through (4) for a square manhole at a 90° deflection to obtain a base value of $\overline{K_L}$ for the particular values of D_L/D_O and B/D_O.
2. To provide for the effects of the round manhole cross section, reduce $\overline{K_L}$ in accordance with the following table:

Reductions of $\overline{K_L}$ for $\frac{D_L}{D_O}$

B/D0 \ DL/D0=	0.6	0.8	1.0	1.2
1.75	0.4	0.3	0.2	0.0
1.33	0.3	0.2	0.1	0.0
1.10	0.2	0.1	0.0	0.0

The reduced values apply for a sharp-edged entrance to the outfall pipe.

3. With a well-rounded entrance to the outfall pipe from a round manhole, reduce $\overline{K_L}$ of step (1) by 0.3 with no further reduction for manhole cross section shape.
4. Follow steps (6) through (9) as detailed for square manholes at a 90° deflection.

C. Deflectors in Square or Round Manholes at 90° Deflection - Figure 7.2.6.6.1.8 Chart 8

Pressure change coefficients are presented in this chart for use in determining the elevation of the pressure line of an upstream pipe connected to an outfall pipe at a 90° angle by means of a square or round manhole modified by flow deflectors. Deflectors in a manhole effectively eliminate the effects related to the shape of the manhole. The basic types of deflector walls which may be constructed in square or round manholes to effect a reduction of the pressure loss are detailed and described in the comprehensive report of the investigation.

The deflectors which are most easily constructed and are as effective as more complex types provide a vertical wall to guide the flow toward the outfall pipe. The wall need not be higher than the outfall pipe diameter and must fill in that part of the manhole opposite the lateral pipe exit so that it is flush with the side of the outfall pipe. Three basic types of such deflector walls are possible and are included in the curves of Figure B.8 Chart 8. These three are (1) walls parallel to the outfall pipe centerline or 0° walls, (2) inclined walls, limited to an angle of about 15° to the outfall centerline if an upstream in-line pipe is to be used, and (3) walls at 45° to both the lateral and outfall pipes, or walls curved on a radius of about the manhole dimension extending from lateral to outfall, and therefore to be used only when no upstream in-line pipe is involved. Rounding of the corner formed between the deflector wall and the manhole floor is not required, and may be detrimental in some cases.

To use the chart:
1. Determine the outfall pipe pressure line elevation-Gen. Instr. 1.
2. Calculate the velocity head in the outfall-Gen. Instr. 2.

3. Classify the type of deflector used:
   a. Parallel wall - 0°
   b. Inclined wall - 5° to 15°
   c. 45° or curved wall.
4. Calculate the ratios D_L/D_O and B/D_O. No distinction between square and round manholes is necessary.
5. If B/D_O is 1.5 or less, enter the lower graph of the chart at the ratio D_L/D_O and read $\overline{K_L}$ at the curve for the appropriate deflector type. In the case of a parallel wall, use the curve for $B/D_O = 1.00$.
6. If B/D_O is more than 1.5 and less than 2.0, use the same dashed curve for 45° or curved deflectors, use the curve for $B/D_O = 1.10$ for 5° to 15° angle deflectors, and use the curve for $B/D_O = 1.20$ for 0° angle deflectors.
7. A rounded entrance to the outfall pipe or one formed by a pipe socket is less effective in reducing the pressure change with deflectors than when deflectors are not used. A reduction of $\overline{K_L}$ by 0.l may be justified.
8. Calculate the change of pressure: $h_L = K_L\left(\frac{V_O^2}{2g}\right)$ (for $Q_L = Q_O$, $K_L = \overline{K_L}$).
9. Add h_L to the elevation of the outfall pressure line at the branch point to obtain the elevation of the lateral pipe pressure line at this point.
10. The water-surface elevation in the manhole will be above the lateral pipe pressure line. To determine the water surface elevation use Figure B.9 Chart 9 as instructed in steps (2) through (8) for deflectors in a manhole at the junction of a 90° lateral with a through main.
11. Check to be sure the water surface elevation is above the pipe crowns to justify using these charts and that it is sufficiently below the top of the manhole to indicate safety from overflow.

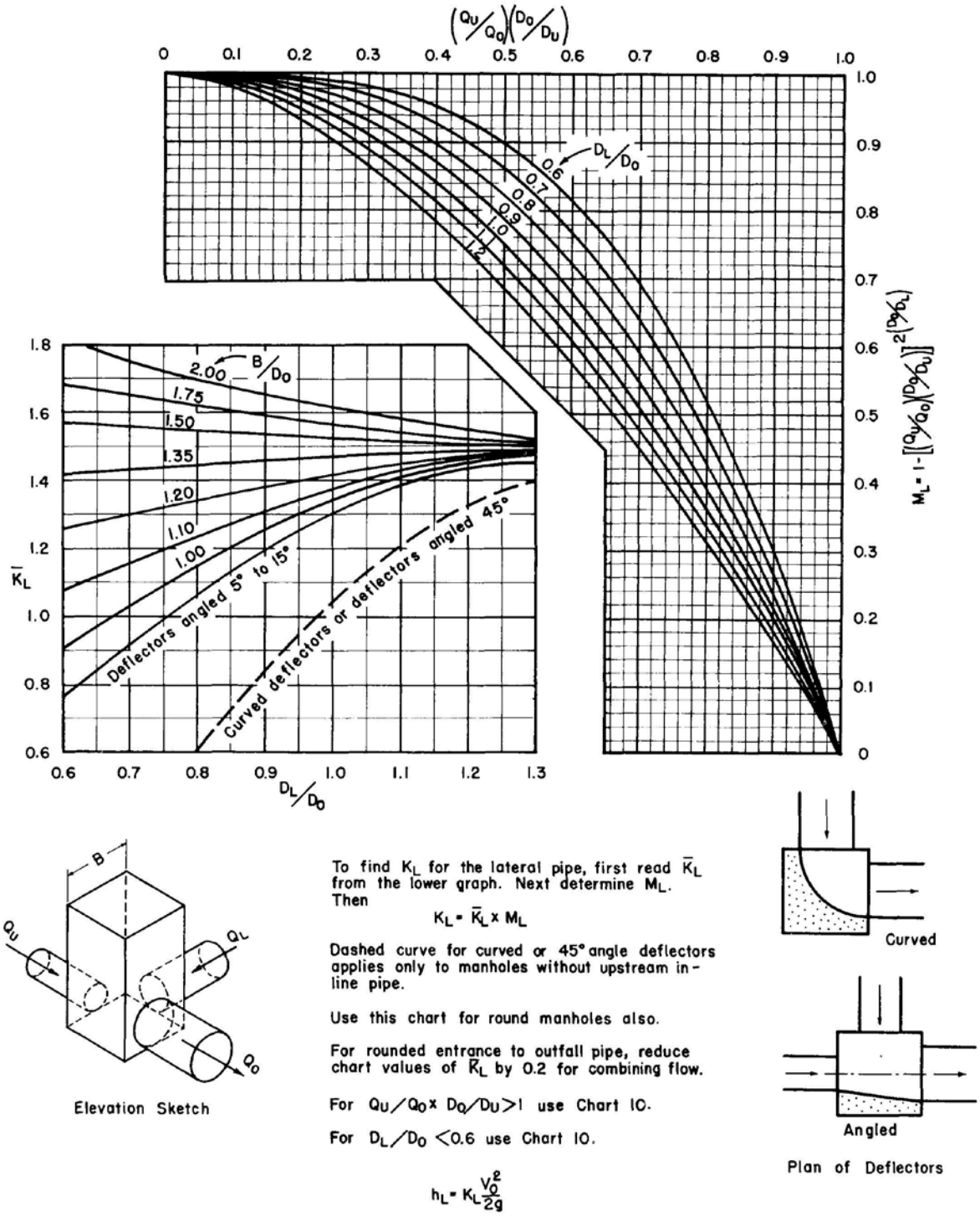


Figure B.8 Chart 8 - Square or Round Manhole At 90° Deflection Or On Through Pipeline At Junction Of 90° Lateral Pipe (Lateral Coefficient)

(Source University of Missouri E.S.B. #41)

B.9 CHART 8 AND CHART 9

A. Square Manhole on Through Pipeline at Junction of a 90° Lateral Pipe - Charts 8 & 9 (Larger Size Laterals: D_L / D_O > 0.6)

Pressure change coefficients for use in determining the elevation of the pressure line of the 90° lateral pipe are obtained from Figure B.8 Chart 8, and the coefficients for the upstream in-line pipe are obtained from Figure B.9 Chart 9. The diameter of the lateral pipe must be at least 0.6 of the diameter of the outfall pipe to permit use of these charts. Pressure changes at junctions of smaller laterals may be obtained through use of Figure B.10 Chart 10. The coefficients given by the charts apply directly to a square-edged entrance to the outfall pipe. Coefficients for a rounded entrance are obtained by reduction of the chart values as stated below. The design of manholes with deflector devices is discussed separately.

To use the charts:

1. Determine the outfall pressure line elevation - Gen. Instr. 1.
2. Calculate the velocity head in the outfall - Gen. Instr. 2.
3. Calculate the ratios Q_U/Q_O, D_U/D_O, and D_L/D_O. If D_L/D_O is less than 0.6, use Figure B.10 Chart 10 instead of Figure B.8 Chart 8 and Figure B.9 Chart 9.
4. Calculate the ratio B/D_O and note if the outfall entrance is rounded.
5. Calculate the factor $\left(\frac{Q_U}{Q_O}\right)\left(\frac{D_O}{D_U}\right)$; if this is greater than 1.00, use Figure B.10 Chart 10 instead of Figure B.8 Chart 8 and Figure B.9 Chart 9.

For lateral pipe:

6. Enter the lower graph of Figure B.8 Chart 8 at the ratio D_L/D_O and read $\overline{K_L}$ at the curve or interpolated curve for the ratio B/D_O.
7. For a rounded outfall pipe entrance or one formed by a pipe socket as defined by Gen. Instr. 6, reduce the chart value of $\overline{K_L}$ by 0.2.
8. Determine the factor ML by entering the upper graph of Figure B.8 Chart 8 at the value of the factor $\left(\frac{Q_U}{Q_O}\right)\left(\frac{D_O}{D_U}\right)$ and at the curve or interpolated curve for D_L/D_O.
9. Calculate $K_L = M_L \times \overline{K_L}$.
10. Calculate the lateral pipe pressure change
11. Add h_L to the elevation of the outfall pipe pressure line at the branch point to obtain the elevation of the lateral pipe pressure line at this point.

For upstream in-line pipe:

12. Enter the lower graph of Figure B.9 Chart 9 at the ratio D_L/D_O and read $\overline{K_U}$ at the curve or interpolated curve for B/D_O.

13. For a rounded entrance to the outfall pipe or one formed by a pipe socket, reduce $\overline{K_U}$ by 0.2.
14. Determine the factor MU from the upper graph of Figure B.9 Chart 9.
15. Calculate $K_U = M_U \times \overline{K_U}$.
16. Calculate the upstream in-line pipe pressure change: $h_U = K_U \left(\frac{V_O^2}{2g}\right)$
17. Add h_U to the elevation of the outfall pipe pressure line at the branch point to obtain the elevation of the upstream in-line pipe pressure line at this point.

For water surface:

18. The water-surface elevation in the manhole will correspond to the upstream in-line pipe pressure line at the branch point.
19. Check to be sure that the water surface elevation is above the pipe crowns to justify using these charts and that it is sufficiently below the top of the manhole to indicate safety from overflow.

B. Round Manhole on Through Pipeline At Junction of a 90° Lateral Pipe-Charts 8 and 9 (Larger Size Laterals: $D_L / D_O > 0.6$)

Pressure change coefficients may also be obtained from Figure B.8 Chart 8 and Figure B.9 Chart 9 for use in determining the elevations of the pressure lines of the 90° lateral pipe and the upstream in-line pipe connected by a round manhole to an outfall pipe.

To use the charts:

1. Proceed as instructed by steps (1) through (6) for a square manhole at a similar junction to obtain a base value of $\overline{K_L}$.

For lateral pipe:

2. To provide for the effects of the round manhole cross-section, reduce $\overline{K_L}$ in accordance with the following table:

   Reduction of $\overline{K_L}$ for $\frac{D_L}{D_O}$

DL/D0= / B/D0	0.6	0.8	1.0	1.2
1.75	0.4	0.3	0.2	0.0
1.33	0.3	0.2	0.1	0.0
1.10	0.2	0.1	0.0	0.0

   The reduced values apply for a sharp-edged entrance to the outfall pipe.

3. With a well-rounded entrance to the outfall pipe from a round manhole, reduce $\overline{K_L}$ obtained in step (2) by 0.1.

4. Determine the factor ML from the upper graph of Figure B.8 Chart 8 and proceed as instructed in steps (8) through (11) for a square manhole to complete the determination of the elevation of the lateral pipe pressure line.

For upstream in-line pipe:

5. Proceed as instructed in steps (12) through (17) for a square manhole at a similar junction to obtain the elevation of the upstream in-line pipe pressure line. Note that no reduction of $\overline{K_L}$ is to be made for effects of the round manhole cross-section.

For water surface:

6. Proceed as instructed by steps (18) and (19) for a square manhole at a similar junction.

C. Deflectors in Square or Round Manholes on Through Pipeline at Junction of a 90° Lateral Pipe-Charts 8 and 9 (Larger Size Laterals: $D_L/D_O > 0.6$)

Pressure change coefficients are also presented in Figure B.8 Chart 8 and Figure B.9 Chart 9 for use in determining the elevations of the pressure lines of the lateral and in-line pipes at a junction of this type, with either a square or a round manhole modified by flow deflectors. Deflectors in a manhole effectively eliminate the effects related to the shape of the manhole. Deflector types are described in the instructions for use of Figure B.8 Chart 8 for a manhole with deflectors at a 90° deflection of a storm drain. The curved and 45° deflectors cannot be used in a manhole on a through pipeline because of the space required for through in-line flow.

To use the charts:

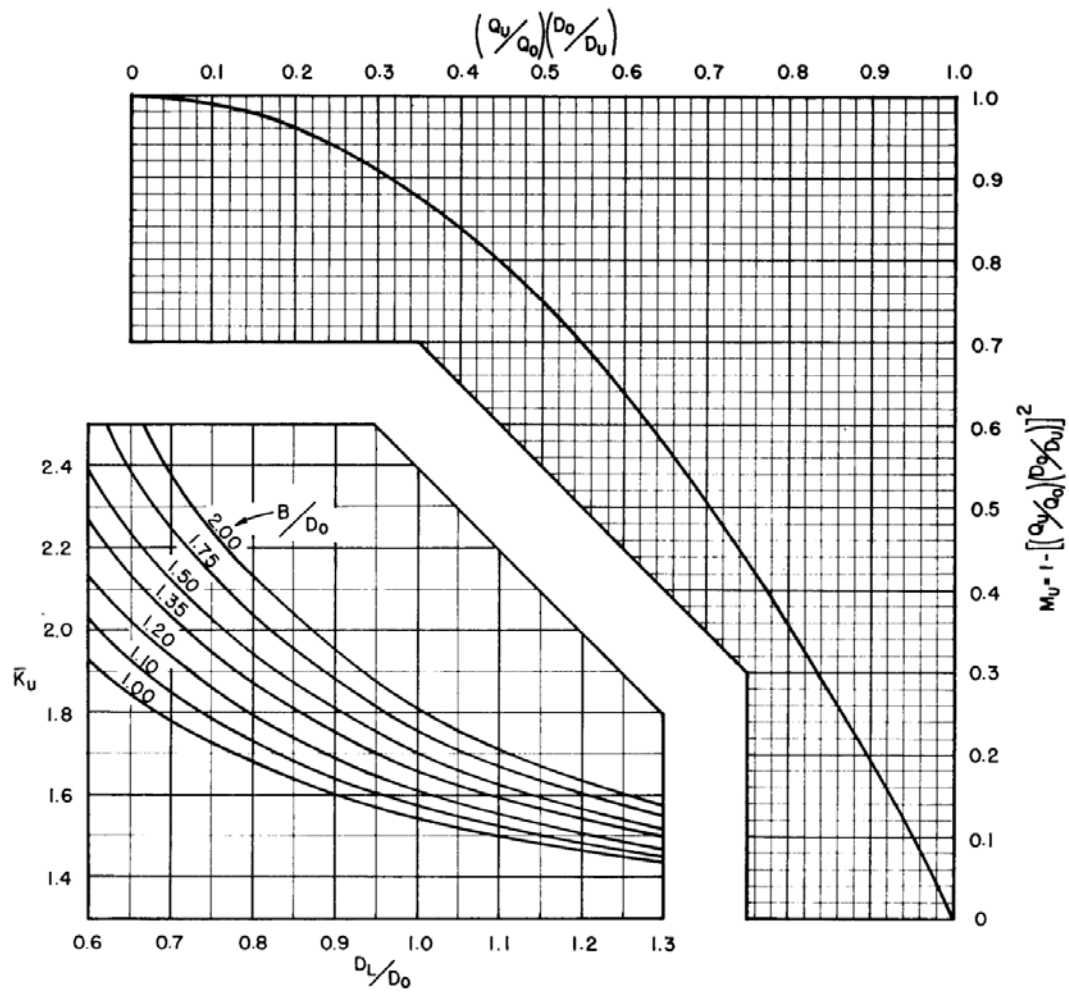
1. Proceed as instructed in steps (1) through (9) for deflectors in a manhole at a 90° deflection, disregarding references to 45° or curved walls. Through use of Figure B.8 Chart 8 these steps will give the elevation of the lateral pipe pressure line at the branch point. As noted in the instructions for a manhole of this type without deflectors, Figure B.10 Chart 10 must be used when $D_L/D_O < 0.6$ or $\left(\frac{Q_U}{Q_O}\right)\left(\frac{D_O}{D_U}\right) > 1.00$.

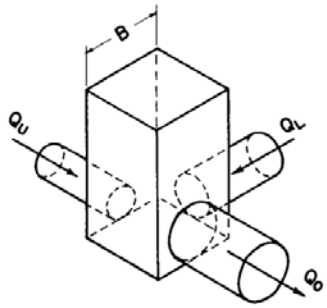
For upstream in-line pipe:

2. Enter the lower graph of Figure B.9 Chart 9 at the ratio D_L/D_O and read $\overline{K_U}$ for all manhole sizes and any deflector wall angle from 0° to 15° at the curve for $B/D_O = 1.00$.
3. For a rounded entrance to the outfall pipe or one formed by a pipe socket, reduce $\overline{K_U}$ by 0.1.
4. Determine the factor M_U from the upper graph of Figure B.9 Chart 9.
5. Calculate $K_U = M_U \times \overline{K_U}$.
6. Calculate the upstream in-line pipe pressure change $h_U = K_U\left(\frac{V_O^2}{2g}\right)$.
7. Add h_U to the elevation of the outfall pipe pressure line at the branch point to obtain the elevation of the upstream in-line pipe pressure line at this point.

For water surface:

8. The water-surface elevation in the manhole will correspond to the upstream in-line pipe pressure line at the branch point.
9. Check to be sure that the water-surface elevation is above the pipe crowns to justify using these charts and that it is sufficiently below the top of the manhole to indicate safety from overflow.





Elevation Sketch

To find K_U for the upstream main, first read $\bar{K}_U$ from the lower graph. Next determine M_U. Then

$$K_U = \bar{K}_U \times M_U$$

For manholes with deflectors at 0° to 15°, read $\bar{K}_U$ on curve for $B/D_O = 1.0$

Use this chart for round manholes also.

For rounded entrance to outfall pipe, reduce chart values of $\bar{K}_U$ by 0.2 for combining flow.

For deflectors refer to sketches on Chart 8.

For $Q_U/Q_O \times D_O/D_U > 1$ use Chart 10

For $D_L/D_O < 0.6$ use Chart 10

$$h_U = K_U \frac{V_O^2}{2g}$$

Figure B.9 Chart 9 - Square Or Round Manhole On Through Pipeline At Junction Of A 90° Lateral Pipe (In-line Pipe Coefficient) *(Source University of Missouri E.S.B. #41)*

B.10 CHART 10 - SQUARE OR ROUND MANHOLE ON THROUGH PIPE LINE AT JUNCTION OF 90° LATERAL PIPE (SMALLER SIZE LATERALS $D_L / D_O < 0.6$)

Pressure change coefficients are presented in Figure B.10 Chart 10 for use in determining the common elevation of the pressure lines of the lateral and in-line pipes at a junction of this type for cases of pipe sizes or flow divisions outside the range over which Figure B.8 Chart 8 and Figure B.9 Chart 9 may be applied. Figure B.8 Chart 8 and Figure B.9 Chart 9 are more reliable within their range and should be used if possible. Neither manhole shape nor size nor relative size of lateral pipe modify the coefficients of Figure B.10 Chart 10. The chart may also be used for direct connection of a 90° lateral to a main without use of a manhole. The coefficients of the chart apply directly to a square-edged entrance to the outfall pipe. Coefficients for a rounded entrance are obtained by reduction of the chart values as stated below. Deflectors in the manhole are not effective in the ranges covered by Figure B.10 Chart 10, and therefore need not be used.

To use the chart:

1. Determine the outfall pipe pressure line elevation - Gen. Instr. 1.
2. Calculate the velocity head in the outfall - Gen. Instr. 2.
3. Calculate the ratios D_L / D_O, D_U / D_O, and Q_U / Q_O – Note that use of Figure B.8 Chart 8 and Figure B.9 Chart 9 is advisable if the size and flow factors are within their range. Figure B.10 Chart 10 should not be used for $Q_U / Q_O < 0.7$ if other solutions are possible.
4. Note whether the outfall entrance is to be rounded or formed by a pipe socket as defined by Gen. Instr. 6.
5. Enter Figure B.10 Chart 10 at the ratio D_U / D_O and read K_U (also equal to K_L) at the curve or interpolated curve for Q_U / Q_O.
6. 6. If $\left(\frac{Q_U}{Q_O}\right)\left(\frac{D_O}{D_U}\right)$ was found to be greater than 1.00 in an attempt to use Figure B.8 Chart 8 and Figure B.9 Chart 9, K_U of step (5) will be negative in sign, thus providing a check on proper use of the charts.
7. For rounded entrance from the manhole to the outfall pipe use the reduced values from the chart.
8. Calculate the change-of pressure $h_U = h_L = K_U \left(\frac{V_O^2}{2g}\right)$, h_U and h_L are positive or negative depending on the sign of K_U as read from the chart.
9. Add a positive h_U to or subtract a negative h_U from the elevation of the outfall pipe pressure line at the branch point to obtain the elevation of the upstream in-line pipe pressure line at this point.
10. The elevation of the lateral pipe pressure line at the branch point and the water surface elevation in the manhole will correspond to the upstream in-line pipe pressure line elevation found in step (9).

11. Check to be sure that the water-surface elevation is above the pipe crowns to justify using these charts and that it is sufficiently below the top of the manhole to indicate safety from overflow.

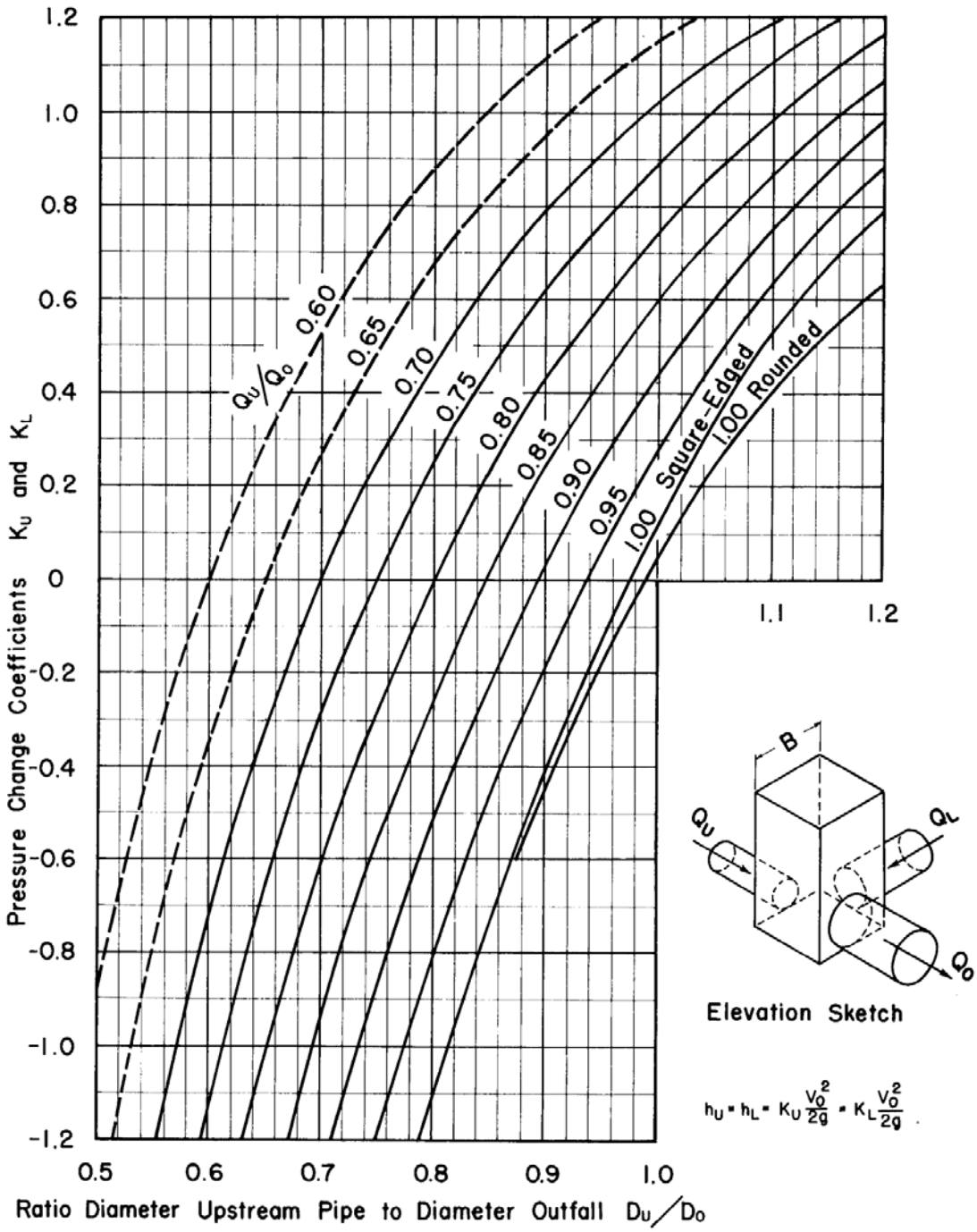


Figure B.10 Chart 10 - Square Or Round Manhole On Through Pipeline At Junction Of A 90° Lateral Pipe (For Conditions Outside Range Of Figure B.8 Chart 8 and Figure B.9 Chart 9) *(Source University of Missouri E.S.B. #41)*

B.11 REFERENCES

- University of Missouri. *Pressure Changes at Storm Drain Junctions - Engineering Bulletin No. 41*. University of Missouri, Columbia, MO, 1958.