City of Bastrop Stormwater Drainage Design Manual

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SECTION 1 INTRODUCTION

SECTION 1 - INTRODUCTION

A. Purpose and Intent Statements

Managing and resolving stormwater drainage issues and flooding problems has historically been one of the most persistent and critical challenges experienced by the City of Bastrop. In the past, the City's stormwater drainage control regulations for new land development have not effectively taken into account the City's unique topographic and geographic landscape. As a result, recent development has aggravated existing stormwater drainage and flooding issues at many locations within the City. Consequently, one of the City's highest priorities is to develop a strong stormwater drainage policy and criteria that ensures that new development does not increase flooding and erosion in the City of Bastrop.

The overarching purpose of this Drainage Design Manual is to establish standard policies and criteria for the design and implementation of stormwater drainage infrastructure that will promote geographically sensitive and fiscally responsible land development within the City and its extraterritorial jurisdiction.

Note that it is assumed that the reader of this document will already have a working knowledge of the basic mathematical theories and methodologies involved with hydrology and hydraulics and is seeking to understand standard City stormwater drainage policies and practices.

Specific goals and objectives of the City's Stormwater Drainage Design Manual include:

1. Minimizing flood risks to citizens and properties related to increases in peak runoff rates, volumes and velocities.
2. Stabilizing and decreasing streambank and channel erosion within downstream receiving waterways.
3. Facilitating comprehensive watershed-based planning that promotes controlled and sustainable land development and future growth.

In order to achieve the goals and objectives listed above, it is the City's intent to require that new land and development strongly consider low-impact development (LID) and natural approaches to stormwater management to mimic and restore pre-development hydrology. LID strategies that are encouraged in this document include:

1. Avoiding traditional engineering approaches to stormwater management that rapidly conveys runoff into large-scale drainage systems and discharges large volumes of stormwater and associated pollutants to downstream receiving waters.
2. Promoting management of stormwater runoff closer to its source by using small, distributed stormwater control devices that seek to slow down, infiltrate, and retain stormwater runoff using native or improved soils, vegetation, and bioengineering.
3. Studying, identifying and preserving sensitive natural areas such as floodplains,

wetlands, and steep slopes, while also reducing impervious land cover.

4. Supporting potential multi-objective functions of stormwater management features by implementing trails, green space, parkland, greenways, and other recreational and natural features, so long as they are compatible with the primary function of the stormwater feature.
5. Focusing on integrating stormwater management into the early concept-level stages of the land development process.

It is also the intent of the City of Bastrop that the requirements outlined herein regulate post-construction stormwater discharges to downstream receiving waterbodies. This design manual may be applied on a site-by-site basis. However, the City of Bastrop recognizes that the preferred method of achieving the stormwater performance standards set forth in this design manual is through the preparation and implementation of comprehensive, systems-level stormwater management plans that cover hydrologic units, such as watersheds, on a municipal and regional scale. Such plans may prescribe regional stormwater devices, practices or systems, any of which may be designed to convey and managed from more than one site prior to discharge to downstream receiving waterbodies. Where such plans are in conformance with the performance standards outlined in the City of Bastrop's Stormwater Drainage Design Manual and have been approved by the City of Bastrop, it is the intent of this document that the approved plan be used to identify post-construction stormwater management measures acceptable for the community.

B. General Provisions

1. Conformance with Comprehensive Plan. All drainage design must comply with the City of Bastrop Comprehensive Master Plan and the effective Flood Insurance Study (FIS) and effective Flood Insurance Rate Maps (FIRM) prepared by the Federal Emergency Management Agency (FEMA) or best available data. The developer shall provide those drainage improvements which traverse or abut the proposed development, where specified in the comprehensive plan. All costs for such improvements shall be paid by the Responsible Party, except where the City Manager determines that the improvements benefit other properties more than that of the proposed subdivision in which case the City Manager shall determine the equitable City participation in such improvements. Such City participation, or any appeal of such requirements, shall be subject to the approval of the City Council.
2. To protect health, safety and environmental quality, it shall be the policy of the City of Bastrop that no new development will be allowed within the one hundred-year floodplain, as delineated by FEMA or based on best available data, unless a Letter of Map Revision (LOMR) is approved by FEMA, that compensating storage be provided for any floodplain encroachments, and that there is no significant rise in the base flood elevation. Undeveloped land within the floodplain may be used for agricultural purposes, be incorporated into adjacent lots outside of the floodplain,

or set aside as private or public open space.

3. Development shall not increase stormwater runoff peak flow discharge or velocities over natural conditions, particularly on adjacent and downstream properties for the two-year, 25-year or 100-year, 24-hour storm events, unless a downstream assessment shows no impact to the downstream receiving stream. When preliminary drainage studies indicate that peak flows or velocities will be increased, then detention basins or other techniques shall be provided to reduce flows to natural conditions.
4. Development within the Gills Branch Watershed shall be required to limit post-developed 100-year, 24-hour design storm peak stormwater runoff discharges to not exceed pre-developed 25-year, 24-hour design storm peak stormwater runoff discharges. When the results of the required downstream drainage assessment indicate that receiving stormwater conveyance systems have less than a 25-year, 24-hour design storm capacity, developments shall be required to reduce 100-year, 24-hour design storm peak runoff discharges to not exceed the receiving stormwater conveyance system capacity as determined in the downstream drainage assessment.
5. The Responsible Party shall be responsible for the conveyance of all storm drainage flowing through or abutting the property to be developed. This responsibility includes the drainage directed to that property by prior development, future development of the watershed, as well as the drainage naturally flowing through the property.
6. The subdivider shall pay for the cost of all drainage improvements required for the development of the subdivision, including the subdivision's proportionate cost for any necessary off-site channels or storm sewers and acquisition of the required easements.
7. The Planning and Zoning Commission shall not recommend for approval and the Council may not approve any plat of a subdivision which does not make adequate provisions for stormwater or floodwater runoff channels or basins. Drainage provisions shall ensure the health and safety of the public and the property in times of flood.
8. Where the improvement or construction of a storm drainage facility is required along a property line common to two (2) or more owners, the Responsible Party hereafter proposing development or use of their property, shall be responsible for all the required improvements on either side of the common property line, regardless of ownership, at the time of development, including the dedication by the legal owner(s) of all necessary rights-of-way or easements, to accommodate

the construction and maintenance of improvements.

9. Where a property Responsible Party proposes development or use of only a portion of their property, provision for stormwater drainage shall only be required in that portion of the property proposed for immediate development or use, except for construction or improvements of a drainage facility outside that designated portion necessary for the proposed development. However, future development runoff shall be considered in the design of the proposed development.

10. The Responsible Party shall dedicate to the City the required drainage easements and/or rights-of-way to contain the drainage improvements or surface water flows. Determination of minimum easements and/or rights-of-way required shall be made by the City Engineer.

11. The Responsible Party shall extend to provision of adequate drainage improvements to accommodate the full effects of the development of their property. Such drainage improvements shall prevent a diversion, impounding or increase of the natural flow of surface waters caused by the development of the property from damaging the property of another. Such improvements may be on-site or off-site, or a combination of both, and shall be made at the expense of the Responsible Party or developer. Such drainage improvements shall be a condition of plat approval.

12. Inundation by a One-Percent Probability (100-Year Frequency) Storm: Any water course, whether natural or manmade, shall have provision to accommodate the rainfall runoff generated by a 100-year frequency storm such that there is no loss of, or be detrimental to, property or to create an undue inconvenience to the public.

    a. Any watercourse with a contributing drainage area greater than ten (10) acres, whether natural or manmade, shall have provision to accommodate the rainfall runoff generated by a 100-year frequency storm such that there is no loss of, or be detrimental to, property or to create an undue inconvenience to the public.

    b. Delineation of the limits of areas subject to inundation by a 100-year frequency storm shall be shown on a drainage plan and shall be based on detailed hydrologic and hydraulic computations prepared by a Registered Professional Engineer of the State of Texas. Effective FEMA floodplain information or best available data shall be shown when available.

    c. Easements shall be provided to contain areas inundated by a 100-year frequency storm along natural and manmade drainage ways and any additional width necessary to provide sufficient ingress and egress for maintenance purposes.

d. A grading plan shall be prepared for each subdivision, by a Registered Professional Engineer of the State of Texas, and show in sufficient detail grading of all roads, streets, drainage structures, channels, swales, or other drainage related features and provide minimum finished floor elevations, based on an acceptable elevation datum, for proposed structures to assure no inundation of such structures by the rainfall run- off by a 100-year frequency storm. All buildings shall have a minimum finished floor elevation of two feet (2') above the base flood elevation water surface elevation generated by a 100-year frequency storm, or as stipulated in the City of Bastrop's Flood Damage Prevention Regulations, whichever is greater.

C. Definitions

Applicant means the owner of land proposed to be subdivided, or their representative when written consent is obtained from the legal owner of the premises. The terms "applicant," "developer," and "subdivider" are used interchangeably in these rules, regulations and procedures.

Best Management Practice or "BMP" means structural or non-structural measures, practices, techniques or devices employed to avoid or minimize sediment or pollutants carried in runoff to waters of the state.

Capital improvements means facilities of a permanent nature, such as streets, drainage, sanitary sewer, etc.

Channel sinuosity equals the length between two points on the channel thalweg divided by the straight-line distance.

City or The City shall mean the City of Bastrop, Texas.

City Council means the City Council of the City of Bastrop, Texas.

City Engineer means the registered engineer designated by the City Manager to review engineering aspects of projects located within the City limits and ETJ.

City Inspector means the person designated by the City Manager to provide inspection services for public improvements or buildings located within the City Limits and ETJ.

City Manager means the person duly approved by the City Council and charged with the responsibility of administering the City's various departments.

City of Bastrop Construction Standards Manual means the Construction Standards Manual adopted by the City Council, as amended.

City Secretary shall mean the City Secretary of the City of Bastrop or the authorized representative of the secretary.

Common area means an area or facility that is owned jointly by the owners within the subdivision and/or members of the property-owners association. Common areas include, but are not limited to, private parks, community buildings and screening walls.

Comprehensive Plan means the comprehensive plan of the City of Bastrop, Texas, as adopted by the City Council of the City of Bastrop, Texas.

Concept Plan means a sketch drawing of initial development ideas superimposed on a topographic map to indicate generally the plan of development and to serve as a working base for noting and incorporating suggestions of the staff, City Engineer, utilities or others who are consulted prior to the preparation of the preliminary plat.

Construction plans means the maps or construction drawings accompanying a subdivision plat that show the specific location and design of all required or proposed improvements to be installed in the subdivision.

Design storm means a hypothetical discrete rainstorm characterized by a specific duration, temporal distribution, rainfall intensity, return frequency, and total depth of rainfall.

Detention pond means a pond or impoundment designed to store stormwater runoff for controlled release during or immediately following the storm event for a limited period of time.

Develop or Development means any manmade change to improved or 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.

Developer means an individual, partnership, corporation, or governmental entity undertaking the subdivision or improvement of land and other activities covered by the subdivision ordinance or the design standards and criteria, including the preparation of a subdivision plat showing the layout of the land and the public improvements involved therein. The term "developer" is intended to include the term "subdivider" even though personnel in successive stages of a project may vary.

Developer's agreement means a written contractual agreement between the City and the developer establishing the terms and conditions for approval and acceptance of the public improvements required for a development.

Director of Planning and Development means the person designated by the City Manager to oversee the City of Bastrop Planning Department.

Drainage easement means an easement created for conveying stormwater across property either on the surface or in an underground system. A drainage easement entitles the City to make necessary improvements within the easement to adequately convey stormwater.

Drainage plan means an engineering study evaluating stormwater runoff and flows that recommends drainage improvements necessary to comply with design standards adopted by the City.

Easement means an interest in land granted to the City, to the public generally, and/or to a private or public utility corporation for installing and/or maintaining public facilities or utilities or providing access to such facility or utility

Energy dissipaters means devices designed to protect downstream areas from erosion by reducing the velocity of flow to acceptable limits.

Engineer means a person duly authorized under the provisions of the Texas Engineering Registration Act, as heretofore or hereafter amended, to practice the profession of engineering.

Erosion means the process by which the land's surface is worn away by the action of wind, water, ice or gravity.

Erosion control means structural and nonstructural techniques to prevent the erosion and sedimentation of soil from rainfall and/or runoff.

Extraterritorial Jurisdiction (ETJ) means the area outside of the City of Bastrop municipal limits in which the City exercises joint zoning authority with Bastrop County.

Final plat means the one official and authentic map of any given subdivision of land prepared from actual field measurement and staking of all identifiable points by a surveyor with the subdivision location references to a survey corner or other established reference and all boundaries, corners and curves of the land division sufficiently described so that they can be reproduced without additional references. Angular measurements and bearings shall be accurate to the nearest tenth of a foot. The final plat of any lot, tract, or parcel of land shall be recorded in the Plat Records of Bastrop County, Texas.

Floodplain means an area identified by FEMA or based on best available data as possibly being flood-prone at or below the base flood elevation (100-year floodplain, or one-percent probability flood event). The issuance of building permits for construction of any structure within such floodplain is regulated by a separate specific ordinance governing the safeguards, preventing actions against flooding, types of uses permitted in flood-prone areas, etc.

Floodway means the channel of a river of other water course and the adjacent land areas that must be reserved to discharge the base flood as defined by FEMA without cumulatively increasing the water surface elevation more than one foot.

Floodway fringe means the area within the floodplain but outside of the floodway.

Geotechnical testing means testing by a qualified professional testing laboratory to determine the engineering characteristics of soil, rock and/or fill material.

Greenbelt means an open space area consisting of primarily natural features, that may be in a floodplain or along a creek channel or be used as a buffer between land uses or be used as an open space linkage between various land uses.

Homeowners Association shall mean an incorporated or unincorporated association that is designated as the representative of the owners of the property in the Suburban Subdivision that: (1) has a membership primarily consisting of the owners of the property covered by the dedicatory instrument for the Suburban Subdivision, and (2) manages and/or regulates the Suburban Subdivision for the benefit of the owners of property in the subdivision.

Hydrograph means a plot of the variation of discharge with respect to time or the variation of stage or other water property with respect to time.

Impervious surface means an area that releases as runoff all or a large portion of the precipitation that falls on it, except for frozen soil. Rooftops, sidewalks, driveways, parking lots and streets are examples of areas that typically are impervious.

In-fill area means an undeveloped area of land located within existing development or which adjacent properties on at least three sides are developed or in public rights-of-way, as determined by the City Engineer.

Infiltration means the entry of precipitation or runoff into or through the soil.

Infiltration system means a device or practice such as a basin, trench, rain garden or swale designed specifically to encourage infiltration, but does not include natural infiltration in pervious surfaces such as lawns, redirecting of rooftop downspouts onto lawns, or minimal infiltration from practices, such as swales or road side channels designed for conveyance and pollutant removal only.

Infrastructure means facilities needed to sustain manufacturing, residential, commercial and all other land use activities. Infrastructure includes water lines, sewer lines, and other utilities, streets and roads, communications, and public facilities, such as fire stations, parks, schools, and other similar type uses.

iSWM TM means the Integrated Stormwater Management Design Manual TM as published by the North Central Texas Council of Governments and as modified and adopted by the City of Bastrop.

Land development activity means any construction related activity that results in the addition or replacement of impervious surfaces such as rooftops, roads, parking lots, and other structures. Measurement of areas impacted by land development activity includes areas that are part of a larger common plan of development or sale where multiple separate and distinct land disturbing construction activities may be taking place at different times on different schedules but under one plan.

Land disturbing construction activity means any man-made alteration of the land surface resulting in a change in the topography or existing vegetative or non-vegetative soil cover, that may result in runoff and lead to an increase in soil erosion and movement of sediment into waters of the state. Land disturbing construction activity includes clearing and grubbing, demolition, excavating, pit trench dewatering, filling and grading activities.

Land use plan means part of the comprehensive plan showing future land use.

Landscape plan means a plan showing the proposed landscape improvements to be made on a site.

Lot of Record means any unplatted tract of land whose boundaries have not been changed since April 20, 1981.

Low-Impact Development (LID) means an approach to land development or re-development that works with nature to manage stormwater as close to its source as possible.

Natural flow means the flow of water or drainage over land whose topography has not been altered.

Outfalls means the outlet of any stormwater conveyance system.

Owner means an entity holding fee title to the property and shall include any part owner, joint owner, tenant in common, tenant in partnership, joint tenant or tenant by the entirety of the whole or of a part of such building or land.

Pervious surface means an area that releases as runoff a small portion of the precipitation that falls on it. Lawns, gardens, parks, forests or other similar vegetated areas are examples of surfaces that typically are pervious.

Planning and Zoning Commission means the City of Bastrop Planning and Zoning Commission.

Plat means the map, drawing, chart, or plan showing the exact layout of a subdivision into lots, blocks, streets, parks, school sites, drainage ways, easements and/or any other element required by this chapter which a subdivider shall submit for approval in accordance with this chapter. It shall include plan, plat or replat, both singular and plural.

Policy means a statement or document which has been enacted by the governing body of the City that forms the basis for enacting legislation or making decisions.

Pre-development condition means the extent and distribution of land cover types present before the initiation of land disturbing construction activity; assuming that all land uses prior to development activity are managed in an environmentally sound manner.

Preliminary plat means a formal document showing the detailed concept of the subdivision, presented with the required accompanying material to the Planning and Zoning Commission for approval. The graphic expression of the proposed overall plan for subdividing, improving and developing a tract shown by superimposing a scale drawing of the proposed land division on a topographic map and showing existing and proposed drainage features and facilities, street layout and direction of curb flow, and other pertinent features with notations sufficient to substantially identify the general scope and detail of proposed development.

Public facilities mean any facilities authorized or franchised by the City for the public welfare, usually including public utilities, governmental buildings and public schools.

Public facilities system means the water, wastewater, roadway, drainage or parks facilities owned or operated by or on behalf of the City to provide services to the public, including existing and new developments and subdivisions.

Public improvements mean facilities such as streets or drainage systems which are dedicated for public use.

Public infrastructure improvement means a water, wastewater, roadway, drainage or park facility that is part of one or more of the City's public facilities systems.

Public open space easement means an easement that restricts construction or plantings so that open space and/or sight visibility is maintained.

Public utility and storm sewer easement means an easement upon a private street not having the same width as the lot which is intended to contain privately owned and maintained pavement as well as publicly owned and maintained water lines, sanitary sewer lines, storm sewers and such other utility or franchise infrastructure as can be reasonably accommodated.

Responsible Party means the owner or any entity holding fee title to the property, or an entity contracted to develop the property.

Retention pond means a pond or other impoundment designed to store stormwater runoff permanently.

Right-of-way means lands dedicated to the public for use as a street, alley or crosswalk.

Runoff means stormwater or precipitation including rain, snow or ice melt or similar water that moves on the land surface via sheet or channelized flow.

Site means the entire area included in the legal description of the land on which the land disturbing construction activity occurred.

Site Development Plan means a plan prepared by a licensed and registered professional land surveyor, and/or a licensed professional engineer that complies with the requirements of City of Bastrop Code of Ordinances Article V. Section 42.

Steep slope means areas that contain slopes over fifteen percent grade and are characterized by increased runoff and erosion hazards.

Stormwater and Stormwater runoff means rainfall runoff, snow melt runoff, and surface runoff and drainage.

Stormwater Management Plan means a comprehensive plan designed to reduce the discharge of runoff from hydrologic units on a regional or municipal scale.

Stormwater Maintenance Plan means the set of tasks that must be performed in order to operate and maintain a stormwater management facility.

Stormwater Maintenance Agreement

Stormwater Pollution Prevention Plan (SWPPP or SW3P) means the plan created by constructors to show their plans for sediment and erosion control. The SWPPP identifies all potential sources of pollution which may reasonably be expected to affect the quality of storm water discharges from the construction site.

Subdivision shall mean the division of any lot, tract or parcel of land into two or more parts to lay out a subdivision of the tract, including an addition to the City or its extraterritorial jurisdiction, to lay out suburban, building, or other lots, or to lay out streets, alleys, squares, parks, or other parts of the tract intended to be dedicated to public use or for the use of purchasers or owners of lots fronting on or adjacent to the streets, alleys, squares, parks, or other parts. A division of a tract under this subsection includes a division regardless of whether it is made by using metes and bounds descriptions in a deed of conveyance or in a contract for a deed, by using a contract of sale or other executory contract to convey, or by using any other method. Each subdivision shall be classified as a rural or standard subdivision. Subdivision includes resubdivision and one-lot plats.

Subdivider means the owner or his appointed representative(s) that proposes to subdivide a tract of land within the corporate City limits of [or] ETJ of the City of Bastrop.

Suburban Subdivision means a subdivision in which the minimum lot width is one hundred and twenty-five feet (125') and the minimum lot size is one (1) acre, if on-site sewer facilities are to be used on the lot; or the minimum lot size is 0.6 acres if the public sewer collection and treatment system serves the lot.

Thalweg means is the line of lowest elevation within a valley or watercourse.

TR-55 means the United States Department of Agriculture, Natural Resources Conservation Service (previously Soil Conservation Service), Urban Hydrology for Small Watersheds, Second Edition, Technical Release 55, June 1986.

Watercourse means a channel, with a well-defined bed and banks, in which water flows as a stream and has a permanent source of supply.

SECTION 2 STORMWATER DRAINAGE POLICY

SECTION 2 - STORMWATER DRAINAGE POLICY

A. Stormwater Drainage Design Goals and Objectives

Drainage shall be designed for two goals (streambank protection and flood mitigation), to be evaluated by three storm events for projects with more than 10,000 square feet of land disturbance or the net addition of 5,000 square feet of impervious surface, as shown in Table 2-1.

Table 2-1. Design Storm Events	
Storm Event Name	**Storm Event Description**
"Streambank Protection"	2-year, 24-hour storm event
"Conveyance"	25-year, 24-hour storm event
"Flood Mitigation"	100-year, 24-hour storm event

1. Streambank Protection: Increased peak flows from urban runoff can increase erosion from more frequent bank full flows. Streambank protection can be provided by minimizing increases of the 2-year, 24-hour storm event by reducing the controlled release of water of the 2-year, 24-hour storm over 24 hours from the site. Reinforcing or stabilizing streambanks downstream may also be used in limited circumstances. A downstream assessment will be required.

2. Flood Mitigation and Conveyance: To protect citizens and property from flooding, increases in the 100-year, 24-hour storm event must be controlled. Flood mitigation can be met by limiting discharges from the site to no more than under pre-development conditions, or by providing adequate conveyance of the 100-year flows downstream of the site. A downstream assessment will be required. Protection during the Conveyance storm event (25-year, 24-hour storm) is designed to minimize localized flooding of streets, sidewalks and property. As stated in Section 1.B.4 of this document, development within the Gills Branch Watershed shall be required to limit post-developed 100-year, 24-hour design storm peak runoff discharges to not exceed pre-developed 25-year, 24-hour design storm peak runoff discharges.

B. Stormwater Drainage Design Process

1. Preliminary Conference and Conceptual Plan Review.

   a. Preliminary Conference, also known as a "Pre-Submittal Meeting" or "Pre-Submittal Meeting for Subdivision". Refer to Code of Ordinances, Chapter 10 – Subdivision Ordinance, Section 5.02.01 Development Process. As a part of the Enhanced Permit Review Process, applicants shall consult with and present a proposed plan (conceptual plan) to the Development Review Committee (DRC)

members as required for comments and guidance of the procedures, specifications, and standards for permits required by the following sections of the Code of Ordinances:
§3.16.001: Permits for moving of structures, demolition, and site work
§3.18.002: Permits for construction, alteration or extension; construction or occupancy of permanent structures.
§3.20.051: Permit to erect or install a sign

b. Before submitting the regulating and conceptual site drainage plan, the Applicant should discuss with the planning staff and City Engineer the procedure set for the adoption of a subdivision plat and the requirements of the "Design Standards," the iSWM TM Design Manual and of any pertinent City ordinances. Planning staff and City Engineer shall also advise the Applicant of existing conditions which may affect the proposed subdivision, such as existing or proposed streets, adjacent subdivisions or properties, floodplain and drainage, sewage, fire protection, reservation of land, and similar matters, referring the Applicant to the proper agencies if services are not provided by the City.

c. Concept Plan Review. Concept plan review will normally be accomplished by submission of supporting plan material and a conference with the Director of Planning and Development.

   (1) Three (3) copies of the Conceptual Plan.

   (2) Two (2) copies of the Site Analysis and Conceptual Site Drainage Plan, in accordance with the requirements described below.

2. Site Analysis: Using field and mapping techniques approved by the City Engineer, the developer's engineer shall collect and review information on the existing site conditions and map the following features:

   a. Topography
   b. Drainage patterns and basins
   c. Intermittent and perennial streams on-site and off-site that contribute to or receive water from the site
   d. Soil types and their susceptibility to erosion
   e. Property lines, adjacent areas and easements
   f. Wetlands and critical habitat areas
   g. Boundaries of wooded areas and tree clusters (tree survey)
   h. Existing FEMA (or best available data) floodplain and floodway boundaries and base flood elevations
   i. Ground cover and vegetation, particularly unique or sensitive vegetation areas to be protected during development
   j. Existing development
   k. Existing stormwater facilities on-site and off-site that will receive discharges from the proposed development
   l. Steep slopes

m. Required buffers and setbacks along waterbodies
n. Proposed stream crossing locations

3. Conceptual Drainage Plans

Based on the Site Analysis, the design engineer shall prepare a Conceptual Drainage Plan for the proposed site layout to give the developer and the City Planning and Engineering staff an initial look at the project as a part of a mandatory Pre-Development meeting. This plan will be submitted along with the Concept Plan. A copy of the Concept Drainage Plan submittal checklist is included in Appendix A. The Design engineer should typically follow the following steps:

a. Use applicable LID techniques to develop the site layout, including:
   (1) Preserving the natural feature conservation areas defined in the site analysis
      (a) Preserve undisturbed natural areas
      (b) Preserve riparian buffers
      (c) Avoid floodplains
      (d) Avoid steep slopes
      (e) Minimize siting on porous or erodible soils
   (2) Use lower impact site design techniques
      (a) Fit design to the terrain
      (b) Locate development in less sensitive areas
      (c) Reduce limits of clearing and grading
      (d) Use open space development
      (e) Consider creative designs
   (3) Reducing impervious surface areas
      (a) Reduce roadway lengths and widths
      (b) Reduce building footprints
      (c) Reduce the parking footprint
      (d) Use fewer or alternative cul-de-sacs
      (e) Create parking lot stormwater "islands"
   (4) Preserving and using the natural drainage system wherever possible
      (a) Use buffers and undisturbed areas
      (b) Use natural drainage ways instead of storm sewers
      (c) Use vegetated swale instead of curb and gutter
      (d) Drain rooftop runoff to pervious areas

While implementation of LID techniques is not mandated, the developer is strongly encouraged to consider the above-referenced LID techniques.

b. Calculate conceptual estimates for the design requirements for the 2-year 24-hour storm volume, 25-year 24-hour storm volume and 100-year, 24-hour storm volume events.
c. Determine any appropriate temporary and permanent structural stormwater controls and identify potential locations on the site.

4. Preliminary Drainage Plans

This step builds on the data developed and LID standards provided in the Conceptual

Drainage Plan by ensuring that requirements and criteria are met, opportunities have been taken to minimize adverse effects of the development and providing more detail. The Preliminary Drainage Plan will be submitted in compliance with Article 10.03 Subdivision Ordinance, Section 4 Platting Procedure, 4.10.6.a. Preliminary Plat, and shall consist of maps, plan sheets, narrative and supporting design calculations (hydrologic and hydraulic) for the proposed stormwater system. A copy of the Preliminary Drainage Plan submittal checklist is included within Appendix B.

5. Final Drainage Plans

This step builds on the data developed and LID standards provided in the Preliminary Drainage Plan. The Final Drainage Plan and Construction Plans shall be submitted to and approved by the City Engineer prior to submitting a Public Improvement Plan and a Site Development Plan in accordance with Code of Ordinances, Chapter 14 Sec. 42 and Chapter 10, Section 5.05 – Public Improvement Plan Requirements. A final drainage plan is also required for a Minor Plat. A copy of the Final Drainage Plan submittal checklist is included within Appendix C.

6. Operations and Maintenance Plan

An Operations and Maintenance Plan shall be submitted along with the Final Drainage Plans to clearly state which entity has responsibility for the operation and maintenance of temporary and permanent stormwater controls and drainage facilities to ensure that they will function in the future. The O&M plan shall include, but not be limited to:

a. Responsible party for all facilities and tasks in the plan
b. Inspection and maintenance requirements
c. Maintenance of permanent stormwater controls and drainage facilities during construction
d. Cleaning and repair of permanent stormwater controls and drainage facilities before transfer of ownership
e. Frequency of inspections for the life of the permanent facility
f. Funding source for long-term maintenance
g. Description of maintenance tasks and frequency
h. Access and safety issues
i. Maintenance easements
j. Any required maintenance agreements, reviewed and approved by the City (sample stormwater maintenance agreement provided as Appendix G)
k. Testing and disposal of sediments
l. Projected lifespan of structures and required replacement intervals and cost

C. Stormwater Drainage Design Criteria

1. Hydrologic Methods: For general guidance on drainage calculations, the design engineer shall use the Integrated Stormwater Manual, Hydrology Technical Manual (http://iswm.nctcog.org/technical-manual.html). The design engineer may use any of the empirical hydrologic methods shown in Table 2-2, subject to the limitations indicated.

2. Hydrologic design procedures shall conform to the following methods where appropriate and shall assume a fully developed watershed upstream of the proposed development. It may be assumed that the undeveloped area will be developed under the same regulations.

a. "Computer Program for Project Formulation-Hydrology" distributed by SCS through Technical Release No. 20 (SCS-TR-20).

b. Hydraulic Engineering Center, Hydrologic Modeling System, U.S. Army Corp of Engineers (HEC-HMS).

c. Other stormwater modeling programs capable of developing and routing hydrographs, subject to approval by the City Engineer.

3. Rainfall Estimation

Rainfall estimates should be based on published values in the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 11: Precipitation-Frequency Atlas of the United States. Rainfall intensity shall be computed using the following Intensity-Duration-Frequency (IDF) equation and coefficients.

$$i = b/(t + d)^e$$

where:

i = rainfall intensity (inches per hour)

t = rainfall duration (minutes) or time of concentration

b, d and e = parameters found in Table 2-3

Rainfall intensities for Bastrop Depth-Duration-Frequency (DDF) values are provided in Table 2-4.

Time of concentration can be calculated by the nomograph or the equation in the iSWM Technical Manual but must remain within the ranges in Table 2-5.

4. Rational Method: For sizing of stormwater conveyance systems with drainage areas less than 100 acres and situations where reflecting storage volume routing effects is not necessary, the Rational Method is acceptable. To determine the runoff rates for the various areas, the standard rational method may be used. The Rational Formula is expressed as follows:

$$Q = CIA$$

where:

Q = maximum rate of runoff (cfs)

C = runoff coefficient representing a ratio of runoff to rainfall

I = average rainfall intensity for a duration equal to the t_C (in/hr)

A = drainage area contributing to the design location (acres)

Table 2-2. Constraints on Using Recommended Hydrologic Methods

Method	Size Limitations[1]	Comments
Rational	0 – 100 acres	Method can be used for estimating peak flows and the design of small site or subdivision storm sewer systems.
Modified Rational[2]	0 – 200 acres	Method can be used for estimating preliminary runoff volumes for storage design. Final storage sizing and design shall use Unit Hydrograph (SCS) Method.
Unit Hydrograph (SCS)[3]	Any Size	Method can be used for estimating peak flows and hydrographs for all design applications. Required for sizing of conveyance measures draining greater than 100 acres.
TXDOT Regression Equations	10 to 100 Sq. Miles	Method can be used for estimating peak flows for rural conveyance design applications.
USGS Regression Equations	3 to 40 Sq. Miles	Method can be used for estimating peak flows for urban conveyance design applications.

[1] Size limitation refers to the drainage basin for the stormwater management facility (e.g., culvert, inlet).
[2] Where the Modified Rational Method is used for conceptualizing, the engineer is cautioned that the method could underestimate the storage volume.
[3] This refers to SCS routing methodology included in many readily available programs (such as HEC-HMS) that utilize this methodology.

Table 2-3. IDF Coefficients for Bastrop

	2 year	5 year	10 year	25 year	50 year	100 year
e	0.841	0.814	0.805	0.793	0.786	0.784
b	67	77	87	100	113	130
d	13.3	11.5	11.1	10.8	10.8	11.3

Source: TxDOT, 2015. New Rainfall Coefficients, Research Report 0-6824

Table 2-4. Rainfall Depth (in inches) for Bastrop by Duration and Recurrence Frequency

Tc(min)	2-year	5-year	10-year	25-year	50-year	100-year
10	0.86	1.07	1.24	1.48	1.67	1.85
15	1.08	1.34	1.56	1.85	2.07	2.30
30	1.53	1.89	2.19	2.59	2.89	3.20
60	2.00	2.50	2.90	3.46	3.87	4.30
120	2.47	3.14	3.71	4.52	5.15	5.83
180	2.74	3.53	4.22	5.22	6.03	6.90
360	3.22	4.20	5.10	6.43	7.54	8.78
720	3.68	4.84	5.94	7.60	9.02	10.60
1440	4.17	5.51	6.81	8.81	10.50	12.60

Design storm depth for given Annual Recurrence Interval in inches. 60 min. = 1 hr.; 120 min. = 2 hrs.; 180 min. = 3 hrs.; 360 min. = 6 hrs.; 720 min. = 12 hrs.;1440 min. = 24 hrs.]
Source: NOAA Atlas 14, Vol. 11, Ver. 2, Location: Lat.: 30.1102 deg., Long.: -97.3187 deg.

Table 2-5 Time of Concentration Ranges

Table 2-5. Time of Concentration Ranges		
Land Use	**Minimum (minutes)**	**Maximum (minutes)**
Residential Development	10	30
Commercial and Industrial	10	25
Central Business District	10	15

Source: iSWM Technical Manual, NCTCOG, Sept. 2014

Runoff coefficients in Table 2-6 must be used, unless otherwise authorized by the City Engineer.

The coefficients given in Table 2-6 are applicable for storms with return periods less than or equal to 10 years. Less frequent, higher intensity storms may require modification of the coefficient because infiltration and other losses have a proportionally smaller effect on runoff (Wright-McLaughlin Engineers, 1969). The adjustment of the Rational Method for use with major storms can be made by multiplying the right side of the Rational Formula by a frequency factor Cf. The modified Rational Formula now becomes:

$$Q = C_f CIA$$

Table 2-6. Recommended Runoff Coefficient Values

Description of Area	Runoff Coefficients (C)
Lawns:	
Sandy soil, flat, 2%	0.10
Sandy soil, average, 2 - 7%	0.15
Sandy soil, steep, > 7%	0.20
Clay soil, flat, 2%	0.17
Clay soil, average, 2 - 7%	0.22
Clay soil, steep, > 7%	0.35
Agricultural	0.30
Forest	0.15
Streams, Lakes, Water Surfaces	1.00
Business:	
Downtown areas	0.95
Neighborhood areas	0.70
Residential:	
Single Family (1/8 acre lots)	0.65
Single Family (1/4 acre lots)	0.60
Single Family (1/2 acre lots)	0.55
Single Family (1+ acre lots)	0.45
Multi-Family Units, (Light)	0.65
Multi-Family, (Heavy)	0.85
Commercial/Industrial:	
Light areas	0.70
Heavy areas	0.80
Parks, cemeteries	0.25
Playgrounds	0.35
Railroad yard areas	0.40
Streets:	
Asphalt and Concrete	0.95
Brick	0.85
Drives, walks, and roofs	0.95
Gravel areas	0.50
Graded or no plant cover:	
Sandy soil, flat, 0 - 5%	0.30
Sandy soil, flat, 5 - 10%	0.40
Clayey soil, flat, 0 - 5%	0.50
Clayey soil, average, 5 - 10%	0.60

Source: iSWM Technical Manual, NCTCOG, Sept. 2014

Table 2-7. Frequency Factors for Rational Formula

Recurrence Interval (years)	C_f
10 or less	1.0
25	1.1
50	1.2
100	1.25

Source: iSWM Technical Manual, NCTCOG, Sept. 2014

The C_f values that can be used are listed in Table 2-7. The product of C_f times C shall not exceed 1.0.

5. Unit Hydrograph Methods:

   The National Resources Conservation Service (formerly the U.S. Soil Conservation Service) unit hydrograph methods are acceptable for any size drainage area and are required for design of stormwater conveyance measures that have drainage areas larger than 100 acres. Unit hydrograph methods shall be used for design of all stormwater storage measures (detention basins). The Engineer can propose to use other hydrologic methods but must have their use approved by the City Engineer. Details of the methodology can be found in the Natural Resources Conservation Service's *National Engineering Handbook Hydrology Chapters* or in the iSWM Technical Manual.

   Detention ponds shall be designed using SCS unit hydrograph methods. The engineer can propose to use other hydrologic methods but must have their use approved by the City Engineer.

   When unit hydrograph methods for computing runoff are proposed, the following NOAA Atlas 14 rainfall depths shall be used, applying the appropriate NOAA Atlas 14 temporal rainfall distributions provided in Table 2-8 below.

Table 2-8. NOAA Atlas 14 Rainfall Depths

Design Storm	2-year	5-year	10-year	25-year	50-year	100-year	500-year
24-hour depth (in)	4.17	5.51	6.81	8.81	10.50	12.60	18.50

Source: NOAA Atlas 14, Vol. 11, Ver. 2, Location: Lat.: 30.1102 deg., Long.: -97.3187 deg.

The appropriate hydrologic soil group must be obtained from the SCS Soil Survey for Bastrop County for the soils that comprise the watershed. Runoff Curve Numbers can then be obtained from Table 2-9.

When a drainage area has more than one land use, a composite curve number can be calculated and used in the analysis. It should be noted that when composite curve numbers are used, the analysis does not account for the location of the specific land uses but sees the drainage area as a uniform land use represented by the composite curve number.

Table 2-9. Runoff Curve Numbers[1]

Cover Description		**Curve numbers for hydrologic soil groups**			
Cover type and hydrologic condition	*Average percent impervious area[2]*	**A**	**B**	**C**	**D**
Cultivated Land:					
Without conservation treatment		72	81	88	91
With conservation treatment		62	71	78	81
Pasture or range land:					
Poor condition		68	79	86	89
Good condition		39	61	74	80
Meadow:					
Good condition		30	58	71	78
Wood or forest land:					
Thin stand, poor cover		45	66	77	83
Good cover		25	55	70	77
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved; curbs and storm drains (excluding right-of-way)		98	98	98	98
Paved; open swales (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Urban districts:					
Commercial and business	85%	89	92	94	95
Industrial	72%	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town house)	65%	77	85	90	92
1/4 acre	38%	61	75	83	87
1/3 acre	30%	57	72	81	86
1/2 acre	25%	54	70	80	85
1 acre	20%	51	68	79	84
2 acres	12%	46	65	77	82
Developing urban areas and newly graded areas (previous areas only, no vegetation)		77	86	91	94

[1] Average runoff condition, and $I_a = 0.2S$

[2] The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. If the impervious area is not connected, the SCS method has an adjustment to reduce the effect.

[3] CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space cover type.

Source: United States Department of Agriculture, Natural Resources Conservation Service (previously Soil Conservation Service), Urban Hydrology for Small Watersheds, Second Edition, Technical Release 55, June 1986.

SECTION 3 STORMWATER DRAINAGE PRACTICES

SECTION 3 - STORMWATER DRAINAGE PRACTICES

A. Downstream Assessments

In evaluating controls for streambank protection and flood mitigation, the downstream effects of the development must be evaluated. The assessment shall extend from the outfall of the proposed development to a point downstream where the discharge no longer has a significant impact on the receiving stream or storm drain system, known as the zone of influence. Generally, the zone of influence is the stream length between the outfall and a point where the drainage area controlled by the detention or storage facility comprises ten percent (10%) of the total drainage area. The downstream assessment should include:

1. Hydrologic analysis of the pre- and post-development on-site conditions
2. Drainage path which defines the extent of the analysis
3. Capacity analysis of all existing constraint points along the drainage path
4. Off-site undeveloped areas are considered as "full build-out" for both the pre- and post-development analyses
5. Evaluation of peak discharges and velocities for the following design storm events:
    a. Streambank protection storm (2-year, 24-hour storm)
    b. Conveyance storm (25-year, 24-hour storm)
    c. Flood mitigation storm (100-year, 24-hour storm)
6. Assessment of whether the post-development discharges are greater than the predevelopment discharges, whether the post-development velocities are greater than the predevelopment velocities, and whether the post-development velocities are greater than the allowed velocities for the receiving system.

    After starting with a simple drainage area analysis using a topographic map, the zone of influence may need to be adjusted after running the pre- and post-development peak flows and velocities.

    If it is shown that no peak flow increases occur downstream, and post-development velocities are acceptable, then control of the flood mitigation storm volume may be waived by the City Engineer. If peak discharges are increased by development, then an on-site structural stormwater control facility must be designed such that the post-development flows do not increase the peak flows, and the velocities are not erosive.

    Note that for all land development occurring within the Gills Branch Watershed, post-developed peak runoff discharges for a 100-year, 24-hour design storm shall not exceed the pre-developed peak runoff discharges for a 25-year, 24-hour design storm.

    Where it is anticipated that additional runoff incidental to the development of the subdivision will overload an existing downstream drainage facility, whether natural or manmade, the Planning and Zoning Commission may withhold approval of the subdivision until appropriate provisions have been made to accommodate the problem, and plans shall be provided which include all necessary off-site improvements including storm sewer systems, channel grading, driveway adjustments, culvert improvements, etc.

In areas where downstream pipes or channels are inadequate to handle proposed increased flows, the City, as one alternative, may consider accepting cash payment in lieu of actual drainage improvements. The developer must show that the proposed pipe system to handle the flow from their development would not function properly without substantial downstream improvements. Prior to permitting any development that will significantly increase flood heights downstream or upstream, a hearing before the Planning and Zoning Commission is required with special notice to the adjacent property owners.

B. Streambank Protection

If the downstream assessment shows that the proposed project does not exceed acceptable downstream velocity or the downstream conditions are improved to adequately handle the increased velocity, then no additional streambank protection is required. If velocities exceed the allowable velocities, then one or more of the following options are required:

1. Reinforce or stabilize downstream conditions using stone riprap, gabions, and/or bioengineered methods. Additional easements downstream may be required and conformance with Corps of Engineers permits is required.
2. Install Stormwater Controls to maintain existing Downstream Conditions to reduce post-development discharges at or below allowable velocity limits.
3. Control the release of the 2-year, 24-hour storm to provide 24-hours of extended detention.

C. Flood Mitigation

When the downstream assessment shows an increase in peak flood discharges, the developer must address downstream flood mitigation using one of the following three options:

1. Provide adequate downstream conveyance systems.
2. Install stormwater controls to maintain existing downstream conditions by providing detention designed and constructed so that there is no increase in downstream peak discharges or water surface elevations resulting from the development.
3. In lieu of a downstream assessment, maintain existing on-site runoff conditions by providing detention that limits runoff from the development site to pre-development conditions. For many developments, the results of a downstream assessment may show that significantly less flood mitigation is required, as well as reducing the potential of exacerbating downstream flooding resulting from the timing of flood

peaks. The developer must confirm that providing detention does not exacerbate peak flows in downstream reaches.

SECTION 4 STORMWATER FACILITY DESIGN STANDARDS

SECTION 4 - STORMWATER FACILITY DESIGN STANDARDS

A. General

1. Drainage facilities shall be provided and constructed as specified by the City Engineer. Hydraulic design procedures shall conform to the following methods where appropriate. The methodology selected is a function of the complexity of the hydraulic design and may use the following methods (or others if approved by the City Engineer).

   a. United States Department of Agriculture, Natural Resources Conservation Service (previously Soil Conservation Service), Urban Hydrology for Small Watersheds, Second Edition, Technical Release 55, June 1986 (hereinafter referred to as T.R. 55).

   b. Hydraulic Design Manual (HDM) prepared and compiled by the Texas Department of Transportation Bridge Division.

   c. Integrated Stormwater Manual, Hydraulics Technical Manual (http://iswm.nctcog.org/technical-manual.html).

   d. Manning's Equation for computing normal depths for flows confined to uniform cross-sections with free surface flow.

   e. The Hydraulic Gradient Method shall be used for closed conduit systems flowing full.

   f. The HEC-RAS, Flood Plain Hydraulics, developed by the U.S. Army Corps of Engineers will be used for non-uniform channel design or analysis and back water surface profiles.

   Notwithstanding, all designs shall be in accordance with good engineering practices and are not to be limited to minimum criteria when it is deemed necessary for the welfare or safety of the public to implement more stringent requirements or criteria.

2. Approval of necessary storm drain facilities and construction requirements shall be the responsibility of the City Engineer. Where there is a question as to the justification of the size of the facility required, the question will be resolved in favor of additional drainage capacity.

3. All drainage structures shall be designed to convey the design storms specified and in such a manner that no ponding, pooling, erosion, sedimentation or other adverse condition would be created.

4. All storm sewers, inlets, head walls and manholes in the drainage system shall be designed and built in accordance with the current City of Bastrop Construction Standards Manual.

5. All drainage facilities shall be constructed on public right-of-way or easements dedicated for this purpose. Drainage easements shall be of a sufficient size to

permit access for maintenance of the drainage facility. The easement shall be designed to facilitate maintenance access to the drainage channel by City crews and equipment. Additional easements shall be required at any access points and the access points shall be designed to restrict access by unauthorized personnel. An access point will typically be required at every intersection of the drainage easement with street right-of-way.

6. When a drainage channel or storm drain pipe, culvert or bridge is proposed, calculations shall be submitted showing the basis for the design and completed plans, profiles and specifications shall be submitted, showing complete construction details and a detailed cost estimate.

7. All drainage improvements shall be designed to an acceptable outfall as approved by the City Engineer.

8. Off-Site Drainage.

   a. Adequate consideration shall be given by the Responsible Party in the development of property to determine how the discharge leaving the proposed development will affect adjacent property.

   b. On lots or tracts of three acres or more where stormwater runoff has been collected or concentrated, it shall not be permitted to drain onto adjacent property except in existing creeks, channels or storm sewers unless proper drainage easements or notarized letters of permission from the affected property owners are provided. Such letters of permission shall be recorded in the property records of Bastrop County.

B. <u>Streets and Roads</u>

Streets may be used for conveyance of surface runoff within the following standards:

1. Streets and Right-of-Way: Depth in the street shall not exceed top of curb or maximum flow spread limits for the conveyance storm (25-year storm), or no more than 6 inches of depth at the edge of pavement. The flood mitigation storm (100-year storm) shall be contained within the rights-of-way or drainage easements.

2. Flow Spread Limits: Inlets shall be spaced so that the spread of flow in the street for the conveyance storm (25-year) shall not exceed the guidelines listed in Table 4-1, as measured from the gutter or face of the curb.

Table 4-1. Flow Spread Limits

Street Classification	**Allowable Encroachment**
Collectors, Arterial, and Thoroughfares (greater than 2-lanes)	• 8 feet or one travel lane, both sides for a divided roadway
Local Residential Streets	• Curb depth or maximum 6 inches at gutter while keeping one 11-foot travel lane open

3. Where inlets are required, inlets shall be spaced so that the maximum travel distance of water in a gutter will not exceed six hundred (600) feet. On-grade inlets will be sized using an allowable capacity of one (1) cubic foot per second of opening for a throat height of five (5) inches. Design of inlets shall conform to the City of Bastrop Construction Standards Manual.
4. Parking Lots: Parking lots shall be designed for the conveyance storm (25-year) not to exceed the top of the curb with maximum ponding at low points of six (6) inches and one (1) foot for the 25- and 100-year storm event, respectively. The flood mitigation storm (100-year) shall also be contained on-site or within dedicated easements.
5. Roadside Swales & Driveway Culverts
    a. Roadside drainage swales shall conform to the following:
        (1) Minimum grade - 0.5%
        (2) Maximum grade in sandy soils - 5%
        (3) Maximum grade in clay soils - 8%
        (4) All open swales, channels, bar ditches or other drainage ways shall have a minimum velocity of two feet per second.
        (5) Maximum velocities:
            (a) coarse sand - 4 feet per second
            (b) fine gravel - 6 feet per second
            (c) sandy silt - 2 feet per second
            (d) clay - 3.5 feet per second
            (e) grass-lined sandy silt - 6 feet per second
            (f) silt clay - 8 feet per second
            (g) poor rock (usually sedimentary) - 10 feet per second
            (h) soft sandstone - 8 feet per second
            (i) soft shale - 3.5 feet per second
            (j) good rock (usually igneous or hard metamorphic) - 12 feet per second
            (k) reinforced concrete lining - 15 feet per second
    b. Rock or riprap retards shall be used to control the erosive characteristics of drainage in roadside swales on steep slopes. Retards shall be designed to reduce drainage water velocity to an acceptable level and to prevent drainage water from encroaching on the driving surface. Retards shall not project onto shoulder surfaces and shall blend into ditch lines so that

normal roadside ditch maintenance is possible.

c. Roadside swales shall be designed to carry the 25-year event, provided that the 100-year event is maintained in the right-of-way or an easement and that 100-year storm flood depths do not exceed one foot within any portion of the roadway. Roadside swales (bar ditches) shall have a maximum front slope of 6:1 (horizontal: vertical). The maximum back-slope shall be 4:1 (horizontal: vertical). Exceptions to the slopes may be made by the City's Engineer for unusual circumstances, provided slopes are adequate for maintenance, soil stability and traffic safety.

d. The design engineer shall calculate the culvert sizes for every lot within the subdivision and provide a table identifying each lot, culvert size and elevations.

e. The length of culvert pipe, where used, shall be sufficient to allow for driveway base width (including radius as applicable) plus three times the pipe diameter plus three feet (3'), but in any case, no less than twenty feet (20'). All driveway culvert ends shall be constructed with safety end treatments.

f. Headwalls, catch basins or other culvert structures shall be designed in accordance with the drainage requirements of these specifications and the Typical Construction Details of the Texas Department of Transportation or these specifications whichever is applicable. No headwall, wingwall or other structural member shall protrude above the surface of the traveled roadway. Flush headwalls at three to one (3:1) maximum or flatter slopes are preferred for any culverts parallel to streets (driveways, etc.).

g. All special designs of roadside ditches, retaining walls, etc., requires the specific approval of the City.

h. All grass-lined drainage systems, including bar ditches shall be seeded per TxDOT right-of-way vegetation standards Item 164, and the developer shall make provisions to establish vegetation per Stormwater Pollution Prevention Plan.

6. Drainage at Drive Approaches

a. Conveyance - Driveway installations requiring conveyance for storm drainage in roadside ditches shall be sized to provide adequate capacity to pass the 25-year storm event.

b. Dip-Type Driveways - Properly designed and installed dip-type driveway installations function better to pass roadside drainage with minimum scour damage to driveway and/or road shoulders or surface and are preferred where terrain will allow economical installation. Standard details are provided in the City of Bastrop’s Construction Standards Manual for both concrete and asphalt surfaces. Installation of dip- type driveways approved under these standards for subdivision development shall be the responsibility of the Developer. If the Developer does not wish to construct these driveways at the time the roadways and other improvements are constructed or prior to the sale of lots, he must provide a cash bond or performance bond in the amount of the driveway construction cost to the City prior to approval of other subdivision improvements. Dip-type driveways may be allowed provided the design event flow can be accommodated. Dip-type driveways shall be constructed of six-inch concrete paving from the edge of pavement to the property line. Such driveways shall not exceed a slope of 0.5 feet over a distance of 10 feet.

c. Culvert Pipe Driveway Installations - Installation of culvert pipe driveway entrances for subdivision development approved under these standards shall be the responsibility of the Developer. If the Developer does not wish to construct these driveways at the time the roadways and other improvements are constructed, he must provide a cash bond or performance bond to the City and/or County in the amount of the driveway construction cost prior to approval of other subdivision improvements.

(1) Culvert Pipe Length - The length of culvert pipe, where used, be sufficient to allow for driveway base width (including radius as applicable) plus three times the pipe diameter plus three feet (3'), but in any case, no less than twenty feet (20').

C. Storm Sewers

1. All storm sewers, inlets, manholes or junctions shall be designed in accordance with the Texas Department of Transportation hydraulic criteria. However, as stated in 2a. below, the hydraulic grade line (HGL) for the design storm event will be allowed to operate under pressure flow conditions.

2. Design Frequency

   a. Pipe Design: The conveyance storm (25-year) event within pipe with hydraulic grade line (HGL) below throat of inlets. In no case shall the system surcharge back through an inlet or inlets.

   b. Right-of-way and Easements: The flood mitigation storm (100-year) event must be contained within the right-of-way or easement.

3. Design Criteria

   a. For ordinary conditions, storm drain pipes shall be sized on the assumption that they will flow full or practically full under the design discharge but will not be placed under pressure head. Capacity of storm sewers shall be determined by using Manning's formula based on hydraulic gradients rather than physical slope of the pipe.

   b. The maximum hydraulic gradient shall not produce a velocity that exceeds

15 feet per second (fps). Table 4-2 shows the desirable velocities for most storm drainage designs. Storm drains shall be designed to have a minimum mean velocity flowing full at 2.5 fps.

Table 4-2. Desirable Velocity in Storm Drains

Description	Maximum Desirable Velocity (feet per second)
Culverts (All types)	15
Storm Drains (Inlet laterals)	No Limit
Storm Drains (Collectors)	15
Storm Drains (Mains)	15

c. The minimum desirable physical slope shall be that which provides a minimum velocity of 2.5 feet per second.

d. If the hydraulic grade line elevation is less than one foot below ground elevation or gutter line for the design flow, adjustments are needed in the system to reduce the elevation of the hydraulic grade line.

e. Manholes: Manholes (inlets and junction boxes) shall be provided at all changes in grade or alignment of sewer intersections, and at a maximum of one thousand (1,000) feet on straight lines. Alternatives to providing manholes at changes in grade and alignment may include providing precast reinforced concrete pipe joints and bends. Design of manholes shall conform to the current City of Bastrop Construction Standards Manual. Access manholes are required at intermediate points along straight runs of closed conduits. Table 4-3 gives the maximum spacing criteria.

Table 4-3. Access Manhole Spacing Criteria
(HEC 22, 2001)

Pipe Size (inches)	Maximum Spacing (feet)
12-24	300
27-36	400
42-54	500
60 and up	600

f. Pipe: Pipe for storm drains located within the public right-of-way shall be reinforced concrete pipe in sizes as shown on the approved plans. The minimum size of the storm sewer shall be eighteen (18) inches and shall be reinforced concrete pipe minimum ASTM C76, Class III. Where, in the opinion of the City Engineer, added strength of pipe is needed for traffic loads over minimum cover or for excessive height of backfill, concrete pipe shall be ASTM C14 Extra Strength or ASTM C76, Class IV or Class V. Pipe shall have a minimum cover of not less than one (1) foot over the top of the pipe. Storm sewers will be required where subsurface conditions indicate a potential for seepage or underground flow as determined by the City Engineer. Alternate pipe materials may be used for areas located on private lands or within the public right-of-way where the City Engineer determines they meet an equivalent or better performance criteria.

g. The developer may install an approved open channel in lieu of installing pipe larger than sixty (60) inches. This open channel shall be at the rear of residential lots and shall be adequately armored with a material approved by the City (e.g., concrete, rock gabions, etc.). In the event it is necessary to locate the drainage facility adjacent to and parallel to a street, it shall be a closed conduit even though pipe sizes larger than sixty inches are required.

h. Outfalls: Whenever possible, outfalls from storm sewers and swales into natural drainage ways shall enter at the grade of the natural drainage channel. The engineer will design drop-type outfall structures, or otherwise provide adequate protection against erosion.

D. <u>Bridges and Culverts</u>

1. For this Section, bridges are defined as cross drainage facilities with a span of 20 feet or larger.

2. Design of culvert and bridge structures shall conform to the TxDOT Standard Specifications for Construction of Highways, Streets and Bridges, latest revision. Culvert and bridge design loading and widths for roads and streets shall conform to the TxDOT standards. Bridge widths shall conform to Design Standards for Farm to Market Roads, secondary roads division, TxDOT, or as directed by the City. Structures of this nature require the specific approval of the City. All street and road culverts shall be constructed of reinforced concrete box culverts or reinforced concrete pipe culverts.

3. Design Frequency for Bridges:

   a. Flood mitigation storm (100-year) for all bridges.

4. Design Criteria for Bridges

   a. Freeboard considerations outlined in Chapter 9 of the TxDOT Hydraulic Design Manual should be followed.

   b. The contraction and expansion of water through the bridge opening creates hydraulic losses. These losses are accounted for by using loss coefficients. Table 4-4 gives recommended values for the Contraction (K_c) and Expansion (K_e) Coefficients.

5. For this Section, culverts are cross drainage facilities that transport runoff under

roadways or other improved areas.

6. Culvert hydraulics shall be analyzed using Federal Highway Administration (FHWA) Hydraulic Design Series Number 5 (HDS-5) HYDRAULIC DESIGN OF HIGHWAY CULVERTS methods.

7. Box culverts shall conform to TxDOT design standards and details.

Table 4-4. Recommended Loss Coefficients for Bridges

Transition Type	Contraction (K_c)	Expansion (K_e)
No losses computed	0.0	0.0
Gradual transition	0.1	0.3
Typical bridge	0.3	0.5
Severe transition	0.6	0.8

Source: TxDOT Hydraulic Design Manual, July 2016

8. Design Frequency for Culverts
   a. Culverts shall be designed for the flood mitigation storm (100-year) or in accordance with TxDOT requirements, whichever is more stringent. Consideration when designing culverts includes: roadway type, tailwater or depth of flow, structures, and property subject to flooding, emergency access, and road replacement costs. Culverts must convey the Conveyance Storm (25-year), and the headwater surface elevation shall not exceed the minimum road surface elevation. The headwater depth for a 100-year frequency storm shall not exceed one foot (1') over the minimum roadway surface elevation.
   b. The flood mitigation storm (100-year) shall be routed through all culverts to be sure building structures (e.g., houses, commercial buildings) are not flooded or increased damage does not occur to the highway or adjacent property for this design event.

9. Design Criteria for Culverts

   a. Velocity Limitations

      (1) The maximum velocity shall be consistent with channel stability requirements at the culvert outlet.

      (2) The maximum allowable velocity for corrugated metal pipe is 15 feet per second. There is no specified maximum allowable velocity for reinforced concrete pipe, but outlet protection shall be provided where discharge velocities will cause erosion conditions.

      (3) To ensure self-cleaning during partial depth flow, a minimum

velocity of 2.5 feet per second is required for the streambank protection storm when the culvert is flowing partially full.

b. Length and Slope

(1) The maximum slope using concrete pipe is ten percent (10%) and for corrugated metal pipe is fourteen percent (14%) before pipe-restraining methods must be taken.

(2) Maximum vertical distance from throat of intake to flow line in a drainage structure is 10 feet (10').

(3) Drops greater than four feet (4') will require additional structural design.

c. Headwater Limitations: The allowable headwater is the depth of water that can be ponded at the upstream end of the culvert during the design flood, which will be limited by one or more of the following constraints or conditions:

(1) Headwater will be non-damaging to upstream property.

(2) Culvert headwater plus twelve inches (12") of freeboard shall not exceed top of curb or pavement for low point of road over culvert, whichever is lower.

(3) Ponding depth will be no greater than the elevation where flow diverts around the culvert.

(4) Elevations will be established to delineate necessary floodplain easements.

(5) The headwater shall be checked for the flood mitigation storm elevation to ensure compliance with flood plain management criteria and the culvert shall be sized to maintain flood-free conditions on major thoroughfares with twelve-inch (12") freeboard at the low-point of the road.

(6) Either the headwater shall be set to produce acceptable velocities or stabilization/energy dissipation shall be provided where these velocities are exceeded.

(7) In general, the constraint that gives the lowest allowable headwater elevation establishes the criteria for the hydraulic calculations.

d. Tailwater Considerations

(1) If the culvert outlet is operating with a free outfall, the critical depth and equivalent hydraulic grade line shall be determined.

(2) For culverts that discharge to an open channel, a stage-discharge curve using Manning's Equation for the channel must be determined.

(3) If an upstream culvert outlet is located near a downstream culvert inlet, the headwater elevation of the downstream culvert will establish the design tailwater depth for the upstream culvert.

(4) If the culvert discharges to a lake, pond, or other major water body, the expected high-water elevation of the water body will establish the culvert tailwater.

e. Other Criteria

(1) In designing debris control structures, the Hydraulic Engineering Circular No. 9 entitled *Debris Control Structures* or other approved reference is required to be used.

(2) If storage is being assumed or will occur upstream of the culvert, refer to *Section 2.0 of the iSWM Hydraulics Technical Manual* regarding storage routing as part of the culvert design.

(3) Reinforced concrete pipe, pre-cast and cast-in-place concrete boxes are recommended for use:

(a) under a roadway,

(b) when pipe slopes are less than one percent (1%), or

(c) for all flowing streams.

(4) Driveway corrugated metal pipe culverts to single residences may be used when approved by the City Engineer.

(5) Use of any storm drain pipe material other than reinforced concrete pipe shall require prior approval from the City Engineer.

(6) Culvert skews shall not exceed forty-five degrees (45°) as measured from a line perpendicular to the roadway centerline without approval.

f. The minimum allowable pipe size for a storm drain main shall be twenty-four inches (24"). Eighteen-inch (18") pipe may be used for storm drain lead lines with approval from City.

g. Erosion, sediment control, and velocity dissipation shall be designed in accordance with *Section 4.0 of the Hydraulics Technical Manual*.

10. Headwalls and Wingwalls

a. All headwall and wingwalls shall conform to TxDOT design standards and details.

b. No headwall, wingwall or other structural member shall protrude above the surface of the traveled roadway.

c. All headwall and wingwalls within the "clear zone" as defined by TxDOT of any roadway shall conform to TxDOT design standards and details for safety end treatment or shall be protected by a traffic barrier.

E. Drainage Channels

1. Design Frequency

a. Open channels, including all natural or structural channels and swales shall be designed for the flood mitigation storm event (100-year).

b. Channels shall be designed with multiple stages. A low flow channel section containing the streambank protection flows (2-year) and a high flow section that contains the conveyance (25-year) and flood mitigation storms (100-year) will improve stability and better mimic natural channel dimensions.

2. Design Criteria

a. Open channels shall incorporate meanders to the maximum extent practical; however, the two-year peak flow shall be conveyed in a channel with the following meander configuration:

(1) Channel sinuosity ratio (distance measured between two points along the channel flow line divided by the straight-line distance between the same two points) shall exceed 1.5;

(2) The angle between the channel centerline and the valley axis is less than 90 degrees;

(3) Sinusoidal curvature patterns may be regular or irregular; and

(4) The ratio of the design radius of curvature to the channel width shall be between
1.5 and 4.5.

b. If the channel slope exceeds ten percent (10%), or a combination of channel linings will be used, additional procedures not presented below are required. References include HEC-15 and HEC-14 (USDOT, FHWA, 1983).

c. HEC-RAS, or similarly capable software approved by the entity with jurisdiction, shall be used to confirm the water surface profiles in open channels.

d. The final design of artificial open channels shall be consistent with the velocity limitations for the selected channel lining. Maximum velocity values for selected lining categories are presented in Table 4-5. Seeding and mulch shall only be used when the design value does not exceed the allowable value for bare soil. Velocity limitations for vegetative linings are reported in Table 4-5. Vegetative lining calculations and stone riprap procedures are presented in *Section 3.2 of the iSWM Hydraulics Technical Manual*.

e. Drainage swales, where approved by the City Engineer, may be used for outfalls to natural or major drainage channels. Swales shall be designed to have a minimum of one (1) foot of freeboard at design flow and side slopes shall not be steeper than 4:1.

f. Channels with slopes less than one percent (1.0%) shall be constructed with a reinforced concrete pilot channel, unless other low flow methods are approved by the City Engineer.

g. Water surface profiles for all channels shall be computed using a standard step backwater model, such as US Army Corps of Engineers (USACE) HEC-RAS. The engineer can propose to use other hydraulic methods but must have their acceptability approved by the City Engineer.

h. Open channels shall meet the criteria of either the Texas State Department of Highways and Public Transportation or S.C.S. TR. No. 25 Design of Open Channels and shall be constructed in accordance with one of the design methods. Design of channels shall consider velocities and shall be shaped, graded, lined, or protected to minimize or prevent scour and erosion from excessive velocities. This requirement shall extend to roadside drainage swales. Concrete or rock retards shall be used when velocities exceed four feet (4') per second with sandy soil conditions or five feet (5') per second with clay soil conditions. All channels or roadside drainage swales without a protective lining shall have an established vegetative or grass cover. The depth of the 100-year frequency storm runoff shall not exceed one foot (1') over the minimum roadway surface elevation.

i. The Applicant may be required by the City Engineer to carry away by pipe or open ditch any spring or surface water that exists prior to, or because of the subdivision. Such drainage facilities shall be located in the road right-of-way where feasible, or in the perpetual unobstructed drainage easements of appropriate width and shall be constructed in accordance with the City of Bastrop Construction Standards Manual.

j. Trapezoidal channels shall have a minimum channel bottom width of six feet (6').

k. Channels with bottom widths greater than six feet (6') shall be designed with a minimum bottom cross slope of 12 to 1 (12:1) or with compound cross sections.

Table 4-5. Roughness Coefficients (Manning's n) and Allowable Velocities for Natural Channels

Channel Description	Manning's n	Max. Permissible Channel Velocity (ft/s)
MINOR NATURAL STREAMS		
Fairly regular section		
1. Some grass and weeds, little or no brush	0.030	3 to 6
2. Dense growth of weeds, depth of flow materially greater than weed height	0.035	3 to 6
3. Some weeds, light brush on banks	0.035	3 to 6
4. Some weeds, heavy brush on banks	0.050	3 to 6
5. Some weeds, dense willows on banks	0.060	3 to 6
For trees within channels with branches submerged at high stage, increase above values by Irregular section with pools, slight channel meander, increase above values by	0.010 0.010	
Floodplain – Pasture		
1. Short grass	0.030	3 to 6
2. Tall grass Floodplain –	0.035	3 to 6
Cultivated Areas		
1. No crop	0.030	3 to 6
2. Mature row crops	0.035	3 to 6
3. Mature field crops	0.040	3 to 6
Floodplain – Uncleared		
1. Heavy weeds scattered brush	0.050	3 to 6
2. Wooded	0.120	3 to 6
MAJOR NATURAL STREAMS Roughness coefficient is usually less than for minor streams of similar description because of less effective resistance offered by irregular banks or vegetation on banks. Values of "n" for larger streams of mostly regular sections, with no boulders or brush	Range from 0.028 to 0.060	3 to 6
UNLINED VEGETATED CHANNELS		
Clays (Bermuda Grass)	0.035	5 to 6
Sandy and Silty Soils (Bermuda Grass)	0.035	3 to 5
UNLINED NON-VEGETATED CHANNELS		
Sandy Soils	0.030	1.5 to 2.5
Silts	0.030	0.7 to 1.5
Sandy Silts	0.030	2.5 to 3.0
Clays	0.030	3.0 to 5.0
Coarse Gravels	0.030	5.0 to 6.0
Shale	0.030	6.0 to 10.0
Rock	0.025	15
For natural channels with specific vegetation type, refer to Table 4-7 for more detailed velocity control.		

Source: iSWM Technical Manual, NCTCOG, Sept. 2014

l. Channel side slopes shall be stable throughout the entire length and the side slope shall depend on the channel material. Roadside swales shall have maximum foreslopes of 4:1 and maximum backslopes of 3:1.

m. Trapezoidal or parabolic cross sections are preferred over triangular shapes.

n. For vegetative channels, design stability shall be determined using low vegetative retardance conditions (Class D as defined in Table 4-7). For design capacity, higher vegetative retardance conditions (Class C as defined in Table 4-7) shall be used.

o. For vegetative channels, flow velocities within the channel shall not exceed the maximum permissible velocities given in Tables 4-5 and 4-6.

p. If relocation of a stream channel is unavoidable, the cross-sectional shape, meander, pattern, roughness, sediment transport, and slope shall conform to the existing conditions insofar as practicable. Energy dissipation will be necessary when existing conditions cannot be duplicated.

q. Streambank stabilization shall be provided, when appropriate, as a result of any stream disturbance such as encroachment and shall include both upstream and downstream banks as well as the local site.

r. Vegetative Design: A two-part procedure is required for final design of temporary and vegetative channel linings.

    (1) Part 1- the design stability component, involves determining channel dimensions for low vegetative retardance conditions, using Class D as defined in Table 4-7.

    (2) Part 2: the design capacity component, involves determining the depth increase necessary to maintain capacity for higher vegetative retardance conditions, using Class C as defined in Table 4-7.

    (3) If temporary lining is to be used during construction, vegetative retardance Class E shall be used for the design stability calculations.

    Design examples outlining the steps of design stability calculations are provided within Section 3.2.6 of the iSWM Technical Manual.

s. For gabions, design velocities range from 10 fps for 6-inch mattresses up to fifteen feet per second (15 fps) for one-foot (1’) mattresses. Some manufacturers indicate that velocities of twenty feet per second (20 fps) are allowable for basket installations. The design of stable rock riprap lining depends on the intersection of the velocity (local boundary shear) and the size and gradation of the riprap material. More information on calculating acceptable riprap velocity limits is available in *Section 3.2.7 of the Hydraulics Technical Manual*.

t. Swales: Drainage swales, where approved by the City Engineer, may be used for outfalls to natural or major drainage channels. Swales shall be designed to have a minimum of one foot (1') of freeboard at design flow and side slopes shall not be steeper than 4:1 and constructed with a reinforced concrete trickle channel.

u. A permanent chain link fence or other fence meeting the requirements of the City shall be constructed along the top of any channel exceeding three feet (3') in depth to enclose the area where it is adjacent to residential lots and in other cases, where it is deemed necessary to restrict access to the channel.

Table 4-6. Maximum Velocities for Vegetative Channel Linings

Vegetation Type	Slope Range (%)[1]	Maximum Velocity[2] (ft/s)
Bermuda grass	0-5	6
Bahia		4
Tall fescue grass mixtures[3]	0-10	4
Kentucky bluegrass	0-5	6
Buffalo grass	5-10 >10	5 4
Grass mixture	0-5[1] 5-10	4 3
Sericea lespedeza, Weeping lovegrass, Alfalfa	0-5[4]	3
Annuals[5]	0-5	3
Sod		4
Lapped sod		5

[1] Do not use on slopes steeper than 10% except for side-slope in combination channel.
[2] Use velocities exceeding 5 ft/s only where good stands can be maintained.
[3] Mixtures of Tall Fescue, Bahia, and/or Bermuda
[4] Do not use on slopes steeper than 5% except for side-slope in combination channel.
[5] Annuals - used on mild slopes or as temporary protection until permanent covers are established.

Source: Manual for Erosion and Sediment Control in Georgia, 1996.

Table 4-7. Classification of Vegetal Covers as to Degrees of Retardance

Retardance Class	Cover	Condition
A	Weeping Lovegrass	Excellent stand, tall (average 30")
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36")
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12")
	Native grass mixture Little bluestem, bluestem, blue gamma other short and long stem Midwest grasses	Good stand, unmowed
	Weeping lovegrass	Good stand, tall (average 24")
	Laspedeza sericea	Good stand, not woody, tall (average 19")
	Alfalfa	Good stand, uncut (average 11")
	Weeping lovegrass	Good stand, unmowed (average 13")
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13")
C	Crabgrass	Fair stand, uncut (10 – 48")
	Bermuda grass	Good stand, mowed (average 6")
	Common lespedeza	Good stand, uncut (average 11")
	Grass-legume mixture: summer (orchard grass redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 – 8 ")
	Centipede grass	Very dense cover (average 6")
	Kentucky bluegrass	Good stand, headed (6 – 12")
D	Bermuda grass	Good stand, cut to 2.5"
	Common lespedeza	Excellent stand, uncut (average 4.5")
	Buffalo grass	Good stand, uncut (3 – 6")
	Grass-legume mixture: fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (4 – 5")
	Lespedeza serices	After cutting to 2" (very good before cutting)
E	Bermuda grass	Good stand, cut to 1.5"
	Bermuda grass	Burned stubble

Note: Covers classified have been tested in experimental channels. Covers were green and generally uniform. Source: HEC-15, 1988.

F. Detention/Retention Structures

1. General

a. Retention (maintains a permanent pool elevation) and detention (no permanent pool storage) shall be designed in accordance with the criteria below.

b. Stormwater detention facilities shall be required where deemed appropriate by the City when it is determined that adverse downstream flooding would occur due to a proposed development. Stormwater detention shall be used to reduce the net increase in stormwater runoff due to development of the property at the 2-, 25-, and 100-year events, unless a downstream assessment shows that none is required. Multi-stage outlet structures may be required. Within the Gills Branch Watershed, stormwater detention shall be used to reduce the net increase in stormwater runoff due to development to reduce the post-developed 100-year storm peak discharge to the pre-developed 25-year storm peak discharge.

c. Retention/detention ponds shall be encompassed by an easement. The facility will remain the maintenance responsibility of the Responsible Party or property-owners association, unless otherwise accepted by the City. Acceptance by the City will be contingent upon the facility being a part of a dedicated park or other such property which meets with the City's approval.

d. Preservation of major floodplains is strongly encouraged and detention/retention may be required if a proposed drainage improvement is found to create actual or potential upstream, adjacent or downstream property damage due to the creation of excessive flood velocities or heights.

e. Runoff from development sites that exceeds 10,000 square feet of land disturbance or a net increase of 5,000 square feet of impervious surface must not exceed pre-development levels for the 2-year, 25-year and 100-year, 24-hour events, unless a downstream assessment determines that it is not required. Multi-phase developments will be considered as a single entity in determining the requirement for detention. For development sites not exceeding the above referenced disturbed area and impervious area thresholds, the City may at their discretion require that stormwater detention be provided.

f. No increase or concentration of stormwater may be conveyed off-site without easements and/or downstream drainage improvements. Increased stormwater runoff attributable to new development must not exceed the capacity of the downstream drainage system. If no downstream drainage system exists, increased stormwater runoff must not adversely affect adjoining property. In cases where the proposed runoff would exceed the capacity of downstream facilities, the developer will be required to provide detention to prevent overloading of downstream systems.

g. In all new developments where stormwater runoff has been collected or concentrated, discharge shall be conveyed off-site by creeks, channels or storm sewer systems. Easements shall be provided by the Responsible Party to the City for off-site drainage facilities, as well as for on-site facilities. All flows shall be discharged in a non-erosive manner.

h. The Responsible Party shall pay for the cost of all drainage improvements required, including any necessary off-site channels or storm sewers and acquisition of the required easements.

i. If it is anticipated that additional runoff caused by the development will overload any existing downstream drainage facility, whether natural or improved, and result in hazardous conditions, approval of the improvements for the proposed subdivision may be withheld until appropriate provisions have been made to accommodate the problem. If existing capacity is not available downstream and property damage could occur, the Responsible Party shall provide a drainage system or detention facility to mitigate the deficiency. In any case, a letter of acknowledgement shall be obtained from the downstream property owner indicating that the downstream property owner is aware of proposed drainage improvements impacting drainage on or to said owner's property.

j. Permanent impoundments of water shall be constructed in such a way that negative effects on aesthetics, function, flooding, health, and safety are minimized. Such improvements shall be allowed at the discretion of the City Engineer. The developer shall be responsible for all necessary permitting required by the Texas Commission on Environmental Quality for impounding public water. The City Engineer may require calculations and/or other documentation that no negative impact is created. All Texas Commission on Environmental Quality (TCEQ) requirements for impoundments and dam safety shall apply. These requirements relate to both the size and the hazard classification of the embankment. Copies of all materials submitted to TCEQ for permitting, along with the TCEQ permits, must be submitted to the City Engineer.

k. All storage facilities shall be designed and analyzed using reservoir routing of an inflow unit hydrograph. The software program or computational method must be approved by the City Engineer. The analysis should consist of comparing the design flows at a point or points downstream of the proposed storage site with and without storage. Design calculations shall show the effects of the detention facility in each of the 2-, 25-, and 100-year storm events. This may require the use of multi-stage control structures. The detention facility shall be designed to provide the required detention for all the above-listed frequencies.

l. The facilities shall be designed using SCS unit hydrograph methodologies or by other approved hydrograph routing methods.

m. Detention ponds may be counted toward the required parkland dedication if designed to accommodate recreational activities.

2. Design Frequency

Detention structures shall be designed for the three storms (streambank protection (2-year), conveyance (25-year), and flood mitigation storms (100-year)) for the critical storm duration that results in the maximum (or near maximum) peak flow.

3. Design Criteria

a. Dry detention basins are sized to temporarily store the volume of runoff required to provide flood protection up to the flood mitigation storm, if required.

b. Extended detention dry basins are sized to provide extended detention of the streambank protection volume over 24 hours and can also provide additional storage volume for normal detention (peak flow reduction) of the flood mitigation storm event.

c. Routing calculations must be used to demonstrate that the storage volume and outlet structure configuration are adequate. See *Section 2.0 of the iSWM Hydraulics Technical Manual* for procedures on the design of detention storage.

d. Detention Basins shall be designed with an 8-foot-wide maintenance access.

e. A freeboard of one (1) foot will be required for all detention ponds. Freeboard distance is measured between the elevation of the emergency spillway crest and the elevation of the top of the detention basin containment embankment/berm.

f. A calculation summary shall be provided on construction plans. For detailed calculations of unit hydrograph studies, a separate report shall be provided to the City for review and referenced on the construction plans. Stage-storage-discharge values shall be tabulated and flow calculations for discharge structures shall be shown on the construction plans.

g. An emergency spillway shall be provided at the flood mitigation maximum storage elevation with sufficient capacity to convey the flood mitigation storm assuming blockage of the outlet works with six inches of freeboard. Spillway requirements must also meet all appropriate state and federal criteria.

h. A landscape plan shall be provided for all detention ponds.

i. All detention basins shall be stabilized against significant erosion and include a maintenance plan.

j. Design calculations will be provided for all spillways and outlet structures.

k. Stormwater maintenance agreements shall be included for all detention structures (example stormwater maintenance agreement is provided as Appendix G).

l. Storage may be subject to the requirements of the Texas Dam Safety Program (see iSWM Program Guidance) based on the volume, dam height, and level of hazard.

m. Earthen embankments six feet (6') in height or greater shall be designed per TCEQ guidelines for dam safety (see iSWM Program Guidance).

n. Vegetative slopes shall be less than ten feet (10') in height and shall have side slopes no steeper than 4:1.

o. Areas above the normal high-water elevations of the detention facility should be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The bottom area of storage facilities should be graded toward the outlet to prevent standing water conditions. A low flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.

4. Outlet Structures

a. Outlet structures shall be designed to intercept sediment and floatables from the 25-year storm. The potential for the impact of sedimentation on the detention facility should be evaluated. A means of access for maintenance of the facility shall be provided.

b. The outlet control structures for storage facilities typically include a principal outlet and an emergency overflow. The principal outlet functions to restrict the outflow and cause the runoff to use the available storage volume. The principal outlet shall be designed to accommodate the multiple frequency storms listed above while maintaining the minimum freeboard of one foot. The emergency overflow shall be paved and provide positive overflow.

c. The outlet control structure may be drop inlets, pipes, culverts, weirs, or orifices. Checks should be made to determine if the outlet structure is controlled by weir or orifice flow. The tailwater on the structure could significantly affect its capacity. The engineer should carefully evaluate the tailwater depth. For detention facilities in a series, the lower facility should not cause inundation of the upper outlet control structure. The calculation of the hydraulic capacity for outlet control structures is based on the type of structure used, using standard hydraulic calculations.

d. Extended detention (ED) orifice sizing is required in design applications that provide extended detention for downstream streambank protection (2-year). The release rate for the orifice shall discharge the ED volume in a period of 24 hours or longer. In this case an extended detention orifice or reverse slope pipe must be used for the outlet.

e. Design Frequency

(1) Streambank protection storm (2-year, 24-hour)

(2) Conveyance storm (25-year, 24-hour)

(3) Flood mitigation storm (100-year, 24-hour)

f. Design Criteria

(1) Estimate the required storage volumes for streambank protection, conveyance storm, and flood mitigation.

(2) Design extended detention outlets for each storm event.

(3) Outlet velocities shall be within the maximum allowable range based on channel material as shown in Tables 4-5 and 4-6.

(4) Design necessary outlet protection and energy dissipation facilities to avoid erosion problems downstream from outlet devices and emergency spillway(s).

(5) Perform buoyancy calculations for the outlet structure and footing. Flotation will occur when the weight of the structure is less than or equal to the buoyant force exerted by the water.

(6) Additional design guidance is in *Section 2.2 of the iSWM Hydraulics Technical Manual*.

5. Energy Dissipation

a. Design Frequency

All drainage system outlets, whether for closed conduits, culverts, bridges, open channels, or storage facilities, shall provide energy dissipation to protect the receiving drainage element from erosion.

(1) Conveyance storm (25-year, 24-hour)

(2) Flood mitigation storm (100-year, 24-hour)

b. Design Criteria

(1) *Energy dissipaters* are engineered devices such as rip-rap aprons or concrete baffles placed at the outlet of stormwater conveyance systems for reducing the velocity, energy and turbulence of the discharged flow.

(2) Erosion problems at culvert, pipe and engineered channel outlets are common. Determination of the flow conditions, scour potential,

and channel erosion resistance shall be standard procedure for all designs.

(3) Energy dissipaters shall be employed whenever the velocity of flows leaving a stormwater management facility exceeds the erosion velocity of the downstream area channel system.

(4) Energy dissipater designs will vary based on discharge specifics and tailwater conditions.

(5) Outlet structures shall provide uniform redistribution or spreading of the flow without excessive separation and turbulence.

(6) Energy dissipaters are a required component of the Final Drainage Plan.

(7) Recommended Energy Dissipaters for outlet protection include the following:

(a) Riprap apron
(b) Riprap outlet basins
(c) Baffled outlets
(d) Grade Control Structures

The reader is referred to *Section 4.0 of the iSWM Hydraulics Technical Manual* and the Federal Highway Administration Hydraulic Engineering Circular No. 14 entitled, Hydraulic Design of Energy Dissipaters for Culverts and Channels, for the design procedures of other energy dissipaters.

SECTION 5 EASEMENTS

SECTION 5 - EASEMENTS

The subdivider shall dedicate or grant easements as follows, and record them in the in the deed records of Bastrop County:

A. General Policy

1. Drainage easements shall generally be located along the existing drainage way and should be of sufficient width for the designed improvements (if any) to be installed and enough extra width for maintenance equipment to be able to work.
2. All drainage easements shall be so designed to allow maintenance equipment to enter the easement and be able to perform the necessary work.

B. Drainage Easements

Where a subdivision is traversed by a watercourse, drainage way, 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 to accommodate future needs as determined by the City of Bastrop Comprehensive Plan and the City Manager. Natural waterways and channels should be used wherever practical to carry runoff. Any modification to an existing waterway and channel requires approval by the City Engineer and City Manager.

Easements shall be retained along drainage ways, which carry drainage away from roads or which convey main drainage from and through the lots or tracts. Easements shall be a minimum of twenty-five-feet (25') wide for open drainage channels or sized to accommodate the 100-year flood plain. A suitable note on the plat must restrict all properties within the subdivision ensuring that drainage easements within the plat boundaries shall be kept clear of fences, buildings, and plantings that would obstruct the flow of water, and other obstructions to the operations and maintenance of the drainage facility.

1. Storm drainage easements of fifteen feet (15') minimum width shall be provided for existing and proposed enclosed drainage systems. Easements shall be centered on the systems. Larger easements, where necessary, shall be provided as directed by the City Engineer.
2. Storm drainage easements along existing or proposed open channels shall be a minimum of twenty-five-feet (25') wide for open drainage channels or sized to accommodate the 100-year flood plain, providing sufficient width for the required channel and such additional width as may be required for ingress and egress of maintenance equipment; to provide clearance from fences and space for utility poles; to allow maintenance of the channel bank; and, to provide necessary slopes along the bank.
3. Where topography or other conditions are such as to make impractical the inclusion of drainage facilities within road rights-of-way, perpetual unobstructed easements for such drainage facilities shall be provided across property outside

the road right-of-way lines and with satisfactory access to the road. Easements shall be indicated on the plat. Drainage easements shall be carried from the road to a natural watercourse or to other drainage facilities.

4. When a proposed drainage system will carry water across private land outside the subdivision, appropriate drainage rights must be secured and indicated on the plat or other instrument as approved by the City Attorney. Easements in areas adjoining a proposed subdivision necessary to provide adequate drainage thereof or to serve such subdivision with utilities, shall be obtained by the subdivider prior to final plat approval. In the case of clear public interest, the City may participate in easement acquisition by power of condemnation.
5. The Applicant shall dedicate an appropriate drainage easement either in fee or by drainage easement or by conservation easement of land on both sides of existing watercourses to a distance to be determined by the City Engineer.
6. Easements for storm drainage facilities shall be provided at locations containing proposed or existing drainage ways.
7. Storm drainage easements shall be provided for emergency overflow drainage ways of sufficient width to contain within the easement stormwater resulting from a 100-year frequency storm less the amount of stormwater carried in an enclosed system of a capacity required by the City of Bastrop.
8. The width of the easements shall be substantiated by a drainage study and drainage calculations or other criteria submitted to and approved by the City Engineer.
9. Floodplain Easements. Floodplain easements shall be provided along natural drainage ways and lakes or reservoirs. Floodplain easements shall encompass all areas beneath the water surface elevation resulting from a storm whose design frequency is 100-years (or a one-percent annual probability), plus such additional width as may be required to provide ingress and egress to allow maintenance of the banks and for the protection of adjacent property, as determined and required by the City Engineer.
10. Detention area easements shall be provided that completely encompass the pond and associated improvements. Detention ponds on nonresidential property shall be maintained by the property owner's association, unless otherwise approved by the City.
11. Streambank Buffer Easements – A 100-foot stream buffer easement shall be provided along any of the major stream channels (Colorado River, Piney Creek, Gills Branch, or any other perennial stream) with no grading or vegetation removal to serve as a streambank buffer for erosion and for water quality protection. No buildings may be constructed within the streambank buffer and any fences within the 100-year floodplain shall be designed to not impede flow, including by debris that may be caught in the fence.

SECTION 6 CONSTRUCTION SITE EROSION CONTROL REQUIREMENTS

SECTION 6 - CONSTRUCTION SITE EROSION CONTROL REQUIREMENTS

A. General

Stormwater pollution prevention plans (SWPPPs) shall be submitted for review to the City Engineer prior to release of construction projects. The developer and their engineer shall be responsible for preparation of a SWPPP in accordance with TCEQ and U.S. Environmental Protection Agency (EPA) requirements. TCEQ and EPA permitting shall also be the responsibility of the developer and their engineer.

B. Required Best Management Practices

Where appropriate, the plan shall include sediment controls to do all of the following to the maximum extent practicable:

1. Each site shall provide an access drive and parking area of sufficient dimensions and design, surfaced with a material that will prevent erosion and minimize tracking or washing of soil onto public or private roadways. All non-paved access drives shall be designed so that stormwater runoff from adjacent areas does not flow down the drive surface.
2. Any significant amount of runoff from upslope land area, rooftops, or other surfaces that drain across the proposed land disturbance shall be diverted around the disturbed area, if practical. Any diversion of upslope runoff shall be done in a manner that prevents erosion of the flow path and the outlet.
3. Any cuts and fills shall be planned and constructed to minimize the length and steepness of slope and stabilized in accordance with the approved erosion control plan timelines and standards of this document.
4. Open channels shall be stabilized as required to prevent erosion.
5. Inlets to storm drains, culverts, and other stormwater conveyance systems shall be protected from siltation until final site stabilization.
6. Water pumped from the site shall be treated by temporary sedimentation basins or other appropriate controls designed for the highest dewatering pumping rate. Water may not be discharged in a manner that causes erosion of the site or receiving channels.
7. All waste and unused building materials shall be properly disposed of and not allowed to be carried by runoff into a receiving channel or storm sewer system.
8. All off-site sediment deposits occurring as a result of a storm event shall be cleaned up by the end of the next workday. All other off-site sediment deposits occurring as a result of land-disturbing activities shall be cleaned up by the end of the workday. Flushing may not be used unless the sediment will be controlled by a filter fabric barrier, sediment trap, sediment basin, or equivalent.
9. All activities on the site shall be conducted in a logical sequence to minimize the area of bare soil exposed at one time. Existing vegetation shall be maintained as long as possible.
10. Soil stockpiles shall be located no closer than 25-feet from lakes, streams, wetlands, ditches, drainage ways, or roadway drainage systems. Stockpiles shall be stabilized by mulching, vegetative cover, tarps, or other means if remaining for

20 days or more.

11. For any disturbed area that remains inactive for greater than 7 working days, or where grading work extends beyond annual permanent seeding deadlines, the City of Bastrop may require the site to be treated with temporary stabilization measures.
12. When the disturbed area has been stabilized by permanent vegetation or other means, temporary BMPs such as silt fences, straw bales, and sediment traps shall be removed and these areas stabilized.