

City of Tomball

Minimum Standards for Stormwater Drainage Design



Adopted: September 6, 2011

Updated: March 31, 2025

Table of Contents

Table of Contents.....	1
DRAINAGE POLICY.....	2
I. REFERENCES.....	5
II. DEFINITIONS AND ACRONYMS	6
III. DESIGN REQUIREMENTS	10
A. Determination of Runoff Peak Flow	10
D. Design of Storm Sewers	13
E. Consideration of Overland Flow	22
F. Design of Roadside Ditches.....	24
G. Design of Open Channels.....	26
H. Stormwater Detention.....	27
IV. SUBMITTALS	40
A. Online Portal (SmartGOV).....	40
B. Submittals for review and comment	40
C. Signature Stage – Submit the following for approval:.....	41
V. QUALITY ASSURANCE	42
VI. SURVEY	42
VII. LOW IMPACT DEVELOPMENT	42

Appendices

- A. Storm Sewer Calculation Table
- B. Roadside Ditch Calculation Table
- C. Time of Concentration Calculation Table
- D. Inlet Spread Calculation Table
- E. Variance Form
- F. City of Tomball Review Sheet

DRAINAGE POLICY

A. Design Requirements

1. The City of Tomball administers drainage criteria, supplemented by Harris County and the Harris County Flood Control District (HCFCD), to ensure newly developed and adjacent areas are protected from structural flooding during a 100-year storm event. This is achieved through the application of various drainage infrastructure elements, including storm sewers, roadside ditches, open channels, detention and overland (sheet) run-off management. The combined system is designed to prevent structural flooding from extreme events up to a 100-year storm.
2. Recognizing that each site has unique characteristics that may affect drainage design, these criteria establish minimum requirements that may be modified, provided that the objectives for drainage standards are maintained. For projects that require a site specific approach and where unique innovative engineering solutions can achieve drainage performance goals, a request for consideration of alternative design standards - such as pipe flow capacity, overland sheet flow management, and detention storage. All such requests shall be reviewed and approved by the City of Tomball Staff to ensure compliance with drainage objectives and regulatory standards.

B. Temporary ponding in streets and roadside ditches is an anticipated and integral component of the overall drainage system, designed to enhance overall stormwater management efficiency. Storm sewers and roadside ditches are designed to balance hydraulic capacity with economic feasibility. These drainage elements are designed to convey less intense and more frequent rainfall events to allow for traffic movement during these events. During larger storm events that exceed the hydraulic capacity of the storm sewer system, excess runoff is managed through controlled overland flow and temporary storage to mitigate risk of structural flooding and enhance flood resilience against extreme weather .

C. The No Adverse Impact (NAI) principle must be complied to ensure that the actions taken by any community, property owner, or developer – whether public or private – don not adversely impact the property, rights, or safety of others. NAI management offers a way to prevent increased flooding, erosion, or other detrimental impacts on the community. Adverse impacts related to drainage improvements are quantified through metrics such as flow rate, water surface elevation, velocity, flow type, erosion, sedimentation, and other measurable adverse impacts to community’s well-being.

All proposed New Development, Redevelopment, or Site Modifications must adhere to the following drainage requirements:

- Existing overland flow patterns shall not be altered so that increase or redirect existing sheet flow to adjacent private or public property.

- The project shall not increase the water surface either upstream or downstream.
- The project shall not increase the flow velocity in and around the project site in a way that causes downstream erosion or infrastructure damage.

Where existing sheet flow is obstructed by construction (e.g., site elevation changes due to fill placement), the developer must re-route the sheet flow **within** the property boundaries to maintain the original drainage configuration or discharge into the public right-of-way (ROW) as permitted. **Except in cases dictated by natural or existing drainage patterns, no sheet flow from developed property shall be allowed to drain onto adjacent private property.** No development shall create or transfer adverse drainage impacts onto neighboring properties.

The estimated volume of displaced sheet flow shall be accurately calculated to ensure that the rerouted flow pattern maintains sufficient capacity, preventing any adverse impact on adjacent properties. No sheet flow from the developed property shall be allowed to drain onto the adjacent right-of-way (ROW).

Any increase in discharge volume shall only be directed to the ROW at a designated and approved point of connection, ensuring that the receiving drainage system has adequate capacity to handle the additional flow. All increased discharge must be conveyed through a properly designed subsurface drainage system, preventing uncontrolled surface runoff and minimizing the risk of erosion, flooding, or infrastructure damage.

- D. The City of Tomball is an active participant in the National Flood Insurance Program (NFIP). The flood insurance program makes flood insurance available to property owners within the City. Low-cost insurance is available for communities that implement flood risk reduction measures. Compliance with NFIP regulations helps mitigate structural flooding, enhancing community resilience and reducing long-term flood damage costs. The City's drainage design criteria are aligned with NFIP requirements to ensure responsible development practices. All developments within the City limits must adhere to the City of Tomball Code of Ordinances to support NFIP regulations. incorporating appropriate flood mitigation measures to minimize risk and maintain eligibility for the program.
- E. Approval of a storm drainage plan and design is an integral component of the review process for all New Developments, the site plan review process for Redevelopments, and the permitting process for Site Modifications. The City of Tomball Staff is responsible for conducting comprehensive plat review, approval, and storm drainage design evaluations to ensure compliance with local drainage criteria, flood mitigation standards, and regulatory requirements. Properly designed drainage systems must be integrated into all development projects to minimize flood risks, protect public infrastructure, and maintain the integrity of the city's stormwater management system.

- F. The City of Tomball will consider joint project funding with private entities for the construction of drainage systems that enhance existing infrastructure or develop new drainage solutions. However, the City's top funding priority will be projects included in the Capital Improvement Plan (CIP).

Where feasible, the City will seek to leverage municipal funding with contributions from private entities, civic organizations, and other public agencies—including Harris County, the Harris County Flood Control District (HCFCD), the Texas Water Development Board (TWDB), Federal Emergency Management Agency (FEMA), and the U.S. Army Corps of Engineers, and other available funding sources—to maximize project impact and efficiency.

For drainage systems that have been identified as deficient but are not currently scheduled for funding under the CIP, the City will consider authorizing privately funded improvements, provided they align with the City's drainage objectives, regulatory standards, and long-term infrastructure plans.

- G. The drainage criteria outlined in this document shall apply to all projects located within the City of Tomball limits and its Extraterritorial Jurisdiction (ETJ). In cases where these criteria conflict with the drainage regulations of Harris County, the Harris County Flood Control District (HCFCD), Montgomery County, or other governing jurisdictions, the most restrictive criteria shall take precedence. This ensures that the highest standards for flood protection, stormwater management, and infrastructure resilience are upheld across all applicable areas. Property owners and public agencies are responsible for not adversely impacting the community, neighbors, future property owners, or City facilities in terms of flood risks, erosion, infiltration and siltation.

I. REFERENCES

- A. City of Tomball Construction Standards and Technical Specifications, September 2017.
- B. Flood Damage Prevention Ordinance, Chapter 10 Article VIII of the City of Tomball Code of Ordinances, January 2025, and any subsequent revisions.
- C. Regulations of Harris County, Texas, for the Approval and Acceptance of Infrastructure (Harris County Infrastructure Regulations), Current Edition.
- D. Policy, Criteria, and Procedure Manual for Approval and Acceptance of Infrastructure, Harris County Flood Control, 2019.
- E. NOAA ATLAS 14 – Precipitation-Frequency Atlas of the United States, Volume 11, Version 2, Texas, 2018.
- F. Hydrology and Hydraulics Guidance Manual, Harris County Flood Control, 2009
- G. Urban Drainage Design Manual- Hydraulic Engineering Circular No. 22 (HEC-22) Fourth Edition, Federal Highway Administration (FHWA), 2024.
- H. Design and Construction of Urban Stormwater Management Systems, ASCE Manual of Practice No. 77, 1993.
- I. Harris County Low Impact Development & Green Infrastructure Design Criteria for Storm Water Management, Harris County Flood Control and Harris County Public Infrastructure Department, 2011.
- J. Hydraulic Design Manual, Texas Department of Transportation, 2019.

II. DEFINITIONS AND ACRONYMS

- A. Conduit – Any closed infrastructure to convey drainage water such as underground storm sewers, pipes, and culverts.
- B. Open Channel - A structure designed to convey storm water using gravity flow with a free surface exposed to the atmosphere.
- C. Continuity Equation – $Q = VA$
Where:
Q - discharge in cfs,
V - flow velocity fps
A - conveyance area in square feet.
- C. Critical Elevation – The maximum hydraulic grade line elevation that a drainage system is allowed when design flow is conveyed through the system. This elevation is related to the level of service of the primary system.
- D. Design Storm Event – The rainfall intensity for the design annual exceedance probability (AEP) upon which the drainage facility is designed.
- E. Development – A tract of land that has been improved (such as grading, paving, building structures, or otherwise changing the runoff characteristics of the land), exclusive of land being used and continuing to be used for agricultural purposes. The term of development includes New Development, Redevelopment, and Site Modifications.
 - 1. New Development: Development of an undeveloped parcel of land.
 - 2. Redevelopment: A change in land use that alters the impervious cover from one type of development to either the same type or another type, or greenfield, and alters the drainage patterns internally or externally to the Development.
 - 3. Site Modifications: A site improvement that alters the area of impervious surface (e.g., an addition to an existing structure or creating additional parking), or a change in existing storm water collection, conveyance or runoff conditions for the developed site.
- F. Disturbed Area – An area of the land or tract that changes the drainage characteristics. This includes any changes in land grading, paving, building structure, or otherwise changing the runoff characteristics of the land. This does not include altering the surface for routine maintenance that is performed to maintain the original line and grade, hydraulic capacity, or original purpose of the site (e.g., the routine grading of existing dirt roads, asphalt overlays of existing roads, the routing clearing of existing ROW, and similar maintenance activities)
- G. Drainage Area – The surface area defined by topographic divides that contributes rainfall

runoff to a common outlet or point of interception. The drainage area represents the drainage system service area and is not limited by the project boundary or street ROW. The possibility of overland flow contributions from adjacent drainage areas during certain extreme events shall be considered for accurate assurance.

- H. Drainage Area Map – The map of watershed which is subdivided into subarea served by a sub drainage system.
- I. FEMA – Federal Emergency Management Agency.
- J. FIRM – Flood Insurance Rate Map published by FEMA
- K. HCED – Harris County Engineering Department.
- L. HCFCD – Harris County Flood Control District.
- M. Hydraulic Grade Line – A line representing the pressure head (water surface elevation) available at any given point within the drainage system.
- N. Impervious Surface – An impervious surface is any land surface that has been compacted or covered with materials that prevent or significantly impede the infiltration of water into the underlying natural soil strata. Impervious surfaces increase surface runoff by reducing the amount of stormwater absorbed into the ground, contributing to increased flood risks and reduced groundwater recharge.

Surface materials that are considered impervious include, but not limited to, bricks, pavers, concrete, asphalt, compacted or decomposed shale, gravel, or granite, or other similar materials. Surface features utilizing such materials and considered impervious include, but not be limited to, decks (whether on pier and beam or directly over soil), foundations (whether pier and beam or slab), building roofs, parking and driveway areas, sidewalks, compacted or rolled areas, paved recreation areas, swimming pools, dry or wet detention ponds, shade structures and other features or surfaces that are built or laid on the surface of the land and have the effect of increasing, concentrating, or otherwise altering water runoff so that runoff is not readily absorbed.

A surface may be classified as permeable if a soil infiltration test demonstrates that the underlying soil allows water infiltration at a rate of 0.5 inches per hour or greater. The infiltration report must be signed and sealed by a Professional Engineer (P.E.) licensed in the State of Texas with evidence that the surface permits water to percolate through to undisturbed soil strata.

O. Manning's Equation - $V = \frac{K}{n} R^{2/3} S^{1/2}$

Where:

v - velocity in feet per second

- k - conversion factor (1.49)
- R - hydraulic radius (conveyance area/wetted perimeter) in feet
- S - friction slope (head loss/length)
- n - Manning’s roughness coefficient (see **Table 1** below)

Table 1 – Manning’s “n” Values

Description	Manning’s “n” Value
Channel	
Grass-Lined	0.040
Riprap-Lined	0.040
Concrete-Lined	0.015
Natural or Overgrown Channels	Usually 0.050-0.080
Conduit	
Concrete Pipe	0.013
Concrete Box	0.013
Dual Wall Polypropylene Pipe	0.012
Corrugated profile-wall polyethylene pipe	0.012

P. Rainfall Frequency – The statistical likelihood or probability of a specific amount of rainfall for a rainfall event with defined characteristics occurring within a defined period and at a particular location. The National Weather Service (NWS) provides authoritative rainfall frequency data through publications such as NOAA Atlas 14, which offers precipitation frequency estimates for various return periods and durations based on historical rainfall records. For storm drainage design, the following rainfall frequencies are typically applied:

1. 2-year frequency – a rainfall intensity having a 50 percent probability of occurrence in any given year with 2-year return period.
2. 5-year frequency – a rainfall intensity having a 20 percent probability of occurrence in any given year with a 5-year return period.
3. 10-year frequency – a rainfall intensity having a 10 percent probability of occurrence in any given year with a 10-year return period.
4. 25-year frequency – a rainfall intensity having a 4 percent probability of occurrence in any given year with a 25-year return period.
5. 100-year frequency – a rainfall intensity having a 1 percent probability of occurrence in any given year with a 100-year return period.
6. 500-year frequency – a rainfall intensity having a 0.2 percent probability of occurrence in any given year with a 500-year return period.

Rainfall frequency data, combined with rainfall intensity-duration-frequency (IDF) curves, is essential for determining peak runoff rates and sizing storm drainage systems to mitigate flooding risks effectively.

- Q. Rational Method Formula – A method for calculating the peak runoff flow rate for a storm drain system with the following formula:

$$Q = CiA$$

Where:

Q - Peak runoff flow rate in cubic feet per second

C - Runoff coefficient (dimensionless) representing the fraction of rainfall that becomes runoff (See Table 2)

A - Drainage area (acres)

i - Rainfall intensity (inches per hour) for the design storm and duration equal to the time of concentration (T_c)

- R. Regional Detention Facility (RDF) – A detention facility designed to collect, temporarily store, and manage surface runoff from a regional drainage area which is often covers more than one development or from one of the major creeks or tributaries. RDF is typically constructed as part of regional flood control and drainage systems to mitigate flooding risks, control peak discharge rates, and improve water quality.
- S. Sheet Flow – Overland stormwater runoff that flows as broad and shallow across surfaces and is not conveyed in a defined channel, ditch, or conduit. Sheet flow commonly occurs when the capacity of the existing drainage or conduit system is exceeded, causing water to spread overland in an uncontrolled manner. This type of flow is a critical consideration in floodplain management and drainage design, as it can lead to erosion, sediment transport, and localized flooding in low-lying areas.
- T. Structural Flooding – Flooding condition where the water surface elevation from a storm event surpasses the top of the building’s slab elevation (for slab-on-grade construction) or the top of the first-floor elevation (for pier-and-beam construction), causing water to enter and inundate the interior of the structure. This condition is a key indicator in flood risk assessments and is used to evaluate the effectiveness of flood mitigation strategies.
- U. Variance – A onetime formal exception to a particular rule or rules granted for extenuating circumstances, approved by City of Tomball Staff.

III. DESIGN REQUIREMENTS

Design of drainage facilities shall meet the requirements of the City of Tomball Standard Specifications and Minimum Construction Standards for Community Improvements (Standard Construction Details). The Regulations of Harris County, Texas, for the Approval and Acceptance of Infrastructure and the Harris County Flood Control District Policy, Criteria and Procedure Manual are used to complement the City of Tomball standards. All outfall pipes, ditches, and structures that enter HCED or HCFCD ROW shall be designed in accordance with the applicable agency's criteria and standards. In cases where criteria conflict arises, the more stringent requirement of these shall be utilized.

A. Determination of Runoff Peak Flow

All drainage improvements shall be designed in accordance with the storm frequency criteria established by the City of Tomball, Harris County Engineering Department, and Harris County Flood Control District. A 25-year storm frequency (4% probability of occurrence) shall be used for the design of storm sewer systems and roadside ditches; a 100-year storm frequency (1% probability of occurrence) shall be applied to outfall systems and detention basins. The peak stormwater runoff rates shall be calculated at each inlet, pipe, roadside ditch, channel, bridge, culvert, outfall, or other designated design point in compliance with the applicable standards for the specified storm frequency requirements.

a. Rational Method for Areas Less than 600 acres

The Rational Method will be utilized to estimate peak flows for project areas up to 600 acres with individual drainage areas not exceeding 200 acres.

For drainage areas exceeding 200 acres, subdivision of the overall area into smaller drainage areas will be required for peak flow computation. This method will be applied to design storm sewer systems serving areas up to 600 acres.

In cases where the study area includes flood-prone regions and requires a FEMA submittal, hydrologic and hydraulic models must comply with FEMA-approved methodologies and standards.

b. The Run-Off Coefficient C values

The C values Rational Method Formula will vary based on the land use. Land use types and C-values which can be used are as follows:

Table 2 – Runoff Coefficients

Land Use Type	Runoff Coefficient, C
Residential Districts	
Lots more than ½ acre	0.35
Lots ¼ – ½ acre	0.45
Lots less than ¼ acre	0.55
Townhomes	0.60
Multi-Family Areas	
Less than 20 Service Units/Acre	0.65
20 Service Units/Acre or Greater	0.80
Business Districts	0.80
Industrial Districts	
Light Areas	0.65
Heavy Areas	0.75
Railroad Yard Areas	0.30
Parks/Open Areas	0.18
Undeveloped	0.30
Agricultural/Pastures	0.20
Lakes/Wet Detention Ponds*	0.95
Dry Detention Ponds	0.85
Compacted Gravel	0.80
Pavement/ROW/Roofs**	0.90

*Includes wet detention facilities computed from the top of slope

**Includes concrete and asphalt

Composite “C” values for mixed-use drainage areas are allowed for use in the Rational Formula. These values are to be obtained by calculating a weighted average of all the different “C” values of the sub-areas contributing to each mixed-use drainage area. Any calculations of these Composite “C” values are to be provided as part of the drainage calculations and provided in the plans.

$$C_w = \frac{\sum_{j=1}^n C_j A_j}{\sum_{j=1}^n A_j}$$

Where:

C_w - Weighted runoff coefficient

C_j - Runoff coefficient for area j

A_j – Sub drainage area (acres)

n - Number of distinct land uses

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

- a. Determination of Time of Concentration:

Time of Concentration (in minutes) is the time required for peak runoff, from the entire upstream contributing area, to reach the point of interest. Time of Concentration can be calculated based upon an analysis of the actual travel time from the most remote point in the drainage area. The travel path should be clearly denoted and shown in the design plans.

$$T_c = \frac{D}{60v} + T_i$$

Where: T_c = time of concentration (minutes)
 T_i = initial time (minutes) - 10 minutes for developed flows and 15 minutes for undeveloped flows
 D = travel distance on flow path (feet)
 v = velocity (ft/sec)

The following minimum and maximum velocities shall be used when calculating the Time of Concentration T_c :

Table 3 – Tc Velocities

SURFACE TYPE	Velocity (ft/sec)
Storm Sewer	3.00
Ditch/Channel	2.00
Paved Area	1.50
Overland	0.50

c. Rainfall Intensity

Harris County Flood Control District (HCFCD) have revised Intensity Duration Frequency (IDF) Curves based on National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Precipitation-Frequency Atlas of the United States. HCFCD developed three (3) Hydrologic Regions based on the Atlas 14 rainfall distribution. The City of Tomball requires the rainfall intensity for storm sewer design to be determined using the Region 1 data.

The intensity calculation is based on duration equal to the time of concentration. The intensity is calculated using the following equation:

$$I = \frac{b}{(t_c + d)^e}$$

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

Table 4 – Rational Method Intensity Coefficients

Coefficient	50 % AEP 2-Year	20 % AEP 5-Year	10 % AEP 10-Year	4 % AEP 25-Year	2 % AEP 50-Year	1 % AEP 100-Year	0.2 % AEP 500-Year
<i>Region 1</i>							
e	0.7372	0.7058	0.6819	0.6446	0.6170	0.5870	0.5111
b (in.)	48.27	51.78	54.26	54.97	54.84	53.93	50.89
d (min.)	9.30	8.19	7.44	6.27	5.45	4.53	2.69

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

B. Watershed Modeling For areas greater than 640 acres

For watersheds with a drainage area exceeding 640 acres, hydrologic analysis will follow the methodology outlined in the **Harris County Flood Control District (HCFCD) Hydrology & Hydraulics (H&H) Manual**.

a. Hydrograph Development Dynamic Conditions

For development of runoff hydrograph for use in dynamic modeling, utilize the Clark Unit Hydrograph Method.

b. Hydrograph Development Static Conditions

For development of detention volume, the approved methodology for hydrograph development shall be based upon the NRCS Dimensionless Unit Hydrograph or Malcom’s Small Watershed Method.

C. Sample Calculation Forms

1. **Appendix A**, City of Tomball Storm Sewer Calculation Table, is a sample calculation form for storm sewers.
2. **Appendix B**, City of Tomball Roadside Ditch Calculation Table, is a sample calculation form for roadside ditches.
3. **Appendix C**, City of Tomball Time of Concentration Calculation Table, is a sample calculation form for time of concentration.
4. **Appendix D**, City of Tomball Inlet Spread Calculation Table, is a sample calculation form for inlet spread.

D. Design of Storm Sewers

1. General Considerations

Drainage systems for curb-and-gutter pavement shall consist of underground closed conduits.

2. Design Frequency

a. Areas of New Development

The design storm event for sizing storm sewers in newly developed areas will be a 25-year rainfall. The storm sewer should be designed so that the design hydraulic grade line shall be at or below the gutter grade for a curb and gutter section, and six inches below the shoulder of a roadside ditch section. In any case where new development interferes with the natural sheet flow of the existing adjacent land, the storm system shall accommodate the runoff. Stubbed out streets next to undeveloped areas shall have storm sewer lines continuing to an approved outfall.

b. Areas of Redevelopment

The existing storm drain (sewer, ditch) will be evaluated using a 25-year design storm, assuming no development takes place. The storm drain will then be evaluated for the 25-year design event with the Development in place.

- 1) If the proposed Redevelopment has an equal or lesser amount of impervious surface and the existing storm drain (sewer, ditch) meets the 5-year level of service, then no modifications to the existing storm drain are required.
- 2) If the proposed development results in the hydraulic gradient of the existing storm drain below the gutter line, no improvements to the existing storm drain are required. Detention shall comply with Paragraph IV.G. Flow discharged to the storm drain shall be in compliance with Paragraph IV.G.5.c.
- 3) If the analysis of the existing conditions finds that the existing storm drain is deficient (i.e., the hydraulic grade line is above the gutter line), the applicant should check with the City to see if a CIP project is proposed that will require an impact fee. If a CIP project is not proposed for the subject system, then on-site detention will be required in accordance with Paragraph IV.G. Flow discharged to the storm drain shall be in compliance with Paragraph IV.G.5.c.

c. City of Tomball Projects (Capital Improvement Programs) or New Development/ Redevelopment that is anticipated to become City Infrastructure and ROW:

- 1) Proposed City capital improvements may indicate a larger diameter storm sewer is planned in the area proposed for drainage improvements. The City of Tomball Staff has information on proposed improvements and should be consulted for impact on new development.
- 2) Below is a brief summary of the drainage design criteria to be used in conjunction with the City's Major Thoroughfare Plan (MTFP). A drainage design hierarchy aligning with the City's latest MTFP roadway classifications is

provided below. For detailed discussion and additional criteria, refer to the following paragraphs.

Table 5 – Roadway Drainage Design Criteria

Roadway Classification (per MTFP)	Arterials	Collectors	Local ¹
Method for Determining Peak Runoff			
Less than 200 Acres	Rational Method	Rational Method	Rational Method
Greater than 200 Acres	NRCS or Malcom’s SWM	NRCS or Malcom’s SWM	NRCS or Malcom’s SWM
Culvert Crossings			
Design Storm	50-yr	25-yr	25-yr
Check Storm	100-yr	100-yr	100-yr
Headwater Control	< or = Existing Headwater Elevation	< or = Existing Headwater Elevation	< or = Existing Headwater Elevation
Maximum Outlet Velocity	Lined: 12 fps	Lined: 12 fps	Lined: 12 fps
	Vegetated Clay: 8 fps	Vegetated Clay: 8 fps	Vegetated Clay: 8 fps
	Vegetated Sand: 6 fps	Vegetated Sand: 6 fps	Vegetated Sand: 6 fps
Minimum Outlet Velocity	Lined: 2.5 fps	Lined: 2.5 fps	Lined: 2.5 fps
	Vegetated: 2.0 fps	Vegetated: 2.0 fps	Vegetated: 2.0 fps
Storm Sewers and Inlets			
Design Storm (HGL 1’ below gutter)	25-yr	25-yr	25-yr
Check Storm	100-yr	100-yr	100-yr
Design Storm Allowable Ponding Width ²	One lane each direction (divided), one-half of travel lane in each direction (undivided)	One-half of travel lane in each direction	One-half of travel lane in each direction
Check Storm Allowable Ponding Width ^{3,4}	One lane each direction open to traffic	One lane each direction open to traffic	No curb overtopping
Pipe Material	Concrete	Concrete or Plastic	Concrete or Plastic
Minimum Pipe Size	Laterals: 24 inch	Laterals: 24 inch	Laterals: 24 inch
	Trunklines: 24 inch	Trunklines: 24 inch	Trunklines: 24 inch
Minimum Pipe Velocity	3 fps	3 fps	3 fps
Maximum Pipe Velocity	12 fps	12 fps	12 fps
Roadside Ditches			
Design Storm	N/A	N/A	10-yr
Check Storm	N/A	N/A	100-yr
Maximum Design Velocity	N/A	N/A	3 fps
Side Slopes	N/A	N/A	3:1 or flatter
Minimum Freeboard	N/A	N/A	Design Storm: 0.5’ below edge of shoulder or grade at ROW, whichever is lower
	N/A	N/A	Check Storm: Within ROW
Outfall Ditches			
Design Storm	Design for No Impact for 100-yr Storm Event. Use City of Tomball and HCFCD Standard Details for Outfalls.		

¹Pavement width of 28 feet per City Ordinance Chapter 40, Article III, Sec. 40-66

²Ponding widths are based on City Details COT-STR-02, COT-STR-03, COT-STR-04, and COT-STR-05. Confirm allowable ponding widths with City Engineer for alternate cross sections.

³Conform with Paragraph IV.C.4 for maximum allowable ponding depths

⁴Open to traffic is defined as no ponding

d. Private Drainage Systems

Drainage facilities draining private areas shall be designed in conformance with appropriate design standards. The City of Tomball will not approve nor accept for maintenance a drainage system on private property unless it drains public stormwater and is located in a drainage easement. The connection of any storm sewer, inlet, ditch or culvert to a public drainage facility will be reviewed and approved by City of Tomball. Stormwater shall not be discharged or flow over any public sidewalk or adjoining property except to existing creeks, ditches, streets, or storm sewers in public ROW or easements.

Drainage to Texas Department of Transportation (TxDOT), HCFCD channels, or Harris County roadways must be approved or documented with a permit, letter or note of no objections to the plan by the Authority Having Jurisdiction (AHJ).

3. Velocity Considerations

- a. Storm sewers should be constructed to flow in subcritical hydraulic conditions if possible.
- b. Minimum velocities should not be less than 3 feet (3') per second with pipe flowing full, under the design conditions.
- c. Maximum velocities at the storm sewer system outfall should not exceed should not exceed 8 feet per second without the use of energy dissipation at the outfall.
- d. Maximum velocities within the storm sewers should not exceed 12 feet per second.

4. Pipe Sizes and Placement

- a. Soil boring with logs shall be made along the alignment of all storm sewers having a cross section equal to or greater than seventy-two inches (72") in diameter or equivalent cross sectional area. Each boring shall be taken at intervals not to exceed five hundred (500') linear feet and at a depth of less than three feet (3') below the flow line of the sewer. The required bedding will be determined from the soil boring.
- b. Use storm sewer and inlet leads with at least 24-inch (24") inside diameter or equivalent cross section. Box culverts shall be at least 3 feet (3') by 2 feet (2').

Closed conduits, circular, elliptical, or box, shall be selected based on hydraulic principles and economy of size and shape.

- i. Only single-family residential projects, without sharing storm outfall with others, shall be permitted to use the point of connection through a curb via a 4-inch schedule 40 pipe OR to connect to the roadside ditch with 12-inch schedule 40 pipe within the ROW. This option is only available if curb or ditch is directly fronting the single-family residential lot.
- c. Larger pipes upstream should not flow directly (via inlet, junction box, manhole) into smaller pipes downstream unless construction constraints prohibit the use of a larger pipe downstream, or the upstream system is intended for use as detention.
- d. Match crowns of trunk storm sewer pipe at any change in pipe size unless severe depth constraints prohibit the matching of crowns.
- e. Locate storm sewers in public street rights-of-way or in approved easements. Proposed storm sewer shall be laid underneath outside curb or edge of pavement with consideration for future maintenance and lane closures. Divided streets may allow proposed storm sewer laid parallel within median.
- f. Conduits shall connect to manholes and inlets preferably on straight alignment, however angled connection no greater than 10 degrees normal to the wall may be provided. Deflection in accordance with manufacturer's specifications will be allowed if on approved drawings.
- g. Minimum horizontal clearance between the exterior of any storm pipe or box culvert shall be at least 48 inches from the exterior of the existing or proposed public or private utility and other appurtenances (i.e., inlet or manhole).
- h. Minimum vertical clearance between the exterior of any storm pipe or box culvert shall be at least 18 inches from the exterior of the existing or proposed public or private utility and other appurtenances.
- i. Siphon design connection shall not be allowed without prior approval from City Engineer.
- j. Conflict manhole shall not be allowed without prior approval from City Engineer.
- k. In all easements restricted to storm sewers, the conduit shall be centered within the limits of the easement. The minimum width of the easement shall be two (2) times the depth plus the diameter of the pipe rounded up to the next highest five foot (5') increment but shall never be less than twenty feet (20').

- iv. Detention Pond – For the design storm event with non-submerged outfall to the receiving pond, the starting tailwater for the design storm sewer shall match the equivalent storm frequency water surface elevation of the detention pond using current rainfall criteria.
- v. For the hydraulic impact analysis, a variable tailwater at the downstream end of the model may be used (reference to TP-100). A variable tailwater condition is recommend for use for detention analyses.
- b. Should the upstream pipe be higher than the hydraulic grade line at drop in pipes invert, then the hydraulic grade line shall be recalculated assuming the starting water surface to be at the top of the pipe at that point.
- c. For the design storm, the hydraulic gradient shall at all times be one foot (1') below the gutter line for all newly developed areas.

6. Manhole Locations

- a. Use manholes at the following locations:
 - i. Size or cross section changes.
 - ii. Inlet lead and conduit intersections.
 - iii. Changes in pipe grade.
 - iv. Access points shall be provided at a maximum spacing of 300 feet (300') measured along the conduit run.
- b. Use manholes for existing monolithic-concrete storm sewers at the same locations as above except for intersections of inlet leads unless a manhole needed to provide maintenance access at those intersections.
- c. Do not place manholes in driveways or in streets in front of or immediately adjacent to a driveway.

7. Inlets

- a. Locate inlets at all low points in gutter.
- b. Valley gutters across intersections are prohibited.
- c. Inlet spacing is a function of gutter slope. The minimum gutter slope shall comply with Minimum Construction Standards for Community Improvements.

- i. For minimum gutter slopes, the maximum spacing of inlets shall result from a gutter run of 600 feet from high point in pavement or the adjacent inlet on a continuously graded street section, with a maximum of 1200 feet (1200') of pavement draining towards any one inlet location.
- ii. Inlet location should be spaced to ensure that spread does not exceed allowable ponding widths provided in Table 3.
- iii. Spread – Calculate the appropriate design storm rainfall flow approaching each inlet from each direction. Additional inlets may be required if the spread exceeds the maximum allowable value. The spread in a typical prismatic curb-and-gutter street may be calculated using the following relationships:

$$Q = \frac{k_g}{n} S_x^{2.67} S_0^{0.5} T^{2.67}$$

$$T = \frac{y}{S_x}$$

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

n = Mannings roughness coefficient

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

S_0 = Longitudinal pavement slope (or gutter slope)(ft/ft)

T = Spread

y = Ponded depth (ft)

Refer to **Table 5** for allowable spread on roadways. Spread calculations must be include

- iv. Use only City of Tomball standard inlets as listed in **Table 6**.

Table 6 – Standard Storm Sewer Inlets

Inlet	Application	Nominal Capacity ¹	City DWG No.
Type A	Parking Lots/Small Areas	2.5 cfs	COT STM-16
Type B-B	Residential/Commercial	5.0 cfs	COT STM-17
Type C	Residential/Commercial	5.0 cfs	COT STM-21
Type C-1	Commercial	10.0 cfs	COT STM-21
Type C-2	Commercial	15.0 cfs	COT STM-21
Type C-3	Commercial	20.0 cfs	COT STM-21
Type D	Parking Lots	2.0 cfs	COT STM-23
Type E	Roadside ditches	20.0 cfs	COT STM-24
Type H-2	Residential Commercial	5.0 cfs	COT STM-22

¹ The nominal capacity values provided in Table 6 are to be used for initial sizing only. The actual inlet size shall be based on hydraulic analysis of the required inlet capacity. Inlet

capacities are calculated using either orifice or weir equations depending upon their location and type of inlet opening.

- d. Do not use beehive grate inlets or other specialty inlets.
- e. Do not use grate top inlets in unlined roadside ditches.
- f. Do not place inlets in the circular portion of cul-de-sac streets without providing justification based on special conditions.
- g. Place inlets at the end of proposed pavement, if drainage will enter or leave pavement.
- h. Do not locate inlets adjacent to esplanade openings.
- i. For new residential development, locate inlets at the center of lots, such that inlets are not located within the driveway and between the radius end points as defined by the driveway radius intersection with the curb or edge of pavement, if possible.
- j. It is desirable to place inlets on side streets intersecting major streets, unless justification based on special conditions can be provided for alternate location.
- k. Type “E” inlets shall not be used in the ROW, with exception for temporary locations for interim drainage in areas of future half boulevard. Use of Type “E” inlets in this application shall be confirmed by the City Engineer.
- l. Only the private development directly behind the inlet shall be permitted to make one connection to that inlet and that connection (lead) shall be made to the back of the inlet. All other private development must connect directly to the storm sewer trunkline even in the trunkline must be extended to the front of such development. The extension is to be designed and constructed in accordance with Section IV.B.4 Pipe Sizes and Placement. Connection shall not be made to the front face or to the short sides of the inlet. Design the connection not to exceed the pipe capacity minute either the nominal capacity listed in **Table 4** or calculated inlet inflow.
- m. For all new construction, convey public or private alleyway drainage to an inlet prior to entering the public street drainage system if an underground drainage system exists.
- n. The engineer shall be required to demonstrate that inlets for design storm events have adequate capacity based on ponding and available opening as to effectively drain storm water from paved sections. A graphical plan and calculations of the

hydraulic gradient and spread calculations shall be furnished by the design engineer.

E. Consideration of Overland Flow

All storm drainage designs will take into consideration of the overland flow of runoff to account for the possibility of system inundation, obstruction, failure, or events that exceed the design storm. A representation of the overland flow scheme must be submitted with the system design.

1. Extreme Event Analysis – The design frequency for consideration of overland sheet flow will consider extreme storm event (up to 100-year storms). These events, which may exceed the capacity of the underground storm sewer system and result in ponding and overland sheet flow, shall be routed to drain along street ROW or open areas and through the development to a primary outlet.
2. Design Analysis – An overland flow analysis of the proposed drainage system shall be prepared by the design engineer. The design engineer shall submit supporting calculations, exhibits, and drawings, which define the conveyance capacity of the roadway, define the flow paths of overland sheet flow and define ponding depths of overland sheet flow.
 - a. Three analysis methods as presented in Technical Paper No. 101, Simplified 100-year Event Analyses of Storm Sewers and Resultant Water Surface Elevations for Improvement Projects in the City of Houston, Harris County, Texas Region will be acceptable to the City.
 - b. Analysis using the U.S. Environmental Protection Agency’s Storm Water Management Model (SWMM) will be acceptable to the City.
3. Relationship of Structures to Street – All structures shall be above the maximum ponding elevation anticipated resulting from the extreme event analysis. All structures shall be constructed as per the Flood Damage Prevention Ordinance (Chapter 10 Article VIII).
 - a. Use of public streets or public ROW for detention purposes is prohibited.
 - b. The maximum ponding elevation for the 100-year event at any point along the street shall not be higher than the natural ground elevation at the ROW line.
 - c. The post-project maximum water surface elevations shall be no higher than the pre-project maximum water surface elevation in surrounding areas and proposed finished slab elevation shall be above the post-project maximum water surface elevation.
4. Design Considerations

Streets shall be designed so that consecutive high points in the street will provide for a gravity flow of drainage to the ultimate outlet. If a detention facility is designed to mitigate peak flows from the extreme event, the overland flow path shall carry the extreme event sheet flow to the detention facility. If the extreme event sheet flow must enter a receiving channel, the overland flow path shall carry the extreme event sheet flow to the channel. In the event that there is no overland flow path, or the overland flow path is insufficient to carry all of the extreme event sheet flow, the inlets and storm sewer at the downstream end of the overland flow shall be sized to carry the extreme event sheet flow from the end of the overland flow path into the detention facility or receiving channel.

- a. Maximum ponding depth is determined by the allowable ponding width for the street classification as listed in **Table 5**.
- b. Sheet flow between lots may be provided only in connection with a defined drainage easement.
- c. A map(s) shall be provided which delineates extreme event flow direction for both offsite, and through a Development. The map shall also show the method of discharge to the primary drainage outlet or detention basin. Positive drainage must be provided to intercept offsite sheet flow.
- d. In areas where ponding occurs and where no sheet flow path exists, a calculation must be provided which demonstrates how the runoff from a 100-year event will be conveyed and remain in compliance with the other terms of this Paragraph.
- e. All developments shall show contours of adjacent properties within two hundred (200) feet and account for natural and existing overland flow or channelized flows.
- f. Selective reaches of the proposed storm sewer may need to be increased in size to adjust the elevations of the 100-year hydraulic grade line (HGL) to not exceed the desired HGL with respect to the roadway allowable ponding widths.
- g. Projects with multiple ponds must additionally show how the extreme event will be conveyed from pond to pond, either an overflow swale or underground pipe or box.

5. Interim Off-Site Sheet Flow

Drainage swales may be used for interim offsite sheet flow in lieu of closed conduits in phased projects and for projects adjacent to existing development. This is required any time the proposed development will cause ponding on an adjacent owner's property.

In areas where the project design incorporates fill adjacent to an abutting property, the design engineer and Contractor shall implement grading and/or perimeter runoff catchment devices during construction to ensure that adjacent parcels bordering the project site do not experience increased interim drainage flows or carry sediment generated as part of construction activities. The interim drainage allowed to leave the property shall not exceed the pre-developed conditions. Where applicable, these practices are in addition to the standard Storm Water Pollution Prevention design and shall include additional ditches redirecting site drainage or temporary piping. This note is not intended to replace or address any liability or responsibility under Texas Water Code 11.086.

F. Design of Roadside Ditches

1. Roadside ditch design is permissible only for single family residential lots or commercial areas equal to or larger than 0.75 acres.
2. The City Engineer may approve deviations from residential and commercial standards based on the particular characteristics of the proposed development. The developer should submit a written variance request on a form (**Appendix E**) for such a deviation along with all supporting material to the City of Tomball Staff prior to initiating detailed project design.
3. Design Frequency
 - a. The design storm event for roadside ditches shall be a minimum of 5-year rainfall. Refer to **Table 5 – Roadway Drainage Design Criteria** for design storm events based on street classification.
 - b. Design capacity for a roadside ditch shall be to a minimum of 0.5 feet below the edge of the pavement or 0.5 feet (0.5') below the natural ground at right-of-way line, whichever is lower, including head loss across the culvert. Design capacity calculations shall include head loss calculations for driveway and roadway culverts that are placed along the roadside ditch.
 - c. The design must include an extreme event analysis to indicate that structures will not be flooded, and the maximum ponding elevation for the extreme event complies with Paragraph IV.C.3
 - d. Outfall drainage to existing roadside ditches shall be limited to tracts with frontage along the roadside ditch. If no frontage to the roadside ditch exists, but it can be shown with detail topographic surveys that the tract ultimately drains to the roadside ditch, then outfall will only be considered with no impact on adjacent properties or the receiving storm system.

4. Velocity Considerations

- a. For grass-lined sections, the maximum design velocity shall be 3.0 feet per second during the design event.
- b. A grass-lined or unimproved roadside ditch shall have side slopes no steeper than three (3) horizontal to one (1) vertical (3:1) or as soil conditions will permit.
- c. Minimum grades for roadside ditches shall be 0.1-foot per 100 feet.
- d. Calculation of velocity will use a Manning's roughness coefficient (n) of 0.040 for earthen sections and 0.025 for ditches with paved inverts.
- e. Use erosion control methods acceptable to the City when design velocities are expected to be greater than three feet (3') per second or where erodible soil conditions are indicated in the geotechnical report.
- f. The top of bank shall not encroach beyond the City ROW or within 2 feet of the edge of pavement.

5. Culverts

- a. Culvert standards for driveways are provided by Drawing No. COT DW-06, COT DW-07, AND COT DW-08 Minimum Construction Standards for Community Improvements.
- b. Culverts shall be placed at all driveway and roadway crossings, and at other locations where appropriate.
- c. Culverts shall be evaluated for inlet and outlet control, as well as normal depth. The highest of the three shall be designated as the computed headwater for design of the culvert section.
- d. Roadside culverts are to be sized based on drainage area. Calculations are to be provided for each block based on drainage calculations. Headlosses in culverts shall conform to TxDOT Hydraulics Manual.
- e. The minimum culvert size shall be 18 inches (18") in residential areas and 24 inches (24") in non-residential areas. Smaller culverts may be allowed with approval from City of Tomball Staff.
- f. In the ETJ or along Harris County ROW, the Regulations for Harris County, Texas for Construction of Driveways and/or culverts on County Easements and ROW shall govern.

- g. All proposed and reasonably expected future culverts shall be included in the hydraulic profile. The proposed culvert shall not create a headloss of more than 0.20 feet (0.20') greater than the normal water surface profile without the culvert.
- h. Stormwater discharging from a ditch into a storm sewer system must be received by use of an appropriate structure. (i.e., stubs with ring grates or Type E Inlets.).
- i. Culverts may not be extended across property frontage to cover the roadside ditch except for driveways.
- j. Safety end treatments will be required on roadways with posted speeds over 30 mph for parallel and cross culverts.
- k. Parallel drainage may elect to use High-Density Polyethylene (HDPE) pipes for private driveways. Cross culverts shall be comprised of Reinforced Concrete Pipe (RCP) or Polypropylene pipe (PP) in accordance with the latest Construction Standards and Technical Specifications.

6. Invert Protection

- a. Ditch invert protection shall be used when velocities exceed 3 feet (3') per second.
- b. Ditch invert protection will be used at the upstream and downstream ends of all culverts.

7. Depth and Size Limitations

- a. The maximum depth for a roadside ditch shall not exceed four feet (4') below the adjacent road centerline top of pavement. There may be instances where extreme conditions may warrant a deeper ditch. In those cases, specific written prior approval must be obtained from the City of Tomball Staff.
- b. Roadside ditch bottoms shall be at least two feet (2') wide, unless design analysis supports a narrower width and prior written approval is obtained from the City of Tomball Staff.
- c. A minimum distance of two feet (2') shall be established and maintained between the right-of-way line and the adjacent edge of the bank of a ditch.
- d. Roadside ditches shall drain streets and adjacent land areas.

G. Design of Open Channels

1. Design Requirements and General Criteria

- a. Open channels shall be designed and constructed according to the methods described in the HCFCD Criteria Manual and shall convey the 100-year event unless otherwise directed by the City of Tomball Staff.
 - b. Design standards for outfalls into channels shall conform to those in the HCFCD Criteria Manual.
2. Determination of Water Surface Elevation
- a. Water surface elevations shall be calculated using Manning's Equation and the Continuity Equation.
 - b. For the design storm event, the water surface shall be calculated to remain within banks.
3. Design of Culverts
- a. Head losses in culverts shall conform to TxDOT Hydraulics Manual, Chapter 8, Culverts.
 - b. Corrugated metal pipe will not be approved for permanent culverts in the City of Tomball ROW except at railroad crossings, and if used underneath the railroad crossing, the culvert shall be designed to railroad loadings.
4. Design of Outfalls – All outfall designs shall conform to the HCFCD Criteria Manual.

H. Stormwater Detention

As a normal consideration, storm water detention shall be required. The intention of stormwater detention is to mitigate the effects of New Development, Redevelopment, or Site Modifications on an existing drainage system. This section of the Manual presents background information on stormwater storage techniques and detailed guidelines and criteria for the design of stormwater storage facilities.

Stormwater detention volume requirements are based on the acreage of the Disturbed Area that results in Impervious Surface or alters stormwater runoff. Stormwater detention volumes are calculated at the minimum rates set forth in the Paragraphs below.

1. Application of Detention

- a. The use of on-site detention is required for all Developments within the City, for new or expanding utility districts within the City's ETJ, and for all Developments outfalling into City facilities. Detention may not be required if the City has developed detention capacity for a drainage watershed, and/or infrastructure improvements, to serve the drainage watershed in compliance with the requirements of this Manual. If the City has developed a plan for a regional detention facility to serve a watershed, then the development is responsible for all costs of constructing the system to convey flows from their project to the regional facility. Under these conditions, the City will consider a funding contribution in lieu of on-site detention volume constructed by the Owner.
- b. Stormwater detention requirements are invoked for redevelopments that include disturbed area resulting in increased Impervious Surface. Existing impervious area will be credited based on site conditions at the time of submittal and shown on a topographical survey. Credit for impervious cover based on historical evidence or imagery that does not exist at the time of submittal is not permitted.
- c. If the drainage system outfalls directly into a channel maintained by HCFCD and the requirements of HCFCD include payment of an impact fee, then no further impact fee will be required by the City.
- d. Project sites that discharge directly into Harris County, HCFCD, or other jurisdictions require their review and approval. For project sites that discharge directly into other jurisdiction and there is a conflict between the detention criteria, the more restrictive criteria shall govern.
- e. All calculations shall be sealed and signed by a Professional Engineer licensed to practice engineering in the State of Texas.
- f. The City no longer allows timing analysis to avoid detention requirements.
- g. A master drainage plan for the purpose of grandfathering projects regarding drainage and detention is as follows:

A master drainage plan establishes the current and future drainage plan for a developmental site. A master drainage plan generally consists of drainage, grading, detention, and other applicable site plans. These site plans contain detailed calculations for impervious area, detention, restrictors, flow rate, etc. signed and sealed by a Registered Professional Engineer in the state of Texas.

For any master drainage plan previously approved by the City with programmed detention that is not based on the effective rainfall data, the City shall allow the development to complete construction of the ultimate detention facility under the previously approved master drainage plan for up to two (2) years from adoption of this Drainage Criteria Manual and/or effective rainfall data.

For any master drainage plan previously approved by the City with programmed detention that is not based on the effective rainfall criteria and has not completed construction of the ultimate detention facility within two (2) years from adoption of this Drainage Criteria Manual and/or effective rainfall criteria, then the detention facility must comply with the current detention requirements at the time of permitting.

- h. Plat, replat, change the use of, or subdividing any tract to reduce stormwater detention requirements will not be permitted. Original tract size on plat or replat, change the use of, subdividing, HCAD and survey will be used to determine stormwater detention requirements.

2. Types of Storage Facilities

- a. Regional Detention – The City has implemented and continues to evaluate and improve regional detention facilities that collect and hold stormwater from more than one development. Participation in regional detention shall be coordinated with the City of Tomball Staff. Excavation within limits of the planned regional detention basin for the purposes of offsetting project detention may be considered and shall be coordinated with the City of Tomball Staff.
- b. In-Line Detention – A type of storage technique occurring within the channel ROW and typically near the headwaters of a watershed or basin. In-line detention within programmed channel reaches adopted in the latest Drainage Master Plan is prohibited.
- c. Off-Line Detention – This type of storage facility diverts a portion of a hydrograph from a nearby channel only when specific parameters are met. These facilities are typically adjacent to a channel with a side weir as acting as the control structure. Off-line detention may be considered on a case-by-case basis and shall be coordinated with the City of Tomball Staff.
- d. On-Site Detention – An on-site detention basin generally receives runoff from a small drainage area consisting primarily of one or more development projects. On-site detention usually consists of one or more detention ponds.
 - i. Parking Lot Detention Storage – The use of parking lot storage to mitigate developed flow may be used but will require prior approval from City of

Tomball Staff. The use of parking lot storage for multifamily developments is prohibited.

- e. Pumped Detention System – Stormwater detention facilities requiring mechanical pumping systems in conjunction with a gravity outfall system.
 - f. Underground Detention – Underground detention may be achieved in pipes, boxes, chambers, modules, or vaults.
 - i. The City will recognize up to 20% of void space in aggregates for underground systems with the appropriate documentation and design documents.
 - ii. All underground detention systems shall be designed such that the bottom of the underground system can be viewed from the ground surface without the need for confined space entry.
 - iii. Pipe and inlet storage – Storm sewer pipe and inlet boxes may be counted as detention storage used to mitigate developed flows subject. The design engineer shall provide a detailed accounting of the pipe storage provided on the plans and prove that the pipes and inlets will fill during a storm event based upon hydraulic or other analysis.
 - g. Low Impact Development (LID) – techniques that may be considered on a case-by-case basis for achieving detention are Bioretention, Infiltration Trenches, Porous Pavement, Vegetative Swales, Green Roof, Hard Roof, and Rain Barrels. Design Engineer shall coordinate with City of Tomball Staff on acceptable methods of detention.
3. Calculation of Detention Volume
- a. Detention volume for redevelopment and new Development areas is calculated on the basis of increased impervious cover or alters stormwater runoff, associated with the project development.
 - b. Detention Volume for a tract containing only one Single Family Residential (SFR) home, follow **Table 7**:

Table 7– Detention Volume for a SFR Tract

SFR Tract Size	Percentage/Total Impervious Area ¹	Detention Required (Y/N)	Detention Volume	Notes
One SFR tract ≤ 15,000 SF	% Total impervious area ≤ 45% of tract	N	N/A	2-3
One SFR tract ≤ 15,000 SF	% Total impervious area > 45% of tract	Y	0.75 ac-ft/ac × impervious area in excess of 45% of tract	2-3
One SFR tract > 15,000 SF	Total impervious area ≤ 9,750 SF	N	N/A	2-3
One SFR tract > 15,000 SF	Total impervious area > 9,750 SF	Y	0.75 ac-ft/ac × impervious area in excess 9,750 SF	2-3

¹ Total impervious area = (existing + proposed) impervious area

² For a tract with multiple lots, the detention exemption shown in Table 7 is not applicable. Refer to Table 8 for detention volume requirements.

³ No sheet flow shall be permitted to an alleyway, neighboring properties, nor a ditch. Without sharing storm outfall with others, a point of connection shall be through a curb via a 4-inch schedule 40 pipe or to the roadside ditch with a 12-inch schedule 40 pipe within the ROW.

⁴ When a tract of land is subdivided into multiple lots, detention is required for all proposed impervious area within the lot. No residential exemption will be granted for the individual lot within this subdivision tract.

c. Detention Volume for other projects not subject to Paragraph IV.F.3.b, follow **Table 8:**

Table 8 – Detention Volume

Tract Size	Detention Required (Y/N)	Minimum Detention Volume Rate	Detention Calculation Method	Notes
Tract ≤ 5 acre	Y	0.75 ac-ft/ac	Method 1	1-3
5 acre < Tract ≤ 200 acre	Y	0.75 ac-ft/ac	Method 2 or 3	1-3
Tract > 200 acre	Y	0.75 ac-ft/ac	HEC-HMS/HEC-RAS	1-4
Tracts in basins with available regional detention	Y	N/A	Tract Area	1-3

¹ No sheet flow shall be permitted to an alleyway, neighboring properties, nor a ditch. Without sharing storm outfall with others, a point of connection shall be through a curb via a 4-inch schedule 40 pipe or to the roadside ditch with a 12-inch schedule 40 pipe within the ROW.

² For project within the City limits or draining to City maintained facilities, the minimum detention rate is 0.75 ac-ft/ac.

³ If the modelling is associated with a FEMA submittal, the models to be used must be acceptable to that agency

⁴ For project over 200 acres, HEC-HMS, HEC-RAS modelling shall be performed. Refer to HCFCO Hydrology and Hydraulic Modeling and Management Standards.

d. Methods For Calculation of Detention Volume

Regardless of the results of the methodology selected, the minimum detention required for all non SFR projects as described in Paragraph IV.F.3.b and **Table 7** shall be 0.75 ac-ft/ac of exceeded impervious surface in addition to floodplain fill mitigation.

For all non SFR projects as described in Paragraph IV.F.3.c and over 5 acres in tract size, the design engineer shall estimate the detention required using Method 2 or Method 3 as presented below. The design engineer shall compare the calculated detention volume from Method 2 or 3 versus minimum detention volume and use whichever method provides the greater volume.

For all projects

i. Roadway Impacts and Mitigation (CIP Projects)

Due to the different characteristics of roadway and land development projects, the impacts associated with roadway project cannot be fully analyzed using typical land development techniques. For CIP projects related to new roadways, widening existing roadways, or converting from roadside ditch to storm sewer drainage, refer to HCFCD Policy Criteria and Procedure Manual Section 6.16 for routing analysis and appropriate mitigation measures.

ii. Method 1 – Simplified Method

The simplified method yields a minimum detention volume by multiplying the total increased impervious area by the minimum detention volume rate of 0.75 ac-ft/ac.

iii. Method 2 – Small Watershed Hydrograph

The Small Watershed Hydrograph Method is a method for developing a curvilinear design hydrograph for small to moderate size drainage areas (less than 640 acres) which peaks at a designated flow rate and contains a runoff volume consistent with the design rainfall as update by Atlas 14.

The Small Watershed Hydrograph Method consists of the following equations:

$$T_p = \frac{V}{1.39Q_p}$$

$$q_i = \frac{Q_p}{2} \left[1 - \cos \left(\frac{\pi t_i}{T_p} \right) \right] \quad t_i \leq 1.25T_p$$

$$q_i = 4.34Q_p e^{\left(-1.3t_i/T_p \right)} \quad t_i > 1.25T_p$$

Where: Q_p = peak discharge (cfs)
 T_p = time to Q_p (seconds)
 V = total volume of runoff for e design storm event (cubic feet)
 t_i and q_i = the respective time and discharge which determine the shape of the hydrograph

Note: Calculator must be in radian mode.

The peak flow rate, Q_p , is obtained from the Rational Method. **Table 9** below gives typical values for the rainfall excess based on percent impervious cover. The actual values may be interpolated from the table. The design engineer shall calculate the actual impervious cover conditions proposed on the project.

Table 9 – Direct Runoff Excess Values¹

Impervious Cover	2-Year	10-year	25-Year	100-Year
	Direct Runoff (in)	Direct Runoff (in)	Direct Runoff (in)	Direct Runoff (in)
Total	4.8	8.2		16.3
0	2.3	4.9		12.2
20	2.7	5.5		12.9
40	3.1	6.0		13.6
60	3.5	6.5		14.3
85	4.0	7.2		15.1

¹ Harris County Flood Control District Policy Criteria and Procedure Mnaual

iv. Method 3 – Unit Hydrograph Method

The Clark Unit Hydrograph may be developed to convert excess rainfall into a runoff hydrograph. The HEC-HMS software program is acceptable to the City for models resulting in a discharge hydrograph produced from a storm event.

- Values for percent impervious for existing and proposed conditions shall be calculated by the design engineer.
- Time of concentration shall be estimated using a velocity-based method.
- Calibrate the watershed storage coefficient (R) such that the resulting peak discharge matches the Rational Method peak flow.
- Point rainfall depths for HCFCD Region 1 can be found in **Table 10** to be used in meteorological models:

Table 10 – Point Rainfall Depth (Inches) Duration-Frequency Values¹

Duration	Depth (in)				
	10-year	25-Year	50-Year	100-Year	500-Year
5-min	0.81	0.96	1.07	1.19	1.49
15-min	1.62	1.91	2.13	2.36	2.95
60-min	3.07	3.64	4.06	4.51	6.58
2 Hours	4.03	4.94	5.67	6.49	10.4
3 Hours	4.66	5.85	6.84	7.99	11.5
6 Hours	5.79	7.47	8.94	10.7	15.9
12 Hours	6.95	9.13	11.1	13.4	20.1
24 Hours	8.22	10.9	13.4	16.3	24.2

¹ Harris County Flood Control District Hydrology & Hydraulics Guidance Manual

- Green and Ampt Loss Method Parameters:

- Initial Storage = 0%

- Volume Moisture Deficit (Initial Deficit) = 0.385

- Wetting Front Suction Head (Suction) = 12.45 inches

- Conductivity = 0.024 in/hr

4. Pumped Detention Systems

- a. All stormwater detention facilities requiring mechanical pumping systems shall limit the volume of pumped flow to 50% of the total basin capacity
- b. Automatic controls shall be incorporated to shut off all pumping when outfall system capacity is reached. Additionally, a gravity return line to the detention facility must be provided for additional head control in the event of failure of automatic level controls. Pumping cannot be resumed until the outfall has receded to one-half (1/2) the depth of the roadside ditch.
- c. The detention facility shall be designed to empty the storage volume within four (4) days. If drain time is longer than four days, increase in detention volume that approximate the drain time shall be designed in accordance with Harris County Engineering Department Regulations.

5. Project Routing Techniques

All projects over 5 acres shall route the design hydrograph through the detention basin. Adjustments of storage capacity and outflow structures, if required, to ensure the maximum allowable outflow rate is not exceeded. This routing should be performed in an appropriate computer program such as HEC-HMS or EPA SWMM (or

others as approved by the City of Tomball Staff). The outflow structure shall be designed to restrict discharge to the 100-year allowable design flows.

If the modelling is associated with a FEMA submittal, the models to be used must be acceptable to that agency.

For project over 200 acres, HEC-HMS and HEC-RAS modelling shall be performed. The HEC-HMS modeling shall include analysis of existing and developed runoff. Refer to HCFCD Hydrology and Hydraulic Guidance Manual.

6. Calculation of Outlet Size

a. Discharge Rates

- i. The maximum allowable release from a development shall be determined based on pre-development conditions and limited to the capacity allowed to the subject tract of the receiving system. The undeveloped peak flow rate shall be determined using the rational method.
- ii. Flow discharge to a storm drain shall not exceed the proportional amount of pipe capacity allocated to the Development. The proportional amount of pipe capacity allocated to the Development shall be determined by the ration of area (acres) of the Development (in storm drain watershed) divided by the total drainage area (acres) of the storm drain multiple the capacity of the storm drain.

b. Outflow Structures

- i. To restrict outflow with a short segment of pipe or reduced opening size, use the orifice equation below:

$$Q = CA\sqrt{2gH}$$

Where: Q = outflow discharge (cfs)

C = coefficient of discharge - 0.8 for short segment of pipe and 0.6 for opening in plates, standpipes, or concrete walls

A = orifice area (square feet)

g = acceleration due to gravity (32.2 feet/second²)

h = head difference between entrance and exit in feet when orifice is fully submerged, or the difference between the water surface elevation at the entrance and the centroid of the orifice in feet when the orifice is partially submerged.

An appropriately sized restrictor system must be installed to ensure detention volume is utilized. The restrictor shall be either of the required diameter or of the equivalent cross-sectional area. The orifice diameter D

shall be a minimum of 6 inches (6"). The outfall pipe containing the restrictor shall be a minimum of eighteen inches (18") or six inches (6") greater than the restrictor pipe size, whichever is larger. The restrictor pipe shall always be placed at the upstream end of a pipe open towards the detention pond to enable cleaning.

All gravity discharges to a roadside ditch or channel shall be designed to prevent erosion of the receiving system.

- ii. To control the design outflow or the emergency overflow from a detention basin with a weir, use the following equation:

$$Q = CLH^{3/2}$$

Where: Q = weir discharge (cfs)

C = weir coefficient (refer to HCFCD PMCM)

L = horizontal length of weir (feet)

H = head on weir (feet)

A weir set below the 100-year developed water surface elevation shall be used to discharge during the 100-year design condition. The weir should be sized so that the peak discharge does not exceed the 100-year allowable discharge rate with the basin full.

7. Emergency Overflow

- a. An emergency overflow structure or route is required for all detention systems. Design Engineer shall design the emergency overflow as a path for the water to follow when water levels exceed the 100-year storm event in the detention pond.
- b. The emergency overflow weir or structure shall be designed to pass the 100-year ultimate developed flow assuming the primary outflow is obstructed without exceeding the low natural or finished ground elevations.
- c. The extreme event must be directed toward public right-of-way or an appropriate drainage easement.

8. Structural and Geometric Parameters for Detention Ponds

- a. The design engineer is responsible for the design of all structural components within the project stormwater design.

- b. Side slopes shall not exceed a slope of four (4) horizontal to one (1) vertical. Site specific geotechnical recommendations may be used in lieu of minimum requirements such that appropriate safety and stability were considered.
- c. Ponds with lengths over fifty (50) feet shall have a pilot channel.
- d. Lined (concrete) pilot channels shall have a minimum width of six (6) feet, a minimum depth of six (6) inches, and a minimum longitudinal slope of 0.002 feet per foot.
- e. Unlined (grass) pilot channels shall have a minimum depth of two (2) feet, maximum side slopes of 4:1, and a minimum longitudinal slope of 0.005 feet per foot.
- f. The bottom slopes of the detention basin should be graded toward the low-flow pilot channel or outfall. The transverse slope of the bottom shall be a minimum slope of 1%, with 2% preferred.
- g. Maintenance Berms will be required. At a minimum, maintenance berms shall be 10 feet from the property line, right of way, or structure. All detention ponds shall have maintenance berms as follows:

Table 11 – Detention Pond Maintenance Berms

Pond Depth (ft)	Berm Width (ft)
≥2'	10
> 2' – 5'	15
> 5' – 10'	20
> 10'	30

- h. Extreme Event Spillways – The drainage system must be designed to adequately deal with an extreme rainfall event. The extreme event shall be designed as an event which includes or exceeds the 100-year flow. The detention basin shall be provided in addition to the outfall structure with a gravity spillway that will protect structures from flooding in the event the capacity of the basin is exceeded.
- i. Freeboard – Detention ponds shall maintain a minimum freeboard of one foot (1') between the top of bank and the 100-year water surface elevation.

In cases where a pond discharges to a shallow outfall point, the City of Tomball Staff may allow a reduction of the minimum freeboard provided the following criteria is met. Note: the following criteria is for a reduction in freeboard and is only required when less than one foot (1') of freeboard is proposed.

- i. The freeboard volume shall never be less than 25% of the total detention storage volume.
- ii. The freeboard shall never be less than 6 inches.

Freeboard shall be measured from the 100-yr design water surface elevation to the minimum top of bank elevation.

- j. Wet bottom basins shall meet the following criteria:
 - i. A minimum of six feet (6') of permanent water depth is required unless the wet bottom is for purposes of wetlands.
 - ii. A ten-foot (10') minimum shelf, one-foot (1') above the static water surface elevation is required.
 - iii. Side slopes shall be a ratio of 4:1 or flatter from above the shelf to natural ground. Side slopes shall be a ratio of 3:1 from shelf to bottom of basin. Alternatives may be approved provided the facility design demonstrates that it can be easily maintained with due consideration of public safety.
- k. If approved for detention through ponding in private parking areas, the maximum depth of ponding cannot exceed six inches (6") directly over the inlet grate. In such cases, the areas shall provide signage stating that the area is subject to flooding during rainfall events.
- l. If approved for detention through ponding in private transport truck only parking, the maximum depth of ponding cannot exceed fifteen inches (15") directly above the inlet. In such cases, the areas shall provide signage stating that the area is subject to flooding during rainfall events.
- m. All mitigation facilities shall be located within or adjacent to the project area.
- n. Level spreaders or flow dispersion trenches are prohibited.

9. Detention Facility Ownership and Easements

- a. Private Facilities:
 - i. Pump discharges into a roadside ditch must require the following:
 - Submittal of pump specifications, including capacity (GPM) of the pump, on the design drawings.
 - Provide a backup pump in the event of a pump failure.

- Provide emergency power from a second source to install a quick connect for a mobile generator.
 - Provide a stilling basin to dissipate the energy from the pump outlet prior to gravity flow into the ditch or storm sewer.
 - ii. The City reserves the right to prohibit the use of pump discharges where their use may aggravate flooding in the public ROW.
 - iii. Responsibility for maintenance of the detention facility must comply with City Ordinance Section 18-287.
 - iv. All private properties being served shall have drainage access to the pond. Dedicated private drainage easements may be required.
 - v. A private maintenance agreement shall be provided when multiple tracts are being served.
- b. Public Facilities:
- i. Facilities will only be accepted for maintenance by the City in cases where public drainage is being provided.
 - ii. The City requires a maintenance work area of 30-foot width surrounding the extent of the detention area. Public rights-of-way or permanent access easements may be included as a portion of this 30-foot (30') width.
 - iii. A dedication of easement shall be provided by plat or by separate instrument.
 - iv. Proper dedication of public access to the detention pond must be shown on the plat or by separate instrument. This includes permanent access easements with overlapping public utility easements.

IV. SUBMITTALS

A. Online Portal (SmartGOV)

The City of Tomball has adopted an online electronic submittal process as of January 1, 2024. All application/plan submittals and inspection requests must be submitted via the online permitting program “SmartGOV”. Previous systems for submitting applications/plans and requesting inspections have been discontinued.

B. Submittals for review and comment

1. Submittals of one-line drawings is recommended and may be required as part of the platting process.
2. Approximate definition of lots and street patterns.
3. City of Tomball Review Sheet. (See **Appendix F**)
4. Any proposed drainage easements.
5. A copy of recorded subdivision plat, survey, metes & bounds description, and deed for property confirming date of parcel creation being prior to August 15, 1983.
6. CenterPoint Energy Address Assignment Letter
7. Floodplain information, including floodplain boundary, if any: FEMA map number, effective map date and zone.
8. Copies of any documents which show approval of exception to City design criteria.
9. Design calculations for time of concentration, composite land use factors, storm line sizes and grades, and for detention facilities, if any.
10. Design calculations for the Hydraulic Grade Line of each line or ditch, and for detention facilities, if any.
11. Drainage Area Map with the following information:
 - a. Description of drainage basin and total development area.
 - b. Existing contour map.
 - c. Existing and Proposed drainage area and sub-drainage area boundaries.
 - d. Existing and Proposed Drainage area (acres) and flow quantity (cfs) draining to each inlet and each pipe segment from storm structure (i.e. manhole, inlet, catch basin, etc.) to storm structure.
 - e. Extreme event (100-year) sheet flow direction.

- f. Existing condition and developed condition sheet flow direction for the surrounding properties.
12. Plan and profile sheets showing stormwater design (public facilities only).
- Projects located within a floodplain boundary or within a floodplain management area shall:
- a. Show the floodplain boundary or floodplain area, as appropriate, on the one-Drainage Area Map.
 - b. Comply with all applicable submittal requirements of City Ordinance Chapter 10 Article VIII.
 - c. Review and approval of this project by the City Floodplain Administrator is required.
13. Profile drawing of roadway (or overland flow path) with exaggerated vertical scale from the upper reach of drainage area to the primary drainage outlet. Show roadway profile at gutter, ground profile at the public right-of-way, and hydraulic gradient lines for the design storm event and 10—year extreme event, or an alternative equivalent drawing accepted by the City.
14. Calculation for proportional amount of pipe capacity allocated to the development along with the drainage area map used for these calculations.
15. If the detention has been provided by other projects, a Memorandum should be provided to explain how the existing detention facility serves this project.

C. Signature Stage – Submit the following for approval:

- 1. Review prints with all comments.
- 2. Original drawings.
 - a. Provide City of Tomball Permit Number on cover page.
 - b. Provide all information requested in Paragraph V.B.
- 3. All required permits from other agencies (i.e., HCFCD approval, HCED approval, TxDOT, etc.)

V. QUALITY ASSURANCE

Prepare calculations and design drawings under the supervision of a professional engineer trained and licensed under the disciplines required by the project scope. The final design drawings and all design calculations must be sealed, signed, and dated by the professional engineer, licensed by the State of Texas, responsible for the development of the drawings.

VI. SURVEY

Projects shall be tied to the National Geodetic Survey (NGS) datum adjustment which matches the Federal Emergency Management Agency (FEMA) rate maps or the most current NGS datum which matches the FEMA rate maps. In the event GPS surveying is used to establish bench marks, at least two references to bench marks relating to the rate maps shall be identified. Equations may be used to translate other datum adjustments to the required adjustment.

VII. LOW IMPACT DEVELOPMENT

Low impact development is a comprehensive land planning and engineering design approach with the goal of maintaining, as the minimum, the pre-development hydrologic regime in a watershed. A conceptual design meeting shall be held with the City of Tomball Staff. Design concepts are approved prior to proceeding to preliminary design.