Drainage Criteria Manual

I. INTRODUCTION

Purpose

This Drainage Criteria Manual provides design guidance for use by developers and engineers in preparation of drainage plans for development within the City of Sealy. It establishes rules and regulations that must be consistently followed and will be enforced throughout the areas of the city. The design methods presented in this manual are intended to provide guidance for determination of runoff rates; methods of storm water collection, conveyance, and detention; and design standards for facilities (ditches, ponds, detention basins, etc.).

Methods of design and analysis other than those included in this Manual may be considered in certain cases where there may be inherent problems with the traditional methods. However, any deviation form this Manual will require consideration and acceptance by the City Engineer before approval will be granted for any work based on these alternatives. The City is in the process of establishing a master drainage plan and implementation process, as the city progresses through this study individual basins and areas may have specific requirements and impact fees.

Policy

Due to the nature of the watershed hydraulics within the City of Sealy and the prevalent existence of flood plains that exceed the banks of the creeks, it shall be the policy of the City of Sealy to maintain zero net increase in storm water runoff rates and to insure no negative impacts are attributable to new development. Although it is the City of Sealy's long-term goal to construct and maintain facilities (i.e., channels and regional detention facilities) that will contain 100-year storm flows within drainage rights-of-way, it is recognized that further impacts cannot be tolerated in the interim period. It is further recognized that impacts to other land owners and jurisdictions outside of the City of Sealy's boundaries are unacceptable, and the City of Sealy is dependent and supportive of the action of others to construct upstream and downstream facilities to accommodate 100-year flows.

Individual developers must provide infrastructure required to meet the City of Sealy's stated objective of zero net increase in runoff rates and no negative impacts. Practically, this will mean that developers will provide adequate on-site detention volume to off-set increased runoff rates and must provide compensating storage volume for all fill placed in the floodplain. Development in the delineated 100-year floodway will be restricted by the City of Sealy. The City of Sealy prefers separate off-line detention facilities, but in-line facilities will be considered on a case-by-case basis and will only be approved after the City of Sealy is satisfied that there will be no negative impacts to adjacent property owners.

II. ADMINISTRATION

Submittal

The City of Sealy has authority for review and approval of development plans for projects within it's city limits. Prior to commencing construction on proposed improvements, a full sized set (22"x24" or 24"x36") of plans, plats, reports, and calculations shall be submitted for review. Proposed plats and plans shall be submitted for each development unless an overall master drainage plan for the development has been previously approved, in which case the applicant must demonstrate compliance with the approved master plan. All plans and reports must be prepared and sealed by a Professional Engineer licensed to practice in the State of Texas.

Site Visit

The City of Sealy may require a representative of the property owner or developer to meet with City of Sealy Representative at the project site prior to drainage plan approval. This meeting shall be for the City of Sealy's benefit and allow the City of Sealy Engineer to better understand the developer's intentions.

Datum

All topographic information shown on plans must be on the same vertical datum as the current FEMA FIRM Map showing the project area.

Drainage Plan Review

The drainage plan shall present the applicant's overall approach to collecting and conveying rainfall runoff to the appropriate drainage artery. It is recommended that prior to preparation of the plan a meeting be arranged between the applicant and the City of Sealy Engineer to discuss the proposed concept for drainage of the project. The design submittal shall contain the following items:

1) Name, address, and phone number of engineer that prepared the plan including contact person.
2) Scale of drawing with a minimum scale of 1" = 100'.
3) Benchmark and reference benchmark with datum and year of adjustment.
4) A detailed location or vicinity map drawn to a scale. The project site shall be accurately located on the map.
5) Date on all submittals with date of all revisions with month, day and year.
6) Signature lines for The City Engineer.
7) Contour lines 1 foot where slopes do not exceed 2.0% and 5 foot intervals for slopes exceeding 2.0% intervals covering covering the entire development and extended beyond the development boundaries at least 50 feet on all sides. At least two contours are required for each project.

8) Preliminary scheme for the passage of sheet flow from adjacent properties.
9) Drainage area divides for project area, with peak run-off rates for each drainage area.
10) Locations of all planned drainage improvements proposed for moving run-off water from the development to the principle drainage artery, i.e., creek, stream, bayou, ditch, etc., and their point(s) of entry into the drainage artery.
11) Points at which structures or pipelines will cross drainage ditches, streams, etc., within the development.
12) Locations of structures or other physical features on the development area to provide orientation as required during field inspection of the site.
13) Location of all existing drainage structures, utility lines, pipelines, and other underground features on the property and adjacent rights-of-way.
14) Location and dimensions of all proposed drainage easements and rights-of-way.
15) Location of major drainage arteries adjacent to or crossing the development.
16) Cross-section of detention facility.
17) Detention calculations including volumetric calculations of detention provided.
18) Drainage area map of receiving system, if discharging to existing storm sewer system. Drainage area of receiving channel if discharging to open ditch or stream. Include calculations to prove capacity is available.
19) Copy of approved permit from TxDOT or County if draining to impacting their system.
20) Copies of documents and letters of request for permission to cross privately held easements or rights-of-way and their approvals to do so.
21) Limits of 100-year flood plain.

<u>Time Limits of Approvals</u>

Approvals shall expire within one (1) year if a construction has not commenced within that time. In cases where approval is given for a master plan and only certain sections are built immediately, the master plan approval will be valid for five (5) years.

Upon written request, the City Engineer may grant extensions of approval for up to (1) year. All requests for extensions must be approved prior to the expiration of the original approval. No more than one (1) extension will be granted.

<u>Revisions to Drainage Plans and Reports</u>

All revisions to either the approved drainage plan or plat must be approved by the City Engineer. The City Engineer may require a re-submittal of a drainage plan or report dependent upon the character and extent of the changes made as determined by the City of Sealy.

III. HYDROLOGY

Hydrology is the study of precipitation. Policy makers and engineers must study and understand hydrology because they are interested in designing and building structures and systems to safely convey and discharge precipitation runoff while minimizing the potential of flooding. They must determine how much water should be collected, conveyed and stored and how fast this process should take place. Other parameters to consider include: discharge rate and other effects to downstream property. The following sections discuss specific parameters and methods to be used in analyzing proposed developments in the unincorporated areas of the City of Sealy. Developers will have the right to use various established methodologies in determining the impact of their proposed developments. The following is just several of many commonly accepted practices.

Storm Frequency

All drainage improvements, at the minimum, shall be designed for the following storm frequencies. The return intervals listed here are minimums, and the individual design engineer or the City of Sealy may choose to exceed these minimums given site specific requirements or constraints.

Type of Facility	Return Interval Storm
Closed Conduit Storm Sewers (for new developments)	2 year
Ditch Culverts (serving 0 to 250 acres)	25 year
Ditch Culverts (serving 250 acres or more)	50 year
Bridges Crossing Ditches	100 year
Major Ditches and Channels	100 year
Detention Facilities	100 year

Frequency Factor (C_f)

The Frequency Factor is used in the Rational Method to scale the magnitude of peak runoff in relationship to the return interval of the storm consistent with observed runoff data. This adjustment factor is used to account for the effects of antecedent moisture conditions that are generally associated with the less frequent storms. Appropriate values of C_f are presented in the following table.

Storm Frequency	Frequency Factor (C_f)
10	1.00
25	1.10
100	1.25

The product of C_f and C used in the Rational Method should not exceed 1.00.

Basin Time of Concentration (T_c)

The storm rainfall Intensity used in Rational Method will be selected based upon the return interval of the storm to be used (specified in the Storm Frequency Table above), and the duration of the storm to be used (based on the study basin's time of concentration.) The time of concentration is the travel time of a drop of water from the most hydraulically remote point in the contributing area to the receiving facility. The major factors affecting the time of concentration for overland flow are flow distance, surface slope, surface roughness, infiltration rate, and rainfall intensity. The time of concentration is computed by dividing the flow distance by the runoff flow velocity. The time of concentration at any point in a storm drainage system is a combination of the inlet time and the travel time in the channel or pipes. The inlet time is the time for water to flow over the watershed surface to the storm sewer inlet or channel. Average velocities for estimating travel time for overland flow can be calculated using methods outline in SCS TR-55 (SCS 1986). Tc is a property of the drainage basin reflective of its area, shape, surface gradient, land use, land cover, and soil type. Tc (in minutes) may be estimated from the following equation:

$$T_c = \text{Length} / (\text{Velocity} * 60) + 10$$

Where:
Length = Flow distance (feet)
Velocity = Flow velocity (fps) (see following table)

Flow Condition	Representative Velocities
Shallow overland flow in undefined channels	0.25 to 0.50 fps
Flow in street curb & gutter or road ditches	0.75 to 1.25 fps
Flow in shallow ditches	1.5 to 3.0 fps
Flow in defined channels	2.0 to 4.0 fps
Flow in closed conduit storm sewers	3.0 to 5.0 fps

The constant value of 60 in this equation is used to convert seconds to minutes and 10 is used as an estimate of initial delay between the start of rainfall and development of actual surface runoff. This method can be applied fairly accurately to large and small basins with either undeveloped or developed surfaces. However, the designer must specify the flow condition and estimated flow velocities for each flow domain on the site (i.e., the first 100' is overland flow followed by 250' in a gutter followed by 400' in closed conduit, etc.) and estimate time of concentration as the sum of all these individual flow conditions. The flow path used as the basis of this calculation should be clearly denoted on the plans with the associated design calculations.

Another method that can be used to estimate time of concentration for developed areas (i.e., storm sewer projects) is in the following form:

$$T_c = 10 * (A)^{0.1761} + 15$$

Where: A = Drainage Basin area (acres)

This method accurately estimates T_c for sewered projects, however it tends to underestimate actual T_c for basins with significant overland flow or open ditch flow, and therefore may overestimate peak runoff flow rates for these basins.

Alternative methods for estimating the basin’s time of concentration will be accepted for reviewed by the City Sealy, and may be allowed for use if the method’s applicability to a specific situation warrants its use over the methods presented.

Storm Intensity (I)

The rainfall intensity is the average rainfall rate in inches per hour for a basin. The rainfall intensity is determined on the basis of design rainfall duration and design frequency of occurrence. For small watersheds and individual developments, the storm intensity should be based upon the time of concentration of the basin being analyzed. For example, in the design of a detention facility serving a basin with a 2-hour time of concentration, an Intensity for a 100-year, 2-hour storm should be selected for use in the analysis.

For large watersheds and regional studies, use a 24-hour duration storm for the analysis and design. Appropriate design storm intensities are shown in TABLE C for various return interval storms.

IV. HYDRAULICS

Hydraulics is the study of fluid flow behavior. Policy makers and engineers must study and understand hydraulics because they are responsible for designing and constructing conveyance and storage facilities capable of managing storm water runoff in a safe and effective manner while reducing the potential for flooding. The following sections discuss specific methods and parameters to be used in analyzing proposed developments in the City of Sealy’s service area.

Open Channel Flow

The vast majority of conveyance capacity within the City of Sealy’s service area is located in the network of open channels that the City of Sealy maintains. Analysis of open channels is performed to determine the depth and velocity of a given flow for an established cross-section. Typical uses are to determine the tailwater elevation at a culvert structure, flood elevation for selected discharge of natural streams and water coursed, and discharge capacities for existing man-made channels. Design of open channels involves the selection of a cross-section, finish surface treatment, and alignment to accommodate a given design discharge. A successful channel design results in a stable structure that does not develop excessive sediment deposits or erosive cuts, maintains a stable cross-section, and is not damaged by entry of uncontrolled surface flows.

The Chezy-Manning equation will be used to estimate a ditch's conveyance capacity. This equation is in the following form:

$$Q = 1.486/n * A * R^{2/3} * S^{1/2}$$

Where:

Q = flow in cfs
A = cross sectional area in ft2
V = velocity of flow in ft/sec
n = roughness coefficient (unitless)
R = hydraulic radius = A/WP in ft
WP = wetted perimeter in ft
S = Slope of the Hydraulic Grade Line (ft/ft)

Typical values for Manning's 'n' are included in TABLE B. The flow area (A) is estimated from the ditch cross-section, and is the area that will be conveying water (also called the wet area). The hydraulic radius is calculated as the wetted area divided by the wetted perimeter. The wetted perimeter is defined as the length of water/surface interface around the perimeter of the wetted area (does not include the water/air interface length). For open channels, the slope of the hydraulic grade line is estimated to be the same as the ditch slope.

Closed Conduit (Pipe) Flow

Storm drain systems are conduits for the collection and transport of surface waters to desired points of discharge. Design is accomplished by application of the Manning Equation either directly, or through charts and nomographs that are based upon the equation. The following guidelines are proposed to be observed during the design of the system(s):

- The system shall be designed to accommodate all intercepted flow for the design storm at each inlet and opening that allows storm water into the system.
- The system shall preferably operate flowing full and within the theoretical limits of open channel flow for the required design flows.
- Design and construction shall take into account any future additions and resulting flows added to the system. No existing system shall have flows added or directed to it that exceed its theoretical design capacity.
- The system shall be evaluated with associated drainage systems for the flow conditions that will result from a 100-year rainfall event and ultimate basin development conditions.
- The system detailed design will adhere sound Engineering judgment and practice.

The Chezy-Manning equation presented earlier is also applicable for estimating flow capacity for closed conduits (i.e., pipes). There are some important distinctions to remember, including:

- Manning's 'n' for pipe materials are significantly different (i.e., smaller) than those for bare earth or vegetative surfaces. See TABLE B for appropriate 'n' values.
- The assumption of hydraulic grade line slope being approximately equal to the pipe slope is only valid under free flow conditions. Once the pipe is full and experiences surcharge conditions, the hydraulic grade line slope will increase as flow increases.

In general, the proposed storm drainage system design shall be designed by the application of the Continuity Equation and Manning's Equation presented as follows:

$$Q = 1.486/n * A * R^{2/3} * S^{1/2}$$

Where:

Q = flow in cfs
A = cross sectional area in ft2
V = velocity of flow in ft/sec
n = roughness coefficient of conduit (unitless)
R = hydraulic radius = A/WP in ft
WP = wetted perimeter in ft
S_f = friction slope of conduit (ft/ft)

Note: Capacity of a given size conduit is based upon an assumption that it is flowing full. Thus, R is equivalent to the cross sectional area divided by the inner circumference, while a value for n and Sf must be chosen.
There are some important distinctions to remember, including:

- Manning's 'n' for pipe materials are significantly different (i.e., smaller) than those for bare earth or vegetative surfaces. See TABLE B for appropriate 'n' values.
- The assumption of hydraulic grade line slope being approximately equal to the pipe slope is only valid under free flow conditions. Once the pipe is full and experiences surcharge conditions, the hydraulic grade line slope will increase as flow increases.

V. DETENTION FACILITIES

To meet City of Sealy's requirements for zero net increase in runoff rates and no negative impacts due to new development, most projects will need to provide on-site detention facilities. Developments which have access to existing or proposed regional detention facilities located offsite of the development may release developed flows to the drainage system if a drainage plan including hydrologic and hydraulic analyses prepared by a licensed professional engineer in a manner acceptable to the City Engineer demonstrates that the detention facility offsets the impact of the increase in impervious area. For offsite detention facilities located downstream of the development, the drainage plan shall also demonstrate that the storm water conveyance system between the development and the detention facility can carry the 100-year runoff without causing a negative impact on the properties adjoining the downstream drainage system.

The City of Sealy will not allow in-line storage within City or County ditches, channels, or streams. The following paragraphs describe general design requirements and allowable methods for generating appropriate designs.

The characteristics of an individual development may be such that additional calculations, plans, and details may be required both for proper review and for construction. The City Engineer shall notify the Developer or the Engineer as this need becomes evident.

<u>General Requirements</u>
As shown in the storm frequency table earlier, detention facilities will be designed to provide enough storage to accommodate a 100-year event for the sub-area it is intended to serve. Detention facilities may be designed to be wet (constant level ponds) or may be designed to drain completely. They must be designed and constructed with stable slopes (3:1), they must provide adequate access and maintenance berms around the entire perimeter (10’ minimum or 2’ x the depth of pond whichever is greater, Example 6’ deep pond would have a 12’ minimum maintenance berm), and they must have erosion control elements (i.e., backslope swales, drop pipes, slope pavement, etc.) as necessary to ensure a stable, low maintenance facility.

All detention facilities less than 2 acres in size must provide for 6 inches of freeboard between the projected 100-year water surface elevation and the top of the berm. All detention facilities over 2 acres must provide 1 foot of freeboard. Outfall structures must be designed to restrict outflow from the detention facility at a rate not to exceed the pre-developed conditions, and must include a controlled release mechanism to safely discharge runoff from storm events in excess of the 100-year design storm.

Detention storage may not be placed in road-side ditches or in curb-and-gutter streets in public or private easements and rights-of-way. Individual property owners are responsible for the maintenance of these detention facilities. The City may periodically inspect to ensure the detention facilities are well maintained and operating according to design.

<u>Volume Requirements</u>

The following paragraphs describe allowable methods for use in determining storage volume requirements. The Sealy area is broken into 4 categories, 1) Exemption from detention, 2) Coefficient Method - Detention of 0.75 ac-ft for the increased impervious area, 3) Detention as established by drainage studies, 4) Detention as required by other agency (TxDOT, Austin County).

Exempt from Detention
Downtown zone: Developments within the downtown zone adopted by the City of Sealy Council may be exempt from detention in areas where no historic flooding has occurred. Areas that have experienced flooding in the past shall provide detention that will ensure no adjacent properties are affected.

Redevelopment: Redevelopment of previously developed tracts is exempt from detention storage as long as the new impervious area is less than or equal to the pre-existing impervious area. If the impervious area increases, detention shall be provided for the new impervious area.

Coefficient Method
For developments less than 50 acres, the developer may chose to use this simplified method for detention volume estimation. Using this method, the developer would provide detention storage using the following equation:

$$\text{Storage} = 0.75 * A_{dev}$$

Where:
Storage = Detention volume required (ac-ft),
A_{dev} = The area of the site that will have modified cover (acres).

Using this method, storage is only provided for the portion of the site that is being developed. For example, on a 4 acre commercial tract with 3.0 acres of building, parking and landscape areas, the developer would be required to provide (3.0 acres)*(0.75 ac-ft/ac) = 2.25 ac-ft of detention storage. The outfall structures will be designed separately as discussed in later paragraphs.

A drainage study may be done in lieu of the coefficient method if deemed necessary by the developer or the city staff.

Drainage Studies - Small Watershed Method

Hydrologic analyses involving watersheds of greater than or equal to 50 acres and less than 640 acres may be completed by use of the runoff rate curves for Austin County to determine peak flow rates and the Malcom Method to develop runoff hydrographs. This methodology takes in account the land type and basin slope. This method is a hydrograph based method that compares an expected inflow hydrograph to an allowable outflow hydrograph to determine required storage volume. Using this method, the required volume of storage is equal to the maximum cumulative difference between the inflow and outflow runoff curves. This methodology may be used for sites smaller than 50 acres to more accurately model drainage for any particular basin or site to minimize storage requirements.

Runoff Rate Curves

The Runoff Rate curves represent a simplified method for the determination of the peak discharge in a relatively small watershed. The curves developed include the 25-year and the 100-year rainfall. The runoff curves are utilized, in addition to site characteristics (including drainage area, percent impervious cover, average channel sloe, average watershed slope, and a weighted n-value for the channel) to compute the peak rate of runoff from a drainage area for the 25-year and the 100-year rainfall events. To compute the peak 25-year and 100-year flow rates the flowing equation applies:

$Q_P = Q_C \times (S^X S_O^Y N^Z)$

Where:

Q_P = peak flow Rate (CFS)

Q_C = Runoff Rate Curves Y-axis value

S = channel slope (ft/mi)

X =value

S_O = watershed slope (ft/mi)

Y = value

N = weighted n

Z = value

Note, peak flow rate for the actual percent impervious value are linearly interpolated from the peak flow rate for the lower and higher percent impervious values.

Hydrograph Development

The H.R. Malcom methodology was utilized to pattern the hydrographs to obtain a curvilinear design with the design rainfall and consist of the following equations:

$T_P = V/1.39Q_P$

$qi = (Q_P/2)(1-\cos(\pi t_i/T_P))$ t_i <or =1.25 T_P

$qi = 4.34\ Q_P e(-1.3\ t_i / T_P)$ $t_i > 1.25\ T_P$

Where:

Q_P = peak design flow rate in cfs

T_P = time to Q_P in seconds

V = total volume of runoff for the design storm in cubic feet

t_i = incremental flow time (min)

q_i = incremental flow rate (CFS)

The variables ti and qi are the respective time and flow rates, which determine the shape of the hydrograph. The total volume of runoff generated by the design storm event is the amount of rain that falls upon the watershed minus loses attributable to surface storage, soil infiltration, evaporation & transpiration, etc. For the purposes of projects within the City of Sealy jurisdiction, designers shall use a cumulative depth of excess rainfall of 9.7 inches when considering a 100-year event. Therefore, the total runoff volume is calculated by multiplying the cumulative depth of excess rainfall for the design storm event (9.7”) by the watershed area

Peak Flow Rates for Hydrograph Development

The peak design flow rate can be calculated directly, either from the County Runoff Rate Curves or the Rational Method.

Total Runoff Volume for Hydrograph Development

The total volume of runoff is dependent on the characteristics of the soil and the degree of urbanization (percent of impervious cover) of the area. Loss rate totals may be estimated using the SCS Curve Number methodology developed by the Soil Conservation Service. The criteria manual provides graphs for the determination of runoff volume for a given rainfall depth and SCS Curve number. The SCS provides information on relating soil group type to curve number as a function of soil cover, land use type and antecedent moisture conditions. The hydrologic soil group descriptions are listed as follows:

- Group A: deep sand, deep loess, aggregated silts
- Group B: shallow loess, sandy loam
- Group C: clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay
- Group D: soils that swell significantly when wet, heavy plastic clays, and certain saline soils

As a basis of general understanding, Group A soils have the lowest runoff potential and Group D soils have the highest runoff potential. The tables are organized according to the SCS cover complex which consists of three factors including, land use, land treatment or practice, and hydrologic condition.

Detention Facility Outflow Hydrographs

Outflow hydrographs are constructed by determining the capacity of the outfall structure under incremental surcharge conditions. A table is generated that contains the estimated outfall rate for the proposed structure given increasing depths of ponding in the detention facility. To determine appropriate detention design, the engineer will provide a mass-balance for water in the detention facility (i.e. change in storage of the system equals the volume of water flowing in minus the volume of water flowing out) for several incremental time steps covering the duration of the storm event. The minimum storage requirement will equal the maximum cumulative storage determined in the time step analysis.

The Small Watershed Method is dependent upon the Rational Method for estimation of the peak flow rate, so it should only be used for basins of less than 640 acres where there is no well defined channel and any flow routing can be considered negligible.

HEC-1 / HEC-2 Computer Modeling

For basins over 640 acres in size, the City of Sealy will require a HEC-1 hydrograph analysis covering the site and the adjacent parts of the watershed. This analysis should verify that the proposed improvements will not increase runoff rates anywhere in the system and therefore will have no negative impacts on adjacent properties. The engineer must submit a complete design report with sufficient detail (program input, program output and discussion of methods and assumptions used) for the City staff to review.

TxDOT and Austin County Review

All sites that outfall or impact adjacent TxDOT or County controlled and maintained facilities will require approval by these entities prior to City of Sealy approval. The engineer will be required to adhere to both TxDOT or County guidelines along with the City of Sealy's guidelines, whichever is greater.

<u>Outfall Restrictor Design</u>

The outfall structure is an important design component of the detention facility. The design of the outfall structure can be as simple as a single pipe segment, and can be as complex as multiple pipes with differing diameters at staggered elevations with overflow weirs and flow orifices. The following paragraphs describe ways to estimate flow conveyance of several flow control structures.

Outflow Rate and design

To comply with the city of Sealy policy to avoid increasing flood risks or flood hazards, maximum allowable outflow rates from detention basins are restricted to the pre-development flows from the 100-year, 25-year and 10-year Storm , 24-hour events.

If a downstream channel has less capacity than a 2 year event, also restrict the outflow less than the amount of the pre-development project site which contributes to the channel when it is flowing full or at its flooding threshold or 0.125 cfs/acre or whichever is less.

When detention basin modifications are necessary to accommodate a proposed storm sewer outfall or a proposed development, design the modifications such that the 100-year, 25-year and 2-year Storm , 24-hour events water surface profiles in the detention basin and downstream channels are not increased above existing conditions.

If the outflow is into a roadside ditch or storm sewer, restrict the maximum allowable outflow to the rate allowed from the proposed site development using criteria adopted by the jurisdiction responsible for the roadside ditch or storm sewer.

The design engineer must certify that the proposed improvements will not have a negative impact on adjacent properties and public right of ways.

Orifice

One of the most simple flow control structures is an orifice. An orifice is a two-dimensional flow structure (i.e., a drilled hole in a concrete wall, a hole in plate steel or a very short section of pipe) with an estimated conveyance capacity dependent upon the difference in water elevations from one side of the orifice to the other and the orifice opening area. The general equation for estimating flow through an orifice is as follows:

$$Q = C * A * (2 * g * H)^{1/2}$$

Where:

Q = Orifice flow capacity (cfs)
C = Orifice coefficient (unitless) [use 0.8]
A = Orifice opening area (sf)
g = Gravitational acceleration constant (32.2 ft/s^2)
H = Differential head across the orifice (ft)

For the design head differential (H) use the 100-year water surface elevation in the detention facility minus the 25-year water surface elevation in the receiving ditch (if known). If discharging directly into a roadside ditch or a storm sewer, use the difference between the100-year water surface elevation at the entrance and the centroid of the orifice in feet when orifice is partially submerged

. The orifice should generally be greater than 6" diameter to reduce problems with clogging and blockage.

Outfall Pipe

The engineer may use one or more a pipe sections as flow control devices. The conveyance capacity of the pipe(s) can be estimated using the Chezy-Manning equation discussed earlier. In using this method, the slope of the hydraulic grade line is equal to the head differential across the structure divided by the length of the pipe section. For the design head differential use the 100-year water surface elevation in the detention facility minus the 25-year water surface elevation in the receiving ditch (if known). If discharging directly into a roadside ditch or a storm sewer, use the difference between the100-year water surface elevation at the entrance and the centroid of the orifice in feet when orifice is partially submerged. The restrictor pipe shall not be less than 6" in diameter.

Overflow Weir

An overflow weir can be used on an outfall structure to restrict and regulate outflow. One of the biggest advantages of this outfall structure is that they do not have a finite conveyance capacity, and can therefore be used for emergency overflows to control larger than 100-year flows.

There are many types of weir designs to chose from when designing an outfall structure, and each has a slightly different equation for estimating flow capacity. One of the simplest to design and construct is a Cipoletti weir consisting of a horizontal weir (of width B) with triangular weirs on either side (at 4:1 slopes) and a depth of flow of H feet. Capacity of a Cipoletti weir can be estimate by the following equation:

$$Q = 3.367 * B * H^{3/2}$$

Where:

Q = Weir capacity (cfs)
B = Weir length (ft)
H = Depth of flow across weir (ft)

VI. DESIGN PARAMETERS

The proper hydraulic design of channels is of primary importance to insuring that nuisance drainage conditions, flooding, sedimentation and erosion problems do not occur or the frequency of their occurrence is at an acceptably low rate. The following minimum design standards shall be applied to construction of new or reconstruction of facilities.

Design Frequency

New facilities shall be designed and constructed to contain and safely convey runoff from the 100-year frequency storm when at all feasible to do so. Consideration must be made for the capacity of existing channels downstream, and no improvement shall be made that increase the frequency of downstream flooding.

Design Flow Velocities

Excessive flow velocity can cause erosion problems, may pose a threat to bank stability and may create safety problems. Additionally, velocities that are too low may allow sediment deposition resulting in loss of channel capacity. Generally, design flow velocities in unlined open channels (for 100-year flows) should be between 2 and 5 fps. Flow velocities in concrete lined channels may increase to be between 5 and 8 fps.

Ditch Channel Slope

Ditches shall have a minimum constructed channel slope of 0.05% to provide for the minimum velocities noted earlier. Excessive slopes may unnecessarily increase the potential for erosion of banks and undermining of bridge and culvert structures, therefore maximum slopes should generally not exceed 1.00%. In areas of steep topography, channel drop structures may be required to limit channel invert slopes.

Ditch Side Slopes

In grass lined channels, maximum side slopes shall be 3:1 (horizontal:vertical) 4:1 is preferred. Side slopes for concrete lined channels shall be based on field conditions and shall be site specific.

Ditch Bottom Width

The bottom width for ditches should generally be no less than 2 feet. A larger bottom width may be required to meet other issues including ditch capacity, design velocity, etc.

Ditch Horizontal Curves

In general, centerline curves for grass channels should be as gradual as possible and should have a radius greater than three times the ultimate ditch top width. Smaller curvature radii can be allowed with adequate slope paving as approved by the City Engineer.

Ditch Confluences

The angle of intersection between the tributary and main channel should be between 15º and 45º (with an optimal value of 30º). Angles in excess of 90º will not be permitted.

Ditch Transitions

Expansions and contractions should be designed to create minimal flow disturbance and thus minimal energy loss. Design consideration must be given to reducing erosion potential and turbulent flow characteristics at ditch transitions.

Ditch Drop Structures

When introducing flow into ditch main channel from shallow surface swales, the designer must include drop pipes to reduce the erosion potential at the confluence. Drop structures shall be appropriately sized for the area being served; with a discharge elevation of 12” above the main channel flowline.

Concrete Lined Channels

As field conditions necessitate, concrete lined channels may be required to provide adequate capacity or erosion protection for less than optimum drainage easement widths. Design of concrete lined channels will be considered by the City of Sealy on a case-by-case basis.

Detention Facilities

Detention facilities shall have:

- Minimum 10-foot wide maintenance berm on all sides or 2 x the total depth of the pond or whichever is greater.
- Outflow weir designed to handle the 100 year runoff
- Maximum side slopes no steeper than 3:1(h:v) without a geotechnical report
- Bottom of facility shall have a Minimum 1% cross slope.
- A concrete pilot channel.
- Emergency power must be provided for pumped systems
- For pumped systems at least two pumps are required, each of which should be sized to pump the design flow rate; if a triplex system is used, any two of the three pumps must be capable of pumping the design flow rate.
- The selected outfall rate must not aggravate downstream flooding.
- Engineer must certify that the pond is constructed in accordance with the City of Sealy guidelines and to plans and specifications for final inspection.
- Maintenance of all detention facilities will be the responsibility of the property owner, routine inspections may be required by the City and violations may occur for inadequate maintenance.
- Inspection and routine maintenance must be done on a yearly basis to ensure the facility works as designed.

Table A

Rational Method 'C' Values

Land Use or Land Cover	Rational Coefficient 'C'
Raw, undeveloped acreage	0.20
Improved, undeveloped acreage (i.e., mowed, filled, graded, etc.)	0.30
Park Land	0.40
Residential – 1 acre lots or larger	0.40
Residential – ½ to 1 acre lots	0.45
Residential – less than ½ acre lots	0.55
Multi-Family	0.75
Commercial/Industrial	0.90

Table B

Manning's 'n' Values

Channel/Pipe Material	Manning's 'n'
Plastic Pipe (PVC & HDPE)	0.013
Clean Cast Iron	0.014
Concrete	0.013
Corrugated Metal	0.025
Smooth Bare Earth	0.018
Natural Channels (good condition)	0.025
Natural Channels (stones & weeds)	0.035
Natural Channels (poor condition)	0.060
Rip-rap	0.035

Table C

Design Intensity Values for Use in the City of Sealy

$$I = b/(T_c + d)^e$$

Storm Frequency	e	b	d
2-year	0.811	69	8
5-year	0.781	75	8.1
10-year	0.757	89	8.1
25-year	0.739	85	8.1
50-year	0.733	92	8.1
100-year	0.719	95	8