attachment 1

development guidelines & stormwater management design criteria for aransas county

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I. INTRODUCTION

To better serve the community in presenting a clear and concise set of criteria for developing a stormwater management plan, this Attachment shall serve as a general overview of the stormwater design requirements, approach, and criteria for Aransas County. This Attachment is not meant as a detailed description of developer requirements but is simply a guide in developing an integrated stormwater management plan. Compliance with this Manual doesn't relieve the developer, engineer or contractor of the responsibility to apply conservative and sound professional judgment to protect the health, safety and welfare of the public, nor does it constitute implicit compliance with the professional practice requirements that may pertain to their activities. Special site conditions and environmental constraints and considerations may require a greater level of protection than would normally be required under these guidelines.

Developers and engineers should familiarize themselves with the *Aransas County Subdivision Regulation,* and the *Floodplain Management and Watershed Protection Order*, and any other applicable documents before undertaking projects within the County. Affected parties, developers, and contractors are advised that these local stormwater requirements do not absolve them of their responsibilities under other applicable Federal or State regulations and that it is their responsibility to address applicable requirements.

A. APPLICABILITY

A *Stormwater Management Plan* is required for all site development projects within the jurisdictional boundaries of Aransas County.

Exemptions: Applicants may request an exemption from the requirements outlined in this Section*.* To qualify for a Minor Impact Exemption, the applicant must meet all of the following conditions:

- The site development must be for an existing platted lot with a proposed single-family residential use or for a proposed development with less than a 20% increase of impervious cover.
- During construction, site erosion and runoff controls and compliance with TCEQ Construction General Permit requirements are required, as applicable.
- Use of Low-Impact Development (LID) Stormwater techniques are required.

Review: It is anticipated that further experience with constructed facilities and issues with the written regulation will necessitate updating the requirements within this Master Plan and Manual. Also, to ensure that the most recent science and technologies are considered modifications, additions or deletions along with updates to the criteria will be needed. Therefore, the Stormwater Management Advisory Committee or Commissioner's Court will initiate in a review and revision process of the Master Plan and Manual on annual basis.

B. GENERAL DESIGN REQUIREMENTS

1. *Designated Flood Plains*

All development and site improvements in FEMA or otherwise designated 100-year flood plains within the jurisdictional boundaries of Aransas County are regulated by the Aransas County Flood Plain Administrator. Typically the FEMA designated 100-year flood plains exist adjacent to the coast; however, modeling efforts have been used to identify areas of stormwater inundation during several storm events and should be considered during the planning efforts of all developments and site improvements. The proposed improvements must abide by applicable requirements within this Manual and other County documents such as the *Aransas County Subdivision Regulations* and the *Floodplain Management and Watershed Protection Order*.

2. *Level of Protection*

Within a watershed with a contributing area of less than 200 acres, streets, storm sewers, culvert crossings and channels shall be designed to convey the 5-year flow with the hydraulic grade line (HGL) below the top-of-curb or contained within the channel. Within a watershed with a contributing area of more than 200 acres, the major conveyance channels and storm sewer shall be designed to convey the 25-year flow with the same HGL conditions.

3. *100-Year Storm Protection*

The capacity of the manmade stormwater system may be exceeded during storm events more intense than the design storm. However, stormwater management systems shall be checked so that no adverse impacts to existing or proposed structures are a result of the 100-year flow from the proposed installation of any fill, improvement, or renovation. This protection requirement attempts to prevent structural flooding for the extreme events up to the 100-yr storm.

4. *Peak Flows*

Peak flows leaving a site shall not be increased as a result of development. Developers / Engineers shall analyze the watershed to show that no impact to the peak flows are anticipated or shall limit the post-development flows to pre-development rates for the required storm event. Detention, as preferred possible alternative for many developments, is discussed in more detail in subsequent sections.

5. *Water Quality*

For quality protection, the drainage system shall incorporate water quality measures, either **demonstrated** or **presumed.** The **presumption** that the development will not cause unacceptable damage will have been achieved if the developer provides a design that ensures that the first inch (1.00") of every runoff event from the added impervious surface of the property is fully contained on site and that the contained volume is drained over a period of not less than 36 hours. The **demonstration** that the development will not cause unacceptable damage will have been achieved if the developer completes an acceptable analysis that proves that on an annual basis the duration of any flow rate which occurs prior to development is not increased after development to a degree that increases sedimentation or erosion or is otherwise problematic.

6. *Ecology*

The "third leg of the stool" for stormwater management is the ecological integrity which is so important to Aransas County. Within Master Plan & Manual is an *Environmental Resources Checklist and Assessment* to be used to help address existing site characteristics.

C. NATURAL DEPRESSIONS

1. *Flood Prone Area*

The Aransas County Commissioner's Court accepted the Floodplain Management and Watershed Protection Order on January 27, 2010 that identified all areas in Aransas County as Flood Prone Areas. This order requires that all builders, developers, and home owners receive a permit to do work within the County's jurisdictional boundaries.

Due to the topography of Aransas County and its natural depressions many areas are subject to inundation during large storm events or even smaller events during very wet periods. As part of the hydraulic modeling component, 2D models were developed to identify such areas. The model information was analyzed for the 10-, 25-, and 100-year storm events. The areas of inundation identified with the 2d models are considered a *Flood Hazard Area* and should be developed with caution and in a way that does not exacerbate flooding conditions and protects existing and proposed structures from the identified stormwater inundation.

2. *Depression Storage*

Due to the important role the depressions play within the drainage, water quality, and ecological components of the natural stormwater system, all attempts shall be made to incorporate these depressions within the localized stormwater management plan. The volume within the natural depressions deeper than 2' and with a surface area larger than 1 Acre shall be calculated and maintained so as to not adversely affect upstream/downstream properties. If there are no practical alternatives to maintain the depression storage volume at its existing location, the loss of volume shall be mitigated for on-site and within the same drainage basin. These depressions can be used toward the required detention storage.

D. CONVEYANCE

1. *Alteration of Flow Path*

Natural flow paths for much of the modeled watersheds have been identified. While it is understood that it may not always be feasible, all possible measures shall be employed to maintain the existing flow path for conveyance systems. Also, stormwater discharge location(s) at the downstream boundary of the property that differ from the predevelopment location shall be prohibited without County Engineer approval. Runoff transfers between watersheds are not permitted, unless a regional stormwater plan is approved by the County Engineer.

2. *Conveyance*

The owner or developer of the property is responsible for conveyance of all existing stormwater flowing through the property, even for extreme events. Design of on-site conveyance systems including channel and drainage easements shall include upstream off-site stormwater flows. If the upstream property has been developed with on-line detention ponds to reduce upstream contributing flows, the existing conditions shall be included in the engineering analysis.

3. *Easements*

The owner or developer of a site or property shall dedicate a public drainage easement sufficient to convey the full flow from the design storm for existing conditions from all upstream sources including the additional requirement for on-site flows, detention areas, and other improvements. The minimum easement width shall be sufficient to contain the required flow within the channel with a 15-foot wide maintenance corridor on one side of the channel or on both sides for channels with a bottom width wider than 30 feet. All detention ponds or other structural BMPs shall also be placed within a public drainage easement to allow for County access and maintenance. Any conveyance device or storage BMP not within a public drainage easement shall have specific maintenance and use conditions identified within the Deed Restrictions. In any case, conveyance systems that handle off-site flows shall be within a public drainage easement without a specific variance from the County Engineer.

4. *Open Channels*

Open channels are a preferred conveyance device and shall be designed with 4:1 side slopes where practicable with established vegetation to protect the channel from erosion. Due to existing right-of-way (ROW) limitations that are prevalent throughout the County, some channels may be allowed with steeper slopes with approval from the County Engineer.

E. DESIGN OPTIONS

There are three options typically used to address flood protection and peak runoff control.

Maintain Existing On-Site Runoff Conditions: The County's primary stormwater conveyance and volume control requirement is to provide flood protection and peak runoff control by requiring on-site storm drainage facilities to limit post-development peak runoff for the design storm events to pre-development conditions. This is typically in the form of detention and is a standard response to the growing concerns of the County.

Regional Stormwater Controls to Maintain Existing Downstream Conditions: It should be noted that the amount of natural depressions throughout Aransas County lend credence to the use of "source controls" or small, on-site detention ponds and low-impact development concepts as a response to increasing stormwater impacts. However, when these on-site "source controls" create an undue limit to the development potential of a site or the requirement of small detention ponds is trending towards the exacerbation of small "mosquito ponds" and creating a health hazard, the developer/engineer can provide off-site regional controls. It is the responsibility of the Developer to acquire the land and design and construct the improvements. The County may also choose, in certain watersheds or in partnerships with a Developer(s), that the most prudent form of stormwater management is a regional facility, in which case the County may decide to impose an ***impact fee*** or enter into a ***Developer's Agreement*** to regain the capital expense.

***Provide Adequate Downstream Conveyance Systems*:** While the policy of Aransas County is to not increase the peak flow, it is understood that detaining stormwater and attenuating the release of the runoff in some areas of a watershed can create or exacerbate drainage problems upstream. This can be typical for coastal developments and those near an ultimate outfall for a watershed. Developers/Engineers seeking a design variance for scenarios such as this shall provide supporting calculations and documentation that the upstream and downstream water surface elevation, based upon the storm events required, is safely maintained without adversely impacting and/or endangering downstream properties, structures, bridges, roadways, or other facilities. Special permission and approval from the County Engineer is required. It should be reiterated, that despite any allowance for not limiting peak runoff within detention facilities, this does not relinquish the stormwater quality requirements. In these instances, Low-Impact Development techniques make for much more plausible management devices.

II. HYDROLOGIC DESIGN CRITERIA

The hydrologic concepts and analysis required for development in the County are presented in more detail within the Manual. One of the primary intentions of this Manual is to provide for public safety, protection of property and minimize on-site, downstream, and upstream flood impacts from storm events. Drainage/flood analysis is based on 2 storm events: the design storm event for conveyance or volume control and the 100-year storm event for protection of property. Hydrologic analyses shall be based upon existing conditions and existing land uses.

A. HYDROLOGY

The hydrologic cycle, while not simple, can be explained for our purposes when divided into four parts: precipitation, infiltration, runoff, and evaporation.

As ***precipitation*** falls to the surface, the first drops of water, in natural conditions, are intercepted by vegetation. This is usually referred to as interception storage. As the rain continues, overcoming the interception storage volume, it infiltrates into the soil (the more permeable the ground, the more precipitation infiltrates) until it reaches a stage where it exceeds the infiltration capacity of the soil. This initial storage and infiltration is typically referred to by hydrologists as the ***initial abstraction***. In hydrologic scenarios throughout most areas, the initial abstraction is limited to this and is a relatively small amount in relation to the total rainfall. However, due to the prevalence of extensive overland sheet flow, very shallow/wide concentrated flow patterns and the natural depressions, probably the most unique, important and defining characteristic of Aransas County's hydrologic regime, the initial abstraction throughout much of the County can significantly increase standard initial abstraction volumes. Much of the Aransas County watersheds were modeled using FLO2D software. Among the many outcomes of this model is an indication and correlation of the initial abstraction within that watershed. These initial abstractions can be used by developers when analyzing their *Stormwater Management Plans*.

After the initial abstraction, including depression storage, has been overcome, **runoff** is generated as surface water cascades to another depression or across a watershed and eventually to the outfall. The cycle is completed as water returns to the atmosphere through **evaporation** from open water surfaces or as **evapotranspiration** from plants that remove water from the groundwater system. What is important in planning stormwater management systems are the ways these components of the hydrologic cycle may change with development and how to integrate these into the management devices.

B. DETERMINING RUNOFF

There are many methods for determining runoff which include simple hand calculation methods like the Rational Method, relatively simple modeling efforts which include TR-20, TR-55, and HEC-HMS, to more intricate models (typically used for more than just runoff) like SWMM, Civil Storm, and ICPR. Due to prevalent use of the Rational Method in the area and the use of HEC-HMS in the watershed modeling, they will be described in this Attachment.

1. Rational Method

For drainage areas up to 200 acres, the peak runoff rate, Q, may be determined by the Rational Method using the following formula:

Q = C·I·A Where: **Q** = the peak runoff rate (*cubic feet per second*)
C = runoff coefficient (*unitless*)
I = design rainfall intensity (*inches per hour*)
A = drainage area (*acres*)

Determining Runoff Coefficients

The runoff coefficient (C) is a function of land use, land cover, soil type, and a host of other hydrologic abstractions. It is, perhaps the most important component of the Rational Method yet can also be the most subjective. It should be noted that conditions throughout developments may vary and that the design engineers may request different C-values than those represented in this Manual with the appropriate documentation and calculations.

For the purposes of this Manual and consistency in the determination of runoff, the Runoff Coefficient values shall be determined using the following table:

Rational Method Runoff Coefficients, (C)

LAND USE	RUNOFF COEFFICIENT (C)
Pasture:	0.15
Cultivated:	0.20
Woodlands:	0.10
Residential:	
Lots greater than 1 acre	0.20
Lots 1/2 to 1 acre	0.30
Townhomes / Trailer Park	0.50
Apartments / Condos	0.60
Commercial:	
Neighborhood Business	0.60
Primary Commercial (Downtown)	0.80
Industrial Districts:	
Light Industrial District	0.60
Heavy Industrial District	0.70
Parks, Greenbelts, Lawns, Cemeteries:	0.25
Streets, Parking Lots and Paved areas:	
Asphalt	0.80
Concrete	0.90

For drainage areas with multiple land uses, runoff coefficients and drainage areas associated with each land use should be determined and the composite runoff coefficient computed using the following equation.

$$C_w = \Sigma (C_i \cdot A_i) / A_t$$

Where:
- C_w = weighted runoff coefficient;
- C_i = runoff coefficients for various land uses;
- A_i = drainage areas corresponding to values of C_i (*acres*)
- A_t = total drainage area (*acres*)

These runoff coefficients apply for storms with a frequency of 2-year to 10-year. Due to the decreasing effect of infiltration and other abstractions for less frequent storms, Aransas County will adopt the TxDOT recommendation of using an adjustment factor, 1.1 for the 25-yr storm and 1.25 for the 100-year storm, when calculating the runoff coefficient for extreme events.

Establishing the Time of Concentration

To determine the rainfall intensity, the rainfall component of the Rational Method, one must calculate the time of concentration. The time of concentration is defined as the time needed for a drop of water to reach the outlet from the most hydraulically remote location within a basin and is calculated as the sum of the travel times within the various consecutive flow segments (overland flow, concentrated flow, and channelized flow). Time of concentration for overland sheet flow and shallow concentrated flow conditions should be calculated using the Kerby and Kerpich equation methods. For storm sewers, creeks and channels, flow velocities may be estimated using Manning's Equation or other appropriate methods.

Sheet Flow - Kerby Equation (limited to 500')

$$T_c = 0.828 * [(L*N)^{0.467}] * S^{-0.235}$$

Where:
- T_c = Overland flow time of concentration (*min*);
- **L** = Length of overland flow (*feet*);
- **N** = Roughness parameter based on overland flow surface (see Table below); and
- **S** = Overland flow slope (*ft/ft)*

Kerby Roughness Coefficient

DESCRIPTION	N
Manicured grass, cultivated	0.20
Pasture, average grassland	0.40
Woodlands	0.60

Shallow Concentrated Flow - Kirpich Equation Time of Concentration

$$T_c = 0.0078 * L^{0.77} * S^{-0.385}$$

Where:
- T_c = Shallow concentrated/channel flow time of concentration (*minutes*);
- **L** = Length of overland flow (*feet*);
- **S** = Dimensionless overland flow slope

Manning's Equation: Manning's equation is an empirical equation which relates channel slope, channel roughness, and channel cross sectional area to flow rate. Standard *n* values found in the Texas Department of Transportation's (TxDOT's) Hydraulic Design Manual shall be used. Manning's equation is as follows:

$$V = (1.49/n) * R^{2/3} * S^{1/2} \quad \text{or} \quad Q = (1.49/n) * A * R^{2/3} * S^{1/2}$$

Where:
Q = flow rate (*cfs*)
V = velocity of flow (*ft/sec*)
n = Manning's roughness coefficient
A = cross-sectional area of the flow (*ft²*)
R = hydraulic radius of the channel (*ft*) (Area/wetted perimeter)
S = channel slope (ft/ft)

Design Rainfall Intensity

The rainfall intensity, used for the Rational Method shall be calculated based on the following formula, which was developed by TxDOT from TP-40 and HYDRO-35:

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

Where: **I** = Rainfall Intensity (*inches/hour)*
T_c = time of concentration (*minutes*)
b, d and e = empirical factors for Aransas County found in the TxDOT Hydraulic Manual (see table below)

Rainfall Intensity in Aransas County (TxDOT)

TIME OF CONCENTRATION, T_c	RAINFALL INTENSITY (in/hr)					
	2-Yr	***5-Yr***	***10-Yr***	***25-Yr***	***50-Yr***	***100-Yr***
	b=73	*b=77*	*b=79*	*b=88*	*b=95*	*b=98*
	d=9.2	*d=8.5*	*d=8.5*	*d=8.5*	*d=8.5*	*d=9.2*
	e=0.821	*e=0.787*	*e=0.753*	*e=0.745*	*e=0.739*	*e=0.725*
15 Min	5.3	6.4	7.3	8.4	9.2	9.7
30 Min	3.6	4.4	5.1	5.8	6.4	6.9
1 Hour	2.3	2.8	3.3	3.8	4.2	4.5
2 Hours	1.3	1.7	2.0	2.4	2.6	2.9
4 Hours	0.8	1.0	1.2	1.4	1.6	1.8
8 Hours	0.5	0.6	0.7	0.9	1	1.15
12 Hours	0.3	0.4	0.45	0.6	0.65	0.75
24 Hours	0.2	0.25	0.3	0.4	0.45	0.5

Since the Rational Method does not calculate volume, there is a method introduced in the Detention Design Criteria section of this Attachment that utilizes the Rational Method for developing hydrographs and volumes.

2. *NRCS PEAK FLOW METHOD*

The NRCS (formerly SCS) hydrologic method requires basic data similar to the Rational Method: drainage area, a runoff factor, time of concentration, and rainfall. This approach, however, is more sophisticated because it also considers time distribution of rainfall, initial abstractions, and an infiltration rate that decreases during the course of the storm. The models used to complete the watershed maps were prepared using the NRCS Method within HEC-HMS Computer model which will be discussed here. The primary steps for the NRCS methods are as follows:

- determine the size of the drainage basin and the longest flow path
- calculate the time of concentration (T_c) in hours
- determine a weighted runoff curve number (CN) that represents the different land cases
- using the rainfall distribution (NRCS Type III), determine total rainfall amounts
- using the unit hydrograph approach, develop the hydrograph of direct runoff from basin

Drainage Basin Delineation

As with all methods, drainage basins can be delineated utilizing topographic maps and field surveys as well as several software tools available. LiDAR information is available on the GIS system available from the County and can be used to assist in the basin delineation.

Time of Concentration

The time of concentration calculations should use the equations and method described above for the Rational Method.

Curve Number

The NRCS curve numbers are an index representing the combined hydrologic effect of soil type, land use, hydrologic conditions, and antecedent soil moisture. Use of the NRCS curve numbers allows direct conversion of inches of rainfall to an equivalent number of inches of water that are actually converted to runoff.

Hydrologic Soil Group

Soils are classified into four Hydrologic Soil Groups (HSGs): Group A, Group B, Group C, and Group D. The classification has been described earlier within this section and soils are discussed in detail in Section 2. The HSG are shown graphically for areas throughout Aransas County on the County's GIS system and can also be found in NRCS soil surveys for the County and are available on the internet or at local NRCS offices.

The following tables include a listing of NRCS curve numbers for typical land use and soil conditions and should be used.

Runoff Curve Numbers for Cultivated Agricultural Land

Cover Type	Treatment	A	B	C	D
Fallow	Bare soil	*77*	*86*	*91*	*94*
Row Crops	Straight row (SR)	*72*	*81*	*88*	*91*
Small grain	SR	*65*	*76*	*84*	*88*

Runoff Curve Numbers for Other Agricultural Lands

Cover Type	A	B	C	D
Pasture, grassland, or range-continuous forage for grazing	*49*	*69*	*79*	*84*
Meadow – continuous grass, protected from grazing and generally mowed for hay	*30*	*58*	*71*	*78*
Brush – brush-weed-grass mixture, with brush the major element	*35*	*56*	*70*	*77*
Woods	*36*	*60*	*73*	*79*

Runoff Curve Numbers for Urban Areas

Cover Type and Hydrologic Condition	Avg. % Imp.	A	B	C	D
Open space (lawns, parks, golf courses, etc.)					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Paved parking lots, roofs, driveways, etc.		98	98	98	98
Dry Detention Ponds		68	79	86	89
Streets and roads:					
Paved; curbs and storm drains (excluding ROW)		98	98	98	98
Paved; open ditches (including ROW)		83	89	92	93
Gravel (including ROW)		76	85	89	91
Dirt (including ROW)		72	82	87	89
Urban districts:					
Commercial and business	*85*	89	92	94	95
Industrial	*72*	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	*65*	77	85	90	92
1/4 acre	*38*	61	75	83	87
1/2 acre	*25*	54	70	80	85
1 acre	*20*	51	68	79	84
2 acres	*12*	46	65	77	82

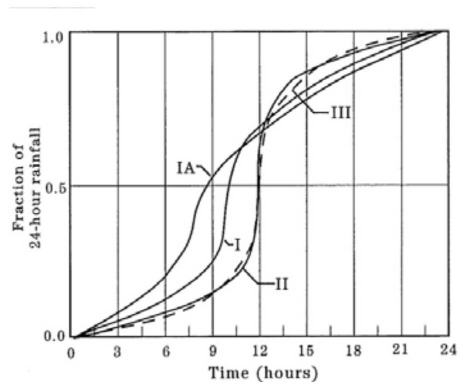
Antecedent Soil Moisture Condition

For analyses using NRCS methods in Aransas County, Antecedent Moisture Condition II should be assumed.

Rainfall Distribution Pattern

Aransas County is in Region III of the TR-55 rainfall distribution map. The Region III curve (dashed) shows a sudden increase and decrease in intensity centered on hour 12 of the 24-hour storm. Approximately half of the total rainfall depth occurs within a couple hours in the middle of the storm. This is a symmetric distribution which produces hydrographs with sharp rising and falling limbs.

24-Hr Rainfall Dist. for Region III (TR-55)



Design Rainfall Events

Precipitation, in Aransas County, normally occurs as rainfall in irregular patterns with respect to both time and location; however, for the purpose of analyzing hydrologic conditions design storm events shall be used.

Rainfall data for Aransas County and the Rockport area was taken from the website for the National Climatic Data Center. The following table should be used when analyzing and modeling stormwater volume and runoff.

Depth Duration for Standard Storms in Aransas County

DURATION	2-YEAR	5-YEAR	10-YEAR	25-YEAR	100-YEAR
15-minute	1.10	1.40	1.60	1.90	2.30
30 minute	1.60	2.00	2.30	2.70	3.40
60-minute	1.90	2.50	2.90	3.50	4.50
2-hour	2.50	3.30	3.80	4.50	5.80
3-hour	2.80	3.60	4.20	5.00	6.70
6-hour	3.20	4.40	5.20	6.50	9.00
12-hour	3.60	5.00	6.00	8.00	10.50
24-hour	4.60	6.50	8.00	10.00	13.50

Rainfall Runoff Equation

A relationship between rainfall and runoff was derived by NRCS from experimental plots for different soils and vegetative cover regimes. There is a runoff equation with many different variables that was developed by the NRCS and can be found in TR-55, but since there are several free graphical and modeling methods readily available such as including TR-20 and HEC-HMS, we will not discuss the equation further.

III. HYDRAULIC ANALYSIS AND DESIGN METHODS

Level of Protection requirements presented earlier in this section shall be used for the hydraulic analysis of stormwater management systems. While it is not the intention of this Manual to rewrite the TxDOT Hydraulic Design Manual with regards to hydraulic design criteria the following shall be used as general design parameters and criteria for open channels and closed conduits.

1. Design Parameters for Open Channels

Cross Sectional Shape: Trapezoidal

Bottom Width: no minimum

Side Slope: 4:1 (H: V), pending soil conditions determined in geotechnical investigation. If soil conditions are prone to slope instability, flatter side slopes or structural stabilization may be required. Also if existing R.O.W. conditions dictate steeper slopes, approval from the County Engineer is required.

Maintenance Strip: 15 feet minimum. If the bottom width of the channel is wider than 30 feet, a maintenance strip of 15 feet shall be required on both sides of the channel. Above-ground utilities shall not be permitted in maintenance strip

Velocity: Maximum velocity for the design storm (5-yr or 25-yr) shall be 5 fps. Channels segments with velocities greater than 5 fps shall have erosion protection

Erosion Protection: Establish vegetative growth, sodding, and/or erosion mats may be required in conjunction with a watering regime after construction. All areas of erosion, erosive channels cut in the side slopes, etc. shall be repaired and stabilized immediately. Alternative methods of erosion protection, concrete lined channels or articulated concrete block, may be required in certain circumstances.

Design Requirements for Transitions, Bends, & Confluences: If a channel has a conveyance flow for the design storm greater than 40 cfs, further erosion protection is required as per the following: transition angles in channel bottom widths shall be less than 20 degrees. Channel bends shall be made as gradually as possible. The recommended minimum bend radius along the channel centerline is 3 times the channel width at the maximum design water surface elevation (WSE). Where smaller radii or sharper angles are required, erosion protection shall be used. The maximum allowable deflection angle for channel bends is 90°. Erosion protection shall be provided at channel confluences for earthen channels.

2. Hydraulic Analysis Methods for Open Channels

Manning's Equation: Manning's equation, presented previously, is considered acceptable for analysis of simple drainage systems (generally straight channels with minimal flow disturbances; i.e., changes in flow direction, changes in cross sectional area, changes in slope, confluences, etc.) in Aransas County. Standard n values found in the Texas Department of Transportation's (TxDOT's) Hydraulic Design Manual shall be used.

HEC-RAS: HEC-RAS is a computer program that has been developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers (USACE). This program can be used to analyze simple channels and complex open channel drainage systems, and can be downloaded free of charge from the USACE's website.

Other Methods: There are several other methods available for modeling complex drainage systems. Supporting information, data, and outputs shall be submitted to the County Engineer for review and approval.

3. Design Parameters for Storm Sewers and Culverts

Minimum Size: 15" - Pipe

Velocity: 2 fps minimum scour velocity
10 fps maximum velocity

Design Loading: Provide sufficient cover to provide H-20 loading under public roadways

HGL: At or below top of curb and no more than 3" above any part of the main drive lane for design-year event

Manhole Spacing: 600 feet maximum spacing; required at each change in pipe size or directional change > 5°. Junction box or inlet may be used in lieu of manhole

4. *Hydraulic Analysis Methods for Closed Conduits*

The most widely used formula for determining the hydraulic capacity of storm drain pipes for gravity and pressure flows is the Manning Equation, presented above. For pipes flowing full, the area is $(\pi/4)D^2$ and the hydraulic radius is D/4, so, the Manning's Equations become:

$$V = (0.590/n) * D^{2/3} * S^{1/2} \quad \text{or} \quad Q = (0.463/n) * D^{8/3} * S^{1/2}$$

Recommended Culvert/Conduit Roughness Coefficients

Type of Culvert	*n*
Concrete Box	0.013
Concrete Pipe	0.013
Smooth-lined metal pipe	0.012
Smooth-lined plastic pipe	0.012
Corrugated Metal Pipe	0.015 – 0.027
Structural Plate Pipe	0.027 – 0.036
Long Span Structural Plat	0.031

Calculate Frictional Losses: The following equation, derived from manning's equation, can be used to determine the frictional losses in a segment or link of storm sewer pipe.

$$H_f = 2.87 * n^2 * V^2 * L / S^{4/3}$$

Where:
- H_f = Frictional loss (*feet*)
- **n** = Manning's roughness coefficient
- **V** = Velocity (*fps*)
- **L** = Length of pipe (*feet*)
- **S** = Pipe slope (*ft/ft*)

Estimate Minor Losses: The following equations can be used to account for minor losses at pipe/culvert entrances and at inlets and manholes respectively.

$$H_e = K_e * V^2 / 2g$$

Where:
- H_e = Entrance loss (*feet*)
- K_e = The entrance loss coefficient, from Table 4.12
- **V** = Velocity in the pipe (*ft/sec*)
- **g** = The acceleration of gravity, 32.2 ft/sec^2

$$H_{I/M} = V_2^2 * K_m * V_1^2 / 2g$$

Where:
- $H_{I/M}$ = Loss at inlet or manhole (*feet*)
- K_m = The minor loss coefficient, Table 4.13
- V_1 = Velocity in the upstream pipe (*ft/sec*)
- V_2 = Velocity in the downstream pipe (*ft/sec*)
- **g** = The acceleration of gravity, 32.2 ft/sec^2

Entrance Loss Coefficients

Type of Structure and Configuration of Entrance	K_e
Concrete Pipe Culverts	
Projecting from Fill	
Socket End (Groove End) of Pipe	0.2
Square-Cut End of Pipe	0.5
Headwall or Headwall & Wingwalls	
Socket End of Pipe (Groove End)	0.2
Square Edge	0.5
Mitered to Follow Fill Slope	0.7
End Section Conforming to Fill Slope	0.5
Corrugated Steel Culverts	
Projecting From Fill	0.9
Headwall or Headwall & Wingwalls	0.5
Mitered to Follow Fill Slope	0.2
End Section Conforming to Fill Slope	0.5
Concrete Box Culverts	
Headwall Parallel to Embankment (No Wingwalls)	0.5
Wingwalls at 30 Degrees to 75 Degrees to Barrel	0.4
Wingwalls at 10 Degrees to 25 Degrees to Barrel	0.5
Wingwalls Parallel (Extensions of Sides)	0.7

Minor Loss Coefficients for Inlets and Manholes

Type of Structure	K_M
Inlet on Main Line	0.50
Inlet on Main Line with Branch Lateral	0.25
Manhole on Main Line with 22.5-Degree Lateral	0.75
Manhole on Main Line with 45-Degree Lateral	0.50
Manhole on Main Line with 60-Degree Lateral	0.35
Manhole on Main Line with 90-Degree Lateral	0.25
Manhole on Main Line with No Change in Pipe Size	0.05

Compute Hydraulic Grade Lines: Once the WSE or Hydraulic Grade Line (HGL) of the furthermost downstream end of the system being analyzed has been calculated or established, the following equation can be used to estimate the HGL from node to node in the upstream direction.

$$HGL_u + V_u^2/2g = HGL_d + V_d^2/2g + h_f + h_m$$

Where:

- HGL_u = HGL at upstream end of storm sewer (*feet*)
- HGL_d = HGL at downstream end of storm sewer (*feet*)
- V_u = Upstream velocity (*fps*) and V_d = Downstream velocity (*fps*)
- g = gravitational constant (32.2 ft^3 / second)
- h_f = frictional losses (*feet*)
- h_m = sum of minor losses (*feet*)

5. Extreme Event Design

All drainage infrastructure shall be designed and laid out in a manner that will accommodate runoff volumes that exceed the capacity of the stormwater system, such that 100-year ponding levels remain below habitable living spaces.

IV. DETENTION DESIGN CRITERIA

There are many areas in the County where flooding occurs because of the lack of proper conveyance and outfalls and there is a concern that future development will exacerbate the existing problem or create future problems. Detention facilities are used to reduce stormwater runoff rates by storing and attenuating the release of excess runoff, providing sufficient storage such that peak runoff rates are not increased when development occurs. Detention basins are not the only effective "on-site" means which can be used to control peak runoff rates and volume increases, low-impact development (LID) techniques, discussed later, can also be integrated.

A. General Detention Policy

In order to provide a reasonable level of flood protection while maintaining a climate favorable for development and economic growth, Aransas County has established this policy for the requirement of analysis and possible inclusion of detention facilities for site developments:

- If the pre-development peak runoff is increased due to the improvements of the proposed development, the post-development peak discharge shall be limited to the pre-development peak discharge. The design storm shall be controlling factor for sizing the pond. A proper overflow device shall also be designed such that the 100-year storm doesn't adversely affect adjacent structures or cause an erosive condition at the pond outfall. Also, to alleviate downstream stress during smaller events, an outfall shall be designed to effectively manage (post development flows don't exceed pre-development) the 2-year storm release when the design storm is a 5-year storm. Similarly, outfalls to manage the 2-, 5-, and 10-year storm releases shall be designed for when the design storm is a 25-year storm.
- If it is determined, through the modeling analysis, that the development or site improvements do not affect upstream or downstream hydraulic conditions, the requirement of detention facilities is waived. It should be noted that this waiver does not include the stormwater quality requirements.
- If the proposed site is immediately adjacent to the ultimate outfall (bay, canal, and river) and the flow does not proceed, either through easement or otherwise, through adjacent land, no detention is required. This does not alleviate the stormwater quality or ecological considerations and requirements.

It is Aransas County's objective that detention facilities be designed and constructed in a manner to enhance aesthetic and environmental quality of the County as much as possible.

1. Design Considerations

A detention facility's location, size and layout are influenced by the natural environment of the site, the type of development, desired function, required volume, and inlet and outlet control elements. While these elements, individually, can be relatively simple there are other constraints that one component can place on the other elements.

The importance of long-term maintenance of stormwater management facilities is understood. Detention facilities shall be in a public drainage easement or public right-of-way for the purposes of County maintenance. If the Developer wishes to maintain the completed facilities, a copy of the Deed Restrictions and Home Owners Association documents detailing the maintenance plan is required prior to platting or development.

For the safety of the community, embankment slopes steeper than three (3) horizontal to one (1) vertical (3H: 1V) are not permitted unless otherwise stabilized. The design engineer shall be responsible for this stabilization and for identifying dangerous conditions within the pond or drainage features that warrant further safety considerations and they shall be addressed accordingly. Dry detention basins may need to have minimum longitude slopes to avoid ponding.

Parking lots may be used for smaller amounts of detention. The maximum allowable depth of ponding for parking lot detention is 9" and may not inundate more than 25% of the total parking area. All parking lot detention areas with a design depth greater than six (6) inches shall have a minimum of 2 signs posted identifying the detention pond area.

Stormwater storage can be classified as detention, extended detention, or retention. The different types of detention facilities to manage this storage can include dry ponds, wet ponds, and constructed wetlands or marshes. The type of pond can be determined either by the intended use, local conditions, or even aesthetic purposes.

A d*ry detention pond* is the most common response to storage and attenuation requirements and is designed to completely drain once the design storm has passed. An extended *detention pond*, commonly designed to manage not only quantity but quality requirements can have certain outfalls that attenuate certain volumes for an extended time (i.e. 1" for 36 hours). Retention facilities, for our discussion purposes, are designed for maintaining a wet pool or wetland typically used for water quality purposes. The volume associated with the two (2') feet below the outfall can be considered when sizing the pond.

2. *Design Criteria*

The different features of a detention facility that will be discussed in further detail include:

- Layout
- Inflow Hydrographs
- Inlet Design
- Initial Volume Calculations
- Stage – Storage Relationships
- Outlet Design
- Stage – Discharge Relationships

Layout

The layout of a detention pond can be influenced by a variety of factors which may include topography, required volume, outfall elevations and type, contributing area, proposed development and inlet conditions, and soil and groundwater conditions. The location of a detention pond, in order to maximize its efficiency within the site is preferably near the outfall location and within the lower areas of the site. The depth of the pond is usually determined by the depth of the outfall channel or storm sewer. While in some regions the walls of the pond are built up above natural ground to reduce the overall area of the pond, the typical sandy (non-cohesive) soils of Aransas County probably do not easily lend itself to this practice. The design engineer shall provide geotechnical evidence that the soils used for this practice are justified.

The recommended length to width ratio, to increase the water quality effectiveness of detention facilities, is of 3L : 1W. This is recommended to allow the pond layout to maximize the flow path between the inlet and the outlet, minimize short circuiting, and avoid dead storage area. Select a side slope based on the site condition, a slope of 4H:1V is recommended for safety reasons. A maintenance shelf around the outside of the pond shall be maintained with a minimum width of 15'.

Inflow Hydrographs

The runoff hydrograph is a graph of the discharge of runoff from a basin or watershed versus time. The hydrograph increases in magnitude shortly after the start of the rainfall event and reaches a peak after the maximum rainfall intensity has occurred. As a watershed becomes more urbanized, the impact of more impervious area, decreased potential for infiltration, and loss of natural depression storage will change the response to rainfall and thus the shape (peak and time) of the resulting hydrograph.

When routing runoff where detention storage will be used an ***inflow hydrograph*** must be developed. Hydrograph methods can be completed by hand or spreadsheets for smaller sites using the modified rational method (discussed below) or rainfall hyetographs however, some contributing areas can be complex and computationally involved so computer programs such as TR-20 and HEC-HMS are often used.

Inlet Design

The stormwater runoff will typically enter the pond through storm sewer pipes, swales, and/or overland flow. The inflow hydrograph shall be used to determine the inflow rate. Standard inlet/outlet design procedures for headwalls, end treatments, and other erosion control methods including concrete lining, rip-rap, and energy dissipaters shall apply.

Initial Volume Calculations

With the inflow hydrograph and the outflow limitation (typically pre -development flows) established, the initial storage volume can be estimated for pond sizing. The method for estimating required storage is dependent upon the method used to calculate the inflow hydrograph. While the NRCS method is typically computed within a model, iterative methods of estimating pond sizing is relatively easy, however, with hand calculation methods can be laborious, and for this the Modified Rational Method can be used.

Modified Rational Method: The Rational Method is traditionally used to determine peak flow, but a hydrograph can be constructed using the following assumptions:

a) Peak Flow occurs at t_c
b) Flow increases linearly from Q = 0 to Q_{peak}
c) Flow continues steadily at Q_{peak} from $t=t_c$ to $2t_c$
d) Flow decreases linearly from $Q=Q_{peak}$ to Q=0 for $t=2t_c$ to $t=3t_c$

The resulting hydrograph is trapezoidal in shape and has a volume given by:

$$\mathbf{V_{in} = 2*60*(t_c * Q_{peak})}$$

Since the stage-discharge has not been determined one can estimate the outfall volume using the allowable discharge rate with the following equation:

$$\mathbf{V_{out} = ½ * 60 * (3 * t_c * Q_{out})}$$

Note: This outfall equation is only for estimating pond size and a stage-storage-discharge relationship table shall be used to quantify pond dimensions.

While the Modified Rational Method is an accepted tool for sizing detention ponds for smaller sites it can become less accurate for larger watersheds. Therefore, it shall be used for ponds with a contributing area of less than 20 acres.

Stage-Storage Relationship

With the inflow hydrograph and an initial volume estimated and a pre-determined discharge elevation (based upon the outfall receiving channel, weir or storm sewer) a stage-storage relationship can be developed. The stage vs. storage data for a pond relates pond water surface elevation to the volume of water stored. Again, with CADD or other computer based applications, this relationship can be determined easily, however, several hand methods are also frequently used.

Outlet Design

With the allowable discharge calculated one can determine the type of and size the outfall structure. The discharge from the outfall structure depends on the stage of the pond, the type of outlet(s), and possibly tailwater effects. For pipe or culverts, the discharge can be designed using the energy equations presented previously in this Attachment or simple computer software such as *Culvert Master*. Weirs can also be used to control the outflow or overflows from the pond. Several different types of weirs can be used from triangular, rectangular, trapezoidal or broad crested weirs. Hydraulic Manual shall be consulted and referenced for proper equations and flow coefficients.

The outlets should be design to manage (post development flows shall not exceed pre-development) the allowable 2-year and 5-year storm events if the design storm is a 5-year storm and the 2-yr, 5-yr, 10-year and 25-year if the design storm is a 25-year event. The 100-year storm shall be checked when designing the emergency overflows so that existing and proposed structures are not inundated due to the proposed improvements.

Stage-Discharge Relationship

With the outfall designed, the stage-discharge relationship is then determined for each outlet. The relationship is included in the spreadsheet or model at increments equal to that for the stage-storage relationship. This can result in a stage-storage-discharge relationship for the pond that is used in conjunction with the inflow hydrograph to determine the suitability of a pond configuration. This table shall then be used to develop a Hydrograph Routing Table taking the Inflow Hydrograph to develop inflow volumes for each time step and the Stage-Storage-Discharge Relationship table to analyze the outflow volumes and the cumulative difference determines a maximum volume required in the pond. This may take a few iterations of pond sizes for both the spreadsheet method and the model methods. An example of this process is near the end of this Attachment.

3. *Required Data*

The following information must be submitted for detention ponds designed by detailed methods:

- Information regarding analytical methods and software to be used, including:
  - Name of software to be used.
  - Type and distribution of precipitation input
  - Method for determining precipitation losses
  - Type of hydrograph, method for routing hydrographs, and method for reservoir routing
- Maps showing sub-basin delineation, topography, flow routes, soil types, existing basin development conditions used in the model or calculations; fully developed conditions used in the model or calculations
- Routing diagram for the runoff model if separate basins are analyzed
- Stage- storage table or graph for the detention pond.
- Stage-discharge table or graph for the outlet structure and overflow spillway (If the structures include weirs, orifices and other uncommon control structure, the designer shall provide hydraulic data).
- If a computer model is used:
  - a printout of the input data file
  - a summary printout of the output
  - plots of hydrographs.

It is understood that with the requirement of multiple storm event release rate controls and possible water quality volume inclusion in the pond (if an extended detention pond), that the outlet structure may be designed as a singular structure with several release rates based upon the elevation/staging within the detention pond. The hydraulic data to support this should be included with the submittals.

V. Stormwater Quality

For water quality protection, the Stormwater Management system shall incorporate water quality and erosion control measures that are either ***demonstrated***, or ***presumed*** to ensure the development causes no unacceptable damage**,** by meeting one of the criteria below:

1. *Presumed Method*

The presumption that the development will not cause unacceptable damage will have been achieved if the developer provides a design that ensures that the first inch (1.00”) of every runoff event from the overall impervious cover, is fully contained on site and that the contained volume is drained over a period of not less than 36 hours, and has done so using drainage practices that are acceptable to the County Engineer. These methods are described elsewhere in this document, but in general include detention methods (detention ponds, retention ponds, extended detention pond, swales with restricted outlets), or infiltration methods (infiltration ponds, infiltration trenches or porous paving) that are designed such that the required containment and release requirements are met, and such that the devices are constructed to appropriate design standards and without engendering a risk to health and welfare or implicitly demanding unacceptable maintenance requirements necessary to assure effective long term performance.

2. *Demonstrated Method*

The demonstration that the development will not cause unacceptable damage will have been achieved if the developer completes an acceptable analysis that proves that on an annual basis the duration of any flow rate which occurs prior to development is not increased after development to a degree that increases sedimentation or erosion or is otherwise problematic. This analysis shall be achieved by continuous simulation modeling or equivalent methods that develop flow duration exceedance curves for all event conditions less than a one year return period. Documentation and other requirements spelled out in this manual shall also be included. It must be shown by analysis that off site increases in erosive potential through increased rate or volume or duration of off-site flow shall be prevented, or else that stabilization or maintenance management measures are put in place and funded for the design lifespan of the development.

In many cases the detention or infiltration requirements for Stormwater Quality can be combined with the detention requirements presented for the Peak Flow control, if an extended detention facility is designed. Also, Stormwater Credits can be used to reduce the required stormwater quality volume.

VI. Stormwater Management Plan

The requirements for the components of a Stormwater Management Plan and the approval process are further described in the subsequent portions of this Attachment.

A. STORMWATER MANAGEMENT PLAN PREPARATION & APPROVAL PROCESS

There are four (4) steps in preparing the Stormwater Management Plan (Plan) and obtaining approval from Aransas County, which is required prior to commencement of construction activities. The steps are discussed in further detail within the Manual.

<u>Step 1 – Pre-Application Meeting with Stormwater Management Plan Approval Flowchart</u>

A Pre-Application Meeting will determine applicability of this Section to the proposed project, and help to educate the applicant regarding the *Plan* and the requirements of this Manual. This meeting will explain the various information submittals and steps required in preparing the *Plan* for approval.

<u>Step 2 – Application Form and Site Analysis and Narrative</u>

The second step of the approval process requires the submittal of:

- Application for Stormwater Management Project Approval
- *Site Analysis and Narrative*
  - A conceptual site plan with proposed layouts, existing and proposed stormwater management and ecological issues and constraints, and conceptual BMPs

The County Engineer will review all information submitted in the Site Analysis and Narrative and will provide comments within 10 working days of receipt of a complete submittal.

<u>Step 3 –Site Layout, Drainage, and BMP Design Plan</u>

The third step requires the submittal of:

- Site Layout, Drainage, and BMP Design Plan
- Construction Erosion Control Plan
- Inspection and Maintenance Program

The County Engineer will review all information submitted in the Stormwater Management Plan and will issue a "Letter of Administrative Completeness", within 15 working of receipt of a complete submittal, with comments. The applicant then resolves comments and provides a final Stormwater Management Plan.

<u>Step 4 – Approval</u>

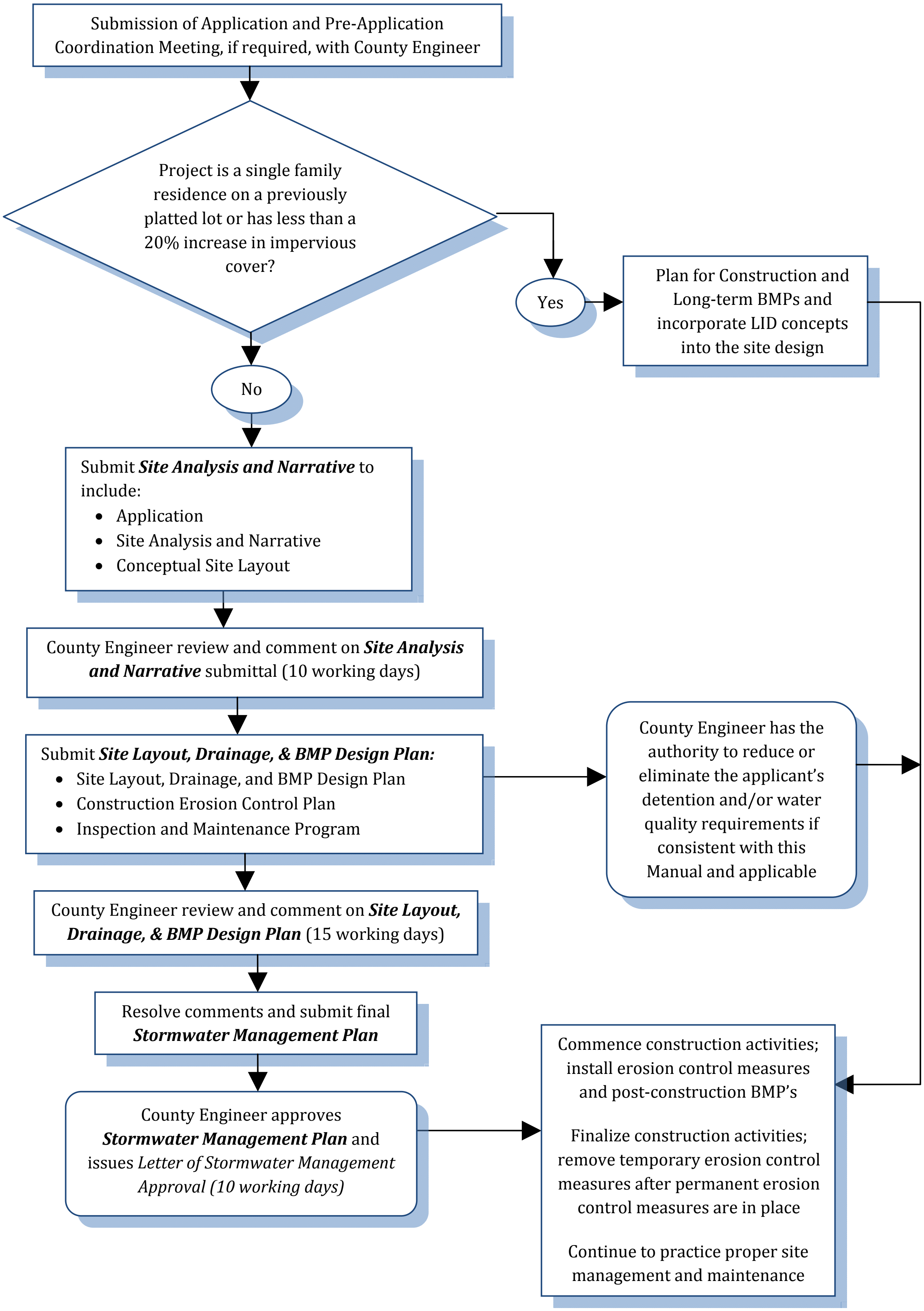
Upon approval of the Stormwater Management Plan, the County Engineer will issue a "Letter of Stormwater Management Approval" within 10 working of receipt of the Plan. Upon receipt of the Letter of Approval, the applicant can then commence construction of erosion control BMPs followed by project construction start-up.

B. INSPECTIONS AND MAINTENANCE

The stormwater control facilities should be inspected and maintained in good working condition, including the removal of any sediment and debris that may accumulate in the system. The County Engineer may inspect all facilities to insure that the work is done appropriately. If any stormwater facilities are planned to remain privately maintained, the *Stormwater Management Plan* shall include a description of maintenance activities detailing the inspection and maintenance operations, equipment necessary to perform these activities, access to the facilities, disposal methods for materials, and information regarding the facility owner(s) and party or parties responsible for the operation and maintenance and the financial security in place for the required maintenance.

The owner shall also make regular inspections of all drainage facilities and erosion control measures to determine the overall effectiveness of the plan and the need for additional control measures. In the event that the owner becomes aware of reduced effectiveness of any element of the stormwater management system, they shall so inform the County Engineer and at that time advise the County Engineer of their plans to achieve compliance. The owner shall clean all sediment and debris from the streets that has resulted from construction activities by the owner or its successors.

STORMWATER MANAGEMENT PLAN APPROVAL FLOWCHART



Application for Stormwater Management Plan

Aransas County	Submittal of this Application is Required for Approval of Site Development Stormwater Management Plans in Aransas County	
1.	**Applicant/Site Owner/Operator Information**	
	Name: Phone:	
	Address: E-mail:	
2.	**Site Development Project Information** Name of the Project:	
	Location of Project:	
	Project Description:	
	Overall Property Acreage: Disturbed Acreage:	
	Impervious Cover %:	
3.	**Exemption Criteria:**	
	Is project an existing single family residential platted lot or does the development plan have less than 20% Impervious Cover	☐ Yes ☐ No
	Will the site plan employ Low Impact Development Stormwater Control Designs?	☐ Yes ☐ No
	Site development will employ construction site erosion and runoff controls?	☐ Yes ☐ No
	If applicant responds Yes to all three questions, the applicant qualifies for the Minor Impact Exemption and is not required to follow the *Interim Guidelines*.	
4.	**Certification** I certify that this application was prepared by duly authorized representative of the applicant and project. Printed Name: Signature:	
5.	**County Records Only** Stormwater Management Plan Project Number:	

Checklist for Stormwater Management Plans

SITE ANALYSIS AND NARRATIVE

- Location map, size, and existing land use of the site;
- Description of existing land use of all adjacent properties;
- General description of existing site topography, natural and manmade features, County's watershed name, drainage patterns, flow paths, receiving waters, soil types and ground cover;
- Identify if the following exist on-site:
    - Any body of water, including natural and manmade drainage paths, identifying each as natural or not.
    - Any natural depressions or areas identified as probable areas of inundation for the 10-, 25-or 100- year storm events *(available through the County FLO2D mapping)*.
    - Any area that may be a jurisdictional wetland, as defined by 33 CFR 328.3(b) *(available through the County's NWI maps).*
    - Submerged lands belonging to the State of Texas that adjoins the property *(specifically for coastal properties)*.
- A general description of the proposed uses and improvements, lot subdivision, roadways, and other pertinent improvements;
- Phasing and timing of project;
- A general description of proposed drainage, water quality, and erosion and sediment control facilities expected to be used on site and the methodology for choosing the facilities;
- Total Site Area and impervious cover planned for the development;
- Provide a description of the potential pollutant activities to be conducted at the site, if applicable. Such activities of interest include chemical storage and/or use, vehicle, equipment or boat repair and maintenance, on-site wastewater treatment, product fabrication or washing/cleaning activities.
- Confirmation that all applicable regulations and public health and safety requirements will be met by the developer/contractor/builder.

Conceptual Plan: A simple drawing to depict the proposed layout, impervious cover areas, general hydrologic information, on-site and adjacent drainage conditions and improvements, and other pertinent information required for site stormwater assessment

SITE LAYOUT, DRAINAGE, BMP DESIGN PLAN

- Contact information of end-user responsible for inspection, maintenance and repair of stormwater management system (i.e. property owner, Homeowners Association, etc...);
- Legend, North arrow & scale;
- Existing property lines, ROWs, structures, impervious surfaces and improvements;
- Existing topography - contours;
    - Location of FEMA 100-year Floodplain, Floodway, and Velocity Zone, Boundaries that encroach on the site.
    - Location of any natural depressions deeper than 2' and greater than 1 acre *(as identified with the available County LiDAR information or on topographical surveys).*
    - Location of any natural identified areas of flood inundation *(FLO2D Model Information available from the County)*;

- Existing drainage patterns, flow paths, stormwater discharge locations, drainage easements;
- Limits of existing disturbed area;
- Proposed lots and/or building locations, ROWs, roadway locations and cross sections impervious surface areas and pavement types;
- Proposed grading (contours or elevations), drainage patterns and basins, discharge locations, and proposed easements;
- Size and Location of all permanent drainage and stormwater quality improvements and BMPs including: culverts, pipes, detention and infiltration ponds, swales, etc;

STORMWATER QUANTITY INFORMATION

- Existing and Proposed curve numbers or C values, time of concentrations, soil type and other pertinent hydrologic information for each drainage basin including contributing drainage area;
- Existing and proposed conditions runoff calculations for each outlet from the site;
- Existing and proposed conditions hydrographs when detention is required;
- Calculations to support the design and sizing of channels, storm sewers, outfalls, weirs, or stormwater management structures and facilities including hydrographs, and stage-storage-discharge tables or graphs for detention basins.

STORMWATER QUALITY INFORMATION

- If the demonstrative approach is chosen, a description for the models used for quality analysis; a copy of all model data sets, and description of the rainfall, land use and BMP dimensions used in developing those data sets; a copy of all model results, specifically identifying which data set gave rise to those results; a copy of all other design calculations (those other than described for the modeling);
- Describe any specific non-structural controls to be implemented.
- Justification for stormwater credits including volumes, acres, distances, etc. for LID components.
- ***If facilities are to be privately maintained,*** include:
    - Inspection Plan, which identifies the procedures that will be used to ensure the timely inspection of the control measures.
    - A description of the maintenance plan for stormwater management devices and practices including operational and physical measures and a proposed schedule;

CONSTRUCTION EROSION CONTROL PLAN

- Contact information of responsible party for inspection, maintenance and repair of construction erosion control measures (i.e. contractor, developer, owner, etc...);
- Designation of undisturbed open space, limits of construction / clearing;
- Proposed drainage patterns, location of existing and proposed stormwater conveyance measures;
- Location of construction site access and temporary sediment control measures, include type (provide details of needed);
- Designate material staging/storage areas (for materials that contribute pollutants to stormwater – i.e. concrete truck washout area or fill material stockpile site);
- Dewatering outfall location and pollution control measures;

- Describe and/or depict temporary BMP Maintenance Plan
- Include these statements if applicable:
  - Sediment will remain on site to the maximum extent practicable
  - Control measures will be properly selected installed and maintained in accordance with the manufacturer's specifications and good engineering practice. If damaged or rendered ineffective, the erosion and sediment controls will be repaired or replaced immediately.
  - Maintenance and repairs will be conducted within 24 hours of an inspection report.
  - All litter, trash and floatable debris will be contained on-site and disposed of properly and in accordance with local, state, and federal regulations

  Note: A Stormwater Pollution Prevention Plan (SWPPP) will serve to satisfy these requirements and should be submitted to the County Engineer.

CONSTRUCTION ACTIVITIES

- Inspection Reports:
  - Inspections of all BMPS will be conducted 14 calendar days and within 24 hours of the end of a storm event of 0.5 inches or greater, OR every 7 calendar days
  - Reports will include what maintenance was done as a result of the inspection.
  - All inspection reports are to be filed with the County within 5 working days of the inspection
- TPDES Construction General Permit ID number
  - Copy of TPDES NOI form if 5 or more acres are disturbed
  - Copy of TPDES Entrance Posting form if 1 or more acres are disturbed
  - Copy of NOT form once construction is completed and re-vegetation meets the permit requirements to terminate permit coverage.

There may be some instances where additional requirements may be imposed on the site upon review of the County Engineer.

VII. Low Impact Development

Over a decade ago, a shift in the way engineers, municipalities, counties, states, and regulatory agencies thought about stormwater management started to take hold. The shift from conventional, end of the pipe techniques that concentrated on drainage efficiency to a management system that identified ways to manage runoff volume control at the source was labeled ***Low Impact Development (LID)***. The term LID, in this document, refers to a range of stormwater management measures that are intended to limit the impacts of development on the hydrologic regime. To simplify for use in Aransas County, the primary goal of LID is to mimic the pre-development site hydrology by using design techniques that infiltrate, detain, and evaporate runoff. Also, use of these techniques helps to ensure adequate groundwater recharge. Both of these outcomes are integral parts of the goals and objectives of Aransas County and its citizens. By dispersing these techniques throughout a development and capturing runoff at the source, or keeping existing depressions *in situ* and making them part of the overall stormwater management system, developers and engineers have the potential to recreate the functional storage and treatment that is supplied by native vegetation or natural depressions, while creating aesthetically pleasing places, and protecting Aransas County's natural environment.

Conventional stormwater management tools utilize methods that are efficient in terms of drainage and rapidly collect and convey stormwater from developments to outfalls often resulting in a transfer of pollutants. While these hard-lined systems are sometimes necessary, LID techniques have been proven to cost less, provide a safe alternative, and be effective at managing and integrating components of the stormwater equation deemed important in Aransas County. Case Studies by the EPA that included LID systems versus conventional systems suggest that an LID approach to stormwater management can not only provide reductions in stormwater volumes as well as improvements in water quality, but also decrease project costs.

A. LID Design Practices

To start the discussion about LID design practices, a few questions must be presented:

What are the site's main predevelopment hydrologic functions and how can they be maintained while allowing full use of the site?
Hydrologic functions such as infiltration, groundwater recharge, and natural storage can be maintained by disconnecting impervious surfaces, using open channel conveyances, and maintaining infiltration areas. Design practices such as these can also result in increased time of concentration and infiltration while allowing integration of natural depression storage into the stormwater management system.

How can site-planning affect the post development hydrology?
Integration of hydrology into the site planning process begins by identifying and preserving sensitive areas that affect the hydrology, including depressions, wetlands and woodlands.

Can we reduce costs while maintaining usable space?
By incorporating LID techniques a developer can significantly reduce costs by reducing impervious surfaces, curb and gutters, inlet structures, and pipes. The diminished increase of runoff, by using LID design practices, can also be used to eliminate or decrease the size of detention ponds.

1. Source Control

Mitigation for the natural hydrologic functions lost with developments should be implemented as close as possible to the point or source of impact which is one of the keys to LID Techniques. This is referred to as a distributed or source control strategy. Source control systems tend to be small and plentiful allowing shallower basins with gentler side slopes. The integration of these facilities into the landscape throughout the site offers more opportunities to mimic the natural hydrologic functions and add aesthetic value.

2. Simplicity

While the momentum for using such techniques has gained over the last decade, as discussed previously, it isn't a design practice that needs to be overly complicated. In fact, the simplest of techniques can be used for most developments.

An example of the simplicity of LID in Aransas County is depicted with the increased runoff from a 150' x 300' (1-acre), single family lot developed from natural woodlands during a 5-year storm event (6.4" in 24 hours). This increased runoff, volume under 1/10 acre-feet, can be contained within a typical shallow swale along the ROW of the property coupled with the extended time of concentration.

Another simple site design technique is to limit the clearing and grading of the overall development thus reducing impacts. Typical sites may accomplish this by:

- Reducing width of driveways and paved surfaces or using permeable surfaces
- Utilizing natural drainage patterns and existing grades; limiting the placement of fill
- Incorporate depressions and Blue Corridors into the stormwater management systems

3. Time of Concentration

Volume control is consistently discussed as the main product of LID techniques, yet another result that is important to consider is the time of concentration. One can easily understand that if natural wooded, brushy sites with flat slopes are replaced with manicured lawns with steeper slope the time for the runoff to reach the outfall is significantly decreased. A decreased T_c results in an increased peak runoff requiring larger conveyance systems and producing greater impacts downstream. Therefore, maintaining a post-development T_c as close to the existing as possible can help reduce costs and downstream impacts. This attenuation of the runoff is one of the major principles behind the requirement of detention ponds and is accentuated with LID which also attempts to retain a significant portion of the rainfall at the source without large detention ponds through infiltration or smaller ponds (rain gardens).

The site conditions which are most often changed in standard developments that decrease the T_c for runoff include shortened flow path, increased slope, and decreased surface roughness (for both overland and channelized flow paths.

B. LID Techniques and BMP Design Criteria

While the following are only a few of the LID techniques, more in-depth discussion about these and many other LID techniques are available from several references mentioned in Appendix 15. Most of the BMPs described in this section are examples of LID techniques widely used throughout Texas and the Country and are especially appropriate for the sandy soils that exist throughout much of Aransas County. The techniques presented in this section are considered to acceptable for use in Aransas County and are discussed in further detail throughout the Manual.

1. Filter Strips

Filter strips are vegetative areas intended to treat sheet flow. Filter strips provide effective stormwater management only when they have relatively flat slopes and low velocities and act as level spreaders to promote sheet flow conditions. The length of the filter strip is the treatment media where most of the pollutants are trapped through filtration and sedimentation as the stormwater sheet flows across these vegetated areas. Filter strips are relatively flat with no side slopes and are typically located adjacent and parallel to paved areas such as parking lots, driveways, and roadways. Dense growth vegetation is required and the filter strip shall be constructed along the entire length of the contributing area. The longitudinal slope (flow path) should be less than 2% developing a maximum velocity of less than 1.5 fps. The following table summarizes the required filter strip width:

Required Filter Strip Widths

Flow Path Across the Paved Surface (ft)	Filter Strip Width (ft)
<60	20
60 to 80	25
80 to 100	30
100 to 120	35
120 to 140	40
140 to 150	45

2. Grass Swales

Grass swales are defined as grass-lined, earthen channels, intended to provide water quality enhancement as well as limit velocities and allow for infiltration. The rational formula (Q=CIA) shall be used to determine the design flow rate and Manning's shall be used to size the swale. The flow velocity shall not exceed 1.5 feet per second. The width of the swale shall be sized to achieve a depth of flow of 6 in. or less based upon the water quality rain event and sized to manage the design storm event. The minimum travel distance shall be at least 50 feet for water quality treatment before its discharge into the receiving stormwater conveyance mechanism. The length of swale should be calculated based on a minimum hydraulic retention time of 2 minutes. Discharges from the grass swale to conveyance system shall not promote erosion.

Sizing Procedure

1. Calculate design flow rate (***Q***) from the drainage area using the rational formula.

   i. $Q = CIA$ Where: Q= Design flow rate (ft^3/sec)
   C = Runoff coefficient (dimensionless)
   I = Intensity (in/hr)
   A = Area in (acres)

2. The Manning's Equation.

   a. Determine the longitudinal swale slope (S). Determine the depth of flow (d) (6 inches or less for stormwater quality volume). Select a channel shape and side slope.

   b. Using Manning's equation with a roughness coefficient (n) for the swale shall be 0.24 for frequently mowed grass, determine the bottom width (b).

   c. Substitute the value of Q calculated above for Q in the Manning's equation to determine the required width.

$$\boldsymbol{Q} = \frac{1.49}{\boldsymbol{N}} \boldsymbol{A}\boldsymbol{R}^{2/3}\boldsymbol{S}^{1/2}$$

Where: n = Roughness coefficient (dimensionless)
A = Cross-sectional area (ft^2)
R = Hydraulic radius (ft) =Area/wetter perimeter
S = Longitudinal slope (dimensionless)

3. Check the velocity of flow (**V**), and if velocity exceeds the recommended maximum of 1.5 fps, widen the proposed cross section and recalculate the bottom width of the swale.

4. Determine the length of the grass swale based on a minimum hydraulic retention time of 2 minutes. The required minimum swale length is 50 feet.

   i. $\boldsymbol{L} = \boldsymbol{V} \times \boldsymbol{t}$ Where: $\boldsymbol{V}$ = velocity in feet per second
   $\boldsymbol{t}$ = hydraulic retention time

3. Rainwater Harvesting

Rainwater Harvesting refers to the collection and storage of stormwater runoff from roof-tops for non-potable purposes such as irrigation. Rainwater harvesting systems can range from a simple barrel at the bottom of a downspout to multiple tanks with pumps and controls. Overflows from the storage device should be diverted to lawns or other areas to promote infiltration. Criteria for the Rainwater Harvesting systems and their maintenance should be included in the deed restrictions.

4. Disconnection of Impervious Cover

Disconnected Rooftop Cover

Disconnected rooftop cover refers to use of overland flow or infiltration areas to treat rooftop runoff. You can direct rooftop runoff along an overland flow path or into an infiltration area to treat rooftop runoff before it enters into a conveyance system.

The contributing area of rooftop shall be no more than 1,000 sq. ft. per disconnection. The disconnection must drain continuously over a vegetated strip or swale for a distance equal to or further than the impervious cover distance traveled. The downspouts must be at least 10 feet away from the nearest impervious cover (sidewalk, driveway, etc.) to avoid a "re-connection". The disconnection of rooftops is calculated on a per lot basis and therefore shall be included in the deed restrictions.

Disconnected Impervious Cover

Disconnected Impervious Cover refers to use of overland flow or infiltration areas to treat runoff from impervious areas. The contributing area of impervious cover shall be no more than 3,000 sq. ft. per disconnection. The disconnection must drain continuously over a vegetated strip or swale for a distance equal to or further than the impervious cover distance traveled.

5. RAIN GARDENS

Rain gardens are vegetated stormwater treatment facilities that capture and temporarily store collected runoff and allow it to filter through the soil. They are typically shallow depressions that contain aesthetically pleasing, water tolerant plantings. These gardens are typically located close to the source of the runoff and serve to detain stormwater with its relatively small amount of volumes as well as allowing for infiltration. Rain gardens are commonly sited to treat stormwater runoff from residential lots and parking areas. Rain gardens are best suited for relatively flat, low areas that have well drained soils, which is consistent with the conditions of most of Aransas County.

Rain gardens are sized based on the size of the impervious area draining to them, the site soil and slope. Rain gardens are typically designed to pond no more than six-inches of water within the shallow surface depression and must allow for the safe passage of runoff from large storm events. Rain gardens should have a level bed and be constructed in areas where soil conditions will allow for the infiltration of collected stormwater. Plants must be able to tolerate extreme moisture conditions but should not require consistent wet soils or standing water. These plants can be difficult to maintain in the south Texas climate.

C. ALTERNATIVE TYPES OF LID TECHNIQUES

1. BIORETENTION / BIO-INFILTRATION FACILITIES

Bioretention facilities are vegetated conveyance or retention depressions that use the vegetation to improve water quality, reduce the runoff volume, and attenuate the peak runoff rate. Bioretention facilities are similar to grassy swales or rain gardens and perform similar functions with the added amended soils with bioretention media which increases infiltration, water retention, nutrient and pollutant removal.

2. POROUS PAVEMENT

Porous pavement is a permeable pavement surface that functions as a temporary reservoir storing stormwater runoff before allowing it to infiltrate into the subsoil. The term porous pavement is a general term that includes the following materials: porous asphalt, porous concrete and porous pavers.

Porous pavement practices can be well suited for roadway, driveway, parking, and sidewalk areas as a replacement for traditional pavement materials. This LID technique has not been included in the stormwater credits due to a lack of historical performance of porous pavements in the area. It is anticipated the use of porous pavements will increase in the future and are likely to be added to the menu of credit options. The designer of the LID device should consult with the County Engineer to add this credit based upon engineering design and data.

D. Stormwater Quality Credits and Incentives

The Stormwater Credits detailed in this document are for:

- Grassy Swales
- Filter Strips
- Disconnected Impervious Cover
- Rain Gardens / Runoff Storage Areas
- Non-Curb and Gutter Street Sections
- Preserving Woodlands

1. Grass Swales

The Stormwater Quality Credit for Grassy Swales shall be in the form of a reduced impervious cover by 20% for the area served by the grassy swale. Maintenance is an important factor if grass swales are to continue to function as originally designed. The grass must be mowed as needed for good growth and to maintain the desired grass height. Sediment must be removed as needed if growth is inhibited or if sediment is blocking the conveyance of the stormwater runoff.

2. Filter Strips

The Stormwater Quality Credit for Filter Strips shall reduce the overall impervious cover for the area served by the filter strip by 10% if the design criteria, presented previously in this attachment, are achieved. Maintenance is the most important factor if water quality filter strips are to continue to function as designed. The maintenance requirement of filter strips is similar to grass swales. Filter strips are a typical practice for commercial areas adjacent to parking lots.

3. Disconnection of Impervious Cover

While the concept of Disconnected Impervious Cover is similar to filter strips or grassy swales, this specifically refers to the use of overland flow and infiltration areas to capture and treat runoff from impervious areas. While this credit is developed with single-family development in mind, one can also utilize this credit with other types of development. If you have utilized the Stormwater Quality Credit for grassy swales or filter strips, you cannot duplicate the credit for the same areas.

The Stormwater Quality Credit for Disconnection of Impervious Cover or Rooftop Cover shall be in the form of a reduced impervious cover by 10% for the area served.

4. Rain Gardens / Runoff Storage Areas

While rain gardens, runoff storage areas, and small retention areas may be designed differently according to aesthetics and plant life, the concept of a small, on-site depression with the capacity to store runoff, even in the smallest of quantities will be given similar consideration based upon that retention volume. It is recognized that some of these devices can be designed to accentuate the infiltration of runoff while also providing a quantified volume of retention. While the presumed infiltration of these devices is not considered in this stormwater quality credit they are certainly encouraged. The designer of the LID device should consult with the County Engineer to increase this credit based upon infiltration. Evidence of increased infiltration based upon accepted engineer practices will be required. An added benefit, as mentioned above, is the detention volume within the rain garden or other small, on-site depression which can be included within the detention requirements. The Stormwater Quality Credit for Rain Gardens and Runoff Storage Areas shall be in the form of a Stormwater quality volume reduction and be directly reduced by the volume of storage designed within the LID device.

5. PRESERVING WOODLANDS/CREATING ECOLOGICAL FEATURES

Woodlands improve water quality and watershed health primarily by decreasing the amount of stormwater runoff and pollutants that reaches our local waters. Woodlands reduce stormwater runoff by capturing and storing rainfall in the canopy and releasing water into the atmosphere through evapotranspiration. In addition, tree roots and leaf litter create soil conditions that promote the infiltration of rainwater into the soil. In addition to these stormwater benefits, trees provide a host of other benefits such as increased property values, habitat for wildlife, and recreation and aesthetic value.

The developed area with the increased curve number or coefficient of runoff for which the stormwater management requirements are in place shall be limited to the disturbed areas only. This should be considered an incentive for a developer to preserve a portion of the site as natural woodlands.

6. NON CURB AND GUTTER STREET SECTION

The Stormwater Credit for a non-curb and gutter street section shall be in the form of a reduced curve number or coefficient of runoff for the overall development area. The presumption of this stormwater credit is based upon the increased T_c from typical curve and gutter streets with minimum gutter slopes, underground conduits, etc. It should be noted that the designer of the streets is responsible for proper edge of road protection, whether in the form of increased stabilization beyond the edge of the roadway or a increased design capacity within the overall pavement section. The Stormwater Credit for Non Curb and Gutter developments shall be an overall reduction of the Curve Number or Coefficient of Runoff increase of 25%.

7. OTHER LID TECHNIQUES

Some facilities have not been included in the Stormwater Quality Credits as a separate facility due to lack of historical data for increased infiltration rates data in the area and the credits for these facilities should be based on the same credits for Rain Garden or grassy swales. The designer of the LID device should consult with the County Engineer to increase this credit based upon infiltration.

VIII. CONSTRUCTION BMPS

Pollution carried by stormwater runoff from a construction site represents a threat to the water quality of the aquatic areas in Aransas County. Control of sediment and erosion at a development site is as important during construction as after completion and should receive the same attention. During construction, exposed soil is highly susceptible to erosion by wind and stormwater runoff. The following sections briefly describe several widely used Construction BMPs and their uses. For more choices of construction BMPs or further details, specifications and installation guidelines of the ones generally described in this document please refer to the EPA's website for the Stormwater Menu of BMPs or the TCEQ's website on Nonpoint Source Water Pollution – Program Management.

A. Reinforced Filter Fabric Fencing

Reinforced filter fabric fences are used as temporary perimeter controls around the exterior of construction sites where a disturbance of soils is proposed. They are typically used at the down slope borders of the site to retain pollutants on-site or on the up slope of the site to divert offsite drainage and within the interior of the site to control minor sheet flow of runoff. They cause runoff to pond, allowing sediment to settle out.

A reinforced filter fabric fence consists of a length of filter fabric stretched between anchoring posts spaced at regular intervals. The filter fabric should be entrenched in the ground between the support posts. Reinforced filter fabric fences apply to construction sites with relatively small drainage areas. They are appropriate in areas where runoff will occur as low-level flow (less than 1 cfs) and drainage areas are small (less than 0.25 acres per 100' fence length). Reinforced filter fabric fences are generally ineffective in locations where the flow is concentrated and are only applicable for *sheet or overland flows*. Remove sediment when the buildup begins to deter proper drainage from the site or poses a concern of sediment transport off-site.

B. Straw Bale Fence

A straw bale barrier is a series of straw bales placed on a level contour to intercept *sheet flows*. Straw bale barriers pond sheet flow runoff, allowing sediment to settle out and are an alternative to silt fencing.

C. Rock Filter Fence

Rock filter fences are a temporary ridge made up of loose gravel, stone, or crushed rock. The main purpose of a rock filter fence is to serve as a check dam in areas of *concentrated flow*, intercepting runoff and causing it to pond, allowing the sediment to settle out. Therefore, rock filter dams are typically used in drainage swales and low flow channels at the downstream end of the construction site.

A rock filter fence consists of 3" to 5" rock contained within a woven wire fabric with a minimum height of 18". Installation of the rock filter fence should be perpendicular to the flow path. Remove sediment when the buildup begins to deter proper drainage from the site or poses a concern of sediment transport off-site.

D. Stabilized Construction Entrance

A stabilized construction entrance is the designated entrance/exit to a construction site that is stabilized to minimize the amount of sediment leaving the area as mud and sediment attached to vehicles.

Construction entrances use a pad of gravel, 3" to 6" rock with a minimum thickness of 8" over a geotextile fabric to separate the gravel from the soil below, keeping the gravel from being ground into the soil. The fabric also reduces the amount of rutting caused by vehicle tires. It spreads the vehicle's weight over a soil area larger than the tire width. Make sure the stabilized site entrances are long and wide enough to allow the largest construction vehicle that will enter the site to fit through with room to spare. If many vehicles are expected to use an entrance in any one day, make the site entrance wide enough for two vehicles to pass at the same time with room on either side of each vehicle. If a site entrance leads to a paved road, make the end of the entrance flared so that long vehicles do not leave the stabilized area when they turn onto or off the paved roadway. The construction entrance shall be a minimum of 50' in length and 16' in width. It is important to remove all sediment on a regular basis to keep the sediment from transporting off-site. Stone and gravel should be added to each stabilized construction site entrance, when needed, to keep the entrance effective.

In addition to using a gravel pad, a vehicle washing station can be established at the site entrance. Using wash stations routinely can remove sediment from vehicles before leaving the site. To further reduce the chance of these sediments polluting stormwater runoff, sweep the paved area adjacent to the stabilized site entrance.

E. Inlet Protection Devices

Inlet protection devices consist of a sediment filter or an impounding area around or upstream of a storm drain, drop inlet, or curb inlet and temporarily pond runoff before it enters the storm drain, allowing sediment to settle out. If the construction activities are directing runoff towards existing inlets they should be implemented before a site is disturbed. Otherwise, they are typically placed when the inlets are constructed and construction activities continue in the area. Inlet protection devices are often used in sequence or with other erosion control techniques.

There are two types of inlet protection that are typically installed. The first type, Type A is reinforced filter fabric fencing around inlet entrances, creating a shield against sediment while allowing water to flow into the drain. This barrier slows runoff while catching soil and other debris at the drain inlet.

The second type, Type B is sand bags used to form a barrier to sediments that permits water runoff to flow over the sandbags

Check all temporary control measures after each storm event. To maintain the capacity of the settling pools, remove accumulated sediment and debris from the area around the inlet when the capacity is significantly reduced.