Town of Westlake

THE TOWN OF WESTLAKE
DISTINCTIVE BY DESIGN

STORM WATER DESIGN MANUAL

Revised September 2022

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INTRODUCTION

This design criteria is needed to update the policies and criteria for storm water facilities within the Town of Westlake and its extraterritorial jurisdiction. New policies and criteria are needed to reflect the changes that have occurred in community standards, technology and environmental regulations that impact storm water management. The primary motivation for this new manual is to guide the community in drainage policy and criteria so that new development does not increase flooding, erosion, and water quality problems.

This drainage design criteria is intended to provide a guideline for the most commonly encountered storm water or flood control designs in the Town of Westlake. It can also be used as a guide for watershed master plans and f o r design of remedial measures for existing facilities. This criteria was developed for users with knowledge and experience in the applications of standard engineering principles and practices of storm water design and management. There will be situations not completely addressed or covered by this design criteria manual. Any variations from the practices established herein must have the acceptance of the Town Engineer or designee. Close coordination with the staff of the Town is recommended and encouraged during the planning, design and construction of all storm water facilities.

Relationship of Town of Westlake to the Regional *integrated* Storm Water Management (*i*SWM) Manual

The Town of Westlake design criteria is the regional *i*SWM manual updated in 2021, developed by the North Central Texas Council of Governments (NCTCOG) with clarifications and modifications indicated in this "Local Criteria Section." The Town of Westlake is adopting the iSWM manual in its entirety with the exception of those sections specifically modified herein.

Precedence of Town of Westlake Local Criteria

The requirements contained within this Town of Westlake Local Criteria shall take precedence over conflicting provisions that may be contained in the *integrated* Storm Water Management Manual approved by the North Central Council of Governments.

Contact Informatin

Contacts for the Town of Westlake Storm Water Management Design Manual can be reached at the Town of Westlake. (website: https://www.westlake-tx.org). For information on the *i*SWM regional manual and program, contact the NCTCOG at 817-695-9191 or at the website: http://iswm.nctcog.org.

GOALS AND OBJECTIVES
OF THE TOWN OF WESTLAKE
STORM WATER MANAGEMENT PROGRAM

1. Establish and implement drainage policy and criteria so that new development does not create or increase flooding problems, cause erosion or pollute downstream water bodies.

2. Facilitate the continuation of comprehensive watershed planning that promotes orderly growth and results in an integrated system of public and private storm water infrastructure.

3. Minimize flood risks to citizens and properties, and stabilize or decrease streambank and channel erosion on creeks, channels, and streams.

4. Improve storm water quality in creeks, rivers, and other water bodies, remove pollutants, enhance the environment and mimic the natural drainage system, to the extent practicable, in conformance with the Texas Pollutant Discharge Elimination System (TPDES) permit requirements.

5. Support multi-use functions of storm water facilities for trails, green space, parks, greenways or corridors, storm water quality treatment, and other recreational and natural features, provided they are compatible with the primary functions of the storm water facility.

6. Encourage a more standardized, integrated land development process by bringing storm water planning into the conceptual stages of land development.

TOWN OF WESTLAKE STORM WATER POLICY STATEMENTS

1. All development within the Town of Westlake Town Limits shall include planning, design, and construction of storm drainage systems in accordance with this Storm Water Management Design Manual, and Planning Commission Rules and Regulations.

2. Conceptual, Preliminary and Final Drainage Studies and Plans may be required for proposed developments within the Town of Westlake, in conformance with this Storm Water Management Design Manual. Specific submittal requirements depend on the complexity of the project and requirements of the Subdivision Ordinance and Zoning Ordinance. The checklists for each stage of this three-tier process are included in the iSWM Manual.

3. All drainage related plans and studies shall be prepared and sealed by a Licensed Professional Engineer with a valid license from the State of Texas. The Engineer shall attest that the design was conducted in accordance with this Storm Water Management Design Manual.

4. For currently developed areas within the Town of Westlake with planned re-development, storm water discharges and velocities from the project should not exceed discharges established by procedures presented in this manual but also shall not exceed discharges and velocities from current (existing) developed conditions, unless the downstream storm drainage system is designed (or adequate) to convey the future (increased) discharges and velocities.

5. All drainage studies and design plans shall be formulated and based upon ultimate, fully developed watershed or drainage area runoff conditions. In certain circumstances where regional detention is in place or a master plan has been adopted, a development may plan to receive less than ultimate developed flow from upstream areas with the approval of the Town Engineer, or Designee. The rainfall frequency criteria for storm water facilities, as enumerated within this Storm Water Management Design Manual, shall be utilized for all drainage studies and design plans.

6. Proposed storm water discharge rates and velocities from a development shall not exceed the runoff from existing, pre-development conditions, unless a detailed study is prepared that demonstrates that no unacceptable adverse impacts shall be created. Adverse impacts include: new or increased flooding of existing structures, significant increases in flood elevations over existing roadways, unacceptable rises in base flood elevations or velocities, and new or increased stream bank erosion or increased occurrence of nuisance flows.

7. If a proposed development drains into an improved channel or storm water drainage system designed under a previous Town of Westlake drainage policy, then the hydraulic capacities of downstream facilities must be checked to verify that increased flows, caused by the new development, shall not exceed the capacity of the existing system or cause increased downstream structure flooding. If there is not sufficient capacity to prevent increased downstream flooding, then detention or other acceptable measures must be adopted to accommodate the increase in runoff due to the proposed development.

8. Storm water runoff may be stored in detention and retention basins to mitigate potential downstream problems caused by a proposed development. Proposed detention or retention basins shall be analyzed both individually and as a part of the watershed system, to assure compatibility with one another and with the Town's storm water management master plans for that watershed (if available). Storage of storm water runoff, near points of rainfall occurrence, such as the use of parking lots, ball fields, property line swales, parks, road embankments, borrow pits and on-site ponds is desirable and encouraged.

9. Alternatives to detention or retention for mitigation of potential downstream problems caused by proposed development include: acquisition of expanded drainage easements, ROW, or property owner agreements; downstream channel and/or roadway bridge/culvert improvements or stream bank erosion protection; and financial contributions to the Town Storm Water Program for future

10. improvements. These alternatives shall be considered by the Town Engineer, or designee, on a case-by-case basis.

11. All proposed developments within the Town of Westlake City Limits shall comply with all local, county, state and federal regulations and all required permits or approvals shall be obtained by the developer.

12. The policy of the Town is to avoid substantial or significant re-routing or transfer of storm water runoff from one basin to another and to maintain historical drainage paths whenever possible. However, the re-routing or transfer of storm water from basin to basin may be necessary in certain instances and shall be reviewed and a variance can be made by the TOWN ENGINEER or designee, in accordance with established variance procedures.

13. Town Maintenance - The Town shall provide for perpetual maintenance, in accordance with adopted Town maintenance standards, of all public drainage structures located within dedicated easements and constructed to the Town's standards. Access shall be provided and dedicated by the developer to all public storm water facilities in developments for maintenance and inspection by the Town. The Town does not generally provide maintenance of vegetative cover inside subdivision or other private properties, even within public drainage easements.

14. Private Maintenance - Private drainage facilities include those drainage improvements which are located on private property and which handle only private water. Private drainage facilities may also include detention or retention ponds, dams, and other storm water controls which collect public water, as well as drainage ways not constructed to Town standards, but which convey public water. Such facilities must be designed in accordance with sound engineering practices and reviewed and inspected by the Town. An agreement for perpetual maintenance of private drainage facilities serving public water shall be executed with the Town prior to acceptance of the final plat. The title and ownership agreement shall run with the land and can be tied to commercial property or to an owner's association, but not to individual residential lots. Access shall be provided by the developer/owner to all private drainage facilities where there may be a public safety concern for inspection by the Town. The Town does not generally provide maintenance of vegetative cover inside subdivision or other private properties, even within public drainage easements. However, if a determination is made by the Town Engineer or designee that the Town needs emergency access to any private improvement or private waters, it has the right to enter the private property for corrective actions. While the Town has the right to this access and actions, it is never under any obligation to do so.

SECTION 1 – STORM WATER MANAGEMENT SYSTEM PLANNING AND DESIGN

Chapter 1 of the *i*SWM Manual provides a foundation for *integrated* Storm Water Management in terms of basic philosophy, principles, definitions, and land development site planning and design practices, and should therefore be utilized for general guidance throughout the development process. In general, the Town of Westlake currently follows the flood control and streambank protection components of the *integrated* planning and design approach. Streambank protection is a requirement in Westlake, but there is not a standard requirement to provide extended detention for the streambank protection volume. To comply with TCEQ permit TXR040000, the MS4 Phase II permit, the Town of Westlake requires the use of best management practices (BMPs) to address post construction water quality for all new development and redevelopment projects. The NCTCOG *i*SWM Manual identifies the use of certain site design practices and structural measures as BMPs to address post construction water quality. It is expected some use of both site design and structural measures shall be used in development projects to meet this requirement. Other modifications are summarized below.

Section 1.1 – Storm Water Site Planning

Depending on the complexity of the project or submittal requirements as dictated in the Code of Ordinances, storm water management plans may be prepared and submitted to the Town of Westlake in the progressive planning stages of a land development project with the Conceptual Site Plan and Preliminary Site Evaluation and Final Plat. The Conceptual Site Plan is an important consideration in that it allows the developer and their design engineer to propose a potential site layout and gives Town staff the opportunity to comment on a storm water management plan concept prior to significant planning and design effort on the part of the design engineer.

Conceptual Storm Water Management Plan (iSWM 1.1.3.5)

In general, the engineer and planner shall follow the conceptual storm water management plan guidelines as presented in Section 1.1.3.5 of the *i*SWM Manual, as applicable to the Town of Westlake.

Preliminary Storm Water Management Plan (iSWM 1.1.3.6)

A preliminary drainage study and storm water management plan shall accompany a preliminary site evaluation submitted for development review, and shall generally include the information listed in Section 1.1.3.6 of the iSWM manual as applicable to the Town of Westlake. The study shall include a downstream assessment of properties that could be impacted by the development. These studies shall include adequate hydrologic analysis to determine the existing, proposed, and fully-developed runoff for the drainage area that is affected by the proposed development and shall include hydraulic studies that define the "adequate outfall". The development storm water management plan shall address existing downstream, off-site drainage conveyance system(s); and shall define the discharge path from the outlet of the on-site storm water facilities to the off-site drainage system(s) and/or appropriate receiving waters. See Section 2.1.9 of the *i*SWM Manual ("Downstream Hydrologic Assessment") for guidance on the details of this downstream assessment. As a minimum, the Town of Westlake requires assessment of the 2-, 10-, 25- and 100- year 24-hour events. This preliminary drainage study and storm water management plan shall include:

1. A topographical map of the entire watershed (not just the area of the proposed development) generally not smaller than 1"=200' (or other such scale approved by the Town Engineer or designee), delineating the watershed boundary(s) and runoff design

point(s), existing and proposed land use and zoning, and the size and description of the outfall drainage facilities and receiving streams.

2. Computation tables showing drainage areas, runoff coefficients, time of concentration, rainfall intensities and peak discharge for the required design storms, for both existing and proposed (ultimate development) conditions, at all design points for each component of the storm water system (streets, pipes, channels, detention ponds, etc.).
3. Any proposed changes to watershed boundaries (i.e. by re-grading, where permissible by Texas Water Code). If significant changes to watershed boundary are made, more extensive analyses of downstream impact and mitigating detention shall be required and a variance obtained from the Town Engineer or designee.
4. FEMA Flood Hazard Areas - if applicable.
5. In addition any required Corps of Engineer's Section 404 permits, Conditional Letters of Map Revision (CLOMR), Letters of Map Revision (LOMR) or other permits relating to lakes and streams required by any federal, state or local authorities. These must be documented in the Drainage Study.
6. Detailed off-site outfall information. This shall include the presence of existing or proposed drainage structures, bridges or systems; documentation of existing versus proposed developed site as well as ultimate runoff, identification of downstream properties which might be impacted by increased runoff, and proposed detention or other means of mitigation. Downstream impacts shall generally be delineated to a point where the drainage from the proposed development has no impact on the receiving stream or on any downstream drainage systems within the "zone of influence".
7. Report with technical documentation.

Final Storm Water Management Plan (*i*SWM 1.1.3.7)

A Final Drainage Study and Storm Water Management Plan for development of all or a portion (i.e. phase one or phase two, etc.) of the overall development shall be prepared and submitted to the Town of Westlake. This submittal shall generally include the information listed in Section 1.1.3.7 of the iSWM manual as applicable to Westlake, including:

1. Conformance with the Preliminary Storm Water Management Plan and Study.
2. Submission of detailed drainage calculations and detailed design plans.
3. The submission of a cover sheet signed by the Town Engineer or designee indicating the approval of the detailed construction drawings for the proposed development is sufficient to clear a plat drainage study comment.
4. Final drainage studies shall be approved based on the submission of a signed cover sheet and drainage map with calculations from the accepted engineering construction drawings. Where Town acceptance of construction plans is not required, the above information required for preliminary drainage studies, as well as construction plans for any drainage improvements, prepared according to criteria in the current Town of Westlake plan review checklists, shall be submitted.
5. Note that unless specifically approved in a Floodplain Development Permit issued through the TOWN ENGINEER or DESIGNEE, no work may be performed in the FEMA regulatory floodway without a FEMA- approved Conditional Letter of Map Revision (CLOMR). No development activities may occur in the FEMA regulatory floodplain without an accepted Floodplain Development Permit.

Section 1.1.2 – *integrated* Storm Water Management (*i*SWM) Site Plans
ADOPTED WITH MODIFICATIONS

In general, the Town of Westlake currently follows the flood control and streambank protection components (corrected spelling) of the integrated planning and design approach. Streambank protection is a requirement in Mansfield, but there is not a standard requirement to provide extended release detention for the streambank protection volume. To comply with TCEQ permit TXR040000, the MS4 Phase II permit, the Town of Westlake requires the use of best management practices (BMPs) to address post construction water quality for all new development and redevelopment projects. The NCTCOG *i*SWM Manual identifies the use of certain site design practices and structural measures as BMPs to address post construction water quality. It is expected some use of both site design and structural measures shall be used in development projects to meet this requirement. These BMPs shall be identified in development site plans, with design criteria and calculations when necessary, at conceptual, preliminary and final submittal stages.

Section 1.1.2.2 – Applicability
ADOPTED WITH MODIFICATIONS

Storm Water Management plans are required for development or within the Town of Westlake, of 0.5 acres or more unless exempted by the Town Engineer, or designee.

Section 1.1.3 – Developer Steps to Prepare an iSWM Site Plan
ADOPTED WITH MODIFICATIONS

See Local Criteria Section 1.1 for a description of Town of Westlake requirements.

Section 1.1.4 – Local Community Plan Review Responsibilities
FOR GUIDANCE

Section 1.1.5 – Local Government Responsibilities during Construction and Operation
ADOPTED WITH MODIFICATIONS

The Town of Westlake Process includes:

Construction Phase

1. <u>Pre-construction Meeting</u> - Where possible, a pre-construction meeting shall occur before any clearing or grading is initiated on the site. This step ensures that the owner-developer, contractor, engineer, inspector, and plan reviewer can be sure that each party understands how the plan shall be implemented on the site.
2. <u>Periodic Inspections</u> - Periodic inspections during construction by Town of Westlake representatives. Inspection frequency may vary with regard to site size and location.
3. <u>Final Inspection</u> - A final inspection is needed to ensure that the construction conforms to the intent of the approved design. Prior to accepting the infrastructure components, issuing an occupancy permit, and releasing any applicable bonds, the owner-developer and contractor shall ensure that: (a) erosion control measures have been removed; (b) storm water controls are unobstructed and in good working order; (c) permanent vegetative cover has been established in exposed areas; (d) any damage to natural feature protection and conservation areas have been mitigated; (e) conservation areas and buffers have been adequately marked or signed; and (f) any other applicable conditions have been met.
4. <u>Record Drawings</u> - Record drawings of the structural storm water controls, drainage facilities, and other infrastructure components shall be provided to the Town of Westlake by the developer in accordance with the Town of Westlake ordinance.

<u>Maintenance</u>

1. Maintenance Plan - If private maintenance is planned, a maintenance plan, prepared by the developer, shall outline the scope of activities, schedule, costs, funding source, and responsible parties. Vegetation, sediment management, access, and safety issues shall be addressed.
2. Notification of Property Owners - If applicable, the Town of Westlake shall notify property owners of any maintenance responsibilities, through a legal disclosure, upon sale or transfer of property. Ideally, preparation of maintenance plans should be a requirement of the *i*SWM Site Plan preparation and review process.
3. Ongoing Maintenance – it shall be clearly detailed in the Final Storm Water Management Plan which entity has responsibility for operation and maintenance of all structural storm water controls and drainage facilities (see Town of Westlake Policy Statements regarding maintenance).
4. Annual Inspections - Annual inspections of private storm water management facilities shall be conducted by the owner and the results shall be provided to the Town of Westlake.

Section *1.1.6 – iSWM Site Plan Design Tools*

FOR GUIDANCE

Section 1.2 – integrated Planning and Design Approach

ADOPTED WITH MODIFICATIONS

In general, the Town of Westlake currently follows the flood control and streambank protection components of the *integrated* planning and design approach. Streambank protection is a requirement in the Town of Westlake, but there is not a standard requirement to provide extended release detention for the streambank protection volume. To comply with TCEQ permit TXR040000, the MS4 Phase II permit, the Town of Westlake requires the use of best management practices (BMPs) to address post construction water quality for all new development and redevelopment projects. The NCTCOG *i*SWM Manual identifies the use of certain site design practices and structural measures as BMPs to address post construction water quality. It is expected some use of both site design and structural measures shall be used in development projects to meet this requirement.

Section 1.2.1 – Introduction

ADOPTED

Section 1.2.2 – Downstream Assessment

ADOPTED WITH MODIFICATIONS.

The downstream assessment described in Section 2.1.9 of the *i*SWM Manual shall include the necessary hydrologic and hydraulic analyses to clearly demonstrate that the limits of the Zone of Influence have been identified, and that along the drainage route to that location, these parameters are met:

1. No new or increased flooding of existing structures.
2. Assume fully-developed upstream conditions based upon the land uses in the Comprehensive Plan. If any area is unknown, the minimum runoff coefficient of c = 0.65 shall be used.
3. No significant increases in flood elevations over existing roadways for the 2-, 25-, and 100-year floods.
4. No significant rise in 100-year flood elevations, unless contained in existing channel, roadway, drainage easement and/or R.O.W.
5. No significant increases in channel velocities for the 2-, 10-, 25-, and 100-year floods. Post-development channel velocities cannot be increased above pre-development velocities, if they exceed the applicable maximum permissible velocity shown in iSWM Table 4.4-2. Exceptions to these criteria shall require certified geotechnical/geomorphologic studies that provide documentation those higher velocities shall not create additional erosion.
6. No increases in downstream discharges caused by the proposed development that, in combination with existing discharges, exceeds the existing capacity of the downstream storm drainage system.

Section 1.2.3 – Water Quality Protection

ADOPTED WITH MODIFICATION

The Town of Westlake shall consider proposals for development that implement site design practices and secondary control measures (as defined in the *i*SWM Manual) as a means of achieving compliance with the MS4 Permit. If these proposals are not sufficient to effectively achieve post construction water quality goals then primary structural post-construction control measures shall be used in conjunction with, or in lieu of, site design practices. The water quality protection volume calculation may only be required if primary structural post-construction control measures are employed.

Section 1.2.4 – Stream Bank Protection

ADOPTED WITH MODIFICATIONS

Streambank protection is a requirement in the Town of Westlake, but there is not a standard requirement to provide extended release detention for the streambank protection volume.

Section 1.2.5 – Flood Control

ADOPTED

Section 1.2.6 – integrated Watershed Planning

ADOPTED

Section 1.3 – integrated Site Design Practices

ADOPTED WITH MODIFICATIONS

This section provides general guidance for potentially reducing costs of storm water infrastructure construction and the negative impacts of development on flooding, stream stability and water quality. Numerous examples of integrated site design practices are included. These are examples of site design BMPs that may assist a project in meeting the post-construction water quality requirements of the MS4 Permit.

Section 1.3.1 – integrated Site Design Credits

FOR GUIDANCE

The Town of Westlake has not adopted a point or credit system at this time. Each development shall be evaluated on the merits of the proposed design practices and post-construction structural control measures.

Section 1.4 – integrated Storm Water Controls

ADOPTED WITH MODIFICATIONS

This section contains a list of broad categories of structural post-construction control measures that are considered BMPs and can be implemented in land development to meet the goals of protecting water quality, minimizing streambank erosion, and reducing flood volumes. Many of the listed storm water control features and techniques enhance the aesthetics and value of land developments, as well as providing a drainage function. The Town of Westlake requires the removal of at least 80% T.S.S.

These BMPs generally fall into a primary or secondary treatment category based on efficiency of removing TSS. Many secondary control measures are also considered site design practices discussed in Section 1.3. Most primary control measures are structural in nature, require the calculation of the water quality protection volume and have a detailed design criteria and procedures discussed in detail in Chapter 5 of the iSWM Manual.

Some proprietary systems may qualify as primary control structures. Evidence of treatment efficiency shall be submitted when these systems are proposed. It is strongly recommended that proprietary systems meet TAPE (Technology Assistance Protocol) or TARP (Technology Acceptance Reciprocity Partnership) approval.

SECTION 2 – HYDROLOGIC ANALYSIS

Section 2.1 – Estimating Runoff

Section 2.1.1 – Introduction to Hydrologic Methods

ADOPTED WITH MODIFICATIONS

Water quality volume and stream bank protection volume applications are encouraged by the Town of Westlake but not specifically required at this time. USGS and TxDOT equations are only allowed with the approval of the Town Engineer, or designee.

Table 2.1.1-2 – See modified version of Table 2.1.1-2 below (differences from iSWM Manual are in bold type.

Table 2.1.1-2 Constraints on Using Recommended Hydrologic Methods

Method	Size Limitations[1]	Comments
Rational[1]	0 – 200 acres	Method for estimating peak flows and the design of small site or subdivision storm sewer systems.
Modified Rational[1,]	0 – 25 acres	Method can be used for detention planning in drainage areas up to 200 acres and for final design in single basins. However, modified rational method is not allowed for basins in series.
Unit Hydrograph (SCS)	Any Size	Method can be used for estimating peak flows and hydrographs for all design applications.
Unit Hydrograph (Snyder's)	100 acres and larger	Method can be used for estimating peak flows and hydrographs for all design applications.
TXDOT Regression Equations	10 to 100 mi^2	Method can be used for estimating peak flows for rural design applications.
USGS Regression Equations	3 – 40 mi^2	Method can be used for comparison with other methods

.
[1] MRM Methodology shall be as defined in Section 1.5.2 of the iSWM Hydrology Technical Manual.

Section 2.1.2 – Symbols and Definitions

ADOPTED

Section 2.1.3 – Rainfall Estimation

ADOPTED WITH MODIFICATIONS

The rainfall intensities listed in the *i*SWM Manual for Tarrant County shall be used throughout the Town of Westlake

Section 2.1.4 – Rational Method

ADOPTED

Section 2.1.4.3 – Equations

ADOPTED

Section 2.1.4.4 – Time of Concentration

ADOPTED.

Section 2.1.4.6 – Runoff Coefficient (C)

ADOPTED WITH MODIFICATIONS

Table 2.1.4-2 presents the nominal Rational Formula Runoff “C” Coefficients for the Town of Westlake. Other coefficients are presented in Table 2.1.4-2 of the *i*SWM Manual.

Table 2.1.4-2 Runoff Coefficients

Description of Land Use	% Impervious	Runoff Coefficient "C"
Residential”R5”	35	0.51
Residential "R2”	37	0.52
Residential "R1”	49	0.59
Residential "R0.5	55	0.63
Multi-family	93	0.86
Commercial/Industrial/House of Worship/School		
4% Open Space (Default if no site plan)	96	0.88
10% Open Space (Site plan required)	90	0.84
20% Open Space (Site plan required)	80	0.78
Parks, Cemeteries	7	0.34
Streets: Asphalt, Concrete and Brick	100	0.90
Drives, Walks, and Roofs	100	0.90
Gravel Areas	43	0.56
Unimproved Areas	0	0.30

Assumptions:

(1) For Residential Calculations:

1. Current CFW development standards for minimum lot size and maximum lot coverage (structure) for each classification
2. Assumed 10.5’ Parkway and 18’ driveway
3. Assumed 29’ B-B street dimension
4. Calculated by applying 90% runoff from impervious areas and 30% runoff from pervious areas

(2) Calculated from designated set-backs

Section 2.1.4.7 – Example Problem

ADOPTED

Section 2.1.5 – SCS Hydrologic Method

ADOPTED

Section 2.1.5.2 – Application

ADOPTED

BY: DATE:	LOSS RATE METHOD	**COMPUTATION SHEET**	SHEET 1 OF 1 SUBWATERSHED
CK'D: DATE:	STREAM ROUTING	**HYDROLOGY BY UNIT HYDROGRAPH METHOD**	MAJOR WATERSHED JOB/FILE NO.:

ANALYSIS POINT	**SUBWATER-SHED AREA (AC)**	**WATERSHED AREA (AC)**	**UNIT HYDROGRAPH COEFFICIENTS**				**PEAK DISCHARGES (CFS)**				**COMMENTS**
			SCS METHOD		**SNYDER'S METHOD**						
			C_N	**Lag (HR)**	C_p	T_p **(HR)**	**Q2**	**Q10**	**Q25**	**Q100**	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**

REMARKS, SKETCHES AND COMPUTATIONS

Figure 2.1.6-1 Computation Sheet – Hydrology by Unit Hydrograph Method

Section 2.1.6 – Snyder's Unit Hydrograph Method

Section 2.1.6.1 – Introduction
ADOPTED

Figure 2.1.6-1 –presents a sample computation sheet for presentation of unit hydrograph method results. This form should be completed even if the computations are performed on acceptable computer programs HEC-1 or HEC-HMS.

Section 2.1.6.2 – Application
ADOPTED WITH MODIFICATIONS

Sections 2.1.6.3 through 2.1.6.6
ADOPTED

Section 2.1.7 – Modified Rational Method

Section 2.1.7.1 – Introduction
ADOPTED

Section 2.1.7.2 - Design Equations
ADOPTED WITH MODIFICATIONS

An exception to the *i*SWM Method is that only "C" coefficients presented in Local Criteria Table 2.1.4-2 and *i*SWM Table 2.1.4-2 (Not sure if or why these shall remain the same once I get electronic versions.**)** are allowed for use in the Modified Rational Method. The remaining methodology is allowed.

Section 2.1.7.3 – Example Problem
ADOPTED

Section 2.1.8 – USGS and TxDOT Regression Methods
ADOPTED

Section 2.1.9 – Downstream Hydrologic Assessment
ADOPTED

Section 2.1.10 – Water Quality Protection Volume and Peak Flow
ADOPTED

Section 2.1.11 – Streambank Protection Volume Estimation
ADOPTED

Section 2.1.12 – Water Balance Calculations
ADOPTED

References **ADOPTED**

Section 3 – HYDRAULIC DESIGN OF STREETS AND CLOSED CONDUITS

Section 3.1 – Storm Water Street and Closed Conduit Design Overview

Section 3.1.1 – Storm Water System Design

ADOPTED

Section 3.1.2 – Key Issues in Storm Water System Design

For Guidance

Section 3.1.3 – Design Storm Recommendations

ADOPTED WITH MODIFICATIONS

The design storms presented in *i*SWM are replaced by the design storms required by Town of Westlake as follows:

Storm Sewer System

The Town of Westlake utilizes additional criteria to improve capacity and levels of protection to adjacent properties to both open flow and closed conduit drainage systems.

a. Unless otherwise directed by the Town Engineer or designee, the 100-year storm is the design storm for closed conduit systems. The closed conduit hydraulic grade line (HGL) must be one and one-half (1.5) feet or more below the top of curb.

b. In addition to the HGL computations, the design engineer shall also verify that the inlet depth is sufficient to provide a height of at least 1.2 HW/D to ensure the system functions as an "entrance/inlet control" system and not a "tailwater control" system. At an HW/D depth of 1.2 or greater, inlets and culverts shall function under sub-critical flow at the entrance/inlet. Most open channels systems flow under super-critical depths, a hydraulic jump can be expected at the entrance to most culverts. The design engineer shall estimate the location and height of this hydraulic jump to know how high to raise any channel or erosion protection features, headwalls finished floor elevations on adjacent lots, etc.

Section 3.2 – On-Site Flood Control System

Section 3.2.1 – Overview

Street capacities shall be designed for the 100-year frequency storm. For streets with a raised curb and gutter, one (1) lane of traffic in each direction shall be maintained during the 100-year frequency storm. At no time shall the depth of flow exceed curb height. For streets with no curb and gutter, and open bar ditches for conveying stormwater flows, the 100-year frequency storm flows must be contained within the bar ditches.

Inlets shall be placed upstream of all intersections with streets with raised curb and gutter to minimize bypass flow across the intersection. No stormwater flow shall be allowed to bypass inlets at the intersection of two thoroughfares. Residential and collector road intersections shall be designed such that flow across a valley gutter shall not exceed two (2) inches in the design frequency storm.

Section 3.2.2 – Symbols and Definitions
ADOPTED

Section 3.2.3 – Street and Roadway Gutters
ADOPTED

Section 3.2.4 – Storm Water Inlets
ADOPTED

Section 3.2.5- Grate Inlet Design
ADOPTED WITH MODIFICATIONS

Section 3.2.6 – Curb Inlet Design
ADOPTED WITH MODIFICATIONS

Curb inlets on grade without a gutterline depression are not permitted by the Town of Westlake.

Section 3.2.6.1 – Curb Inlets in Sumps
ADOPTED WITH MODIFICATIONS

In order to accommodate the standard curb inlet configuration presented in Mansfield's "Standard Construction Details", the following supplement to Section 3.2.4.1 of *i*SWM from Hydraulic Engineering Circular 22 by FHA (August, 2001) is presented.

The weir for a depressed curb-opening inlet is at the edge of the gutter, and the effective weir length is dependent on the width of the depressed gutter and the length of the curb opening. The weir location for a curb-opening inlet that is not depressed is at the lip of the curb opening, and its length is equal to that of the inlet.

The equation for the interception capacity of a depressed curb-opening inlet operating as a weir is:

$$Q_i = C_w (L + 1.8 W) d^{1.5}$$

where:

C_w = 1.25 (2.3 In English Units)
L = length of curb opening (ft)
W = lateral width of depression (ft)
D = depth at curb measured from the normal cross slope (ft), i.e., $d = T S_x$

The weir equation is applicable to depths at the curb approximately equal to the height of the opening plus the depth of the depression. Thus, the limitation on the use of the above equation for a depressed curb-opening inlet is:

$d \leq h + a/(1000)$ ($d \leq h + a/12$, in English units)

where:

h = height of curb-opening inlet, (ft)
a = depth of depression, (in)

Section 3.2.7 – Combination Inlets
ADOPTED WITH MODIFICATIONS

Combination inlets on grade are not permitted by the Town of Westlake.

Section 3.2.8 – Closed Conduit Systems
ADOPTED WITH MODIFICATIONS

Materials

Only reinforced concrete pipe (RCP) is allowed in public Right(s)-of-way and/or Easements. Wye and tee (T) connections supplied by the pipe manufacturer are required. Radial pipe can also be fabricated by the pipe manufacturer and shall be used through all curved alignments. However, the design engineer shall be use bends or large radii curves where practical. When field connections or field radii must be used, all joints and gaps must be fully grouted with a concrete collar to prevent voids or long-term cave-ins caused by material washout into the storm sewer system by substandard field connections.

Minimum allowable size shall be 18 inches, and driveway permits shall be required from the Development Services Division.

HDPE/CPVC pipe may be allowed for certain off-pavement applications only as approved by the Town Engineer or designee on a case-by-case basis. In no case shall HDPE/CPVC pipe be approved for installation under publicly maintained pavement. HDPE/CPVC storm drain shall be installed in accordance with all manufacturer's specifications and shall meet or exceed ASTM D-2321, Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications. Furthermore, Class I aggregate (NCTCOG Aggregate Grade 4) shall be required for pipe embedment (to a minimum of 6" above the top of pipe).

In selecting roughness coefficients for concrete pipe, consideration shall be given to the average conditions at the site during the useful life of the structure. The 'n' value of 0.015 for concrete pipe shall be used primarily in analyzing old sewers where alignment is poor and joints have become rough. If, for example, concrete pipe is being designed at a location where it is considered suitable, and there is reason to believe that the roughness would increase through erosion or corrosion of the interior surface, slight displacement of joints or entrance of foreign materials. A roughness coefficient shall be selected which in the judgment of the designer, shall represent the average condition. Any selection of 'n' values below the minimum or above the maximum, either for monolithic concrete structures, concrete pipe or HDPE, shall have to have written approval of the Town Engineer or designee.

The following recommended coefficients of roughness are listed in Table 3.2.8-1 and are for use in the nomographs contained herein, or by direct solution of Manning's Equation.

Table 3.2.8-1 Manning's Coefficients for Storm Drain Conduits*	
Type of Storm Drain	**Manning's n**
Concrete Pipe (Design n = 0.013)	0.012-0.015
Concrete Boxes (Design n = 0.015)	0.012-0.015
Corrugated Metal Pipe, Pipe-Arch and Box (Annular or Helical Corrugations - see Table 3.2-6 in *i*SWM Manual. **NOTE: TOWN OF WESTLAKE DOES NOT ALLOW CMP FOR NEW CONSTRUCTION**	0.022-0.037
Profile Wall High Density Polyethylene (HDPE) or Polyvinyl Chloride (PVC)	0.010-0.013
*NOTE: Actual field values for conduits may vary depending on the effect of abrasion, corrosion, deflection, and joint conditions.	

Section 3.2.8.2 – Access Holes (Manholes) Adopted with Modifications

Manholes shall be located at intervals not to exceed five-hundred (500) feet for pipe fifty-four (54) inches in diameter or smaller. For any pipes sixty (60) inches in diameter and larger (or equivalent size box culverts), the maximum spacing of manholes is one-thousand (1,000) feet. Manholes shall preferably be located at street intersections or sewer junctions. When the storm drain is a concrete box culvert instead of a reinforced concrete pipe, four (4) foot diameter manhole risers may be instead of vaults to provide access. In all cases, steps (or rungs) shall be installed from the base of the manhole to the top of the manhole Maximum vertical spacing of the steps shall not exceed twelve (12) inches.

Section 3.2.8.3– Minimum Grades and Desirable Velocities Adopted with Modifications

The minimum grades for storm sewers are listed in Table 3.2.8-**2**. Any variances to the values below must have the prior acceptance of the Town Engineer or Designee.

Pipe Size	Concrete Pipe Slope
(Inches)	(Slope ft/ft)
18	0.005
21	0.0015
24	0.0013
27	0.0011
30-96	0.001

Table 3.2.8-2

The maximum hydraulic gradient shall not produce a velocity that exceeds twenty (20) feet per second (fps). The table above shows the desirable maximum velocities for the majority of closed conduit storm sewer systems. Storm drains shall be designed to have a minimum mean velocity flowing full at 2.5 fps. A storm sewer main is defined as any pipe connected to two or more inlets.

The maximum velocities for various types of culverts are shown in Table 3.2.8-**3**. Any variances to these values must have the prior acceptance of the Town Engineer or Designee.

Culvert	Maximum Allowable Velocity
(Description)	(Feet per second)
Culverts (All Types)	15
Storm Drain (Inlet Laterals)	25
Storm Drain (Mains)	20

Table 3.2.8-3

Full or Part Full Flow in Storm Drains

All storm drains shall be designed by the application of the Continuity Equation and Manning Equation either through the appropriate charts or nomographs or by direct solutions of the equations as follows:

$$Q = A\,V, \text{ and}$$

$$Q = \frac{1.486}{n} A\, r^{2/3} S_f^{1/2} \quad \text{where,}$$

Q = Runoff in cubic feet per second.

A = Cross-sectional area of pipe or channel.

V = Velocity of flow.

n = Coefficient of roughness of pipe or channel.

r = Hydraulic radius = A/P

S_f = friction slope in feet per foot in pipe or channel.

p = Wetted perimeter.

The size of pipe required to transport a known-quantity of storm runoff is obtained by substituting known values in the formula. In practice, the formula is best utilized in the preparation of a pipe flow chart which interrelates values of runoff, velocity, slope and pipe geometry. With two of these variables known or assumed. The other two are quickly obtained from the chart. A pipe flow nomograph for circular conduits flowing full graphs is shown in iSWM Figure 3.2.16. Nomographs for flow in conduits of other cross-sections are available in TxDOT Hydraulic Design Manual, dated March 2004, Chapter 6, Section 2. For circular conduits flowing partially full, graphs are presented in iSWM Figure 3.2-18a.

Hydraulic Gradient and Profile of Storm Drain

In storm drain systems flowing full (or partially full as discussed above) all losses of energy through resistance with flow in pipes, by changes of momentum or by interference with flow patterns at junctions, must be accounted for by accumulative head losses along the system from its initial upstream inlet to its outlet. The purpose of accurate determinations of head losses at junctions is to include these values in a progressive calculation of the hydraulic gradient along the storm drain system. In this way, it is possible to determine the water surface elevation which shall exist at each structure. The rate of loss of energy through the storm drain system shall be represented by the hydraulic grade line. Since the hydraulic grade line measures the pressure head available at any given point within the system.

The hydraulic grade (HGL) line shall be established for all storm drainage design in which the system operates under a head. In open channels, the water surface itself is the hydraulic grade line. The hydraulic grade line is often controlled by the conditions of the sewer outfall; therefore, the elevation of the tailwater pool must be known. The hydraulic gradient is constructed upstream from the downstream end, taking into account all of the head losses that may occur along the line. iSWM Section 3.2.8.10 provides a table of coincident design frequencies to assist with tailwater determination. The hydraulic gradient shall begin at the higher of the tailwater pool or depth of flow in the pipe at the downstream end for the downstream design storm.

All head losses shall be calculated as if the storm drain system is in a sub-critical flow regime whether the system is flowing partially full or surcharged. Hydraulic calculations shall reflect partially full pipe where appropriate. Supercritical flow is allowed in main lines only with the acceptance of the Town Engineer or designee. If the system is in supercritical regime the section should be marked "SUPERCRITICAL FLOW" in both plan and profile views. The presence of supercritical regime should be confirmed by analyzing from downstream as well as upstream.

The friction head loss shall be determined by direct application of Manning's Equation or by appropriate nomographs or charts as discussed in the first paragraph of this subsection. Minor losses due to turbulence at structures shall be determined by the procedure described in Section 3.2.8.11 of the *i*SWM manual. All HGL calculations shall be carried upstream to the inlet.

The hydraulic grade line shall in no case be above the surface of the ground or street gutter for the design storm. Allowance of head must also be provided for future extensions of the storm drainage system. In all cases the maximum HGL must be 12" below the depressed gutter lip at any inlet.

All head losses shall be calculated as if the storm drain system is in a sub-critical flow regime whether the system is flowing partially full or surcharged. Hydraulic calculations shall reflect partially full pipe where appropriate. Super-critical flow is allowed in main lin lines only with the acceptance of the Town Engineer or designee. If the system is in supercritical regime, the HGL is the water surface and should be clearly marked "SUPERCRITICAL FLOW." The presence of super-critical flow regime should be confirmed by analyzing the HGL (or EGL) from downstream as well as upstream. In the case of long lengths of storm sewer mains, the water surface elevation (WSE) is the depth of flow or also known as the d/D ratio.

Minor Head Losses at Structures Calculations

The following head losses at structures shall be determined for manholes, wye branches or bends in the design of closed conduits. See Figure 3.1 and Figure 3.2 for details of each case. Minimum head loss used at any structure shall be one-tenth (0-10) foot.

The basic equation for most cases, where there are both upstream and downstream velocities, takes the form as set forth below with the various conditions of the coefficient "Kj" shown in Table 3.2.8-4.

$$h_j = \left(\frac{V_2^2}{2g}\right) - K_j \left(\frac{V_1^2}{2g}\right)$$

hj = Junction or structure head loss in feet

V_1 = Velocity in upstream pipe/culvert in fps

V_2 = Velocity in downstream pipe/culvert in fps

K_j = Junction or structure coefficient of loss

In the case where the manhole is at the very beginning of a line, or the line is laid with bends or on a curve, the equation becomes the following without any velocity of approach.

$$h_j = Kj \frac{V_2^2}{2g}$$

60^0 Bend – 85%; 45^0 Bend – 70%; 22 $1/2^0$ Bend – 40%

The values of the coefficient "K_j" for determining the head loss due to obstructions in pipes are shown in Table 3.2.8-5 and the coefficients are used in the following equation to calculate the head loss at the obstruction:

$$h_j = K_j \frac{V_2^2}{2g}$$

Table 3.12 Junction or Structure Coefficient of Loss

Case No.	Reference Figure	Description of Condition	Coefficient K_j
I	3.8	Inlet on Main Line	0.50
II	3.8	Inlet on Main Line with Branch Lateral	0.25
III	3.8	Manhole on Main Line with 45º Branch lateral	0.50
IV	3.8	Manhole on Main Line with 90º Branch Lateral	0.25
V	3.8	Manhole on Main Line with no Branch	1.0
VI	3.9	45º Wye Connection or cut-in	0.75
VII	3.9	Inlet or Manhole at Beginning of Line	1.25
VIII	3.9	Conduit on Curves for 90º * Curve radius = diameter Curve radius = 2 to 8 diam. Curve radius = 8 to 20 diam.	 0.50 0.25 0.10
IX	3.9	Bends where radius is equal to diameter 90º Bend 60º Bend 45º Bend 22-1/2º Bend Manhole on line with 60º Lateral Manhole on line with 22/1/2º Lateral	 0.50 0.43 0.35 0.20 0.35 0.75

* Where bends other than 90º are used, the 90° bend coefficient can be used with the following percentage factor applied: 60º- 85%, 45º – 70%, 22.5º – 40%

Table 3.13 Head Loss Coefficients Due To Obstructions

A/A_o*	K_j	A/A_o*	K_j
1.05	0.10	3.0	15.0
1.1	0.21	4.0	27.3
1.2	0.50	5.0	42.0
1.4	1.15	6.0	57.0
1.6	2.40	7.0	72.5
1.8	4.00	8.0	88.0
2.0	5.55	9.0	104.0
2.2	7.05	10.0	121.0
2.5	9.70		

* A/A_o = Ratio of area of pipe to area of opening at obstruction.

The friction head loss shall be determined by direct application of Manning's Equation or by appropriate nomographs or charts as discussed in the first paragraph of this subsection. Minor losses due to turbulence at structures shall be determined by the procedures described in Section 3.2.8.11 of the iSWM manual. All HGL calculations shall be carried upstream to the last inlet or headwall in the proposed project. The ending HGL elevation at an inlet or structure shall be compared to the ratio of 1.2 HW/D to ensure both the HGL and/or headwater depth remains at least twelve (12) inches below the gutter lip. The green font is because I know we refer to this requirement more than once and I don't think we are consistent. So I want to be sure we check that everywhere.

The HGL shall in no case be above the surface of the adjacent ground or street gutter lip for the design storm. Allowance of head must also be provided for future extensions of the storm drainage system. In all cases, the maximum HGL must be 1.5-feet below the gutter lip at any inlet in the design frequency storm.

The values of "Kj" for determining the head loss due to sudden enlargements and sudden contractions in pipes or box culverts are shown in Table 3.2.8-6, and the coefficients are used in the following equation to calculate the head loss at the change in section:

$$H_j = K_j \frac{V^2}{2g}$$

V = Velocity in smaller pipe

Section 3.3 – General Design and Construction Standards

LOCAL CRITERIA SECTION ONLY

Utilities

In the design of a storm drainage system, the engineer is frequently confronted with the problem of crossings between the proposed storm drain and existing or proposed utilities such as water, gas and sanitary sewer lines. The Town of Westlake prefers a minimum of two (2) vertical feet of clearance with all conflicting utilities. All utilities in the vicinity of a proposed storm drain shall be clearly indicated on both plan and profile sheets.

Headwalls, Culverts, and Other Structures

For headwalls, culverts and other structures, Standard Construction Details adopted by the Town of Westlake shall be used. The appropriate detail sheets for non-standard structures should be included in any construction plans. All headwalls and culverts should be extended to or beyond the street right-of- way.

Minimum Pipe Sizes and Depths

Minimum pipe sizes are 24" diameter for mains and 18" diameter for inlet leads. Minimum sizes of conduits of other shapes should have equivalent cross-sectional areas. Minimum depth of storm sewer from outside top of conduit to proposed top of curb is 30 inches.

Inlets

Curb inlets shall be 10, 15 or 20 feet in length and shall have depressed gutterline openings. No curb inlet less than ten (10) feet shall be allowed without prior acceptance by the Town Engineer, or designee. Recessed inlets shall be provided on minor collectors through arterial streets as described in Table 3.1.3-1. Proposed inlet lengths greater than 20 feet must be approved by the TOWN ENGINEER, or designee. Care should be taken in laying out inlets to allow for adequate driveway access between the inlet and the far property line. Due to excessive clogging, grate inlets are not allowed on public storm drain except as specifically accepted by the TOWN ENGINEER, or designee.

Streets

To minimize standing water, the minimum street grade shall be 0.60%. Along a curve, this grade shall be measured along the outer gutter line. The minimum grade along a cul-de-sac or eyebrow gutter shall be 0.60%. Alternatively, elbows may be designed with a valley gutter along the normal outer gutter line, with two percent cross slope from curb to the valley gutter. The minimum grade for any valley gutter shall be 0.60%. Where a crest or sag is designed on a residential street, a PVI shall be used instead of a vertical curve where the total gradient change is no more than one and one-half percent ($\Delta \leq 1.5\%$).

Flow in Driveways and Intersections

At any intersection, only one street shall be crossed with surface drainage and this street shall be the lower classified street. Where an alley or street intersects a street, inlets shall be placed in the intersecting alley or street whenever the combination of flow down the alley or intersecting street would cause the capacity of the downstream street to be exceeded. Inlets shall be placed upstream from an intersection whenever possible. Surface drainage from a 25-year event may not cross any street classified as a thoroughfare or collector. Not more than 5.0 cfs in a 25-year event may be discharged per driveway at a business, commercial, industrial, manufacturing, or school site. Also, not more than 5.0 cfs may be discharged in a 25-year event from a street intersection with a major collector or arterial. In all cases, the downstream storm drainage system shall be adequate to collect and convey the flow, and inlets provided as required. The cumulative flows from existing driveways shall be considered and inlets provided as necessary where the flow exceeds the specified design capacity of the street.

Section 3.4 – Easements for Closed Conduit Systems

LOCAL CRITERIA SECTION ONLY

Minimum easement requirements for storm sewer pipe shall be as follows:

Table 3.4-1 Closed Conduit Easements

Pipe Size	Minimum Easement Width Required
39” and under	15 Feet
42” through 54”	20 Feet
60” through 66”	25 Feet
72” through 102”	30 Feet

The outside face of the proposed storm drain line shall be placed at least five (5) feet off either edge of the storm drain easement. The proposed centerline of overflow swales shall normally coincide with the centerline of the easement.

Box culverts shall have an easement width equal to the width of the box plus twenty (20) additional feet. The edge of the box should be located at least five (5) feet from either edge of the easement.

Drainage easements shall generally extend beyond an outfall headwall to provide for velocity dissipation devices and an area for maintenance operations. Drainage easements along a required outfall channel or ditch shall be provided until the flowline reaches an acceptable outfall.

References

ADOPTED WITH MODIFICATIONS

Texas Department of Transportation, March 2004, Hydraulic Design Manual, Austin, Texas.

Section 4 – HYDRAULIC DESIGN OF CULVERTS, BRIDGES, OPEN CHANNELS, AND DETENTION STRUCTURES

Section 4.1 – Storm Water Open Channels, Culverts, Bridges, and Detention Structure Design Overview

Section 4.1.1 – Storm Water System Design

ADOPTED

Section 4.1.2 – Key Issues in Storm Water System Design

ADOPTED

Section 4.1.3 – Design Storm Recommendations

ADOPTED WITH MODIFICATIONS

Roadway Culvert Design

100-year storm for fully developed watershed conditions.

Bridge Design

100-year storm for fully developed watershed conditions.

Open Channel Design

100-year storm for fully developed watershed conditions

Energy Dissipation Design

100-year design for fully developed watershed conditions.

Storage (Detention Basin Design)

2-year, 10-year, 25-year and 100-year storm for the critical storm duration (i.e. 3 hour, 6 hour or 24 hour duration) that results in the maximum (or near maximum) peak flow. Analysis should consider both existing watershed plus developed site conditions and fully developed watershed conditions.

Section 4.2 – Culvert Design

Section 4.2.1 – Overview

ADOPTED

Section 4.2.2 – Symbols and Definitions

ADOPTED

Section 4.2.3 – Design Criteria

ADOPTED WITH MODIFICATIONS

The Town of Westlake requires a 100-year design storm for fully developed watershed with the upstream water surface elevation (WSEL) 1' below the adjacent curb.

Only reinforced concrete culvert structures are acceptable.

Section 4.2.4 – Design Procedures

ADOPTED

Section 4.2.4.4 – Nomographs

ADOPTED WITH MODIFICATIONS

Nomographs are not allowed by the Town of Westlake for final sizing of culverts with drainage areas greater than 10 acres. The use of nomographs for culverts with drainage areas greater than

10 acres requires approval of the CITY ENGINEER. The reference for nomographs is FHWA HDS-5. A backwater analysis using HEC-RAS is required for culverts with areas greater than 10 acres.

Section 4.2.5 – Culvert Design Example

ADOPTED WITH MODIFICATIONS

This procedure is acceptable for preliminary sizing of all culverts and final sizing of culverts with drainage areas of 10 acres or less unless accepted by the Town Engineer, or designee.

Section 4.2.6 – Design Procedures for Beveled-Edged Inlets

ADOPTED WITH MODIFICATIONS

This procedure is acceptable for preliminary sizing only.

Section 4.2.7 – Flood Routing and Culvert Design

FOR GUIDANCE

Section 4.3 – Bridge Design

Section 4.3.1 – Overview

ADOPTED

Section 4.3.2 – Symbols and Definitions

ADOPTED

Section 4.3.3 – Design Criteria

ADOPTED

Section 4.3.4 – Design Procedures

ADOPTED WITH MODIFICATIONS

Backwater analysis shall be required using HEC-RAS for any proposed bridge to determine accurate tailwater elevations, velocities, headlosses, headwater elevations, profiles and floodplains affected by the proposed structure. If the current effective FEMA model is a HEC-2 model, the engineer has the option to either use that model, or convert to HEC-RAS for analysis of proposed conditions.

Section 4.4 – Open Channel Design

ADOPTED WITH MODIFICATIONS

Normal Depth (Uniform Flow) vs. Backwater Profile Depths:

For uniform flow calculations, the theoretical channel dimensions, computed by the slope-area methods outlined in the *i*SWM manual, are generally to be used only for an initial dimension in the design of an improved channel. The Town Engineer, or designee may grant exceptions for small channels meeting the following criteria:

1. Drainage area 10 acres or less.
2. Completely contained on the development site ;
3. No nearby downstream restrictions (no significant backwater effects).

4. Flow conditions consistent with uniform flow assumption.

The Town of Westlake requires a HEC-RAS backwater/frontwater analysis on any proposed open channel with a drainage area greater than 10 acres to determine the actual tailwater elevations, channel capacity and freeboard, and impacts on adjacent floodplains. If the current effective FEMA model for the stream is a HEC-2 model, the engineer has the option to either use that model, or convert to HEC-RAS for analysis of proposed conditions.

Supercritical Flow Regime

Supercritical flow shall not be allowed except under unusual circumstances, with special acceptance of the Town Engineer, or designee. However, for lined channels the analysis should include a mixed-flow regime analysis, to make sure no supercritical flow occurs. The Town of Westlake requires that the computed flow depths in designed channels be outside of the range of instability, i.e. depth of flow should be at least 1.2 times critical depth.

Channel Transitions or Energy Dissipation Structures or Small Dams

A HEC-RAS model is a standard requirement for design of channel transitions (upstream and downstream), energy dissipation structures, and small dams. A backwater analysis shall be required by the City, to determine accurate tailwater elevation, headlosses, headwater elevations and floodplains affected by the proposed transition into and out of an improved channel, any on-stream energy dissipating structures, and small dams (less than 6 feet). If the current effective FEMA model for the stream is a HEC-2 model, FEMA no longer recognizes HEC-2 as an acceptable model for submittal; therefore, the engineer shall convert to HEC-RAS for analysis of proposed conditions. For larger dams, a hydrologic routing shall be required, as well as hydraulic analysis, to determine impacts of the proposed structure on existing floodplains, floodways and adjacent properties.

Section 4.4.1 – Overview

ADOPTED

Section 4.4.2 – Symbols and Definitions

ADOPTED

Section 4.4.3 – Design Criteria

ADOPTED

Section 4.4.3.1 – General Criteria

ADOPTED WITH MODIFICATIONS

Earthen Channels

Natural creeks shall remain in open natural condition when possible to preserve natural drainageways. When unable to preserve the natural creek the Town of Westlake encourages the use of constructed vegetated or permeable channels designed to create a more natural environment.

1. An earthen channel shall have a trapezoidal shape with side slopes not steeper than a 4:1 ratio and a channel bottom at least eight (8) feet in width with a minimum invert of one (1) foot in depth..
2. The 100-year frequency storm with fully developed upstream conditions plus one (1) foot of freeboard must be provided within drainage easements.
3. The side slopes and bottom of an earthen channel shall be smooth, free of rocks, and contain a minimum of six (6) inches of topsoil. The side slopes and channel bottom shall be re-vegetated with grass or other acceptable vegetative material. No channel shall be accepted by the City until a uniform (e.g., evenly distributed, without large bare areas) vegetative cover at least 2” in height with a density of 70% has been established.
4. Each reach of a channel requiring vehicular access for maintenance must have a ramp. In

general, reaches with maintenance access ramps should be located between bridges or culverts but individual situations may vary. Ramps shall be at least ten (10) feet wide and have 15% maximum grade. Twelve-foot (12') width is required if the ramp is bound by vertical walls.

5. Minimum channel slope is 0.0020 ft/ft unless accepted by the TOWN ENGINEER or designee.

6. Erosion protection to be provided at upper limits of improvements and outfall to the receiving stream.

7. All improved earthen channels shall include either " Composite Low Flow" channel or "Trickle" channel. Criteria for each of these channels is as follows:
   a. Low Flow Composite Channels-
      1) Drainage area greater than 300 acres.
      2) Minimum design discharge - 2% of fully developed 100 year peak discharge.
      3) Maximum depth - 5 feet. Maximum side slope 4:1 (H:V).
      4) Minimum bottom width- 8 feet unless accepted by the TOWN ENGINEER or designee.
      5) Lined with riprap or gabions if design velocity exceeds 5 feet/second (also see iSWM sections 4.4.3 and 4.4.4).
      6) Some meanders in alignment are acceptable as long as width of shelf between top of bank of low flow channel and toe of slope of main channel is not less than 10 feet. Minimum lateral slope of shelf is 1%.
   b. Trickle Channels-
      1) Drainage area less than or equal to 300 acres.
      2) Design discharge - 2% of fully developed 100 year peak discharge.
      3) Concrete or permeable armor such as gabions, mat or interlocking block-lined.
      4) Minimum bottom width- 8 feet unless accepted by the TOWN ENGINEER or designee.
      5) Maximum depth -5 feet. Maximum side slope dependent on type of lining.

8. The following guidelines shall be considered for buffer areas or zones along natural or constructed earthen channels:
   a. A minimum Erosion Control Setback on each side of natural channels based on a 4:1 (H:V) slope from the bottom of the bank to the natural ground adjacent to the bank plus an additional 15 feet. See Figure 4.4.3-1.
   b. Include adjacent delineated wetlands or critical habitats.
   c. Other buffer widths shall be considered if supported by specific engineering and environmental studies.

9. Landscaping shall be installed to allow earthen channels to evolve into a more natural environment. Tree or shrub plantings shall be required to enhance habitat of channels by providing shade once mature plant growth has been reached. Mature plantings must be considered in setting design Manning's "n" values.

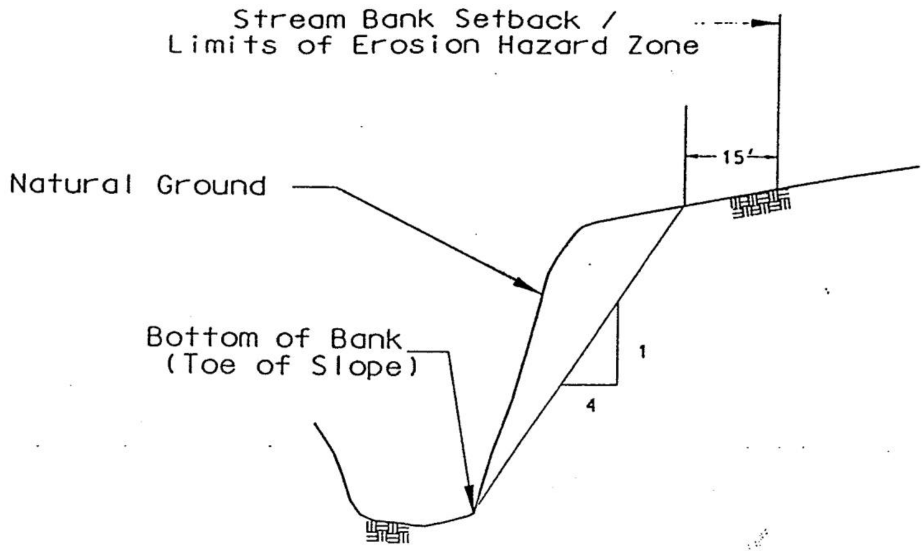

Figure 4.4.3-1 Minimum Erosion Control Setback

Lined Channels

In general, lined channels are discouraged and must have acceptance of the Town Engineer or designee.

1. Lined Channels shall be trapezoidal in shape and lined with reinforced concrete (or flexible lining material as accepted by the Town Engineer, or designee.). Side slopes shall generally be no steeper than 2:1 unless accepted by the Town Engineer, or designee, as appropriate for the lining material. The lining shall extend to and include the water surface elevation of the 100 year fully developed storm plus one foot freeboard.

2. The lined channel bottom must be a minimum of 8' in width. (A minimum bottom width of 6 feet for overflow structures of storm sewer system sumps or where access is not a concern, as approved by the Town Engineer, or designee.)

3. The maximum water flow velocity in a lined channel shall be fifteen (15) feet per second except that the water flow shall not be supercritical in an area from 100' upstream from a bridge to 25' downstream from a bridge. Hydraulic jumps shall not be allowed from the face of a culvert to 50' upstream from that culvert. In general channels having supercritical flow conditions are discouraged (See Section 4.4).

4. Whenever flow changes from supercritical to subcritical channel protection shall be provided to protect from the hydraulic jump that is anticipated (see comment in Item 3).

5. The design of the channel lining shall take into account the super elevation of the water surface around curves and other changes in direction. The outside wall of the lining shall be raised in an amount equal to the super-elevation of the channel so freeboard always exists to the design frequency storm.

6. A chain link fence six (6) feet in height or other fence as accepted by the Town Engineer, or designee may be required on each side of a lined channel.

7. The Town Engineer, or designee, may require a geotechnical study and /or an underground drainage system design option prior to approval of concrete lined channels.

Soil Retention Blankets

Soil Retention Blankets shall be required on all earthen channel side slopes and bottoms. Guidance is provided by the Texas Department of Transportation (TxDOT) concerning synthetic blankets and mats for use as slope protection and flexible channel liners. These systems shall be installed per the manufacturer's recommendations to provide stable retention of the slopes in accordance with the design.

A soil retention blanket (SRB) is used for short and/or long-term protection of seeded and sodded slopes, ditches, and channels. SRB's can be manufactured out of wood, straw or coconut fiber mat, synthetic mat, paper mat, jute mesh or other material. The SRB shall be one of the following classes and types:

1. Class 1. "Slope Protection"
   - Type A. Slopes 3(h):1(v) or flatter – Clay soils
   - Type B. Slopes 3(h):1(v) or flatter – Sandy soils
   - Type C. Slopes steeper than 3(h):1(v) – Clay soils
   - Type D. Slopes steeper than 3(h):1(v) – Sandy soils

2. Class 1. "Flexible Channel Liner"
   - Type E. Shear Stress < 2 lbs./sf
   - Type F. Shear Stress < 4 lbs./sf
   - Type G. Shear Stress < 6 lbs./sf
   - Type H. Shear Stress < 8 lbs./sf
   - Type I. Shear Stress < 10 lbs./sf
   - Type J. Shear Stress < 12 lbs./sf

3. Mulches 6:1 or flatter slopes
   - Clay or Tight Soils
   - Sandy or Loose Soils

Section 4.4.3.2 – Velocity Limitation

ADOPTED WITH MODIFICATIONS

Channel Velocities

1. Lined Channels – Maximum velocities = 15 fps. (Exceptions can be granted by the Town Engineer, or designee, with justifiable technical reasons)
2. Grass Lined Channels – Maximum velocities = 6 fps. Higher values can be justified by a sealed geotechnical study/analysis of soil type and conditions.

Section 4.4.4 – Manning's n Values

ADOPTED

Section 4.4.5 – Uniform Flow Calculations

ADOPTED

Section 4.4.6 – Critical Flow Calculations

ADOPTED

Section 4.4.7 –Vegetative Design

ADOPTED

Section 4.4.8 – Stone Riprap Design
ADOPTED

Section 4.4.8.1 – Introduction
ADOPTED WITH MODIFICATIONS

The "Method # 2" procedure in *i*SWM for stone riprap design is adopted by Town of Westlake. Please note that Equation 4.4.16 in the *i*SWM Manual is INCORRECT and should be expressed as $\mathbf{T_0' = T_0 * (1 - (Sin^2 \phi / Sin^2 \theta))}$. A properly designed geotextile is required under the bedding layer. Regardless of computed thickness, the minimum allowable riprap thickness is twelve (12) inches.

The Town of Westlake may allow grouted stone riprap as an erosion control feature. However, the design thickness of the stone lining shall not be reduced by the use of grout. See the U.S. Army Corps of Engineers design manual ETL 1110-2-334 on design and construction of grouted riprap.

Section 4.4.8.2 – Method # 1: Maynard & Reese
FOR GUIDANCE

Section 4.4.8.3 – Method # 2: Gregory
ADOPTED

Section 4.4.8.4 – Culvert Outfall Protection
ADOPTED

Section 4.4.9 – Gabion Design
ADOPTED

Section 4.4.10 – Uniform Flow - Example Problems
ADOPTED

Section 4.4.11 – Gradually Varied Flow
ADOPTED

Section 4.4.12 – Rectangular, Triangular and Trapezoidal Open Channel Design
ADOPTED

Section 4.5 – Storage Design
ADOPTED WITH MODIFICATIONS

Storm water detention is not a mandated requirement in all cases in the Town of Westlake, but shall be provided to mitigate increased peak flows in the TOWN'S waterways in specific circumstances. The purpose of the mitigation is to minimize downstream flooding impacts or streambank erosion from upstream development. In some instances, detention may be shown to exacerbate potential flooding conditions downstream. Therefore, the "Zone of Influence" criteria (Reference Section 2.1.9.2 of *i*SWM) shall be applied in addition to these criteria.

"Dry" Detention Basins

1. Detention Basins shall be required when downstream facilities within the "Zone of Influence" are not adequately sized to convey a design storm based on current TOWN criteria for hydraulic capacity. Detention basins may not be required if downstream improvements that shall result in sufficient hydraulic capacity are proposed by the TOWN within a relatively short period of time.

2. Calculated proposed storm water discharge from a site shall not exceed the calculated discharges from existing conditions, unless sufficient downstream capacity above existing discharge conditions is available.
3. The Modified Rational Method is allowed for planning and conceptual design for watersheds of 200 acres and less. For final design purposes the Modified Rational Method is allowed only for watersheds of 25 acres and less (see Table 2.1.1-2).
4. Detention Basins draining watersheds over 25 acres shall be designed using a detailed unit hydrograph method acceptable to the Town of Westlake. These include Snyder's Unit Hydrograph (>100 acres) and SCS Dimensionless Unit Hydrograph (any size). The SCS method is also allowed for basins with watersheds less than 25 acres (see Table 2.1.1-2).
5. Detention Basins shall be designed for the 2-year, 10-year, 25-year and 100-year storm for the critical storm duration (i.e. 3-hour, 6-hour, or 24-hour storm duration) that results in the maximum (or near maximum) peak flow.
6. Detention Basins shall be designed with access for tracked earthwork equipment with a 10-foot crown width on any embankment.
7. Earthen (grassed) embankment slopes shall NOT exceed 4:1. Concrete lined or structural embankment can be steeper with the acceptance of the Town Engineer, or designee.
8. A calculation summary shall be provided on construction plans. For detailed calculations of unit hydrograph studies, a separate report shall be provided to the Town Staff for review and referenced on the construction plans. Stage-storage-discharge values shall be tabulated and flow calculations for discharge structures shall be shown on the construction plans.
9. An emergency spillway shall be provided at the 100-year maximum storage elevation with sufficient capacity to convey the fully urbanized 100-year storm assuming blockage of the closed conduit portion outlet works with six inches of freeboard. Spillway requirements must also meet all appropriate state and Federal criteria.
10. Design calculations shall be provided for all spillways.
11. All detention basins shall be stabilized against significant erosion and include a maintenance plan.
12. State rules and regulations regarding impoundments shall be observed including 30 TAC Chapter 299, Dams and Reservoirs (TCEQ).
13. In accordance with Texas Water Code §11, all surface impoundments not used for domestic or livestock purposes must obtain a water rights permit from the TCEQ. A completed permit for the proposed use, or written documentation stating that a permit is not required, must be obtained. All detention facility designs shall include a landscaping plan
14. Retention/detention ponds shall resemble natural ponds; in addition:
    (a) The pond should expand gradually from the inlet towards the outlet, insuring that there are no "dead zones". That is, water entering the pond gradually spreads out and uniformly displaces the water already present in the pond.
    (b) The length-to-width ratio should be three to one or greater, to provide a long flow path.
    (c) The average permanent pond depth should be greater than five feet.
    (d) A ten- to 20-foot-wide shallow bench shall be provided along the shores of the permanent pond for safety and to encourage the development of bottom growth in these areas. This vegetation will enhance the biologic treatment characteristics of the pond and also enhance the "natural" appearance of the pond.
    (e) Where slope erosion protection is needed for the side slopes of a pond, rock or geotextiles are required as approved by the town manager or his designee. Exposed concrete surfaces shall be faced with embedded rock or masonry. Bare concrete shall only be permitted with the express written permission of the board of aldermen. Side slopes should be no steeper than 4:1 where feasible for reasons of public safety and maintenance.

"Wet" Detention Basins and Amenity Ponds

Wet detention basins maintain a permanent pool with additional storage capacity to detain storm water. Amenity ponds may or may not include this additional storage. The depth of a wet or amenity pond is generally seven (7) to ten (10) feet to prevent algal growth, although greater depths are possible with artificial mixing. The objective is to avoid thermal stratification that could result in odor problems or recycling of nutrients. Gentle artificial mixing may be needed in small ponds because they are effectively sheltered from the wind. If properly designed, constructed, and maintained, wet ponds shall not only reduce peak storm water flows, but also improve water quality and can be an attractive feature of a development.

Below are guidelines for wet detention basins in addition to those presented under “Dry” Detention Basins.

(a) Must be appropriately aerated according to normal pool size unless specifically accepted by the Town Engineer, or designee.
(b) Provisions shall be made to ensure that normal water surface elevation is maintained through the use of ground wells or the Town’s water supply unless surface water supply can be justified based on drainage area to pond. (general requirement is 12 acres of drainage area for every acre-foot of normal pool storage).
(c) Ten-foot (10’) wide maintenance access shall be provided with a slope of 6:1 or flatter.
(d) A debris filter must be provided for all outlet structures.
(e) Design shall provide adequate capacity for trapped sediment for five (5) years.
(f) To minimize short-circuiting, the inlet and outlet should be placed at opposite ends of the pond or baffling shall be installed to direct the water to the opposite end before returning to the outlet. Dead space should be avoided.
(g) To limit water loss by infiltration through the bottom of the pond either an artificial liner or a clay liner may be used. Natural material may be used if a geotechnical report is provided by a licensed professional engineer to assure it shall not leach out the bottom or sides of the pond.
(h) Reference *i*SWM Section 5.2.21 “Storm Water Ponds” for additional guidance on the design of Wet Ponds. The water quality and streambank protection criteria described in this *i*SWM section are not currently required by the City.

Section 4.5.1 – General Storage Concepts

ADOPTED

Section 4.5.2 – Symbols and Definitions

ADOPTED

Section 4.5.3 – General Storage Design Procedures

ADOPTED

Section 4.5.4 – Preliminary Detention Calculations

ADOPTED

Section 4.6 – Outlet Structures

ADOPTED

Section 4.7 – Energy Dissipation

Section 4.7.1 – Overview

ADOPTED WITH MODIFICATIONS

Channel Transitions, Energy Dissipation Structures, or Small Dams

A backwater analysis is required by the Town of Westlake, using HEC-RAS, to determine accurate tailwater elevation and velocities, headlosses, headwater elevations, velocities and floodplains affected by the proposed transition into and out of 1) An improved channel, 2) Any on-stream energy dissipating structures, and 3) Small dams (less than 6 feet). If the current effective FEMA model for the stream is a HEC-2 model. FEMA no longer recognizes HEC-2 as an acceptable model for current applications. The engineer shall convert the current effective HEC-2 model to HEC-RAS for analysis of proposed conditions. For larger dams, a hydrologic routing shall be required, as well as hydraulic analysis, to determine impacts of the proposed structure on existing floodplains and adjacent properties.

Exceptions may be granted for small outfall channels (with the acceptance of the Town Engineer, or designee) with drainage areas of 10 acres or less and no nearby downstream restrictions.

Examples of Open Channel Transition Structures

Details and Specifications and application guidance for Harris County Flood Control District Straight Drop Structure and Bureau of Reclamation Baffled Chute (Basin IX) can be found in Harris County Flood Control District Policy Criteria& Procedure Manual (See references section for description). A computer program associated with FHWA Hydraulic Engineering Circular No. 14 is "HY8Energy" dated May 2000. This program provides guidance in the selection and sizing of a broad range of energy dissipaters including some of those listed in Chapter 4 of the *i*SWM manual.

Section 4.7.2 – Symbols and Definitions

ADOPTED

Section 4.7.3 – Design Guidelines

ADOPTED

Section 4.7.4 – Riprap Aprons

ADOPTED

Section 4.7.5 – Riprap Basins

ADOPTED

Section 4.7.6 – Baffled Outlets

ADOPTED

Section 4.7.7 – Grade Control Structures

ADOPTED

Section 4.8 – Easements for Open Channels and Detention Ponds

LOCAL CRITERIA SECTION ONLY

Drainage Easement Criteria:

1. Drainage easements are required for both on-site and off-site public storm drain channels and ponds. Results of a backwater hydraulic analysis (plus freeboard) shall determine easement requirements. Buffer zones must also be provided for access and to guard against nuisances created from natural erosion processes. Also see Item 6 below.
2. Floodway/Drainage easements shall be provided on-site along FEMA streams with delineated floodways. Floodway easements shall encompass the entire area of the floodway shown on the Effective FEMA Flood Insurance Rate Map.
3. Drainage easements shall include a minimum of ten-foot (10') margin on both sides beyond actual top of bank for improved earthen channels. Retaining walls are not permitted within or adjacent to a drainage easement in order to reduce the easement width.
4. Natural creeks shall have a dedicated drainage easement encompassing the 100-year fully developed floodplain plus ten (10) feet on each side of this floodplain. The minimum finished floor elevation for lots impacted by natural creeks shall be a minimum of two (2) feet above the fully developed 100 year water surface elevation.
5. Concrete Lined Channels and Gabion Lined Channels shall have drainage easements dedicated to meet the requirements of the width of the channel, the one-foot freeboard above the 100 year fully developed water surface elevation, and any access routes. The minimum finished floor elevation for lots adjacent to Concrete Lined and Gabion Lined Channels shall be a minimum of two (2) feet above the fully developed 100 year water surface. The top of the lining in curves shall provide the two (2) foot of freeboard in the design frequency storm.
6. All detention and retention structures shall be located within drainage easements. Maintenance shall be provided by the developer/land owner. The Town of Westlake provides maintenance only on regional detention facilities. The limit of the easement shall include all freeboard as stated in Section 4.5 plus any access route around the perimeter of the facility.

7. The entire reach or each section of any drainage facility must be readily accessible to maintenance equipment. Additional easement(s) shall be required at the access point(s) and the access points shall be appropriately designed to restrict access by the public.

References

ADOPTED WITH MODIFICATIONS

Harris County Flood Control District, October 2004, Policy, Criteria and Procedure Manual for Approval and Acceptance of Infrastructure, Houston, Texas.

U.S. Army Corps of Engineers, August, 1992, Design and Construction of Grouted Riprap, ETL 1110-2-334.

U.S. Army Corps of Engineers, July 1991/June 1994, Hydraulic Design of Flood Control Channels, EM 1110-2-1601.

U.S. Department of the Interior Bureau of Reclamation , Hydraulic Design of Stilling Basins and Energy Dissipaters, January 1978, Engineering Monograph No. 25.

CHAPTER 5 - STORM WATER CONTROLS

ADOPTED

Chapter 5 of the *i*SWM Manual contains an exhaustive discussion and detailed examples of structural post-construction controls that can be implemented in land development to meet the goals of protecting water quality, minimizing streambank erosion, and reducing flood volumes. It is an excellent planning and design resource document and has valuable design examples that the Town of Westlake encourages local developers to consider in their site planning. Other measures not included in this section may be considered provided there is appropriate support for their use in the region.

*i*SWM APPENDICES

Appendix A **Rainfall Tables for North Central Texas**
Adopted

Appendix B **Hydrologic Soils Data**
Adopted

Appendix C **Federal, State and Regional Regulations and Programs**
Adopted

Appendix D **Dams and Reservoirs in Texas**
Adopted

Appendix E ***i*SWM Worksheets and Checklists**
Adopted

Appendix F **Landscaping and Aesthetics Guidance**
Adopted

Appendix G **Storm Water Computer Models**
Adopted with Modifications

In addition to Storm Water Computer Models listed in Appendix G of the *i*SWM Manual, the Town of Westlake accepts appropriately applied versions of the following computer models.

1. STORMCAD by Haestad Methods and GeoPac by Bentley for analysis and design of storm sewer.
2. Gabion Design Programs by Maccaferri:
   a. Macra 1 for Channel Design
   b. GawacWIN for Retaining Wall Design
3. SWFHYD (formerly NUDALLAS) by Fort Worth District, U.S. Army Corps of Engineers for hydrologic routing studies (use only where model currently exists).
4. AdICPR (Advanced Interconnected Pond Routing) by Streamline Technologies, Inc. for complex hydrograph routing particularly detention ponds in series.
5. InfoWorks by Wallingford for complex dynamic hydrologic and hydraulic modeling.

Appendix H **Storm Water Control Design Examples**
Adopted