CITY OF FORT WORTH

AN iSWM COMMUNITY

STORMWATER CRITERIA MANUAL

September 29, 2015

FORT WORTH®

Stormwater Management

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Foreword

Adoption of Manual by City of Fort Worth

This Stormwater Criteria Manual is adopted and becomes effective on September 29, 2015.

Relationship to Previous Manuals

The original City of Fort Worth (CFW) Storm Drainage Criteria and Design Manual was developed in 1967 and amended in 1975, 1986, and 1994. In 2006, updated design criteria were developed in conjunction with the first version of the NCTCOG's iSWM Manual™. In 2012, the manual was revised to incorporate the City's grading permit requirements and revised values for impervious cover in hydrologic calculations. The CFW criteria presented in this 2015 manual are generally consistent with those in the 2012 version. The 2015 revision incorporates local provisions into the document and reflects the development process changes implemented by the City of Fort Worth in 2013 – 2015. The intent of this revision is primarily to more clearly define the steps and requirements of stormwater development review for the City of Fort Worth. As such, all process requirements are now listed in Chapter 2.0 of this manual. As in 2012, the over-arching motivation for this manual is to provide efficient guidance for effective mitigation of the impacts of new development and construction on the character of stormwater runoff.

Purpose and Limitations of Manual

This manual is intended to provide a guideline for the most commonly encountered stormwater or flood control designs in the CFW. It shall be used as a guide for watershed master plans and for design of remedial measures for existing facilities. This manual was developed for users with knowledge and experience in the applications of standard engineering principles and practices of stormwater design and management. There will be specific situations not completely addressed or covered by this manual. Other methods of design or variances to the criteria may be requested using Form CFW-7 of Appendix A. Any variations from the practices established in this manual must have the expressed written approval of the Director of the Department of Transportation and Public Works (TPW) or designee. Close coordination with the staff of the CFW is recommended and encouraged during the planning, design and construction of all stormwater facilities.

The design procedures as presented herein are based on the historical rainfall records of duration, intensity, and frequency of storms that have occurred in the past in the Fort Worth area. This is the customary and accepted basis for the design of drainage facilities. There is no assurance, however, that rainfall will not occur in the future that will temporarily overload the drainage facilities. The degree of protection afforded by the procedures included herein is considered consistent with good municipal practice in this region.

Please note that all references in blue italics refer to the 2010 NCTCOG *iSWM Technical Manuals*, such as *Planning, Hydrology, Hydraulics, Site Development Controls*.

Goals and Objectives for Stormwater Management

A proper understanding of the City's adopted goals and objectives for stormwater management, as summarized in Chapter 1 is essential for the proper application of this Manual.

Contact Information

Additional information on Fort Worth's Stormwater management program and policies can be obtained at www.fortworthtexas.gov/stormwater/ or by contacting the SDS staff at SDS@fortworthtexas.gov. For information on the iSWM regional manual and program, contact the NCTCOG at 817-695-9220 or at the website http://iSWM.nctcog.org/.

Acknowledgments

The City of Fort Worth acknowledges the extensive efforts of the North Central Council of Governments and their consultants in the development of the iSWM regional program and manuals. The City also wishes to acknowledge the significant contribution by consulting engineers, planners, developers, and community leaders in the Fort Worth area who dedicated many hours of meetings, review of policy and criteria, and development of specific recommendations that were incorporated in the 2012 Manual and this 2015 document:

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Halff Associates, Inc. coordinated the development of the 2012 Fort Worth local criteria. Freese and Nichols, Inc. coordinated the revisions to the 2012 criteria which are incorporated into the current 2015 manual.

Errata Sheet

Overview of the iSWM Program

The iSWM Program for Construction and Development is a cooperative initiative that assists municipalities and counties to achieve their goals of water quality protection, streambank protection, and flood mitigation, while also helping communities meet their construction and post-construction obligations under state stormwater permits.

Development and redevelopment by their nature increase the amount of imperviousness in our surrounding environment. This increased imperviousness translates into loss of natural areas, more sources for pollution in runoff, and heightened flooding risks. To help mitigate these impacts, more than 60 local governments are cooperating to proactively create sound stormwater management guidance for the region through the *"integrated"* Stormwater Management (iSWM) Program.

The iSWM Program is comprised of four types of documentation and tools as shown in Figure 1.1. These are used to complement each other and to support the development process.

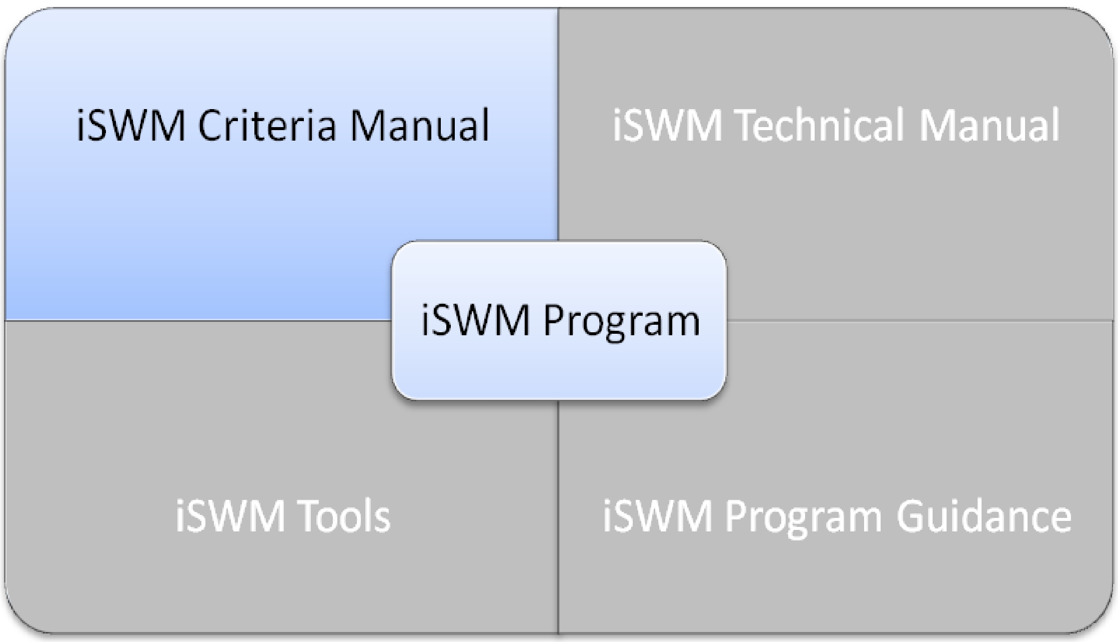


Figure 1.1 iSWM Program Support Documents and Tools

The four parts of iSWM are:

Stormwater Criteria Manual (this manual) – This document provides a description of the development process, utilizing the design concepts and regional criteria adopted as part of the iSWM focus areas. This document incorporates locally adopted design criteria as required by the CFW in conjunction with the iSWM criteria.

iSWM Technical Manual – This set of documents provides technical guidance including equations, descriptions of methods, fact sheets, etc. necessary for design. The *iSWM Technical Manual* includes categories for Planning, Water Quality, Hydrology, Hydraulics, Site Development Controls, Construction Controls and Landscape. The *iSWM Technical Manual* is referenced in this document.

iSWM Tools – This includes web-served training guides, examples, design tools, etc. that could be useful during design.

iSWM Program Guidance – This includes reference documents that guide programmatic planning rather than technical design.

The *iSWM Technical Manual*, Tools, and Program Guidance provide references and additional information that will be helpful in the development of an iSWM plan which will comply with the CFW criteria.

1.0 Stormwater Goals and Objectives

1.1 Introduction

The purpose of this manual is to provide design criteria and a framework for incorporating effective and environmentally sustainable stormwater management into the site development and construction processes.

The City's primary goal is to manage stormwater so that drainage conditions do not get worse as new areas are developed – while making improvements in the areas of the City that are already developed.

We can accomplish this goal by:

1. Developing detailed watershed plans that promote orderly growth and result in an *integrated* system of public and private stormwater infrastructure.
2. Adopting development policies and standards that prevent flooding, preserve streams and channels, and minimize water pollution without discouraging either new or infill development and Preliminary iSWM acceptance.
3. Fully complying with regulatory permit requirements.
4. Operating the stormwater system in a more efficient and effective manner.
5. Informing the public about stormwater issues in the community.
6. Securing funding that is adequate for meeting these needs and is recognized by the public as fair and equitable.

The City's planning and design objectives described in this manual are to:

1. Regulate the drainage policy and criteria for new development and redevelopment so the new development does not increase flooding problems, cause erosion or pollute downstream water bodies.
2. Facilitate the development of comprehensive watershed planning that promotes orderly growth and results in an *integrated* system of public and private stormwater infrastructure.
3. Minimize flood risks to citizens and properties, and stabilize or decrease streambank and channel erosion on creeks, channels, and streams.
4. Improve stormwater 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 stormwater facilities for trails, green space, parks, greenways or corridors, stormwater quality treatment, and other recreational and natural features, provided they are compatible with the primary functions of the stormwater facility.
6. Encourage a more standardized, *integrated* land development process.

The criteria provided in this manual will help to meet sustainable development goals and objectives. There are many ways that sustainable development may be achieved while following these criteria.

Chapter Summary

The Stormwater Criteria Manual consists of five chapters:

Chapter 1 – Stormwater Goals and Objectives

Chapter 2 – Stormwater Development Process

Chapter 3 – Stormwater Design Criteria

Chapter 4 – Stormwater Construction Criteria

Chapter 5 – References

1.2 Abbreviations and Definitions

For convenience, two terms which are used frequently throughout this manual are abbreviated:

- CFW – City of Fort Worth
- TPW – Department of Transportation and Public Works

Several stormwater and development terms are used in this manual which have unique or special meanings. They are defined below:

1. **Adequate Outfall** – Outfall that does not create adverse flooding or erosion conditions downstream (No Adverse Impact) from the development through the downstream end of the Zone of Influence. In all cases shall be subject to the approval of the Director of the Transportation and Public Works Department. Refer to Section 3.1, Table 3.1.
2. **BMP or Best Management Practice** – A physical, chemical, structural, or managerial practice or device that prevents, reduces, or treats the pollution of stormwater, or reduces or treats erosion, or minimizes runoff.
3. **Development** – A contiguous tract of land (or a tract of land separated only by roadway and/or drainage right-of-way or easements) to be considered as a single development for purposes of this policy.
4. **Downstream Assessment** – Determination of the downstream limit of properties that could be impacted by the development (see Zone of Influence).
5. **Drainage Study** – Studies of the proposed development and drainage areas, which may include a downstream assessment, shall be included as part of the Preliminary and Final iSWM Plans. The necessary hydrologic and hydraulic analyses to clearly demonstrate that the limits of the Zone of Influence have been identified shall be included.
6. **Early Grading Permit** – The approval by the CFW to proceed with grading only for the disturbance of 1.0 acre or more, after review and acceptance of the early grading permit application.
7. **Engineer or Engineer of Record** – The person authorized to practice engineering in Texas who is responsible for preparing engineering plans for a development.
8. **Floodplain Development Permit** – A permit required before any development activity shall begin within a floodplain or FEMA designated Special Flood Hazard Area (SFHA). This shall require a separate submittal to the CFW Floodplain Administrator.
9. **Fully Developed Conditions** – For watershed hydrology, fully developed conditions include all existing developed areas which shall reflect current land use or current zoning, whichever yields the greatest runoff, and all existing undeveloped areas which shall reflect anticipated future land use designated by zoning classification, by the City's Comprehensive Plan, or by an accepted concept plan, or in the ETJ, NCTCOG future land use maps.

10. **Grading Permit** – The approval by the CFW to proceed with the disturbance of 1.0 acre or more, after review and approval of the Final iSWM Plan, and any additional City required permits. A grading permit is required prior to any construction activity 1.0 acre or more.
11. **iSWM Construction Plan** – A plan and notes indicating the installation and maintenance of BMPs and application of pollution prevention procedures used to control erosion, sediment, construction materials, and waste during the construction phase of improvements in conformance with the criteria contained in this Manual. This plan shall be included within the construction plan set required for development within the CFW.
12. **iSWM Plan** – An *integrated* stormwater management plan (SWMP) that conforms to the criteria contained in this Manual (See Drainage Study).
13. **Maintenance Plan or Operations and Maintenance Plan** – A plan prepared in accordance with this Manual for the purpose of describing maintenance and operational requirements of a structural BMP and interchangeably used with the "CFW Stormwater Facility Maintenance Plan."
14. **Natural Creeks** – Those drainageways that are generally unimproved, that often exhibit a meandering course, and which are not proposed to be improved to City standards for earthen channels. Natural creeks are generally not dredged, mowed or otherwise maintained by the City and should be contained within floodplain easements rather than drainage easements.
15. **Offsite Drainage Area** – An area which drains to the proposed development.
16. **Private Water** – Runoff water which is generated on private property and flowing within the property or from one property to another. Drainage easements and drainage facilities which contain only private water shall not be maintained by the City.
17. **Public Water** – The concentration of surface water flowing through or from public land or right-of-way. Public water must be contained within a dedicated right-of-way, floodplain or drainage easement.
18. **Stormwater Fee Credits** – An incentive provided by the CFW to encourage the voluntary use of BMPs which improve stormwater management. See Appendix F.
19. **Stormwater Facility Maintenance Agreement or Maintenance Agreement (SWFMA)** – A legal agreement between the CFW and a property owner, including HOAs and POAs, for perpetual maintenance of a structural BMP.
20. **Stormwater Pollution Prevention Plan or SWPPP** – The site design, operations, and inspections plan required by the Environmental Protection Agency (EPA) and the Texas Council on Environmental Quality (TCEQ) for the control of erosion and sediment during construction.
21. **Zone of Influence** – A "zone of influence" from a proposed development extends to a point downstream where the discharge from a proposed development no longer has a significant impact, as defined in Chapter 3.1, Table 3.1 and Chapter 3.7.3, upon the receiving stream or storm drainage system, and downstream properties. The Zone of Influence for any proposed development must be defined by the development engineer by a drainage study that: (1) determines the extent of the downstream drainage route subject to impacts from a proposed development, and (2) delineates what existing conditions are in place or what proposed mitigation is planned so that "no adverse impacts" from the new development will occur.

1.3 Applicability of Stormwater Criteria

The Stormwater Criteria is applicable under the following conditions for development and redevelopment as illustrated below and in Table 1.1.

Table 1.1 Applicability
Applicable for iSWM Site Design and Construction:
Land disturbing activity or platting of 1.0 acre or more OR land disturbing activity of less than 1.0 acre where the activity is part of a common plan of development that is 1.0 acre or more.

A common plan of development consists of construction activity that is completed in separate stages, separate phases, or in combination with other construction activities. To be considered as a common plan of development for purposes of this policy, a tract must meet one or more of the following characteristics:

- Included in a single concept plan submitted to the CFW,
- Included in a single preliminary plat submitted to the CFW,
- Is comprised of contiguous land (or land separated only by roadway and/or drainage rights-of-way or easements) under the same root ownership,
- Is encumbered by a single Master Drainage Study or Plan,
- Is encumbered by a single Developer's Agreement, TIF, 380 Agreement or other public/private partnership agreement,
- Is overlaid by a common Homeowner's or Property Owner's Association (HOA, POA), or
- Is owned or managed by a common Master Developer.

CFW requires a Grading Permit or an accepted and current iSWM plan prior to any land disturbance of 1.0 acre or more. After construction and grading activities are completed and disturbed areas are stabilized, a Grading Certificate must be provided by the Contractor or Engineer which affirms that construction has been completed in substantial compliance with plans accepted by the CFW and all temporary BMP's have been removed.

Development and redevelopment are not specifically defined in this manual. Rather, the applicability of this criteria is based on land disturbance activities. If an existing site has been cleared and/or graded within the prior five years of the date of the developer's initial application submittal, the developer may consider the land conditions prior to the clearing and grading to be the existing site conditions.

New development or redevelopment, subject to the applicability requirements shown in Table 1.1, which are located in critical or sensitive areas, or as identified through a watershed study or plan, may be subject to additional performance and/or regulatory criteria. Furthermore, these sites may need to utilize certain structural controls in order to protect a special resource or address certain water quality or drainage problems identified for a drainage area or watershed.

Site Design below Applicable Criteria

Site developments that do not meet the applicability requirements will not require an iSWM plan submittal. However, all developments within the CFW city limits and ETJ shall comply with the City of Fort Worth Subdivision Ordinance and development permitting requirements, including but not limited to building permits, floodplain development permits, SWPPP, grading permits, and urban forestry permits.

Adoption of Standards

For projects which have an accepted drainage study and/or iSWM plan, including phased developments which have some existing constructed phases after the adoption of the iSWM criteria in June 2006, findings in accepted studies will remain valid. The applicability of the current drainage criteria is presented below in the Applicability of the iSWM Standards Adoption Language.

> *Concept, Preliminary and Final iSWM Plans, as well as drainage design calculations accepted by the City of Fort Worth after the adoption of the City's drainage design standards and criteria on June 1, 2006 shall be considered valid when:*
>
> - *The proposed project is a phase of a mulit-phase development that has a valid preliminary plat*
> - *The drainage infrastructure of the proposed phase will connect directly to drainage infrastructure of a phase of the same development with drainage infrastructure designed and constructed based on the standards in previous versions of the City's iSWM manual.*
>
> *All iSWM plans and stormwater design projects submitted after the September 29, 2015 adoption date not meeting the criteria above shall use the current iSWM standards and will be valid for a period of time that is concurrent with the accepted preliminary or final plat for the project.*

If a proposed development maintains or decreases the percent imperviousness onsite, an iSWM submittal will be required to provide confirmation of maintained or decreased percent imperviousness and show no additional impacts.

For applicable sites, the building permit process shall require a drainage review of the Final iSWM Plan to ensure that the site runoff is consistent with existing runoff patterns or has been appropriately addressed.

2.0 Stormwater Development Process

This chapter discusses the CFW stormwater development process and review requirements. The submittal process, development paths and subsequent iSWM plans are described.

2.1 iSWM Submittals

Stormwater development review submittals shall be submitted to Transportation and Public Works Department – Stormwater Division at the City of Fort Worth located at 1000 Throckmorton, Fort Worth, Texas, 76102. All drainage reviews shall be submitted to the Stormwater Development Services Department. Digital submittals are highly encouraged and recommended. Information regarding digital submittals shall be available on Buzzsaw. The checklists are available in an editable form online through Buzzsaw and shall be included in the digital submittal. For additional information on the use of Buzzsaw contact the Stormwater Development Services Department at sds@fortworthtexas.gov. Upon receiving a stormwater submittal for review, the submittal package will receive a cursory review for completeness of submittal requirements. Incomplete submittals shall not be accepted. The checklists for each submittal are located in Appendix A of the iSWM Criteria Manual and listed below.

1. Preliminary iSWM Checklist – Form CFW – 1
2. Final iSWM Checklist – Form CFW – 2
3. Grading Permit Application – Form CFW – 9
4. Final Grading Certificate – Form CFW – 10

2.2 iSWM Plan Submittal Requirements

The requirement of each plan is dependent on the development path underway, as shown in Figure 2.1 at the end of this chapter. It should be noted that the process diagram provided in Figure 2.1 is for Stormwater development reviews only and does not include additional reviews required by other City of Fort Worth Departments. It shall be the applicant’s responsibility to inquire regarding pertinent permitting and review submittals required for their project.

The level of drainage review is dependent on the type of development activity proposed. iSWM reviews are required for Grading Permits, Concept Plans, and Platting on properties with land disturbance of 1.0 acre or more, or smaller land disturbances part of a common plan of development. Requirements for each review are further described in this chapter.

An appropriate level drainage study of existing, proposed, and fully developed conditions will be required as part of each iSWM plan. The drainage study is necessary to determine appropriate easement needs, and perform a downstream assessment to determine the zone of influence. The Preliminary iSWM Plan will include only enough detail to determine approximate onsite controls and to establish adequate downstream capacity to the zone of influence to support future development of the project. A Preliminary iSWM Plan shall contain general volume and location information when detention is to be utilized. Detailed design calculation for detention requirements will be required for approval of public infrastructure construction documents and for Final iSWM Plan and final plat approval. The Final iSWM Plan will include the necessary hydrologic and hydraulic analysis to clearly demonstrate that the limits of the zone of influence have been identified, and that along the drainage route to that location, the parameters listed in Table 3.1 and Chapter 3.7.3 are met.

Concept Plan

A concept plan is intended for multi-phase developments and is required by the CFW Planning and Development Department when:

- Preliminary plats are proposed to be presented in stages
- Total land area of contiguous parcels under the same ownership and control is greater than one square mile (640 acres), and
- The area is located wholly or partially within the CFW or proposed for annexation to the City.

Additional information regarding the Conceptual iSWM Plan in support of concept plan is provided below and in Chapter 2.3, Step 2.

Conceptual iSWM Plan

The Conceptual iSWM Plan is required for the approval of a concept plan. The Conceptual iSWM Plan requirements are included as a subset of the Preliminary iSWM Checklist located in Appendix A, Form CFW – 1. Additional information regarding the Conceptual iSWM Plan is provided in Chapter 2.3, Step 2.

Platting

A preliminary plat requires an accepted Preliminary iSWM Plan. Subsequently, a final plat, a minor, short form final or a replat requires an accepted Final iSWM Plan.

Preliminary iSWM Plan

A Preliminary iSWM Plan is required for preliminary plans and preliminary platting. The Preliminary iSWM Plan requirements are provided on the Preliminary iSWM Checklist located in Appendix A, Form CFW – 1. Additional information regarding the Preliminary iSWM Plan is provided in Chapter 2.3, Step 3.

Grading Permit Application

Upon acceptance of a Preliminary iSWM Plan, if a proposed development of 1.0 acre or more requires earthwork only, an early grading permit may be obtained by completing a Grading Permit Application. A final grading permit shall be required for construction activities and may be obtained by completing a Grading Permit Application. The Grading Permit Application, provided in Appendix A, Form CFW – 9, lists the requirements necessary to obtain an early or final grading permit. Additional information regarding the application for a grading permit is provided in Chapter 2.3, Step 4. Grading permit applicants should refer to the City of Fort Worth Grading Ordinance for further information.

Final iSWM Plan

A Final iSWM Plan is required for final construction plans and final platting. The Final iSWM Plan requirements are provided on the Final iSWM Checklist located in Appendix A, Form CFW – 2. Additional information regarding the Final iSWM Plan is provided in Chapter 2.3, Step 5.

Additional Development Information

Proposed developments that are located within a FEMA Special Flood Hazard Area (SFHA) designated floodplain shall require a Floodplain Development Permit. Questions regarding the Floodplain Development Permit should be directed to the Floodplain Administrator at the CFW.

Proposed developments may require an urban forestry permit. Questions regarding the urban forestry permit should be directed to the Planning and Development Department at the CFW.

The Final iSWM Plan shall be required and accepted prior to obtaining a building permit, if applicable by ordinance or this manual. Prior to a Certificate of Occupancy being issued, a Final Grading Certificate prepared by an engineer or the contractor, as appropriate, shall be submitted. The Final Grading Certificate shall state that the site grading and drainage improvements are constructed in substantial compliance with the accepted plans. If the improvements were not constructed in substantial compliance with the plans, appropriate documentation shall be provided to substantiate any changes. If changes were made to public facilities, the City shall require an engineer to document field changes by submitting certified as-built plans and documenting changed calculations and proposed corrective actions, if required. The final grading certificate, building permit, and certificate of occupancy are administered by the CFW Planning and Development Department.

Construction of public infrastructure shall require submittal of construction plans for review through the Infrastructure Plan Review Center (IPRC). These plans will be reviewed for conformance with the CFW drainage criteria and also consistency with the Conceptual, Preliminary and Final iSWM Plans previously submitted.

2.3 Development of an iSWM Plan

This chapter describes the typical contents and general procedure for preparing an iSWM plan, and the final construction plans and iSWM Construction Plan, required as part of the Final iSWM Plan. The level of detail involved in each submittal will depend on the project size and the individual site and development characteristics. Detailed criteria for the calculations required in the iSWM plans and construction plans are covered in Chapter 3 of this manual.

Stormwater master plans are an important tool used to assess and prioritize both existing and potential future stormwater problems and to consider alternative stormwater management solutions. The CFW may have individual watershed plans, or several developers may choose to work cooperatively to develop a unified approach to watershed planning, development controls, permit compliance, multi-objective use of floodplain and other areas, and property protection. The CFW Stormwater staff should be consulted on any regional approaches considered.

There are five steps defined in the preparation of Stormwater development review submittals. In general, each of the following steps builds on the previous step to result in the Final iSWM Plan, construction drawings and iSWM Construction Plan.

Step 1 – Baseline Data Collection and Analysis

Step 2 – Prepare Conceptual iSWM Plan (Concept Plans Only)

Step 3 – Prepare Preliminary iSWM Plan

Step 4 – Prepare Grading Permit Application (Early and/or Final)

Step 5 – Prepare Final iSWM Plan, Construction Drawings, iSWM Construction Plan, and Stormwater Facilities Maintenance Agreement (SWFMA)

Step 1 –Baseline Data Collection and Analysis

The site developer shall become familiar with the CFW stormwater management, development requirements and design criteria that apply to the site. These requirements include:

- Stormwater Criteria Manual (this manual)
- Available online iSWM Program documents, which include:
  - iSWM Technical Manual
  - iSWM Tools
  - iSWM Program Guidance
- State and Federal Regulatory Requirements
- Other CFW Ordinances and Criteria (Not regulated by the Stormwater Division)
  - Platting Procedures
  - Zoning Requirements
  - Development Codes and Procedures
  - Tree and Landscape Requirements
  - Special Use Permits
  - Drainage Master Plans and Watershed Plans
  - Erosion Control Plans
  - Floodplain Development Ordinance

  - Grading Plan Ordinance
  - Construction/Building Permit Notifications and Requirements
  - Urban Forestry Requirements

Information regarding the above items can be obtained from this manual or at a pre-development conference with the CFW.

A critical part of any project involves the proposed developer working closely with various departments within the City. Integrating the stormwater management practices with other regulatory requirements will promote a sustainable development.

Opportunities for special types of development (e.g., clustering) or special land use opportunities (e.g., conservation easements or tax incentives) should be investigated. In addition, there may be an ability to partner with the local community for the development of greenways or other riparian corridor or open space developments.

All applicable state and federal regulatory requirements must also be met.

In addition to understanding all applicable regulations and ordinances, it is also necessary to collect and review information on the existing site conditions and map the following site features:

- Topography
- Drainage patterns and basins
- Intermittent and perennial streams on-site and off-site waters that will receive discharges from the proposed development
- Soil types and their susceptibility to erosion
- Ground cover and vegetation, particularly unique or sensitive vegetation areas to be protected during development.
- Existing development
- Existing Stormwater facilities on-site and off-site facilities that will be receive discharges from the proposed development
- Property lines, adjacent areas and easements
- Wetlands and critical habitat areas
- Boundaries of wooded areas and tree clusters
- Floodplain boundaries
- Steep slopes
- Required buffers and setbacks along water bodies
- Proposed stream crossing locations
- Other required protection areas

Upon completion of the baseline data collection and analysis, it is recommended and encouraged to schedule a stormwater pre-development conference with the CFW Stormwater Development Review Services staff. This meeting will allow a dialogue to begin between the developer and the City regarding the site conditions and potential areas of concern prior to work being done for the development. To schedule a pre-development conference with the Stormwater staff, please send an email to sds@fortworthtexas.gov.

The site analysis shall be summarized in the relevant iSWM plan along with any other supporting documents. The data collected and analyzed during this step of the development process shall be used as the starting point for preparing the iSWM plans and the iSWM Construction Plan.

Step 2 – Prepare Conceptual iSWM Plan (Concept Plans Only)

If a concept plan is not required or submitted, proceed to Step 3.

For larger master plan developments with multiple phases of development, a concept plan may be required. The concept plan allows the design engineer to propose a potential site layout and gives the developer and CFW a "first look" at the stormwater management system for the proposed development. Specific requirements for the concept plan shall be obtained through the CFW Planning and Development Department. If a concept plan is required, a Conceptual iSWM plan will be required.

For a Conceptual iSWM Plan, the following steps shall be followed in analyzing the drainage conditions for a concept plan:

1. Use *integrated* Site Design Practices. Note: *integrated* Site Design Practices are encouraged but not required within the CFW. Examples include:
    - Preserving the natural feature conservation areas defined in the site analysis
    - Fitting the development to the terrain and minimizing land disturbance
    - Reducing impervious surface area through various techniques
    - Preserving and utilizing the natural drainage system wherever possible
2. Determine the credits for *integrated* Site Design (Appendix F) and water quality volume reduction (Appendix F) as applicable, to be accounted for in the design of structural and non-structural stormwater controls on the site.
3. Calculate conceptual estimates of the design requirements for streambank protection and flood mitigation based on the conceptual plan site layout.
4. Perform screening and conceptual selection of appropriate temporary and permanent structural stormwater controls and identification of potential site locations.

Drainage requirements for the Conceptual iSWM Plan are presented as a subset of requirements specifically noted on the Preliminary iSWM Plan Checklist found in Appendix A (Form CFW – 1).

It should be noted that acceptance of the Conceptual iSWM Plan does not imply acceptance of the Preliminary and/or Final iSWM Plans. Those plans will be required and reviewed as development proceeds.

Step 3 – Prepare Preliminary iSWM Plan

The Preliminary iSWM Plan ensures that requirements and criteria are complied with and opportunities are taken to minimize adverse impacts from the development. An accepted Preliminary iSWM Plan is prerequisite of preliminary plat approval. This step builds on the data compiled in Step 1 by developing the existing and proposed runoff calculations and identifying proposed stormwater controls as well as the zone of influence associated with the development. The checklist for the Preliminary iSWM Plan in Appendix A (Form CFW-1) outlines the data that shall be included in the Preliminary iSWM Plan.

The Preliminary iSWM Plan, which includes a preliminary drainage study, must accompany a preliminary plat submitted for development review for any proposed development 1.0 acre or more in land disturbance. At a minimum the information listed in the Preliminary iSWM Checklist (Form CFW-1) shown in Appendix A – City of Fort Worth Detailed Checklists and Forms shall be required. The study shall include a downstream assessment of properties that could be impacted by the development. Unless using the simplified methods described in Chapter 3.7.2, these studies will include the hydrologic analysis to determine the existing, proposed, and fully-developed runoff for the drainage area that is affected by the proposed development and will include a hydraulic analysis that defines the adequate outfall as defined in Table 3.1. It will include a capacity analysis of all existing constraint points such as pipes, culverts/bridges, or channels from the point of stormwater discharge from the development (edge condition) downstream through the zone of influence. For development projects involving properties 100 acres or less, the downstream assessment will be limited to the zone of influence, determined either by the study or established as the point where the property being developed comprises 10% of the total drainage area (*see the iSWM Hydrology Technical Manual, Section 2.4*). Consideration of critical infrastructure and logical analysis end points (ie. bridges, road crossings, creek or river confluences) will be required when using the 10% rule. It shall be the discretion of the reviewer to request the 10% analysis be extended if critical downstream infrastructure has not been included in the analysis. For development projects involving properties more than 100 acres in size, the “adequate outfall point” will be defined by the hydrologic and hydraulic analyses. The Preliminary iSWM Plan shall include the items listed in the Preliminary iSWM Checklist, located in Appendix A, Form CFW – 1.

Simplified methodology have been developed which may be used for the preliminary iSWM plan. Further discussion of these methods is provided in Chapter 3.7.2.

It should be noted that acceptance of the Preliminary iSWM Plan does not imply acceptance of the Final iSWM Plan. Those plans will be required and reviewed as development proceeds.

Step 4 – Prepare Grading Permit Application

Grading permits are available for early grading and final grading on a site of 1.0 acre or more. Early grading permits are applicable to clearing, grubbing, and grading only, with no construction allowed. A final grading permit is required even if an early grading permit is obtained. The final grading permit allows for infrastructure and building construction. The grading permit application is located in Appendix A (Form CFW – 9). All single family residential grading plans must conform to Chapter 3.8.2 (Subdivision Drainage Site Grading) and Appendix E (Single Family Residential Lot Drainage Types).

Changes in existing drainage divides shall be identified and data shall be required to document that capacity is available in the existing system to carry the additional flow to the system.

Grading permit applications should be submitted through the CFW Permit Center. Electronic submittals of the grading permit application are currently not available. At the application submittal, a completed grading permit application form, administrative fee, signed/sealed grading plan sheet(s) and a digital copy of the SWPPP will be required.

It should be noted that the early grading permit is for earthwork only and will be at the risk of the owner/developer. Grading permit issuance will require an accepted preliminary iSWM plan for an early grading permit or accepted final iSWM plan for a final grading permit, review and acceptance of the submitted grading plan sheets by Stormwater Development Services, review and acceptance of the SWPPP by the Environmental Department, approval through Part One of the Urban Forestry Permit, and an accepted Floodplain Development Permit, as applicable, by the Floodplain Manager.

Step 5 – Prepare Final iSWM Plan, Construction Drawings, iSWM Construction Plan, and Stormwater Facilities Maintenance Agreement

The Final iSWM Plan, construction drawings, and the iSWM Construction Plan shall be prepared together and submitted to the CFW for approval prior to final plat approval or any construction activities on the development site. The Final iSWM Plan adds further detail to the Preliminary iSWM Plan and reflects changes that are requested or required by the CFW. When public infrastructure will be constructed, submittals also must conform to the Infrastructure Plan Review Center (IPRRC) requirements. Changes identified during IPRC and/or Final iSWM Plan Review which result in changes to the preliminary plat will not require a resubmittal of the Preliminary iSWM plan. Changes will be reviewed as part of the Final iSWM plan review.

The Final iSWM plan, which includes a final drainage study, shall be prepared for development of all or a portion (i.e. phase one or phase two, etc.) of the overall development and submitted to the CFW. This submittal shall include at a minimum the information listed in the Final iSWM Checklist (Form CFW-2) shown in Appendix A – City of Fort Worth Detailed Checklists and Forms. Note that a downstream assessment for the Final iSWM Plan is not required for small infill developments which meet the specific criteria outlined in Chapter 3.7.2.

Please note:

1. The Final iSWM Plan shall be accepted upon conformance with Preliminary iSWM comments, final iSWM checklist requirements, and a drainage area map with calculations from the accepted engineering construction drawings. Drainage calculations presented on the construction plans must conform to calculations submitted in the Final iSWM Plan. Where City approval of construction plans is not required, the above information required for the iSWM plan, as well as construction plans for any drainage improvements, prepared according to criteria in the current TPW plan review checklists, shall be submitted. For changes during IPRC Review, Preliminary iSWM resubmittal is not required. Changes will be reviewed as part of Final iSWM Review.
2. If a stormwater facility is provided which qualifies for a Stormwater Fee Credit, the engineer must submit an application to the CFW along with supporting documentation which shows compliance with the Stormwater Credit Manual and iSWM standards for water quality treatment. The Stormwater Credit Manual is shown in Appendix F – Stormwater Utility Fee Credit Policy.
3. A Final Grading Permit and accepted Final iSWM Plan will be required prior to the issuance of a commercial building permit for a grading activity of 1.0 acre or more or smaller sites that are part of a larger common plan of development. See the Grading Permit Application (Form CFW-9) in Appendix A for submittal information. The Final Grading Permit will be required, even if an Early Grading Permit was obtained at an earlier stage.
4. Construction phase requirements shall comply with IPRC requirements.

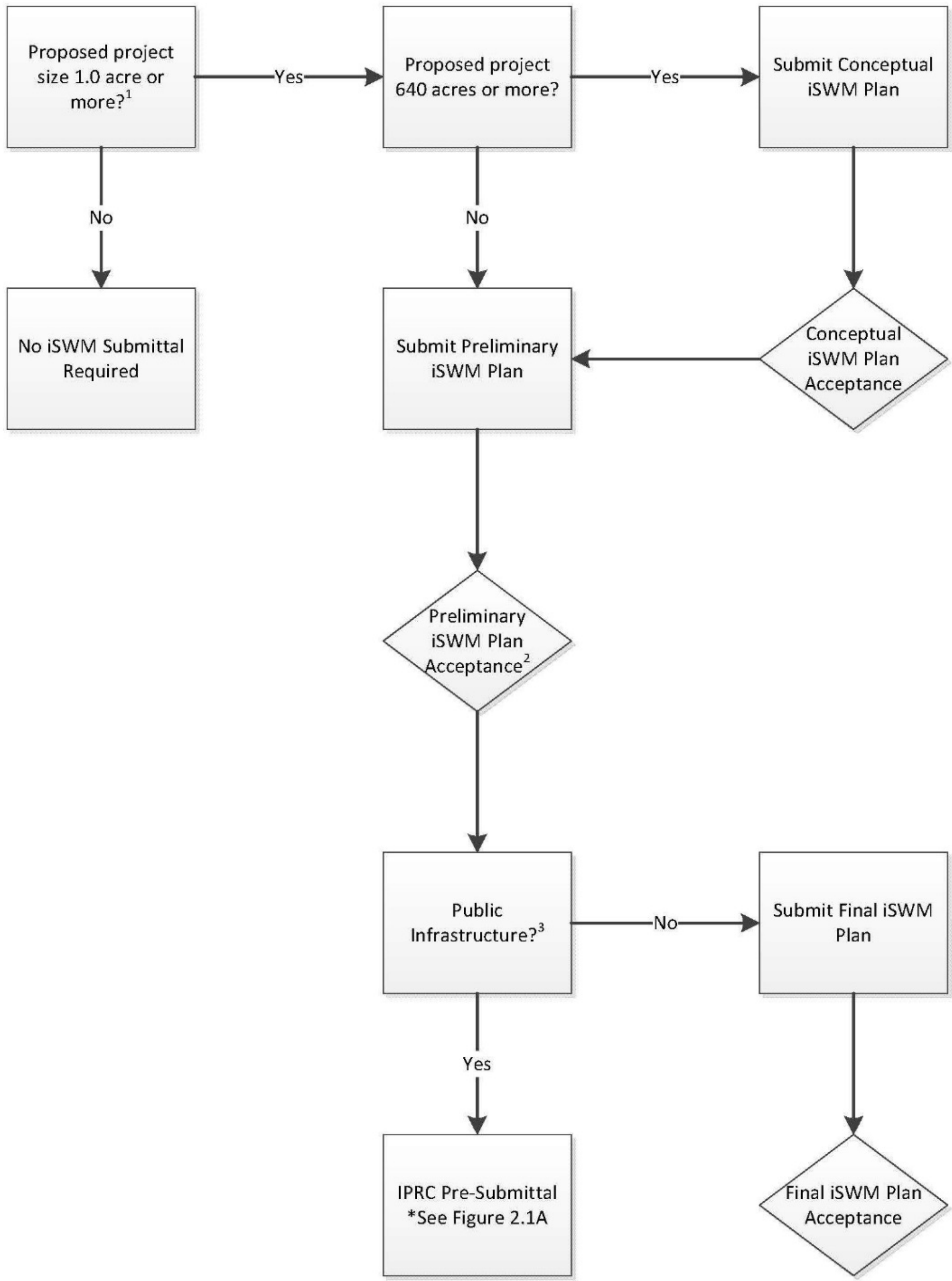
A Stormwater Facility Maintenance Agreement (SWFMA) is required for each stormwater control that will not be wholly maintained by the CFW. This agreement must outline both preventive maintenance tasks as well as major repairs, identify the schedule for each task, assign clear roles to effected parties, and provide a maintenance checklist to guide future owners including an annual self-inspection to be provided to the CFW. Please refer to the Stormwater Facility Maintenance Agreement Checklist provided in Appendix A, Form CFW – 8.

An Operations and Maintenance Plan shall be developed in accordance with CFW requirements and shall be included with the Final iSWM Plan. It should clearly state which entity has responsibility for operation and maintenance of temporary and permanent stormwater controls and drainage facilities to ensure they function properly from the time they are first installed.

The Operations and Maintenance Plan shall include but is not limited to:

- Responsible party for all tasks in the plan
- Inspection and maintenance requirements
- Maintenance of permanent stormwater controls and drainage facilities during construction
- Cleaning and repair of permanent stormwater controls and drainage facilities before transfer of ownership
- Frequency of inspections for the life of the permanent structures
- Description of maintenance tasks and frequency of maintenance
- Access and safety issues
- Maintenance easements
- Reviewed and accepted maintenance agreements

Guidance for development of Operation and Maintenance Plans has been provided with each temporary and permanent Best Management Practice (BMP) included in the *iSWM Construction Controls Technical Manual*.



Note: CFW SWM Goal = 10 business days per review and an average of no more than 3 review cycles per project.

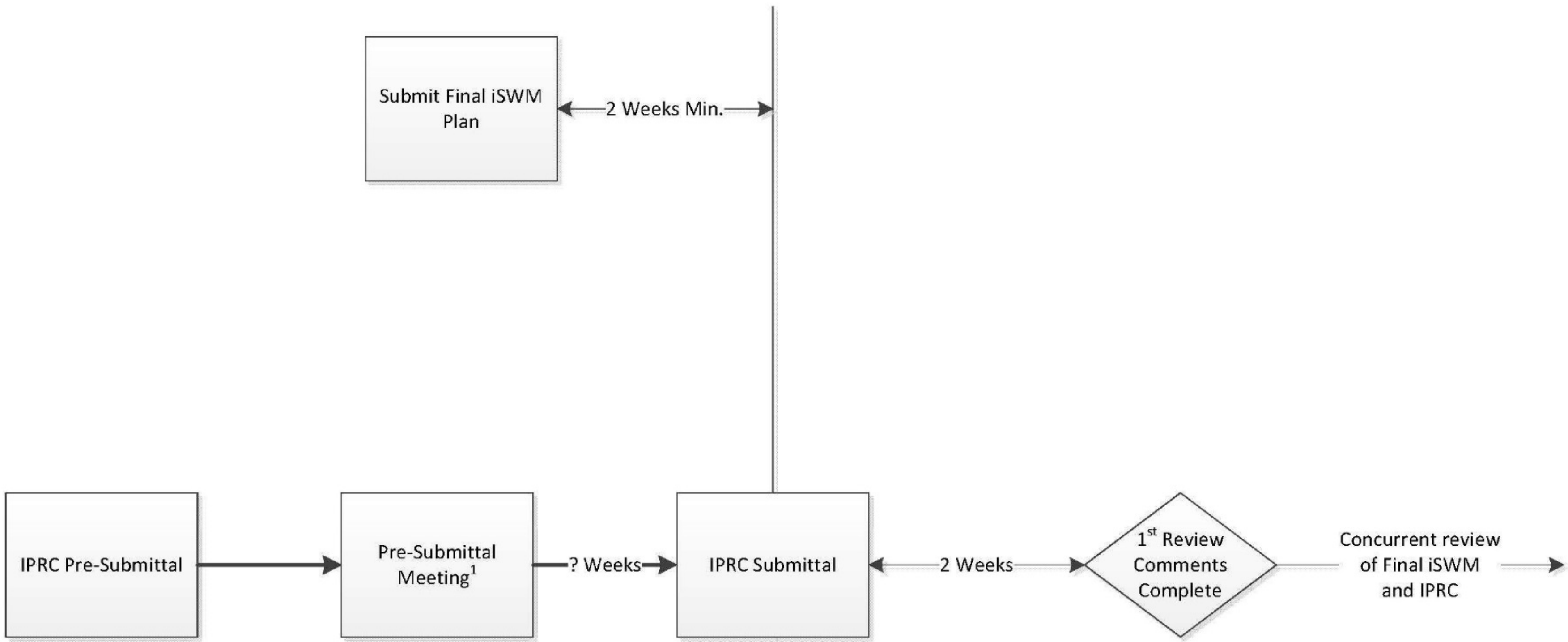
[1]Applicability is for land disturbing activity of 1.0 acre or more, or part of a larger common plan of development (See Table 1.1).

[2]Preliminary and Final iSWM plans may be submitted together.

[3]Improvements in the ROW with Stormwater Systems OPCC $20,000 or greater require a submittal to the IPRC.

Version Date: 09/29/2015

Figure 2.1 Stormwater Development Review Process - iSWM



[1]SWM Comments based on Preliminary iSWM and SWM PDC, if used.

Version Date: 09/29/2015

Figure 2.2 Stormwater Development Review Process - IPRC

3.0 Stormwater Design Criteria

This chapter presents an *integrated* approach for meeting stormwater runoff quality and quantity management goals by addressing the key adverse impacts of development on stormwater runoff. Its framework consists of three focus areas, each with options in terms of how the focus area is applied.

Design Focus Areas

The stormwater management focus areas and goals are:

- **Water Quality Protection**: Remove pollutants in stormwater runoff to protect water quality. Note: Water quality protection is encouraged but not mandatory in the CFW.
- **Streambank Protection**: Regulate discharge from the site to minimize downstream bank and channel erosion.
- **Flood Mitigation and Conveyance**: Control runoff within and from the site to minimize flood risk to people and properties for the conveyance storm as well as the flood mitigation storm.

Water quality design criteria are voluntary in Fort Worth. The controls may be used, however, to obtain Stormwater Fee Credits, in which case iSWM standards are applicable. Information on Stormwater Fee Credits is contained in Appendix F of this manual.

While water quality protection is encouraged but not required in the CFW, steps for water quality protection are beneficial to sustainable development and are recommended in the development process.

Each of the Design Focus Areas should be used in conjunction with the others to address the overall stormwater impacts from a development site. When used as a set, the Design Focus Areas are intended to control the entire range of hydrologic events, from the smallest runoff-producing rainfalls up to the 100-year, 24-hour storm.

3.1 Design Options

There are multiple options provided to meet the criteria for water quality protection, streambank protection, conveyance, and flood mitigation. These design options are summarized in Table 3.2 and described in additional detail in Chapter 3.7.2.

Design criteria for streambank protection and flood mitigation are primarily based on a downstream assessment. The purpose of the downstream assessment is to protect downstream properties and channels from increased flooding and erosion potential due to upstream development. A downstream assessment is required to determine the zone of influence and the extent of improvements necessary for streambank protection and flood mitigation. Downstream assessments shall be performed for streambank protection, conveyance, and flood mitigation storm events as described in Table 3.1, Table 3.3 and Chapter 3.7.3. Note that sites demonstrating no increase in impervious cover and sites proposing detention storage, with a total land disturbance of less than 5 acres and a contributing drainage area of less than 25 acres at outfall will not require a downstream assessment. In cases where detention is proposed to waive downstream assessment, detention volume must adequately address the increase in discharge due to the proposed development.

If calculations indicate that a development causes no adverse impacts to existing conditions, then it is possible that mitigation would not be required.

Table 3.1 Zone of Influence (Adequate Outfall) Determination		
Item	**Parameter**	**Requirements**
1	Habitable Structures	• No new or increased flooding (0.00 feet) of existing insurable (FEMA) structures (habitable buildings).
2	Flood Elevations	• No increase greater than 0.1 feet in 1-, 5-, and 100-year flood elevations over existing roadways. No increase greater than 0.1 feet and 100-year flood elevations, unless contained in existing channel, roadway, drainage easement and/or R.O.W.
3	Floodplain Ordinance	• Where provisions of the City's floodplain ordinance may be more restrictive, the floodplain ordinance shall have authority over the above provisions.
4	Channel Velocities	• Proposed channel velocities for 1-, 5-, and 100-year storms cannot exceed the applicable maximum permissible velocity shown in Table 3.16 and Table 3.17 of this manual. Exceptions to these criteria will require certified geotechnical /geomorphologic studies that provide documentation that the higher velocities will not create additional erosion. • If existing channel velocities exceed maximum permissible velocities shown in Table 3.16 and Table 3.17, no more than a 5% increase in velocities will be allowed.
5	Downstream Discharges	• No increase in downstream discharges caused by the proposed development that, in combination with existing discharges, exceeds the existing capacity of the downstream storm drainage system or existing right-of-way.
6	Downstream Assessment	• For 1-5 acre sites with proposed detention and draining a watershed less than or equal to 25 acres, a downstream assessment is not required. The detention volume must adequately address the increase in discharge due to the proposed development. • For watersheds of one hundred (100 ac) acres or less at any proposed outfall, the downstream assessment may use the 10% rule of thumb (as delineated in *Section 2.4 of the Hydrology Technical Manual*) or a detailed study in order to determine the zone of influence. • For all other watersheds, the zone of influence will be defined by a detailed hydrologic and hydraulic analysis. • A downstream assessment exemption may be acquired for small infill developments which meet the specific criteria outlined in Chapter 3.7.2.

**Section 2.0 of the Hydrology Technical Manual* gives additional guidance on calculation discharges and velocities, as well as determining the downstream extent of the assessment.

Table 3.2 Summary of Options for Design Focus Areas			
Design Focus Area	**Reference Chapter**	**Required Downstream Assessment**	**Design Options**
Water Quality Protection (Not currently required by the CFW) Please note, water quality protection may be required by TRWD or other agencies.	3.5	No	**Option 1:** Use *integrated* Site Design Practices for conserving natural features, reducing impervious cover, and using the natural drainage systems
			Option 2: Treat the Water Quality Protection Volume (WQ_V) by reducing total suspended solids from the development site for runoff resulting from rainfalls of up to 1.5 inches (85^{th} percentile storm)
			Option 3: Assist in implementing off-site community stormwater pollution prevention programs/activities as designated in an accepted stormwater master plan or TPDES Stormwater permit
Streambank Protection	3.6	Yes	**Option 1:** Reinforce/stabilize downstream conditions
			Option 2: Install stormwater controls to maintain or improve existing downstream conditions
			Option 3: Provide on-site controlled release of the 1-year, 24-hour storm event over a period of 24 hours (Streambank Protection Volume, SP_V)
Flood Mitigation and Conveyance	3.7 and 3.8	Yes/No	**Flood Mitigation (3.7)** **Option 1:** Provide adequate downstream conveyance systems (Requires a downstream assessment or application of the Simplified Finding of No Significant Impact as presented in Chapter 3.7.2)
			Option 2: Install stormwater controls on-site to maintain or improve existing downstream conditions. A downstream assessment is waived for on-site controls in the form of detention when proposed site has less than 5 acres of land disturbance and is draining less than 25 acres at the outlet of the basin. Detention must completely mitigate the increase in peak discharge due to proposed development. Simplified detention volume estimation presented in Chapter 3.7.2 may be used for Preliminary iSWM only.
			Option 3: In lieu of a downstream assessment, mimic existing on-site runoff conditions (Does not require a downstream assessment)
			Option 4: When downstream impacts are limited to a single adjacent property, the developer may obtain a notarized letter of permission from the affected property owner acknowledging the impacts from the subjected property in lieu of mitigation.
			Conveyance (3.8) Minimize localized site flooding of streets, sidewalks, and properties by a combination of on-site stormwater controls and conveyance systems

3.2 Design Storms

The CFW requires the following storm events to be used in the *integrated* stormwater design.

Table 3.3 Storm Events

Storm Event Name	Storm Event Description	Design Standard[2]
"Water Quality"[1]	Criteria based on a volume of 1.5 inches of rainfall, not a storm frequency	
"Streambank Protection"	1-year return period	• Low flow channels and velocity check
"Conveyance"	5-year return period	• Secondary check for street inundation and open travel lanes
"Flood Mitigation"	100-year return period	• Open channels • Primary standard for street and storm drain in conjunction

[1]Currently encouraged but not required in the CFW

[2]See Chapter 3.8 for specific design criteria

Throughout the manual the storms will be primarily referred to by their storm event names.

3.3 Design Criteria

The Design guidelines for the CFW are:

1. All development within the CFW City Limits or its Extra-territorial Jurisdiction (ETJ) shall include planning, design, and construction of storm drainage systems in accordance with this Stormwater Criteria Manual, Plan Commission Rules and Regulations, and Policy for the Installation of Community Facilities. Please see definition of development and project size limitations for specific design requirements under "Abbreviations and Definitions" in Chapter 1.2.
2. All drainage related plans and studies shall be prepared and sealed by a Licensed Professional Engineer with a valid license and a valid registered Firm number from the State of Texas. The engineer shall attest that the design was conducted in accordance with this Criteria Manual.
3. For currently developed areas within the CFW with planned re-development, stormwater discharges and velocities from the project should not exceed discharges and velocities from the existing developed conditions. Alternatively, a notarized letter of permission may be obtained from the affected property owner, acknowledging the proposed impact, as shown in Table 3.2, Option 4 under Flood Mitigation.
4. All drainage analyses and design plans shall be formulated and based upon fully developed watershed or drainage area runoff conditions from the upstream area. In certain circumstances where detention is in place with a valid SWFMA or a master plan has been adopted, a development may plan to receive less than fully developed flow from upstream with the approval of TPW. The rainfall frequency criteria for stormwater facilities, as enumerated within this Criteria Manual, shall be utilized for all drainage studies and design plans.
5. Stormwater must be carried to an "adequate or acceptable outfall". An adequate outfall is one that does not create or increase flooding or erosion conditions downstream and is in all cases subject to the approval of the TPW. See additional clarification in Table 3.1 and Chapter 3.7.3.
6. Proposed stormwater discharge rates and velocities from a development shall not exceed the rates and velocities from existing conditions, unless a detailed study is prepared that demonstrates that no adverse impacts will be created, as defined in Table 3.1 and Chapter 3.7.3.

7. If a proposed development drains into an improved channel or stormwater drainage system designed under a previous CFW drainage policy (Prior to 2006), then the hydraulic capacities of downstream facilities must be checked to verify that increased flows, caused by the new development, will not exceed the capacity of the existing system or cause increased downstream structure flooding. If there is not sufficient capacity to prevent exceedance of existing rights of way or increased downstream flooding, then detention or other acceptable measures must be adopted to accommodate the increase in runoff due to the proposed development. For projects which have an accepted drainage study and/or iSWM plan, including phased developments which have some existing constructed phases after the adoption of the iSWM criteria in June 2006, findings in accepted studies will remain valid.
8. Stormwater runoff may be stored in detention and retention basins to mitigate potential downstream impacts 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 City's overall Stormwater Management Master Plan for that watershed (if available). Storage of stormwater runoff, near to the 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. When detention is used to attenuate peak discharge from a proposed development, runoff must be controlled for the applicable storms listed in Table 3.3 so that detained proposed peak discharges do not adversely impact downstream flooding and stream bank conditions, as described in Design Guidelines 5 and 6, above. Where detention is used to completely offset the impact of the development, the proposed site is 5.0 acres or less and the contributing basin has a drainage area less than 25 acres at outlet, a downstream assessment may be waived.
10. Alternatives to detention or retention, for mitigation of potential downstream impacts caused by proposed development, include: acquisition of expanded drainage easements, ROW, or letter of consent; downstream channel and/or roadway drainage system improvements or stream bank erosion protection; and financial contributions to the CFW Stormwater Program for previously identified future improvements (not presently an active program for CFW). These alternatives will be considered, as presented by the developer, by the Director of the Transportation and Public Works Department, on a case-by-case basis.
11. Stream bank stabilization and protection features to reduce or prevent erosion and sedimentation for creeks, streams, and channels shall be required, as specified in this Manual, and to ensure the intent of Design Guidelines 5 and 6, above.
12. All proposed developments within the CFW City Limits or Extra-territorial Jurisdiction (ETJ) shall comply with all local, county, state and federal regulations and all required permits or approvals shall be obtained by the developer.
13. The policy of the CFW is to avoid substantial or significant transfer of stormwater drainage runoff from one basin to another and to maintain historical drainage paths whenever possible. However, the transfer of stormwater drainage from basin to basin may be necessary in certain instances and will be reviewed and a variance shall be requested from the TPW using Form CFW-7 in Appendix A – City of Fort Worth Detailed Checklists and Forms.

3.4 Hydrologic Design Criteria

3.4.1 *Types of Hydrologic Methods*

There are a number of empirical hydrologic methods available to estimate runoff characteristics for a site or drainage sub basin. However, the following methods have been selected to support hydrologic site analysis for the design methods and procedures included in this manual:

- Rational and Modified Rational Method
- SCS Unit Hydrograph Method
- Snyder's Unit Hydrograph Method
- USGS & TXDOT Regression Equations
- iSWM Water Quality Protection Volume Calculation
- Water Balance Calculations

Table 3.4 provides the CFW limitations on the use of several accepted hydrologic methods.

Table 3.4 City of Fort Worth 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[1,2, 3]	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] Note: Calculations previously accepted by CFW using "C" coefficients from the 2006 manual shall be considered acceptable.
[2] MRM Methodology shall be as defined in Section 1.5.2 of the iSWM Hydrology Technical Manual.
[3] A City provided Modified Rational Method tool is available and its use is encouraged. Please contact SDS staff at SDS@fortworthtexas.gov.

- CFW requires that the "C" coefficients presented in Table 3.5 be used in all Rational and modified Rational Method computations. It should be noted that calculations previously accepted by the CFW using "C" coefficients from the 2006 Manual shall be considered acceptable, as described in Chapter 1.3. Where existing land use does not correspond to Table 3.5, a composite "C" value may be calculated using 0.9 for impervious areas and 0.3 for pervious areas.
- Rainfall distribution for the SCS Unit Hydrograph shall be based on the Frequency Rainfall Data provided in *Section 5.0 of the Hydrology Technical Manual* centered at the midpoint of the rainstorm (12th hour of a 24-hour storm) unless otherwise accepted by the TPW.
- The percent impervious values presented in Table 3.5 shall be used in the SCS Unit Hydrograph calculations.

- The "Frequency Factors" referenced in *Section 1.2.3 of the Hydrology Technical Manual* are not required by the CFW.

- Figure 3.1 presents a sample computation summary sheet for the presentation of unit hydrograph method results. This form should be completed even if the computations are performed on an acceptable computer program such as HEC-1 or HEC-HMS. Refer to Appendix B for acceptable modeling programs.
- An alternative method to determine Snyder's Lag is to determine the time of concentration (travel time) by the methodology described in *Section 1.3.6 of the Hydrology Technical Manual* and multiply this time of concentration by 0.6.
- The TxDOT and USGS Regression methods should only be used for comparison of the reasonableness of other accepted determinations, not for final results or design unless specifically accepted by TPW.
- iSWM Water Quality Protection Volume (WQv) calculation method is not currently required by CFW.
- Fully Developed Conditions – For watershed hydrology, fully developed conditions include:
    - All existing developed areas shall reflect current land use or current zoning, whichever yields the greatest runoff.
    - All existing undeveloped areas shall reflect anticipated future land use designated by zoning classification, by the City's Comprehensive Plan, or by an accepted concept plan.
- If the anticipated offsite future development is unknown (not zoned or included in a comprehensive plan or other land plan), a minimum weighted runoff coefficient of 0.75 or equivalent SCS Curve Number with 75% impervious cover shall be used.

Table 3.5 presents the Rational Method Runoff "C" Coefficients for the CFW. The basis of these coefficients is the standard zoning classification used by the City ("A-43, "A-21", etc.) An example of the determination of these coefficients is presented in

- Figure 3.2.

Table 3.5 Runoff Coefficients

Description of Land Use	**% Impervious**	**Runoff Coefficient "C"**
Residential "A-43" one-acre lots (1) (2)	35	0.51
Residential "A-21" half-acre lots	37	0.52
Residential "A-10" 10,000 SF lots	49	0.59
Residential "A-7.5" (3)	55	0.63
Residential "A-5" (3)	61	0.67
Residential "MH", "A-R", "B", "R-1", & "R-2" (3)	65	0.69
Multi-family		
“CR”	64	0.69
“C”	79	0.77
“D”	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
Railroad Yard Areas	29	0.47
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

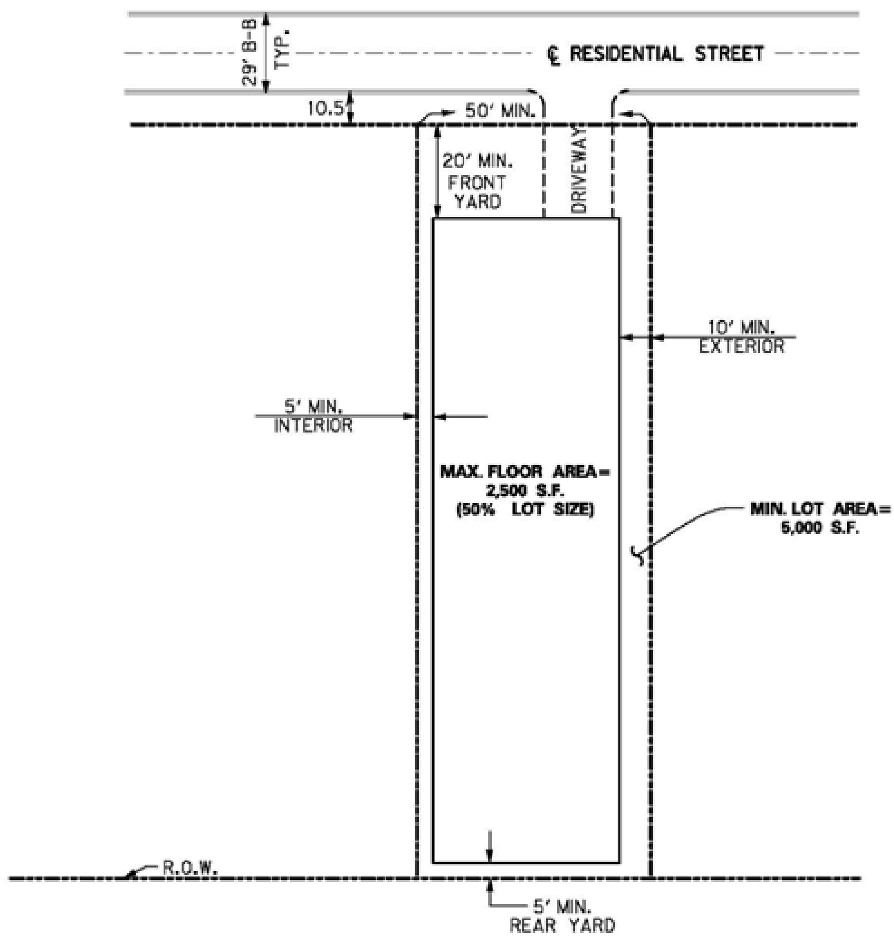
Assumptions:

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

(2) Calculated from designated set-backs

BY: DATE:	LOSS RATE METHOD		COMPUTATION SUMMARY SHEET								SHEET 1 OF 1 SUBWATERSHED
CK'D: DATE:	STREAM ROUTING		HYDROLOGY BY UNIT HYDROGRAPH METHOD								MAJOR WATERSHED JOB/FILE NO.:
ANALYSIS POINT	**SUBWATERSHED 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)**	Q_1	Q_5	Q_{100}		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**11**		**12**
REMARKS, SKETCHES AND COMPUTATIONS											

Figure 3.1 Computation Summary Sheet for Hydrology by Unit Hydrograph Method



APPROX. USE OF LOT

AREA = 5,000 S.F. + R.O.W. (25'x50')

= 6,250 S.F. MAX.

C	USE	A	MAX. CA
0.9	STREET (14.5x150)	725	652.5
0.9	DRIVEWAY AND SIDEWALK	677	609.3
0.9	ROOF	2,500	2,250.0
0.3	LANDSCAPE AREA	2,348	704.4
	TOTAL CA		4,216.2
	CALC. C=CA/A		0.67

APPROXIMATION OF RUNOFF COEFFICIENT

C=0.67

Figure 3.2 Sample Calculation Sheet for Runoff Coefficient "C"

3.4.2 *Rainfall Estimation*

Rainfall intensities are provided in *Section 5.0 of the Hydrology Technical Manual* for the sixteen (16) counties within the North Central Texas Council of Governments. The intensities are based on a combination of data from Hydro-35 and USGS. These intensities shall be used for all hydrologic analysis within the applicable county.

3.5 Water Quality Protection

3.5.1 *Introduction*

iSWM requires the use of *integrated* Site Design Practices as the primary means to protect the water quality of our streams, lakes, and rivers from the negative impacts of stormwater runoff from development. The *integrated* Site Design Practices shall be designed as part of the iSWM Plans. In addition to the *integrated* Site Design Practices, required water quality protection can be achieved by two additional options: (1) by treating the water quality protection volume and (2) assisting with off-site pollution prevention activities. These three approaches are described below.

The CFW has currently opted to implement the streambank protection and flood mitigation and conveyance goals, but not the water quality protection component. The CFW does not require water quality protection for development but strongly encourages this to be done. The CFW provides a stormwater fee credit (reduction) as an incentive for voluntary compliance with this component of stormwater management. See Appendix F for more information regarding fee credits.

3.5.2 *Option 1: integrated Site Design Practices and Credits*

The *integrated* Site Design Practices are methods of development that reduce the “environmental footprint” of a site. They feature conservation of natural features, reduced imperviousness, and the use of the natural drainage system. In this option, points are awarded for the use of different Site Design Practices. A minimum number of points are needed to meet the iSWM requirements for Water Quality. Additional points can be gained to qualify for development incentives. See Appendix F for additional details.

List of *integrated* Site Design Practices and Techniques

Twenty *integrated* Site Design Practices are grouped into four categories listed below. Not all practices are applicable to every site.

- Conservation of Natural Features and Resources
    1. Preserve Undisturbed Natural Areas
    2. Preserve Riparian Buffers
    3. Avoid Floodplains
    4. Avoid Steep Slopes
    5. Minimize Siting on Porous or Erodible Soils
- Lower Impact Site Design Techniques
    1. Fit Design to the Terrain
    2. Locate Development in Less Sensitive Areas
    3. Reduce Limits of Clearing and Grading
    4. Utilize Open Space Development
    5. Consider Creative Designs
- Reduction of Impervious Cover
    1. Reduce Roadway Lengths and Widths

2. Reduce Building Footprints
3. Reduce the Parking Footprint
4. Reduce Setbacks and Frontages
5. Use Fewer or Alternative Cul-de-Sacs
6. Create Parking Lot Stormwater "Islands"

- Utilization of Natural Features for Stormwater Management

1. Use Buffers and Undisturbed Areas
2. Use Natural Drainageways Instead of Storm Sewers
3. Use Vegetated Swale Instead of Curb and Gutter
4. Drain Rooftop Runoff to Pervious Areas

More detail on each site design practice is provided in the *integrated* Site Design Practice Summary Sheets in *Section 2.2 of the Planning Technical Manual*.

Integration of Site Design Practices into Site Development Process

During the site planning process described in Chapter 2.3, Step 1, there are several steps involved in site layout and design, each more clearly defining the location and function of the various components of the stormwater management system. To be more effective and easier to incorporate, *integrated* Site Design Practices should be part of this overall development process as outlined in Table 3.6.

Table 3.6 Integration of Site Design Practices with Site Development Process

Site Development Phase	Site Design Practice Activity
Site Analysis	• Identify and delineate natural feature conservation areas (natural areas and stream buffers) • Perform site reconnaissance to identify potential areas for and types of credits • Determine stormwater management requirements
Conceptual Plan	• Preserve natural areas and stream buffers during site layout • Reduce impervious surface area through various techniques • Identify locations for use of vegetated channels and groundwater recharge • Look for areas to disconnect impervious surfaces • Document the use of site design practices
Preliminary and Final Plan	• Perform layout and design of credit areas – integrating them into treatment trains • Ensure *integrated* Focus Areas are satisfied • Ensure appropriate documentation of site design credits according to local requirements

Table 3.6 Integration of Site Design Practices with Site Development Process	
Site Development Phase	**Site Design Practice Activity**
Construction	• Ensure protection of key areas • Ensure correct final construction of areas needed for credits • Inspect and maintain implementation of BMPs during construction
Final Inspection	• Develop maintenance requirements and documents • Ensure long term protection and maintenance • Ensure credit areas are identified on final plan and plat if applicable

3.5.3 *Option 2: Treat the Water Quality Protection Volume*

Treat the Water Quality Protection Volume by reducing total suspended solids from the development site for runoff resulting from rainfall of 1.5 inches (85th percentile storm). Stormwater runoff equal to the Water Quality Protection Volume generated from sites may be treated using a variety of on-site structural and nonstructural techniques with the goal of removing a target percentage of the average annual total suspended solids.

A system has been developed by which the Water Quality Protection Volume can be reduced, thus requiring less structural control. This is accomplished through the use of certain reduction methods, where affected areas are deducted from the site area, thereby reducing the amount of runoff to be treated. For more information on the Water Quality Volume Reduction Methods see *Section 1.3 of the Water Quality Technical Manual*.

Water Quality Protection Volume

The Water Quality Protection Volume (WQ_v) is the runoff from the first 1.5 inches of rainfall. Thus, a stormwater management system designed for the WQ_v will treat the runoff from all storm events of 1.5 inches or less, as well as a portion of the runoff for all larger storm events. For methods to determine the WQ_v, see *Section 1.3 of the Water Quality Technical Manual.*

Water Quality requirements are encouraged but not required by the CFW. Information is included for reference if the developer chooses to pursue such alternatives.

Recommended Stormwater Control Practices

Below is a list of recommended structural stormwater control practices. While these stormwater control practices are not mandatory in the CFW, they are highly recommended for sustainable development. This information is provided for reference if the developer chooses to pursue such an option. These structural controls are recommended for use in a wide variety of applications and have differing abilities to remove various kinds of pollutants. It may take more than one control to achieve a certain pollution reduction level. A detailed discussion of each of the controls, as well as design criteria and procedures, can be found in the *Site Development Controls Technical Manual.* Refer to Table 3.7 for details regarding primary and secondary controls.

- Bioretention
- Enhanced swales (dry, wet, wetland)
- Alum treatment
- Detention
- Filter strips
- Sand filters, filter boxes, etc.
- Infiltration wells and trenches
- Ponds
- Porous surfaces
- Proprietary systems
- Green roofs
- Rainwater harvesting
- Wetlands
- Submerged gravel wetlands

Using Other or New Structural Stormwater Controls

Innovative technologies are encouraged and will be reviewed for applicability. Any such system will be required to provide sufficient documentation as to its effectiveness and reliability. Third party proof of performance, maintenance, application requirements, and limitations will be required prior to approval of innovative new technology.

More specifically, new structural stormwater control designs will not be accepted until independent performance data shows that the structural control conforms to local and/or state criteria for treatment, conveyance, maintenance, and environmental impact.

Suitability of Stormwater Controls to Meet Stormwater Management Goals

The stormwater control practices recommended in this manual vary in their applicability and ability to meet stormwater management goals:

Primary Controls

Primary structural stormwater controls have the ability to fully address one or more of the steps in the *integrated* focus areas if designed appropriately. Structural controls are recommended for use with a wide variety of land uses and development types. These structural controls have a demonstrated ability to effectively treat the Water Quality Volume (WQv) and have been shown to be able to remove 70% to 80% of the annual average total suspended solids (TSS) load in typical proposed urban runoff when designed, constructed, and maintained in accordance with recommended specifications. Several of these structural controls can also be designed to provide primary control for downstream streambank protection (SPv) and flood mitigation. These structural controls are recommended stormwater management facilities for a site wherever feasible and practical.

Secondary Controls

A number of structural controls are recommended only for limited use or for special site or design conditions. Generally, these practices either: (1) do not have the ability on their own to fully address one or more of the Steps in the *integrated* Focus Areas, (2) are intended to address hotspot or specific land use constraints or conditions, and/or (3) may have high or special maintenance requirements that may preclude their use. These types of structural controls are typically used for water quality treatment only. Some of these controls can be used as pretreatment measures or in series with other structural controls to meet pollutant removal goals. Such structural controls are not recommended for residential developments.

Table 3.7 summarizes the stormwater management suitability of the various stormwater controls in addressing the *integrated* Focus Areas. The *Site Development Controls Technical Manual* provides guidance on the use of stormwater controls as well as how to calculate the pollutant removal efficiency for stormwater controls in series. The *Site Development Controls Technical Manual* also provides guidance for choosing the appropriate stormwater control(s) for a site as well as the basic considerations and limitations on the use of a particular stormwater control.

Table 3.7 Suitability of Stormwater Controls to Meet *integrated* Focus Areas

Category	*integrated* Stormwater Controls	TSS/ Sediment Removal Rate	Water Quality Protection	Streambank Protection	On-Site Flood Control	Downstream Flood Control
Bioretention Areas	Bioretention Areas	80%	P	S	S	-
Channels	Enhanced Swales	80%	P	S	S	S
	Channels, Grass	50%	S	S	P	S
	Channels, Open	-	-	-	P	S
Chemical Treatment	Alum Treatment System	90%	P	-	-	-
Conveyance System Components	Culverts	-	-	-	P	P
	Energy Dissipation	-	-	P	S	S
	Inlets/Street Gutters	-	-	-	P	-
	Pipe Systems	-	-	P	P	P
Detention	Detention, Dry	65%	S	P	P	P
	Detention, Extended Dry	65%	S	P	P	P
	Detention, Multi-purpose Areas	-	-	P	P	P
	Detention, Underground	-	-	P	P	P
Filtration	Filter Strips	50%	S	-	-	-
	Organic Filters	80%	P	-	-	-
	Planter Boxes	80%	P	-	-	-
	Sand Filters, Surface/Perimeter	80%	P	S	-	-
	Sand Filters, Underground	80%	P	-	-	-
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	40%	S	-	-	-
Infiltration	Downspout Drywell	80%	P	-	-	-
	Infiltration Trenches	80%	P	S	-	-
	Soakage Trenches	80%	P	S	-	-
Ponds	Wet Pond	80%	P	P	P	P
	Wet ED Pond	80%	P	P	P	P
	Micropool ED Pond	80%	P	P	P	P
	Multiple Ponds	80%	P	P	P	P
Porous Surfaces	Green Roof	85%	P	S	-	-
	Modular Porous Paver Systems	[2]	S	S	-	-
	Porous Concrete	[2]	S	S	-	-
Proprietary Systems	Proprietary Systems[1]	[1]	S/P	S	S	S
Re-Use	Rain Barrels	-	P	-	-	-
Wetlands	Wetlands, Stormwater	80%	P	P	P	P
	Wetlands, Submerged Gravel	80%	P	P	S	-

P = Primary Control: Able to meet design criterion if properly designed, constructed and maintained.
S = Secondary Control: May partially meet design criteria. Designated as a Secondary control due to considerations such as maintenance concerns. For Water Quality Protection, recommended for limited use in accepted community-designated areas.
\- = Not typically used or able to meet design criterion.
[1] = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data, if used as a primary control. Third-party sources could include Technology Acceptance Reciprocity Partnership, Technology Assessment Protocol – Ecology, or others.
[2] = Porous surfaces provide water quality benefits by reducing the effective impervious area.

3.5.4 *Option 3: Assist with Off-Site Pollution Prevention Programs and Activities*

The CFW does not currently require off-site pollution prevention activities; however, some communities have implemented pollution prevention programs/activities in certain areas to remove pollutants from the runoff after it has been discharged from the site. This may be especially true in intensely urbanized areas facing site redevelopment where many of the BMP criteria would be difficult to apply.

3.6 Streambank Protection

The second focus area is in streambank protection. There are three options by which a developer can provide adequate streambank protection downstream of a proposed development. The first step is to perform the required downstream assessment as described in Table 3.1, Table 3.2 and Chapter 3.7.3. If it is determined that the proposed project does not exceed acceptable downstream velocities or the downstream conditions are improved to adequately handle the increased velocity through the limits of the zone of influence, then no additional streambank protection is required. If on-site or downstream improvements are required for streambank protection, easements or letters of consent will need to be obtained in accordance with Chapter 3.11. If the downstream assessment shows that the velocities are within acceptable limits, then no streambank protection is required. Acceptable limits for velocity control are contained in Table 3.16 and Table 3.17.

Option 1: Reinforce/Stabilize Downstream Conditions

If the increased velocities are greater than the allowable velocity of the downstream receiving system, then the developer must reinforce/stabilize the downstream conveyance system. The proposed modifications must be designed so that the downstream system is protected from the proposed velocities. The developer must provide supporting calculations and/or documentation that the downstream velocities do not exceed the allowable range once the downstream modifications are installed.

Allowable bank protection methods include stone riprap and bio-engineered methods. Chapter 3.8.4 of this manual and *Sections 3.2 and 4.0 of the Hydraulics Technical Manual* give design guidance for designing stone riprap for open channels, culvert outfall protection, riprap aprons for erosion protection at outfalls, and riprap basins for energy dissipation.

Option 2: Install Stormwater Controls to Maintain Existing Downstream Conditions

The developer may use on-site controls to keep downstream proposed discharges at or below allowable velocity limits. The developer must provide supporting calculations and/or documentation that the on-site controls will be designed such that downstream velocities for the three storm events (Streambank Protection, Conveyance, and Flood Mitigation) are within an allowable range once the controls are installed.

Option 3: Control the Release of the 1-yr, 24-hour Storm Event

Twenty-four hours of extended detention may be provided for on-site, post-developed runoff generated by the 1-year, 24-hour rainfall event to protect downstream channels. The required volume for extended detention is referred to as the Streambank Protection Volume (denoted SP_v). The reduction in the frequency and duration of bankfull flows through the controlled release provided by extended detention of the SP_v will reduce the bank scour rate and severity.

To determine the SP_v refer to Chapter 3.0 of the Hydrology Technical Manual.

It should be noted that a 10% stormwater fee credit is available as an incentive for using this option. See Appendix F for more information.

3.7 Flood Mitigation

3.7.1 *Introduction*

Flood analysis is based on the design storm events as defined in Chapter 3.2, Table 3.3 for the conveyance storm and the flood mitigation storm.

The intent of the flood mitigation criteria is to provide for public safety; to minimize on-site and downstream flood impacts from the three storm events; to maintain the boundaries of the mapped 100-year floodplain; and to protect the physical integrity of the on-site stormwater controls and the downstream stormwater and flood mitigation facilities.

Flood mitigation must be provided for on-site conveyance systems, as well as downstream outfalls as described in the following chapters.

3.7.2 *Flood Mitigation Design Options*

There are four options by which a developer may address downstream flood mitigation. These options closely follow the four options for Streambank Protection. When on-site or downstream modifications are required for downstream flood mitigation, easements or letters of consent will need to be obtained in accordance with Chapter 3.11.

The developer will provide all supporting calculations and/or documentation to show that the existing downstream conveyance system has capacity (Q_f) to safely pass the fully developed flood mitigation storm discharge, including any increase due to the proposed development, or demonstrate no adverse impact.

Flood mitigation criteria are intended to protect public safety by ensuring minimal upstream, on-site and downstream flood impacts. Table 3.2 of this Criteria Manual provides four options for Flood Mitigation in the CFW:

1. Option 1 – Confirm Adequate Downstream Conveyance Systems (Downstream Assessment)
2. Option 2 – Provide On-Site Stormwater Controls (Detention)
3. Option 3 – Mimic Existing On-Site Runoff Conditions (Low Impact Design)
4. Option 4 – Obtain letter from impacted downstream property owner (limited to impacts on one single adjacent property).

Option 1 – Provide Adequate Downstream Conveyance Systems

Provide calculations for analysis of the downstream conveyance system to confirm adequate capacity is available to convey the increased runoff, due to development, within a drainage structure, easement, or right-of-way. This downstream assessment can include any available existing conveyances systems (existing drainage pipes, channels, natural creeks and streams, easements or right-of-ways specified for drainage use). If the existing drainage systems do not have capacity to convey the increased runoff from the development, additional stormwater controls will be necessary to safely discharge runoff without:

1. Causing new or increased flooding upstream of the development
2. Causing new or increased flooding on the development site
3. Causing new or increased flooding downstream of the development

The developer may provide additional conveyance by providing and/or modifying the off-site, downstream conveyance system through construction of additional drainage capacity or acquisition of drainage easements to contain impacts. The design and analysis of such systems will be required to show that the proposed systems safely convey the required design storm events. Systems are required to be analyzed to an adequate outfall, (i.e. a downstream assessment is required) as defined in Table 3.1 and Chapter 3.7.3.

If the downstream assessment shows that all above runoff conditions have been met as defined in Table 3.1 and Chapter 3.7.3 of this manual, no on-site drainage controls are required to mitigate for increased runoff from the site due to the proposed development.

Simplified Finding of No Significant Impact

For small infill developments that meet specific criteria below, the downstream assessment may be waived. This policy was developed based on an analysis by Dr. Cuneyt Erbatur, P.E., CFM, LEED AP, of Dunaway Associates.

Requirements:

1. The proposed development is less than 5 acres of disturbed land.
2. The site developed drains directly to an existing roadway and does not redirect drainage area from one street or watershed to another.
3. The receiving roadway has a longitudinal slope of at least 1%.
4. The site area is less than 10% of the existing offsite area drainage to the same receiving roadway.
5. The existing offsite area (excluding the site to be developed) has a rational C value of at least 0.6.

Submittal of calculations to confirm these conditions will be required at the time of Preliminary iSWM submittal. Once reviewed and accepted by the CFW SDS the site development can be considered as having no significant impact and no mitigation is required.

Option 2 – Provide On-Site Stormwater Controls (Detention)

In the event that downstream conveyance systems, including receiving streams, do not have sufficient capacity, on-site stormwater controls may be proposed to mitigate the impact of increased discharges from the site to a level that meets the requirements of Table 3.1 and Chapter 3.7.3.

Downstream assessment may be waived for either of the following conditions:

1. Sites proposing detention storage with a contributing drainage area of less than 25 acres at detention outfall, and
2. Sites proposing detention when the total site disturbance is less than 5.0 acres.

In cases where detention is proposed to waive downstream assessment, detention volume must adequately address the increase in discharge due to the proposed development.

Simplified Detention Volume Estimation

At the preliminary plat stage, a conservative detention volume estimate from the table below may be used in lieu of more detailed detention hydrologic calculations. Table 3.8 below may only be used for sites that do not redirect drainage area from one watershed to another. Please note that the final iSWM submittal will still require detailed drainage and design calculations. The table below may be used in lieu of detailed drainage calculations at the preliminary plat and preliminary iSWM plan stage only.

Table 3.8 Simplified Detention Volume

Development Area	Detention Volume Required*
0-25 acres	0.20 acre-feet per acre
More than 25 acres	0.25 acre-feet per acre

*If no calculations are submitted

If this detention estimate is used in lieu of a downstream assessment, the preliminary plat must show the volumes graphically in the approximate location and at the approximate size. In addition, the plat shall include the following text: “This plat identifies preliminary need and locations for storm water storage facilities known as detention ponds. It is expressly understood and agreed by the owner or owner’s designee of any specific lot or tract within the platted subdivision that the owner or owner’s designee of lots or tracts shall be responsible to provide for the final detention volume mitigation during the site development. The preliminary detention storage volume estimate is noted at each location. The final detailed analysis detention volume and required easement may be more or less than shown on this plat.

The detention pond design shall be in accordance with the City of Fort Worth Stormwater Criteria Manual current at the time the Final iSWM Plan is submitted.

Option 3 – Mimic Existing On-Site Runoff Conditions

A downstream assessment is not required. This option only requires that on-site improvements are provided to maintain/mimic existing discharges. This option requires reduced percent imperviousness using *integrated* Site Design practices to mimic the existing runoff conditions (discharge and velocity). No downstream assessment is required in this option, however, it should be noted that a downstream assessment may reduce the amount of on-site detention required. Calculations shall be submitted to substantiate the proposed discharges.

Stormwater controls include the various types of structural and non-structural controls as described in this manual (Chapter 3) and listed below.

1. Stormwater Facilities
2. *Integrated* Site Design Practices
3. Regional Approaches
4. Erosion Control BMPs

Option 4 – Obtain Letter From Impacted Downstream Property Owner

When downstream impacts are limited to a single adjacent property, the developer may obtain a notarized letter of permission from the affected property owner acknowledging the impacts in lieu of mitigation.

3.7.3 *Acceptable Downstream Conditions*

As part of the iSWM plan development, the downstream impacts of development must be carefully evaluated for the two focus areas of Streambank Protection and Flood Mitigation. The purpose of the downstream assessment is to protect downstream properties from increased flooding and downstream channels from increased erosion potential due to upstream development. The importance of the downstream assessment is particularly evident for larger sites or developments that have the potential to dramatically impact downstream areas. The cumulative effect of smaller sites, however, can be just as dramatic and, as such, following the *integrated* Focus Areas is just as important for the smaller sites as it is for the larger sites.

The assessment, defined by the development engineer, shall extend from the outfall of a proposed development to a point downstream where the discharge from a proposed development no longer has a significant impact, as defined in Table 3.1, on the receiving stream or storm drainage system. The CFW shall be consulted to obtain studies, records and maps related to the National Flood Insurance Program and the availability of Flood Insurance Studies and Flood Insurance Rate Maps (FIRMs) which may be helpful in this assessment. The assessment shall be a part of the Preliminary and Final iSWM Plans, and must include the following:

- Detailed drainage study and calculations for existing and proposed conditions (include digital submittal of hydrologic and hydraulic models, if utilized)
- Pre- and post-project conditions drainage area maps. Drainage area maps shall be of same scale and limits for both pre- and post-project conditions. Drainage area maps must clearly delineate all contributing areas draining to or through the entire site. Drainage area maps shall have topographic contour intervals no greater than two (2) feet.
- Discharges at critical downstream design points
- Separate analysis for each outfall from the proposed development
- Preliminary iSWM Plan shall include delineation of adequate outfalls and determination of zones of influence.

- Final iSWM Plan shall include final hydrology with all calculations, delineation of adequate outfalls and determination of zones of influence, required mitigation and final stormwater controls identified with sizes with the structural details and specifications, as required.
- Written narrative supporting methodology and conclusions of analysis.
- Analysis must confirm that conditions regarding an acceptable outfall, as defined in Table 3.1, are met at each outfall location.

Section 2.0 of the Hydrology Technical Manual gives additional guidance on calculating the discharges and velocities, as well as determining the downstream extent of the assessment.

3.8 Stormwater Conveyance Systems

3.8.1 *Introduction*

Stormwater system design is an integral component of both site and overall stormwater management design. Good drainage design must strive to maintain compatibility and minimize interference with existing drainage patterns; control flooding of property, structures, and roadways for design flood events; and minimize potential environmental impacts on stormwater runoff.

Stormwater collection systems must be designed to provide adequate surface drainage while at the same time meeting other stormwater management goals such as water quality, streambank protection, habitat protection, and flood mitigation.

Design

Unless regional detention is in place or a master plan has been completed which indicates a plan for reduced discharges, fully developed watershed conditions shall be used for determining runoff for the conveyance storm and the flood mitigation storm unless otherwise accepted by TPW.

3.8.2 *Subdivision Drainage Site Grading*

An engineered overall site grading plan shall be submitted with the subdivision's paving and drainage plans. The plan shall be consistent with the drainage area map included in the iSWM plan. The plan shall include flow arrows and Type A, B, or C drainage for each lot within the subdivision as described in Federal Housing Administration (FHA) Land Planning Bulletin No. 3, as amended (see Appendix E). Type 1 or 2 block grading as shown in the FHA information is preferred. Type 3 and block 4 grading is allowed only if:

- a swale, flume or channel is constructed at the rear of the lot to intercept runoff; and
- runoff from 3 or more lots is collected and conveyed within an underground drainage system, swale, flume or channel contained within a dedicated easement.

The engineer may utilize berms and swales to redirect flows. Grass swales shall have a minimum slope of 2% except where contained within a drainage easement, in which case a 1% minimum slope can be allowed. The engineer shall provide more detailed information in addition to the lot grading type (A, B, or C) by indicating spot elevations on each lot. For Type B lots, side-yard swales should extend from behind the rear building line to the street, in order to collect runoff from the roof. Roof drains, if used in along the rear building line of these lots, should use splash blocks to direct the runoff into the side swales.

The finished floor elevation and surrounding grading must conform to current building codes adopted by the City and provide a minimum height of the finished floor of twelve (12) inches above the surrounding ground. Areas within 10' of the foundation should be sloped to drain away from the foundation. Minimum slopes of 2% for structural improvements and 5% for non-structural elements, respectively, must be maintained away from the footing. See Figure 3.3.

If the site is complex and an overall site grading plan cannot be developed in accordance with the HUD standards, an individual grading plan for each lot shall be submitted by an engineer prior to issuing the Building Permit. The individual grading plans shall be coordinated with surrounding lots. For these complex plans, an "as-built" letter shall be submitted prior to final inspection.

Four (4) inches of topsoil shall be provided for all disturbed areas not protected by impervious cover, in order to sustain vegetation after construction has been completed.

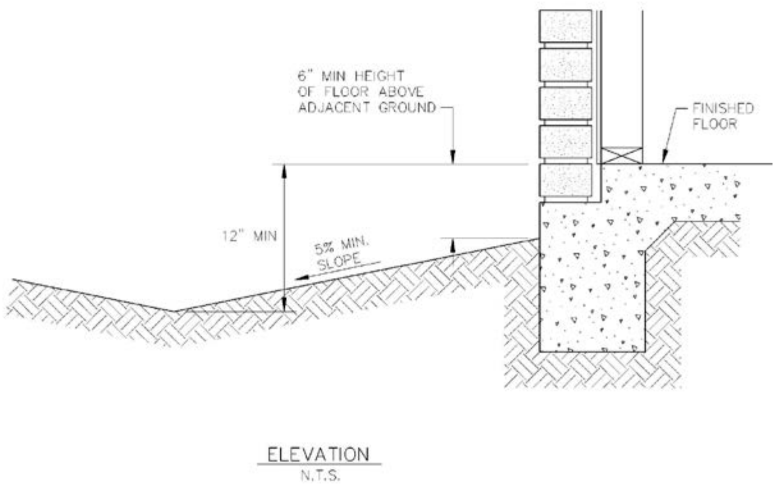


Figure 3.3 Grading Requirements Next to Building Foundation

3.8.3 *Hydraulic Design Criteria for Streets and Closed Conduits*

Introduction

This chapter is intended to provide criteria and guidance for the design of on-site flood mitigation system components including:

- Street and roadway gutters
- Stormwater inlets
- Parking lot sheet flow
- Storm drain pipe systems

Streets and Stormwater Inlets

Design Frequency

- Streets and roadway gutters: conveyance storm event
- Inlets on-grade: conveyance storm event
- Parking lots: conveyance storm event
- Storm drain pipe systems: conveyance storm event and flood mitigation storm event.
- Low points: flood mitigation storm event
- Combined Street ROW and storm drain pipe systems: flood mitigation storm event
- Drainage and floodplain easements: flood mitigation storm event

Design Criteria

The iSWM Inlet Design Methodology (*iSWM Hydraulics Technical Manual*) is adopted. Under the CFW classification system, inlets have been classified into two major groups namely: Inlets in Sumps and Inlets on Grade with Gutter Depression. The only curb inlets that are allowed by the CFW are those in sumps and depressed inlets on grade. Grate inlets and combination inlets are allowed only by permission of the Director of TPW.

Figures presented in the following chapters shall be used to document all closed conduit calculations even if calculations are performed on an acceptable computer program unless otherwise accepted by TPW.

A "rooftop" section should be used for concrete streets and a parabolic section for asphalt streets. Note that the nomograph in *Figure 1.2 of the iSWM Hydraulics Technical Manual* does not completely address cases where the crown elevation is lower than the top of curb elevation. For those cases a combination of *Figure 1.2 and 1.3 in the* iSWM Hydraulics Technical Manual can be used or a standard hydraulics program such as HEC-RAS or FlowMaster can be applied.

The design storms required by the CFW are as follows:

Storm Sewer System

The design storm is the fully developed land use conditions for the flood mitigation storm for the combination of the closed conduit and surface drainage system, to the limits of ROW.

Runoff from the fully developed conveyance storm must be contained within the permissible spread of water in the gutter. The flood mitigation storm flow must be contained within the ROW. Adequate inlet capacity shall be provided to intercept surface flows before the ROW capacity is exceeded. Note: the capacity of the underground system may be required to exceed the conveyance storm in order to satisfy the flood mitigation storm criteria.

The 5-year closed conduit Hydraulic Grade Line (HGL) must be equal to or below the gutter line for pipe systems and one (1) foot or more below the curb line at inlets. For sump conditions without an existing structural overflow, the 100-year HGL must be one (1) foot below the curb at the inlet. For situations where no ROW exists, the 100-year HGL must be below finished ground. The 100-year HGL will be tracked carefully throughout the system and described in the hydraulic calculations tables provided herein and on the construction drawings.

Inlets in Sumps

Curb opening inlets in sumps (Type CO-S) are addressed in *Section 1.2.7 of the Hydraulics Technical Manual.* Drop inlets in sumps (Y Inlet) are addressed in *Section 1.2.9 of the Hydraulics Technical Manual.*

In sag or sump conditions, the storm drain and sump inlets should be sized to intercept and convey a minimum of the 25-year storm and a positive structural overflow is required to provide for the remainder of the flood mitigation storm. The positive overflow structure must be concrete or other acceptable non-earthen structure with a minimum bottom width of four (4) feet extending from the sump inlet to the storm sewer outfall. It must be designed to pass at least 20 cfs with one (1) foot of freeboard from the top of curb to the adjacent finish floor elevations (minimum finish floor elevations for all lots adjacent to said overflows must be shown on the plat).

All flumes that pass through sidewalks shall have a bolted-down, rust-proof, 3/8-inch (min.) steel plate with a pedestrian-rated walking surface. The plate shall be recessed into the concrete sidewalk from face of curb to the property line. The plate must be secured to the concrete with bolts and flush with the top of sidewalk. A center support may be added depending on the width of the flume. Fences must be kept behind the curb line of the flume. Where a structural overflow is not feasible, a variance must be requested from TPW. If no structural overflow is constructed, the sump inlets must be designed with a 50% clogging factor. In a cul-de-sac where no structural overflow is feasible, additional on-grade inlet capacity may be provided upstream of the sump in lieu of additional sump inlets.

An explanation of the Inlets in Sumps Calculation Sheet is included in is included in the following sections.

Inlets on Grade with Gutter Depression (Type CO-D, Figure 3.6)

The hydraulic efficiency of storm-water inlets varies with gutter flow, street grade, street crown, and with the geometry of the inlet depression. The design flow into any inlet can be greatly increased if a small amount (5% to 10%) of gutter flow is allowed to flow past the inlet. When designing inlets, prevention of clogging or from interference with traffic often takes precedence over hydraulic considerations. The computation sheet for Type CO-D Inlet in Table 3.7.

The depression of the gutter at a curb opening inlet (See Figure 3.6) below the normal level of the gutter increases the cross-flow towards the opening, thereby increasing the inlet capacity. Also, the downstream transition out of the depression causes backwater which further increases the amount of water captured. Depressed inlets should be used on all public streets and alleys. Recessed depressed inlets shall be used on all arterials.

The capacity of a depressed curb inlet on grade will be based on the methodology presented in *Section 1.2.7 of the iSWM Hydraulics Technical Manual.*

Drop Inlets (Area Drains)

1. Drop inlets serving a drainage area of 10 to 25 acres will be designed with a 50% clogging factor.
2. Grading plans to direct flow into drop inlets will be included in the construction plans. Where earthen swales or other means of collecting and directing runoff into drop inlets are needed, they should be contained in appropriately sized drainage easements.
3. Consideration should be given to a structural overflow in the same manner as described for sump inlets.
4. Drop inlets shall be located where they can be easily accessed for inspection and maintenance by the City.

Headwalls

1. A headwall will be used to collect a drainage area of twenty-five (25 ac) acres or more flowing to one spot.
2. Areas that have been channelized or discharged from a storm drain system will use a headwall to reintroduce the flow to a new storm drain system. These provisions do not apply to special multi-stage outlet structures draining detention facilities.

Stormwater Inlets Computation Sheets

Explanation of the Inlets in Sumps Computation Sheet (Type CO-S, Figure 3.4)

In order to facilitate the computations required in determining the various hydraulic properties for curb opening inlets and Y Inlets (drop inlets) in sumps use the Computation Sheet for Curb Opening and Drop Inlets shown in Figure 3.5. See Figure 3.4 for an illustration of a curb opening inlet.

Table Column Description

Column 1	Inlet number and designation.
Column 2	Slope of gutter in ft. per ft.
Column 3	Crown slope of pavement in ft. per ft. For parabolic crowns enter type of street section.
Column 4	Total gutter flow in cfs. For inlets other than the first inlet in a system, gutter flow is the sum of runoff from contributing area plus carry-over flow from inlet or inlets upstream.
Column 5	Depth of gutter flow in feet from the spread of water calculations in Figure 1.2 (*iSWM Hydraulics Technical Manual*), *Section 1.2.4* or from direct solution of Manning's equation for triangular gutters.
Column 6	Depth of gutter depression in ft. (0.33 ft for a standard recessed curb inlet)
Column 7	Depth of water at inlet opening in ft. Column 5 plus Column 6.

Column 8	Capacity of curb opening inlet or drop inlet in cfs per ft. of length of opening or perimeter around inlet from Figures 1.10, 1.12 or 1.14 in the *iSWM Hydraulics Technical Manual* or by direct solution.
Column 9	Assumed length of inlet opening or perimeter in feet.
Column 10	Capacity of inlet in cfs. Column 8 times Column 9.
Column 11	Carry-Over flow passing inlet (into overflow swale) in cfs. Column 4 minus Column 10.
Column 12	Percent of flow captured by inlet. Column 10 divided by Column 4 times 100.

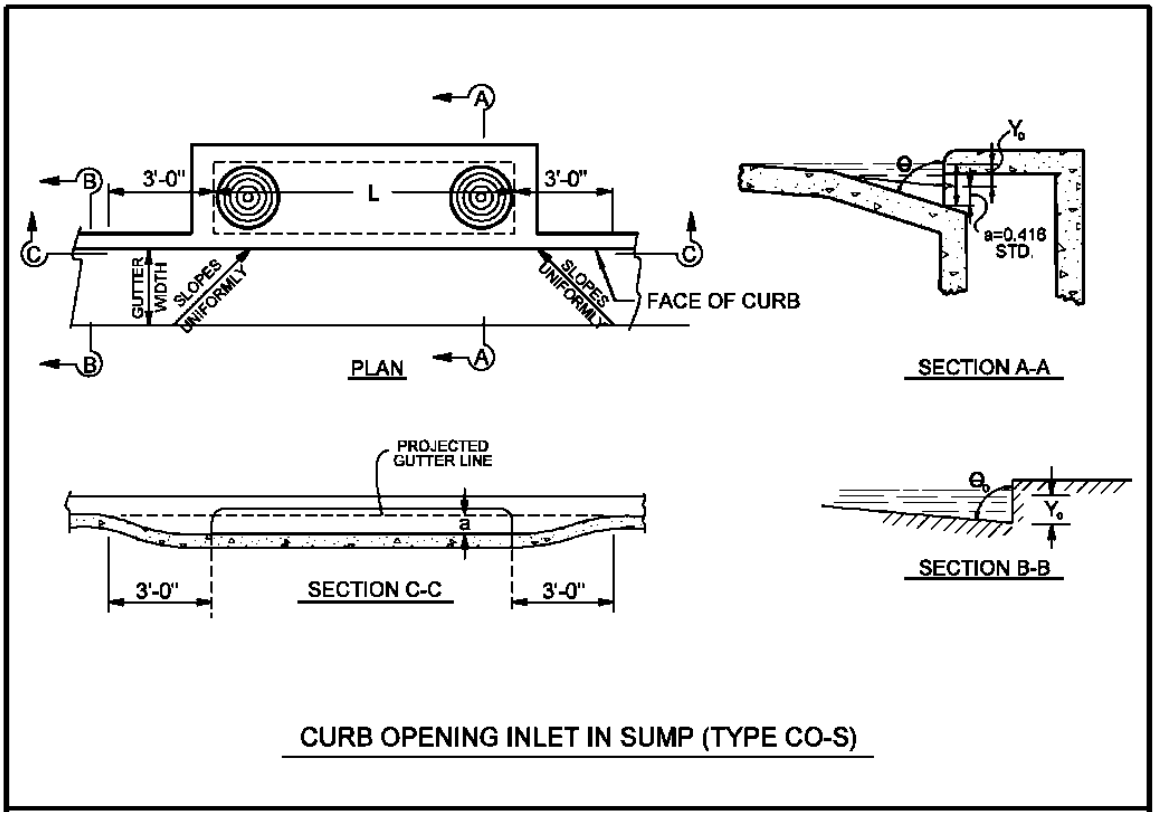


Figure 3.4 Type CO-S Inlet

BY:	COMPUTATION SHEET NO. IV-1	SHEET __ OF __
DATE:	FOR DETERMINING CAPACITY OF	STREET: ________
CK'D:	CURB OPENING INLETS AND DROP INLETS IN SUMPS	MAJOR WATERSHED: ___________
DATE:	n = .016	JOB/FILE NO.: ____

INLET NO.	GUTTER SLOPE So FT./FT.	CROWN SLOPE OF PVM'T θo FT./FT.	GUTTER FLOW Qo C.F.S.	DEPTH OF GUTTER FLOW Yo FT.	DEPTH OF DEPRESSION a FT.	DEPTH OF FLOW AT OPENING Y FT.	CAPACITY OF INLET PER FOOT OF LENGTH Q/L C.F.S/FT.	LENGTH OF INLET OPENING L OR P FT.	CAPACITY OF INLET Q C.F.S.	CARRY-OVER INTO OVER FLOW C.F.S.	PERCENT Q100 CAPTURED BY INLET	NOTES
1	2	3	4	5	6	7	8	9	10	11	12	13

REMARKS, SKETCHES AND COMPUTATIONS

Figure 3.5 Computation Sheet for Curb Opening and Drop Inlets

Explanation of the Inlets On Grade with Gutter Depression (Type CO-D, Figure 3.6) Computation Sheet

In order to facilitate the computations required in determining the various hydraulic properties for Curb Opening Inlets Type CO-D on grade (depressed), Figure 3.7, the Computation Sheet for On Grade Curb Inlets has been prepared.

Table Column Description:

Column 1	Design Point for Inlet
Column 2	Inlet number(s)
Column 3	Location of inlet by storm drain station number
Column 4	Drainage area designation for incremental area
Column 5	Drainage area size (acres)
Column 6	Runoff coefficient “C” provided in Table 3.5 located in Chapter 3.4.1 under “Types of Hydrologic Methods”
Column 7	Time of concentration (minutes)
Column 8	Longitudinal slope (ft/ft)
Column 9	Cross slope of the pavement (ft/ft)
Column 10	Cross slope of the gutter measured from the cross slope of the pavements. The cross slope is equal to the gutter depression (in) divided by the width of the depressed gutter (in)
Column 11	Depth of gutter flow "yo" in approach gutter from spread of water determinations in the *iSWM Hydraulics Technical Manual, Figure 1.3,* or from direct solution of Manning's equation for triangular gutters: $yo = 1.245\ Qo^{3/8}\ (n^{3/8}/So^{3/16})\ (1/z)^{3/8}$. When the crown is overtopped, a composite analysis will be required.
Column 12	Spread of flow is calculated using *Figure 1.2 in the iSWM Hydraulics Technical Manual* or from direct solution of Manning’s Equation
Column 13	Equivalent cross slope is computed by using *Figure 1.3 and 1.4 in the iSWM Hydraulics Technical Manual* to determine the ratio of flow in the depressed gutter section to the total flow
Column 14	Street crown section type (straight crown [“rooftop”] or parabolic)
Column 15	Manning’s roughness coefficient (n) for pavement values located in *Section 1.2.4 of the iSWM Hydrologic Technical Manual Table 1.2*
Column 16	5-year rainfall intensity (in/hr), From *Section 5.0 in the iSWM Hydrology Technical Manual* Tarrant County Rainfall Table
Column 17	5-year runoff, Q=CAi (cfs)
Column 18	5-year carryover flow from upstream inlet (cfs)
Column 19	5-year total gutter flow (Column 17 + Column 18) (cfs)
Column 20	100-year rainfall intensity (in/hr), From *Section 5.0 in the iSWM Hydrology Technical Manual* Tarrant County Rainfall Table
Column 21	100-year runoff, Q=CAi (cfs)
Column 22	100-year carryover flow from upstream inlet (cfs)
Column 23	100-year total gutter flow (Column 20 + Column 21) (cfs)
Column 24	Total right-of-way capacity (normally 2.5” over top of curb) (cfs)

Column 25 This indicates the controlling storm for inlet spacing, depending on which criteria (5-year in street or 100-year in ROW) may be exceeded. This indicates whether the inlet is sized for the 5-year or 100-year flows

Column 26 Length required for total interception of the design storm determination in *Figure 1.8 of the iSWM Hydraulics Technical Manual* or by direct solution of Manning's Equation. Please note that the example in Figure 1.8 does not consider inlet depression (slope).

Column 27 Actual length (L) in feet of the inlet which is to be provided (10', 15', or 20')

Column 28 Ratio of the length of inlet provided (L) to the length of the inlet required for 100% interception (L_T). Column 26 divided by Column 29

Column 29 The efficiency of the provided inlet determined by *Figure 1.9 in the iSWM Hydraulics Technical Manual.*

Column 30 Discharge (Q_i) in cubic feet per second in which the inlet in question actually intercepts in the design storm. Column 19 or 23 multiplied by Column 27

Column 31 Carry-over flow (q) is the amount of water which passes the inlet in a conveyance storm. A substantial portion of the 5-year flow should be picked up by the inlet. The carry-over flow should be accounted for in further downstream inlets.

Column 32 Carry-over flow (q) is the amount of water which passes the inlet in a flood mitigation storm. The carry-over flow should be accounted for in further downstream inlets and should be reflected in the inlet bypass flow (Column 17) in the Storm Drain Hydraulics Table, Figure 3.10 (minor variances may occur due to travel time routing in the Hydraulics Table).

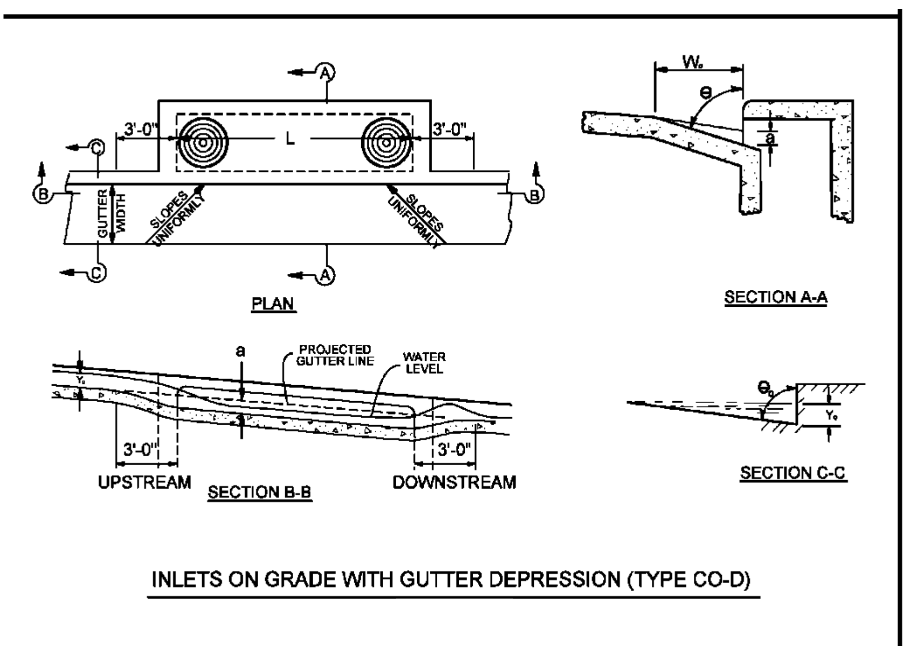


Figure 3.6 Type CO-D Inlet

COMPUTATION SUMMARY SHEET
FOR DETERMINING CAPACITY OF
CURB OPENING INLET ON GRADE (DEPRESSED)

Inlet			Drainage Area				Long Slope	Cross Slope of Pavement	Cross Slope of Gutter	Depth of Flow	Spread of Flow	Equivalent Cross Slope	Street	Manning's coefficient	5-year	5-year	5-year Carryover	5-year Total	100-year	100-year	100-year Carryover	100-year Total	Right-of-Way	Design	Length Required	Actual Provided		Efficiency	Inlet Capacity	5-year Carryover	100-year Carryover	
Design Point	Inlet No.	Station	Area No.	Area (acres)	Runoff Coeff. "c"	Conc. Time (min)	"S" (ft/ft)	"Sx" (ft/ft)	"S'x" (ft/ft)	"Yo" * (ft)	"T" ** (ft)	"Se" (ft/ft)	Section (type)	pavement "n"	Intensity (in/hr)	Runoff (cfs)	Flow (cfs)	Gutter Q (cfs)	Intensity (in/hr)	Runoff (cfs)	Flow (cfs)	Gutter Q (cfs)	Capacity (cfs)	Storm ***	"L_T" (ft)	Length "L" (ft)	L/L_T	"E"	"Qi" (cfs)	Flow "q" (cfs)	Flow "q" (cfs)	COMMENTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33

Notes:
* Assumption of full curb in all conditions may lead to overestimation of inlet capacity.
** When the crown is overtopped, a composite analysis will be required.
*** This is the controlling storm for inlet spacing, depending on which criteria (5-year in street or 100-year in ROW) may be exceeded)

Figure 3.7 Computation Summary Sheet for On Grade Curb Inlets

Streets and ROW

Depth in the street shall not exceed top of curb or exceed maximum spread of water limits for the fully developed conveyance storm. Limiting the spread of water allows one or more lanes to remain dry during the conveyance storm and helps prevent hydroplaning of vehicles. The fully developed flood mitigation storm shall be contained within the right-of-ways or easements.

Parking Lots

Parking lots shall be designed for the conveyance storm not to exceed top of curb with maximum ponding at low points of one (1) foot. The flood mitigation storm shall be contained on-site or within dedicated easements.

Spread of Water Limits

Inlets shall be spaced so that the spread of water in the street for the conveyance storm shall not exceed the guidelines provided below.

For all applications, the engineer/developer must use roadway sections as approved by CFW.

The following spread of water values shall be used for the various types of streets.

Arterials (Divided)

1. **Permissible Spread of Water**-The permissible spread of water in gutters of major divided thoroughfares shall be limited so that one traffic lane on each side remains clear during the conveyance storm. Gutter flow shall be based on maximum storm duration of 15 minutes. The flood mitigation storm shall be contained within the ROW.
2. **Conditions**-Inlets shall be located at street intersections, and at low points of grade or where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located, when possible, on side streets when grades permit. In no cases shall the gutter depression at inlets exceed the standard. In super-elevated sections, inlets placed against the center medians shall have no gutter depression. Furthermore, inlets and superelevated sections shall be placed to intercept flow before it can cross the street.

Arterials (Not Divided)

1. **Permissible Spread of Water**-The permissible spread of water in gutters of major undivided thoroughfares shall be limited so that one traffic lane in each direction will remain clear during the conveyance storm.
2. **Conditions**-Inlets shall preferably be located at street intersections, low points of grades, or where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located, when possible, on the side streets when grades permit. In no case shall the gutter depression at inlets exceed the standard.
3. **Super-elevated Sections**-Intercept gutter flow at the point of zero crossfall to prevent flow from crossing the thoroughfare. Unless expressly accepted by the TPW, stormwater will not be allowed to cross major thoroughfares on the surface in valley gutters or otherwise.

Collector Streets

1. **Permissible Spread of Water**-The permissible spread of water in gutters of collector streets shall be limited so that one standard lane of traffic will remain clear during the conveyance storm.
2. **Conditions**-Inlets shall preferably be located at street intersections, low points of grade or where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located, when at all possible, on the side streets when grade permits. In no case shall the gutter depression at inlets exceed the standard.

Minor Streets (Residential)

1. **Permissible Spread of Water**-The permissible spread of water in gutters for minor streets shall be limited by the height of the curb for the conveyance storm. The flood mitigation storm shall be contained within the R.O.W.
2. **Conditions**-Inlets shall be located at street intersections, low points of grade or where the gutter flow exceeds the permissible spread of water criteria. In no case shall the gutter depression at inlets exceed the standard.

Storm Drain Pipe Design

Design Frequency

- Flood Mitigation storm, less any gutter, roadway, ROW, and flume flows.

Design Criteria

Velocities in sewers are important mainly because of the possibilities of excessive erosion on the storm drain inverts. Table 3.9 shows the maximum desirable velocities for most storm drainage design. Velocities in excess of those shown on this table must be accepted by TPW. Supercritical flow in main lines should be avoided unless accepted by TPW.

- The maximum hydraulic gradient shall not produce a velocity that exceeds 20 feet per second (fps). Table 3.9 shows the desirable maximum velocities for most storm drainage design. Storm drains shall be designed to have a minimum mean velocity flowing full at 2.5 fps. A main is defined as any pipe connected to two or more inlets.

Table 3.9 Desirable Velocity in Storm Drains

Description	Maximum Allowable Velocity
Culverts (All types)	15 fps
Storm Drains (Inlet laterals)	25 fps
Storm Drains (Mains)	20 fps

This chapter replaces the Closed Conduit System sections 1.2.9, most of 1.2.10, and 1.2.11 of the *iSWM Hydraulics Technical Manual.* Storm Drain Outfalls located within section 1.2.10 (page HA-49) are adopted. Although, use of Table 1.10 may be substituted by a detailed hydrologic and hydraulic study. It is the purpose of this chapter of the manual to consider the significance of the hydraulic elements of storm drains and their appurtenances to the storm drainage system. This chapter is generally excerpted from the 1967 CFW Design Criteria Manual.

Velocities and Grades

Storm drains should operate with velocities of flow sufficient to prevent excessive deposits of solid materials, otherwise objectionable clogging may result. The controlling velocity is near the bottom of the conduit and considerably less than the mean velocity of the sewer. Storm drains shall be designed to have a minimum mean velocity (flowing full) of 2.5 fps. Table 3.10, Minimum Grades for Storm Drains, indicates the minimum grades for concrete pipe (n = 0.013), flowing at 2.5 fps.

Table 3.10 Minimum Grades for Storm Drains	
Pipe Size (Inches)	**Concrete Pipe Slope FT./Ft.**
21	0.0015
24	0.0013
27	0.0011
30-96	0.0010

Materials

Only reinforced concrete pipe is allowed under pavement for public storm drains in the CFW except as noted hereafter: profile-wall thermoplastic pipe (corrugated exterior with smooth interior), including High-Density Polyethylene (HDPE) pipe and Corrugated PVC (CPVC), may be used in the following specific situations:

- Profile-wall thermoplastic pipe is permitted for use in driveway culverts (i.e. across roadside ditches). Minimum allowable size shall be fifteen (15) inches, and driveway permits will be required from the TPW Street Management office.
- Profile-wall thermoplastic pipe may be allowed for certain off-pavement applications only as accepted by TPW on a case-by-case basis (using Request for Variance Form CFW-7).
- A request for variance (Form CFW-7) shall be required for profile wall HDPE pipe up to thirty-six (36) inch in diameter under publicly maintained concrete pavement in residential streets. No exceptions to this rule will be considered for installation of HDPE/CPVC pipe under other publicly maintained street sections.
- Profile-wall thermoplastic pipe used as storm drain shall be installed in accordance with the appropriate CFW Standard Detail, and 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. Note that Class I aggregate (CFW Standard Construction Specification Documents – Section 330510 (Old TPW Item 402.2) or NCTCOG Aggregate Grade 4) shall be required for pipe embedment.

All contractors shall be trained and certified by the manufacturer prior to installing HDPE/CPVC pipe. A copy of the training certification and proof of insurance shall be provided to the City before any work shall commence.

Roughness Coefficients

In selecting roughness coefficients for concrete pipe, consideration will 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 existing sewers where alignment is poor and joints have become rough. 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 will be selected which in the judgment of the designer, will 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, will have to have written approval of the TPW.

Table 3.11 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 1.8 in iSWM Hydraulics Technical Manual.* **NOTE: CFW DOES NOT ALLOW CMP FOR NEW CONSTRUCTION**	0.022-0.037*
Profile Wall Thermoplastic 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.	

*Note: analysis of existing conditions may require a different value than the stated design coefficients.

Manholes

Manholes shall be located at intervals not to exceed 550 feet for pipe 54 inches in diameter or smaller. For pipes sixty (60) inches in diameter and larger or equivalently sized boxes, the maximum interval is 800 feet. Manholes must be installed at the upstream end of a system and where a storm drain leaves the pavement, unless the outfall is within fifty (50) feet of the roadway and directly accessible. Manholes shall preferably be located at street intersections, sewer junctions, changes of grade and changes of alignment. When the storm drain is a concrete box instead of an RCP, four (4) foot diameter manhole risers may be installed instead of vaults to provide access. In all cases, steps or ranges shall be installed from the ground surface to the flowline of the pipe.

Full or Part Full Flow in Storm Drains

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

Q = A V, and

$Q = \frac{1.486}{n} A\, r^{\frac{2}{3}}\, S_f^{\frac{1}{2}}$, 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 graph is shown in *iSWM Hydraulics Technical Manual Figure 1.17.* Equations for flow in conduits with other cross-sections are available in the TxDOT Hydraulic Design Manual, dated October 2011, Chapter 6, and Section 2. For circular conduits flowing partially full, graphs are presented in *iSWM Hydraulics Technical Manual Figure 1.19a.*

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 will exist at each structure. The rate of loss of energy through the storm drain system shall be represented by the hydraulic grade line, which measures the pressure head available at any given point within the system.

The HGL shall be established for all storm drainage design in which the system operates under a head. The HGL is often controlled by the conditions of the sewer outfall; therefore, the elevation of the tailwater must be known. The hydraulic gradient is calculated upstream from the downstream end, taking into account all of the head losses that may occur along the line. The *iSWM Hydraulics Technical Manual Table 1.10* provides a table of coincident design frequencies to assist with tailwater determination. The hydraulic gradient shall begin at the higher of the tailwater or depth of flow in the pipe at the downstream end. An alternative to the use of *Table 1.10* is the performance of a detailed hydrologic and hydraulic study to determine coincident tailwater.

All head losses shall be calculated if the storm drain system is in a subcritical 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 approval of TPW. If the system is in supercritical regime the section should be marked “SUPERCRITICAL FLOW.” 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 subchapter. Minor losses due to turbulence at structures shall be determined by the procedure of last subchapter of this chapter (“Minor Headlosses at Structures) or in the *iSWM Hydraulics Technical Manual.* All HGL calculations will be carried upstream to the inlet.

The HGL shall in no case be above the surface of the ground or street gutter for the conveyance storm. Allowance of head must also be provided for future extensions of the storm drainage system. In all cases the maximum HGL must be twelve (12) inches below top of curb at any inlet for the conveyance storm.

Minor Head Losses at Structures

Detailed information on the calculation of minor head losses at structures is provided in the proceeding section. Figure 3.8 and Figure 3.9 provide details of minor losses for manholes, wye branches, and bends in the design of closed conduits. Minimum head loss used at any structure shall be 0.10 foot.

Storm Drain Design Example

An example of storm drain design is provided in the proceeding sections.

Hydrologic Methodology with MWH InfoWorks/SWMM Programs

InfoWorks SD by MWH Soft and the Stormwater Management Model (SWMM) family of programs have been applied to several complex storm sewer systems in the CFW. These programs include several hydrologic subarea runoff procedures. In addition to the hydrologic methods described in Chapter 3.4.1, the CFW accepts the following procedures when applying these programs:

- With case-by-case approval by TPW, the SWMM Method in which the flow is routed using a single linear reservoir, whose routing coefficient depends on surface roughness (Manning’s n), surface area, ground slope and catchment width.

- A version of the Unit Hydrograph Method in which a triangular unit hydrograph is developed using the time to peak (time of concentration times 0.6), total runoff time (time to peak times 2.67) and the peak of the unit hydrograph (2 divided by total runoff time). Refer to Appendix B, CFW Stormwater computer models for more information.

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 3.8 and Figure 3.9 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 velocity, takes the form as set forth below with the various conditions of the coefficient "Kj" shown in Table 3.12.

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

h_j = Junction or structure head loss in feet.

V_1 = Velocity in upstream pipe in fps.

V_2 = Velocity in downstream pipe 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.

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

60º Bend - 85%; 45° Bend - 70%; 22-1/2° Bend - 40%

The values of the coefficient “K_j” for determining the loss of head due to obstructions in pipes are shown in Table 3.13 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 values of the coefficient "K_j" for determining the loss of head due to sudden enlargements and sudden contractions in pipes are shown in Table 3.14, and the coefficients are used in the following equation to calculate the head loss at the change in section:

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

V = Velocity in smaller pipe

Table 3.14 Head Loss Coefficients Due To Sudden Enlargements and Contractions

D_2* / D_1	Sudden Enlargements K_j	Sudden Contractions K_j
1.2	0.10	0.08
1.4	0.23	0.18
1.6	0.35	0.25
1.8	0.44	0.33
2.0	0.52	0.36
2.5	0.65	0.40
3.0	0.72	0.42
4.0	0.80	0.44
5.0	0.84	0.45
10.0	0.89	0.46
~	0.91	0.47

* D_2/D_1 = Ratio of larger to smaller diameter

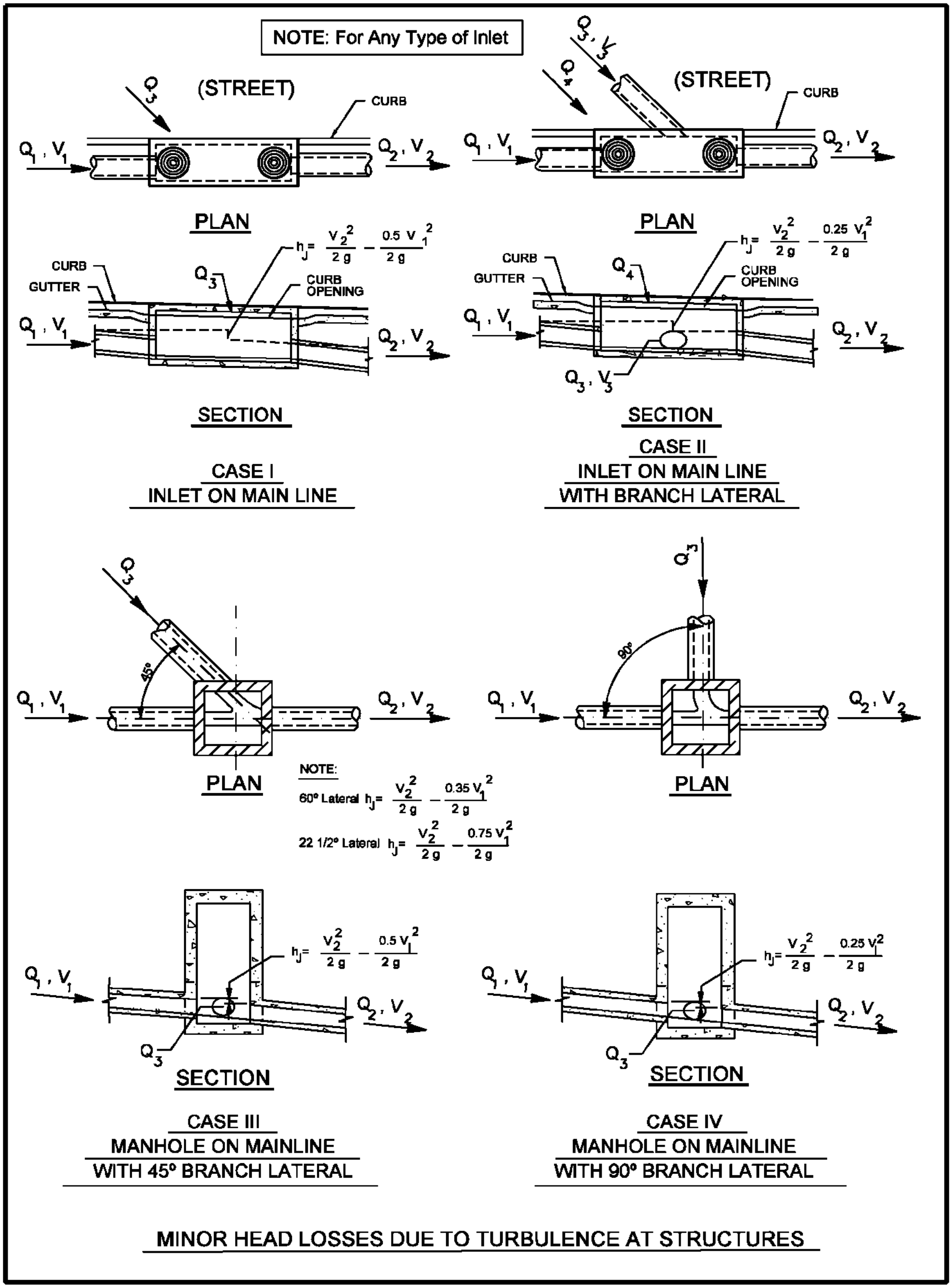


Figure 3.8 Minor Head Losses at Structures (1 of 2)

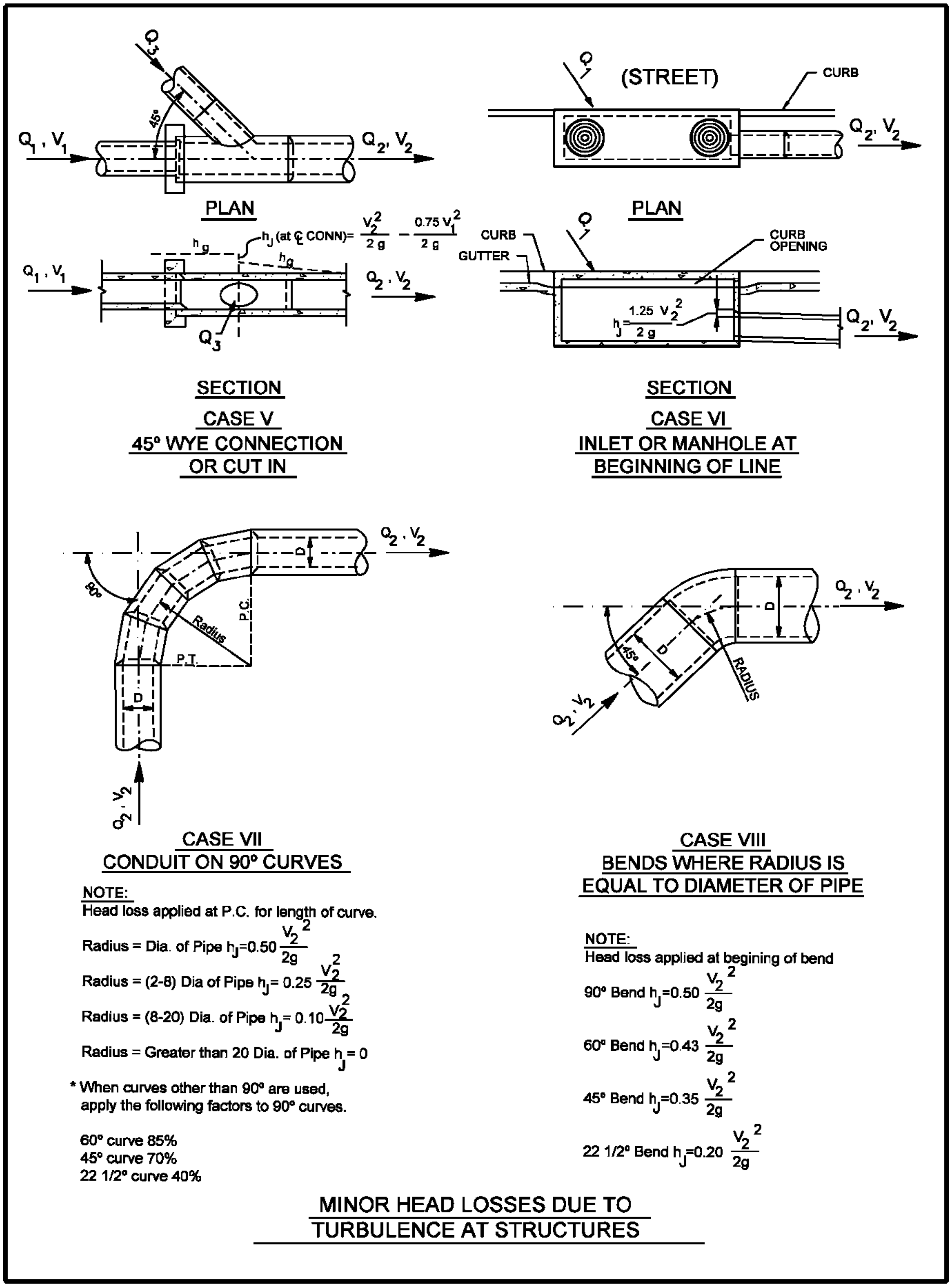


Figure 3.9 Minor Head Losses at Structures (2 of 2)

Storm Drain Design Examples

All storm drains shall be designed by the application of the Manning Equation either directly or through appropriate charts or nomographs. In the preparation of hydraulic designs, a thorough investigation shall be made of all existing structures and their performance on the waterway in question.

An example of the use of the method used in the manual for the design of a storm drainage system is outlined below and shown on Figure 3.10, Computations Sheet for Storm Drains. The design theory has been presented in the preceding chapters with their corresponding tables and graphs of information.

Preliminary Design Considerations

- Prepare a drainage map of the entire area to be drained by proposed improvements. The scale of the map shall not be less than 1 inch = 200 feet for project area although smaller scale maps for large offsite drainage areas may be used. A maximum contour interval of 2 feet shall be provided.
- Prepare a layout of the proposed storm drainage system, locating all inlets, manholes, mains, laterals, ditches, culverts, etc.
- Outline the drainage area for each inlet in accordance with present and future street development.
- Indicate on each drainage area the code identification number and the direction of surface runoff by small arrows. Provide a runoff table showing area, “C” factor for each portion and composite “e”, Tc, I5, Q5, I100 and Q100. Provide zoning classifications or land use data.
- Show all existing underground utilities.
- Establish design rainfall frequency.
- Establish minimum inlet time of concentration.
- Establish the typical cross section of each street.
- Establish permissible spread of water on all streets within the drainage area.
- Plot profile of existing natural ground along the center line of the proposed storm drain.
- Extend downstream plan and profile beyond the end of the pipe to a point of acceptable outfall. The flowline or invert of proposed outlet shall be equal to or slightly higher than receiving stream.

Runoff Computations

Storm drain hydraulics are shown on the computation sheet provided on Figure 3.10. The first 18 columns of the computation sheet cover the tabulation for runoff calculations:

Table Column Description

Column 1	Enter the downstream storm drain station number.
Column 2	Enter the upstream storm drain station number. This is the design point. Design should start at the farthest upstream point.
Column 3	Enter the distance (in feet) between the storm drain stations.
Column 4	Enter the designation of the drainage area(s) at the design point in Column 2 corresponding to the designations shown on the drainage area map.
Column 5	Enter the area in acres for the drainage area identified in Column 4.
Column 6	Enter the total drainage area in acres within the system corresponding to storm drain station shown in Column 2.
Column 7	Enter the runoff coefficient “C” for the drainage area shown in Column 5.
Column 8	Multiply Column 5 by Column 7 for each area.
Column 9	Determine the total “CA” for the drainage system corresponding to the inlet or manhole shown in Column 2.

Column 10 Determine inlet time of concentration (See *Section 1.2.4 iSWM Hydrology Technical Manual).*

Column 11 Determine flow time in the storm drain in minutes. The flow time is equal to the distance in Column 3 divided by 60 times the velocity of flow through the storm drain in ft/sec.

Column 12 Total time of concentration in minutes. Column 10 plus Column 11. Note that time of concentration only changes at a downstream junction with another drainage area(s). It remains the same from an inlet or junction to the next inlet or junction picking up additional drainage areas. The junction of two paired inlets with each other is not a downstream junction.

Column 13 The intensity of rainfall in inches per hour for the conveyance storm frequency from the appropriate county rainfall table in the *iSWM Hydrology Technical Manual.*

Column 14 The intensity of rainfall in inches per hour for the flood mitigation storm frequency from the appropriate county rainfall table in the *iSWM Hydrology Technical Manual.*

Column 15 The conveyance storm runoff in cfs. Column 9 times Column 13.

Column 16 The flood mitigation storm runoff in cfs. Column 9 times Column 14.

Column 17 The proposed inlet bypass during a flood mitigation storm. This should generally correspond to the carry-over flow “q” in Column 31 of the On-Grade Inlet Capacity Calculations Table (minor variances may occur due to travel time routing in the Hydraulics Table).

Column 18 Design Discharge for the storm drain system (“Qpipe”) in cfs. This should be the greater of a substantial portion of Q5 (Column 15) or Q100-Qbypass (Column 16 minus Column 17).

Hydraulic Design

After the computation of the quantity of storm runoff entering each inlet, the size and gradient of pipe required to carry the design storm are determined. Any number of computer programs are available to provide design assistance for pipe sizing to the engineer. However, storm drain hydraulics must be converted and reported in Figure 3.10, Computation Sheet for Storm Drains. The hydraulic grade line (HGL) must be calculated for all storm drain mains and laterals using appropriate head loss equations. In all cases, the storm drain HGL must remain below grade and must be at least one (1) foot below top of curb at any inlet for the conveyance storm.

In partial flow conditions, the HGL represents the actual water surface within the pipe. Note that for partial flow conditions, the velocity of the flow should be calculated based on actual area of flow, not the full flow area of the pipe or box.

Although the table is presented from upstream to downstream, the calculations are normally performed from the outfall upstream to each inlet. Unless partial flow conditions exist, the beginning hydraulic gradient (Column 22 of the last downstream section) must begin at either the top of pipe or at the hydraulic gradient of the receiving stream at the coincident frequency provided in *Table 1.10 of the Hydraulic Technical Manual*, whichever is higher. It is also acceptable to perform a detailed hydrologic and hydraulic study of the watershed of the receiving stream to determine the connected outfall hydraulic gradient.

Table Column Description

Column 19 Enter the selected pipe size.

Column 20 Enter the appropriate Manning’s roughness coefficient “n” from Table 3.18

COMPUTATION SHEET
HYDRAULIC COMPUTATIONS FOR STORM DRAINS

STORM DRAIN HYDRAULIC CALCULATIONS TABLE

FROM	TO	Pipe	Drainage Area			Runoff	Incr.	Total	Time of Concentration			5-year	100-year	Q5	Q100	Inlet	Q	Pipe			HGL		HEAD LOSS CALCULATIONS							Design	Invert Elev.		T/C	
		Length	Incremental		Total Area	"c"	cA	cA	Inlet	Travel	Total	Intensity	Intensity	Runoff	Runoff	bypass	pipe	Size	n	Sf	D/S	U/S	V1 (in)	V2 (out)	$V1^2/2G$	$V2^2/2G$	Kj	$KjV1^2/2G$	Hk	HGL	FROM	TO	ELEV.	
		feet	No.	Area					min.	min.	min.	in/hr.	in/hr.	cfs	cfs	cfs	cfs	in.		ft/ft	Elev.	Elev.	ft/sec	ft/sec	ft.	ft.		ft.	ft.	Elev.	ft.	ft.	ft.	COMMENTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
LINE A																																		
4+00	5+42	142	A1	35.00	35.00	0.65	22.75	22.75	15.00		15.00	4.86	7.98	110.57	181.55	14.50	167.05	48	0.013	0.0135	818.17	820.09	13.29	13.29	2.74	2.74	0.00	0.00	0.00	820.09	813.16	816.00	822.50	A1=future phases
1+86	4+00	214	A2	0.50	35.50	0.65		23.08	15.00	0.18	15.18	4.86	7.98	112.14	184.14	11.80	172.34	54	0.013	0.0077	816.08	817.72	13.29	10.84	2.74	1.82	0.50	1.37	0.45	818.17	811.02	813.16	819.50	
1+43	1+86	43	A3	0.18	35.68	0.65	0.12	23.19	15.00	0.51	15.51	4.86	7.98	112.71	185.07	0.00	185.07	54	0.013	0.0089	814.96	815.34	10.84	11.64	1.82	2.10	0.75	1.37	0.74	816.08	809.59	810.52	818.00	
0+50	1+43	93	A4	0.56	36.24	0.65	0.36	23.56	15.00	0.57	15.57	4.86	7.98	114.48	187.98	0.00	187.98	60	0.013	0.0052	814.10	814.59	11.64	9.57	2.10	1.42	0.50	1.05	0.37	814.96	808.53	809.09	817.78	min Hk = 0.10'
0+00	0+50	50			36.24	0.65		23.56	15.00	0.57	15.57	4.86	7.98	114.48	187.98	0.00	187.98	60	0.013	0.0075	813.23	813.61	9.57	9.57	1.42	1.42	0.35	0.00	0.50	814.10	808.23	808.53	---	45° BEND
LINE A-2																																		
A 1+86	n. inlet	22	see note	0.25	0.25	0.65	0.09	0.16	15.00		15.00	4.86	7.98	1.24	2.65	0.00	2.65	21	0.013	0.0003	818.17	818.18	0.00	1.10	0.00	0.02	1.25	0.00	0.02	818.20	812.02	815.00	819.50	half A1 bypass + half A2
A 1+86	s. inlet	24	see note	0.25	0.25	0.65	0.09	0.16	15.00		15.00	4.86	7.98	1.24	2.65	0.00	2.65	21	0.013	0.0003	818.17	818.18	0.00	1.10	0.00	0.02	1.25	0.00	0.02	818.20	812.02	815.00	819.50	half A1 bypass + half A2
LINE A-3																																		
A 1+86	n. inlet	22	see note	0.18	0.18	0.65	0.09	0.12	15.00		15.00	4.86	7.98	9.28	14.08	0.00	14.08	21	0.013	0.0079	816.08	816.25	0.00	5.86	0.00	0.53	1.25	0.00	0.67	816.91	811.52	813.50	818.00	half (A1+A2 bypass) + half A3
A 1+86	s. inlet	24	see note	0.18	0.18	0.65	0.09	0.12	15.00		15.00	4.86	7.98	9.28	14.08	0.00	14.08	21	0.013	0.0079	816.08	816.27	0.00	5.86	0.00	0.53	1.25	0.00	0.67	816.93	811.52	813.50	818.00	half (A1+A2 bypass) + half A3
LINE A-4																																		
0+20	s, inlet	18	A4/2	0.28	0.28	0.65	0.18	0.18	15.00		15.00	4.86	7.98	0.88	1.45	0.00	1.45	21	0.013	0.0001	814.97	814.97	0.00	0.60	0.00	0.01	1.25	0.00	0.01	814.98	811.67	813.07	817.57	
0+20	0+37	17	A4/2	0.28	0.28	0.65	0.18	0.18	15.00		15.00	4.86	7.98	0.88	1.45	0.00	1.45	21	0.013	0.0001	814.97	814.97	0.00	0.60	0.00	0.01	1.25	0.00	0.01	814.98	811.67	813.07	817.57	north inlet
0+00	0+20	20			0.56	0.65	0.00	0.36	15.00		15.00	4.86	7.98	1.77	2.90	0.00	2.90	24	0.013	0.0002	814.96	814.96	0.60	0.92	0.01	0.01	0.75	0.00	0.01	814.97	810.22	811.42	817.78	
LINE B																																		
5+98	6+15	17	B1/2	3.20	3.20	0.65	2.08	2.08	15.00		15.00	4.86	7.98	10.11	16.60	6.49	10.11	21	0.013	0.0041	817.70	817.77	0.00	4.20	0.00	0.27	1.25	0.00	0.34	818.12	814.73	815.04	819.54	west inlet
4+50	5+98	148	B1/2	3.20	6.40	0.65	2.08	4.16	15.00	0.07	15.07	4.86	7.98	20.22	33.20	12.98	20.22	24	0.013	0.0080	816.02	817.20	4.20	6.44	0.27	0.64	0.50	0.14	0.51	817.70	813.00	814.48	819.48	
2+15	4+50	235	B2	5.20	11.60	0.65	3.38	7.54	15.00	0.45	15.45	4.86	7.98	36.64	60.17	23.53	36.64	30	0.013	0.0080	813.76	815.63	6.44	7.46	0.64	0.87	0.75	0.48	0.38	816.02	810.15	812.50	818.00	
0+50	2+15	165	B3	2.50	14.10	0.65	1.63	9.17	15.00	0.98	15.98	4.86	7.98	44.54	73.14	20.00	53.14	36	0.013	0.0063	812.27	813.31	7.46	7.52	0.87	0.88	0.50	0.43	0.44	813.76	808.00	809.65	815.65	
0+00	0+50	50	B4	1.80	15.90	0.65	1.17	10.34	15.00	1.34	16.34	4.86	7.98	50.23	82.47	0.00	82.47	48	0.013	0.0075	811.53	811.91	7.52	6.56	0.88	0.67	0.35	0.31	0.36	812.27	805.00	807.00	814.00	channel HGL=811.53
LINE B-1A																																		
B 5+98	n. inlet	17	B1/2	3.20	3.20	0.65	2.08	2.08	15.00		15.00	4.86	7.98	10.11	16.60	6.49	10.11	21	0.013	0.0041	817.70	817.77	0.00	4.20	0.00	0.27	1.25	0.00	0.34	818.12	814.73	815.04	819.54	east inlet
LINE B-2 A&B																																		
B 4+50	e. inlet	18	B2/2	2.60	2.60	0.65	1.69	1.69	15.00		15.00	4.86	7.98	13.11	19.98	11.77	8.21	21	0.013	0.0027	816.02	816.07	0.00	3.41	0.00	0.18	1.25	0.00	0.23	816.29	812.50	813.50	818.00	includes B1 bypass
B 4+50	w. inlet	18	B2/2	2.60	2.60	0.65	1.69	1.69	15.00		15.00	4.86	7.98	13.11	19.98	11.77	8.21	21	0.013	0.0027	816.02	816.07	0.00	3.41	0.00	0.18	1.25	0.00	0.23	816.29	812.50	813.50	818.00	includes B1 bypass
LINE B-3 A&B																																		
B 2+15	e. inlet	18	B3/2	1.25	1.25	0.65	0.81	0.81	15.00		15.00	4.86	7.98	10.97	18.25	10.00	8.25	21	0.013	0.0027	813.76	813.81	0.00	3.43	0.00	0.18	1.25	0.00	0.23	814.04	810.65	811.15	815.65	includes B2 bypass
B 2+15	w. inlet	18	B3/2	1.25	1.25	0.65	0.81	0.81	15.00		15.00	4.86	7.98	10.97	18.25	10.00	8.25	21	0.013	0.0027	813.76	813.81	0.00	3.43	0.00	0.18	1.25	0.00	0.23	814.04	810.65	811.15	815.65	includes B2 bypass
LINE B-4																																		
0+20	w. inlet	18	B4/2	0.90	0.90	0.65	0.59	0.59	15.00	0.00	15.00	4.86	7.98	2.84	14.67	0.00	14.67	24	0.013	0.0042	812.44	812.51	0.00	4.67	0.00	0.34	1.25	0.00	0.42	812.94	808.65	809.50	814.00	includes B3 bypass
0+20	0+38	18	B4/2	0.90	0.90	0.65	0.59	0.59	15.00	0.00	15.00	4.86	7.98	2.84	14.67	0.00	14.67	24	0.013	0.0042	812.44	812.51	0.00	4.67	0.00	0.34	1.25	0.00	0.42	812.94	808.65	809.50	814.00	east inlet; B3 bypass
0+00	0+20	15			1.80	0.65	0.00	1.17	15.00	0.00	15.00	4.86	7.98	5.69	29.34	0.00	29.34	33	0.013	0.0031	812.27	812.31	4.67	4.94	0.34	0.38	0.75	0.25	0.12	812.44	807.00	807.90	814.00	

Notes:
1 Time of concentration (and intensity) only changes at downstream junctions. Paired inlets do not constitute a downstream junction.
2 HGL must be below grade along main or at least 1' below top of curb at each inlet (including entry loss of 1.25v2/2g).
3 Inlet spacing shall be determined by 5-year to top of curb or 100-year filling right-of-way, whichever is most restrictive.
4 Minimum head loss shall be 0.10 feet in a subcritical flow regime. Supercritical flow regimes do not generate head losses.

Figure 3.10 Computations Sheet for Storm Drains

Table Column Description

Column 21 Enter the required slope of the frictional gradient (hydraulic gradient) determined by Manning's equation. The pipe shall be designed on a grade such that the inside crown of the pipe coincides or is below the HGL when flowing full. In a partial flow condition, the friction slope is the slope of the water surface and should follow the slope of the pipe.

Column 22 This is the beginning hydraulic gradient of the line. It is equal to the Design HGL (Column 31) for the next downstream segment, or the beginning HGL of the system as described above.

Column 23 This is the upstream HGL before the structure and is calculated as Column 22 plus the friction loss (Column 3 times Column 21).

Column 24 Velocity of flow in incoming pipe (main line) at the junction, inlet or manhole at the design point identified in Column 2.

Column 25 Velocity of flow in outgoing pipe (i.e. the pipe segment being analyzed) at junction, inlet or manhole at design point identified in Column 2.

Column 26 Velocity head of the velocity in Column 24.

Column 27 Velocity head of the velocity in Column 25.

Column 28 Head loss coefficient "Kj", at junction, inlet or manhole at design point from Table 3.12, Table 3.13, or Table 3.14, or from Figure 3.8 and Figure 3.9.

Column 29 Multiply Column 26 by Column 28.

Column 30 Head Loss at Structure. At a junction or change in pipe size, this is Column 27 minus Column 29. At a bend or inlet, this is Column 27 times Column 28. In all cases this is 0.10' minimum.

EXCEPTION: In a supercritical flow regime with partial flow conditions, head losses are not generated at upstream junctions. These may be designated as "SUPERCRITICAL PARTIAL FLOW" in the head loss calculations, but must be supported by Froude Number in the comments column. Any other proposed deviations from standard head loss calculations due to other unusual flow regimes must be accepted by TPW on a case-by-case basis.

Column 31 Design HGL at the design point identified in Column 2. Column 23 plus Column 30. This is the beginning HGL (Column 22) for any upstream pipe discharging into that junction.

Column 32 Invert elevation for the pipe being analyzed at the downstream storm drain station in Column 1.

Column 33 Invert elevation for the pipe being analyzed at the design point (upstream storm drain station) in Column 2.

Column 34 Top of curb elevation at the design point in Column 2.

The above procedure is followed for each section of the storm drain. At the outfall, the hydraulic gradient of the line must be at the same elevation or above the gradient of the conduit or channel receiving the storm runoff discharge. *See Sections 1.2.10 iSWM Hydraulics Technical Manual* for guidance on outfall hydraulic gradients. In lieu of the guidance in the *Sections 1.2.10 iSWM Hydraulics Technical Manual* it is acceptable to perform a detailed hydrologic and hydraulic study of the watershed of the receiving stream to determine the connected outfall hydraulic gradient.

With the hydraulic gradient established for a particular line, considerable latitude is available for the physical placement of the pipe flow line elevations. The inside top of the pipe must be on or below the hydraulic gradient, thus allowing the pipe to be lowered where necessary to maintain proper cover and to minimize grade conflicts with existing utilities.

3.8.4 *Hydraulic Design Criteria for Channels, Culverts, Bridges and Detention Structures*

Introduction

This chapter is intended to provide design criteria and guidance on several on-site flood mitigation system components, including culverts, bridges, vegetated and lined open channels, storage design, outlet structures, and energy dissipation devices for outlet protection.

Open Channels

Design Frequency

The CFW requires that open channels are designed for the flood mitigation storm for fully developed watershed conditions. Channels may be designed with multiple stages (e.g., a "low-flow" or "pilot" channel section for common recurring flows, and a high flow section that contains the design discharge). The "low-flow" or "pilot" channel shall convey 2% of the design flood mitigation storm discharge.

General Criteria

- If relocation of a stream channel is unavoidable, the cross-sectional shape, meander, pattern, roughness, sediment transport, and slope shall conform to the existing conditions insofar as practicable. Energy dissipation will be necessary when existing conditions cannot be duplicated.
- Streambank stabilization shall be provided, when appropriate, as a result of any stream disturbance such as encroachment and shall include both upstream and downstream banks as well as the local site.
- HEC-RAS, or similarly capable software accepted by the City, shall be used to confirm the water surface profiles in open channels. Refer to Appendix B, Table B.1, Stormwater Modeling Programs and Design Tools for other additional acceptable hydraulic software programs.
- The final design of artificial open channels shall be consistent with the velocity limitations for the selected channel lining. Maximum velocity values for selected lining categories are presented in Table 3.16 and Table 3.17. Seeding and mulch shall only be used when the design value does not exceed the allowable value for bare soil. Velocity limitations for vegetative linings are reported in Table 3.17. Vegetative lining calculations and stone riprap procedures are presented in this Chapter and in *Section 3.2 of the Hydraulics Technical Manual.*
- The design of stable rock riprap lining depends on the intersection of the velocity (local boundary shear) and the size and gradation of the riprap material. More information on calculating acceptable riprap velocity limits is available in *Section 3.2.7 of the Hydraulics Technical Manual.* The Gregory Method shall be used for riprap designing in CFW.

Normal Depth (Uniform Flow):

For uniform flow calculations, the theoretical channel dimensions, computed by the slope-area methods outlined in this manual, are to be used only for an initial dimension in the design of an improved channel. Exceptions will be for small outfall channels (with the approval of TPW) with the following options:

- Completely contained on the development site for on-site drainage.
- Where no off-site drainage easement is required (i.e. not crossing or adjacent to another property that could be flooded if design storm occurs).
- No nearby downstream restrictions.
- Where peak discharge is 10 cfs or less.

Backwater Profile (Gradually Varied Flow):

CFW requires a hand computed or HEC-RAS backwater/frontwater analysis on any proposed open channel to determine the actual tailwater elevations, channel capacity and freeboard, and impacts on adjacent floodplains. If a stream or creek has an effective FEMA model, the engineer will be required to use a computer program for the analysis. 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 will not be allowed except under unusual circumstances, with special approval of the City staff, through an accepted variance request Appendix A, form CFW-7. However, for lined channels, the hand computed frontwater or HEC-RAS analysis should include a mixed-flow regime analysis, to confirm no supercritical flow occurs. CFW 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 1.1 times critical depth.

Channel Transitions or Energy Dissipation Structures or Small Dams

A HEC-RAS model or complete hand computed backwater analysis is a standard requirement for design of channel transitions (upstream and downstream), energy dissipation structures, and small dams. A backwater analysis will be required by the CFW, either hand computed or HEC-RAS, 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 six (6) feet). 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. For larger dams, a hydrologic routing will be required, as well as hydraulic analysis, to determine impacts of the proposed structure on existing floodplains and adjacent properties.

<u>Design Criteria</u>

Lined Channels (Figure 3.11 and Figure 3.12)

1. Channels shall be trapezoidal in shape and lined with reinforced concrete in accordance with City Standards and Specifications with side slopes of two (2) feet horizontal to one (1) foot vertical or otherwise to such standards, shape and type of lining as may be accepted by the TPW. The lining shall extend to and include the water surface elevation of the 100-year design storm plus one (1) foot of freeboard for the fully developed flood mitigation storm.
2. The channel bottom must be a minimum of eight (8) feet in width. (Overflow structures for storm sewer system sumps may have a minimum bottom width of six (6) feet.)
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 feet upstream of a bridge to twenty-five (25) feet downstream of a bridge. Hydraulic jumps shall not be allowed from the face of a culvert to fifty (50) feet upstream from that culvert. In general, channels having supercritical flow conditions are discouraged.
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, above).
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.
6. A chain link fence six (6) feet in height or other fence as accepted by the TPW shall be constructed on each side of the concrete or gabion channel lining.
7. TPW may require a geotechnical study and/or an underground drainage system design for concrete lined channels.
8. See CFW Standard Details for concrete lined channel section.

Earthen Channels (Figure 3.13 and Figure 3.14)

1. An earthen channel shall have a trapezoidal shape with side slopes not steeper than a 4:1 (horizontal and vertical) ratio and a channel bottom at least twelve (12) feet in width.
2. One (1) foot of freeboard above the flood mitigation frequency fully developed water surface elevation must be provided within all designed channels at all locations along the channel.
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. No channel shall be accepted for maintenance by the City until a uniform (e.g., evenly distributed, without large bare areas) vegetative cover with a density of 70% has been established.
4. Each reach of a channel must have a ramp for maintenance access. Ramps shall be at least ten (10) feet wide and have 15% maximum grade. Twelve (12) feet width is required if the ramp is bounded by vertical walls.
5. Minimum channel slope is 0.0020 ft/ft (0.20%) unless accepted by TPW.
6. Erosion protection shall be provided at outfall to the receiving stream. The outfall of the earthen channel shall meet the flowline of the receiving stream or a drop structure shall be provided.

Roadside Ditches (Figure 3.15)

1. A roadside ditch (“rural”) street section is permissible only as specifically accepted by TPW. No median ditches are allowed.
2. The design storm for roadside ditches shall be the fully developed conditions for the flood mitigation storm. The flood mitigation storm shall not exceed the right-of-way capacity defined as the natural ground at the right-of-way line or top of roadside ditch, unless contained within a designated drainage easement.

Design Considerations

1. For grass lined sections, the maximum design velocity shall be as defined in Table 3.17 for the flood mitigation design storm (Higher velocities justified by a sealed geotechnical study).
2. A grass lined or unimproved roadside ditch shall have minimum two (2) feet bottom width and side slopes no steeper than four horizontal to one vertical (4:1). There shall be a four (4) foot strip at maximum 2% cross slope between the edge of pavement and the beginning of the ditch.
3. Minimum grades for roadside ditches shall be 0.0040 ft/ft (0.40%).
4. Manning’s roughness coefficient for analysis and design of roadside ditches are presented in Table 3.15, Table 3.16, and Table 3.17 and in *Section 3.2.3 in the iSWM Hydraulics Technical Manual.*
5. Maximum depth will not exceed four (4) feet from center-line of pavement (highest elevation in pavement section) except as specifically accepted by TPW.
6. If the ditch extends beyond the right-of-way line, an additional drainage easement shall be dedicated extending at least two (2) feet beyond the top of bank. Utility easements must be separate and beyond any drainage easements.
7. Hydraulic analysis of roadside ditches will require a HEC-RAS analysis for discharges greater than 10 cfs or where conditions other than normal depth are anticipated.

Culverts in Roadside Ditches

1. Culverts will be placed at all driveway and roadway crossings and other locations where appropriate.
2. Erosion protection will be provided at the upstream and downstream ends of all culverts.
3. The size of culvert used shall not create a head loss of more than two-tenths (0.20) foot greater than the normal water surface profile without the culvert unless one (1) foot of freeboard within the roadside ditch is provided. For rural subdivisions or other specific cases, a HEC-RAS analysis may not be

required with approval from TPW. In this case, roadside culverts are to be sized based on drainage area, assuming inlet control. Calculations are to be provided for each block based on drainage calculations.

4. Roadside ditch culverts will be no smaller than twenty-four (24) inches inside diameter or equivalent for roadway crossings and fifteen (15) inches for driveway culverts.
5. A driveway culvert schedule shall be included on the face of the plat. It shall include, for each lot, culvert flowline depth below top of pavement, number and size of pipe required, and horizontal distance from edge of pavement to center of culvert (based on horizontal control requirements above).

Channel Velocity Limitations

Maximum allowable:

- Lined Channels – Maximum velocities equal to fifteen (15 fps) feet per second. Exceptions can be granted by TPW, with justifiable, technical reasons.
- Grass Lined Channels – Maximum velocities refer to Table 3.17. Higher values can be justified by a sealed geotechnical study/analysis of soil type and conditions.

Critical Flow Calculations

Section 3.2.5 Critical Flow Calculations of the *iSWM Hydraulics Technical Manual* is for reference only.

Vegetative Design

Section 3.2.6 Vegetative Design of the *iSWM Hydraulics Technical Manual* is for reference only.

Stone Riprap Design

Riprap design is to be by Method #2 (Gregory Method) described in *Section 3.2.7 of the iSWM Hydraulics Technical Manual.* A properly designed geotextile material is required under the granular bedding. The CFW standard specifications give guidance on the type of geotextile to be used. Regardless of computed thickness the minimum allowable riprap thickness is twelve (12) inches.

Section 3.2.7 of the iSWM Hydraulics Technical Manual, Stone Riprap Design Method #1: Maynard and Reese, is for reference only.

Grouted Riprap

The CFW will allow grouted stone riprap as an erosion control feature. However, the design thickness of the stone lining will 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. The Gregory Method shall be utilized. Table 3.20 shall be used to report results of the rip rap design utilizing the Gregory method.

Uniform Flow – Example Problems

Section 3.2.9 Uniform Flow – Example Problems in the *iSWM Hydraulics Technical Manual* are for reference only.

Rectangular, Triangular, and Trapezoidal Open Channel Design

Section 3.2.11 Rectangular, Triangular, and Trapezoidal Open Channel Design – Example Problems in the iSWM Hydraulics Technical Manual are for reference only.

Table 3.15 City of Fort Worth Manning's Roughness Coefficients for Design

Lining Type	Manning's n*	Comments
Grass Lined	0.035 0.050	Use for velocity check Use for channel capacity check (freeboard check)
Concrete Lined	0.015	
Rock Riprap	0.040	$n = 0.0395 d_{50}^{1/6}$ where d_{50} is the stone size of which 50% of the sample is smaller
Grouted Riprap	0.028	FHWA (Federal Highway Administration)

*Note: For analysis, Manning's coefficients shall be the prevailing condition.

Table 3.16 Roughness Coefficients (Manning's n) and Allowable Velocities for Natural Channels

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

Table 3.16 Roughness Coefficients (Manning's n) and Allowable Velocities for Natural Channels

Channel Description	Manning's n	Max. Permissible Channel Velocity (ft/s)
UNLINED NON-VEGETATED CHANNELS		
Sandy Soils	0.030	1.5 to 2.5
Silts	0.030	0.7 to 1.5
Sandy Silts	0.030	2.5 to 3.0
Clays	0.030	3.0 to 5.0
Coarse Gravels	0.030	5.0 to 6.0
Shale	0.030	6.0 to 10.0
Rock	0.025	15.0
For natural channels with specific vegetation type, refer to Table 3.17 for more detailed velocity control.		

Table 3.17 Maximum Velocities for Vegetative Channel Linings

Vegetation Type	Slope Range (%)[1]	Maximum Velocity[2] (ft/s)
Bermuda grass	0-5	6.0
Bahia		4.0
Tall fescue grass mixtures[3]	0-10	4.0
Kentucky bluegrass	0-5	6.0
Buffalo grass	5-10 >10	5.0 4.0
Grass mixture	0-5[1] 5-10	4.0 3.0
Sericea lespedeza, Weeping lovegrass, Alfalfa	0-5[4]	3.0
Annuals[5]	0-5	3.0
Sod		4.0
Lapped sod		5.0

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

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

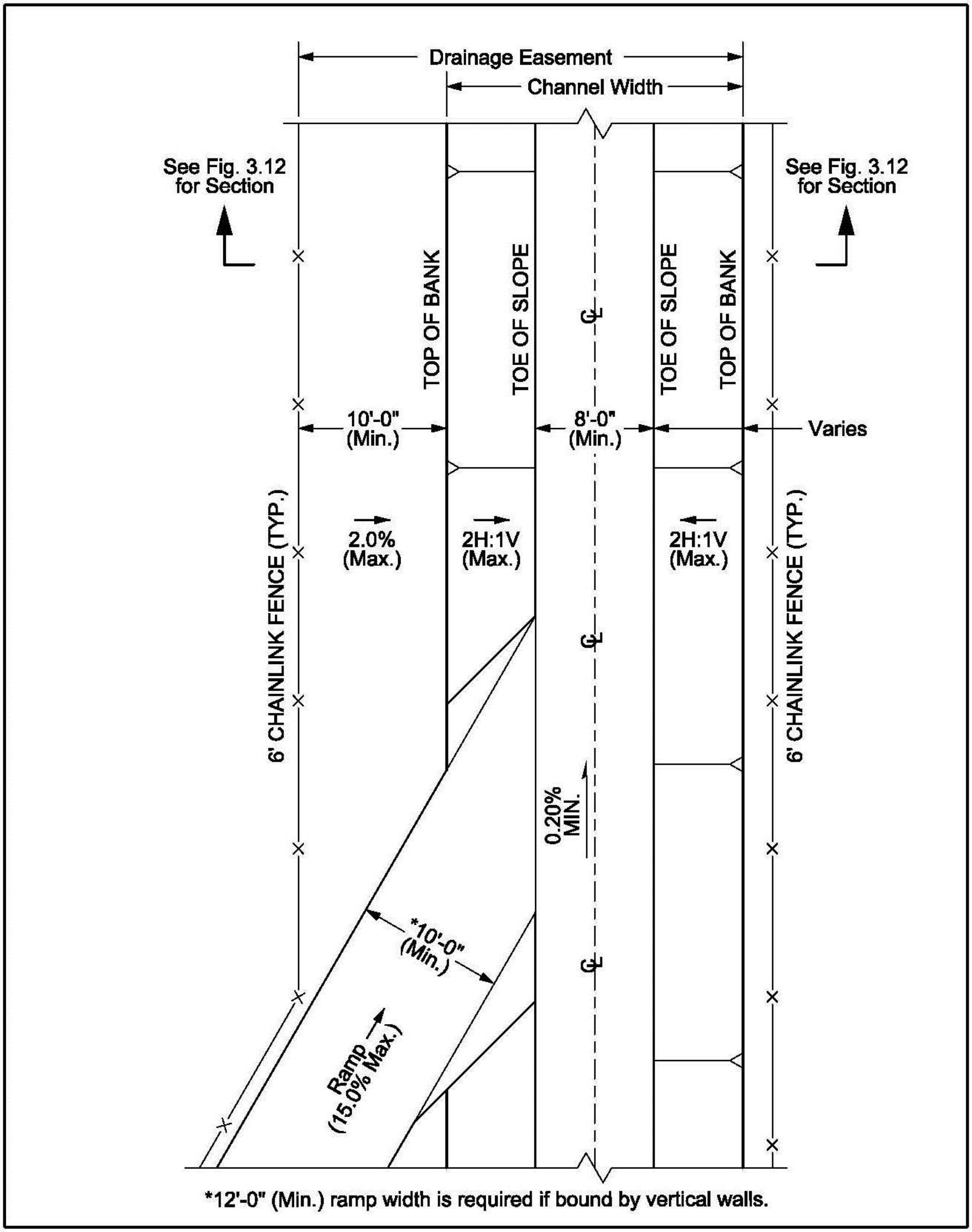


Figure 3.11 Typical Plan – Trapezoidal Concrete-Lined Channel

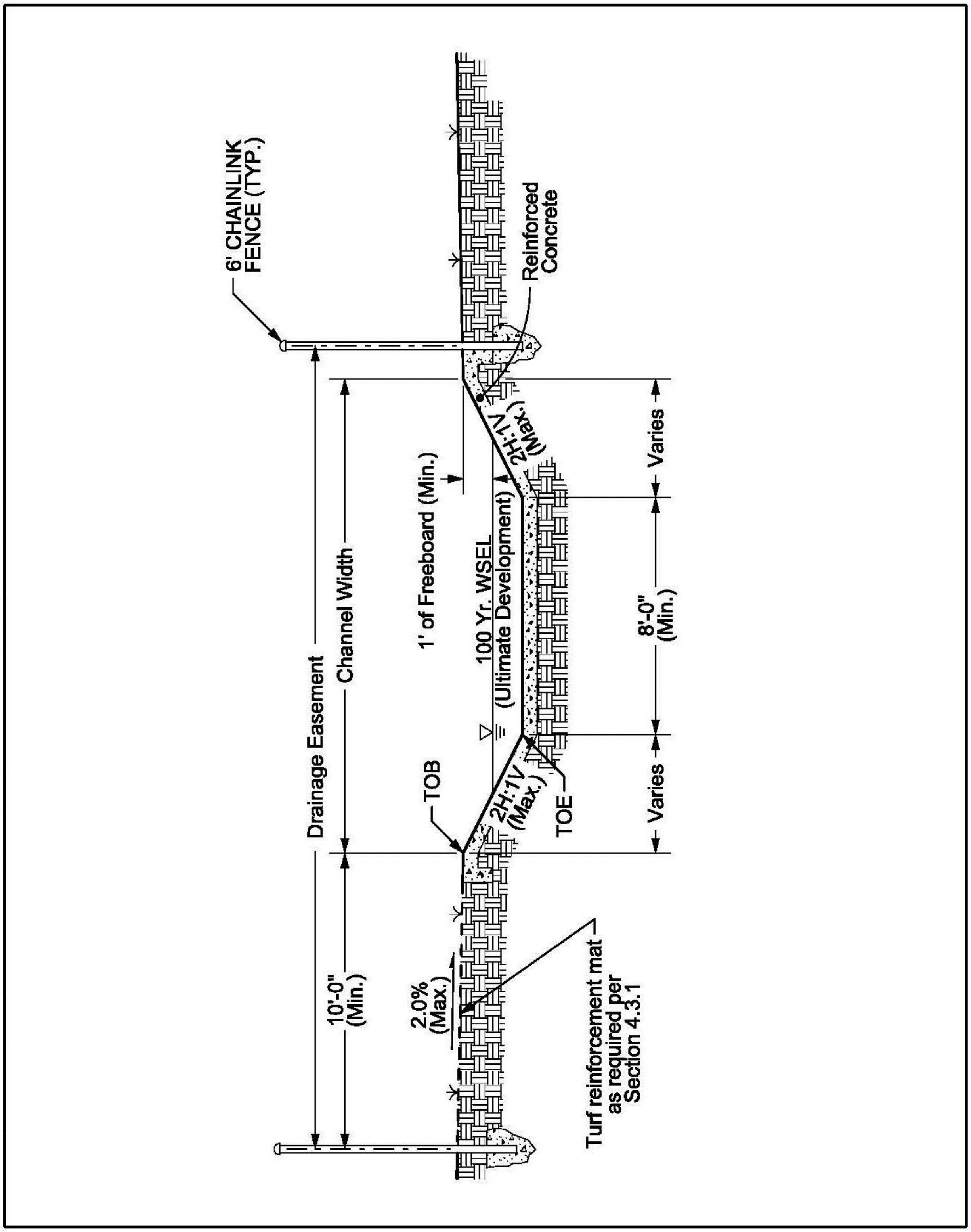


Figure 3.12 Typical Section – Trapezoidal Concrete-Lined Channel

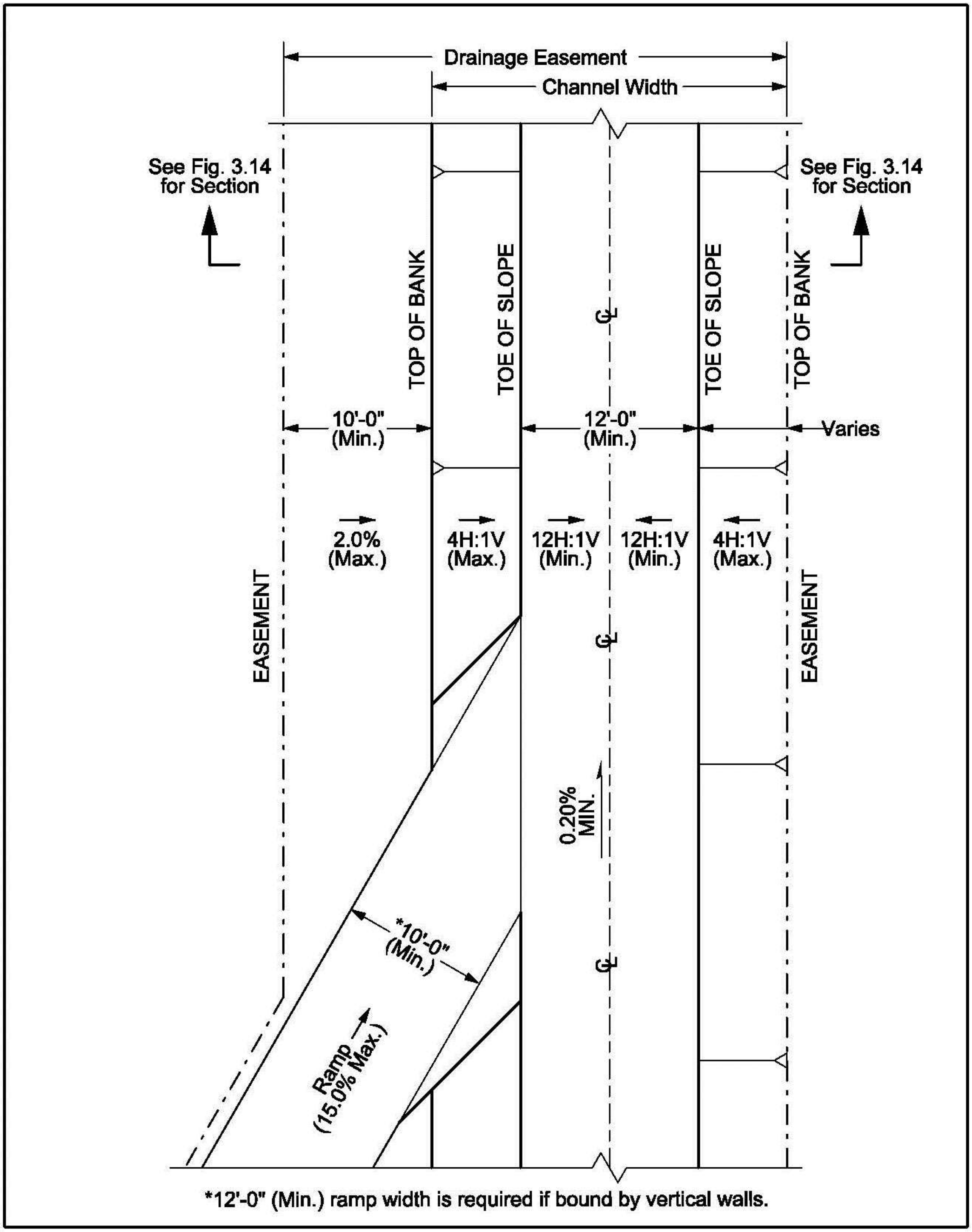


Figure 3.13 Typical Plan – Trapezoidal Earthen Channel

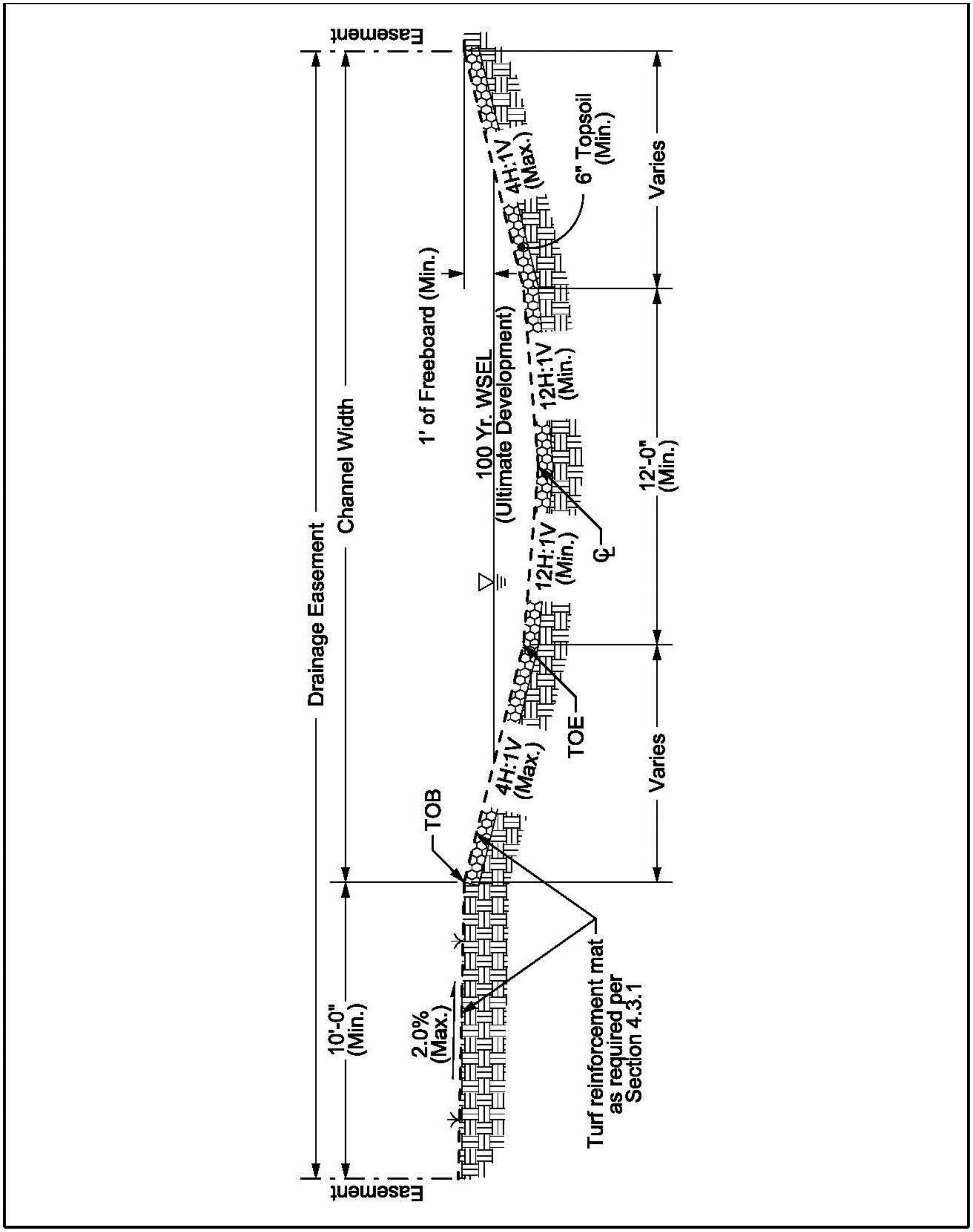


Figure 3.14 Typical Section – Trapezoidal Earthen Channel

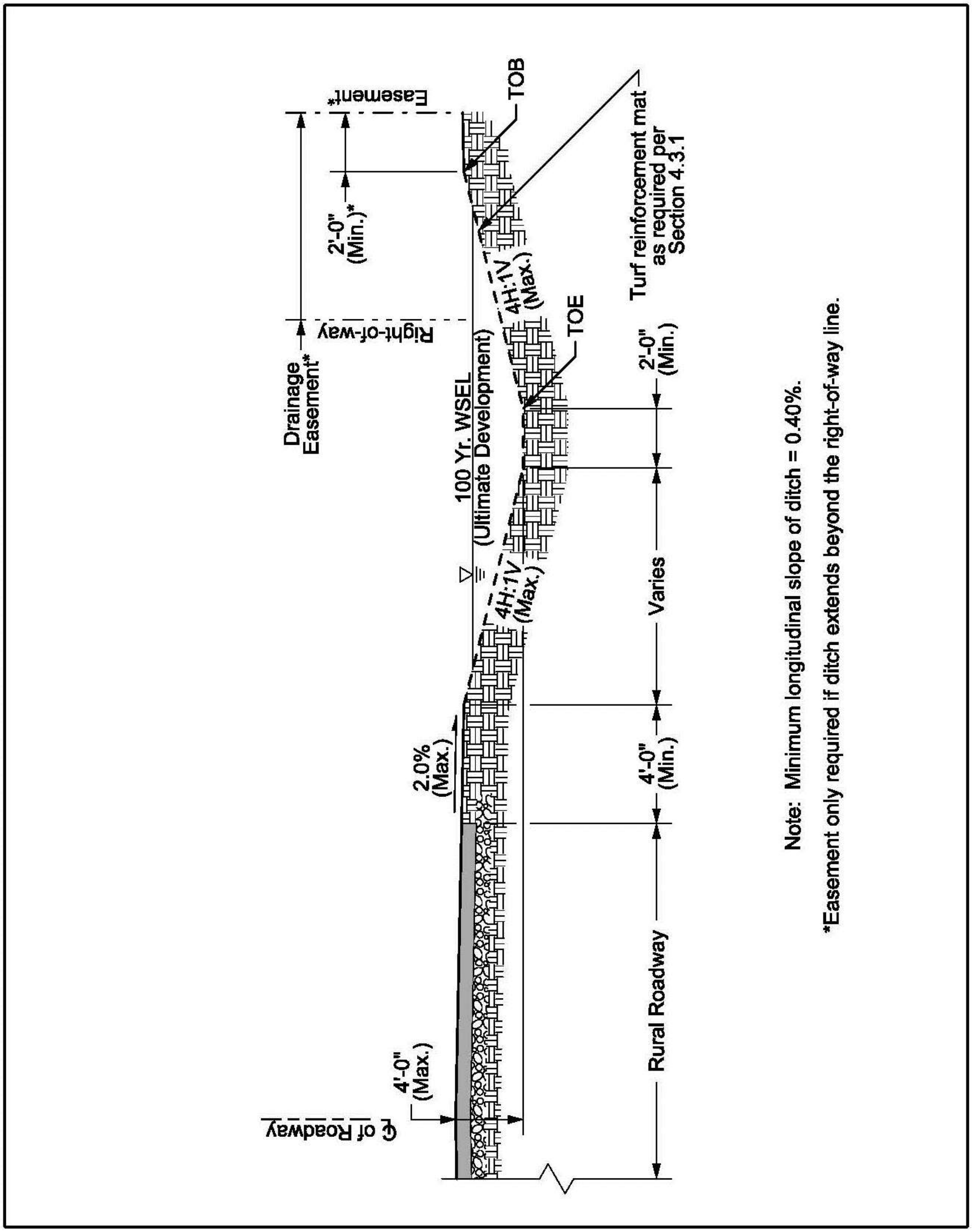


Figure 3.15 Typical Section – Rural Roadside Ditch

Vegetative Design (For Reference Only)

- A two-part procedure is required for final design of temporary and vegetative channel linings.
    - Part 1, the design stability component, involves determining channel dimensions for low vegetative retardance conditions, using Class D as defined in Table 3.18.
    - Part 2, the design capacity component, involves determining the depth increase necessary to maintain capacity for higher vegetative retardance conditions, using Class C as defined in Table 3.18.
- If temporary lining is to be used during construction, vegetative retardance Class E shall be used for the design stability calculations.
- If the channel slope exceeds 10%, or a combination of channel linings will be used, additional procedures not presented below are required. References include HEC-15 (USDOT, FHWA, 1986) and HEC-14 (USDOT, FHWA, 1983).

Table 3.18 Classification of Vegetal Covers as to Degrees of Retardance

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

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

Culverts

<u>Design Frequency</u>

Culverts are cross drainage facilities that transport runoff under roadways or other improved areas.

- Culverts shall be designed for the fully developed conditions flood mitigation storm or in accordance with TxDOT requirements, whichever is more stringent. Consideration when designing culverts includes: roadway height, tailwater or depth of flow, structures and property subject to flooding, emergency access, and road replacement costs.
- The flood mitigation storm shall be routed through all culverts to confirm building structures (e.g., houses, commercial buildings) are not flooded or increased damage does not occur to the roadway or adjacent property for this design event.
- For multiple barrel culverts the CFW requires the placement of one of the barrels at the flowline of the stream with the other barrels at a higher elevation to create a single flow path for lower flow and reduce sediment and debris accumulation. Where practical the low-flow portion of the low barrel(s) should convey 2% of the design 100-year discharge.

<u>Design Criteria</u>

Velocity Limitations

- The maximum velocity shall be consistent with channel stability requirements at the culvert outlet.
- Refer to Table 3.9 for maximum allowable velocities for reinforced concrete pipe. Outlet protection shall be provided where discharge velocities will cause erosive conditions.
- To ensure self-cleaning during partial depth flow, a minimum velocity of two and a half (2.5 fps) feet per second is required for the streambank protection storm when the culvert is flowing partially full.

Length and Slope

- The maximum slope using concrete pipe is 10% before pipe-restraining methods must be taken.
- Maximum vertical distance from throat of intake to flowline in a drainage structure is ten (10) feet.
- Drops greater than four (4) feet will require additional structural design.

Headwater Limitations

- The allowable headwater is the depth of water that can be ponded at the upstream end of the culvert during the design flood, which will be limited by one or more of the following constraints or conditions:
    1. Headwater will be non-damaging to upstream property.
    2. Culvert headwater plus twelve (12) inches of freeboard shall not exceed top of curb or pavement for low point of road over culvert, whichever is lower.
    3. Ponding depth will be no greater than the elevation where flow diverts around the culvert.
    4. Elevations will be established to delineate floodplain zoning.
- Either the headwater shall be set to produce acceptable velocities or stabilization/energy dissipation shall be provided where these velocities are exceeded.
- In general, the constraint that gives the lowest allowable headwater elevation establishes the criteria for the hydraulic calculations.

Tailwater Considerations

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

- For culverts that discharge to an open channel, the stage-discharge curve for the channel must be determined. See *Section 2.1.4 of the Hydraulics Technical Manual* on methods to determine a stage-discharge curve.
- If an upstream culvert outlet is located near a downstream culvert inlet, the headwater elevation of the downstream culvert will establish the design tailwater depth for the upstream culvert.
- If the culvert discharges to a lake, pond, or other major water body, the expected high water elevation of the particular water body will establish the culvert tailwater.

Other Criteria

- In designing debris control structures, the Hydraulic Engineering Circular No. 9 entitled Debris Control Structures or other accepted reference is required to be used.
- If storage is being assumed or will occur upstream of the culvert, refer to *Section 2.0 of the Hydraulics Technical Manual* regarding storage routing as part of the culvert design.
- Culvert skews shall not exceed 45 degrees as measured from a line perpendicular to the roadway centerline without approval.
- The minimum allowable pipe diameter shall be twenty-four (24) inches. A minimum diameter of eighteen (15) inches may be used for driveway culverts.
- Erosion, sediment control, and velocity dissipation shall be designed in accordance with *Section 4.0 of the Hydraulics Technical Manual*.

CFW requires a backwater analysis, by hand, or HEC-RAS to evaluate the proposed structure for final design. The Culvert Hydraulics Checklist Appendix A – City of Fort Worth Detailed Checklists (Form CFW-3) should be completed for each design.

Corrugated Metal Pipe Culvert

CMP culvert is not allowed in the CFW.

Nomographs

Nomographs are not allowed by CFW for final sizing of culverts. The reference for nomographs is FHWA HDS-5. A backwater analysis using HEC-RAS is required.

Culvert Design Example

Section 3.3.5 Culvert Design Example of the iSWM Hydraulics Technical Manual is adopted with the following modifications. The nomographs procedure is acceptable for preliminary sizing only.

Design Procedures for Beveled-Edged Inlets

Section 3.3.6 Design Procedures for Beveled-Edged Inlets of the iSWM Hydraulics Technical Manual is adopted with the following modifications. The nomographs procedure is acceptable for preliminary sizing only.

Flood Routing and Culvert Design

Section 3.3.7 Flood Routing and Culvert Design of the *iSWM Hydraulics Technical Manual* is for reference only.

Erosion, Sediment Control, Velocity Dissipation

See *Section 3.2.7 iSWM Hydraulics Technical Manual Gregory Method*, for culvert outfall protection for riprap sizing, gradation, and bedding. Use *Section 4.0* of that Manual for spatial dimensions of riprap and other energy dissipation design.

Bridges

Design Frequency

Bridges are cross drainage facilities with a span of twenty (20) feet or larger.

- Bridges shall be designed for the flood mitigation storm for fully developed watershed conditions or in accordance with TxDOT requirements, whichever is more stringent

Design Criteria

- A backwater analysis using HEC-RAS is used for final design of the proposed structure. For bridges up to 100 feet long, measured from abutment to abutment, two (2) feet of freeboard is required from design water surface elevation to low chord. For a bridge greater than one hundred (>100) feet long, one (1) foot of freeboard is required. Exceptions on freeboard must be accepted by TPW. Complete Bridge Hydraulics Documentation Checklist (Appendix A – City of Fort Worth Detailed Checklists, Form CFW-4).
- Backwater analysis will be required using HEC-RAS, for any proposed bridge, to determine accurate tailwater elevations, velocities, head losses, 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.
- The contraction and expansion of water through the bridge opening creates hydraulic losses. These losses are accounted for through the use of loss coefficients. Table 3.19 gives recommended values for the Contraction (K_c) and Expansion (K_e) Coefficients.

Table 3.19 Recommended Loss Coefficients for Bridges

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

Additional design guidance is located in *Section 3.4 of the Hydraulics Technical Manual.*

Detention Structures (Figure 3.17 and Figure 3.18)

Design Frequency

The streambank protection, conveyance, and flood mitigation storms for the 24-hour storm duration shall be used for design of detention structures. Analysis should consider both the existing watershed plus developed site conditions and fully developed watershed conditions.

Design Criteria

Stormwater detention shall be provided to mitigate increased peak flows in the CFW waterways in specific circumstances as defined below. The purpose of the mitigation is to minimize downstream flooding impacts from upstream development. In some instances, detention may be shown to exacerbate potential flooding conditions downstream. Therefore, the Zone of Influence criteria shall be applied in addition to these criteria. Design data for dams will be submitted to the CFW on Form CFW-5, Preliminary and Final Dam Maintenance Emergency Action Plan.

1. Detention Basins may be required when downstream facilities within the Zone of Influence are not adequately sized to convey a design storm based on current City criteria for hydraulic capacity.

Detention basins shall not be required if downstream improvements that will result in sufficient hydraulic capacity are proposed by the City within a relatively short period of time (12 months or less).

2. Proposed stormwater 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 (see *Chapter 1.5.2 in the iSWM Hydrology Technical Manual*) 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. Modified Rational Method is not acceptable for basis in series. Note that the only Modified Rational Method allowed is defined in *Chapter 1.5 in the iSWM Hydrology Technical Manual.* The purpose of the preliminary plat is to denote future improvements that shall be required. Sizing is not exact and may result in undersized detention/retention pond requirements.
4. Detention Basins draining watersheds over 25 acres shall be designed using a detailed unit hydrograph method acceptable to the City of Fort Worth. These include Snyder's Unit Hydrograph (greater than one hundred (>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 1.2 in the iSWM Hydrologic Technical Manual*).
5. Detention Basins shall be designed for the Streambank Protection, Conveyance, and Flood Mitigation storms for the 24-hour storm duration. Analysis of additional storm return events may be required where storm sewers are included in the watershed.
6. Detention basin embankments shall have a ten (10) foot crown width. For access to the pond bottom, provide a maintenance ramp of at least ten (10) feet wide with a maximum slope of 15%. Twelve (12) feet width is required next to vertical walls.
7. Detention Basins shall be designed with at least one ten (10) foot wide maintenance access location, with a 15% maximum grade.
8. A freeboard of one (1) foot will be required for all detention ponds.
9. Grassed side slopes shall be 4:1 or flatter and less than twenty (20) feet in height. Slopes protected with concrete riprap shall be no steeper than 2:1. A detailed geotechnical investigation and slope stability analysis is required for grass and concrete slope pavement slopes greater than twelve (12) feet in height. Concrete lined or structural embankment can be steeper with the approval of the TPW. See final stabilization requirements in Chapter 4.3.1.
10. A calculation summary shall be provided on construction plans. For detailed calculations of unit hydrograph studies, a separate report shall be provided to the City for review and referenced with date, engineer and title on the construction plans. Stage-storage-discharge values shall be tabulated and flow calculations for discharge structures shall be shown on the construction plans.
11. An emergency spillway shall be provided at the 100-year maximum storage elevation with sufficient capacity to convey the fully urbanized flood mitigation storm assuming blockage of the closed conduit portion outlet works with six (6) inches of freeboard. Spillway requirements must also meet all appropriate state and federal criteria. Design calculations will be added for all spillways.
12. All detention basins shall be stabilized against significant erosion and shall include a maintenance plan.
13. A landscape plan shall be provided for all detention ponds.
14. Stormwater Facility Maintenance Agreements (SWFMA) will be provided for all detention and retention facilities.
15. Detention basin outlet structures shall be designed to minimize the likeliness of clogging and shall include features to prevent activation of the emergency spillway if such activation would create an

uncontrolled discharge. The use of orifice plates or non-standard structures is subject to the approval of TPW.

16. Dry detention basins are sized to temporarily store the volume of runoff required to provide flood protection up to the flood mitigation storm, if required. Dry detention basin design should consider multiple uses such as recreation. As such, pilot channels should follow the edges of the basin to the extent practical. The bottom of the basin shall have a minimum grade of 1% per Figure 3.17, although swales may have minimum grades of 0.5%. Concrete flumes shall be provided for slopes less than 0.5% and may have slopes as shallow as 0.2%. They shall be at least six (6) feet wide.
17. Extended detention dry basins are sized to provide extended detention of the streambank protection volume over 24 hours and can also provide additional storage volume for normal detention (peak flow reduction) of the flood mitigation storm event.
18. Routing calculations must be used to demonstrate that the storage volume and outlet structure configuration are adequate. See *Section 2.0 of the Hydraulics Technical Manual* for procedures on the design of detention storage.
19. State TCEQ rules and regulations regarding impoundments shall be followed. According to current (2009) guidelines, dams fall under the jurisdiction of the TCEQ Dam Safety Program if they meet one or more of the following criteria (See *NCTCOG iSWM Program Guidance – Dam Safety and Water Rights*):
    - they have a height greater than or equal to 25-feet and a maximum storage capacity greater than or equal to fifteen (15) acre-feet;
    - they have a height greater than six (6) feet and a maximum storage capacity greater than or equal to fifty (50) acre-feet.
    - they are a high or significant hazard dam as defined in the regulations (relating to Hazard Classification Criteria), regardless of height or maximum storage capacity; or
    - they are used as a pumped storage or terminal storage facility.
20. In accordance with Texas Water Code §11.142, all permanent surface impoundments not used solely 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.

Items 6, 9, 11, 12, 19 and 20 also apply to amenity ponds.

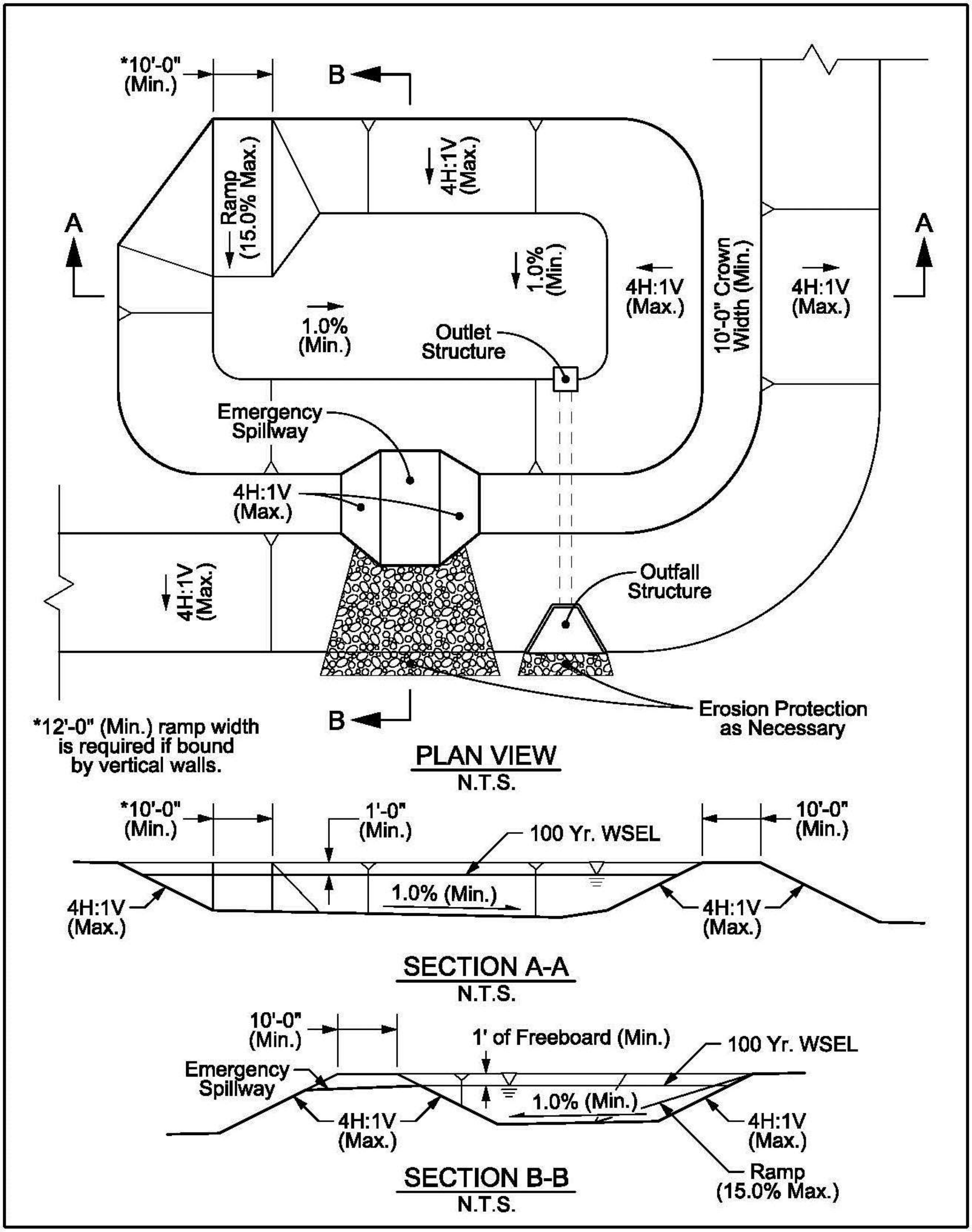


Figure 3.16 Dry Detention Pond Schematic

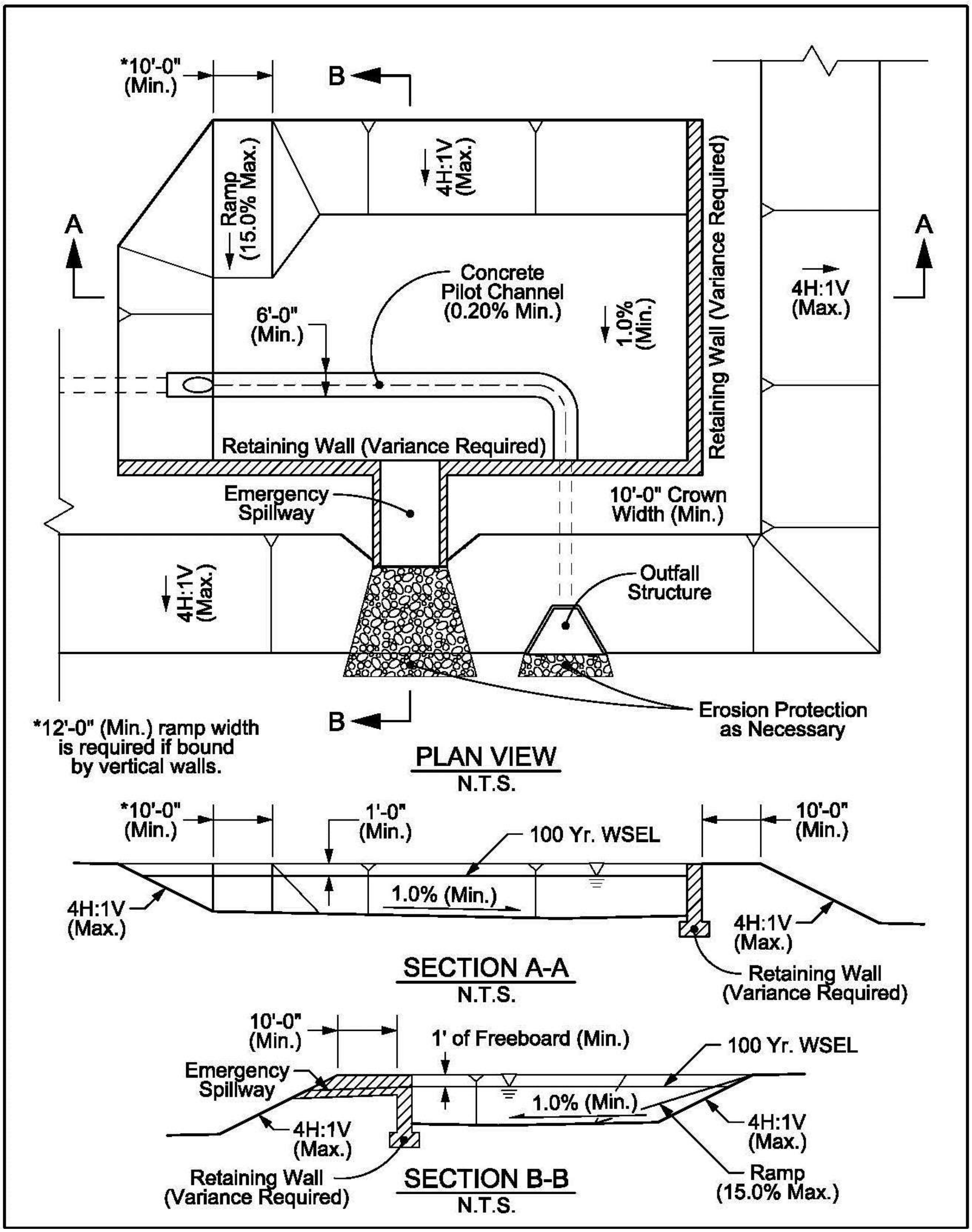


Figure 3.17 Dry Detention Pond W/Pilot Channel Schematic

Outlet Structures

Extended detention (ED) orifice sizing is required in design applications that provide extended detention for downstream streambank protection or the ED portion of the water quality protection volume. The release rate for both the WQ_v and SP_v shall discharge the ED volume in a period of 24 hours or longer. In both cases an extended detention orifice or reverse slope pipe must be used for the outlet. For a structural control facility providing both WQ_v extended detention and SP_v control (wet ED pond, micropool ED pond, and shallow ED wetland), there will be a need to design two outlet orifices – one for the water quality control outlet and one for the streambank protection drawdown.

Design Frequency

- Water quality storm
- Streambank protection storm
- Conveyance storm
- Flood mitigation storm

Design Criteria

- Estimate the required storage volumes for streambank protection, conveyance storm, and flood mitigation.
- Design extended detention outlets for each storm event.
- Outlet velocities shall be within the maximum allowable range based on channel material as shown in Table 3.16 and Table 3.17.
- Design necessary outlet protection and energy dissipation facilities to avoid erosion downstream from outlet devices and emergency spillway(s).
- Perform buoyancy calculations for the outlet structure and footing. Flotation will occur when the weight of the structure is less than or equal to the buoyant force exerted by the water.

Additional design guidance is located in Section 2.2 of the *Hydraulics Technical Manual.*

Energy Dissipation

Design Frequency

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

- Conveyance storm
- Flood mitigation storm (100-year)
- Assume fully developed watershed conditions

Design Criteria

- Energy dissipaters are engineered devices such as rip-rap aprons or concrete baffles placed at the outlet of stormwater conveyance systems for the purpose of reducing the velocity, energy and turbulence of the discharged flow.
- Erosion at culvert, pipe and engineered channel outlets are common. Determination of the flow conditions, scour potential, and channel erosion resistance shall be standard procedure for all designs.
- Energy dissipaters shall be employed whenever the velocity of flows leaving a stormwater management facility exceeds the erosion velocity of the downstream area channel system.
- Energy dissipater designs will vary based on discharge specifics and tailwater conditions.
- Outlet structures shall provide uniform redistribution or spreading of the flow without excessive separation and turbulence.

- Energy dissipaters are a required component of the *iSWM* Construction Plan.

Recommended Energy Dissipaters for outlet protection include the following:

- Riprap apron
- Riprap outlet basins
- Baffled outlets
- Grade Control Structures

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

Channel Transitions, Energy Dissipation Structures, or Small Dams

A backwater analysis is required by the CFW, using HEC-RAS or other accepted computer programs as defined in Appendix B, to determine accurate tailwater elevation and velocities, head losses, 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 six (6) feet). 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. For larger dams, a hydrologic routing will be required, as well as hydraulic analysis, to determine impacts of the proposed structure on existing floodplains and adjacent properties.

Examples of Open Channel Transition Structures

See drawings in Appendix C – City of Fort Worth Miscellaneous Details and Specifications Straight Drop Structure, Bureau of Reclamation Baffled Chute (Basin IX). The computer program associated with FHWA Hydraulic Engineering Circular No. 14 is “HY8” dated March 2012. This program provides guidance in the selection and sizing of a broad range of energy dissipaters including some of those listed in *Section 4.0 of the iSWM Hydraulics Technical Manual.*

Stone Rip Rap Design – Gregory Method Results Table

Table 3.20 Rock Rip Rap Sizing – Gregory Method shall be used to report results of the Gregory channel riprap design method. Table 3.21 shall be used to report the results of the Gregory Culvert Outfall Protection Method. A properly designed bedding layer is required under the granular bedding.

Table 3.20 Rock Riprap Sizing – Gregory Method				
From *Section 3.2.7 iSWM Hydraulics Technical Manual*, September 2014				
Step 1: Calculate Boundary Shear:	Units	Size by Frequency (Select Largest)		
		100-year	5-year	1-year
Q = peak discharge	cfs			
b = bottom width of channel	feet			
y = depth of peak flow	feet			
γS **=** specific weight of stone (150-175 lb/ft³)	lb/ft³			
A = cross-sectional area of flow	ft²			
WP = wetted perimeter	feet			
R = hydraulic radius of channel = **A/WP**	feet			
S = slope of energy gradient	ft/ft			
To = average tractive stress on channel bottom = **γ_w*R*S** (γ_w = 62.4 lb/ft³)	lb/ft²			
Φ = Angle of side slope (14° for 4:1 slopes)	degrees			
Θ = Angle of repose of rock, usually 40°)	degrees			
To' = average tractive stress on channel side slopes = **To[1-(Sin2Φ/Sin2Θ)]**1/2	lb/ft²			
Step 2: Determine the tractive stress in a bend in the channel:				
T = the greater of To or To' from above	lb/ft²			
r = centerline radius of bend (10000' if straight)	feet			
w = water surface width at upstream end of bend	feet			
Tb = local tractive stress in bend = **3.15T(r/w)**-1/2	lb/ft²			
Step 3: Determine D50 size of riprap stone (size at which 50% of the gradation is finer weight):				
T = Design shear stress (greatest of To, To' or Tb)	lb/ft²			
D50 = required average stone size = **T/0.04γ_s-γ_w)**	feet			
Maximum d50 (controlling size)	inches			
Step 4: Select minimum riprap thickness from grain size curves (*Fig. 3.12 to 3.17 iSWM Hydraulics Technical Manual*).				
D50 (max)= (Select from smaller side of band at 50% finer gradation)	lb/ft²			
Riprap Size = (min thickness is 12")	inches			
Step 5: Select riprap gradations table (*Fig. 3.18 to 3.19 iSWM Hydraulics Technical Manual*)				
Riprap Gradation Figure based on riprap thickness in Step 4	Figure			
Step 6: Select bedding thickness from grain size curves (*Fig. 3.12 to 3.17 iSWM Hydraulics Technical Manual*)				
Bedding Gradation Figure	Figure			
Note: See steps 7-10 in the *Section 3.2.7 for iSWM Hydraulics Technical Manual* additional guidance.				

Table 3.21 Rock Riprap Sizing – Culvert Outfall Protection				
From *Section 3.2.7 iSWM Hydraulics Technical Manual*, September 2014				
Determine D50 size of riprap stone (size at which 50% of the gradation is finer weight):	Units	Size by Frequency (Select Largest)		
		100-year	5-year	1-year
V = outfall velocity	ft/sec			
γ_S = specific weight of stone (150-175 lb/ft³)	lb/ft³			
D50 = $\mathbf{V^{1/2}/[1.8*(2g(\gamma_s-\gamma_w)/\gamma_w)^{1/2}]}$ (γw = 62.4 lb/ft³)	feet			
Maximum d50 (controlling size)	inches			

3.9 Stormwater Control Selection

3.9.1 *Control Screening Process*

Outlined below is a screening process for structural stormwater controls that can effectively treat the water quality volume, as well as provide water quantity control. This process is intended to assist the site designer and design engineer in the selection of the most appropriate structural controls for a development site and to provide guidance on factors to consider in their location. *This information is also contained in the iSWM Technical Manual – Site Development Controls section.*

The following four criteria shall be evaluated in order to select the appropriate structural control(s) or group of controls for a development:

- Stormwater treatment suitability
- Water quality performance
- Site applicability
- Implementation considerations

In addition, the following factors shall be considered for a given site and any specific design criteria or restrictions need to be evaluated:

- Physiographic factors
- Soils
- Special watershed or stream considerations

Finally, environmental regulations shall be considered as they may influence the location of a structural control on site or may require a permit.

The following steps provide a selection process for comparing and evaluating various structural stormwater controls using a screening matrix and a list of location and permitting factors. These tools are provided to assist the design engineer in selecting the subset of structural controls that will meet the stormwater management and design objectives for a development site or project.

Step 1 Overall Applicability

The following are the details of the various screening categories and individual characteristics used to evaluate the structural controls.

Table 3.22 - Stormwater Management Suitability

The first category in the matrix examines the capability of each structural control option to provide water quality treatment, downstream streambank protection, and flood control. A blank entry means that the structural control cannot or is not typically used to meet an *integrated* Focus Area. This does not necessarily mean that it should be eliminated from consideration, but rather it is a reminder that more than one structural control may be needed at a site (e.g., a bioretention area used in conjunction with dry detention storage).

Ability to treat the Water Quality Volume (WQv): This indicates whether a structural control provides treatment of the water quality volume (WQv). The presence of “P” or “S” indicates whether the control is a Primary or Secondary control, respectively, for meeting the TSS reduction goal.

Ability to provide Streambank Protection (SPv): This indicates whether the structural control can be used to provide the extended detention of the streambank protection volume (SPv). The presence of a “P” indicates that the structural control can be used to meet SPv requirements. An “S” indicates that the structural control may be sized to provide streambank protection in certain situations, for instance on small sites.

Ability to provide Flood Control (Qf): This indicates whether a structural control can be used to meet the flood control criteria. The presence of a “P” indicates that the structural control can be used to provide peak reduction of the flood mitigation storm event.

<u>Table 3.23 - Relative Water Quality Performance</u>

The second category of the matrix provides an overview of the pollutant removal performance for each structural control option when designed, constructed, and maintained according to the criteria and specifications in this manual.

Ability to provide TSS and Sediment Removal: This column indicates the capability of a structural control to remove sediment in runoff. All of the Primary structural controls are presumed to remove 70% to 80% of the average annual TSS load in typical urban proposed runoff (and a proportional removal of other pollutants).

Ability to provide Nutrient Treatment: This column indicates the capability of a structural control to remove the nutrients nitrogen and phosphorus in runoff, which may be of particular concern with certain downstream receiving waters.

Ability to provide Bacteria Removal: This column indicates the capability of a structural control to remove bacteria in runoff. This capability may be of particular concern when meeting regulatory water quality criteria under the Total Maximum Daily Load (TMDL) program.

Ability to accept Hotspot Runoff: This last column indicates the capability of a structural control to treat runoff from designated hotspots. Hotspots are land uses or activities that produce higher concentrations of trace metals, hydrocarbons, or other priority pollutants. Examples of hotspots might include: gas stations, convenience stores, marinas, public works storage areas, garbage transfer facilities, material storage sites, vehicle service and maintenance areas, commercial nurseries, vehicle washing/steam cleaning, landfills, construction sites, industrial sites, industrial rooftops, and auto salvage or recycling facilities. A check mark indicates that the structural control may be used on hotspot site. However, it may have specific design restrictions. Please see the specific design criteria of the structural control for more details in the Site Development Controls Technical Manual. Local jurisdictions may have other site uses that they designate as hotspots. Therefore, their criteria should be checked as well.

<u>Table 3.24 - Site Applicability</u>

The third category of the matrix provides an overview of the specific site conditions or criteria that must be met for a particular structural control to be suitable. In some cases, these values are recommended values or limits and can be exceeded or reduced with proper design or depending on specific circumstances. Please see the specific criteria section of the structural control for more details.

Drainage Area: This column indicates the approximate minimum or maximum drainage area considered suitable for the structural control practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway can be permitted if more than one practice can be installed. The minimum drainage areas indicated for ponds and wetlands should not be considered inflexible limits and may be increased or decreased depending on water availability (baseflow or groundwater), the mechanisms employed to prevent outlet clogging, or design variations used to maintain a permanent pool (e.g., liners).

Space Required (Space Consumed): This comparative index expresses how much space a structural control typically consumes at a site in terms of the approximate area required as a percentage of the impervious area draining to the control.

Slope: This column evaluates the effect of slope on the structural control practice. Specifically, the slope restrictions refer to how flat the area where the facility is installed must be and/or how steep the contributing drainage area or flow length can be.

Minimum Head: This column provides an estimate of the minimum elevation difference needed at a site (from the inflow to the outflow) to allow for gravity operation within the structural control.

Water Table: This column indicates the minimum depth to the seasonally high water table from the bottom or floor of a structural control.

Table 3.25 - Implementation Considerations

The fourth category in the matrix provides additional considerations for the applicability of each structural control option.

Residential Subdivision Use: This column identifies whether or not a structural control is suitable for typical residential subdivision development (not including high-density or ultra-urban areas).

Ultra-Urban: This column identifies those structural controls appropriate for use in very high-density (ultra-urban) areas, or areas where space is a premium.

Construction Cost: The structural controls are ranked according to their relative construction cost per impervious acre treated, as determined from cost surveys.

Maintenance: This column assesses the relative maintenance effort needed for a structural stormwater control, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging), and reported failure rates. It should be noted that all structural controls require routine inspection and maintenance.

The *Site Development Controls iSWM Technical Manual* contains an exhaustive discussion and detailed examples of stormwater 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 CFW encourages local developers to consider in their site planning. Although it is primarily oriented toward water quality issues, these stormwater controls bring additional and valuable benefits for flood control and streambank protection. Many of the listed stormwater control features and techniques enhance the aesthetics and value of land developments, as well as providing a drainage function.

Although the City of Fort Worth is currently emphasizing the streambank protection and flood control components of the *integrated* stormwater management approach, the Stormwater Control (Chapter 3.9) of applicable features may be implemented in local developments and redevelopments. The CFW does not mandate the use of any of these stormwater controls, but recognizes the inherent values of their application in overall stormwater management.

Therefore, the CFW adopts for design guidance and technical reference sections of the *iSWM Technical Manual*. There are, however, no CFW requirements for achieving Stormwater Quality (WQ_v) or Channel Protection (SP_v) volumes. Stormwater utility fee credits may be available for design practices meeting these standards. See Appendix F for detailed information.

Table 3.22 Stormwater Treatment Suitability					
Category	***integrated* Stormwater Controls**	**Stormwater Treatment Suitability**			
		Water Quality Protection	**Streambank Protection**	**On-Site Flood Control**	**Downstream Flood Control**
Bioretention Areas	Bioretention Areas	P	S	S	-
Channels	Enhanced Swales	P	S	S	S
	Channels, Grass	S	S	P	S
	Channels, Open	-	-	P	S
Chemical Treatment	Alum Treatment System	P	-	-	-
Conveyance System Components	Culverts	-	-	P	P
	Energy Dissipation	-	P	S	S
	Inlets/Street Gutters	-	-	P	-
	Pipe Systems	-	P	P	P
Detention	Detention, Dry	S	P	P	P
	Detention, Extended Dry	S	P	P	P
	Detention, Multi-purpose Areas	-	P	P	P
	Detention, Underground	-	P	P	P
Filtration	Filter Strips	S	-	-	-
	Organic Filters	P	-	-	-
	Planter Boxes	P	-	-	-
	Sand Filters, Surface/Perimeter	P	S	-	-
	Sand Filters, Underground	P	-	-	-
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	S	-	-	-
Infiltration	Downspout Drywell	P	-	-	-
	Infiltration Trenches	P	S	-	-
	Soakage Trenches	P	S	-	-
Ponds	Wet Pond	P	P	P	P
	Wet ED Pond	P	P	P	P
	Micropool ED Pond	P	P	P	P
	Multiple Ponds	P	P	P	P
Porous Surfaces	Green Roof	P	S	-	-
	Modular Porous Paver Systems	S	S	-	-
	Porous Concrete	S	S	-	-
Proprietary Systems	Proprietary Systems[1]	S/P	S	S	S
Re-Use	Rain Barrels	P	-	-	-
Wetlands	Wetlands, Stormwater	P	P	P	P
	Wetlands, Submerged Gravel	P	P	S	-

P = Primary Control: Able to meet design criterion if properly designed, constructed and maintained.

S = Secondary Control: May partially meet design criteria. May be a Primary Control but designated as a Secondary due to other considerations. For Water Quality Protection, recommended for limited use in accepted community-designated areas.

\- = Not typically used or able to meet design criterion.

[1] = The application and performance of propriety commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data if used as a primary control.

Table 3.23 Water Quality Performance

Category	*integrated* Stormwater Controls	Water Quality Performance			
		TSS/ Sediment Removal Rate	Nutrient Removal Rate (TP/TN)	Bacteria Removal Rate	Hotspot Application
Bioretention Areas	Bioretention Areas	80%	60%/50%	-	✓
Channels	Enhanced Swales	80%	25%/40%	-	✓
	Channels, Grass	50%	25%/20%	-	
	Channels, Open	-	-	-	
Chemical Treatment	Alum Treatment System	90%	80%/60%	90%	✓
Conveyance System Components	Culverts	-	-	-	
	Energy Dissipation	-	-	-	
	Inlets/Street Gutters	-	-	-	
	Pipe Systems	-	-	-	
Detention	Detention, Dry	65%	50%/30%	70%	✓
	Detention, Extended Dry	65%	50%/30%	70%	✓
	Detention, Multi-purpose Areas	-	-	-	
	Detention, Underground	-	-	-	
Filtration	Filter Strips	50%	20%/20%	-	
	Organic Filters	80%	60%/40%	50%	✓
	Planter Boxes	80%	60%/40%	-	
	Sand Filters, Surface/Perimeter	80%	50%/25%	40%	✓
	Sand Filters, Underground	80%	50%/25%	40%	✓
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	40%	5%/5%	-	
Infiltration	Downspout Drywell	80%	60%/60%	90%	
	Infiltration Trenches	80%	60%/60%	90%	
	Soakage Trenches	80%	60%/60%	90%	
Ponds	Wet Pond	80%	50%/30%	70%	✓
	Wet ED Pond	80%	50%/30%	70%	✓
	Micropool ED Pond	80%	50%/30%	70%	✓
	Multiple Ponds	80%	50%/30%	70%	✓
Porous Surfaces	Green Roof	85%	95%/16%	-	✓
	Modular Porous Paver Systems	[2]	80%/80%	-	
	Porous Concrete	[2]	50%/65%	-	
Proprietary Systems	Proprietary Systems [1]	[1]	[1]	[1]	
Re-Use	Rain Barrels	-	-	-	
Wetlands	Wetlands, Stormwater	80%	40%/30%	70%	✓
	Wetlands, Submerged Gravel	80%	40%/30%	70%	✓

✓ = Meets suitability criteria.

\- = Not typically used or able to meet design criterion.

[1] = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data if used as a primary control.

[2] = Porous surfaces provide water quality benefits by reducing the effective impervious area.

Table 3.24 Site Applicability

Category	*integrated* Stormwater Controls	Site Applicability				
		Drainage Area (acres)	**Space Req'd (% of Tributary imp. Area)**	**Site Slope**	**Minimum Head Required**	**Depth to Water Table**
Bioretention Areas	Bioretention Areas	5 max[3]	5-7%	6% max	5 ft	2 ft
Channels	Enhanced Swales	5 max	10-20%	4% max	1 ft	Below WT
	Channels, Grass					
	Channels, Open					
Chemical Treatment	Alum Treatment System	25 min	None			
Conveyance System Components	Culverts					
	Energy Dissipation					
	Inlets/Street Gutters					
	Pipe Systems					
Detention	Detention, Dry		2-3%	15% across pond	6 to 8 ft	2 ft
	Detention, Extended Dry		2-3%	15% across pond	6 to 8 ft	2 ft
	Detention, Multi-purpose Areas	200 max		1% for Parking Lot; 0.25 in/ft for Rooftop		
	Detention, Underground	200 max				
Filtration	Filter Strips	2 max[3]	20-25%	2-6%		
	Organic Filters	10 max[3]	2-3%		5 to 8 ft	
	Planter Boxes		6%			
	Sand Filters, Surface/Perimeter	10 max[3] / 2 max[3]	2-3%	6% max	5 ft per 2-3 ft	2 ft
	Sand Filters, Underground	5 max	None			
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	1 max[3]	None			
Infiltration	Downspout Drywell					
	Infiltration Trenches	5 max	2-3%	6% max	1 ft	4 ft
	Soakage Trenches	5 max	27 ft per 1000 ft^2 imp. area	6% max	1 ft	4 ft
Ponds	Wet Pond		2-3%	15% max	6 t 8 ft	2 ft, if hotspot or aquifer
	Wet ED Pond	25 min[3]				
	Micropool ED Pond	10 min[3]				
	Multiple Ponds	25 min[3]				
Porous Surfaces	Green Roof					
	Modular Porous Paver Systems	5 max	Varies			
	Porous Concrete	5 max	Varies			
Proprietary Systems	Proprietary Systems [1]	[1]	[1]			
Re-Use	Rain Barrels					
Wetlands	Wetlands, Stormwater	25 min	3-5%	8% max	3 to 5 ft (shallow) 6 to 8 ft (pond)	2 ft, if hotspot or aquifer
	Wetlands, Submerged Gravel	5 min			2 to 3 ft	Below WT

- = Not typically used or able to meet design criterion.

[1] = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data if used as a primary control.

[2] = Porous surfaces provide water quality benefits by reducing the effective impervious area.

[3] = Drainage area can be larger in some instances.

Table 3.25 Implementation Considerations						
Category	***integrated* Stormwater Controls**	**Implementation Considerations**				
		Residential Subdivision Use	**High Density/Ultra Urban**	**Capital Cost**	**Maintenance Burden**
Bioretention Areas	Bioretention Areas	✓	✓	Moderate	Low
Channels	Enhanced Swales	✓		High	Low
	Channels, Grass	✓		Low	Moderate
	Channels, Open	✓		Low	Low
Chemical Treatment	Alum Treatment System	✓	✓	High	High
Conveyance System Components	Culverts	✓	✓	Low	Low
	Energy Dissipation	✓	✓	Low	Low
	Inlets/Street Gutters	✓	✓	Low	Low
	Pipe Systems	✓	✓	Low	Low
Detention	Detention, Dry	✓		Low	Moderate to High
	Detention, Extended Dry	✓		Low	Moderate to High
	Detention, Multi-purpose Areas	✓	✓	Low	Low
	Detention, Underground		✓	High	Moderate
Filtration	Filter Strips	✓		Low	Moderate
	Organic Filters		✓	High	High
	Planter Boxes		✓	Low	Moderate
	Sand Filters, Surface/Perimeter		✓	High	High
	Sand Filters, Underground		✓	High	High
Hydrodynamic Devices	Gravity (Oil-Grit) Separator		✓	High	High
Infiltration	Downspout Drywell	✓	✓	Low	Moderate
	Infiltration Trenches	✓	✓	High	High
	Soakage Trenches	✓	✓	High	High
Ponds	Wet Pond	✓		Low	Low
	Wet ED Pond	✓		Low	Low
	Micropool ED Pond	✓		Low	Moderate
	Multiple Ponds	✓		Low	Low
Porous Surfaces	Green Roof		✓	High	High
	Modular Porous Paver Systems		✓	Moderate	High
	Porous Concrete		✓	High	High
Proprietary Systems	Proprietary Systems [1]	[1]	✓	High	High
Re-Use	Rain Barrels	✓	✓	Low	High
Wetlands	Wetlands, Stormwater	✓		Moderate	Moderate
	Wetlands, Submerged Gravel	✓	✓	Moderate	High

✓ = Meets suitability criteria
\- = Not typically used or able to meet design criterion.
[1] = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data if used as a primary control.

Step 2 Specific Criteria

The last three categories in the Structural Control Screening matrix provide an overview of various specific design criteria and specifications, or exclusions for a structural control that may be present due to a site's general physiographic character, soils, or location in a watershed with special water resources considerations.

Table 3.26 - Physiographic Factors

Three key factors to consider are low-relief, high-relief, and karst terrain. In the North Central Texas, low relief (very flat) areas are primarily located east of the Dallas metropolitan area. High relief (steep and hilly) areas are primarily located west of the Fort Worth metropolitan area. Karst and major carbonaceous rock areas are limited to portions of Palo Pinto, Erath, Hood, Johnson, and Somervell counties. Special geotechnical testing requirements may be needed in karst areas. The local reviewing authority should be consulted to determine if a project is subject to terrain constraints.

- Low relief areas need special consideration because many structural controls require a hydraulic head to move stormwater runoff through the facility.
- High relief may limit the use of some structural controls that need flat or gently sloping areas to settle out sediment or to reduce velocities. In other cases, high relief may impact dam heights to the point that a structural control becomes infeasible.
- Karst terrain can limit the use of some structural controls as the infiltration of polluted waters directly into underground streams found in karst areas may be prohibited. In addition, ponding areas may not reliably hold water in karst areas.

Table 3.27 - Soils

The key evaluation factors are based on an initial investigation of the NRCS hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.

The design of structural stormwater controls is fundamentally influenced by the nature of the downstream water body that will be receiving the stormwater discharge. In addition, the designer should consult with the appropriate review authority to determine if their development project is subject to additional structural control criteria as a result of an adopted local watershed plan or special provision.

In some cases, higher pollutant removal or environmental performance is needed to fully protect aquatic resources and/or human health and safety within a particular watershed or receiving water. Therefore, special design criteria for a particular structural control or the exclusion of one or more controls may need to be considered within these watersheds or areas. Examples of important watershed factors to consider include:

Table 3.28 - Special Watershed or Stream Considerations

High Quality Streams (Streams with a watershed impervious cover less than approximately 15%). These streams may also possess high quality cool water or warm water aquatic resources or endangered species. The design objectives are to maintain habitat quality through the same techniques used for cold-water streams, with the exception that stream warming is not as severe of a design constraint. These streams may also be specially designated by local authorities.

Wellhead Protection: Areas that recharge existing public water supply wells present a unique management challenge. The key design constraint is to prevent possible groundwater contamination by preventing infiltration of hotspot runoff. At the same time, recharge of unpolluted stormwater is encouraged to maintain flow in streams and wells during dry weather.

Reservoir or Drinking Water Protection: Watersheds that deliver surface runoff to a public water supply reservoir or impoundment are a special concern. Depending on the available treatment, a greater level of pollutant removal may be necessary for the pollutants of concern, such as bacteria pathogens, nutrients, sediment, or metals. One particular management concern for reservoirs is ensuring stormwater hotspots are adequately treated so they do not contaminate drinking water.

Step 3 Location and Permitting Considerations

In the last step, a site designer assesses the physical and environmental features at the site to determine the optimal location for the selected structural control or group of controls. Table 3.29 provides a condensed summary of current restrictions as they relate to common site features that may be regulated under local, state, or federal law. These restrictions fall into one of three general categories:

- Locating a structural control within an area when expressly prohibited by law
- Locating a structural control within an area that is strongly discouraged, and is only allowed on a case by case basis. Local, state, and/or federal permits shall be obtained, and the applicant will need to supply additional documentation to justify locating the stormwater control within the regulated area.
- Structural stormwater controls must be setback a fixed distance from a site feature.

This checklist is only intended as a general guide to location and permitting requirements as they relate to siting of stormwater structural controls. Consultation with the appropriate regulatory agency is the best strategy.

Table 3.26 Physiographic Factors

Category	*integrated* Stormwater Controls	Physiographic Factors		
		Low Relief	High Relief	Karst
Bioretention Areas	Bioretention Areas	Several design variations will likely be limited by low head		Use poly-linear or impermeable membrane to seal bottom
Channels	Enhanced Swales	Generally feasible. However, slope <1% may lead to standing water in dry swales	Often infeasible if slopes are 4% or greater	
	Channels, Grass			
	Channels, Open			
Chemical Treatment	Alum Treatment System			
Conveyance System Components	Culverts			
	Energy Dissipation			
	Inlets/Street Gutters			
	Pipe Systems			
Detention	Detention, Dry		Embankment heights restricted	Require poly or clay liner, Max ponding depth, Geotechnical tests
	Detention, Extended Dry			
	Detention, Multi-purpose Areas			
	Detention, Underground			GENERALLY NOT ALLOWED
Filtration	Filter Strips			
	Organic Filters			
	Planter Boxes			
	Sand Filters, Surface/Perimeter	Several design variations will likely be limited by low head		Use poly-linear or impermeable membrane to seal bottom
	Sand Filters, Underground			

Table 3.26 Physiographic Factors

Category	*integrated* Stormwater Controls	Physiographic Factors		
		Low Relief	High Relief	Karst
Hydrodynamic Devices	Gravity (Oil-Grit) Separator			
Infiltration	Downspout Drywell	Minimum distance to water table of 4 ft		GENERALLY NOT ALLOWED
	Infiltration Trenches	Minimum distance to water table of 2 ft	Maximum slope of 6%; trenches must have flat bottom	GENERALLY NOT ALLOWED
	Soakage Trenches	Minimum distance to water table of 4 ft	Maximum slope of 6%; trenches must have flat bottom	GENERALLY NOT ALLOWED
Ponds	Wet Pond	Limit maximum normal pool depth to about 4 ft (dugout) Providing pond drain can be problematic	Embankment heights restricted	Require poly or clay liner Max ponding depth Geotechnical tests
	Wet ED Pond			
	Micropool ED Pond			
	Multiple Ponds			
Porous Surfaces	Green Roof			
	Modular Porous Paver Systems			
	Porous Concrete			
Proprietary Systems	Proprietary Systems [1]			
Re-Use	Rain Barrels			
Wetlands	Wetlands, Stormwater		Embankment heights restricted	Require poly-liner Geotechnical tests
	Wetlands, Submerged Gravel			

1 = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data if used as a primary control.

Table 3.27 Soils

Category	*integrated* Stormwater Controls	Soils
Bioretention Areas	Bioretention Areas	Clay or silty soils may require pretreatment
Channels	Enhanced Swales	
	Channels, Grass	
	Channels, Open	
Chemical Treatment	Alum Treatment System	
Conveyance System Components	Culverts	
	Energy Dissipation	
	Inlets/Street Gutters	
	Pipe Systems	
Detention	Detention, Dry	Underlying soils of hydrologic group “C” or “D” should be adequate to maintain a permanent pool. Most group “A” soils and some group “B” soils will require a pond liner.
	Detention, Extended Dry	

Table 3.27 Soils		
Category	***integrated* Stormwater Controls**	**Soils**
	Detention, Multi-purpose Areas	
	Detention, Underground	
Filtration	Filter Strips	
	Organic Filters	
	Planter Boxes	Type A or B
	Sand Filters, Surface/Perimeter	Clay or silty soils may require pretreatment
	Sand Filters, Underground	
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	
Infiltration	Downspout Drywell	Infiltration rate > 0.5 inch/hr
	Infiltration Trenches	Infiltration rate > 0.5 inch/hr
	Soakage Trenches	Infiltration rate > 0.5 inch/hr
Ponds	Wet Pond	"A" soils may require pond liner "B" soils may require infiltration testing
	Wet ED Pond	
	Micropool ED Pond	
	Multiple Ponds	
Porous Surfaces	Green Roof	
	Modular Porous Paver Systems	Infiltration rate > 0.5 inch/hr
	Porous Concrete	
Proprietary Systems	Proprietary Systems [1]	
Re-Use	Rain Barrels	
Wetlands	Wetlands, Stormwater	"A" soils may require pond liner
	Wetlands, Submerged Gravel	

1 = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data if used as a primary control.

Table 3.28 Special Watershed Considerations				
Category	***integrated* Stormwater Controls**	**Special Watershed Considerations**		
		High Quality Stream	**Aquifer Protection**	**Reservoir Protection**
Bioretention Areas	Bioretention Areas	Evaluate for stream warming	Needs to be designed with no exfiltration (ie. outflow to groundwater)	
Channels	Enhanced Swales		Hotspot runoff must be adequately treated	Hotspot runoff must be adequately treated
	Channels, Grass			
	Channels, Open			
Chemical Treatment	Alum Treatment System			
Conveyance System Components	Culverts			
	Energy Dissipation			
	Inlets/Street Gutters			

Table 3.28 Special Watershed Considerations

Category	*integrated* Stormwater Controls	Special Watershed Considerations		
		High Quality Stream	Aquifer Protection	Reservoir Protection
	Pipe Systems			
Detention	Detention, Dry			
	Detention, Extended Dry			
	Detention, Multi-purpose Areas			
	Detention, Underground			
Filtration	Filter Strips			
	Organic Filters			
	Planter Boxes			
	Sand Filters, Surface/Perimeter	Evaluate for stream warming	Needs to be designed with no exfiltration (ie. outflow to groundwater)	
	Sand Filters, Underground			
Hydrodynamic Devices	Gravity (Oil-Grit) Separator			
Infiltration	Downspout Drywell			
	Infiltration Trenches		Maintain safe distance from wells and water table. No hotspot runoff	Maintain safe distance from bedrock and water table. Pretreat runoff
	Soakage Trenches			
Ponds	Wet Pond	Evaluate for stream warming	May require liner if "A" soils are present Pretreat hotspots 2 to 4 ft separation distance from water table	
	Wet ED Pond			
	Micropool ED Pond			
	Multiple Ponds			
Porous Surfaces	Green Roof			
	Modular Porous Paver Systems			
	Porous Concrete			
Proprietary Systems	Proprietary Systems [1]			
Re-Use	Rain Barrels			
Wetlands	Wetlands, Stormwater	Evaluate for stream warming	May require liner if "A" soils are present Pretreat hotspots 2 to 4 ft separation distance from water table	
	Wetlands, Submerged Gravel			

1 = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data if used as a primary control.

Table 3.29 Location and Permitting Checklist	
Site Feature	**Location and Permitting Guidance**
Jurisdictional Wetland (Waters of the U.S) U.S. Army Corps of Engineers Regulatory Permit	• Jurisdictional wetlands must be delineated prior to siting structural control. • Use of natural wetlands for stormwater quality treatment is contrary to the goals of the Clean Water Act and should be avoided. • Stormwater should be treated prior to discharge into a natural wetland. • Structural controls may also be restricted in local buffer zones. Buffer zones may be utilized as a non-structural filter strip (i.e., accept sheet flow). • Should justify that no practical upland treatment alternatives exist. • Where practical, excess stormwater flows should be conveyed away from jurisdictional wetlands.
Stream Channel (Waters of the U.S) U.S. Army Corps of Engineers Section 404 Permit	• All Waters of the U.S. (streams, ponds, lakes, etc.) should be delineated prior to design. • Use of any Waters of the U.S. for stormwater quality treatment is contrary to the goals of the Clean Water Act and should be avoided. • Stormwater should be treated prior to discharge into Waters of the U.S. • In-stream ponds for stormwater quality treatment are highly discouraged. • Must justify that no practical upland treatment alternatives exist. • Temporary runoff storage preferred over permanent pools. • Implement measures that reduce downstream warming.
Texas Commission on Environmental Quality Groundwater Management Areas	• Conserve, preserve, protect, recharge, and prevent waste of groundwater resources through Groundwater Conservation Districts • Groundwater Conservation District pending for Middle Trinity. • Detailed mapping available from Texas Alliance of Groundwater Districts.
Texas Commission on Environmental Quality Surface Water Quality Standards	• Specific stream and reservoir buffer requirements. • May be imperviousness limitations • May be specific structural control requirements. • TCEQ provides water quality certification – in conjunction with 404 permit • Mitigation will be required for imparts to existing aquatic and terrestrial habitat.

Table 3.29 Location and Permitting Checklist

Site Feature	Location and Permitting Guidance
100-year Floodplain Local Stormwater review Authority	• Grading and fill for structural control construction is generally discouraged within the 100-year floodplain, as delineated by FEMA flood insurance rate maps, FEMA flood boundary and floodway maps, or more stringent local floodplain maps. • Floodplain fill cannot raise the floodplain water surface elevation by more than limits set by the appropriate jurisdiction.
Stream Buffer Check with appropriate review authority whether stream buffers are required	• Consult local authority for stormwater policy. • Structural controls are discouraged in the streamside zone (within 25 feet or more of streambank, depending on the specific regulations).
Utilities Local Review Authority	• Call appropriate agency to locate existing utilities prior to design. • Note the location of proposed utilities to serve development. • Structural controls are discouraged within utility easements or rights of way for public or private utilities.
Roads TxDOT or DPW	• Consult TxDOT for any setback requirement from local roads. • Consult DOT for setbacks from State maintained roads. • Approval must also be obtained for any stormwater discharges to a local or state-owned conveyance channel.
Structures Local Review Authority	• Consult local review authority for structural control setbacks from structures. • Recommended setbacks for each structural control group are provided in the performance criteria in this manual.
Septic Drain fields Local Health Authority	• Consult local health authority. • Recommended setback is a minimum of 50 feet from drain field edge or spray area.
Water Wells Local Health Authority	• 100-foot setback for stormwater infiltration. • 50-foot setback for all other structural controls.

3.10 General Design Standards

Utilities

General – 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.

Water Lines – All existing water lines in the immediate vicinity of the proposed storm drains shall be clearly indicated on both the plan and profile sheets. When design indicates that an intersection of the storm drain line and the water main exists and the proposed storm drain cannot be economically relocated, then the existing water line shall be adjusted per Water Department specifications.

Sanitary Sewers – All existing or proposed sanitary sewers in the immediate vicinity of the proposed storm drains shall be clearly indicated on both plan and profile sheets. When design indicates that an intersection of the storm drain line and the sanitary sewer exist, then either line should be adjusted by relocation. If neither line can be economically relocated, then an alternative design may be considered, provided it is supported by hydraulic calculations and accepted by TPW and the Water Department. The alternative design may include a box section in the storm drain to go over or under the sanitary sewer, or a sanitary sewer crossing through the storm drain. If the latter is chosen, the crossing must be installed in a manhole or vault to provide both access and additional capacity. In either alternative, the sanitary sewer must be ductile iron pipe or other material accepted by the Water Department.

All Other Utilities – All other utilities in the immediate vicinity of the proposed storm drain shall be clearly indicated on both the plan and profile sheets. Gas lines and other utilities not controlled by elevation shall be adjusted when the design indicates that an intersection of the storm drain line and the utility exists and the proposed storm drain cannot be economically relocated.

Headwalls, Culverts, and Other Structures

For headwalls, culverts and other structures, standard details adopted by the Texas Department of Transportation (TxDOT) shall be used. The appropriate detail sheets should be included in any construction plans. Existing City standard headwalls may be used, provided that all slopes are modified to 4:1 or flatter. All headwalls and culverts should be extended to or beyond the street right-of-way. TxDOT-accepted pedestrian rail shall be used for any headwall within ten (10) feet of a sidewalk or other normal pedestrian area.

Minimum Pipe Sizes

Minimum pipe sizes are twenty-four (24) inch diameter for mains and twenty-one (21) inch diameter for inlet leads. Minimum sizes of conduits of other shapes should have equivalent cross-sectional areas. Any storm drain line with two or more inlets shall be considered a main line.

Pipe Size Changes

Pipe collars or pre-fabricated transition sections shall be provided for all pipe size changes. Pipe invert elevations shall be maintained at pipe size change locations.

Pipe Connections and Curved Alignment

Prefabricated wye and tee connections and other unusual configurations can usually be fabricated by the pipe manufacturer. Radial pipe can also be fabricated by the pipe manufacturer and shall be used through all curved alignments. When field connections or field radii must be used, all joints and gaps must be fully grouted to prevent voids and cave-ins caused by material washout into the storm drain. The City may require the installation of junction boxes at locations where new storm drain pipes are proposed to connect directly to existing storm drain pipes and angle of greater than 60º.

Inlets

All curb inlets shall be five (5), ten (10), fifteen (15) or twenty (20) feet in length and shall have depressed openings. Recessed inlets shall be provided on arterial streets. Proposed inlet lengths greater than twenty (20) feet must be accepted by TPW. Care should be taken in locating inlets to allow for adequate driveway access between the inlet and the far property line. Standard inlet depth is 4.5 feet at the lateral line and 4.0 feet at the opposite end, with the bottom sloped to drain to the lateral line. Manhole steps shall be installed for any inlet over five (5) feet deep. Lateral lines shall be plumbed into the inlet at a manhole opening to expedite mechanical cleaning and inspection. A storm drain main may pass through an inlet if the system configuration allows and may substitute for manhole access.

Drop inlets shall be minimum four (4) foot square and shall have manhole access and steps. Due to excessive clogging, grate inlets are not allowed on any public storm drain except as specifically accepted by TPW.

Streets

To minimize standing water, the minimum street grade shall be 0.50%. Along a curve, this grade shall be measured along the outer gutter line. The minimum grade along a cul-de-sac or elbow gutter centerline shall be 0.70%. Elbows may be designed with a valley gutter along the normal outer gutter line, with 2% cross slope from curb to the valley gutter. The minimum grade for any valley gutter shall be 0.50%. Where a crest or sag on a residential street, a PVI shall be used instead of a vertical curve where the total gradient change is no more than 1.5% ($\Delta \leq 1.5\%$) for a residential or collector street and no more than 1% for an arterial street.

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 5-year flood may not cross any street classified as a thoroughfare or collector. Not more than three (3.0 cfs) cubic feet per second in a conveyance storm may be discharged per driveway at a business, commercial, industrial, manufacturing, or school site. In all cases, the downstream storm drainage system shall be adequate to collect and convey the flow, and inlets provide 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.

3.11 Easements, Plats, and Maintenance Agreements

Easements

Easements are required for all drainage systems that convey stormwater runoff across a development and must include sufficient area for operation and maintenance of the drainage system. Types of easements to be used include:

Easements for Open Channels and Detention Ponds

- **Drainage easements** shall be required for both on-site and off-site public stormwater drainage improvements, including standard engineered channels, storm drain systems, detention and retention facilities and other stormwater controls (Public Water). The developer shall obtain downstream drainage easements until adequate outfall is determined. Drainage easements shall include a ten (10) foot margin on one side beyond actual top of bank for improved earthen channels. Retaining walls are not permitted within or adjacent to a drainage easement in a residential area in order to reduce the easement width. Retaining walls adjacent to the channel are allowed in non-residential areas only if the property owner provides an agreement for private maintenance.
- **Floodplain easements** shall be provided on sites along natural or improved earthen drainageways (other than standard engineered channels) to encompass the fully developed 100-year floodplain plus a ten (10) foot buffer on one side. The buffer shall be part of the floodplain easement itself and not a separate easement. Floodplain easements are not routinely maintained by the City.
- **Natural creeks** shall have a dedicated floodplain easement containing the inundation area of a 100-year frequency storm based on fully developed conditions, plus a ten (10) foot buffer horizontally adjacent to the inundation area. The minimum finished floor elevation for lots impacted by natural creeks shall be a minimum of two (2) feet above the 100-year fully developed water surface elevation. In addition, a riparian area along the creek may be placed in a drainage easement for perpetual, limited maintenance by the CFW, subject to the approval of the CFW and an agreement to preserve natural conditions and habitat within the riparian area.
- **Concrete-Lined Channels and Gabion-Lined Channels** shall have drainage easements dedicated to meet the requirements of the width of the channel, the one (1) foot freeboard, access easement and the fence.

- **Temporary drainage easements** are not accepted in the CFW.
- **Private drainage easements,** not dedicated to the City, may be required for private stormwater drainage improvements, including private detention ponds, serving multiple lots or for stormwater controls on a property. (No Public Water)
- **Access easements** shall be provided for access to public stormwater drainage improvements where necessary for maintenance.
- **Dam easements** shall be provided to encompass any proposed dams (including any dams already existing) and spillway structures. The 100-year water surface of any impounded lake shall be covered by a floodplain easement as described above. Dams and spillways shall comply with applicable City policy and state regulations.
- No construction shall be allowed within a floodplain easement without the written approval (floodplain permit) of the City of Fort Worth flood plain administrator or designee, and then only after detailed engineering plans and studies show that no increased flooding will result, and that no obstruction to the natural flow of water will result.
- In certain circumstances where detention is in place or a master drainage plan has been adopted, a development may plan to receive less than fully developed flow conditions from upstream with the approval of the TPW.
- Any parallel utility easements must be separate and outside of drainage easements for channels and roadside ditches.
- Easements for stormwater controls including detention basins, sediment traps and retention ponds, shall be negotiated between the City and the Property Owner, but will normally include essential access to all embankment areas and inlet and outlet controls. Essential access is defined as access in at least one location.
- 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 (including motorcycles).
- Drainage easements for structural overflows, swales, or berms shall be of sufficient width to encompass the structure or graded area.

Minimum easement width requirements for storm drain pipe are shown in Table 3.30 and shall be as follows:

- The outside face of the proposed storm drain line shall be placed 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.
- For pipe sizes up to 54”, a minimum of five (5) additional feet shall be dedicated when shared with utilities, where a shared easement is approved by variance.
- Box culvert minimum easement width shall be determined using Table 3.30 based on an equivalent box culvert width to pipe diameter.
- For parallel storm drain systems with a combined width greater than eight (8) feet the minimum easement shall be equal to the width of the parallel storm drain system plus twenty (20) additional feet.
- Drainage easements will generally extend at least twenty-five (25) feet past an outfall headwall to provide an area for maintenance operations. Drainage easements along a required outfall channel or ditch shall be provided until the flowline reaches an acceptable outfall. The minimum storm drain shall not be on property line, except where a variance has been granted.

Table 3.30 Closed Circuit 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

Easement Requirements for Closed Conduit Systems

- 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 five (5) feet from either edge of the easement.
- Drainage easements shall encompass the entire width of an overflow flume plus five (5) feet on each side. For an easement containing both a concrete flume and a storm drain, the wider of the two easement criteria shall control.
- Alternatively, a drainage right-of way or HOA lot (not part of any adjacent lot) may be dedicated for the width of the flume provided that an additional easement is dedicated for any storm drain pipe to meet the total width requirements specified above.

Plats

All platting shall follow established development standards for the CFW. Plats shall include pertinent drainage information that will be filed with the plat. Elements to be included on the final plat include:

- All public and private drainage easements not recorded by separate instrument
- Easements to be recorded by separate instrument shall be documented on the plat
- Minimum finished floor elevations shall be 2’ above the 100 year fully developed condition and shall be shown on plat.
- All floodplain easements
- Legal disclosure for drainage provisions upon sale or transfer of property
- Documentation of maintenance responsibilities and agreements including transfer of responsibility upon sale of the property
- Channel and floodplain easements must be platted as either parks or HOA lots to assure long term maintenance.

Maintenance Agreements

All drainage improvements constructed within a development and any existing or natural drainage systems to remain in use shall require a maintenance agreement that identifies responsible parties for maintenance. Both private and public maintenance responsibility shall be negotiated between the municipality and the owner and documented in the agreement. The maintenance agreement shall be written such that it remains in force upon sale of transfer of the property.

A *Stormwater Facility Maintenance Agreement* must be prepared by the engineer for each stormwater control that will not be wholly maintained by the CFW, as part of the Operations and Maintenance Plan submittal. This agreement must outline both preventive maintenance tasks as well as major repairs, identify the schedule for each task, assign clear roles to affected parties, and provide a maintenance checklist to guide future owners, including an annual self-inspection to be provided to the CFW. Multiple stormwater controls may be contained within a single Stormwater Facility Maintenance Agreement. When areas are identified for detention that also serve other purposes for the development (e.g. parking lots, loading docks) the requirement for a Stormwater Facilities Maintenance Agreement may be waived.

City Maintenance

The CFW will provide for perpetual maintenance, in accordance with adopted city maintenance standards, of all public drainage facilities located within dedicated easements and constructed to the CFW standards. In addition, limited perpetual maintenance may be provided by the CFW for riparian areas placed in a drainage easement preserved in their natural state, subject to the approval of the CFW. Access shall be provided and dedicated by the developer to all public stormwater facilities in developments for maintenance and inspection by the CFW.

Private Maintenance (SWFMA Required)

- 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, retaining walls adjacent to channels in nonresidential areas, and other stormwater controls which collect public water, as well as drainageways not constructed to City standards but which convey public water. Such facilities must be designed in accordance with sound engineering practices and reviewed and inspected by the City.
- An agreement for perpetual maintenance of private drainage facilities serving public or private water shall be executed with the City prior to acceptance of the final iSWM Plan. This 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.

Maintenance Agreement Requirements

Details of the agreement must be set forth in a series of exhibits:

1. Exhibit A Legal Description-This includes the Metes and Bounds, a Surveyor’s Drawing of the area occupied by the facility, and a copy of the preliminary or final plat containing the facility.
2. Exhibit B Design Plan and Specifications-these are summary documents intended for the use of future owners in conducting routine maintenance, inspections and repairs.
    a. Design Data and Calculations-This can be in the form of a letter or statement from the engineer which summarizes critical design calculations related to the functionality of the facility such as storage volume or TSS removal, and attest to the facility conforming to applicable iSWM standards.
    b. Schematic Plan-This should be prepared by the engineer from construction drawings to show the general layout of the facility. Major features requiring regular or special maintenance should be shown and labeled in general terms understandable to a layman. A profile should be given

showing critical elevations that control the function and capacity of the facility, and one or more cross-sections should be provided to indicate the general grading of the facility. A typical example of a schematic plan for a simple detention basin is shown in Figure 3.18.

   c. Landscaping-Vegetation should be shown consistent with the accepted Landscape Plan, either on the Schematic Plan or as a separate drawing.

3. Exhibit C Operations and Maintenance Plan-Specific maintenance tasks should be defined for each element of the facility. Maintenance tasks specific to the facility should be described in simple terms consistent with nomenclature contained in the Schematic and Landscape plans. An inspection and maintenance frequency should be established for each task.
4. Exhibit D Maintenance Checklist-A checklist consistent with the Operations and Maintenance Plan shall be provided for the use of future owners in performing routine and special maintenance tasks. This list should describe work required and frequency in language that is easy to understand and specific for the facility to be maintained. This form will be completed by the Owner and submitted to the CFW annually as part of a regular self-inspection program. See Form CFW-6 in Appendix A for an example checklist for a simple detention basin.

Additional guidance for facility maintenance is provided in the *iSWM Technical Manual,* for several types of stormwater controls. The engineer must certify that the construction has been completed in accordance with the general plans and Schematic Plan. After approval of construction by the CFW, an engineer is expected to provide guidance to the owner's representative in implementing the accepted maintenance program and to co-sign the first annual inspection after the construction. A checklist for preparing a Stormwater Facility Maintenance Agreement is provided Appendix A, Form CFW-8.

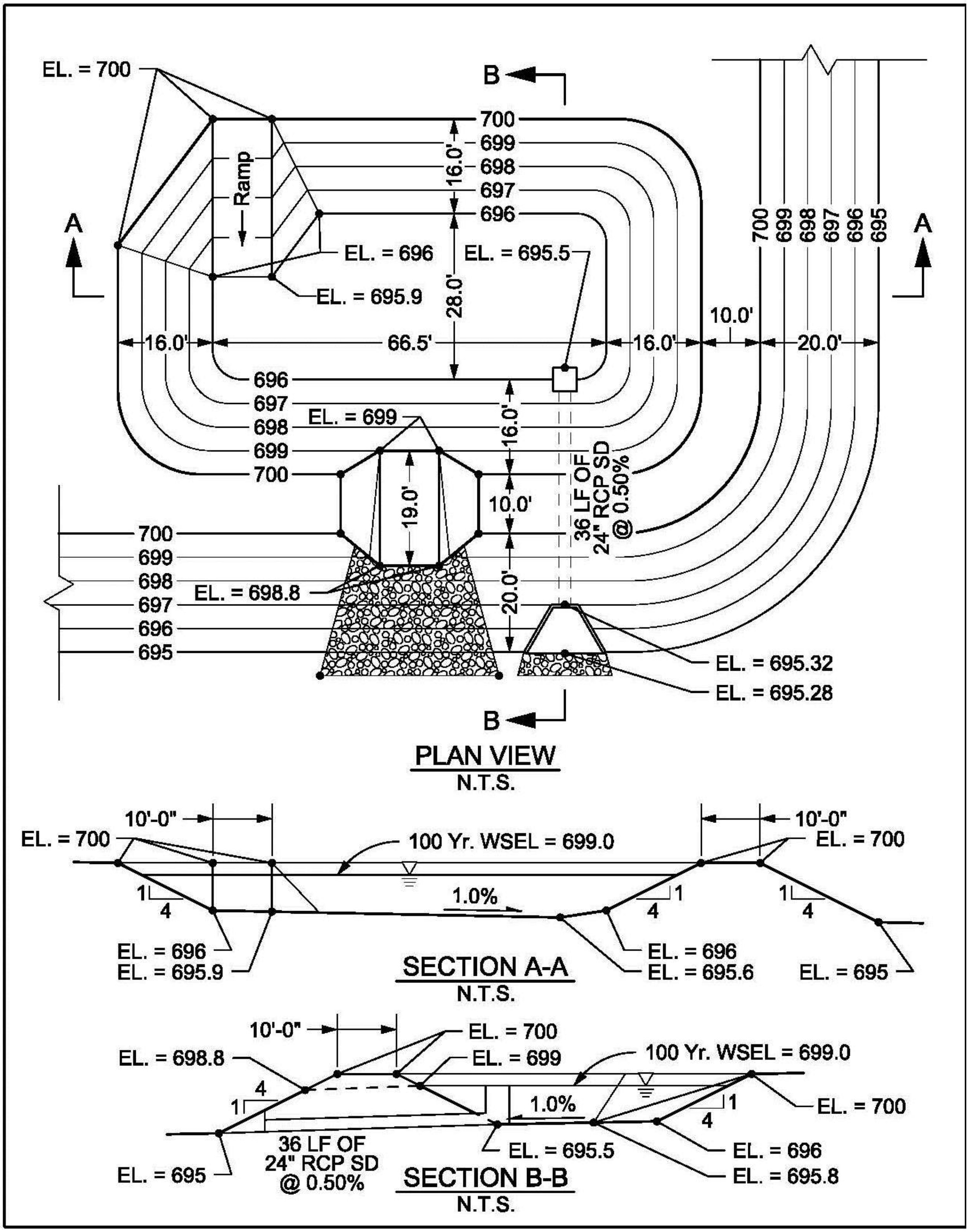


Figure 3.18 Typical Detention Pond Exhibit B – Example

4.0 Stormwater Construction Criteria

This chapter presents an *integrated* approach for reducing the impact of stormwater runoff from construction activities on downstream natural resources and properties. The purpose is to provide design criteria for temporary controls during construction that protect water quality by:

- Preventing soil erosion;
- Capturing sediment on-site when preventing erosion is not feasible due to construction activities; and
- Controlling construction materials and wastes to prevent contamination of stormwater.

Temporary controls to protect water quality are known as Best Management Practices (BMPs). The design of the BMPs is to be coordinated with and done at the same time as the Preliminary and Final iSWM Plans. Construction BMPs complement and work with the site grading and drainage infrastructure.

Erosion Control BMPs are designed to minimize the area of land disturbance and to protect disturbed soils from erosion. Protection can be accomplished by diverting stormwater away from the disturbed area or by stabilizing the disturbed soil. Erosion control BMPs are most important on disturbed slopes and channels where the potential for erosion is greatest. The design of erosion control BMPs must be coordinated with related grading, drainage and landscaping elements. (e.g. channel armoring, velocity dissipaters, etc.)

Sediment Control BMPs are temporary structures or devices that capture soil transported by stormwater. The BMPs are designed to function effectively with the site drainage patterns and infrastructure. An effective design ensures that the sediment control BMPs do not divert flow or flood adjacent properties and structures. Some types of permanent drainage structures, such as retention basins, can also be designed to function as a sediment control BMP during construction.

Material and Waste Control BMPs prevent construction materials and wastes from coming into contact with and being transported by stormwater. These BMPs consist of a combination of notes to direct contractor and temporary construction controls.

The iSWM Construction Criteria are the minimum requirements for temporary controls during construction. The state permit and requirements for stormwater discharges associated with construction activities must also be followed. More information on state requirements is provided in Chapter 4.2.

4.1 Applicability

The CFW has established minimum guidelines for controlling construction runoff for all land disturbance activities, even where there is less than 1.0 acre of disturbed surface.

Construction activities shall comply with the SWPPP requirements in the effective TPDES General permit relating to Stormwater Discharges from Construction Activities, of the Stormwater Pollution Control Ordinance and the appropriate federal (Environmental Protection Agency) and state (Texas Commission on Environmental Quality) regulations. When the ordinance and applicable regulations are in conflict, the most stringent requirements shall apply.

See Appendix D (Sediment and Erosion Control Guidelines for Small Sites).

4.2 Introduction

iSWM requires the use of temporary controls during construction to prevent or reduce the discharge of sediment and other pollutants from the construction site. The temporary controls are known as Best Management Practices (BMPs). BMPs may be activities, prohibitions, maintenance procedures, structural controls, operating procedures and other measures to prevent erosion and control the discharge of sediment and other pollutants.

Construction BMPs shall be considered when developing the Preliminary iSWM Plan and shall be coordinated with the Final iSWM Plan. Construction BMPs fall into three general categories: Erosion

Control, Sediment Control, and Material and Waste Control. The first category prevents erosion, and the second catches soil from erosion that does occur. It is generally more effective and less expensive to prevent erosion than to treat turbid runoff. Material and waste controls are for other sources of stormwater pollutants on a construction site.

The following priorities shall be applied to the selection of construction BMPs:

- Retain native topsoil and natural vegetation in an undisturbed state by incorporating natural drainage features and buffer areas into the site design.
- Limit the area of disturbance and vehicle access to the site.
- Limit the extent of clearing operations, and phase construction operations to minimize the area disturbed at any one time.
- Stabilize disturbed areas as soon as possible (not at the end of construction), particularly in channels and on cut/fill slopes.
- Minimize the disturbance of steep slopes during construction, and minimize slope length and steepness.
- Coordinate stream crossings, and minimize the construction of temporary stream crossings.
- Provide sediment controls, including but not limited to perimeter controls, where stormwater discharges will occur from disturbed areas.
- Prevent tracking of sediment off-site through the establishment of stabilized construction entrances and exits.
- Control sediment and other contaminants from dewatering activities.
- Control discharges of construction materials and wastes.

State Requirements

In addition to the CFW requirements outlined in this chapter, land disturbing activities must comply with the Texas Commission on Environmental Quality (TCEQ) requirements under General Permit Number TXR150000, commonly referred to as the "Construction General Permit." This permit contains requirements for a Stormwater Pollution Prevention Plan (SWP3), state and local notifications, and installation, maintenance, and inspection of best management practices on construction sites. The *Water Quality Technical Manual* contains guidance for preparing a SWP3. However, compliance with the Construction General Permit is beyond the scope of this Criteria Manual and is the sole responsibility of the construction site operator(s).

4.3 Criteria for BMPs during Construction

The iSWM Construction Plan shall include, but shall not be limited to, the following:

- Topography.
- Limits of all areas to be disturbed by construction activity, including off-site staging areas, utility lines, batch plants, and spoil/borrow areas.
- Location and types of erosion control, sediment control, and material and waste control BMPs;
- Construction details and notes for erosion control, sediment control, and material and waste control BMPs.
- Inspections and maintenance notes.

BMPs and notes shall be provided for all the elements listed in this chapter, unless site conditions render an element not applicable. BMPs shall be selected and designed according to the technical criteria in the *Construction Controls Technical Manual.* Site data gathered and analyzed in Step 1 of the *integrated* Development Process shall be the basis for selecting BMPs.

The minimum design storm for temporary BMPs is the 2-year, 24-hour duration storm event.

Plans for temporary BMPs shall be prepared by a Certified Professional in Erosion and Sediment Control (CPESC) or a licensed engineer or registered landscape architect in the State of Texas who has documented experience in hydrology and hydraulics and erosion and sediment control.

CFW allows flexibility to use BMP's not listed in the *Construction Controls Technical Manual* with approval of TPW.

Capacity calculations shall be included in the iSWM Construction Plan.

It is the responsibility of the engineer to design appropriate BMP's for each site. If the most appropriate BMP is not in the NCTCOG BMP Manual, the engineer shall submit calculations and references for design of the BMP to CFW.

4.3.1 *Erosion Controls*

Erosion control is first line of defense and the primary means of preventing stormwater pollution. They shall be designed to retain soil in place and to minimize the amount of sediment that has to be removed from stormwater runoff by other types of BMPs. Fact Sheets for different types of Erosion Control BMPs are in the *iSWM Technical Manual.*

Limits of Disturbance

On the iSWM Construction Plans, clearly show the limits of the area to be disturbed and the area in acres draining to each outfall.

Design Criteria

- Minimize the disturbance of steep slopes.
- Constrain the disturbed area to the minimum necessary to construct the project.
- Include the contractor’s staging area, borrow/spoil area, utilities and any other areas on or off site that will be disturbed in support of the construction activity.
- Specify construction fencing or similar protective measures to prevent disturbance of natural drainage features, trees, vegetative buffers and other existing features to be preserved.

Slope Protection

Slope protection shall be provided for disturbed or cut/fill slopes that are one vertical on three horizontal (3H:1V) or steeper, fifty (50) feet in length or longer, or on highly erodible soils. Show the location and type of BMPs to be used on the plans.

Design Criteria

- Where feasible, add notes that prohibit disturbing the slope until final site grading.
- Where a stabilized discharge point is available, provide temporary berms or swales to direct stormwater away from the slope until the slope is stabilized.
- Check dams shall be used within swales that are cut down a slope.
- Temporary terraces, vegetated strips or equivalent linear controls shall be specified at regular intervals to break-up slopes longer than fifty (50) feet until the slope is stabilized.
- Specify final stabilization measures to be initiated within 14 days of completing work on the slope.
- Hydromulch is prohibited for slope stabilization unless the slope is one vertical on five horizontal (5H:1V) or less.

Channel Protection

Show the location and type of BMPs used to prevent the erosion of channels, drainage ways, streambanks, and outfalls until permanent structures and final stabilization measures are installed.

Design Criteria

- Provide temporary energy dissipaters at discharge points.
- If final channel stabilization consists of vegetation, anchored erosion control blankets, turf reinforcement mats, or an equivalent BMP that is resistant to channel flow shall be installed until the vegetation is established.
- If the BMPs include check dams, velocity dissipaters or other structures that extend into the channel, the BMPs shall be designed by a licensed engineer to function under the flow conditions produced by the design storm. The engineer shall verify that the BMPs will not divert flow or cause flooding of adjacent properties and structures.
- Specify final stabilization measures to be initiated within 14 days of completing work on the channel.

Temporary Stabilization

Portions of a site that have been disturbed but where no work will occur for more than 21 days shall be temporarily stabilized as soon as possible, and no later than 14 days from cessation of work, except when precluded by seasonal arid conditions or prolonged drought.

Temporary stabilization shall consist of providing a protective cover, without large bare areas, that is designed to reduce erosion on disturbed areas. Temporary stabilization may be achieved using the following BMP's: temporary seeding, soil retention blankets, fibrous mulches, hydro-mulches and other techniques that cover 100% of the disturbed areas until final stabilization can be achieved or until further construction activities take place.

Design Criteria

- Stabilization measures shall be appropriate for the time of year, site conditions, and estimated duration of use.
- Stabilization BMPs shall be provided for soil stockpiles.

Final Stabilization

Final stabilization practices shall be specified for disturbed areas that are not covered by buildings, pavement or other permanent structures upon completion of construction. Final stabilization measures shall be coordinated with the site's landscaping plan.

Design Criteria

- Final stabilization shall be specified to start within fourteen days of completing soil disturbing activities.
- If space is available, top soil shall be stockpiled during construction and distributed onto the surface of disturbed areas prior to final stabilization.
- If top soil has not been stockpiled, soil amendments (compost, fertilizer, etc.) shall be specified with the final stabilization measures.
- Final stabilization measures must provide a perennial vegetative cover with a uniform density of 70% of the native background vegetative cover or equivalent permanent measures (riprap, gabion, or geotextiles).
- Hydro-mulch will not be allowed in vegetated swales, channels or other drainage ways. BMPs may remain in place during stabilization; however, BMPs shall be removed after stabilization is achieved. The plan for final stabilization shall be coordinated with the permanent BMPs in the SWPPP and with the landscaping plan, if applicable.
- Include notes requiring temporary BMPs be removed within 30 days of establishing final stabilization.
- A Notice of Termination must be filed in accordance with the TCEQ TPDES General Permit TXR15000, usually within 30 days after final stabilization of operational control. All parties that submitted a NOI

shall submit a NOT within 30 days after final stabilization is established. When the owner of a residential subdivision transfers ownership of individual lots to builders before final stabilization is achieved, the SWPPP shall include controls for each individual lot in lieu of final stabilization. These controls shall consist of stabilization of the right-of-way and placement of structural BMPs at the low point of each individual lot or equivalent measures to retain soil on each lot during construction. Additionally, the builder must submit a valid NOI before or NOT can be submitted by the owner.

4.3.2 *Sediment Controls*

Sediment control BMPs shall be designed to capture sediment on the site when preventing erosion is not feasible due to on-going construction activity. Sediment control BMPs and their locations shall be designed to change with the different phases of construction as site conditions and drainage patterns change. Sediment controls for the initial phase of construction shall be installed before any site disturbing activities begin. Fact Sheets for different types of Sediment Control BMPs are in *Section 3.0 of the Construction Controls Technical Manual*.

Sediment Barriers

Sediment barriers may be linear controls (silt fence, compost socks, sediment logs, wattles, etc.), check dams, berms, sediment basins, sediment traps, active treatment systems and other structural BMPs designed to capture sediment suspended in stormwater.

Design Criteria

- Sediment barriers shall be designed to treat the volume of runoff from the design storm.
- Sediment barriers are not required for areas of the site that are undisturbed.
- If linear controls are used as the only sediment barrier for a project, the linear control shall be provided at a rate of 100 linear feet per quarter-acre of disturbed area. A series of linear controls may be needed throughout the site and are not limited to the perimeter.
- Linear controls shall not be used across areas of concentrated flow, such as drainage ditches, swales and outfalls.
- A sediment basin shall be provided where stormwater runoff from 10 acres or more of disturbed area flows to a common drainage location, unless a basin is infeasible due to site conditions or public safety. The basin shall be designed for the volume of runoff from the total area contributing (on-site and off-site) to the common drainage location, not just the volume from the disturbed portion of the contributing area. Stormwater diversion BMPs may be used to divert stormwater from upslope areas away from and around the disturbed area to minimize the design volume of the sediment basin.
- Both existing topography and graded topography shall be evaluated when determining if 10 acres or more discharges to a common location.
- If a sediment basin is infeasible on a site of 10 acres or more, a series of smaller sediment traps and/or linear controls shall be provided throughout the site to provide an equivalent level of protection.
- Permanent detention and retention basins may be used as a sediment basin during construction if all sediment is removed upon completion of construction.

Perimeter Controls

A linear BMP shall be provided at all down slope boundaries of the construction activity and side slope boundaries where stormwater runoff may leave the site. Linear sediment barriers may be used to satisfy the requirement for perimeter controls.

Storm Drain Inlet Protection

Storm drain inlet protection shall not be used as a primary sediment control BMP unless all other primary controls are infeasible due to site configuration or the type of construction activity. Inlet protection is intended to be a last line of defense in the event of a temporary failure of other sediment controls.

Design Criteria

- Special approval is required by CFW regarding location and design of any inlet controls. Where permitted, the operator will be expected to diligently monitor storm conditions and to remove them when there is a risk of flooding.
- Inlet protection shall only be specified for low point inlets where positive overflow is provided.
- Drainage patterns shall be evaluated to ensure inlet protection will not divert flow or flood the roadway or adjacent properties and structures.

Construction Access Controls

BMPs shall be provided to prevent off-site vehicle tracking of soil and pollutants.

Design Criteria

- Limit site access to one route during construction, if possible; two routes for linear projects.
- Design the access point(s) to be at the upslope side of the construction site. Do not place the construction access at the lowest point on the construction site.
- Specify rock stabilization or an equivalent BMP for all access points.
- Include notes requiring soil tracked onto public roads be removed at a frequency that minimizes site impacts and prior to the next rain event, if feasible.
- Using water to wash sediment from streets is prohibited.

Dewatering Controls

Water pumped from foundations, vaults, trenches and other low areas shall be discharged through a BMP or treated to remove suspended soil and other pollutants before the water leaves the site. The plans shall include notes that prohibit discharging the water directly into flumes, storm drains, creeks or other drainage ways. Where state or local discharge permit requirements exist for the pollutant(s) suspected of being in the water, the plan shall include the discharge permit conditions.

4.3.3 *Material and Waste Controls*

Notes shall be placed on the iSWM Construction Plan for the proper handling and storage of materials and wastes that can be transported by stormwater. At a minimum, notes shall be provided for the materials and wastes in Table 4.1. Additional notes and BMPs shall be provided if other potential pollutants are expected to be on-site. Construction details shall be provided when necessary to ensure proper installation of a material or waste BMP.

All material and waste sources shall be located a minimum of fifty (50) feet away from inlets, swales, drainage ways, channels and waters of the U.S., if the site configuration provides sufficient space to do so. In no case shall material and waste sources be closer than twenty (20) feet from inlets, swales, drainage ways, channels and waters of the U.S.

Table 4.1 Requirements for Materials and Wastes

Material or Waste Source	Requirements
Sanitary Facilities	Sanitary facilities shall be provided on the site, and their location shall be shown on the iSWM Construction Plan. The facilities shall be regularly serviced at the frequency recommended by the supplier for the number of people using the facility.
Trash and Debris	Show the location of trash and debris storage on the iSWM Construction Plan. Store all trash and debris in covered bins or other enclosures. Trash and debris shall be removed from the site at regular intervals. Containers shall not be allowed to overflow.
Chemicals and Hazardous Materials	The amount of chemicals and hazardous materials stored on-site shall be minimized and limited to the materials necessary for the current phase of construction. Chemicals and hazardous materials shall be stored in their original, manufacturer's containers inside of a shelter that prevents contact with rainfall and runoff. Hazardous material storage shall be in accordance with all Federal, state and local laws and regulations. Storage locations shall have appropriate placards and secondary containment equivalent to 110% of the largest container in storage. If an earthen pit or berm is used for secondary containment, it shall be lined with plastic. Containers shall be kept closed except when materials are added or removed. Materials shall be dispensed using drip pans or within a lined, bermed area or using other spill/overflow protection measures.
Fuel Tanks	On-site fuel tanks shall be provided with a secondary enclosure equivalent to 110% of the tank's volume. If the enclosure is an earthen pit or berm, the area shall be lined with plastic. Show the location of fuel tanks and their secondary containment on the iSWM Construction Plan.
Concrete Wash-out Water	An area shall be designated on the iSWM Construction Plan for concrete wash-out. A pit or bermed area, lined with plastic, or an equivalent containment measure shall be provided for concrete wash-out water. The containment shall be a minimum of 6 CF for every 10 CY of concrete placed plus a one (1) foot freeboard. The discharge of wash-out water to drainage ways or storm drain infrastructure shall be prohibited.
Hyper-chlorinated Water from Water Line Disinfection	Hyper-chlorinated water shall not be discharged to the environment unless the chlorine concentration is reduced to 4 ppm or less by chemically treating to dechlorinate or by on-site retention until natural attenuation occurs. Natural attenuation may be aided by aeration. Water with measurable chlorine concentration of less than 4 ppm is prohibited from being discharged directly to surface water. It shall be discharged onto vegetation or through a conveyance system for further attenuation of the chlorine before it reaches surface water. Alternatively, permission from the sanitary sewer operator may be obtained to discharge directly to the sanitary sewer.
Vehicle/Equipment Wash Water	Vehicle and equipment washing is prohibited on the site unless a lined basin is provided to capture 100% of the wash water. The wash water may be allowed to evaporate or hauled-off for disposal.
Soil Stabilizers	Lime or other chemical stabilizers shall be limited to the amount that can be mixed and compacted by the end of each working day. Stabilizers shall be applied at rates that result in no runoff. Stabilization shall not occur immediately before and during rainfall events. Soil stabilizers stored on-site shall be considered a hazardous material and shall meet all the requirements for chemicals and hazardous materials.
Concrete Saw-cutting Water	Slurry from concrete cutting shall be vacuumed or otherwise recovered and not be allowed to discharge from the site. If the pavement to be cut is near a storm drain inlet, the inlet shall be protected by sandbags or equivalent temporary measures to prevent the slurry from entering the inlet.

4.3.4 *Installation, Inspection and Maintenance*

The iSWM Construction Plan shall include details and notes that specify the proper installation, inspection and maintenance procedures for BMPs. The BMPs for the initial phase of construction must be implemented before starting any activities that result in soil disturbance, including land clearing. Notes shall indicate the sequence of BMP installation for subsequent phases of construction.

Notes on the iSWM Construction Plan shall indicate the frequency of inspections and the areas to be inspected. Inspections shall include:

- Inspecting erosion and sediment controls to ensure that they are operating correctly;
- Inspecting locations where vehicles enter or exit the site for evidence of off-site tracking;
- Inspecting material and waste controls to ensure they are effective; and
- Inspecting the perimeter of disturbed areas and discharge points for evidence of sediment or other pollutants that may have been discharged.

Erosion, sediment, and material and waste controls shall be repaired, replaced, modified and/or added if inspections reveal the controls were not installed correctly, are damaged, or are inadequate or ineffective in controlling their targeted pollutant.

Notes for maintenance of BMPs shall require the removal of sediment from BMPs when the sediment reaches half of the BMP's capacity or more frequently. Sediment discharged from the site shall be removed prior to the next rain event, where feasible, and in no case later than seven days after it is discovered. Upon completion of construction, sediment shall be removed from all storm drain infrastructure and permanent BMPs before the temporary BMPs are removed from the site.

Refer to Chapter 3.11 for further information on maintenance agreements.

5.0 References

City of Fort Worth Public Works Department, Storm Water Management Design Manual, March 2006 Fort Worth, Texas.

City of Fort Worth Public Works Department, Storm Drainage Criteria and Design Manual, December 10, 1967, amended June 1, 1975, December 17, 1986, and September 20, 1994, Fort Worth, Texas.

Harris County Flood Control District, October 2009, Policy, Criteria and Procedure Manual for Approval and Acceptance of Infrastructure, Houston, Texas.

Integrated Stormwater Management Criteria Manual for Site Development and Construction, December 2009, NCTCOG, Arlington, TX

integrated Stormwater Management Planning Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

integrated Stormwater Management Program Guidance: Dam Safety and Water Rights, 2010 Edition, Revised April 2010. NCTCOG, Arlington, TX.

integrated Stormwater Management Water Quality Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

integrated Stormwater Management Hydrology Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

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integrated Stormwater Management Site Development Controls Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

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integrated Storm Water Management Landscape Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

Texas Department of Transportation, October 2011, Hydraulic Design Manual, Austin, 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, March 1978, Engineering Monograph No. 25.

Appendix A – City of Fort Worth Detailed Checklists and Forms

Form CFW-1 Preliminary iSWM Checklist

Form CFW-2 Final iSWM Checklist

Form CFW-3 Culvert Hydraulics Documentation Checklist

Form CFW-4 Bridge Hydraulics Documentation Checklist

Form CFW-5 Preliminary and Final Dam Maintenance and Emergency Action Plan

Form CFW-6 Inspection Checklist for Simple Detention Basin

Form CFW-7 Request for Variance from City of Fort Worth - Stormwater

Form CFW-8 Engineer's Checklist for Stormwater Facility Maintenance Agreement

Form CFW-9 Grading Permit Application

Form CFW-10 Final Grading Certificate

TRANSPORTATION AND PUBLIC WORKS DEPT.
STORMWATER MANAGEMENT

PRELIMINARY iSWM CHECKLIST

Please attach additional sheets as necessary for comments and descriptions.
Fold all sheets to 8½" x 11" or 9" x 12" and bind with a clip.

1. Project Information

A. *Name of Project:* ______________________ B. *Date:* ______________

C. *Location of Project:* ______________________ D. *Type of Project (circle one): Development / CIP*

E. *Project Description:* ______________________ F. *Total Disturbed Area (acres):* __________

G. *Proposed land uses (CFW zoning designations (N/A for City CIPs)* ______________________

H. *Anticipated Start of Construction:* ______________________

I. *Name of Owner (Fort Worth for City CIPs):* ______________________ J. *Telephone No.:* __________

K. *Owner Contact Name (N/A for City CIPs):* ______________________ L. *FAX No.:* __________

M. *Owner Address (N/A for City CIPs):* ______________________

N. *Engineer's Name:* ______________________ O. *Texas P.E. No.:* __________

P. *Engineering Firm:* ______________________ Q. *Telephone No.:* __________

R. *Engineer Address:* ______________________

S. *Engineer's Email:* ______________________ T. *FAX No.:* __________

Note: Highlighted items only required for Conceptual iSWM. All items are required for Preliminary iSWM.

2. Items to be Provided (Identify sheet number if included with plans or write "attached" if included as an attachment with this checklist)

_______ *Preliminary Plat or Site Plan*
_______ *Pre-Development Aerial Photo with composite impervious area calculations for site – See #3 below*
_______ *Pre-Development Drainage Area Map(s) – See #4 below*
_______ *Post-Development Drainage Area Map(s) – See #5 below*
_______ *Narrative – See #6 below*
_______ *Simplified Methods Utilized and Documentation Provided*
_______ *Waiver Requests (Optional)*

Additional Notes:

_______ *Developed under manual other than current manual (Identify Year)*
_______ *Calculations dependent on a phase developed under previous criteria (Identify Year)*

Plan File Number *(if available):* ______________

For City Use: Project Manager: ______________ *Date:* __________

_____ *Preliminary Plans, Checklist, and Referenced Attachments Posted on Buzzsaw*

Checklist completed correctly and in sufficient detail: Yes / No

Comments: ______________________

TPW / SW Accepted: Yes / No By: ______________ *Date:* ______

Case No.: ______________ *CIP No:* ______________

Comments: ______________________

Form CFW-1

	Yes	No	N/A	Comments and Descriptions
3. Pre-Development Impervious Area Map(s)				
A. *Project boundaries*	___	__	___	___
B. *Aerial photo representing existing conditions (no more than 5-years before submittal)*	___	__	___	___
C. *Site specific composite C value (use 0.9 for impervious areas, 0.3 for pervious area, and 0.56 for gravel paved areas to calculate composite C. Offsite composite C values can be based on land use)*	__	__	__	___
4. Pre-Development Drainage Area Map(s) containing the following information:				
A. *Project boundaries*	___	__	___	___
B. *Existing topography (2-foot contours)*	___	__	___	___
C. *USDA soil types (if using hydrographs). A separate soil map may be submitted*	___	__	___	___
D. *Perennial or intermittent stream centerlines*	___	__	___	___
E. *Delineation of FEMA floodplains, studied floodplains, floodplain easements and open channels*	___	__	___	___
F. *Location of wetlands*	___	__	___	___
G. *Locations of dams and impoundments*	___	__	___	___
H. Existing roads, buildings, and other impervious areas	___	__	___	___
I. *Location and size of major utility lines and easements*	___	__	___	___
J. *Location, size, and City File Number for existing stormwater conveyance systems such as storm drains, inlets, catch basins, channels, swales, and areas of overland flow*	___	__	___	___
K. *Locations and dimension of existing channels, bridges, or culvert crossings*	___	__	___	___
L. *Delineation of watershed boundaries with flow areas*	___	__	___	___
M. *Delineation of offsite drainage areas*	___	__	___	___

Form CFW-1

	Yes	No	N/A	Comments and Descriptions
N. *Time of concentration calculations for each area and lag time calculations for hydrograph methods. Delineation of longest flow path required unless using the minimum lag time*	___	__	___	___
O. *Computation tables showing drainage areas, runoff coefficients or curve number, time of concentration or lag times, rainfall intensities and peak discharges for the 1, 5, and 100-year storms*	___	__	___	___

5. Post Development Drainage Area Map(s) showing the following information for the project site:

	Yes	No	N/A	Comments and Descriptions
A. *Project boundaries*	___	__	___	___
B. *Existing topography (2-foot contours) and proposed grading contours or spot elevations.*	___	__	___	___
C. *Perennial or intermittent stream centerlines*	___	__	___	___
D. *Delineation of FEMA floodplains, studied floodplains, floodplain easements and open channels*	___	__	___	___
E. *Locations of dams and impoundments*	___	__	___	___
F. *Location and size of major utility lines and easements*	___	__	___	___
G. *Location, size, and City File Number for existing stormwater conveyance systems such as storm drains, inlets, catch basins, channels, swales, and areas of overland flow*	___	__	___	___
H. *Location and dimension of existing channels, bridges or culvert crossings*	___	__	___	___
I. *Location of all proposed site outfalls or locations where runoff leaves the site*	___	__	___	___
J. *Proposed zoning or land use*	___	__	___	___
K. *Delineation of watershed boundaries with flow arrows*	___	__	___	___
L. *Delineation of offsite drainage areas*	___	__	___	___
M. *Proposed modifications to watershed boundaries*	___	__	___	___

	Yes	No	N/A	Comments and Descriptions
N. *Composite runoff coefficients calculations for each drainage area for the rational method or Curve Number (CN) calculations for the hydrograph method.*	___	__	___	___
O. *Time of concentration calculations for each area and lag time calculations for hydrograph methods. Delineation of longest flow path required unless using the minimum lag time*	___	__	___	___
P. *Computation tables showing drainage areas, runoff coefficients or curve number, time of concentration or lag times, rainfall intensities and peak discharges for the 1, 5, and 100-year storms. Include ultimate conditions if applicable*	___	__	___	___
Q. *Delineate the entire zone of influence*	___	__	___	___
R. *Show downstream constrictions with runoff controls (Mitigation documentation not required until Final iSWM)*	___	__	___	___
S. *Proposed facilities with private maintenance (If detention is proposed, provide volume required)*	___	__	___	___

6. **Written Narrative:** Provide a written narrative and supporting methodology to demonstrate zone of influence and adequate outfall determination and conclusions for all design storms. Methodology must be in accordance with Chapter 3 of the Drainage Manual and *Chapter 2.0, Downstream Assessment of the Hydrology Section of the Technical Manual*. The narrative may be in the form of notes on the iSWM plan, letter report, or formal report, depending on the scope of the project. Note: For conceptual – level submittals, the narrative shall be limited to a summary of the proposed project and expected drainage impacts. Methodology shall be described in a future submittal.

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Form CFW-1

7. **Planning Concerns:** (Planning concerns may include previous drainage or watershed studies, known history of flooding or excessive erosion downstream, downstream drainage constrictions, wetlands, 404 permit areas, existing dams subject to TCEQ regulations, impoundments subject to TCEQ water rights permitting, and existing environmental concerns)

____

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8. **Low-Impact Design:** (Does this project provide opportunities for low-impact design including preservation of floodplains or natural valley storage, preservation of natural streams and drainage patterns, preservation of steep slopes, preservation of trees and undisturbed natural vegetation, preservation of wetland areas or other natural features, drain runoff to pervious areas, utilization of natural drainage system, reduction of pavement and other impervious covers)

____

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9. **Description of Any Proposed Waiver Requests:** (for informational purposes only; all Waiver Requests must follow the procedure outlined in the Drainage Manual)

____

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____

____

10. Other Comments:

____

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____

(seal)	I certify that this Preliminary iSWM Checklist and referenced documents were prepared under my responsible supervision and that the information presented on this checklist and attachments is correct to the best of my knowledge. I also understand that an acceptance of this plan by the City does not waive any City standards or requirements unless a specific waiver request has been submitted and approved. Signed ________________________________ Date ____________________ Print Name:______________________________

Form CFW-1

FORT WORTH

TRANSPORTATION AND PUBLIC WORKS DEPT.
STORMWATER MANAGEMENT

FINAL iSWM CHECKLIST

Please attach additional sheets as necessary for comments and descriptions.
Fold all sheets to 8½" x 11" or 9" x 12" and bind with a clip.

Fort Worth Stormwater Management

1. Project Information (for Items 1.C to 1.T, N/C = No Change from Preliminary SWM Plan)

A. *Name of Project:* ______ B. *Date:* ______

C. *Location of Project:* ______ *D. Type of Project (circle one): Development / CIP*

E. Project Description: ______ *F. Total Disturbed Area (acres):* ______

G. *Proposed land uses (CFW zoning designations (N/A for City CIPs)* ______

H. *Anticipated Start of Construction:* ______

I. *Name of Owner (Fort Worth for City CIPs):* ______ J. *Telephone No.:* ______

K. *Owner Contact Name (N/A for City CIPs):* ______ L. *FAX No.:* ______

M. *Owner Address (N/A for City CIPs):* ______

N. *Engineer's Name:* ______ O. *Texas P.E. No.:* ______

P. *Engineering Firm:* ______ Q. *Telephone No.:* ______

R. *Engineer Address:* ______

S. *Engineer's Email:* ______ T. *FAX No.:* ______

2. References: (Identify sheet number if included with plans or write "Attached" if included as an attachment with this checklist)**.**

______ *Final Plat or Site Plan*
______ *Final iSWM Construction Plan (with Exhibits)*
______ *Additional Attachments as Specified*
______ *Waiver Requests (As Applicable)*

Additional Notes:

______ *Developed under manual other than current manual (Identify Year)*
______ *Calculations dependent on a phase developed under previous criteria (Identify Year)*

Plan File Number *(if available):* ______

For City Use: Project Manager: ______ *Date:* ______
______ *Final Plans, Checklist, and Referenced Attachments Posted on Buzzsaw*
Checklist completed correctly and in sufficient detail: Yes / No
Comments: ______
TPW / SW Accepted: Yes / No By: ______ ______ *Date:* ______
Case No.: ______ *CIP No:* ______
Comments: ______

Form CFW-2

3. Changes or Modifications to Preliminary iSWM Plan (May be reprinted with changes tracked or highlighted)

____

____

____

	Yes	No	N/A	Comments and Descriptions
4. Additional Study Attachments (include if applicable)				
A. Dam Safety Checklist	__	__	__	________
B. Executed Maintenance Agreement (with Maintenance Plan)	__	__	__	________
C. Landscaping Plan (for Stormwater controls)	__	__	__	________
D. Copy of approved Waiver Request	__	__	__	________
E. Calculation of proposed Stormwater Fee Credits	__	__	__	________
5. Applicable Local, State and Federal Permits (Indicate acquired or application pending)				
A. CLOMR, LOMR or LOMA	__	__	__	________
B. TCEQ water rights permit	__	__	__	________
C. 404 permit	__	__	__	________
D. Urban Forestry Permit	__	__	__	________
E. Floodplain Development Permit	__	__	__	________
6. Hydrologic Analysis and Stormwater Management Design Plan (separate Attachment, either A or B)				
A. Approved Infrastructure Plans (with TPW CFA).	__	__	__	________
B. Site iSWM Plan showing final hydrology, Identification of all stormwater controls with summary calculations, delineation of adequate outfalls, zones of influence, required mitigation, and structural details and specifications as required	__	__	__	________

Form CFW-2

	Yes	No	N/A	Comments and Descriptions
C. Has the capture and treatment of stormwater been considered in terms of water quality?	__	__	__	________

7. iSWM Construction Plan

	Yes	No	N/A	Comments and Descriptions
A. Applicable sheets titled "iSWM Construction Plan" in plans	__	__	__	________
B. Existing topography and natural drainage features and post project topography and drainage features	__	__	__	________
C. Limits of disturbance, including off-site areas that will be disturbed and natural features to be protected within the disturbed areas. ***Disturbed area (ac) shown on plan sheet***	__	__	__	________
D. Location, details, and notes for erosion controls	__	__	__	________
E. Location, details, and notes for sediment controls	__	__	__	________
F. Location, details, and notes for waste controls (toilets, demolition material, and other potential sources of pollution	__	__	__	________
G. BMP Design Calculations for erosion, sediment, and waste controls	__	__	__	________
H. Inspection and maintenance notes	__	__	__	________
I. Sequence of BMP installation based on sequence of construction phases	__	__	__	________
J. *Schedule and phasing of temporary and permanent stabilization on different area of the site*	__	__	__	________
K. *Temporary structures that will be converted into permanent stormwater controls*	__	__	__	________
L. *If final site drains 10 or more acres are sediment traps being used?*	__	__	__	________

Form CFW-2

	Yes	No	N/A	Comments and Descriptions
M. *Are top soils banked on-site? (If no, then provide comments describing provisions being made for soil amendments)*	__	__	__	____________________
N. *Prepared by an engineer or other qualified professional*	__	__	__	____________________
8. Landscaping Plan				
A. Arrangement of planted areas, natural areas, and other landscaped features	__	__	__	____________________
B. Information required to construct landscaping elements	__	__	__	____________________
C. Descriptions and standards for methods, materials, and vegetation that are to be used	__	__	__	____________________

(Seal)	I certify that this Final iSWM Checklist and referenced documents were prepared under my responsible supervision and that the information presented on this checklist and attachments is correct to the best of my knowledge. I also understand that an acceptance of this plan by the City does not waive any City standards or requirements unless a specific waiver request has been submitted and approved. It is the intent of the information provided in this checklist and within the plans regarding the iSWM Construction Plan to be used as the general guidelines of the Storm Water Pollution Prevention Plan for this project to establish a minimum basis of compliance with local, state, and federal regulations. The contractor must amend plans whenever there is a change in design, construction, operation, or maintenance of the plan, or when the existing plan proves ineffective. The contractor shall be solely responsible for implementation, maintenance, monitoring, and permitting of all erosion, sediment, and waste control aspects associated with the project. Signed ______________________ Date ______________ Print Name:______________________

Form CFW-2

CULVERT HYDRAULICS DOCUMENTATION CHECKLIST

Project:			Date:
Road:	Watershed:		Stream:
Type of work:			
FEMA considerations (Detailed or Approx. Study?):			
Culvert location:			
Culvert size & shape:			
Culvert material:	Fill height:	Skew angle:	
Hydrologic method used: Hydrograph USGS Station ____________________ Other (specify) ___________________________________			
Design frequency (yrs):		Drainage area:	
Channel analysis:	Channel slope (m/m):	N values (channel):	
100 Yr Proposed discharge (cfs):	100-Year Fully developed discharge - Q_{100} (cfs):		
100 Yr Proposed tailwater (ft):	100-Year Fully developed tailwater (ft):		
100 YR Proposed headwater (ft):	100-Year Fully developed headwater (ft):		
Allowable highwater (ft):			
100 Yr Proposed velocity thru bridge (fps):	100-Year Fully developed velocity thru bridge (fps):		
Design unconstricted velocity (fps)	100-Year unconstricted velocity (fps)		
% Flow overtopping road for Q_{100}:	Height of water over road for Q_{100} (ft):		
Est. overtopping frequency (years):			
Headwater computation method: THYSYS-CULVERT HEC-RAS* HEC 2 Other ______________________________ *Required by CFW			
Comparison with existing hydraulic condition:			
Meets FEMA requirements__________Yes____________No_____N/A			
Outlet velocity excessive______Yes___No			
Outlet protection/control:			
Safety end treatment:			
Comments:			

Form CFW-3

BRIDGE HYDRAULICS DOCUMENTATION CHECKLIST

Project:		Date:
Road:	Watershed:	Stream:
Type of work:		
FEMA considerations (Detailed or Approx. Study?):		
Bridge Length:	Pier Configuration:	
Bridge Width:	Bridge Low Chord and Roadbed Elev.:	
Hydrologic Method Used: Hydrograph Only Gauged - USGS Station ____________________ Other____________________________________		
Design Frequency (yrs):*		Drainage Area:
Channel Dimensions:	Channel slope(ft/ft):	N value:

STATION	DESIGN PROPOSED			100 YR EXISTING			100 YR PROPOSED			100 YR FULLY DEVELOPED		
	Q (cfs)	V (fps)	WSEL (ft)	Q (cfs)	V (fps)	WSEL (ft)	Q (cfs)	V (fps)	WSEL (ft)	Q (cfs)	V (fps)	WSEL (ft)
EXIT												
FULL V												
BRIDGE												
APPR (CONSTR)												
APPR (UNCONS)												

Headwater computation method: HEC-RAS_________________ OTHER_________________	
Bridge/Roadway overtopping: _____Yes _____No	Overtopping Frequency(years):
% Flow overtopping road:	Height of water over road(ft):
Existing Bridge Length(ft):	Meets FEMA requirements: Yes_______No______N/A
Type of Bridge Rail:	Skew:
Abutment protection (rock riprap, etc):	
Comments:	
*Complete for cases where "design frequency" (such as TxDOT structures) may be different than 100-year.	

Form CFW-4

FORT WORTH

TRANSPORTATION AND PUBLIC WORKS DEPT.
STORMWATER MANAGEMENT

PRELIMINARY AND FINAL
DAM MAINTENANCE AND EMERGENCY ACTION PLAN

Fort Worth Stormwater Management

Please attach additional sheets as necessary for comments and descriptions.
Fold all sheets to 8½" x 11" or 9" x 12" and bind with a clip.

1. Project Information

A. Name of Development: ______________________ *B. Case No.:* ______________________

C. Dam Name, Number or Tributary: ______________________ *D. Date:* ______________________

E. Name of Owner: ______________________ *F. Telephone No.:* ______________________

G. Owner Contact Name: ______________________ *H. E-mail:* ______________________

I. Owner Address: ____

J. Engineer's Name: ______________________ *K. Texas P.E. No.:* ______________________

L. Engineering Firm: ______________________ *M. Telephone No.:* ______________________

N. Engineer Address: ______________________ *O. E-mail:* ______________________

2. Dam Summary Information (Item H not required for Preliminary Submittal)

A dam that meets the TCEQ guidelines must be registered with the TCEQ, have a breach analysis, hazard assessment, and emergency action plan per 30 TAC §299.

A. Dam height (feet):* ______________________

B. Impoundment surface area (acres): ______________________

C. Watershed size (acres): ______________________

D. Approx. impoundment volume (acre-feet): ______________________

*Height measured from the crest of the dam to the bottom of the outfall channel

For City Use: Reviewer: ______________ *Date:* ______________

Accepted *Not Accepted* *Case No.:* ______________

Comments: ____

____

Form CFW-5

E. Who will own and maintain dam (HOA, City park, etc.)? ____

F. Was dam previously registered and/or inspected by TCEQ? When? ____

G. TCEQ impoundment size classification (30 TAC §299.12): ____ *Exempt* ____ *Small* ____ *Intermediate* ____ *Large*

H. Hazard Assessment (from 6.B. below per 30 TAC §299.13): ____ *N/A* ____ *Low* ____ *Significant* ____ *High*

3. Attachments

_____ **Water Rights Permit (where applicable)**

_____ **Breach Analysis (where applicable)**

_____ **Emergency Action Plan (final submittal)**

	Yes	No	N/A	Comments and Descriptions
4. State Water Rights				
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. For proposed City-owned dams, a completed permit, or written documentation from TCEQ stating that a permit is not required, must be submitted prior to final acceptance by the City.				
Has water rights permit been obtained or applied for? (For proposed City-owned dams, attach permit correspondence)	__	___	___	____________________
5. Dam and Pond Site Map(s), showing:				
A. Proposed and existing contours, with recent aerial	__	___	___	____________________
B. Existing and proposed FEMA floodplain limits	__	___	___	____________________
C. Street and lot layout around dam and inundation area	__	___	___	____________________
D. Contributing watershed (reduced scale if necessary)	__	___	___	____________________
E. Hydrologic calculations for Q100 and PMF	__	___	___	____________________
F. Location, size and capacity of proposed spillway	__	___	___	____________________
G. Conceptual or final spillway and erosion protection design	__	___	___	____________________

Form CFW-5

	Yes	No	N/A	Comments and Descriptions
6. Dam Breach Analysis – Attach and Include: (Required for Final Submittal only, for dams meeting the guidelines in Chapter 3.8.4 for Detention Structures in this manual).				
A. Breach analysis for "sunny day", "barely overtopping" or Q100, and Probable Maximum Flood (PMF) conditions	__	___	___	________________________________
B. Hazard Assessment based on potential for loss of life or property damage in breach/non-breach comparison	__	___	___	________________________________
C. Emergency Action Plan per current City standards	__	___	___	________________________________

(seal)	I certify that this Conceptual Stormwater Management plan, including this checklist, required attachments, and additional comments, was prepared under my responsible supervision and that the information presented on this checklist and attachments is correct to the best of my knowledge. I also understand that an acceptance of this plan by the City does not waive any City standards or requirements unless a specific waiver request has been submitted and accepted. Signed ____ Date ________________________ Print Name:_____________________________________

Form CFW-5

INSPECTION CHECKLIST FOR SIMPLE DETENTION BASIN

Facility Name: ____ **Facility Agreement Number:** _____________

Basin/Pond Number: _______ **Inspected By:** ________________________________ **Date:** ____________________

Type of Inspection: Annual ____, Quarterly ____, Monthly ____, Routine ____, or Storm Event ____, (# days since event ______)

Basin Conditions:

1. Is there standing water or wet spots? Yes___ No ___ Comments ____________________________
2. Does sides or bottom show signs of erosion, settling, cracking, etc? Yes___ No ___ Comments ____________________________
3. Does dam or emergency spillway show signs of erosion, settling, cracking, or other problems? Yes___ No ___ Comments ____________________________
4. Is there evidence of animal burrowing in dam? Yes___ No ___ Comments ____________________________
5. Is there evidence of changes in shape or volume of basin? Yes___ No ___ Comments ____________________________
6. Do vegetated areas need mowing? Yes___ No ___ Comments ____________________________
7. Are there trees or woody growth in dam? Yes___ No ___ Comments ____________________________
8. Are there areas that need to be re-vegetated? Yes___ No ___ Comments ____________________________
9. Is there any accumulation of silt, trash, debris or litter in the basin? Yes___ No ___ Comments ____________________________
10. Are there any other basin maintenance activities needed? Yes___ No ___ Comments ____________________________

Structural Components:

1. Are pipes, channels, trash racks, etc. free of obstructions? Yes___ No ___ Comments ____________________________
2. Are pipes, spillway or trash racks in need of repair? Yes___ No ___ Comments ____________________________
3. Is the low flow or trickle channel in need of repair? Yes___ No ___ Comments ____________________________
4. Is the outfall channel in need of repair? Yes___ No ___ Comments ____________________________
5. Are there any other structural maintenance activities needed? Yes___ No ___ Comments ____________________________

Plan for correcting deficiencies:

____

____

____

____

Signature:

____

Owner's Representative

Date:

____

Form CFW-6

REQUEST FOR VARIANCE
FROM CITY OF FORT WORTH – STORMWATER

Submitted by:______________________________ Phone:_____________________ Email:_______________

Company:____Date:________________

Proposed Project Description

Name:____

Type:____

Location:____(include map)

Existing Condition (show information on map or drawing)

CFW Maintained Facilities:____

Existing Right-of-Way for CFW facility:____

Topography:____

Other Pertinent Data Related to Variance Request:

____

____

____

Variance Request

Specific criteria you want to vary:____

____

____

Explain why the criteria needs to be varied or is not applicable:___________________

____

____

Explain how the basis for the criteria will be satisfied:___________________________

____

____

List attachments supporting variance request (preliminary design report excerpt, construction drawings, calculations, photographs, map, etc.:

Justification of Decision:____

____

____

Notes:____

____

____

Variance Decision: Accepted ☐ Denied ☐

Reviewer Signature:________________________________ Date:________________________

Form CFW-7

Transportation and Public Works Dept.
Stormwater Management

ENGINEER'S CHECKLIST FOR STORMWATER FACILITY MAINTENANCE AGREEMENT

Please attach additional sheets as necessary for comments and descriptions. Fit all sheets to 8½" x 11".

ORGANIZATION INFORMATION

1. Company (Applicant)	**Address:**
2. Contact's Information: Contact Name Mailing Address Telephone Number(s) Email	**3. Execution Information:** Signatory's Name Mailing Address Telephone Number(s) Email

4. Property Location:
(Note: If the property has not been addressed, please enter the legal description)

5. Associated Plat Numbers:
(Note: if request is related to multiple plat applications, please list each individually)

6. Associated Building Permit Numbers:
(Note: if request is related to multiple permits, please list each individually)

7. Associated iSWM Master Numbers:

AGREEMENT & ATTACHMENT INSTRUCTIONS

If the property owner is a **corporation**, the agreement must be signed by the President or a Vice-President of the company. If a **partnership**, the agreement must be signed by the managing partner. If the applicant is a **sole proprietor**, he/she signs the agreement on behalf of him or herself. Additionally, for corporations and partnerships, a copy of the *Articles of Incorporation*, showing signature authority for whoever signs the agreement must also be submitted (Note: Applicants may also submit a board resolution or power of attorney authorizing an agent or assign to sign on behalf of the property owner. The agreement must be completely filled out and three copies submitted to the Planning and Development Department. Signatures on all three agreement drafts must be original and notarized. Lastly, please submit a copy of the deed for the noted property.

NOTE: Agreement and all attachments should be submitted on 8 ½" x 11".

Form CFW-8

	Yes	No	N/A	Comments/Descriptions
1. Legal Agreement – Standard agreement form provided by Department of Law.	☐	☐	☐	
2. Exhibit "A" - Legal Description (Attached)				
A. Metes and Bounds.	☐	☐	☐	
B. Surveyor's Drawing, with seal affixed and marked as "Drainage Easement".	☐	☐	☐	
C. Preliminary Plat.	☐	☐	☐	
3. Exhibit "B" - Design Plan and Specifications (Attached)				
A. Design Calculations – in accordance with iSWM.	☐	☐	☐	
B. Schematic Plan (See Example Detention Plan Schematic)- prepared in accordance with approved construction plans:	☐	☐	☐	
• Plan View showing critical structural elements .	☐	☐	☐	
• Critical structural elements are clearly labeled in layman terms.	☐	☐	☐	
• Profile including a longitudinal section showing all critical structural elements with elevations.	☐	☐	☐	
• Cross-sections as needed to show size and general grading.	☐	☐	☐	
NOTE: All Schematics should be submitted on 8 ½" x 11".				
C. Landscaping shown per approved Landscape Plans.	☐	☐	☐	
4. Exhibit "C" - Operations and Maintenance Plan (Attached)				
A. Routine Maintenance Specifications:				
1. Mowing as needed to control weeds and woody plants.	☐	☐	☐	
2. Trash removal from critical structural elements.	☐	☐	☐	
3. Additional maintenance.	☐	☐	☐	
B. Non-routine Maintenance Activities:				
1. Bank repair and stabilization.	☐	☐	☐	
2. Re-vegetation - required when 30% or more of area is unprotected.	☐	☐	☐	

Form CFW-8

	Yes	No	N/A	Comments/Descriptions
3. Sediment removal from the detention/retention facility when:	☐	☐	☐	______
• Detention basin – when water depth is reduced 25% or more, or basin does not drain within 72 hours.	☐	☐	☐	______
• Retention pond – when water depth is 4’ or less.	☐	☐	☐	______
• Sediment traps/forebay – when depth is reduced by 50% or more.	☐	☐	☐	______
4. Structural repair/replacement for all damaged or deteriorated structures, trickle channel, trash rack, etc.	☐	☐	☐	______
5. Mechanical equipment repairs.	☐	☐	☐	______
6. Other maintenance Activities.	☐	☐	☐	______
5. Exhibit “D” - Maintenance Checklist *				
A. Covers ordinary needs, in layman terms.	☐	☐	☐	______
B. Structural components labeled consistent with Schematic Plan.	☐	☐	☐	______

*See attached Inspection Checklist for Detention Basin

NOTE: All Exhibits should be submitted on 8 ½” x 11”.

(seal)	I certify that this Stormwater Facility Maintenance Agreement, checklist, required attachments, and additional comments, was prepared under my responsible supervision and that the information presented on this checklist and attachments is correct to the best of my knowledge. I also understand that an acceptance of this plan by the City does not waive any City standards or requirements unless a specific waiver request has been submitted and approved. Signed__________________________Date__________________ Print Name:__________________________

Form CFW-8

GRADING PERMIT APPLICATION

Applicant to Complete Sections I through VII Below: Permit No._______________

Questionnaire For: Commercial Construction or Grading activities.

What Type of Grading Permit is being applied for? (circle one) EARLY FINAL

Note: A Final Commercial Grading Permit is required even if an Early Grading Permit is obtained.

I. Identification:

Project Name: ____
Project Location: ____

Owner:

Name: ______________________________ e-mail:__________________
Address: _____________________________ Phone: __________________

Contractor:

Name: ____
Address: ____
Emergency Telephone No.:____________________ e-mail:__________________

II. Do you have an approved iSWM Plan? (circle one) yes no

An iSWM Plan (integrated Storm Water Management Plan) may have been approved if a Plat, Infrastructure Plans, or a Unified Residential Plan has been approved after March 2006.

If yes provide case/plan number(s), if known:

SWM ____________________ SWPPP __________________________
Plat ____________________ Urban Forestry Plan____________________
DOE Number ______________ Unified Residential Development Plan ________

III. What is the total land disturbance associated with this permit? ________ Acres

IV. Are you prepared to submit an iSWM plan now? (circle one) yes no

V. Are you prepared to submit a SWPPP plan now? (circle one) yes no

VI. Are you prepared to submit an Urban Forestry plan now? (circle one) yes no

VII. Signature of Applicant or Authorized Agent:

Signature: ____
Name: ____
Name of Company: ____
Address: ____
Phone No.: ____

VIII. Conditions of Approval

Approval is contingent upon compliance with City grading and development requirements including drainage, floodplain management, urban forestry and construction runoff control. A site grading plan sealed by an engineer is required for all land disturbances of 1.0 acre or more.

City Action:

Reviewer____________________________________Date________________

Accepted / Not Accepted Comments ______________________________

CFW-9

FORT WORTH

Fort Worth Stormwater Management

FINAL GRADING CERTIFICATE

Effective Date______________ **Case No.** (*From Early/Final Grading Permit*) ___________

This certification is required after construction and grading activities are complete and prior to Certificate of Occupancy being issued.

OWNER/ DEVELOPER/ PERMITTEE INFORMATION

Project Name ____

Project Location ____

Project Description ____

____

____

Owner/Developer/Permittee ____

Address ____

Phone No. ______________________________ e-mail ____________________

DESIGN PROFESSIONAL OR CONTRACTOR (Responsible Party)

Name ____

Address ____

Phone No. ______________________________ e-mail ____________________

License/Certificate No ______________________________ Expiration Date ____________________

To the best of my knowledge and personal inspection, the above described project has been constructed in substantial compliance with the plans dated___________ as accepted by the City of Fort Worth AND temporary BMPs have been removed.

Signature ______________________________ Date ____________________

Printed Name ______________________________

(Seal)

Form CFW-10

Appendix B – City of Fort Worth Stormwater Computer Models

Appendix B: Stormwater Computer Models

B.1 Introduction

Stormwater management is becoming increasingly complex. The simple notion of collecting runoff and sending it efficiently to the nearest stream is being replaced with considerations of stormwater quantity and quality control, infrastructure management, master planning and modeling, financing, complaint tracking, and more. Information needs are critical to a successful local program. North Central Texas communities need to both invest in and be aware of new and emerging technologies that can provide the ability to collect, organize, maintain and effectively use vast amounts of data and information for their community's stormwater management activities.

There is a great deal of computer software that has been developed based on the intensive research effort in urban hydrology, hydraulics and stormwater quality. Computer models use the computational power of computers to automate the tedious and time-consuming manual calculations. Most models also include extensive routines for data management, including input and output procedures, and possibly including graphics and statistical capabilities.

Computer modeling became an integral part of storm drainage planning and design in the mid-1970s. Several agencies undertook major software developments and these were soon supplemented by a plethora of proprietary models, many of which were simply variants on the originals. The proliferation of personal computers in the 1990s has made it possible for virtually every engineer to use state-of-the-art analytical technology for purposes ranging from analysis of individual pipes to comprehensive stormwater management plans for entire cities.

In addition to the simulation of hydrologic and hydraulic processes, computer models can have other uses. They can provide a quantitative means to test alternatives and controls before implementation of expensive measures in the field. If a model has been calibrated and verified at a minimum of one site, it may be used to simulate non-monitored conditions and to extrapolate results to similar ungauged sites. Models may be used to extend time series of flows, stages and quality parameters beyond the duration of measurements, from which statistical performance measures then may be derived. They may also be used for design optimization and real-time control.

A local staff or design engineer will typically use one or more of these pieces of software in stormwater facility design and review, according to the design objectives and available resources. However, it should be kept in mind that proper use of computer modeling packages requires a good knowledge of the operations of the software model and any assumptions that the model makes. The engineer should have knowledge of the hydrological, hydraulic and water quality processes simulated and knowledge of the algorithms employed by the model to perform the simulation.

B.2 Types of Models

In urban stormwater management there are typically three types of computer models that are commonly used: *hydrologic*, *hydraulic* and *water quality* models. There are also a number of other specialty models to simulate ancillary issues (some of which are sub-sets of the three main categories) such as sediment transport, channel stability, lake quality, dissolved oxygen and evapotranspiration, etc.

B.2.1 Hydrologic Models

Hydrologic models attempt to simulate the rainfall-runoff process to tell us “how much water, how often.” They use rainfall information or models to provide runoff characteristics including peak flow, flood hydrograph and flow frequencies. Hydrologic models can be either:

- *Deterministic – giving one answer for a specific input set, or*
- *Stochastic – involving random inputs giving any number of responses for a given set of parameters;*
- *Continuous – simulating many storm events over a period of time, or*
- *Single Event – simulating one storm event;*
- *Lumped – representing a large area of land use by a single set of parameters, or*
- *Distributed – land areas are broken into many small homogeneous areas each of which has a complete hydrologic calculation made on it.*

B.2.2 Hydraulic Models

Hydraulic models take a known flow amount (typically the output of a hydrologic model) and provide information about flow height, location, velocity, direction, and pressure. Hydraulic models share some of the differing characteristics of hydrologic models (continuous vs. single event) and add the following:

- *One-dimensional – calculating flow information in one direction (e.g. downstream) only, or*
- *Multi-dimensional – calculating flow information in several dimensions (e.g. in and out of the channel and downstream);*

- *Steady – having a single unchanging flow velocity value at a point in the system, or*
- *Unsteady – having changing flow velocities with time;*

- *Uniform – assuming the channel slope and energy slope are equal, or*
- *Non-uniform – solving a more complex formulation of the energy and momentum equations to account for the dynamic nature of flows.*

For most problems encountered in hydraulics, a simple one-dimensional, steady model will work well. But if the volume and time distribution of flow are important (for example, in a steeper stream with storage behind a series of high culvert embankments) an unsteady model is needed. If there is a need to predict with accuracy the ebb and flow of floodwater out of a channel (for example in a wide, flat floodplain where there are relief openings under a road) then a 2-dimensional model becomes necessary. If pressure flow and the accurate computation of a hydraulic grade line are important an unsteady, a non-uniform model with pressure flow calculating capabilities is needed.

B.2.3 Water Quality Models

The goal in water quality modeling is to adequately simulate the various processes and interactions of stormwater pollution. Water quality models have been developed with an ability to predict loadings of various types of stormwater pollutants.

Water quality models can become very complex if the complete cycle of buildup, wash-off and impact are determined. These models share the various features of hydrologic and hydraulic models in that it is the runoff flow that carries the pollutants. Therefore, a continuous hydrologic model with estimated pollution concentrations becomes a continuous water quality pollution model. Water quality models can reflect pollution from both point and nonpoint sources.

Water quality models tend to have applications that are targeted toward specific pollutants, source types or receiving waters. Some models involve biological processes as well as physical and chemical processes. Often great simplifications or gross assumptions are necessary to be able to model pollutant accumulations, transformations and eventual impacts.

Detailed short time increment predictions of “pollutographs” are seldom needed for the assessment of receiving water quality. Hence, the total storm event loads or mean concentrations are normally adequate. Simple spreadsheet-based loading models involve an estimate of the runoff volume which, when multiplied by an event mean concentration, provide an estimate of pollution loading. Because of the lack of ability to calibrate such models for variable physical parameters, such simple models tend to be more accurate the longer the time period over which the pollution load is averaged. An annual pollutant load prediction may tend toward a central estimate, while any specific storm prediction may be grossly in error when compared to actual loadings because antecedent conditions vary widely from week to week. Simulation models have the ability to adjust a number of loading parameters for calibration purposes and can simulate pollution accumulation over a long period. They can then more reliably predict loadings for any specific storm event.

While calibration data is not always needed in hydrologic or hydraulic models for an acceptably accurate answer, in water quality models the non-calibrated prediction is often off by orders of magnitude. Water quality predictions are not credible without adequate site-specific data for calibration and verification. However, even without specifically accurate loading values relative effects of pollution abatement controls can be tested using uncalibrated models.

B.2.4 Computer Model Applications

Stormwater computer models can also be categorized by their use or application:

Screening-level models are typically equations or spreadsheet models that give a first estimate of the magnitude of urban runoff quality or quantity. At times this is the only level that is necessary to provide answers. This is true either because the answer needs to be only approximate or because there is no data to justify a more refined procedure.

Planning-level models are used to perform "what if" analysis comparing in a general way design alternatives or control options. They are used to establish flow frequencies, floodplain boundaries, and general pollution loading values.

Design-level models are oriented toward the detailed simulation of a single storm event for the purposes of urban stormwater design. They provide a more complete description of flow or pollution values anywhere in the system of concern and allow for adjustment of various input and output variables in some detail. They can be more exact in the impact of control options, and tend to have a better ability to be calibrated to fit observed data.

Operational models are used to produce actual control decisions during a storm event. They are often linked with SCADA systems. They are often developed from modified or strongly calibrated design models, or can be developed on a site-specific basis to appropriately link with the system of concern and accurately model the important physical phenomena.

B.3 Summary of Acceptable Models

Computer models can be simple, representing only a very few measured or estimated input parameters or can be very complex involving twenty times the number of input parameters. The "right" model is the one that: (1) the user thoroughly understands, (2) gives adequately accurate and clearly displayed answers to the key questions, (3) minimizes time and cost, and (4) uses readily available or collected information. Complex models used to answer simple questions are not an advantage. However, simple models that do not model key necessary physical processes are useless.

There is no one engineering model or software that addresses all hydrologic, hydraulic and water quality situations. Design needs and troubleshooting for watershed and stormwater management occur on several different scales and can be either system-wide (i.e., watershed) or localized. System-wide issues can occur on both large and small drainage systems, but generally require detailed, and often expensive, watershed models and/or design tools. The program(s) chosen to address these issues should handle both major and minor drainage systems. Localized issues also exist on both major and minor drainage systems, but unlike system-wide problems, flood and water quality solution alternatives can usually be developed quickly and cheaply using simpler engineering methods and design tools.

Table B.1 lists several widely used computer programs and modeling packages which are acceptable to CFW. The use of a program that is not on this list must be accepted by TPW.

For the purposes of this table, major drainage systems are defined as those draining to larger receiving waters. These are typically FEMA-regulated streams, or lakes or reservoirs. Minor drainage systems are smaller natural and man-made systems that drain to the more major streams. Minor drainage systems can have both closed and open-channel components and can include, but are not limited to, neighborhood storm sewers, culverts, ditches, and tributaries.

Table B.1 Stormwater Modeling Programs and Design Tools

	Major System Modeling	Minor System Modeling	Hydrologic Features	Hydraulic Features	Water Quality Features	Unsteady Flow	2-D Flow
Hydrology Software							
HEC-1	X		X				
HEC-HMS	X		X				
PondPack		X	X	X			
StormCAD							
GEOPAK		X	X	X			
SWFHYD[1]	X		X				
Hydraulics Software							
HEC-RAS	X	X		X		X	
InfoWorks SD	X	X	X	X	X	X	X
XPSWMM	X	X	X	X		X	X
EPA SWMM	X	X	X	X	X	X	
ICPR	X	X	X	X		X	
Water Quality Software							
HSPF	X		X		X		
BASINS	X		X	X	X		
QUAL2K	X			X	X		
Design Tools							
Macra1(Gabion Channels)	X	X		X			
GeowacWIN (Gabion Retaining Walls)	X	X		X			
HY8 (Culverts and Energy Dissipators)	X	X		X			
CulvertMaster		X		X			
FlowMaster		X		X			

[1]Only where model currently exists

Appendix C – City of Fort Worth Miscellaneous Details and Specifications

Straight Drop Spillways

Overview

The three parts of a straight drop spillway (see Figure C.1) are:

- Upstream draw down reach
- Drop opening
- Downstream hydraulic jump reach

The drop is usually constructed of steel sheet piling. Reinforced concrete lining and riprap are placed upstream and downstream of the drop structure for erosion and scour protection.

Design Criteria

Design criteria for straight drop spillways are:

- Comply with general design criteria for all transition control structures as described in the "General Design Criteria" below.
- Design steel sheet piling to prevent bending or rotating.
- Coat steel sheet piling in accordance with industry standards to reduce rusting and scaling.
- Use concrete lining on the entire cross-section upstream and downstream of the drop.
- Tie the concrete lining to the steel sheet piling drop structure.
- Use a minimum six (6) inch thick slab on the downstream concrete lining due to the impact load and potential severe turbulence.
- Determine length of concrete lining upstream and downstream of the drop.
- Include twenty (20) feet of riprap at the ends of the concrete slope paving to decrease flow velocities and protect the concrete toe from scour (see Chapter 3.9 Stone Riprap Design)

General Design Criteria

General design criteria for transition control structures are:

- Design for a range of flows and tailwater conditions up to and including the 1% exceedance event.
- Conduct a geotechnical investigation to assist with design of the structure.
- Locate transition control structures where flow is straight. Avoid channel bends and high turbulence areas, if possible.
- Provide structural erosion protection where maximum velocities are exceeded upstream and downstream of the transition control structure and where the hydraulic jump occurs.
- For drop structures in lateral channels at the confluence with the receiving channel:
    - Locate the drop just inside the ultimate right-of-way of the receiving channel.
    - Design the hydraulic jump to occur before it enters the receiving channel.

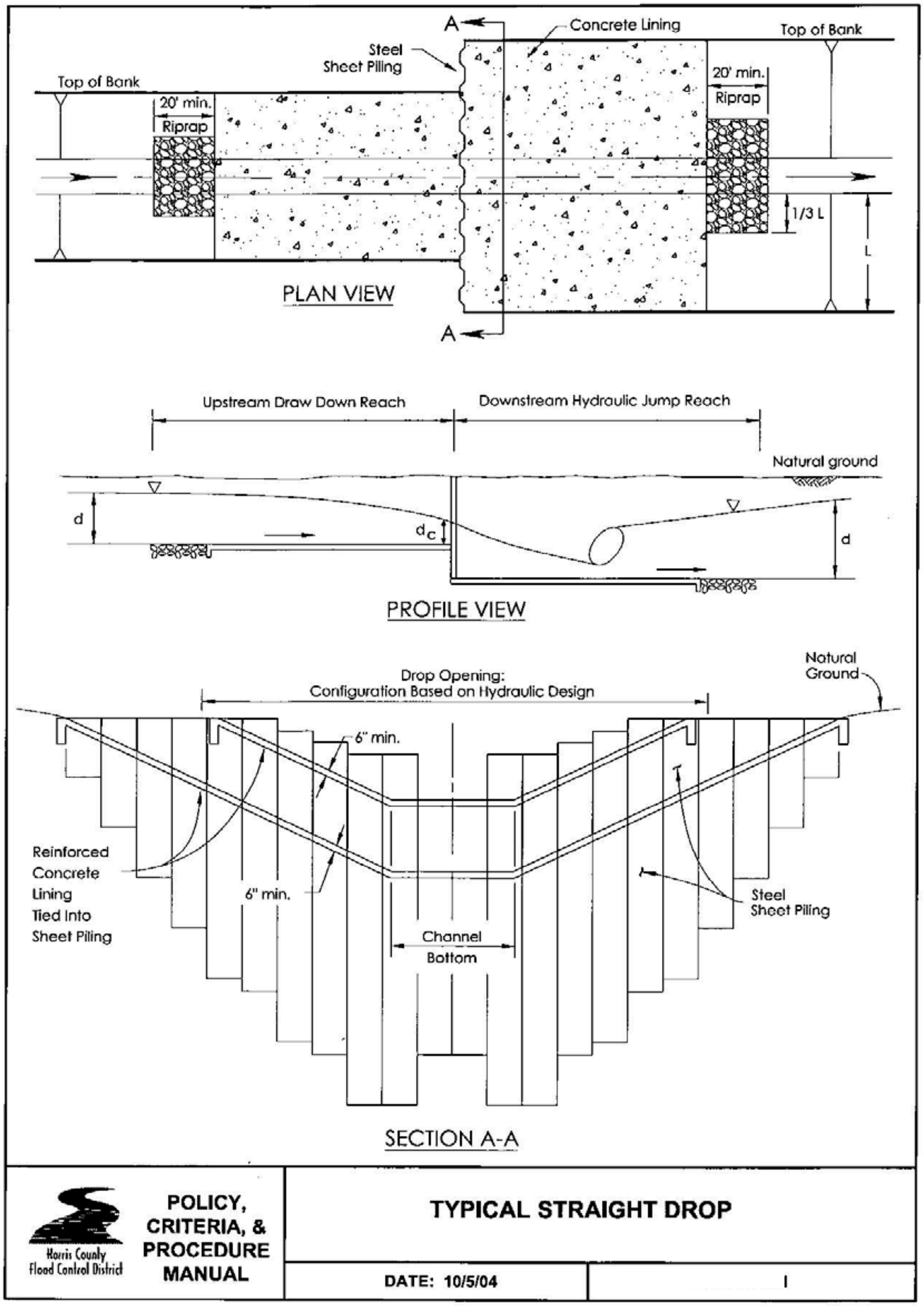


Figure C.1 Typical Straight Drop

Baffled Chutes

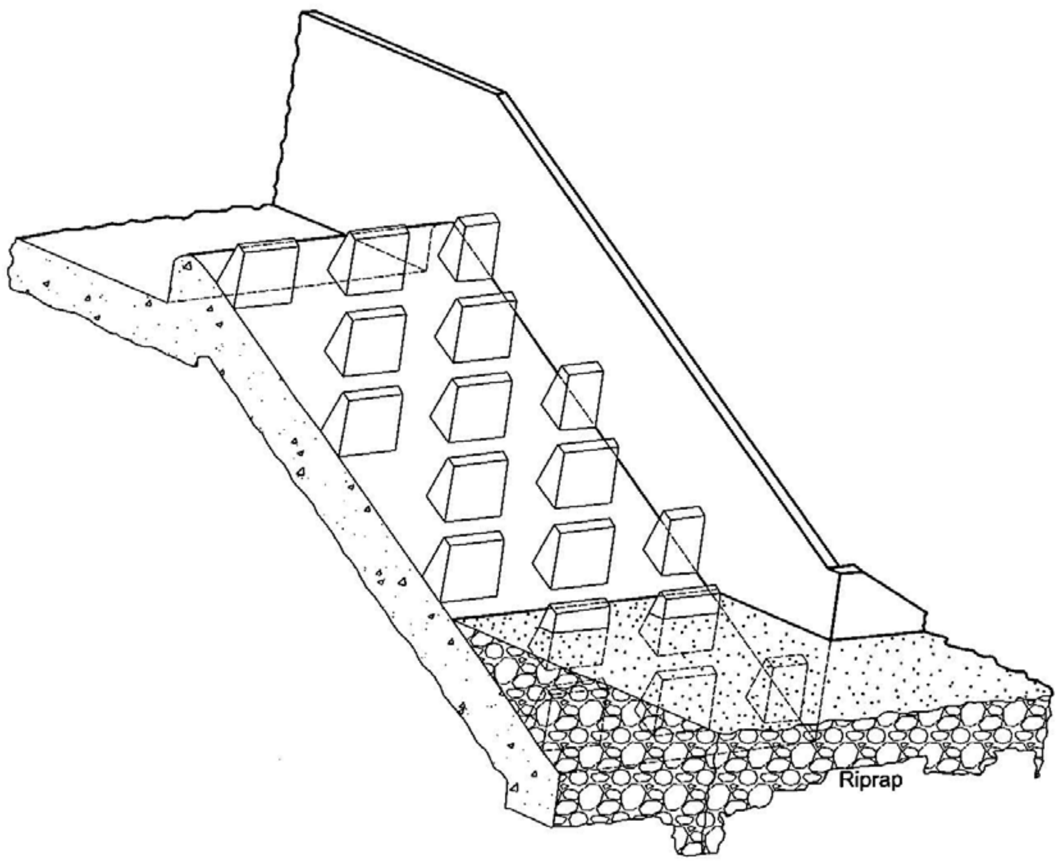
Overview

Baffled chutes are used to dissipate energy at abrupt changes in channel flowline and require no tailwater to be effective. They are generally selected over straight drop spillways for larger drop heights and where lateral channels drop into main channels. Baffle blocks prevent undue acceleration of the flow as it passes down the chute. Since the flow velocities entering the downstream channel are low, no stilling basin is needed. A generic baffled chute is shown in Figure C.2.

Design Criteria

Design criteria for baffled chutes:

- Comply with minimum design criteria for all transition control structures in the previous General Design Criteria.
- Use concrete lining on the entire cross section for the structure.
- Include twenty (20) feet of riprap at the upstream end of the concrete lining to decrease flow velocities and protect the concrete toe from scour (see Chapter 3.9 Stone Riprap Design).
- Use an applicable structural and hydraulic design methodology for baffled chutes.
- Use fully developed watershed conditions for establishing the design flow rate to avoid rebuilding the baffled chute as the watershed develops.



See "Hydraulic Design of Stilling Basins and Energy Dissipators," Engineering Monograph No. 25, U.S. Department of the Interior, Bureau of Reclamation, 1984.

Harris County Flood Control District — POLICY, CRITERIA, & PROCEDURE MANUAL	**BAFFLE BLOCK DROP**	
	DATE: 10/5/04	

Figure C.2 Baffle Block Drop

Appendix D – Sediment and Erosion Control Guidelines for Small Sites

SEDIMENT AND EROSION CONTROL GUIDELINE FOR SMALL SITES

As a builder, you are responsible for controlling soil and sediment on your job site during construction. This fact sheet provides some general guidelines that may be used for sites that involve construction activity that disturbs less than one acre of soil and are not required to obtain a Construction Stormwater Permit, but have the potential to discharge sediment and other non-stormwater discharges prohibited by city ordinance.

PERIMETER CONTROLS

Perimeter controls are used to capture sediment before it leaves the construction site. These types of controls include vegetative buffers, silt fencing, sediment traps and sediment logs. Sediment traps are small stormwater detention areas that allow sediment to settle out of runoff. A type of trap shown below (see sketch below) is called a cut-back curb. Cut-back curbs are small traps used to pond water behind the curb and gutter system. Frequent monitoring and maintenance of sediment traps is needed to ensure that deposited sediment doesn't reduce their capacity.

INLET PROTECTION

The purpose of inlet protection devices is to reduce the amount of sediment carried into the storm drain system. The device slows runoff and filters out sediment particles at the storm drain. Inlet protection devices are the last line of defense for capturing sediment and should only be used if no other control measures are adequate as they can cause property damage due to flooding if not frequently inspected and maintained.

STABILIZED CONSTRUCTION EXIT

A stabilized construction exit is used to reduce the amount of sediment tracked from a site onto the street by vehicles or equipment. A stabilized construction exit is typically made by creating a driveway from 1.5 inches or larger aggregate on top of a geotextile mat located where vehicles or equipment exit the site.

TEMPORARY COVER

Temporary cover is used to reduce erosion and should be applied immediately to areas where construction activity has ceased and is not planned to resume within 21 days or to temporary stockpiles of materials stored on site. Stockpiled material consists of gravel, sand, excavated soil, topsoil or any other similar material. These piles should never be placed where stormwater is conveyed (e.g., curb and gutter, drainage ditch).Temporary cover may be obtained by planting fast-growing plants like rye, oats, or winter wheat, or it may be obtained by spreading straw, wood chips, erosion control blankets or geotextile fabric over the area.

WASTE DISPOSAL

All waste and construction debris should be properly stored to prevent spills, leaks or discharges and to protect it from being carried away from the site by wind or water. All waste and debris should be properly disposed of in compliance with local, state and federal regulations.

CONCRETE WASH WATER

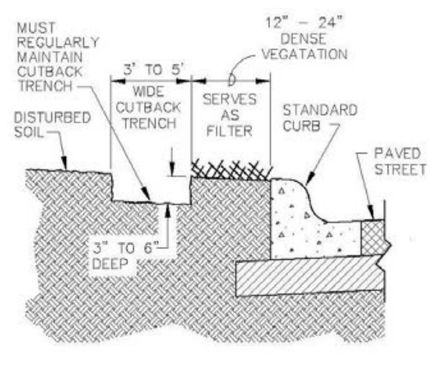
Concrete wash water must never be discharged or allowed to drain into the storm drain or adjacent properties. Wash water disposal must be limited to a defined area of the site or to an area designated by the developer for cement washout. The area must be sufficient to contain all wash water and residual cement.

INSPECTIONS AND HOUSEKEEPING

To ensure your control measures are in good condition and working properly, they should be inspected weekly and after any storm event. Good housekeeping should be practiced at all times. Housekeeping includes cleaning and maintaining all erosion and sediment control devices, cleaning sediment off streets, and picking up all debris that has been deposited off site by wind or water. Soil or sediment that has been deposited or tracked onto any street should be removed by the end of the day or before the next rain event.

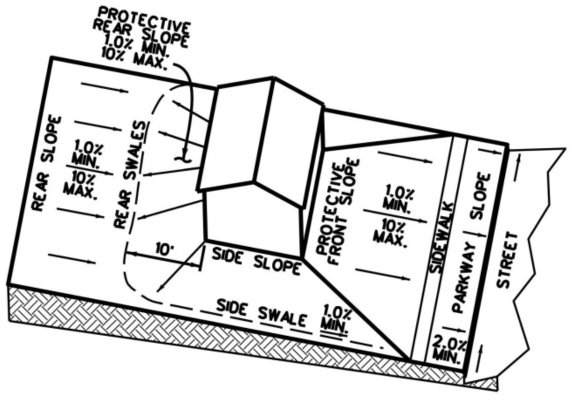
REMOVAL OF EROSION CONTROLS

Erosion control devices should remain in place and maintained until permanent vegetation is established. Once permanent vegetation is established, the control measures can then be removed.

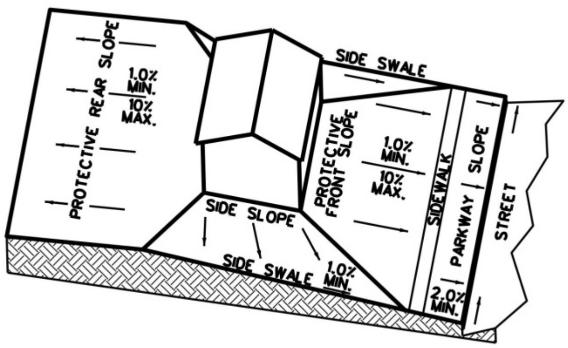


SECTION UNDERCUT LOT
NOT TO SCALE

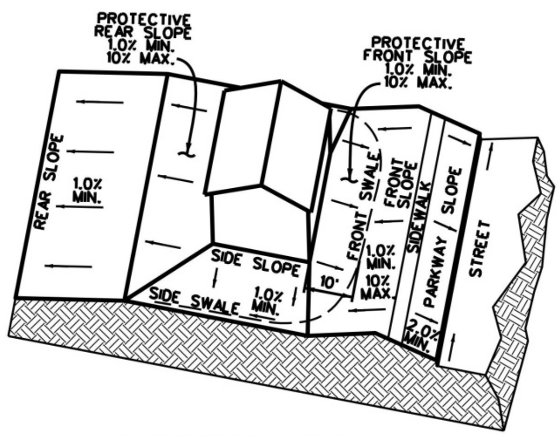
Appendix E – Single Family Residential Lot Drainage



LOT GRADING TYPE A
ALL DRAINAGE TO STREET



LOT GRADING TYPE B
DRAINAGE TO FRONT AND REAR LOT LINE



LOT GRADING TYPE C
ALL DRAINAGE TO REAR LOT LINE

GENERAL NOTES:

1. EXCEPT AS NOTED, BUILDING PAD GRADING TO BE PERFORMED BY HOUSE CONTRACTOR AFTER COMPLETIONOF SUBDIVISION IMPROVEMENTS.
2. ALL FINISH FLOOR ELEVATION SHALL BE MINIMUM OF 8" ABOVE THE HIGHEST GRADE ADJACENT TO BUILDING PAD. SEE CURRENT BUILDING CODE.FLOOR ELEVATIONS SHOWN ARE BASED ON THE MINIMUM FRONT SETBACK. ALL GRADING TYPE A & B LOT FINISH FLOORS SHALL BE AT LEAST 1.0 FT. ABOVE THE ROAD CROWN ALONG LOT FRONTAGE.
3. DRIVEWAY SLOPES BREAKS SHALL NOT EXCEED AN ALGEBRAIC DIFFERENCE OF ±14% WITHOUT PROPER VERTICAL CURVE.
4. MEANDER SWALES AROUND SPECIMEN TREES AND DO NOT DISTURB WETLAND VEGETATION.

TYPICAL FHA/VA THREE
DIMENSIONAL GRADING PLAN

Single Family Residential Lot Drainage Types

(Federal Housing Administration,

Land Planning Bulletin No. 3)

Block Grading Types

(Source: Federal Housing Administration Land Planning Bulletin No. 3)

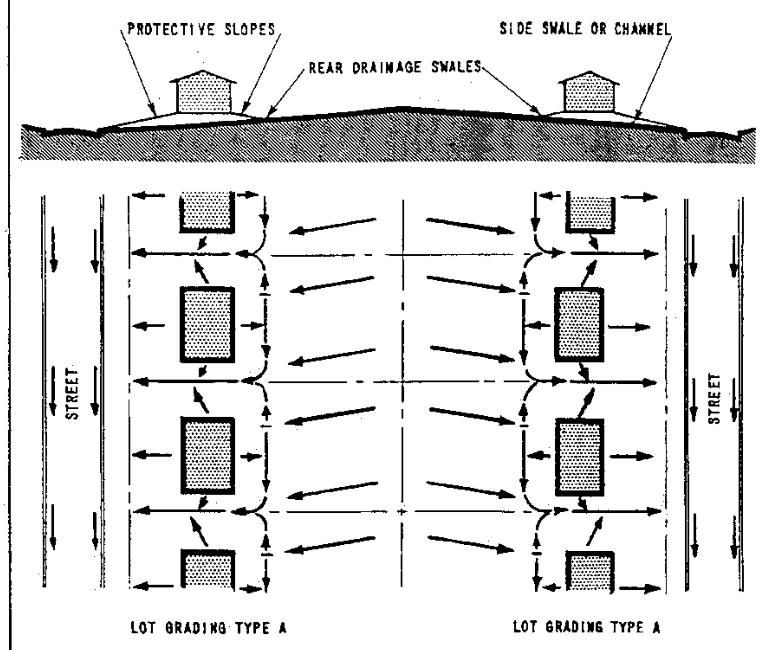
Block Grading Type 1 has a ridge along the rear lot lines and each lot is graded to drain surface water directly to the street independent of other properties. It is the most simple and desirable type of block grading. Topography, however, will often require other types of block grading types.

Block Grading Type 2 for a gentle cross-slope involves drainage of some surface water from lots of the high side of the block across the lower tier of lots. Difficulties are not encountered, however, if slopes are gentle and if the water always drains over short routes to the streets and does not concentrate or accumulate in volume at any point inside the block.

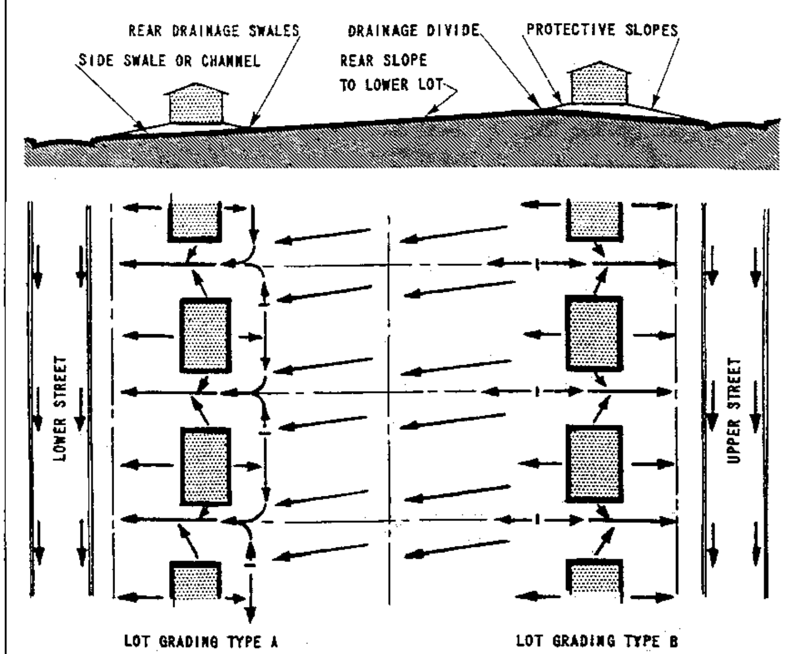
Block Grading Type 3 for steep cross-slopes and Type 4 for a valley along rear lot lines require special provision for block drainage and erosion control.

Erosion is controlled by provision of intercepting drainage swales in easements at the top of the rear lot incline or at intermediate locations along it, and by treatment of the steep slope itself.

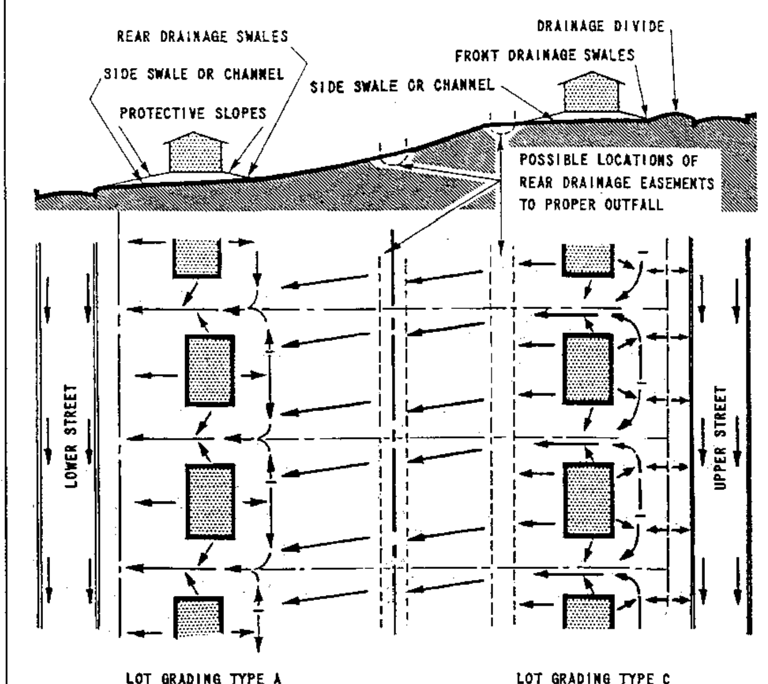
Drainage easements in Block Types 3 and 5 must have alignment, width, and improvements appropriate for the expected use and maintenance. Assurance of a permanent outfall is essential. The easements must be permanently established by proper legal methods, with continuous maintenance assured by public authority, property-owners' association or individual owners, as appropriate to the situation. Walls, buildings and any other obstructions to drainage flow, such as dense planting or tight fencing, must be legally prohibited in the easement area.



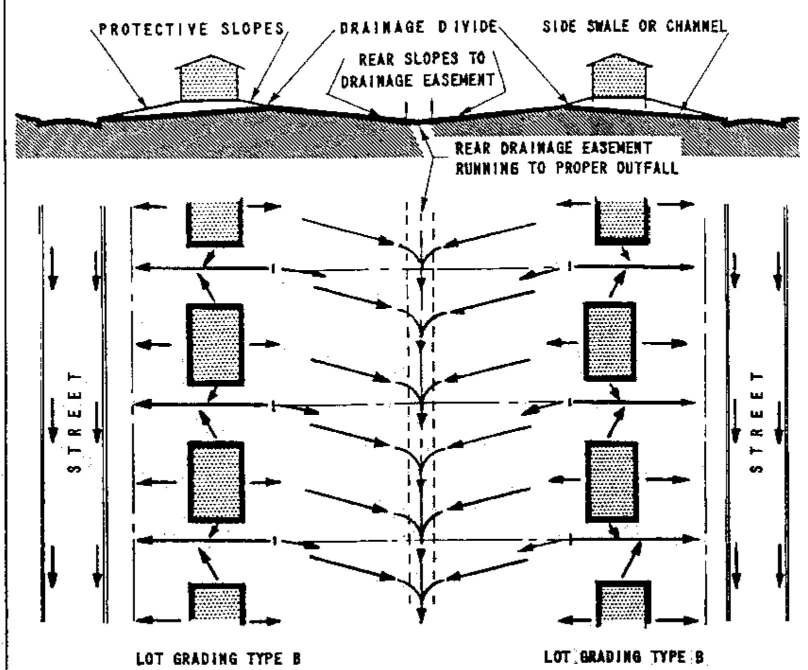
BLOCK GRADING TYPE 1: RIDGE ALONG REAR LOT LINES



BLOCK GRADING TYPE 2: GENTLE CROSS-SLOPE



BLOCK GRADING TYPE 3: STEEP CROSS-SLOPE



BLOCK GRADING TYPE 4: VALLEY ALONG REAR LOT LINES

Appendix F – Stormwater Utility Fee Credit Policy

Stormwater Utility Fee Credit Policy

Development Incentives and *Integrated* Design Point System

FORT WORTH

Transportation and Public Works Department

STORM WATER UTILITY FEE CREDIT POLICY

Authority and Purpose

The City of Fort Worth (City) adopted a Storm Water Utility in July 2006 to provide stable and equitable funding for its storm water management program. Developed properties are charged monthly fees based primarily on the amount of impervious area on a parcel of property. The ordinance establishing the utility also gives the Transportation and Public Works Director the authority (Section 12.5-343 (C)) to grant credits to rate payers who voluntarily use storm water management techniques or Best Management Practices (BMP's) to offset the impacts of their property on storm water runoff. These credits are applied as percent discounts to regular monthly storm water fees.

A general scheme of granting credits was developed by a citizen task force and presented to the City Council for comment in 2008. The purpose of this Credit Manual is to set out the specific conditions that must be achieved to qualify for these credits and to establish the administrative procedures for applying the credits to individual properties.

Eligibility

Only non-single family residential properties are eligible for a credit.

Types of Credits

Individual properties can be eligible for multiple credits up to a maximum total credit per property of 40%. Individual credits are available for the following BMP's:

- Industrial Permit Compliance 10%
- Detention Maintenance 5%
- Zero Discharge 40%
- Channel Protection Detention 10%
- Water Quality Treatment 25%
- Inlet Trash Collection 10%
- Parking Lot Sweeping 5%
- Student Education 10%
- Adopt a Creek 10%

Each credit listed above is given to encourage voluntary practices which will benefit the storm water program. In the case of Industrial Permit Compliance credit, the credit builds upon existing requirements established by the Texas Commission on Environmental Quality (TCEQ) and is available for participating in a voluntary self-assessment and reporting system, and for achieving a higher level of compliance with current regulations. A credit is also given for detention maintenance to encourage self-assessment and reporting related to operating and maintaining those facilities in accordance with adopted O&M plans.

No credit is given for detention per se, since detention is often required by regulations which prohibit increase in discharge rates which adversely impact downstream infrastructure and properties. Under those circumstances, it is sometimes economical to "over-detain" so that the discharge rate is less than pre-developed conditions, in which case the detention might alleviate existing flooding conditions downstream. In those situations, the City may be willing to enter into a cost-share relationship in order to achieve desirable public benefits downstream. These cases, however, will be handled on an individual basis and in accordance with the City's adopted policies.

Engineering Documentation

Several of the individual credits apply to the treatment of runoff from specific impervious areas and may or may not apply to the property as a whole. Technical information may be required from a licensed Professional Engineer to establish the impervious area served by a particular BMP as well as documenting compliance with City's design standards. These requirements are cited below as they apply to specific credits.

Administration of Credit Program

The storm water credits program will be administered as follows:

- The Engineering Manager will be responsible for the overall administration of the program.
- The Drainage Review Engineer will be the point of contact for accepting and reviewing applications for all credits except for the Industrial Permit Compliance credit. The Drainage Review Engineer will review and approve applications for these credits and certify the total amount of credit associated with each application.
- The Environmental Services Division (ESD) will be responsible for administering the Industrial Permit Compliance credit. This will include reviewing and approving applications, inspections, and annually certifying that credits should be extended or terminated each year.
- A Storm Water Utility Database Technician (GIS) will be responsible for amending the storm water account records to reflect changes in credits. Credits for Industrial Permit Compliance will be approved by the ESD; all other credits will be approved by the Drainage Review Engineer.
- A Storm Water inspector will receive and review annual self-inspection reports and conduct independent inspections of storm water control features (BMP's) as appropriate to insure that these facilities are being maintained properly and in accordance with adopted Maintenance Plans.

Annual Reporting

Annual self-reports will be required on March 31 to document program compliance for the preceding calendar year. If the self-reports are incomplete or are not submitted to the City by the required date, the facility shall be considered to be in non-compliance with the credit program requirements and the fee credit will be suspended. Fee credit suspension will remain in effect for a minimum of 3 months and will not be reinstated until the complete annual report is received with documentation that the program is being implemented as intended.

Industrial Facility Credit

Industrial facilities in the City of Fort Worth that are required by the TCEQ to obtain coverage under the Multi-Sector General Permit (TXR050000) for storm water discharge, or another applicable storm water general permit (TXG110000, TXG340000) or individual permit, may be eligible for a 10% credit applied to the City's storm water utility fee, if:

(a) The industry facility is consistently in compliance with all permit requirements;
(b) Permit required water quality testing results are consistently at or below their benchmark levels or permit required effluent limits during each sampling event. For results that exceed benchmarks or effluent limits appropriate actions, documented in the Storm Water Pollution Prevention Plan, must be taken to reduce pollutant discharge. Continued elevated levels may result in suspension from the fee credit program;
(c) Copies of the water quality test results are submitted to the City, and
(d) A copy of the facility's annual compliance inspection report and a copy of the facility Storm Water Pollution Prevention Plan required by the permit are provided to the City.

Facilities with a No Exposure Certification (NEC) also are eligible for the fee credit if compliance with all NEC requirements is maintained.

Detention Maintenance Credit

A 5% credit will be given for impervious areas draining into detention basins and retention ponds which are maintained in accordance with a city approved maintenance plan. The owner of the facility must submit an annual self-report every March 31 in order to document that the required maintenance is being provided.

Zero Discharge Credit

A credit of 40% will be given for impervious areas which drain to a retention pond that is designed and operated to contain runoff from a 100 year 24 hour storm without discharge. This credit is intended for those situations where rainwater runoff is stored for later re-use.

Water Quality Treatment Credit

A 25% credit will be given for impervious areas draining to a water quality treatment control that removes 70% or more of the Total Suspended Solids (TSS) for the Water Quality Protection Volume as defined in the City's *Storm Water Management Design Manual (Design Manual).* Pro-rated credits may be applied where less than 70% TSS removal is achieved. Engineering certification will be required to show that these facilities are designed and constructed in accordance with applicable City standards and meet the level of treatment herein specified.

Channel Protection Detention Credit

A 10% credit will be given for impervious areas draining to a detention or retention facility that is designed to discharge a one year storm over 24 hours. The purpose of this control is to reduce the impact of increased flows and velocities that are normally associated with urban development.

Engineering certification will be required to show that the control complies with applicable City design standards.

Inlet Trash Collection

A 10% credit will be given for impervious areas draining to inlets that are designed and operated to collect litter and sediment for minor flows of less than one year storm frequency. Approval must be given for the specific design of the fitting, including manufacturer's recommended maintenance frequency. Annual self-reporting will be required.

Parking Lot Sweeping

A 5% credit will be given for parking lots swept at least once weekly. Annual self-reporting will be required to document coverage and sweeping frequency.

Student Education

A 10% credit will be given for impervious areas contained within public or private educational facilities for K-12 grades, where an average of one hour/student of age appropriate storm water related teaching is provided each year. Eligible topics include flood protection, public safety and environmental stewardship related to storm water runoff, subject to approval by the City. Annual self-reporting will be required.

Adopt a Creek

A 5% credit will be given for impervious areas associated with a public or private school served by a creek or channel. The purpose of this credit is to reward the removal of litter from along creeks and channels within the City while fostering a greater sense of environmental stewardship on the part of those individual who participate in the clean-up activity. Details have not yet been developed to govern this credit, but semi-annual clean-up projects are envisioned where civic organizations would provide volunteers in a one day/year activity that would be supported by the City providing organization, trash bags, solid waste pick-up, promotion and public recognition including appropriate signage.

Property Owner Associations

In the case of a detention basin or water quality treatment control such as a properly designed wet pond, the credit for that control may be applied to the nearest impervious area owned by the property owner association responsible for maintaining the control even though run-off from the impervious area subject to the credit is not treated by the control. For example, a property owner association parking lot might not drain to a control maintained by the association, but the credit could still be applied as though it did, up to the 40% maximum credit limit.

Fees

No fees are required to submit an application for a storm water credit. The cost of administering this program will be borne solely by the Storm Water Program.

Application for Credits

All applicants must complete the attached Application for Storm Water Fee Credit. Industrial facilities applying for the Industrial Permit Compliance credit must also complete the Supplemental Industrial Permit Information form. All required attachments indicated in the forms or specified above must be included for the application to be considered complete.

The initial review of Storm Water Utility Credit Applications will be completed within 60 days of the receipt of the application form and required documentation. The application forms will be checked for completeness and accuracy. If deficiencies are found during the review, a deficiency letter will be sent to the applicant's contact person. Upon receipt of required additional information, the review will resume and be completed within 60 days of receipt of additional information.

For the Industrial Permit Compliance credit and certain other credits, an inspection may be required. Where this is required, a City inspector will contact the applicant to schedule an initial facility inspection to establish current compliance status, discuss any deficiencies that require correction, and schedule a follow-up inspection if necessary.

Upon initial qualification, a letter will be sent to the applicant notifying them of approval of the credit. The fee reduction will be applied the next regular billing cycle.

Inspections

Upon application for a credit, the applicant shall grant the City a right-of-entry to inspect the site at any time in order to verify the information submitted and to confirm compliance with applicable program requirements. If, after its review or inspection, the City finds the application to be inaccurate or the facility to be out of compliance, the applicant will be notified in writing and given up to 45 days to correct the deficiency. The applicant must provide written documentation to the City within 45 days of the original notice by the City that the facility is now meeting all program requirements along with evidence that the deficiency has been corrected. If the deficiency is not satisfactorily corrected, the fee credit will be terminated on the following billing cycle. The credit suspension will remain in effect a minimum of 6 months, after which time the facility may reapply for the fee credit. The reapplication must include evidence that the deficiency has been corrected and that the facility has been in compliance with program requirements for at least three months prior to reapplication.

APPROVED:

William A. Verkest, P.E. Date

FORT WORTH

Application for Storm Water Fee Credit

(Please Type or Print)

Check One: ☐ This is the first application for credit for this facility.

☐ This is a reapplication for renewed credit after a credit suspension.

PART I

A	**Facility Information**		
1. Facility Name:			
2. Physical Address of Facility: (enter in spaces below)			
Street Number:	Street Name:		Zip Code:
3. Mailing Address: Is mailing address same as above? ☐Yes ☐ If no, provide below			
Street Number:	Street Name:		
City:	State:	Zip Code:	
B	**Applicant Contact Information**		
1. Name:		2. Title:	
3. Phone No.: ( ) Ext:		4. Fax No.: ( )	
5. E-mail address:			
C	Credits applied for (check all that apply)		

☐ **Industrial Permit Compliance** (complete *Supplemental Industrial Permit Information Form* and include all required attachments)

☐ **Zero Discharge** (submit drainage study by licensed Professional Engineer)

☐ **Detention Maintenance** (submit approved Maintenance Plan)

☐ **Channel Protection Detention** (submit design and calculations sealed by Professional Engineer)

☐ **Water Quality Treatment** (submit design and calculations sealed by Professional Engineer)

☐ **Inlet Trash Collection (**submit drainage map, inlet design details and manufacturer's recommendations for operation and maintenance)

☐ **Student Education** (submit information regarding curriculum and student hours).

☐ **Adopt a Creek** (submit information regarding proposed clean up project, including location of creek or channel, date of activity, number of volunteers expected, and specific support by City forces needed to accomplish project)

☐ **Parking Lot Sweeping** (submit map and schedule showing areas and frequency of sweeping to be accomplished)

CFW Storm Water Utility Fee-Credit Application Page 6

FORT WORTH

Storm Water Fee Credit Application

PART II	**Signature and Approval**

I hereby state that the information in this application, including all attachments and supplemental forms, is true to the best of my knowledge and acknowledge that any attempt to purposely supply incorrect information may result in denial of the credit application. I further understand the review of the documents submitted by me may take up to sixty (60) days to complete and that submissions which do not contain the correct information or that are otherwise incomplete will be delayed an additional sixty (60) days after the date the corrected or missing information is provided to the City.

________________________ ________________________ ________________

Signature of Applicant Title Date

Submit application and all attachments to: City of Fort Worth TPW S*torm Water Management Division* 1000 Throckmorton St. Fort Worth TX 76102 **ATTN: Storm Water Utility Fee Review**	Case No. ________ SW Act No.__________ **Credits approved: ________%** Approved by ___________ Date __________

CFW Storm Water Utility Fee-Credit Application Page 7

FORT WORTH

Storm Water Fee Credit Application

Supplemental Industrial Permit Information Form

A	Permit Information

1. Facility Name:
(as listed on NOI or NEC)

2. TPDES Permit No.: 3. Primary SIC Code: 4. Industrial Sector:

5. Date Industrial Operations Began:
for current owner/operator

6. Date NOI or NEC Filed with TCEQ:

B	Compliance with Current TPDES Storm Water Permit

1. Have all schedules of the current permit relating to monitoring, training, implementation of Best Management Practices (BMPs) and compliance with the Storm Water Pollution Prevention Plan (SWPPP) been met for the preceding 12 month period?

-or-

For facilities with a No Exposure Certification, have all eleven of the no exposure requirements been met for the preceding 12 month period?

☐Yes ☐No

If the answer is no, provide a summary description of the current permit requirement/schedule that has not been met, cause for non-attainment, compliance schedule, and current efforts to complete this activity (attach additional pages if necessary).

FORT WORTH

Storm Water Fee Credit Application

Supplemental Industrial Permit Information Form

C	Attachments
	All required attachments must be included for the application to be considered complete (not required for facilities with No Exposure Certification).

ATTACHMENT 1	A copy of your Storm Water Pollution Prevention Plan: Include records for spills, Best Management Practice (BMP) maintenance, training, employee education, periodic inspections, and quarterly visual monitoring for the previous 12 month period. A copy of the permit does not need to be included.
ATTACHMENT 2	Most recent Annual Comprehensive Site Compliance Evaluation Report
ATTACHMENT 3	Annual Hazardous Metals Monitoring (Numeric Effluent Limitations) Have you obtained a waiver from hazardous metals testing for all or a portion of the metals and outfalls? Waivers may be obtained on a metal by metal basis, or on an outfall by outfall basis. ☐ A waiver has been obtained for all metals at all outfalls. Attach a copy of the signed waiver (form TCEQ-10425). ☐ A waiver has been obtained for only a portion of the metals and/or outfalls. Attach a copy of the signed waiver (form TCEQ-10425) and a copy of your most recent results (use EPA form 3320-1). ☐ A waiver has not been obtained. Attach a copy of your most recent results (use EPA form 3320-1).
ATTACHMENT 4	Benchmark Monitoring Report. Not all facilities must conduct benchmark monitoring. No SIC codes in Sectors I, P, R, V, W, X, Z, AB, AC, or AD require benchmark monitoring. Is Benchmark Monitoring required for your facility? ☐Yes ☐No If yes, attach a copy of your most recent Report of Benchmark Monitoring Data submitted to TCEQ (Form TCEQ-20091).

Point System

All sites that wish to receive CFW stormwater fee credits must provide on-site enhanced water quality protection. Under the *integrated* Site Design Practice option, sites that accumulate a minimum number of points by incorporating *integrated* Site Design Practices are considered to have provided enhanced water quality protection.

The point system is made up of three components:

1. The initial percentage of the site that has been previously disturbed sets the minimum requirement. This is shown in the left-hand column of Table F.1.
2. A minimum required total of Water Quality Protection (WQP) points are needed to meet the basic water quality criteria. This minimum is shown in the center column of Table F.1.
3. Optional additional points can be accumulated through additional use of Site Design Practices to be eligible for developer incentives. Each developer incentive attained requires ten (10) additional Site Design Practice points above the minimum required points as shown in the right-hand column of Table F.1.

As shown in Table F.1, the initial percentage of site disturbance sets the minimum required points necessary to meet Water Quality Protection criteria. If a developer wishes to go beyond this minimum then the number of additional points required to attain specific development incentives is also given.

Table F.1 *integrated* Site Design Point Requirements

Percentage of Site(by Area) with Natural Features Prior to Proposed Development	Minimum Required Points for Water Quality Protection (WQP)	Additional Points Above WQP for Development Incentives
> 50%	50	10 points each
20 - 50%	30	10 points each
< 20%	20	10 points each

The minimum number of points required to achieve WQP, as shown in the center column of Table F.1, depends on the proportion of undisturbed natural features that exist on the site before it is developed. It is assumed that disturbing a site that has little previously disturbed area will cause more relative environmental impact than a site that has already incurred significant site disturbance. Therefore, disturbing a “pristine” site carries a higher restoration/preservation requirement.

For the purpose of this evaluation, undisturbed natural features are areas with one or more of the following characteristics:

- Unfilled floodplain
- Stand of trees, forests
- Established vegetation
- Steep sloped terrain
- Creeks, gullies, and other natural stormwater features
- Wetland areas and ponds

The number of points credited for the use of *integrated* Site Design Practices is shown in Table F.2. To determine the qualifying points for a site, the developer must reference Table F.2 and follow the guidance for each practice in the *Planning Technical Manual*.

Using the area of the site that is eligible for a practice as a basis, points are given for the percent of that area to which the *integrated* Site Design Practice is applied. For example, if a planned site has four (4) acres of riparian buffer and the developer proposes to preserve two (2) acres, then the site would qualify for 50 percent of the 8 credit points for iSWM Site Design Practice 2 (Preserve Riparian Buffers), because 50 percent of the site design practice was incorporated. The actual points earned for iSWM Site Design Practice 2 would be 4 points (0.50 * 8 pts = 4 pts). To comply with water quality protection and to apply for site design credits, the developer must submit the completed table and associated documentation or calculations to the CFW.

It should be noted that the Water Quality Protection Volume requirement is encouraged but not mandatory in the CFW, except as may be required by Tarrant Regional Water District for new facilities connecting directly with the Trinity River.

Table F.2 Point System for *integrated* Site Design Practices

***i*SWM Practice No.**	**Practice**	**Percent of Eligible Area Using Practice**	**Maximum Points**	**Actual Points Earned (% practice used * max. points)**
Conservation of Natural Features and Resources				
1	Preserve/Create Undisturbed Natural Areas		8	
2	Preserve or Create Riparian Buffers Where Applicable		8	
3	Avoid Existing Floodplains or Provide Dedicated Natural Drainage Easements		8	
4	Avoid Steep Slopes		3	
5	Minimize Site on Porous or Erodible Soils		3	
Lower Impact Site Design				
6	Fit Design to the Terrain		4	
7	Locate Development in Less Sensitive Areas		4	
8	Reduce Limits of Clearing and Grading		6	
9	Utilize Open Space Development		8	
10	Incorporate Creative Design (e.g. Smart Growth, LEED Design, Form Based Zoning)		8	
Reduction of Impervious Cover				
11	Reduce Roadway Lengths and Widths		4	
12	Reduce Building Footprints		4	
13	Reduce the Parking Footprint		5	
14	Reduce Setbacks and Frontages		4	
15	Use Fewer or Alternative Cul-de-Sacs		3	
16	Create Parking Lot Stormwater “Islands”		5	
Utilization of Natural Features				
17	Use Buffers and Undisturbed Areas		4	
18	Use Natural Drainageways Instead of Storm Sewers		4	

Table F.2 Point System for *integrated* Site Design Practices				
***i*SWM Practice No.**	**Practice**	**Percent of Eligible Area Using Practice**	**Maximum Points**	**Actual Points Earned (% practice used * max. points)**
19	Use Vegetated Swale Design		3	
20	Drain Runoff to Pervious Areas		4	
Subtotal – Actual site points earned			**100**	
Subtract minimum points required (Table F.1) -				
Points available for development incentives				
Add 1 point for each 1% reduction of impervious surface +				
Total Points for Development Incentives				

Development Incentives

The developer can use *integrated* Site Design Practice points in excess of the minimum required for water quality protection to qualify for development incentives provided by the City. Additional points can be earned for redevelopment sites. Each reduction of one (1) percent imperviousness from existing conditions qualifies for one (1) site design point. The total points available for development incentives shall be calculated per Table F.2. Each incentive requires ten (10) additional points above the minimum point required to meet water quality criteria, as stated in Table F.1.

A list of available development incentives includes:

1. Narrower pavement width for minor arterials
2. Use of vegetated swales in lieu of curb and gutter for eligible developments
3. Reduced ROW requirements, i.e. Sidewalk/Utility Easements
4. Increased density in buildable area, floor area ratios, or additional units in buildable area
5. Expedited plans review and inspection
6. Waiver or reduction of fees
7. Local government public-private partnerships
8. Waiver of maintenance, public maintenance
9. Stormwater user fee credits or discounts
10. Rebates, local grants, reverse auctions
11. Low interest loans, subsidies, tax credits, or financing of special green projects
12. Awards and recognition programs
13. Reductions in other requirements

The Development Incentives and *Integrated* Design point system described above are not adopted by CFW. CFW development policies, however, encourage the incorporation of stormwater controls for achieving stormwater quality goals through the acceptance of perpetual, limited maintenance of preserved streams and by affording flexibility in placing stormwater quality treatment controls in land required for other purposes such as parks or commercial landscape areas.

The CFW has adopted a stormwater fee credit system, which provides monthly fee discounts where BMP's are provided. These include credits for the following structural BMP's:

- Water Quality Controls—25% credit

- Channel Protection Detention—10% credit
- Detention Basins—5% credit for maintenance and annual self-inspection in accordance with Private Maintenance Agreement

These credits apply to fees associated with impervious areas treated by these controls. Water quality and channel protection controls must be designed in accordance with standards adopted in this manual.