CITY OF Tulsa
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# Stormwater Management Criteria Manual

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**Prepared by:**
**City of Tulsa - Engineering Services Department**

*2317 South Jackson Avenue*
*Tulsa, OK 74107*

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# Chapter 100 EXECUTIVE SUMMARY

## 101 INTRODUCTION

This MANUAL, City of Tulsa Revised Ordinances, Title 11-A Stormwater Drainage (referred to as Ordinances), as well as current policies and criteria specific to each chapter of the MANUAL.

### 101.1 Manual Contents

This MANUAL contains stormwater management criteria relative to drainage policies and procedures for submittal and review of drainage designs and reports. The procedures and criteria are specific regarding hydrological procedures for stormwater runoff, hydraulic analysis for channels, storm sewer systems, stormwater detention, culverts and bridges, stormwater pollution protection, as well as requirements for maintenance and operation of drainage facilities.

### 101.2 Executive Summary

The Executive Summary is arranged in three parts. The first part, **Administrative Provisions,** describes the requirements for stormwater analysis contained in these chapters:

- General Provisions
- Stormwater Policy and Standards
- Oklahoma Stormwater Law
- FEMA and City of Tulsa Regulatory Floodplain Management
- Drainage and Detention Report

The second part presented, **Technical Provisions,** describes the technical criteria and standards for hydrological and hydraulic analysis contained in these chapters:

- Rainfall and Runoff
- Open Channels, Culverts, Bridges and Other Hydraulic Structures
- Street Drainage, Storm Sewer Inlets and Storm Sewer Pipe System Design
- Detention Pond Design

The third part summarizes the **Other Requirements** regarding:

- Construction-Storm Water Pollution Prevention Plan
- Post-Construction Stormwater Pollution Prevention Plan
- Maintenance and Design

# 102 ADMINISTRATIVE PROVISIONS

## 102.1 General Provisions

This chapter outlines the amendment and revision to the MANUAL, the enforcement responsibilities and the criteria for interpretation of those provisions.

- This chapter outlines the variance, technical variance and appeal process for relief from the requirements of this MANUAL.

All documentation and plans required by this manual must be approved by the ADMINISTRATOR and CITY ENGINEER. Projects and tasks proposed in the plans and documents required by this MANUAL shall be implemented as proposed. Any changes or amendments to the plans or documentation must be approved by the ADMINISTRATOR and CITY ENGINEER in accordance with the established review procedures.

For the purposes of this MANUAL the ADMINISTRATOR is the City of Tulsa Floodplain Administrator. The ADMINISTRATOR shall have jurisdiction over all projects submitted for approval by the Development Services Division. CITY ENGINEER is defined as the Director of Engineering Services Department. The CITY ENGINEER shall have jurisdiction over all projects submitted for approval by the Engineering Services Department.

## 102.2 Stormwater Policy and Standards

The drainage policies for the City of Tulsa have been codified in the ordinances. The general goals and objectives are presented in Chapter 300 and are summarized below:

- All drainage analysis will be based on the storm runoff from a fully urbanized watershed for floods up to and including the 1% (100-year) storm in order to account for the additional runoff volume occurring in a fully urbanized watershed due to additional impervious areas.
- The design of any development with drainage areas larger than 40 acres shall provide for the maximum use of open channels and natural streams and detention or retention storage to control runoff rates.
- The Administrator may require open channels for drainage ways for just cause. Open channels are required when delineated in the approved master drainage plans.
- Development shall be constructed in such a way that it will not increase the frequency of flooding or the depth of inundation of structures.
- The peak flows from development shall be controlled by on-site detention, or by regional detention identified in the adopted City master drainage plans

Fee-in-lieu of on-site detention may be paid when it can be demonstrated that the development will not aggravate drainage, flooding of downstream structures or properties.

## 102.3 Drainage and Detention Report Requirements

Chapter 500 outlines the requirements for Drainage and Detention Reports for all developments, including single lot developments.

### 102.3.1 Infrastructure Design Procedures (IDP)

The procedure for the review and approval of an Infrastructure Development Permit is found in the City of Tulsa Infrastructure Design Procedures (IDP) Manual.

# 103 TECHNCIAL PROVISIONS

## 103.1 Hydrology Analysis

This chapter describes the computational techniques to be used for all hydrologic analyses of stormwater conveyance and/or stormwater detention systems.

- HEC-HMS is the preferred computer program for performing hydrologic analysis. Other computer software may be used with the approval of the CITY ENGINEER.

A brief description of the HEC-HMS computer models is presented in Section 602. The user is referred to the US Army Corps of Engineers documentation for specific details. The design storms to be used are presented in Section 603.

A brief description of the approved hydrology methods and the acceptable parameters for the Tulsa area are presented in Sections 604 through 606. HEC-HMS is the preferred computer program for flood plain discharge calculations and Stormwater detention facilities. A brief description of the HEC-HMS and A brief description of the Rational Method is given in Section 608. ***The use of the Rational Method (Section 608) is limited to watersheds with a time of concentration of less than 10 minutes for the entire watershed draining to the point of discharge from the project.***

## 103.2 Hydraulic Analysis

This chapter describes the computational techniques to be used for all hydraulic analysis of storm water conveyance and/or storm water detention systems.

- Hydraulic analyses will be required for all floodplain studies that include the design or evaluation of bridges, culverts, hydraulic structures, natural open channels and improved open channels.

  All channel and flood plain analyses will require the use of a HEC-RAS computer model.

- Fully urbanized conditions in the upstream watershed shall be used to determine the final design. The 1% (100-year) storm fully urbanized discharge shall be the design discharge. The

50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), 1% (100-year), and 0.2% (500-year) floods shall be studied.

## 103.3 Street Drainage, Storm Sewer Inlets and Pipe Design

The chapter discusses the required design criteria for residential, arterial and collector streets within the City. When the drainage in the street exceeds allowable limits, a storm sewer system or an open channel is required to convey the Stormwater runoff.

**Design Storm:** Storm sewers shall be designed to pass the 1% (100-year) storm.

- **First Upstream Inlet:** For non-residential streets, the first inlet shall be located no more than 400 feet from the high point in the street profile or at the point where the outside lane would be inundated (typically 0.38' depth), whichever is less.
- **Special Exemption for Street Rehabilitation Projects:** For construction projects in areas where storm sewers are not upgraded, all inlets shall be designed to fully utilize the existing storm drainage system.

### 103.3.1 Storm Sewer Systems

The City standards allow reinforced concrete pipe and corrugated polypropylene pipe in public systems and private sewers systems. Flexible pipe materials are restricted to areas outside the street right of way in private systems only.

## 103.4 Detention Ponds

The chapter presents the requirements for the design and evaluation of all stormwater storage/detention facilities for the City of Tulsa.

- A detention facility, when required, will temporarily store the increased stormwater runoff associated with development to the pre-development runoff rate of the site
- The City of Tulsa defines two types of detention: on-site and regional:
    - On-site detention is defined as a privately owned and generally privately maintained open space, parking lot, or underground facility which serves the development.
    - Regional detention is publicly owned and maintained and generally is part of a planned open space park system or greenbelt area serving a larger portion of the watershed.

    The design of detention facilities that have a certain storage volume and/or dam height are subject to regulation by the Oklahoma Water Resources Board.

# 104 OTHER REQUIREMENTS

## 104.1 Construction Stormwater Pollution Prevention Plan

This chapter presents information necessary to comply with Federal and State laws and regulations regarding construction storm water pollution prevention plans as well as with the policies established by the CITY. Information is provided regarding construction storm water pollution prevention plans along with references to the regulations, design methods, and design details.

This Chapter includes information on:

- Regulatory Basis - From the national urban runoff program (NURP) in the 1970s and Clean Water Act (CWA) 305(b) reports submitted to Congress in the 1980's to the rules established under the Oklahoma Pollution Discharge Elimination System (OPDES), as promulgated under Oklahoma Administrative Code (OAC) 252:605. Specifically, ODEQ regulates discharges associated with construction activities.
- Areas with construction activities that disturb or plan to disturb 1 or more acres must obtain a Storm Water discharge permit. This permit was issued to effect compliance with the Phase II Storm Water regulations issued December 8, 1999.
- Activities Permitted Through EPA
- Activities to be Completed Under a Storm Water Pollution Prevention Permit for Construction - Including steps to be completed under OKR10 for a Storm Water Permit for Construction Activities, including the Storm Water Pollution Prevention Plan (SWP3).
  - Notice of Intent (NOI)
  - Fees
  - Notice of Termination (NOT)
  - Inspections
- Best Management Practices for Construction Activities - Including structural and non-structural methods to prevent erosion and sediment from leaving the construction site through storm water runoff, tracking or wind-dispersion.
- A summary of BMPs commonly used on construction sites.
- Information on selection of Storm Water Controls

## 104.2 Maintenance and Design

The purpose of this chapter is to present background and information necessary to comply with federal and state laws and regulations regarding post-construction storm water pollution prevention and with the policies established by the CITY presented in this MANUAL. Information is provided regarding post-construction storm water pollution prevention along with references to the regulations, design methods, and design details. Specific design standards and criteria have been adopted by the CITY that improves the ability to maintain drainage facilities in an efficient and cost-effective manner.

# Chapter 200 GENERAL PROVISIONS

This document together with all future amendments shall be known as the "City of Tulsa Stormwater Management Criteria Manual" (referred to as MANUAL), being part of City of Tulsa Revised ORDINANCES, Title 11-A Stormwater Drainage (referred to as ORDINANCES). These are the standards for stormwater drainage facilities as referenced in Chapter 3 of the ORDINANCES and identified as City Drainage Standards.

## 201 APPLICATION

Every person, firm, agency, institution or corporation, and every city, county, state or federal government entity, who seeks to develop, redevelop, grade, regrade, excavate, landfill, berm or dike within the city of Tulsa shall be bound by Chapter 3 of the ORDINANCES (Watershed Development Regulations) and the provisions of this MANUAL.

## 202 PURPOSE AND INTENT

Presented in this MANUAL are the minimum requirements necessary to promote the general public health, safety and welfare benefits by providing for, operating, constructing, equipping, maintaining, acquiring and owning a storm water drainage system. All development, redevelopment, grading, regrading, excavation, landfill, berming or diking of land within the City of Tulsa, public or private, shall conform to the provisions set forth in this MANUAL.

## 203 ENACTMENT AUTHORITY

This MANUAL has been prepared and adopted pursuant to the authority granted by title 11A of the ORDINANCES.

## 204 AMENDMENT AND REVISIONS

The policies, standards and criteria presented in this MANUAL are basic guidelines which may be amended as new technology is developed and/or experience is gained in the use of this MANUAL indicating a need for revision. Amendments and revisions to the MANUAL will be made in accordance with ORDINANCES. Drainage analyses submitted for approval within thirty (30) days after the effective date of amendments or revisions are exempt from the changes.

## 205 ENFORCEMENT RESPONSIBILITY

It shall be the duty of the Floodplain Administrator (ADMINISTRATOR) or his or her designee to enforce the provisions of this MANUAL for all projects that are submitted for approval to the Development Services Division. It shall be the duty of the Director of Engineering Services Department (CITY ENGINEER) or his or her designee to enforce the provisions of this MANUAL for all other projects that are submitted to the CITY for approval.

# 206 INTERPRETATION

In their duties to enforce the provisions of the MANUAL, the ADMINISTRATOR and the CITY ENGINEER shall interpret the provisions according to the following criteria:

## 206.1 Minimum Standards

In their interpretation and application, the provisions of this MANUAL shall be the minimum requirements for promotion of the health, safety, convenience, order and general welfare of the community. The CITY ENGINEER and the ADMINISTRATOR may, at his/ her discretion, set aside these criteria for promotion of the health, safety, convenience, order and general welfare of the community.

## 206.2 Other Regulations

This MANUAL is not intended to interfere with, abrogate, or annul any other regulation, statute, or other provision of law.

Where any provision of this MANUAL imposes restrictions different from those imposed by any other provision of this MANUAL or any other regulation or provision of law, that provision which is more restrictive or imposes higher standards shall govern.

## 206.3 Other Agreements

This MANUAL is not intended to abrogate any easement, covenant, or any other private agreement or restriction, provided that where the provisions of this MANUAL are more restrictive or impose higher standards or requirements than such easement, covenant, or other private agreement or restriction, the provisions of this MANUAL shall govern.

# 207 VARIANCES

For the purpose of this manual, there is defined a variance and a technical variance. A variance is grant of relief from the requirements of the ORDINANCES when specific enforcement would result in unnecessary hardship. A variance therefore permits development or construction in a manner otherwise prohibited by the ORDINANCES.

A technical variance is a relief from specific technical requirements of the MANUAL, due to site or project conditions which, if enforced, would result in unnecessary hardships. A technical variance will not be granted when, in the opinion of the ADMINISTRATOR, the technical variance would conflict with the requirements of the ORDINANCES.

### 207.1 Variance Procedure

The Stormwater Drainage and Hazard Mitigation Advisory Board (SDHMAB) shall act upon requests for variances in accordance with the provisions of the ORDINANCES, subject to the procedural and substantive standards set forth in the ORDINANCES.

If the applicant for a Watershed Development permit disagrees with the interpretation of the provisions of the ORDINANCES by the ADMINISTRATOR and/or CITY ENGINEER, the applicant may request the ADMINISTRATOR to review the interpretation. If the ADMINISTRATOR and/or CITY ENGINEER agree with the applicant, the appeal will be granted; otherwise the applicant must submit a request for a variance to the ADMINISTRATOR and/or CITY ENGINEER.

All requests for variances shall be submitted in writing to the ADMINISTRATOR and/or CITY ENGINEER, shall state the provision for which a variance is requested, shall mail written notices of such variance request to all owners of property within 300 feet of the subject property boundary and shall provide evidence, data, or other information in support of the request. The ADMINISTRATOR and/or CITY ENGINEER will: (1) review the decision of staff to determine if a correct interpretation of the ordinance has been made, and (2) rule on the request for variance.

### 207.2 Technical Variance Procedure

All requests for technical variances shall be submitted in writing to the ADMINISTRATOR, shall state the provision for which a technical variance is requested; and shall provide evidence, data, or other information in support of the request. The ADMINISTRATOR will review and rule on the request and provide his findings in writing.

## 208 APPEALS

If a request for a variance or technical variance is denied by the ADMINISTRATOR and/or CITY ENGINEER, the applicant may appeal the decision to the Stormwater Drainage and Hazard Mitigation Advisory Board, in accordance with the ORDINANCES. The applicant may also appeal a decision of the SDHMAB to the City Council.

## 209 REVIEW AND APPROVAL

All documentation and plans required by this MANUAL must be approved by the ADMINISTRATOR and/or CITY ENGINEER. The ADMINISTRATOR and/or CITY ENGINEER will review and approve Infrastructure Development Permits prior to their implementation. The ADMINISTRATOR and/or CITY ENGINEER may submit any documents as required to other city or other jurisdictional agency, for review and comments prior to his approval.

Projects and tasks proposed in the plans and documents required by this MANUAL shall be implemented as proposed. Any changes or amendments to the plans or documentation must be approved by the ADMINISTRATOR and/or CITY ENGINEER in accordance with the established review procedures.

# Chapter 300 STORMWATER POLICY AND STANDARDS

## 301 GOALS

Drainage and flood control in the City of Tulsa and its environs are an integral part of the comprehensive planning process. Drainage is a subsystem of a larger and more comprehensive urban system. The goals of the City of Tulsa are:

- **To protect the general health, safety, and welfare of the residents of the City of Tulsa**
- **To minimize property damage from flooding**
- **To minimize water quality degradation by preventing siltation and erosion of the City waterways**
- **To ensure the safety of the City's streets and rights-of-way**
- **To increase the recreational opportunities of the City of Tulsa and to encourage the retention of open space**
- **To foster other beneficial uses of the real property within the boundaries of the City of Tulsa**
- **To ensure corrective measures which are consistent with the overall goals, policies, standards and criteria of the City of Tulsa.**
- **To preserve environmental quality, social well-being and economic stability.**
- **To minimize future operations and maintenance expenses.**
- **To minimize need for rescue and relief efforts associated with flooding which is generally undertaken at the expense of the public.**
- **To ensure that all development within the City of Tulsa provides for the proper handling of storm water runoff from a site such that for all studied frequency floods there are: no increases in peak downstream discharges or velocities and no increases in water surface elevations which result in additional damages to downstream structures.**

## 302 PRINCIPLES

### 302.1 Urban Sub-System

The City of Tulsa considers stormwater drainage a sub-system of the overall urban system and requires development planning to include the allocation of space for drainage facilities that are compatible with the City of Tulsa Comprehensive Plan.

### 302.2 Multi-Purpose Resource

The City of Tulsa considers storm runoff a multi-purpose resource with the potential for other uses and encourages these multi-purpose uses. Natural drainage channels and techniques shall be given priority consideration in preparation of stormwater drainage system designs and shall be designed or improved as an integral part of the landscape of the area in accordance with the following guidelines:

A. Storm sewers shall be utilized in all development up to a drainage area of 40 acres. Storm sewers may be used or required for larger drainage areas where there are no viable alternatives to fit the site or geographic conditions or to meet the requirements of this MANUAL at the discretion of the CITY ENGINEER. Storm sewers may be used to alleviate existing drainage problems and when required in the approved Master Drainage Plans, subject to the approval of the CITY ENGINEER.

   However, the design of any development shall provide for the maximum use of open channels and natural streams and detention storage (where required) to control runoff rates. Open channels are allowed when delineated in the approved Master Drainage Plans for those areas smaller than 40 acres that would otherwise be storm-sewered. The City may require open channels for other drainage ways for just cause.

B. Drainage channel improvements shall be developed and designed to preserve and protect trees and other worthy botanical and geological features to the maximum extent practicable. Vegetation shall be preserved when feasible. Riparian habitat shall be maintained when feasible, during improvements

C. Wherever channel improvements are required to accommodate storm runoff in a specified manner, the designs shall provide maximum practical utilization of turf, sodding, and natural ground surface protection techniques in order to protect the environment by reducing erosion potential.

D. Water quality control measures shall be incorporated into stormwater management designs, subject to approval of the CITY ENGINEER. Additionally, impacts on receiving water quality shall be assessed for all flood management projects.

### 302.3 Jurisdictional Boundaries

The City of Tulsa will cooperate with other jurisdictions to unify drainage efforts and assure an integrated plan, as outlined in the ORDINANCES, Chapter 1, Section 103H, which gives the CITY ENGINEER the authority to "Seek the cooperation of counties and municipalities within the area in minimizing the contribution of all stormwater drainage systems to flooding and, in particular, cooperate with other affected political jurisdictions in preparing and implementing master drainage plans."

### 302.4 Preventive Measures

The City of Tulsa considers preventive drainage measures to be less costly to the taxpayer than retro-fit drainage measures over the total life of the project and will have planned and implemented, where possible, those measures during urbanization.

# 303 WATERSHED DEVELOPMENT ORDINANCE

## 303.1 Purpose

Chapter 3 of the ORDINANCES provides for watershed development regulations "To protect the general health, safety, and welfare of the residents of the City of Tulsa from the hazards and danger of stormwater run-off" and to minimize water quality degradation.

## 303.2 Drainage Policies

Section 206.3.1 of Ordinance No. 16959 established a set of drainage policies which are incorporated into this MANUAL. It was amended by Ordinances 17285 and 21316. These policies (with titles and emphasis added) are repeated below for reference purposes.

### 303.2.1 Stormwater Drainage System Capacity

"The stormwater drainage system shall be designed to pass the stormwater run-off received from upstream and from the subject property in a 1% (100–year) frequency rainstorm under full urbanization."

In this MANUAL, the "1% (100–year) frequency rainstorm under full urbanization" is the **"regulatory 1% (100-year) storm"**.

### 303.2.2 Development Impact on Flooding

"Development shall be constructed so that it will not increase the frequency of flooding or the depth of inundation of structures."

### 303.2.3 Development Impact on Flood Peaks

"Peak flows shall not be increased at any location for any storm, up to and including the Regulatory 1% (100-year) Storm, which will result in the inundation of unprotected structures not previously subject to inundation as a result of that same frequency storm."

### 303.2.4 Detention Requirements for Development

"Regulation of peak flows to allowable levels, as determined by subparagraphs (b) [303.2.2] and (c) [303.2.3] of the ORDINANCES, shall be achieved by on-site or off-site storage as provided in the City Drainage Standards."

This requirement will be subject to the conditions of the master drainage plan and any determination on allowing the developer to pay a fee in lieu of stormwater detention.

#### 303.2.5 Increase in Downstream Conveyance

"Subject to requirements for Watershed Development Permits and of the City Drainage Standards, downstream conveyance may be improved to compensate for increased flows if such improvements comply with the policies of this chapter."

#### 303.2.6 Dumping

"Dumping of any material into the stormwater drainage system without a permit is prohibited unless specifically authorized in the Permit."

## 304 REGIONAL AND LOCAL PLANNING

### 304.1 Stormwater Management Master Drainage Plans

#### 304.1.1 Master Drainage Plans

The City of Tulsa will prepare, adopt and periodically update master plans for the drainage ways within its jurisdictional boundaries. These master plans set forth the guidelines for improvement and maintenance of the existing and future drainage facilities for all future development and any redevelopment. A project in compliance with the master plan will also be in general compliance with this MANUAL.

#### 304.1.2 Criteria for Master Drainage Plans

In preparation of the master drainage plans and updates to master drainage plans, the policy, standards and criteria set forth in this MANUAL shall be used as a guideline for identifying required facilities. However, the benefit/cost relationship must also be considered when retro-fitting drainage facilities, and therefore the CITY ENGINEER may relax the criteria as deemed necessary.

#### 304.1.3 State Funded Projects

When projects will be funded (in whole or in part) by the State of Oklahoma, the more stringent criteria will apply to the project.

#### 304.1.4 Operation and Maintenance

Continual maintenance of storm drainage facilities is required to ensure they will function as designed. Maintenance of detention facilities involves removal of debris and sediment and repair of the embankment and appurtenances. Sediment and debris must also be periodically removed from channels and storm sewers. Trash racks and street inlets must be regularly cleared of debris to maintain discharge capacity. Channel bank erosion, damage to drop structures, crushing of pipe inlets and outlets, and deterioration to the facilities must be repaired to avoid reduced conveyance capability, unsightliness, and ultimate failure.

## 304.2 Maintenance Access

The City of Tulsa requires that maintenance access be provided to all storm drainage facilities for operational and maintenance purposes through acceptance of the project by the City. After acceptance, permanent access shall be protected by a dedicated right of way or easement. The right of way or easement shall be shown on final plats or final development plans and shall clearly state that the purpose is for stormwater management facilities.

### 304.2.1 Interim Stormwater Drainage System Maintenance

Drainage facilities provided by the developer shall be fully and properly maintained from construction through final acceptance of the development improvements by the City of Tulsa.

### 304.2.2 Private Stormwater Drainage System Maintenance

It shall be the responsibility of all property owners to maintain private drainage facilities as follows:

A. Mow and provide maintenance of drainage channels and their slopes for that portion of the channel lying within their property limits
B. Keep clear all drainage channels within the boundaries of their properties in accordance with the requirements of this MANUAL
C. Prevent any and all drainage interferences, obstructions, blockages, or other adverse effects upon drainage into, through, or out of the property
D. Control the erosion of the drainage channels and the deposition of materials into the drainage channels from the property.

### 304.2.3 Easements and Rights-of-Way

Easements will be required for all stormwater management facilities not in public rights of way; including:

- Storm sewers
- Channels
- Storage areas
- Other hydraulic structures
- All portions of the public stormwater drainage system that cross more than 2 lots or 2 properties

Easements shall:

- Not allow restriction of the drainage purposes.
- Clearly identify that the purpose includes operation and maintenance of stormwater management facilities

- Be shown on all plats, including widths and specific purposes (i.e.: storm sewer, maintenance access, channel, etc.)

The widths of easements are determined by:

- The size of the storm sewer, its depth, and the equipment needed to remove, replace or repair the sewer.
- The width of the easement for channels, storage areas and other structures is generally determined by the size of the facility and the equipment needed for maintenance, typically covering the entire facility plus 20 feet for maintenance access.

### TABLE 3-1 - OPERATIONS, MAINTENANCE EASEMENTS & RESERVE AREAS

| REQUIRED OPERATIONS, MAINTENANCE EASEMENTS & RESERVE AREAS (NOT WITHIN A PUBLIC RIGHT OF WAY) | |
|---|---|
| **DRAINAGE FACILITY** | **MINIMUM EASEMENT RESERVE AREA WIDTH** |
| **1. Storm Sewer** | **Refer to the** City of Tulsa Infrastructure Development Process Manual**, Chapter 800.** |
| **2. Storm Sewer Overflow, Where Required** | **As required to contain surface overflow in an overland drainage easement. Refer to Policy 305.4.3. C** |
| **3. Open Channel** | **Top width plus 20 feet; five feet on one side and 15 feet on the side with the maintenance access road.** |
| **4. Post-development 1% (100-year) Regulatory Floodplain** | **Area sufficient to contain the regulatory 1% (100-year) post-development floodplain** |
| **5. Open Space Detention Facilities** | **For regional detention facilities - as required to access and contain storage volume and associated facilities plus 15 feet of maintenance access around the perimeter.**<br>**For onsite detention facilities - as required to access and contain storage volume and associated facilities plus 10 feet of maintenance access around the perimeter.**<br>**Access to the outlet works shall be provided either via a 15' top width or other arrangements approved by the CITY ENGINEER.** |
| **6. Parking Lot and Underground Detention Facilities** | **As required to access and contain storage volume and associated facilities.** |

Drainage easements (see **Table 3-1** above) shall be shown on the Final Plats and Final Development Plan and shall state that the City has the right of access on the easements which shall be kept clear of obstructions to the flow and/or maintenance access.

## 304.3 Water Quality Control

Chapter 5 of the ORDINANCES establishes methods to regulate City of Tulsa's municipal separate storm sewer system and enables the City to comply with all applicable state and federal laws and regulations, including the federal Clean Water Act, 33 U.S.C. §§ 1251, et seq., the Oklahoma Environmental Quality Act, 27A O.S. 2001, §§ 1-1-101, et seq., and stormwater regulations contained in 40 CFR Part 122, EPA Administered Permit Programs - the National Pollutant Discharge Elimination System (NPDES). The objectives of this chapter shall permit the City of Tulsa to:

- Regulate the contribution of pollutants into the municipal separate storm sewer system through the stormwater discharges of any user;
- Control the introduction into the municipal separate storm sewer system of spills, dumping, or the disposal of materials other than stormwater;
- Prohibit illicit discharges into the municipal separate storm sewer system;
- Carry out inspections, surveillance and monitoring procedures necessary to determine compliance and noncompliance with this chapter;
- Comply with its Oklahoma Pollution Discharge Elimination System (OPDES) Municipal Storm Water Discharge Permit conditions and any other federal or state law or regulation pertaining to stormwater quality; and
- Provide for enforcement remedies that include fines for violations of this Chapter.

### 304.3.1 Oklahoma Water Resources Board

In recognition of the policies of the Oklahoma Water Resources Board, the City of Tulsa will cooperate with state agencies in programs that prevent the violation of the state's water quality standards, pursuant to Title 82 O.S. 1981, Paragraph 1085.2.

### 304.3.2 OPDES Stormwater Permit

In recognition of the OPDES stormwater discharge permit, the City of Tulsa requires the planning and incorporation of measures into future development plans that will improve the quality of urban storm runoff. The recommended measures, or Best Management Practices, shall be in accordance with the OPDES stormwater discharge permit and the criteria set forth in this MANUAL for control of erosion and sedimentation from construction activities (Chapter 1000) and criteria for water quality enhancement (Chapter 1100).

## 304.4 Watershed Transfer of Storm Runoff

The inter-basin transfer of stormwater between the following watersheds is not allowed:

- BIGHEART CREEK
- HARLOW CREEK
- PARKVIEW CREEK
- OAK CREEK
- LOWER BASIN
- BIRD CREEK
- CHERRY CREEK
- RED FORK CREEK
- COAL CREEK
- COOLEY CREEK
- CROW CREEK
- SWAN CREEK
- TRAVIS CREEK
- DIRTY BUTTER CREEK
- DOWNTOWN TULSA
- FLAT ROCK CREEK
- FRED CREEK
- FRY DITCH NO 2
- GARDEN CITY BASIN
- HAIKEY CREEK
- JOE CREEK EAST BRANCH
- JOE CREEK WEST BRANCH
- LITTLE JOE CREEK
- MINGO CREEK
- MINGO CREEK TRIBUTARIES LB1-LB12 AND RB1-RB12
- MOOSER CREEK
- HAGER CREEK
- NICKEL CREEK
- PERRYMAN DITCH BASIN
- SOUTH TULSA
- SPUNKY CREEK
- ADAMS CREEK
- SALT CREEK
- VENSEL CREEK

- Intra-basin transfers between sub-basins within those drainage basins shown above are allowed, subject to approval of the ADMINISTRATOR, on a case-by- case basis, if such intra-basin transfers cause no increase in flooding.

### 304.5 Acceptance of Existing Stormwater Drainage Systems

The City of Tulsa will consider acceptance of existing stormwater drainage facilities not constructed under these criteria for ownership and maintenance without modification to the system using the following guidelines:

A. The system must be capable of conveying the regulatory 1% (100-year) storm flow using the criteria presented in this MANUAL.

B. The system must be reasonably maintainable with legal access to all facilities using the standards for access presented in these criteria.

C. Facilities submitted as part of previously approved plats, but not building permits, will be considered for acceptance.

D. Channels must meet the minimum standards of:
   1. Maximum side slopes of 4:1
   2. Maximum regulatory 1% (100-year) storm design flow velocity as set forth in these criteria with suitable vegetation and other erosion control facilities
   3. The regulatory 1% (100-year) storm flow must be contained within the channel banks

E. Storm sewer systems must meet the minimum standards of:
   1. Manholes at changes in pipe sizes and vertical alignment.
   2. The requirements for manholes at changes in horizontal alignment will be considered on a case by case basis.
   3. Manholes or other appropriate maintenance access must not be spaced farther apart than 500 feet, per Table 8-1**.**
   4. The sewer must be structurally sound and not subject to imminent failure.

## 305 TECHNICAL STANDARDS AND CRITERIA

### 305.1 Drainage Design and Technical Criteria

The City of Tulsa requires that all storm drainage facilities be planned and designed in accordance with the criteria set forth in this MANUAL. The criteria will be revised or amended as new technology is documented.

### 305.2 Drainage Construction Plans

Approval of plans for construction of any development drainage facility shall be subject to the procedures/requirements of the IDP current manual.

### 305.3 Storm Runoff Determination

#### 305.3.1 Unit Hydrograph Method

The City of Tulsa requires that the timing of peak flows be taken into account by using a hydrograph method for computing storm runoff for the design of stormwater conveyance systems (channels, bridges, storm sewer systems), and for the design of detention systems (detention ponds). These systems shall be designed for fully urbanized conditions using computer models HEC-HMS (other models may be used with the approval of the CITY ENGINEER).

### 305.3.2 Rational Method

The Rational Method may be used to compute frequency discharges for a project if the time of concentration is less than 10 minutes for the entire watershed draining to the point of discharge from the project. The Rational Method may be used for individual curb and gutter inlet design. The Rational Method shall not be used for detention pond design or for bridge design. When using the Rational Method, a C value of 0.90 shall be used for business and industrial areas. Multipliers shall be applied for all development when the rational method is used as specified in Chapter 600 of this Manual. A "C" value for residential property shall be used as specified in Chapter 600 or computed using actual impervious surfaces, whichever is greater.

## 305.4 Drainage Facility Performance

The City of Tulsa requires the following minimum performance standards for drainage facilities:

### 305.4.1 Detention

For all stormwater detention facilities, the releases shall not exceed the pre-development runoff conditions for the 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), and 1% (100-year), 24-hour storms under fully urbanized conditions and must be conveyed to a public stormwater conveyance system with no increase in flow rates downstream. **Table 3-2** below outlines the various requirements.

**TABLE 3-2 - FREEBOARD REQUIREMENTS FOR STORMWATER DETENTION FACILITIES**

| Embankment or Excavated Pond | 1% (100-year) water surface elevation depth | 1% (100-year) water surface elevation | 0.2% (500-year) water surface elevation |
|---|---|---|---|
| Embankment or Excavated | < 18-inches | Contained within a dedicated stormwater detention easement | No freeboard requirement related to the 0.2% storm |
| Embankment | 18-inches to 6 feet | Contained within the detention facility with one foot of freeboard to the top of the embankment* | Contained within the detention facility with no freeboard to the top of the embankment |

| Embankment or Excavated Pond | 1% (100-year) water surface elevation depth | 1% (100-year) water surface elevation | 0.2% (500-year) water surface elevation |
|---|---|---|---|
| Embankment | > 6 feet | Requirements based on 0.2% water surface elevation | Contained within the detention facility with one foot of freeboard to the top of the embankment. * |
| Excavated | >18-inches | Contained within the detention facility with one foot of freeboard to the top of the surrounding grade* | No freeboard requirement related to the 0.2% storm |
| *unless more stringent OWRB dam safety requirements control, as outlined in Title 785:25-3-3 of the Oklahoma Administrative Code, found at http://www.oar.state.ok.us | | | |

### 305.4.2 Open Channels and Swales

A. Facilities shall be designed to convey the flood produced by the regulatory 1% (100- year) storm with one (1) foot of freeboard.
B. Facilities with vegetative linings shall be designed with sufficiently high roughness coefficients (minimum 0.05) in anticipation of infrequent mowing and for improved stormwater quality as indicated in Section 703.2 unless otherwise approved by the City Engineer.

### 305.4.3 Storm Sewers and Overland Relief Swales

A. Storm sewer systems shall be designed to convey the regulatory 1% (100-year) flow rate under fully urbanized conditions.
B. When storm sewers are located between buildings or lots rather than in the right of way of a street, an overland drainage easement shall be platted that prohibits structures from blocking the flow. A swale shall be designed within the overland drainage easement. The sump shall be lined up with the centerline of the swale. The swale shall be sized to convey the regulatory 1% (100-year) flow rate under fully urbanized conditions for the area draining to the inlet(s) in the sump immediately upstream from the sump.
C. All buildings that are adjacent to an overland drainage easement shall have 1' of freeboard above the 1% water surface elevation in the swale to the finished floor elevation. Finished floor or building pad elevations shall be shown on the plat.
D. The overland drainage easement language shall state on the plat that the easement is provided for overland flow of stormwater, that the area shall be maintained by the property owner at its prescribed elevation and that the owner is prohibited from constructing anything that inhibits the intended overland relief that may occur from street inlets to prevent building flooding.

### 305.4.4 Bridges and Culverts

A. All bridges shall be designed to pass the flow produced by the regulatory 1% (100-year) storm with 1 foot of freeboard from the water surface to the low chord of the bridge or the inside top of a culvert or culverts with a clear opening of 20 feet in width or more.

B. Culverts shall be designed to pass the flow produced by the regulatory 1% (100-year) storm with 1 foot of freeboard from the water surface to the inside top for structures under roadways for which backwater from 100% blockage would flood upstream properties, regardless of the flow rate.

C. Culverts with a clear opening less than 20 feet in width may be designed to pass the flow produced by the regulatory 1% (100-year) storm under fully urbanized conditions with maximum headwater to culvert diameter (or rise) ratio of 1.5. These culverts shall be designed to have overland relief in an overland drainage easement or right-of-way assuming 100% blockage of the culvert.

D. Culverts and longitudinal street grades for all streets shall be designed without street overtopping for floods produced by all storms up to and including the regulatory 1% (100-year) storm, with one foot of freeboard required at arterial street crossings.

E. Culverts shall be designed such that backwater from the culvert does not inundate any structures.

F. Culverts and embankment protective measures shall be designed to minimize embankment damage during overflow.

## 305.5 Roadway Drainage Systems

### 305.5.1 Storm Sewer Systems

The City of Tulsa allows the use of streets in the stormwater drainage system for storm runoff with the limitation that the depth of flow at the gutter flow line shall not cause inundation of more than the outside lane or inundation of the crown of the street, whichever is less. The City of Tulsa does not allow the use of streets for cross street flow, except as discussed in Section 801.6.

### 305.5.2 Curb Inlets

All new curb inlets shall be offset inlets as detailed in Chapter 800.

### 305.5.3 Location of Storm Sewer Line

Storm sewer lines shall be placed behind the curb if possible or in the center of driving lanes, but never in the wheel path of any street, or along the centerline of arterial streets with an even number of lanes.

### 305.5.4 Roadside Ditches

Roadside ditches shall convey the regulatory 1% (100-year) flow rate, and have a maximum depth of 30 inches, regardless of right-of-way width or cross slope, with a paved bottom. Maximum roadside ditch cross slope shall be 3:1.

# 306 DRAINAGE IMPROVEMENT RESPONSIBILITY

## 306.1 Developer Responsibility

It shall be the responsibility of any individual engaged in the activity of land development or improvement to:

A. Control and manage all drainage within and from the development including the control and management of any determined, approved increase in runoff volume or rate.

B. Prepare all drawings, plans, specifications, statements, studies, justifications, impacts and other data required by this MANUAL to assure that all assigned responsibilities have been sufficiently and correctly incorporated.

C. Provide detention facilities, or storm sewers, or improved or natural channels, or a combination thereof to assure control and management of increased runoff.

D. Prevent soil deposition, sedimentation, and erosion from any surface of the site into a drainage way provided or created within the development, and from the site into downstream drainage ways.

E. Prevent any and all drainage obstructions from interfering with drainage through or adjacent to the development from discharge sources upstream. Temporary or permanent bypass channels or other improvements may be required.

F. Improve or modify any and all stormwater drainage systems and channels lying within the development to a level that meets all requirements of this MANUAL.

G. As an option to onsite stormwater detention, and at the discretion of the CITY ENGINEER, the developer may improve or modify stormwater drainage systems downstream from the development for problem areas identified in the Master Drainage Plans (and provide easements or rights of way for such) in accordance with the recommendations of the Master Drainage Plans.

H. Prevent any aggravation of existing flooding, drainage, erosion, runoff, pollution, or other stormwater management problem within any adjacent area either upstream or downstream.

I. Provide for transferring ownership and maintenance of drainage facilities to a homeowner’s association.

J. Comply with other applicable provisions of this MANUAL.

### 306.2 Property Owner Responsibility

The property owner shall control all stormwater runoff and drainage from points and surfaces on the property and maintain channels or other drainage facilities within his property in accordance with section 304.2 of this MANUAL.

### 306.3 City of Tulsa Responsibility

The responsibility of the City of Tulsa, shall be to:

A. Repair and maintain the channels and their slopes when located within or upon public rights-of-way, or as stated in the language of a dedicated drainage easement.
B. Make necessary improvements to the stormwater drainage systems of the City as defined by the adopted master plans that are not a part of private development.
C. Improve and maintain floodway and floodplain areas that are dedicated public areas, rights-of-way, park lands, or publicly-owned buildings or development.
D. Improve and maintain all publicly-owned stormwater drainage systems outside the floodplain fringe area, as defined the Chapter 1300, Glossary.

### 306.4 Engineer Responsibility

The responsibility of the engineer in the planning and design of public drainage facilities is as follows:

A. The engineer shall prepare the necessary drainage analysis and facility designs in accordance with the provisions of this MANUAL and shall certify that they are in compliance, subject to approved technical variances.
B. The engineer shall use sound professional judgment and standard engineering practice when recommending technical variances.

## 307 DEVELOPMENT POLICY

### 307.1 Downstream Effects

All development, including infill development that increases the total impervious area above that which previously existed and/or concentrates the flow offsite in a manner different from that which previously existed and is detrimental to adjacent properties shall have mitigating stormwater controls.

### 307.2 Downstream Drainage System Capacity

No increased flow from development will be allowed beyond the capacity of the downstream drainage system.

### 307.3 Fee-In-Lieu of Onsite Detention

All development, including infill development, may pay a fee-in-lieu of onsite stormwater detention, subject to the discretion of the CITY ENGINEER depending on its location in the watershed and the potential for adverse impacts downstream. The property owner's engineer must submit his or her recommendation for allowing a fee-in-lieu of onsite detention to be paid, along with all supporting data.

### 307.4 Site Drainage Plans

All development projects, including single lot residential projects, shall submit drainage plans. The Drainage and Detention Report, as required, is discussed further in Chapter 5, Section 503.

## 308 LOT DRAINAGE

Any development of a lot within the City of Tulsa, including development in new subdivisions, development in existing subdivisions that do not have a detailed drainage plan, and infill development, shall be accomplished in accordance with the following requirements:

All lots shall be developed and graded in accordance with the latest adopted Building Code by the City of Tulsa.

A. Each lot is required to accept and convey off-site drainage of upstream areas as if they were fully developed.

B. The development on each lot shall not alter the pre-development course of water flowing onto the lot in such a manner as to restrict drainage from the upstream areas or to cause additional damage to upstream structures.

C. The development on each lot shall not produce off-site drainage in such a manner as to cause additional damage to downstream structures.

D. Off-site drainage from each lot shall be diverted into a public storm water conveyance system or, if that is not possible, off-site drainage shall be accomplished in a manner to be approved by the CITY such that no additional damage to downstream structures occurs.

E. Drains or swales shall be constructed to ensure drainage away from the structure.

F. The first finished floor of any structure shall be 12" above the flow line of the street drainage system at the point where surface water from the front of the lot drains into said drainage system. See Section 308 **K**. if surface water from the front of the lot does not drain to the street.

G. Lots shall be graded to drain surface water away from foundation walls such that the lowest adjacent grade to the structure is a minimum of 12" above the drainage path flow line of surface water flowing around the structure. This grading shall have a minimum fall of 6 inches within the first 10 feet. If lot lines, walls, slopes or other physical barriers prohibit 6 inches of fall within 10 feet, the nearest adjacent grade must still be a minimum of 12" above the drainage path flow line.

H. Impervious surfaces within 10 feet of the building foundation shall be sloped a minimum of 1.5 percent away from the building.

I. Crawlspaces shall not be used for mechanical and electrical equipment or storage purposes of any kind except for that area of the crawlspace that is 12" above the flow line of the street drainage system at the point where surface water from the front of the lot drains into said drainage system. If surface water from the front of the lot does not drain to the street, only the area within the crawlspace that is one foot above the lowest adjacent grade may be used.

J. Driveways shall be shaped so that the high point of the driveway is at least 6-inches higher than the adjacent gutter or edge of paving.

K. Storm water runoff from buildings that is collected in an underground collection system shall be: a) diverted to the street drainage system or b) discharged on the downhill portion of the lot at a point that is not less than 1/3 of the distance between the property line and the building away from the property line.

### 308.1 Lot Drainage for New Developments

In addition to the requirements in Section 308, each lot in a new residential or commercial development shall be accomplished in accordance with the following guidelines:

A. The portion of the subdivision plans dealing with each individual lot will be submitted with each building permit to show how the individual lot is to be graded. The information submitted will identify and define solutions to drainage problems at each lot.
B. No more than 2 lots or ½ acre shall be allowed to drain onto an adjacent lot unless it drains into an approved stormwater drainage system component within a drainage easement.

### 308.2 Lot Drainage in Existing Subdivisions That Do Not Have a Detailed Drainage Plan and Infill Lot Development

In addition to the requirements in Section 308, each infill lot development shall be accomplished in accordance with the following guidelines:

A. A single lot grading and drainage plan shall be submitted showing the flow pattern of stormwater as it enters and the leaves the property. See **Figure 5-1**, **Figure** 5-2 and **Figure 5-3**.

After review of the grading and drainage plan by Development Services, a more detailed Drainage and Detention Report may be required in accordance with Section 503.

# Chapter 400 FLOODPLAIN MANAGEMENT POLICY AND STANDARDS

## 401 GOALS

To protect the general health, safety and welfare of the residents of the City of Tulsa from flood hazards, the City's Floodplain Management goals are:

- **To minimize flood damage within flood-prone areas**
- **To prevent new flooding problems**
- **To correct existing flooding problems**
- **To improve the natural and beneficial functions of floodplains by encouraging the retention of open space**
- **To enhance the community's safety and quality of life**
- **To preserve environmental quality, social well-being and economic stability**
- **To minimize future operations and maintenance expenses**
- **To minimize need for rescue and relief efforts associated with flooding which is generally undertaken at the expense of the public**
- **To ensure that all development is reasonably safe from flooding by reviewing all floodplain development/building permits**
- **To assure compliance with the National Flood Insurance Program (NFIP) and locally adopted floodplain development requirements and building codes**
- **To provide technical assistance to residents with information on flood hazards, floodplain map data, flood insurance and proper construction measures**

## 402 BACKGROUND

The City of Tulsa requires a watershed development permit to be issued before developing, redeveloping, building, mining, dredging, drilling, excavating, grading, regrading, paving, filling, berming, or diking of any property within the City. There are five types of watershed development permits: floodway, floodplain, stormwater drainage, stormwater connection, and earth change permits.

Tulsa's floodplain regulations, policies and standards are applied to all properties located within the adopted floodplain maps, including both the City of Tulsa Regulatory Floodplain and Federal Emergency Management Agency (FEMA) Special Flood Hazard Area (SFHA).

### 402.1 National Flood Insurance Program (NFIP)

Congress passed the National Flood Insurance Act of 1968, thereby establishing the National Flood Insurance Program (NFIP) making flood insurance available to private individuals as a means to mitigate flood losses (National Flood Insurance Act, amended 1997). The NFIP offers federally subsidized flood insurance to homeowners, renters and business owners in communities that voluntarily join the NFIP. Communities may participate in the NFIP by agreeing to adopt and enforce land use guidelines that meet or exceed FEMA requirements that reduce the risk of flooding to developments in the designated floodplain. This act made flood insurance, previously unattainable from private insurance companies, available for a reasonable cost under federal provisions. The NFIP is presently administered by FEMA under the US Department of Homeland Security (DHS).

There are three main elements guiding the NFIP: insurance, mapping and regulations.

### 402.1.1 Insurance

As an incentive to reduce flood losses, the NFIP federally subsidizes flood insurance for residential or commercial structures located both within and outside of floodplains when a community participates in the NFIP. Flood insurance becomes mandatory for structures located within a designated Special Flood Hazard Area (SFHA) when the property is financed with a federally-backed loan or mortgage. Regular homeowner's insurance policies rarely cover the cost of flood damages.

The City of Tulsa entered the NFIP's Emergency Program in November 1970 and joined the Regular Program in August 1971 when the initial Flood Insurance Rate Map (FIRM) was identified. Flood insurance premiums are based in part on the date a building was constructed. FEMA considers Pre-FIRM construction to be completed on or before December 31, 1974 or before the effective date of the initial FIRM for the City, whichever is later. Therefore, in the City of Tulsa, all structures built before December 31, 1974 are termed "pre-FIRM" structures and all structures built after December 31, 1974 are considered and rated as "post-FIRM" structures. The insurance rates differ for the two types of structures. Pre-FIRM structures pay subsidized rates for insurance that are not based on flood risk. The flood insurance for post-FIRM buildings is based on actuarial rates which can be expensive if the risk is high. The federal government underwrites the risk for both structure and contents coverage purchased by a property owner from a private insurer. Flood insurance is additionally available to homeowners whose property is located outside of a designated SFHA for a reduced rate. Renters may also purchase contents-only coverage under the NFIP.

Flood insurance zone designations classify risk areas and are assigned to a community's FIRM based on the results of engineering analyses. Flood insurance rates vary by location of the insured building according to the zone as well as the elevation of the structure and its mechanical components above the expected flood level.

### 402.1.2 Mapping

FEMA Floodplain - Flood Insurance Rate Map (FIRM) - Special Flood Hazard Area (SFHA)

FEMA has prepared detailed Flood Insurance Studies (FIS) for the City of Tulsa. The studies provide water surface elevations for floods of various magnitudes including the 1-percent annual chance flood (also known as the 100-year flood or base flood) and the 0.2-percent annual chance flood (the 500-year flood). These base flood elevations (BFE) and the boundaries of the 100- and

500-year floodplains are shown on FIRMs, which are the primary tool for identifying the extent and location of the SFHA in the community as well as for flood insurance rating purposes. Any proposed changes to the FIRM must be approved by FEMA in a Letter of Map Change (LOMC).

#### 402.1.2.1 City of Tulsa Regulatory Floodplain - Master Drainage Plans (MDP)

The City of Tulsa has developed Regulatory Floodplain Maps that are of a higher standard than the FEMA FIRMs. Master Drainage Plans (MDPs) or Basin Plans delineate the floodplain boundaries of tributary streams based on full urbanization with existing drainage facilities. The MDPs also provide water surface elevations (WSE) for the fully urbanized 1-percent annual chance flood. The boundaries of the 100-year floodplains are shown on the City of Tulsa Regulatory Floodplain Maps along with the FEMA SFHA, which identify the extent and location of all of the regulatory floodplains within the City. These maps are available from the City of Tulsa Engineering Services Department or online at: www.cityoftulsa.org and represent those areas for which floodplain regulations are applicable. Any proposed changes to the City of Tulsa Regulatory Floodplain must be approved by the T-LOMR process.

### 402.1.3 Regulations

The City of Tulsa has adopted floodplain regulations that are set forth in the Tulsa Revised Ordinances, Title 11-A Watershed Development Regulations and Title 51 Building Codes. These regulations may be accessed online at www.cityoftulsa.org.

All proposed development on lots or parcels within or adjacent to the regulatory floodplains shall require review by the ADMINISTRATOR for compliance with building codes and watershed development regulations. For residential structures, all new construction and substantial improvements shall have the lowest floor elevated at least one (1) foot above the BFE or WSE, whichever is greater. For non-residential structures, all new construction and substantial improvements shall have the lowest floor elevated at least one (1) foot above the BFE or WSE, whichever is greater or be floodproofed to at least one (1) foot above the BFE or WSE, whichever is greater. All new mechanical, electrical and utility equipment servicing the building must be at least one (1) foot above the BFE or WSE, whichever is greater.

Development shall be constructed in such a way that it will not increase the frequency of flooding or the depth of inundations of structures. Peak flows from development shall be controlled by on-site detention or by regional detention. Fees-in-lieu of on-site detention may be paid when a regional detention facility has been master planned or when it can be demonstrated that the development will not aggravate flooding downstream.

## 403 FLOODPLAIN MAP AMENDMENTS AND REVISIONS

Growth, development, and the urbanization of previously undeveloped areas as well as new flood studies and master drainage plans have all contributed to the need for floodplain map amendments and revisions. With more accurate floodplain maps, property owners are able to make better informed decisions based on current and relevant information. The various types of map changes are described and the following procedures shall be used to request changes to both the FEMA Floodplain and the City of Tulsa Regulatory Floodplain Maps.

## 403.1 FEMA Floodplain Map Amendments and Revisions

FEMA has designated Special Flood Hazard Areas (SFHA) on the Flood Insurance Rate Map (FIRM) for the City of Tulsa (see FEMA website to view the FIRM). The FIRM delineates flood risk information for "existing conditions" at the time of the Effective Flood Insurance Study (FIS) for each creek. The NFIP regulations allow FEMA to revise and amend the FIRM and FIS reports as warranted, **or** after receiving and evaluating a request from community officials (the ADMINISTRATOR) and individual property owners. Therefore, any development that takes place in, or otherwise affects the SFHA shall require the approval of the ADMINISTRATOR and the submittal of adequate supporting data for review and approval by FEMA.

FEMA's role in floodplain management is detailed on FEMA's website. This site additionally provides the requirements for each of the following methods of obtaining FEMA approval of a revisions or amendment to the FIRM.

## 403.2 Letter of Map Amendment (LOMA)

Limitations imposed by the scales at which the FIRM for the City of Tulsa is prepared may have resulted in individual properties being inadvertently included in SFHAs. To correct these inadvertent inclusions, a Letter of Map Amendment (LOMA) may be applied for from FEMA. A LOMA results from an administrative procedure that involves the review of technical data submitted by the owner or lessee of property who believes the property has incorrectly been included in a designated SFHA. A LOMA amends the currently effective FEMA map and establishes that a specific property or structure is not located in an SFHA.

## 403.3 Letter of Map Revisions Based on Fill (LOMR-F)

The placement of fill in the floodplain shall require hydraulic studies to determine the upstream and downstream effect and to verify no rise in the BFE. The ADMINISTRATOR shall approve a Letter of Map Revision based on Fill (LOMR-F) in the City of Tulsa if supporting documentation is provided verifying compliance with City ORDINANCES, including compensatory storage.

## 403.4 Conditional Letter of Map Revision (CLOMR)

FEMA's review and comment on a project that is proposed within the SFHA is referred to as a Conditional Letter of Map Revision (CLOMR). A CLOMR comments on whether the proposed project meets the minimum floodplain management criteria of the NFIP and, if so, what revisions will be made to the City's FIRM if the project is completed as proposed. Any project that includes grading activity within the FEMA-designated loodway will require a CLOMR.

### 403.5 Letter of Map Revision (LOMR)

A Letter of Map Revision (LOMR) is a request that FEMA officially revise the FIRM to reflect "existing conditions", such as an "as-built" project. Adequate supporting data shall be submitted to FEMA after approval of the ADMINISTRATOR. A LOMR is required as a follow-up to the CLOMR, or if any work has been completed within the designated floodway, or if the project requires any change in the effective hydraulic model, the delineated 1% (100-year) floodplain boundaries, or the effective flood profiles. Changes in the updated hydraulic modelling used to prepare the new mapping shall include the appropriate tie-in upstream and downstream so that the model remains continuous.

Certificates of Occupancy will not be issued until the LOMR is approved by FEMA.

Detailed information on the LOMR and submittal requirements can be obtained at the Map Service Center on the FEMA website.

### 403.6 City of Tulsa Regulatory Floodplain Map Amendments and Revisions

The City of Tulsa has designated the City of Tulsa Regulatory Floodplain on the Regulatory Floodplain Map Atlas that are of a higher regulatory standard than the FEMA FIRMs. The floodplain boundaries of City of Tulsa Regulatory Floodplain are based on the fully urbanized 100-year floodplain with existing drainage facilities. Water surface elevations (WSE) for the fully urbanized 1% annual chance flood are located within tables and profiles of the accompanying Master Drainage Plans (MDP). The ORDINANCES and this MANUAL authorize the City of Tulsa to revise and amend the Regulatory Floodplain Map Atlas as warranted, or after receiving and evaluating a request from community officials (the ADMINISTRATOR) and individual property owners. Therefore, any proposed development that proposes any changes the City of Tulsa Regulatory Floodplain shall require the prior approval of the ADMINISTRATOR and CITY ENGINEER as well as the submittal of adequate supporting data for review and approval by the ADMINISTRATOR and CITY ENGINEER

#### 403.6.1 Tulsa - Conditional Letter of Map Revision (T-CLOMR)

The City of Tulsa's review and comment on a project that is **proposed** within the City of Tulsa Regulatory Floodplain is referred to as a Tulsa - Conditional Letter of Map Revision (T-CLOMR). A T-CLOMR comments on whether the proposed project meets the minimum floodplain management criteria of the Watershed and Floodplain Development Regulations and, if so, what revisions will be made to the City's Regulatory Floodplain Map Atlas if the project is completed as proposed. A T-CLOMR is required to be obtained from the City before a project can be built if the project would require any change in the effective hydraulic model, the delineated 1% (100-year) floodplain boundaries, or the effective flood profiles. All projects, including Infrastructure Development Process (IDP) projects that propose to revise the City of Tulsa Regulatory Floodplain will require a T-CLOMR to be approved by the City prior to the approval of the development or

IDP. Changes in the updated hydraulic modelling used to prepare the new mapping shall include the appropriate tie-in upstream and downstream so that the model remains continuous.

### 403.6.2 Tulsa - Letter of Map Revision (T-LOMR)

A Tulsa - Letter of Map Revision (T-LOMR) is a request that the City of Tulsa officially revise the Regulatory Floodplain Map Atlas to reflect "existing conditions", such as an "as-built" project within the City of Tulsa Regulatory Floodplain. A T-LOMR is required as a follow-up to the T-CLOMR, or if the project requires any change in the effective hydraulic model, the delineated 1% (100-year) floodplain boundaries, or the effective flood profiles. Certificates of Occupancy will not be issued until the T-LOMR is approved by the City. Changes in the updated hydraulic modelling used to prepare the new mapping shall include the appropriate tie-in upstream and downstream so that the model remains continuous.

### 403.6.3 T-CLOMR and T-LOMR Floodplain Revision Procedure and Submittal Requirements

All Tulsa Regulatory Floodplain Map Revisions requests must follow the requirements set forth in this MANUAL and submitted documents must be reviewed and approved by the City prior to construction. If the proposed project also modifies the FEMA SFHA a Conditional Letter of Map Revision (CLOMR) must be approved by FEMA before the start of construction. A floodplain map revision fee as published in Tulsa Revised Ordinances, Title 49, Chapter 12, shall be paid at the time of submittal. Tulsa Regulatory Floodplain Map Revision fees are in addition to any FEMA fees associated with a CLOMR or LOMR.

The following procedure shall be used to request revisions to the City of Tulsa Regulatory Floodplain. T-CLOMR and T-LOMR requests must include two (2) copies of the application forms along with the appropriate supporting information. At a minimum the submittal must include, but is not limited to, the following:

1. Completed T-CLOMR and T-LOMR application forms.
2. Written narrative summary of proposed project and submittal. Knowing the project and purpose of the request better ensures the needs of the requester are met.
3. A drainage report, in compliance with the ORDINANCES and this MANUAL, shall include the scope of the project, methodology used for the study, modeling used and assumptions made. The project and report shall show zero rise in the "with project" or "as built" project floodplain elevations.
4. Appropriate hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models. If available, the current effective hydrologic and hydraulic model will be supplied by the City of Tulsa. The engineer requesting the revision shall prepare and submit corrected effective and proposed effective models. The corrected effective and proposed effective model shall be for the entire reach as in the current effective model supplied by the City.
5. Certified topographic map with all floodplain boundary delineations.

6. Annotated Regulatory Floodplain Map to reflect changes due to project with current effective floodplain and proposed effective floodplain boundary delineations.
7. GIS shapefiles (in Oklahoma State Plane) with layers for both the proposed Regulatory Floodplain (T-CLOMR) and as-built (T-LOMR) boundaries.
8. Revised flood profile in the same format as the FEMA Flood Insurance Study.
9. As-built plans or survey for T-LOMRs and design plans for T-CLOMRs for all hydraulic structures or grading within the floodplain along the revised reach, including any plans to be used for construction of stormwater projects.
10. The approved 404 Permit issued by the USACE.
11. All documents must be prepared by a registered professional engineer licensed by the State of Oklahoma and contain the date, signature and seal of the engineer.
12. Review fee payment, if applicable.

**Submittal Location**

Two (2) copies of the completed package with digital files should be submitted to:

City of Tulsa
Planning and Development Department
Development Services Division
175 E 2nd St, Suite 450
Tulsa, OK 74103
Attn: Floodplain Administrator

Before the City of Tulsa will replace the adopted Regulatory Floodplain Map boundaries with the revised, the requester must: (a) provide all of the data used in determining the revised floodplain boundaries, flood profiles, etc.; (b) provide all data necessary to demonstrate that the physical modifications to the floodplain meet floodplain regulations, have been adequately designed to withstand the impacts of the fully urbanized 1% annual chance flood event, and will be adequately maintained; and (c) demonstrate that the revised information (e.g., hydrologic and hydraulic analyses and the resulting floodplain boundaries) is consistent with the effective Regulatory Floodplain Map information.

After completion of the proposed project and final inspection the project engineer must submit final record drawings to the City showing any changes to the original approved design as well as a revised hydraulic model if needed to reflect the “as built” changes.

If the project modifies the SFHA, the project engineer must also submit a LOMR to FEMA for approval. Building permits shall not be issued using the revised water surface elevations or floodplain boundaries until the map revision processes are complete and the revised floodplain is adopted by FEMA and/or the governing body of the City of Tulsa.

# 404 PERMITTING

## 404.1 Watershed and Floodplain Development Permits

Watershed and Floodplain Development Permit applications will be reviewed by the ADMINISTRATOR for compliance with the adopted ORDINANCES and the potential effects the proposed development could have on the stormwater drainage system. Permit drawings submitted shall be subject to approval prior to application for building permit and the beginning of construction. Watershed Development Permit drawings shall accompany the application form and shall contain the minimum information described in the ORDINANCES and this MANUAL for the following five (5) Watershed Development Permit classifications: Floodway, Floodplain, Stormwater Drainage, Stormwater Connection and Earth Change.

### 404.1.1 Floodway (FW) Watershed Development Permit

**"A Floodway Watershed Development Permit shall be obtained prior to any development or earth change where the same is located in the floodway."**

Minimum Submittal Requirements:

a. All submittal requirements listed in 404.1
b. Owner's statement and signature as follows:

**"I hereby certify that the approved development, drainage and/or grading plans will be implemented under the direct engineering supervision of a registered Professional Engineer."**

c. Hydraulic and Hydrologic analysis for any alterations within the floodway, including HEC-RAS model and floodway encroachment runs
d. All applicable Floodway Development requirements as detailed in Tulsa Revised Ordinances, Title 11-A and Title 51
e. For proposed Floodway revisions, all appropriate FEMA submittal data for CLOMR and/or LOMR, as required by ADMINISTRATOR

### 404.1.2 Floodplain (FP) Watershed Development Permit

**"A Floodplain Watershed Development Permit shall be obtained prior to any development or earth change where the same is located in the regulatory floodplain,"**

Minimum Submittal Requirements:

a. All submittal requirements listed in 404.1

b. All applicable Floodplain Development requirements as detailed in Tulsa Revised Ordinances, Title 11-A and Title 51
c. For proposed Floodplain revisions, all appropriate FEMA submittal data for CLOMR and/or LOMR and T-CLOMR and/or T-LOMR submittal data, as required by ADMINISTRATOR

### 404.1.3 Stormwater Drainage (SD) Watershed Development Permit

**"A Stormwater Drainage Watershed Development Permit shall be obtained prior to any development whose discharge at the point it leaves the site is greater than that which can be conveyed in a fifteen (15) inch diameter conduit."**

Minimum Submittal Requirements:

a. All submittal requirements listed in 404.1
b. All applicable Watershed Development requirements as detailed in Tulsa Revised Ordinances, Title 11-A
c. Plans and profiles showing the stormwater drainage systems, any paving to be constructed in connection with or as a part of the proposed work together with a map showing the drainage areas of lands tributary to the site and estimated run-off of the areas served by any drains,

### 404.1.4 Stormwater Connection (SC) Watershed Development Permit

"All other development being more than earth change and exempted herein shall be required to obtain a Stormwater Connection Watershed Development Permit." This category of permit is intended to cover all other activities and is required with earth change permits.

The following are approved connections to the stormwater drainage system:

a. If the subject tract is located on a curb or gutter street and an existing storm sewer inlet is located in the street adjacent to the subject tract, then the construction on an inlet on the subject tract and connecting it to the existing inlet in the street **is preferred;** or;
b. If the subject tract is located on a street with a borrow-ditch then the construction on an inlet on the subject tract discharging stormwater through a pipe with a standard City of Tulsa headwall into the borrow-ditch along the roadway **is preferred**, or, a concrete flume may be constructed to carry the stormwater discharge to the borrow-ditch.

c. In either of the above-mentioned cases, the stormwater may be allowed to discharge overland (sheet flow) to the existing stormwater drainage system by not constructing a curb on the downstream side if the parking lot.

The following are not approved connections to the stormwater drainage system because they cause erosion and sedimentation of the stormwater drainage system:

a. Slots cut into the curb allowing stormwater to discharge overland or into the borrow-ditch;
b. Grass lined flumes carrying the stormwater discharge from parking areas in to the borrow-ditch.

Minimum Submittal Requirements:

a. All submittal requirements listed in 404.1
b. All applicable Watershed Development requirements as detailed in Tulsa Revised Ordinances, Title 11-A
c. The finished floor elevation of the lowest floor of any proposed building shall be 6" inches above the highest adjacent grade to the proposed building. The highest adjacent grade is defined as the highest finished grade outside the proposed building at one of the four corners.
d. Plans shall reflect how the stormwater run-off is being handled in the existing condition and after the proposed development is in place, including plans, profiles and details showing the connection to the stormwater drainage system
e. The stormwater drainage system to be constructed under the Stormwater Connection (SC) Watershed Development Permit shall be designed in accordance with the provisions outlined in the MANUAL.
f. If the proposed stormwater drainage system is designed to receive off-site stormwater or require maintenance to be provided by the DEPARTMENT, then an easement will be required on the stormwater drainage system.

### 404.1.5 **Earth Change (EC) Watershed Development Permit**

**"An Earth Change Watershed Development Permit shall be obtained prior to any earth change. "**

The ORDINANCES define an earth change as: excavating, grading, regrading, landfilling, berming, or diking of land within the City of Tulsa.

Minimum Submittal Requirements:

a. All submittal requirements listed in 404.1
b. All applicable Watershed Development requirements as detailed in Tulsa Revised Ordinances, Title 11-A

### 404.1.6 **Multiple Permits**

From the preceding classification descriptions is can be seen that some developments may be exempt while others require one or more permits. All development is required to obtain a Watershed Development Permit unless specifically exempted in the Watershed Development Regulations. At the opposite end of the process, the proposed developments one acre or larger in area, with earth change located in a floodway, which include a stormwater drainage system that will connect to an existing public system would require four watershed development permits (FW, FP, SD, and EC).

# Chapter 500 DRAINAGE AND DETENTION REPORT REQUIREMENTS

## 501 INTRODUCTION

A Drainage and Detention Report is required for all development within the City of Tulsa. For residential subdivisions or commercial developments, a Full Drainage and Detention Report shall be required. The Full Report requirements are detailed in Section 502. For single lot residential developments, a Single Lot Drainage and Detention Report shall be required. The Single Lot Report requirements are detailed in Section 503.Drainage and Detention Report will identify and define solutions to the problems which may occur on site and off site as a result of the development. In addition, those problems that exist on site prior to development must be addressed during design. All reports shall be typed and bound together or submitted in PDF format.

The drawings, figures, plates, and tables shall be bound with the Report or included in a folder/pocket at the back of the Report. The Full Report shall include a cover letter presenting the preliminary design for review and shall be prepared by or supervised by an engineer licensed in Oklahoma.

## 502 FULL DRAINAGE & DETENTION REPORT REQUIREMENTS

The Full Drainage and Detention Report - Full Submittal Checklist is included at the end of this Section as Exhibit 5-1.

### 502.1 Summary Statement

The report shall contain a certification sheet as follows:

**"I hereby certify that this report (plan) for the drainage design of (Name of Development) was prepared by me (or under my direct supervision) in accordance with the provisions of City of Tulsa Stormwater Management Criteria Manual for the owners thereof."**

__________________________________
Registered Professional Engineer
State of Oklahoma No.______________
(Affix Seal) Date ________________
CA#______________________________

### 502.2 Cover Letter

The cover letter for the Drainage and Detention Report shall include the following:

"SUBDIVISION" or "DEVELOPMENT" DRAINAGE PLAN

A. Goals and Policies

1. Discuss how the proposed drainage plan meets the Stormwater Management goals and adheres to the floodplain policy(ies) of the ORDINANCES.
2. A summary statement concerning the effects the proposed developments will have on the existing and future drainage system of the area.
3. Discuss any deviation of the proposed drainage plan from the goals and policies described in this MANUAL.

B. Drainage System Components

1. Discuss the overall concept of the proposed system.
2. Discuss the interaction of the major drainage and the proposed system.

C. Criteria

1. Discuss proposed deviation from the MANUAL and methodology, as set forth in the standards, approved by the CITY, if appropriate.
2. Discuss the design criteria for the storm drainage design of the proposed system.

## 502.3 Report Contents

The Drainage and Detention Report shall be formatted in accordance with the following outline and contain all of the applicable information listed:

I. GENERAL LOCATION AND DESCRIPTION
- A. Location
  1. Name and address of Legal Owner
  2. Vicinity sketch
  3. Legal description of property
  4. Boundary line survey
  5. Township, range, section, 1/4 section
  6. Local streets within and adjacent to the subdivision
  7. Major drainageways and facilities
  8. Names of surrounding developments
- B. Description of Property
  1. Area in acres
  2. Ground cover (type of trees, shrubs, vegetation)
  3. Major drainageways
  4. Soil types and Hydrologic Soil Groups

II. DRAINAGE BASINS AND SUB-BASINS
- A. Major Basin Description
  1. Reference to major drainageway planning studies such as Master Drainage Plans, flood hazard delineation reports, flood insurance rate maps and LOMR's.
  2. Major basin drainage characteristics

3. Identification of all drainage system components within 50-feet of the property boundary.
4. Overall drainage area boundary and drainage sub-area boundaries.

B. Sub-Basin Description

1. Historic drainage patterns of the property in question
2. Off-site drainage flow patterns and impact of development

III. DRAINAGE DESIGN CRITERIA

A. Regulations

1. Discussion of the optional criteria selected or the deviation from the MANUAL, if any.

B. Development Criteria Reference and Constraints

1. Previous drainage studies (i.e., project masterplans) for the site in question that influence or are influenced by the drainage design and how the plan will affect drainage design for the site.
2. Discussion of the drainage impact of site constraints such as streets, utilities, railways, existing structures, and development of site plan.

C. Hydrological Criteria

1. Design rainfall values used.
2. Hydrologic analysis for runoff and on-site or regional stormwater detention facilities as required.
3. Hydrologic analysis for compensatory storage requirements for any alterations of the floodplain.
4. Runoff calculation method including precipitation loss method and hydrologic soil groups
5. Hydrologic analysis for runoff to insure conveyance
6. Stormwater detention facility discharge and storage calculation method
7. Design storm recurrence intervals
8. Discussion and justification of any criteria or calculation methods used that are not presented in or referenced by the MANUAL.

D. Hydraulic Criteria

1. Routing of off-site drainage flow through the development.
2. Location of watercourse and the appropriate hydraulic analysis for any alteration of a watercourse.
3. Hydraulic analysis for runoff to insure conveyance
4. Hydraulic analysis for compensatory storage requirements for any alterations of the floodplain.
5. References for calculation of stormwater detention facility capacity
6. Detention outlet type
7. Grade control structure criteria used
8. Discussion of any drainage facility design criteria used that are not presented in the MANUAL.

IV. DRAINAGE FACILITY DESIGN

A. General Discussion of:

1. Proposed and typical drainage patterns
2. Compliance with off-site runoff considerations
3. The content of tables, charts, figures, plates, or drawings presented in the report
4. Anticipated and proposed drainage patterns

B. Specific Discussion of:
1. Drainage problems encountered and solutions at specific design points
2. Detention storage and outlet design
3. Photographs of downstream channel condition
4. Maintenance access and aspects of the design
5. Actual maintenance agreement
6. Easements and/or ROW dedications required

V. CONCLUSIONS

A. Compliance with new Standards
1. Stormwater Management Criteria Manual
2. Applicable Master Drainage Plan
3. Best Management Practices implemented

B. Drainage Concept
1. Effectiveness of drainage design to control damage from storm runoff.
2. Influence of proposed development on the Master Drainage Plan recommendation(s).

VI. REFERENCES

A. Reference all criteria and technical information used

VII. APPENDICES

A. Hydrologic Computations
1. Land use assumptions regarding adjacent properties
2. Path(s) chosen for computation of time-of-concentration, including lengths types and slopes of each type of flow (grass, concrete, etc.).
3. Stormwater runoff at specific design points onsite and offsite.
4. Historic and fully developed runoff computations at specific design points
5. Hydrographs at critical design points if applicable

B. Hydraulic Computations
1. Culvert capacities
2. Storm sewer capacity
3. Street capacity
4. Storm inlet capacity including inlet control rating at connection to storm sewer
5. Open channel design
6. Check and/or channel drop design
7. Detention area/volume capacity and outlet capacity calculations

C. All appropriate FEMA (Federal Emergency Management Agency) submittal data to achieve a Letter of Map Revision (LOMR), as described in **403 - FLOODPLAIN MAP AMENDMENTS AND REVISIONS**.

D. Digital copies of all computer models.

## 502.4 Required Report Exhibits

### 502.4.1 Sheet-1 General Location Map

A map shall be provided in sufficient detail to identify drainage flows entering and leaving the development and general drainage patterns. The map should be at a standard engineering scale between 1" = 200' to 1" = 2000' and show the path of all drainage from the upper end of any off-site basins to the defined major drainageways. The map shall identify any major construction (i.e., developments, irrigation ditches, existing detention facilities, culverts, main storm sewers), along the entire path of drainage. The size of the drawings shall be a multiple of 8 1/2" x 11".

### 502.4.2 Sheet-2 Floodplain Information

A copy of the regulatory floodplain map showing the location of the subject property and an official City of Tulsa Flood Zone Determination shall be included with the report. The size of drawings shall be a multiple of 8 1/2" x 11". Regulatory Floodplain maps can be found at the City of Tulsa website listed under City Services.

Sheet-3 - Drainage Plan

Map(s) of the proposed development at a scale of 1" = 20' to 1" = 200' on a 22" x 34" drawing shall be included. The plan shall show the following:

A. Existing and proposed contours at 2-foot maximum intervals. In terrain where the slope is relatively flat, spot elevations with drainage arrows may be substituted.
B. Property lines and easements with purposes noted: Name, address and telephone number of legal owner of property; vicinity sketch.
C. Streets, roads and highways adjacent to the property.
D. Existing drainage facilities and structures, natural or man-made, including, roadside ditches, drainageways, gutter flow directions, and culverts. All pertinent information such as material, size, shape, slope, and location shall also be included.
E. Overall drainage area boundary and drainage sub-area boundaries.
F. Proposed type of street flow (i.e., vertical or combination curb and gutter), roadside ditch (rehabilitation only), gutter flow directions, and cross pans.
G. Proposed storm sewers and open drainageways, including inlets, manholes, culverts, retaining walls, erosion control measures, and other appurtenances.
H. Proposed outfall point for runoff from the developed area and facilities to convey flows to the final outfall point without damage to downstream properties.
I. Routing and accumulation of flows at various critical points for the minor storm runoff.
J. Path(s) chosen for computation of time-of-concentration.
K. Details of detention storage facilities and outlet works.

L. Location and elevations of all defined floodplains affecting the property.
M. Location and elevations of all existing and proposed utilities affected by or affecting the drainage design.
N. Routing of off-site drainage flow through the development.
O. Construction sequence bar graph.
P. Maintenance requirements and schedule.

### 502.4.3 **Erosion Control Plan**

The City of Tulsa Permit Center's Placement of Erosion Control Inspection (PEC) process has specific requirements for stormwater pollution prevention and controls. See **Figure 5-3** for a sample drawing.

## 503 SINGLE LOT DRAINAGE RESIDENTIAL REQUIREMENTS

The Single Lot Drainage and Detention Report - Single Lot (Duplex) Submittal Checklist is included at the end of this section as Exhibit 5-2.

The following requirements are to be used in the planning, design, and construction of new homes, additions to existing homes, outbuildings, swimming pools, and other significant activities that could change the drainage patterns and characteristics of property that could impact neighboring properties:

- All residential properties must accept and convey drainage without causing damage to adjoining properties. Flow coming from off-site onto the property cannot be blocked. Flow from off-site must be conveyed so that it does not cause damage to neighbors. Any additional flow originating on the property must be collected and conveyed to the street, if possible, or other approved drainage conveyance facility.
- All new houses must have roof drainage directed to the street or other approved conveyance (exceptions will be made on a case-by-case basis).
- All home builders must prepare and submit a preliminary survey of the site showing an established bench mark if the property is in a floodplain or showing an assumed elevation at a known beginning point. Minimum elevations required are the property corners, finished floor of building, and others as needed. Existing topography maps (from INCOG, subdivision plans, or other sources) should be used, if available.
- All existing drainage pipes and drainage features must be shown on the house plans.
- Existing and proposed flow conditions must be shown on the house plans.
- A drainage drawing must be prepared showing the flow on the property prior to construction. A separate drainage drawing must be prepared showing spot elevations and directional water flow arrows, including off-site incoming and outgoing flow for the site after the construction has been completed. Both the

present and final plans must be submitted with the residential permit application. See enclosures for examples of the minimum that will be required.

- Storage buildings must have the same drainage documentation as houses if they require a permit.

Every residential building permit and earth change permit must have an erosion control plan. The plan must be approved prior to installation. Construction, including any fill on the site, cannot be started until the approved plan is in place and inspected by the City. The erosion control measures must continue to be functional and provide the required level of protection throughout the duration of construction.

## 503.1 General Requirements

The Single Lot Drainage and Detention Report will identify and define solutions to the problems which may occur on site and off site as a result of the development. In addition, those problems that exist on site prior to development must be addressed during design. All reports shall be typed and bound together or submitted in PDF format. The drawings, figures, plates, and tables shall be bound with the report (if larger than 11” x 17”, include in a folder/pocket at the back of the Cover Letter.)

## 503.2 Cover Letter

The cover letter for the Drainage and Detention Report shall include the following:

<u>SINGLE LOT DRAINAGE PLAN</u>

1. Discuss how the proposed drainage plan meets the Stormwater Management goals and adheres to the floodplain policy(ies) of the ORDINANCES.
2. Discuss the overall concept of the proposed system.
3. Discuss the interaction of the major drainage and the proposed system.
4. Discuss proposed deviation from the MANUAL and methodology, as set forth in the standards, approved by the CITY, if appropriate.
5. Discuss the design criteria for the storm drainage design of the proposed system.

## 503.3 On-Site Drainage Plan

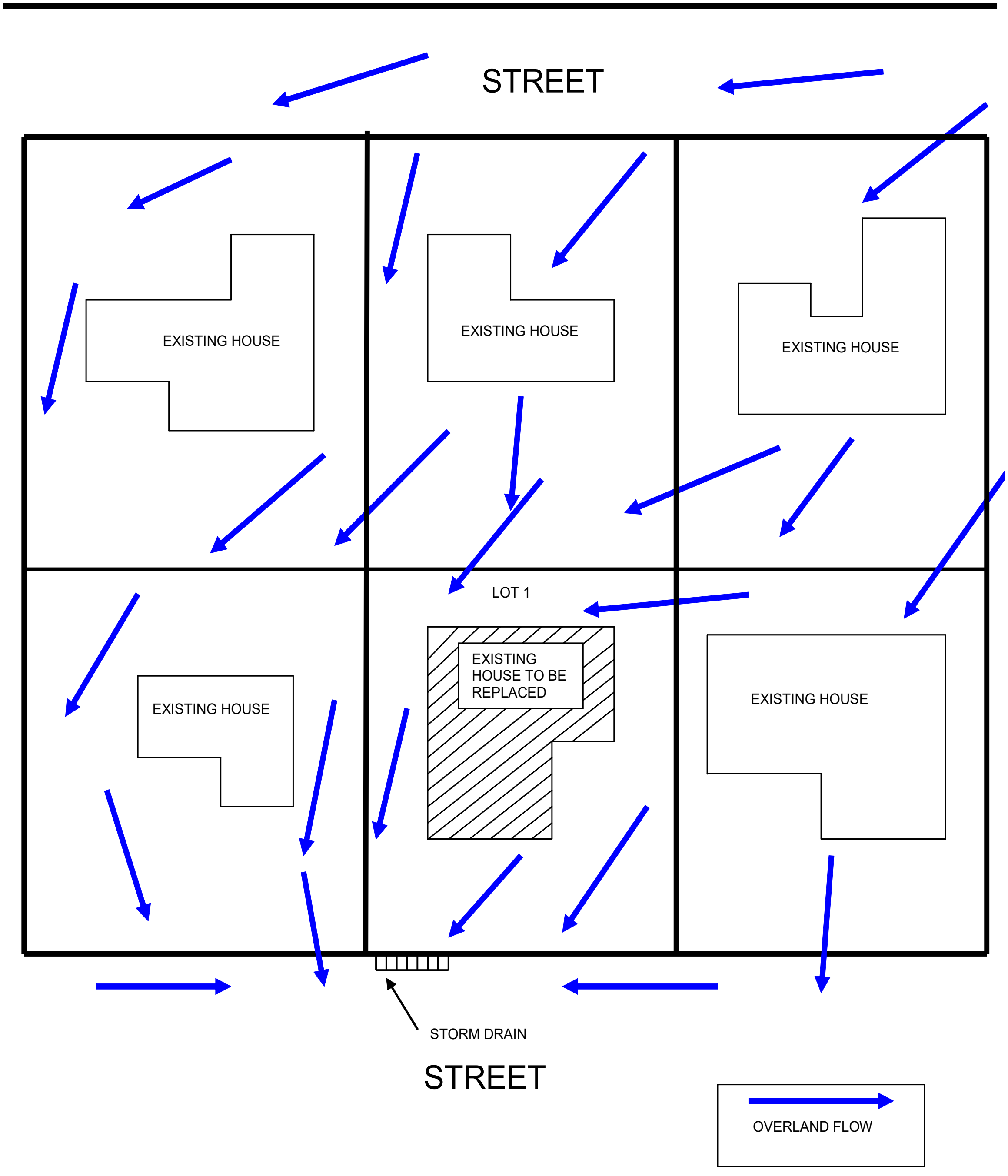
The Drainage and Detention Report shall contain all of the <u>applicable</u> information listed:

<u>SINGLE LOT DRAINAGE PLAN</u>

1. A drawing shall be provided that shows the overall drainage area boundary that flows to the property.
2. A drawing shall be provided that shows existing and proposed contours at the property with a 2-foot maximum interval. In terrain where the slope is relatively flat, spot elevations may be substituted.

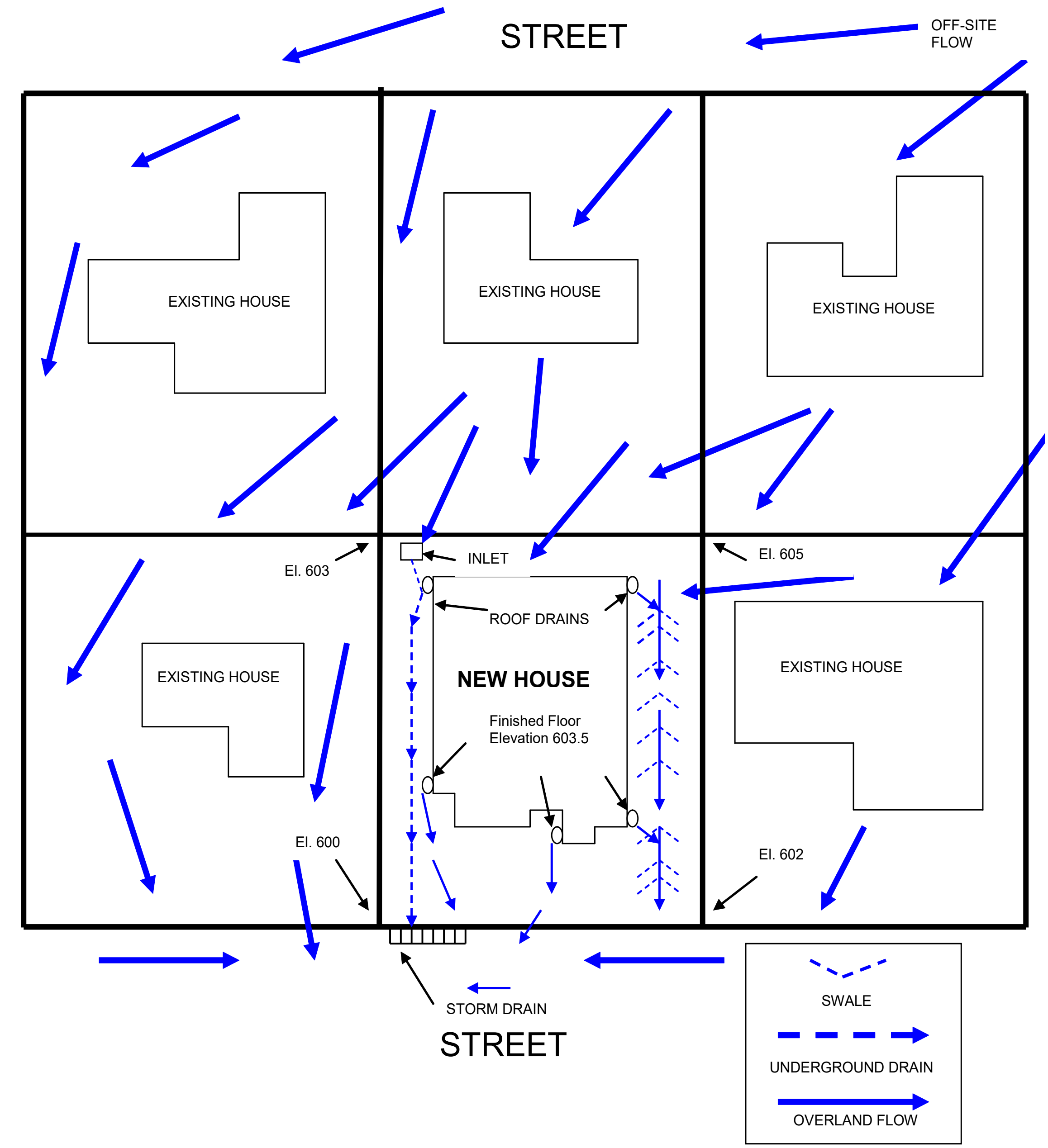
3. A drainage drawing shall be provided showing flow direction arrows on the property prior to construction. A separate drainage drawing shall also be provided showing spot elevations and directional water flow arrows, including off-site incoming and outgoing flow for the site after the construction has been completed. The flow direction arrows shall indicate how local flow is directed away from structures and how off-site flow is directed across the property. (see **Figure 5-1** and **Figure 5-2** for example drawings showing the flow direction arrows)
4. A drawing shall be provided showing the erosion control plan (see **Figure 5-3** for an example drawing).
5. Property lines, and easements with purposes shall be noted on the drawing.
6. Streets, roads and highways adjacent to the property shall be shown.
7. Existing drainage facilities and structures, natural or man-made, including, roadside ditches, drainageways, gutter flow directions, and culverts shall be shown. All pertinent information such as material, size, shape, slope, and location shall also be included.
8. Proposed storm water conveyance features, including best management practices for the proper handling of storm water runoff shall be shown.
9. Proposed outfall point for runoff from the property and facilities to convey flows to the final outfall point without damage to downstream properties shall be shown.
10. Location and elevations of all defined floodplains affecting the property shall be shown.

## FIGURE 5-1 - CURRENT DRAINAGE PATHS



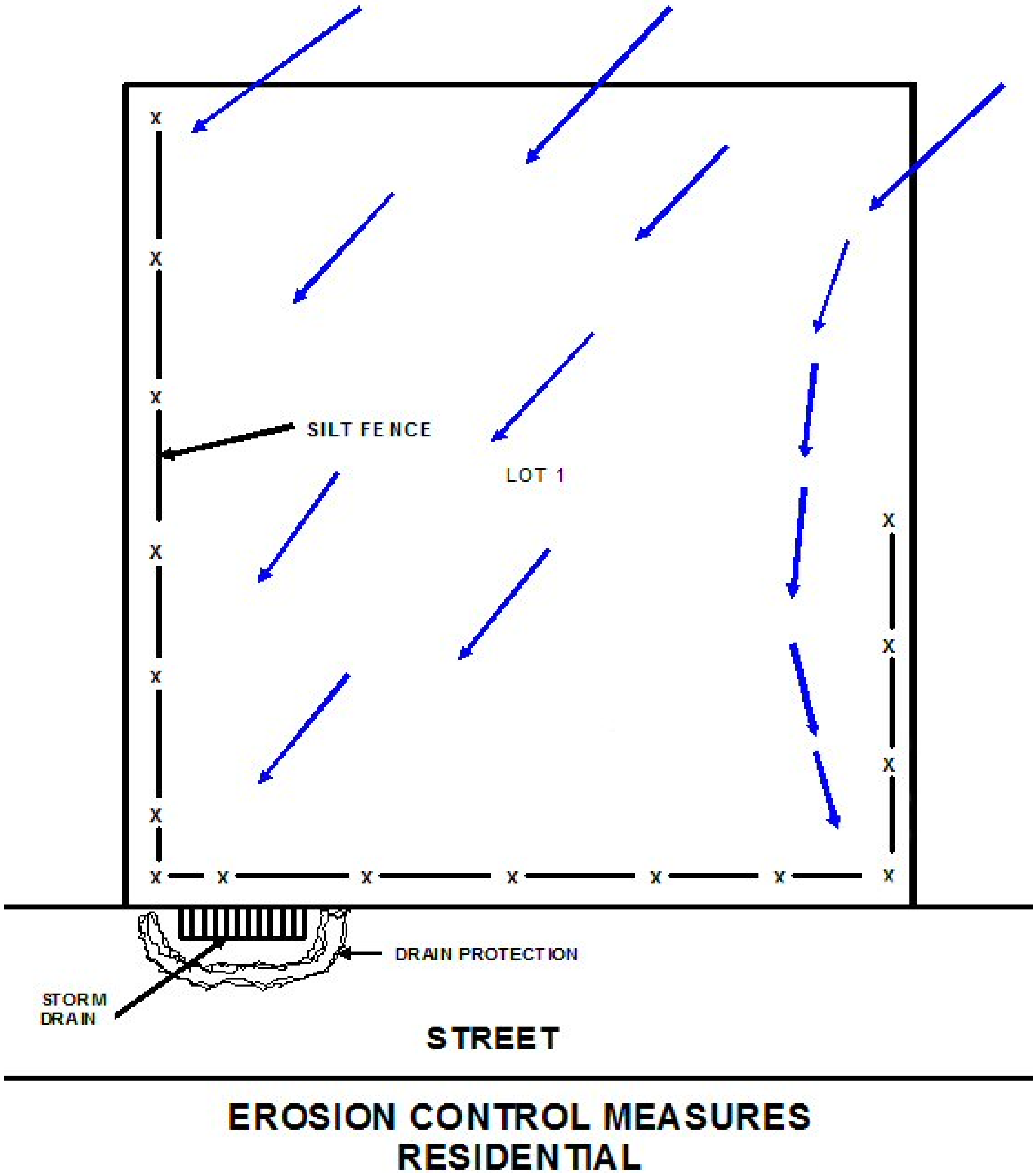

**CURRENT DRAINAGE PATHS**

## FIGURE 5-2 - POST CONSTRUCTION DRAINAGE PATHS




**POST CONSTRUCTION DRAINAGE PATHS**
**(for example only)**

## FIGURE 5-3 - EROSION CONTROL MEASURES - RESIDENTIAL



# EXHIBIT 5-1 - DRAINAGE AND DETENTION REPORT- FULL SUBMITTAL

**DRAINAGE AND DETENTION REPORT - FULL SUBMITTAL CHECKLIST**

**TYPE OF DEVELOPMENT**

**DATE**:____________

☐ Subdivision ☐ Public Infrastructure

☐ Infill Development ☐ Commercial/ Industrial

☐ Single Lot (See Single Lot Checklist (Figure 5-2) if development does not require a storm sewer connection or on-site detention)

Subdivision: ____________________________________________________________

Location: ____________________________________________________________

Engineer:____________________________________________________________

Firm:____________________________________________________________

Phone:__________________________ e-mail:_______________________________

**CHECKLIST**

| | |
|---|---|
| | **GENERAL REQUIREMENTS** |
| ☐ | Typed and bound on 81/2" x 11" paper OR submitted in PDF format |
| ☐ | Drawings, figures, plates and tables bound with report (if larger than 11" x 17", include in a folder/pocket at the back of the Report) |
| ☐ | Cover letter presenting preliminary design for review. |
| ☐ | Report prepared by or supervised by an engineer licensed in Oklahoma. |
| | **CERTIFICATION SHEET** |
| ☐ | Certification Sheet as shown in Section 503.1.1 of Stormwater Management Criteria Manual |
| | **SUMMARY STATEMENT** |
| | **Goals and Policies** |
| ☐ | Discuss how the proposed drainage plan meets the Stormwater Management goals and adheres to the floodplain policy(ies) of the ORDINANCES. |
| ☐ | A summary statement concerning the effects of proposed developments will have on the existing and future drainage system of the area. |
| ☐ | Discuss any deviation of the proposed drainage plan from CITY policies. |
| | **Drainage System Components** |
| ☐ | Discuss the overall concept of the proposed system. |
| ☐ | Discuss the interaction of the major drainage and the proposed system. |
| | **Criteria** |
| ☐ | Discuss proposed deviation from the MANUAL and methodology, as set forth in the standards, approved by the CITY, if appropriate. |
| ☐ | Discuss the design criteria for the storm drainage design of the proposed system. |

| GENERAL LOCATION AND DESCRIPTION |
|---|
| **Location** |
| ☐ Name and Name and address of Legal Owner |
| ☐ Vicinity Sketch |
| ☐ Legal description of property |
| ☐ Boundary line survey |
| ☐ Township, range, section, 1/4 section |
| ☐ Local streets within and adjacent to the Development |
| ☐ Major drainageways and facilities |
| ☐ Names of surrounding developments |
| **Description of Property** |
| ☐ Area in acres |
| ☐ Ground cover (type of existing and proposed trees, shrubs, vegetation) |
| ☐ Major drainageways |
| ☐ Soil Types and Hydrologic Soil Groups |
| **DRAINAGE BASINS AND SUB-BASINS** |
| **Major Basin Description** |
| ☐ Reference to major drainageway planning studies such as Master Drainage Plans, flood hazard delineation reports, and flood insurance rate maps |
| ☐ Major basin drainage characteristics |
| ☐ Identification of all drainage system components within 50-feet of the property boundary. |
| ☐ Overall drainage area boundary and drainage sub-area boundaries. |
| **Sub-Basin Description** |
| ☐ Historic drainage patterns of the property in question |
| ☐ Off-site drainage flow patterns and impact of/on development |
| **DRAINAGE DESIGN CRITERIA** |
| **Regulations** |
| ☐ Discussion of the optional criteria selected or the deviation from the MANUAL, if any. |
| **Development Criteria Reference and Constraints** |
| ☐ Previous drainage studies (i.e., project masterplans) for the site in question that influence or are influenced by the drainage design and how the plan will affect drainage design for the site |
| ☐ Discussion of the drainage impact of site constraints such as streets, utilities, railways, existing structures, and development of site plan |
| **Hydrological Criteria** |
| ☐ Design rainfall |
| ☐ Hydrologic analysis for runoff and on-site or regional stormwater detention facilities as required. |
| ☐ Hydrologic analysis for compensatory storage requirements for any alterations of the floodplain. |
| ☐ Runoff calculation method, including precipitation loss method |
| ☐ Hydrologic analysis for runoff to insure conveyance. |
| ☐ Detention discharge and storage calculation method |
| ☐ Design storm recurrence intervals |
| ☐ Discussion and justification of any criteria or calculation methods used that are not presented in or referenced by the MANUAL |
| |

| Hydraulic Criteria | |
|---|---|
| ☐ | Routing of off-site drainage flow through the development. |
| ☐ | Location of watercourse and the appropriate hydraulic analysis for any alteration of a watercourse. |
| ☐ | Hydraulic analysis for runoff to insure conveyance. |
| ☐ | Hydraulic analysis for compensatory storage requirements for any alterations of the floodplain. |
| ☐ | references for calculation of facility capacity |
| ☐ | Detention outlet type |
| ☐ | Grade control structure criteria used |
| ☐ | Discussion of any drainage facility design criteria used that are not presented in the MANUAL |

| DRAINAGE FACILITY DESIGN | |
|---|---|
| **General Discussion of:** | |
| ☐ | Proposed and typical drainage patterns |
| ☐ | Compliance with off-site runoff considerations |
| ☐ | The content of tables, charts, figures, plates, or drawings presented in the report |
| ☐ | Anticipated and proposed drainage patterns |
| **Specific Discussion of:** | |
| ☐ | Drainage problems encountered and solutions at specific design points |
| ☐ | Detention storage and outlet design |
| ☐ | Photographs of downstream channel condition |
| ☐ | Maintenance access and aspects of the design |
| ☐ | Actual maintenance agreement |
| ☐ | Easements and/or ROW dedications required |
| **CONCLUSIONS** | |
| **Compliance with Standards** | |
| ☐ | Stormwater Management Criteria Manual |
| ☐ | Applicable Master Drainage Plan |
| ☐ | Best Management Practices implemented |
| **Drainage Concept** | |
| ☐ | Effectiveness of drainage design to control damage from storm runoff |
| ☐ | Influence of proposed development on the Master Drainage Plan recommendation(s) |
| **REFERENCES** | |
| ☐ | Reference all criteria and technical information used |
| **APPENDICES** | |
| **Hydrologic Computations** | |
| ☐ | Land use assumptions regarding adjacent properties |
| ☐ | Path(s) chosen for computation of time-of-concentration. |
| ☐ | Stormwater runoff at specific design points onsite and offsite. |
| ☐ | Historic and fully developed runoff computations at specific design points |
| ☐ | Hydrographs at critical design points if applicable |
| **Hydraulic Computations** | |

| | |
|---|---|
| ☐ | Culvert capacities |
| ☐ | Storm sewer capacity |
| ☐ | Street capacity |
| ☐ | Storm inlet capacity including inlet control rating at connection to storm sewer |
| ☐ | Open channel design |
| ☐ | Check and/or channel drop design |
| ☐ | Detention area/volume capacity and outlet capacity calculations |
| **All appropriate FEMA (Federal Emergency Management Agency) submittal data to achieve a Letter of Map Revision (LOMR).** | |

| **Sheet 1 General Location Map** | |
|---|---|
| ☐ | A map shall be provided in sufficient detail to identify drainage flows entering and leaving the development and general drainage patterns. The map should be at a scale of 1" = 200' to 1" =2000' and show the path of all drainage from the upper end of any off-site basins to the defined major drainage ways. The map shall identify any major construction (i.e., developments, irrigation ditches, existing detention facilities, culverts, main storm sewers), along the entire path of drainage. The size of the drawings shall be a multiple of 8 1/2" x 11". |
| **Sheet 2 - Floodplain Information** | |
| ☐ | A copy of the regulatory floodplain map showing the location of the subject property shall be included with the report. The size of drawings shall be a multiple of 8 1/2" x 11". |
| **Sheet 3 - Drainage Plan** | |
| ☐ | Map(s) of the proposed development at a scale of 1" = 20' to 1" = 200' on a 22" x 34" drawing shall be included. The plan shall show the following: |
| ☐ | Existing and proposed contours at 2-foot maximum intervals. In terrain where the slope is relatively flat, spot elevations with drainage arrows may be substituted. |
| ☐ | Property lines, and easements with purposes noted: Name, address and telephone number of legal owner of property; vicinity sketch. |
| ☐ | Streets, roads and highways adjacent to the property. |
| ☐ | Existing drainage facilities and structures, natural or man-made, including, roadside ditches, drainage ways, gutter flow directions, and culverts. All pertinent information such as material, size, shape, slope, and location shall also be included. |
| ☐ | Overall drainage area boundary and drainage sub-area boundaries. |
| ☐ | Proposed type of street flow (i.e., vertical or combination curb and gutter), roadside ditch, gutter flow directions, and cross pans. |
| ☐ | Proposed storm sewers and open drainage ways, including inlets, manholes, culverts, retaining walls, erosion control measures, and other appurtenances. |
| ☐ | Proposed outfall point for runoff from the developed area and facilities to convey flows to the final outfall point without damage to downstream properties. |
| ☐ | Routing and accumulation of flows at various critical points for the minor storm runoff. Path(s) chosen for computation of time-of-concentration. |
| ☐ | Details of detention storage facilities and outlet works. |
| ☐ | Location and elevations of all defined floodplains affecting the property. |
| ☐ | Location and elevations of all existing and proposed utilities affected by or affecting the drainage design. |
| ☐ | Routing of off-site drainage flow through the development. |

# EXHIBIT 5-2 - SINGLE LOT CHECKLIST

| SINGLE LOT CHECKLIST | |
|---|---|
| **GENERAL REQUIREMENTS** | |
| ☐ | Typed and bound on 81/2" x 11" paper **OR** submitted in PDF format |
| ☐ | Cover letter presenting design for review. |
| ☐ | Drawings, figures, plates and tables bound with report (if larger than 11" x 17", include in a folder/pocket at the back of the Cover Letter) |
| **COVER LETTER** | |
| ☐ | Discuss how the proposed drainage plan meets the Stormwater Management goals and adheres to the floodplain policy(ies) of the ORDINANCES. |
| ☐ | Discuss the overall concept of the proposed drainage system. |
| ☐ | Discuss the interaction of the major drainage and the proposed system. |
| ☐ | Discuss proposed deviation from the MANUAL and methodology, as set forth in the standards, approved by the CITY, if appropriate. |
| ☐ | Discuss the design criteria for the storm drainage design of the proposed system. |
| **ON-SITE DRAINAGE PLAN** | |
| ☐ | A drawing shall be provided that shows the overall drainage area boundary that flows to the property. |
| ☐ | A drawing shall be provided that shows existing and proposed contours at the property with a 2- foot maximum interval. In terrain where the slope is relatively flat, spot elevations may be substituted. |
| ☐ | Flow direction arrows shall be provided to indicate how local flow is directed away from structures and how off-site flow is directed across the property. |
| ☐ | Property lines, and easements with purposes shall be noted on the drawing. |
| ☐ | Streets, roads and highways adjacent to the property shall be shown. |
| ☐ | Existing drainage facilities and structures, natural or man-made, including, roadside ditches, drainageways, gutter flow directions, and culverts. All pertinent information such as material, size, shape, slope, and location shall also be included. |
| ☐ | Proposed storm water conveyance features, including best management practices to mitigate adverse impacts. |
| ☐ | Proposed outfall point for runoff from the property and facilities to convey flows to the final outfall point without damage to downstream properties. |
| ☐ | Location and elevations of all defined floodplains affecting the property. |

# Chapter 600 RAINFALL AND RUNOFF

## 601 INTRODUCTION

For projects that include stormwater conveyance systems and/or detention systems, all hydrologic analyses that are submitted for approval by the CITY shall utilize the computational techniques presented in this Chapter.

A. HEC-HMS is the preferred computer program for hydrologic analysis.
B. Stormwater conveyance systems and detention systems shall be sized for 1% (100-year) storm assuming full undetained urbanization of the undeveloped portions of the watershed (1% Regulatory Storm).
C. In order to compare the effects of the project, existing conditions shall be computed and compared to the “with project” conditions at the point of discharge from the project and at points downstream as specified by the ADMINISTRATOR to ensure that there is no increase in the discharges.
D. FEMA and The City of Tulsa Map Revisions will be required if the project includes any development, including fill, re-grading, channelization, or the construction of hydraulic structures, in the effective FEMA floodplain or City of Tulsa Regulatory Floodplain.

## 602 HEC-HMS COMPUTER MODEL

### 602.1 Introduction

Unit hydrograph computations are required for all hydrologic studies when the time of concentration for the entire watershed draining to the point of discharge from the project is greater than 10 minutes. HEC-HMS is the preferred computer program for performing these computations. HEC-HMS is a hydrologic simulation model developed by the US Army Corps of Engineers Hydrologic Engineering Center in Davis, California and is the successor to HEC-1. Other models may be used with the approval of the CITY ENGINEER.

### 602.2 Stream Network Modeling

For use with the HEC-HMS program, a river basin is subdivided into an interconnected system of stream network components using topographic maps and other geographic information. Basin components are developed by the following steps:

A. The study area watershed boundary is delineated first. This can be done using a topographic map and, in an urban area, supplemented by investigating the storm sewer drainage system.
B. The watershed is then sub divided into a number of sub basins as required to accurately model the runoff. Each sub basin is intended to represent an area of the watershed which, on average, has the same hydrologic properties. These properties shall be described by

either the SCS (Section 605) or the Snyder's (Section 606) unit hydrograph method. Precipitation loss rates are also described for each sub basin.

C. Routing reaches are then determined to convey the hydrographs to downstream points. Routing reaches can be contained within the channel, a combination of channel and overbank flow, all overbank flow, storm sewer flow, or a routing through a reservoir. These routing reaches shall be described by the Kinematic Wave, Storage-Discharge (Modified Puls), or Lag method, depending on the type of routing reach. See Section 607.
D. Diversions may be required if water leaves a portion of the system. For example, water may leave the overland flow portion of the system at a particular point and enter the storm sewer system where it is then routed downstream by a different method than the overland flow. The storm sewer flow should be diverted from the network and returned at the appropriate point.
E. Precipitation data is entered into the HEC-HMS model as described in Section 603.

# 603 DESIGN STORM

All projects that involve collection system design, hydraulic structure design, detention design, or floodplain analysis shall be evaluated for the following conditions:

A. The design storm for all projects requiring a hydrological analysis shall be the 1% (100-year), 24-hour storm.
B. In order to determine the effects of the project on more frequent and less frequent flooding, and for water quality considerations, the 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), 1% (100-year) and 0.2% (500-year) storms shall be evaluated.
C. In order to compare the effects of the project, existing conditions shall be computed and compared to the "with project" conditions at the point of discharge from the project and at points downstream as specified by the ADMINISTRATOR to ensure that there is no increase in flooding. This applies to all frequency storms that are studied.

## 603.1 Rainfall Depth-Duration Relationship - National Oceanic and Atmospheric Administration (NOAA)

NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 8, Version 2.0, provides total rainfall depths for 50% (2-year) through 0.2% (500-year) storms with storm durations of 5-minutes to 24-hours for the City of Tulsa and are presented in **Table 6-1**. These rainfall depth-duration data are for the TULSA Station ID: 34-8987 and shall be used in all HEC-HMS models to calculate existing and future development discharges for frequency storms. The latest rainfall adopted by NOAA can be obtained on the NOAA website for the TULSA Station.

## 603.2 Storm Area

The rainfall depth-duration data presented in **Table 6-1** are point rainfall depths. As watershed area increases, it is unlikely that the rainfall will be evenly distributed over the entire watershed. Therefore, a storm area equal to the area of the entire watershed shall be used.

### 603.3 Storm Duration

All hydrologic studies shall use a storm duration of 24 hours.

### 603.4 Balanced Rainfall Distribution

A balanced rainfall distribution shall be used. The maximum intensity duration shall be set to 5 minutes and positioned at the 50 percent location of the storm.

### 603.5 Computational Time Interval

The computational time interval for all hydrologic studies shall be set to a time that is not more than 0.29 times the time of concentration for the smallest sub basin. This is a limitation set by the HEC-HMS program to allow the hydrologic model to more accurately capture the true shape of the computed hydrographs.

## 604 APPROVED HYDROLOGY METHODS

There are two approved hydrology methods for computing frequency discharges:

A. The City of Tulsa requires that the timing of peak flows be taken into account by using a hydrograph method for computing storm runoff. Unit hydrograph computations will require the use of a HEC-HMS computer model (other models may be used with the approval of the CITY ENGINEER) to simulate the stormwater runoff of the watershed.
B. The Rational Method may be used to compute frequency discharges for a project if the time of concentration is less than ten (10) minutes for the entire watershed draining to the point of discharge from the project.

### 604.1 Approved Unit Hydrograph Methods

There are two approved unit hydrograph methods:

A. The SCS unit hydrograph method.
B. The modified Snyder's unit hydrograph method.

### 604.2 Approved Routing Methods

There are three approved routing methods to convey hydrographs to downstream points:

A. The Kinematic Wave method may be used in channel and storm sewer routings.
B. The Storage-Discharge (Modified Puls) routing shall be used for channel/overbank and reservoir routings.
C. The Lag method may be used for storm sewer flow.

# 605 SCS UNIT HYDROGRAPH METHOD

## 605.1 Introduction

The SCS methodology combines the effect that specific soils and soil cover (i.e., vegetation) have on the runoff from a storm into one parameter called the Soil-Cover Complex number (CN). For a specific type of land use, soil type, and cover condition in a watershed, a CN value can be determined. Then, utilizing the total rainfall value and the CN value, the storm runoff volume is calculated from a given total rainfall. Next, the peak flow rate and hydrograph shape are determined by applying the runoff to the SCS dimensionless unit hydrograph which is defined by calculating the lag time of the basin.

A. When using the SCS unit hydrograph method for a sub basin, the SCS basin lag time shall be used in conjunction with the CN value to determine runoff.

## 605.2 CN Determination

The soil type and vegetative covers of a watershed are generally classified separately. A combination of a specific soil type and a specific cover is referred to as a Soil-Cover Complex Number (CN) and a measure of this complex can be used as a watershed parameter in estimating runoff. The CN for each sub area in the hydrologic analysis can be derived by first determining the classification of the soil, and then choosing the CN from **Table 6-2** for the applicable cover type and hydrologic condition.

The local Natural Resources Conservation Service office has soil survey data for Tulsa County. These data were mapped with soil series and complexes and can be obtained at the NRCS office. Generalized soils maps, on a county basis, can also be obtained from the NRCS). Once the soil series is known, the soil can be placed into the proper hydrologic soil group.

## 605.3 Basin Characteristics

Several sub basin characteristics that are needed for the SCS Unit Hydrograph Method:

A. Drainage area of the sub basin,
B. Longest flow path length,
C. Characteristics of individual flow paths that make up the longest flow path (e.g., overland, grassed channel, gutter),
D. Slope of individual flow paths, and,
E. Land use types and areas throughout the basin (e.g., agricultural, residential, business).

The drainage basin boundary and area can be determined from available topographical maps, and the land use and flow path characteristics can be obtained from aerial photos, field investigations, or detailed topographical maps.

## 605.4 Basin Lag Time ($T_{lag}$)

A dimensionless unit hydrograph has been developed by the SCS (Reference 26) based upon the evaluation of a large number of natural unit hydrographs from various watersheds. To determine the SCS unit hydrograph Basin Lag Time ($T_{lag}$) for a specific basin, first calculate the Time of Concentration ($T_c$) for the basin by summing the overland flow times for the various surfaces using the procedures outlined in Section 605.4.1. The Basin Lag Time ($T_{lag}$) is then calculated using Equation 601:

$$T_{lag} = 0.6\ T_c \tag{601}$$

Where: $T_{lag}$ = basin lag time (hours)

$T_c$ = time of concentration (hours)

### 605.4.1 Time of Concentration

The Time of Concentration ($T_c$) for the basin is made up of two time components, according to the following equation:

$$T_c = t_I + t_T \tag{602}$$

Where: $T_c$ = time of concentration (minutes)

$t_I$ = initial, inlet, or overland flow time (minutes)

$t_T$ = travel time in the ditch, channel, gutter, storm sewer, etc. (minutes)

A. For urban areas, the time of concentration consists of an overland flow time ($t_I$) plus the time of travel ($t_T$) in the storm sewer, shallow channelized flow, paved gutter, roadside drainage ditch, or drainage channel.
B. For non-urban areas, the time of concentration consists of an overland flow time ($t_I$) plus the time of travel in a combined form, such as a small swale, channel, or drainageway.
C. Overland flow time $t_I$ varies with surface slope, surface cover and distance of surface flow and is estimated using the appropriate line in **Figure 6-1**.
D. From the upstream end of the overland travel reach, after approximately 150 feet, sheet flow usually becomes shallow concentrated flow collecting is swales, small rills, and gullies. Therefore, below the top 150’ of the overland travel reach the “Grassed Waterway” or “Paved Area (Sheet Flow) & Shallow Gutter Flow” lines or equations in **Figure 6-1** shall be used.
E. The latter portion ($t_T$) of the time of concentration can be estimated from the hydraulic properties of the storm sewer, gutter, swale, ditch, or drainageway, or may be calculated using the "Paved Area (Sheet Flow) & Shallow Gutter Flow" line in **Figure 6-1**.

# 606 SNYDER'S UNIT HYDROGRAPH METHOD

## 606.1 Introduction

The Snyder's unit hydrograph method provides equations to define the coordinates of the peak and the time base of the unit hydrograph. These equations relate basin characteristics and empirical coefficients to define the shape of the unit hydrograph by deriving the time to peak and a peaking coefficient. Modifications to the Snyder's unit hydrograph method have been developed by the Tulsa District Corps of Engineers that account for urbanization.

A. When using the Snyder's unit hydrograph method for a sub basin, the time to peak and peaking coefficient shall be used in conjunction with an initial loss of 0.5 inches per hour and a constant loss rate of 0.08 inches per hour to determine runoff.

## 606.2 Unit Hydrograph Equations

There are four basic equations used in defining the limits of the synthetic unit hydrograph. These equations define the basin time to peak for rural conditions and urbanized conditions, the unit hydrograph peak runoff rate, and the unit hydrograph peaking coefficient.

### 606.2.1 Unit Hydrograph Time To Peak Coefficient, $t_p$

The basin time to peak can be calculated using the following equation which uses constants developed from empirical studies for the City of Tulsa:

$$t_p = 1.40\left[L\left(\frac{L_{ca}}{S^{0.5}}\right)\right]^{0.376} \qquad (604)$$

Where: $t_p$ = time to peak of the unit hydrograph from midpoint of unit rainfall, without adjustment, in hours.

$L$ = length along stream from study point to upstream limits of the watershed, in miles.

$L_{ca}$ = length along stream from study point to a point along stream adjacent to the centroid of the watershed, in miles.

$S$ = weighted average slope of basin along the stream to upstream limits of the watershed, in feet per mile.

### 606.2.2 Unit Hydrograph Time To Peak Coefficient Adjustment for Urbanization

To account for the effects of urbanization on the time to peak an adjustment factor is introduced. The adjustment factor is based on the percentage of channel improvements within the basin. This parameter was chosen by the Corps of Engineers because they felt it more directly measured the physical effects of urbanization than percent of basin development. With this assumption in mind, Equation 605 is used to adjust $t_p$.

$$t'_p = t_p\, 10^{-(0.0034)\%\,Ch} \qquad (605)$$

Where: $t'_p$ = adjusted time to peak

$t_p$ = time to peak calculated from Equation 604

% Ch = percent of channel improved

The percentage of the channel improved is defined as that percentage, as measured along the main watercourse to the basin divide, which has been modified by clearing or straightening, divided by the total length of the watercourse. In the upper reaches of the watershed, this includes storm sewers, gutters, and other modifications to natural drainageways.

#### 606.2.3 Unit Hydrograph Peak, $q_p$

The peak runoff rate of the unit hydrograph ($q_p$) can be calculated using the following equation:

$$q_p = 375\, t_p^{-0.906} \qquad (606)$$

Where: $q_p$ = peak rate of runoff in cfs per square mile

$t_p$ = time to peak of unit hydrograph from midpoint of unit rainfall, in hours.

#### 606.2.4 Runoff Hydrograph Peak Coefficient $C_p$

The peaking coefficient of the unit hydrograph is defined by the following equation:

$$C_p = \frac{q_p t_p}{640} \qquad (607)$$

Where: $q_p$ = peak rate of runoff, in cfs per square mile.

$t_p$ = time to peak of the unit hydrograph.

## 607 ROUTING OF HYDROGRAPHS

### 607.1 Introduction

For all hydrologic studies submitted to the City of Tulsa which involve routing of sub basin hydrographs, the following routing methods shall be used as indicated:

| Routing Method | Flow Condition |
|---|---|
| Kinematic Wave | Flow completely contained in the channel,<br><br>Flow contained in storm sewer |
| Storage-Discharge (Modified Puls) | Overbank flow<br><br>Reservoir routing |
| Lag | Flow contained in full storm sewer |

## 607.2 Kinematic Wave

The Kinematic Wave routing method is appropriate when the flow is contained in a channel or storm sewer where flood wave attenuation is not significant. In those cases, Manning's equation can be simplified to say that the flow rate at any given time is equal to the time rate of change of the cross section area of flow plus the rate of change in flow with distance. The Kinematic Wave routing method is therefore defined in the HEC-HMS model by the reach length, roughness, shape, width or diameter, and side slope of a typical cross section in the routing reach.

## 607.3 Storage-Discharge (Modified Puls

The Storage-Discharge (Modified Puls) routing method shall be used if there is overbank flow in the reach, and also for reservoir routings.

### 607.3.1 Overbank Flow Routing Reach

When flood flows exceed the channel carrying capacity, water flows into the overbank areas and, depending on the characteristics of the overbanks, can be slowed greatly, and often ponding will occur. The Storage Discharge (Modified Puls) routing method accounts for the significant effects that overbank flow has on the attenuation and translation of a flood wave.

The storage-discharge relationship for a routing reach can be defined by calculating the storage volume (acre-feet) in the reach for each discharge that passes through the reach from low flow to beyond the highest flow that will be studied. This can be accomplished by hydraulic analysis of the reach for a range of discharges with HEC-RAS or HEC-2. Care should be taken to include the non-conveyance portions of all the cross sections, such as ineffective flow areas.

In addition to the storage-discharge relationship for a routing reach, the number of routing "subreaches" must also be determined for use in the HEC-HMS model. The number of subreaches is determined by comparing the hydrograph travel time to the computational interval:

$$\text{Subreaches} = \frac{K}{\Delta t} \qquad (608)$$

Where: K = Average Travel Time, in minutes

$\Delta t$ = Computational Time Interval, in minutes

The K value is reported as the “Trvl Tme Avg” variable in the HEC-RAS summary table for the reach. The computational time interval, $\Delta t$, is defined in the Control Specifications section of the HEC-HMS model.

#### 607.3.2 Reservoir Routing

Reservoir routing using the Storage-Discharge (Modified Puls) method is accomplished by defining the elevation-area-capacity relationship of the reservoir and by defining the outflow rating curve.

The outflow rating curve should take into account all of the available outflow structures (low flow pipes, notched weirs, overflow spillways, etc.). The built-in outflow structures routines in HEC-HMS may be used or individual rating curves may be calculated and added together as appropriate. Care should be taken to properly account for tailwater conditions downstream of the outlets.

#### 607.3.3 Lag Method

The Lag method for routing hydrographs may be used to translate flows in storm sewers that are flowing full from an upstream point to a downstream point. The lag method does not attenuate the peak flow; it merely translates it by the given number of minutes. The lag time can be estimated by assuming 5 feet per second velocity of the flood wave through the storm sewer system.

## 608 RATIONAL METHOD

For hydrologic studies involving a single sub basin when the time of concentration for the entire watershed draining to the point of discharge from the project is less than ten (10) minutes, it is not necessary to take into account the timing of peak flows or the use of Cf, (Wright-McLaughlin modifier), as detailed in the Oklahoma Department of Transportation Drainage Manual (2014 Edition).

### 608.1 Rational Formula

The Rational Method is based on the formula:

$$Q = CiA \qquad (609)$$

Where: Q = Peak discharge, cubic feet per second

C = Runoff coefficient, dimensionless (see **Table 6-3**)

$i$ = Rainfall intensity for a duration equal to the time of concentration, inches/hour

A = Watershed area, acres

### 608.1.1 Runoff Coefficient

Runoff Coefficients for different land use or surface characteristics are found in **Table 6-3.**

- **Table 6-3** gives a range of Runoff Coefficients. The higher value shall be used unless justification can be given for use of a lower value.
- If the sub basin is not homogeneous in its land use type, a composite runoff coefficient should be calculated by averaging the areas of different runoff coefficients.

### 608.1.2 Rainfall Intensity

The rainfall intensity is the average rainfall rate in inches per hour for the period of maximum rainfall of a given frequency having a duration equal to the time of concentration. The following equations have been modified from the ODOT Roadway Drainage Manual recommendation for Zone 4 to more closely match the very short times of concentration used in inlet design and parking lot stormwater detention design. These formulae shall be used in the Tulsa area to calculate the average rainfall intensity:

20% (5-Year) Rainfall Frequency $$I = \frac{50.0}{(t_b+11.0)^{0.75}} \quad (610)$$

1% (100-Year) Rainfall Frequency $$I = \frac{120.0}{(t_b+15.0)^{0.80}} \quad (611)$$

0.2% (500-Year Rainf Frequency $$I = \frac{153.0}{(t_b+15.0)^{0.80}} \quad (612)$$

Where: I = Average rainfall intensity, inches/hour

$t_b$ = Rainfall duration ($T_c$, time of concentration), minutes

### 608.1.3 Time of Concentration

The Time of Concentration ($T_c$) for the basin is made up of two time components, according to the following equation:

$$T_c = t_I + t_T \quad (613)$$

Where: $T_c$ = time of concentration (minutes)

$t_I$ = initial, inlet, or overland flow time (minutes)

$t_T$ = travel time in the ditch, channel, gutter, storm sewer, etc. (minutes)

A. For urban areas, the time of concentration consists of an overland flow time ($t_I$) plus the time of travel ($t_T$) in the storm sewer, paved gutter, roadside drainage ditch, or drainage channel.
B. For non-urban areas, the time of concentration consists of an overland flow time ($t_I$) plus the time of travel in a combined form, such as a small swale, channel, or drainageway.
C. There are seven curves shown in **Figure 6-1** representing seven different overland flow types based on surface cover. The flow types vary from "forest with heavy ground litter" to "pavement".
D. Overland flow time $t_I$ varies with surface slope, surface cover and distance of surface flow and is estimated using the appropriate line in **Figure 6-1**. Overland flow only occurs in the top 150 feet of the longest reach and the appropriate curve (any of the seven curves) should be used based on the surface cover.
E. If the overland travel reach exceeds 150 feet, the "Grassed Waterway" or "Pavement and small upland gullies" line in **Figure 6-1** should be used to calculate $t_T$.

## 609 FEMA MAP REVISIONS

All studies involving a FEMA map revision require the approval of the ADMINISTRATOR. The ADMINISTRATOR will determine if a complete hydrologic re-study is required because of substantial changes in the basin that affect the runoff.

A. If a complete hydrologic re-study is required, the procedures outlined in this Chapter shall be used to define the 10% (10-), 2% (50-), 1% (100-), and 0.2% (500-year) frequency discharges.
B. If a complete hydrologic re-study is not required by the ADMINISTRATOR, the frequency discharges used in the effective FEMA hydraulic model shall be used.

## TABLE 6-1 – TOTAL RAINFALL DEPTHS
## NOAA Atlas 14, Volume 8, Version 2
## Tulsa Station ID: 34-8987

| | Total Rainfall - Inches | | | | | | |
|---|---|---|---|---|---|---|---|
| | Percent Chance (Recurrence Interval) | | | | | | |
| Duration | 50% (2-Yr) | 20% (5-Yr) | 10% (10-Yr) | 4% (25-Yr) | 2% (50-Yr) | 1% (100-Yr) | 0.2% (500-Yr) |
| 5-min | 0.489 | 0.603 | 0.706 | 0.861 | 0.990 | 1.13 | 1.49 |
| 15-min | 0.873 | 1.08 | 1.26 | 1.54 | 1.77 | 2.02 | 2.66 |
| 1-hr | 1.64 | 2.05 | 2.43 | 2.98 | 3.45 | 3.94 | 5.21 |
| 2-hr | 2.05 | 2.59 | 3.07 | 3.79 | 4.37 | 5.00 | 6.59 |
| 3-hr | 2.34 | 2.98 | 3.54 | 4.36 | 5.04 | 5.75 | 7.56 |
| 6-hr | 2.85 | 3.61 | 4.28 | 5.27 | 6.09 | 6.94 | 9.13 |
| 12-hr | 3.35 | 4.18 | 4.92 | 6.04 | 6.96 | 7.94 | 10.5 |
| 24-hr | 3.87 | 4.80 | 5.64 | 6.89 | 7.92 | 9.03 | 11.9 |

Reference Online NOAA Atlas 14 , Volume 8, Version 2 Point Precipitation Frequency Estimates for Tulsa Station ID: 34-8987 (2019)

# TABLE 6-2 - RUNOFF CURVE NUMBERS - SCS METHOD

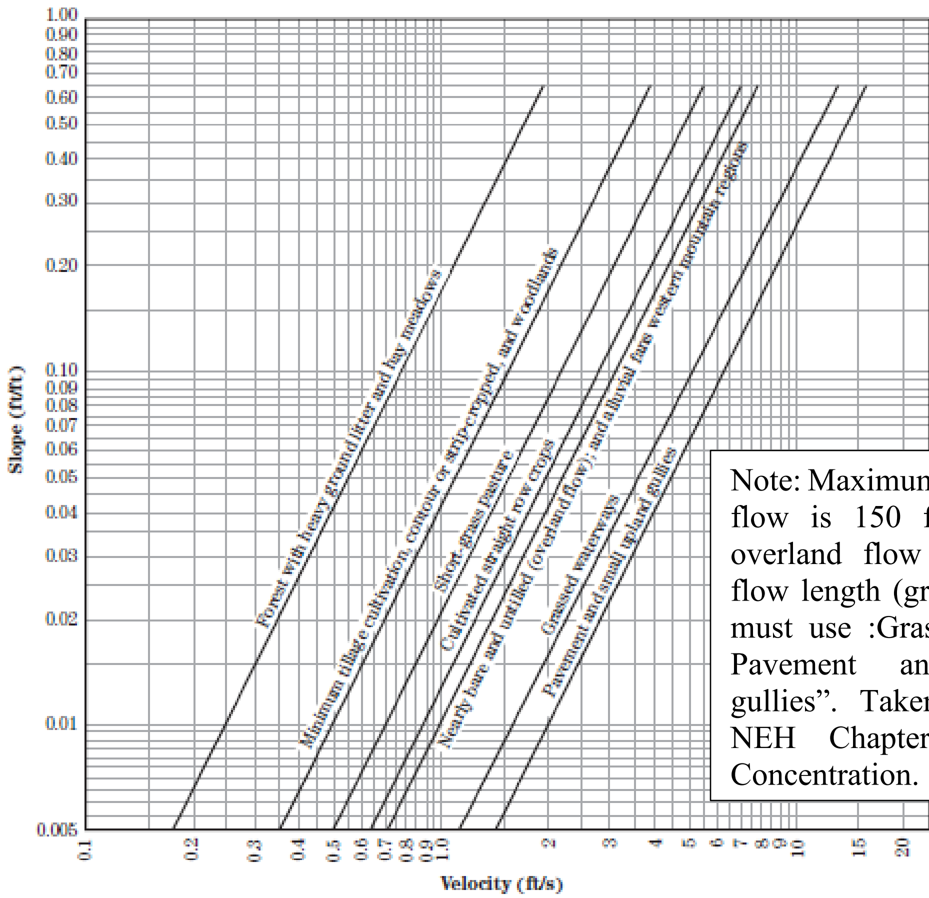
| Cover Type and Hydrologic Condition | Percent Impervious | Curve Numbers for Hydrologic Soil Group | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| **Fully Dev. Urban Areas (Vegetation Established)** | | | | | |
| Open space (lawns, parks, golf courses, cemeteries, etc.): | | | | | |
| Poor condition (grass cover < 50%) | 0 | 68 | 79 | 86 | 89 |
| Fair condition (grass cover 50% to 75%) | 0 | 49 | 69 | 79 | 84 |
| Good condition (grass cover > 75%) | 0 | 39 | 61 | 74 | 80 |
| Impervious areas: | | | | | |
| Paved parking lots, roofs, driveways, etc. | 100 | 98 | 98 | 98 | 98 |
| Streets and roads: | | | | | |
| Paved with curbs and storm sewers | 100 | 98 | 98 | 98 | 98 |
| Paved with open ditches | 80 | 83 | 89 | 92 | 93 |
| Gravel | 100 | 98 | 98 | 98 | 98 |
| Dirt | 80 | 72 | 82 | 87 | 89 |
| Urban districts: | | | | | |
| Commercial and business | 85 | 89 | 92 | 94 | 95 |
| Industrial | 72 | 81 | 88 | 91 | 93 |
| Residential districts by average lot size: | | | | | |
| 1/8 acre or less (town houses) | 65 | 77 | 85 | 90 | 92 |
| 1/4 acre | 38 | 61 | 75 | 83 | 87 |
| 1/3 acre | 30 | 57 | 72 | 81 | 86 |
| 1/2 acre | 25 | 54 | 70 | 80 | 85 |
| 1 acre | 20 | 51 | 68 | 79 | 84 |
| 2 acres | 12 | 46 | 65 | 77 | 82 |
| **Developing Urban Areas (No Vegetation)** | | | | | |
| Newly graded areas - no vegetation | 0 | 77 | 86 | 91 | 94 |

## TABLE 6-3 - RUNOFF COEFFICIENTS AND PERCENT IMPERVIOUSNESS FOR THE RATIONAL METHOD

| LAND USE OR SURFACE CHARACTERISTIC | PERCENT IMPERVIOUSNESS | RUNOFF COEFFICIENTS |
|---|---|---|
| BUSINESS: | | |
| Commercial areas | 70 to 95 | 0.70 - 0.90 |
| Neighborhood areas | 60 to 80 | 0.50 - 0.70 |
| RESIDENTIAL: | | Use percent impervious for runoff coeficient **or** calculate composite runoff coefficient (0.40 minimum) |
| Single Family | 40 to 60 | |
| Multi-unit (detached) | 45 to 55 | |
| Multi-unit (attached) | 65 to 75 | |
| 1/2 acre lot or larger | 20 to 40 | |
| Apartments | 65 to 75 | |
| INDUSTRIAL: | | |
| Light uses | 70 to 80 | 0.50 - 0.80 |
| Heavy uses | 80 to 90 | 0.60 - 0.90 |
| PARKS, CEMETERIES | 4 to 8 | 0.40 - 0.60 |
| PLAYGROUNDS | 10 to 20 | 0.40 - 0.50 |
| SCHOOLS | 40 to 60 | 0.40 - 0.60 |
| RAILROAD YARDS | 35 to 45 | 0.40 - 0.60 |
| UNDEVELOPED AREAS | | |
| Cultivated | 30 to 70 | 0.40 - 0.60 |
| Pasture | 20 to 60 | 0.40 - 0.50 |
| Woodland | 5 to 40 | 0.40 - 0.50 |
| Offsite flow (land use not defined) | 35 to 55 | 0.40 - 0.90 |
| STREETS: | | |
| Paved | 90 to 100 | 0.70 - 0.95 |
| DRIVES AND WALKS | 90 to 100 | 0.75 - 0.90 |
| ROOFS | 85 to 95 | 0.75 - 0.95 |

# Figure 6-1 - Velocity Versus Slope for Shallow Concentrated Flow

**Figure 15–4** Velocity versus slope for shallow concentrated flow




Note: Maximum length for overland flow is 150 feet. Velocities for overland flow for the additional flow length (greater than 150 feet) must use :Grassed waterways" or Pavement and small upland gullies". Taken from the NRCS NEH Chapter 6 – Time of Concentration.

**Table 15–3** Equations and assumptions developed from figure 15–4

| Flow type | Depth (ft) | Manning's *n* | Velocity equation (ft/s) |
|---|---|---|---|
| Pavement and small upland gullies | 0.2 | 0.025 | $V = 20.328(s)^{0.5}$ |
| Grassed waterways | 0.4 | 0.050 | $V = 16.135(s)^{0.5}$ |
| Nearly bare and untilled (overland flow); and alluvial fans in western mountain regions | 0.2 | 0.051 | $V = 9.965(s)^{0.5}$ |
| Cultivated straight row crops | 0.2 | 0.058 | $V = 8.762(s)^{0.5}$ |
| Short-grass pasture | 0.2 | 0.073 | $V = 6.962(s)^{0.5}$ |
| Minimum tillage cultivation, contour or strip-cropped, and woodlands | 0.2 | 0.101 | $V = 5.032(s)^{0.5}$ |
| Forest with heavy ground litter and hay meadows | 0.2 | 0.202 | $V = 2.516(s)^{0.5}$ |

15–8 (210–VI–NEH, May 2010)

# Chapter 700 OPEN CHANNELS, CULVERTS, BRIDGES & OTHER HYDRAULICS STRUCTURES

## 701 INTRODUCTION

### 701.1 Introduction

Hydraulic analyses that are submitted for approval by the CITY shall utilize the criteria presented in this Chapter.

A. Hydraulic analyses will be required for all floodplain studies that include the design or evaluation of bridges, culverts, hydraulic structures, natural open channels and improved open channels.
B. All hydraulic analyses will require the use of a HEC-RAS computer model (other models may be used with the approval of the CITY ENGINEER) to simulate the flow of water through the study reach.
C. The model will describe the channel and overbanks for existing and proposed conditions, including all bridges, culverts, and other hydraulic structures.
D. Fully urbanized conditions in the upstream watershed shall be used to determine the design discharges in the hydraulic model. The Regulatory 1 % (100-year) Flood discharge shall be the design discharge. The 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), 1% (100-year), and 0.2% (500-year) floods shall be studied.

## 702 HYDRAULICS OF OPEN CHANNELS

Presented in this section are the basic equations and computational procedures for uniform, gradually varied and rapidly varied flow. These flow conditions may be encountered in any open channel hydraulic analysis and are illustrated in Figure 7-1. HEC-RAS is the preferred computer program for performing hydraulic analyses: it uses the computational guidelines outlined below (other hydraulic computer programs may be used with the approval of the CITY ENGINEER). HEC-RAS is a hydraulic simulation model developed by the US Army Corps of Engineers Hydrologic Engineering Center in Davis, California and is the successor to HEC-2. The user is encouraged to review the many hydraulics textbooks available including the HEC-RAS User's Manual for a more detailed discussion.

### 702.1 Uniform Flow

Uniform flow (norl depth) occurs only in channels with uniform cross section, roughness and slope.

- The depth of flow is the same at every section of the channel.
- The water surface is parallel to the channel bottom.
- The energy grade line (EGL) and the bottom slope are the same.
- Manning's Equation can be used to compute normal depth.

$$Q = \left(\frac{1.49}{n}\right) AR^{\frac{2}{3}}S^{\frac{1}{2}} \quad (701)$$

Where Q = Discharge in cfs
n = Roughness coefficient (Table 7-2
A = Area in square feet
R = Hydraulic radius, A/P, feet
P = Wetted perimeter, feet
S = Slope of the energy grade line (EGL) in ft/ft

## 702.2 Gradually Varied Flow

The most common flow regime in stormwater drainage analyses is gradually varied flow.

- Occurs due the backwater created by culverts, bridges, hydraulic structures, or the natural variations in cross sectional configuration (constrictions, bends, changes in roughness, slope, etc.).
- Gradually varied flow is indicated by small changes in velocity and depth along the channel.
- The flow depth will be greater than normal depth in the channel.
- The water surface profile must be computed using backwater techniques (HEC-RAS).

## 702.3 Critical Flow

The design of any kind of channel in the critical flow regime is not permitted in the City of Tulsa.

A. To determine if the critical flow regime exists in any channel reach, the Froude Number, which is a measure of turbulence, shall be calculated.
B. See Section 703 for design guidelines for the Froude Number in natural channels and improved channels.
C. If the Froude Number approaches the respective limit for a channel type, measures must be taken to lower the Froude Number. Drop structures are recommended to flatten the slope of the channel.
D. The definition of the Froude Number (F) as follows:

$$F = \frac{V}{(gD)^{0.5}} \quad (702)$$

Where F = Froude Number

V = Velocity (fps)

g = Acceleration of gravity (32.2 ft./sec.$^2$)

D = Hydraulic Depth (ft) = A/T

A = Channel flow area ($ft^2$)

T = Top width of flow area (ft)

## 702.4 Rapidly Varied Flow (Hydraulic Jumps)

The calculation of the location and extent of the hydraulic jump can be accomplished using the hydraulic modeling program HEC-RAS by accurately providing a detailed description of the downstream cross sections, the rapidly varied flow reach, and the upstream cross sections. Interpolated cross sections are accepted.

A. When a hydraulic jump occurs, there is a great deal of turbulence and erosive forces are generated as the flowing water loses velocity and energy.
B. It is important to know where the jump occurs and the extent of the jump so that adequate channel protection (e.g. rip rap or concrete lining) may be provided in that reach. This applies to natural channels as well as to improved channels.
C. For hard-lined facilities such as pipes or concrete channels, the forces and the change in energy can affect the structural stability or the hydraulic capacity.
D. For natural and grass lined channels, the erosive forces at the outlet of culverts must be controlled otherwise serious damages will result.

In improved channel hydraulics, rapidly varied flow is encountered in the vicinity of a hydraulic jump and may occur at weir structures, at energy dissipators, at grade control structures (i.e., check drops), inside of or at the outlet of storm sewers or concrete box culverts or at the outlet of an emergency spillway for a detention pond.

In natural channels hydraulic jumps may occur where there are greatly varying channel configurations or slope and it is therefore necessary to calculate the location and extent of the hydraulic jump so that adequate channel protection may be provided in that reach.

## 702.5 Weir Flow

Weirs are commonly used for spillway outlets in detention ponds or at check dams in improved channels. Also, when studying existing conditions, roadway overtopping may occur and the roadway itself acts as a broad crested weir. The general form of the equation for horizontal crested weirs is:

$$Q = CLH^{\frac{3}{2}} \quad (703)$$

Where Q = discharge (cfs)

C = weir coefficient (see **Table 7-1**)

L = horizontal length (feet)

H = total energy head (feet)

Another common weir is the v-notch weir. The general form of the equation is as follows (Reference- 28).

$$Q = 2.5\, tan\, (\frac{\Theta}{2}) H^{\frac{5}{2}} \quad (704)$$

Where $\Theta$ = angle of the notch at the apex (degrees)

When designing or evaluating weir flow the effects of submergence must be considered. Also, there are factors to account for contraction of the weir. See Reference 28 from Chapter 1400 for detailed procedures.

### 702.6 Energy Dissipators

Energy dissipators are used to keep design velocities within acceptable limits for the type of channel as defined in Section 703 by utilizing blocks, sills, or other roughness elements to impose exaggerated resistance to the flow. Typically, the energy dissipator will induce a controlled hydraulic jump to achieve the design downstream channel velocity. Refer to Reference 29- Hydraulic design of stilling basins and energy dissipators for design guidelines. City of Tulsa Standard drawings STD 779 and STD 780 shall be used for standard and baffle block energy dissipators.

### 702.7 Channel Drops

The most common use of channel drops is to control the longitudinal slope of channels to keep design velocities within acceptable limits. Refer to the 1982 draft revisions of the "Riprap Drop Structures" section in the USDCM (References 5,6,18 and 33) for design guidelines.

## 703 CHANNEL TYPES AND DESIGN GUIDELINES

The channels in the City of Tulsa are defined as natural or improved.

- Natural channels have long reaches with little or no man-made improvements.
- Natural channels are the preferred stormwater conveyance system within the City of Tulsa.
- Improved channels have reaches that include grass lining, concrete sides and bottom, rock lining, or other man-made features.
- Improved channels require maintenance access and fencing as specified by Chapter 1200.

The following is a discussion of each channel type and the design guidelines to be used when studying each.

## 703.1 Natural Channels

Natural channels should be left in as near a natural condition as possible, however, if the natural channel exhibits erosive tendencies, some on-site modification (e.g.: grade control structures, channel bank protection, etc.) may be required to assure stabilized conditions.

A. Hydraulic analyses using HEC-RAS are required to identify the erosion tendencies. Erosion tendencies shall be addressed in the design report submitted with construction drawing specifications.
B. Modification of a natural channel within the normal high water line may require a U.S. Army Corps of Engineers Section 404 Permit or letter of clearance.
C. One variation of the natural channel is to leave the main channel area undisturbed (i.e., the area between the top of banks and the adjacent vegetative area) and to improve the over-bank conveyance by excavating or grading the floodplain area. This minimal impact alternative preserves the more environmentally sensitive area adjacent to the base flow and increases the capacity of the total system to convey the 100-year ultimate urbanization flow. See Figure 7-2.

### 703.1.1 Design Flow

The natural channel typically cannot convey the Regulatory 1% (100-year) Flood discharge in the channel alone and will utilize the overbanks as effective flow area. When studying natural channel reaches, it is necessary to accurately model the channel and overbanks with the latest currently available topographic data.

### 703.1.2 Manning's "n" Values

Natural channel "n" values range from 0.025 to 0.10. See **Table 7-2.** Overbank "n" values range from 0.03 to 0.20.

### 703.1.1 Froude Number

Natural channel reaches with a Froude Number (a measure of turbulence) greater than 0.9 for the 100-year design flow shall be protected from erosion.

### 703.1.2 Channel Velocity:

The computed channel velocities in natural channels, along with the computed Froude Number, should be used to determine the necessity of channel protection from erosion. Channel velocities should not be increased due to the design of a project.

### 703.1.3 Freeboard

All structures to be constructed adjacent to natural channels shall be elevated to be a minimum of two (2) feet above the Regulatory 1% (100-year) Flood discharge profile.

### 703.1.4 Longitudinal Slope

When designing a project that includes a natural channel reach, the longitudinal slope of the channel (and the channel itself) should be left in its natural state. Grade control structures like check dams may be required to decrease the flowline slope and to control erosion.

### 703.1.5 Curvature

A natural channel is naturally sinuous.

### 703.1.6 Super Elevation

Super elevation in natural channels is not considered.

## 703.2 Grass Lined Channels

Grass lined channels are improved channels with side slopes of grass.

A. This type of channel has less environmental impact than harder channel improvements and is therefore preferable.
B. Biodegradable erosion control mats that are designed to increase the erosion resistance of grass lined channels may be used with approval from the CITY ENGINEER
C. roughness and less mowing improves water quality, however roughness coefficients must be adjusted accordingly.

### 703.2.1 Design Flow

Regulatory 1% (100-year) Flood discharge.

### 703.2.2 Manning’s “n” Values

Channel “n” values typically range from 0.03 to 0.05, depending on how well the channel is maintained. Higher “n” values should be used if the grass lining is very poorly maintained. See **Table 7-2**.

### 703.2.3 Channel Velocity

The maximum computed channel velocity in a grass lined channel shall not exceed 6.0 feet per second, except in sandy soil where the maximum velocity shall not exceed 5.0 feet per second.

### 703.2.1 Froude Number

The maximum Froude Number (a measure of turbulence) shall be no higher than 0.8.

### 703.2.2 Freeboard

The minimum freeboard shall be 1.0 feet above the Regulatory 1% (100-year) Flood profile, including super elevation at channel bends (see below). All structures to be constructed adjacent to channels shall be elevated to be a minimum of two (2) feet above the Regulatory 1% (100-year) Flood profile. Freeboard shall not be obtained by the construction of levees or by extending the side slopes above final grade.

### 703.2.3 Longitudinal Slope

Grass lined channels typically will have slopes less than 1.0 percent, but the slopes will be dictated by velocity and Froude Number requirements. Where the natural topography is steeper than desirable, grade control structures shall be utilized to maintain design guidelines.

### 703.2.4 Curvature

The center line curvature shall have a minimum radius of three times the top width of the design flow, but not less than 100 feet.

### 703.2.5 Super Elevation

The super elevation at a channel bend shall be calculated with the following equation:

$$h = \frac{V^2 Tw}{g r_c} \tag{711}$$

where
- h = height of super elevation
- V = channel velocity
- Tw = top width of design flow
- g = acceleration of gravity = 32.2 ft/sec$^2$
- $r_c$ = centerline radius of curvature

### 703.2.6 Channel Cross Section

Typical grass lined channel cross sections which incorporate the above design guidelines are shown on Figure 7-3, Figure 7-4, and Figure 7-5. The maximum grass lined channel side slope is 4:1.

### 703.2.7 Trickle Channel

A trickle channel is required if the slope of the channel is less than 1%, or if the channel bottom width is less than four feet. City of Tulsa Standard Drawing STD 782 shall be used for all trickle channels with aeration of the flowing water by grooved concrete.

### 703.2.8 Grass

The requirements for seeding and mulching shall be in accordance with the Oklahoma Department of Transportation "Standard Specifications for Highway Construction", current edition. The seed mixture, the bulk seed rate per acre, the watering requirements, and the fertilizer grade shall be indicated on the plans and will be subject to approval by the CITY ENGINEER.

## 703.3 Concrete Lined Channels

Concrete lined channels are improved channels with concrete sides and bottom.

A. Concrete lined channels are to be used only when the topography or right of way restrictions will not allow a channel type with less environmental impact.
B. To assess the environmental impact, all concrete lined channels require a U.S. Army Corps of Engineers Section 404 Permit or letter of clearance.
C. Concrete lined channels shall not be designed for critical or super critical flow.
D. Grade control structures may be required to meet the following design guidelines.

### 703.3.1 Design Flow

Regulatory 1% (100-year) Flood discharge.

### 703.3.2 Manning's "n" Values

Channel "n" values typically range from 0.013 to 0.025. See **Table 7-2**.

### 703.3.1 Froude Number

The maximum allowable Froude Number (a measure of turbulence) shall be 0.9.

### 703.3.2 Channel Velocity

The maximum computed channel velocity in a concrete lined channel shall not exceed 18.0 feet per second.

### 703.3.3 Freeboard

Adequate channel freeboard above the designed water surface shall be provided and shall not be less than that determined by the following:

$$H_{FB} = 2.0 + 0.025Vd^{\frac{1}{3}} \quad (712)$$

Where $H_{FB}$ = freeboard height (feet)

$V$ = velocity (fps)

$d$ = depth (feet)

Freeboard shall be in addition to super elevation, standing waves, and/or other water surface disturbances. These special situations should be addressed in the Design Report submitted with the construction drawings and specifications (Chapter 500). Freeboard shall not be obtained by the construction of levees or by extending the side slopes above final grade.

#### 703.3.4 Longitudinal Slope

The slope of concrete lined channels will be dictated by velocity and Froude Number requirements. Where the natural topography is steeper than desirable, grade control structures shall be utilized to maintain design guidelines.

#### 703.3.5 Curvature

The center line curvature shall have a minimum radius twice the top width of the design flow but not less than 100 feet.

#### 703.3.6 Super Elevation

The super elevation at a channel bend shall be calculated using equation 711.

#### 703.3.7 Channel Cross Section

The cross section of a concrete lined channel shall be either trapezoidal (see Figure 7-7) or rectangular (see Figure 7-8). City of Tulsa Standard Drawings STD 783 and STD 784 are for applicable standard details and specifications shall be used for concrete channel design. STD 783 and 784 are schematic only. Design of channel sections to be addressed in Design Report and in Construction Drawings.

### 703.4 Rock Lined Channels

Rock lined channels are improved channels constructed of ordinary rip rap, grouted rip rap, or man-made interlocking block systems. Situations for which rock linings might be appropriate are:

- Where major flows, such as the 100-year flood are found to produce channel velocities in excess of allowable non-eroding values in natural channels (Section 703.1), or in grass lined channels (Section 703.2);
- Where channel side slopes must be steeper than 3:1;

- For low flow channels; and
- Where rapid changes in channel geometry occur such as channel bends and transitions.

When designing rip rap lined channels, all appropriate standard drawings, details and specifications dealing with rock size, shape, gradation, specific gravity, blanket thickness, type of bedding under the rock and slope of the rock layer should be followed.

- Grouted rip rap sections shall not be allowed except for rehabilitation projects only.
- Gabion baskets shall not be allowed except for maintenance of existing gabion basket channels.

#### 703.4.1 **Design Flow**

Regulatory 1% (100-year) Flood discharge.

#### 703.4.2 **Manning's "n" Values**

Channel "n" values typically range from 0.02 to 0.033. See **Table 7-2**.

#### 703.4.1 **Froude Number**

The maximum allowable Froude Number (a measure of turbulence) shall be 0.8.

#### 703.4.2 **Channel Velocity**

The maximum allowable computed channel velocity in rock lined channels varies with the type of rock lining. The design channel velocity should be addressed in the Design Report submitted with the construction drawings and specifications (Chapter 500).

#### 703.4.3 **Freeboard**

The minimum freeboard shall be 1.0 feet above the Regulatory 1% (100-year) Flood profile, including super elevation at channel bends (see below). All structures to be constructed adjacent to natural channels shall be elevated to be a minimum of one foot above the Regulatory 1% (100-year) Flood profile. Freeboard shall not be obtained by the construction of levees or by extending the side slopes above final grade.

#### 703.4.4 **Longitudinal Slope**

The slope of rock lined channels will be dictated by velocity and Froude Number requirements. Where the natural topography is steeper than desirable, grade control structures shall be utilized to maintain design guidelines.

### 703.4.5 Curvature

The center line curvature shall have a minimum radius twice the top width of the design flow but not less than 100 feet.

### 703.4.6 Super Elevation

The super elevation at a channel bend shall be calculated using Equation 711.

### 703.4.7 Channel Cross Section

Typical rock lined channel cross sections use the same design guidelines as grass lined channels and are shown on Figure 7-3, Figure 7-4, and Figure 7-5.

## 703.5 Composite Lined Channels

The design standards for composite lined channels will vary in accordance with the materials utilized for construction. For grass, concrete, or rock lined portions of the channel, refer to Sections 703.2, 703.3 and 703.4, respectively. For other lining types, the engineer will be required to submit the appropriate documentation in support of the use of the materials proposed. Refer to Figure 7-9 for typical examples of composite channels.

## 703.6 Other Channel Linings

The use of other channel lining materials (e.g. large interlocking concrete blocks) may be permitted if approved by the CITY ENGINEER. The CITY ENGINEER will consider linings other than grass, rock, or concrete depending on:

A. Manufacturers recommendations for the specific product,
B. Requirements for local erosion protection of steep side slopes (i.e.: steeper than 3:1),
C. Areas of local turbulence in grass lined channels,
D. The experience and recommendations of the CITY ENGINEER.

The designer will be required to submit the technical data in support of the proposed material. Additional information or calculations may be requested by the CITY ENGINEER to verify assumptions or design criteria. The following minimum criteria will also apply.

### 703.6.1 Design Flow

Regulatory 1% (100-year) Flood discharge.

### 703.6.2 Manning's "n" Values

Channel "n" values shall be by the manufacturer's data with consideration that the channel will be maintained by the CITY.

### 703.6.1 Froude Number

The maximum allowable Froude Number (a measure of turbulence) shall be 0.8.

### 703.6.2 Channel Velocity

The maximum allowable computed channel velocity will be dependent on the construction material utilized.

### 703.6.3 Freeboard

The minimum freeboard shall be 1.0 feet above the Regulatory 1% (100-year) Flood profile, including super elevation at channel bends (see below). All structures to be constructed adjacent to channels shall be elevated to be a minimum of two (2) feet above the Regulatory 1% (100-year) Flood profile. Freeboard shall not be obtained by the construction of levees or by extending the side slopes above final grade.

### 703.6.4 Longitudinal Slope

The slope of the lined channels will be dictated by velocity and Froude Number requirements. Where the natural topography is steeper than desirable, grade control structures shall be utilized to maintain design guidelines.

### 703.6.5 Curvature

The center line curvature shall have a minimum radius twice the top width of the design flow but not less than 100 feet.

### 703.6.6 Super Elevation

The super elevation at a channel bend shall be calculated using Equation 711.

### 703.6.7 Channel Cross Section

Typical lined channel cross sections use the same design guidelines as grass lined channels and are shown on Figure 7-3, Figure 7-4, and Figure 7-5.

## 703.7 Roadside Ditches

Since the preferred method of providing drainage along a street is a curb and gutter with a storm sewer system, roadside ditches are acceptable only in certain cases and must be approved by the CITY ENGINEER.

A. The criteria for the design of roadside ditches are similar to the criteria for grass lined channels.

B. Roadside ditches are allowed only when adequate right-of-way is provided, along arterial streets.
C. Rehab projects in areas with existing roadside ditches shall be approved by the CITY ENGINEER.
D. Utilities will not be allowed within the ditch section unless approved by the CITY ENGINEER.
E. Refer to Figure 7-6 for typical roadside ditch cross sections and refer to current City of Tulsa design standards.

### 703.7.1 Design Flow

Regulatory 1% (100-year) Flood discharge. Where the design flow exceeds the capacity of the roadside ditch, a storm sewer system shall be required.

### 703.7.2 Manning's "n" Values

Channel "n" values typically range from 0.018 to 0.04. See **Table 7-2**.

### 703.7.3 Channel Velocity

The maximum allowable computed channel velocity in roadside ditches is 5 feet per second for Type 1 ditch, and 7 feet per second for Types 2 or 3.

### 703.7.4 Freeboard

No freeboard requirement.

### 703.7.5 Longitudinal Slope

The slope of roadside ditches will be dictated by velocity. Where the natural topography is steeper than desirable, grade control structures shall be utilized to maintain design guidelines.

### 703.7.6 Curvature

The center line curvature shall have a minimum radius of 25 feet.

### 703.7.7 Super Elevation

No super elevation requirement.

### 703.7.8 Channel Cross Section

Typical roadside ditch cross sections are shown on Figure 7-6.

#### 703.7.9 Trickle Channel

A trickle channel is required in all roadside ditches along arterial streets and in new development, as specified by the CITY ENGINEER.

#### 703.7.10 Driveway Culverts

Driveway culverts shall be sized to pass the 1% (100-year) design flow in accordance with Policy 306.5.4.B and 306.5.4.C. The minimum size culvert shall be an 18” RCP (or equivalent).

## 704 BRIDGE AND CULVERT HYDRAULICS

### 704.1 Definitions

For the purposes of this Section, a bridge is defined as a hydraulic structure that is constructed with abutments and superstructures which are typically concrete, steel or other materials or a culvert or culverts with a clear opening of 20 feet in width or more. Bridges are generally constructed with earth or rock inverts. Since the superstructures are not an integral part of the abutments and could therefore potentially move, the hydraulic criteria for bridges are different than for culverts.

A culvert is defined in this Section as a closed conduit for the passage of water under an embankment, such as a road, railroad or trail. A culvert is distinguished from a storm sewer in the following manner: flow generally enters a culvert by an open channel, generally at a similar elevation, while flow generally enters a storm sewer by means of storm inlets above the sewer; the geometry of the culvert inlet plays a major role in determining the required size or capacity of the culvert, whereas the capacity of a storm sewer is generally determined by the slope of the sewer; a culvert generally crosses under a road, railroad or trail, while a storm sewer generally follows the street alignment. The hydraulic design guidelines for a culvert are presented in this Section while the design guidelines for a storm sewer are presented in Chapter 800.

### 704.2 Bridge Design Guidelines

#### 704.2.1 Design Standards

The following design standards shall apply except as modified by this MANUAL.

- "ODOT, Office of Design, Section 6, Policies and Procedures".
- "Standard Specifications for Highway Construction", ODOT.
- FHWA publication: “Hydraulics of Bridge Waterways”

#### 704.2.2 Requirements

All bridges that cross FEMA studied streams and City of Tulsa Regulatory Flood Plain shall follow the FEMA and Floodplain Administrator’s submission and review requirements.

### 704.2.3 Zero Rise

There shall be no increase in flooding (zero rise in water surface elevation) for the design discharge and the existing conditions 1% (100-year) discharge upstream or downstream of the bridge.

### 704.2.4 Bridge Hydraulic Design Program

HEC-RAS is the preferred hydraulic design program for bridges.

### 704.2.5 Design Discharge

The design discharge for all bridge structures shall be the Regulatory 1% (100-year) Flood discharge.

### 704.2.6 Freeboard

Freeboard is defined as the vertical clearance of the lowest structural member of the bridge superstructure or inside top of a culvert as defined in Policy 305.4.4.A above the water surface elevation of the design frequency flood. The minimum freeboard shall be 1 foot for the Regulatory 1% (100-year) Flood as defined in Policy 306.5.4.A, unless approved by the CITY ENGINEER.

### 704.2.7 Backwater

Backwater is defined as the rise in the flood water surface due to the restrictions created by the construction of the bridge. The maximum backwater shall be 1 foot as required by the CITY floodplain regulations.

### 704.2.8 Velocity

The maximum channel velocity through the bridge opening is limited by the design guidelines for the type of channel and protection provided (see Section 703) through the bridge.

### 704.2.9 Hydraulic Analysis

The hydraulic design calculations for all bridges must be prepared and certified by a licensed Oklahoma Professional Engineer using the hydraulic modeling program HEC-RAS or HEC-2 (or other program approved by the CITY ENGINEER).

### 704.2.10 Inlet and Outlet Configurations

The design of all bridges shall include adequate wing walls of sufficient length to prevent abutment erosion and to provide slope stabilization from the embankment to the channel. Erosion protection on the inlet and outlet transition slopes shall be provided to protect from the erosive forces of eddy current.

## 704.3 Culvert Design Guidelines

### 704.3.1 Design Standards

The following Oklahoma Department of Transportation Standards shall apply except as modified by this MANUAL.

- "ODOT, Office of Design, Section 6, Policies and Procedures".
- "Standard Specifications for Highway Construction", ODOT, latest edition.
- FHWA publication: Hydraulic Design of Highway Culverts.

### 704.3.2 FEMA Requirements

All culverts that cross FEMA studied streams and City of Tulsa Regulatory Floodplain shall follow the FEMA and Floodplain Administrator's submission and review requirements.

### 704.3.3 Zero Rise

There shall be no increase in flooding (zero rise in water surface elevation) for the design discharge and the existing conditions 100-year discharge upstream or downstream of the culvert.

### 704.3.4 Culvert Hydraulic Design Program

HEC-RAS is the preferred hydraulic design program for culverts. Other design programs may be approved by the CITY ENGINEER.

### 704.3.5 Design Discharge

The design discharge for all culverts shall be the Regulatory 1% (100-year) Flood discharge.

### 704.3.6 Freeboard

Freeboard is defined as the vertical clearance between the inside top of the culvert above the water surface elevation of the design frequency flood. For culverts defined in Policy 305.4.4.B, the minimum freeboard shall be 1 foot for the 100-year frequency flood.

### 704.3.7 Headwater

For culverts defined in Policy 305.4.4.C, for the Regulatory 1% (100-year) Flood, the maximum headwater to culvert diameter (or rise) ratio shall be 1.5.

### 704.3.8 Backwater

Backwater is defined as the rise in the flood water surface due to the restrictions created by the construction of the culvert. The maximum backwater shall be 1 foot as required by the CITY floodplain regulations.

### 704.3.9 Velocity

The minimum velocity in the culvert shall be 3 feet per second for any studied flow rate to assure a self-cleaning condition. The maximum velocity in the culvert shall be 20 feet per second. The velocity at the outlet of the culvert will require channel protection or an energy dissipator according to the design guidelines applicable for the downstream channel type (Section 703).

### 704.3.10 Hydraulic Analysis

The hydraulic design calculations for all culverts must be prepared and certified by a licensed Oklahoma Professional Engineer using the hydraulic modeling program HEC-RAS (or other program approved by the CITY ENGINEER). The hydraulic data presented in **Table 7-3** shall be used in the design and evaluation of culverts.

### 704.3.11 Inlet and Outlet Configurations

Culverts are to be designed with erosion protection at the inlet and outlet areas. The City of Tulsa Standard Pipe Headwalls 15" to 42" (City of Tulsa Standard Drawing STD 776) shall be used for culvert entrance and outlet protection. For larger culverts, headwalls and wing walls of similar design are required. Other culvert protection methods, such as flared end sections, may be used with the approval of the CITY ENGINEER. The headwalls or end section are to be located a sufficient distance from the edge of the shoulder or back of walk to allow for a maximum slope of 3H:1V to the back of the structure.

### 704.3.12 Construction Materials

All culverts within the CITY shall be constructed of reinforced concrete or corrugated polypropylene. Reinforced Concrete Box (RCB) culverts or Reinforced Concrete Pipe (RCP) culverts are acceptable. Only culverts sizes 18” inches to 60” inches may be constructed of corrugated polypropylene in accordance with City of Tulsa specifications.

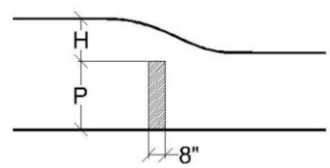
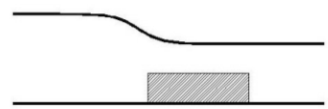
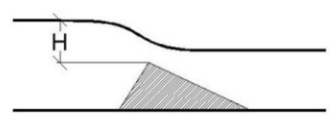
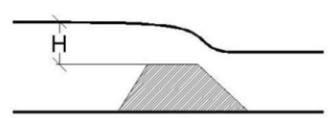
### 704.3.13 Shapes

Numerous cross sectional shapes are acceptable including circular, rectangular, elliptical, pipe-arch, and arch.

### 704.3.14 Driveway Crossings

Driveway culverts shall be sized to pass the 100-year design flow in accordance with Policy 306.5.4.B and 306.5.4.C. The minimum size culvert shall be an 18" RCP (or equivalent).

## TABLE 7-1 - WEIR COEFFICIENTS

| WEIR SHAPE | WEIR COEFF. | COMMENTS | SCHEMATIC |
|---|---|---|---|
| **Sharp Crested** | | |  |
| Projection ratio (H/P = 0.4) | 3.4 | H>1.0 | |
| Projection ratio (H/P = 2.0) | 4.0 | H>1.0 | |
| **Broad Crested** | | |  |
| With sharp upstream corner | 2.6 | Minimum value | |
| With rounded upstream corner | 3.0 | critical depth | |
| **Triangular with vertical upstream slope** | | |  |
| 1:1 downstream slope | 3.8 | H>0.7 | |
| 4:1 downstream slope | 3.2 | H>0.7 | |
| 10:1 downstream slope | 2.9 | H>0.7 | |
| **Triangular with 1:1 upstream slope** | | |  |
| 1:1 downstream slope | 4.1 | H>1 | |
| 3:1 downstream slope | 3.5 | H>1 | |
| **Trapezoidal section** | | |  |
| 1:1 U/S slope, 2:1 D/S slope | 3.4 | H>1 | |
| 2:1 U/S slope, 2:1 D/S slope | 3.4 | H>1 | |
| **Road Crossings** | | | |
| Gravel | 3.0 | H>1 | |
| Paved | 3.1 | H>1 | |

## TABLE 7-2– MANNING'S "N" VALUES FOR OPEN CHANNELS

| | CHANNEL TYPE | n VALUE RANGE | RECOMMENDED VALUE |
|---|---|---|---|
| A. | Earth Lined (ditches/canals) | | |
| | 1. Clean, weathered | 0.018 to 0.025 | 0.022 |
| | 2. Clean, gravel | 0.022 to 0.030 | 0.025 |
| | 3. Some weeds | 0.022 to 0.033 | 0.027 |
| | 4. Not maintained | 0.30 to 0.40 | 0.035 |
| B. | Grass Lined (manmade) | | |
| | 1. Well maintained | 0.03 to 0.05 | 0.03 |
| | 2. Poorly maintained | 0.05 to 0.10 | 0.05 |
| C. | Natural Streams | 0.025 to 0.10 | Note 1 |
| | Overbank Areas | 0.03 to 0.20 | |
| D. | Rock Lined | | |
| | 1. Ordinary rip rap | 0.02 to 0.03 | 0.02 |
| | 2. Gabions | 0.02 to 0.03 | 0.02 |
| | 3. Grouted rip rap | 0.023 to 0.03 | 0.027 |
| | 4. Slope mattress | 0.025 to 0.033 | 0.028 |
| E. | Concrete Lined | | |
| | 1. Float finished/wood forms | 0.013 to 0.016 | 0.015 |
| | 2. Slip formed | 0.013 to 0.016 | 0.015 |
| | 3. Gunite | 0.016 to 0.025 | 0.015 |

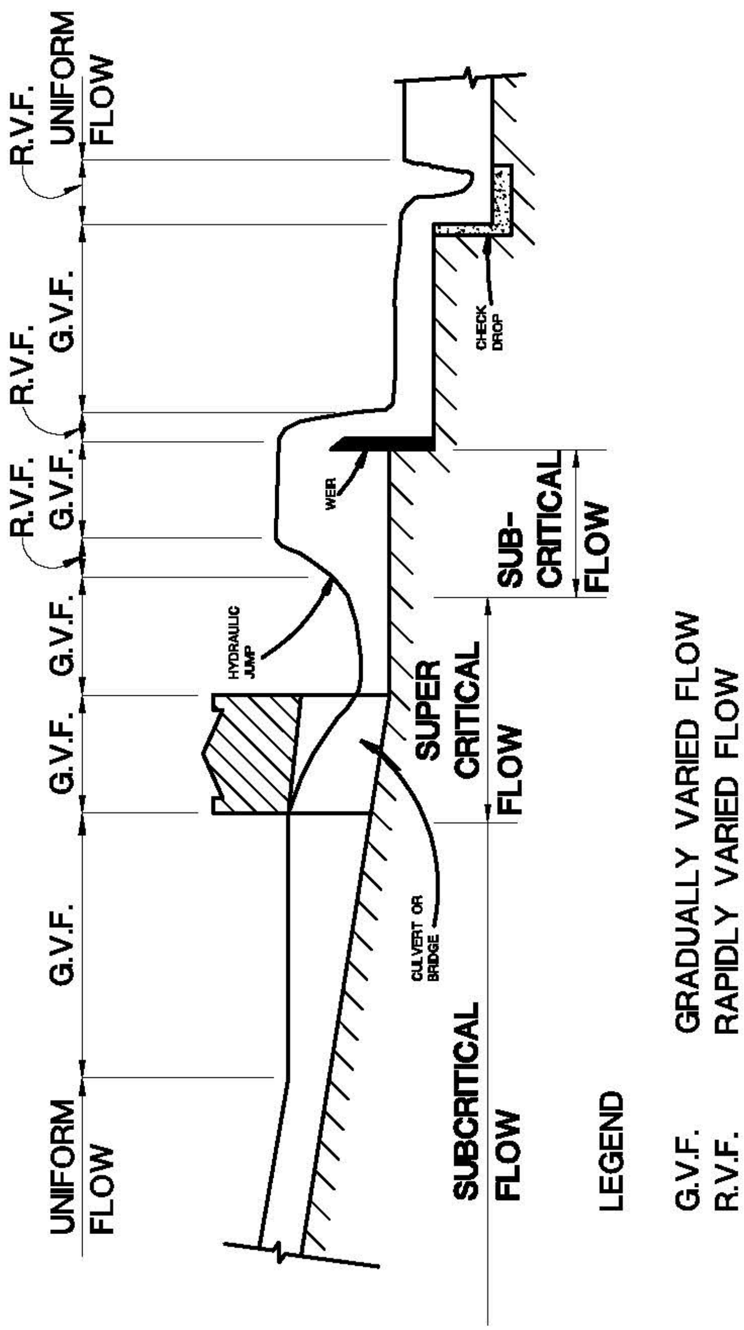
Note 1 Refer to Chow, V.T., Open Channel Hydraulics, McGraw-Hill Book Company, 1959, Table 5-6

## TABLE 7-3 - HYDRAULIC DATA FOR CULVERT END LOSSES

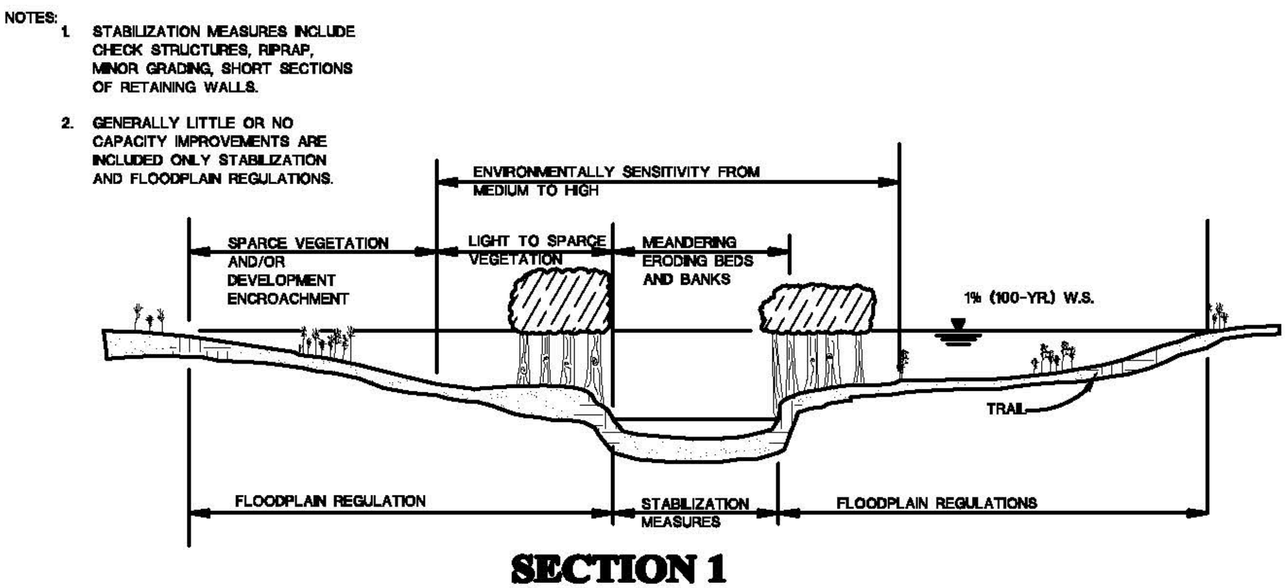
| Structure and Entrance Type | Coefficient (k) |
|---|---|
| **Pipe, Concrete and Corrugated Polypropylene (CPP)** | |
| Projecting from fill, socket end (groove-end) | 0.2 |
| Projecting from fill, square cut end | 0.5 |
| Headwall or headwall and wingwalls | |
| Socket end of pipe (groove-end) | 0.2 |
| Square-edge | 0.5 |
| Rounded (radius = 1/12D) | 0.2 |
| Mitered to conform to fill slope | 0.7 |
| End section conforming to fill slope (1) | 0.5 |
| Beveled edges, 33.7° or 45° bevels | 0.2 |
| Side tapered or slope tapered inlet | 0.2 |
| **Pipe, or Pipe-Arch, Corrugated Metal (2)** | |
| Projecting from fill (no headwall) | 0.9 |
| Headwall or headwall and wingwalls square-edge | 0.5 |
| Mitered to conform to fill slope, paved or unpaved slope | 0.7 |
| End section conforming to fill slope (1) | 0.5 |
| Beveled edges, 33.7° or 45° bevels | 0.2 |
| Side tapered or slope tapered inlet | 0.2 |
| **Box, Reinforced Concrete** | |
| Headwall parallel to embankment (no wingwalls) | |
| Square edged on 3 sides | 0.5 |
| Rounded on 3 edges to radius of 1/12 box dimension or beleled edges on 3 sides | 0.2 |
| Wingwalls at 30° to 75° to Box | |
| Square edged at crown | 0.4 |
| Crown edge rounded to radius of 1/12 box dimension or beveled top edge | 0.2 |
| Wingwall at 10° to 25° to Box | |
| Square edged at crown | 0.5 |
| Wingwalls parallel (extension of sides) | |
| Square edged at crown | 0.7 |
| Side tapered or slope tapered inlet | 0.2 |

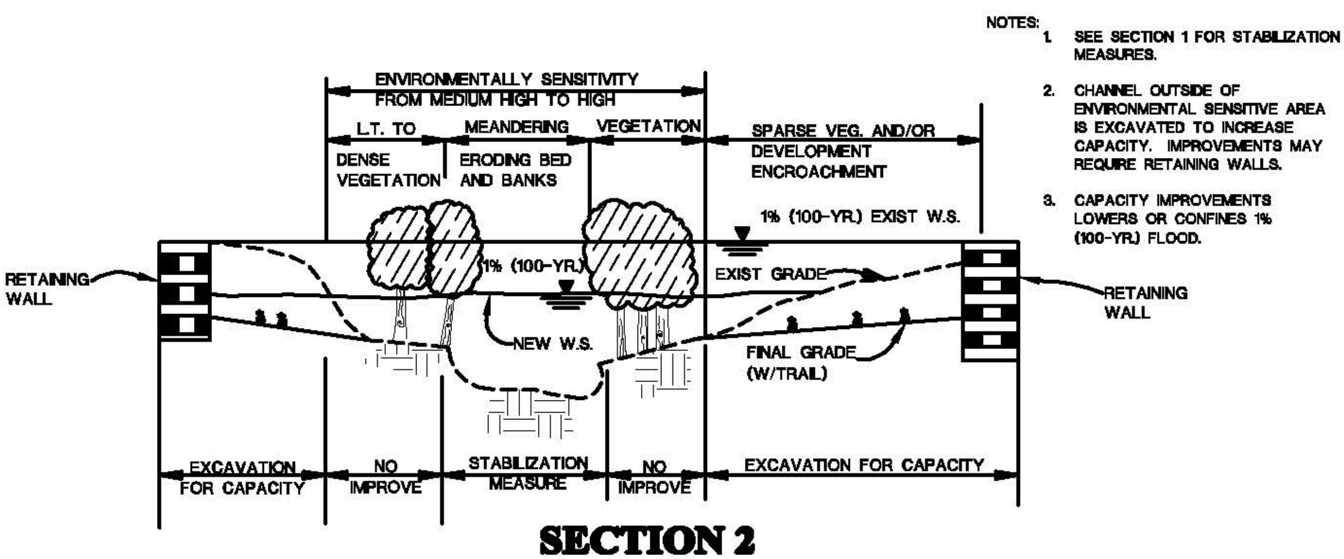
(1) Commonly available from manufacturers.
(2) CGMPs are not allowed for new construction. Provided for evaluation of existing CGMPs only.

## FIGURE 7-1 - TYPICAL FLOW REGIMES

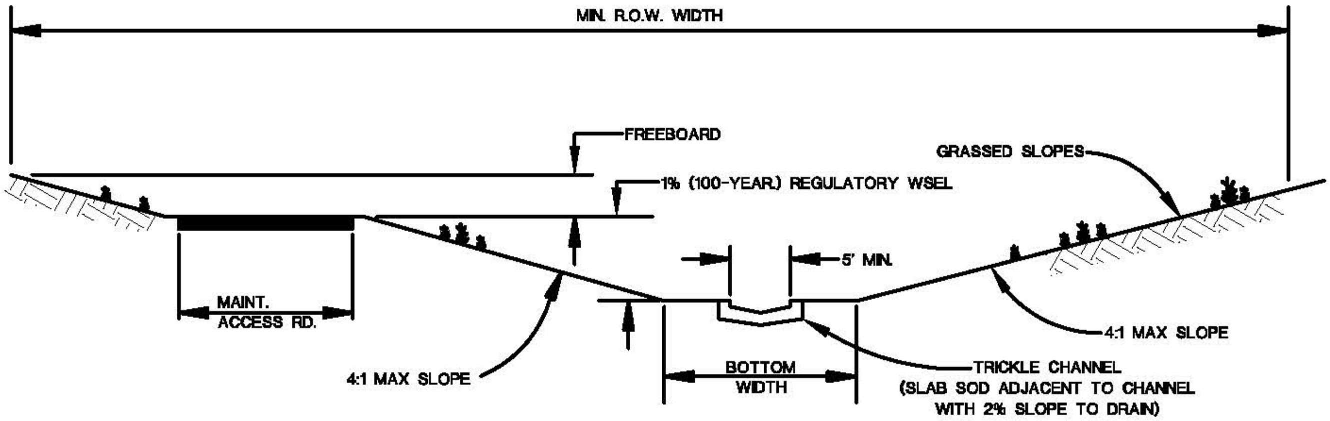


## FIGURE 7-2 - TYPICAL NATURAL CHANNELS AND MINIMAL IMPACT ALTERNATIVES



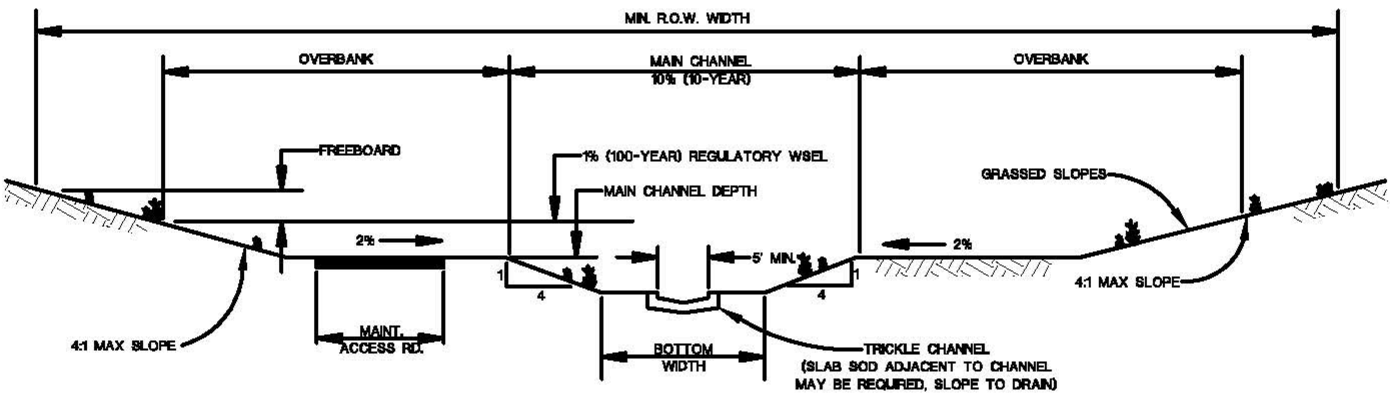
# FIGURE 7-3 - TYPICAL GRASS LINED CHANNEL SECTION TYPE A




NOTES:

1. BOTTOM WIDTH: CONSISTENT WITH MAXIMUM ALLOWABLE DEPTH AND VELOCITY REQUIREMENTS, SHALL NOT BE LESS THAT TRICKLE CHANNEL WIDTH.
2. TRICKLE CHANNEL: REQUIRED IF THE SLOPE OF THE CHANNEL IS LESS THAN 1% OR IF THE CHANNEL BOTTOM IS LESS THAN 4'.
3. FREEBOARD: FREEBOARD TO BE A MINIMUM OF 1-FOOT.
4. MAINTENANCE ACCESS ROAD: MINIMUM WIDTH TO BE 20 FEET.
5. ROW WIDTH: MINIMUM WIDTH TO INCLUDE FREEBOARD AND MAINTENANCE ACCESS ROAD.
6. CHANNEL SIDE SLOPE: MAXIMUM SIDE SLOPE FOR GRASSED CHANNELS IS 4:1
7. FROUDE NUMBER: MAXIMUM VALUE SHALL NOT EXCEED 0.8.
8. THE MAXIMUM ALLOWABLE FLOW VELOCITY IS 6 FPS FOR EROSION RESISTANT SOILS OR 5 FPS FOR EROSIVE SOILS.
9. CHECK DROPS (SEE B)

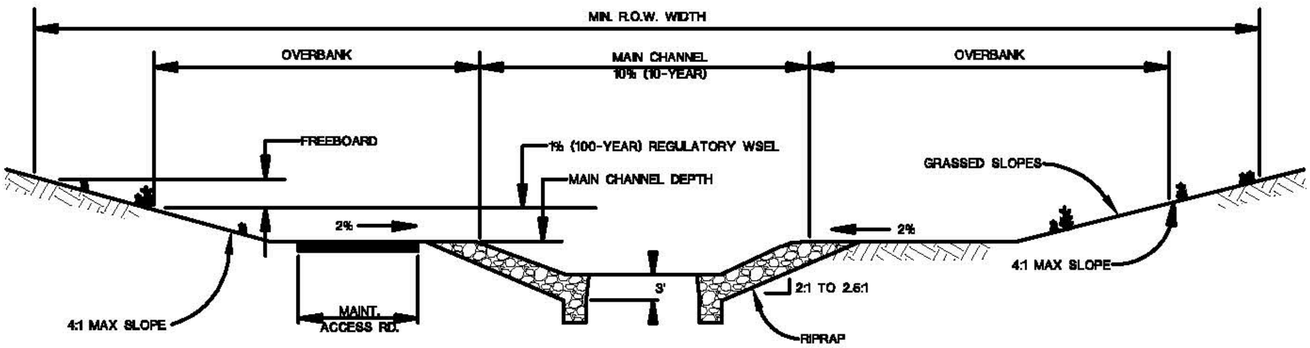
## FIGURE 7-4 - TYPICAL GRASS LINED CHANNEL SECTION TYPE B




NOTES:

1. MAIN CHANNEL: CAPACITY TO BE 10% (10-YEAR) FLOW.
2. TRICKLE CHANNEL: REQUIRED IF THE SLOPE OF THE CHANNEL IS LESS THAN 1% OR IF THE CHANNEL BOTTOM WIDTH IS LESS THAN 4'.
3. FREEBOARD: FREEBOARD TO BE A MINIMUM OF 1-FOOT.
4. MAINTENANCE ACCESS ROAD: MINIMUM WIDTH TO BE 20 FEET.
5. ROW WIDTH: MINIMUM WIDTH TO INCLUDE FREEBOARD AND MAINTENANCE ACCESS ROAD.
6. CHANNEL SIDE SLOPE: MAXIMUM WIDTH TO INCLUDE FREEBOARD AND MAINTENANCE ACCESS ROAD.
7. FROUDE NUMBER: MAXIMUM VALUE SHALL NOT EXCEED 0.8.
8. CHECK DROPS MAY BE REQUIRED TO LIMIT CHANNEL VELOCITIES.

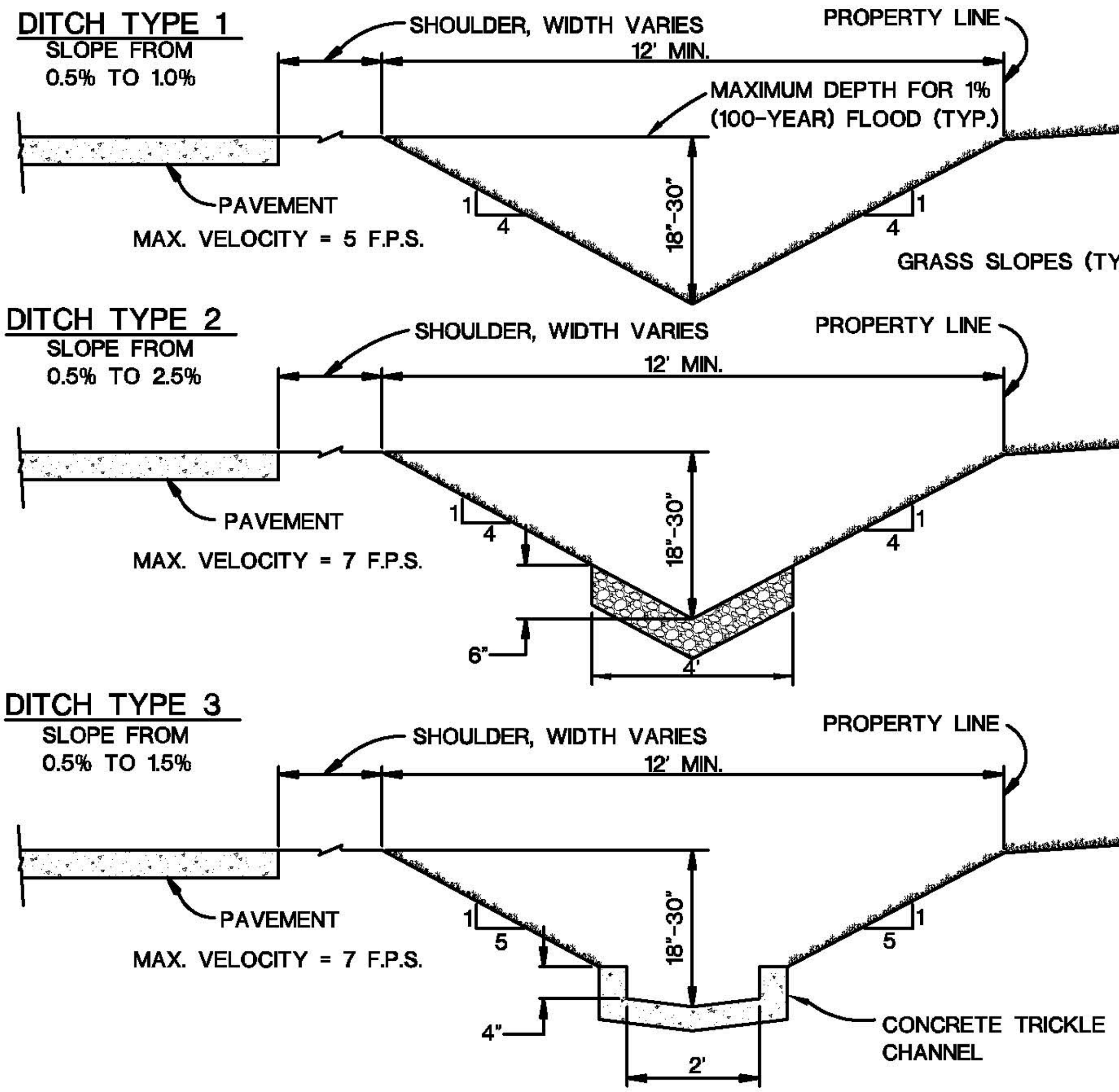
## FIGURE 7-5 - TYPICAL GRASS LINED CHANNEL SECTION TYPE C




NOTES:

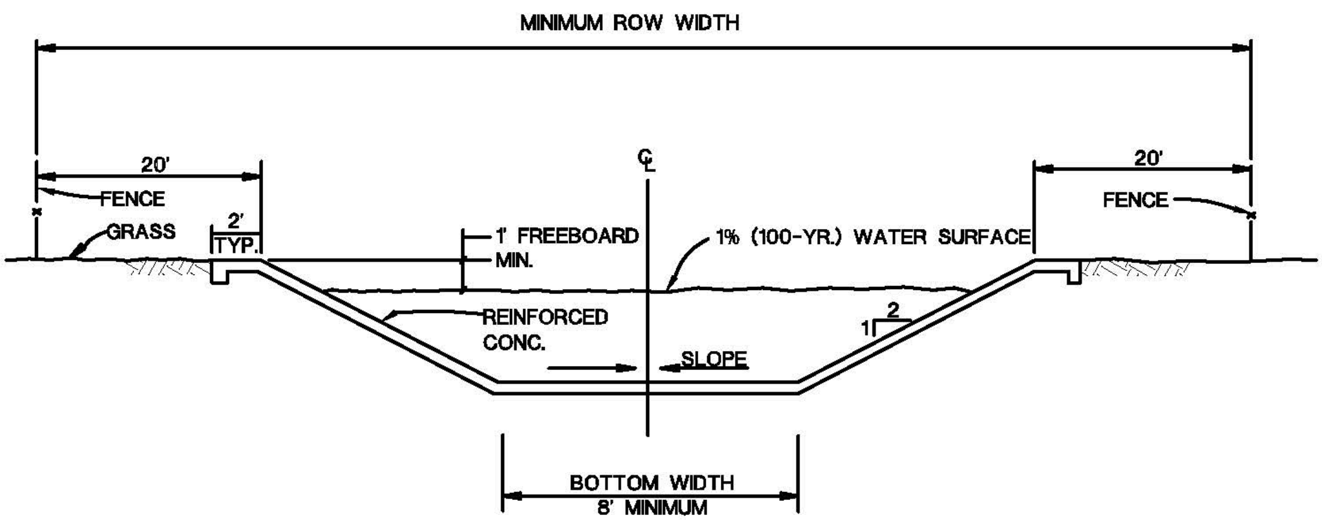
1. THIS SECTION IS REQUIRED FOR CHANNELS IN EROSIVE (SANDY) SOILS.
2. MAIN CHANNEL: CAPACITY TO CONVEY THE 50% (2-YEAR) TO 20% (5-YEAR) FLOOD. MAXIMUM 10% (10-YEAR) VELOCITY IS 5 FPS. PROTECT SLOPES WITH RIPRAP. USE MANNING'S N-VALUE OF 0.03 FOR HYDRAULIC CALCULATIONS.
3. FREEBOARD: FREEBOARD TO BE A MINIMUM OF 1 FOOT.
4. MAINTENANCE ACCESS ROAD: MINIMUM WIDTH TO BE 20 FEET.
5. ROW WIDTH: MINIMUM WIDTH TO INCLUDE FREEBOARD AND MAINTENANCE ACCESS ROAD.
6. CHANNEL SIDE SLOPE: MAXIMUM SIDE SLOPE FOR GRASS CHANNELS IS 4:1.
7. FROUDE NUMBER: MAXIMUM VALUE SHALL NOT EXCEED 0.8.
8. OVERBANK: FLOW IN EXCESS OF MAIN CHANNEL CAPACITY TO BE CONVEYED IN THIS AREA. AREA MAY BE UTILIZED FOR OPEN SPACE USE.
9. CHECK DROPS (SEE B).

## FIGURE 7-6 - ROADSIDE DITCH SECTIONS




NOTES: FOR DITCH SLOPES GREATER THAN MAXIMUM ALLOWABLE, CHECK DROPS (2' MAXIMUM HEIGHT) WILL BE REQUIRED.

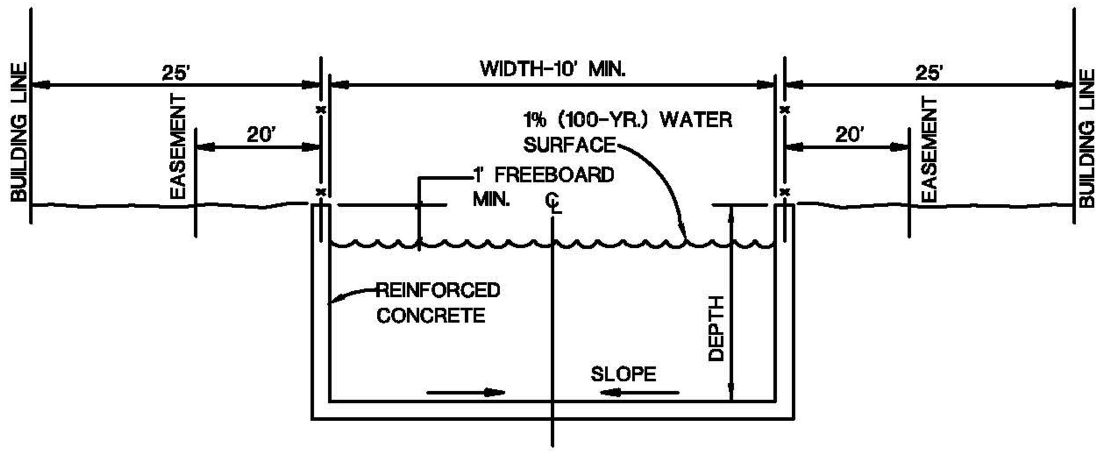
## FIGURE 7-7 - TYPICAL CONCRETE LINED CHANNEL TRAPEZOIDAL CROSS SECTION




NOTES:

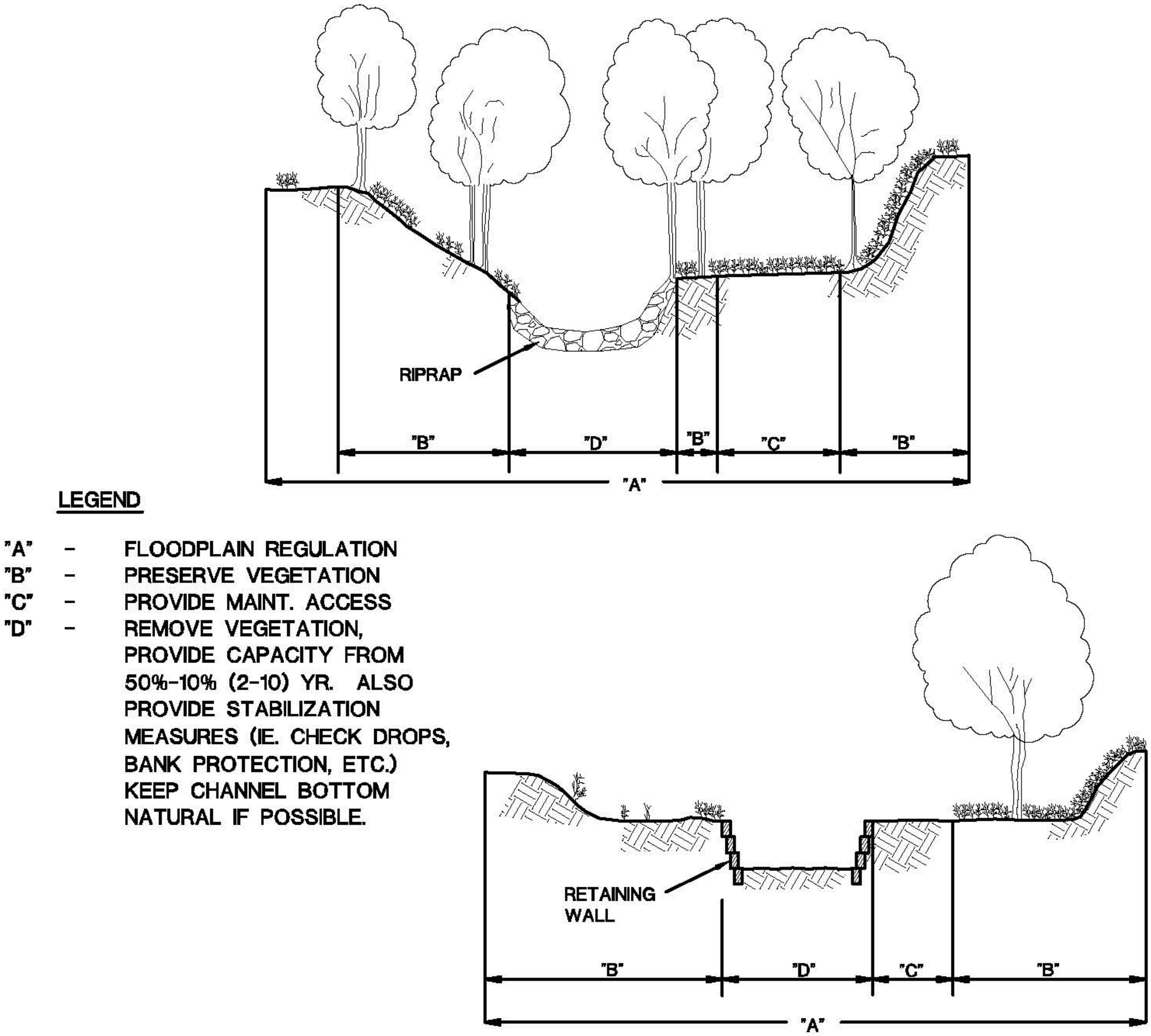
1. DESIGN FLOW: REGULATORY 1% FLOOD DISCHARGE
2. MANNING'S "n" VALUE: 0.013 TO 0.025 (SEE TABLE 702).
3. MAX FROUDE NUMBER: 0.9
4. MAX CHANNEL VELOCITY: 18.0 F.P.S.
5. FREEBOARD: SEE SECTION 703.3.5
6. LONGITUDINAL SLOPE: DICTATED BY VELOCITY AND FROUDE NUMBER. GRADE CONTROL STRUCTURES SHALL BE USED TO MAINTAIN DESIGN GUIDELINES.
7. MINIMUM CURVATURE: CENTERLINE CURVATURE RADIUS GREATER THAN TWICE TOP WIDTH, BUT NOT LESS THAN 100'.
8. SUPER ELEVATION: CALCULATED USING EQUATION 711.
9. SEE STANDARD 783 FOR CONSTRUCTION DETAILS.

## FIGURE 7-8 - TYPICAL CONCRETE LINED CHANNEL RECTANGULAR CROSS SECTION




NOTES:
1. DESIGN FLOW: REGULATORY 1% FLOOD DISCHARGE
2. MANNING'S "n" VALUE: 0.013 TO 0.025 (SEE TABLE 702).
3. MAX FROUDE NUMBER: 0.9
4. MAX CHANNEL VELOCITY: 18.0 F.P.S.
5. FREEBOARD: SEE SECTION 703.3.5
6. LONGITUDINAL SLOPE: DICTATED BY VELOCITY AND FROUDE NUMBER. GRADE CONTROL STRUCTURES SHALL BE USED TO MAINTAIN DESIGN GUIDELINES.
7. MINIMUM CURVATURE: CENTERLINE CURVATURE RADIUS GREATER THAN TWICE TOP WIDTH, BUT NOT LESS THAN 100'.
8. SUPER ELEVATION: CALCULATED USING EQUATION 711.
9. SEE STANDARD 784 FOR CONSTRUCTION DETAILS.

## FIGURE 7-9 - TYPICAL COMPOSITE LINED CHANNEL EXAMPLES



# Chapter 800 STREET DRAINAGE, STORM SEWER INLETS AND PIPE DESIGN

## 801 CRITERIA FOR STREET DRAINAGE

### 801.1 Introduction

A. The design of public streets within Tulsa is performed under the direct control of the CITY ENGINEER. When the drainage in the street exceeds allowable limits, a storm sewer system (Chapter 800) or an open channel (Chapter 700) is required to convey the excess flows. Storm sewers shall be designed to pass the 1% storm.
B. Inlets shall be designed to pass the 1% storm using the criteria established in Chapter 804, unless exempted as noted in Section **103.3**.
C. For non-residential streets, the first inlet shall be located no more than 400 feet from the high point in the street profile or at the point where the outside lane would be inundated (typically 0.38'), whichever is less. For residential streets, the first inlet shall be located no more than 400 feet from the high point in the street profile or at the point where the cross flow would occur (0.38'), whichever is less.

#### 801.1.1 Drainage Areas to Inlets

A. The actual tributary area, up to a distance of 300 feet from the centerline, will be used to calculate the storm runoff peaks.
B. Areas beyond the 300 feet limit are required to drain into the nearest drainage system as defined in Chapter 1300, Glossary.

#### 801.1.2 Runoff Coefficients

A. For drainage areas with a time of concentration less than 10 min. the rational method may be used. A runoff coefficient, C, of 0.9 shall be used for all areas adjacent to an arterial street to accommodate future commercial use.
B. For drainage areas with a time of concentration greater than 10 min the SCS Unit Hydrograph Method or the Snyder's Unit Hydrograph shall be used. A curve number, CN, of 95 shall be used adjacent to an arterial street to accommodate anticipated commercial use. Rational Method to be used for Inlet/Street design. Time concentration greater than 10 minutes not allowed on new construction,
C. In commercial areas the Snyder's Unit Hydrograph Time to Peak coefficient shall be adjusted to account for urbanization as discussed in Section 606.2.2.
D. The CITY ENGINEER will allow for special circumstances regarding the actual development assumptions.

## 801.2 Street Drainage Design

### 801.2.1 Drainage Areas to Inlets

A. Runoff will not be allowed to cross more than two residential lots before entering a public storm drainage system (including streets) as defined in Chapter 1300, Glossary.
B. Where concentrated overland flow enters the right of way it will be required to drain into the nearest drainage system in lieu of entering the street.

### 801.2.2 Cross Slope

A. For new construction non-residential streets, the cross slope shall be 1/4 inches per foot, with 3/8 inches per foot required on outside lanes.
B. For new construction residential streets, the cross slope shall be 3/8 inches per foot.

## 801.3 Location of Storm Sewers

A. The preferred location for a storm sewer within a street ROW is behind the curb.
B. Where this is not possible, storm sewers shall be placed in a location that is not within the wheel paths of the pavement, unless approved by the CITY ENGINEER.

## 801.4 Driving Lane Inundation

A. For residential streets, the depth of street flow is limited to 0.38 feet.
B. For arterial and collector streets, the depth of street flow is limited to inundation of the outside lane (typically 0.38').

## 801.5 Ponding in Sump Locations

A. The depth of ponding permitted in arterial or collector streets is limited to the outside lane of traffic (typically 0.38').
B. The depth of ponding permitted in residential streets is limited to 0.38'.

## 801.6 Cross Flow

A. Cross flow is allowed at residential intersections only, provided the total flow immediately downstream of the intersection does not exceed the street capacity.

# 802 HYDRAULIC EVALUATION - CURB AND GUTTER SECTIONS

## 802.1 Allowable Gutter Capacity - Curb and Gutter Sections

The flow capacity of a street section with curb and gutter on a continuous grade is calculated using the modified Manning's formula. A uniform section is required for new streets. The composite section is shown for analysis of existing street capacities only.

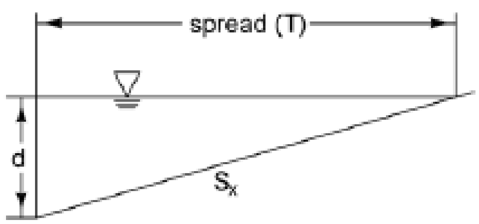
$$Q = \left(\frac{K_u}{n}\right)\left(S_x^{\frac{5}{3}}\right)\left(S_l^{\frac{1}{2}}\right)\left(T^{\frac{8}{3}}\right) \qquad (801)$$

or in terms of T

$$T = \left(\frac{Q*n}{K_u \times S_x^{\frac{5}{3}} \times S_l^{\frac{1}{2}}}\right)^{3/8} \qquad (802)$$

Where Q = flow rate, ft/s

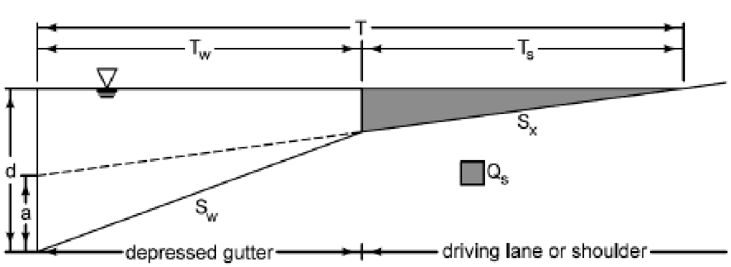
$K_u$ = 0.56
n = Manning's coefficient (.016 asphalt, .013 concrete)
T = width of flow (spread), ft
$S_x$ = cross slope, ft/ft
$S_l$ = longitudinal slope, ft/ft




In a uniform section with a Manning's n value of 0.016, a cross slope of 3/8"/ft, and a given flow rate the depth of flow in the gutter, $Y_T$, is calculated as:

$$Y_T = \left(\frac{Q}{1120 \times S^{\frac{1}{2}}}\right)^{\frac{3}{8}} \qquad (803)$$

Given $Y_T = S_x T$




A composite (depressed) section is more complicated than the simple triangle section and requires different calculations.

If a composite section is proposed, see Hydraulic Engineering Circular No. 22 (Reference 34) 3rd Edition for specific procedures.

**NOTE:** If a composite gutter section is selected for design, the calculations can be simplified by assuming a uniform cross slope of Sx. A uniform cross slope produces a wider spread than a composite section for the same value of Q. Assuming a uniform cross slope results in more conservative (closer) inlet spacing.

# 803 STORM SEWER INLET DESIGN CRITERIA

## 803.1 Inlet Types

Figure 8-1! Reference source not found. shows the allowable inlet types used in the City of Tulsa. Standard drawings are accessible via the internet at:

- https://www.cityoftulsa.org/government/departments/engineering-services/specifications-checklists-and-details/
- www.okladot.state.ok.us/roadway/standards.htm.

## 803.2 Location of Curb Inlets

### 803.2.1 Required Locations

Curb inlets are required when the allowable depth of flow in the gutter is exceeded. Inlets shall also be located at in the following locations:

A. At all low points in the gutter grade
B. On side streets at intersections where runoff would flow onto an arterial street or highway
C. Upgrade from bridges to prevent runoff from flowing onto the bridge deck.

### 803.2.2 Additional Requirements

A. Inlets at intersections shall be located in such a manner that no part of the inlet will encroach upon the curb return.
B. If possible, inlets on a continuous grade in the interior of a block should be placed upstream of a nearby driveway.
C. The design drawings shall include the flowline and top of curb elevations on all inlets.

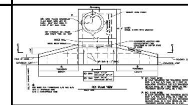
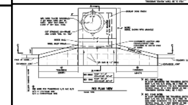
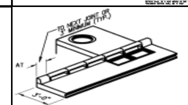
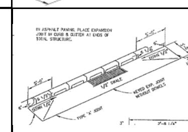
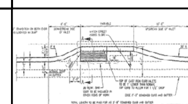
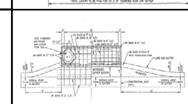
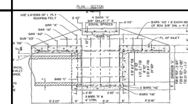
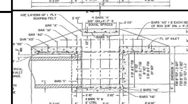
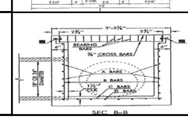
### 803.2.3 Use of Concrete Inlets

A. Recessed 6” metal frame inlets are to be used in all new residential neighborhoods.
B. Recessed 10” metal frame inlets are to be used in all new commercial construction/industrial developments and along arterial and collector streets.
C. Cast iron curb inlets shall be used in street rehabilitation and reconstruction projects where the curb returns, right of way, utilities cause excessive conflicts.

## 803.3 Spacing Between Curb Inlets

A. The spacing between curb inlets shall be such that depth of flow or width of spread requirements is not violated.
B. The maximum spacing between inlets shall not exceed 400 feet or one block, whichever is less.

# FIGURE 8-1 - ALLOWABLE INLET TYPES AND CLOGGING FACTORS

| Standard No. | Description | Design Procedure | | Allowable Locations | Inlet Location on Street | Clogging Factor | Inlet Location on Street | Clogging Factor |
|---|---|---|---|---|---|---|---|---|
| RCI 0648<br>RCI 0696 | Recessed 6" Metal Frame Inlet w/Access Manhole Back of Curb - 4' and 8' length | Section 804.3.1 and 804.3.2 |  | Residential Neighborhood | Continous Grade | 1.0 | Sump | 0.8 |
| RCI 1048<br>RCI 1096 | Recessed 10" Metal Frame Inlet w/Access Manhole Back of Curb - 4' and 8' length | Section 804.3.1 and 804.3.2 |  | Collector or Arterial Streets, Commercial and Industrial Areas | Continous Grade | 1.0 | Sump | 0.8 |
| 761, 762 | Non-Recessed Standard Inlets and Grates w/Access Manhole Back of Curb | Sections 804.2.1, 804.2.2, 804.3.3 and 804.3.3 |  | Street Rehabilitation Projects | Continous Grade | 1.0 | Sump | 0.7 |
| 764, 765, 766, 767 | Non-Recessed Standard Reinforced Concrete Storm Sewer Inlets with Cast Iron Curb Openings and Grates | Sections 804.2.1, 804.2.2, 804.3.3 and 804.3.4 |  | Street Rehabilitation Projects | Continous Grade | 1.0 | Sump | 0.7 |
| 768 | Recessed Cast Iron Curb Inlets with grates (no access manhole back of curb) | Sections 804.2.1, 804.2.2, 804.3.3 and 804.3.4 |  | Residential, Collector or Arterial Streets | Continous Grade | 1.0 | Sump | 0.7 |
| 768 | Recessed Concrete Curb Inlets without grates with access manhole back of curb | Sections 804.3.7 and 804.3.8 |  | Residential, Collector or Arterial Streets, outside of a ___' radius | Continous Grade | 1.0 | Sump | 0.8 |
| 770, 771, 772 | Standard Drop Inlets (15-inch through 48-inch pipes) | Section 804.4 |  | Sump areas in Medians, R/W, drainage easements and reserves | | | Sump | 0.8 |
| 773 | Standard Three Way Drop Inlet (48-inch pipe) | Section 804.4 |  | Sump areas in Medians, R/W, drainage easements and reserves | | | Sump | 0.8 |
| ODOT Standard SMD-2 | ODOT Standard Median Drain with Type 1 Grate only | Section 804.4 |  | Sump areas in Medians, R/W, drainage easements and reserves | | | Sump | 0.6 |

## 803.4 Interception and Bypass

A. Inlets on continuous grades may bypass no more than 30 percent of the flow.
B. Depth of flow and width of spread requirements must not be violated unless otherwise approved by the City Engineer.
C. The bypassed flow will be added to the design flow for the next downstream inlet.

## 803.5 Clogging Factors

A. Hydraulic design equations and charts presented in this MANUAL were developed with the assumption that all openings are clear, i.e., no portion of the curb or grate opening is clogged with leaves, sticks, cans, mud, or other urban litter.
B. The following clogging factors are required to reduce the theoretical interception given by the hydraulic design charts. A clogging factor of 0.8 is interpreted to mean that the inlet capacity obtained from the equations or charts is multiplied by 0.8 to obtain the allowable capacity, i.e., the allowable capacity of the inlet is 80% of the theoretical capacity.
C. The method by which these clogging factors are incorporated with the hydraulic design charts is detailed in Section 804.

## 803.6 Inlets in Sump Condition

A. When inlets are placed in a sump, an emergency overland drainage easement shall be provided in accordance with Policy 305.4.3 based on 100% clogging of the sump inlet.

# 804 STORM SEWER INLET DESIGN TECHNICAL CRITERIA

## 804.1 General

A. Hydraulic design procedures have been prepared for all inlet types and are included at the end of this section. The current state-of-the-practice for designing non-recessed storm inlets is presented in the FHWA publication Urban Drainage Design Manual Third Edition.
B. The City of Tulsa requires new inlets to be recessed unless they are being installed as part of a street rehabilitation project. Guidelines for design of recessed concrete inlets are presented in this chapter and are taken from the FHWA publication Hydraulic Characteristics of Recessed Curb Inlets and Bridge Drains.
C. The guidelines for design of recessed metal curb openings without grates are presented in this chapter and are based on the Kansas Director of Transportation (KDOT) publication K-TRAN Research Project KU-98-3, Hydraulic Performance of Set-Back Curb Inlets.
D. All metal hoods shall be marked "Dump No Waste, Drains to River".

## 804.2 Storm Sewer Inlet Grates

A. Grated inlets without a curb opening are not permitted within City of Tulsa streets. Hydraulic information is provided for analysis of existing inlets.
B. The vane grate (in combination with a curb opening) is the only grate approved by the City of Tulsa within the street ROW.

### 804.2.1 Grates on Continuous Grade

- **Figure 8-2** is used to estimate the flow rate that is intercepted by a vane grate on a continuous grade or in a sump.
- The potential for clogging is taken into account by multiplying the intercepted flow by the clogging factor to obtain the allowable capacity.

### 804.2.2 Grates in a Sump Condition

The flow captured by a vane grate in a sump can be calculated according to the following equation:

$$Q = 7.22d^{0.5} \quad (804)$$

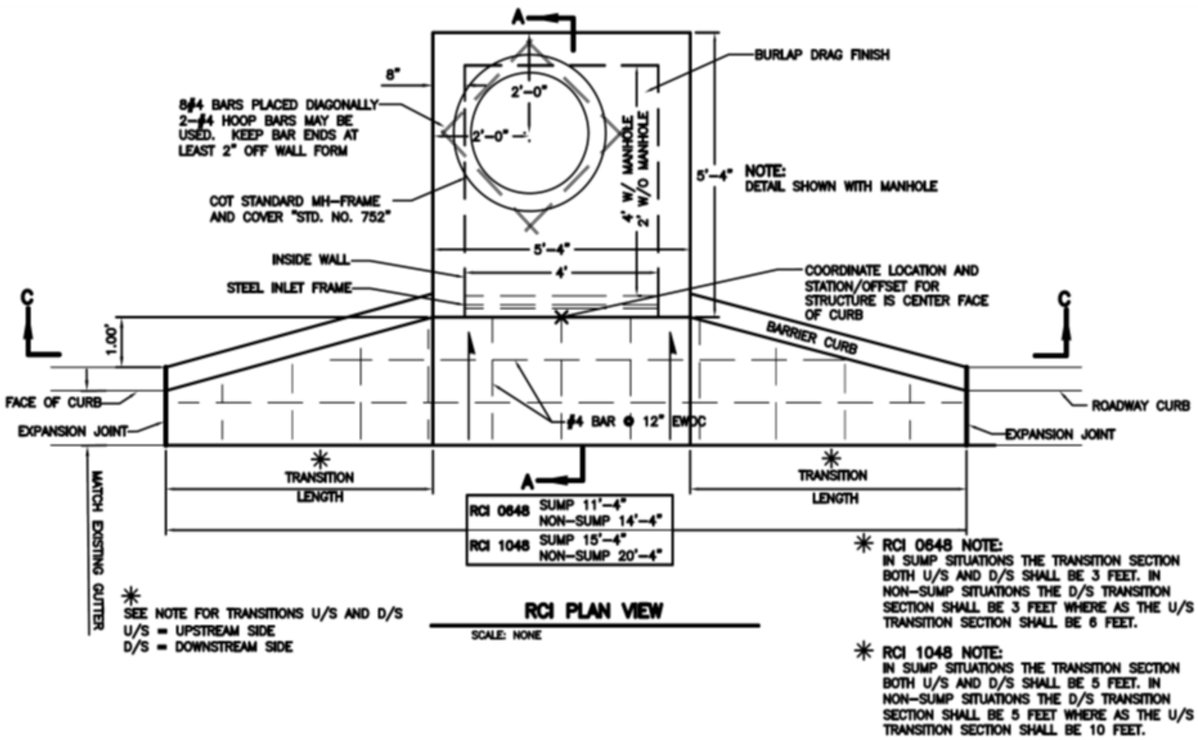
Where d = depth of flow above the grate

- The potential for clogging is taken into account by multiplying the calculated capacity by the clogging factor.

## 804.3 Curb Opening Inlets

New construction will include Recessed 6-Inch and 10-inch Height Metal Frame Curb Opening with Access Manhole Back of Curb. The only type of non-recessed curb opening inlet approved by the City of Tulsa is the cast iron curb inlet with grate.

### 804.3.1 Recessed 6-Inch and 10-inch Height Metal Frame Curb Opening with Access Manhole Back of Curb on a Continuous Grade




The diagram of the 6-inch and 10-inch inlet is shown above. The length of the opening is either 4 feet or 8-feet.

For the 10-inch opening, the upstream transition is 10 feet and the downstream transition is 5 feet. In a sump condition, both transitions are 5 feet.

For the 6-inch opening, the upstream transition is 6 feet and the downstream transition is 3 feet. In a sump condition, both transitions are 3 feet.

Captured flow on Recessed Metal Frame Curb Openings is calculated in the following manner:

1. Calculate the flow rate for 100% efficiency as follows:

$Q_o$ = $(a + bL_o)(S_o)^x$ (805)

Where $Q_o$ = Largest flow that is captured completely
a = -0.35 (for 3/8 per inch or 3% cross slope, 6-inch curb opening), **or**
a = -0.4 (for 1/4 per inch or 2% cross slope, 6-inch curb opening)
a = 1.25 (for 3/8 per inch or 3% cross slope, 10-inch curb opening), **or**
a = 1.0 (for 1/4 per inch or 2% cross slope, 10-inch curb opening)
b = 0.2 (for 3/8 per inch or 3% cross slope, 6-inch curb opening), **or**
b = 0.1 (for 1/4 per inch or 2% cross slope, 6-inch curb opening)
b = 0.25 (for 3/8 per inch or 3% cross slope, 10-inch curb opening), **or**
b = 0 (for 1/4 per inch or 2% cross slope, 10-inch curb opening)
x = -0.78 (for 3/8 per inch or 3% cross slope, 6-inch curb opening), **or**
x = -0.7 (for 1/4 per inch or 2% cross slope, 6-inch curb opening)
x = -0.5 (for either cross slope, 10-inch curb opening)
$L_o$ = Length of opening in feet (4 feet or 8 feet)
$S_o$ = Street grade in percent

2. If $Q_t$ is equal to or less than $Q_o$, $Q_t = Q_o$

Where $Q_t$ = Total approach flow (806)

3. If $Q_T$ is greater than $Q_o$, $Q_c$ is calculated as follows:

$Q_a$ = $(c + dL_o)(S_o)^X$ (807)

$Q_c$ = $Q_O + (Q_a - Q_o)\left[1 - exp\left\{-(\frac{Q_t - Q_o}{Q_a - Q_o})\right\}\right]$ (808)

Where $Q_a$ = The upper limit constant on the captured discharge

c = 3.9 (for 3/8 per inch or 3% cross slope, 6-inch opening), **or**
c = 3.5 (for 1/4 per inch or 2% cross slope, 6-inch opening)
c = 2.9 (for 3/8 per inch or 3% cross slope, 10-inch opening), **or**
c = 3.2 (for 1/4 per inch or 2% cross slope, 10-inch opening)
d = 1.65 (for 3/8 per inch or 3% cross slope, 6-inch opening), **or**
d = 0.8 (for 1/4 per inch or 2% cross slope, 6-inch opening)
d = 1.8 (for 3/8 per inch or 3% cross slope, 10-inch opening), **or**
d = 1.7 (for 1/4 per inch or 2% cross slope, 10-inch opening)

$Q_c$ = Total captured flow

4. The bypassed flow ($Q_b$) is that flow greater than $Q_c$, or

$Q_b$ = $Q_t - Q_c$ (809)

The clogging factor for Recessed 6-Inch and 10-inch Height Metal Frame Curb Opening with Access Manhole Back of Curb on a grade is 1.0 and does not affect this calculation.

### 804.3.2 Recessed Metal Frame Curb Opening with Access Manhole Back of Curb in a Sump

The flow in the curb opening is weir flow, and is calculated as:

$$Q = 3.1 \times L \times d^{1.5} \qquad (810)$$

Where L = Length of Curb Opening
d = Depth of flow

At a depth approximately equal to the height of opening, the flow changes to orifice control, calculated as:

$$Q = 0.65 \times A \times (2 \times g \times d)^{0.5} \qquad (811)$$

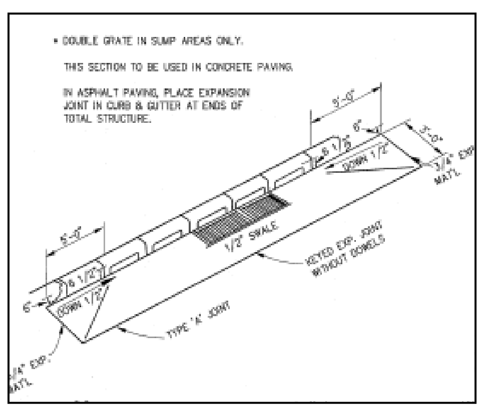
Where A = Area of Opening
g = 32.2 ft/sec$^2$
d = Depth of Flow above Centroid of Area

In the transition zone between weir flow and orifice flow, 1.0-1.4 times the opening height, the smaller of the flow calculations will control.

The clogging factor for a Recessed 6-Inch and 10-inch Height Metal Frame Curb Opening with Access Manhole Back of Curb in a sump is 0.8. The capacity of the inlet is equal to the capacity computed above multiplied by 0.8.

### 804.3.3 Non-Recessed Cast Iron Curb Opening Inlets with Grates on Continuous Grade

The following discusses the acceptable method for designing a vane grate opening with a curb opening in front of the grate on continuous grade. The procedure can be found in Urban Drainage Design Manual Second Edition, Chapter 4. The charts are found in the same manual in Appendix A.

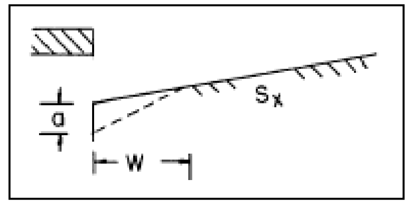


<u>Curb Opening Inlet Capacity</u>

1. Calculate the length of curb opening required for total interception using the following formula:

$$L_T = 0.6Q^{0.42}S^{0.3}\left[\frac{1}{(nS_x)}\right]^{0.6} \qquad (812)$$

2. The inlet efficiency E of curb-opening inlets shorter than the length required for total interception is expressed by the following formula. (See Chart 7B, Urban Drainage Design Manual Second Edition)




$$E = 1-\left[1-\left(\frac{L}{L_t}\right)\right]^{1.8} \qquad (813)$$

Where L = length of curb-opening, ft

3. The flow captured by the curb inlet is calculated using the following formula:

$$Q_i = E \times Q_t \qquad (814)$$

<u>Grate Inlet Capacity</u>. The chart for intercepted flow for a 3/8" cross slope is shown in **Figure 8-2.** Using the flow bypassing the curb opening inlets as Q, the flow spread, T, is calculated as follows:

$$T = \left[\frac{Qn}{K_u {S_x}^{5/3} {S_l}^{1/2}}\right]^{0.375} \qquad (815)$$

Where
Q = flow rate, ft/s
Ku = 0.56
n = Manning's coefficient
T = width of flow (spread), ft
Sx = cross slope, ft/ft
$S_l$ = longitudinal slope, ft/ft

The ratio of frontal flow to total gutter flow is computed using the following equation:

$$E_o = 1 - \left[1 - \left(\frac{1.33}{T}\right)\right]^{2.67} \quad (816)$$

1. The interception capacity of a grate inlet on grade is equal to the efficiency of the grate multiplied by the total gutter flow as represented in equation 816.

$$Q_i = E_o Q \quad (817)$$

The clogging factor for Non-Recessed Cast Iron Curb Opening Inlets with Grates on Continuous Grade on a grade is 1.0 and does not affect this calculation.

### 804.3.4 Non-Recessed Cast Iron Curb Opening Inlets with Grates in a Sump

Equation 818 is used to calculate the flow intercepted by a cast iron curb opening with grate in a sump.

$$Q = 7.22d^{0.5} \quad (818)$$

Where d = depth of flow above the grate

The flow intercepted by an additional curb opening can be calculated using equation 819.

$$Q = 3.1Ld^{1.5} \quad (819)$$

Where L = Length of Curb Opening

d = Depth of flow

Using equations 818 and 819 the total flow intercepted by a City of Tulsa standard cast iron curb inlet with grates in a sump can be estimated as:

$$Q = \left(7.22d^{0.5}\right)G + \left(8.34d^{1.5}\right)T \quad (820)$$

Where Q = Design Flow, cfs

d = Ponding Depth, ft

G = Number of Grates

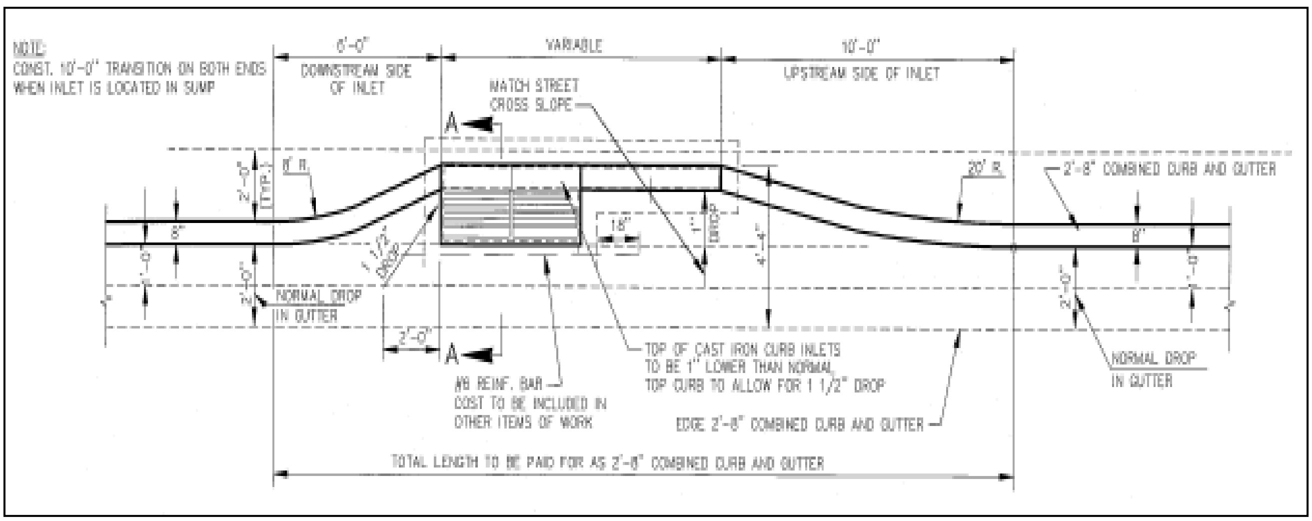
T = Number of Throats

The chart showing the grate capacity is shown in **Figure 8-2**. The procedure for sizing a cast iron curb opening inlet with a grate in a sump can be summarized as follows:

1. Estimate an inlet configuration.
2. Using equation 820, determine the maximum flow capacity of the estimated inlet configuration by calculating the flow at a ponding depth of 0.38 feet.
3. Multiply the maximum flow capacity by the clogging factor (0.7) to obtain the allowable capacity.
4. If the design flow is greater than the allowable inlet capacity, revise the inlet configuration and repeat step 2. If the design flow is less than the inlet capacity, determine the ponding depth by iterating the depth in equation 820 until the calculated flow is approximately equal to the design flow.

Note: Maximum use of curb openings should be used in increase the flow capacity due to the higher probability of grate clogging.

### 804.3.5 Recessed Cast Iron Curb Opening Inlets with Grates on Continuous Grade

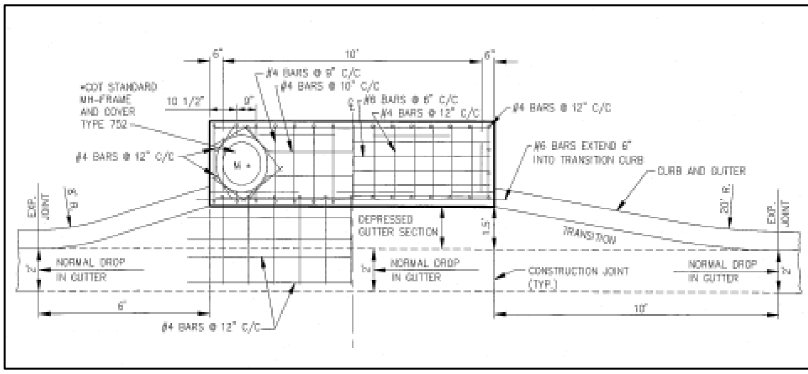


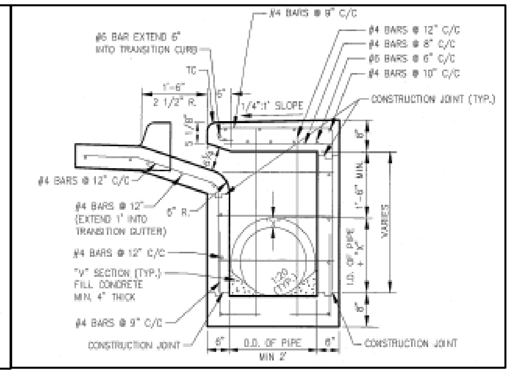

The recessed cast iron curb opening inlets with grates on a continuous grade shall be analyzed using the methods described for non-recessed curb opening inlets on a continuous grade in Section 804.3.3.

### 804.3.6 Recessed Cast Iron Curb Opening Inlets with Grates in a Sump Condition

The recessed cast iron curb opening inlets with grates in a sump shall be analyzed using the methods described for non-recessed curb opening inlets with grates in a sump in Section 804.3.4.

## 804.3.7 Recessed Concrete Curb Opening Inlets on Continuous Grade- Only to be used in Rehabilitation projects only. Use new standards for all new construction






Captured flow on recessed concrete curb openings is calculated in the following manner:

1. Calculate the flow rate for 100% efficiency as follows:

$$Q_{100} = L_{eff} 0.70 Y_T \quad (821)$$

Where $Q_{100}$ = Captured flow for 100% efficiency $l_{eff}$
$L_{eff}$ = 26 feet (10 foot actual opening)
$Y_T$ = Approach depth in the gutter (from Equation 803)

2. If $Q_A$ (approach Q) is equal to or less than $Q_{100,}$ $Q_C$ (captured flow) = $Q_A$
3. If $Q_A$ is greater than $Q_{100,}$ $Q_C$ is calculated as follows:

$$L_r = \frac{Q_a}{0.70 Y_T} \quad (822)$$

Where $L_r$ = Effective Length that would be required for 100% capture

$$Q_C = Q_A \left[0.0526\left(\frac{L_{eff}}{L_r}\right) + 2.86\left(\frac{L_{eff}}{L_r}\right) - 1.92\left(\frac{L_{eff}}{L_r}\right)^3\right]$$

The bypassed flow ($Q_B$) is that flow greater than $Q_{100}$, or

$$Q_B = Q_A - Q_C \quad (823)$$

#### 804.3.8 Recessed Concrete Curb Opening Inlets in a Sump Condition

Equation 824 is used to estimate the depth of flow in the weir flow depth range.

$$Q = 3.1Ld^{1.5} \quad (824)$$

or

$$d = \left(\frac{Q}{3.1L}\right)^{\frac{2}{3}} \quad (825)$$

Where L = Length of Curb Opening
d = Depth of flow

At a depth approximately equal to the height of opening, the flow changes to orifice control, calculated as:

$$Q = 0.65A(2gd)^{0.5} \quad (826)$$

or

$$d = \left(\frac{Q}{0.65A(2g)^{0.5}}\right)^2 \quad (827)$$

Where A = Area of Opening
g = 32.2 ft/sec$^2$
d = Depth of flow

In the transition zone between weir flow and orifice flow, 1.0-1.4 times the opening height, the smaller of the flow calculations (higher of the depth calculations) will control.

The clogging factor for a Recessed Concrete Curb Opening Inlets in a Sump Condition is 0.8. The capacity of the inlet is equal to the capacity computed above multiplied by 0.8.

### 804.4 Drop Inlets

Drop inlets are only permitted within street rights-of-way with unpaved medians or within local drainage easements or reserves outside of the street ROW.

Drop inlets will typically operate in a sump condition, since the opening is perpendicular to the direction of flow and the inlet (and local grading) blocks the flow. The inlet will operate as a weir to a depth of flow just above the top of the opening. Above this depth, the inlet operation will transition to orifice control, with the capacity calculated based on a head computed above the centerline of the opening.

The capacities for drop inlets are calculated using a weir coefficient of 3.1, an orifice coefficient of 0.6, and a clogging factor of 0.8. The inlet operates as a weir to depths equal to the opening height and as an orifice at depths greater than 1.4 times the opening height. At depths between 1.0 and 1.4 times the opening height, flow is in a transition stage.

$$Q = 3.1Ld^{1.5} \quad (828)$$

or $$d = \left(\frac{Q}{3.1L}\right)^{\frac{2}{3}} \quad (829)$$

Where L = Length of Opening
d = Depth of Flow

At a depth approximately equal to the height of opening, the flow changes to orifice control, calculated as:

$$Q = 0.6A(2gd)^{0.5} \quad (830)$$

or $$d = \left(\frac{Q}{0.6A(2g)^{0.5}}\right)^2 \quad (831)$$

Where A = Area of Opening
g = 32.2 ft/sec$^2$
d = Depth of Flow Centroid of Area

In the transition zone between weir flow and orifice flow, 1.0-1.4 times the opening height, the smaller of the flow calculations (higher of the depth calculations) will control.

### 804.5 Multiple Inlets

Multiple inlets occur when more than one inlet (of the same type) is used in a continuous series, resulting in greater flow interception capacity. To calculate the capacity of multiple inlets, the most upstream inlet is first evaluated using procedures described above to determine the amount of flow intercepted. Each subsequent inlet is assumed to have efficiency equal to the first inlet and will pick up a proportional amount of the remaining flow.

## 805 Allowable Capacity - Roadside Ditch Sections

Where allowed, the capacity of a roadside ditch is computed using Manning's equation presented in Chapter 700. The entire 1% (100-year) storm shall be contained within the ditch and right of way without encroaching on the roadway. Driveway culverts shall be designed to pass the 1% (100-year) storm within the right of way without encroaching on the roadway. Side slopes must be 1 foot vertical to 3 feet horizontal or flatter. The bottom of the ditch must be paved if the velocities exceed 5 feet per second. The maximum depth is 30 inches.

Roadside ditches are not preferred in new developments, but exceptions may be made where geological constraints are present on the site. A technical variance request must be submitted by the owner/engineer and be approved by the City Engineer.

# 806 Storm Sewer Pipe Design

## 806.1 General

A storm sewer system is required when other parts of the drainage system no longer have capacity for additional runoff without exceeding design criteria.

## 806.2 Design Criteria

### 806.2.1 Design Storm Frequency and Bypass

Section 801.1 discusses the 1% (100-year) flood design storm. It is impractical to intercept all the runoff approaching an inlet on grade, therefore, a portion of the flow will generally be allowed to bypass the inlet. To maximize storm sewer efficiency no more than 30% of the approaching flow is allowed to bypass an inlet on grade.

### 806.2.2 Vertical Alignment

#### 806.2.2.1 Cover

A. The sewer grade shall maintain the minimum cover necessary to withstand AASHTO HS-20 loading on the pipe or the pipe manufacturer's recommendation, whichever is greater.
B. The minimum cover depends upon the pipe size, type and class, and soil bedding condition, but shall not be less than 1 foot from the top of pipe to the finished grade at any point.
C. If the pipe encroaches into the street sub-grade, approval from CITY ENGINEER is required.

#### 806.2.2.2 Manholes

A. Manholes will be required whenever there is a change in size, alignment, or slope and where there is a junction of two or more sewers.
B. The maximum spacing between manholes for various pipe sizes shall be in accordance with **Table 8-2**.
C. For large storm sewers (i.e.: cross sectional area greater than 25 square feet), manholes may be placed at a maximum distance of 500 feet.

#### 806.2.2.3 Clearance between utility lines

A. For new construction, the minimum clearance between storm sewer and water mains or storm sewer and sanitary sewer, either above or below, shall be 24 inches.
B. When a 24" clearance between existing water mains cannot be obtained, ductile iron pipe (with proper bedding) or concrete encasement of the water line will be required

C. When a 24" clearance between existing sanitary sewer cannot be obtained, the sanitary sewer shall have an impervious encasement or be constructed of structural sewer pipe (i.e.: ductile iron pipe) for a minimum of 10-feet on each side of the storm sewer crossing.

#### 806.2.2.4 Siphons

A. Siphons or inverted siphons are not allowed in the storm sewer system.

### 806.2.3 Horizontal Alignment

A. Radius Pipe is not allowed.
B. A minimum horizontal clearance of 5 feet is required between sanitary sewer or water utilities and the storm sewer.
C. The permitted locations for storm sewer within a street ROW are listed in Section 801.3.

### 806.2.4 Pipe Size

A. The minimum storm sewer diameter allowed in a closed system is 15 inches.
B. The minimum pipe size for an open culvert is 18 inches.
C. If a lateral pipe extends outside of the street ROW or easements then manholes shall be included on the lateral within the street ROW, in accordance with **Table 8-2**.

### 806.2.5 Storm Sewer Capacity

A. Storm sewers may be surcharged when approved by the CITY ENGINEER, and when adequate joint treatment and/or depth is specified to prevent joint separation.

### 806.2.6 Storm Sewer Velocities

**A.** The velocity shall be based on the Manning's n-values presented in
B. Table 8-3.
C. The maximum full flow velocity shall be less than 20 fps.

- Higher velocities may be approved by the CITY ENGINEER if the design includes adequate provisions for uplift forces, dynamic impact forces and abrasion.

D. To avoid excessive accumulations of sediment, the minimum velocity in a pipe based on half-full flow shall be 2.5 fps.

### 806.2.7 Energy and Hydraulic Grade Restrictions

A. The energy grade line (EGL) for the design flow shall be no more than one foot above the final grade at manholes, inlets, or other junctions.

B. The HGL shall not exceed the grate or weir elevations of inlet or manholes unless approved by the CITY ENGINEER. In some conditions, use of a bolt-down manhole cover may be allowed.
C. The hydraulic grade line (HGL) and the energy grade line (EGL) shall be calculated by accounting for friction, expansion, contraction, bend, manhole, and junction losses, as described in Section 806.3.

### 806.2.8 **Storm Sewer Outlets**

A. All storm sewer outlets into open channels shall be constructed with a slope wall or prefabricated culvert end section.
B. Erosion control shall be provided at the outlet in accordance with Chapter 1200.

## 806.3 **HYDRAULIC EVALUATION**

### 806.3.1 **Evaluation of Head Losses in Storm Sewer Systems**

A. The HEC-22 Urban Drainage Design Manual Current Edition details the methods for evaluation of head losses in storm sewer systems.
B. As a minimum, evaluation of the following head loss types is required for calculation of hydraulic grade lines and energy grade lines:

- Pipe Friction Losses
- Exit Losses
- Bend Losses
- Transition Losses
- Junction Losses
- Inlet and Access Hole Losses

## 806.4 DESIGN OF STORM SEWER SYSTEM

This procedure outlines a typical storm sewer design.

Step 1: Prepare a working plan layout and profile of the storm drainage system establishing the following design information:

A. Location of all inlets.

B. Direction of Flow.

C. Location of access holes and other structures.

D. Number or label assigned to each structure, obtained from Stormwater Engineering Design Personnel.

Step 2: Using the hydrologic model prepared for the storm sewer system, identify the 1% flow rates at all locations in the system that will be affected by inflow.

Step 3: Complete the following information on the design form for each run of pipe starting with the upstream most storm drain run:

A. "From" and "To" stations, Columns 1 and 2

B. "Length" of run, Column 3

C. “Bypass Q” Column 4. Flow bypassed from the Inlet corresponding to “From” downstream to the Inlet corresponding to “To”. This information is obtained from the Inlet Design Table on the plans.

D. "Junction Q," Column 5 Insert the Junction flow value from the hydrologic model.

E. "Junction Q less bypass” Column 6 Colum 5 minus Column 4.

F. "Slope," Column _ Place the pipe slope value in Column 21. The pipe slope will be approximately the slope of the finished roadway. The slope can be modified as needed.

G. "Pipe Dia.," Column 7. Size the pipe using relationships and charts presented in Urban Drainage Design Manual Current Edition, Section 7.1.3 to convey the discharge by varying the slope and pipe size as necessary. The storm drain should be sized as close as possible to a full gravity flow. Since most calculated sizes will not be available, a nominal size will be used. The designer will decide whether to go to the next larger size and have part full flow or whether to go to the next smaller size and have pressure Flow.

H. "Capacity Full," Column 8. Compute the full Flow capacity of the selected pipe using the following equation:

$$Q = VA \tag{832}$$

Where

$$V = \frac{1.49}{n}\left(\frac{d}{4}\right)^{\frac{2}{3}} S^{\frac{1}{2}} \tag{833}$$

I. "Velocity," Column 9. Compute the full flow and design flow velocities (if different) in the conduit and place the larger of the values in Column 9. If the pipe is flowing full, the velocities can be determined from V = Q/A, equation 833, or chart 25 in Urban Drainage Design Manual Current Edition. If the pipe is not flowing full, the velocity can be determined from chart 26, Urban Drainage Design Manual Current Edition

J. "Velocity Head," Column 10. Compute the velocity head using the following equation:

$$V_H = \frac{V^2}{2g} \tag{834}$$

K. "Pipe Loss," Column 11. Compute the pipe losses using the following formula:

$$H_L = \frac{(185n^2L)}{d^{\frac{4}{3}}V_H} \tag{835}$$

L. "Head Loss," Column 12. Calculate a head loss caused by the junction:

$$H_{ah} = \frac{K_{ah}}{d^{\frac{4}{3}}V_H} \tag{836}$$

Values for $K_{ah}$ are given in Table 7-5a of the Urban Drainage Design Manual Current Edition. The methodology is discussed in Section 7.1.6.7 of the same manual.

M. "Invert Elev's.," Columns 13 and 14. Compute the pipe inverts at the upper (U/S) and lower (D/S) ends of this section of pipe, including any pipe size changes that occurred along the section.

Step 5 Repeat steps 3 and 4 for all pipe runs to the storm drain outlet. Use equations and nomographs to accomplish the design effort.

Step 6 Check the design by calculating the energy grade line and hydraulic grade line as described in the Urban Drainage Design Manual Second Edition, Section 7.5.

## TABLE 8-1 - STORM SEWER ALIGNMENT AND SIZE CRITERIA

**A. MANHOLE SPACING:**

| PIPE SIZE | MAXIMUM SPACING FOR MANHOLES | MINIMUM MANHOLE SIZE |
|---|---|---|
| 15" to 24" | 300 ft | 4 ft |
| 27" to 36" | 400 ft | 5 ft |
| 42” | 400 ft | 6 ft |
| 48" | 500 ft | 6 ft |
| 54" to 66" | 500 ft | 8 ft |
| > 66" | 500 ft | Junction Structure |

**B. MINIMUM PIPE DIAMETER:**

| TYPE | MINIMUM EQUIVALENT PIPE DIAMETER | MINIMUM CROSS-SECTIONAL AREA |
|---|---|---|
| Main Trunk | 15 in | 1.23 sq. ft. |
| Lateral from inlet[1] | 15 in | 1.23 sq. ft. |

[1] Minimum size of later shall also be based upon a water surface inside the inlet with a minimum distance of 1’ below the grate or throat.

## TABLE 8-2 - HYDRAULIC DATA FOR PIPE

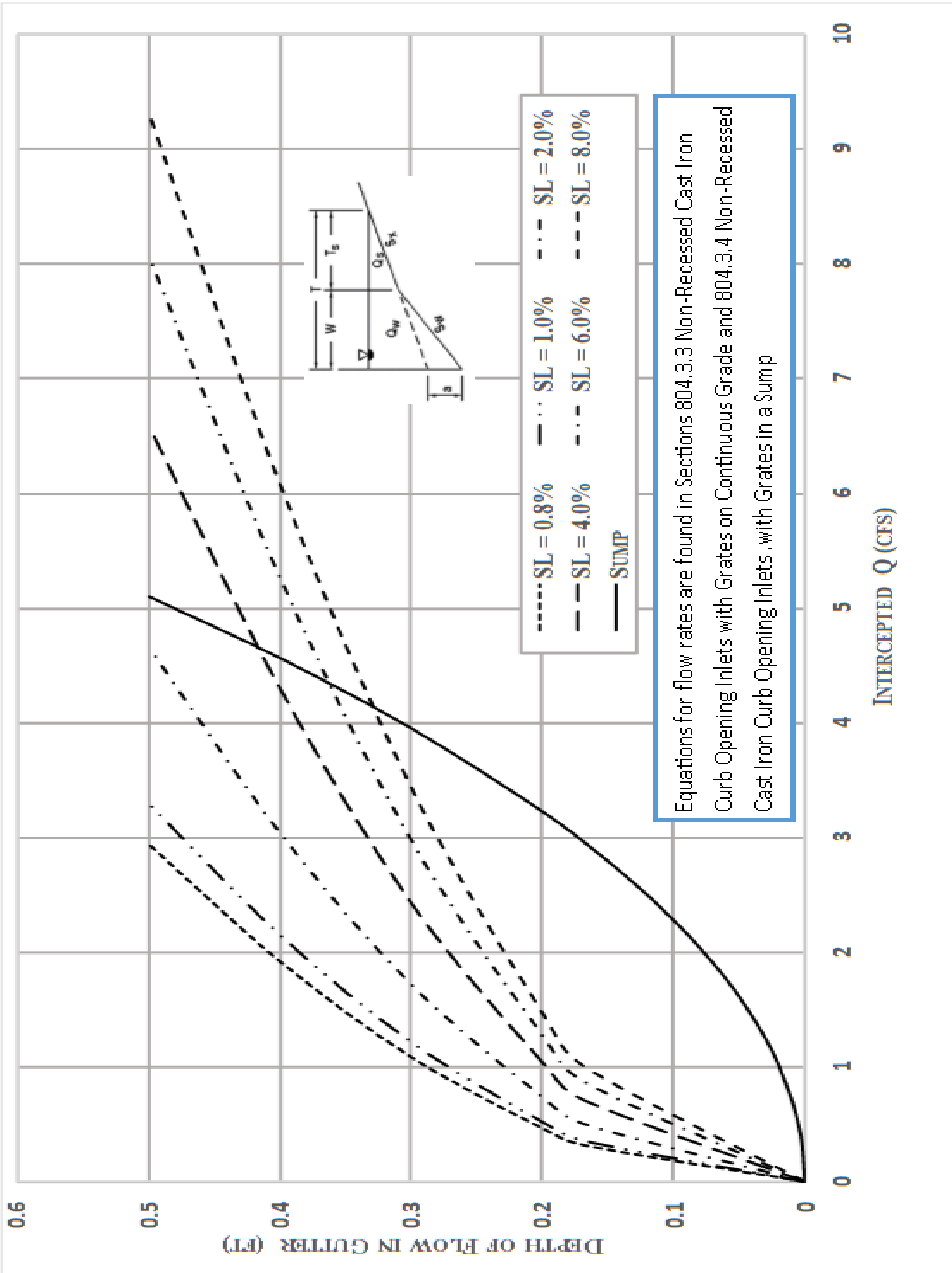
| MATERIAL | N-VALUE |
|---|---|
| **(A) - CONCRETE** | |
| Pre-Cast (Public) | 0.013 |
| Cast-in-Place (Public) | |
| Steel forms | 0.013 |
| Wood forms | 0.015 |
| **(B) - PLASTIC** | |
| Corrugated Polyethylene (Private) | 0.012 |
| Corrugated Polyethylene (smooth inter.) (Private) | 0.011 |
| Polyvinyl chloride (smooth interior) (Private) | 0.012 |

Public Storm sewers within the CITY shall be constructed using reinforced concrete or corrugated polypropylene. If a storm sewer system will remain private, flexible pipe may be allowed. Flexible pipe materials are restricted to areas outside the street pavement. The materials, pipes, or appurtenances shall meet one or more of the following standards:

## TABLE 8-3 - CONSTRUCTION MATERIALS

| PIPE MATERIAL | STANDARD |
|---|---|
| Reinforced Concrete Pipe | |
| Round | ASTM C-76 or AASHTO M-170 |
| Elliptical | ASTM C-507 or AASHTO M-207 |
| Joints | ASTM C-443 or AASHTO M-198 |
| Arch | ASTM C-506 or AASHTO M-206 |
| Pre-Cast Concrete Manholes | ASTM C-478 or AASHTO M-199 |
| Pre-cast Concrete Box | ASTM C-789/C-850, AASHTO M-259/273, ODOT |
| Concrete Cast-in-Place pipe | ODOT Standard |
| Corrugated PVC Pipe | ASTM D-3034 or ASTM F-949 |
| Corrugated Polypropylene Pipe | ASTM F-2881 & AASHTO M330, City of Tulsa 215 |

## FIGURE 8-2 - INTERCEPTED FLOW FOR A VANE GRATE ON A CONTINUOUS GRADE AND IN A SUMP



# Chapter 900 DETENTION

## 901 INTRODUCTION

The criteria presented in this section shall be used in the design and evaluation of all stormwater storage/detention facilities for the City of Tulsa. The review of all planning submittals will be based on the criteria presented in this Chapter.

The main purpose of a detention facility is to store the stormwater runoff associated with increased watershed imperviousness due to development and to discharge this runoff at a rate similar to the runoff rate from the watershed without development. The City of Tulsa defines two types of detention: on-site and regional:

- On-site detention is defined as a privately owned and generally privately maintained open space, parking lot, or underground facility which serves the development.
- Regional detention is publicly owned and maintained and generally is part of a planned open space park system or greenbelt area serving a larger portion of the watershed.

The design of detention facilities that have a certain storage volume and/or dam height are subject to regulation by the Oklahoma Water Resources Board. The classification criteria and design requirements are available for download at the OWRB website on the Rules and Regulations page. All detention facilities shall be designed to meet OWRB requirements or the requirements set forth in this Chapter, whichever is more stringent.

## 902 POLICIES AND STANDARDS

The policies and standards for detention facilities are established in Chapter 300 of this MANUAL and in City of Tulsa Revised ORDINANCES, Title 11-A, Section 304. The following is a summary of the policies.

A. The stormwater drainage system for all developments shall be designed to pass the stormwater runoff received from upstream and from the subject property during a 1% (100-year) frequency rainstorm under fully urbanized conditions.
B. All development shall be constructed such that it will not increase the frequency of flooding or the depth of inundation of structures during the 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), and 1% (100-year) flood events.
C. Peak flows shall not be increased at any location, upstream or downstream of any development for the 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), and 1% (100-year) flood events unless there is adequate conveyance so that no structures are damaged and approved by the CITY ENGINEER.
D. At the discretion of the CITY ENGINEER, the regulation or mitigation of peak flows to allowable levels shall be achieved by on-site detention, regional detention or improved conveyance to compensate for increased flows from the development.
E. The CITY ENGINEER may allow a fee-in-lieu of detention if it can be proven by the developer that there is no increase in flooding downstream from the detention free development.

F. Compensation shall be provided for filling or development which diminishes the flood storage capacity of any regulatory flood plain area by providing compensatory storage or other method as determined by the CITY ENGINEER.
G. The flow chart presented in **Figure 9-1** represents the process for deciding the appropriateness of fee-in-lieu of on-site detention.
H. All detention facilities shall be bound by an easement or dedicated right-of-way. (See **Table 3-1**)

# 903 GENERAL DESIGN CRITERIA

## 903.1 General Design Criteria

General design criteria for all detention facilities are presented below.

A. The primary function of a detention facility is to reduce stormwater runoff from a development to the rate of runoff prior to the development.
B. All detention facilities shall be designed using the unit hydrograph method to determine the effects of the storage on the peak discharges for the 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), and 1% (100-year) flood events.
C. HEC-HMS is the preferred hydrologic modeling programs, but other programs may be used with approval from the CITY ENGINEER.
D. Multi-stage outlet works are acceptable and are encouraged because of the water quality benefits.
E. Outlet works should be designed with as large an opening as possible to still maintain the design objectives.
F. Pump systems to evacuate the detention facility during Flood events are not allowed.
G. Grass side slopes should be no steeper than 4:1.
H. For regional detention ponds the top of the embankment shall be 15 feet wide at a minimum.
I. For on-site detention ponds the top of the embankment shall be 10 feet wide at a minimum. Access to the outlet works shall be provided either via a 15' top width or other arrangements approved by the CITY ENGINEER.
J. Detention facilities may be either wet or dry depending upon multiple-use and water quality considerations.
K. Safety of the detention pond and outlet works shall be addressed in design. This includes embankment stability and the consequences of embankment failure.
L. Detention facilities shall be environmentally sound and compatible with the neighborhood and, where feasible, multi-use should be included.

## 903.2 General Design Submittals

All calculations and plans for detention facilities shall be presented to the CITY for review and approval. Information submitted shall include:

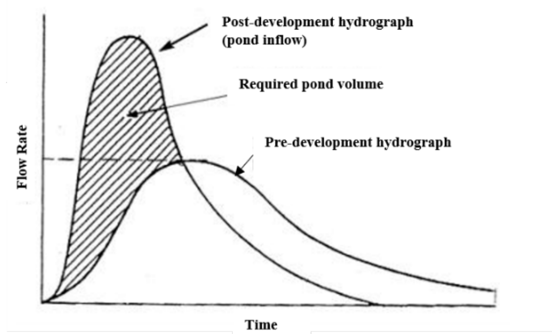
A. Inflow and outflow hydrographs.
B. A comparison of the pre-project and with-project peak discharges at the point(s) of discharge from the development and at points downstream as required by the CITY ENGINEER.

C. Elevation-Storage-Discharge relationships.
D. Discharge rating curves for each component of the outflow structure.
E. Tailwater rating curves at the outlet. Tailwater shall be considered when designing the outlet structure.
F. Erosion protection measures at the outlets and spillway.
G. Embankment design in accordance with OWRB guidelines, including slope protection in case of overtopping, slope stability, and maintenance access.
H. Multiple use plans.
I. Trash rack design.

## 904 ON-SITE DETENTION

Subject to Ordinance 11-A and policies set forth in Chapter 300 and Section 902, the following factors must be considered when designing on-site detention:

A. The effectiveness of an on-site detention facility in controlling the peak discharges at downstream points is highly dependent on the location of the facility in the overall drainage basin. Studies have shown that on-site detention may actually increase downstream peak discharges by delaying the hydrograph from the development and causing it to combine with downstream hydrographs into a larger flood peak. For this reason, all on-site detention designs shall consider the effects on peak discharges downstream as required by the CITY ENGINEER.
B. On-site detention facilities are recognized by the CITY to be effective in controlling the peak discharges from the development immediately downstream of the development, and as a valuable part of a Low Impact Development.




C. The stormwater detention facility must contain the volume of the post-development hydrograph up to the point on the falling limb where the post-development flowrate equals the pre-development flowrate. The rising side of the post-development hydrograph after routing through the stormwater detention facility must not occur sooner than the rising side of the pre-development hydrograph.
D. On-site detention facilities shall be designed so that there is no increase in the peak discharge from any point of the development during the 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), and 1% (100-year) flood events. This applies at the point(s) of discharge from the development as well as at points downstream, as required by the CITY ENGINEER.
E. The erosive effects of the increased runoff volume from the on-site detention facility shall be mitigated by armoring the stream bank downstream.
F. On-site detention can be very effective in improving water quality. Chapter 1100 outlines Low Impact Development (LID) practices that can be incorporated into on-site detention.

# 905 REGIONAL DETENTION

Regional detention is part of the CITY's comprehensive plan to mitigate increased peak discharges due to upstream urbanization. Regional detention facilities are generally owned and maintained by the CITY and are part of the Master Drainage Planning for each major watershed within the CITY that may also include channelization, improved bridges and culverts, and non-structural measures. Meant to serve a large portion of the watershed, regional detention facilities regulate the inflow to provide peak discharge reductions downstream and work in combination with the other features of the Master Drainage Plan. When designing regional detention, the following factors must be considered.

A. Regional detention facilities should discharge into a 1% (100-year) conveyance system (improved channel, storm sewer system, or natural channel with adequate overbank conveyance and regulation).
B. The Oklahoma Water Resources Board may have jurisdiction over the design of regional detention facilities, depending on the dam height and/or storage volume. OWRB guidelines shall be followed where applicable.
C. Regional detention facilities shall be designed so that there is no increase in the fully urbanized peak discharge for the 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), and 1% (100-year) flood events.
D. Water quality considerations of the urban runoff leaving the on-site detention facility shall be considered and implemented when feasible as stipulated in Chapters 1000 and 1100 of this MANUAL.

# 906 COMPENSATORY STORAGE

Compensatory storage is defined as the storage provided to compensate for filling or development within the regulatory floodplain.

A. The volume of the compensatory storage required shall be equal to the fill material volume placed above the natural ground up to the Regulatory 1% (100-year) Flood profile.
B. The volume shall be provided by excavating the natural ground ABOVE the channel flow line and shall be contiguous with the main channel.
C. A separate storage area outside the floodplain or a sump area within the floodplain is not acceptable, except where such storage is provided for in the drainage basin master plan.

# 907 FEE-IN-LIEU OF ON-SITE DETENTION

All development, including infill development, will be subject to pay a fee-in-lieu of detention at the discretion of the CITY ENGINEER. The fee-in-lieu rate will be in accordance with the ORDINANCES. The fee will be based on the proposed increase in impervious area, using the impervious area in the 1977 aerial photos as a basis, taking into account any changes since that time due to previous permits. If the development plan includes making improvements to the downstream capacity of the existing stormwater system, a credit shall be given, based on the amount of increase planned.

In order to be eligible for a fee-in-lieu of on-site detention, the following conditions must be met.

A. The Master Drainage Plan for the watershed in which the development is located must include downstream storage or other improvements identified for "in lieu of" payments in place of on-site detention.
B. The developer must adequately demonstrate that "in lieu of" downstream storage or other improvements will mitigate the increased runoff from the development.
C. There cannot be any direct identifiable adverse impacts to downstream properties.

# 908 DESIGN STANDARDS FOR OPEN SPACE DETENTION

## 908.1 Oklahoma Water Resources Board

All detention facilities shall be designed to meet OWRB requirements or the requirements set forth in this Chapter, whichever is stricter in terms of dam safety.

## 908.2 Grading

Grass slopes on earthen embankments shall be 4 horizontal to 1 vertical unless otherwise permitted by the CITY ENGINEER. Rip rap covered embankments shall not be steeper than 2:1. The minimum bottom slope in grassed detention facilities shall be 2.0 percent measured perpendicular to the trickle channel.

## 908.3 Freeboard

The embankment elevation shall provide one foot of freeboard as described in **Table 3-2**.

## 908.4 Trickle Channel

All grassed bottom detention ponds shall include a concrete trickle channel or equivalent performing materials design. Longitudinal slopes shall be no less than 0.5%.

## 908.5 Outlet Configuration

The outlet shall be designed to provide discharges from the pond that are equal to or less than pre-development discharges for the 50% (2-year), 20% (5-year), 10% (10-year), 2% (50-year), and 1% (100-year) flood events. Orifice or slotted weir configurations should be as large as possible to meet the design requirements. An emergency spillway shall be provided to pass the 0.2% (500-year) flood with the required freeboard. The crest elevation of the spillway shall be at or above the 1% (100-year) flood elevation in the facility. See **Figure 9-2** for a general outlet works schematic, **Figure 9-3** for examples of outlet structures, and **Figure 9-4** for orifice plate details.

### 908.6 Embankment Protection

Whenever a detention pond uses an embankment to contain water, the embankment, spillway crest, and spillway apron shall be protected from catastrophic failure due to overtopping.

### 908.7 Vegetation

All open space detention areas shall be planted with permanent Bermuda sod, native dry-land grasses, or other native plants that are compatible with the multi-use plan and irrigated as required until established.

### 908.8 Maintenance Access

All open space detention areas shall be bounded by an easement or dedicated ROW for the purposes of obtaining access from a public ROW and for maintenance activities. Maintenance access ramps shall be provided and constructed with a drivable slope no steeper than 10%. Porous type driving surface material is preferred.

## 909 DESIGN STANDARDS FOR PARKING LOT DETENTION

### 909.1 Depth

The maximum allowable design depth of the ponding is 18-inches for the 1% (100-year) flood and 9-inches for the 20% (5-year) flood to minimize the probability of significant vehicular damage.

### 909.2 Outlet Configuration

The minimum pipe size for the outlet is 18" diameter where a drop inlet is used to discharge to a storm sewer or drainage way. Where a weir or a small dimension outlet through a curb is used, the size and shape are dependent on the discharge/storage requirements. See **Figure 9-5** for a sample parking lot weir outlet configuration.

### 909.3 Performance

HEC-HMS (or other approved hydrologic modelling software) may be used to design the parking lot detention so that the 20% (5-year) flood depth is no greater than 9-inches and the 1% (100-year) flood depth is no greater than 18-inches. The outlet shall be designed so that there is no increase in off-site peak discharge.

To assure that the detention facility performs as designed, maintenance access shall be provided. The outlet shall be designed to minimize unauthorized modifications which effect function. Any repaving of the parking lot shall be evaluated for impact on volume and release rates and are subject to approval by the CITY ENGINEER prior to issuance.

### 909.4 Flood Hazard Warning

All parking lot detention areas shall have a minimum of two signs posted identifying the detention pond area. The signs shall have a minimum area of 1.5 square feet and contain the following message:

"WARNING"

"This area is a stormwater detention pond and is subject to periodic flooding to a depth of (“x” during a 1% (100-year) storm)."

Any suitable materials and geometry of the sign are permissible, subject to approval by the CITY ENGINEER.

## 910 DESIGN STANDARDS FOR UNDERGROUND DETENTION

The requirements for underground detention are as follows:

### 910.1 Materials

Underground detention shall be constructed using reinforced concrete pipe, reinforced concrete box culvert, concrete vaults, or other material as approved by the CITY ENGINEER. The material thickness, cover, bedding, and backfill shall be designed to withstand HS-20 loading.

### 910.2 Configuration

Pipe (storage) segments shall be sufficient in number, area, and length to provide the required minimum storage volume for the 1% (100-year) design. As an option, the 10% (10-year) design can be stored in the pipe segments and the difference for the 1% (100-year) stored above the pipe in an open space detention (Section 908) or in a parking lot detention (Section 909). The minimum diameter of the pipe segments shall be 36 inches.

The pipe segments shall be placed side by side and connected at both ends by a manifold system or an approved alternative (see **Figure 9-6**). The pipe segments shall be continuously sloped at a minimum of 0.25% to the outlet. Maintenance access points shall be provided on each line segment and near the outlet works to facilitate syseem cleanout (see Section 910.4) See **Figure 9-6** for a typical underground detention layout.

Permanent buildings or structures shall not be placed above the underground detention.

### 910.3 Inlet and Outlet Works

The outlet from the detention shall consist of a short (maximum 25 ft.) length(s) of RCP with an 18" minimum diameter. A two-pipe outlet may be required to control all design frequencies. The invert of the lowest outlet pipe shall be set at the lowest point in the detention pipes. The outlet pipe(s) shall discharge into a standard manhole or into a drainage way with erosion protection provided. If an orifice plate is required to control the release rates, the plate(s) shall be hinged to open into the detention pipes to facilitate back flushing of the outlet pipe(s).

Inlet to the detention pipes can be by way of surface inlets and/or by a local private storm sewer system.

### 910.4 Maintenance Access

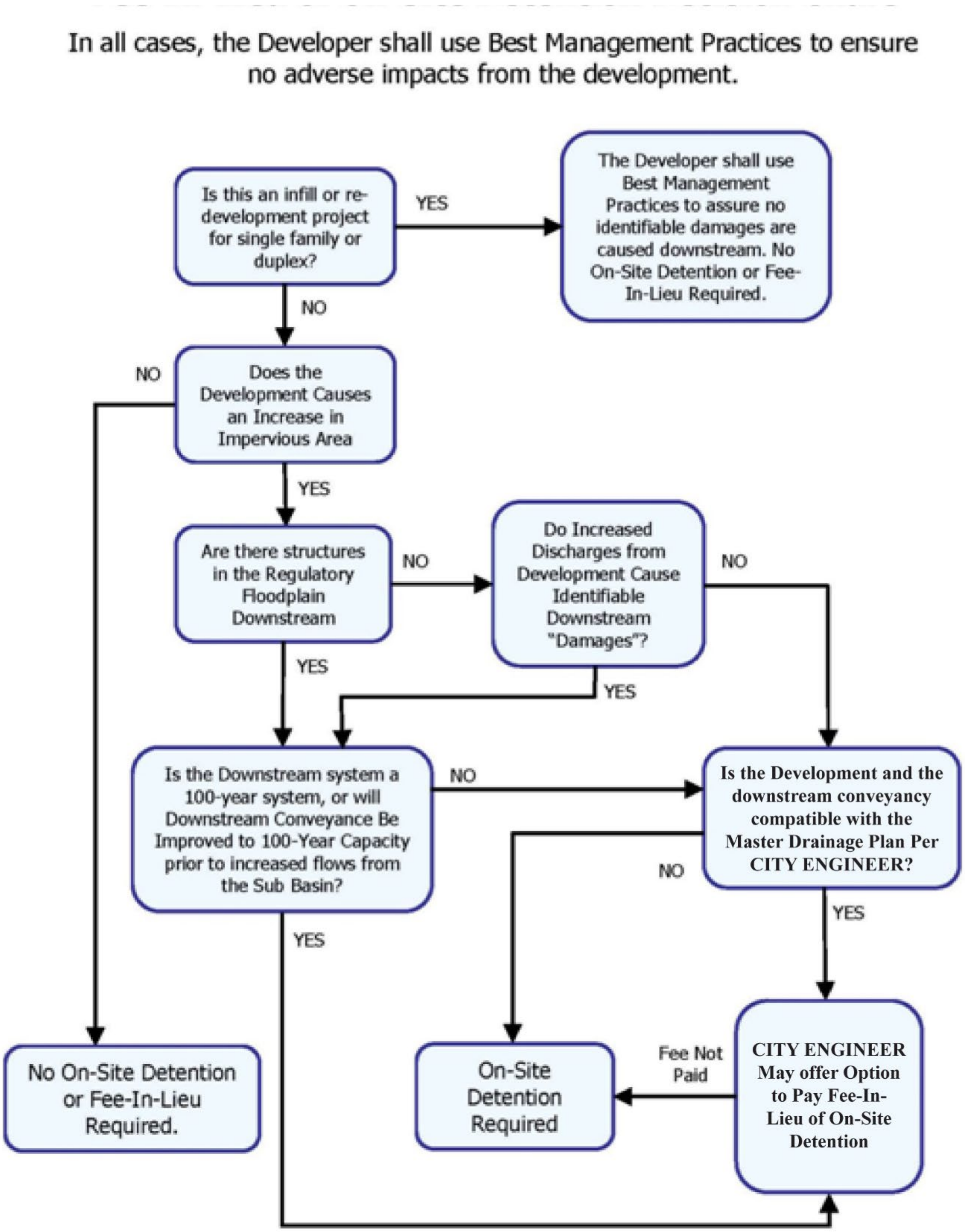
Access easements to the detention site shall be provided. To facilitate cleaning of the pipe segments, 30-inch diameter maintenance access ports shall be placed according to the following schedule:

**MAINTENANCE ACCESS REQUIREMENTS**

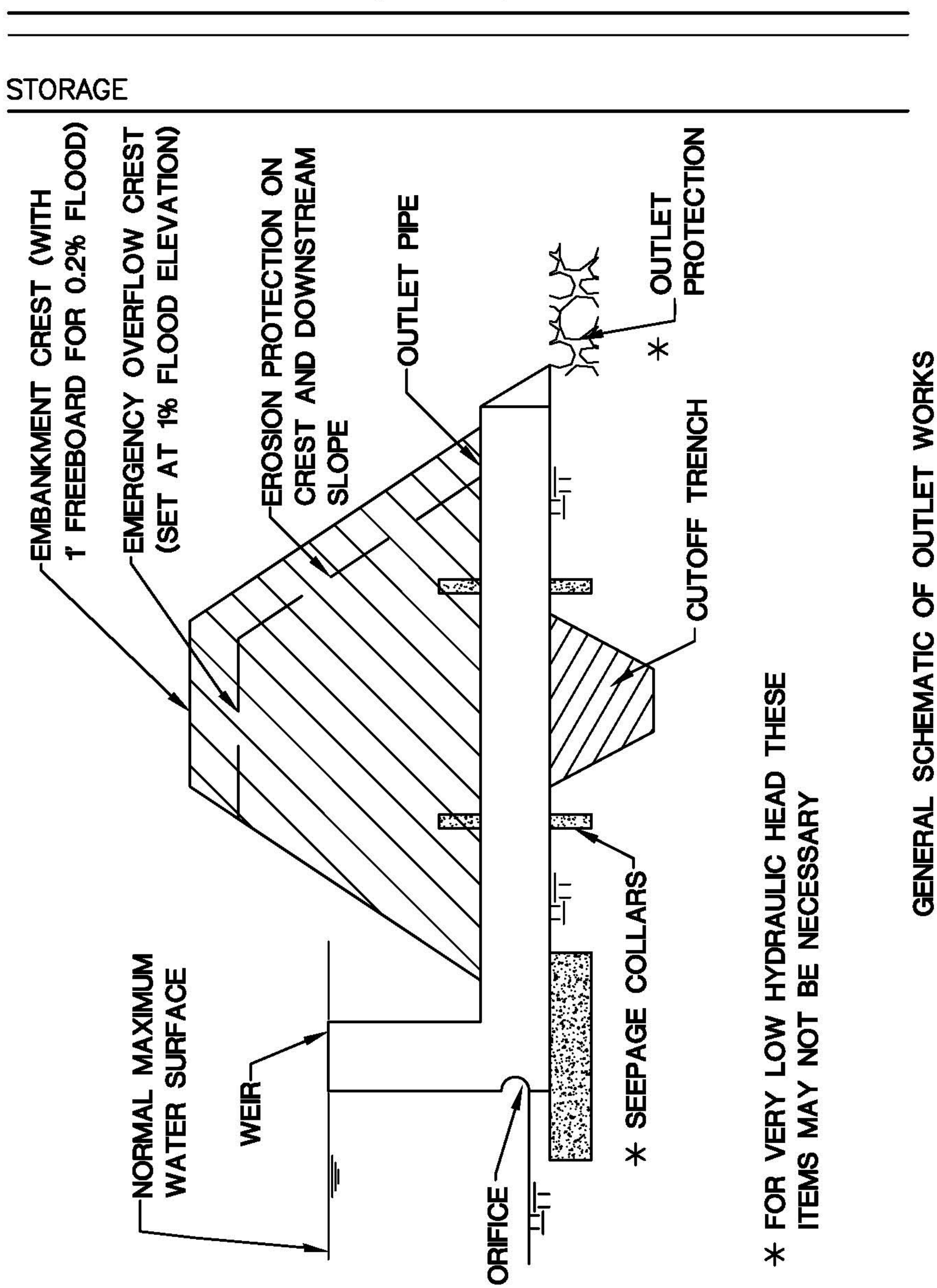
| DETENTION PIPE SIZE (INCHES) | MAXIMUM SPACING (FT) | MINIMUM FREQUENCY |
|---|---|---|
| 36 to 54 | 150 | Every pipe segment |
| 60 to 66 | 200 | Every other pipe segment |
| > 66 | 200 | One at each end of the battery of pipes |

The manholes shall be constructed in accordance with the detail on **Figure 9-6**.

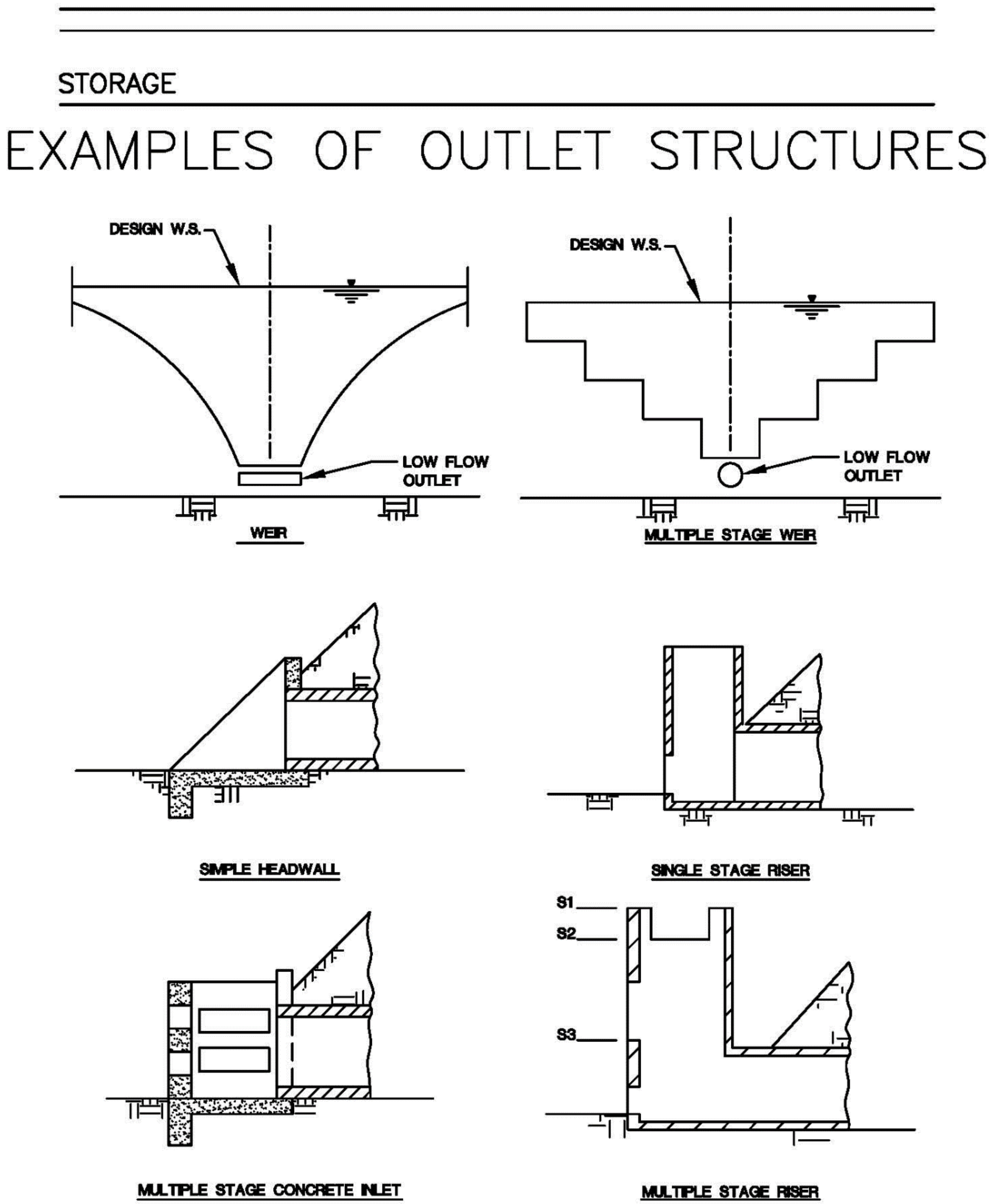
## FIGURE 9-1 - FEE-IN-LIEU OF ON-SITE DETENTION DECISION CHART



## FIGURE 9-2 - GENERAL SCHEMATIC OF OUTLET WORKS



## FIGURE 9-3 - EXAMPLES OF OUTLET STRUCTURES



## FIGURE 9-4 - ORIFICE PLATE DETAILS

STORAGE

ORIFICE PLATE DETAILS

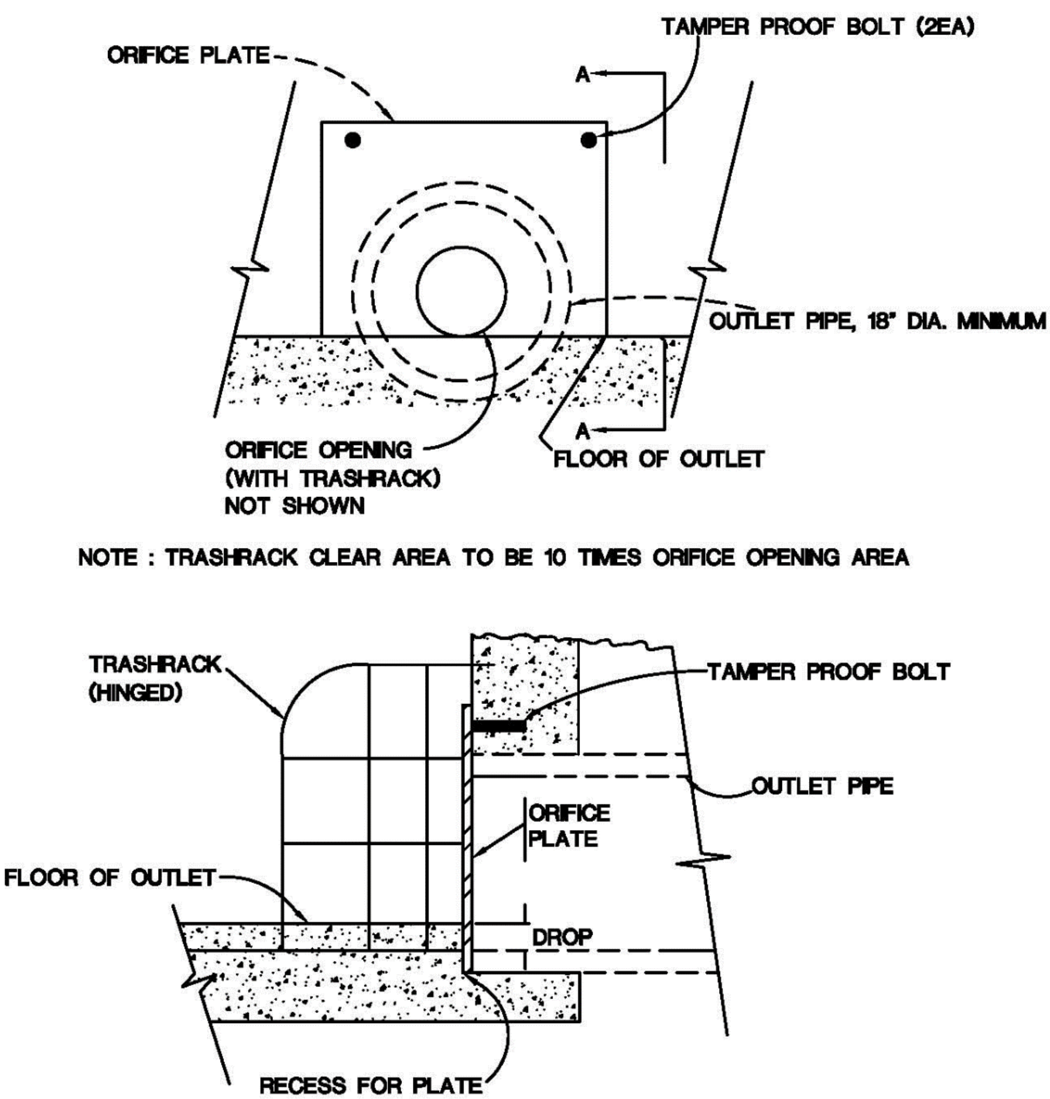
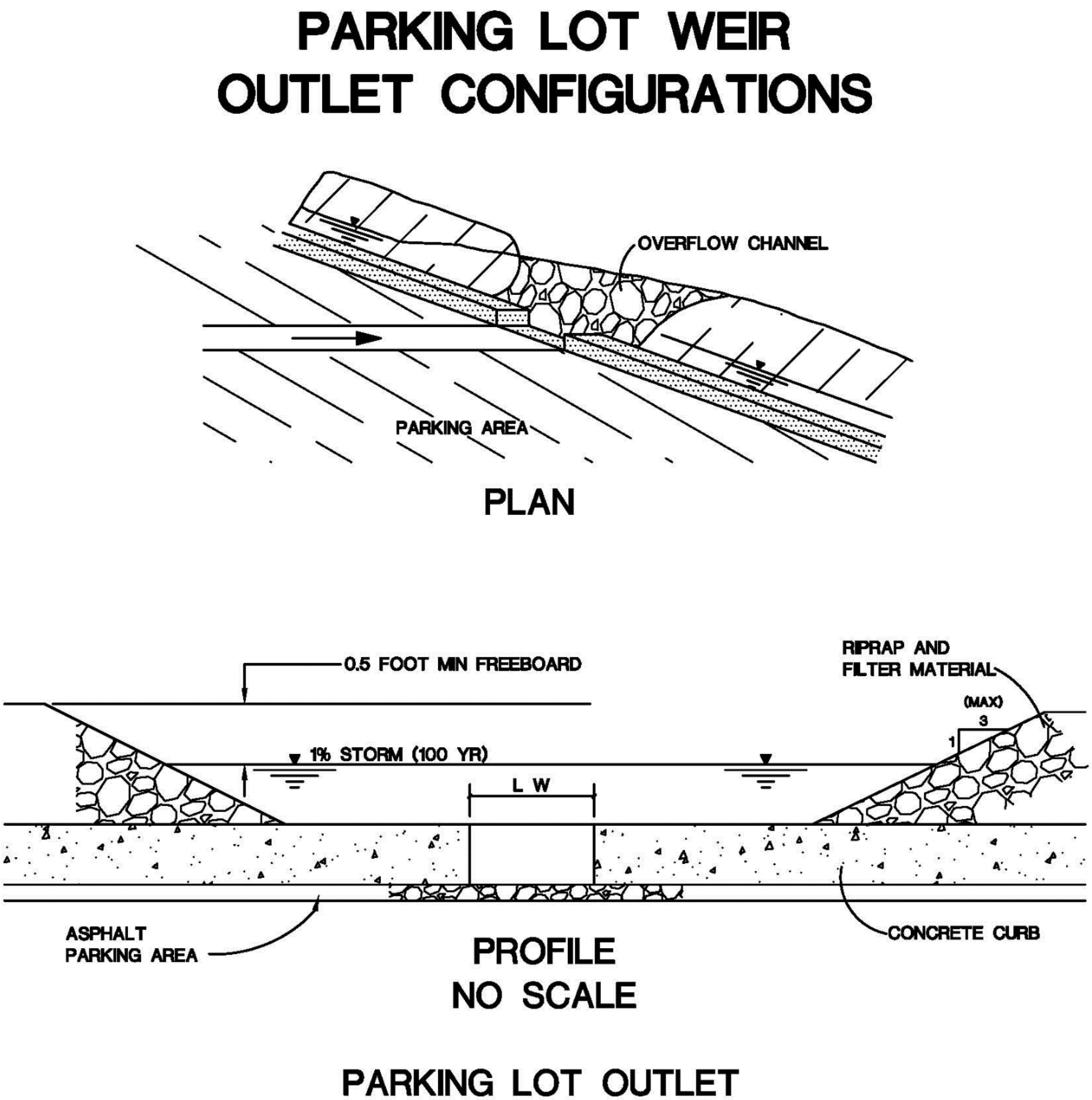
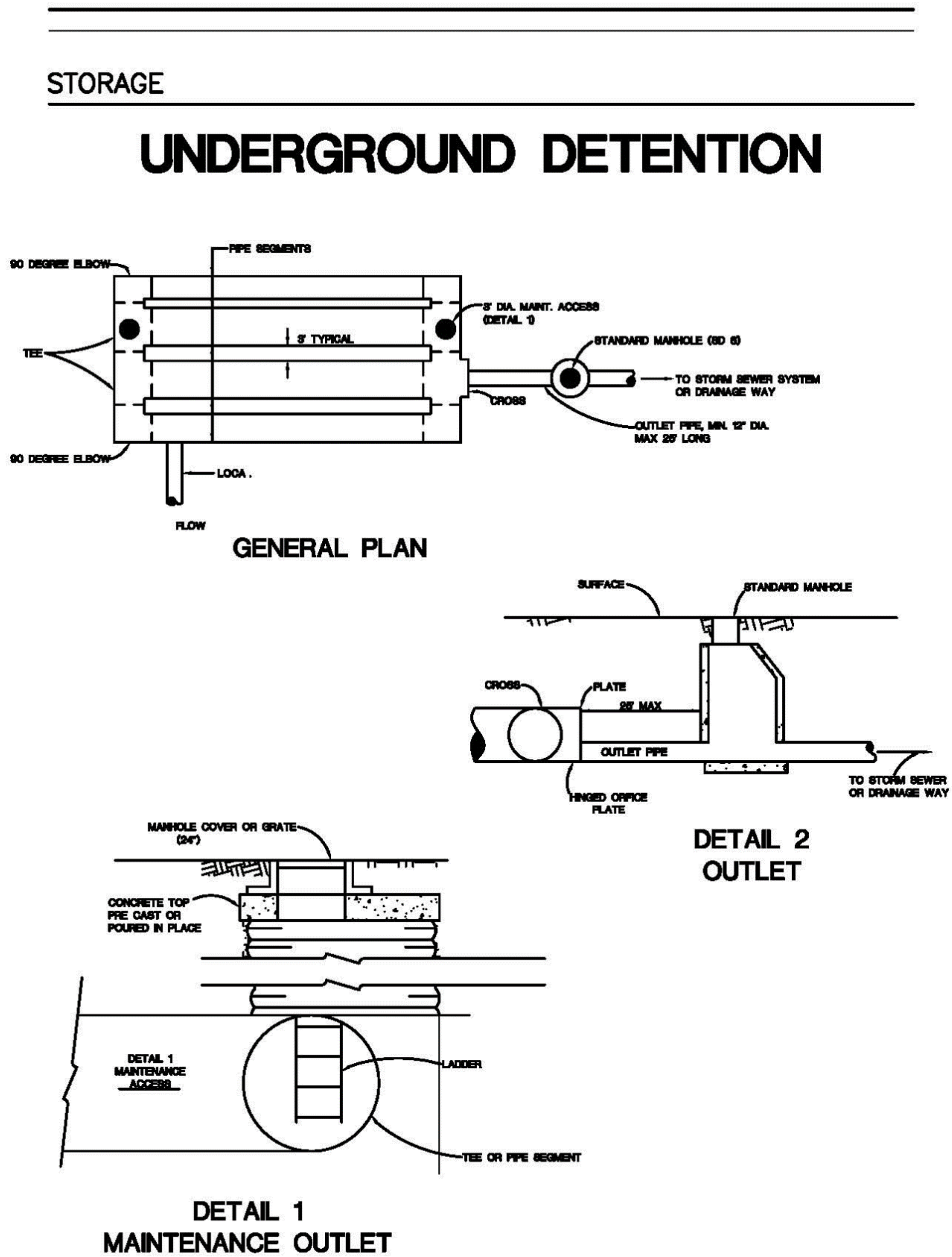


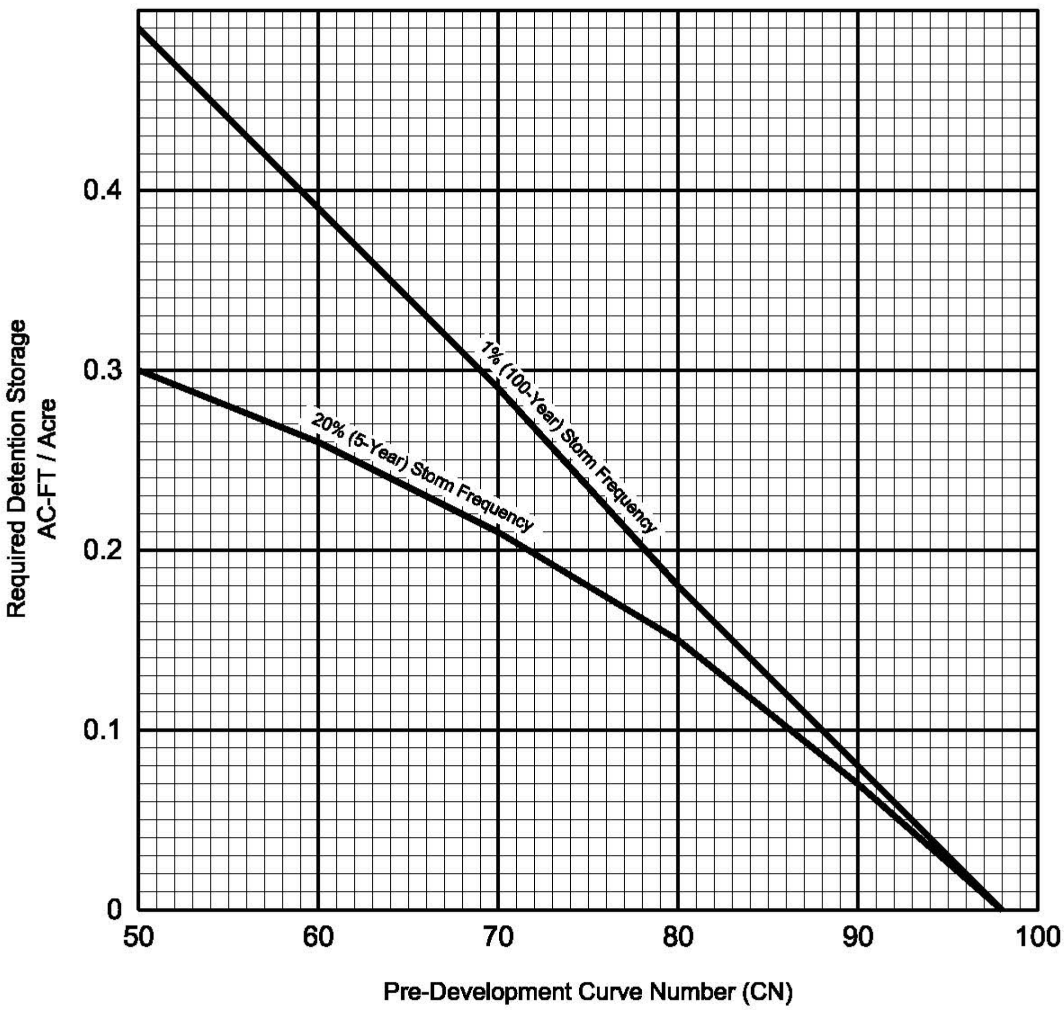
**FIGURE 9-5 - PARKING LOT WEIR OUTLET CONFIGURATIONS**



## FIGURE 9-6 - UNDERGROUND DETENTION



## FIGURE 9-7 - UNIT VOLUME DETENTION CURVES FOR PARKING LOT DETENTION




Equation for 1% (100-Year)

$$y = -0.0103x + 1.0069$$

Equation for 20% (5-Year)

$$y = -0.0000625x^2 + 0.0031x + 0.2999$$

Where:

$y$ = Required Storage (AF/Acre)
$x$ = Pre-Development CN

Note:

Outlet structure should be designed so that with-project discharge is not higher than pre-development conditions.

# Chapter 1000 CONSTRUCTION PHASE STORMWATER POLLUTION PREVENTION

## 1001 INTRODUCTION

The purpose of this chapter is to present background and information necessary to comply with federal and state laws and regulations regarding construction phase storm water pollution prevention and with the policies established by the CITY presented in this MANUAL. Information is provided regarding construction storm water pollution prevention along with references to the regulations, design methods, and design details.

## 1002 CONSTRUCTION PHASE STORM WATER POLLUTION PREVENTION

### 1002.1 Regulatory Basis

For construction sites, the Oklahoma Department of Environmental Quality (ODEQ) permitting process is conducted according to the rules established under the Oklahoma Pollution Discharge Elimination System (OPDES), as promulgated under Oklahoma Administrative Code (OAC) 252:605. Specifically, ODEQ regulates discharges associated with construction activities. Under Phase II, construction activities that disturb or plan to disturb **1 or more acres** must obtain a General permit for Construction Activities within the State of Oklahoma. This permit was issued to effect compliance with the Phase II Storm Water regulations issued December 8, 1999.

It is highly recommended that anyone conducting construction within the City of Tulsa read Title 11-A, Chapter 5 (Pollution Ordinance), prior to beginning any dirt moving activities.

### 1002.2 Activities Requiring a Stormwater Control Measures

Per City of Tulsa ORDINANCES, construction site operators for construction that will disturb soil of any area are required to implement and maintain site-specific storm water Best Management Practices (BMPs) to address erosion and sediment control for the duration of the project.

Construction disturbing greater than 1.0 acre of land, including disturbances less than 1.0 acres but within a planned development totaling greater than 1.0 acre, requires coverage under the OKR10 for Construction and must also have a Storm Water Pollution Prevention Plan (SWP3). For complete information on the OKR10 and to access the Addendums referred to in these sections, please refer to the ODEQ State Permit OKR10.

A copy of the SWP3 is required as part of land development submittals to the CITY. The CITY will review and approve SWP3s as part of the plan review process. A checklist summarizing the CITY's review criteria is available in the IDP manual.

### 1002.2.1 Timing of BMPs

Erosion and sediment control BMPs shall be initiated prior to construction soil disturbance and maintained throughout the construction process. Prior to soil disturbance, a construction site must pass a pre-construction erosion control (PCEC) inspection conducted by the CITY.

### 1002.2.2 Activities to be Completed

Steps to be completed under OKR10 for a Storm Water Permit for Construction Activities include:

A. Preparation of a Storm Water Pollution Prevention Plan
B. Filing a Notice of Intent with ODEQ
C. Payment of Permit Fees
D. Completion of Best Management Practices and Inspections
E. Update SWP3 as necessary
F. Filing a Notice of Termination

### 1002.2.3 Storm Water Pollution Prevention Plan (SWP3)

The initial step in obtaining a Storm Water Permit for Construction Activities is to develop a SWP3 according to ODEQ requirements. In general, the SWP3 will:

A. Identify potential sources of pollution that may reasonably be expected to affect the quality of storm water discharges from the construction site;
B. Describe Best Management Practices (BMPs) that will be used to divert flows from exposed soils, store flows, or otherwise limit runoff and the discharge of pollutants from exposed areas of the site, as well as non-structural practices that mitigate erosion and sediment movement; and,
C. Describe a program to assure compliance with the terms and conditions of your permit through monitoring and inspections.

A copy of the complete SWP3 must be submitted to the ODEQ for review if:

A. Any area of the construction site is located within the watershed of an Outstanding Resource Water (see Addendum F to OKR10). There are no Outstanding Resource Waters in the City of Tulsa.
B. Any area of the construction site is located within a sensitive water and watershed (see Addendum A to OKR10).
C. The area to be disturbed on the construction site is forty (40) acres or more.

A copy of the SWP3 and all related documents must be maintained on site at all times and updated as necessary, during construction. This SWP3 and all associated documents must be made available to the CITY upon request.

If the permittee is disturbing 1 acre of greater, a CITY Earth Change (EC) permit is required. In order to receive an EC, a copy of the SWP3 along with an executable NOI must be submitted to the CITY for review.

Steps to be completed under the CITY's Pollution Ordinance (Title 11-A, Chapter 5) include:

A. When the site is > 1 acres, insure the site has coverage under an OKR10.

B. Adequate BMPs are in place and maintained throughout the life of the project. BMP adequacy is defined in Title 11-A, Chapter 5, Section 505.

#### 1002.2.3.1 Notice of Intent (NOI)

Prior to initiation of construction activities requiring an OKR10 , the owner/operator must file a NOI with the ODEQ. An online NOI from ODEQ is available in Addendum B of OKR10. The NOI must be filed and authorization received from ODEQ prior to discharge of storm water from the construction activities. As stated in 1002.4.1, a copy of the NOI must be submitted to the CITY in order to receive and EC permit.

#### 1002.2.3.2 Notice of Termination (NOT)

The OKR10 permit will remain in effect until a NOT is filed with the ODEQ and the CITY. A NOT must be filed within thirty (30) days of the following events:

A. Final stabilization has been achieved on all portions of the site for which the permittee is responsible;
B. At residential sites: temporary stabilization has been completed and the residence has been transferred to the homeowner;
C. When another owner/operator has assumed control over all areas of the site that have not been finally stabilized. The NOT must be submitted with the new owner/operator's NOI.

#### 1002.2.3.3 Inspections

BMPs shall be inspected every 14 days or within 24 hours of a precipitation event greater than ½" inch by the construction site operator. If any visible sediment is observed to be leaving the site within 48 hours, any corrective actions taken must be documented in the SWP3. Maintenance needs for BMPs, including replacement or sediment removal, shall also be assessed during inspections.

### 1002.3 Best Management Practices for Construction Activities

Best Management Practices (BMPs) include structural and non-structural methods to prevent erosion and sediment from leaving the construction site through storm water runoff, tracking or wind-dispersion. A wide variety of BMPs are available for use on construction sites. A partial BMP list can be found at the City of Tulsa website.

It is the responsibility of the construction site operator to select, implement and maintain the proper BMPs for the site. Hydrologic and hydraulic analysis methodology used to size construction phase BMPs shall be consistent with guidance provided in other sections of this MANUAL. Sizing and selection of BMPs shall also be consistent with guidance provided in OKR10 and ensure compliance with Title 11-A, Chapter 5.

The list below is a summary of BMP's commonly used on construction sites:

A. Minimizing Disturbed Area. Minimize the amount of land stripped of vegetation and graded to reduce erosion. Undisturbed lands have their own natural soil erosion retardance that disturbed soils do not. Staging of construction areas is one of the more effective ways of keeping erosion from occurring, or at least reducing it significantly.
B. Controlling Erosion. Permanent or temporary soil surface stabilization must be applied to all disturbed areas and soil stockpiles as soon as possible but no later than 14 days after final grade is reached on any portion of the site. Temporary soil surface stabilization should also be applied as soon as possible, but no later than 14 days after disturbance, to disturbed areas that may not be at final grade but will remain unused temporarily. Numerous erosion control products are available. Selection is based on soil types, slopes, and areas of disturbance.
C. Temporary Revegetation. Temporary revegetation is required on all disturbed areas as soon as practicable, at most within 14 days, if the area is to remain dormant, or absent of further disturbance, and before final stabilization takes place. All temporary seeding shall be properly mulched.
D. Revegetation. Vegetation is not considered established until a ground cover is achieved which is equivalent to at least 70 percent of the pre-existing vegetation and is sufficiently mature to control soil erosion and can survive severe weather conditions.
E. Providing Surface Roughening. Surface roughening may be performed after final grading to create depressions two to four inches deep and four to six inches apart.
F. Stabilizing Roads and Soil Stockpiles. Road cuts, road fills and parking lot areas should be covered as early as possible with the appropriate aggregate base course where this is specified as part of the pavement. Seed and mulch or otherwise stabilize using soil binders all non-paved portions of roads as soon as possible after final grading has occurred, but in no case later than 14 days after grading has been completed.

   Seed and mulch soil stockpiles within 14 days after completion of stockpile establishment. Mulch without seeding is acceptable if expected to be in place 30 to 60 days. Seeding should be used if stockpile will be in place >60 days. If stockpiles are located within 100 feet of a waterway, additional sediment controls, such as diversion dikes or silt fences should be provided.

G. Minimizing Vehicle Tracking. Whenever construction vehicles enter onto paved roads, provisions must be made to prevent the transport of sediment (mud and dirt) by vehicles tracking onto the paved surface. Whenever sediment is transported onto a public road, regardless of the size of the site, at a minimum the roads shall be cleaned at the end of each day.

H. Providing Slope Diversion Dikes. Diversion dikes located above disturbed areas may be discharged to a permanent or temporary channel. Diversion dikes located midslope on a disturbed area must discharge through a sediment trap or basin to a temporary drain. Diversion dikes located at the base of a disturbed area must discharge to a sediment trap or basin.
I. Trapping Sediment. Sediment entrapment facilities include silt fences, wattles, silt dikes, silt socks, rock check dams, curb socks, and sediment basins/traps. Per OKR10, no straw bales will be allowed as BMP's. All runoff leaving a disturbed area shall pass through a sufficient number of sediment entrapment facilities to prevent sediment discharge from the site. The spacing and design of such devices is a function of device type, drainage areas, flow path lengths, soil types, and slopes.
J. Working Within or Crossing a Waterway. Construction vehicles shall be kept out of waterways to the maximum extent practicable. Where an actively-flowing watercourse must be crossed regularly by construction vehicles, a temporary stream crossing and/or channel diversion must be provided.
K. Protecting Outlets. The outlets of temporary slope drains, culverts, sediment traps and sediment basins must be protected from erosion and scour.
L. Protecting Inlets. All storm sewer inlets made operable during construction must have sediment entrapment facilities installed to prevent sediment-laden runoff from entering the inlet. All storm sewer inlets receiving inflow from disturbed site areas be protected from soil entry during construction.
M. Properly Storing Chemicals, Oils and Other Materials. Areas used for staging of construction activities and the storage of chemicals, petroleum-based products and waste materials, including solid and liquid waste, shall be designed to prevent discharge of pollutants in the runoff from a construction site.
N. Prevent Air-borne Dispersal. Air-borne dispersal of soil prior to stabilization should be prevented by wetting with water or other methods.
O. Disposal of Temporary Measures. All temporary erosion and sediment control measures shall be removed within 30 days after final stabilization is achieved, or after the temporary measures are no longer needed, whichever occurs earliest, or as authorized by the municipality or other local jurisdiction.
P. Maintaining BMPs. All temporary and permanent erosion and sediment control practices shall be maintained and repaired by the Permit Holder or Owner during the construction phase as needed to ensure continued performance of their intended function. All facilities must be inspected and replaced if necessary, following each precipitation or snowmelt event that results in runoff in excess of 0.5 inches.

### 1002.3.1.1 Selecting Storm Water Controls

The following guidelines are recommended in developing the site BMP's:

A. Define the layout of buildings and roads. This will have been decided previously as a part of the general development plan. If building layout is not final, the road areas stabilized with pavement and the drainage features related to roads should be defined as they relate to the plan.

B. Determine the limits of clearing and grading. If the entire site will not undergo excavation and grading, or excavation and grading will occur in stages, the boundaries of each cut-and-fill operation should be defined. Buffer strips of natural vegetation may be utilized as a control measure, if effective.
C. Determine on-site drainage areas. The size of drainage catchments will determine the types of sediment controls to be used. Areas located off the site that contribute overland flow runoff to the site must also be addressed. Measures to limit the size of upland overland flow areas, such as diversion dikes, may be initially considered at this stage.
D. Determine extent of temporary channel diversions. If permanent channel improvements are a part of the plan, the route, sizing and lining needed for temporary channel diversions should be determined. Location and type of temporary channel crossings can be assessed.
E. Determine permanent drainage features. The location of permanent channels, storm sewers, roadside swales and post-construction storm water controls such as ponds, wetlands, bioswales, or rain gardens, if known, should be defined.
F. Select erosion controls. All areas of exposed soil will require a control measure be defined dependent on the duration of exposure. These can be selected based on the schedule of construction.
G. Select sediment controls. Select the controls needed for each phase of the construction project. Each phase will have different demands for the control of erosion and sedimentation. For example, overlot grading will require controls that may be of little use when individual homes are being built and each lot is being disturbed after the streets and drainage systems are in place.
H. Determine staging of construction. The schedule of construction will determine what areas must be disturbed at various stages throughout the development plan. The opportunity for staging cut-and-fill operations to minimize the period of exposure of soils needs to be assessed and then incorporated into the final SWP3, at which time the initial sequence for installing sediment controls and erosion controls is defined.
I. Identify locations of topsoil stockpiles. Areas for storing topsoil should be determined and then proper measures to control their erosion and sediment movement off these sites specified.
J. Identify location of temporary construction roads, vehicle tracking controls, and material storage areas. These three elements can be determined in the context of previously defined parts of the site construction management plan.

# Chapter 1100 LOW IMPACT DEVELOPMENT

## 1101 INTRODUCTION

The CITY, in conjunction with Oklahoma State University and the University of Oklahoma, is developing a Low Impact Development Design Criteria Manual, hereafter referred to as the LID Manual. The purpose of the manual is to present background and information necessary to comply with federal and state laws and regulations regarding post-construction storm water pollution prevention and with the policies established by the CITY presented in this MANUAL. Information is provided regarding post-construction storm water pollution prevention along with references to the regulations, design methods, and design details.

LID Manual chapter to be added by future amendment & resolution

# Chapter 1200 MAINTENANCE AND DESIGN

## 1201 INTRODUCTION

Drainage facility maintenance involves many different functions, including: organization, operational requirements, financing, identification of responsibility, problem identification and determining the frequency of activities. In addition, the maintenance staff can provide valuable input to the design of drainage facilities. Whereas all of these functions are part of the Maintenance Division of the City, this chapter will focus primarily on the design considerations as they relate to the maintenance goals and objectives.

## 1202 POLICY

The City of Tulsa Revised ORDINANCES, Title 11-A, Stormwater Drainage identifies the following finding of fact:

> **"The presently existing storm water drainage facilities of the City of Tulsa require continuous operation, maintenance, renewal and replacement."**

Recognizing the importance of drainage facility operations, maintenance, renewal and replacement, the City established policies regarding maintenance. These policies are delineated in this MANUAL in Chapter 300, Section 304.2 "Operations and Maintenance".

## 1203 GOALS AND OBJECTIVES

The City has established the following goals and objectives regarding the design of drainage facilities with maintenance activities in mind:

### 1203.1 Minimize the cost of maintenance activities by:

A. Providing input to the planning and design review to identify requirements that facilitate maintenance activities.

B. Participating in construction progress meetings to assure that maintenance design features are properly constructed.

C. Reducing life cycle costs through timely maintenance activities.

### 1203.2 Maintain and enhance aesthetic benefits of drainage ways by

A. Including design aspects that promote multiple uses of drainage ways
.

B. Providing access for maintenance.

# 1204 CITY MAINTENANCE ACTIVITIES

The City mainly engages in two types of maintenance activities; routine (or preventative) and remedial maintenance. Routine activities include facility cleaning, mowing, application of herbicides and pesticides and other regular maintenance.

Remedial activities include inlet and manhole installation and repair, repair of storm sewers, minor reconstruction of ditches and channels, erosion control and mechanized channel cleaning. Remedial activities also include the maintenance of all detention pond outlet works.

A major portion of the maintenance budget is allocated to mowing. Currently, the City has the following categories for mowing of detention areas and channels:

A. No mowing of natural channels.
B. Four times per year.
C. Once a month for four months during the 7-month growing season.
D. Once every two weeks during the 7-month growing season.
E. Special circumstances such as parks.

The City prefers a mowing standard of once every two weeks during the growing period, subject to budget constraints. This schedule appears to provide the best services.

# 1205 DESIGN CRITERIA THAT FACILITATES MAINTENANCE ACTIVITIES

Presented in this section are the design criteria that have been incorporated into the City standards through this MANUAL in order to facilitate maintenance activities. These measures will serve to minimize the maintenance requirements, not eliminate the need.

## 1205.1 Open Channel Systems

Many design aspects must be addressed in an open channel drainage system to facilitate maintenance activities. These design aspects affect channels, bridges, check drops and storm sewer outlets and include:

A. Access.
B. Side slope protection.
C. Trickle channels.
D. Erosion control.
E. Vandalism control.
F. Control of concentrated flow along the channel edge.

To assure that these design aspects are included in the open channel system, specific criteria have been identified. These criteria are discussed below.

### 1205.1.1 Access

Vehicle access is important to the maintenance of the drainage system.

A. Ramps paralleling the system are required.
B. Where access ramps/roads intersect a public ROW, traffic control barriers are required to prevent unofficial vehicle access, while still allowing for pedestrian access.
C. Legal access shall be assured by showing all easements and ROW's for drainage on the recorded Final Plats and Final Development Plans (Policy Section 304.2.5).
D. The easement shall be defined to minimize obstructions to maintenance activities.

### 1205.1.2 Channel Side Slopes

Grass lined channel side slopes shall be flat enough (4:1 maximum) to allow for cost effective mowing of the grass/sod and general clean-up activities. This slope also provides adequate stability for installation of temporary erosion control measures to allow for vegetative growth.

### 1205.1.3 Trickle Channel

Trickle channels (see Standard Detail 782 and Section 703.7) are required for all grass lined channels to minimize the bed erosion from routine base flows and frequent, minor storms. Trickle channels also provide better access to the channel bottom for mowing operations by providing a controlled path for local groundwater flow which minimizes the area of saturated soils.

In some cases, a trickle channel may not be consistent with the Corps of Engineers Section 404 Permit or CITY's Municipal Separate Storm Sewer System OPDES Permit.

### 1205.1.4 Erosion

There are three design considerations for erosion:

### 1205.1.5 Maximum velocity limitations

Depending on the channel liner material, maximum velocity limitations are imposed in the standards (see Sections 703.1 through 703.7) to minimize general erosion.

### 1205.1.6 Localized turbulence

The following discussion covers the most likely location where localized turbulence may occur, and the mitigation requirements:

A. Transitions from culverts/bridges to an open channel. Standards for culvert and bridge transitions (Section 704.2) require riprap protection (or other suitable materials) or a separate stilling basin to minimize erosion.

B. Transitions in the channel cross section. Channel transitions are to be evaluated using a backwater analysis (Section 702) and additional protection is required when problems are identified.
C. Changes in the flow direction at the outside of curves in the horizontal alignment. These should also be evaluated using a backwater analysis (Section 702) and additional protection is required when problems are identified.
D. Outlets of storm sewers into the channel, including the opposite bank. Storm sewer outlets must include headwalls, flared end section, riprap, stilling basin or other erosion protection method. Banks opposite the sewer outlet must also include erosion protection, when the channels are small.
E. Downstream of check drops. The design of the check drops includes a stilling basin for protection (Section 702.7).

#### 1205.1.7 **Protection of the toe of slope**

Protection of the toe of the channel slope is provided by trickle channels (Section 703.2). Where trickle channels are not provided, additional protection at the toe, such as riprap, should be considered by the designer.

#### 1205.1.8 **Vandalism**

Vandalism can be minimized by:

A. A chain link fence is required for concrete channel safety and also minimizes access to the channel to minimize vandalism.
B. Use of the riprap for channel protection (Section 703) includes the recommendation to bury the smaller gradation sizes to minimize vandalism.
C. By grouting the riprap (Section 703.4), both vandalism and general silt/trash accumulations are minimized.

#### 1205.1.9 **Concentrated Surface Flow into Channel**

Concentrated surface flow into channels shall be collected in an appropriate drop inlet and conveyed to the channel flowline via a storm sewer line.

### 1205.2 **Storm Sewer Systems**

Facilities included in the storm sewer system include inlets, storm sewers, manholes, junction structures and curb/gutters. In addition to reducing the land area requirements, storm sewers can also reduce the maintenance costs of the drainage system. The minimum size for storm sewers (Chapter 806) has been established, in part, for maintenance purposes.

### 1205.2.1 Access

Access to the storm sewer is required (Policy Section 304.2) for both routine maintenance and rehabilitative maintenance. For sewers in a public ROW, the access is adequate. For sewers not in public ROW's an easement is required. The access must be contiguous with a public ROW.

A. For routine maintenance, a minimum width of 15 feet is required.
B. For rehabilitative maintenance, the easement width requirements for sewers not within public ROW's (see Section 304.2.5) is dependent on the area required to either repair the sewer internally or remove and replace the sewer.

### 1205.2.2 Manholes

Manholes are required at frequent intervals, depending on the pipe size (Chapter 800) to allow for inspection, routine and rehabilitative maintenance.

A. The invert of the manhole is shaped with a smooth transition to contain base flows and to allow for maintenance activities.
B. For multi-barrel installations, access to each barrel is required.
C. Manhole access shall be provided through a 26" diameter standard manhole lid and frame.
D. The opening is to be located directly over the ladder rungs using an eccentric pre-cast cone section, or offset opening in a flat top manhole.

### 1205.2.3 Pipe Material and Alignment

The criteria for the selection of allowable storm sewer materials (Section 806.2) are based in part on a minimum life span of 50-years. Other criteria of Section 806.2 were specified to address the potential abrasion of the invert area of the pipe.

A. Storm sewers must be placed with a straight grade between manholes (Section 806.2) to prevent sediment from collecting in a low portion and clogging the pipe.
B. The pulled joint method for constructing sewers on curves is not permitted, due to the potential for the joints to leak into the subgrade and cause structural problems.
C. Curvilinear pipe is not allowed.

### 1205.2.4 Flow Velocity

The size and slope of the storm sewer is selected to provide a minimum flow velocity of 2.5 feet per second to minimize the deposition of silt and sediment. The velocity is calculated for the 50% (2-year) frequency discharge.

### 1205.2.5 Inlet Types and Spacing

The maximum spacing recommendations for inlets (Section 803.3) is based on the increased economic efficiency achieved by optimizing the amount of flow intercepted versus the number of inlets. However, the spacing also minimizes the amount of flow in the streets, which reduces the damage to the pavement and therefore the street maintenance requirements.

#### 1205.2.6 Streets and Parking Lots

The maximum allowable depth of flow in the gutter shall not exceed the top of curb (Section 305.5).

Where roadside ditches are utilized, the recommended longitudinal and side slopes minimize the erosion and sedimentation maintenance (Section 703.7).

Before discharging the runoff from a parking lot to the street, the flow must be first collected in a storm sewer. This minimizes the surface flow in the street and therefore street maintenance requirements.

#### 1205.2.7 Record Drawings

The requirement for documentation of the actual construction conditions by record drawings (Section 505) will provide the necessary information to address routine and rehabilitative maintenance problems.

### 1205.3 Stormwater Detention Systems

Facilities included in the stormwater detention system include embankments, spillways, outlet works, wet pond perimeters and dry pond bottom areas. Because detention ponds are often multi-purpose, the maintenance of the facility for aesthetic reasons becomes more important.

#### 1205.3.1 Embankments

The maximum allowable embankment slope presented in Section 908 is required for embankment stability, ease of mowing, access for repairs and general overall appearance. The blanket easement required around the detention (Sections 304.2 and 908.8) is to provide for maintenance access to the entire site. A ramp up the embankment may be required for access.

#### 1205.3.2 Spillways

The main function of a spillway is to provide embankment protection by allowing a specified design flood to pass without serious damage to the structure. To minimize the damage to the spillway during operation, an earth embankment spillway is typically provided with:

A. A concrete weir control wall to check erosion, and
B. Riprap or other protection along the outlet channel to minimize the erosion from high velocity discharge.
C. Vegetated slopes should not be steeper than 4:1 for ease of mowing.
D. Entrance channels to spillways should be protected from clogging by appropriate debris structures placed upstream of the spillway inlet channel.

### 1205.3.3 Outlet Works and Trash Racks

The outlet works should be designed with a trash rack covering the entire entrance area to the low flow opening. The clear opening area of the trash rack should be at least 3 times the cross sectional area of the outlet works to allow for some clogging without substantially increasing the flow velocity through the rack and therefore the head losses for the outlet works.

### 1205.3.4 Bottom Areas

Detention ponds are natural sediment traps, which is the reason that detention is a Best Management Practice for control of urban runoff (See Chapter 1000). However, access must be provided to the bottom to allow for removal and proper disposal of the accumulated sediments and other pollutants such as heavy metals and nutrients. The type of surface and location of the access is to be approved by the City. The maintenance division shall be consulted during design.

For dry ponds,

A. The bottom may serve as a multi-purpose function for recreation and therefore must be re-vegetated and a trickle channel provided to prevent a bog from forming.
B. Trickle channels are required for the pond tributaries to prevent local erosion.
C. A two (2) percent cross slope of the pond bottom is the minimum to keep the bottom well drained (Section 908).
D. Under-drains can also be used to keep the bottom dry for multi-purpose uses, but they have been shown to clog and require extensive maintenance to keep them operational.

For wet ponds,

A. The bottom area will normally be inundated.
B. If the pond is designed for water quality purposes (Chapter 1000), the perimeter may be such that wetland growth is established and special maintenance activities are necessary (Section 908).
C. If the pond does not include wetland growth and the facility is multi-purpose, then protection of the perimeter area from wave erosion is recommended.
D. This protection can be a hardened slope or wall constructed from rock, concrete or other materials around the perimeter. This also provides a definitive edge for mowing purposes.

### 1205.3.5 Record Drawings

The requirement for documentation of the actual construction conditions by record drawings (Section 505) will provide the necessary information to address routine and rehabilitative maintenance problems.

### 1205.3.6 Maintenance Manual

When a detention area is included in the development plan, the designer must include a manual identifying the maintenance activities and the frequency required. The designer must also consider the need for aerators in wet ponds.

## 1205.4 Natural Channels

The maintenance requirements for natural channels are a special case in open channel systems. Typically, natural channels will have only a few structures, such as erosion check structures or localized bank stabilization. Maintenance design for these structures would be the same as for open channel systems (Section 703.1).

Vehicle access, along an all-weather maintenance trail, and an overland drainage easement shall be provided to all areas of natural channels.

## 1205.5 Wetlands Areas

The use of wetlands for treatment of urban runoff water quality has been shown to be effective (Chapter 1000). However, wetlands in an urban environment become an additional maintenance burden for the City and steps must be taken to minimize the maintenance costs. Maintenance design of wetlands must address the following:

A. Removal and disposal of dead leafy vegetation.
B. Requirement for constant flow movement to prevent stagnation.
C. Suitable access.
D. Rodent and algae control.
E. Replacement of woody vegetation such as willows, cyprus, pecan, river birch, sycamore and other trees.

When a wetland area is included in the development plan, the designer must include a manual identifying the maintenance activities and the frequency required. The designer must also consider the need for suitable flow of water to maintain the wetlands plan species.

# Chapter 1300 GLOSSARY

## 1301 ENGINEERING AND RELATED TERMS

### 1301.1 Definitions

The definitions set forth in this Glossary are for general use in this MANUAL to provide a universal understanding of the text. Certain specialized definitions are defined in each individual chapter where they apply.

ADMINISTRATOR: For the purposes of this MANUAL the terms "ADMINISTRATOR" and "CITY ENGINEER" are somewhat interchangeable. It shall be the duty of the Floodplain Administrator (ADMINISTRATOR) or his or her designee to enforce the provisions of this MANUAL for all projects that are submitted for approval to the Development Services Division. It shall be the duty of the Director of Engineering Services Department (CITY ENGINEER) or his or her designee to enforce the provisions of this MANUAL for all other projects that are submitted to the CITY for approval.

Alternate Depths: For a given rate of flow and a given specific head two depths of flow are possible, one lower than critical and one higher than critical. These are known as alternate depths. See also Critical Depth.

Appurtenances to Sewers and Drains: Structures, devices, and appliances, other than pipe or conduit, which are an integral part of a stormwater drainage system, such as manholes, storm water inlets, drop structures, detention storage facilities, etc.,

Applicant: A person, partnership, corporation, or public agency requesting permission to engage in construction.

Apron: A floor or lining of concrete, or other suitable material at the upstream or downstream end of a Reinforced Box Culvert or Reinforced Concrete Pipe, at the discharge side of a spillway, a chute, or other discharge structure, to protect the waterway from erosion, from falling water or turbulent flow.

Backfill: (1) The operation of filling an excavation after it has once been made, usually after some structure has been placed therein and (2) the material placed in an excavation in the process of backfilling.

Backwater: The water retarded above a dam, bridge, or culvert or backed up into a tributary by a flood in the main stream. In this Manual, backwater is also defined as the rise in the flood water surface due to the restrictions created by the construction of a bridge.

Backwater Profile: The term applied to the longitudinal profile of the water surface in an open channel.

Baffle Chute: Deflector vanes, guides, grids, gratings, or similar devices constructed or placed in flowing water, to: (1) check or effect a more uniform distribution of velocities; (2) absorb energy; (3) divert, guide, or agitate the liquids; and (4) check eddy currents.

Berm: A horizontal strip or shelf built into an embankment or cut, to break the continuity of an otherwise long slope, usually for the purpose of reducing erosion, improving stability, or to increase the thickness or width of cross section of an embankment.

Bridge: A hydraulic structure that is constructed with abutments and superstructures which are typically concrete, steel, or other materials, or a culvert or culverts with a clear opening of 20 feet in width or more. Bridges are generally constructed with earth or rock inverts. Since the superstructures are not an integral part of the abutments and could therefore potentially move, the hydraulic criteria for bridges are different than for culverts.

Bypass Flow: The quantity of water which continues past an inlet.

Carry Over Flow: The quantity of water which continues past an inlet.

Catch Basin: A basin combined with a storm sewer inlet to trap solids.

Catchment Area: See Drainage Area.

Channel: (1) A natural or artificial watercourse of perceptible extent which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a definite bed and banks which serve to confine the water. Also see Watercourse.

Channel Storage: The volume of water stored in a channel during a rainfall event. Generally considered in the attenuation of the peak of a flood hydrograph moving downstream.

Check Drop: A structure of concrete, rock or other materials used to flatten the grade of a channel to reduce erosion tendencies of the flow.

Chute: An inclined conduit or structure used for conveying water at a high elevation to lower levels. For vertical structures see Drop.

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Coefficient of Roughness "n": A factor in the Manning formula, for computing the average velocity of flow of water in a watercourse or conduit, which represents the effect of roughness of the confining material of the watercourse or conduit upon the energy losses in the flowing water.

Construction: Any alteration of land for the purpose of achieving its development or changed use, including particularly any preparation for, building of, or erection of a drainage structure.

Construction Plans: Drawings depicting the construction details of the City approved drainage facilities required for development.

Control: (1) A section or reach, either natural or artificially created, of an open conduit or stream channel where conditions exist, such as the existence of a dam or a stretch of rapids, that make the water level above it a fairly stable index, at some or all stages, of the discharge. Controls may be complete or partial. Complete control exists where the elevation of the water surface above the control is entirely independent of fluctuations of water level downstream from it. Partial control exists where downstream fluctuations have some effect upon upstream water levels. (2) The cross section in a waterway which restricts a given rate of flow and which determines the energy head required to produce the flow. In the case of open channels, it is the point where the flow is at critical depth, hydraulic conditions above the point being wholly dependent upon the characteristics of the control section and entirely independent of hydraulic conditions below the point. In the case of closed conduits, it is the point where the hydrostatic pressure in the conduit and cross sectional area of flow are definitely fixed, except where the flow is limited at some other point by a hydrostatic pressure equal to the greatest vacuum that can be maintained unbroken at that point.

Control Crest: A moveable device on the crest of the spillway of a dam, which raises or lowers the water surface behind the dam. The device may consist of temporary or permanent flash boards, a drum or tilting gate, or a bear-trap crest.

Course (of a stream): The path taken for passage of water.

Critical Depth: The particular depth of flow in an open channel with a given discharge at which the specific energy is at a minimum; i.e., the depth at which a given discharge flows in a given channel with a minimum specific energy. The given discharge may flow at an alternate depth above or below critical in the given channel but the specific energy of the flow at either alternate depth will be greater than for the flow at critical depth.

Critical Flow: Flow at critical depth.

Cross-Street Flow: Flow across the traffic lanes of a street, as distinguished from sheet flow of water falling on the pavement surface.

Culvert: A closed conduit for the passage of water under an embankment, such as a road, railroad or trail. A culvert is distinguished from a storm sewer in the following manner: flow generally enters a culvert by an open channel, generally at a similar elevation, while flow generally enters a storm sewer by means of storm inlets above the sewer; the geometry of the culvert inlet plays a major role in determining the required size or capacity of the culvert, whereas the capacity of a storm sewer is generally determined by the slope of the sewer; a culvert generally crosses under a road, railroad or trail, while a storm sewer generally follows the street alignment.

Box Culvert: Generally a rectangular or square concrete structure for carrying large amounts of water under a roadway. This term is sometimes applied to long underground conduits.

Dam: A barrier constructed across a watercourse for the purpose of creating a temporary or permanent reservoir.

Datum: A plane, level or line from which heights and depths are calculated or measured.

Debris Basin: A basin formed behind a low dam, or an excavation in a stream channel, to trap debris or bed load carried by a stream. The value of a basin depends on cleaning-out of debris periodically to restore its capacity.

Department: The City of Tulsa Engineering Services Department.

Stormwater Detention: A temporary storage of a determined quantity of storm water runoff for a specified period of time with a release rate that is either fixed or variable, the purpose being to attenuate the peak of the inflow hydrograph.

Developer: Any person, persons, corporation, or other entity who in his or her own behalf, or as an agent of another, engages in development, subdivision, construction of structures, or alteration of land in preparation therefore.

Development: Any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, berming, diking, excavating, or drilling operations.

Discharge: The flow of water from a pipe or from a drainage basin. If the discharge occurs in some course or channel, it is correct to speak of the discharge of a stream or river.

Diversion: In hydrologic modeling, the flow rate that is removed from the drainage system at a certain point, usually to be returned to the system at a downstream point. As in the water diverted from the overland flow by a storm sewer.

Drainage: A general term applied to the removal of surface or sub-surface water from a given area. The term is commonly applied herein to surface water.

Drainage Area: The geographical area drained by a river and its tributaries; an area characterized by all runoff being conveyed to the same outlet Also called Catchment Area, Watershed, Drainage Basin, and River basin.

Drainage System: The surface and subsurface system for the removal of water from the land, including both the natural elements of streams, marshes, swales, and ponds whether of an intermittent or continuous nature, and the man-made element which includes culverts, ditches, channels, retention facilities, detention facilities, gutters, streets, and storm sewer systems.

Drainageway: A route or watercourse along which water moves or may move to drain an area.

Drawdown Curve: The longitudinal profile at the water surface of an open channel as it accelerates through supercritical flow, such as weir flow over a dam.

Drop Inlet Culvert: A culvert installed with a drop inlet on one end that exits at the other end through a headwall.

Drop Structures: A structure of concrete, rock or other materials used to flatten the grade of a channel to reduce erosion tendencies of the flow.

Easement: Land set aside for the limited use of another's adjacent property.

Energy Gradient: The total energy level of water at all points along a longitudinal line. It is the sum of velocity head, pressure head and elevation of a flowing body of water.

Environmental Design: Designing projects with a plan for the total environment. It is the process of addressing surrounding environmental constraints and opportunities.

Erosion: Wearing away of the lands by running water and waves, abrasion and transportation.

Drainage Facilities: Any drainage and/or flood control structure including but not limited to storm inlets, storm sewers, manholes, junction boxes, outlet structures, channels, erosion control structures and devices, culverts, bridges, dams and detention reservoirs.

Flood: Water from a river, stream, watercourse, ocean, lake, or other body of standing water that temporarily overflows or inundates adjacent lands and which may affect other lands and activities through stage elevation, backwater and/or increased ground water level.

a. Base Flood: The 100-year flood.

b. Design Flood: The 100-year flood.

c. Flash Flood: A flood of short duration with a relatively high peak rate of flow, usually resulting from a high intensity rainfall over a small area.

d. Maximum Probable Flood: The largest momentary flood discharge believed possible from a consideration of meteorological conditions in the watershed.

e. Standard Project Flood (Corps of Engineers): Flood which may be expected from the most severe combination of meteorological, hydrologic and/or tidal conditions that are considered reasonably characteristic of the geographic area under specific consideration, excluding extremely rare combinations.

Flood Control: The elimination or reduction of flood losses by the construction of flood storage reservoirs, channel improvements, dikes and levees, by-pass channels, or other engineering works. Sometimes called the structural alternate.

Flood Frequency: The chance of occurrence each year of a flood expressed as a percent or in years. For example, a 100 year flood has a 1 percent chance of occurrence each year and a 50 year flood has a 2 percent chance of occurrence each year.

Floodplain: The relatively flat or lowland area adjoining a river, stream, watercourse, lake, or other body of standing water which has been or may be covered temporarily by flood water. For administrative purposes, the floodplain may be defined as the area that would be inundated by the regulatory flood.

Floodplain Fringe: That portion of the floodplain that lies between the regulatory floodplain and the FIS floodplain.

FIS Floodplain: The floodplain as determined by FEMA in the flood insurance study.

Floodplain Management: The operation of an overall program of corrective and preventive measures for reducing flood damage, including but not limited to, emergency preparedness plans, flood control works, and floodplain management regulations.

Floodplain Regulations: A general term applied to the full range of codes, ordinances and other regulations relating to the use of land and construction as influenced by water. The term encompasses zoning ordinances, subdivision regulations, building and housing codes, encroachement line statutes, open-area regulations and other similar methods of control affecting the use and development of the areas.

Flood Probability: The probability of a flood of given size being equaled or exceeded in a given period. A probability of one percent would be the flood expected to be equaled or exceeded once in 100 years; a probability of ten percent would be the flood expected to be equaled or exceeded once in 10 years.

Flood Proofing: A combination of structural changes and adjustments to properties subject to flooding primarily for the reduction of flood damages.

Flood Storage: Storage of water during floods to reduce downstream peak flows.

Floodway: Floodway is that portion of the FIS floodplain required for the reasonable passage or conveyance of the design flood. This is the area of significant depths and velocities and due consideration should be given to effects of fill, loss of cross sectional flow area, and resulting increased water surface elevations.

Freeboard: The vertical distance between the normal maximum level of the surface of the water in a channel, bridge, culvert or dam, etc., and the top of the, channel, bridge, culvert or dam.

Frequency Curve: A curve that expresses the relation between the frequency of occurrence and the magnitude of the variable.

Frequency Determination: Frequency determinations, including that of the 100-year flood, typically based upon the Log-Pearson Type III distribution (with the log-normal as a special case) or by alternate studies such as the United States Water Resources Council Bulletin No. 15, "A Uniform Technique for Determining Flood Flow Frequencies."

Froude Number: A flow parameter, which is a measure of the extent to which gravitational action affects the flow, computed as $F = \frac{V}{gD^{0.5}}$, where V is the velocity (ft/sec), g is the gravitational constant (32.2 ft/sec$^2$) and D is the flow depth (feet) A Froude number greater than 1 indicates supercritical flow and a value less than 1 indicates subcritical flow.

Gabion: A wire basket containing earth or stones, deposited with others to provide protection against erosion.

Grade: (1) The inclination or slope of a channel, canal, conduit, etc., or natural ground surface, usually expressed in terms of the percentage of number of units of vertical rise (or fall) per unit of horizontal distance. (2) The elevation of the invert of the bottom of a conduit, canal, culvert, sewer, etc. (3) The finished surface of a canal bed, road bed, top of an embankment, or bottom of an excavation.

Gradient: The rate of change per unit of length, usually applied to such things as elevation, velocity, pressure, etc.

Gutter: The portion of the street adjacent to the curb that forms the triangular channel section for street flow to an inlet.

Head: The amount of hydrostatic pressure, measured in feet, required to pass a certain flow rate downstream.

Headwater: (1) The upper reaches of a stream near its source. (2) The water upstream from a structure.

Hydraulics: An exalted branch of science that deals with practical applications of the mechanics of water movement, used generally to identify the depth of water or pressure head at a particular location in a stream or conduit for a particular flow rate.

Hydraulic Gradient: A hydraulic profile of the level of the water, representing the sum of the depth of flow and the pressure head. In open channel flow it is the water surface.

Hydraulic Jump: The hydraulic jump is an abrupt rise in the water surface which occurs in an open channel when water flowing at supercritical velocity is discharged into water flowing at subcritical velocity. The transition through the jump results in a marked loss of energy, evidenced by turbulence of the flow within the area of the jump. The hydraulic jump is often used as a means of energy dissipation.

Hydrograph: A graph showing stage, flow, velocity or other property of water versus time at a given point on a stream or conduit, due to the upstream watershed's response to a rainfall event.

Hydrology: The exalted science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the earth, and specifically herein relates to the determination of flow rates at particular locations due to the response of a watershed to rainfall events.

Impervious: A term applied to a material through which water cannot pass, or through which water passes with great difficulty. Surfaces of concrete, asphalt and compacted gravel are considered impervious.

Infiltration: The process by which water on the ground surface enters the soil.

Inlet: (1) An opening into a storm sewer system for the entrance of surface storm runoff, more completely described as a storm sewer inlet. (2) The upstream connection between the surface of the ground and a drain or sewer, for the collection of surface or storm water.

Intensity: As applied to rainfall, a rate usually expressed in inches per hour.

Invert: The flowline, bottom, or lowest portion of the internal cross section of a conduit, or open channel.

Lag Time: 1) The time difference between the center of mass of rainfall and the runoff peak. See Time of Concentration 2) the time required for a hydrograph peak to travel to the next point downstream.

Left Bank: The left-hand bank of a stream cross section when the observer is facing downstream.

Lining: The material such as earth, concrete, rock, etc., making up the sides and bottom of a ditch, channel, and reservoir.

Lip: A small wall on the downstream end of an apron, to break the flow from the apron.

Major Maintenance: The maintenance activity for a drainage system which includes repair or replacement of paved channel liners, revetments, riprap, bridges, culverts, storm sewers, headwalls, wing walls, soil lost due to erosion, and other hydraulic structures.

Manhole: A structure used in storm sewer line construction or an access hole usually with a flush cover, through which a person may pass to gain access to an underground or enclosed structure or storm sewer line.

Manual: The City of Tulsa Stormwater Management Criteria Manual (note: also referred to as CITY DRAINAGE STANDARDS in Title 11A, Tulsa Revised ORDINANCES)

Stormwater Master Plan: The Tulsa Flood and Stormwater Management Plan as adopted by the City Council, or any of the individual watershed Stormwater Master Plans that are included within the Tulsa Flood and Stormwater Management Plan.

Minor Maintenance: Those maintenance activities within a drainage system including mowing, replacement of vegetation, and filling of erosion gullies.

Nappe: The sheet or curtain of water overflowing a weir or dam. When freely overflowing any given structure, it has a well-defined upper and lower surface.

Natural Drainage: The path of surface water along the existing surface topography.

Natural State: The cover and topography of land before any development; or in areas where there has already been development, the state of the area and topography of land on the date of December 22, 1977.

Orifice: An opening with closed perimeter, and of regular form in a plate, wall, or partition, through which water may flow.

Outfall: The point of location where storm runoff discharges from a sewer or drain. Also applies to the outfall sewer or channel which carries the storm runoff to the point of outfall.

Peak Rate of Runoff: The maximum rate of runoff during a given runoff event.

Percolation: To pass through a permeable substance such as rainfall percolating into the ground.

Permeability: The property of a material such as the ground which permits the percolation of water.

Pervious: A term applied to a material such as natural ground through which water passes relatively freely.

Pipes, Tile Drain: Pipes which are laid in covered trenches underground with either open joints or with perforations to collect and carry off excess ground water.

<u>Stormwater Pollution:</u> The result of rainwater or snowmelt that picks up pollutants and sediments as it runs off roads, highways, parking lots, lawns, agricultural lands, septic systems, and other land-use activities that can generate pollutants.

<u>Precipitation</u>: Any moisture that falls from the atmosphere, including snow, sleet, rain and hail.

<u>Probability Curve</u>: A curve which expresses the relation of the accumulative frequency of occurrence of a given event, based upon an extended record of past occurrences. The curve is usually plotted on specially prepared coordinate paper, with ordinates representing magnitude equal to, or less than, the event, and abscissas representing probability, time or other units of incidence.

<u>Rainfall Excess</u>: As applied to runoff analysis, refers to the portion of rainfall which becomes surface runoff.

<u>Rainfall Intensity Curve</u>: A curve which expresses the relation between rate of rainfall and duration. Each curve is generally for a period of years during which the intensities shown will not, on the average, be exceeded more than once.

<u>Rational Formula</u>: A formula for estimating the peak rate of runoff from a given drainage basin.

<u>Reach</u>: Any length of river or channel.

<u>Record Drawings</u>: Those drawings which show the "as constructed" information on the construction plans.

<u>Recurrence Interval</u>: The average interval of time within which a given event will be equaled or exceeded once. For an annual series (as opposed to a partial duration series) the probability of occurrence in any one year is the inverse of the recurrence interval. Thus, a flood having a recurrence interval of 100 years has a 1 percent probability of being equaled or exceeded in any one year.

<u>Regulatory Floodplain</u>: That portion of the floodplain subject to inundation by the 1% (100-year) flood of the undeveloped portions of the watershed in accordance with the comprehensive plan assuming full undetained upstream urbanization.

<u>Retention</u>: Long term storage of stormwater runoff with no controlled released during or after a storm, except for evaporation and infiltration.

<u>Return Period</u>: The average interval of time within which a given event will be equaled or exceeded once. For an annual series (as opposed to a partial duration series) the probability of occurrence in any one year is the inverse of the recurrence interval. Thus, a flood having a recurrence interval of 100 years has a 1 percent probability of being equaled or exceeded in any one year.

Reynold's Number: A flow parameter that can be used to determine whether flow will be laminar (fluid motion is smooth and continuous on paths that are straight and parallel to the channel walls) or turbulent (chaotic and fluctuates with time).

Riprap: Broken stones or boulders placed compactly or irregularly on dams, levees, ditches, dikes, channels, etc., for protection of earth surfaces against erosion.

Right Bank: The right-hand bank of a stream cross section when the observer is facing downstream.

Routing, Hydraulic: The derivation of an outflow hydrograph of a channel or stream from a known inflow hydrograph by determining progressively the timing and shape of the flood wave at successive points along a stream or channel.

Runoff: That part of the precipitation which reaches a stream, drain, sewer, etc., directly or indirectly.

Runoff Coefficient: A decimal number used in the Rational Formula which defines the runoff characteristics of the drainage area under consideration.

Scour: The erosive action of running water in streams or channels in excavating and carrying away material from the bed and banks.

Sediment: Material of soil and rock origin transported, carried, or deposited by water.

Stilling Basin: A basin or reservoir installed in a storm drainage system to retard velocity, causing sedimentation and providing storage for deposited solids.

Siphon: Inverted siphons (sometimes called sag culverts or sag lines) are used to convey water by gravity under roads, railroads, other structures, various types of drainage channels and depressions. An inverted siphon is a closed conduit designed to run full and under pressure. Siphons are not allowed in the City of Tulsa.

Slope: See Grade.

Slope, Critical: The slope or grade of a channel that is exactly equal to the loss of head per foot resulting from flow at a depth that will give uniform flow at critical depth; the minimum slope of a conduit which will produce critical flow.

Slope, Friction: The friction head or loss per unit length of channel or conduit. For uniform flow the friction slope coincides with the energy gradients, but where a distinction is made between energy losses due to bends, expansions, impacts, etc., a distinction must also be made between the friction slope and the energy gradient. The friction slope is equal to the bed or surface slope only for uniform flow in uniform open channels.

Spillway: A passageway in or about a dam or other hydraulic structures, for the escape of excess water.

Spillway, Side Channel: A spillway along the side of a channel intended to pass high flows into an overflow basin.

Storage with Respect to Channel Design:

Overbank Storage: The temporary storage volume of storm runoff water in the overbanks, away from the main channel.

Channel Storage: The volume of storm runoff water present in the channel.

Detention Storage: The volume of water that is temporarily stored in a detention basin.

Depression Storage: That portion of the rainfall that is collected and held in natural or man-made depressions and does not become part of the general runoff.

Design Storm: The time variation of rainfall. For analysis purposes, a "design storm" or pre-determined rainfall pattern is used based on "typical" Oklahoma storms.

Storm frequency: The chance of occurrence each year of a flood expressed as a percent or in years. For example, a 1% (100 year) flood has a 1 percent chance of occurrence each year and a 2% (50 year) flood has a 2 percent chance of occurrence each year.

Storm Sewer: A continuous closed conduit for conducting storm water that has been collected by inlets or collected by other means. A storm sewer system is a system of inlets, pipes, manholes, junctions, outlets, and other appurtenant structures designed to collect and convey storm runoff to a defined drainage way.

Stormwater Drainage and Hazard Mitigation Advisory Board: The Advisory Board established by Title 11A, Chapter 1, Section 104 of the Tulsa Revised Ordinances.

Statistical Analysis: A method of analyzing a series of past events using mathematical and probability techniques to predict future occurrences.

Stream Flow: A term used to designate the water which is flowing in a stream channel, canal, ditch, etc.

Street Flow: The total flow of storm runoff in a street, usually being the sum of the gutter flows on each side of the street. Also the total flow where there are not curbs and gutters.

Watercourse: A natural or artificial channel for passage of water.

Watershed: The contributing drainage area to drainage facility expressed as acres, square miles or other unit of area. Also see "drainage area".

## 1301.2 Acronyms

The acronyms listed are also for general use in this MANUAL to clarify the source and meaning of each. These acronyms are also defined in each individual chapter as they apply.

| | |
|---|---|
| AASHTO | American Association of State Highway Transportation Officials |
| ASTM | American Society for Testing and Materials |
| BIGP | Baseline Industrial General Permit |
| BMP | Best Management Practices |
| CGMP | Corrugated Metal Pipe |
| CLOMA | Conditional Letter of Map Amendment |
| CLOMR | Conditional Letter of Map Revision |
| CMPA | Corrugated Metal Pipe Arch |
| CN | Curve Number - SCS Soil-Cover Complex Number |
| CWA | Clean Water Act |
| DFIRM | Digital Flood Insurance Rate Map |
| DSE | Design Storm Event |
| EGL | Energy Grade Line |
| EPA | Environmental Protection Agency |
| FEMA | Federal Emergency Management Agency |
| FIRM/FIS | Flood Insurance Rate Map / Flood Insurance Study |
| FHWA | Federal Highway Administration |
| HEC | Hydrologic Engineering Center - Corps of Engineers |
| HGL | Hydraulic Grade Line |
| HMS | Hydrologic Modeling System (HEC-HMS Computer Program) |

| | |
|---|---|
| HYDRO-35 | Hydrometeorological Report Number 35 |
| IDP | Infrastructure Design Procedures |
| LID | Low Impact Development |
| LOMA | Letter of Map Amendment |
| LOMR | Letter of Map Revision |
| NAVD | North American Vertical Datum |
| NGVD | National Geodetic Vertical Datum |
| NFIP | National Flood Insurance Program |
| NOAA | National Oceanic and Atmospheric Administration |
| NOI | Notice of Intent |
| NOT | Notice of Termination |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | U.S. Dept. of Agriculture Natural Resource Conservation Service (formerly SCS - Soil Conservation Service) |
| NURP | National Urban Runoff Program |
| NWS | National Weather Service |
| ODEQ | Oklahoma Department of Environmental Quality |
| ODOT | Oklahoma Department of Transportation |
| OPDES | Oklahoma Pollution Discharge Elimination System |
| OWRB | Oklahoma Water Resources Board |
| PFPI | Privately Financed Public Improvement |
| PVC | Polyvinyl Chloride |
| RAS | River Analysis System (HEC-RAS Computer Program) |
| RCB | Reinforced Concrete Box (culvert) |

| | |
|---|---|
| RCP | Reinforced Concrete Pipe (culvert) |
| ROW | Right of Way |
| SFHA | Special Flood Hazard Area |
| SWP3 | Storm Water Pollution Prevention Plan |
| TP40 | Technical Paper 40 (U.S. Department of Commerce, National Weather Service |

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# Chapter 1500 OKLAHOMA STORMWATER LAW

BY Ruth M. Wright, Attorney, Boulder, Colorado; State Representative, Colorado State Legislature; House Minority Leader; Member, Legal Services Committee

## 1501 PREFACE

For easy reference, the basic principles of Oklahoma stormwater law have been summarized in the Summary and Conclusions section. However, it is worthwhile to put them in context and, therefore, City officials, planners and engineers are encouraged to read this entire chapter. Attorneys, of course, may wish to refer to the cited cases for further amplification. All cases cited in the text are listed in alphabetical order at the end of this chapter in Appendix A.

## 1502 INTRODUCTION

Manmade alterations to watercourses can change the natural flow of water and possibly cause injury to persons or property and spawn lawsuits requesting damages for the injury or injunctions to prevent further injury. In addition, as government steps in to attempt to manage surface waters, watercourses, and floodplains by constructing flood control facilities or by controlling development in the floodplain, a host of other legal confrontations arise.

A body of law has developed in the courts and to a lesser degree by statutes, to govern these various situations and define the right and duties of private parties and governments.

This chapter sets out the legal framework for stormwater planning in Oklahoma. It is essential that municipalities and counties, and their planners and engineers, have a sound legal basis for their work so that legal obstacles do not impede implementation at a future date. In addition, potential liability due to injury caused by stormwater facilities should be avoided.

## 1503 SUMMARY AND CONCLUSIONS

1. **The overriding rule in Oklahoma stormwater law is that natural watercourses and surface water conditions should be maintained wherever possible. Where they are changed, the changes must be designed so that resulting flow conditions will not cause more harm than under natural conditions.**

2. **The best approach in planning and designing drainage works is to attempt to retain natural and historic conditions of flow.**

3. **A riparian landowner along a watercourse may take measures to protect him from the harmful effects of flood waters, but it is fundamental that no one may change, divert, obstruct, or otherwise interfere with the natural flow of a watercourse without being liable for damages to persons and properties injured by such actions.**

4. **The floodplain of the ordinary flood is part of the watercourse.**

**5. While a landowner has the right to improve his property, this right is qualified by the "golden maxim" of the common law that one must so use his own property as not to injure the rights of another. This maxim is used by courts in stormwater cases.**

**6. Where an upper landowner collects surface water, sends it down in a different manner or concentrated form, or in unnatural quantities or velocities, or discharges it in a different location, he is liable for any damage caused thereby. Conversely, a lower landowner may not cast surface waters back onto upper land to the detriment of the upper landowner. The basic principle is that a landowner cannot prevent injury to his own property by transferring that injury to his neighbor's property. Oklahoma courts call this "the common enemy rule modified by the rule of reason."**

**7. Where one party has caused unnatural water to flow onto another's property, the second party has a right to repel such waters; however, this right is strictly limited to placing the parties in the same conditions as prior to any construction. Nor may a party, in repelling such waters, cause injury to innocent third parties.**

**8. Where a party interferes with natural detention, either by filling it in or by cutting through its banks, he is liable for injury to lower landowners caused by changes in surface water runoff.**

**9. Artificial ponds and on-site detention are recognized as beneficial for flood and erosion control. They should be encouraged, not only because they protect against potential liability for concentrating or increasing surface water runoff, but also because in an urban setting they tend to reduce the size required for storm sewers. This is a cost advantage.**

**10. A riparian owner on a watercourse may construct embankments or other structures necessary to maintain his bank of the stream or to restore it to its original course.**

**11. Any embankments constructed to detain or retain water should be safe from failure in the event of larger floods. The Maximum Probable Flood would be a prudent criterion.**

**12. An "extraordinary flood" is one whose magnitude could not be anticipated or foreseen using ordinary diligence. If injury to persons or property is due solely to an extraordinary flood, there is no liability. However:**

**a. If a person's negligence, commingled with an extraordinary flood, was a contributing proximate cause of the harm, such person is liable.**

**b. It is negligent to build a structure (e.g., inadequate bridge or culvert), which causes damage during an ordinary flood; liability results, if such a structure is a proximate cause of injury during an extraordinary flood.**

**c. In only a few Oklahoma cases has the defense of "extraordinary flood" been successful against liability.**

**d. The flood of record on a watercourse is an ordinary flood for all subsequent events. When an even greater flood occurs, it then becomes the new standard, and there is a duty to meet the new conditions.**

**e. With the technological advances in meteorology and hydrology, and with storm events and floods now being discussed nationwide in terms of their statistical probability, it may become increasingly difficult to convince a court or jury that the flood which caused injury was an extraordinary flood.**

**13. Wherever possible, artificial channels should follow natural thalwegs. Transbasin diversions which increase natural flow should be avoided unless the additional waters are fully accommodated in the design so that no injury can occur from the new flows.**

**14. Installation of inadequately sized drainage structures should be avoided, especially if such structures cause development and filling of the natural watercourse so that larger flood flows cause damage to properties which would not have been damaged otherwise.**

**15. Nonstructural floodplain management provides a basis for master planning which has the least exposure for the city in terms of potential liability. It is a natural approach to solving urban drainage problems before they develop, or before they get worse.**

**16. Municipalities are treated like private parties in watercourse and surface water cases. Governmental immunity as a defense against liability has rarely been mentioned, and never successfully used, in Oklahoma watercourse and surface water cases. Therefore, it would be imprudent for a city to depend on governmental immunity to protect it from liability in stormwater cases. However, the Governmental Tort Claims Act may be operable to some extent in future cases.**

**17. Governmental entities can be found to have taken or damaged property by flooding under Article 2, Section 24, of the Oklahoma Constitution.**

**18. Floodplain regulations should be viewed not as governmental interference with private property rights, but as protection of private property against the unlawful uses of other private properties, which individually or cumulatively would cause flood injury which would not have occurred prior to the development.**

**19. Municipalities and counties have statutory authority to adopt floodplain regulations and become participating communities in the National Floodplain Insurance Program. Their locally adopted regulations must be no less stringent than the federal requirements and the requirements adopted in rules of the Oklahoma Water Resources Board. Such regulations cannot supersede but should implement Oklahoma watercourse law articulated in Oklahoma Supreme Court decisions.**

**20. Floodplain zoning, even though it is a valid use of a governmental entity's police powers, can be challenged as a "taking" of specific properties without just compensation;**

**whether or not the regulation results in a "taking" is a decision by the trier of fact (jury or judge) under the facts of the case.**

**21. The federal insurance program's one-foot rise criterion for floodway/ flood-fringe delineation appears to be inappropriate in Oklahoma. Since this criterion permits full development of the floodplain to the point where the one-percent floodwaters would be one foot higher than under natural conditions, it is almost by definition stating that a city's regulations will result in cumulatively causing more harm than formerly by raising flood levels. Under Oklahoma watercourse law, if such changes actually cause injury, liability results. The Oklahoma Water Resources Board regulations, however, provide additional criteria for defining and developing in the flood-fringe which are consistent with Oklahoma watercourse law.**

**22. New urban development should be required to not materially increase the amount of storm runoff nor change natural drainage conditions. This will protect lower properties. It will also protect the developer from liability, and not place the city in a potential liability position for having permitted the development to alter drainage conditions which result in injury. On the other hand, if the city requires the developer to maintain natural runoff conditions, by whatever means are suitable, it is only complying with the basic principles of Oklahoma law.**

**23. Drainage planning should be based on runoff which will result from future urban development which can be reasonably anticipated.**

**24. It is essential to get the facts before undertaking a drainage plan or design. The following questions should be addressed:**

**a) What causes the drainage problem? Where does the water come from? From what lands?**

**b) Can natural runoff conditions be maintained or recreated?**

**c) Is there an identifiable channel or thalweg where the storm runoff will flow? Is it continuous downstream?**

**d) Would the proposed corrective action handle the "ordinary flood", that is, a flood whose magnitude can be anticipated by using ordinary diligence? Would it handle the flood of record on that watercourse? Would it handle the one-percent frequency runoff event? In the case of a much larger flood, such as the Standard Project Flood or the Maximum Probable Flood, would the corrective works cause the excessive floodwaters to flow in a different location or direction or at higher velocity than they would naturally?**

# 1504 DISTINCTION BETWEEN WATERCOURSE WATERS AND SURFACE WATERS

Stormwater law developed across the United States by courts deciding the rights, duties, and liabilities between private landowners in specific cases. A basic distinction has been made between "watercourse waters" and "surface waters". Surface waters are waters which run in a diffused manner overland, or in depressions and swales, while a watercourse has definite banks and bed. Floodwaters which overflow the banks of the watercourse and follow the course of the stream to its natural outlet, or which upon subsidence return to the stream, are also held to be governed by the law of watercourses. Floodwaters which have entirely lost their connection with the stream, however, and spread out over the adjoining countryside never to return to the stream, would probably be governed by surface water law. While a "nice" distinction in the law, an obvious problem is at what point in their flow do surface waters collecting in swales and gullies suddenly become watercourse waters. Where state courts have adopted surface water rules which are incompatible with their watercourse rules, the courts are in a real dilemma. Even though the waters are hydrologically all part of the same system, liability may hinge totally on how they are categorized in a specific case.

## 1504.1 Law of Watercourses

Watercourse law is based on the rights and duties established between riparian property owners, that is, owners of land along the banks of a river or lake. The fundamental principle of the riparian system is that each riparian has an equal right to make a reasonable use of the water of a stream subject to the equal rights of the other riparians to do likewise. A riparian right is reciprocal in character as to other riparian rights. Therefore, a riparian owner must exercise his rights in a reasonable manner and extent so as not to interfere unnecessarily with the corresponding rights of others. Applying these principals to flooding situations, a riparian owner does not have the right to protect his property from the ordinary flood if this causes damage to others in time of flooding. This would prohibit, for example, a riparian from building a dike which would divert ordinary floodwater onto his neighbor's property.

## 1504.2 Law of Surface Waters

There are two basic doctrines which courts have adopted regarding surface waters. These are the "common enemy rule" and the "civil law rule". A third has evolved in recent years called the "reasonable use rule".

As originally conceived, under the "common enemy rule" a landowner could do anything he pleased with surface waters to protect his property from the "common enemy" regardless of the harm it might do to others. The upper landowner could divert or drain surface waters onto the lower land, or the lower landowner could block surface waters flowing onto his property, even if it flooded the upper property. Since the water must go somewhere, this would appear to inevitably result in contests in engineering where might makes right. Therefore, most courts have modified the rule, giving landowners the right to obstruct or divert surface waters, but only where it is incidental to the ordinary use, improvement or protection of their land, and is done without malice or negligence.

Under the "civil law rule", the upper landowner has an easement for the natural drainage from his property over the lower property and the lower landowner must take such water. However, the key word here is "natural" meaning those waters which flowed from the land before alteration or development. If he does send down a greater volume, or at greater velocity, or in a different location, he is liable if it does more harm than would have occurred under the former conditions.

The "reasonable use rule" is based on tort rather than on property law. In tort law, liability is based on negligence. A person can be held negligent if he has not acted like a "reasonably prudent man" in a given situation, and such actions are the proximate cause of the injury. In surface water cases, the test for liability would be the same.

## 1505 OKLAHOMA WATERCOURSE AND SURFACE WATER LAW

Oklahoma courts have also differentiated between watercourse waters and surface waters. A watercourse has been described in Chicago, R. I. & P. Ry. Co. v. Groves, 20 Okla. 101, 93 P. 755 (1908); Chicago, R. I. & P. Ry. Co. v. Morton, 57 Okl. 711, 157 P. 917 (1916); Garrett v. Haworth, 183 Okl. 569, 83 P.2d 822 (1938), as follows:

> "Where the natural confirmation of the surrounding country necessarily collects therein so large a body of water, after heavy rain or the melting of large bodies of snow, as to require an outlet as to some common reservoir, and whether such water is regularly discharged through a well-defined channel with which the force of the water has made for itself, and which is the accustomed channel through which it flows or has ever flowed, it constitutes a watercourse of waterway."

In addition, areas covered during normal floods by the floodwaters of a watercourse constitute a portion of that watercourse. Town of Jefferson v. Hicks, 23 Okl. 684, 102 P. 79 (1909); Chicago, R. I. & P. Ry. Co. v. Groves, (already cited); Cole v. Missouri, K. & O.R. Co., 20 Okl. 227, 94 P. 540 (1908).

Surface waters, on the other hand are:

> "those which, in their natural state, occur on the surface of the earth and places other than definite streams, lakes or ponds, and they may originate from any source and may be flowing vagrantly over broad lateral areas, or occasionally for brief periods, in natural depressions. The essential characteristics of such waters are that they are short lived flows diffused over the ground, and are not concentrated or confined in bodies of water conforming to the definition of lakes or ponds." Dobbs v. Missouri Pacific R. Co., 416 F. Supp. 5, (E.D. Okl. 1975), a federal case involving floodwaters, quoting this definition from an Oklahoma water resources case, Oklahoma Water Res. Bd. v. Central Okl.M.C. Dist., 464 P.2d 748(Okl.1969).

Fortunately, however, the rules which the Oklahoma courts have adopted regarding these two categories are totally compatible with each other; therefore, the distinction has not been critical and in some cases has not even been made. However, since the theories on which the two categories are based are somewhat different, the distinction should still be noted. In addition, the distinction is convenient and useful. Engineers make useful distinctions too, for example, major and minor drainage. One must never forget, however, that these waters are all part of the same hydrologic system.

Oklahoma has adopted the usual riparian principles of watercourse law whereby landowners have reciprocal rights and duties towards each other. It has adopted the "common enemy rule" for surface waters, but modified it by "the rule of reason". This rule results in liability for landowners who alter natural runoff if such alterations cause injury to others. There is a wealth of cases decided by the Oklahoma Supreme Court since the early 1900's and they are remarkably consistent.

In the first two cases before the Oklahoma Supreme Court, in 1904 and 1908, the court analyzed the competing doctrines for both surface and watercourse waters and chose and articulated compatible principles which have controlled its decisions ever since. The Oklahoma courts have never had the dilemma of the surface waters/watercourse waters dichotomy because the results are virtually the same for both categories.

In the 1904 case, Davis v. Frey, 14 Okl. 340, 78 P. 180 (1904), surface waters flowed into a natural depression forming a 15-acre pond from which they evaporated or percolated into the ground. Defendant (upper landowner) cut a channel into the bank of this natural ponding area to drain it. Stormwaters, instead of being detained, flowed immediately onto the lower landowner's farm, damaging his crops. In finding the upper landowner liable, the court adopted the rule from an Iowa case:

> "If the ditch in question increased the quantity of water upon the plaintiff's land to his injury, or without increasing the quantity, threw it upon the plaintiff's land in a different manner from what the same would naturally have flowed upon it, to his injury, the defendant was liable for the damage thus occasioned, even though the ditch was constructed by the defendant in the course of the ordinary use and improvement of his farm. We recognize the fact . . . that surface water . . . is a common enemy, which each landowner may reasonably get rid of in the best manner possible, but in relieving himself he must respect the rights of his neighbors, and cannot be justified by an act having the direct tendency and effect to make that enemy less dangerous to himself and more dangerous to his neighbor." (14 Okl. 341, 78 P. 181.)

Then in 1908 the first of many railroad cases came before the court. Chicago, R. I. & P. Ry. Co. v. Groves, 20 Okl. 101, 93 P. 755 (1908). The railroad company had built an embankment across a ravine on the plaintiff's land with culverts which were inadequate to carry water which collected in the ravine after heavy rains. The railroad argued that the ravine was not a watercourse and, therefore, it was not violating a statute requiring railroads to restore streams and watercourses so as not to materially impair their usefulness. The court, however, held that the railroad had the duty to provide:

> "sufficient drainage and an outlet to carry off such waters as might be reasonably expected to flow along such channel . . . so as to force the water off . . . in like manner and in the same channel or place as it flowed prior to the construction of said embankment." (20 Okl. 101, 93 P. 755).

The court further stated that while a landowner has the right to improve his property, this right is qualified by the

> "golden maxim of the common law that one must so use his own property as not to injure the rights of another." (20 Okl. 101, 93 P. 755).

Interestingly, the cases cited and quoted are those which would generally be considered surface water cases, that is, they compare the civil law rule with the common enemy rule. It cites the Davis case as holding that an owner of land cannot collect water into an artificial channel and pour it upon the land of another to his injury, and goes on to state that such an owner cannot interfere with the flow of water in a natural channel either. In finding the railroad liable, the court does not appear to base its decision on statutory liability, but on common law principles; therefore, it appears to be saying that whether or not these are surface waters or watercourse waters, such obstructions result in liability.

In one case we have surface water injuring a lower landowner. In the other case we have watercourse waters injuring an upper landowner. The principle upon which liability is based is essentially the same -- one cannot change natural flow conditions to the detriment of another's property. These two cases set the stage for integrating the principles of surface water and watercourse water from the outset.

If there was any doubt regarding liability in such cases this was quickly dispelled in rapid succession by three more railroad cases and one against a city. Cole v. Missouri, K. & O. R. Co., 20 Okl. 227, 94 P. 540 (1908), held that where an upper riparian (the railroad) changes the channel and obstructs the flow of a watercourse so that at times of ordinary high waters it flows over the lower riparian's land in greater volume with more violence, or in a different course or manner than it would flow in its natural state, he is liable. The railroad company still argued surface waters and the common enemy rule, but the court stated that water which overflows its banks in times of flooding does not thereby become surface water.

In Town of Jefferson v. Hicks, 23 Okl. 684, 102 P. 79 (1909), the facts were as follows: the plaintiff's farm on one side of the river was somewhat higher than the town site on the other side. Floodwaters would flow through the town, so the town put up a levee, forcing floodwaters onto the plaintiff's land. The court held that the owner of land situated on a watercourse may construct an embankment to protect his lands from flooding; but he may not place the embankment in such a way that ordinary floods will erode, destroy or injure other landowners on the watercourse. Since recurring floods would continue to cause injury, money damages alone was not an adequate remedy. The plaintiff was granted an injunction; that is, the town had to remove its levee.

In Chicago, R. I. & P. Ry. Co. v. Johnson, 25 Okl. 760, 107 P. 662 (1910), the railroad had built a ditch which accumulated waters from upland farmers and carried them through its roadbed onto plaintiff's farm. In finding the railroad liable for the resulting damage, the court held that one cannot collect waters into an artificial channel or volume and pour it onto the land of another to his injury.

If there had still been any question regarding surface waters being treated any differently than watercourse waters, it was settled in Chicago, R. I. & P. Ry. Co. v. Davis, 26 Okl. 434, 109 P. 214 (1910). The court held that a railroad company has no more right to obstruct, collect or conduct surface waters and force them to be discharged upon lands of another, than it has to do the same with watercourse waters. It is as liable for the resulting injury in the one situation as in the other:

> "The wrong intended to be guarded against is the diversion of water, causing it to flow upon the lands of another without his will, which did not naturally flow there; and it is not deemed material whether the water is diverted from a running stream, or is surface water caused to flow where it did not flow before." (26 Okl. 438, 109 P. 218).

See also Culbertson v. Green, 206 Okl. 210, 243 P.2d 648 (1952).

The basic theme which runs throughout the cases is that one may not alter the natural flow conditions if such changes cause injury to others. This fundamental theme has been amplified and fleshed out in many cases over decades, and the following legal principles have evolved.

## 1505.1 Interference with a Watercourse

**A riparian landowner may take measures to protect himself generally from the harmful effects of flood waters, but it is fundamental that no one may change, divert, obstruct, or other wise interfere with the natural flow of a watercourse without having to pay damages to persons and properties injured thereby. Liability was found in the following situations:**

Atchison T. & S. F. Ry. Co. v. Hadley, 168 Okl. 588, 35 P.2d 463 (1934). A railroad embankment and jetties created a narrow "bottle neck", greatly increasing the natural velocity of the current.

Chicago, R. I. & P. Ry. Co. v. Groves, 20 Okl. 101, 93 P. 755 (1908). A watercourse was obstructed by embankment with an inadequate capacity.

Chicago, R. I. & P. Ry. Co. v. Maynard, 31 Okl. 685, 122 P. 149 (1911). A railroad embankment obstructed a watercourse and floodwaters damaged crops.

Castle v. Reeburgh, 75 Okl. 22, 181 P. 297 (1919). A dam interfered with a watercourse.

Lowden v. Bosler, 196 Okl. 205, 163 P.2d 957 (1945). The defendant built jetties which restricted the flow and raised the water level. Roiling waters deflected onto plaintiff's property.

Garrett v. Haworth, 183 Okl. 569, 83 P.2d 822 (1938). A watercourse was obstructed.

Chicago, R. I. & P. Ry. Co. v. Schirf, 267 P.2d 574 (Okl. 1954). A railroad trestle was filled in, causing waters to back up onto plaintiff's land.

Godlin v. Hockett, 272 P.2d 389 (Okl. 1954). To protect his subdivision, defendant dredged and deepened a creek and built a dike up to 8 feet high, diverting floodwaters onto other riparian lands in increased volume and with greater depth.

Regier v. Hutchins, 298 P.2d 777 (Okl. 1956). Defendant put an embankment across the oxbow of a river, inundating plaintiff's land to a greater extent than formerly and preventing the water from receding as quickly.

Town of Jefferson v. Hicks, 23 Okl. 684, 102 P. 79 (1909). Defendant town built a levee to protect the town from floodwaters, but the levee caused flooding of plaintiff's land on the other side of the river.

George v. Greer, 207 Okl. 494, 250 P.2d 858 (1952). Defendant built a dike which caused water, which would otherwise have gone over his own land, to go onto plaintiff's land.

### 1505.2 Altering Surface Water Runoff

**Where an upper landowner collects surface water, sends it down in a different manner or concentrated form, or in unnatural quantities or velocities, or discharges it in a different location, he is liable for any damage caused thereby. Conversely, a lower landowner may not cast surface waters back onto upper land to the detriment of the upper landowner. The basic principle is that one cannot prevent injury to one's own property by transferring that injury to one's neighbor's property. Oklahoma courts call this "the common enemy rule modified by the rule of reason."** Chicago, R. I. & P. Ry. Co. v. Johnson, 25 Okl. 760, 107 P. 662 (1910); Gulf, C. & F. Ry. Co. v. Richardson, 42 Okl. 457, 141 P. 1107 (1914); Chicago, R. I. & P. Ry. Co. v. Taylor, 173 Okl. 454, 49 P.2d 721 (1935); Chicago, R. I. & P. Ry. Co. v. Davis, 26 Okl. 434, 109 P. 214 (1910); Kansas City Southern Ry. Co. v. Hurley, 61 Okl. 241, 160 P. 910 (1916); St. Louis & S. F. R. Co. v. Dale, 36 Okl. 114, 128 P. 137 (1912); Wichita Falls & N. W. Ry. Co. v. Stacey, 46 Okl. 8, 147 P. 1194 (1915); Haenchen v. Sand Products Co., Inc. , 1981 OK CIV APP 6, 626 P.2d 332; Moneypenny v. Dawson, 2006 OK 53, 141 P.3d 549.

### 1505.3 Right to Maintain or Restore Original Bank of Watercourse

**A riparian owner on a watercourse may construct embankments or other structures necessary to maintain his bank of the stream, or to restore the stream to its original course when it has encroached upon his land, without becoming liable for injury that such action might cause to other riparian lands.**

In Gulf C. & S. F. Ry. Co. v. Clark, 101 F. 678 (8th Cir. 1900), the defendant had built an embankment and railroad on solid land, some distance from the bank of the river. The river gradually washed away the bank until it swept away part of the embankment. So the defendant built a dike which encroached on the new channel but not on the channel as originally located. Defendant was not liable.

In Sinclair Prairie Oil Co. v. Fleming, 203 Okl. 600, 225 P.2d 348 (1950), defendant built a fence on the location of the original bank which had washed out in a flood, causing plaintiff's land to erode. Defendant was not liable.

In Pechacek v. Hightower, 269 P.2d 342 (Okl. 1954), both the plaintiff and the defendant built levees. There was a question whether plaintiff did more than just restore, but the court held that the jury should have been instructed that the plaintiff had a right to restore her bank.

## 1505.4 Limited Right to Repel Unnatural Waters

**Where one party has caused unnatural water to flow onto another's property, the second party has a right to repel such waters. This right is limited, however, to placing the parties in the same conditions as prior to any construction. Nor may a party, in repelling such waters, caused injury to innocent third parties.**

In Dowlen v. Crowley, 170 Okl. 59, 37 P.2d 933 (1934), plaintiff built a dike which cast high waters onto defendant's land, whereupon defendant started to build his own dike. Plaintiff brought an action to stop him. The defendant showed that his dike would not cause more water to flow onto plaintiff's land than if there were no dikes at all. The court refused to halt defendant's dike, stating:

> "A riparian proprietor has no right to construct by dike, dam, or otherwise, anything which in time of ordinary flood will throw the water in larger volume on the lands of another so as to overflow and injure them, and, when flood waters are diverted by one landowner to the land of another, that other has the right to repel it." (170 Okl. 59, 37 P.2d 933).

In a similar situation involving surface waters rather than a watercourse the court took the same position. Rainey v. Cleveland, 203 Okl. 283, 220 P.2d 261 (1950). Plaintiff (upper landowner) had built ditches and levees which in time of heavy local rains collected and discharged waters onto defendant's land in an excessive, unusual and unnatural volume. Defendant put up a levee for protection. Plaintiff's request for an injunction was denied. Since plaintiff had no right to discharge such waters, defendant had the right to protect himself. See also King v. Cade, 205 Okl. 666, 240 P.2d 88 (1951). The Lynn v. Rainey, 400 P.2d 805 (Okl. 1965), court went even further. Here the upper landowner (plaintiff) was discharging accumulated surface waters onto the lower property. Defendant bought the lower property with these conditions in place, and then built a protective barrier which flooded the upper property. In denying the plaintiff's request for injunction, the court held that the plaintiff still had no legal right to discharge accumulated surface waters, either by easement, license or prescription. Therefore the defendant had the right to protect himself.

Where a dike built as protection to repel unnatural waters harms a third party, however, such dike may not be maintained. In Gregory v. Bogdonoff, 307 P.2d 841 (Okl. 1957) a drainage district had built a levee to protect a town. This levee turned a greater volume of water onto defendant's property, so he built a dike. This dike, however, caused damage to plaintiff's property (innocent third party), so the court ruled he had to remove it.

## 1505.5 Detention Ponds

**Where a party interferes with natural detention, either by filling it in or by cutting through the banks, he is liable for injury to lower landowners caused by change in surface water runoff. Artificial ponds which catch surface water are recognized as beneficial for flood and erosion control, where they do not unreasonably interfere with water rights.**

The very first surface water case decided by the Oklahoma Supreme Court in 1904, involved natural detention which created a 15-acre pond. As described in an earlier section, the upper landowner was liable for cutting through its banks resulting in injury to the lower farmer's lands. Davis v. Fly, already cited. In Carter v. Gundy, 259 P.2d 528 (Okl. 1953), defendant's land had formerly been in agriculture and had a low spot which constituted a natural lake in which water gathered and stood after rains. In preparation for residential development, he knocked down a bluff thereby filling in the natural lake. Water which formerly stood on his land now flowed onto plaintiff's land, carrying sand, silt, and debris. Defendant was liable.

In a water rights case a lower property owner objected to an upper proprietor's building a dam to catch water which flowed across his land. The court held these waters to be surface waters, and not stream waters where riparian rights would attach. Regarding the benefits to be derived from such farm ponds in general, however, the court heard testimony by the Oklahoma Water Resources Board to the effect that there were almost 200,000 farm ponds along dry gullies, draws and intermittent stream channels and that such ponds aided in flood and erosion control. The court recognized that such ponds and lakes are beneficial and should be encouraged where they do not unreasonably interfere with the rights of others. Oklahoma Water Res. Bd. v. Central Okl. M. C. Dist., 464 P.2d 748 (Okl. 1969).

As such farmlands are converted into subdivisions the farm ponds may be destroyed. The lower property owners probably do not have a right to the maintenance of an artificial pond which causes less runoff than naturally, although the length of time the pond has been there and other factors may affect this decision. However, since urbanization of agricultural land creates more runoff than formerly, it may be prudent for a developer and a city to retain the detention so that natural conditions are not exceeded by the development.

## 1505.6 Ordinary and Extraordinary Floods

**If injury to persons or property is due solely to an "extraordinary flood", there is no liability. If, however, someone's negligence, commingled with the "extraordinary flood", was a contributing proximate cause of the injury, such person is liable. Building structures which would cause injury to others during ordinary floods is held to be negligence; therefore, such negligence results in liability even during extraordinary floods. A flood of record is an ordinary flood. If a flood of greater magnitude occurs, it becomes the new standard and a duty arises to accommodate the new standard.**

Oklahoma, like most other jurisdictions, makes a distinction between the ordinary and the extraordinary flood, sometimes called an "act of God." If the injury is due solely to an extraordinary flood, then there is no liability. Chicago, R. I. & P. Ry. Co. v. Turner, 141 Okl. 267, 284 P. 855 (1930). It is the defendant's burden to prove that the event was an extraordinary one. Oklahoma City v. Tarkington, 178 Okl. 430, 63 P.2d 689 (1936). However, if the defendant was negligent, and his negligence commingled with the act of God caused the injury, then the defendant is liable. Chicago, R. I. & P. Ry. Co. v. Morton, 57 Okl. 711, 157 P. 917 (1916) (both bridge and culvert inadequate to pass ordinary floods) and Gulf, C.& S. F. Ry. Co. v. Anderson, 136 Okl. 97, 276 P. 711 (1929) (culvert inadequate for ordinary flood and partially clogged with debris). The plaintiff has the burden of proving defendant's negligence, and that, but for such negligence, the loss would not have occurred. Armstrong, Byrd & Co. v. Illinois Cent. R. Co., 26 Okl. 352, 109 P. 216 (1910). In Town of Jefferson v. Hicks, the distinction was made as follows, quoting 13 Ency. of Law (2d Ed.):

> "An ordinary flood is one, the repetition of which, though at uncertain intervals, might, by the exercise of ordinary diligence in investigating the character and habits of the stream, have been anticipated. An extraordinary flood is one of those unexpected visitations whose coming is not foreseen by the usual course of nature, and whose magnitude and destructiveness could not have been anticipated and prevented by the exercise of ordinary foresight." (23 Okl. 685, 102 P. 80).

Some cases have simply found that the subject floods were ordinary, and therefore the defendant is liable. Town of Jefferson v. Hicks, already cited. Regier v. Hutchins, 298 P.2d 777 (Okl. 1956). In most cases, however, the instructions to the jury (instructions from the judge inform the jury of the law controlling the case) are as follows:

> "You are. . .instructed that an 'act of God' such as an unprecedented rainfall and resulting flood, which will excuse from liability, must not only be the proximate cause of the loss, but it must be sole cause. If, however, the injury is caused by an act of God, commingled with the negligence of the defendant as an efficient and contributing cause, and the injury would not have occurred except for such negligence, the defendant would be liable." Chicago, R. I. & P. Ry. Co. v. Morton, 57 Okl. 713, 157 P. 919 (1916).

When the jury finds the defendant liable based on this instruction, one cannot tell whether the jury decided the flood was ordinary, or whether it decided it was extraordinary but commingled with defendant's negligence. See the following cases where defendants were found liable: Missouri, K. & T. Ry. Co. v. Johnson, 34 Okl. 582, 126 P. 567 (1912); Chicago, R. I. & P. Ry. Co. v. McKone, 36 Okl. 41, 127 P. 488 (1912); Chicago, R. I. & P. Ry. Co. v. Bahr, 78 Okl. 78, 188 P. 1058 (1920); Walton v. Bryan, 188 Okl. 358, 109 P.2d 489 (1941); Steirs v. Mayhall, 207 Okl. 219, 248 P.2d 1047 (1952); Black v. Ellithorp, 382 P.2d 23 (Okl. 1963).

Four cases, all arising out of the same fact situation, help to clarify the interrelationship between the "act of God" and defendant's negligence. The floods of 1923 in the Oklahoma City area were held to be extraordinary floods. The June flood was higher than any previous floods, and the October flood was about 5 times as great as the June flood. In prior years a railroad company had built a bridge and embankment which had sufficient capacity to pass ordinary floodwaters. Then Oklahoma City and the railroad closed these openings to create a settling basin for the city, raised the embankment, diverted the water and constructed a waterway through the embankment. In Oklahoma Ry. Co. v. W. H. Boyd, 140 Okl. 45, 282 P. 157 1929), evidence showed that this new opening had only one-third the capacity of the former opening. A civil engineer testified that the new channel had a capacity of only 12,000 cfs, while in his judgment the amount of water to be reasonably anticipated required a capacity of 37,500. The defendant was found negligent. In two additional cases, arising from the same situation, only the measure of damages came before the appellate court, the defendants having been found liable. Oklahoma Ry. Co. v. Woods, 164 Okl. 215, 23 P.2d 217 (1933) and Oklahoma Ry. Co. v. Mary Boyd, 167 Okl. 151, 28 P.2d 537 (1934). Then in 1936, Oklahoma City v. Rose, 176 Okl. 607, 56 P.2d 775 (1936), came before the court involving the same city construction as before. Once again the jury at the trial court level had found the defendant liable. However, in this case the uncontradicted evidence in the record showed that the city's single opening in the embankment had more capacity than the prior three openings combined (about 30,000 cfs); that the greatest flood on record prior to construction was 13,640 cfs. In addition, the city had constructed these structures after consulting with nationally known authorities on the subject and the expenditure of a considerable sum of money in making such investigations. The recommendations of these authorities had been followed. With this evidence, the court reversed the jury's findings as a matter of law. It held that the defendant had not been negligent and that the injuries were due solely to an "act of God."

There have been very few Oklahoma cases in which the "extraordinary flood" has been a successful defense against liability. Armstrong, Byrd & Co. v. Illinois Cent. R. Co., 26 Okl. 352, 109 P. 216 (1910); Chicago, R. I. & P. Ry. Co. v. Turner, 141 Okl. 267, 284 P. 855 (1930); Oklahoma City v. Rose, already cited. The first hurdle is proving that the flood was extraordinary. Great strides have been made in meteorology and hydrology. Storms and floods are discussed in terms of their statistical probability. The federal insurance program, many state and local floodplain maps, and floodplain management programs are based on the one-percent flood (100-year flood). The U.S. Army Corps of Engineers uses the Standard Project Flood for design purposes (about a 500-year flood). It may, therefore, become increasingly difficult to convince a court or a jury that a given flood was one which could not be anticipated in the exercise of ordinary diligence, whose coming was unforeseen, and whose magnitude could not have been anticipated by the exercise of ordinary foresight (the Oklahoma court's definition of an extraordinary flood).

In addition, when a flood of greater magnitude than the flood of record occurs, this becomes the new standard. Then one must respond in a timely fashion to the new flood conditions. In Missouri, K. & T. Ry. Co. v. Johnson, 34 Okl. 582, 126 P. 567 (1912), a company had built a roadbed, bridge and culvert across a narrow valley just below the plaintiff's property; these were adequate for conditions known at that time, that is, in 1903. Then came the May, 1908, flood which put eight feet of water onto plaintiff's land, more than ever before in the history of the river. Then in October of that same year an even larger flood occurred, flooding plaintiff's land twelve feet deep. In finding the railroad company liable for the October flood damages the court made the following analysis:

> "(I)f nothing had occurred since the original construction of the road to demonstrate the insufficiency of the construction prior to the October flood, defendant would have been entitled to an instructed verdict. If, however, after the original construction of the road, and prior to the flood in question here, other floods of an unprecedented character came, demonstrating the faulty construction of the roadbed, or the inadequacy of the waterway left under the bridge, then ... a new standard of obligation was erected for the defendant, and it was its duty to meet the new conditions thus established." (34 Okl. 584, 126 P. 569).

Note that the "new standard of obligation" was created in May of 1908, that is, just five months prior to the flood injuries for which defendant was liable. See also Pahlka v. Chicago, R. I. & P. Ry. Co. , 62 Okl. 223, 161 P. 544 (1916).

Then, of course, another factor is that the defendant can still be held liable even in the extraordinary flood event if his negligent actions were a proximate and contributing cause of the injury. Here the cases hold that if defendant's structures were inadequate for the ordinary flood, then he is liable even in the extraordinary flood event. If one assumes that the one-percent flood is an extraordinary event, then a defendant could still be held liable for injury resulting from the one-percent or greater flood if he has not accommodated the ordinary flood and if that was a contributing proximate cause of injury. On the other hand, if one assumes that the one-percent flood is now considered to be an ordinary flood, then if the defendant does not adequately provide for the one-percent flood and this was a contributing proximate cause of flood damages, he can also be liable for the greater flood event.

## 1505.7 Municipal Liability in Surface Water Cases

**Municipalities are treated like private parties in surface water cases.**

In Gulf, C. & S. F. Ry. Co. v. Richardson, 42 Okl. 457, 141 P. 1107, (1914) the court had to rule specifically on the issue of whether or not municipalities were a breed apart. The city had gathered surface waters via its streets and discharged them onto the railroad right-of-way. The railroad, in turn, wished to place culverts through its roadbed which would discharge these waters onto plaintiff's land. The trial court enjoined the railroad but discharged the city. In reversing and remanding the court stated:

> "The law makes no distinction in such cases between natural and artificial persons in the duty it imposes. The law holds the proprietor of the estate to the same obligation in the disposition of surface waters, whether he be a farmer, a municipality, or a railway corporation." (42 Okl. 457, 141 P. 1110).

Five years previously, of course, the court had already required the Town of Jefferson to remove its dike which was diverting floodwaters of a watercourse onto Hicks' property. Town of Jefferson v. Hicks, already cited. Other cases involving municipalities described in previous sections of this report are Oklahoma Ry. Co. v. W. H. Boyd, 140 Okl. 45, 282 P. 157 (1929); Oklahoma Ry. Co. v. Woods, 164 Okl. 215, 23 P.2d 217 (1933); Oklahoma R. Co. v. Mary Boyd, 167 Okl. 151, 28 P.2d 537 (1934); Oklahoma City v. Rose, 176 Okl. 607, 56 P.2d 775 (1936); Oklahoma City v. Tarkington, 178 Okl. 430, 63 P.2d 689 (1936). Additional cases are described below.

In Incorporated Town of Idabel v. Harrison, 42 Okl. 469, 141 P. 1110 (1914), the town had constructed drainage ditches along a number of streets. These ditches gathered surface waters which fell over a large area of land, conducting them to a street abutting plaintiff's residential lots. Heavy rains resulted in injury to plaintiff's property. The court held that it was settled law that the owner of the land has no right to gather and accumulate surface waters and conduct them in large volumes onto land of an adjoining proprietor to his injury. See also City of Ardmore v. Orr, 35 Okl. 305, 129 P. 867(1913).

In Oklahoma City v. Bethel, 175 Okl. 193, 51 P.2d 313 (1935) the city had built a municipal storm sewer system designed to drain a considerable area of the city. The outlet was to a ditch, which was inadequate to carry the collected storm waters from a 3.96-inch rain. The plaintiff's amusement park was flooded. The court held the following jury instructions to be proper:

> "(I)n the exercise of its corporate powers a municipal corporation has no power or authority to collect water by artificial means and to discharge it or permit it to discharge or overflow upon the premises of an adjacent owner in greater volumes or

> velocity than it would naturally flow there prior to the construction of such sewer." (175 Okl. 197, 51 P.2d 317).

In addition, it stated that the following was a general and almost universal rule (quoting 43. C. J. 1145):

> "A municipality cannot, without rendering itself liable for the resulting damage, exercise its right to construct drains or sewers and grade or otherwise improve streets so as to collect surface waters in artificial channels and discharge it in increased quantities, or in new and destructive currents, upon private property." (175 Okl. 197, 51 P.2d 317).

It should be noted that in neither of these two cases is there evidence that the city owns the lands which are being drained, that is, these are not the classic "lower landowner versus upper landowner" situations. The courts do not even discuss the matter. Apparently the rules of surface waters are not narrowly applied to actual owners of property; or, the ownership requirement, if any, is satisfied by the fact that the city owns the drainage facilities. Taking this concept one step further, consider the following situation: A subdivider takes agricultural land and builds thereon homes, carports, sidewalks, streets and storm sewers, all in accordance with city specifications as established in city ordinances. The city has annexed the property and approved the subdivision plat. The public facilities (streets, storm sewers, water lines, etc.) are dedicated to the city as part of the subdivision and annexation process. Because of the impermeability of the development, and because storm sewers and streets facilitate movement of runoff, the subdivision causes more surface water, with greater velocity, and in a different manner to be discharged onto lower property owners. No compensating detention facilities were incorporated into the project in an attempt to maintain natural runoff conditions, nor were such detention facilities required by the city. The lower property owners sue both the developer and the city for the harm to their property caused by the changed runoff. How will the court rule regarding defendant city, which did not actually build these facilities, but which approved and controlled the subdivision development?

There are three additional cases which may be pertinent in the above hypothetical situation. These cases hold that the duty to prevent injury caused by altering surface water and watercourses conditions is a <u>nondelegable</u> duty. <u>Oklahoma Ry. Co. v. W. H. Boyd</u>, 140 Okl. 45, 282 P. 157 (1929), described in a previous section, involved raising the railroad embankment, closing culverts, and diverting water through a new culvert, in order to form a municipal settling basin. The defendant railroad raised the defense that the city, not the company, had actually done the construction, and was its only beneficiary. The court, however, was not convinced by this argument. It held that the railroad company, being:

> "under obligation imposed upon it by law to leave sufficient openings through its embankment for the flow of water to be reasonably anticipated, could not delegate the duty of rebuilding the embankment to another, so as to escape liability for the violation of a positive legal duty owing to third persons." (140 0kl. 50, 282 P. 162).

It held the city and the railroad to be <u>joint</u> tortfeasors. In <u>Allied Hotels, Ltd. v. Barden</u>, 389 P.2d 968 (Okl. 1964), a Ramada Inn was built which caused surface water to flow in greater volume onto plaintiff's residence. The motel owner argued that all of the construction had been performed by an independent contractor. Again, the court held that an owner owes a nondelegable duty to adjacent landowners to refrain from causing injury. One who owes such a duty to third persons cannot escape the obligation of performing his duty by engaging for its performance by a contractor. See also Garrett v. Haworth, 183 Okl. 569, 83 P.2d 822 (1938).

Large subdivisions annexing to cities or developing inside corporate boundaries are a fact of modern life. Many municipal facilities such as water lines sewers, streets, and storm drains in such subdivisions are no longer actually constructed by municipal crews but are constructed by the subdivider in accordance with city specifications and approval. In light of the fact that municipalities are treated like other parties in surface water cases, would a court really discharge the city of responsibility in such situations? Or would it find that the city and the developer are joint tortfeasors; that since the city owns or will own the public facilities built by the developer, it cannot avoid liability by attempting to delegate a nondelegable duty to another party; and that it cannot, via a third party (the developer), collect and discharge water onto other properties in greater volumes or velocity than would naturally flow there prior to such construction?

The Plaintiff farmers in Luker v. Board of County Commissioners of Greer County, 2002 OK CIV APP 108, 84 P.3d 773 sued the County for failing to repair a dike and failing to maintain road ditches and culverts, which failures caused flooding of the Lukers' farm. The trial court found that the County's "maintenance and repairs of the roadways and drainage system around (the Lukers' property) were reasonable and for the benefit of most of the landowners" in the area, not just the Lukers. The court denied the requested remedies.

## 1505.8 Municipal liability in Watercourse Cases

**Municipalities are treated like private parties in watercourse cases.**

In Herwig v. City of Guthrie, 182 0kl. 599, 78 P.2d 793 (1938), the city had built a dam across the channel creating a water supply reservoir. Plaintiff had property upstream and above the high water line of the reservoir and maintained that the lake retarded the ordinary rapid flow of water across her land to such an extent that sediment was deposited, forming a "secondary dam" and that this obstruction caused overflow and injury. The trial court had directed the verdict for the city, but the appellate court reversed. The question of whether the city had obstructed a natural watercourse, and whether this had resulted in injury to the upper riparian, were questions of fact for the jury to decide.

A city has also been liable where it failed to remove a temporary dike which was built to divert river water while it repaired a water line, and the dike caused flooding to a farmer's land and crops. Elk City v. Rice, 286 P.2d 275 (Okl. 1955).

In Murduck v. City of Blackwell, 198 Okl. 171, 176 P.2d 1002 (1947), the city was liable for injury to plaintiff s land caused by interference with his drain tile. The city had built a water supply reservoir whose high water line was higher than the outlet to the drain tile. When the river overflowed its banks, water which formerly could have been drained from plaintiff s land via the drain, backed up, causing injury to crops and buildings.

These cases find cities liable for interfering with or obstructing watercourses. A municipality is liable when it constructs the obstruction itself, or when it contracts for such construction. Would it also be liable for granting a permit to a private party to construct an obstruction if it knows or should have known such obstruction would cause flooding on other properties? If the dike in Town of Jefferson v. Hicks (already cited) had been built not by the town to protect the town, but by a subdivider to protect his subdivision which was part of the town, and with the town's approval, would Hicks have had a cause of action against the town? A city's permitting the placing of fill to elevate a subdivision to protect it from flooding would be a similar situation, if such fill diverts ordinary floodwaters onto property where it would not have flowed previously, or not to the same height or velocity. Another would be the channelizing of a watercourse by a developer as required by a city, which causes greater volumes and velocity of floodwater on downstream property. These are issues which will probably eventually be raised in Oklahoma courts.

## 1505.9 Governmental Immunity

**Governmental immunity as a defense against liability has rarely been mentioned, and never successfully used, in Oklahoma watercourse and surface water cases; however, the Governmental Tort Claims Act, as amended from time to time, may affect this area of the law.**

As can be seen from the above cases, municipalities are treated like private parties in surface water and watercourse cases. Where is the traditional defense known as "governmental immunity"? The concept of governmental immunity was derived from the old English common law principle that "the King can do no wrong." While it has long since been abrogated in England, many states still embrace the doctrine, including Oklahoma. In fact, with the rising cost of insurance, there has been a trend nationwide to define and limit governmental liability through state legislation.

Throughout the United States, including Oklahoma, the courts have distinguished between a municipality's governmental and its proprietary functions. Courts have held that the municipalities are immune when they exercise their "governmental" functions, but liable for their (or their employees') tortious acts when exercising their "proprietary" function. Obviously there are gray areas in between. See the discussion in City of Oklahoma v. Hill, 6 Okl. 114, 50 P. 242 (1897).

In the area of watercourse and surface water law, there are only a few Oklahoma cases which even address governmental immunity, even indirectly. In an early case, Town of Norman v. Ince, 8 Okl. 412, 58 P. 632 (1899), the town had built a large water standpipe, which overflowed continuously from the day it was erected, flooding plaintiffs lots. The town argued that it could not be liable for damages arising from the proper exercise of the authority conferred upon it by charter or statute, unless a statute or fundamental law expressly gave a right to seek damages. This appears to be a governmental-immunity-type argument, absent a specific statute creating liability. The court rejected that theory. It held that such authority is not a defense when the municipal actions are in the nature of a trespass or a nuisance, and these actions were considered to be such an invasion of private property to constitute an appropriation of it to public use. This case and others are cited in a law review article entitled "Liability Without Fault," where the author argues that courts are really finding liability based on strict liability, rather than trespass or nuisance. 3 Okl.L.Rev. (1950); see especially pages 47-49. See also City of Chickasha v. Looney , 36 Okl. 155, 128 P. 136 (1912). Reinforcing this argument that courts are holding municipalities strictly liable is the statement from City of Skiatook v. Carroll, 163 Okl. 149, 21 P.2d 498 (1933):

> "This court has persistently followed the common-law rule that it is unlawful to direct surface water from its usual and ordinary course, to collect it in volume, and to convey it by artificial means onto the property of a private individual." 163 Okl. at 149, 21 P.2d at 498.

One case where the defense of governmental immunity was specifically addressed is Oklahoma City v. Hoke, 75 Okl. 211, 182 P. 692 (1919). The city rebuilt its water supply dam to a higher level after a flood, causing plaintiff s property to be flooded. Here governmental immunity was rejected on the traditional basis that in supplying water, a city is operating like a business corporation (proprietor) and therefore not immune. In Richards v. City of Lawton, 629 P.2d 1260 (Okl. 1981) the city was dismissed on procedural grounds, but the court stated that governmental immunity was not a shield in that situation. The city had raised the street level above plaintiff's property and inadequately maintained the drainage ditches. These actions were proprietary. In addition, it found that an Oklahoma statute regarding liability due to grade changes was an additional basis for liability. (11 Okl.St.Ann, Section 36-111).

Mention must be made of Oklahoma's Governmental Tort Claims Act, 51 51 Okl.St.Ann, Sections 151 through 171. It specifically adopts sovereign immunity from liability for torts for the state and its political subdivisions and all employees acting within the scope of their employment. It wipes out the differentiation between governmental and proprietary functions, thereby granting immunity for proprietary actions. It establishes the maximum amount of damages which can be collected for tortious acts. There is a very broad definition of a "tort". It also specifically exempts from liability acts or omissions which are in the discretion of the governmental entity. A 1984 amendment added the following:

> "The liability of the state or political subdivision under this act shall be exclusive and in place of all other liability of the state, a political subdivision, or employee at common law or otherwise". 51 Okl.St.Ann, Section 153B.

This language is broad indeed. What was the legislative intent? What affect it will have on future watercourse and surface water cases is difficult to judge. Perhaps none, but perhaps some. The act obviously eliminated the distinction between governmental and proprietary functions previously used by the Oklahoma Courts. But does the 1984 language prevent lawsuits based on nuisance or trespass? Does it prevent granting equitable remedies such as injunctions? As a "tort claim act" it certainly does not prevent an action in inverse condemnation for a taking of private property without compensation. This is also a constitutional right which cannot be changed by statute.

In any case, it can still be said that at least since 1899 municipalities have been held liable in watercourse and surface water cases based on a variety of theories. It would, therefore, be imprudent for any municipality to depend on governmental immunity in such cases.

In the case of Truelock v. City of Del City, 1998 OK 64, 967 P.2d 1183, the City of Del City was held liable under the Governmental Tort Claims Act for damage caused by its failure to maintain drainage and sewer improvements which it had installed in a utility easement.

## 1505.10 **Taking or Damaging Property Without Just Compensation**

**Governmental entities can be found to have taken or damaged property by flooding under Article 2, Section 24, of the Oklahoma Constitution.**

Section 24 of Article 2 of the Oklahoma Constitution states, "Private property shall not be taken or damaged for public use without just compensation." Landowners whose property has been permanently or temporarily flooded or where there are other consequential damages due to governmental actions may allege violations of this constitutional provision. (A permanent taking can also be sometimes called inverse condemnation). As the Oklahoma Supreme Court has stated,

> "(I)t makes little sense to rule that a taking is present when a citizen's land is covered with steel and cement, yet not present when land is covered with water." State of Oklahoma v. Hoebel, 594 P.2d 1213, (Okl. 1979).

In City of Wewoka v. Mainard, 155 0kl. 156, 8 P.2d 676 (1932) the city built a reservoir which partially flooded land on which plaintiff owned mineral rights. The court held that for all practical purposes the flooded property had been totally taken and found the city liable for appropriating his mineral rights by flooding.

The flooding in Oklahoma City v. Collins-Dietz-Morris Co., 183 Okl. 264, 79 P.2d 791 (1938) was only temporary during the construction phase of a city project. Here the court depended on the "damage" wording of the Constitution and found the city liable.

In another case the governmental entity had actually taken less than an acre of plaintiff's land; however, plaintiff was also awarded money for consequential damages of an additional 157 acres of land which would become inaccessible during times of flooding. Grand River Dam Authority v. Rose, 195 Okl. 698, 161 P.2d 766 (1945). But see Oklahoma Turnpike Authority v. Strough, 266 P.2d 623 (Okl. 1954) where the court decided that the damages plaintiff claimed were not obvious consequences of the defendant's actions, so he would have to wait until the injury actually occurred and sue at that time.

A property owner may also use the "taking" clause when he challenges a government's use of its powers to regulate property, such as floodplain zoning. This is discussed in a subsequent section.

In the case of Morain v. City of Norman, 1993 OK 149, 863 P.2d 1246, an open, paved drainage ditch lay between two properties occupied by the Plaintiffs' apartment houses and office buildings. The ditch, though not originally constructed by the City of Norman, was part of the City's surface water drainage system, and the City maintained the ditch. This ditch, however, was inadequate to drain the area, and flooding was common.

Later, the City of Norman approved a residential subdivision, including drainage improvements, upstream of the Plaintiffs' properties. Increased drainage from this subdivision aggravated the Plaintiffs' flooding problem.

The Plaintiffs sued the City of Norman, in two causes of action: (1) that the City had created a public nuisance, causing injury to them, and (2) that the City had "taken" their property in inverse condemnation. The trial court found the City liable for the nuisance, ordered the City to pay money damages to the Plaintiffs, and also ordered the City to abate the nuisance (that is, to re-design and re-construct the ditch to alleviate the flooding). But the trial court ruled that no Constitutional "taking" of Plaintiffs' property had occurred. Both the Plaintiffs and the City of Norman appealed the judgment of the trial court.

The Supreme Court of Oklahoma agreed with the trial court that the City of Norman had not "taken" Plaintiffs' property, inasmuch as the City committed no overt act, and exercised no dominion or control over the subject property, and any flooding was not so substantial as to destroy the land's usefulness. The Court cited the Hoebel case, above, and also Mattoon and April (see Section 405.2, below).

The Supreme Court also ruled that the City of Norman was not liable for creating a nuisance, since the City had not constructed any of the drainage structures, was under no duty to improve the structures (in other words, construction and maintenance of drainage improvements are discretionary acts), and could not be held liable for the mere approval of plans and issuance of permits. According to Oklahoma's Governmental Tort Claims Act (see Section 404.9, above),

> The state or a political subdivision shall not be liable if a loss or claim results from:…

> 5. Performance of or the failure to exercise or perform any act or service which is in the discretion of the state or political subdivision or its employees; …
>
> 12. Licensing powers or functions including, but not limited to, the issuance, denial, suspension or revocation of or failure or refusal to issue, deny, suspend or revoke any permit, license, certificate, approval, order or similar authority;

It should be noted that Morain is a case about governmental liability to landowners; it says nothing about the injured landowner's ability to sue other parties, for example, the builder of the drainage structure, the developer of the subdivision, insurance companies etc. A landowner also has important rights, discussed above, to build his or her own structures to protect himself or herself from stormwater.

In the cases of Underwood v. ODOT, 1993 OK CIV APP 40, 849 P.2d 1113, and Corbell v. ODOT, 1993 OK CIV APP 45, 856 P.2d. 575 , the State Department of Transportation (ODOT) was found to have Constitutionally "taken" the Plaintiffs' property, causing almost continual flooding after replacing drainage culverts in connection with ODOT's road improvements. See also the companion case of Rummage v. ODOT, 1993 OK CIV APP 39, 849 P2d 1109.

### 1505.11 **Remedies**

**Wherever the law recognizes a right, it also provides a remedy. In stormwater law, several remedies are available.**

If the illegal act has caused injury, such as destroying crops, damages are assessed. Castle v. Reeburgh, 75 Okl. 22, 181 P. 297 (1919). If the situation is such that injury could recur in future floods, the court may grant damages in the amount of the permanent depreciated value of the property. Chicago, R.1. & P. Ry. Co. v. Davis, 26 Okl. 434, 109 P. 214 (1910).

A more appropriate remedy, however, may be to remove the offending structure, in which case the court will grant an injunction (after the fact). Town of Jefferson v. Hicks, already cited.

Where such a structure has not yet been built, but the court is convinced that it would cause injury in the future, it may grant an injunction to prevent its construction. McLeod v. Spencer, 60 0kl. 89, 159 P. 326 (1916).

Or the court may combine several remedies, Miller v. Marriott, 48 Okl. 179, 149 P. 1164 (1915) (damages and injunctions), or fashion a remedy appropriate for the situation. Where defendant's drainage ditch was causing erosion to plaintiff's land, and the land could be protected at small expense by structural improvements, the court denied the injunction but required the improvements. Kollman v. Pfenning, 196 Okl. 186, 163 P.2d, 534 (1945).

# 1506 MANAGEMENT OF STORMWATER BY MUNICIPALITIES

Management of stormwater in a city is as important to the health, safety, and welfare of its citizens as providing water, sewer, transportation, streets, parks, and recreational facilities. It is part of the total urban system and includes managing surface waters, watercourses, and their floodplains. As urbanization occurs, changes are made in natural flow conditions. Whether by default or inaction, or by positive action and policies, a city is affecting stormwater flows.

## 1506.1 Managing Surface Waters

It is obvious from the many surface water decisions that if natural runoff conditions are changed -- in amount, velocity, location, etc. -- to do more harm than formerly, liability results. Where a city simply requires that a developer build streets, storm sewers, shopping centers and parking lots so as to move storm runoff as quickly as possible off the development, it is placing the developer in a very vulnerable position regarding liability to lower property owners. The city itself may be in a vulnerable position for authorizing or requiring such action. If, on the other hand, the city requires that the developer maintain natural runoff conditions, by whatever means are suitable, it is only complying with the basic principles of Oklahoma law. On-site detention of various kinds, such as parking lots, rooftops, and landscaping features, can be encouraged or required by the city. On the other hand, it is risky to allow transbasin diversions, which by definition will bring in additional water to the new basin. This should be avoided where possible, or fully accommodated in the design so no injury can occur from the new flows. It is obvious from the many cases cited that the courts consistently look at the pre-development hydrologic situation as a baseline. Any changes from that baseline which cause injury may result in liability.

## 1506.2 Managing Watercourses and Floodplain Regulation

Activities along the watercourse and its floodplain are considerably more complex in cities than in rural areas. This makes implementing watercourse law in cities more complex because: (1) it may be the cumulative effect of many structures, rather than any single structure, which causes the harm, and (2) it may involve not only how the property is to be developed, but whether it can be developed at all. This immediately gets into the realm of constitutionality, as the prohibiting regulation is challenged as an unconstitutional "taking" of private property without compensation. It is important, however, to analyze such regulations in terms of Oklahoma watercourse law.

Oklahoma decisions state that it is unlawful to interfere with the flow of ordinary floodwaters to the detriment of other property owners. Ordinary floodwaters include those which can be anticipated by a reasonably diligent analysis of the stream, its characteristics, and its history. With today's technology, a diligent analysis would certainly include rainfall/runoff relationships and storm rainfall probability. The ordinary flood includes, at a minimum, the flood of record and may include larger floods. If one affects the flow so that it would result in harm to others during an ordinary flood, one is also liable even when the flood damage occurs during an extraordinary flood.

Certainly, the city's own activities should comply with watercourse law. Regarding private developments, the city may be the only entity which has the overview, and the overall authority, to implement the law. In a rural situation it may be fairly easy to point the finger at the transgressor who interferes with the flood flows. In the urban situation it may be an accumulation of filling, channelizing, diking and placing structures which results in the unlawful interference. As courts have said again and again, no one is permitted to sacrifice his neighbor's property for his own benefit. Floodplain regulation, then, should not be viewed as governmental interference with private property rights, but as protection of private property against unlawful use of other private property, which individually or cumulatively would cause flood injury which would not have occurred prior to development. The individual property owner who is harmed or sees a potential threat should not have to fend for himself by suing for damages or an injunction; it may be very difficult to prove cause and effect in an urban cumulative situation. On the other hand where, by its own policies and regulations, a city permits violation of Oklahoma watercourse law, the city itself may be vulnerable to liability where it authorized the developments.

Floodplain regulation, therefore, is a key element in implementing Oklahoma watercourse law in the complex urban setting where it is exceedingly difficult, if not impossible, for private individual landowners to obtain relief in court against the cumulative actions of many other property owners. A major additional incentive to floodplain regulation is the National Flood Insurance Act of 1968, 42 U.S.C.A., Section 4001 et. seq. The Act was designed to deal with the escalating flood losses nationwide and to provide relief in the form of insurance to property owners. On the one hand, subsidized insurance became available, but only to properties in those communities which participated in the program. On the other hand, to become a "participating community" the local government had to adopt certain minimum floodplain regulations to prevent unwise floodplain development which would otherwise be spurred on by the availability of subsidized insurance.

Prior to 1980, questions were raised whether local governments had the authority to adopt such controls. The Attorney General of Oklahoma issued Opinion No. 70-234 in 1970 (see Appendix B). The opinion concluded that cities and towns had the authority to participate in the program and to establish the necessary land use and control measures to provide for prudent use of flood prone areas. He also concluded that counties did not have such authority in their individual capacities; however, with certain limitations, counties could do so where they had created a Metropolitan Area Planning Commission or a Lake Area Planning and Zoning Commission.

Many Oklahoma communities became participating communities based only on the Attorney General's 1970 opinion. (Refer to "Flood Control in Oklahoma: An Example of Land Use Preceding Land Use Planning," 29 Okl. L. Rev. 16 (1976) for an excellent historical discussion of the issue and need for adoption by the Oklahoma Legislature of a statute granting specific authority to local government to adopt floodplain regulations.)

The City of Tulsa adopted floodplain zoning in the early 1970s which became the subject of a lawsuit when property owners continued a landfill operation contrary to the floodway zoning. The City sought an injunction and the property owners counterclaimed, requesting the court to declare the floodway zoning unconstitutional and unenforceable. A major issue was whether the floodway zoning was a new comprehensive zoning plan requiring a hearing with notice by publication only, or whether it was a "change" in zoning requiring written notification to all property owners within 300 feet of the subject property. The City had complied with the former, but not with the latter. The City argued that this was a huge comprehensive area encompassing many square miles and that written notice to all affected landowners would be costly, time consuming and cumbersome. However, the

Oklahoma Supreme Court eventually held that the ordinance was a "change," and therefore required the written notice. Morland Development Co. v. City of Tulsa, 596 P.2d 1255 (Okl. 1979). The City of Tulsa settled out of court regarding damages to the property owners and subsequently controlled developments in the floodplain through the building permit process. The majority on the court did not address the question of whether or not Tulsa had the power to promulgate floodplain regulations, deciding the issue was not properly before the court on appeal. Justice Barnes, however, in a concurring opinion, stated that he believed the issue was so important that the court should have addressed it and then articulated the reasons why he believed cities had such authority.

Perhaps in response to the Tulsa case, during the following year the Oklahoma Legislature adopted the Floodplain Management Act, 82 Okl.St.Ann, Sections 1604 through 1619 (see Appendix C) authorizing municipalities, counties, and the State to promulgate floodplain regulations. The Act also establishes hearing and notice requirements for adoption of floodplain regulations, the notice being by publication only. Since the wording of Section 1610B does not necessarily address the distinction made by the court in the Tulsa case, without further analysis this author cannot establish whether or not the Legislature intended to supersede the mailing notice requirement or not.

In addition to granting authority to adopt floodplain regulations, the Act further reinforces Oklahoma watercourse law. The floodplain is defined as land which may be covered by flooding, but not limited to the 100-year flood. This indicates that larger floods should be considered. It stresses the need to preserve the capacity of the floodplain to carry and discharge regional floods. It requires that floodplain regulations include controls on all construction in the floodplains which may divert, retard, or obstruct floodwater. After adoption of floodplain regulations and delineating floodplains, all future development is prohibited unless a special permit is granted; however, such permits may be issued only when the applicable floodplain board decides that such development is not a danger to persons or property. Under certain conditions variances may be granted; however, the granting of such a variance does not relieve the recipient from any liability imposed by other laws of the state. One can assume such other laws include the body of watercourse law developed by Oklahoma courts.

There is one section, however, which appears to contradict Oklahoma watercourse law.

Section 1617 states:

> "No new structure, fill, excavation or other floodplain use that is unreasonably hazardous to the public or that unduly restricts the capacity of the floodway to carry and discharge the regional flood shall be permitted without securing written authorization from the floodplain board in which the floodplain is located. Any person violating the provisions of this section shall be guilty of a misdemeanor."

The floodway is earlier defined as the channel of a stream, watercourse or body of water and those portions of floodplains which are reasonably required to carry and discharge the floodwater or floodflow of any river or stream, that is, that portion which carries the deepest and highest velocity floodwaters. This section appears to allow a board to issue written authority for a new structure, fill or excavation which is unreasonably hazardous and does unduly restrict the floodway. A warning is in order here. Any person placing such fill or building such structure, and potentially the governmental entity authorizing them, would be highly vulnerable to a lawsuit under Oklahoma watercourse law.

The Act establishes three areas of jurisdiction: cities, unincorporated areas of counties and state lands. Each of these entities may create a floodplain board and each is authorized to adopt its own floodplain regulations and delineations. The Oklahoma Water Resources Board (OWRB), however, has promulgated regulations controlling state lands (see Appendix D), which also are the minimum standards for the local entities. (Phone conversation with Mr. Cecil Beardon, OWRB staff member, May, 1980). More stringent regulations may be adopted by the local boards and submitted to the OWRB for approval. More stringent regulations have never been disapproved.

The OWRB rules also reinforce Oklahoma stormwater law. Additional purposes for adopting floodplain regulations include protecting public health, safety, and welfare by restricting damageable floodplain improvements and rises in flood elevations which increase flood damage potential elsewhere; protecting adjacent upstream and downstream private and public landowners from increases in flood elevations, velocities, or both, which could increase the potential for flood damages; and protecting individuals from buying lands which are unsuited for intended purposes because of flood hazard.

The issue raised above regarding the complexity of enforcing watercourse law in the urban setting, where it may be the cumulative effect of developments which cause the flood damage, is recognized in Section 1200.3 of the OWRB rules.

> "All calculations of damaging or potentially damaging increases in flood stage or velocity shall assume a reasonably equal degree of encroachment of existing and potential use in the floodplain and shall take into account the cumulative impact of such encroachment."

This section goes on to recommend approaches to minimize damages, including locating structures outside the 100-year floodplain altogether, limiting construction in the flood fringe, and placing habitable structures on elevating members (not fill), or provisions to pass the flood through or over non-habitable structures. All of these suggestions are designed to prevent the use of property by one landowner which would cause flood damage to other properties.

The OWRB rules also require that any designation and mapping of the regulatory floodplain be done using accepted engineering principles reflecting the current state of the art. Thereafter such maps shall not be changed unless reservoir or channel improvements have been constructed, the original delineation is shown to be in error, or there are changed conditions which modify the original computations.

Since the flood insurance program is a federal program, all of the floodplain regulations also have to comply with minimum federal standards. Again, an entity may adopt more stringent standards.

Both federal and OWRB rules establish the floodplain which is to be regulated (regulatory floodplain) as that portion of the floodplain which is susceptible of being covered by the regulatory flood (a 100-year flood, i.e., one that has a one percent chance of occurring in any given year). The regulatory floodplain is then divided into the floodway and flood fringe. The federal program provides that the flood fringe is that portion that can be encroached upon without raising the regulatory flood elevation more than one foot. By definition, then, a city is admitting that it is permitting fill and structures which will raise the level of flooding. Such higher levels may cause flood damage to properties which would not previously have been injured. The OWRB rules however, provide additional criteria. They define the flood fringe as that area which may be developed to the extent the regulatory floodway is preserved and natural conditions allowed. They further state that the flood fringe may be filled or used provided this does not increase the potential for damages or velocities, in addition to the usual wording that such uses do not increase the regulatory flood elevations more than one foot. These additional criteria are consistent with Oklahoma watercourse law which protects landowners from the actions of other landowners which could adversely affect them in times of flooding.

A second floodplain zoning case is Matoon v. City of Norman, 617 P.2d 1347 (Okl. 1980) and 633 P.2d 735 (Okl. 1981). The facts as described by the court are as follows. In 1975 the City adopted an ordinance prohibiting all but certain limited uses on lands along tributaries determined to be within a Flood Hazard District. Plaintiffs land was in one of those districts. On behalf of himself and all landowners in Norman similarly situated (about 500) he claimed 1) that the ordinance was a "taking" of the properties without just compensation and 2) that the City had diverted waters into certain tributaries, and because of inadequate maintenance of these drainage channels, had caused flooding of properties in the districts. The trial court found the ordinance to be a valid exercise of the City's police power and, therefore, did not constitute a taking requiring compensation. The court sustained the City's demurrer to the petition (that is, the facts of the case never went to trial). The Oklahoma Supreme Court reversed, deciding that both the taking issue and the diversion/flooding issue involved questions of fact which could not be decided on a demurrer. Back at the trial court the question was then raised whether the case was a proper class action. The court decided it was not and refused to certify the suit as a class action. This issue then went up on appeal, the Oklahoma Supreme Court affirming the trial court's decision. At that point the plaintiff dropped the suit. The substantive issue of whether or not the ordinance constituted a taking was never tried. The case, therefore stands for:

1. A city's diversion of additional water into a channel and inadequate maintenance thereof may result in liability for flooding of properties (adding just one more case to the many previously cited).

2. Even though a floodplain zoning ordinance is a valid exercise of police power, under some fact situations it may constitute a taking of specific properties; the test of whether there can be recovery is whether or not there is a "sufficient interference" with the landowner's use and enjoyment to constitute a taking. This is a question of fact for the trier of fact to decide.

3. Land use regulations may amount to an actual or de facto taking if there is an overt act by the governmental agency resulting in an assertion of dominion and control over property. (A detailed analysis of the Mattoon case by the Oklahoma Supreme Court itself can be found in April v. City of Broken Arrow, 775 P.2d 1347 (0kl. 1989).)

The latest floodplain case is April v. City of Broken Arrow, 775 P.2d 1347 (0kl. 1989). In 1975 a landowner requested and obtained single-family residential zoning for his unimproved land. At the time he was told the land was in the 100-year floodplain and in an adopted Flood Hazard Area and that all building pads would have to be one foot above the 100-year flood elevation. Then in January of 1978 he requested a higher density residential zoning. In March of that year the City adopted ordinances which placed much more stringent restrictions on all such lands and later denied the landowner's request for the higher density. He sued the city for inverse condemnation, alleging that his property was taken without just compensation. The trial court jury awarded him $240,000 for diminution in the value of his land.

The Oklahoma Supreme Court reversed. It dealt with two issues: first, whether the adoption of the land-use ordinances constituted a taking without just compensation for which a landowner may seek damages under an action in inverse condemnation, and secondly, whether the doctrine requiring exhaustion of administrative remedies precludes judicial review. It answered "no" to the first question and "yes" to the second.

The court found that the landowner had never asked for any permit to build, and, therefore, had also never been denied. The adoption of the ordinances in and of themselves do not constitute a taking. He had not exhausted his administrative remedies and there was not evidence that the pursuit of those remedies would have been futile. At the most the landowner's suit was premature. The court went on to say:

> "In balancing the private and public interests herein Owner's potential use of all property, under our system of government, is subordinate to the right of City's reasonable regulations, ordinances, and all similar laws that are clearly necessary and bear a rational relation to preserving the health, safety and general welfare of the residents of Broken Arrow. 775 P.2d at 1352.

In regard to the specific ordinances adopted by the city, the court stated:

> "We hold such limitations substantially advance City's legitimate goals of: one, reducing risks of loss of life and property; two, protecting the public's interest in health; three, preserving the aesthetic environment and fiscal integrity of Haikey's flood prone areas; four, enabling landowners to develop their property located within the floodplain, as well as allowing landowners to purchase federally-sponsored flood hazard insurance to protect their investments. 775 P.2d at 1354.

The Oklahoma Supreme Court, then, recognizes the need for good floodplain management and the public and private benefits to be derived. It is being consistent with its predecision courts going back over the century.

## 1507 FINANCING THE PROJECT: THE DRAINAGE AND FLOOD CONTROL UTILITY AND FEE

Communities have long found it difficult to finance drainage projects. More than two decades ago Billings, Montana, developed an imaginative solution. It decided to view drainage projects as part of a drainage utility, just like water and sewer projects, and would charge customers for the services provided. Property owners whose runoff drained into city storm sewers would be considered customers of the storm sewer utility just like citizens whose homes used city water and sewer services. The fee charged would essentially be based on the difference between historic runoff and the amount of runoff from the property in its developed state. The reasoning was that under natural conditions a considerable amount of stormwater percolates into the ground. However, where land is covered with homes, carports, parking lots, etc., the surface is impermeable, producing much more runoff, at greater velocity, causing higher peak flows than naturally. Commercial establishments which usually have more impervious surface than residential property, would be charged a higher rate. The proposal was challenged in court in City of Billings v. Nore, 148 Mont. 96, 417 P.2d 458 (1966). The proposal was upheld as constitutional and equitable, and has since been implemented.

Since then many other communities including Tulsa, Oklahoma and Boulder, Colorado, have also adopted and implemented the drainage utility and fee. Additional refinements to the basic concept have been made, such as:

1. Giving credit for on-site detention; since the amount of runoff will be less, the drainage fee is reduced; giving credit is an incentive to on-site storage, which keeps runoff as close to natural as possible.

2. Providing that the revenue produced by the fee can be used not only for structural projects, but also for nonstructural measures such as floodplain administration and purchase of land or easements to preserve a natural drainageway.

3. Providing for calculating actual runoff from a particular parcel, such as a shopping center, in order to more precisely determine the fee.

4. Adding a surcharge to the drainage fee for developed properties situated in a floodplain or flood hazard area because of the extraordinary public costs involved in protecting the properties and in providing emergency services in the event of a flood.

A drainage plan is of little value unless it is implemented. While some aspects can be implemented through zoning, subdivision regulations and building permits, corrective actions are usually costly, and financial resources are needed to implement such projects. This drainage fee concept, based on the difference between natural runoff and developed runoff, is particularly appropriate under Oklahoma's surface water law.

# APPENDIX A - CASES CITED AND OTHER PERTINENT CASES

Allied Hotels, Ltd. v. Barden, 389 P.2d 968 (Okl. 1964).

April v. City of Broken Arrow, 775 P.2d 1347 (Okl. 1989).

Armstrong Byrd & Co., v. Illinois Cent. R. Co., 26 Okl. 352, 109 P.216(1910).

Atchison, T. & S.F. Ry Co. v. Hadley, 168 Okl. 588, 35 P.2d 463.

Black v. Ellithorp, 382 P.2d 23 (Okl. 1963).

Carter v. Gundy, 259 P.2d 528 (Okl. 1953).

Castle v. Reeburgh, 75 0k]. 22, 181 P. 297 (1919).

Chicago, R.I. & P. Ry. Co. v. Bahr, 78 0k] 78, 188 P. 1058 (1920).

Chicago, R.I. & P. Ry. Co. v. Davis, 26 Okl. 434, 109 P. 214 (1910).

Chicago, R.I. & P. Ry. Co. v. Groves, 20 Okl. 101, 93 P. 755 (1908).

Chicago, R.I. & P. Ry. Co. v. Johnson, 25 Okl. 760, 107 P. 662 (1910).

Chicago, R.I. & P. Ry. Co. v. MayLiard, 31 Okl. 685, 122 P. 149 (1911).

Chicago, R.I. & P. Ry. Co. v. McKone, 36 Okl. 41, 127 P. 488 (1912).

Chicago, R.I. & P. Ry. Co. v. Morton, 57 Okl. 711, 157 P. 917 (1916).

Chicago, R.I. & P. Ry. Co. v. Schirf, 267 P.2d 574 (Okl. 1954).

Chicago, R.I. & P. Ry. Co. v. Taylor, 173 0k]. 454, 49 P.2d 721(1935).

Chicago, R.I. & P. Ry. Co. v. Turner, 141 Okl. 267, 284 P. 855(1930).

City of Ardmore v. Orr, 35 0kl. 305, 129 P. 867 (1913).

City of Billings v. Nore, 148 Mont. 96, 417 P.2d 458 (1966).

City of Chickasha v. Looney, 36 Okl. 155, 128 P. 136 (1912).

City of Oklahoma V. Hill, 6 Okl. 114, 50 P. 242 (1897).

City of Skiatook v. Carroll, 163 Okl. 149, 21 P.2d 498 (1933).

City of Wewoka v. Mainard, 155 Okl. 156, 8 P.2d 676 (1932).

Cole v. Missouri, K.& 0. R. Co., 20 0kl. 227, 94 P. 540 (1908).

Corbell v. ODOT, 1993 OK CIV APP 45, 856 P.2d. 575

Culbertson v. Green, 206 0kl. 210, 243 P.2d 648 (1952).

Davis v. Fly, 14 Okl. 340, 78 P. 180 (1904).

Dobbs v. Missouri Pacific R. Co., 416 F.Supp. 5 (E.D. Okl. 1975).

Dowlen v. Corwley, 170 Okl. 59, 37 P.2d 933 (1934).

Elk City v. Rice, 286 P.2d 275 (Okl. 1955).

Garrett v. Haworth, 183 Okl. 569, 83 P.2d 822 (1938).

George v. Greer, 207 Okl. 494, 250 P.2d 858 (1952).

Godlin v. Hockett, 272 P.2d 389 (Okl. 1954).

Grand River Dam Authority v. Rose, 195 0kl. 698, 161 P.2d 766 (1945).

Gregoly v. Bogdanoff, 307 P.2d 841 (Okl. 1957).

Gulf, C. & S. F. Ry Co v. Anderson, 136 Okl. 97, 276 P. 711 (1929).

Gulf, C. & S. F. Hy. Co. v. Clark, 101 F. 678 (8th Cir. 1900).

Gulf, C. & S. F. Ry. Co. v. Richardson, 42 Okl. 457, 141 P. 1107(1914).

Haenchen v. Sand Products Co., Inc._, 1981 OK CIV APP 6, 626 P.2d 332

Herwig v. City of Guthrie, 182 Okl. 599, 78 P.2d 793 (1938).

Incorporated Town of Idabel v. Harrison, 42 Okl. 469, 141 P. 1110(1914).

Kansas City Southern R . Co v. Hurley, 61 Okl. 241, 160 P. 910(1916).

King v. Cade, 205 Okl. 666, 240 P.2d 88 (Okl. 1951).

Kollman v. Pfenning, 196 Okl. 186, 163 P.2d 534 (1945).

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Luker v. BOCC of Greer County, 2002 OK CIV APP 108, 84 P.3d 773

Lynn v. Rainey, 400 P.2d 805 (Okl. 1965).

Mattoon v. City of Norman, 617 P.2d 1347 (Okl. 1980) and 633 P.2d
735 (Okl. 1981).

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Moneypenny v. Dawson, 2006 OK 53, 141 P.3d 549

Morain v. City of Norman, 1993 OK 149, 863 P.2d 1246

Morland Development Co. v. City of Tulsa, 596 P.2d 1255 (Okl. 1979).

Murduck v. City of Blackwell, 198 Okl. 171, 176 P.2d 1002 (1947).

Oklahoma City v. Bethel, 175 Okl. 193, 51 P.2d 313 (1935).

Oklahoma City v. Collins - Dietz - Morris Co., 183 Okl. 264, 79 P.2d 791 (1938).

Oklahoma City v. Hoke, 75 Okl. 211, 182 P. 692 (1919).

Oklahoma City v. Rose, 176 Okl. 607, 56 P.2d 775 (1936).

Oklahoma City v. Tarkington, 178 Okl. 430, 63 P.2d 689 (1936).

Oklahoma Ry. Co. v. Mary Boyd, 167 Okl. 151, 28 P.2d 537 (1934).

Oklahoma Ry. Co. v. W. H. Boyd, 140 Okl. 45, 282 P. 157 (1929).

Oklahoma Ry. Co. v. Woods, 164 Okl. 215, 23 P.2d 217 (1933).

Oklahoma Turnpike Authority v. Strough, 266 P.2d 623 (Okl. 1954).

Oklahoma Water Res. Bd. v. Central Okl. M. C. Dist., 464 P.2d408 748 (Okl. 1969).

Pahika v. Chicago, R. 1. & P. Ry. Co., 62 Okl. 223, 161 P. 544(1916).

Pechacek v. Hightower, 269 P.2d 342 (Okl. 1954).

Raincy v. Cleveland, 203 Okl. 283, 220 P.2d 261 (1950).

Regier v. Hutchins, 298 P.2d 777 (Okl. 1956).

Richards v. City of Lawton, 629 P.2d 1260 (Okl. 1981).

Rummage v. ODOT, 1993 OK CIV APP 39, 849 P2d 1109

Sinclair Prairie Oil Co. v. Fleming, 203 Okl. 600, 225 P.2d 348412(1950).

State of Oklahoma v. Hoebel, 594 P.2d 1213 (1979).

Stiers v. Mayhall, 207 Okl. 219, 248 P.2d 1047 (1952).

St. Louis & S. F. R. Co. v. Dale, 36 Okl. 114, 128 P. 137 (1912).

Town of Jefferson v. Hicks, 23 Okl. 684, 102 P. 79 (1909).

Town of Norman v. Ince, 8 Okl. 412, 58 P. 632 (1899).

Truelock v. City of Del City, 1998 OK 64, 967 P.2d 1183

Underwood v. ODOT, 1993 OK CIV APP 40, 849 P.2d 1113

Walton v. Bryan, 188 Okl. 358, 109 P.2d 489 (1941).

Wichita Falls & N.W. Ry. Co. v. Stacey, 46 Okl. 8, 147 P. 1194(1915).

## LAW REVIEW ARTICLES CITED

"Flood Control in Oklahoma: An Example of Land Use Preceding Land Use Planning" 29 Okl. L. Rev. 16 (1976).

"Liability without Fault", 3 Okl. L. Rev. 1 (1950).

# APPENDIX B - ATTORNEY GENERALS OPINION

**ENTRY_DATE**: 123196
**APPELLANT**: Representative Rex Privett / Senator Finis W. Smith
**JURISDICTION**: Attorney General of Oklahoma - Opinion
**HEARING_DATE**: September 17, 1970
**TEXT_OF_RULE**:

NATIONAL FLOOD INSURANCE PROGRAM - CITY AUTHORITY TO PARTICIPATE

Oklahoma cities and towns have the authority under State law to participate in the National Flood Insurance Program of 1968 as implemented and amended in 1969, and to effectuate their participation, have the authority to establish and enforce land use and control measures as defined in the Act to mean zoning ordinances and such other and necessary application of the police power as may be required to provide safe standards of occupancy for, and prudent use of, flood prone areas.

However, counties, except as they may join in cooperative activities with municipalities in the formation of a Metropolitan Area Planning Commission or qualify to form and exercise the functions of a Tulsa Area Planning and Zoning Commission, do not have the authority as counties to establish such land use and control measures under currently effective laws. In consequence, their authority to participate in the National Flood Insurance program is restricted to doing so when engaged in the activities referred to in this paragraph above.

The Attorney General has had under consideration your recent letter relative to the National Flood Insurance Act, of 1968, as amended in 1969. You ask, in effect, the following questions:

1. Do cities, towns, and counties in Oklahoma have the authority to participate in this National Flood Insurance program?

2. Do they have the authority to establish land use and control measures, zoning ordinances, subdivision regulations, and other applications and extensions of the normal police power to provide safe standards of occupancy for, and prudent use of, flood areas?

Title 42 U.S.C.A. 4011, provides in relevant part that:

"(a) To carry out the purposes of this chapter, the Secretary of Housing and Urban Development is authorized to establish and carry out a national flood insurance program which will enable interested persons to purchase insurance against loss resulting from physical damage to or loss of real property or personal property related thereto arising from any flood occurring in the United States."

Title 42 U.S.C.A. 4012, provides in part as follows:

"(c) The Secretary shall make flood insurance available in only those states or areas (or sub-division thereof) which he has determined have -

" (1) Evidenced a positive interest in securing flood insurance coverage under the Flood Insurance Program, and

"(2) Given satisfactory assurance that by December 31, 1971, adequate land use and control measures will have been adopted for the State or area (or sub-division) which are consistent with the comprehensive criteria for land management and use developed under Section 4102 of this Title, and that the application and enforcement of such measures will commence as soon as technical information on floodways and on controlling flood elevations is available."

Title 42 U.S.C.A. 4022, provides:

"After December 31, 1971, no new flood insurance coverage shall be provided under this chapter in any area (or sub-division thereof) unless an appropriate public body shall have adopted adequate land use and control measures (with effective enforcement provisions) which the Secretary finds are consistent with the comprehensive criteria for land management and use under Section 4102 of this Title."

Title 42 U.S.C.A. 4102(a), authorizes the Secretary to carry out studies and investigations, using available state, local and federal sources, with respect to the adequacy of state and local measures in flood prone areas, etc. It provides under (b) that such studies and investigations shall include, but not be limited to, laws, regulations, or ordinances relating to encroachments and obstructions on stream channels and floodways, the orderly development and use of flood plains of rivers or streams, floodway encroachment lines and flood plain zoning, building codes, building permits, and subdivision or other building restrictions. It further provides, under (c), that the Secretary shall from time to time develop comprehensive criteria designed to encourage where necessary the adoption of permanent state and local measures which, to the maximum extent feasible, will --

"(1) Constrict the development of land which is exposed to flood damage where appropriate,

"(2) Guide the development of proposed construction away from locations which are threatened by flood hazards,

"(3) Assist in reducing damage caused by floods, and

"(4) Otherwise improve the long range land management and use of flood prone areas."

Under 11 O.S. 401 through 11 O.S. 412 , as amended in 1968, 1969 and 1970, Oklahoma cities and towns are authorized to establish land use and control measures, and to adopt and enforce ordinances, subdivision regulations, building codes, and other regulations pertaining to the public health and welfare in respect to areas within the jurisdiction of their respective legislative bodies.

The 32nd Oklahoma Legislature, at its second regular session, enacted Senate Bill No. 320, effective April 28, 1970, which provided in its Title for "County Planning and Zoning." However, the body of the Act contains no reference to zoning or authority to establish regulations, other than with respect to "Planning."

Title 19 O.S. 863.1 through 11 O.S. 863.29 (1961), as amended, provided for city county planning, and zoning by counties having cities with a certain population and more than 50% of their incorporated area within the county. However, in Elias v. City of Tulsa, Okl. 408 P.2d 517 (1965), the Supreme Court held:

". . . that Chapter 19Aa, S.L. 1955, 19 O.S. Supp. 1955, 863.1-863.43 is unconstitutional."

Title 19 O.S. 866.1 through 19 O.S. 866.36 , as amended, provides for the creation, by one or more counties and certain municipalities located therein, of Metropolitan Area Planning Commissions. Specific powers are given to participating counties to establish zoning regulations, building codes, construction codes, and housing codes, for all the area located within three miles of the municipality, or within one-fourth mile of any State or Federal Highway located anywhere in the county, or within one-half mile of any water supply or reservoir owned by the municipality, excluding, however, any incorporated area....

Title 19 O.S. 866.2 and 19 O.S. 866.36 (1969) were respectively 1 and 2 of O.S.L. 1965 Regular Session, Thirtieth Legislature, ch. 403, which was approved July 5, 1965, and contained the emergency clause and a provision for codification in Title 19 O.S. Supp. 1965. Section 866.2, as reenacted provides:

".... In every county of this state having an upstream terminal port and turnaround where navigation ends, or in any county containing all or any part of a reservoir or reservoirs constructed by the United States Army Corps of Engineers or by the Grand River Dam Authority, such county is hereby granted authority, at the discretion of the board of county commissioners, to establish zoning regulations, a building code and construction codes, and a housing code in accordance with the provisions of this act for all or any part of the unincorporated area within the county ...." (Emphasis added)

Section 19 O.S. 866.2 was amended by the addition of the following paragraph:

"In the counties in which a Lake Area Planning and Zoning Commission is authorized as provided above, said commission may be created by the Board of County Commissioners of said counties as provided in this act and said commission may exercise all the powers and authority hereinafter provided for City-County Planning and Zoning Commissions. The jurisdiction of any such Lake Area Planning and Zoning Commission is limited to a three mile perimeter from the normal elevation lake shoreline of any such lake." (Emphasis added)

Despite the lack of specific reference thereto in Section 19 O.S. 866.2 , it is apparent that the Legislature intended the first quoted portion thereof to be applicable to counties which were participants in the creation of a Metropolitan Area Planning Commission, and also had within their jurisdictions an upstream terminal and navigational turnaround or a reservoir built by the U.S.C.E. or G.R.D.A.

Confirmation of the Legislative intent is shown by the language constituting a part of amended Section 866.36, hereinafter quoted.

Title 19 O.S. 866.36 (1969), provides for creation of a Lake Area Planning and Zoning Commission by any one or more counties having within their jurisdiction a lake constructed by the United States Corps of Engineers or by the Grand River Dam Authority.

Said section contains the following:

".... A Lake Area Planning and Zoning Commission may be formed to include all or any part of a county in which there is a lake constructed by the Corps of Engineers or by the Grand River Dam Authority regard less of the population of said county or the cities and towns therein. More than one county may cooperate in a joint Lake Area Planning and Zoning Commission. Funds for the operation of a Lake Area Planning and Zoning Commission may be appropriated by any county, city or town in the area affected by such Planning Commission. A Lake Area Planning and Zoning Commission when properly formed shall be authorized to exercise all the powers and duties set forth in this act." (Emphasis added)

It is therefore, the opinion of the Attorney General that your questions numbered 1 and 2 must be answered in the following manner: Oklahoma cities and towns presently have authority under State statutes to participate in the National Flood Insurance Program of 1968, and to establish land use and control measures, and to adopt and enforce zoning ordinances, subdivision regulations, building codes and other regulations to provide safe standards of occupancy for and prudent use of flood prone areas pursuant to such participation.

However, counties as such do not presently have such authority, or the power to establish such land use and control measures or to engage in such zoning and regulatory activities, acting in their individual capacities, but may, subject to the limitations and under the provisions of 19 O.S. 866.2 (1969), do so where they have created a Metropolitan Area Planning Commission, and under Section 19 O.S. 866.36 where they can and have formed a Lake Area Planning and Zoning Commission.

( Carl G. Engling )

**CITATIONS**: 70-234 (1970) ag

# APPENDIX C - OKLAHOMA FLOODPLAIN MANAGEMENT ACT

**Title 82. Waters and Water Rights**

**Chapter 23 - Oklahoma Floodplain Management Act**

§ 1618. Application of Act

§ 1619. Repealed by Laws 1989, HB 1135, c. 154, § 2, emerg. eff. July 1, 1989

§ 1620. Floodplain Administrator - Designation, Duties, Accreditation

§ 1620 .1. Accreditation Standards for Floodplain Administrators

# OKLAHOMA WATER RESOURCES BOARD

Title 785 - Oklahoma Water Resources Board

Chapter 55 - Development on State Owned or Operated Property Within Floodplains and Floodplain Administrator Accreditation

Subchapter 1 General Provisions

Subchapter 3 Development on State Owned or Operated Property Within the Floodplains

Subchapter 5 Variances and Exemptions on State Owned or Operated Property Within the Floodplains

Subchapter 7 Floodplain Administrator Accreditation Program