CITY OF ALLIANCE

DRAINAGE CRITERIA MANUAL

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DRAINAGE CRITERIA MANUAL

by

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1.0 INTRODUCTION

1.1 Background

The provision for adequate drainage is necessary to preserve and promote the general health, welfare and economic well-being of the community. Drainage is a regional feature that effects all governmental jurisdictions and all property. The characteristics of drainage make it necessary to formulate a program that balances both public and private interests. This manual was developed as one part of the overall drainage program being implemented in the City of Alliance.

1.2 Purpose

The purpose of this manual is to set forth the policies and technical criteria to be used in the analysis and design of drainage systems within the City of Alliance. When planning drainage facilities, certain underlying principles provide direction for the effort. These principles are made operational through a set of policy statements. The application of drainage policy is facilitated by the technical criteria and data. When considered in a comprehensive manner and on a regional level, drainage facilities can be provided in a manner that will minimize flood losses and disruption, enhance the general health and welfare of the region, and help assure optimum economic and social benefits.

This manual shall apply to all facilities constructed within the City of Alliance Planning area on public right-of-way, easements dedicated for public use and to all privately owned and maintained storm water facilities. This manual is the minimum design and technical criteria for analysis and design of storm drainage facilities. All subdivisions, planned unit developments or any other proposed construction submitted for approval under the provisions of the manual, shall include adequate storm drainage system analysis and appropriate drainage system design. Such analysis and design shall meet or exceed the criteria set forth herein. Options to the provisions of this criteria may be suggested by the applicant but the burden of proof that the option meets or exceeds the criteria set forth herein is the responsibility of the applicant.

1.3 Approval

This manual has been adopted by the City Council of the City of Alliance on ______ day of _____ , 1989 and shall apply to lands within the planning jurisdiction of the City of Alliance.

The City Engineer shall be responsible for review of all drainage plans and designs submitted under the requirements of this manual. An approval by the City does not relieve the owner, engineer, or designer from the responsibility of insuring that the calculations, plans, specifications, construction, and record drawings are in compliance with the manual as stated in the owner's engineer's certification.

1.4 Revisions

The policies and criteria presented in this manual may be amended from time to time upon the approval of the City Council as new technology is developed or as experience is gained through the use of this manual. The City Engineer shall monitor the performance and effectiveness of the policies and criteria contained in the manual and will recommend amendments and revisions as needed.

2.0 DRAINAGE POLICIES

2.1 General Statement

In general the policy statements in this manual address 6 areas of concern: (1) General Drainage Planning and Management; (2) Major and Minor Drainage Considerations; (3) Downstream Impacts of Drainage Improvements; (4) Natural Channels; (5) Storm-water Quality; (6) Maintenance of Drainage Facilities. The policy statements are presented below along with explanations as to the purpose and need of the policy.

2.2 Drainage Planning

2.2.1 Master Drainage Planning

Storm-water management problems are interrelated and geographically dependent. As part of the drainage program, the City of Alliance will initiate a detailed drainage management study for each individual drainage basin. Each study will be based on a hydrologic routing of flood flows within the basin in order to determine how basin development will affect the drainage pattern, and whether improvements will be necessary. The result of the studies will be a master drainage plan for each basin.

Where the master drainage plan indicates that public improvements are justified, mechanisms to fund those improvements and provide for their future maintenance is of particular concern.

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THE POLICY OF THE CITY SHALL BE TO DEVELOP A DRAINAGE MASTER PLAN FOR EACH INDIVIDUAL DRAINAGE BASIN WITHIN THE CITY. THIS WILL, AT A MINIMUM, INDICATE SITE REQUIREMENTS FOR NEW DEVELOPMENTS AND WHAT PUBLIC IMPROVEMENTS, IF ANY, ARE NEEDED NEW DEVELOPMENT WITHIN INDIVIDUAL BASINS SHALL BE REQUIRED TO MEET THE SPECIFICATIONS OF THE MASTER DRAINAGE PLAN FOR THAT GIVEN AREA.

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The process of developing the Master Drainage Plan should be directed by general framework goals. These goals are:

- Economic efficiency
- Regional development
- Environmental preservation and enhancement
- Social and recreational needs fulfillment
- Responsible funding and implementation policy

2.2.2 Planning for New Development

Responsible development planning includes careful consideration of the changes in drainage that will occur as a result of the development. This includes the effects of the increased runoff, the point of discharge of that runoff, and the effects of offsite runoff though the new development site. Planning for new development must also conform to the requirements of the Master Drainage Plan for the basin and meet the criteria set forth in this manual.

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NEW DEVELOPMENTS IN THE CITY OF ALLIANCE WILL BE REQUIRED TO PROVIDE A DRAINAGE PLAN. APPROVAL OF THE DRAINAGE PLAN BY THE CITY ENGINEER MUST BE GRANTED BEFORE THE DEVELOPMENT CAN OCCUR. THIS WILL APPLY TO SUBDIVISIONS, PLANNED UNIT DEVELOPMENTS AND OTHER SUCH SITE IMPROVEMENTS WHICH WILL ALTER THE EXISTING DRAINAGE PATTERNS OF THE SITE OR CHANGE THE PEAK FLOW OR VOLUME OF RUNOFF FROM THE SITE.

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The drainage plan will include a detailed study of offsite runoff onto the site, any channels or storm sewers that exist on the site, any flood plains that exist on the site and the effects of the proposed change in drainage patterns on the site and its release from the site. In addition, this drainage plan shall consider the criteria in this manual in order to evaluate the overall site drainage and it's effects on the proposed improvements.

2.2.3 Drainage Submittal Requirements

A requirement for new development shall be submittal of drainage plans. The drainage planning requirements will be set forth by the policies and criteria presented in this manual and by the requirements of the applicable Master Drainage Plan (TEC 1989). The submittal will require at a minimum, engineering drawings containing the necessary information outlined below and a drainage report supplementing the drawings as described below. For subdivisions and planned unit developments, as development regulations require, the drainage plans and drainage report will be made part of the submittal package.

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THE POLICY OF THE CITY WILL BE TO REQUIRE DRAINAGE PLANS AND DRAINAGE REPORTS ON ALL NEW DEVELOPMENTS. THESE PLANS AND REPORTS SHOULD ADDRESS THE DRAINAGE PLANS OF THE DEVELOPMENT AND HOW IT RELATES TO THE MASTER DRAINAGE PLAN. DETAILED ANALYSIS OF THE HYDROLOGY AND HYDRAULICS OF THE SITE WILL BE INCLUDED TO PROVIDE INFORMATION NECESSARY TO EVALUATE THE PROPOSED DESIGN. THIS ANALYSIS WILL SHOW HOW THE PROPOSED PLAN WILL INTERFACE WITH UPSTREAM AND DOWNSTREAM DRAINAGE FACILITIES.

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The requirements for submittal of preliminary and final drainage plans and reports are described below.

2.2.4 Preliminary Drainage Report

This report shall be submitted to the City Engineering Department as required by the City of Alliance Subdivision Regulations. The purpose of the preliminary drainage report is to present a conceptual plan for handling drainage prior to actual sizing of facilities. This report shall be approved by the City Engineer prior to submittal of the final drainage report. The preliminary drainage report shall include, but not be limited to the following items:

1. The report shall include an analysis of overall drainage considerations which will include a map of the major watershed in which the development is located. This map shall be of sufficient detail to identify the various paths of flows of drainage waters from the development and identify any major constriction such as other development along the path of drainage. In addition, this analysis must identify areas off site of the development from which drainage water shall enter the development.

2. The report must show peak flows for drainages entering and leaving the development for the minor and major storms. Assumptions for upstream development must take into account planned development upstream and be based on information and discussions with adjacent property owners and the Basin Master Plan. These assumptions should be clearly stated and justifications for the assumptions must be presented. Flows shall be computed for the existing and future developed conditions of the site. Data and procedures utilized in determining peak flows shall be included for verification of the results.

3. Provisions for site drainage shall be displayed on a 24" x 36" format. These drawings shall contain the preliminary design for the minor and major drainage systems within the development. Drainage plans shall be submitted in two separate phases showing the effects of the minor storm runoff and major storm runoff, and each shall include the following information:

   a. Topographic contours (2-ft. contour interval proposed and existing) on USGS Datum.

   b. Location and elevations of USGS Bench Marks. All elevations shall be on USGS Datum.

   c. Property lines.

   d. Streets, names, and grades.

e. Existing drainage facilities and structures, including roadside ditches, drainageways, gutter flow directions, culverts, etc. All pertinent information such as size, shape, slope, location, etc., that will facilitate review and approval of drainage plans.

f. Overall drainage area boundary and drainage sub-area boundaries.

g. Proposed type of curb and gutter (vertical or combination) and gutter flow directions, including cross pans. (Type of curb and gutter must be approved by the City Engineer).

h. Proposed piping and open drainageways, including proposed inlets, manholes, culverts, and other appurtenances. (All appurtenances must be approved by the City Engineer).

i. Proposed outfall point(s) for runoff from the study area.

j. Routing and accumulative flows at various critical points for the minor storm runoff.

k. Routing and accumulative flows at various critical points for the major storm runoff.

l. Minimum floor elevations for protection from minor and major storm runoff.

5. Documentation and data utilized in the preliminary sizing of the drainage facilities shall be submitted in the report.

6. Soil classification reports, and if requested by City Engineer, depth and seasonal fluctuations of the underground water table throughout the development. Details of any proposed subsurface drainage systems or proposed alterations to existing subsurface drainage systems shall be provided.

7. Details of the relationship of proposed drainage facilities to existing or planned drainage facilities in surrounding properties or developments shall be included in the report. A statement shall be included indicating the relationship of the proposed drainage facilities to the Master Drainage Plan for the affected basin. In cases where the point of of outfall or peak flow from the property is other than historic, binding agreements from affected property owners permitting such discharge shall be submitted.

8. In cases where all or any part of a development falls within a flood hazard area in the Master Drainage Plan as designated, the flood hazard area shall be shown on the plan, along with computed flood-water surface elevations.

9. The preliminary drainage report and plans must be prepared under the direct supervision of a State of Nebraska registered professional engineer, and certified using the following certification:

   I hereby certify that this report (plan) for the preliminary drainage design of ____________________ was prepared by me (or under my direct supervision) for the owners thereof and meet or exceed the criteria in the City of Alliance Drainage Criteria Manual and Standard Specifications.

   ____
   Registered Professional Engineer
   State of Nebraska No.___________
   (Seal)

2.2.5 Final Drainage Report

The final drainage report shall be submitted for approval along with the final plat and construction drawings. When approved, the report will be signed by the City Engineer and shall constitute only conceptual approval of the drainage plan. The report shall include information submitted in the preliminary report, with any additions, modifications, or corrections required. In addition, the final drainage report shall include the following:

1. Results of street capacity calculations at critical street sections for minor storm runoff and major storm runoff.

2. Hydraulic grade lines for all storm sewers for the minor and major storms.

3. Backwater profiles for open channel, including minor and major storm runoff with input data and procedures used for the calculations.

4. Results of culvert design calculations with all input data and procedures used.

5. Inflow and outflow design hydrographs for detention facilities.

6. Stage-volume curves, outlet rating curves, spillway rating curves, and the method used to determine the rating curves.

7. An erosion control plan where soil or slope conditions dictate. This plan should indicate methods to be used during and after construction to control erosion and sediment deposition in the development. (As a supplement to the report, 24" x 36" drawings may be necessary to illustrate the methods and structures to be used.)

8. A statement which describes the safety hazards that may be associated with the various drainage structures and the provisions that have been included in the design to minimize safety hazards.

9. Certification similar to paragraph 2.2.5, Item 9 for the preliminary report. In the certification references to "preliminary" shall be changed to "final".

2.2.6 Final Drainage Plans

All storm drainage plans shall be checked for conformance with the minimum design criteria set forth in this Manual and within the City of Alliance Standard Specifications prior to approval. Prior to submission of the final construction drawings, one complete set of prints shall be submitted for review and comment. The prints will be returned if changes are required or recommended. Two complete sets of revised prints shall then be submitted for final approval along with the original review print.

Construction plans and details will show the following information:

Street names and easements with width dimensions
Existing or planned utilities and structures, including -
- water
- gas
- telephone
- storm drain
- irrigation ditches
- sanitary sewers
- electric

a. Plan

North arrow
Property lines and ownership or subdivision information

b. Profile

Vertical and horizontal grids with scales
Ground surface existing (dotted) and proposed (solid)
Existing utility lines where crossed
Bench marks (USGS Datum)
Elevations (USGS Datum)

c. Proposed construction - All construction shall conform to the City of Alliance Standard Specifications.

Pipes

Plan and profile showing -

size, type, and structural class of pipe, including ASTM specification
grades
inlet and outlet details
manhole details (station number and invert elevations)
bedding and backfilling details

Open channels
plan showing stationing
profile, including water-surface profiles
grades
typical cross section
lining details

Special structures (manholes, culverts, headwalls, trash gates, etc.)

plan
elevation and water-surface profiles
details of design and appurtenances

Streets, curb and gutter

The following details should be shown on each and every page of all drawings:

a. Title block (lower right-hand corner)

b. North arrow

c. Scale 1" = 5' vertical, 1" = 50' horizontal, where possible (Plan and Profile)

d. Date and revisions

e. Name of professional engineers or firm

f. Professional engineer's seal and signature

g. Statement:

All work shall be constructed in accordance with City of Alliance Standard Specifications as provided by the City Engineer, except as noted.

ACCEPTED BY: ______________________________
City Engineer

DATE: ______________________________

2.3 Major and Minor Drainage

Every urban area has two separate and distinct drainage systems whether or not they are actually planned for and designed. One is the initial or minor system and the other is the major system. To provide for orderly urban growth, reduce future costs, prevent loss of life and major property damage, both systems must be planned and properly engineered.

Minor Storm Provisions - The minor storm drainage system is necessary to reduce street maintenance costs, provide protection against frequently occurring storm runoff and provide convenience to residents. The minor drainage system cannot economically carry major runoff such as a 100 year event. The minor drainage system provides drainage through the use of common storm drainage facilities such as, storm sewers, street gutters etc. for more frequent storms such as a 2 year, or 10 year event. The purpose of the minor drainage system is to prevent property damage and minimize inconvenience of minor storm events.

Major Storm Provisions - In addition to providing storm drainage facilities for the minor storm events, provisions shall be taken to prevent loss of life and major property damage for the 100 year storm runoff. Such provisions are known as the major drainage system.

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THE POLICY OF THE CITY SHALL BE TO REQUIRE ALL NEW DEVELOPMENT TO INCLUDE THE PLANNING FOR, DESIGN AND CONSTRUCTION OF MINOR AND MAJOR STORM DRAINAGE SYSTEMS IN ACCORDANCE WITH THE CRITERIA PRESENTED HEREIN. DESIGN OF FACILITIES WITHIN THE MAJOR DRAINAGE SYSTEM SHALL BE BASED ON RUNOFF EXPECTED FROM THE 100-YEAR RAINFALL.

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2.4 Downstream Impacts

As property is developed from rural agricultural land use to urban land use the characteristics of the resulting runoff changes both by quantity, quality and in the way it is released from the property. This change in runoff can have significant effects on downstream properties. The land use change may not only effect properties immediately downstream, but also other properties through the remainder of the basin.

The drainage water from the City of Alliance is generally released onto downstream agricultural lands. Past experience has indicated that this practice impacts the areas where it is released and it is necessary to carefully consider the impact of storm water runoff on downstream properties. In some cases storm water releases have been eliminated by the use of retention basins. The consideration of the impact of storm water runoff on downstream properties is a part of the master drainage planning process, but consideration must also be given to each individual site, particularly where downstream conditions are still undeveloped, and in areas on the edge of the city where master planning may not be completed.

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THE POLICY OF THE CITY WILL BE TO REQUIRE NEW DEVELOPMENT TO STUDY THE IMPACTS OF DRAINAGE WATER RELEASES ONTO DOWNSTREAM PROPERTIES PARTICULARLY WHERE THE IMPACT HAS NOT BEEN CONSIDERED AS PART OF A MASTER DRAINAGE PLAN. THIS WOULD REQUIRE OBTAINING PERMISSION OF DOWNSTREAM PROPERTY OWNERS TO CHANGE THE CHARACTERISTICS OF STORM-WATER RELEASES ONTO THEIR PROPERTY.

AT NO POINT IN TIME, AND UNDER NO CONDITIONS, WILL THE CITY OF ALLIANCE ASSUME ANY LIABILITY FOR DISTRESS TO AFFECTED LANDS AND/OR PROPERTY OWNERS AS A RESULT OF THE DEVELOPMENT(S) UNDER CONSIDERATION. IT SHALL BE EXCLUSIVELY THE DEVELOPERS RESPONSIBILITY TO PROVIDE FOR DRAINAGE FACILITIES THAT ELIMINATE ADVERSE IMPACTS ON DOWNSTREAM PROPERTY OWNERS.

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2.5 Major Drainageways

Major drainageways consist primarily of historic and natural drainageways which provide outfall points for the minor drainage system but also provide capacity to carry the major drainage. Natural channels, an important part of the urban drainage system, have desirable characteristics, including the ability to provide flood storage and provide natural stability of the channel. The use of natural channels to accommodate urban runoff is encouraged. Where upstream development causes increases in peak flows in natural channels consideration must be given to mitigate the effects on the channel. The improvement of natural drainageways to carry the increased runoff due to urbanization should include consideration of the recreational and esthetic potential of the drainageway.

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THE POLICY OF THE CITY WILL BE TO REQUIRE MANAGEMENT AND REGULATION OF FLOODPLAINS ALONG ALL MAJOR DRAINAGEWAYS. DEVELOPMENT ALONG THE MAJOR DRAINAGEWAYS WILL BE IN CONFORMANCE WITH CURRENT FLOOD PLAIN ORDINANCES. IMPROVEMENTS TO MAJOR DRAINAGEWAYS WITHIN NEW DEVELOPMENT AREAS WILL BE PLANNED FOR AND DESIGNED IN ACCORDANCE WITH THE CRITERIA PRESENTED HEREIN. THE IMPROVEMENTS SHOULD BE DESIGNED TO PROVIDE FOR RECREATIONAL OPPORTUNITIES AND ESTHETIC ENHANCEMENT IN ADDITION TO FLOOD CONTROL PURPOSES.

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2.6 Storm Water Detention and Retention

In some locations the use of storm water detention or retention is necessary to control or eliminate runoff from development. The use of uniform requirements for detention or retention of storm water runoff is not proposed. Detention of runoff is the storing of runoff water for purposes of controlling peak rate of release from the site. Storm water retention is the total storage of all runoff to eliminate release of stormwater from the surface of the site. The only release of water from a retention basin is through infiltration or evaporation. The use of retention basins which rely on infiltration is discouraged because of the potential long term effects on ground-water quality in the area.

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THE POLICY OF THE CITY WILL BE TO REQUIRE DETENTION OR RETENTION STORAGE OF STORM WATER RUNOFF AS DIRECTED BY INDIVIDUAL MASTER DRAINAGE PLANS AND A HYDROLOGIC ROUTING ANALYSIS. IN AREAS WHERE MASTER DRAINAGE PLANS HAVE NOT BEEN COMPLETED THE CITY ENGINEER MAY REQUIRE DETENTION OR RETENTION STORAGE IN AREAS WHERE SUCH STORAGE IS DEEMED NECESSARY TO PROTECT DOWNSTREAM PROPERTIES.

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2.7 Storm Water Quality

Storm water runoff from urban areas commonly involves concentrations of trace metals, organic materials,nutrients, salts and sediment. Sediment production from developed urban areas however, is usually not a major problem; the greatest source of sediment is from new construction and erosion from unstable channel reaches. Historically, water quality from storm-water runoff has not been a major problem and has not been regulated.

Recent congressional legislation (Title 4 Section 405 of HR1) passed on February 4, 1987, includes provisions for permitting of storm water discharge. Although for communities of less than 100,000 people regulations will not take effect until October 1992. By this date there will be permitting requirements for storm water developed by U.S. Environmental Protection agency or the State of Nebraska. Until the permitting regulations have been drafted there is no action that can be taken except in selecting drainage options which will provide the greatest control of the water quality of runoff.

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THE POLICY OF THE CITY WILL REQUIRE PLANNING FOR WATER QUALITY MANAGEMENT OF STORM WATER RUNOFF FROM DEVELOPMENTS. THE MANAGEMENT WILL CONSIST OF MEETING FEDERAL AND STATE REQUIREMENTS AS THEY BECOME APPLICABLE. THE MANAGEMENT OF OVERALL WATER QUALITY OF STORM DRAINAGE WILL AT A MINIMUM REQUIRE THE DEVELOPER TO SUBMIT AN EROSION CONTROL PLAN FOR ALL NEW DEVELOPMENT IN ACCORDANCE WITH THE CRITERIA PRESENTED IN THIS MANUAL.

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2.8 Operation and Maintenance

Operation and maintenance of storm water drainage facilities is required to ensure that they will perform as designed. Channel bed and bank erosion, drop structure damage, pipe inlets and outlets, and overall deterioration to the facilities must be routinely inspected and repaired as necessary to avoid reduced conveyance capacity, displeasing esthetics and ultimate failure.

Sediment and debris must also be periodically removed from channels, storm sewers and detention basins. Trashracks and street inlets must also be routinely cleared of debris to maintain system capacity.

Grass lined channels and detention basins must have sufficient vegetative cover to prevent erosion, but must also have slopes that are flat enough to allow for efficient mowing and maintenance.

The operation and maintenance must be taken into consideration during the design process so as to avoid facilities that would be costly to operate and maintain, or otherwise require special maintenance equipment that the city may not own.

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THE CITY DRAINAGE POLICY REQUIRES THAT ACCESS BE PROVIDED TO ALL STORM WATER STRUCTURES FOR MAINTENANCE AND OPERATIONAL INSPECTIONS. DEVELOPERS SHALL BE RESPONSIBLE FOR ESTABLISHING PROGRAMS TO MAINTAIN INITIAL DRAINAGE SYSTEMS INCLUDING INLETS, PIPES, CULVERTS, CHANNELS, DITCHES, DETENTION BASINS AND RETENTION BASINS LOCATED ON THEIR LAND UNLESS SPECIFIED OTHERWISE BY SUBDIVIDER AGREEMENTS. IN ANY EVENT, DEVELOPERS SHALL MAINTAIN DRAINAGE FACILITIES UNTIL ACCEPTED BY THE CITY. DEVELOPERS SHALL PROVIDE FOR PERPETUAL MAINTENANCE OF PRIVATE DRAINAGE FACILITIES THROUGH MECHANISMS ACCEPTABLE TO THE CITY ENGINEER.

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3.0 RAINFALL DETERMINATION

3.1 General

Precipitation-frequency relationships are prerequisites for valid drainage planning and design. Procedures developed by the National Oceanic and Atmospheric Administration and published in Precipitation Frequency Atlas of the United States, Technical Paper 40, have been adapted for use in the City of Alliance. (Hereinafter this publication will be referred to as TP 40.) The data and procedures used in this section will be revised periodically to keep information current. The user is expected to use the most up-to-date version of this manual.

The design storm frequencies to be used for the City of Alliance are specified in Table 3.1-1.

Table 3.1-1

Design Storm Frequencies

	Design Storm Return Period	
Land use	Minor storm	Major storm
Residential	2-year	100-year
Public building areas, commercial and business areas	10-year	100-year
Parks, greenbelts, etc.	2-year	100-year
Open channels and drainageways	-	100-year
Detention and retention ponds	-	100-year

3.2 Procedures

Precipitation-frequency relationships for the City of Alliance were derived by using two methods to develop the data. Using data from TP 40, the variations of precipitation-frequency relationships at Alliance were analyzed.

The precipitation data for the City of Alliance have been computed from TP 40. These data should be used with the procedures presented in Section 3.4 of this Manual to determine the design hydrology of the watersheds in the Alliance area.

Figure 3.2-1 is the Intensity Frequency Duration Curve and Table 3.2-1 presents the Design Storms for the city. The use of the table and figure is explained in Section 3.3.

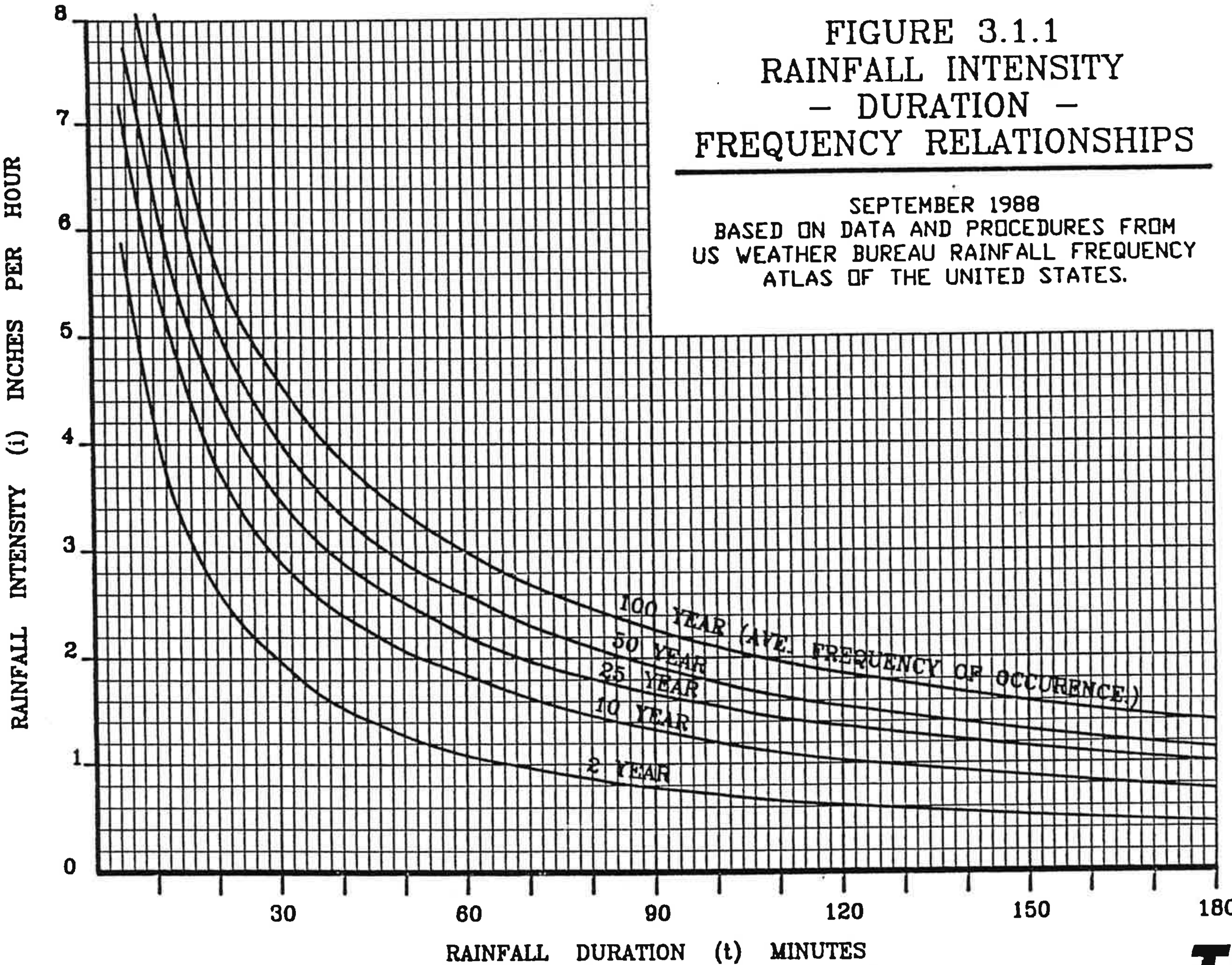
Table 3.2-1

Precipitation Intensity Duration Data
City of Alliance

DURATION (min.)	2 Year Ttl. (In)	2 Year Int. (In/hrs)	10 year Ttl. (In)	10 year Int. (In/hrs)	25 year Ttl. (In)	25 year Int. (In/hrs)	50 year Ttl. (In)	50 year Int. (In/hrs)	100 year Ttl. (In)	100 year Int. (In/hrs)
5	0.49	5.88	0.61	7.32	0.64	7.68	0.75	9.00	0.85	10.20
15	0.79	3.16	1.10	4.40	1.27	5.08	1.48	5.92	1.68	6.72
30	0.99	1.98	1.46	2.92	1.73	3.46	2.05	4.10	2.30	4.60
60	1.10	1.10	1.85	1.85	2.20	2.20	2.60	2.60	3.00	3.00
120	1.22	0.61	2.04	1.02	2.69	1.35	3.07	1.54	3.70	1.85
180	1.30	0.43	2.22	0.74	3.00	1.00	3.40	1.13	4.16	1.39

FIGURE 3.1.1
RAINFALL INTENSITY – DURATION – FREQUENCY RELATIONSHIPS

SEPTEMBER 1988
BASED ON DATA AND PROCEDURES FROM US WEATHER BUREAU RAINFALL FREQUENCY ATLAS OF THE UNITED STATES.



TEC

3.3 Runoff Computational Techniques

3.3.1 Runoff Analysis

Runoff from a design storm event must be computed before drainage works can be intelligently planned or engineered. Although the best method for determining runoff is to analyze measured runoff from known storm patterns, this is seldom possible, and one must be able to accurately estimate the runoff. Various hydrologic and hydraulic techniques are available for computing runoff on ungaged watersheds, and the engineer responsible for runoff computations must exercise his professional judgment, and understand the limitations of the particular method he selects.

This section illustrates selected runoff computational techniques that not only are considered appropriate for the City of Alliance, but also can be utilized without computers and extensive basin calibration. The engineer familiar with the more sophisticated techniques should be encouraged to use them, but his results must be compatible, since the techniques herein are the standard guidelines for the City of Alliance.

Most of the simpler techniques for computing runoff were not developed for a wide range of conditions. Computational techniques recommended for use in Alliance are presented below.

Rational Method. This method (see Section 3.3.2) is recommended for storm sewer, culvert design, and overland flow from areas generally less than 200 acres. The Rational Method is applicable to both minor and major storm runoff.

Other Methods. For areas larger than 200 acres the use of data from the Master Drainage Plan for the City of Alliance should be utilized. If this data is not sufficient for design purposes, techniques consistent with the methodology used in that basin planning are recommended.

3.3.2 Rational Method [1]/

For basins that are not complex and have 200 acres or less, it is recommended that the design storm runoff be analyzed by the Rational Method. This method was introduced in 1889, and is used in most engineering offices in the United States. Even though it has frequently come under academic criticism for its simplicity, no other practical drainage design method has been evolved to a level of general acceptance by the practicing engineer. The Rational Method, if judiciously applied, can produce satisfactory results on small watersheds.

Rational Formula

The Rational Method is based on the Rational Formula:

$$Q = CIA \qquad \text{(Eq. 3.3.2-1)}$$

where:

Q = maximum rate of runoff, in cubic feet per second.

C = runoff coefficient, which is the ratio between the maximum rate of runoff from the area and the average rate of rainfall intensity, in inches per hour, for the period of maximum rainfall of a given frequency of occurrence having a duration equal to the time of concentration.

I = average intensity of rainfall in inches per hour for a duration equal to time of concentration (usually time required for water to flow from most remote point of area to point being investigated).

A = area, in acres

Basic Assumptions

1. The computed maximum rate of runoff to the design point is a function of the average rainfall rate during the time of concentration to that point.

2. The maximum rate of rainfall occurs during the time of concentration, and the design rainfall depth during the time of concentration is converted to the average rainfall intensity for the time of concentration.

3. The maximum runoff rate occurs when the entire area is contributing flow.

Limitations

The greatest drawback to the Rational Method is that it normally provides only the peak flow on the runoff hydrograph. When the basins become complex and where subbasins come together, the Rational Method will tend to overestimate the actual flow, which results in oversizing drainage facilities. The Rational Method provides no direct data to route hydrographs through the drainage facilities. One reason the Rational Method is limited to small areas is that good design practice requires the routing of hydrographs for larger basins for economic design.

1/ This section was adapted from Resource Consultants 1979.

Another disadvantage of the Rational Method is that with typical design procedures one normally assumes that all of the design flow is collected at the design point and that there is no "carry-over water" running overland to the next design point. This is not the fault of the Rational Method however, but of the design procedure. The Rational Method must be modified, or another type of analysis used, when analyzing an existing system that is underdesigned or when analyzing the effects of a major storm on a system designed for the minor storm.

Intensity

The intensity, I, 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. This is determined from Figure 3.2-1.

Runoff Coefficient

In the Rational Method, the runoff coefficient, C, is the variable least susceptible to precise determination and requires judgment and understanding on the part of the engineer. Although its use in the formula implies a fixed ratio for any given drainage area, in reality this is not the case. The coefficient represents the integrated effects of infiltration, detention storage, evaporation, retention, flow routing, and interception, which all affect the time distribution and peak rate of runoff. Table 3.3.2-1 presents recommended ranges for C values.

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surface in the drainage area. This procedure is often applied to typical "sample" blocks as a guide to selection of reasonable values of the coefficient for an entire area.

The range and recommended (Table 3.3.2-1) coefficients are applicable for storms up to the 10-year frequency. Less frequent higher-intensity storms will require modification of the coefficient, because infiltration and other losses have a proportionally smaller effect on runoff.

Table 3.3.2-1

Runoff Coefficients for Rational Method
(From: American Soc. of Civil Engineers and Water Pollution Control Fed. [1970] and Seelye [1960])

Character of surface	Runoff coefficients	
	Range	Recommended
Pavement--asphalt or concrete	0.70-0.95	0.90
Gravel, from clean and loose to clayey and compact	0.25-0.70	0.50
Roofs	0.70-0.95	0.90
Lawns (irrigated) sandy soil		
Flat, 2 percent	0.05-0.15	0.10
Average, 2 to 7 percent	0.15-0.20	0.17
Steep, 7 percent or more	0.20-0.30	0.25
Lawns (irrigated) heavy soil		
Flat, 2 percent	0.13-0.17	0.15
Average, 2 to 7 percent	0.18-0.22	0.20
Steep, 7 percent	0.25-0.35	0.30
Pasture and non-irrigated lawns		
Sand		
Bare	0.15-0.50	0.30
Light vegetation	0.10-0.40	0.25
Loam		
Bare	0.20-0.60	0.40
Light vegetation	0.10-0.45	0.30
Clay		
Bare	0.30-0.75	0.50
Light vegetation	0.20-0.60	0.40
Composite areas		
Urban		
Single-family, 4-6 units/acre	0.25-0.50	0.40
Multi-family, >6 units/acre	0.50-0.75	0.60
Rural (mostly non-irrigated lawn area)		
<1/2 acre - 1 acre	0.20-0.50	0.35
1 acre - 3 acres	0.15-0.50	0.30
Industrial		
Light	0.50-0.80	0.65
Heavy	0.60-0.90	0.75
Business		
Downtown	0.70-0.95	0.85
Neighborhood	0.50-0.70	0.60
Parks	0.10-0.40	0.20
Rural open space		

The adjustment of the Rational Method for use with major storms can be made by multiplying the right side of the Rational Formula by a frequency factor C_f, which is used to account for antecedent precipitation conditions. The Rational Formula now becomes:

$$Q = CC_fIA \qquad \text{(Eq. 3.3.2-2)}$$

where:

Recurrence interval (years)	C_f
2 to 10	1.0
25	1.1
50	1.2
100	1.25

The product of C times C_f should not exceed 1.0

<u>Time of Concentration</u>

A basic assumption underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the most remote part of the drainage area under consideration to the point under consideration. In the application of the method, the time of concentration must be estimated so that the average rainfall rate of a corresponding duration can be determined from the rainfall intensity-duration-frequency curves that are prepared for the design area (see Section 3.2).

For urban storm sewers, the time of concentration consists of an inlet time, or time required for runoff to flow over the surface to the nearest inlet, and time of flow in the sewer to the point under consideration. The latter time can be closely estimated from the hydraulic properties of the sewer. Inlet time, on the other hand, will vary with surface slope, depression storage, surface cover, antecedent rainfall, and infiltration capacity of the soil, as well as distance of surface flow. In general, the higher the rainfall intensity the shorter the inlet time. Common urban practice varies the inlet time from 10 to 30 minutes. The time of concentration has no relationship to the time of beginning of rainfall, but it is related to the position of the peak rainfall intensity. When dealing with pipe systems, the time of concentration may be readily calculated from the inlet time plus time of flow in each successive pipe run. The latter value is calculated from the velocity of flow in the pipes.

The inlet time can be estimated by calculating the various overland distances and flow velocities taken from the most remote point. Two common errors are (1) to assume velocities that are too small for the areas near the collectors, and (2) not to review the runoff from only a part of the basin which is sometimes greater than that computed for the whole basin. This error is most often encountered in long basins, or a basin where the upper portion contains grassy park land and the lower is developed urban land. Often the remote areas have flow that is very shallow, and in this case the velocities cannot be calculated by "channel" equations, but special overland flow analysis must be considered. Fig. 3.3.2-1 can be used to help estimate time of surface flow.

Fig. 3.3.2-1 is a solution of the following equation:

$$T_c = \frac{1.87(1.1-CCf)D^{1/2}}{S^{1/3}} \qquad \text{(Eq. 3.3.2-3)}$$

where:

T_c = time of concentration, in min.

S = slope of basin, in percent

CC_f = Rational Method runoff coefficient

D = length of basin, in feet

The overland flow path perpendicular to the contours is not necessarily the best decision when studying a proposed development, since the land will be graded, and swales will often intercept the natural contour and conduct the water to the streets, thus cutting down on the time of concentration.

Application of the Rational Method

The first step in applying the Rational Method is to obtain a good topographic map and define the boundaries of all of the relevant drainage basins. Basins to be defined include all basins tributary to the area of study and subbasins in the study area. A field check and possible field surveys should be made for each basin.

The major storm drainage basin does not always coincide with the minor storm drainage basin. This is often the case in urban areas where a low flow will stay next to a curb and follow the lowest grade, but when a large flow occurs the water will be deep enough so that part of the water will overflow street crowns and flow into a new subbasin.

Major Storm Analysis

When analyzing the major runoff occurring on an area that has a storm sewer-system sized for the minor storm, care must be used when applying the Rational Method. Normal application of the Rational Method assumes that all of the runoff is collected by the storm sewer. In this initial design, the time of concentration is, in part, dependent upon the flow time in the sewer. During the major runoff, however, the sewers should be fully taxed and cannot accept all the water flowing to the inlets. This additional water then flows by the inlets and continues overland, generally at a significantly lower velocity than the water in the storm sewers. This requires an analysis of different concentration times between underground flow and overland flow. This difference in travel times provides opportunities for the storm sewer to continue flowing full for a longer

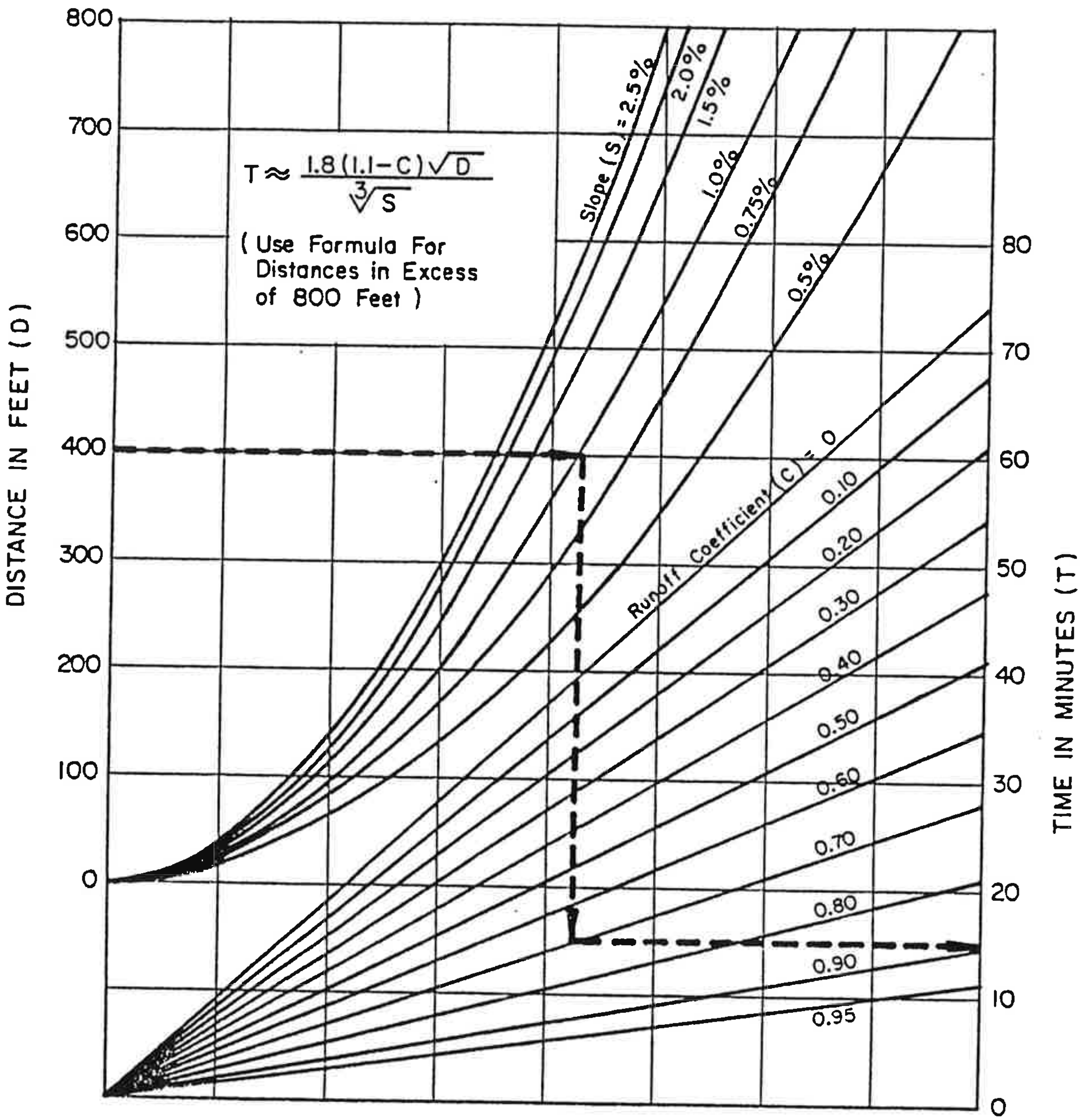


Figure 3.3.2-1 SURFACE FLOW TIME CURVES
(From : Dept. of Transportation, 1970)

period and, in effect, to carry significant portions of the major runoff. The basis for this increased benefit is that the excess water from one inlet will flow to the next inlet downhill, using the overland route. If that inlet is fully taxed, the water will often continue on until capacity is available in the storm sewer. The analysis of this aspect of the interaction between the storm-sewer system and the major storm runoff is complex. The most useful procedure for this analysis is the routing of hydrographs through the two routes concurrently.

3.4 Streets in the Drainage System

This Section presents recommended design of street drainage systems. It includes the design criteria as well as the procedures for determining drainage performance for urban and rural streets Properly planned street drainage will help avoid or even eliminate the need for storm sewers.

3.4.1 Design Criteria

Design criteria for the collection and movement of runoff water on public streets are based on frequency of traffic interference; that is, streets are classified as to whether they are local, collectors/arterials, other arterials or rural highway, (HWS 1981) and the character of the street determines whether certain traffic lanes can be fully inundated during the minor design storm return period, or whether no encroachment is allowed on any traffic lane (Table 3.4.1-1). Section 3.4.2 outlines procedures for drainage design of urban streets, and Section 3.4.3 for rural streets. Minimum grade for all gutters shall be 0.35 percent.

Depth of allowable cross street flow (Table 3.4-1) differs for minor and major storms. Cross street flow falls in two general categories: (1) runoff that has been flowing in a gutter, then flows across the street to the opposite gutter or to an inlet; and (2) flow from some external source, such as a drainageway, that will flow across the crown of a street when the conduit capacity beneath the street is exceeded. Culverts should be used whenever it is necessary to transport runoff across streets without curb and gutter.

In rural areas where no curb and gutter exists, the allowable capacity for the drainage ditch should be calculated through the use of Manning's formula with an appropriate roughness coefficient. If the natural channel slope would cause erosive velocity, suitable channel protection such as drop structures, checks, or riprap shall be employed. Design depths shall be limited to 1.5 feet, and preferably to less than 1.0 foot. Section 3.4.3 describes design procedures for rural street drainage.

Table 3.4.1-1

Allowable Use of Streets and of Cross Street Flow as Part of Drainage System during Minor and Major Storm Runoff

Street Classification[1]	Minor storm runoff (Maximum roadway encroachment)	Major storm runoff (Allowable depth & inundation)
Local	No curb overtopping; where no curbing exists, encroachment shall not extend over property lines. Flow may spread to crown of street.	Inundation: Residential dwellings, public, commercial, and industrial buildings shall not be inundated at ground line, unless buildings are floodproofed.
Collector/Arterials/ Other Arterials	No curb overtopping; (same as above). Flow spread must leave at least one lane free of water in each direction.	(same as above)
Rural Highway	No encroachment is allowed on any traffic lane.	Inundation: (same as above). Depth of water at street crown shall not exceed 6" to allow operation of emergency vehicles. Depth of water over gutter flowline shall not exceed 18".

Allowable Cross Street Flow

Local	Where cross pans allowed, depth of flow shall not exceed 6".	Depth of water over gutter flowline shall not exceed 18".
Arterial and Highway	None	Depth of water at crown shall not exceed 6".

3.4.2 Storm Drainage Design for Urban Streets

The suggested procedures for design of street drainage in urban areas are at the designer's option, so long as they are in compliance with criteria in all Sections of this Manual.

Street Capacity for Minor Storm

Street carrying capacity for the minor storm shall be determined by:

1. Pavement encroachment for computed theoretical flow conditions (see Table 3.4.1-1).

2. An empirical reduction of the theoretical allowable rate of flow to account for practical field conditions.

Street Capacity for Major Storm

Allowable flow for the major storm shall be determined by:

1. Theoretical capacity based upon allowable depth and inundated area (see Table 3.4.1-1).

2. Reduced allowable flow due to velocity considerations.

Calculating Theoretical Capacity of Gutters Along Streets

When the allowable pavement encroachment has been determined, the theoretical gutter carrying capacity for a particular encroachment shall be computed through use of the modified Manning's formula:

$$Q = 0.56\frac{Z}{n} S^{1/2} y^{8/3} \qquad \text{(Eq. 3.4.2-1)}$$

where:

Q = discharge in cfs

Z = $1/S_x$ where S_x is the cross slope of the pavement; adjusting for future pavement, overlays, add 1%.

y = depth of water in feet at face of curb

S = longitudinal grade of street

n = Manning's roughness coefficient (for most situations of gutter flow, an n of 0.016 should be used)

Experiments have proved that this form of the equation is more accurate than would be obtainable by computing the hydraulic radius based on the wetted perimeter for the area of the cross section. The equation applies directly to a section having a straight cross slope.

The compound section, with the gutter having a Z-value of 12, is widely used for streets because the hydraulic capacity for a given spread of water on the pavement is substantially increased.

Since more water is concentrated close to the curb, the compound section also increases the capacity of inlets to intercept flow. To facilitate computation of inlet capacity, the compound section can be converted to an equivalent straight cross slope having the same capacity as the compound section for a given depth "d" measured from the gutter flow line.

The equivalent straight-slope section can be computed by the following equation (adapted from Urban Land Institute et al., 1975):

$$Z_3 = Z_1 \left[1 + (Z_2/Z_1 - 1) \left(\frac{T-W}{T + W(Z /- 1)} \right)^{8/3} \right] \qquad \text{(Eq. 3.4.2-2)}$$

where:

Z_3 = reciprocal of cross slope of equivalent section

Z_1 = reciprocal of cross slope of gutter

Z_2 = reciprocal of cross slope of pavement (increase design slope by 1% to allow for future pavement overlays)

W = width of gutter in feet (this often will be identical to the width of the depression of a curb opening inlet since it is impractical to extend the inlet depression appreciably beyond the gutter width)

T = top width of water surface

Allowable Gutter Flow for Minor Storm

The actual flow rate allowable per gutter shall be calculated by multiplying the theoretical capacity by the corresponding factor obtained from Fig. 3.4.2-1. The designer will then be able to develop discharge curves for standard streets.

Velocity Considerations for Gutters During Major Storms

A recommended criterion is that the velocity in the deepest part of the gutter be limited to 10 feet per second. This velocity is readily computed by the Manning equation using the depth at a point 6 inches from the face of the curb as the hydraulic radius. The mean velocity for the entire cross section is not a good measure. If the calculated velocity exceeds 10 feet per second, the allowable discharge in the gutter must be reduced until velocity is within the limit. The designer is then faced with the problem of where and how to reduce the runoff entering this

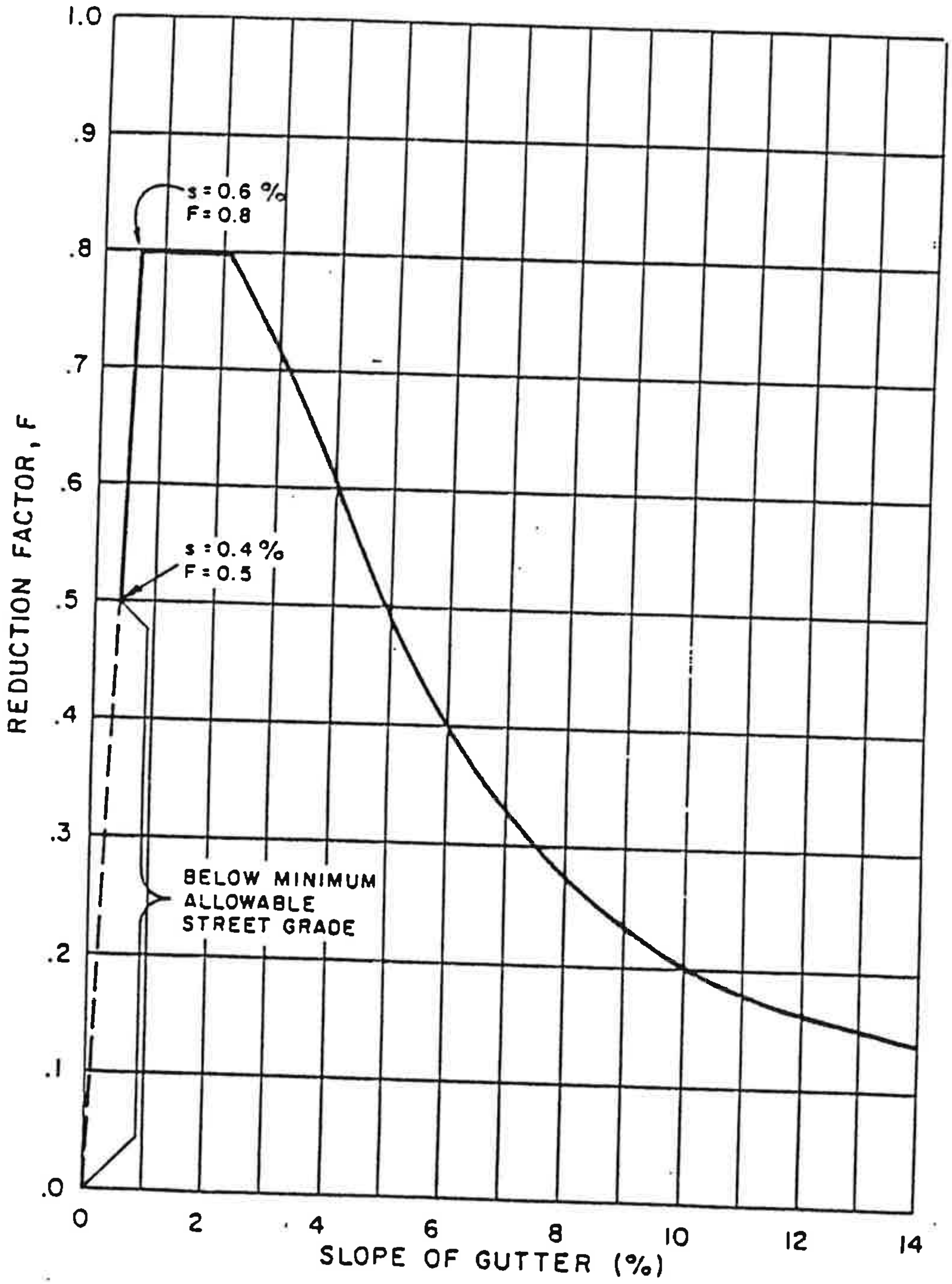


Fig. 3.4.2-1 REDUCTION FACTOR FOR ALLOWABLE GUTTER CAPACITY

APPLY REDUCTION FACTOR FOR APPLICABLE SLOPE TO THE THEORETICAL GUTTER CAPACITY TO OBTAIN ALLOWABLE GUTTER CAPACITY.

gutter. Additional inlets could be installed upstream, but this is expensive. If possible, some way should be found to divert runoff to some path other than the steep street, preferably by a revised street layout. Future street resurfacing which will reduce capacity should be considered in the calculations.

Ponding

Ponding will occur in areas where runoff is restricted to the street surface by sump inlets, street intersections, low points, intersections with drainage channels, or other reasons.

Limitations by street classification for minor and major storms (Table 3.4.1-1) should determine the allowable depth at inlets, gutter turnouts, culvert headwaters, etc.

Intersections

The following considerations should be given to the design of drainage at intersections. In general, the allowable cross-street flow criteria given in Table 3.4.1-1 should be used.

Capacity of gutters entering an intersection. The capacity of each gutter entering the intersection can be determined by methods presented above. When determining the theoretical capacity of the intersection, use the criteria below:

Continuous grade across intersection: When the gutter slope will be continued across an intersection, as when cross pans are utilized, the slope used for calculating capacity should be that of the gutter flowline crossing the street.

Flow Direction Change at Intersection: When the gutter flow must undergo a direction change at the intersection greater than 45 degrees, the slope used for calculating capacity should be the average of the gutter slopes through the direction change.

Flow Interception by Inlet: When gutter flow will be intercepted by an inlet on continuous grade at the intersection, the average gutter slope shall be utilized for calculations.

Allowable Capacity of Gutters Approaching an Intersection. The allowable capacity for gutters approaching an intersection should be calculated by applying a reduction factor to the theoretical capacity as covered in the following sections.

Flow Approaching an Arterial Street: When the direction of the flow is toward an arterial street, the allowable carrying capacity shall be calculated by applying the reduction factor from Fig. 3.4.2-2 to the theoretical gutter capacity. The grade used to determine the reduction factor shall be the same effective grade used to calculate the

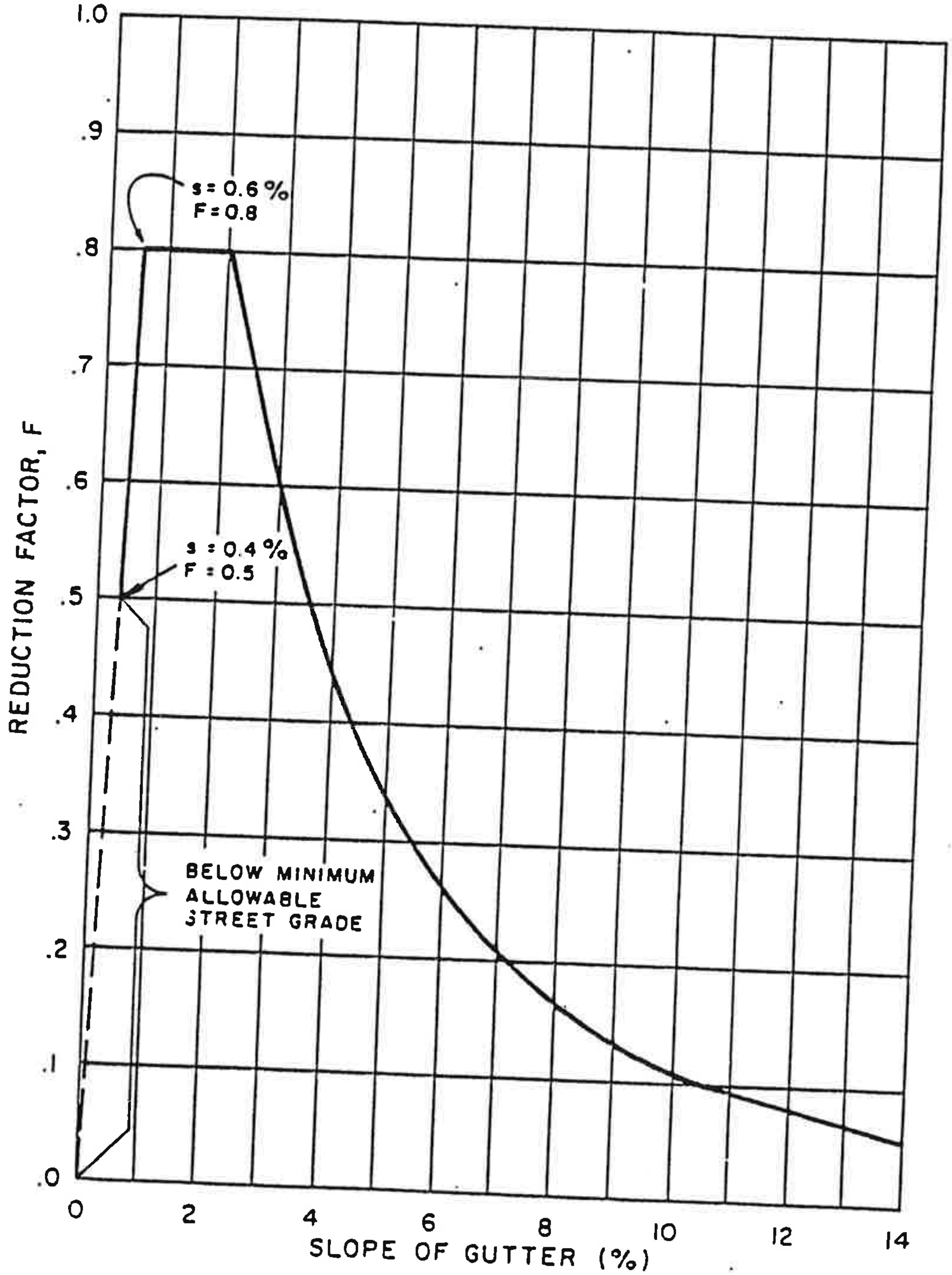


Fig. 3.4.2-2 REDUCTION FACTOR FOR ALLOWABLE GUTTER CAPACITY WHEN APPROACHING AN ARTERIAL STREET

APPLY REDUCTION FACTOR FOR APPLICABLE SLOPE TO THE THEORETICAL GUTTER CAPACITY TO OBTAIN ALLOWABLE GUTTER CAPACITY APPROACHING ARTERIAL STREET.

Flow Approaching Local Streets: When the direction of flow is toward a local street, the allowable carrying capacity shall be calculated by applying the reduction factor from Fig. 3.4.2-1 to the theoretical gutter capacity. The slope used to determine the reduction factor shall be the same effective slope to calculate the theoretical capacity.

3.4.3 Storm Drainage Design for Rural Streets

Rural streets are characterized by the use of roadside ditches for drainage purposes, as opposed to curbs and gutters on urban streets. Although most of the requirements in Section 3.4.2 for urban streets are applicable for rural streets, certain special considerations for proper design of rural streets are necessary. Permissible velocities for roadside drainage ditches are the same for both minor and major storm runoff (Table 3.4.3-1).

Street Capacity for Minor Storm

Street carrying capacity for the minor storm shall be determined by (1) pavement encroachment allowed, and (2) maximum allowable velocity to prevent scour.

Pavement Encroachment

The same limitations govern rural streets as those for urban streets (see Table 3.4.1-1).

Allowable Capacity

Once the pavement encroachment has been established, the maximum allowable velocity for the drainage channel shall be determined from Table 3.4.3-1. For the minor runoff, design velocities for all linings should not fall below 2 fps, to minimize problems with sediment deposition.

The allowable capacity for the drainage ditch should be calculated through the use of Manning's formula with an appropriate n value. If the natural channel slope would cause excessive velocity, suitable channel protection such as drop structures, checks, or riprap shall be employed. Design water depths shall be limited to 1.5 feet, and preferably to less than 1.0 foot.

Street Capacity for Major Storm

Street carrying capacity for the major storm shall be determined by (1) allowable depth and inundated area, and (2) maximum allowable velocity for acceptable scour.

Allowable Depth and Inundated Areas. The same limitations govern rural streets as those for urban streets (see Table 3.4.1-1).

Allowable Capacity. Based upon the allowable depth and inundated area, the allowable capacity for the major storm should be calculated the same as that for minor storms (see Table 3.4.1-1).

Ponding

The same limitations govern rural streets as those for urban streets for both minor and major storm situations.

Table 3.4.3-1

Permissible Velocities for Roadside Drainage Ditches
for both Minor and Major Storm Runoff

Roadside channels with erodible linings (earth; no vegetation):

Soil type or lining	Slope range (%)	Permissible velocity (fps)
Fine sand (sugar sand)	--	2.0
Sandy loam	--	2.5
Silt loam	--	3.0
Ordinary firm loam	--	3.5
Graded, silt to cobbles (noncolloidal)	--	5.5
Alluvial silts (noncolloidal)	--	3.5
Alluvial silts (colloidal)	--	5.0
Coarse gravel (noncolloidal)	--	6.0

Roadside channels, lined with various grass covers (uniform stand; well maintained):

Cover	Slope range (%)	--Soils that are-- Erosion resistant	Easily eroded
Bermuda grass Crested wheatgrass Buffalo grass Kentucky bluegrass Smooth brome Blue grama	0- 5	6.0	5.0
	5-10	5.0	4.0
	Over 10	4.0	3.0
Grass mixture	0- 5	4.0	3.0
	5-10	3.0	2.5
Lespedeza sericea Weeping lovegrass Yellow bluestem Kudzu Alfalfa Crabgrass Common lespedeza Sudan grass	0-5	3.0	2.0

Cross Street Flow

The same limitations govern rural streets as those for urban streets for minor and major storm situations (see Table 3.4.1-1).

Intersections

Culverts should be used whenever it is necessary to transport runoff across intersections on rural streets. The same limitations govern rural streets as those for urban streets for pavement encroachment and depth of runoff over intersections as well as for both types of storm situations (see Table 3.4.1-1).

Design of Roadside Drainage Ditches

Certain aspects of roadside drainage ditch design are discussed in Section 8, Open Channels. For situations not specifically covered in this Manual, see "Design of Roadside Drainage Channels," Hydraulic Design Series No. 4 (U. S. Department of Commerce, Bureau of Public Roads, 1965) or other similar reference.

3.4.4 Special Considerations for Business Districts

Although not a necessity, it is in the best interest of highly concentrated business areas, to design for use of reduced allowable pavement encroachment area, inundated areas, raised walk over curbs at intersections, or additional inlets to intercept flow before it reaches intersections. Generally, these areas should be storm sewered even if other criteria do not so indicate.

In highly concentrated business areas, where large volumes of pedestrian traffic are likely, the use of walk-over curbs at intersections should be considered. If utilized, it would appear that no flow be allowed to continue around the corner and, therefore, inlets would be required at nearly every corner. For the storm frequency being contemplated, the effect water may have on pedestrian walking areas should be compatible with that on streets. Based upon vehicular traffic use, all streets would probably classify as arterial or major arterial, which requires one water-free travel lane for the minor design storm, and the walk-over curbs should be available for limited pedestrian use.

Where business buildings are constructed to property lines, the reduced clearance between buildings and heavy traffic must be considered. Splash from vehicles striking gutter flow may damage store fronts and make walking on sidewalks impossible. Ponded water and gutter flow exceeding 2 feet in width are difficult to negotiate by pedestrians.

3.5 Storm Sewers and Culverts

The design and criteria for storm sewers and culverts presented herein shall be utilized for design performance of storm-sewer systems in the City of Alliance.

The term, storm-sewer system, refers to the system of inlets, conduits, manholes, and other appurtenances, which are designed to collect and convey storm runoff from the minor storm to a point of discharge into a major drainage outfall. Storm sewers are a portion of the minor drainage system which includes street gutters, roadside drainage ditches, culverts, storm sewers, small open channels, and any other feature designed to handle runoff from the minor storm. Alternate terms for the storm-sewer system are convenience system or minor drainage system. These names are derived from the function of the storm sewers, which is to prevent inconvenience and frequently recurring damage caused by frequent storm runoff.

Culverts may be of any shape and constructed as required by existing topographic features; however, the size, shape, location, and type of construction of culverts shall be subject to the approval of the City Engineer.

3.5.1 Design Criteria - Storm Sewers

The storm-sewer system and subsequent storm inlets shall commence at all locations where the allowable street capacity is exceeded or wherever ponding of water is likely to occur due to the minor storm. Storm sewers are needed only when the other parts of the minor system no longer have capacity for additional runoff. A good major system of drainage, coupled with wise street layout, can often eliminate the need for storm sewers. The more lacking the major system, the more costly the storm sewers.

Pipe Size

The average flow velocity for a minor storm flow in any conduit shall not be less than 2.0 feet/second. All storm sewers shall be of sufficient structural strength to withstand an AASHO H-20-44 loading. The minimum allowable pipe size for storm sewers shall be 15 inches for all sewers, or a minimum cross-sectional area of 1.23 square feet. If noncircular sections are used, the minimum dimension shall be 12 inches to provide space for cleaning equipment.

Clearance Space

The minimum clearance between storm sewer and water main, either above or below, shall be 12 inches or as required by other governmental or health agencies. In all cases, suitable backfill and/or other protection as deemed necessary by the City Engineer shall be provided to prohibit settling or failure of either pipe system.

The minimum clearance between storm sewer and sanitary sewer, either above or below, shall also be 12 inches. However, when a sanitary sewer main lies above a storm sewer, or within 18 inches below, the sanitary sewer shall have an impervious casement or be constructed of structural sewer pipe for a minimum of 10 feet on each side of where the storm sewer crosses.

Manholes

Manholes shall be placed wherever there is a change in size, direction, elevation or slope, where there is a junction of two or more systems or laterals, or when the maximum allowable distance is reached, as follows:

Vertical pipe dimension	Maximum allowable distance between manholes and/or cleanouts
15 to 36 inches	400 feet
37 to 60 inches	500 feet
61 inches and larger	750 feet

Inlets, Outlets, and Curb Openings

Storm-sewer inlets shall be designed so that the encroachment of gutter flow on the street or intersection does not exceed requirements of Table 3.4.1-1.

The only inlet types allowed on streets with curb and gutter are specified in the City of Alliance Standard Specifications or as approved by the City Engineer.

All curb openings shall be installed with the opening at least 2 inches below the gutter slope.

The outlet pipe of the storm inlet shall be sized on the basis of the theoretical capacity of the inlet, with a minimum diameter or equivalent diameter of 15 inches.

Because of possible debris plugging, pavement overlaying, parked vehicles, and other factors which decrease inlet capacity, the reduction factors to be used shall be:

Drainage condition of street	Inlet type	Percentage of theoretical Capacity
Sump	Combination curb opening (R) and area inlet (D)	80%
Continuous grade	Curb opening (R)	80%

3.5.2 Design Criteria - Culvert

Culvert installations shall be designed with an emergency overflow for the major storm on all streets other than major arterials. Culverts under all roads shall have sufficient capacity to pass the runoff from the major storm and maintain the allowable cross street flow as presented in Table 3.4.1-1.

The culvert, including inlet and outlet structures, shall properly take care of water, bedload, and debris at all stages of flow.

A culvert cannot carry any more water than can enter the inlet. Frequently culverts and open channels are carefully designed with full consideration given to slope, cross section, and hydraulic roughness, but without regard to the inlet limitations. Culvert designs that use uniform flow equations rarely carry their design capacity due to limitations imposed by the inlet.

Culvert inlets shall be designed to minimize entrance and friction losses. Inlets shall be provided with either flared-end sections or headwalls with wingwalls. Projecting ends will not be acceptable. For large structures, provisions shall be made to resist possible structural failure due to hydrostatic uplift forces.

Culvert outlets shall be designed to avoid sedimentation, undermining of the culvert, or erosion of the downstream channel. Outlets shall be provided with either flared-end sections or headwalls with wingwalls. Additional outlet control in the form of riprap, channel shaping, etc., may be required where excessively high discharge velocities occur.

Culverts shall be analyzed to determine whether discharge is controlled by inlet or outlet conditions for both the minor storm discharge and the major storm discharge.

The recommended maximum headwater to diameter ratios are:

Storm frequency	Headwater to diameter (HW/D)
10-year	Equal to or less than 1.0
100-year	Equal to or less than 1.5

The values may be exceeded provided excessive ponding above culvert entrances will not cause property or roadway damage, culvert clogging, saturation of fills, detrimental upstream deposits of debris, or inundation of existing or future utilities and structures.

The required size of the culvert shall be based upon adequate hydraulic design analysis. However, to minimize maintenance requirements, the minimum allowable culvert size for culverts under City streets shall be 18" for circular culverts or a minimum cross-sectional area of 1.77 square feet. For culverts in roadside ditches, the minimum size shall be 15" for circular culverts or a 1.23-square-foot cross-sectional area.

3.5.3 Inlets

Two types of storm-water inlets, the curb-opening inlet and the grated inlet are acceptable for storm-sewer systems in Alliance. Grated inlets will only be used in instances where the City Engineer permits the use due to special consideration. Inlets are further classified as being on a continuous grade or in a sump. The term "continuous grade" refers to an inlet located so that the grade of the street has a continuous slope past the inlet; that is, water is flowing past, as opposed to ponding at, the inlet. The "sump" condition exists whenever water is restricted to the inlet area because the inlet is located at a low point. This may be due to a change in grade of the street from positive to negative, or due to the crown slope of a cross street when the inlet is located at an intersection.

Curb-Opening Inlets

It is recommended that curb-opening inlets be generally utilized in the design of storm-sewer systems, particularly when a sump condition exists. Although a curb-opening inlet will not guarantee against plugging, it is the most dependable type of inlet.

A curb-opening inlet is a vertical opening in a curb through which the gutter flow passes. The gutter may be undepressed or depressed in the area of the curb opening. A special type of curb opening inlet, often referred to as a deflector inlet, has flow deflectors in the gutter adjacent to the opening. As with all types of openings, a curb opening inlet may be either on a continuous grade or in a sump condition. The curb-opening inlet does not clog readily, which is its major advantage. The large dimensions of the clear opening compared to that of a grated inlet allows trash to pass into the storm-sewer system rather than be trapped at the inlet.

The capacity of a curb opening inlet is significantly increased by depressing the opening. A characteristic of the curb opening inlet is its relative inefficiency on streets of steep grade, which can be effectively counteracted by the installation of deflector veins in the gutter adjacent to the opening. The veins create a standing wave which causes the water to flow into the curb opening. Generally, deflectors on curb inlets are recommended on grades in excess of 5 percent.

Grated Inlets

The term grated or gutter inlet refers to an opening in the gutter covered by one or more grates through which the water falls. As with other inlets, grated inlets may be either depressed or undepressed and may be located either on a continuous grade or in a sump.

The term "longitudinal bar grate" refers to a grate in which the bars are oriented parallel to the direction of flow. Transverse bars refer to bars located at some angle, usually perpendicular, to the direction of flow. A large number of tests have been conducted to determine various characteristics of grated inlets. These tests have indicated that longitudinal bar inlets are far more efficient and less apt to be plugged by trash than are grates made wholly of transverse bars or incorporating transverse bars in the design of longitudinal openings.

The major disadvantage of the grated inlet is a tendency to plug with trash, which significantly reduces efficiency from the theoretical value, and in some cases renders the inlet inoperable. Some tests indicate that properly designed longitudinal bar grated inlets on a continuous grade are reasonably immune to plugging. However, the tests also indicate that plugging is possible even for properly designed grates. The use of a grated inlet in a sump condition or with transverse bars virtually assures that some plugging will occur and will decrease the capacity of the inlet.

Depressing the grated inlet will significantly increase its capacity, but the interference to traffic caused by the depression may make the depression undesirable. Also, grated inlet design must consider safety problems of bicycle traffic near the curb of the street.

Inlets shall be so located that they shall not interfere or impede the use of handicap sidewalk ramps.

3.6 Open Channels

This section of the Manual provides a criteria for the planning and design of open channels for storm-water runoff in the City of Allliance. For complex channel systems, the engineer should consult other references for details of design procedures. Some references are listed in Section 3.9. All designs, however, shall be approved by the City Engineer before construction begins.

3.6.1 Design Criteria

Drainage design can include two types of open channels--natural and man-made. These channels can be lined or unlined. Preferably, open channels should be unlined with grass cover, have slow flow characteristics, be wide and shallow, and be natural in their appearance and functioning. However, lined channels will be required where constrictions or excess velocities dictate. All channels must be designed to handle minor and major flows.

In addition to storm flows, trickle flows that occur from lawn watering, snowmelt, and underground drainage can create undesirable muddy and marshy areas if neglected in the design of the drainage system.

Unlined Channels

The shape of the unlined channel may be almost any type suitable to the location and to the environmental conditions. Often the shape can be chosen to suit open space and recreational needs, and thus, create additional sociological benefits.

Grass-lined channels may be considered to be the most desirable artificial channels because the channel storage, the lower velocities, and the sociological benefits create significant advantages over other types. The design must give full consideration to esthetics, sediment deposition, scour, as well as hydraulics.

For the major storm design flow, however, certain design criteria must be included:

Side Slopes. The flatter the side slope, the better; 5:1 is a normal minimum. Under special conditions the slopes may be as steep as 4:1 which is also the steepest limit practical for mowing equipment. For slopes steeper than 5:1 approval of the City Engineer is required.

Depth. The maximum depth should be limited to 3.5 feet, though 4.0 feet is acceptable where good maintenance can be expected and where durations of peak flows are short lived.

Bottom Width. The bottom width should be at least 6 to 8 times the depth of flow.

Velocity. The maximum velocity for the major storm design runoff shall be as shown in Table 3.6.1-1. This permits an economical cross section and yet keeps scour problems within reasonable limits. Without a satisfactory grass cover established, the annual flows will cause serious channel cutting and bank cutting at bends.

Design Slopes. Grass-lined channels, to function well, normally have slopes from 0.2 to 0.6 percent. Where the natural topography is steeper than desirable, drops should be utilized.

Curvature. The less sharp the curves, the better the channel will function. In general, centerline curves should not have a radius of less than twice the design flow top width, but not less than 100 feet.

Design Discharge Freeboard. Bridge deck bottoms and sanitary sewers often control the freeboard along the channel banks in urban areas. Where they do not control, the allowance for freeboard should depend somewhat upon the conditions adjacent to the channel. For instance, localized overflow in certain areas may be desirable because of ponding benefits. In general, a minimum freeboard of 1 to 2 feet should be allowed, although in certain cases, as little as 8 inches might be satisfactory. When considering freeboard requirements, regime of flow transitions must be considered in determining potential wave height.

Trickle Channel. Trickle channels or underdrain pipes are required on all grassed channels in urban areas. Trickle channels are preferred because of maintenance. Waterways that are normally dry prior to urbanization will often have continuous base flow after urbanization because of lawn irrigation. A trickle channel is subject to erosion, and must therefore be amply protected with appropriate erosion-control devices. Trickle channels should be designed to carry 0.5 to 1 percent of the major storm flow.

Table 3.6.1-1

Permissible Velocities for Channels Lined with Grass
(From: Chow, 1959)

Cover	Slope range (%)	Permissible velocity (fps)[1/] Erosion-resistant soils	Easily eroded soils
Bermuda grass	0- 5	8	6
	5-10	7	5
	> 10	6	4
Buffalo grass, Kentucky bluegrass, smooth brome, blue grama	0- 5	7	5
	5-10	6	4
	> 10	5	3
Grass mixture	0- 5	5	4
	5-10	4	3
	(Do not use on slopes steeper than 10%)		

[1/] The values apply to average, uniform stands of each type of cover. Use velocities exceeding 5 fps only where good covers and proper maintenance can be obtained.

Lined Channels

Lined channels must be designed to withstand the various forces and actions that tend to overtop the bank, deteriorate the lining, and erode unlined areas.

3.7 Storm-Water Detention and Retention

The increased storm-water runoff from development sometimes creates adverse effects downstream. In many instances, detention of storm water is the most adequate method of reducing the peak runoff. In some areas no historic outfall exists and it may be necessary to utilize storm water retention (storage of all storm-water runoff) to provide drainage protection. Storm water retention is discouraged and should be used only upon approval of the City Engineer. This section deals with the criteria for detention and retention ponds in Alliance. Uniform use of detention criteria throughout a basin can cause increases in peak flows for a stream. Therefore, the use of detention must depend upon the site conditions, and the effects of increased runoff downstream of the site.

3.7.1 Criteria

Storm-water detention facilities shall be required where release of storm water will adversely affect areas downstream of development. Detention requirements for each new development in the City of Alliance will be set forth in the Master Drainage Plan for that area of the City. Where no master plan exists, requirements for detention will be established on a site-by-site basis by the City Engineer. In general, detention or retention will be required where development will significantly change historic drainage conditions.

Maintenance of Detention and Retention Structures

Since maintenance is a major problem, the design of a detention structure should include, (1) plans for controlling debris and sediment, (2) plans for controlling trickle flows to prevent muddy wet areas, (3) provisions for adequate slope protection, and (4) adequate means of ingress and egress.

Emergency Spillways

The emergency spillway should be designed to avoid overtopping by storms in excess of the major storm, and to avoid overtopping the structure due to clogging of the outlet during the major storm. A minimum of 2 feet of freeboard will be required between the spillway and the top of the embankment. These emergency provisions should include an easement for the overflow path to a major drainageway.

Outlet Facilities

Outlet facilities should be adequate to provide for draindown of the detention structure within 12 to 24 hours following the major storm. This will allow for multiple-day events which are common to this region.

In the case of a retention area, the losses from the retention pond through infiltration and evaporation can be considered, but the pond should be sized to retain multiple day events without overtopping. The estimate of infiltration from those ponds must include consideration of the effects of sediments, (silts and clays), which may wash into the ponds and reduce infiltration rates.

Planning for Detention

When planning for detention storage of storm water, the first concern is to determine the performance criteria for the storage. The engineer will need to make a detailed analysis of downstream conditions. In addition, the drainage master plan for the basin will provide additional input for detention criteria. The greatest limitation will be whether the existing channel will be available to carry the runoff.

Hydraulic Design

The hydraulic design of detention facilities should be undertaken by a hydrologist knowledgeable in urban storm-water runoff. The Rational Method is not recommended except for very small basins because the method does not create a hydrograph for design purposes.

Types of Detention Storage Areas

On-site Ponds. The construction of on-site ponds provides significant storm runoff detention benefits when properly planned and designed. The use of such ponds, which have recreational benefits, is particularly encouraged in planned unit development areas where larger areas of grass and open space are common.

On-site ponds are useful even when they store only a fraction of an acre-foot, though ponds storing several acre-feet are usually feasible. Controlled outlets for the surcharge storage can be used, and such outlets usually can be designed to release the equivalent of 1/2-inch per hour, based upon the impervious tributary area.

Park Storage. Most urban areas contain parks, both the neighborhood type and the large central type. Parks, like recreational fields, create little runoff of their own, however, parks provide excellent detention storage potential for the storage of runoff from adjacent areas. The use of parks for the temporary detention of storm runoff water can measurably increase benefits to the public. And, therefore, the use of parks for such purposes is encouraged.

Road Embankments. The temporary detention of storm runoff water behind road embankments is good practice and is encouraged. The reader is referred to Section 3.6 of this Manual dealing with inlets and culverts for design criteria relative to the use of ponding behind road embankments. It is, of course, necessary to review damage potential to upstream property.

The design criteria to be used for the temporary detention of water behind road embankments should include consideration of the major storm runoff, that is, the runoff to be expected once each 100 years.

Planning for such use of embankments must be done with thorough consideration to potential damages which could occur to the embankment, the structure, and to adjacent property.

3.8 Water Quality

Water quality requirements of storm water outfalls have not currently been established. As these requirements are developed this section of the Manual will be revised to reflect the current state and federal requirements. The biggest water quality concern from storm-water runoff is that of sediment. Therefore, criteria to control sediment runoff in Alliance are presented below.

The control of erosion is essential to maintain the soil resources of an area and to preserve water quality. This Section has been written as a guide to sediment control practices.

3.8.1 Design Criteria

Erosion-control measures will be required only where the soils and topography indicate erosion is likely to occur. The City Engineer will evaluate the soil and topographic information submitted for each development as part of the preliminary requirements and may request the developer to provide an erosion-control plan.

The following principles, adapted from the standards and specifications set forth by the U. S. Department of Agriculture, Soil Conservation Service (1975), should apply to control erosion and sedimentation in developments in the City of Alliance.

Plan the Development to Fit the Particular Topography, Soils, Waterways, and Natural Vegetation at a Site

Initially, this is best achieved through adoption of a general land use plan based upon a comprehensive inventory of soil, water, and related resources.

Slope length and gradient are key elements in determining the volume and velocity of the runoff and its associated erosion. As both slope length and steepness increase, the rate of runoff increases and the potential for erosion is magnified. Where possible, steep slopes should be left undisturbed. By limiting the length and steepness of the designed slopes, runoff volumes and velocities can be reduced and erosion hazards minimized.

Soils which contain a high proportion of silt and very fine sand are generally the most erodible. The erodibility of these soils is decreased as the percentage of clay or organic matter content increases. Well drained and well graded gravel-sand mixtures with little silt are the least erodible soils. By reducing the length and steepness of a given slope, even a highly erodible soil may show little evidence of erosion. Long steep slopes should be broken by benching, terracing, or constructing diversion structures.

The natural vegetative cover is extremely important in controlling erosion since it (1) shields the soil surface from the impact of falling rain, (2) increases infiltration of water into the soil, (3) reduces the velocity of the runoff water, (4) holds soil particles in place, and (5) filters surface runoff.

<u>Expose the Smallest Practical Area of Land for the Shortest Possible Time</u>

When earth changes are required and the natural vegetation is removed, keep the area and the duration of exposure to a minimum. Plan the phases or stages of development so that only the areas which are actively being developed are exposed. All other areas should have a good cover of temporary or permanent vegetation or mulch. Grading should be completed as soon as possible after it is begun, and then permanent vegetative cover should be established in the area. As soon as slopes are cut and fill slopes are brought up to grade, these areas should be revegetated. This is known as staged seeding. Minimizing grading of large or critical areas during the season of maximum erosion potential (May 1 through September 30) reduces the risk of erosion.

After the best decision has been made as to land use, and the development process begins, effective erosion control and sediment reduction depends upon careful site planning, judicious selection of conservation practices, adequate design, accurate installation, and sufficient maintenance.

<u>Apply Soil-erosion Control Practices as a First Line of Defense Against On-site Damage</u>

Erosion should be controlled on the site to prevent excessive sediment from being produced. Keep soil covered as much as possible with temporary or permanent vegetation or with various mulch materials. Special grading methods such as roughening a slope on the contour or tracking with a cleated dozer may be used. Other practices include using diversion structures to divert surface runoff from exposed soils and grade-stabilization structures to control surface water. "Gross" erosion in the form of gullies should be prevented by use of these water-control devices. Lesser types of erosion, such as sheet and rill erosion, should be prevented, if possible, but often scheduling or the large number of activities required makes this impractical. However, when erosion is not adequately controlled, sediment control is more difficult and expensive.

<u>Apply Sediment-control Practices as a Perimeter Protection to Prevent Off-site Damage</u>

This principle relates to controlling sediment once it is produced and preventing it from getting off-site. Diversion ditches, sediment traps, geotextiles, vegetative filters and sediment basins are examples of practices to control sediment. Vegetative and structural sediment-control measures can be classified as either temporary or permanent depending on whether or not they will remain in use after development is complete. Generally, sediment can be retained on the site by two methods: (1) filter runoff as it flows through an area, and (2) impound the sedimentladen runoff for a period of time so that the soil particles settle out. The best way to control sediment, however, is to prevent erosion as discussed in the third principle.

Implement a Thorough Maintenance and Follow-up Operation

This fifth principle is very vital to the success of the four other principles. A site cannot be effectively controlled without thorough periodic checks of the erosion- and sediment-control practices. These practices must be maintained just as construction equipment must be maintained and materials checked and inventoried. An example of applying this principle would be to start a routine "end-of-day check" to make sure that all control practices are working properly.

Usually, these five principles are integrated into a system of vegetative measures and structural measures along with management techniques to develop a plan to prevent erosion and sediment control. In most cases a combination of limited grading, limited time of exposure, and a judicious selection of erosion-control practices and sediment-trapping facilities will prove to be the most practical method of controlling erosion and the associated production and transport of sediment.

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