STORMWATER DESIGN CONSIDERATIONS

HYDROLOGY, HYDRAULICS, DETENTION/RETENTION, STORMWATER QUALITY AND GRADING

CITY OF DELTA

STORMWATER MANAGEMENT MANUAL

SUBMITTED TO:

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VI. HYDROLOGY

List of Figures

List of Tables

VI. HYDROLOGY

A. DESIGN STORMS

1. Correlation Between Rainfall and Runoff Frequencies Rainfall depths are statistically assigned to various rainfall frequencies, but it does not follow that rainfall and runoff frequencies coincide. In addition to rainfall, runoff is a function of loss rates and base flow, which vary with time and antecedent soil moisture conditions. For example, a 100 year rainfall onto abnormally dry soil may very well result in less runoff than would occur if a 25 year rainfall fell on damp soil. Notwithstanding the indirect relationship, it is much simpler to assume that a given frequency storm results in the same frequency storm runoff event, which assumption will be used in this manual for the establishment of design considerations.

2. Design Storm Frequency and Duration Required design storm frequencies used in drainage analyses shall be provided in Table VI-1.

For peak runoff analyses, the selected storm duration must at least be equal to the total watershed time of concentration; that is, subbasin time of concentration plus reach travel times. Otherwise, runoff from lower portions of the basin will cease before the peak runoff from above arrives. However, total runoff volume is usually also of interest, in which case the duration should be increased beyond the watershed time of concentration to prevent unacceptable truncation of runoff volume. Drainage basins which have unusually large amounts of floodplain storage (wide floodplains and/or large areas of swamps) may require a storm of perhaps 50%-100% more duration than the time of concentration in order to properly analyze attenuation caused by these large natural storage areas.

Unless there is substantiated reason for a variance, selected storm durations shall conform with Table VI-2.

B. RAINFALL

Rainfall data has been compiled for the City of Delta, and published in two formats for ready use in the Rational Method and Unit Hydrograph Methods. The one method uses intensity-duration frequency (IDF) curves or tables, and the other, total storm precipitation data, as may be found in NOAA Atlas II.

1. IDF Data (Rational Method) The normal format of IDF data is in curve form. However, this requires constant reading and/or interpretation from a figure. Table "A-1" in Appendix "A" presents IDF data at one minute increments for both the 5- and 100-year rainfall events. Interpolating between minutes is unnecessary, because time of concentration values can and should be rounded to whole numbers.

TABLE "VI-1" DESIGN STORM FREQUENCY		
Drainage Feature	**5-Yr Storm**	**100-Yr Storm**
Water quality control	X	
On-site runoff collection and conveyance facilities [street flow below inundation limits (see Appendix "G"), inlets, most local storm sewers, and smaller channels].	X	
Detention/retention to prevent an increase in: total watershed runoff and also sub-watershed runoff to any downstream property or drainage facility.	X*	X*
Drainage Fee – Not currently available in the City of Delta		X**
Major channels and outfall facilities [usually culverts, open channels, and streets above inundation limits, but may include inlets and storm sewers].		X
Concentrated flows may not conflict with minimum finish floor freeboard criteria, specified in Section I-A-3-b, and must be conveyed within drainage easements or tracts.		X

* Detention/retention is required unless the Drainage Fee option (not currently available in the City of Delta) is allowed and exercised.

** See Section VIII B for requirements and conditions.

TABLE "VI-2" DESIGN STORM DURATION			
Hydrological Method	**Time of Concentration Developed Condition Tc_d (minutes)**		
	4-10	8-20	20+
Rational Method	*	*	*
Modified Rational Method or other methods based thereon	24 hr **	24 hr **	24 hr **
Unit hydrograph, such as SCS, and other non-Rational Method procedures	2 hr	6 hr	24 hr
** Not applicable – all calculations are based upon intensity-duration-frequency (IDF) data presented in Appendix "A", without additional consideration for storm duration. ** Where storm duration applies, such as for precipitation depth, the 24-hour event shall be used.			

2. **Total Storm Precipitation (Unit Hydrograph Methods)** Some form of total storm precipitation data is used for unit hydrograph methods. Data is provided in the National Weather Service NOAA Atlas II, with further refinement provided in a local analysis for the Delta. Basin average total storm precipitation values for the City of Delta are provided in Appendix "A".

3. **Rainfall Depth Adjustments** More intense rainfalls occur over smaller localized areas and, when averaged over larger areas, the intensity is less. Therefore peak point rainfall amounts should be reduced for larger watershed areas. The National Weather Service has prepared a figure for use in reducing basin average total storm precipitation for larger areas. A copy of the figure is provided in Appendix "A".

C. DRAINAGE AREA

1. **Watershed Basins** Watershed basins for both pre- and post-development conditions shall be shown and identified on a Grading and Drainage Plan. Where applicable, watershed areas shall include one-half of adjacent perimeter street runoff, both for detention/retention requirements and collection and conveyance facilities.

2. **Subbasin Delineation** The process of breaking down a watershed into subbasins should be done with careful consideration given to the purpose of the study, critical concentration points where information is desired, and technical restraints of the method of analysis.

Defining these factors prior to beginning the delineation will help to ensure that the model remains within the limitations of the methodology used and will also help avoid extensive revisions.

a. <u>Concentration Points</u> Identify locations where peak flow rate or runoff volumes are desired. The following locations, as a minimum, should be considered:

   i) Confluences of watercourses where a significant change in peak discharge may occur;

   ii) Drainage structures, such as inlets, culverts, and detention/retention basins;

   iii) Crossing of watercourses with streets or to ensure conformance with street inundation requirements; and

   iv) Jurisdictional boundaries.

b. <u>Subbasin Size</u> Using the concentration point locations, estimate a target average subbasin size to strive for. This is particularly important when using unit hydrograph procedures.

c. <u>Time of Concentration</u> When using unit hydrograph procedures, it is well to preliminarily estimate the time of concentration (Tc) for the smallest and largest subbasin based upon subbasin size and slopes. If HEC-1 will be used, Tc values must conform with criteria specified in Section V-A-2 of Appendix "P" (page P-24). Conformance may require modification of subbasin delineation.

d. <u>Homogeneity</u> Considerations for subbasin homogeneity, in order to meet the basin average assumption, are:

   i) The subbasin sizes should be as uniform as possible;

   ii) Each subbasin should have nearly homogeneous land-use and surface characteristics. For example, mountain, hillslope, and valley areas should be separated into individual subbasins wherever possible; and

   iii) Soils and vegetation characteristics for each subbasin should be as homogeneous as reasonably possible.

The average subbasin size may need to be adjusted (addition of concentration points) as required, in order to satisfy the key assumptions upon which the analysis method is based.

3. <u>Area Calculations</u> Watershed areas may be calculated by geometry or estimated by planimeter.

D. TIME OF CONCENTRATION AND LAG TIMES

1. **Introduction** There is a delay in time, after rainfall over a watershed, before the runoff reaches its maximum peak. This delay is a watershed characteristic called lag. Lag is related to time of concentration and may be estimated from it. Both lag and time of concentration are made up of travel times, which are also used in flood routings and hydrograph construction. This subsection discusses methods for estimating travel time, lag, and time of concentration.

   While both lag and the time of concentration may be dependent upon surface and subsurface flow, and are dependent upon hydraulic conditions beyond what simple average velocity procedures account for, estimations are nonetheless simplified by considering only surface flow and times based upon estimated velocities. Consequently, all procedures presented herein are in effect short-cut approximations wherein one or more watershed characteristics are omitted.

2. **Time of Concentration** Time of concentration (Tc) is defined as the time after commencement of rainfall excess when all portions of the drainage basin are contributing simultaneously to flow at the point of interest, or outlet of the subbasin.

   There have been many equations developed to estimate time of concentration, most of which are named, dated, and provided with remarks regarding applications in Applied Hydrology. Coupled with recently prescribed procedures in HEC-12 and TR-55, and also given consideration of commonly used applicable equations, criteria prescribed herein for estimating Tc values are based upon travel time components and a select number of estimation procedures.

   Tc values consist of at least one, and very often two or three of the following components:

(i)	To	=	Overland flow travel time (300 feet maximum distance, 5 minutes minimum time);
(ii)	Ts	=	Shallow concentrated flow travel time; and
(iii)	Tch	=	Channel flow travel time.

   The total Tc value is the summation of the individual components.

   Time of concentration procedures are discussed more thoroughly in Appendix "E" and the SCS TR-55.

3. **Lag Time** There are many definitions for lag time (T_L), most of which are unique to a specific method of analysis. With SCS unit hydrograph procedures, T_L is the time from the center of rainfall mass to the peak of the unit graph. Also with SCS methods, lag is often assumed to be 0.6Tc, although this is based upon subbasins which have a fairly uniform distribution of runoff and natural watershed conditions. Caution should be exercised in using it for other applications. As an alternative, lag may be estimated without determining a Tc value. For watersheds smaller than 2000 acres, NEH-4 provides an equation said to

be based upon a broad set of conditions including forests, meadows, smooth lands, and paved parking areas. On the other hand, remarks provided in Applied Hydrology indicate that the equation is generally "found to be good" on completely paved areas, but overestimates T_L for mixed areas. The equation is:

$$T_L = \frac{L^{.8}\,(1000/CN - 9)^{.7}}{1900\ S^{.5}}$$

where:

T_L	=	Lag time in hours;
L	=	Hydraulic length of the subbasin in feet;
CN	=	SCS curve number for the subbasin, which must be between 50 and 95 for method validity; and
S	=	Average subbasin slope in %.

4. Required Calculation Procedures Calculation methods of Tc shall be as specified in Appendix "E". T_L may be determined by multiplying Tc by a factor of 0.6, where appropriate. T_L may also, with caution, be calculated by the equation above.

E. RAINFALL LOSSES

1. General Discussion Rainfall excess is that portion of the total rainfall depth that drains directly from the land surface by overland flow. When performing a flood analysis using a rainfall-runoff model, the determination of rainfall excess is of utmost importance. Rainfall excess integrated over the entire watershed results in runoff volume, and the temporal distribution of the rainfall excess will, along with the hydraulics of runoff, determine the peak discharge. Therefore, the estimation of the magnitude and time distribution of rainfall losses should be performed with the best practical technology, considering the objective of the analysis, economics of the project, and consequences of inaccurate estimates.

   Rainfall losses are generally considered to be the result of evaporation of water from the land surface, interception of rainfall by vegetal cover, depression storage on the land surface (paved or unpaved), and infiltration of water into the soil matrix. A schematic representation of rainfall losses for a uniform intensity rainfall is shown in Figure "VI-1".

2. Rainfall Loss Periods Three periods of rainfall losses are illustrated in Figure "VI-1", and these must be understood and their implications appreciated before applying the procedures in this manual. First, there is a period of initial loss when no rainfall excess (runoff) is produced. During this initial period, the losses are a function of the depression storage, interception, and evaporation rates plus the initially high infiltration capacity of the soil. The accumulated rainfall loss during this period with no runoff is called the initial abstraction. The end of this initial period is noted by the onset of ponded water on the surface, and the time from start of rainfall to this time is called the time of ponding (Tp).

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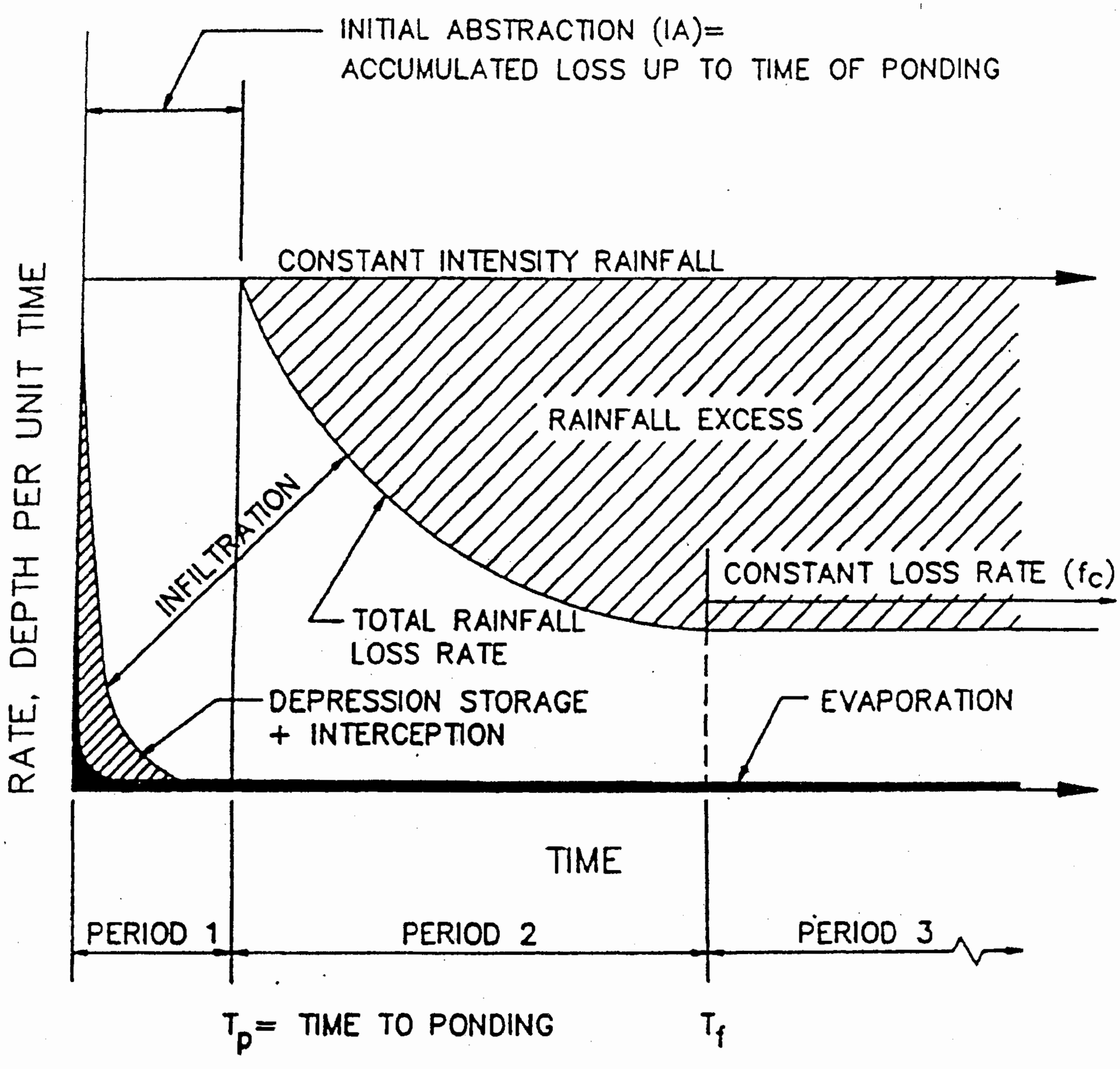

SCHEMATIC OF RAINFALL LOSSES FOR A UNIFORM INTENSITY RAINFALL	FIGURE "VI-1"

It is important to note that losses during this first period are a summation of losses due to all mechanisms including infiltration.

The second period is marked by a declining infiltration rate and generally very little losses due to other factors.

The third and final period occurs for rainfalls of sufficient duration for the infiltration rate to reach the steady-state, equilibrium rate of the soil (fc). The only appreciable loss during the final period is due to infiltration.

3. **Rainfall Loss Simplifications** The actual loss process is quite complex and there is a good deal of interdependence of the loss mechanisms on each other and on the rainfall itself. Therefore, simplifying assumptions are usually made in the modeling of rainfall losses, which is represented in Figure "VI-2". As shown, it is assumed that surface retention loss is the summation of all losses other than those due to infiltration, and that this loss occurs from the start of rainfall and ends when the accumulated rainfall equals the magnitude of the capacity of the surface retention loss. It is also assumed that infiltration does not occur during this time. After the surface retention is satisfied, infiltration begins. If the infiltration capacity exceeds the rainfall intensity, then no rainfall excess is produced. As the infiltration capacity decreases, it may eventually equal the rainfall intensity. This would occur at the time of ponding (Tp) which signals the beginning of surface runoff. As illustrated in both Figures "VI-1" and "VI-2", after the time of ponding the infiltration rate decreases exponentially and may reach a steady-state, equilibrium rate (fc).

   With some rainfall loss methods, such as the Rational Method runoff coefficient "C" and the SCS curve number "CN", the infiltration capacity curve is assumed to be constant. This is a major drawback of these two procedures. Other methods, such as the Green and Ampt procedure, allow for the exponential decrease in infiltration rates, and therefore, with proper use, allow for better model representation of the actual process.

   Rational Method "C" values, SCS curve numbers, and Green and Ampt Method procedures are discussed in Appendices "B", "C", and "D", respectively.

4. **Composite Rainfall Loss Coefficients** Watersheds and subbasins generally have at least two surface types with very dissimilar runoff characteristics, particularly in urban areas. These surface types could be analyzed as separate subbasins in hydrologic analyses, but this would usually be cumbersome. The more common approach is to combine the surface type areas together and obtain weighted averages, based upon area, of the rainfall loss coefficients or parameters.

   The arithmetic involved in obtaining a weighted average or composite value is not usually a problem; where caution must be applied is in modeling and combining procedures. Most runoff estimating methods are computerized, and allow for inputting the percent of the total area which is impervious. For a pervious/impervious watershed, runoff loss parameters should be selected that reflect the characteristics of the pervious subwatershed,

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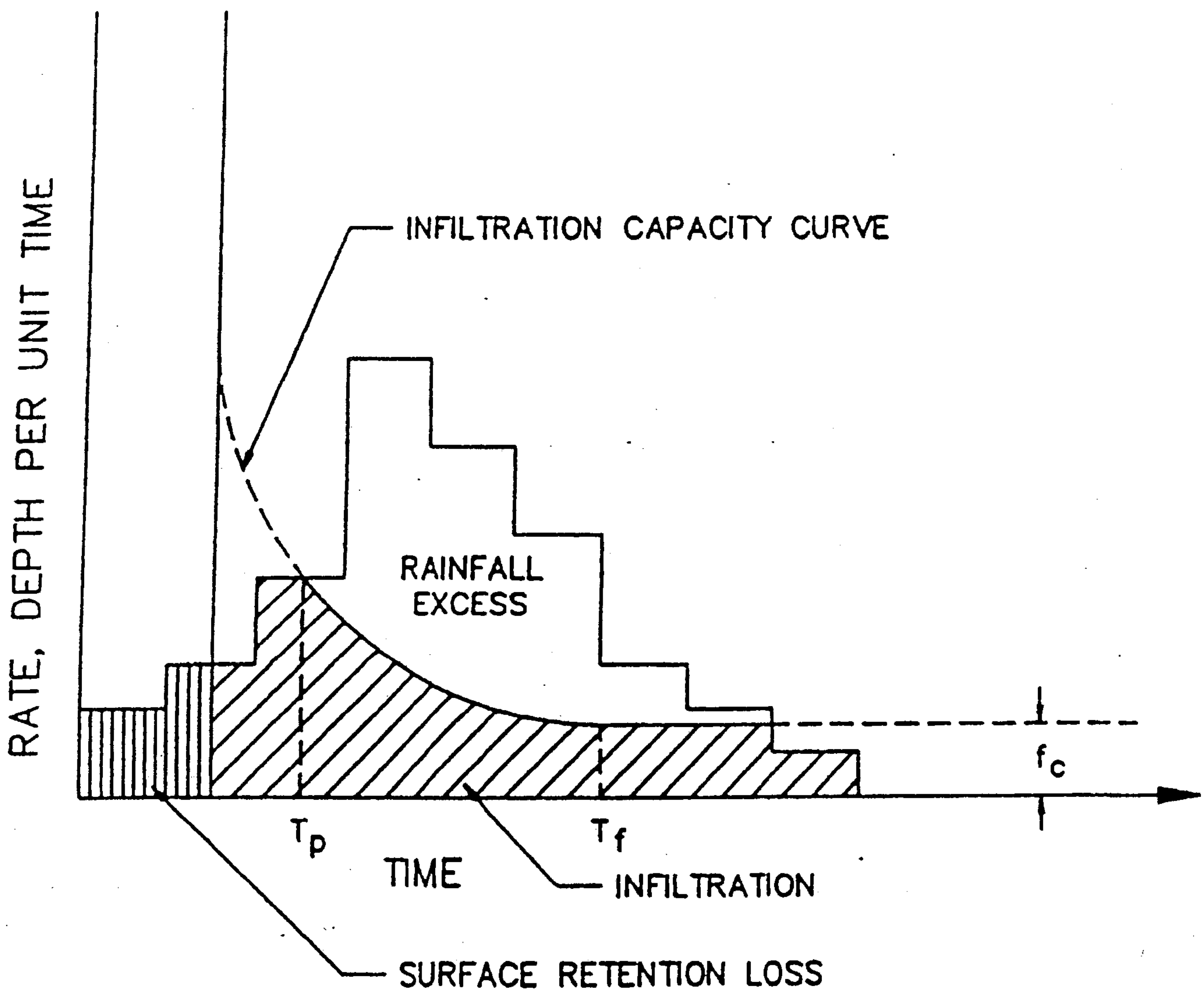


SIMPLIFIED REPRESENTATION OF RAINFALL LOSSES | FIGURE "VI-2" not the composite watershed. Runoff from the impervious area would not be based on runoff loss parameters, but on an impervious area with direct runoff potential.

Where storage capacity is available (on-lot retention, surface depression, lakes, ponds), these must also be accounted for. Many methods allow for direct input of surface depression storage while others do not. Surface depression and/or on-lot retention, lakes, and ponds may also be accounted for through storage or diversion routines where precipitation on the pervious areas contributes to available storage volume prior to the start of excess runoff.

In order to properly apply rainfall loss coefficients or parameters, one must understand the method used, and use good judgement in applying the method to a given watershed.

F. <u>**RUNOFF ESTIMATION**</u> There are many methods of estimating runoff, each with its own advantages and disadvantages, applications and limitations, an understanding of which is important to avoid misuse and obtain the desired level of accuracy. Only the two most commonly used methods are discussed here, although other methods may also be acceptable.

1. <u>**Rational Method**</u> Despite its many limitations, the simplicity of the Rational Method for small watersheds has resulted in its common use around the world through most of this century.

a. <u>**Method Description**</u> The Rational Method is based upon the equation

$$Q = CIA$$

Where:

C	=	Runoff coefficient (see Table "B-1" in Appendix "B");
I	=	Storm intensity in inches per hour (see Table "A-1" in Appendix "A");
A	=	Area in acres;
Q	=	Inches per acre per hour, which is approximately equal to 1 cubic foot per second (CFS), and is therefore generally considered to be measured in units of CFS.

b. <u>**Assumptions and Limitations**</u> As with all hydrological methods, several simplifying assumptions are involved, each of which limits the use or reduces the accuracy of the results. Assumptions have been listed in many publications, particularly in APWA and Singh. Only selected assumptions are noted here which are deemed to be of greatest value in understanding limitations and use. Assumptions are written in italics, with the corresponding limitation or application following.

1) *Runoff is directly proportional to rainfall; that is, rainfall loss remains constant throughout a storm event.* This assumption does not allow for the temporal variability of infiltration. Instead of a loss or infiltration rate decay as was shown in Figures "VI-1" and "VI-2", the Rational Method runoff coefficient "C" produces a rainfall loss that remains at a constant rate. Therefore, the "C" value must be "averaged" as best as possible considering the duration of the storm, rainfall intensity, and other factors. This is similar to many other rainfall loss methods. However, with other "constant loss rate" methods, such as the SCS curve number, there is a means of considering an initial abstraction to account for higher initial losses, followed by the lower average loss rate. The Rational Method has no such provision, so the selection of a "C" value must not only consider surface treatment, soil type, and rainfall intensity, but storm duration as well. Selection of a realistic "C" value becomes quite difficult.

2) *Storm duration is equal to the watershed time of concentration.* This will rarely be the case. If the Tc is less than the duration, part of the storm rainfall is ignored, which becomes more significant the larger the drainage area involved. Thus, larger basins should <u>not</u> be analyzed using the Rational Method if detention volume must be determined (using the Modified Rational Method).

3) *Peak discharge occurs at the time of concentration and beyond.* This implies that runoff from a basin will increase in a linear manner from 0% to 100% peak runoff, which occurs at the Tc and beyond. This will only happen if:

   i) runoff occurs nearly uniformly from all parts of the watershed (i.e., the runoff coefficient is nearly the same over the entire drainage area; and

   ii) the shape of the drainage area and runoff characteristics are such that runoff-contributing areas within the watershed increase in a linear manner.

   Also implied is the assumption that, for durations less than Tc, the effect of the reduction in contributing area is greater than that of increased rainfall intensity associated with a shorter Tc.

   The above assumption and implied assumptions require that the drainage basin is small enough to provide nearly homogeneous conditions, and delineated in a manner that will result in nearly linear runoff characteristics.

4) *Rainfall intensity remains uniform over the entire watershed during the time period equal to the Tc.* Generally, design storms are local thundershowers that do not have uniform rainfall intensities over large areas; therefore, spacial variability of rainfall requires that the overall size of the watershed must be limited.

5) *Rainfall intensity remains constant during the time period equal to the Tc.* Given the temporal variability of rainfall, this assumption is only valid if the Tc is short, suggesting that the watershed is small.

The above assumptions and corresponding limitations indicate that, while popular, the appropriate use of the Rational Method is quite limited. Basin size must be small, particularly if the Modified Rational Method will be used for sizing detention facilities.

c. **Allowed Use** Use of the Rational Method is commonly allowed for up to 100-200 acres for peak discharge estimations, and up to 25 acres if used to size detention facilities by means of the Modified Rational Method. However, a serious consideration of the method assumptions described, particularly the spatial and temporal constancy of rainfall intensity over a basin in a design storm, would suggest that even 100 acres is much too large of an area for use of the Rational Method. Therefore, it is recommended that the use of the Rational Method be limited to watersheds having a total area of 25 acres or less. Also, runoff coefficients shall be taken from Table "B-1" in Appendix "B".

2. **NRCS Methods** The heading of this section is plural, because actually there are two methods or procedures developed by NRCS that may be used together or independently of each other, and there has sometimes been confusion regarding this. Consequently, the two methods will be discussed separately herein, with only references made as to their potential combined use. The methods are the NRCS curve number and the NRCS unit hydrograph procedures.

a. NRCS Curve Number The NRCS curve number (CN) as a rainfall loss parameter and also as a runoff estimating procedure may both be referred to as the NRCS-CN method. The CN method is recommended by NRCS for up to 100 square miles.

1) CN Uses The rainfall loss parameter CN can be used in equation form to estimate storm runoff. It may also be used with chart or graphical procedures that are based on TR-20 unit hydrograph analyses to estimate runoff. Whether by equation, graphical, or tabular method, runoff estimation is performed without use of a unit hydrograph. On the other hand NRCS unit hydrograph procedures require use of a rainfall loss parameter, which does not necessarily have to be a CN value. The balance of discussion regarding CN values is applicable regardless of the use.

2) Initial Abstraction (IA) Initial abstraction is the total of all losses before runoff begins, including surface depression storage, interception, evaporation, and infiltration. The curve number is interrelated with initial abstraction, and IA is usually assumed to be 0.2 times the total water storage retention capacity of the soil and plants. Using HEC-1, another value may be used if desired, however.

3) Sensitivity Peak flow and volume results are very sensitive to curve number values, underlining the importance of careful fieldwork and selection of CN values. This has been emphasized by a previous work prepared by the author (Williams 1990). The case study basin was 0.3125 square miles (approximately 206 acres). Precipitation was 3.73 inches using the SCS 24 hour Type II unit hydrograph with a lag time of 0.47 hours. The CN value was 80. In turn, each of the parameters was raised and lowered by 12½%. The results indicate that CN value change was more than twice as sensitive as precipitation change, four times as sensitive as basin area change, and six times as sensitive as lag time change. Although the above results are by no means representative of all watersheds, it does underscore the importance of careful CN selection.

4) Method Results The SCS CN parameter was originally developed to predict changes in runoff due to a change in land use, and was not proposed as a deterministic model for estimating flood runoff from a particular rainfall, or as a probabalistic model to estimate a design flood. This is emphasized in Handbook of Hydrology, where a study by Wood and Blackburn is referenced. The study involved 1600 runoff plots in Nevada, Texas, and New Mexico. They discovered that the difference between observed and computed peak flows exceeded ±50% in 67% of the cases.

Notwithstanding, the SCS-CN method continues to be popular due to simplicity and public knowledge of it.

5) CN Values and Use The above discussion pertains to the SCS-CN method, limitations, and applications. Presentation of SCS published CN values along with guidelines for use are reserved for Appendix "C".

b. SCS Unit Hydrograph The SCS unit hydrograph (UH) procedure is only recommended up to 4000 acres. It does not require the use of SCS curve numbers if used in HEC-1. The balance of discussion regarding the SCS-UH method applies regardless of the rainfall loss parameter used.

1) Unit Hydrographs A unit hydrograph is a direct runoff hydrograph resulting from a unit depth of excess rainfall produced by a storm of uniform intensity and specified duration. In U.S. units, the unit depth is one inch. To calculate a flood hydrograph, the unit hydrograph is applied to the hyetograph of rainfall excess to estimate the hydrograph of surface runoff, then base flow if any is added to produce the complete flood hydrograph.

Unit hydrographs may be developed for a specific basin, or they may be synthetic: that is, the unit runoff rate and distribution pattern is established based upon a set of basin characteristics, and that unit hydrograph may then reasonably be applied to any other basin that has similar hydrological characteristics. Common synthetic unit hydrographs in use are the Clark, Snyder, and SCS.

Synthetic unit hydrographs are transformed to flood hydrographs by applying vertical and horizontal "dimensions". The vertical scale is set by providing rainfall and loss information to allow conversion to the excess runoff depth appropriate for the basin characteristics and rainfall quantity. The horizontal scale is set by providing a time parameter, such as the lag time. With these two dimensional values added, the unit hydrograph distribution or shape pattern takes on size which is intended to correspond with the basin area and design storm rainfall.

The SCS-UH was derived from a large number of unit hydrographs for rural watersheds varying widely in size and geographic location. Notwithstanding, the SCS-UH is often applied to areas hydrologically very different than those from which the procedure was derived.

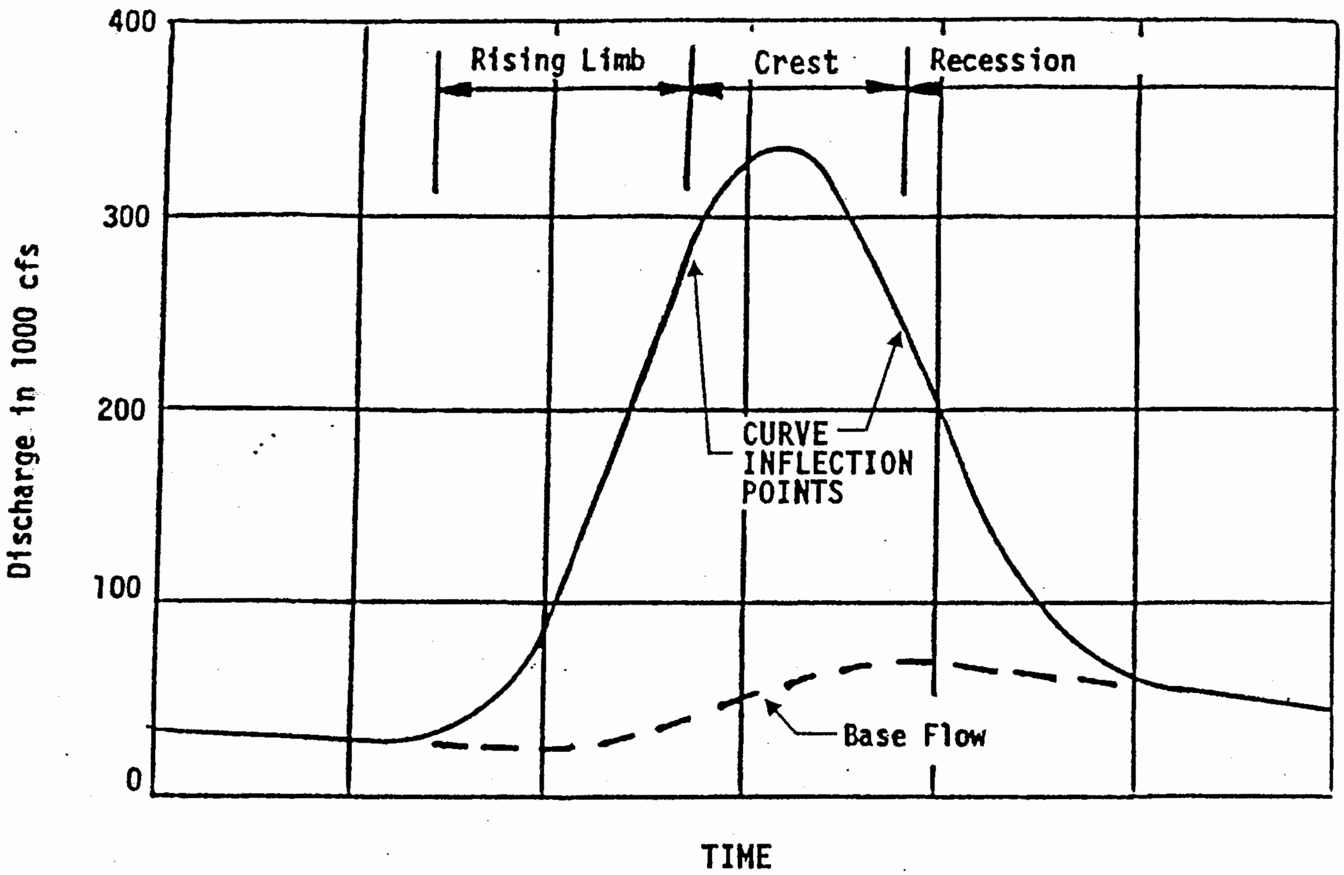
The shape of the SCS-UH is governed by several factors; of note is that the time to peak (Tp) is 0.2 times the time-of-base of the hydrograph. Also of note is that, at the time of peak, 37.5% of the runoff volume has occurred. When applying the SCS-UH, the calculation interval should be short enough to catch at least four points on the rising limb (see Figure VI-3), and more are preferable in order to not "miss" or "skip over" the hydrograph peak due to an inappropriately large calculation interval. Additional guidance on time interval is given in Appendix "P" for use in HEC-1.

2) <u>UH Assumptions</u> The unit hydrograph concept implies two assumptions. The first assumption is basin linearity; that is, that various magnitudes of rainfall will result in a corresponding magnitude of runoff. To minimize errors that would result from this assumption, unit hydrographs should be derived from floods having magnitudes similar to those for which the UH will be used. In other words, not only should basin physical parameters match the basin types for which the unit hydrograph applies, but flood levels also ought to be similar for best results.

The second assumption is that the basin is a lumped system; that is, that rainfall and excess is uniform all over the basin. While this does not occur, it does not appear to be a significant factor if basin size and conditions for the method are appropriate.

c) <u>Rainfall Distributions</u> A drawback of the Rational Method was the assumption of constant rainfall intensity throughout the storm duration. The SCS-UH procedure is not subjected to the same limitation.

The SCS developed dimensionless rainfall distributions using the Weather Bureau's Rainfall Frequency Atlases. The rainfall frequency data for areas less than 400 square



TYPICAL HYDROGRAPH

FIGURE VI-3

miles, for durations to 24 hours and frequencies from 1 to 100 years, were used. Data Analysis indicated the need for regional distributions.

The rainfall distributions are based on the generalized rainfall depth-duration-frequency relationships shown in technical publications of the Weather Bureau, and rainfall depths for durations from 30 minutes to 24 hours were obtained from these publications and used to derive the storm distributions. Using increments of 30 minutes, incremental rainfall depths were determined. For example, the 30-minute depth was subtracted from the one-hour depth and the one-hour depth was subtracted from the 1.5-hour depth. The distributions were formed by arranging these 30-minute incremental depths such that the greatest 30-minute depth is assumed to occur at about the middle of the rainfall period, the second largest 30-minute incremental depth in the next 30 minutes, and the third largest in the preceding 30 minutes. This continues with each decreasing order of magnitude until the smaller increments fall at the beginning and end of the rainfall period. This procedure results in the maximum 30-minute depth being contained within the maximum 1-hour depth, and the maximum 1-hour depth is contained within the maximum 1.5-hour depth, etc. Because all of the critical storm depths are contained within the storm distributions, and the distributions may be appropriate for designs on both small and large watersheds.

The resulting distributions are provided in Appendix "A", with Type II being most applicable with Delta County. While the distributions may not agree exactly with actual distributions from all locations in the region for which they are intended, the differences are within the accuracy of the rainfall depths read from the Weather Bureau atlases.

3. **SCS-UH Comparison with the Rational Method** It may be useful to compare the SCS-UH method to the Rational Method by comparing the assumptions on which they are based and corresponding limitations.

a. Constant Versus Variable Loss Rate The Rational Method assumes that loss is constant throughout a storm event, and high initial abstraction cannot be accounted for except by lowering the "C" value, which is a severe limitation. With SCS methods, initial abstraction can be applied. However, once runoff begins, the SCS-CN method assumes a constant loss rate, similar to the Rational Method. On the other hand, the SCS-UH method may use other types of rainfall loss parameters, such as Green and Ampt, that do vary temporally.

b. Storm Duration The storm duration must be equal to or greater than the Tc for the SCS-UH method, but if it exceeds the Tc, it does not cause a loss of rainfall or truncation of runoff values like the Rational Method does. This is a significant advantage to the SCS-UH method, allowing applicability to larger watersheds and better results of volume calculations.

c. Temporal Constancy of Rainfall A major shortfall of the Rational Method is the assumption of constant rainfall throughout the storm duration. The SCS allows input of a rainfall distribution pattern, and is appropriate for use on larger areas.

d. SCS-UH Advantage It should be apparent from the above that the SCS-UH method, particularly when using a variable loss rate procedure such as Green and Ampt, has a wider range of applicability and greater possibility for yielding dependable results than does the Rational Method.

4. Other Methods Other methods of runoff estimation besides the Rational Method and SCS methods (with SCS-CN or Green and Ampt loss procedures) may be used as applicable. However, because of their popularity, those are the only two methods discussed in any detail in this manual. Use of SCS-UH procedures as applied in HEC-1 is further discussed in Appendix "P".

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VII. HYDRAULICS

List of Figures

List of Tables

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VII. HYDRAULICS

A. "n" VALUES

Manning "n" value selection may be from information provided in Appendix "F" or from other sources, provided that they are selected and used in accordance with procedures and guidelines presented in Appendix "F". It is recommended that Appendix "F" be read prior to selection of "n" values from other sources.

B. STREETS, CURBS, AND GUTTERS

1. **Hydraulic Calculations** Use of Manning's modified equation is required for calculating flow on street pavement. The equation is:

$$Q = 0.56\,(Z/n)\,S^{.5} d^{2.67}$$

Where:

Q	=	Flow rate in CFS;
Z	=	Inverse pavement cross slope, ft/ft;
n	=	Manning's "n" value;
S	=	Longitudinal slope of the street or gutter, ft/ft; and
d	=	Depth of gutter flow in feet.

2. **Two-Year Runoff Design Criteria**

   a. Runoff shall not overtop curbs nor extend outside of the street section.

   b. The maximum depth of flow in valley pans and gutters is 6 inches.

   c. No backup from detention/retention facilities into streets is allowed.

   d. Collector roads shall have at least one 8-foot wide traffic lane in each direction remaining free of inundation.

   e. Arterial roads shall have at least one 8-foot wide traffic lane in each direction and the center turning lane remaining free of inundation.

3. **100-Year Runoff Design Criteria**

   a. The maximum depth of flow in streets is 1.0 feet.

   b. No backup from detention/retention facilities into streets is allowed.

c. The maximum depth of flow shall not exceed 6" for a 12' lane width at the center of the street or building access to allow for emergency vehicles.

4. Street Inundation Limits Inundation limits and spread per the above criteria are shown in Appendix "G".

C. INLETS

1. Design Methods Interception design shall be per HEC-12. Design guidelines for local conditions are provided in Appendix "G".

2. Clogging Factors Grates, orifices, and other small hydraulic structures are subject to clogging by trash, leaves, and other debris. Drainage facilities shall be designed to accommodate clogging potential. For example, metering devices used to prevent an increase in runoff release may not be oversized, but a grate or screen may precede the metering device, and be adequately oversized to allow sufficient water flow even under clogged conditions. Using this design procedure, the metering device should not clog, and may function properly as designed. On the other hand, stormwater collection facilities, such as catch basin inlets, are not "pre-screened" from debris, and will receive significant amounts of clogging material. Thus, stormwater collection inlets shall be designed for clogging per procedures presented below.

   a. Grate Only Interception capacity shall be allowed at 50% of HEC-12 calculated capacity for on-grade conditions. (Grates only are not allowed in sump or sag conditions.)

   b. Curb Opening Only Interception capacity shall be allowed at 80% of HEC-12 calculated capacity.

   c. Combination Inlet: On-Grade Two types of conditions may exist:

      (i) When the curb opening and grate are equal in length and placed side by side, ignore curb opening capacity and use 100% of HEC-12 calculated grate capacity; and

      (ii) When the curb opening extends upstream from the grate, allowable curb opening interception is 80% of the HEC-12 calculated capacity for the portion that is upstream from the grate, and 0% for that portion adjacent to the grate, and grate interception allowed is 100% of the HEC-12 calculated capacity for the reduced flow rate not intercepted by the upstream curb opening. Note that this second condition is not provided for by City/County Standard details.

   d. Combination Inlet: Sag or Sump Two types of conditions may exist:

(i) when ponded depth does not exceed 0.5 foot, use grate at 100% of HEC-12 calculated grate capacity, and ignore curb opening capacity; and

(ii) when ponding depth is at least 1.0 foot, use grate at 50% and curb opening at 100% of HEC-12 calculated capacities.

e. Slotted Inlet Under normal circumstances, slotted drains may only be used in conjunction with a grate or combination catch basin inlet, and would have the allowed interception percentage rates of HEC-12 calculated capacities as do curb inlets. However, slotted drains may not be used in sag conditions.

3. Inlet Locations Inlets shall be located to prevent non-conformance with street inundation limits as explained in subsection "B" above and as shown in Appendix "G". At intersections and low points, inlets are required as shown on Figure "VII-1".

D. FLOW IN CONDUITS

1. Methods of Calculation Flow in conduits shall be calculated using the Manning equation, various forms of which are presented in Appendix "H".

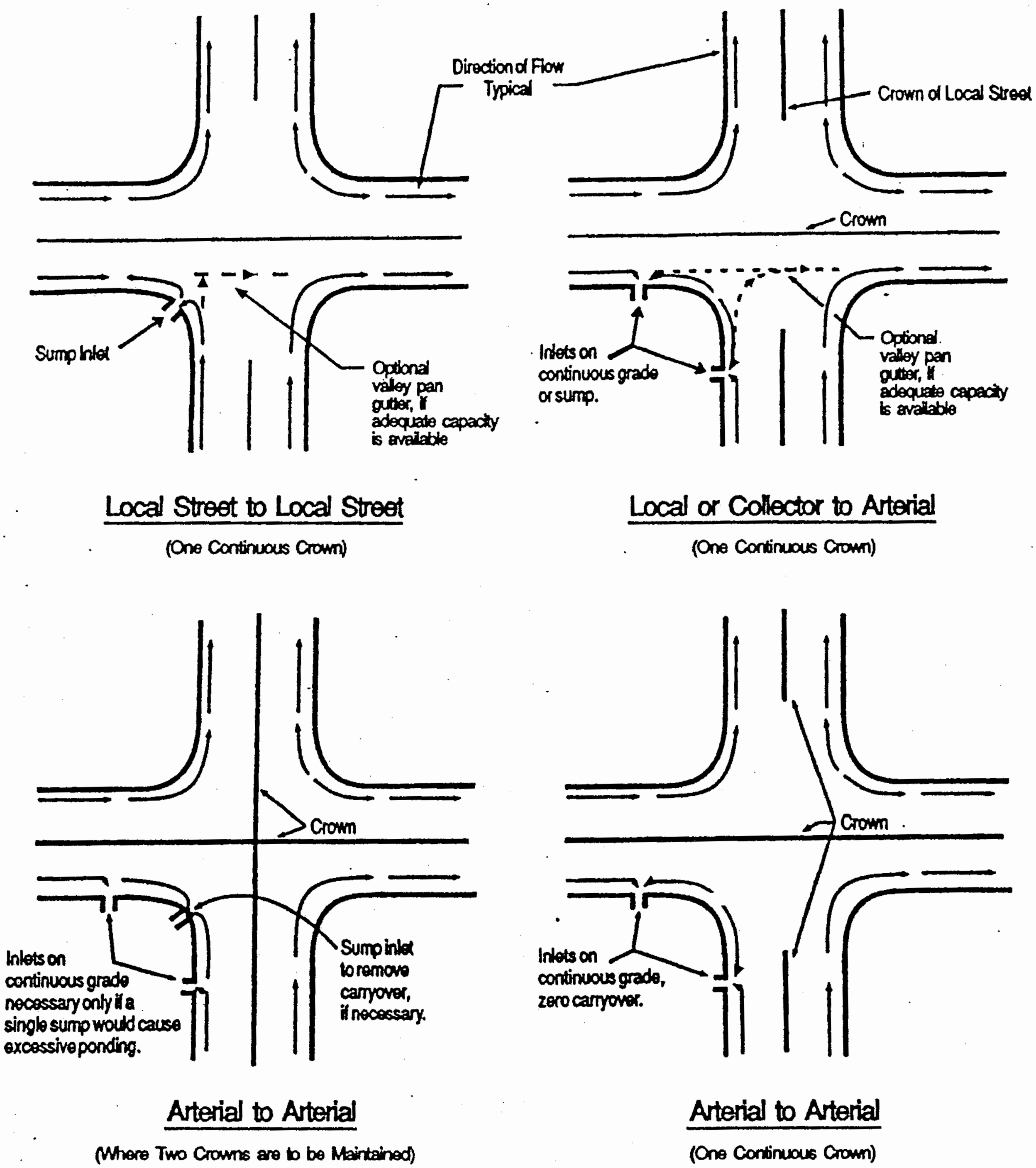
2. Flow Velocity Minimum pipe flow velocity in the two-year storm shall be 2.5 fps for positive-slope drainage conveyance systems, and 5.0 fps for inverted siphons. Bleedoff lines for detention facilities may have slower flow velocities.

3. Minimum Pipe Size The minimum pipe size for public facilities shall be 8 inches. The minimum on-site pipe size for direct conveyance shall be 6 inches. Private bleed-off lines may be as small as 4 inches in diameter. However, all pipes must be of adequate size to convey calculated runoff, and must provide a 2-year flow velocity of at least 2.5 fps as previously indicated.

4. Hydraulic Gradeline Calculations If pipelines are subject to backwater conditions, or normal flow at greater than 80% depth in the design storm, full hydraulic gradeline calculations must be submitted. These will involve starting with the tailwater condition at the outlet and working upstream through the pipe system, accounting for not only frictional losses through the pipe, but also expansion and contraction losses through manholes, bends, and other structures. The hydraulic gradeline may raise above the top of pipe (in other words, the pipe may be surcharged or slightly pressurized) but the hydraulic gradeline may not raise to within 1.0 foot of any manhole rim, inlet grate, or other surface opening without special approval. Calculations may be performed by hand or they may be performed by computer analysis.

Storm sewer design information is provided in Appendix "H".

MODIFIED FROM FIGURE 3.5 DRAINAGE DESIGN MANUAL FOR MARICOPA CO., VOL II,
URBAN STORM DRAINAGE CRITERIA MANUAL, FIGURE 5-2



These examples show the minimum required inlets.
Additional inlets may be necessary based upon
allowable carrying capacity of gutters.

INTERSECTION INLET LOCATIONS	FIGURE VII-1

5. Pipeline Design The ability of a pipeline to maintain full cross-sectional area and function without cracking, breaking, or undergoing excessive deflection is of prime importance. Therefore, pipelines proposed for drainage purpose shall be designed not only for size, but also material type and pipe and bedding class.

E. OPEN CHANNEL FLOW

1. Calculation Methods Computer methods such as HEC-2, WSPRO, WSP-2, FESWMS-2DH, or other approved methods may be used to calculate water surface profiles. Calculations may also be performed by hand using the Manning equation for subcritical flow, with backwater calculations as appropriate. The Manning equation to be used is:

$$Q = \frac{1.486\, a^{1.67} S^{0.5}}{n p^{.67}}$$

2. Channel Flow

   a. Supercritical Flows Flows are supercritical when the Froude number is greater than one. In natural and unlined man-made channels, flows are usually supercritical only in short segments between subcritical flow reaches. Hence the common practice of analyzing stream channels for supercritical velocities and subcritical depths when flow conditions are near critical. For designed channels, it is best to avoid transitioning flow regimes as much as possible.

   b. Subcritical Flows Flows are subcritical when the Froude number is less than one. Subcritical flows near critical have potential for changing to supercritical, and therefore subcritical depths are assumed, but the potential of supercritical velocities should not be overlooked. For designed channels, it is best to avoid transitioning flow regimes as much as possible.

   c. Acceptable Design Flow Regime Channels must be designed to avoid as much as possible transition from subcritical to supercritical flow and vice versa. Therefore, channels must convey the design storm with the Froude number conforming to the following:

$$F_r \leq 0.86 \text{ and } F \leq 1.13.$$

   d. Freeboard Channels designed for Q_{100} must meet freeboard requirements specified in Section I-A-3-b on page I-2. In addition to freeboard below building finish floors, channels shall also have additional freeboard if embankments are higher than the surrounding terrain. The additional freeboard shall be as specified in Appendix "I".

e. Side Slopes The steepest permitted side slopes are as follows:

- 4H:1V for channels on public lands or parks;
- 3H:1V for seeded or sod surfaces;
- 2H:1V for riprap or approved slope protection; and
- Vertical walls with safety rails only where approved by the City Engineer, or County Development Engineer.

The slopes of all new channels shall be protected from erosion by seeding and mulching, sodding, or other approved ground cover.

f. Unlined Channels In order to prevent excessive erosion, maximum velocity limits for flows in channels are per Table "VII-1".

TABLE "VII-1"
ALLOWABLE CHANNEL FLOW VELOCITIES

Channel Cover*	Maximum Velocity	
	Erosion Resistant Soil	Easily Eroded Soil
a) Bare Soil (Not allowed for new channels)	4.0	2.5
b) Buffalo Grass, Bluegrass, Smooth Brome, Blue Grama, Native Grass Mix	7.0	5.0
c) Lespedeza, Lovegrass, Kudzu, Alfalfa, Crabgrass	4.5	3.0
*Assuming a good stand of grass		
Source: UD&FCD		

g. Minimum Velocity Minimum channel flow velocity in the two-year storm is 2 fps.

3. Additional Design Guidelines Design procedures for channel curvature, superelevation, exit transitions, drop structures, and liners shall conform to guidelines presented in Appendix "I".

F. RIPRAP EROSION PROTECTION Riprap design for protection of channels, embankments, culvert ends, and other drainage facilities shall adhere to procedures and guidelines presented in Appendix "J".

G. <u>WEIR AND ORIFICE FLOW</u> Weirs and orifices are often analyzed incorrectly. Each is discussed in Appendix "K", and procedures and guidelines presented therein shall be adhered to.

H. <u>CULVERT DESIGN</u> Culverts shall be designed using the Federal Highway Administration's nomographs which are provided in publication HDS-5. Much information contained therein has been reproduced and provided in Appendix "L" for convenience. Minimum flow velocity for the 2-year storm shall be 2.5 fps. Flow velocity in the 100-year storm should not exceed 15 fps.

I. <u>OTHER HYDRAULIC STRUCTURES</u> All other drainage and hydraulic structures which are required, including headwalls, flumes, spillways, and various energy dissipation and erosion control facilities shall be designed in accordance with hydraulic engineering principles. Excellent resources are FHWA's HEC-11, HEC-14, and HEC-15, and also other publications listed in Section II pages II-6 and II-7.

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VIII. DRAINAGE FEE, DETENTION, AND RETENTION

<u>List of Figures</u>

<u>List of Tables</u>

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VIII. DRAINAGE FEE, DETENTION, AND RETENTION

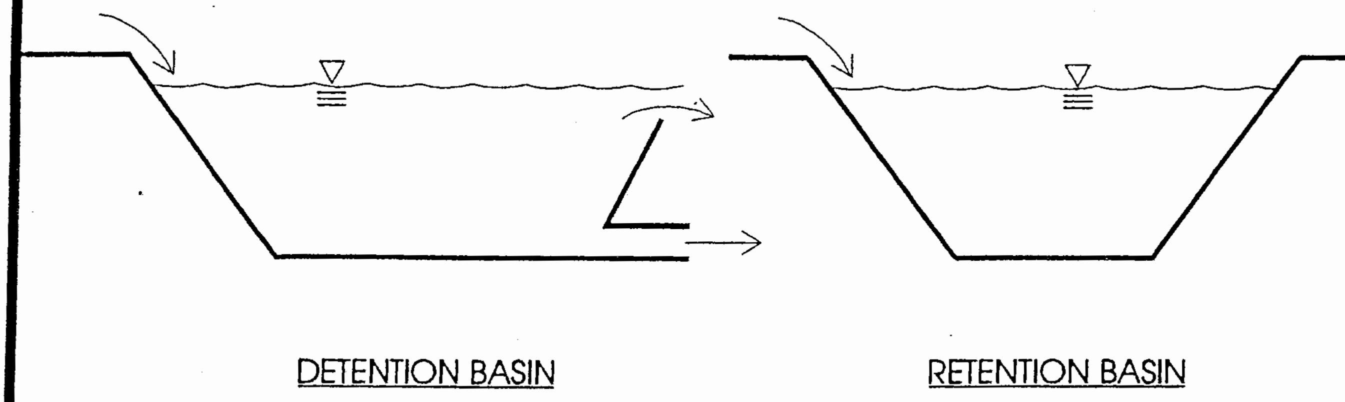
A. GENERAL DISCUSSION

Preceding an in-depth discussion of drainage fees and stormwater storage, general concepts pertaining to these subjects are presented.

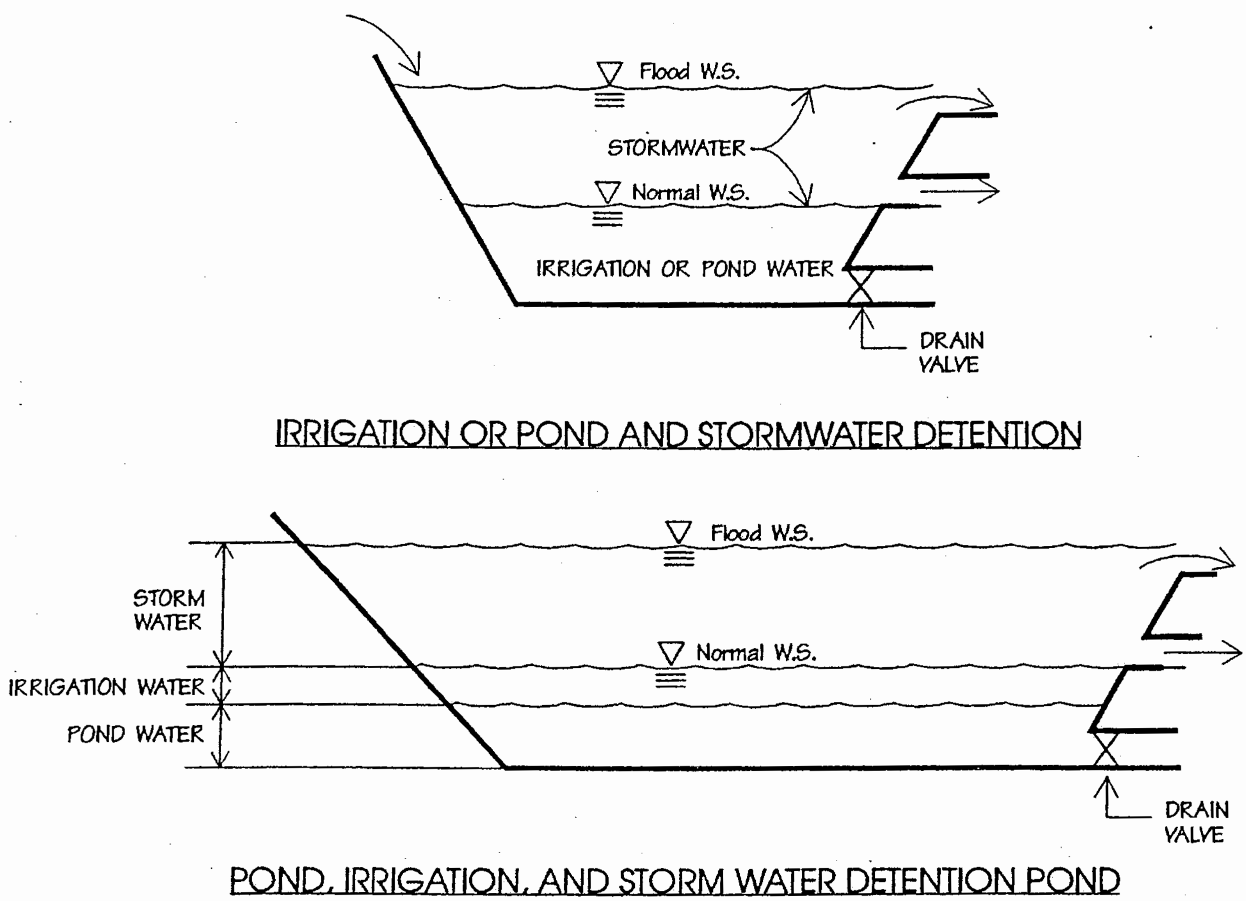
1. **Drainage Fee Versus Runoff Storage** The traditional method of mitigating adverse drainage impacts due to development has been to provide stormwater storage facilities. These reservoirs store excess runoff which would otherwise result in a higher than historic peak runoff rate leaving a site. This method of mitigation does work, but it is not always the most economical or desirable to implement, particularly for non-subdivision applications. However, it would not be wise to altogether remove requirements for runoff mitigation because of these factors for, even with commercial development, small additive incremental increases may have a significant impact on downtown property. In lieu of waiving mitigation requirements, it may be better under certain circumstances, to allow an alternative means of mitigation, even if the mitigation is less direct. A feasible alternative is payment of a drainage fee which would be used to partially fund construction of larger scale public drainage facilities, and thereby indirectly mitigate adverse drainage impacts. Both methods of mitigation have their benefits, and there are circumstances under which one or the other of these methods should not be used. Therefore, a policy allowing flexibility with administrative control is desirable.

2. **Detention Versus Retention** Stormwater storage reservoir types are numerous, but they essentially fit into one of two categories: detention or retention. A detention basin or pond "detains" water temporarily, releasing water through a pipe or channel by means of a weir, orifice, or pump. Because of the ability to be releasing flow during inflow, the overall volume of storage required for a given storm event is reduced. Another advantage of the detention basin is the positive means of outflow, resulting in fewer problems with long-term ponding. A retention basin or pond "retains" water without any initial release during inflow. Once the storm event is over, pond drainage may occur due to evaporation and percolation into the soil. In some instances, retention basins may also involve a gated pipe or pump which is closed or inoperative during the storm event. However, if a gated pipe or pump is an available or desirable option, it would normally be advantageous to release water during stormwater inflow, which would change the basin from a retention basin to a detention basin. The difference in detention and retention basins is depicted in Figure VIII-1.

3. **Wet Pond versus Dry Basin** With respect to stormwater detention and retention reservoirs, the words "pond" and "basin" are used interchangeably. Both forms may be used to refer to reservoirs that remain dry except during storm events, and also for reservoirs which permanently store water for other purposes, but receive additional water during storm events. Confusion may be avoided by addition of the words "wet" and "dry", which in common use precede "pond" and "basin", respectively. Thus, a pond and basin



DETENTION AND RETENTION BASIN | **FIGURE VIII-1**



NOTE: Although the irrigation water will cycle between the pond normal surface and the maximum depth shown, all hydraulic analysis shall be based upon the full amount of irrigation water being present.

WET POND COMBINATIONS | **FIGURE VIII-2**

are the same and may be wet or dry, but a wet pond and dry basin each have a specific meaning.

4. **Wet Pond Combinations** Wet ponds may be desirable compared to dry basins in some circumstances. It may be that ample storage volume exists to provide an aesthetic or recreational pond below required stormwater reservoir volume, or perhaps even irrigation storage volume, or all three uses. The only limiting criterion is that required stormwater reservoir volume must be provided in addition to the maximum expected irrigation and/or other purpose storage volume. This is depicted in Figure VIII-2.

5. **Sedimentation Forebay** Stormwater runoff contains suspended solids. Often it is desirable to remove a large portion of the suspended solids prior to discharging runoff to downstream facilities and receiving waters. A common method of removing sediment is to construct a sedimentation forebay, usually upstream and in conjunction with a stormwater reservoir. To be effective, forebays must store runoff water sufficiently to let the majority of suspended solids, usually in the 70% by volume range, settle out of the stormwater. Size requirements will vary depending upon inflow rates, volumes, the design storm selected, the typical particle size of the suspended solids, forebay shape, and other considerations. Both initial and maintenance costs are high; consequently, sedimentation forebays have not been used extensively, although more recent EPA emphasis on water quality has resulted in increased interest in and use of forebays.

B. DRAINAGE FEE

A drainage fee alternative to providing stormwater reservoir capacity has **not** been established for development within the City of Delta, but the option is currently being considered. The basic conditions under with this alternative are an option, and how it is administered, are outlined herein.

1. **Enabling Conditions** All proposed development must provide for on-site runoff collection and conveyance in accordance with adopted policies. However, an option to providing detention/retention and metered outlet facilities may be allowed in the City by the City Director of Public Works or his designee if:

i.) site runoff to private property will not increase due to development; and

ii.) the Director or his designee determines that off-site public streets or other public drainage conveyance facilities are adequate to receive and convey additional runoff from the proposed development site without adversely impacting the public's facilities, interest, health, or safety.

Generally, options will be restricted to proposed developments which are 5 acres or less for all phases and/or filings. There may be circumstances, however, where the Director or his designee may allow an option for larger sites if they are located low in a watershed basin or adjacent to major outfall facilities.

2. Basic Information Requirements The Director or his designee shall require submittal of certain information on the part of the developer in order to determine if the drainage fee option is allowed or if construction of drainage detention/retention facilities is required. Such information may include but is not necessarily limited to the type and percent change of impervious surfaces, measurements of property including elevations, distance to conveyance structure(s), type of conveyance structure(s), availability of regional detention facilities, flood control structures, and location of the development within the watershed.

3. When An Option Is Allowed and Selected Upon written approval from the Director or his designee, the developer shall be given the option of paying a drainage fee in lieu of providing drainage detention/retention and metering facilities. If and when the developer elects to use the approved drainage fee option, such election does not waive the requirements for:

   i) providing an on-site Grading and Drainage Plan; and

   ii) construction of on-site collection and conveyance facilities and providing drainage calculations as required therefor. However, payment of the drainage fee, when approved by the Director or his designee, shall constitute compliance with policy regarding development-related increased runoff.

4. Fee Amount The drainage fee shall be determined by application of the following formula:

$$\text{Drainage Fee (\$)} = 10{,}000\,(C_{100d} - C_{100h})\,A^{.7}$$

where C_{100} = 100 year Rational Method composite runoff coefficient, with subscripts "d" and "h" pertaining to the proposed developed and current existing or historic conditions, respectively (See Appendix "B"); and

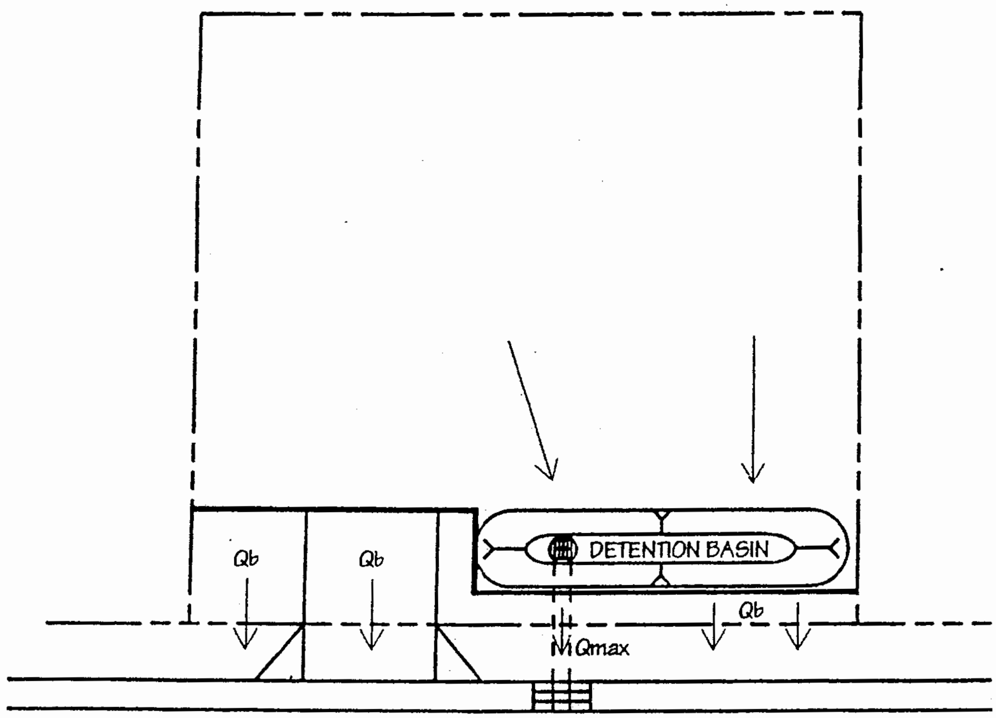
A = Area to be developed in acres.

The method or formula to use in calculating the drainage fee, may change from time to time, by resolution of the City Council. Change will be based upon projections, estimates, or opinions of the Director or his designee, of the need for additional specific facilities and/or upon the need of the drainage system.

5. When Fees Are Due Drainage fees shall be paid to the City and will be allocated for the construction of drainage facilities at locations determined by the City, in its sole and absolute discretion, to be of greatest priority. Fees shall be paid prior to the recording of residential plats, or prior to issuance of planning clearance for all other development.

C. GENERAL DETENTION AND RETENTION CRITERIA

1. Design Storm Criteria Peak runoff from a site may not be increased in the 5 and 100-year storms due to development. The site runoff may be a composite of detention/retention basin release/overflow and direct runoff, both of which must be considered. If direct runoff is allowed from the site, the sum of the direct runoff plus the release from the detention basin must not exceed the historic rate. This is depicted in Figure VIII-3.



Maximum release from detention pond Qmax ≤ Historic peak Q_h minus direct bypass runoff Qb

$Q_{max} \le Q_h - Q_b$

TOTAL SITE RUNOFF	FIGURE VIII-3

2. Multiple Recurrence Interval Were only a single storm recurrence interval considered in detention release, the pond and outlet works would be considered a single stage or single recurrence facility. These are fairly simple to design, but unfortunately have limited usefulness. During storms having less intensity than the design storm, released runoff rates actually exceed historic conditions, and may be as high as the historic design storm peak runoff rate. During storms having greater intensity than the design storm, ponds are filled before the developed runoff rate has subsided to historic peak levels, again resulting in the

historic rate being exceeded. Single recurrence interval control criteria therefore is of little hydraulic benefit except for at the single design storm frequency. Consequently, state-of-the-art practice is to require multiple recurrence interval control, generally for two design storms. The criteria stipulated in (1) above results in a dual recurrence interval control; that is, pond release is regulated for both the 5 and 100-year storm event. In effect, this also proportionately controls release rates for all events between the 5 and 100-year storm.

3. <u>Geometric Requirements</u> For proper function and safety considerations, geometric requirements shall be as shown on Figure VIII-4.

4. <u>Inflow Capability</u> Storage reservoir facilities are provided to mitigate flooding for up to the 100-year storm runoff event. However, if the basin is improperly located, or if the site grading and conveyance facilities of streets, swales, channels, inlets, and pipes are not properly and adequately designed, then the 100-year runoff will not even reach the basin. A comprehensive design is required to insure that flows will reach the basin.

5. <u>Dry Basin Bottom Drainage</u> Most drainage conveyance systems are designed to divert even minor nuisance flows to stormwater storage facilities. For dry basins, this can present an aesthetic and maintenance problem. Conveyance facilities to a dry basin should be capable of transporting flow to the outlet facility rather than causing a soggy bog condition that cannot properly be maintained. Facilities conveying trickle or nuisance flows, such as from irrigation sprinklers, should be adequate to convey approximately 0.5 cfs. Reference is made to Figures VIII-5a, 5b, & 5c.

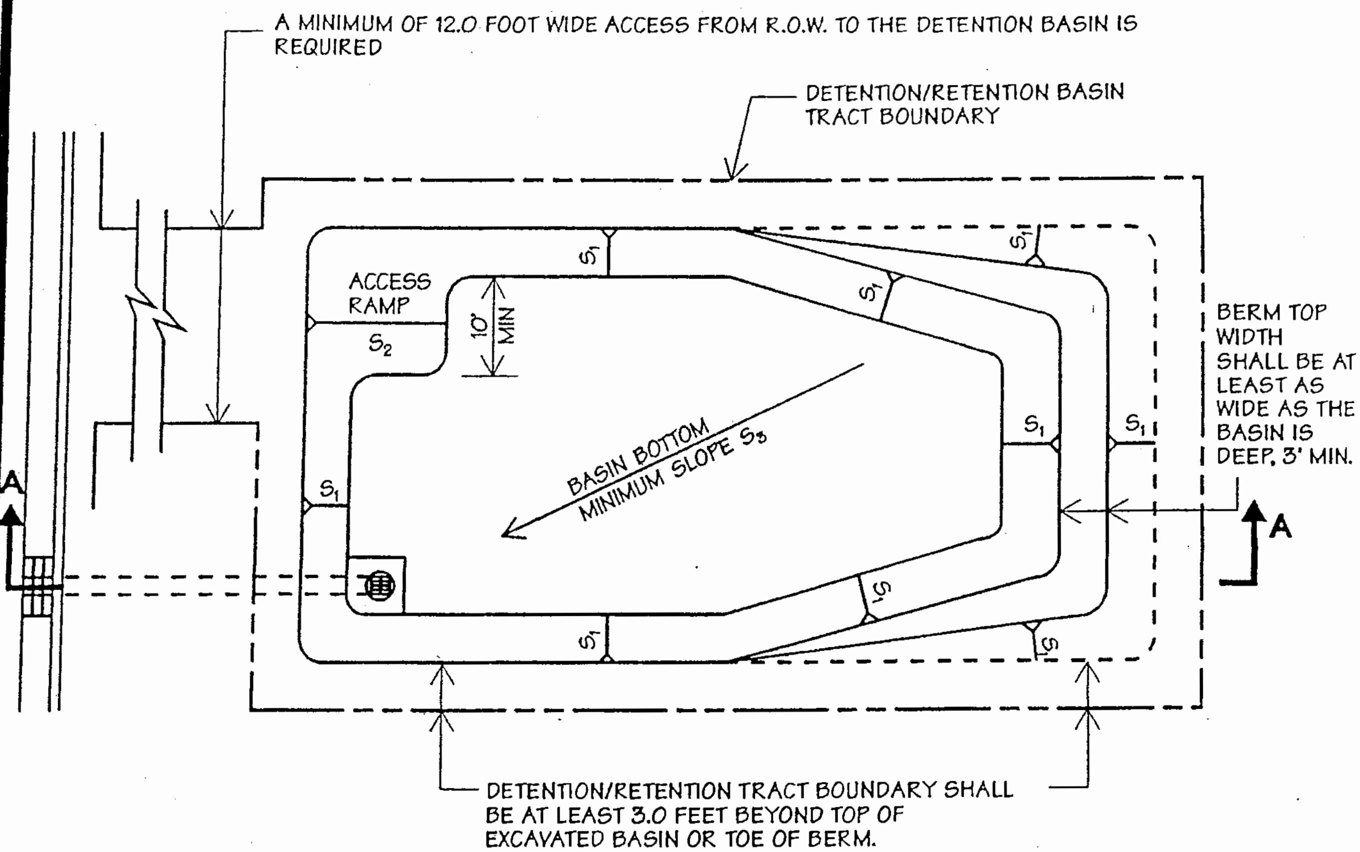
   The outlet facility for a retention basin would be a dry well or rip-rap filled dissipation pit. For a detention basin, the nuisance flows shall be conveyed to the basin outlet.

6. <u>Accessibility and Maintenance</u> All reservoirs or ponds which serve more than a single lot or site must be provided with a detention/retention tract dedicated for such purpose. Maintenance of required volume and inflow and outflow works is necessary for the facility to function as required.

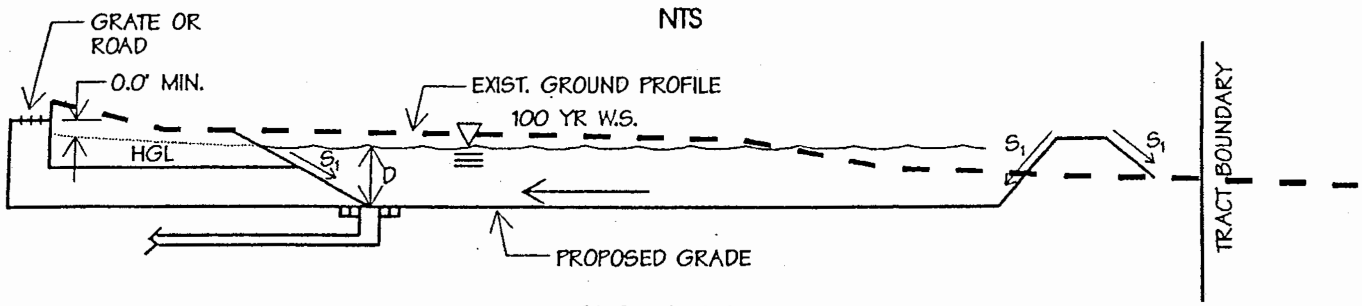
7. <u>Calculating Storage Volume Available</u> Storage volume shall be calculated by the methods shown prescribed in Figure VIII-6.

8. <u>Ground Cover and Landscaping</u> After final grading, the slopes and bottom of each detention and retention basin shall be protected from erosion by seeding and mulching, sodding or other approved ground cover and shall be in accordance with jurisdictional Specifications.

   The planting of trees and shrubs on the slopes of storm water basins is also encouraged. Temporary and/or permanent irrigation systems shall be provided as required for the type of ground cover and landscape installed and approved.



PLAN VIEW
NTS



SECTION A-A
NTS

STEEPEST S_1: 4H:1V FOR BASINS ON PUBLIC LANDS AND PARKS
3H:1V FOR SEEDED OR SODDED SLOPES
2H:1V FOR RIPRAP OR OTHER APPROVED SLOPE PROTECTION
VERTICAL WALLS WITH SAFETY RAILING LIMITED TO ONE SIDE ONLY WHERE APPROVED BY THE CITY ENGINEER OR COUNTY DEVELOPMENT ENGINEER.

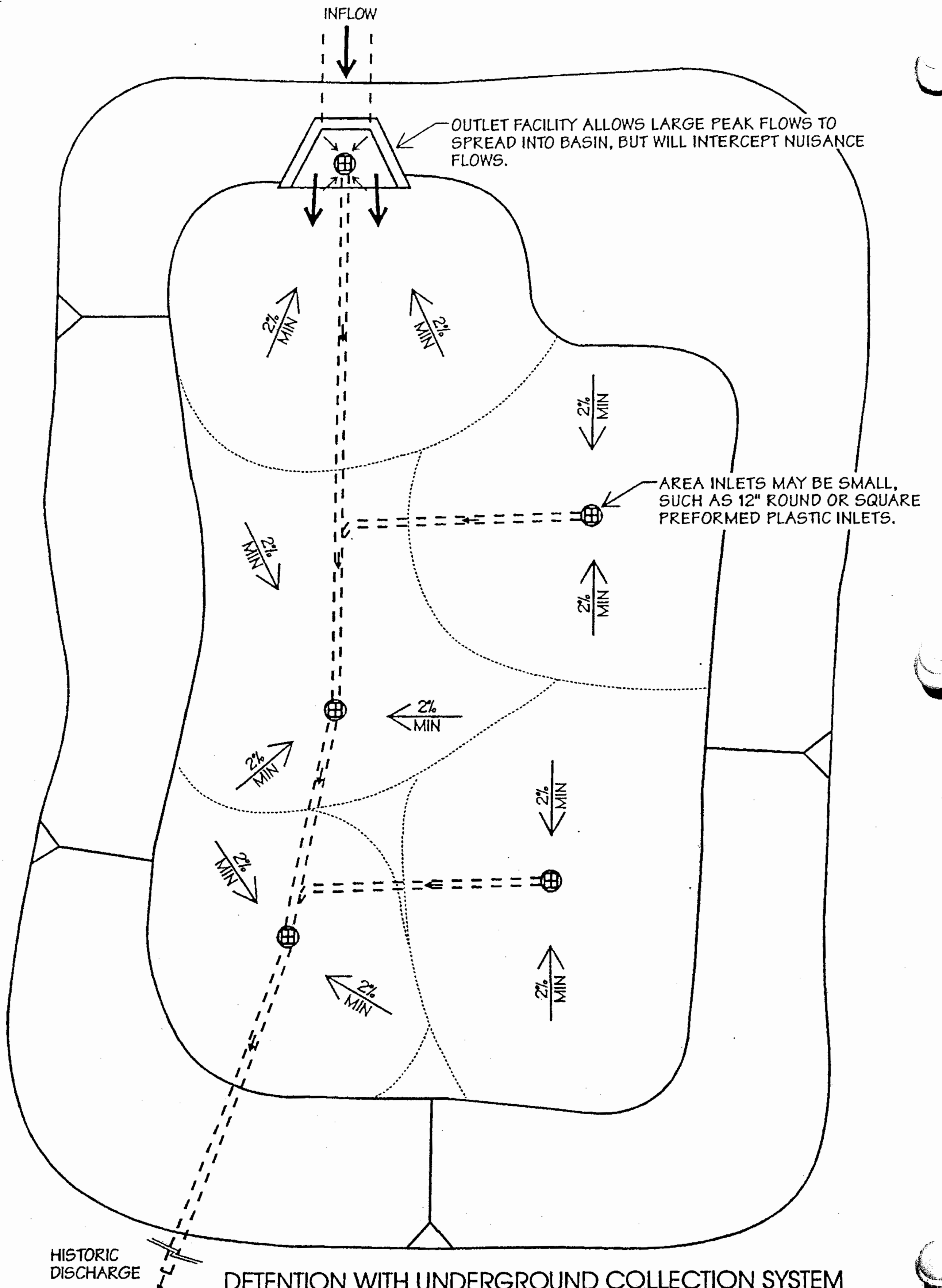
STEEPEST S_2: 6H:1V FOR ACCESS RAMP, ALL SURFACES

MINIMUM S_3: 0.5% FOR CONCRETE CHANNEL
1.0% FOR ASPHALT (PARKING LOT)
2.0% FOR ALL OTHER SURFACES

MAXIMUM D: 4' RETENTION BASIN
8' WET OR DRY DETENTION FACILITY
>8' SPECIAL APPROVAL REQUIRED, BUT MAY BE ALLOWED FOR MULTIPLE USE PONDS OR FOR STEEP TERRAINS

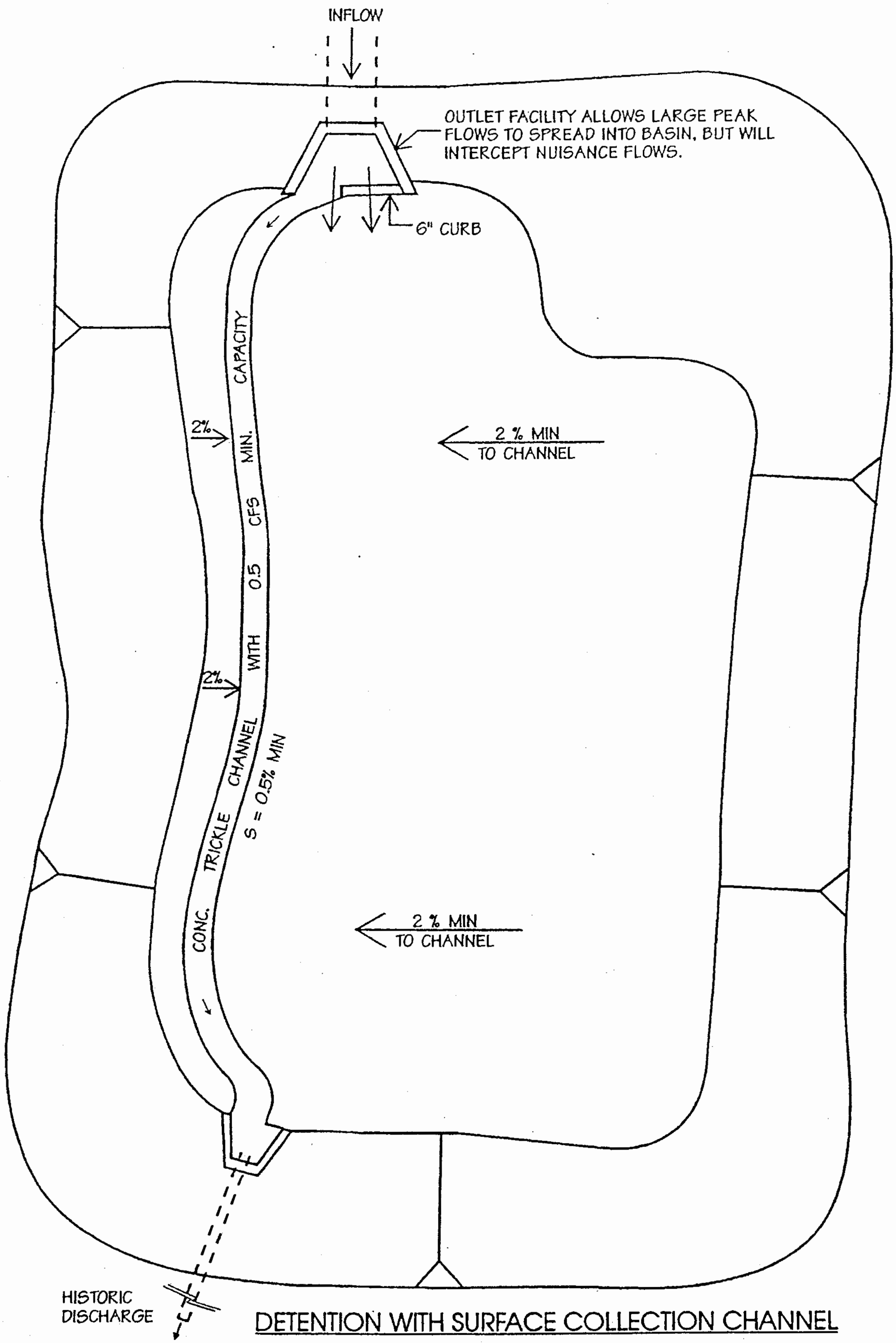
MINIMUM D: 4' WET PONDS (SEE PAGE VIII-1)

DETENTION/RETENTION BASIN GEOMETRIC REQUIREMENTS | **FIGURE VIII-4**



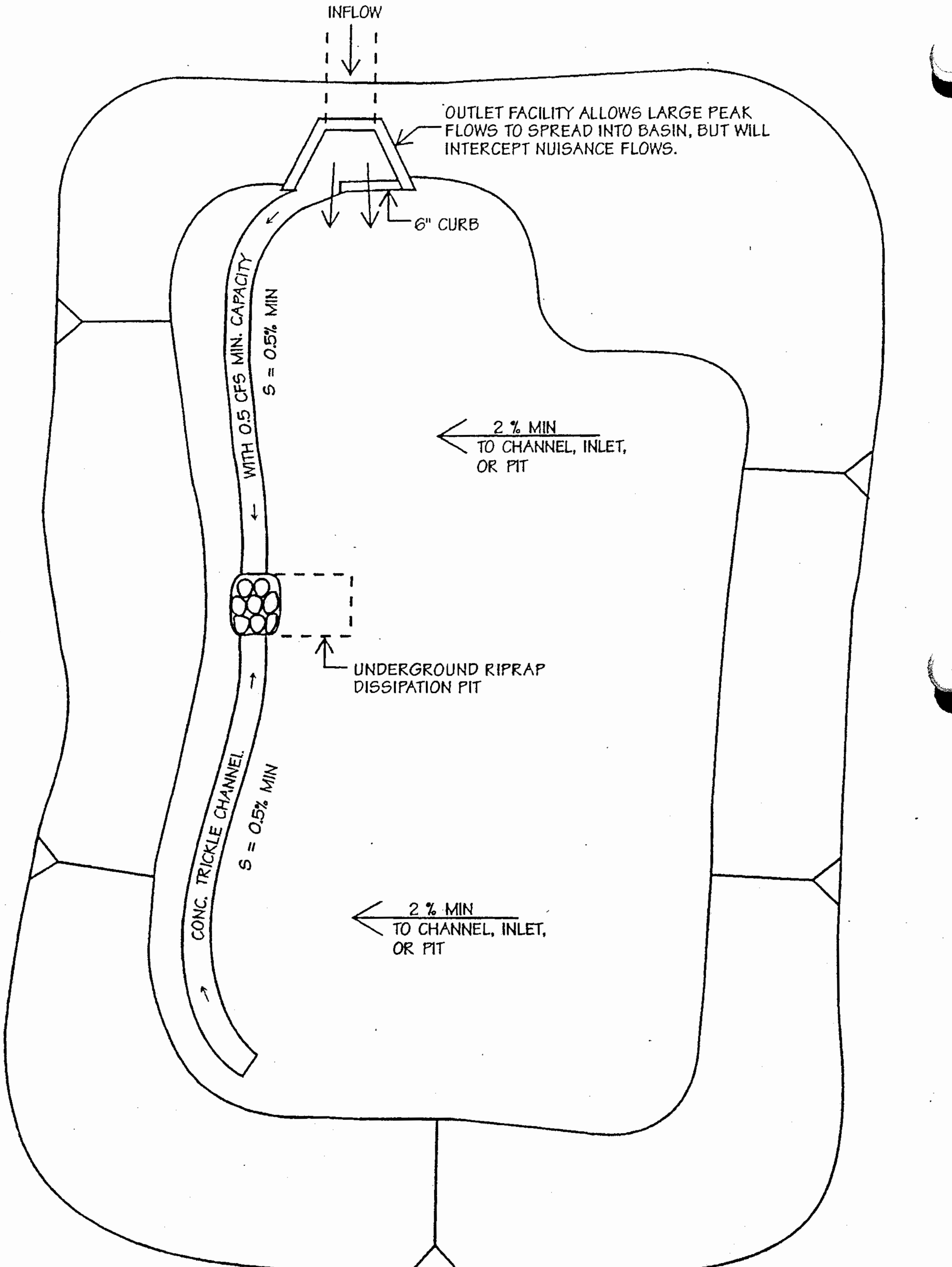
DETENTION WITH UNDERGROUND COLLECTION SYSTEM

DRY BASIN TRICKLE FLOW CONVEYANCE	FIGURE VIII-5a



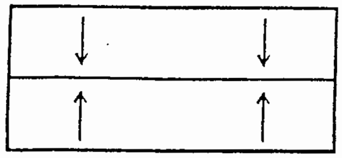
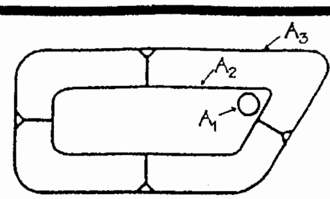
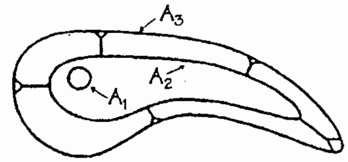
DETENTION WITH SURFACE COLLECTION CHANNEL

DRY BASIN TRICKLE FLOW CONVEYANCE	FIGURE VIII-5b



RETENTION WITH SURFACE COLLECTION CHANNEL
(THE SAME CONCEPT APPLIES TO AN UNDERGROUND SYSTEM)

DRY BASIN TRICKLE FLOW CONVEYANCE | **FIGURE VIII-5c**

BASIN SHAPE		 
BASIN TYPE	VERTICAL WALLS AND/OR PRISMATIC BASINS	FAIRLY UNIFORM SHAPE AND SIDE SLOPES OR HIGHLY IRREGULAR SHAPE AND SIDE SLOPES
VOLUME CALCULATION METHOD	AVERAGE END AREA METHOD	CONIC METHOD
EQUATION	$V = \left(\frac{A_n + A_{n+1}}{2}\right) L$	$V = \Sigma V_{n\ to\ n+1}$ $V_{n\ to\ n+1} = [A_n + A_{n+1} + (A_n A_{n+1})^{.5}]\frac{h}{3}$

WHERE:
- V = Volume (ft)
- A_n = Horizontal area (ft^2) at elevation "n"
- A_{n+1} = Horizontal area (ft^2) at elevation "n+1"
- h = Vertical height (ft) between elevation "n" and "n+1"
- $V_{n\ to\ n+1}$ = Volume between elevation "n" and "n+1"
- L = Length (ft) between two ends

NOTE: The above equations may be used in succession for incremental heights within a basin. An area should be selected at all significant changes in shape or side slope.

CALCULATING STORAGE VOLUME | **FIGURE VIII-6**

D. DETENTION FACILITY SIZE AND OUTLET WORKS

1. Outlet Control Structures Outlet control structures are an important and integral component of stormwater detention facilities because they control rates of pond release, water depth, and storage volume. It is impossible to calculate required storage volumes with acceptable accuracy without also knowing outlet capacities. Unfortunately, outlet capacities are affected by ponded depths, and ponded depths are impacted by storage volume. In other words, a detailed design process would normally be iterative. This is not a problem for computer analyses, but could be tedious if done by hand calculations. However, procedures are provided herein that will simplify hand-calculated analyses.

2. Computer Calculations Many programs exist for analyzing and aiding in the design of detention/outlet facilities. Generally, input data consists of elevation-area or elevation-volume data, type of outlet and spillway or defined stage/discharge information, if any, and outlet facility parameters or allowed release rate. User effort is minimal, and with proper use, results are acceptable.

   Computer methods of detention pond sizing are allowable, and even recommended, but:

   i) They must not unreasonably truncate the runoff period or, if they do, adjustment must be made to account for it; and

   ii) Input must account only for realistic release rates which may be obtainable from designed outlet facilities, and may not exceed the historic peak runoff Qp_h minus runoff that will bypass the detention facility Qb. Generally, the average outflow release Qr is less than Qp_h - Qb.

3. Manual Calculation Procedures Manual calculations of detention basin sizing are allowed only if all of the following conditions are met:

   i) The total watershed is not larger than 25 acres;

   ii) The Rational Method is used to estimate runoff; and

   iii) The Modified Rational Method is used per procedures presented in Appendix "N".

E. RETENTION PONDS

1. Conditions of Use Retention ponds are stormwater holding basins that are not designed to bleed off to a stormwater conveyance facility during storm activity. Water is removed only by evaporation, soil percolation, or a manually operated delayed release. These are allowed for small runoff volumes only, and under the following circumstances:

   i. Groundwater is not a problem in the area;

i. Percolation tests indicate that it is likely that required retention water can be dissipated within 48 hours (tests must be performed under the direction of an engineer and submitted to the City of review);

ii. Soil percolation will not damage nearby structures or facilities (a letter regarding adverse impact, if any, and consequent recommendation is required from a geotechnical engineer, and must be submitted to the City of review); and

iii. The retention pond must have a minimum size such that overflow occurs only after the generated runoff has subsided to undeveloped flow rates for the 100-year event.

2. **Overflow capacity** Retention basins need not be sized to contain the full 100-year runoff generated on a site. A reduced storage volume may mitigate the developed peak runoff and not overflow until the developed runoff generated has subsided to Q_{max}, which is the historic peak runoff rate Q_{100h} minus direct runoff which bypasses the retention basin, Qb.

3. **Total Retention (Without Overflow)** The largest storage volume requirement is when a retention basin is used without overflow. The advantage of this type of retention basin compared with an overflow type is normally a Drainage Report would not be required. The only need for drainage calculations beyond the simple volume equation would be if they were necessary to adequately size on-site conveyance facilities. Also, with 100% retention of the 100-year storm runoff, spillway requirements are minimized.

The volume to be stored is simply the total 100-year, 24 hour rainfall precipitation, times the site area, times the 100-year developed runoff coefficient. In equation form, the volume is

$$V = P_{100\,24hr} \times A \times C_{100d}$$

$$V(ft^3) = \frac{P_{100\,24hr}(inches)}{12} \times AREA\,(FT^2) \times C_{100d}$$

[See Tables A-2a and Figure A-1 in Appendix "A" for values of $P_{100\,24hr}$]

4. **Partial Retention (With Outflow)** If a retention basin is designed to overflow at the rate of Q_{max} in the 100-year storm event, the required volume is less than that required for total retention. However, additional drainage calculations are required, although not extensive. Also, with planned overflow, normal spillway design and erosion procedures are necessary.

The procedure is to determine at what time the developed condition runoff has subsided to the historic peak rate. Since development cannot result in an increase in runoff, we may set $Qp_{100d} = Qp_{100h}$; or $C_{100d}I_{100d}A = Qp_{100h}$. Development does not change the acreage – only the runoff coefficient "C". To offset the increase in "C", the intensity "I" must decrease, which has a corresponding critical time of duration Td. Use of Modified Rational Method principles then allows direct calculation of the volume. The procedure is systemized below.

1. Determine the historic 100-year storm runoff rate Qp_{100h} using the Rational Method equation: $Qp_{100h} = C_{100h}I_{100h}A$.

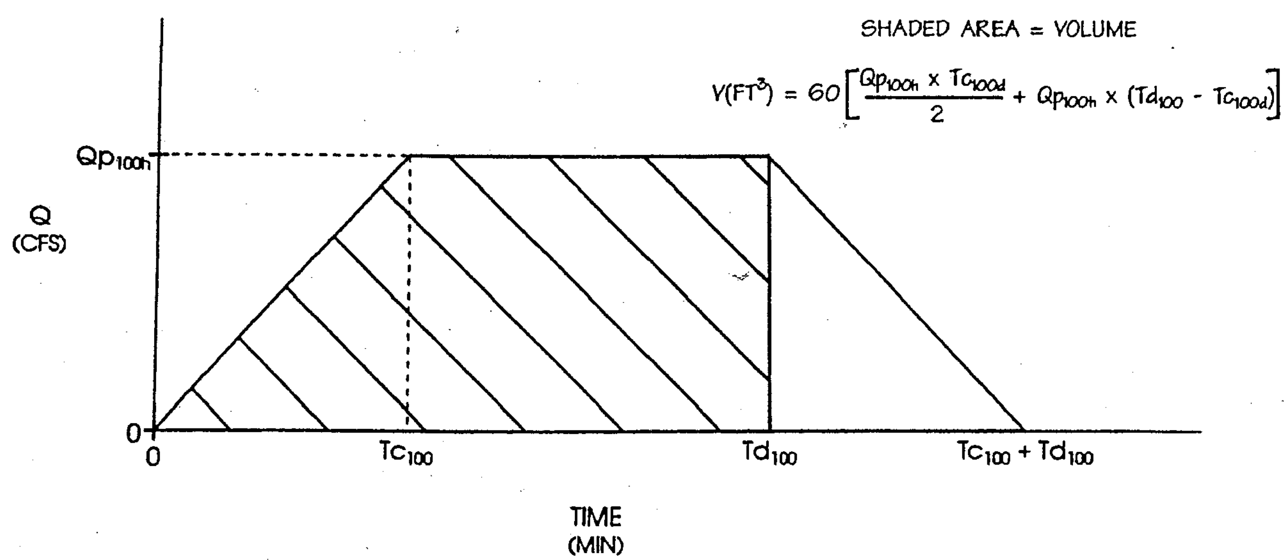
2. Determine the 100-year developed runoff coefficient C_{100d} and time of concentration Tc_{100d}.

3. Determine the critical 100-year intensity "Id_{100}" as follows: $Id_{100} = \dfrac{Qp_{100h}}{C_{100d}A}$.

4. From Table "A-1a or b" in Appendix "A", or from approximate equations $Td_{100} = \dfrac{104.94}{I_{100d}} - 18.80$ [Grand Valley], or $Td_{100} = \dfrac{111.88}{I_{100d}} - 18.69$ [Outside of Grand Valley], determine the time of critical duration T_{d100}.

5. The area under the Modified Rational Method "hydrograph" represents the volume. This is depicted in Figure VIII-7, and the equation is

$$V(FT^3) = 60\left[\frac{Qp_{100h} x Tc_{100d}}{2} + Qp_{100h} \text{ x } (Td_{100} - Tc_{100d})\right]$$

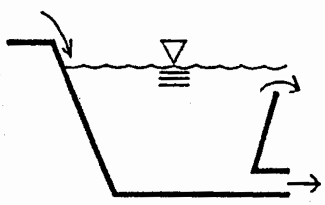
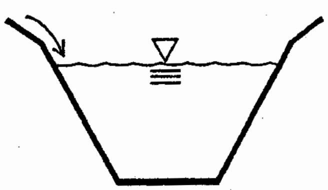
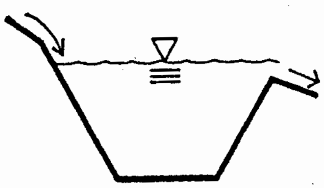


PARTIAL RETENTION "HYDROGRAPH"

FIGURE VIII-7

F. SUMMARY

The foregoing has identified four ways or means of satisfying policy to mitigate stormwater increase which occur with development, and presents procedures for use in applying the methods. Table VIII-1, "FEE AND STORMWATER STORAGE SUMMARY", provides a brief comparison and reference of the four methods.

DIAGRAM	TYPE	EQUATION	REFERENCE	REQUIREMENTS
	DRAINAGE FEE	NOT YET AVAILABLE		• Option is available only under City jurisdiction, and must be approved by the City • Fee • Grading & Drainage Plan • Under certain circumstances, a minimal Drainage Report could be required to show that on-site drainage conveyance facilities are adequate
	DETENTION BASIN	COMPUTER METHODS OR MODIFIED RATIONAL METHOD & VOLUME-STAGE-DISCHARGE	VIII-12 AND APPENDIX "N"	• Grading and Drainage Plan • Complex Drainage Report • Stormwater storage area (least volume) • Detention basin outlet facilities
	TOTAL RETENTION (NO OVERFLOW)	$V(FT^3) = \frac{P_{100\,24hr}}{12} \times AREA(FT^2) \times C_{100d}$ where $P_{100\,24hr}$ is in inches, as provided in Appendix "A" Table "A-2" or Figure "A-1".	VIII-13	• Must meet conditions • Grading & Drainage Plan • Under certain circumstances, a minimal Drainage Report could be required to show that on-site drainage conveyance facilities are adequate • Stormwater storage area (most volume)
	PARTIAL RETENTION (WITH OVERFLOW)	$V(FT^3) = 60\left[\frac{Qp_{100h} \times Tc_{100d}}{2} + Qp_{100h} \times (Td_{100} - Tc_{100d})\right]$	VIII-13	• Must meet conditions • Grading & Drainage Plan • Simple Drainage Report • Stormwater storage area (medium volume) • Spillway

FEE AND STORMWATER STORAGE SUMMARY — **TABLE VIII-1**

IX. STORMWATER QUALITY

List of Figures

List of Tables

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IX. STORMWATER QUALITY

A. GENERAL DISCUSSION

Urbanization affects stormwater runoff by increasing the following:

i) The volumes and rates of surface runoff;

ii) The concentrations and the types of pollutants found in stormwater; and

iii) The loads of pollutants carried and their transfer rates to receiving waters.

Urbanization results in an increase in impervious areas and enhanced efficiency of surface runoff. The influx of commercial, residential, and industrial products into an area often results in new pollutants in greater concentrations than before urbanization occured.

B. WATER QUALITY REGULATIONS

On November 16, 1990, EPA issued final regulations on the control of stormwater from municipal and industrial stormwater discharges. The stormwater program is under the NPDES (National Pollutant Discharge Elimination System) part of the Clean Water Act. The regulation is meant to reduce the amount of pollutants entering streams, lakes, and rivers as a result of runoff from residential, commercial and industrial areas. The regulations (40 CFR 122.26) cover specific types of industries, and storm sewer systems for municipalities with over 100,000 population. Industrial stormwater permits are also required for Counties having a population over 100,000.

In Colorado, the program is under the Colorado Department of Public Health and Environment, Water Quality Control Division. The Colorado program is referred to as the Colorado Discharge Permit System, or CDPS, instead of NPDES.

Water quality regulations affect both municipalities and industries.

1. **Municipalities** Municipalities have a two step application process. Part I requires an inventory of all their outfalls. It also includes a substantial amount of monitoring, and gathering information about existing programs that control stormwater quality. In Part II of the municipal application, the cities develop a Stormwater Management Plan. In general, this includes controls on connections to the storm sewer system, developing policy on such practices as street sweeping, roadway deicing, erosion control during construction, etc., and establishing a long term monitoring program. It also involves developing educational programs, such as raising the awareness level of residents about where their used oil or antifreeze goes when they dump it in the storm drain.

2. Industries Industrial facilities which discharge stormwater to surface waters either directly or indirectly through municipal separate storm sewers must be covered by a permit.

The Water Quality Control Division (WQCD) has determined that the use of general permits is the appropriate procedure for handling the expected thousands of industrial stormwater applications within the State.

a. General Permits The general permit process is faster and more streamlined than the individual permit process, for both the permit-issuing agency and the permittee. For example, there will be no stormwater monitoring requirements in the general permit application, which reduces the financial burden on the permittee and the paperwork/review burden on WQCD.

b. Exemption for Minor Municipalities Since the regulations were published, there have been some changes. Under the industrial portion, there is now a temporary exemption for industrial facilities owned by municipalities with less than 100,000 population (minor municipalities). This designation also includes counties with an unincorporated population of less than 100,000. Stormwater discharges associated with industrial activity (except for airports, powerplants, or uncontrolled sanitary landfills), that are owned or operated by a minor municipality are not required to apply for or obtain a stormwater permit at this time. As an example, a minor municipality would not be required to apply for a permit for its gravel pit, but would need to apply if it owned or operated an airport.

The above exemptions are not permanent, but are instead placed in Phase II of the stormwater program.

3. Types of Colorado Stormwater General Permits Permits are required for the following activities:

- Light Industry General Permit (Permit No. COR-010000)
- Heavy Industry General Permit (Permit No. COR-020000)
- Construction General Permit (Permit No. COR-030000)
- Metal Mining General Permit (Permit No. COR-040000)
- Sand and Gravel General Permit (Permit No. COG-500000)
- Coal Mining General Permit (Permit No. COG-850000)

4. Application Deadlines

Application for all permit types except construction	30 days prior to anticipated date of discharge (facility startup)
Application for construction permits	10 days prior to the start of construction

5. Construction Activity Permits Most applications for NPDES/CDPS permits pertain to construction activity. Consequently, the balance of Section IX and Appendix "M" pertain to construction activity permits and associated Stormwater Management Plans (SWMPs) and Best Management Practices (BMPs).

6. Contacts The NPDES/CDPS is not a local program, nor enforced by local government. Information regarding requirements and changes should be directed jurisdictional agencies as listed below.

Colorado Department of Health
Water Quality Control Division
WQCD-PE-B2
4300 Cherry Creek Drive South
Denver, Colorado 80222-1530
Attention: Permits and
Enforcement Section

- Kathy Dolan, Sarah Plocher, Dan Beley, (303) 692-3590

U.S. EPA, Region VIII
Water Management Division
NPDES Branch 8WM-C
999 18th St.
Denver, Colorado 80202-2466

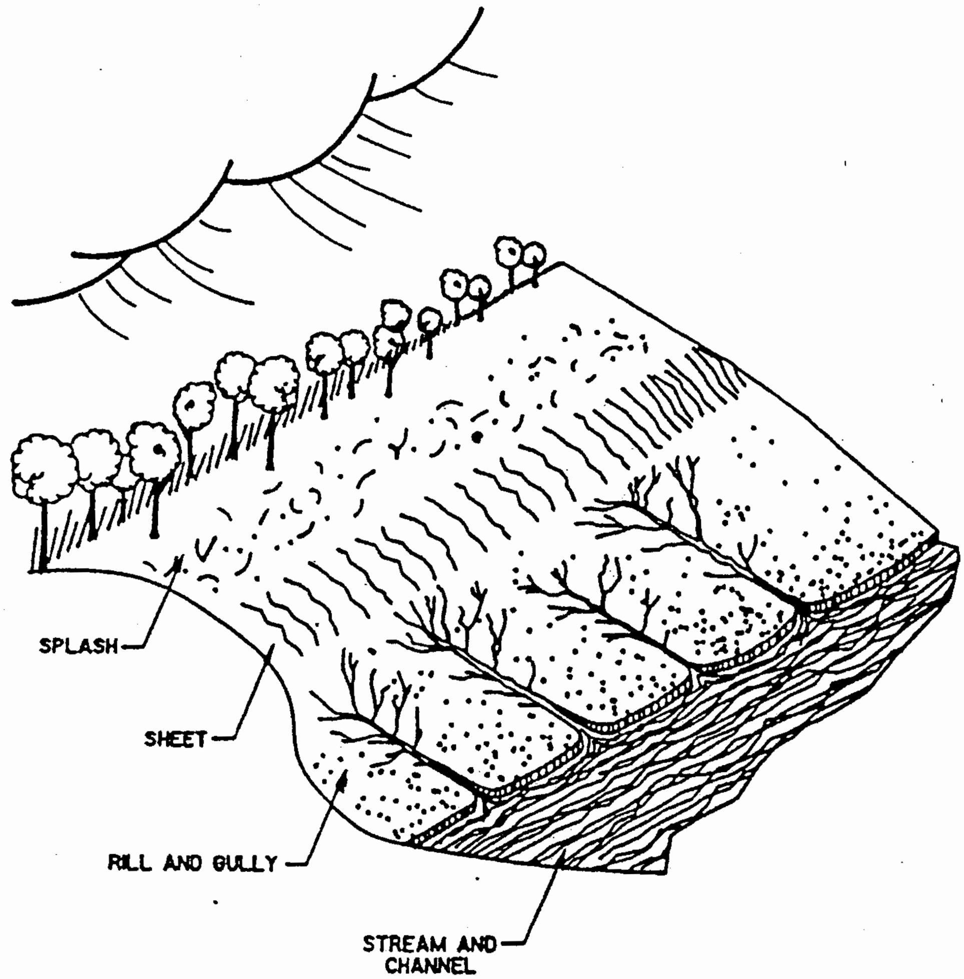
- Region VIII EPA, Vern Berry, 293-1630
- National EPA Stormwater Hotline, (703) 821-4823

C. NPDES/CDPS CONSTRUCTION ACTIVITY PERMIT

The intent of the NPDES stormwater permitting program for construction activities is to focus on the stormwater quality issues associated with construction practices and activities. The three main design goals of the permitting program for stormwater discharges associated with construction activities are discussed below.

1. Reduce Erosion Soil erosion is the process by which soil particles are removed from the land surface by wind, water or gravity (Figure IX-1). Surface erosion is caused by rainfall and sheet flow, and stream erosion is caused by concentrated flow in rills, gullies, and channels.

Figure IX-1
Four Types of Soil Erosion



a. <u>Surface Erosion</u> Rainfall events cause erosion from: 1) the impact of raindrops on bare soil; and 2) sheet erosion, or soil loss, occurring from shallow flow of water running across the land surface. Because the rainfall impact and sheet flow have low velocities, this type of erosion will normally result in minimum surface erosion on undisturbed land. Even in semi-arid climates where vegetative cover is minimal, natural desert soil conditions (including desert pavement and compacted hardpan formed from evaporites), provide protection against surface erosion. Construction activities remove the protective cover of vegetation and the natural soil resistance to erosion.

b. <u>Stream Erosion</u> Urbanization increases downstream erosion through construction activities, increased impervious area, reduced natural sediment supply, and permanent drainage improvements. These changes to the natural flow pattern increase the flow velocity and peak volume, increasing the erosion potential. Site design and construction practices, including temporary drainage structures, should be reviewed for potential erosion impacts, particularly at outlet structures.

2. Minimize Sedimentation Providing for on-site erosion control will also minimize soil loss during construction. Methods to reduce flow velocities and prevent runoff from flowing across disturbed areas will reduce the volume of sediment which must be controlled. In addition to the methods for erosion control, sediment control includes management and structural measures which prevent excessive sediment from being transported off-site in runoff or as air-borne particulates.

   a. Sediment Control Downstream buffer zones of natural vegetation are suitable for sediment removal from shallow runoff from a graded site. Perimeter methods for sediment control during construction are appropriate for removing sediment from shallow sheet flow from upstream drainage areas of 10 acres or less. Perimeter sediment controls include berms, silt fences, straw bales, and other barrier methods which slow the flow and remove sediment before the flow leaves the construction site.

      For drainage areas of 10 acres or less with concentrated flow, temporary sediment traps, sandbag barriers, and gravel filter berms are more appropriate. When the upstream disturbed drainage area is 10 acres or more, a temporary sediment basin with a sediment storage volume of 3,600 cubic feet per disturbed acre is required.

      A site may be divided into drainage areas of less than 10 acres for sediment control, or maintained in larger drainage areas with use of sediment basins. The choice will depend on the project configuration, final drainage plans, and construction sequencing.

   b. Dust Control The majority of dust generated and emitted into the air at a construction site is related to earth moving, demolition, construction traffic on unpaved surfaces, and wind over disturbed uncompacted soil surfaces.

3. Non-Stormwater Discharge Control The NPDES General Permit for construction sites generally prohibits most discharges which are not stormwater. Table IX-1 lists typical non-stormwater discharges which may be allowed if they do not cause a significant pollution problem. However, any sediment-laden waters should be filtered or detained in sediment traps or basins. The discharges should not occur where the flow may encounter oil, grease, or other potential pollutants. Care should also be taken to make sure the release of these waters does not cause downstream erosion or any other adverse impacts.

Table IX-1 Allowable Non-Stormwater Discharges Under the NPDES General Stormwater Permit For Construction Sites
• Discharges from fire fighting. • Fire hydrant flushing. • Potable water sources, including water line flushing from the disinfection of newly installed potable water systems. • Uncontaminated groundwater, including dewatering activities. • Foundation or footing drains where the flows are not contaminated with process materials such as solvents. • Naturally occurring water such as springs, wetlands, and riparian habitat. • Irrigation water discharged during seeding, planting, and maintenance. • Pavement wash waters for dust control and general housekeeping practices, provided spills or leaks of toxic or hazardous materials have not occurred and where detergents are not used.

Construction activities might include handling potential pollutants, special wastes, or certain hazardous wastes which could be accidentally discharged. These materials might be brought to the site as part of the construction project, or the materials may be existing on-site. During construction, spills of potential pollutants might take place. If the spill is equal to or exceeds the *reportable quantity* (RQ) for a 24-hour period (as defined by the EPA in 40 CFR Part 110, 40 CFR Part 117, and 40 CFR Part 302), then by federal law the contractor *must* report the spill and take appropriate measures to clean up the spill.

Spill events are best avoided and managed by addressing the potential for a spill or discharge of materials within the SWMP for control and prevention of release of non-stormwater discharges and elimination of pollutant sources. Table IX-2 lists construction materials which are potential sources of pollutants in stormwater runoff.

Table IX-2 Potential Pollutant Sources From Construction Activities and Materials to be Addressed in the SWMP
• Acids • Concrete trucks and concrete wash water • Construction chemicals • Construction waste • Contaminated soils • Dewatering • Demolition materials and site waste materials • Fertilizers/detergents • Hazardous products • Paint • Pesticides and sterilization agents • Petroleum products • Sandblasting grit • Sanitary, domestic, and special wastes • Solvents

D. BEST MANAGEMENT STRATEGIES

Effective control of stormwater pollution from a construction project starts at the planning and design stage, with adequate evaluation of the physical conditions of the project site and development of strategies for stormwater pollution controls which are best suited for the site and the construction stage. There are three management strategies for controlling stormwater pollution.

1. Temporary Controls For control of site erosion and sedimentation problems during construction, best management strategies for a construction site shall be developed and applied. Various temporary controls are discussed below.

   a. Limiting Exposure of Disturbed Areas The staging and timing of construction can minimize the size of exposed areas and the length of time the areas are exposed and subject to erosion. The grading may be staged so that only small areas are exposed to erosion at any one time, with only the areas that are actively being developed exposed. As soon as construction is complete in one area, stabilize the remaining exposed graded areas. A key aspect of this management strategy is to retain the existing vegetation and ground cover where feasible, especially along existing washes and along the downstream perimeter of the site.

b. Vegetation and Mulch Stabilization Native vegetation provides the first and best line of defense against erosion and sedimentation and usually does so at the least cost, while minimizing the need to revegetate or provide structural controls.

Temporary ground covers such as temporary seeding, mulch, chemical, and fabric stabilizers provide quick continuous ground cover to protect the soil from erosion until permanent vegetation can be established or permanent construction is installed.

While temporary vegetative ground cover can be a very effective method of preventing erosion, the re-establishment of vegetation in arid regions is not always practical. Timing of re-vegetation efforts is critical to the success of any revegetation effort. A more practical approach, especially for areas where the stabilization is temporary, may be the use of magnesium chloride or lignum sulfate. These two chemical measures do not have an adverse impact on plant life and are a low-cost stabilization treatment. Unacceptable treatments include oil treatment or sodium chloride. Ground cover of gravel, decomposed granite, wood chips, or mulch may also be used separately or with vegetation.

c. Slope Protection Slope length and steepness are among the most critical factors in determining erosion potential. Increasing slope length and steepness increases the velocity of runoff, which greatly increases its erosion potential.

To prevent erosive velocities from occurring on long or steep slopes, the slopes may be terraced at regular intervals. Terraces will slow down the runoff and provide a place for small amounts of sediment to settle out. Slope benches are usually constructed with ditches along them or are back-sloped at a gentle angle toward the hill. These benches and ditches intercept runoff before it can reach an erosive velocity and divert it to a stable outlet.

Overland flow velocities can be kept low by minimizing slope steepness and length, and also by providing a rough surface for runoff to cross. Driving a bulldozer up and down a slope (called trackwalking) creates tread marks parallel to the contours. These miniature terraces both slow runoff velocity and provide flat places for vegetation to hold. Raking or discing the soil surface before seeding also keeps runoff velocities down and increases plant establishment rates. Vegetation, once established, will further reduce runoff rates.

d. Perimeter Controls When vegetative cover is removed from land, the soil becomes highly susceptible to erosion. Runoff may cause erosion if allowed to cross the exposed soils, particularly when the denuded areas are on slopes. Use of perimeter controls, such as dikes or ditches, to divert upland runoff away from a disturbed area to a stable outlet is recommended. The two most common applications of these diversion devices are to intercept runoff on cut or fill slopes and to prevent runoff from entering a disturbed area, such as a group of building pads. The flow can then be taken to the downstream area of the project site and released back into the natural drainage pattern. Depending on the size of the drainage, slope, and other factors affecting erosion, the diverted water may require a spreading basin or other temporary form of energy dissipator before returning to the natural downstream drainage.

In constructing any perimeter channel or berm to divert flow, the contractor must insure that these controls do not adversely impact surrounding properties. The contractor is also reminded that these structures for sediment control are only for the average runoff. The structures are temporary and need not provide for large capacity flows.

e. <u>Sediment Trapping</u> Some erosion during construction is unavoidable. The function of a sediment barrier is to prevent sediment from leaving a site after the soil has been eroded from its place of origin. Sediment-laden runoff should be detained on-site so that the soil particles can settle out before the runoff enters receiving waters.

The most common sediment barriers are sediment basins and traps, straw bale dikes, and silt fences. Locate sediment basins and traps at low points below disturbed areas. Use earth dikes or swales to route drainage from disturbed areas on gentle to moderate slopes.

Storm runoff temporarily ponds up behind these barriers, which allows sediment to settle out. Gradually the water seeps out, leaving the silt behind.

2. <u>Permanent Controls</u> Permanent controls deal with the final improvements and configuration of the construction project and site. Permanent improvements are normally considered during the design phase of a project and are reflected on the plans or in the specifications. However, unforeseen natural or man-made factors may require revisions to the permanent improvements planned or the addition of permanent measures. Permanent controls typically include the following design elements:

i) Final land grading, contours and drainage patterns;

ii) Street alignment and building locations;

iii) Control of the quantity or quality of stormwater runoff by such means as detention/retention basins, porous pavement, dry wells, debris basins, etc;

iv) Channel stabilization, energy dissipators, or other drainage structures; and

v) Permanent landscaping, rock riprap, or other permanent ground cover designed to stabilize the soil or slopes.

In arid areas in the west, permanent erosion and sediment control measures are very important because of the difficulty in re-establishing vegetation through natural processes. Grading and construction may leave areas subject to erosion and sedimentation both on-site and off-site long after construction is complete because of the nature of arid soils and native vegetation, and also because of the intensity of rainfall events when they do occur. Project planning and the design of permanent controls are typically necessary. Permanent controls for long term erosion protection in arid regions may include permanent irrigation and landscape improvements to increase effectiveness.

Permanent controls are designed before the contractor begins site construction. During construction, the contractor is responsible for installation of the permanent controls. After the project is complete, it will be the responsibility of the owner, private or public, to provide for the long term operation and maintenance of these permanent controls. EPA's design goal for post-construction conditions is for the reduction of sediments in runoff which exceed the pre-development conditions.

3. Control of Non-Stormwater Pollution Of primary importance during construction will be the proper storage, handling, use, and disposal of all chemicals and materials. While construction specifications and documents may provide some guidance for the contractor to follow, the operator is responsible for compliance with NPDES regulations prohibiting the discharge of non-stormwater discharge and any or all environmental regulations for the type of chemicals, materials, and waste that results from the construction activities.

Stormwater runoff from a construction site can pick up and transport construction waste including various chemicals, wash waters, and solids. Potential pollutants from a construction site include pesticides, herbicides, oil, gasolines, degreasers, concrete products, paints, sealers, and fertilizers, as well as wood, paper, and other solid debris. Good construction operation practices must be used to handle, store, and dispose of these potential pollutants to prevent their transport by stormwater runoff. Education of construction site supervisors and employees on the need and purpose of local, state, and federal regulations of construction materials and chemicals is also a part of best management practices for construction site housekeeping activities. Table IX-3 provides a listing of recommended construction activities, BMPs, and pollutants to be addressed in the SWMP.

Table IX-3
Construction Activities and BMPs for Construction Site Operations

Activity	Best Management Practice (BMP)	Pollutants Addressed
Clearing or grading land	• Control runoff and dust during construction and install sediment controls per SWMP • Clean and maintain sediment basins • Proper disposal of debris. • Inspection and maintenance.	Sediment, nutrients, other pollutants attached to the sediment
Handling fresh concrete or other cement-related mortars	• Never wash fresh concrete mortar into a storm drain or stream. • Use designated wash-out areas. • When building concrete aggregate driveways, wash fines to the side, to straw bales or to a sediment basin.	Toxic and acidic pollutants, sediments.
Painting, sanding, plastering, applying drywall, paper, or tile, or other activities using paints, solvents, or adhesives	• Keep residues such as paint chips from entering storm drain. • Keep paints, solvents, and other chemicals and their waste containers and soiled rags covered from the rain. • Prepare for and clean up spills. • Minimize wastes and properly dispose of all wastes. • Fix any oil leaks in equipment.	Toxics, including metals, oils and greases
All activities producing or handling wastes, such as batteries and solvents	• Minimize wastes and properly dispose of all wastes. • Ensure that all workers know proper procedures. • Provide secure storage site/construction yard. • Erect barriers or isolate area to prevent contact with stormwater runoff.	Toxic pollutants, including metals
Adjacent to a stream	• Preserve the stream corridor and take steps to maintain the stream channel and vegetation.	Sediment.
General contracting and construction management	• Make sure all applicable BMPs are followed. • Ensure all local, state, and federal permits are in place and followed.	All.
Training new employees	• Include training about water quality BMPs. • Ensure all employees understand the project SWMP.	Potentially all.

E. STORMWATER MANAGEMENT PLAN (SWMP)

When the layout of the site has been decided upon, a plan to control erosion and sedimentation from the disturbed areas may be formulated. The site planner may use the best management practices (BMPs) described in this manual as a guide. These BMPs establish a minimum level of control for typical site conditions impacting construction projects. The site planner should determine which of the management practices are applicable to the site and select practices which can be used to satisfy the goal of preventing stormwater pollution. The following factors should be considered.

1. General Considerations

i) Site conditions affecting sedimentation and erosion
- Soil type.
- Natural terrain and slope.
- Final slopes and grades.
- Location of concentrated flows, storm drains, and streams.
- Existing vegetation and ground cover.

ii) Climatic factors, particularly in arid and semi-arid regions
- Seasonal rainfall patterns.
- Quantity of rainfall.
- Intensity of rainfall.

iii) Type of construction activity.

iv) Construction schedules.

v) Construction sequencing and phasing of construction.

vi) Size of construction project and area to be graded.

vii) Location of the construction activity relative to adjacent uses and public improvements.

2. Determine Limits of Clearing and Grading Decide exactly which areas must be disturbed in order to accommodate the proposed construction. Pay special attention to critical areas, avoiding disturbance whenever possible.

3. Divide the Site Into Drainage Areas Determine how runoff will travel over the site. Consider how erosion and sedimentation can be controlled in each small drainage area before looking at the entire site. Remember, it is easier to control erosion than to contend with sediment after it has been carried downstream.

4. Select Erosion and Sediment Control Practices Erosion and sediment control practices can be divided into three broad categories: stabilization controls, structural controls, and management measures. BMPs include design of stabilization and structural practices. Management measures are construction management techniques which, if properly utilized, can minimize the need for physical controls and possibly reduce costs.

a. Stabilization Practices The first line of defense is preserving the existing ground cover until final improvements are to be constructed. Additionally, native vegetation as a perimeter buffer or buffer adjacent to washes provides passive methods to control silt. Where land disturbance is necessary, temporary seeding, or mulching can be used on areas which will be exposed for long periods of time.

Erosion and sediment control plans must contain provisions for stabilization of disturbed areas which will remain permanently exposed and will not be subsequently paved, built upon, or landscaped.

b. Structural Controls Structural practices are generally more costly than vegetative controls. However, they are usually necessary since not all disturbed areas can be protected with vegetation in arid and semi-arid regions. Structural controls are often used as a second or third line of defense to capture sediment before it leaves the site during construction. Structural controls may also be part of the final construction improvement plan so that detention basin sites may be utilized as sediment traps during construction.

Regulations require that for common drainage locations serving an area with 10 or more disturbed acres at one time, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent control measures, shall be provided, where attainable, until final stabilization of the site. For drainage locations serving less than 10 acres, sediment basins and/or sediment traps should be used. Where a sediment basin or trap is not attainable, at a minimum, silt fences — or equivalent sediment controls — are required for all sideslopes and downslope boundaries of the construction area.

c. Stormwater Management Maintenance of permanent controls after the construction activities have been completed is essential. Permanent practices include: stormwater detention structures (including wet ponds); retention structures; flow attenuation by vegetative swales; and any combination of methods.

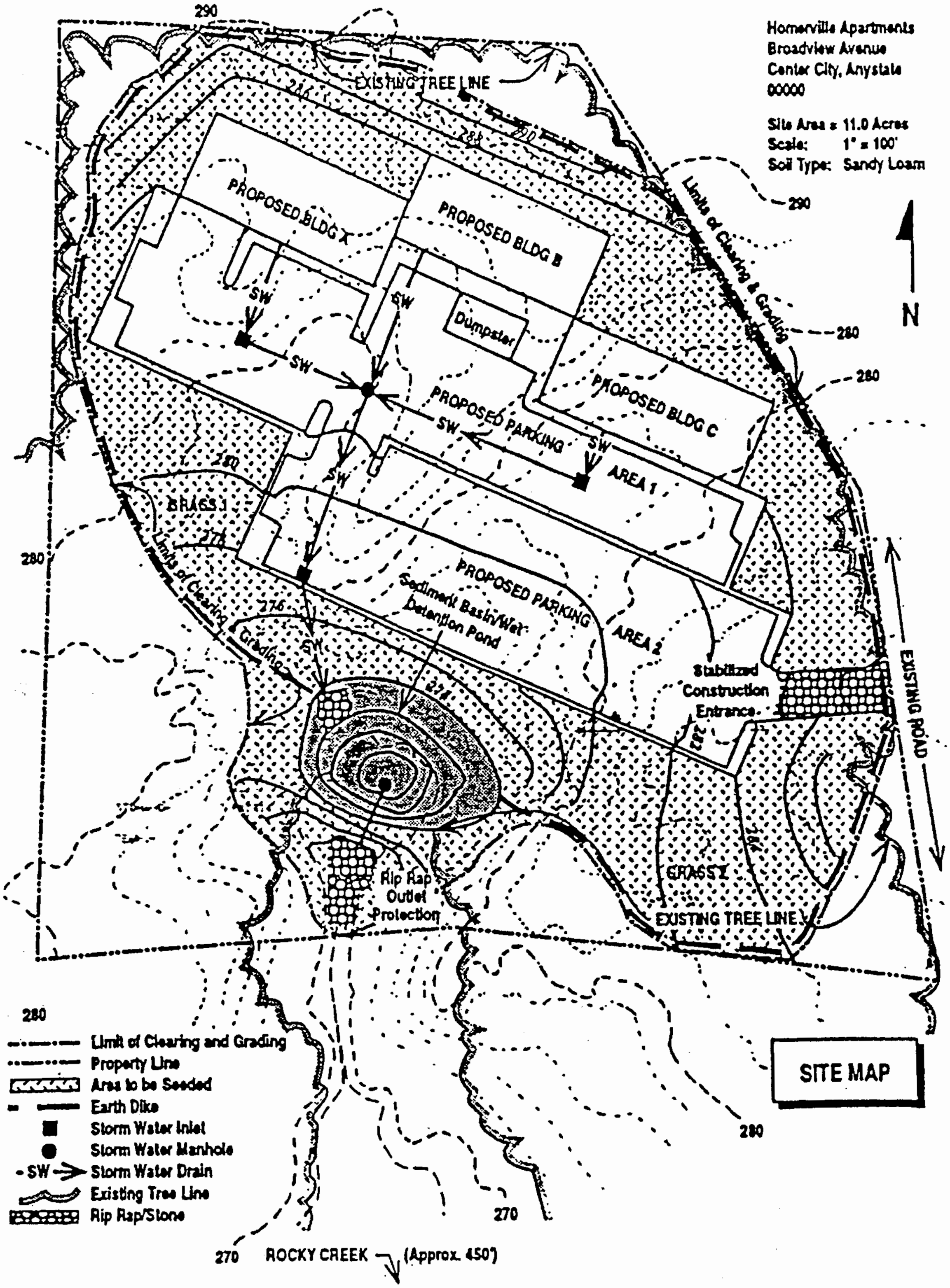
d. Other Controls Other control methods, such as waste disposal, off-site vehicle tracking of sediments, dust control methods, vehicle cleaning and maintenance locations, and the material storage locations, must also be addressed.

e. Management Measures Good construction management is as important as physical practices for erosion and sediment control, and there is generally little or no cost involved. Following are some management considerations which can be employed.

- Sequence construction so that no area remains exposed for unnecessarily long periods of time.
- Temporary stabilization should be done immediately after grading.
- When possible, avoid grading activities during July, August, and September since these months have the highest potential for erosive rainfall.
- On large projects, stage the construction — if possible — so that one area can be stabilized before another is disturbed.
- Develop and carry out a regular maintenance schedule for the erosion and sediment control practices.
- Physically mark off limits of land disturbance on the site with tape, signs, or other methods so the workers can see areas to be protected.
- Make sure that all workers understand the major provisions of the SWMP.
- Implementation of the erosion and sediment control and oversight of the SWMP should be designated to one individual.

f. <u>Compliance</u> The SWMP *must* comply with state or local erosion control ordinances.

g. <u>SWMPs</u> A sample SWMP which exemplifies some of the concepts presented in this section is shown on Figure IX-2.



SAMPLE SWMP SITE MAP

FIGURE IX-2

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X. GRADING

TABLE OF CONTENTS

PAGE

List of Figures

List of Tables

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X. GRADING

A. ROADWAYS

Grading of streets and roads is a part of street design, but is included herein because much of street grading pertains to proper drainage.

1. Street Grading

Unless conditions warrant otherwise, gutter flowlines on opposite sides of a street shall be at the same elevation in straight road sections. In curved non-parallel sections, such as around "eyebrows" or "elbows" and cul-de-sacs, flowline elevations may be different.

Refer to Chapter 6 "Roadway" of City of Delta Standards and Specifications for the Design and Construction of Public Improvements for required minimum longitudinal slopes for roadways.

2. Driveways

Access driveways shall be graded so that the back of the driveway is at least as high as the adjacent top of curb. If the site served by the driveway is lower than the road, then the driveway may have a grade break and slope down once the curb elevation is obtained. This practice helps prevent street runoff from entering private property during lower intensity storms.

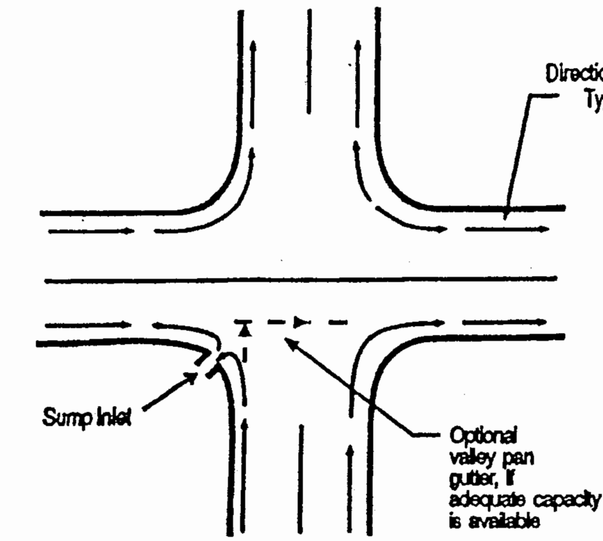
Care should also be given to stormwater once the driveway grade break occurs. Proper design should include provisions for stormwater that it doesn't drain into the garages or other finished floors.

At attached sidewalk sections, the grade at the back of walk must be at least 0.3 feet above the adjacent flowline.

3. Runoff Flow Depths

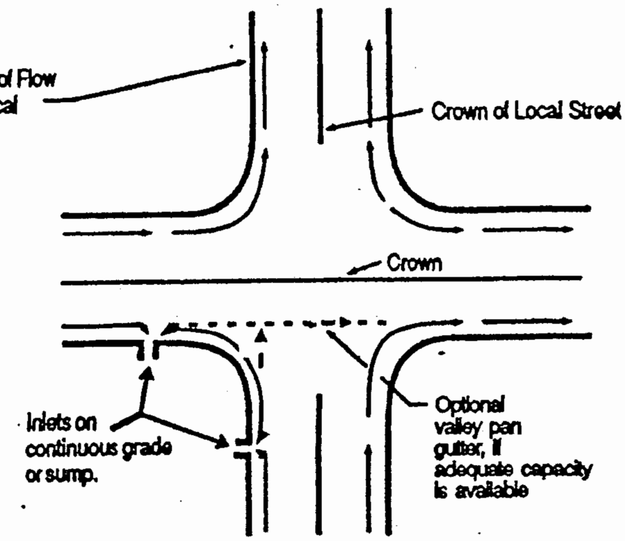
Street grades shall be adequate, along with other drainage facilities, to allow conformance with maximum street inundation and flow depth criteria presented in Section VII and Appendix "G".

MODIFIED FROM FIGURE 3.5 DRAINAGE DESIGN MANUAL FOR MARICOPA CO., VOL II, & URBAN STORM DRAINAGE CRITERIA MANUAL, FIGURE 5-2



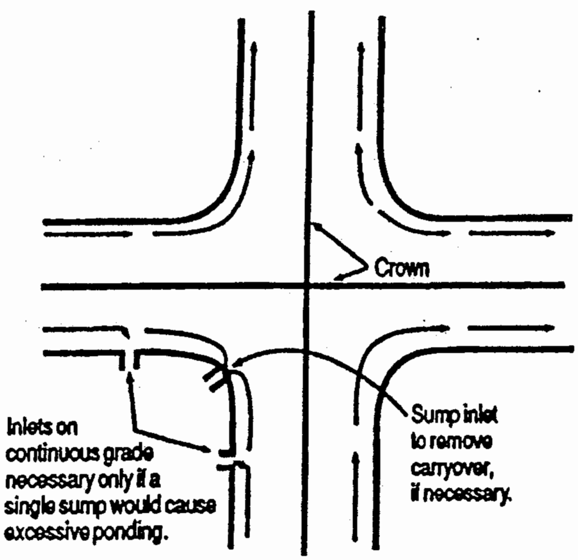
Local Street to Local Street

(One Continuous Crown)



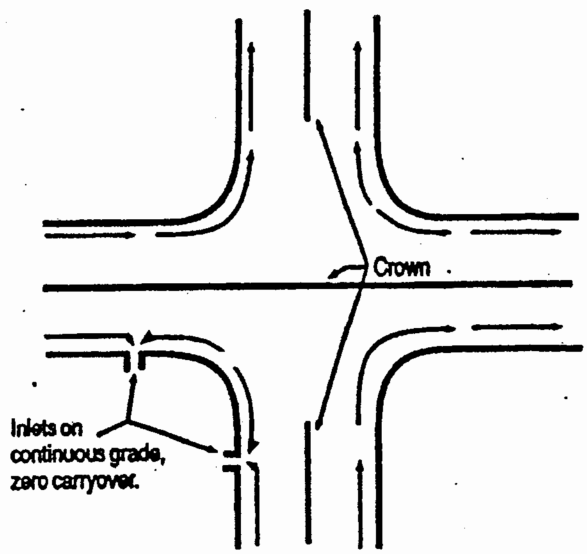
Local or Collector to Arterial

(One Continuous Crown)



Arterial to Arterial

(Where Two Crowns are to be Maintained)

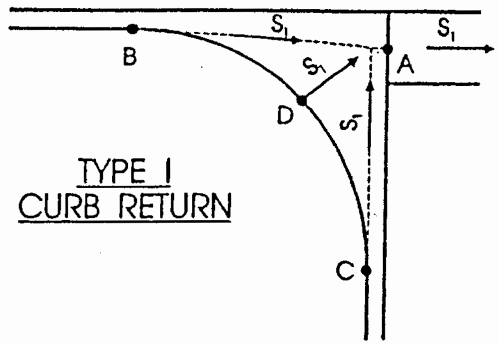


Arterial to Arterial

(One Continuous Crown)

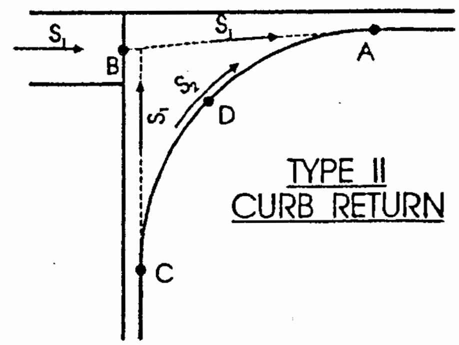
These examples show the minimum required inlets. Additional inlets may be necessary based upon allowable carrying capacity of gutters.

INTERSECTION GRADING CONCEPTS	FIGURE X-1



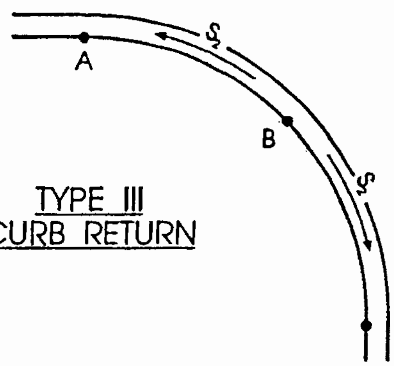
TYPE I CURB RETURN

CURB RETURN RADIUS (FT)	RELATIVE ELEVATION (Min, Max)			
	A	B	C	D
20	0.0	0.10, 1.00	0.10, 1.00	0.04,0.4
25	0.0	0.13, 1.25	0.13, 1.25	0.05,0.5
30	0.0	0.15, 1.50	0.15, 1.50	0.06,0.6



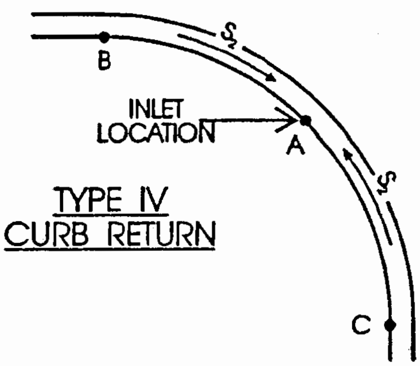
TYPE II CURB RETURN

CURB RETURN RADIUS (FT)	RELATIVE ELEVATION (Min, Max)			
	A	B	C	D
20	0.0	0.10, 1.00	0.20, 2.0	0.10, 1.00
25	0.0	0.13, 1.25	0.25, 2.5	0.13, 1.25
30	0.0	0.15, 1.50	0.30, 3.0	0.15, 1.50



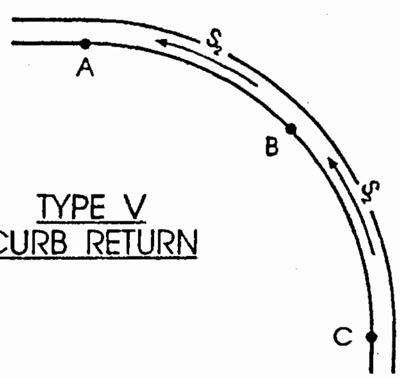
TYPE III CURB RETURN

CURB RETURN RADIUS (FT)	RELATIVE ELEVATION (Min, Max)		
	A	B	
20	0.0	0.10, 1.00	
25	0.0	0.13, 1.25	
30	0.0	0.15, 1.50	



TYPE IV CURB RETURN

CURB RETURN RADIUS (FT)	RELATIVE ELEV. (Min, Max)		
	A	B	C
20	0.0	0.10, 1.00	0.10, 1.00
25	0.0	0.13, 1.25	0.13, 1.25
30	0.0	0.15, 1.50	0.15, 1.50



TYPE V CURB RETURN

CURB RETURN RADIUS (FT)	RELATIVE ELEVATION (Min, Max)		
	A	B	C
20	0.0	0.10, 1.00	0.20, 2.0
25	0.0	0.13, 1.25	0.25, 2.5
30	0.0	0.15, 1.50	0.30, 3.0

$0.50\% \leq S_1 \leq 5.0\%$

$0.64\% \leq S_2 \leq 6.4\%$

Minimum and maximum allowed elevation drops at intersections are indicated for each curb return type. All elevations shown are relative to point A.

INTERSECTION GUTTER SLOPES & GRADES | **FIGURE X-2**

B. DRAINAGE FACILITY SLOPES AND GRADES

1. Slopes Minimum and maximum slopes shall be as shown in Table X-2.

TABLE X-2
DRAINAGE FACILITY SLOPES
(Applicable to bottoms and side slopes of channels, swales, basins, and overlot surfaces)

SLOPE LIMIT	SURFACE TYPE				
	Mainte-nance Access Ramp	Sod or Seed and Mulch	Riprap	Asphalt	Concrete
Minimum	2%	2%	2%	1.0%	0.5%
Maximum	6H:1V	3H:1V*	2H:1V	**	**

* For public detention/park facilities, maximum slope is 4H:1V. Also, all unpaved slopes and surfaces shall be protected from erosion by seeding and mulching, sodding or other approved ground cover.

** Maximum slope depends upon the application.

2. Freeboard There may be specific cases where freeboard for 100-year storm events is required. Normally, however, finish floor criteria of 1.0 foot above 100-year water surfaces and 0.50 foot above lot outfalls will be adequate. Conditions meriting freeboard may include but are not limited to channel or pond embankments which are significantly higher than surrounding ground where a breach could result in substantial failure of the embankment, or areas presenting high blockage or clogging potential.

3. Highwater Ponding (non-flowing backup water) from 100-year storm events shall not occur on streets. Therefore, detention/retention and other drainage facilities must be designed accordingly.

C. LOT AND SITE GRADING

Developed lots shall be graded with minimum and maximum slopes as prescribed in Table X-2 toward drainage facilities and streets, all in accordance with criteria presented in this manual. Site grading should prevent an inflow of runoff that has not historically contributed to or passed through the site such as at driveways and other low spots. Increased lot runoff due to development shall be directed away from private property in order to conform with stormwater law presented in Section III and as expounded upon in Section VIII as pertaining to detention and retention facilities. Finish floor elevations shall provide the minimum freeboard specified in Section I-A-3-b on page I-2, and also be a minimum of 0.5 foot above the site outfall.

In the 100-year storm event, retention and detention water on parking areas shall not exceed 1.0 foot in depth, and a 12 foot wide emergency lane through driveways or parking lots must be available with no more than 0.5 foot of ponding depth.

D. GRADING PLAN REQUIREMENTS

A Grading and Stormwater Management Plan shall be submitted during the subdivision review process. The Plan shall show typical lot grading and sufficient detail to demonstrate appropriate stormwater management for each lot as well as the entire subdivision.

1. The Grading and Stormwater Management Plan shall show proposed contours for cuts, fill, basins, swales, channels, etc. Adding proposed contours, swales and channels to a Grading and Stormwater Management Plan will illustrate how each lot will drain in relation to the rest of the subdivision. There are two primary types of lot grading schemes that can be used to assure that surface drainage is directed towards public right-of-way (public road, public lane, or any easement where the City is party to an agreement granting the City interest-in the land) and away from neighboring private property:

    a. Back to Front Grading Scheme (Type "A")

    For this type of lot grading, the rear lot must be higher in elevation than the street grade in front of the property. Back to front provides for a ridge (high point) along the rear lot lines allowing each lot to slope directly towards the street. Finished floor elevations of adjacent buildings must be set high enough to allow for a side swale or channel to be formed between the homes.

    b. Split Grading Scheme (Type "B")

    For this type of lot grading, the house is set at the high point on the lot. The lot is graded so that a portion of the surface drainage flows toward the street with the remaining drainage flowing to the rear lot line. The drainage that collects along the rear lot line will require an easement and maintainable conveyance facility to properly deliver the accumulated runoff to a street. A property line should not split the conveyance facility and related easement. Finished floor elevations of adjacent buildings must be set high enough to allow for a side swale or channel to be formed between the homes.

Some amount of lot grading will be required in most subdivisions to allow the contractor or homeowner to incorporate one of the above schemes into their lot grading. Easements and sufficient longitudinal slope to carry runoff from the rear property lines to the public right-of-way must be provided and shown on the Grading and Stormwater Management Plan. Unique topographic situations and design concepts may suggest grading schemes other than the two recommended above. Specially designed lots that vary from the above may be analyzed on a case by case basis. No developed lot should discharge on to another property in a physically or legally uncontrolled manner outside of a natural drainage way.

Figure X-3 shows the two lot grading schemes that can be employed to drain stormwater away from private property and into the public right-of-way. Each lot shown on the Grading and Stormwater Management Plan must be designated as a Type "A", Type "B", or Specially Designed Lot. Designating each lot as a Type "A", Type "B", or Specially Designed Lot will provide the homebuilder the information needed to grade the lot per the approved Grading and Stormwater Management Plan.

2. The Grading and Stormwater Management Plan shall also show proposed retaining walls, cut and fill slopes, and other significant grading factors. Some developable parcels within the City of Delta present unique topographic constraints that require sloping, benches, and/or retaining walls to hold back the earth and provide a reasonably sized building envelope. Proposed cut and fill slopes along with the location of the retaining walls must be shown on the Grading and Stormwater Management Plan. In addition to showing the location of a proposed retaining wall, sufficient detail must be provided to demonstrate how runoff will drain around and away from the wall into drainage facilities.

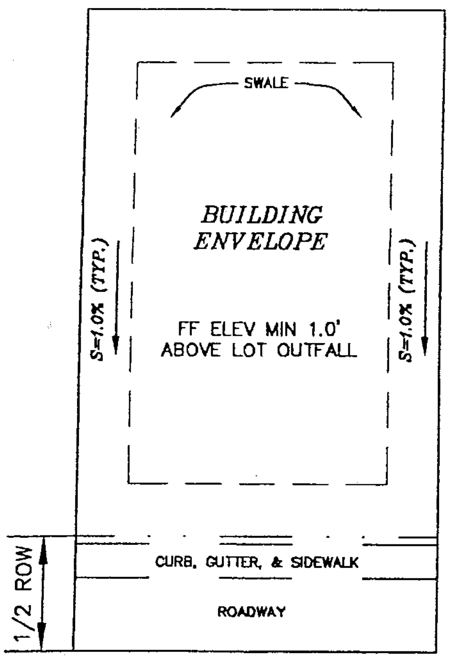
3. The Grading and Stormwater Management Plan shall also provide the minimum finished floor (lowest top of foundation) elevations for each lot. The lowest top of foundation elevations must be at least 1.0 feet above the 100-year floodplain level and at least 1.0 feet above the lot outfall. The lot outfall is defined as the highest point on the property boundary where runoff will discharge. For Lot Grading Type "A" and "B", the outfall is the elevation of the property pin on the high side of the lot adjacent to the public right-of-way. The finished floor elevation must also be set high enough to allow a swale of channel to be constructed between the homes per the above discussion.

4. In addition to requiring contours, swales, channels, cut and fill slopes, typical lot grading and finished floor elevations, the Public Works Director may require individual lot grading plans. Individual lot grading plans will be required in those instances where overlot grading cannot be accomplished due to significant site constraints (rock outcroppings, areas of no disturbance, etc.) or when lot grading must be designed to accommodate historic runoff from an adjacent property.

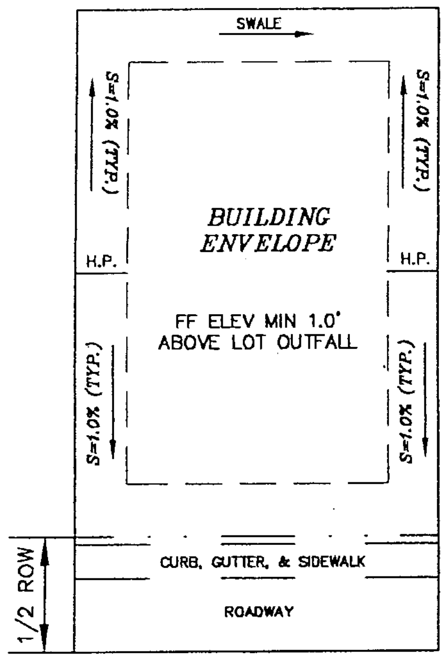
   Individual lot grading plans will be required to contain the following information:

   - One plot plan on 8½ x 11" paper showing all existing and proposed structure locations, parking, setbacks to all property lines, driveway location, and width of all easements and rights-of-way which abut the parcel.

- Existing elevations around the lot perimeter
- Minimum elevation of the top of foundation wall (6" above the adjacent finished grade, 0.5' above the lot outfall, and at least 1.0' above the 100-year floodplain)
- Minimum slope away from the house for at least 5 feet is 8 percent grade (approximately 1" per foot).
- Minimum slope on lot except as above is 2 percent grade (approximately ¼" per foot).
- Show location of swales and drainage channels.
- Show locations of fencing proposed for the lot. The bottom of fences placed in or across swales must be kept above the normal water surface elevation within the swale.
- Minimum depth of swales is 6 inches.
- Minimum transverse slope of swales is 1 percent.
- Maximum side slopes of swales is 3:1.



TYPICAL LOT GRADING
TYPE 'A'
"BACK TO FRONT"



TYPICAL LOT GRADING
TYPE 'B'
"SPLIT"

NOTE: REFER TO CITY OF DELTA STORMWATER MANAGEMENT MANUAL SECTION D. GRADING PALN REQUIREMENTS FOR ADDITIONAL DETAILS.

GRADING SCHEMES *FIGURE X–3*

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APPENDIX "A"
PRECIPITATION

TABLE OF CONTENTS PAGE

List of Figures

List of Tables

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APPENDIX "A"
PRECIPITATION

1. **General Discussion**

It has already been discussed in Section VI that a given magnitude (or frequency) of flood runoff is not necessarily nor probably the result of the same magnitude (or frequency) precipitation. This is due to many conditions, particularly soil moisture at the commencement of the storm. It also may be affected by snowmelt. However, as stated in Section VI, rather than concern ourselves over rainfall versus runoff, design criteria is simply based upon a design storm and rainfall. Therefore, this appendix will discuss only rainfall information for the various design storms that must be analyzed as required by policy.

2. **Intensity-Duration-Frequency (IDF)**

When using the Rational Method, IDF data is required. The total basin time of concentration (Tc) is assumed to be equal to the storm duration. At that duration, Tc value, there is an associated statistical rainfall intensity for each frequency or magnitude of storm. Hence the name "Intensity-Duration-Frequency", or simply IDF.

IDF data are usually presented in curve format, requiring each user to read and interpolate curves with each use. However, IDF data need only be presented to the nearest one minute duration, and then only for durations less than one hour. Watersheds having a larger Tc should not be analyzed using the Rational Method and IDF data. Therefore, it may be convenient to provide the information in table form. Table "A-1" presents the IDF data for the City of Delta. IDF curves are also presented on Page A-3 for design storms in addition to the 5 year and 100 year frequencies.

3. **Basin Average Total Storm Precipitation**

When using NRCS rainfall distributions which are based upon a percent of rainfall, a basin average total precipitation depth is required. These same depths may also be used to calculate volume of runoff for total retention (see Section VIII and Appendix "N"). Depths at various storm durations for various frequencies (known as Depth-Duration-Frequency, or DDF) are provided in Table "A-2" for the City of Delta.

4. **Area Rainfall Depth Reduction Curves**

The larger the watershed area, the less likely that the same level of intensity will be constant spatially. Curves have been provided which allow reduction of the values provided in Table "A-2" and Figure "A-1" for larger watersheds. These have been reproduced and are provided in Figure "A-2".

TABLE "A-1"

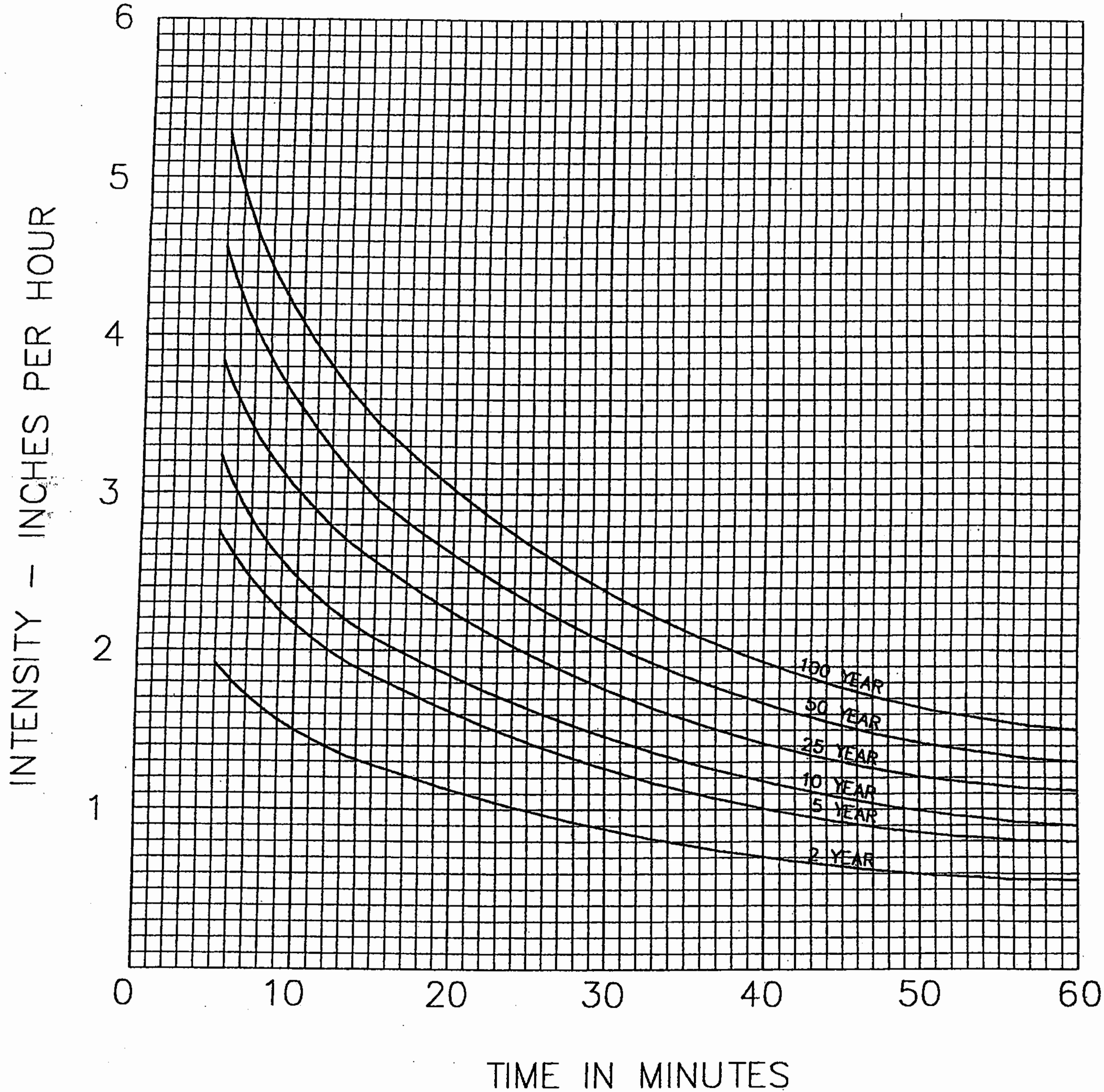
INTENSITY-DURATION-FREQUENCY TABLE

DELTA, COLORADO

Minutes	5-Year	100-Year		Minutes	5-Year	100-Year
5	2.75	5.30		33	1.18	2.22
6	2.60	4.90		34	1.14	2.18
7	2.45	4.65		35	1.11	2.13
8	2.35	4.45		36	1.09	2.09
9	2.25	4.25		37	1.07	2.05
10	2.15	4.10		38	1.05	2.00
11	2.08	3.92		39	1.02	1.97
12	2.00	3.80		40	1.01	1.94
13	1.93	3.68		41	0.99	1.90
14	1.89	3.55		42	0.97	1.87
15	1.82	3.43		43	0.95	1.83
16	1.80	3.35		44	0.92	1.80
17	1.75	3.25		45	0.91	1.78
18	1.70	3.18		46	0.90	1.74
19	1.64	3.10		47	0.89	1.71
20	1.61	3.02		48	0.88	1.69
21	1.56	2.95		49	0.87	1.67
22	1.52	2.88		50	0.86	1.64
23	1.50	2.81		51	0.85	1.62
24	1.46	2.75		52	0.83	1.60
25	1.42	2.69		53	0.82	1.59
26	1.39	2.62		54	0.81	1.58
27	1.35	2.56		55	0.81	1.56
28	1.32	2.50		56	0.80	1.54
29	1.29	2.43		57	0.80	1.53
30	1.26	2.39		58	0.80	1.52
31	1.22	2.32		59	0.80	1.51
32	1.20	2.28		60	0.80	1.50

Precipitation values are inches/hour.

INTENSITY–DURATION–FREQUENCY CURVES FOR DELTA, COLORADO



5. **NRCS Rainfall Distribution**

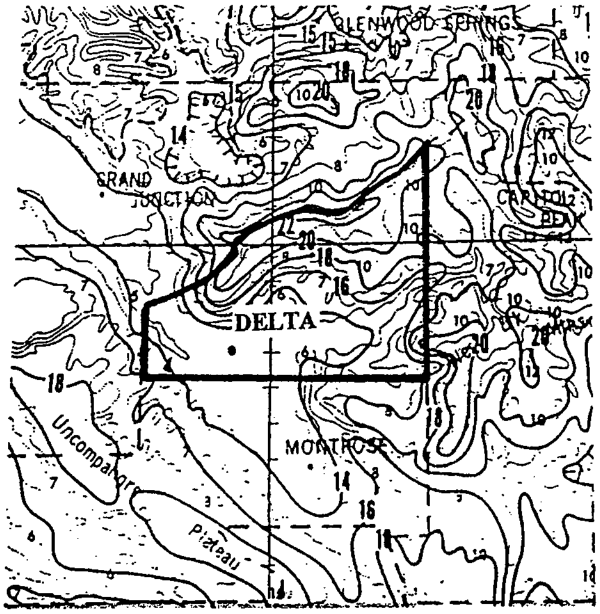
Rainfall distributions have been developed by the NRCS for several storm durations. The information is usually in "S" curve form, showing the percent of total precipitation depth at a given time. In HEC-1, data is entered either on PI or PC records; that is, incremental precipitation or cumulative precipitation. The data are based on increments of time which are specified on the "IN" record "JXMIN" parameter. Since the rainfall distribution data will most likely be used as tabular input into a computer file, information from curves has been converted to a tabular cumulative precipitation versus time format. Additionally, it is presented in a way that may be directly inserted into a HEC-1 free format input file. The NRCS rainfall distribution data is provided in Table "A-3".

TABLE "A-2"
DEPTH-DURATION-FREQUENCY (DDF)
FOR THE CITY OF DELTA

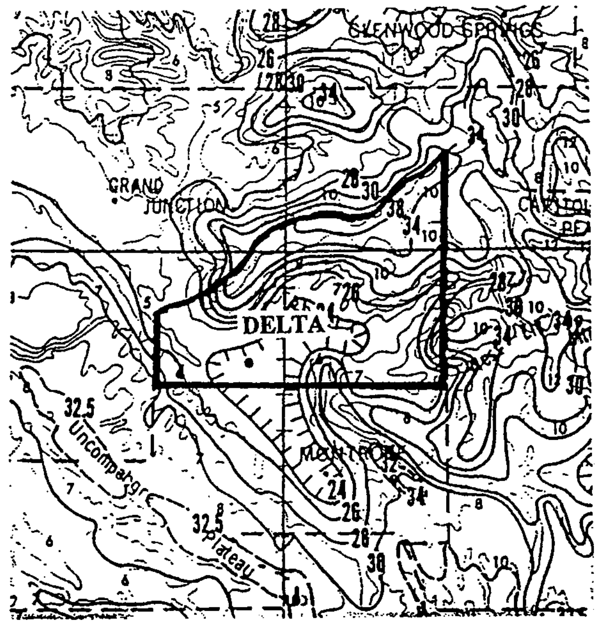
Storm Duration (Hours)	Precipitation Depth (inches)	
	5-Year Storm	100-Year Storm
2	0.90	1.60
6	1.08	1.80
24	1.40	2.40
Source: Delta County 2003		

ISOPLUVIALS ARE REPRODUCED FROM NOAA ATLAS 2, VOLUME III

Black lines are isopluvials of storm precipitation in tenths of an inch (i.e. 26 = 2.6 inches). Gray lines are elevation contours in 1000's of feet (i.e. 5 = 5000 feet).

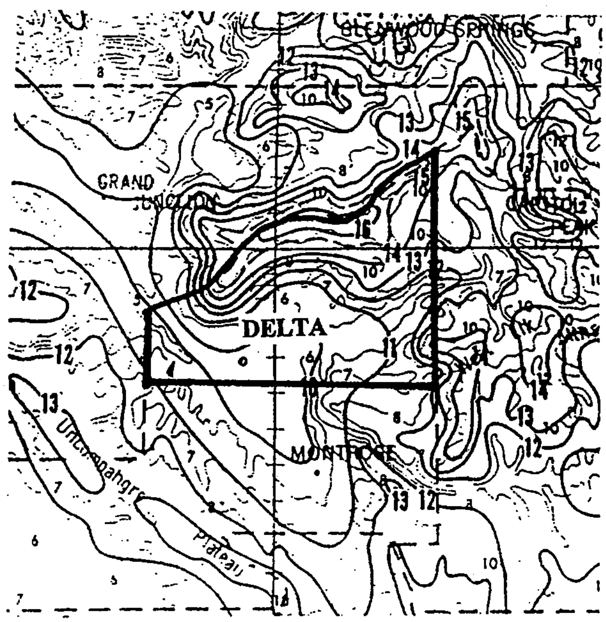


5-YEAR STORM

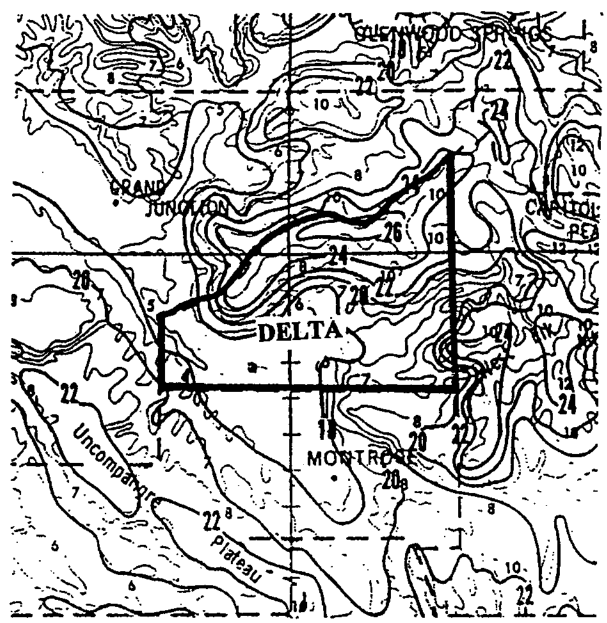


100-YEAR STORM

24 HOUR STORM DURATION



5-YEAR STORM



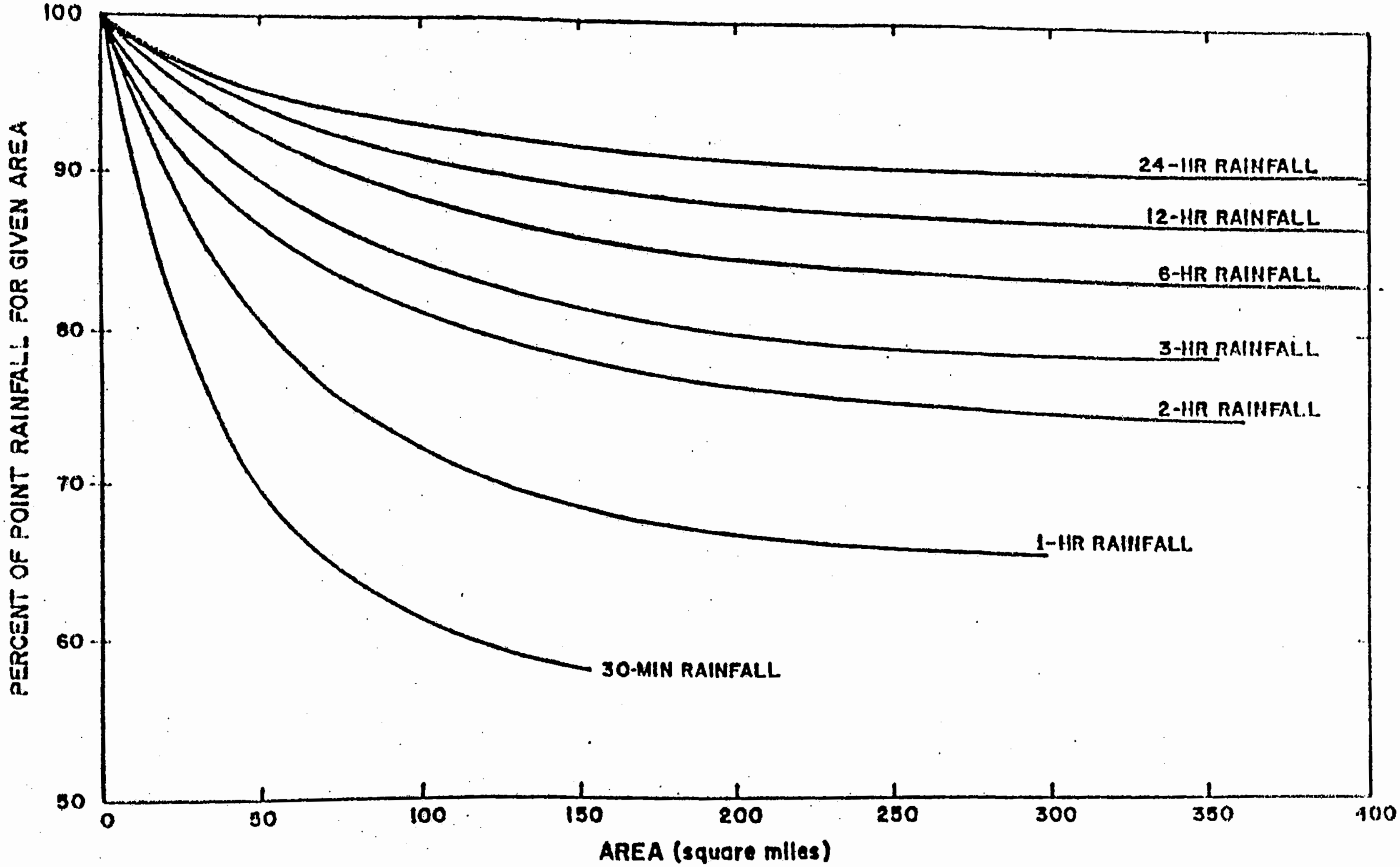
100-YEAR STORM

6 HOUR STORM DURATION

CITY OF DELTA TOTAL STORM PRECIPITATION

FIGURE "A-1"

SOURCE: ACOE 1993



AREA RAINFALL DEPTH REDUCTION CURVES

FIGURE "A-2"

TABLE "A-3"
SCS RAINFALL DISTRIBUTIONS
(Arranged for HEC-1 Free Format,
Cumulative Rainfall Precipitation Data in Bold)

```
*
* SCS 2-HOUR RAINFALL DISTRIBUTION
* "JXMIN" VALUE ON "IN" RECORD IS 2
*
PC,.0000,.0042,.0086,.0130,.0176,.0223,.0272,.0322,.0374,.0428
PC,.0483,.0541,.0601,.0664,.0729,.0797,.0869,.0945,.1026,.1112
PC,.1203,.1303,.1411,.1530,.1662,.1808,.1995,.2227,.2544,.3593
PC,.6632,.7351,.7647,.7830,.8031,.8197,.8343,.8475,.8593,.8701
PC,.8801,.8881,.8977,.9057,.9133,.9206,.9274,.9339,.9401,.9461
PC,.9519,.9574,.9627,.9679,.9729,.9777,.9824,.9870,.9914,.9958
PC,1.0000
```

```
*
* SCS 6-HOUR RAINFALL DISTRIBUTION
* "JXMIN" VALUE ON "IN" RECORD IS 12
*
PC,.000,.014,.029,.045,.062,.080,.100,.140,.280,.480
PC,.600,.685,.750,.800,.840,.875,.900,.918,.932,.942
PC,.951,.960,.968,.975,.981,.986,.990,.994,.997,.999
PC,1.000
```

```
*
* SCS 24-HOUR TYPE II RAINFALL DISTRIBUTION
* "JXMIN" VALUE ON "IN" RECORD IS 15
*
PC,.000,.002,.005,.008,.011,.014,.017,.020,.023,.026
PC,.029,.032,.035,.038,.041,.044,.048,.052,.056,.060
PC,.064,.068,.072,.076,.080,.085,.090,.095,.100,.105
PC,.110,.115,.120,.126,.133,.140,.147,.155,.163,.172
PC,.181,.191,.203,.218,.236,.257,.283,.387,.663,.707
PC,.735,.758,.776,.791,.804,.815,.825,.834,.842,.849
PC,.856,.863,.869,.875,.881,.887,.893,.898,.903,.908
PC,.913,.918,.922,.926,.930,.934,.938,.942,.946,.950
PC,.953,.956,.959,.962,.965,.968,.971,.974,.977,.980
PC,.983,.986,.989,.992,.995,.998,1.00
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*
* SCS TYPE IIA RAINFALL DISTRIBUTION
* "JXMIN" VALUE ON "IN" RECORD IS 15
* (NOT FOR USE MARICOPA COUNTY)
*
PC,.000,.001,.002,.003,.004,.006,.008,.010,.012,.014
PC,.017,.020,.023,.027,.031,.035,.039,.044,.050,.058
PC,.068,.088,.112,.200,.680,.722,.750,.768,.785,.797
PC,.805,.812,.819,.826,.833,.839,.844,.848,.852,.856
PC,.860,.864,.868,.872,.876,.880,.884,.888,.892,.896
PC,.900,.904,.908,.911,.914,.917,.920,.923,.926,.929
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PC,.977,.979,.981,.983,.985,.987,.989,.991,.992,.993
PC,.994,.995,.996,.997,.998,.999,1.00
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