Stormwater Detention/Retention Manual

Pima County
Department of Transportation
& Flood Control District
City of Tucson

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Acknowledgments

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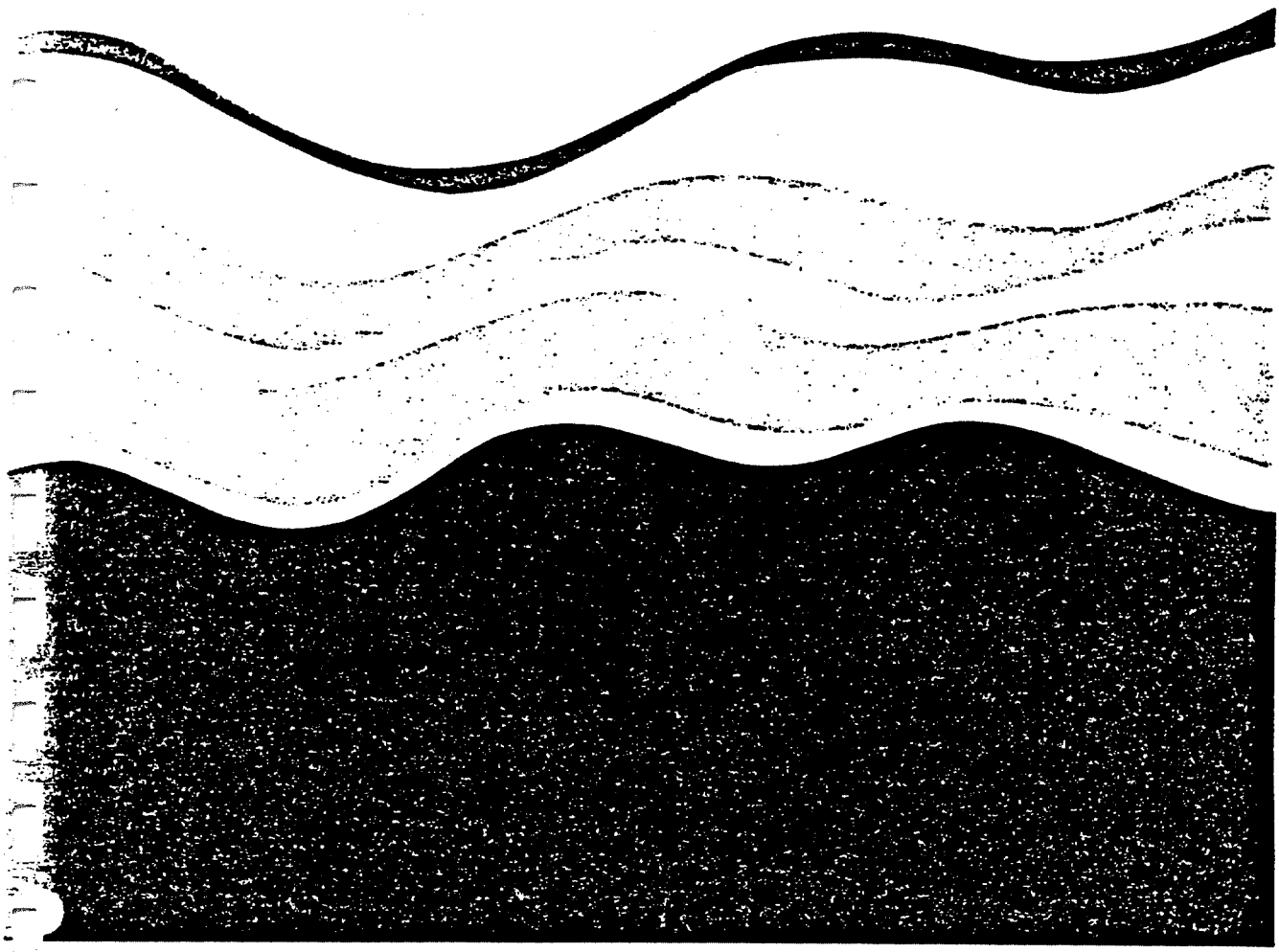
CHAPTER I

Introduction



I. Introduction

1.1 Goals and Objectives

The purpose of this manual is to establish uniform policies, criteria, and methodologies for the planning and design of stormwater detention/retention facilities within Pima County and the City of Tucson. It is intended that detention/retention facilities designed in accordance with the guidelines presented herein will meet the following goals: 1) independently satisfy Pima County and/or City of Tucson floodplain management ordinance provisions with regard to stormwater detention/retention; 2) result in detention/retention facilities which are multi-use and visually appealing; and 3) ensure that the implementation of stormwater retention facilities will not jeopardize the quality of groundwater resources.

A summary of policies and criteria is provided within Section 1.4. It is important that this section be thoroughly read and completely understood prior to applying the design procedures contained within the body of this manual. One of the major objectives of this manual is to provide guidelines towards ensuring that future detention/retention facilities will be planned and designed in such a way that they will be considered as amenities by the affected community. In the attempt to achieve this goal, Chapter 4 provides detailed policies and criteria regarding the grading and landscaping of proposed detention/retention basins for multiple uses.

The technical engineering details associated with the analysis and design of detention/retention facilities are addressed within Chapters 2 and 3. Much of the material contained within these chapters is targeted for use by practicing engineers in the water-resources field, or other individuals with equivalent knowledge or training. Consequently, an understanding of the basic concepts of hydrology and hydraulics has been assumed. No attempt has been made to discuss the theory or derivations of the methods presented herein; rather, a simplified step-by-step approach is presented. Should additional information be desired, the user is encouraged to consult the selected reference list provided at the end of this manual. Additionally, a technical memorandum which describes the methodologies used in developing many of the equations and procedures presented in this manual is on file at the offices of the Pima County Flood Control District and the City of Tucson Engineering Division.

1.2 Applicability

The methods and policies presented within this manual are applicable to the planning and design of stormwater detention and retention facilities within Pima County and the City of Tucson, Arizona. Due to both the hydrologic complexities associated with large watersheds and the desire to maintain simplicity within this manual, the methods of hydrologic and hydraulic analysis presented within Chapter 2 and Chapter 3 should be applied to watersheds having drainage areas **no greater than one square mile** unless specific authorization to the contrary is granted by the appropriate reviewing agency (i.e., either Pima County or the City of Tucson). Detention basins which receive runoff from upstream watersheds that are greater than one square mile in area shall be considered as

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regional facilities, and generally will be planned and designed in conjunction with basin-management studies or specific flood control projects performed under the direction of Pima County or the City of Tucson. The channel-routing procedures presented in this manual (such as in Chapter 2) are applicable only to watersheds of ten square miles or less. For watersheds greater than ten square miles, more sophisticated mathematical modeling of watersheds is required.

Chapter 4, which addresses surface treatments, grading, and multi-use concepts, is also intended to be applicable only to the planning and design of detention/retention facilities which intercept flow from drainage areas no greater than one square mile. For the planning and design of regional facilities, the reader is referred to the document entitled "Guidelines for the Development of Regional Multiple-Use Detention/Retention Basins in Pima County, Arizona," available from the Pima County Department of Transportation and Flood Control District.

Use of this manual does not supercede the need for acquiring various permits required for the construction and operation of detention/retention facilities. The reader is advised that such permits are required by the State and by local governmental agencies.

1.3 Detention/Retention Concepts

One of the unavoidable consequences associated with the urbanization of watersheds is an increase in the frequency, magnitude, and volume of runoff from previously undeveloped drainage areas. Problems associated with development include increased flooding, erosion to public and private improvements, and diminishing adequacy of storm drains and culverts to convey the increased runoff. In recognition of these problems, Pima County and the City of Tucson have implemented stormwater detention/ retention requirements, as one aspect of urban stormwater management, through the inclusion of specific detention/retention requirements within their respective floodplain management ordinances.

The concept of stormwater detention involves the temporary storage of runoff for subsequent release, at controlled rates, into downstream conveyance systems. Retention, however, consists of the on-site storage of runoff which is not subsequently discharged into a downstream watercourse; but rather may be consumed by evapo-transporation, domestic re-use, or drained into the subsurface through infiltration. Some detention/retention facilities are merely single-purpose (i.e., for flood-control uses only). However, it is much more favorable, from both a social and economic standpoint, to provide multiple-use facilities. Listed below, and illustrated on Figures 1.1 to 1.5, are some examples of multiple-use detention/retention concepts which have been successfully implemented throughout the country.

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Open Space and Common Areas
Landscaped areas and common areas, typically provided in conjunction with high-density residential areas, provide an excellent opportunity for detention/retention of runoff. Such functional open space may be employed to meet rezoning requirements.

Figure 1.1

Pedestrian Plazas and Courtyards
Similar to common areas in residential areas, pedestrian plazas, courtyards and landscaped areas can be used for stormwater storage within commercial/industrial areas.

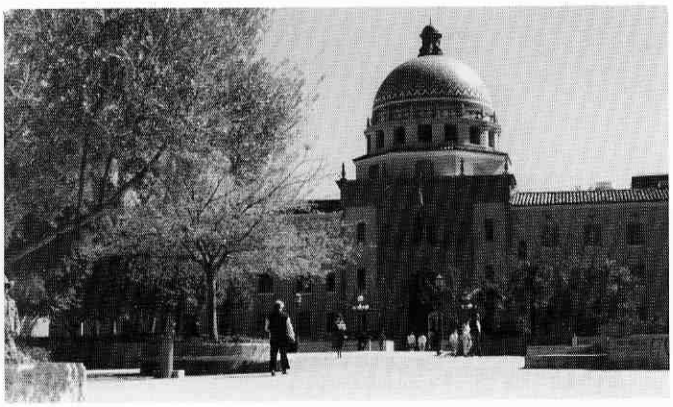

Figure 1.2

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Roadway Embankment Storage
When feasible, use of a roadway fill slope as an embankment provides an economical means of stormwater storage. This concept has been termed "blue-green" storage in some areas.

Figure 1.3

Parking Lot Detention
Commercial and industrial developments which have large parking lots can typically utilize these areas very economically for stormwater storage.

Figure 1.4

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Regional Detention Basins
Large-scale detention basins provide an excellent opportunity to develop regional park facilities and permanent ponds for recreation and open-space uses.

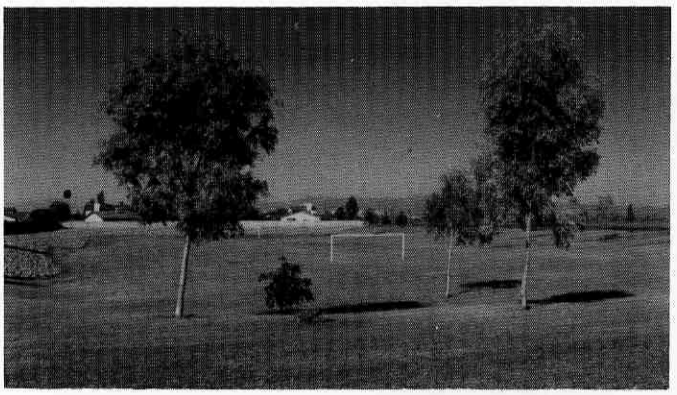

Figure 1.5

1.4 Policies

This section provides a summary of the general policies relating to stormwater detention/retention that are in effect for both Pima County and the City of Tucson. The reader is referred to the current Pima County and City of Tucson Floodplain Management Ordinances for specific requirements and to the appropriate staff for relevant departmental policies, including site-specific policies not covered in this general document. Many of the policies listed within this section have also been included in appropriate sections within the body of this manual.

A Balanced Drainage Basin is one which has been identified as having the potential for a severe increase in flood hazards as a result of increased urbanization within the basin. Stormwater detention/retention facilities shall be incorporated within all new developments to the extent necessary to ensure that, at a minimum, the post development 2-, 10-, and 100-year peak discharges from the site will not exceed the predevelopment values.

A Critical Drainage Basin is one which has been identified as already having severe flooding problems as a result of existing watershed conditions. Stormwater detention/retention facilities shall be incorporated within all new developments to the extent necessary to ensure a reduction in the existing 2-, 10-, and 100-year peak discharges from the site. The amount of reduction required shall be determined by the regulatory agency which has jurisdiction (i.e., either Pima County or the City of Tucson), and shall typically be based upon the flow capacity of a critical channel reach or critical drainage structure located downstream of the stormwater detention/retention facilities.

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Stormwater detention criteria may be waived for certain developments that meet the hydrologic criteria presented within Section 2.3 of this manual, with approval of the regulatory agency.

Stormwater detention requirements may not be waived if the proposed development is located within a critical basin and any portion of a critical channel reach or a critical drainage structure is located downstream of the development or if other conditions exist which the County or City Engineer deem justifiable for requiring detention.

Threshold retention systems which retain, at a minimum, the volumetric difference between the developed and existing 2-year runoff or the difference in peak discharges, whichever is greater, shall be incorporated within all new developments which meet the following criterion:

> Any residential development larger than one acre in size which has a density three to six units per developed acre, and that are located within a watershed which has not been classified as a critical or balanced basin.

Threshold retention systems which retain, at a minimum, the volumetric difference between the developed and existing 5-year runoff or the difference in peak discharge, whichever is greater, shall be incorporated within all new developments which meet the following criteria:

> All commercial or industrial developments larger than one acre in size.
>
> Any residential development larger than one acre in size which has a density greater than six units per developed acre.
>
> Any residential development larger than one acre in size which has a density greater than three units per developed acre, and that are located within a watershed which has been classified as a critical or balanced basin. This criterion may also be applied, at the discretion of the appropriate reviewing agency (i.e., either Pima County or the City of Tucson), to drainage basins which have not been previously identified as being "critical" but are not currently considered suitable for additional urban development without more thorough study.

In locations where stormwater retention is not feasible due to physical constraints (e.g., close proximity of bedrock or groundwater), the following additional detention requirements may be imposed in lieu of threshold retention:

> The detention requirement will be, at a minimum, the difference in volume between the developed and the existing 2-year runoff volumes or the difference in peak discharges, whichever is more restrictive, with the difference in volume and/or peaks between the developed and the existing 5-year runoff volumes being the maximum to be detained. The maximum peak discharge to be released from a detention basin is one (1) cfs in a drainage basin designated

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as "balanced" or "critical" and three (3) cfs in a non-designated drainage basin, with exceptions to be determined by the Pima County or City of Tucson Engineer. The 2-year/5-year criteria shall be applied in the same manner as it is applied for establishing threshold retention requirements.

Detention/retention systems which utilize a method of subsurface disposal (e.g., dry wells, engineered basin floors, trenches, etc.) shall be located such that the infiltration surface will be a minimum distance, both horizontally and vertically, from any functioning water well. The Pima County Flood Control District or the City of Tucson Engineering Divison should be contacted regarding the applicable criteria to be used for the specific type of development proposed.

Infiltration rates of dry wells, infiltration trenches, or basin floors shall not be used as outflow rates in flood-routing procedures.

On-line detention facilities shall not be allowed on channels which drain a catchment area greater than 100 standard acres in size upstream of the detention-basin outlet structure(s), unless approval to do so is first granted by the appropriate reviewing agency (i.e., either Pima County or the City of Tucson).

The use of rooftops as storage areas for runoff is not an acceptable method of meeting the detention/retention criteria of either Pima County or the City of Tucson.

Individual lot-storage systems within single-family residential developments are not acceptable for meeting the detention/ retention criteria of either Pima County or the City of Tucson.

Maintenance of local detention/retention facilities, provided in conjunction with new developments, shall generally be the responsibility of the private property owner or neighborhood association. Records of annual maintenance procedures shall also be kept on file by the private property owner or neighborhood association for periodic review by the appropriate agency (i.e., Pima County or the City of Tucson). The appropriate reviewing agency shall also reserve the authority to periodically inspect privately-owned detention/retention facilities to ensure satisfactory maintenance is being provided. There may be instances where public ownership and maintenance may be appropriate, and shall be handled on a case-by-case basis.

Access shall be provided to all detention/retention facilities, as needed, for maintenance purposes. The appropriate reviewing agency (i.e., either Pima County or the City of Tucson) should be contacted regarding specific access requirements.

Channel design, in conjunction with detention/retention facilities, should be undertaken only after first giving consideration to the following recommended hierarchy: 1) natural channels, 2) channels with grade-control structures, 3) fully-lined channels. In other words, a natural channel design should be considered first, unless stability problems absolutely dictate the need for grade controls or full channel lining.

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Detention/Retention basins should be designed for multiple uses where feasible.

Grading requirements for detention/retention facilities are provided within this chapter and within Chapter 4. All applicable grading ordinances and policies of the appropriate reviewing agency should also be met.

Landscaping of detention/retention facilities should incorporate the design criteria established within Chapter 4 of this manual.

The Pima County or City of Tucson Parks and Recreation Department should be contacted regarding proposed stormwater detention/retention in designated public areas within residential, commercial, and industrial developments.

The policies, criteria, and requirements stated within this manual are intended as minimum standards. More specific or restrictive requirements may be developed for individual watersheds in conjunction with the undertaking of specific basin-management studies, rezoning requirements, area-plan policies, or community-plan policies. The specific requirements developed as a part of any basin-management plan that may be adopted by either Pima County or the City of Tucson shall supercede the more general requirements presented within this manual.

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1.5 Glossary of Terms

The following glossary contains terms which may be found throughout this manual. In certain instances, the definitions provided represent a specific connotation of the term as it is used within the manual.

Balanced Basin — A watershed or sub-watershed which has been identified as having the potential for a severe increase in flood hazards as a result of increased urbanization within the basin.

Basin Floor — A rock-filled volume within the bottom of a stormwater storage facility, and designed for the purpose of temporarily storing runoff and subsequently disposing of same by the process of infiltration into the subsurface.

Concentration Point — A hydrologic term which describes any specific point within a watershed where the surface drainage is to be analyzed.

Critical Basin — A watershed or sub-watershed which has been identified as having severe flooding problems as a result of existing watershed conditions.

Culvert — A short, closed conduit, typically designed for conveying flow through an embankment.

Drainage Basin — A geographical area which contributes surface runoff to a particular point of interest. The term "drainage basin" and "watershed" are used interchangeably within this manual

Dry Well — An engineered hole with grated inlet designed to accept stormwater runoff, thereby allowing it to drain into the subsurface strata which lie immediately above the groundwater table.

Embankment — An artificial mound of earth which can act to impound water.

Emergency Spillway — An outflow spillway from a stormwater storage facility which is provided to allow for the safe overflow of floodwaters should situations arise that were not taken into account under normal design assumptions.

Flow Hydrograph — The functional relationship between time and flow discharge, as observed at a particular point within a watershed. Hydrographs are typically represented either graphically or in tabular form.

Flood Peak — The largest value of the flow discharge which occurs during a flood event, as observed at a particular point within the watershed.

Flood Routing — The mathematical simulation of a flood wave as it moves downstream through a watercourse or detention basin.

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Infiltration — The movement of water through the surface of the soil. In this manual, the terms "percolation" and "infiltration" will be used interchangeably; however, strictly speaking, the term "percolation" is defined as the movement of water through soil strata (i.e., water infiltrates through the soil surface, and then percolates through the underlying strata).

Infiltration Trench — A rock-filled trench, possibly containing a perforated pipe, designed for the purpose of temporarily storing runoff, and then subsequently disposing of it into the subsurface by infiltration.

Inflow — Runoff which flows into a stormwater storage facility from the upstream watershed.

Multi-Purpose Basin — A detention/retention basin which provides benefits in addition to the primary function of flood control. Such benefits may include recreation, water harvesting, visual buffers, or parking.

Off-Line Detention/Retention Basin — A stormwater storage facility which is located near or adjacent to a watercourse, (i.e., the channel does not flow directly into the basin). Inflow to the basin is typically accomplished by means of side weirs.

On-Line Detention/Retention Basin — A stormwater storage facility which is located within the path of a watercourse, and thereby typically intercepts the entire flow from the upstream watershed.

Off-Site Drainage — Stormwater runoff emanating from remote areas which affect the site under investigation.

On-Site Drainage — Stormwater runoff which emanates directly from the site under investigation.

Orifice — A small hole designed for draining a stormwater storage facility.

Outflow — Runoff which exits a stormwater storage facility by means of an outlet structure.

Outlet — The point at which stormwater runoff flows out of a detention/retention facility. Outlets may consist of culverts, weirs, orifices, dry wells, etc., or any combination thereof.

Return Period — The average interval of time within which a particular magnitude of flood should be equalled or exceeded at least once (e.g, a flood magnitude having a return period of 100 years will be equalled or exceeded, on the average, once every 100 years).

Rise Time — The time interval from the beginning of runoff to the time of peak discharge, as represented by the flood hydrograph.

Scour — The removal of material from the bed and banks of a channel as a result of flowing water.

Sediment Trap — An area within a stormwater storage facility which is designed to trap the majority of incoming sediments for the purpose of facilitating maintenance.

Stage — The height of water within a stormwater storage facility, as measured above an established datum.

Stormwater Detention Basin — A facility which temporarily stores surface runoff, and then releases it at a controlled rate through a positive outlet.

Stormwater Retention Basin — A facility which stores surface runoff, but is not provided with a positive outlet. No flow is discharged directly into a downstream watercourse from a retention basin, but may be drained into the subsurface by infiltration.

Subsurface Disposal — Drainage of stormwater runoff into the subsurface by the processes of infiltration and percolation. This may be accomplished through use of dry wells, engineered basin floors, infiltration trenches, etc.

Threshold Retention — A provision which requires retention of the volumetric difference, or the difference in peak discharge, whichever is greater, between the pre- and post-development onsite runoff volumes for the 2-year to 5-year flow events.

Time of Concentration — The time required for surface runoff to travel from the hydraulically most remote part of the drainage basin to the point of concentration.

Trash Rack — A metal bar or grate structure located at the inlet of an orifice or culvert, and designed so as to prevent blockage of the inlet by water-borne debris.

Weir (Broad Crested) — An open-channel control section, with a horizontal crest above which fluid pressure may be considered hydrostatic. It is normally placed across a stream or a ditch either for the purpose of diverting or for the purpose of measuring the flow of water.

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1.6 List of Symbols

A	Watershed area.
C_p	Fractional portion of a drainage basin which contributes sediment.
C_w	Weighted runoff coefficient.
Cw_{dev}	Weighted runoff coefficient for developed site conditions.
Cw_{ex}	Weighted runoff coefficient for existing site conditions.
n_b	Watershed basin factor.
O	Detention basin outflow.
P_c	Precipitation depth at t_c.
P_n	Precipitation depth for n-year storm.
P_t	t-hour rainfall depth, for 100-year storm.
P_1	One-hour rainfall depth.
q	Discharge at time t.
Q_i	Detention basin inflow.
Q_o	Peak outflow from detention basin.
Q_p	Peak discharge.
S	Detention basin storage for a particular routing time interval.
T	Flow travel time.
t	Time from beginning of runoff.
T_{AB}	Flow travel time between points A and B
t_c	Time of concentration.
T_r	Hydrograph rise time.
T_r'	Rise time of the 100-year synthetic flood hydrograph for on-site drainage.
Tr''	Rise time of the 100-year synthetic flood hydrograph for an entire watershed.
Δt	Routing time interval.
v	Runoff volume at time t.
V	Runoff volume.
V_d	Estimate of storage volume required for detention.
V_r	Required storage volume for retention.
V_s	Estimate of total required storage volume.
V_{SD}	Additional detention/retention basin volume required to account for sedimentation impacts.

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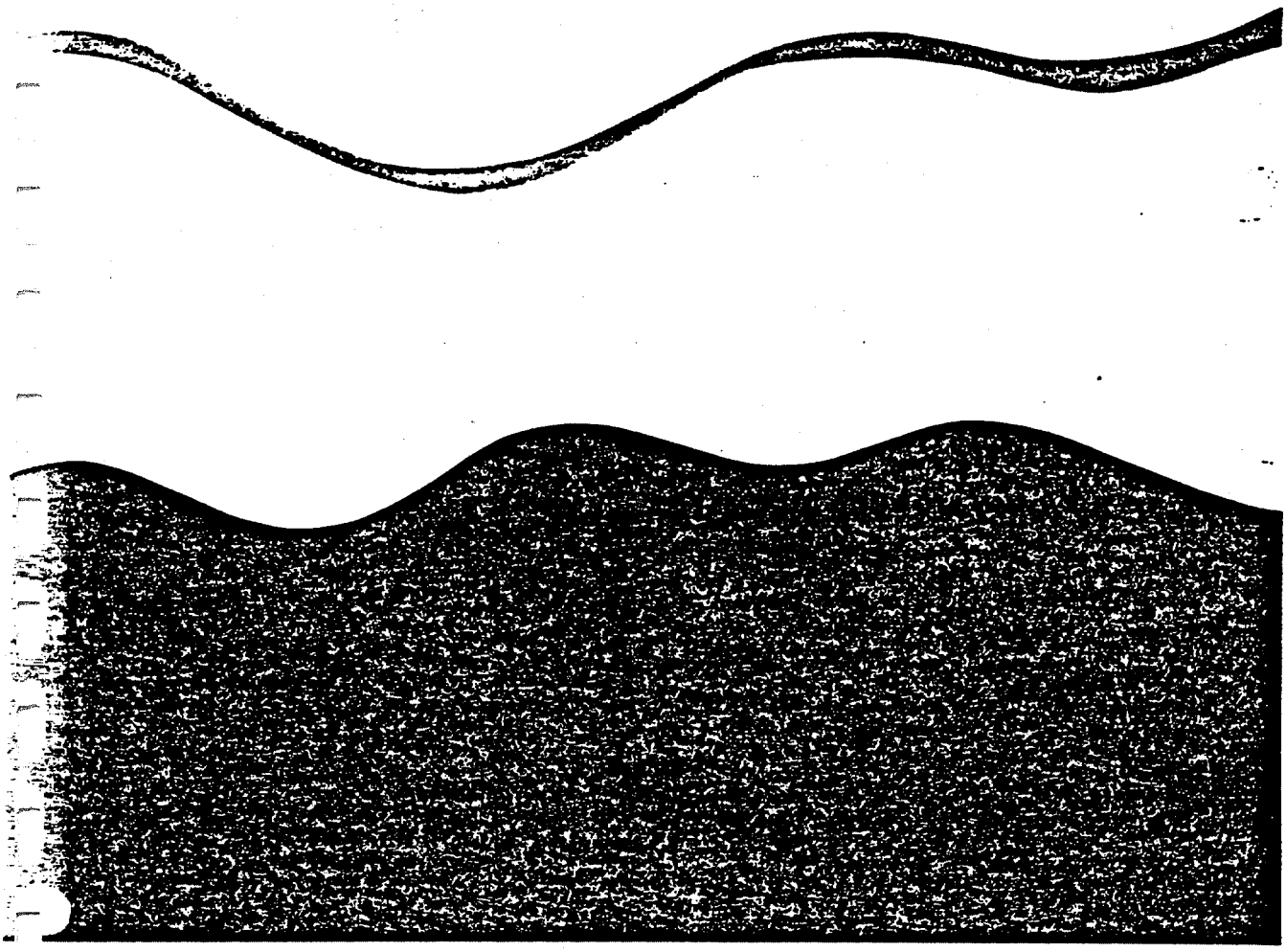
Detention/Retention Requirements



II. Detention/Retention Requirements

2.1 Balanced and Critical Basins

Balanced and Critical Basins refer to those watersheds which have been identified as either already having severe flooding hazards, or having a high probability of increased flood hazards as a result of future urbanization. Stormwater detention/retention is required for all new development proposed within both Balanced and Critical Basins, regardless of size or land-use density. The appropriate reviewing agency should be contacted for a list of basins designated as critical or balanced and maps showing locations of the basins. The future classification of basins as "critical" shall typically be done so in conjunction with basin-management studies of the affected watersheds.

Balanced Basin
A Balanced Basin is one which has been identified as having the potential for a severe increase in flood hazards as a result of increased urbanization within the basin. Stormwater detention/retention facilities shall be incorporated within all new developments to the extent necessary to ensure that, at a minimum, the post-development 2-, 10-, and 100-year peak discharges from the site will not exceed the pre-development conditions.

Critical Basin
A Critical Basin is one which has been identified as already having severe flooding problems as a result of existing watershed conditions. Stormwater detention/retention facilities shall be incorporated within all new developments to the extent necessary to ensure a reduction in the existing 2-, 10-, and 100-year peak discharges from the site. The amount of reduction required shall be determined by the regulatory agency which has jurisdiction (Pima County or City of Tucson), and shall typically be based upon the flow capacity of a critical channel reach or critical drainage structure located downstream of the stormwater detention/retention facilities.

2.2 Threshold Retention

Threshold retention systems must be incorporated within residential developments which are larger than one acre in size and planned for three or more units to the acre, and within all commercial or industrial developments larger than one acre in size. Threshold retention is required in order to mitigate the effects of urbanization upon increasing floodwater volumes, as well as for the purpose of enhancing groundwater-recharge potential. The retention requirement will be, at a minimum, the volumetric difference between the developed and existing 2-year runoff. The volumetric difference between the developed and existing 5-year runoff will be the maximum required to be retained. The 2-year pre-development discharge must be allowed to exit retention facilities, if it is necessary to maintain downstream, riparian vegetation.

The 2-year threshold retention criteria shall apply to the following types of developments:

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Any residential development larger than one acre in size which has a density of three to six units per developed acre, and that is located within a watershed which has not been classified as a critical or balanced basin.

The 5-year threshold retention criteria shall apply to the following types of developments:

All commercial or industrial developments larger than one acre in size.

Any residential development larger than one acre in size which has a density greater than six units per developed acre.

Any residential development larger than one acre in size which has a density greater than three units per developed acre, and that is located within a watershed which has been classified as a critical or balanced basin.

Threshold retention requirements may be waived in certain cases when stormwater retention is not feasible due to constraints imposed by subsurface conditions (e.g., close proximity of bed rock or ground-water table). In such cases, the following detention criteria may be imposed in lieu of threshold retention requirements, and in addition to any other applicable detention requirements:

The detention requirement will be, at a minimum, the difference in volume between the developed and the existing 2-year runoff volumes or the difference in peak discharges, whichever is more restrictive, with the difference in volume and/or peaks between the developed and the existing 5-year runoff volumes being the maximum to be detained. The maximum peak discharge to be released from each detention basin is one (1) cfs in a drainage basin designated as "balanced" or "critical" and three (3) cfs in a non-designated drainage basin, with exceptions to be determined by Pima County or the City of Tucson. A percolation test and/or hydrogeological site analysis is required to validate a request for provision of on-site detention of runoff in lieu of retention.

2.3 Location Within Watershed

The criteria presented within this section of the manual can be used to determine if stormwater detention requirements may be waived for a particular development. In certain circumstances, urbanization of parcels of land located at the extreme downstream end of a watershed will not create increases in flood peaks before the flow has entered a "major channel," where the effect upon any potential increase in the peak flow rate of the "major channel" would be inconsequential in any event. For purposes of this analysis, the term "major channel" refers to watercourses having drainage areas of 100 square miles or larger at the point that the criteria provided within this section is applied. This includes, but is not necessarily limited to, the following watercourses:

Santa Cruz River
Rillito Creek
Pantano Wash
Canada del Oro Wash
Tanque Verde Creek
Brawley Wash
Altar Wash

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However, when applying the criteria presented within this section, approval by the regulatory agency which has jurisdiction over the affected portion of the basin in question must be obtained prior to the classification of any additional watercourse as a "major channel." In certain instances, approval may be granted for other watercourses which demonstrate adequate downstream capacity to convey the 100-year flood peak to a logical downstream conclusion under conditions of ultimate watershed urbanization.

If either one of the two criteria presented within this section are satisfied, stormwater detention requirements may be waived for specific developments. This section applies only to stormwater detention. Threshold retention requirements shall remain unaffected by the application of these criteria. Additionally, as previously stated, stormwater detention requirements may not be waived if the proposed development is located within a critical basin and any portion of a critical channel reach or a critical drainage structure is located downstream of the development, or if other conditions exist which the County or City Engineer deem justifiable for requiring detention.

Criterion 1

Stormwater runoff discharges directly from the proposed development into a watercourse which meets the criteria of a "major channel," as defined in Section 2.3.

Criterion 2

A. Equation 2.1, as expressed below, is satisfied.

B. If the proposed development is located on a secondary tributary channel of the "major channel" (e.g., Channel #2 of Figure 2.1) then it must be demonstrated that the secondary tributary has adequate capacity to convey the future 100-year flood peak emanating from that portion of sub-watershed which contains not only the proposed development, but all areas upstream thereof. For instance, segment BC of Channel #2, in Example 2.1, must have adequate capacity to convey a 100-year flood peak emanating from those areas draining into Channel #2 upstream of Point C, based upon conditions of ultimate watershed urbanization. However, in this example, it would not be required to demonstrate that segment AB of Channel #1 had adequate capacity, since flood peaks would not be increased on this "primary" tributary as a result of the proposed development (i.e., provided Equation 2.1 is satisfied).

Note: For purposes of this manual, the term "primary tributary" refers to a channel which flows directly into a "major channel." A secondary tributary is one which flows directly into a primary tributary, etc. Streets may not be considered as tributaries.

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Equation 2.1 is expressed as follows:

$$\frac{T + T_r'}{T_r''} \leq 0.40$$

Equation 2.1

Where

T = 100-year flow travel time between the downstream point of the proposed development and the confluence with a watercourse which meets the criteria of a "major channel," as defined in Section 2.3. The parameter T shall be calculated by means of the "incremental time of concentration method," as illustrated in Example 2.1 of this manual.

T_r' = Rise time of the 100-year synthetic flood hydrograph for on-site drainage emanating from the proposed development (for developed conditions).

T_r'' = Rise time of the 100-year synthetic flood hydrograph at its confluence with the "major channel" for drainage emanating from the entire watershed. In this instance, T_r'' shall be determined using the assumption that the entire watershed is fully developed and uncontrolled (i.e., it should be assumed that no stormwater detention/retention facilities presently exist, or will exist in the future, within the watershed).

Note: Equation 2.1 shall only be applied to watersheds having drainage areas equal to or less than ten square miles at a confluence point with a "major channel," since the synthetic flood hydrograph used for this analysis begins to lose its applicability as the watershed increases in size beyond this limit.

Peak discharges and times of concentration used in this analysis shall be calculated by the Pima County hydrology method or the City of Tucson Flood Peak Estimator Procedure. Hydrograph rise times shall be determined by the method to be subsequently described within Chapter III of this manual.

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Example 2.1

A 60-acre parcel, proposed for high-density urban development, is located in the extreme lower portion of a 4033-acre sub-watershed of the Rillito Creek, which has been identified as a Balanced Basin. Determine if stormwater detention may be waived as a condition of development (see Figure 2.1).

I. Applying Criterion 1

The parcel does not discharge directly into a "major channel" (i.e., Rillito Creek); therefore, Criterion 1 is not satisfied. In this instance, Criterion 2 must be examined. If Criterion 1 had been satisfied the detention requirement would have been waived, and no further analysis would be necessary.

II. Criterion 2A

Calculate T: By application of the Pima County Hydrology Method, the following times of concentration (t_c) are calculated for fully-developed watershed conditions.

Channel #1
t_c at Point A = 61 min.
t_c at Point B = 57 min.

Channel #2
t_c at Point B = 25 min.
t_c at Point C = 17 min.

The travel time through the reach of Channel #1 located between Points A and B (T_{AB}) is calculated by subtracting the times of concentration at these two points:

$$T_{AB} = 61 - 57 = 4 \text{ min.}$$

The travel time through the reach of Channel #2 located between Points B and C (T_{BC}) is calculated in a similar manner:

$$T_{BC} = 25 - 17 = 8 \text{ min.}$$

The total travel time (T) for use in Equation 2.1 becomes the sum of T_{AB} and T_{BC}:

$$T = 4 + 8 = 12 \text{ min.}$$

Note: Incremental travel times are calculated for each channel segment located between the "major channel" and the subject parcel. The total travel time (T) is then calculated as the sum of the incremental travel times.

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Calculate T_r':
By applying the Pima County Hydrology Method to the on-site runoff from the 60-acre parcel (assuming developed conditions), a time of concentration of six minutes is obtained. This corresponds to a rise time, T_r', on the synthetic flood hydrograph of 14 minutes.

Calculate T_r'':
A value of T_r'' = 53 minutes is calculated for the entire 4033-acre subwatershed at Point A (assuming fully-developed watershed conditions), in the same manner as T_r' was calculated for the 60-acre parcel.

Substituting T, T_r', and T_r'' into Equation 2.1 yields:

$$\frac{T + T_r'}{T_r''} = \frac{12 + 14}{53} = 0.49.$$

Since this value is greater than 0.40, detention requirements would not be waived for this development. In addition, if the value had been less than or equal to 0.40, the detention requirement would only have been waived if it could be demonstrated that the capacity of the reach of Channel #2 located between Points B and C would be adequate to convey the future 100-year flood peak predicted to occur along this reach which emanates from the drainage area situated upstream of Point B (i.e., Criterion 2B, as described on page 4, must also be satisfied).

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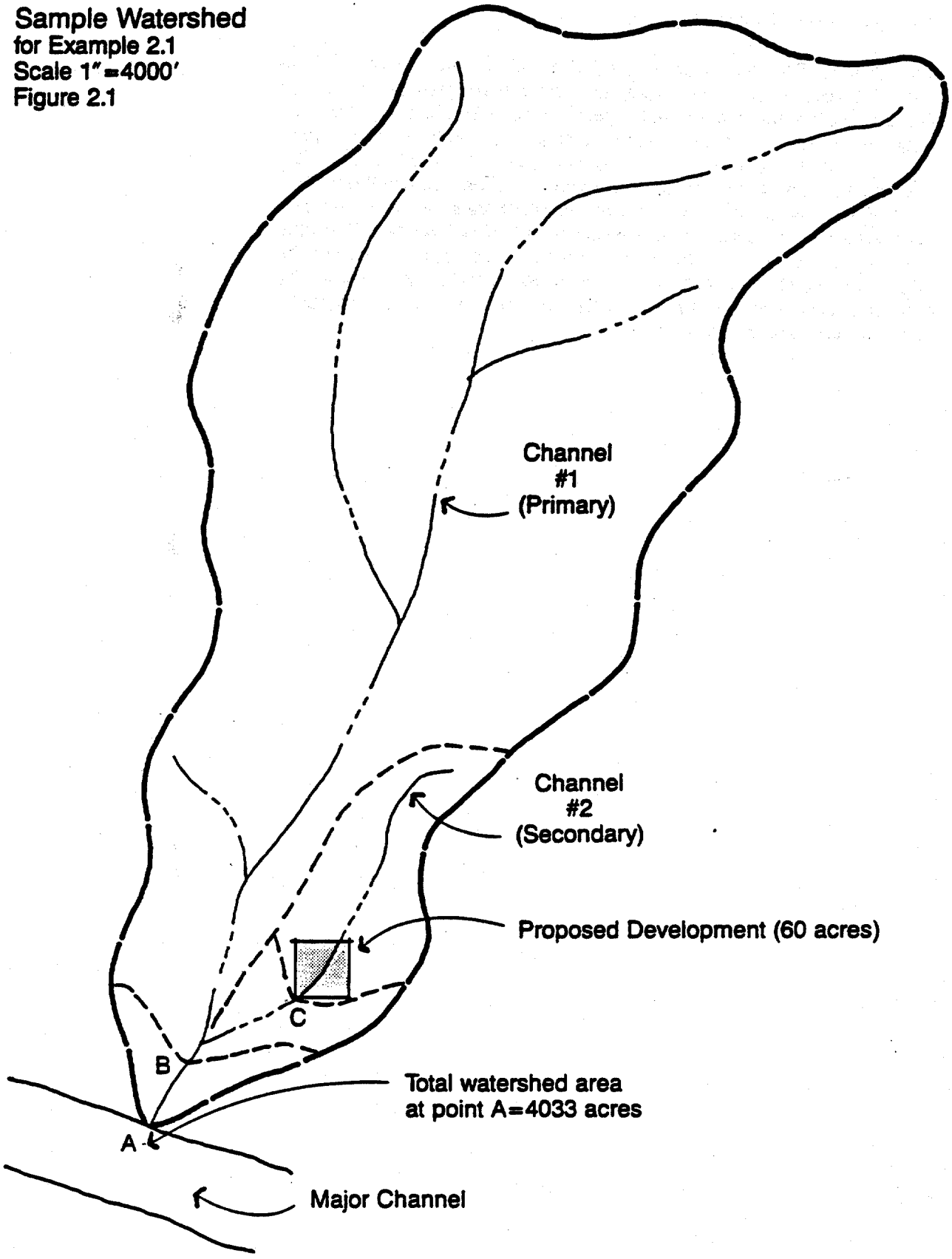
Sample Watershed
for Example 2.1
Scale 1"=4000'
Figure 2.1



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2.4 Retention Feasibility Map

The Retention Feasibility Map included within this manual (Figure 2.2) is intended as a general guide for the planning of retention systems which include facilities for disposing of stormwater runoff into the subsurface (e.g., dry wells, engineered basin floors, infiltration trenches, etc.). The information on soil permeability rates is very generalized, and is not intended to be used for design purposes. Rather, its intent is to provide an indication of the relative feasibility of utilizing infiltration facilities for stormwater disposal. Percolation tests will be required on a site-by-site basis to obtain permeability rates which are to be used for final retention facility design. The permeability ranges provided herein are for near-surface soils only (i.e., zero to five-foot depths). Therefore, they are not applicable to dry-well systems, which typically penetrate into deeper strata.

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Retention Feasibility
Figure 2.2

Legend

Least Feasible

Very shallow soil depths, generally less than 35″ to bedrock.

Soils which generally have slow to moderately slow permeability.

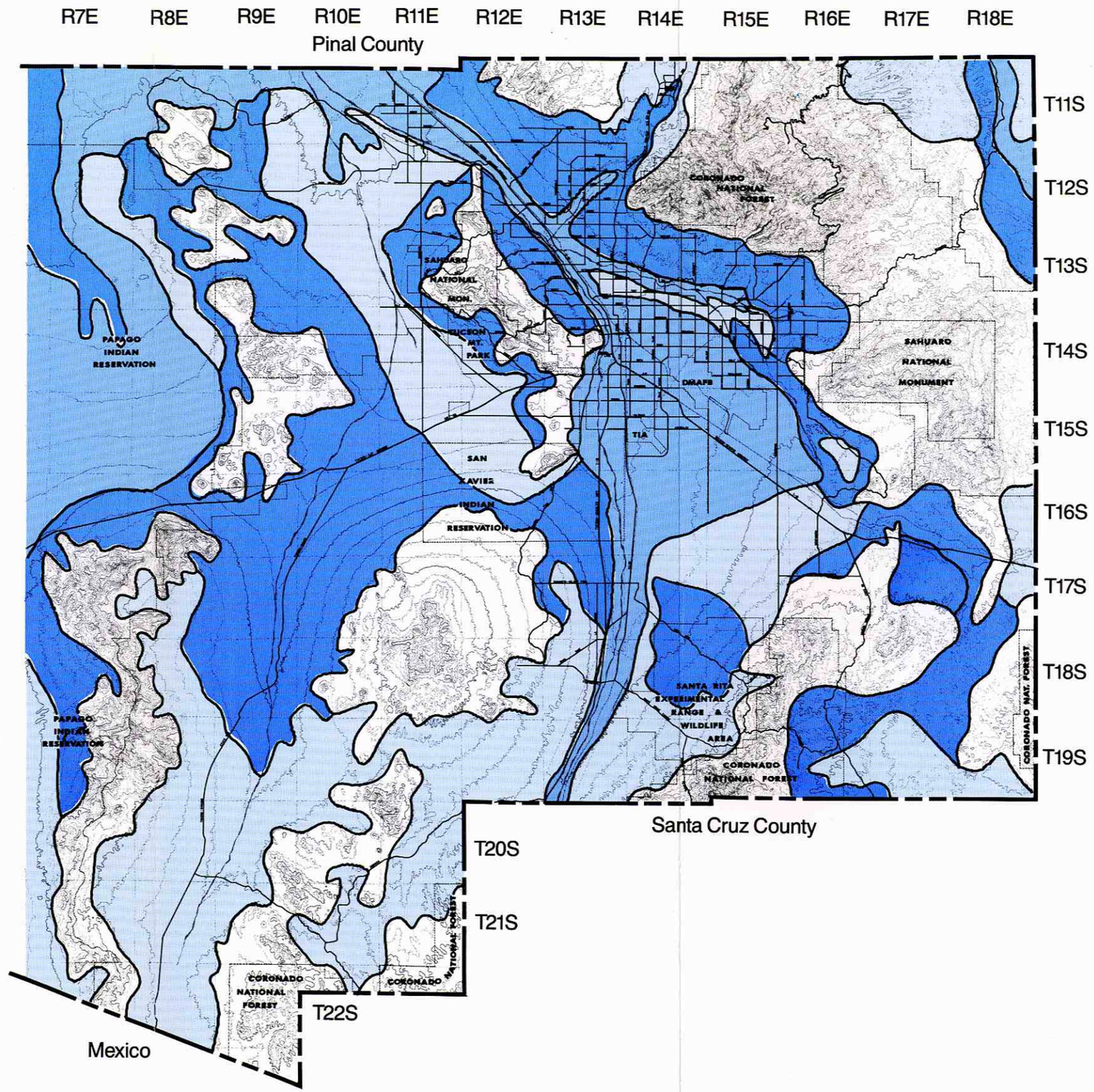
Soils which generally have moderate permeability.

Soils which generally have moderate to moderately rapid permeability.

Most Feasible

North

0 5 10 Miles



2.5 Depth To Groundwater Map

Figure 2.3 provides depth to ground water information for eastern Pima County and the City of Tucson. This map is provided to aid the reader in assessing retention feasibility with respect to the criteria regarding the proximity of retention-facility disposal points to the groundwater table. This criteria may be obtained from the Pima County Flood Control District, or the City of Tucson Engineering Division. Figure 2.3 of this manual will be updated periodically to reflect future changes in groundwater levels. Either the Office of the Pima County Engineer or the Office of the City Engineer should be contacted to obtain any current updates to this map, as they become available.

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Depth To Groundwater

Tucson Basin and Avra Valley
Figure 2.3

Legend

Known Water Level Contour

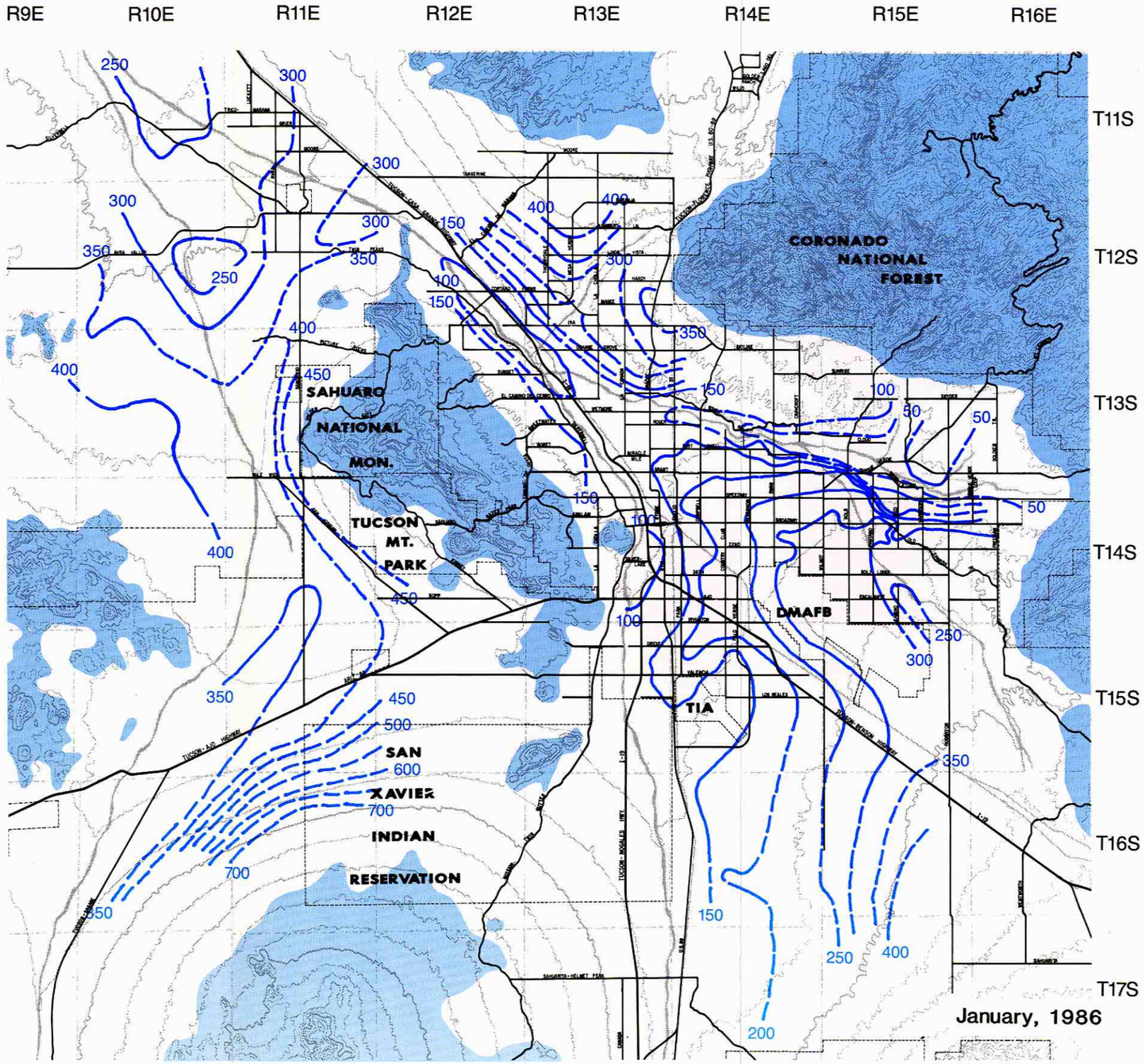
Inferred Water Level Contour

Bedrock or Mountainous Area

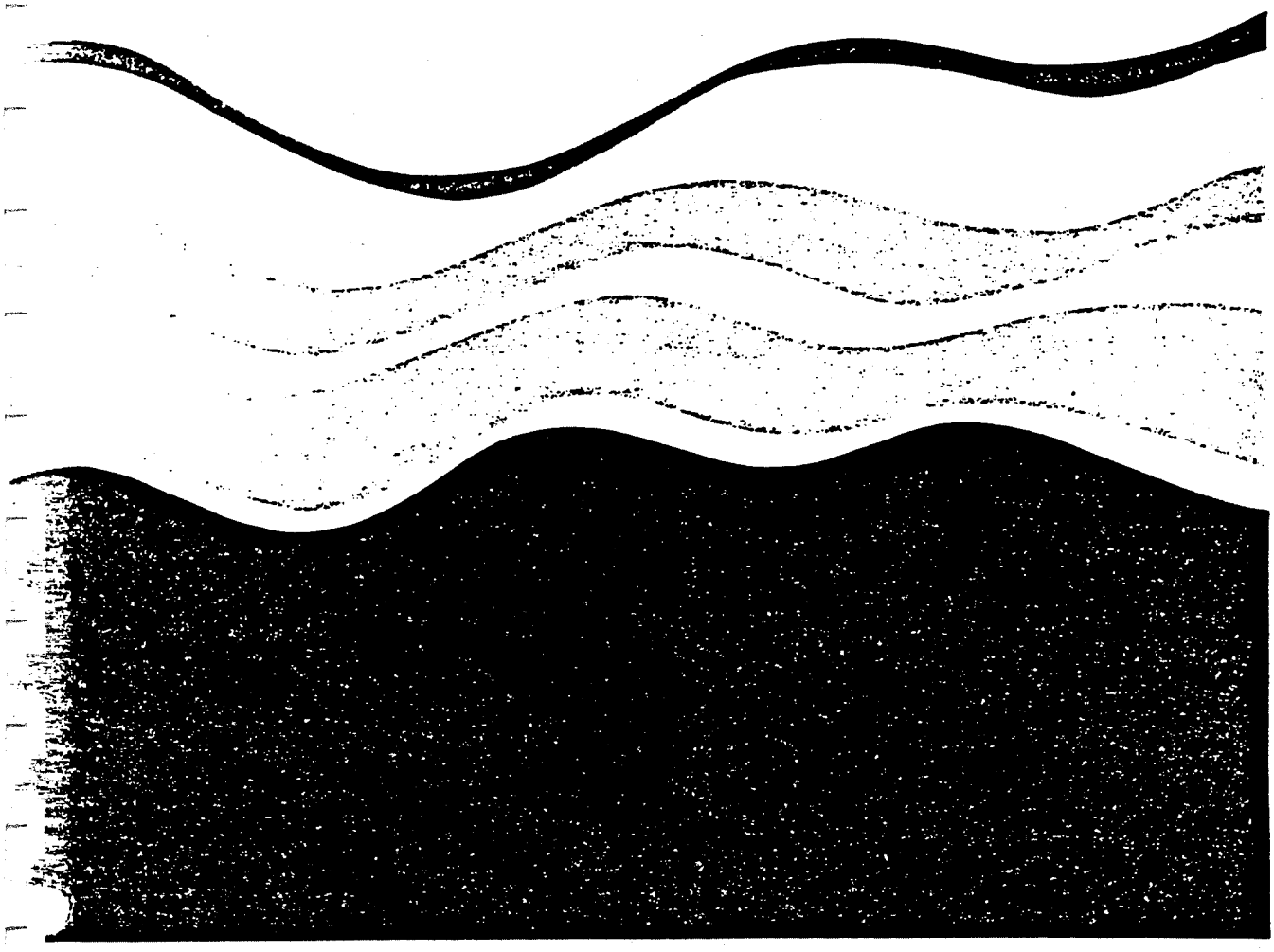
Water Level Contour Interval 50 Feet

North

0 5 10 Miles



Design Criteria and Procedures



III. Design Procedures and Criteria

This chapter provides certain procedures, equations, and data to be used in the analysis and design of detention/retention facilities. The topics addressed herein consist of: 1)determination of hydrologic parameters; 2)design of detention/retention facilities; 3)sedimentation impacts; and 4) criteria for specific types of detention/retention facilities. The analysis methods presented within this chapter are to be applied to detention/retention facilities which intercept runoff from drainage areas no greater than one square mile, unless specific authorization to the contrary is granted by the appropriate reviewing agency (i.e., either Pima County or the City of Tucson).

3.1 Hydrology

3.1.1 Precipitation

Table 3.1 of this manual provides a tabulation of one-hour precipitation depths which are to be used in conjunction with the analysis and design of detention/retention facilities within Pima County and the City of Tucson. The precipitation values provided within this table are to be used with both the Pima County and City of Tucson methods for estimating peak flows, as well as with the various analysis methods presented within this manual. It should also be noted that the procedures presented within this manual are strictly applicable only for those watersheds which will be controlled by detention/ retention measures that have drainage areas which do not exceed one square mile in size.

3.1.2 Peaks and Volumes

Peak-discharge rates to be used in conjunction with the design and analysis of detention/retention facilities shall be determined by use of either the Pima County Hydrology Method or the City of Tucson Flood Peak Estimator Procedure, whichever is applicable. The rainfall values used with these procedures shall be those provided in Table 3.1 of this manual.

Rainfall Depths of Various Return-Period Events
for Watershed Areas Up To One Square Mile
in Pima County, Arizona

Return Period (Years)	Rainfall Depth (Inches)		
	1-Hour	2-Hour	3-Hour
2	1.10	1.25	1.32
5	1.50	1.71	1.80
10	1.90	2.17	2.28
25	2.30	2.62	2.76
50	2.70	3.08	3.24
100	3.00	3.42	3.60

Table 3.1

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The total volume of runoff from a flood event shall be determined from Equation 3.1.

$$V = \frac{C_w P_n A}{12}$$

Equation 3.1

Where;

V = runoff volume, in acre feet;
C_w = weighted runoff coefficient;
P_n = n-hour precipitation depth, in inches; and,
A = Watershed area, in acres.

Note: The methods of determining flood peaks and volumes presented within this section are only applicable when no upstream detention measures exist. If upstream detention does exist, then either Method B of Section 3.1.3 must be used; or, computer modeling of the watershed must be employed.

3.1.3 Inflow Hydrographs

Method A

The following method shall be used to generate synthetic flood hydrographs for the purpose of flood routing, detention-basin design, and other procedures contained within this manual which require hydrograph analysis. This method is only applicable for watersheds which a)are uncontrolled (i.e., no upstream stormwater detention exists); b)are hydrologically homogenous; and c)have a drainage area of less than one square mile in size.

1. Peak Discharge (Q_p), Runoff Volume (V), and Time of Concentration (T_c) for the design flow(s) are to be calculated by the methods described within Section 3.1.2 of this manual.

2. The hydrograph Rise Time (T_r) is determined in the following manner:

   a. For $T_c \leq 60$ minutes, read the corresponding value for T_r from Table 3.2.

   b. For $T_c > 60$ minutes, determine T_r from the following equation:

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$$T_r = \frac{0.7869\ P_n\ T_c}{P_c}$$

Equation 3.2

Where;
T_r = hydrograph rise time, in hours;
T_c = time of concentration, in hours;
P_n = *n-hour precipitation depth, in inches; and,
P_c = **precipitation depth at Tc, in inches.

*n-hour refers to the 2-, 3-, 6-, 12-, or 24-hour precipitation depths, where "n" should normally be the smallest of these values which is greater than T_c.

**P_c is calculated by linear interpolation between the calculated rainfall depths which bracket T_c. (e.g., if T_c = 2.5 hours then P_c is halfway between the 2-hour and 3-hour rainfall depths).

3. Hydrograph coordinates (t, q, v) are calculated from the ratios provided on Table 3.3.

Where,
t = time from beginning of runoff, in minutes;
q = discharge at time t, in cubic feet per second (cfs);
v = total runoff volume, at time (t), in acre-feet;
Q_p =peak discharge of hydrograph, in cfs; and,
V = total runoff volume of hydrograph, in acre-feet.

4. For those cases where the hydrograph must be represented in equal time increments (e.g., for reservoir routing), such increments may be obtained either by interpolating between the values determined from Step #3, or by reading the values from a graphical representation of the hydrograph.

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Hydrograph Rise Times for $T_C \leq 60$ Minutes
(T_C and T_r are in minutes)

T_C	T_r	T_C	T_r
5	13.6	33	31.9
6	14.2	34	32.3
7	15.0	35	33.0
8	15.8	36	33.5
9	16.6	37	34.2
10	17.5	38	34.7
11	18.1	39	35.2
12	18.7	40	36.0
13	19.4	41	36.6
14	19.9	42	37.2
15	20.7	43	37.8
16	21.3	44	38.4
17	21.9	45	38.7
18	22.5	46	39.3
19	23.1	47	40.0
20	23.7	48	40.4
21	24.5	49	41.1
22	25.0	50	41.8
23	25.7	51	42.2
24	26.2	52	42.9
25	27.0	53	43.3
26	27.6	54	43.7
27	28.1	55	44.5
28	28.8	56	45.0
29	29.3	57	45.4
30	29.9	58	46.3
31	30.7	59	46.7
32	31.3	60	47.2

Table 3.2

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Ratios for Generation of Pima County
Synthetic Flood Hydrograph

t/T_r	q/Q_p	v/V	t/T_r	q/Q_p	v/V
0	0	0	1.6	0.545	0.671
0.1	0.025	0.002	1.7	0.482	0.707
0.2	0.087	0.007	1.8	0.424	0.742
0.3	0.160	0.020	1.9	0.372	0.773
0.4	0.243	0.036	2.0	0.323	0.799
0.5	0.346	0.063	2.2	0.241	0.841
0.6	0.451	0.096	2.4	0.179	0.875
0.7	0.576	0.136	2.6	0.136	0.900
0.8	0.738	0.180	2.8	0.102	0.917
0.9	0.887	0.253	3.0	0.078	0.932
1.0	1.000	0.325	3.4	0.049	0.953
1.1	0.924	0.400	3.8	0.030	0.965
1.2	0.839	0.464	4.2	0.020	0.973
1.3	0.756	0.523	4.6	0.012	0.979
1.4	0.678	0.578	5.0	0.008	0.983
1.5	0.604	0.627	7.0	0	1.000

Table 3.3

Method B

For those cases where an inflow hydrograph must be determined from a watershed which **does** contain upstream detention facilities, the following simplified method may be employed. The method is presented in example format, and considers only one detention basin within the upstream watershed. If more than one upstream detention basin exists, the same procedure should be applied in a systematic fashion from the upstream-most detention basin, downstream to the point of interest. Referring to Figure 3.1, the following procedures shall be employed:

1. Determine the outflow hydrograph from the basin located at Point B for the design storm under investigation. This information can be obtained from the design analysis performed for the basin (if available), or from the reservoir-routing method presented within Section 3.3 of this manual.

2. Compute the flow travel time between Points B and A (i.e., T_{BA}) using the incremental time-of-concentration method presented within Section 2.3 of this manual.

3. Generate a hydrograph (using Method A of this manual) for that portion of the watershed upstream of Point A, but **excluding** that portion of the watershed which drains into the detention basin at Point B (i.e., excluding sub-basin B of Figure 3.1).

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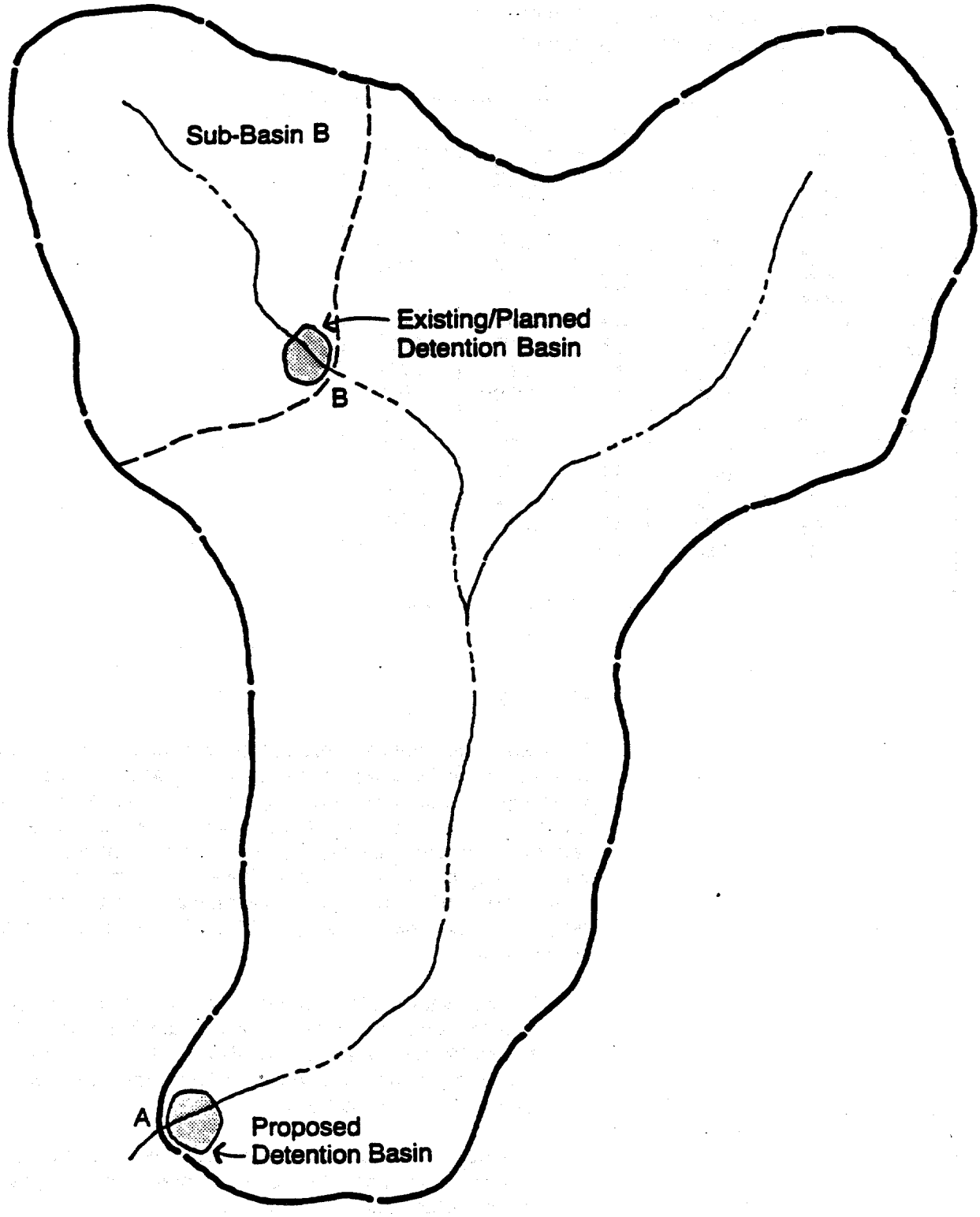

Sample Watershed
For Method B
Figure 3.1

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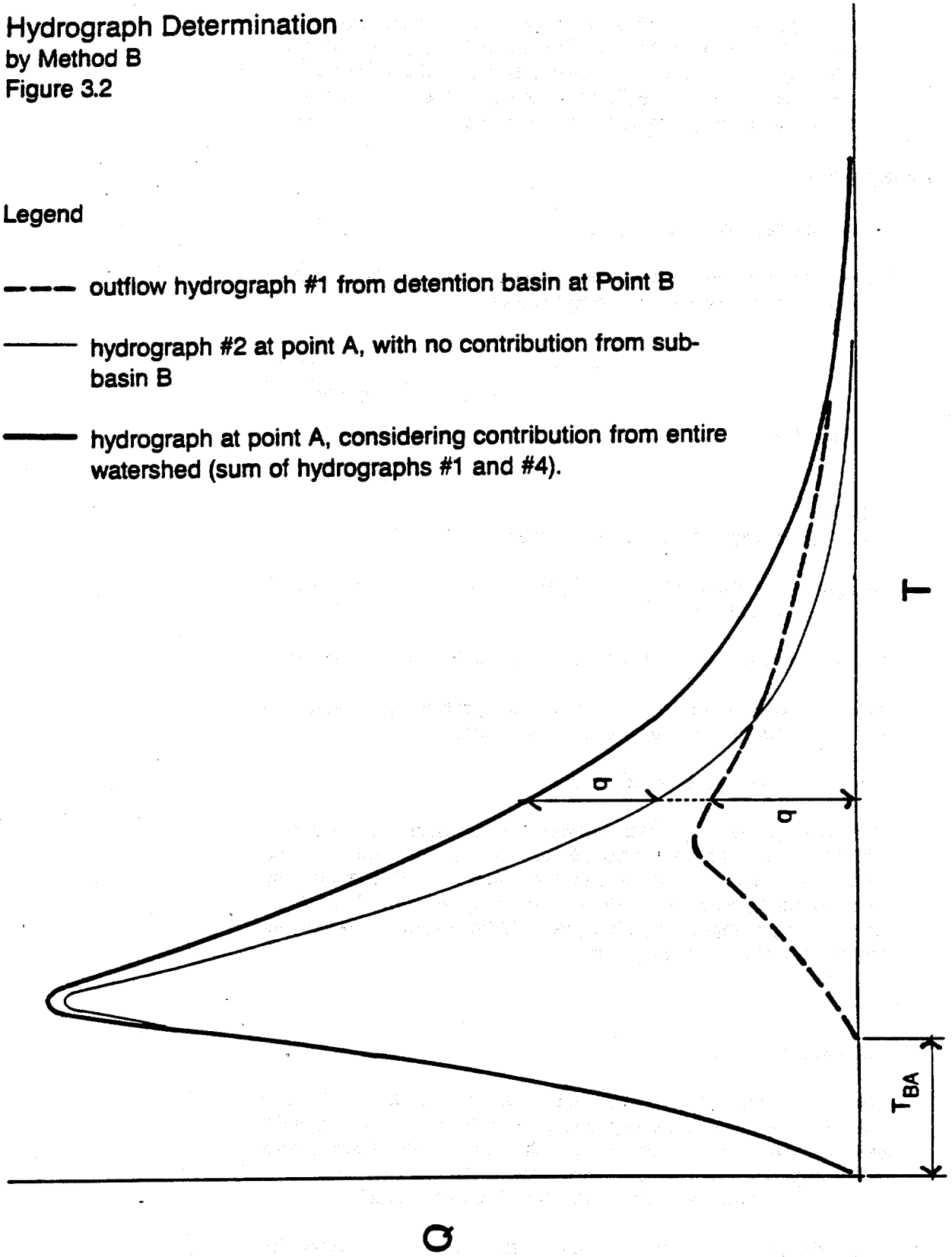
Hydrograph Determination
by Method B
Figure 3.2

Legend

— — — outflow hydrograph #1 from detention basin at Point B

——— hydrograph #2 at point A, with no contribution from sub-basin B

▬▬▬ hydrograph at point A, considering contribution from entire watershed (sum of hydrographs #1 and #4).



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4. The actual hydrograph at Point A is the sum of the hydrograph generated from Step 3 of this procedure and the outflow hydrograph obtained during Step 1, lagged by the travel time T_{BA} calculated during Step 2. This procedure is most easily accomplished graphically, as shown in Figure 3.2 of this manual.

3.2 Retention

3.2.1 Required Storage Volume

The volume of storage required to satisfy threshold retention criteria shall be calculated by the following method:

Equation 3.3

$$V_r = \frac{1}{12}(Cw_{dev} - Cw_{ex})\,P_1 A$$

Where,

V_r = storage volume required, in acre feet;

Cw_{dev} = weighted runoff coefficient for urban (i.e., developed) conditions;

Cw_{ex} = weighted runoff coefficient for existing site conditions;

P_1 = one-hour rainfall depth for the 2-year or 5-year storm, as determined from Table 3.1, in inches; and,

A = drainage area, in acres.

Note: Cw_{dev} and Cw_{ex} are to be determined from the Pima County or City of Tucson hydrology procedures. However, estimates of these runoff coefficients may be obtained from Table 3.4 of this manual only for determining preliminary values of required retention storage. Additionally, the drainage area (A) in equation 3.3 refers only to the area being developed (i.e., the on-site area).

3.2.2 Method of Disposal

The preferred method for disposal of retained runoff is by infiltration into the subsurface. Various options for accomplishing this include dry wells, engineered basin floors and trenches, perforated pipes, and landscape irrigation. Specific design criteria and references for these types of facilities are included within Section 3.5 of this manual.

In locations where infiltration is not a feasible method of stormwater disposal, additional detention may be required, as described in Section 2.2, or pump systems may be used. Such systems will operate in

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such a manner that the retained stormwater will be slowly released from the retention basin after natural runoff has ceased. Guidelines regarding rates of release of runoff are contained within Section 2.2.

Runoff Coefficients

Return Interval	*P_1	Runoff Coefficients (Cw) for Applicable Soil Types in Pima Co. and the City of Tucson				Runoff Coefficients (Cw) for Various Degrees of Land Use Upon Applicable Soil Types in Pima County and the City of Tucson (percent in parenthesis represents amount of impervious cover)														
						(10%) Rural			(20%) Suburban			(40%) Mod. Urban			(70%) Hvy. Urban			(90%) Comm./Ind.		
		B	C	D	I	B	C	D	B	C	D	B	C	D	B	C	D	B	C	D
2-year	1.1	.09	.19	.28	.90	.17	.26	.34	.25	.33	.40	.41	.47	.53	.66	.69	.71	.82	.83	.84
5-year	1.5	.24	.37	.46	.92	.31	.43	.51	.38	.48	.55	.51	.59	.64	.72	.76	.78	.85	.87	.87
10-year	1.9	.37	.50	.59	.94	.43	.54	.63	.48	.59	.66	.60	.68	.73	.77	.81	.84	.88	.90	.91
25-year	2.3	.47	.59	.68	.95	.52	.63	.71	.57	.66	.73	.66	.73	.79	.81	.84	.87	.90	.91	.92
50-year	2.7	.55	.66	.74	.96	.59	.69	.76	.63	.72	.78	.71	.78	.83	.84	.87	.89	.92	.93	.94
100-year	3.0	.60	.70	.77	.96	.64	.73	.79	.67	.75	.81	.74	.80	.85	.85	.88	.90	.92	.93	.94

*P_1 = one hour rainfall depth, in inches.

Table 3.4

3.3 Detention

3.3.1 Estimating Detention Storage Volume

The equations presented within this section are intended to provide estimates of storage volume required for various types of detention facilities. The results obtained from applying these equations are not suitable for design purposes. These methods are only intended to be used for obtaining preliminary estimates of required storage volume, and for providing a "starting point" for the reservoir-routing techniques presented within the next section of this manual. The storage-volume estimates obtained from Equations 3.4 to 3.7 can generally be expected to yield values within ±20 percent of the results obtained from detailed reservoir routing. For this reason, it is recommended that a factor of 1.2 be applied to the values obtained from the equations, when assessing preliminary site feasibility. A factor of 1.30 should be applied if significant sediment inflow is expected in the basins. However, for design purposes, the actual amount of additional volume required to account for

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sedimentation shall be determined by the method described within Section 3.4 of this manual. Note that storage-volume estimates should be calculated for both 100-year and 10-year runoff events since, in some instances, the 10-year storm may require more detention-storage volume than does the 100-year storm.

Figure 3.3 of this manual provides a graphical representation of the inflow/outflow hydrographs which were utilized in developing Equation 3.4 to 3.7. For the sake of simplicity, and without the loss of significant accuracy, the hydrographs used to develop these equations were represented as triangles. However, for purposes of reservoir routing and final detention-basin design, curvilinear hydrographs (as developed from the methods described in Section 3.1.3) shall be used.

Type I: "On-line" Detention Basin Without Retention

The simplest type of detention basin is one which is constructed "on-line" (i.e., intercepting the entire flow from the upstream watershed), with the invert of its outlet structure at the level of the basin floor. However, use of an "on-line" basin requires approval of the appropriate reviewing agency. Equation 3.4 is the mathematical relationship to be used for estimating the volume of storage required for this type of basin.

Equation 3.4

$$V_S = \frac{C_W P_t A}{12}\left[1 - \frac{Q_o}{Q_i}\right]$$

Where;

V_S = estimate of required storage volume, in acre feet;

C_W = weighted runoff coefficient of the upstream watershed for the design storm under investigation;

P_t = t-hour rainfall depth for the design storm under investigation, in inches;

A = watershed area, in acres;

Q_o = detention basin outflow, in cfs; and,

Q_i = detention basin inflow, in cfs.

Type II: "On-line" Detention Basin With Retention
(Applicable only for watersheds of 100 acres or less).

This is a Type I detention basin, but which also serves as a retention facility i.e., retention storage is provided below the invert of the lowest outlet structure. Equation 3.5 is the mathematical relationship to be used for estimating the volume of storage required for this type of basin.

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$$V_S = \frac{C_W P_t A}{12}\left[1 - \frac{Q_o}{Q_i}\left[1 - \left[\frac{P_n}{3C_W P_t}(Cw_{dev} - Cw_{ex})\right]^{\frac{1}{2}}\right]\right]$$

Equation 3.5

Where;

Cw_{dev} = weighted runoff coefficient for the proposed development, considering urbanized conditions for the n-year storm ($2 \leq n \leq 5$);

Cw_{ex} = weighted runoff coefficient for the proposed development, considering existing conditions for the n-year storm ($2 \leq n \leq 5$);

P_n = precipitation depth, in inches, for the n-year storm ($2 \leq n \leq 5$).

Symbols not otherwise noted are defined as in Equation 3.4.

Type III: "Off-Line" Detention Basin

An "off-line" basin is located near or adjacent to a channel (i.e., the channel does not flow directly into the basin). Typically, inflow to the basin is accomplished by means of side weirs, or other overflow structures, and begins only after the channel stage reaches a minimum height. Stored water is returned to the channel by means of a small-capacity outlet structure. This type of facility may only be implemented adjacent to a prismatic channel which has been stabilized both horizontally and vertically (e.g., a concrete channel with a trapezoidal or rectangular cross section). An off-line detention basin generally has the advantage of requiring less storage volume, for a certain level of peak reduction, than does an on-line facility. Equation 3.6 is the mathematical relationship to be used for estimating the volume of storage required for "off-line" basins, which either may or may not include "off-line" retention.

$$V_S = \frac{C_W P_t A}{12}\left[1 - \frac{Q_o}{Q_i}\left[2 - \frac{Q_o}{Q_i}\right]\right]$$

Equation 3.6

Symbols not otherwise noted are defined as in Equation 3.4.

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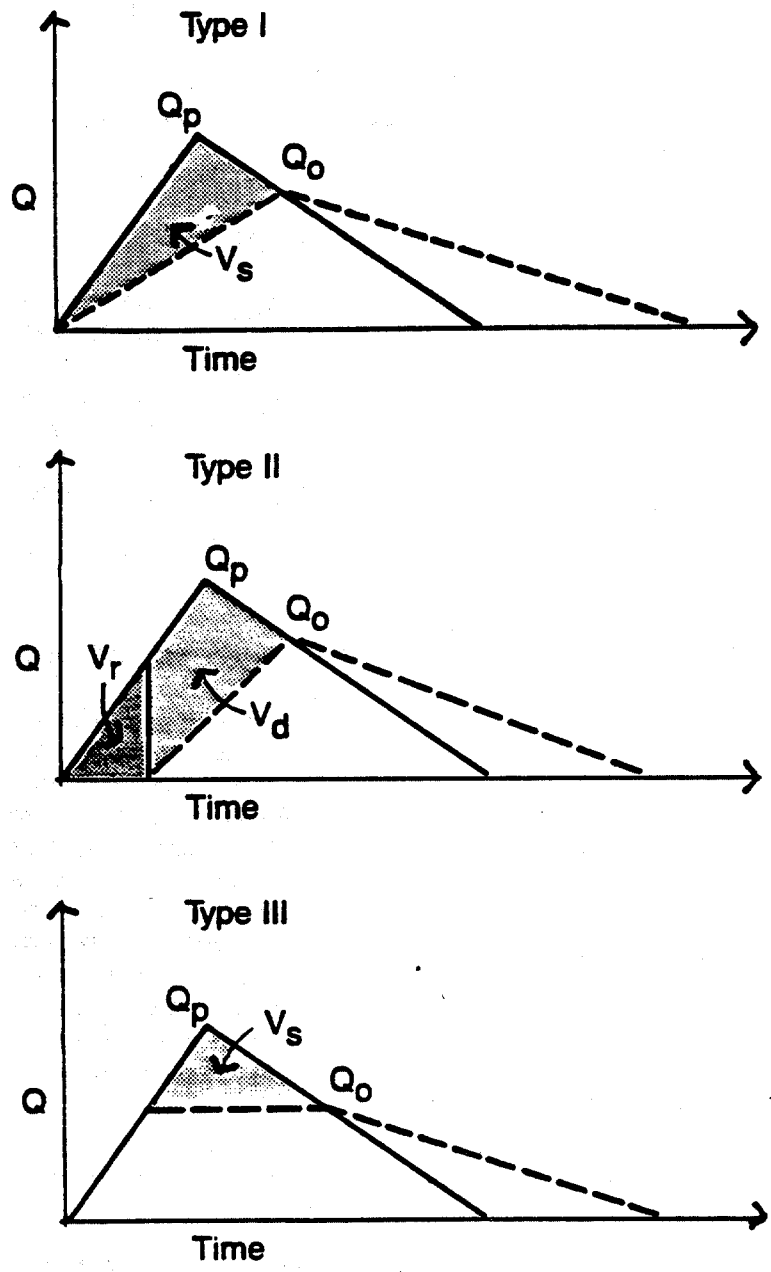
Graphical Representation of Inflow/Outflow Hydrographs
for Type I, II, III & IV Basins

Figure 3.3



Legend

——— Inflow Hydrograph
– – – – Outflow Hydrograph
V_d Storage Volume Required For Detention
V_r Storage Volume Required For Retention
V_s Total Storage Volume ($V_d + V_r$)

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3.3.2 Outflow Hydrograph Determination (Reservoir Routing)

The outflow hydrograph from a proposed detention basin shall be determined utilizing the storage-indication method of flood routing. Other very similar hydrologic-routing methods, such as "modified Puls," [30] may also be utilized, provided that the method is first approved by the appropriate review agency (Pima County or City of Tucson).

Following is a step-by-step description of the procedure which should be followed in performing the storage-indication method of flood routing. Example 3.1 of this manual provides a practical example of the application of the method, as it would be solved by hand calculation. However, due to the amount and repetitive nature of the calculations involved, portions of this method are particularly suitable for computer application.

Storage-Indication Method for Detention-Basin Routing

1. Compute both the "existing" and "urbanized" conditions flood peaks for the detention-basin location.

2. Develop the inflow hydrograph for urbanized conditions, using the methods presented within Section 3.1 of this manual.

3. Develop an initial detention-basin configuration, using the storage-volume estimates obtained from the equations provided within Section 3.3.1 of this manual. An initial outlet-structure configuration should be chosen using best engineering judgment.

4. Develop a stage-storage relationship for the assumed detention-basin configuration.

5. Develop a stage-discharge relationship for the assumed detention-basin/outlet-structure configuration. In this regard, the Federal Highway Administration (FHWA) has developed numerous hydraulic design nomographs which may be helpful in developing stage-discharge curves for culvert outlets [23 and 24]. It should be noted that the minimum HW/D ratio used in the FHWA nomographs varies between the values of 0.3 and 0.5. For determining outflow values at lesser headwater depths, it is acceptable to interpolate between a HW/D ratio of zero and the minimum value provided by the FHWA nomographs.

6. Construct a storage-discharge relationship from the stage-storage and stage-discharge relationship(s) obtained from Steps 4 and 5.

7. Select a routing time interval (Δt). For the initial estimate, this value should be no greater than 0.1 times the rise time of the inflow hydrograph (i.e., $0.1T_r$). The inflow hydrograph must be discretized using this time increment.

8. Prepare the working table and working curve, as shown in Example 3.1. It may be convenient to plot the working curve on logarithmic graph paper due to the wide range of values that

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generally need to be represented. Check the working curve to ensure that it does not exceed the "equal-values" line at any point on the curve. If it does exceed the "equal-values" line, the routing time interval (Δt) is too large. Reduce the routing time and repeat Step 7. The "equal-values" line refers to the locus of points on the working curve that satisfy the equation $S/\Delta t + O/2 - O = 0$ (see Example 3.1 Step 8).

9. Prepare the routing table and perform the routing. The desired outflow hydrograph results from this step.

10. Prepare a graphical representation of the inflow and outflow hydrographs for each flow analyzed (e.g., 2-, 10- and 100-year flows).

This routing procedure (i.e., Steps 3 through 9) may need to be performed numerous times, with different basin and outlet configurations, until the required degree of multi-level, flood-peak reduction is attained.

Example 3.1

A neighborhood detention basin is to be designed in conjunction with a 35-acre apartment development, which is proposed to be located within a critical basin. As a condition of development, the regulatory agency requires that peak flows must be reduced to 85 percent of the existing 2-, 10-, and 100-year peak values. Estimate the maximum required (i.e., 100-year) detention-basin volume, choose an outlet configuration, and perform the flood-routing computations for the 100-year flood event (retention storage will be ignored for this example).

Step 1 – Compute the "Existing" and "Urbanized" Flood Peaks

By application of the Pima County Hydrology method, the following hydrologic data is obtained:

From Table 3.1 of this manual, the one-hour, 100-year precipitation depth (P1) = 3.00".
The Watershed Area (A) = 35 Acres.

Existing Conditions	**Urbanized Conditions**
impervious cover = 10%	impervious cover = 70%
basin factor (n_b) = 0.035	n_b = 0.020
weighted runoff coefficient (C_w) = 0.65	C_w = 0.86
time of concentration (T_c) = 12 min.	T_c = 5 min.
peak flow (Q_{100}) = 173 cfs	Q_{100} = 317 cfs

Peak outflow (Q_o) from the detention basin for urbanized conditions, during the 100-year flood must be limited to Q_o = .85 (173) = 147 cfs.

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Step 2 – Develop the Design Inflow Hydrograph

The following tabular hydrograph is obtained from the method presented within Section 3.1.3.

Rise Time (T_r) = 13.6 min.
Peak Discharge (Q_p) = 317 cfs

Synthetic Inflow Hydrograph for Example 3.1

Time (min)	Discharge (cfs)	Time (min)	Discharge (cfs)
0	0	28	94
2	17	30	75
4	50	32	61
6	91	34	50
8	140	36	40
10	202	38	32
12	274	40	27
14	309	42	23
16	272	44	19
18	233	46	16
20	198	48	14
22	169	50	11
24	140	52	9
26	115	54	8

Table 3.5

Step 3 – Estimate the Required Storage Volume

Equation 3.4 provides an estimate of the required storage volume for an "on-line" detention basin without retention storage.

$$V_S = \frac{1}{12} C_w P_t A \left[1 - \frac{Q_o}{Q_p} \right]$$

Therefore,

$$V_S = \frac{1}{12} (.86)(3)(35) \left[1 - \frac{147}{317} \right] = 4.0 \text{ acre-feet.}$$

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By applying a factor of 1.2, the preliminary estimate, or so-called "first estimate," of storage volume becomes 1.2 x 4.0 = 4.8 acre-feet.

As a first approximation, a basin having a surface area of about two acres, a bottom area of about 1.5 acres, 6:1 side slopes, and a depth of three feet is chosen. A primary outlet structure, consisting of a two-cell, five-foot-wide, three-foot-high concrete box culvert is also chosen. This particular outlet structure will just convey the required 147 cfs at a depth of three feet. Additionally, the basin will store about five acre-feet of stormwater at a depth of three feet.

Step 4 – Develop the Stage-Storage Relationship

Based on the assumed basin configuration, a stage-storage relationship is developed by calculating storage volumes for various depths in the basin. This relationship can be expressed either graphically, or in tabular form, as shown in Table 3.6.

Stage-Storage Relationship
for Example 3.1

Stage/Depth (ft)	Storage (af)
0	0
0.5	0.76
1.0	1.56
1.5	2.40
2.0	3.28
2.5	4.20
3.0	5.16

Table 3.6

Step 5 – Develop the Stage-Discharge Relationship

From hydraulic design charts prepared by the Federal Highway Administration [23, 24], a stage-discharge relationship is developed for the assumed outlet structure (i.e., a two-cell, five-foot-wide by three-foot-high

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CBC). For convenience in developing the storage-discharge relationship (see Step 6), the same stage increments that were used in Step 4 are used in Table 3.7.

Stage-Discharge Relationship
for Example 3.1

Stage/Depth (ft)	Discharge (cfs)
0	0
0.5	9
1.0	30
1.5	55
2.0	85
2.5	115
3.0	150

Table 3.7

Step 6 – Develop the Storage-Discharge Relationship

By combining Tables 3.6 and 3.7, a storage-discharge relationship is obtained as shown in Table 3.8.

Storage-Discharge Relationship
for Example 3.1

Stage/Depth (ft)	Storage (af)	Discharge (cfs)
0	0	0
0.5	0.76	9
1.0	1.56	30
1.5	2.40	55
2.0	3.28	85
2.5	4.20	115
3.0	5.16	150

Table 3.8

Step 7 – Select the Routing Time Interval (Δt)

$\Delta t \leq 0.1\ T_r$
$0.1\ T_r = 0.1 \times 13.6 = 1.36$ min.
choose $\Delta t = 1.36$ min $= .0227$ hrs.

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Step 8 – Prepare the Working Table

A working table for the routing time interval (Δt) is prepared as demonstrated in Table 3.9.

Working Table for Example 3.1
(Δt = 0.0227 hrs)

(1) Stage/Depth (ft)	(2) Outflow (O) (cfs)	(3) O/2 (cfs)	(4) Storage (S) af	(5) Storage (S) (cfs-hrs)*	(6) S/Δt (cfs)	(7) S/Δt + O/2 (cfs)
0	0	0.0	0.00	0.0	0	0
0.5	9	4.5	0.76	9.2	406	410
1.0	30	15.0	1.56	18.9	833	848
1.5	55	27.5	2.40	29.0	1281	1309
2.0	85	42.5	3.28	39.7	1751	1793
2.5	115	57.5	4.20	50.8	2242	2300
3.0	150	75.0	5.16	62.4	2755	2830

Table 3.9

*1af = 12.10 cfs-hrs

(2): from Table 3.7

(3) = (2)/2

(4): from Table 3.6

(5) = (4) × 12.10

(6) = (5)/Δt (Δt in hours)

(7) = (6) + (3)

Step 8 (cont.) – Construct the Working Curve

The working curve is a graphical representation of the relationship between (S/Δt + O/2) and O (from the working table). Generally, it is more convenient to plot the working curve on logarithmic graph paper. The line of "equal values" should also be plotted. If the working curve exceeds this line at any location, a smaller value of Δt should be selected, and Steps 7 through 9 repeated. The working curve for this example is provided on Figure 3.4.

Step 9 – Prepare the Routing Table and Perform the Routing

The routing table and the routing procedure for this example is illustrated in Table 3.10. The results of the routing procedure indicate that the 100-year peak outflow from the assumed detention would be 113 cfs, at a storage volume of 4.14 acre-feet. Since the requirement is to

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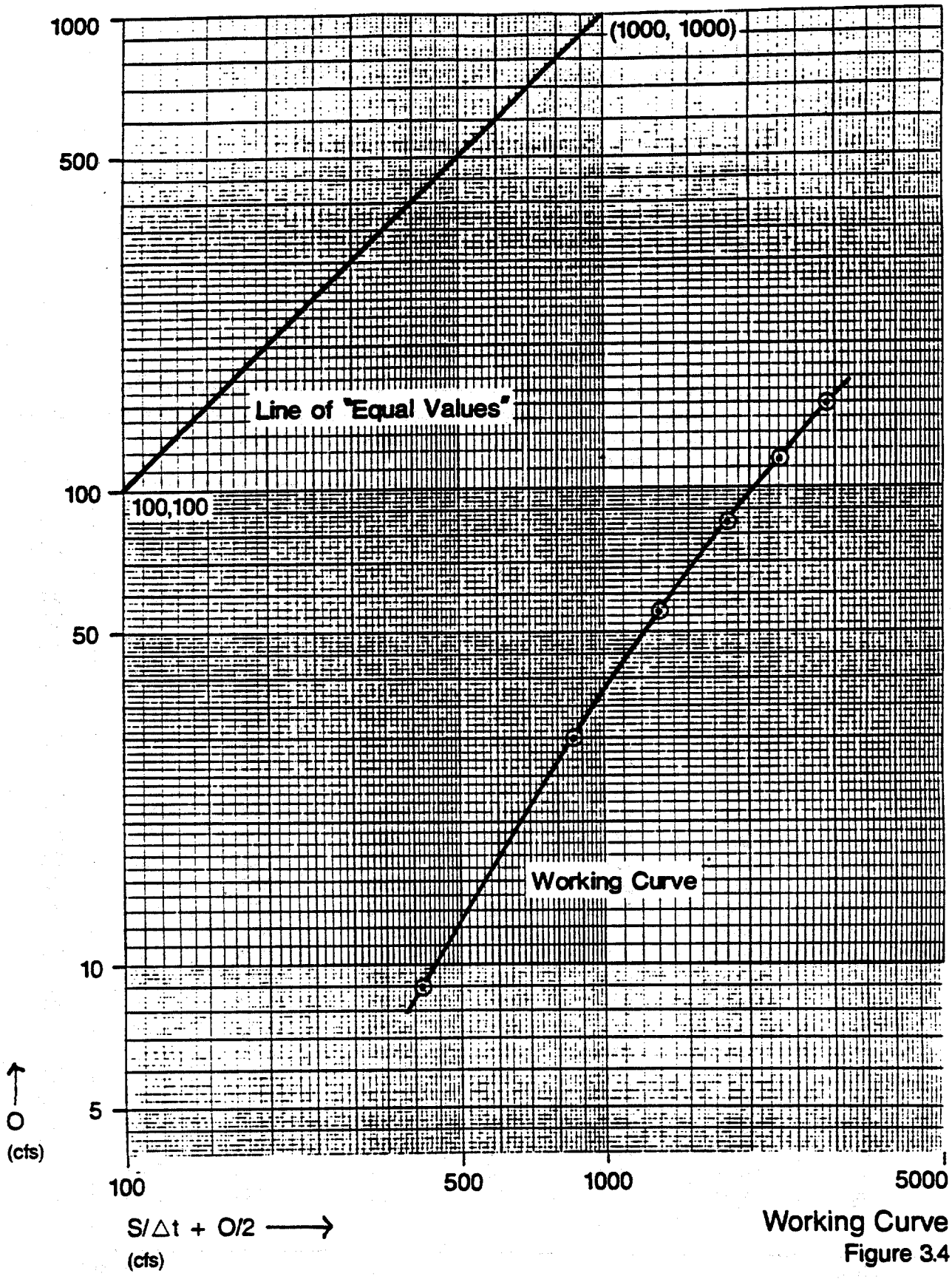

Working Curve
Figure 3.4

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provide a maximum 100-year outflow of 147 cfs, this basin configuration is somewhat over-designed. Steps 3 through 9 may be repeated, with modified basin/outlet configurations, until an optimum design is achieved.

Step 10 – Prepare a Graphical Representation of the Inflow and Outflow Hydrographs

As the final step, a graphical representation of the inflow and outflow hydrographs, as well as the "existing conditions" hydrographs should be prepared as shown on Figure 3.5.

Routing Table for Example 3.1

(1)	(2)		(3)	(4)	(5)	(6)	
Time Step	Time		Inflow (cfs)	S/Δt +O/2 (cfs)	Outflow (cfs)	Storage (af)	Stage (ft)
	(hrs)	(min)					
0	0	0	0	0	0	0.00	0.0
1	0.0227	1.4	8	4	0+	0.01	0.0+
2	0.0453	2.7	28	22	0+	0.04	0.0+
3	0.0680	4.1	51	61	1	0.11	0.1
4	0.0907	5.4	77	123	3	0.23	0.2
5	0.1133	6.8	110	214	5	0.40	0.3
6	0.1360	8.2	144	337	7	0.62	0.5
7	0.1587	9.5	184	493	13	0.91	0.7
8	0.1813	10.9	235	689	22	1.27	0.9
9	0.2040	12.2	282	925	34	1.70	1.2
10	0.2267	13.6	317	1190	49	2.18	1.5
11	0.2493	15.0	292	1446	64	2.65	1.8
12	0.2720	16.3	265	1661	77	3.04	2.0
13	0.2947	17.7	239	1836	88	3.36	2.1
14	0.3173	19.0	214	1975	96	3.61	2.2
15	0.3400	20.4	191	2081	102	3.80	2.3
16	0.3627	21.8	172	2161	107	3.95	2.4
17	0.3853	23.1	152	2216	110	4.05	2.4
18	0.4080	24.5	134	2249	112	4.11	2.5
19	0.4307	25.8	117	2263	113*	4.13	2.5
20	0.4533	27.2	102	2259	113	4.13	2.5
21	0.4760	28.6	88	2242	112	4.10	2.4
22	0.4987	29.9	76	2213	110	4.04	2.4
23	0.5213	31.3	66	2174	108	3.97	2.3
24	0.5440	32.6	56	2127	105	3.89	2.3
25	0.5667	34.0	50	2076	102	3.79	2.3
26	0.5893	35.4	43	2020	98	3.69	2.2
27	0.6120	36.7	37	1962	95	3.59	2.1
28	0.6347	38.1	32	1901	91	3.48	2.1

Table 3.10

* = peak outflow

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Procedure Used to Develop Table 3.10:

1. Columns (2) and (3) are obtained from the synthetic inflow hydrograph (Table 3.5).
2. Column (4) is calculated as follows:
   (4) = previous (4) – previous (5) + [previous (3) + (3)]/2.
   For example, @ time step #5: 490 = 298 – 10 + 202.
3. Column (5): outflow is obtained from the working curve (Figure 3.4) for the corresponding value of ($S/\Delta t + O/2$).
4. Column (6) is obtained by interpolation between values on the storage-discharge relationship (Table 3.8) for the corresponding value of basin outflow in column (5).

3.3.3 Principal Outlet Structures

Multi-Frequency Outlets

Due to provisions within both the Pima County and City of Tucson Floodplain Management Ordinances which require attenuation of the 2-, 10-, and 100-year peak flows, multi-frequency outlet structures may be necessary in the design of many stormwater detention facilities. There are no standardized procedures for the design of an "optimum" multi-frequency outlet structure. The potential combinations of suitable outlets for any particular basin are numerous, and limited only by the creativity and experience of the engineer. Figure 3.6 provides three examples of typical multi-frequency outlet structures, consisting of combinations of orifices, weirs, standpipes, culverts, and spillways. The minimum allowable pipe size for outlet structures is 12 inches in diameter. However, orifice plates with smaller openings may be attached to further reduce the flow capacity of a pipe. An alternative to this type of "compound" outlet structure is the proportional weir. The proportional weir has the unique characteristic of a linear stage-discharge relationship. Properly designed, this allows for an outlet structure that serves to attenuate the entire range of peak discharges between the design frequencies. In other words, with the proportional weir, not only can the 2-, 10-, and 100-year peak flows be attenuated to pre-development values; but so can the entire range of flows between the 2- to 100-year flood frequencies (e.g., 25-year, 50-year, etc.). Specific design criteria for the proportional weir can be found in Sandvik [25] and French [22].

In all cases when multi-frequency flood detention is required, reservoir routing shall be performed for the 2-, 10-, and 100-year frequency floods, at a minimum. The reservoir routing shall demonstrate that post-development flood peaks for these three flow events are no greater than pre-development flood peaks, as required by the applicable Floodplain Management Ordinance of either Pima County or the City of Tucson. Additionally, graphical representations of the inflow and outflow hydrographs for the 2-, 10-, and 100-year flows shall be provided within the hydrologic/hydraulic report.

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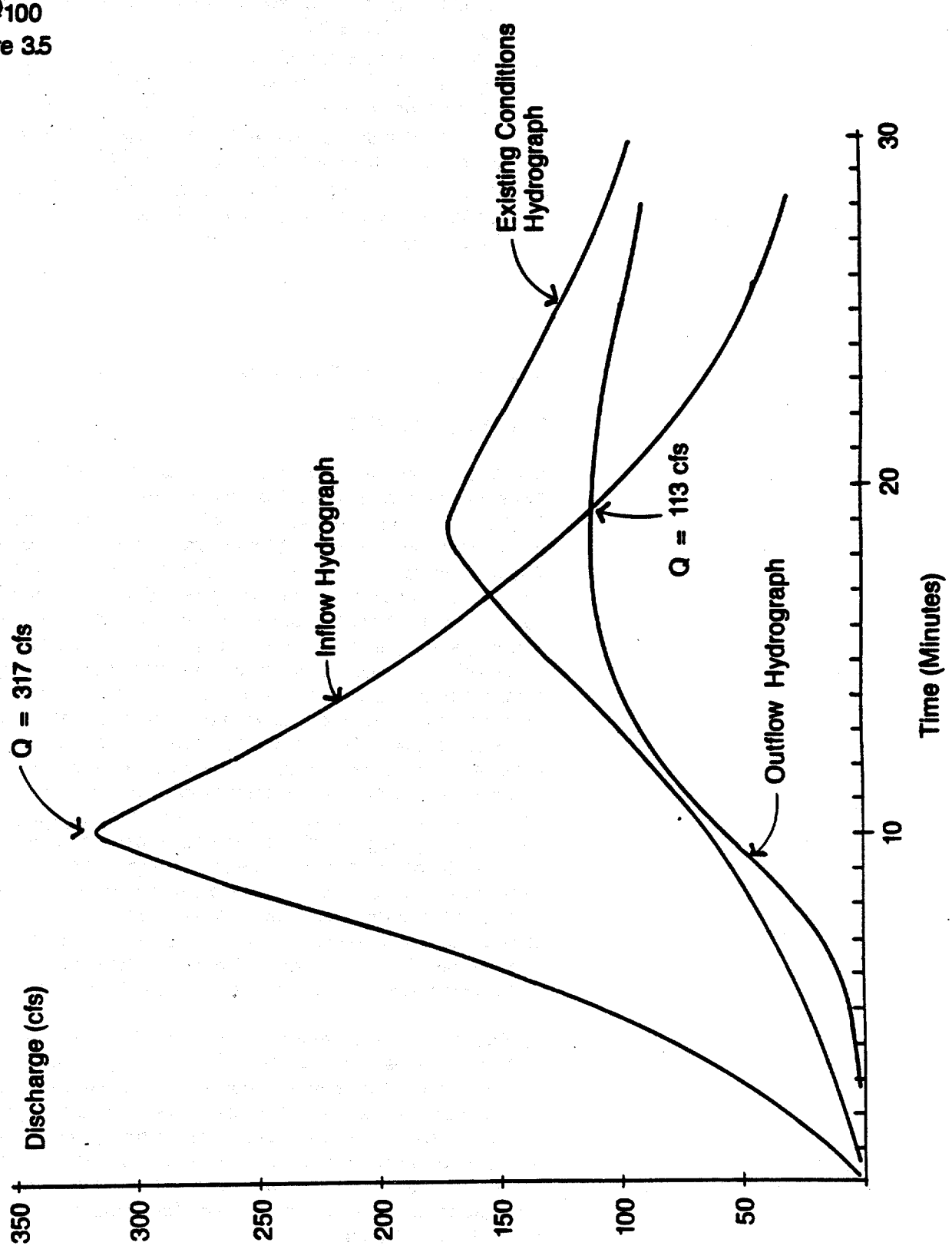
Inflow/Outflow Hydrograph
for Q_{100}
Figure 3.5



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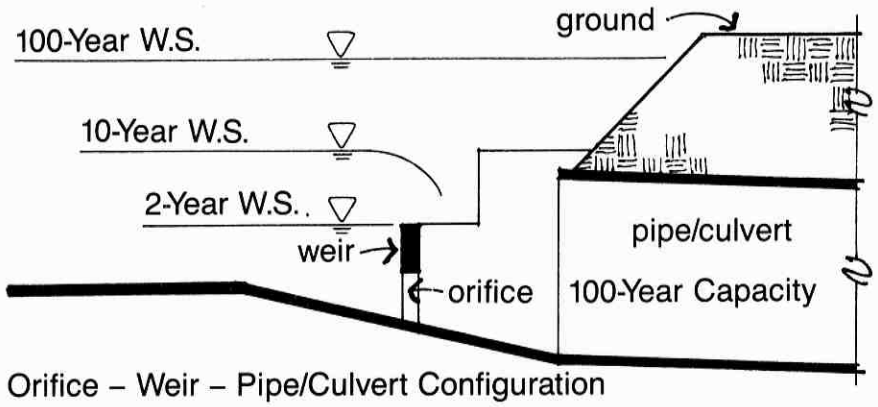
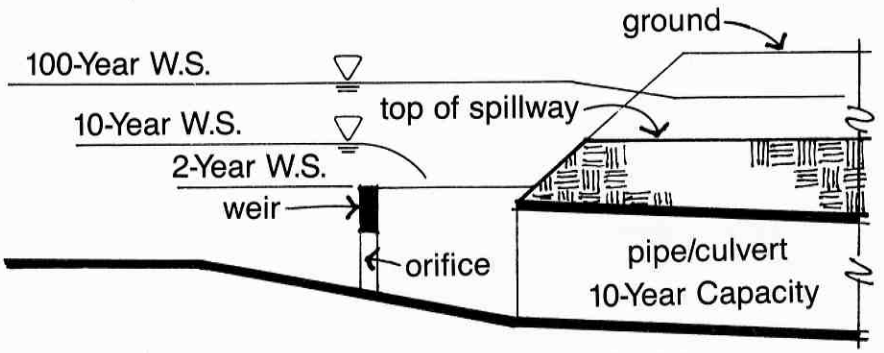
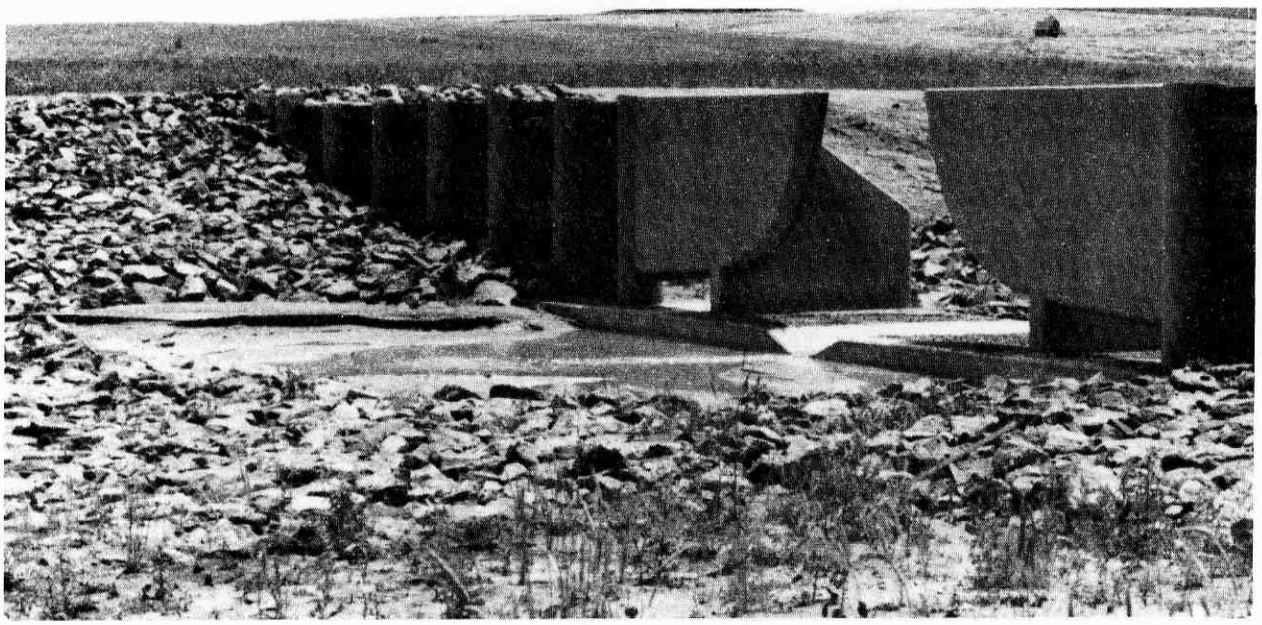
Typical Multi-frequency Outlet Structures
Figure 3.6



Orifice – Weir – Pipe/Culvert Configuration



Orifice – Weir – Pipe/Culvert – Spillway Configuration



Proportional Weir

Trash Racks

Trash racks shall be provided for all pipe and orifice outlets which are 24 inches or less in diameter, and for all grated outlet structures. Trash racks shall be designed to be removable, and have a surface area of at least ten square feet. Openings in the trash rack should not exceed one-half the area of the outlet pipe for mesh screens, or one-third the diameter of the outlet for bar screens. The minimum opening should be no less than one inch. Design of the trash rack should consider the likelihood that unclogging may be necessary when the basin is filled with water. Additionally, a concrete pad is recommended around the portion of the outlet structure to be located within the basin in order to facilitate maintenance of the trash rack.

Erosion Control Downstream of Outlets

Adequate erosion-control measures shall be provided downstream of outlets for detention/retention basins. Such measures should incorporate the criteria provided within "Drainage and Channel Design Standards for Local Drainage," as prepared by the Pima County Department of Transportation and Flood Control District [52].

Local scour at culvert outlets, as well as long-term channel degradation downstream of the basin, must be considered as an integral part of the design of any stormwater detention/retention facility. In the case of on-line detention basins, downstream channel response shall be analyzed assuming no sediment is being supplied from upstream reaches. In many instances, this will result in the need to either install grade-control structures at frequent intervals or to completely line channels with non-erodible material downstream of detention facilities. Protection against local scour at detention-basin outlets shall be designed in accordance with the criteria provided in reference [52] for scour at culvert outlets. This includes such measures as cut-off walls, dumped rock, and rock-lined basins. In cases where velocities of flow at detention-basin outlets exceed existing channel velocities, an energy dissipator shall be provided to allow flows to return to existing conditions, to as great an extent as possible, prior to exiting onto the downstream property.

3.3.4 Embankments

It is recommended that, whenever possible, detention/retention facilities should be constructed with the storage volume located entirely below the natural ground surface adjacent to the basin. However, in some instances this may not be possible, and embankments may be necessary in order to provide the required storage volume. Since the use of embankments may create a potential downstream flood hazard due to failure of the embankment, the following design considerations must be addressed in conjunction with their use:

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State Dam Safety Requirements

The Arizona Department of Water Resources (ADWR), Division of Safety of Dams, has legal jurisdiction over all dams (embankments) which exceeds certain height and storage limits. A "jurisdictional dam," as defined by ADWR, is ". . . either 25 feet or more in height or stores more than 50 acre-feet. If it is less than six feet in height regardless of storage capacity or does not store more than 15 acre-feet regardless of height, it is not in jurisdiction." The ADWR should be contacted regarding specific dam-safety requirements in conjunction with the design of any embankment which might come under their jurisdiction.

Emergency Spillways

As the name implies, emergency spillways are provided for the safe overflow and/or bypass of incoming floodwaters should situations arise that were not taken into account by normal design assumptions. Such situations may include the blockage of the primary outlet structure(s), or the occurrence of a storm event larger than that for which the basin was designed.

Emergency spillway sections shall be incorporated into the design of any detention/retention basins which employ embankments as a mechanism for storing floodwaters. The function of the emergency spillway shall be to ensure that floodwaters which might otherwise overtop the embankment will exit the detention basin and flow downstream in the same manner and direction as would have occurred under predevelopment conditions.

The design of emergency spillways shall incorporate adequate erosion control and energy dissipating measures to ensure the stability of the embankment. The minimum design standard for emergency spillways shall be the unattenuated 100-year peak discharge, as determined by the Pima County or City of Tucson Flood Peak Procedures, for any embankment which does not fall within the jurisdiction of the ADWR. Embankments which do fall within the jurisdiction of the ADWR shall comply with the applicable ADWR design requirements.

Seepage Through Embankments

The flow of water through a pervious foundation produces seepage forces as a result of the friction between the percolating water and the soil medium. As the water percolates upward at the toe of the embankment, the seepage forces lift the soil by reducing its effective weight. In certain cases, this "piping" of the foundation soil can result in the failure of the embankment. Since this process occurs over an extended period of time, it will generally not be a problem with detention basins that drain within a few hours. However, detention/retention facilities that are designed for recreation and/or water re-use purposes, and therefore store water behind an embankment for an extended time, shall be analyzed for potential seepage problems. The analysis shall include an appropriate soils investigation, in conjunction with flow-net or other suitable seepage-analysis techniques. If the analysis indicates that potentially harmful

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seepage through or underneath an embankment is possible, then applicable methods of seepage control shall be incorporated in the design. Methods which have been successfully used to reduce seepage include slurry trenches, sheetpiling, and concrete cut-off walls.

An additional consideration is the seepage of retained runoff into soils having shrink/swell characteristics, and seepage into collapsible soils. If structures are to be located adjacent to retention basins, then appropriate geotechnical investigations should be undertaken which address these items.

3.3.5 Low-Flow Channels

Low-flow channels and sloped basin floors should be incorporated in the design of all "dry" detention basins in order to prevent any ponding of nuisance water. Low-flow channels should be designed with a minimum longitudinal slope of 0.005 feet/foot, and should be designed with a capacity to convey the pre-development 2-year flood peak, if practical. Concrete-lined low-flow channels may be designed with a minimum longitudinal slope of 0.002 feet/foot. The basin floor shall be graded to drain either toward the low-flow channel or the outlet structure. The minimum floor slope shall be 0.005 feet/foot.

3.4 Sedimentation Impacts

3.4.1 Estimating Sediment Delivery

Deposition of sediment is an unavoidable consequence associated with the construction of detention basins on natural watercourses within Pima County and, to a somewhat lesser degree, the City of Tucson. In order to mitigate the effects of sedimentation, detention basins must be designed in a manner that incorporates additional storage volume which will allow for a certain amount of sediment build up. Additionally, an inspection and maintenance schedule should be implemented to periodically monitor sedimentation within the detention basin, and to remove excess sediment as necessary.

The additional storage volume which is to be incorporated in the design of "on-line" detention facilities (see definition of "on-line" detention in Section 5, Chapter 1), shall be determined from Equation 3.8. This volume is approximately equal to ten times the average-annual sediment yield from watersheds within Pima County and the City of Tucson, and roughly one-half to two-thirds the sediment transport expected during a 100-year flow event.

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$$V_{SD} = 500\ A\ C_p$$

Equation 3.8

Where;

V_{SD} = additional detention/retention-basin volume required for sedimentation within an "on-line" facility, in cubic feet;

A = drainage area contributing to detention/retention basin, in acres, and;

C_p = fractional portion of the drainage area which will be contributing sediment. Areas which will not contribute sediment include all impervious areas, sodded areas, and other areas which have surface treatments that prevent soil loss.

The additional storage volume which is to be incorporated in the design of "off-line" detention facilities (again, see definition in Section 5, Chapter 1) shall be 75 percent of V_{SD}, as determined from Equation 3.8.

3.4.2 Methods for Control of Sedimentation

Sedimentation impacts upon detention/retention facilities shall be controlled through a periodic inspection and maintenance schedule. In order to facilitate future maintenance, permanent concrete markers shall be installed at the level of the basin floor in order to define the limits for sediment removal. Additionally, graduated posts shall be installed at each concrete marker to a height necessary for adequate delineation of the upper level of sediment build-up, which corresponds to the additional volume (i.e., V_{SD}) provided by Equation 3.8. At a minimum, sediment build-up shall be inspected on an annual basis, and shall also be inspected after any major inflow to the basin. Excess sediment shall be removed from the basin at such a time that one-half of V_{SD} has accumulated. This level of sediment build-up shall be clearly marked on the graduated posts installed within the basin. All sediment removed from the detention/retention basins shall be disposed of either at an authorized sanitary landfill or at any other suitable location approved by Pima County or the City of Tucson.

Sediment removal within a detention basin may be facilitated by the use of a "sediment trap" at the basin inlet, which will concentrate the majority of incoming bed load within a small portion of the facility. Sediment traps should be provided in conjunction with all detention basins which are intended as multi-use facilities. A conceptual sketch of a typical detention-basin sediment trap is provided on Figure 3.7. Following is a list of guidelines for the design of efficient sediment traps.

1. The additional sedimentation volume V_{SD}, as determined from Equation 3.8, should be provided within the sediment trap at an elevation below the invert of the inflow channel.

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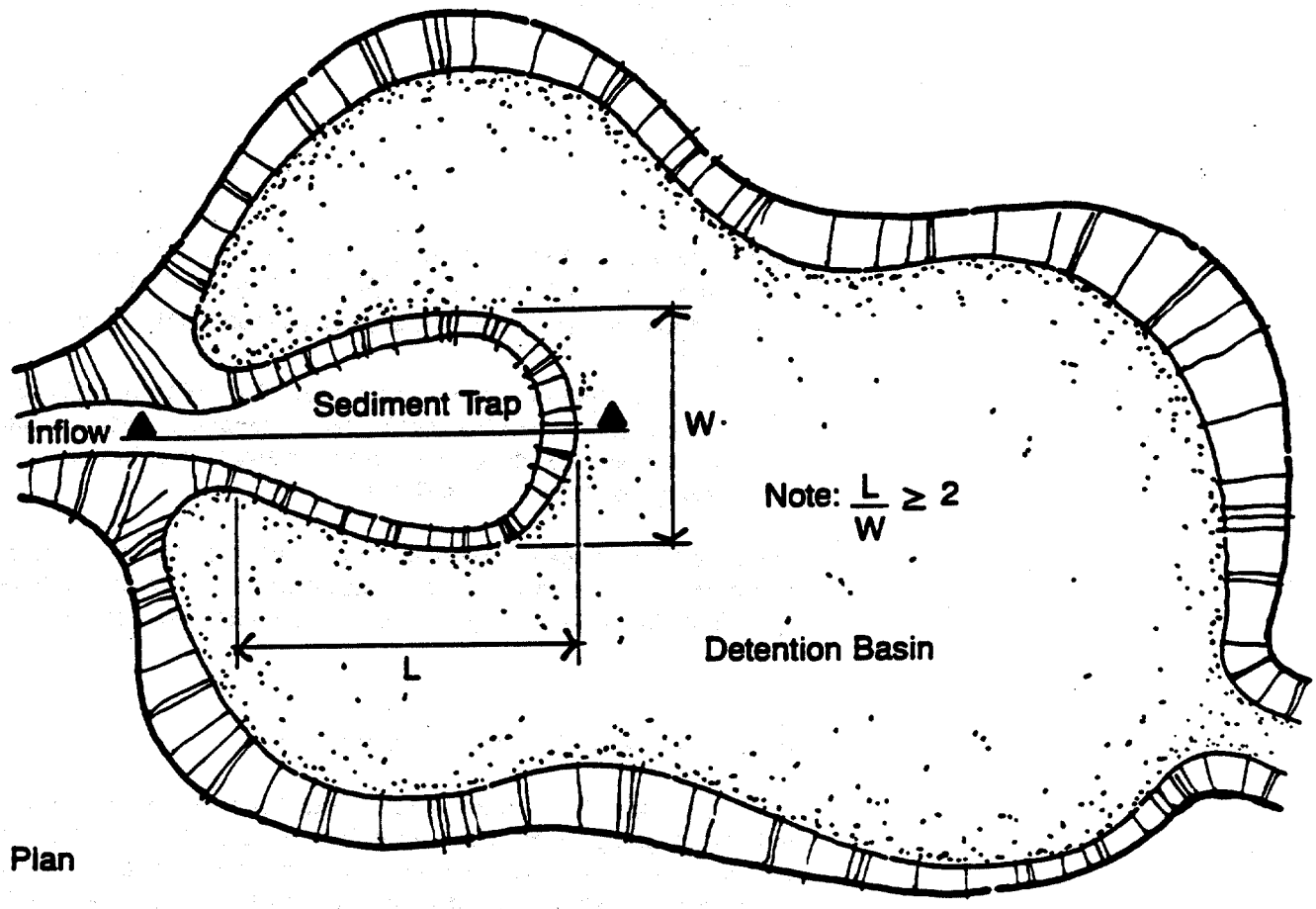

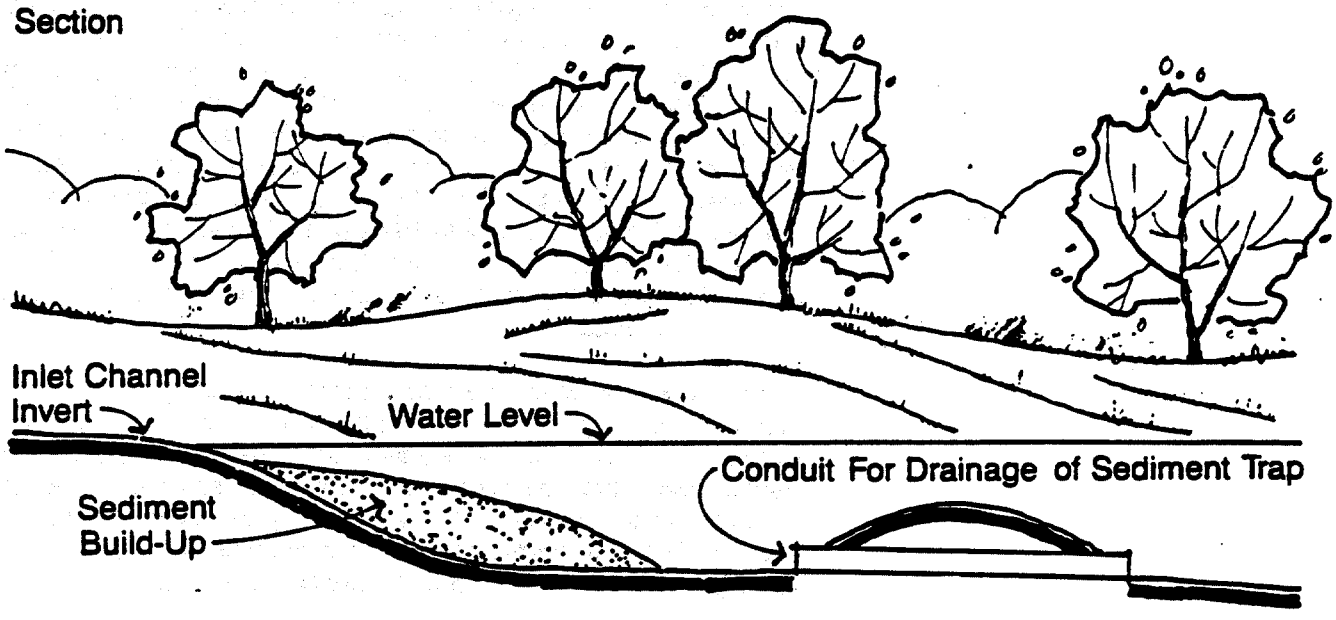

Sediment Trap Concept

Figure 3.7

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2. The length/width ratio of the sediment trap should be a minimum of 2:1, with the length measured along a line between the inlet and outlet.

3. The basin shape should be wedge-shaped, with the narrow end located at the inlet to the basin (see Figure 3.7).

4. Provisions for total drainage of the sediment trap must be provided.

3.5 Criteria for Special Detention/Retention Methods

3.5.1 Surface Storage

Surface storage refers to any stormwater storage facility which detains or retains runoff at ground level. Except in certain cases, when land-use restraints may dictate the use of underground storage, stormwater storage facilities within Pima County and/or the City of Tucson will rely quite heavily upon surface storage as a means for satisfying detention/retention requirements.

Various types of detention/retention facilities which utilize surface storage include:

Open Space and Common Areas.
Landscaped areas and common areas, which are typically provided in conjunction with higher-density residential development, afford an excellent opportunity for on-site detention/retention. Positive drainage toward the outlet structure(s) is especially important within this type of facility in order to prevent the accumulation of standing water, and therefore preserve the aesthetic appeal of such a facility.

Pedestrian Plazas and Courtyards.
Similar to the common areas of residential development, pedestrian plazas and courtyards can be used for stormwater storage within commercial/industrial areas. Such facilities should be designed to avoid public inconvenience, especially during frequent, small-magnitude storm events.

Roadway Embankment Storage.
When feasible, use of roadway fill slopes as an embankment for a detention basin provides an economical means of stormwater storage. Special considerations must be given both to the stability of the embankment and to the protection of the embankment from erosion. Additionally, State of Arizona dam-safety requirements may need to be addressed if the embankment height and/or the potential storage volume exceeds certain limits (see Section 3.3.4).

Regional Detention Basins.
For the purposes of this manual, regional detention basins refer to stormwater storage facilities which intercept the flow from an upstream watershed that has a drainage area greater than one square mile. Design of such facilities within Pima County and/or the City of Tucson is intended

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to be in conjunction with the implementation of basin management plans prepared by, or under the direction of, the Pima County Flood Control District or the City of Tucson Engineering Division. In general, the criteria and methods presented within this manual are not applicable to the analysis and design of regional detention basins.

Listed below are certain criteria which will apply to the design of surface storage detention/retention facilities that are planned to be located within either the City of Tucson or Pima County:

1. Grading of any surface storage facility shall comply with the requirements specified within Chapters 1 and 4 of this manual.

2. Sedimentation within detention/retention basins shall be inspected and controlled, as specified within Section 3.4 of this manual.

3. Maximum disposal times of stormwater runoff for detention/retention basins shall be as follows:

   a. 12 hours for detention/retention facilities which intercept runoff from an upstream watershed area which is up to ten acres in size.

   b. 24 hours for detention/retention facilities which intercept runoff from an upstream watershed area that is greater than ten acres in size.

4. Detention basins which do not incorporate stormwater retention must provide positive drainage from all points within the basin to the outlet structure. If areas of standing water develop over time, regrading of the basin will be required to insure positive drainage.

5. A soils report shall be required in conjunction with the design of each surface storage facility which utilizes infiltration as a method of basin drainage. The report shall, as a minimum, address soil classification, soil erodibility, soil permeability, slope stability, and ground-water elevations.

6. Outlet structures for detention facilities shall be constructed, whenever possible, such that they are physically opposite inlet structures.

7. No "on-line" detention facilities shall be permitted if any portion of the wash is in a natural state upstream of the proposed basin, or if the upstream watershed is greater than 100 acres, unless approval is first granted by Pima County or the City of Tucson.

8. Grated outlet structures shall not be overdesigned to account for debris blockage and clogging. Rather, a debris screen or trash rack shall be designed to prevent blockage of any outlet structure which incorporates grates.

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9. The Pima County or City of Tucson Parks and Recreation Department should be contacted regarding the detention or retention of runoff within any public areas.

10. Finished-floor elevations of structures shall be a minimum of one foot above the 100-year water-surface elevation of any adjacent detention/retention basin.

3.5.2 Parking Lot Storage

A special case of surface storage is the use of parking lots for detention/retention. The use of parking lots is an economical option for meeting detention/retention requirements in high-density commercial and industrial developments. Planning of areas within a parking lot which will accept ponding should be such that pedestrians are inconvenienced as little as possible. Deeper areas should be confined to remote areas of parking lots, whenever possible. The maximum depth of ponded water within any parking lot location shall be one (1) foot. Drainage of parking lots can be accomplished by means of dry wells (if permitted), curb openings, weirs, storm drains, orifices in walls, gated outlets, etc.

The minimum longitudinal slope permitted within parking-lot storage facilities is 0.005, unless concrete valley gutters are provided. With concrete valley gutters, a minimum longitudinal slope of 0.002 may be permitted.

3.5.3 Rooftop Storage

The use of rooftops as storage areas for runoff is not an acceptable method of meeting the detention/retention criteria of either Pima County or the City of Tucson.

3.5.4 Underground Storage

This type of storage involves the construction of underground tanks, pipes, or vaults which accept stormwater runoff by means of storm-drain pipes and catch basins. Due to the high cost of of this type of installation, it is generally limited to high-density developments, where surface storage is not feasible due to either the scarcity or high cost of land, or both.

Underground storage facilities must be provided with some method of drainage (e.g., gravity drains, pumps, or infiltration). In all cases, manholes (or some other means of access to the underground storage facilities) must be provided for maintenance purposes.

3.5.5 Subsurface Disposal

Methods for underground disposal of stormwater runoff which have been successfully used throughout the country include slotted drains, infiltration trenches, and engineered basin floors. The analysis and design of these methods is well documented within a Federal Highway Administration publication entitled **Underground Disposal of Stormwater Runoff**

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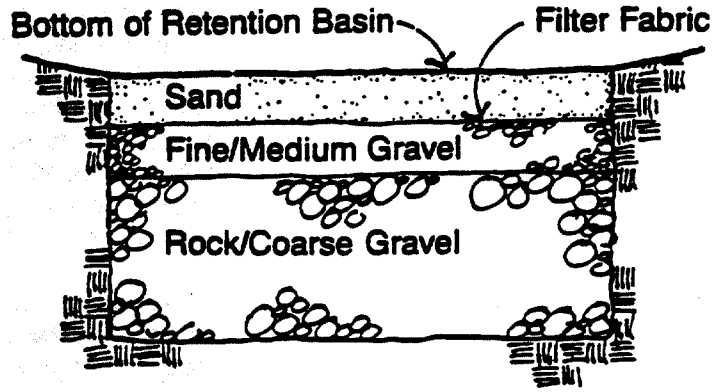
[57]. This publication is available from the offices of both the City and County Engineer and from the University of Arizona library. The engineer engaged in the design of such facilities is referred to this publication for specific design criteria. A conceptual sketch of a typical engineered-basin-floor installation is provided on Figure 3.8

Due to the generally deep groundwater levels and permeability of sub-surface strata within the semi-arid southwest, the most common method of sub-surface disposal of stormwater, historically, has been by the use of dry wells. Figure 3.9 provides an example of a typical dry-well installation.



Conceptual Cross Section
Engineered Basin Floor
Figure 3.8

The following list of requirements and criteria shall be utilized in the design and construction of dry wells (or other methods of subsurface disposal of stormwater). The reader is also referred to current dry-well policies adopted by both Pima County and the City of Tucson.

1. The infiltration surface of the subsurface disposal facility must be located a specified minimum distance from the static groundwater table, both horizontally and vertically, depending on the type of development proposed. The Pima County Flood Control District or the City of Tucson Engineering Division should be contacted for specific criteria regarding this item.

2. The design of dry wells must include provisions for trapping sediment within a settling chamber. This measure will significantly increase both the efficiency and useful life of the well. Once a year, at a minimum, the settling chamber shall be inspected, and it shall also be inspected after any major inflow to the dry well. Sediment shall be removed from the chamber at such a time that approximately one-half of its capacity is filled. This level of sediment build-up shall be clearly marked on the inside of the settling chamber. All sediment removed from a settling chamber shall be disposed of either at an authorized sanitary landfill or at any other suitable location approved by Pima County or the City of Tucson.

3. A test well shall be installed for any retention facility utilizing dry wells for stormwater disposal. This test well may then be utilized as one of the functioning dry wells within the retention facility. For

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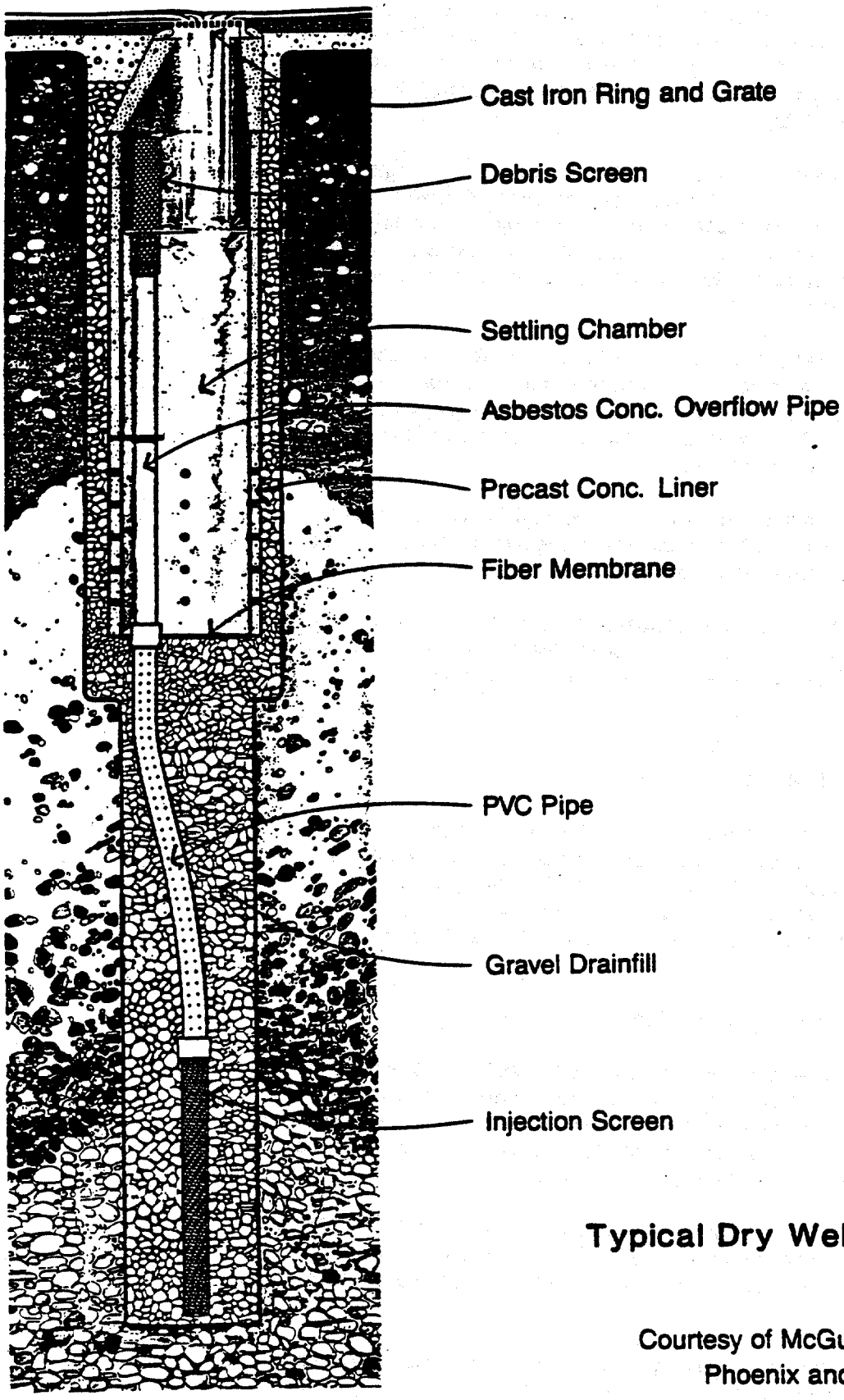

Typical Dry Well Installation

Figure 3.9

Courtesy of McGuckin Drilling, Inc.
Phoenix and Tucson, Arizona

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purposes of design, the "initial" well-injection rates (determined from the test well) shall be multiplied by the factor 0.5 in order to establish "aged" well-injection rates to be used for purposes of determining the required number of dry wells ultimately needed within the facility.

4. Infiltration rates of dry wells, infiltration trenches, or engineered basin floors shall not be used as outflow rates in flood-routing procedures. Any detention/retention basin which relies solely upon infiltration as its method of drainage shall be sized to contain the maximum storage volume that would be required without considering an outflow rate.

5. Disposal methods which utilize infiltration shall not be permitted for stormwater runoff which carries significant concentrations of sediment. This includes stormwater runoff flowing through sand-bed channels, as well as stormwater runoff emanating from a predominantly natural watershed.

6. During site development, all dry wells shall be securely covered with filter cloth or other materials to prevent the introduction of excessive sediment into the settling chamber.

7. Retention of runoff emanating from industrial developments and infiltration of runoff to the sub-surface will be handled on a case-by-case basis by the appropriate reviewing agency.

3.6 Basin Design Requirements

Requirements regarding basin side slopes, depths, security barriers, and use of multiple basins are provided below. These requirements are reiterated and expanded upon in Chapter 4, Section 4.3.1, where they are given in conjunction with guidelines for plan-view basin shapes, design of multiple basins, basin screening, and design of inlet and outlet structures. Refer to Section 4.3.1 for illustrations exemplifying these requirements.

3.6.1 Basin Side-Slopes and Depths

Varying side-slope gradients shall be provided for basins one acre and larger. Smooth transitions must be provided between grades, and the recommended horizontal distance for each slope gradient should vary by at least two feet (example: 3:1, 5:1, 7:1). Continuous uniform slopes shall not exceed 20% of the basin perimeter.

In basins containing human-activity zones, access slopes of 8:1 or flatter must be coordinated with these zones. There shall be a maximum of 100 feet either to the base of an access slope or to a 4:1 basin side-slope.

Transitions from slopes to level ground at the top and bottom of basins shall be smooth curves.

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The following slope/depth ratios are required for multi-use basins:

1) A maximum of 2:1 for protected side-slopes and 3:1 for unprotected slopes, where depths are less than three feet;

2) A maximum of 4:1, where depths are equal to or greater than three feet.

A benched configuration is required for basins in excess of six feet deep. Benches within basins shall be proportioned so the bench width is at least three times the height of the slope above it, measured from the lowest point on the top of the slope above the bench. The minimum width of a bench shall be six feet.

The maximum depth to first bench, or basin floor, shall conform to the previous slope depth ratios.

All detention basin floors must be graded to drain.

3.6.2 Security Barriers

Basins designed in accordance with the requirements contained in this manual should prelude the need for fencing, such as chain-link. However, in the following instances security barriers are required. These barriers may consist of vegetation, masonry, wood, or chain-link. Vegetation, or a combination of vegetation and structural materials, is preferred.

Security barriers must be provided at the top of all basin slopes steeper than 4:1, where water depths exceed two feet.

Vegetative barriers must be of a width equal to or greater than overall height, with density sufficient to restrict access. If vegetative screening is to be used, plant materials must be in place and established at the time the occupancy permit is requested.

A minimum 42-inch barrier height is required for all basins.

Detail sections of proposed fences, if required, are to be shown on paving and grading plans or development plans, as appropriate.

Local, private-basin fences must be 42 inches, or higher, on any side of basin where buildings or other restrictive structures are within five feet of the basin, and have no points of exit or entry into the basin area.

Fencing, if required, shall not restrict the hydraulic capacity of structures.

Railings must be provided, as required by the Uniform Building Code, for retaining walls on any inlet and outlet structure headwalls and wingwalls.

Signs must be provided to inform the public of the basin purpose, and the potential safety hazard from stormwater detention/retention.

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3.6.3 Multiple Basins

Where the single-basin depth required exceeds ten feet, or where the basin volume exceeds 50 acre-feet, multiple basins shall be used or guidelines from the manual entitled "Guidelines for the Development of Regional Multiple-Use Detention/Retention Basins in Pima County, Arizona" shall be employed.

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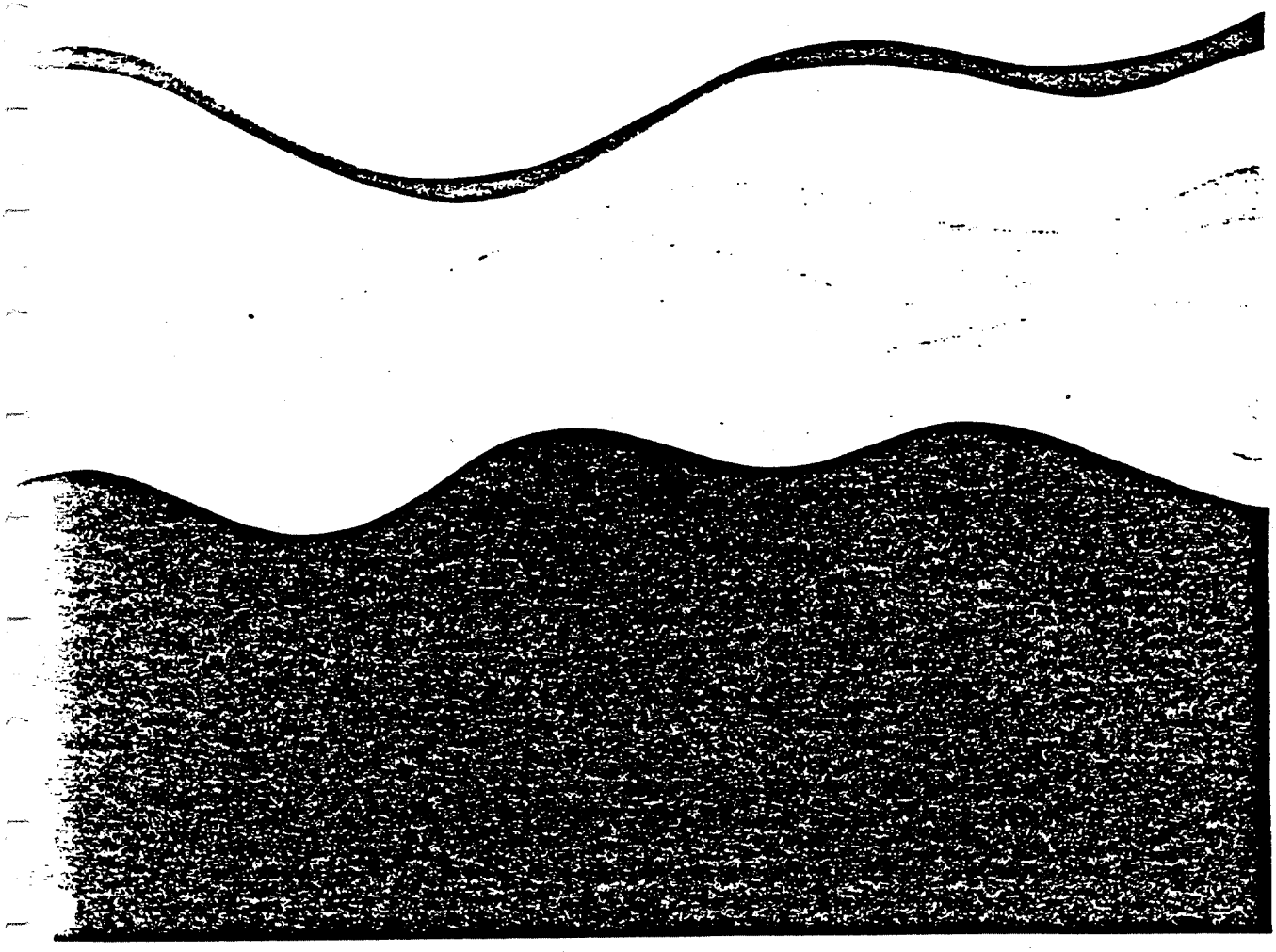
Multiple Use Concepts and Aesthetic Design Guidelines



CHAPTER IV

IV. Multiple-Use Concepts and Aesthetic Design Guidelines

This chapter addresses aesthetic considerations of detention/retention basin design primarily with regard to multiple-use concepts, grading, and landscaping. The goal of all detention/retention basins is to be multi-use, regardless of size. Multiple-use alternatives are presented, as well as guidelines for basin siting and surface treatments. Requirements previously listed in Section 3.6 regarding basin grading, use of multiple basins, and security barriers are also expanded upon and illustrated in this chapter.

4.1 Basin Siting

Location of retention/detention basins can influence effectiveness in controlling stormwater, potential for use by surrounding residents, and perception of the site as an amenity.

Guidelines for siting are presented here for the most commonly observed and recommended basin locations. These include, but are not limited to:

Project Scale Sites
Individual parcels (commercial and industrial sites only)
Roadside locations

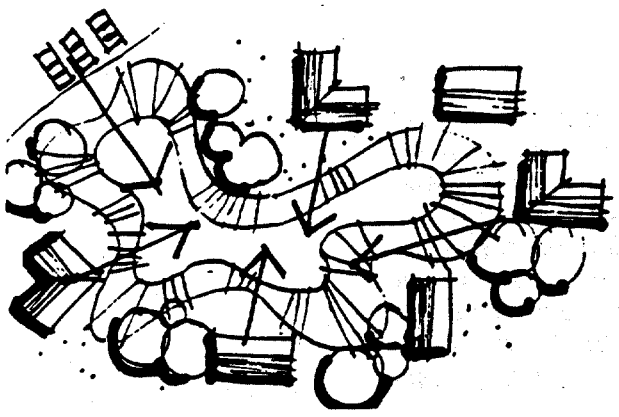
4.1.1. Project Scale Sites

Where individual lot retention is not feasible or desired, a common facility may be provided to detain or retain runoff from the project. This scale of basin may be employed at industrial or office parks, multi-family housing complexes, or within single family neighborhoods.

In a residential setting, a project-scale basin provides more than a visual amenity. A centralized location may encourage active use of the basin area for recreation or relaxation.

Guidelines: Basin Siting in Residential Projects

Locate basin in a centralized area for easy access and visibility.



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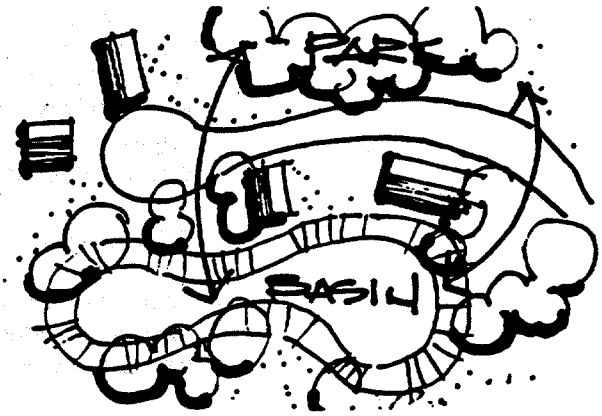
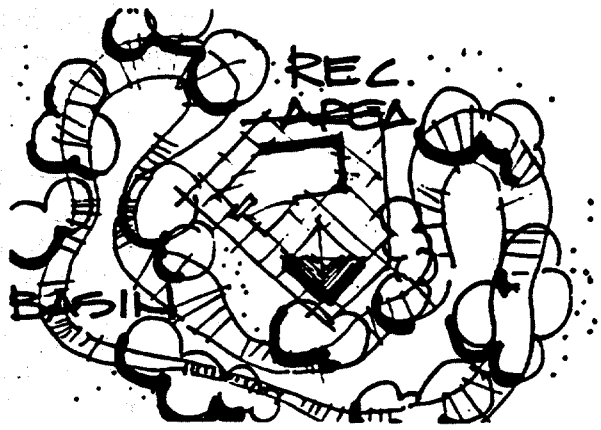
Provide open space links from basin to any existing or planned open space system. These can be pedestrian or bike paths, or buffer areas between different land uses.



Coordinate basin site with other on-site recreation facilities.



Coordinate basin site with community open space and recreation facilities (schools, churches, or parks).

4.1.2. Individual Parcels

Retention of stormwater runoff on individual lots may occur on industrial or commercial sites. This manual does not apply to single-family residential lots. Larger scale sites have the option of combining basins with parking areas, peripheral landscaped areas, buffer strips, street frontage, or with open space between and around buildings. On smaller parcels, basins are more likely to be integrated with landscaped areas only. Lot shape and size, land use, and required stormwater volumes for retention/detention purposes all play important roles in siting basins, and in their size. Comply with all applicable ordinances, regulations and design policies when siting retention/detention basins.

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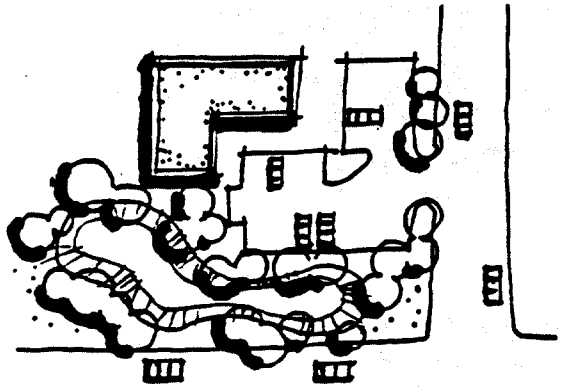
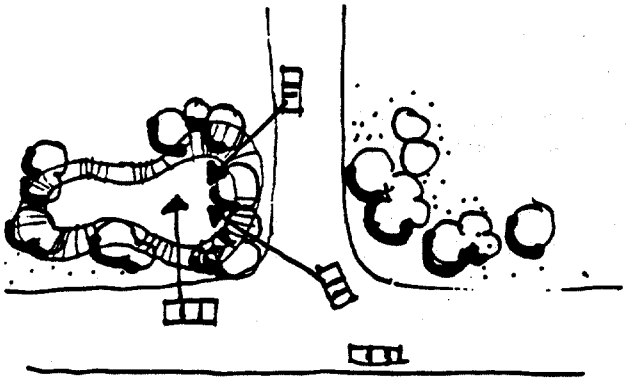
Guidelines: Basin Siting on Individual Parcels

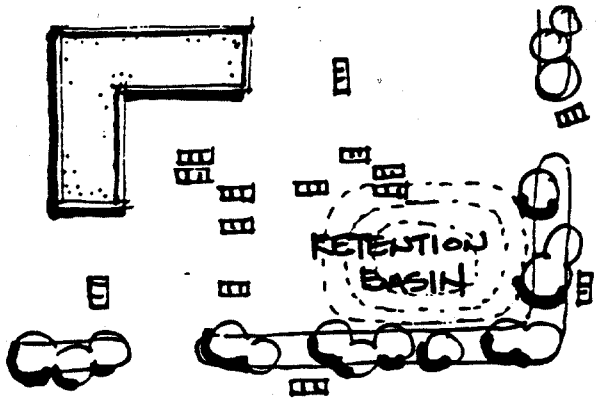
Locate basins in landscaped areas where possible. The appropriate reviewing agency (Pima County of City of Tucson) should be consulted regarding restrictions on use of drywells for retention purposes in landscaped areas.



Respond to basin views from adjacent streets and major vantage points.



If retention storage on pavement is unavoidable, locate in less frequently used areas.



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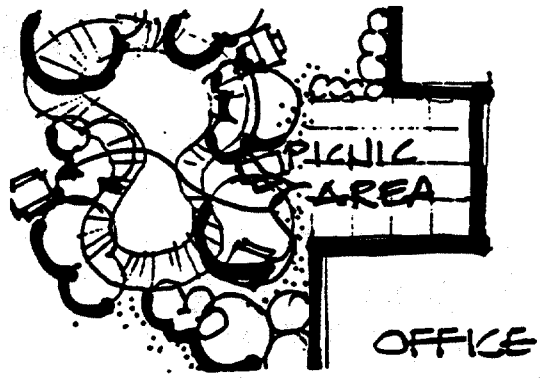
Site basin to encourage multiple use.



4.1.3. Regional Facilities

In an urban/suburban context, several developers may collaborate to construct a common basin to serve more than one project. At this scale, connection to community recreation or open space systems is important. Oftentimes, facilities of this size can create an open space system, or be the catalyst in planning for one. Refer to "Guidelines for the Development of Regional Multiple-Use Dentention/Retention Basins in Pima County, Arizona" [76] for information regarding such basins.

Guidelines: Siting Regional Basins

Include comprehensive assessments of environmental impacts (vegetation, wildlife, hydrology, viewsheds) in the siting process.

Larger numbers and varieties of people may be affected by site selection and multiple-use opportunities; research and planning efforts should reflect this.

4.1.4. Roadside Basins

Retention basins located along roadways can function as a buffer or screen between neighborhoods and major streets, and create an attractive entry space for a new development project. Comply with all applicable right-of-way, traffic safety, and landscape ordinance requirements and policies when siting roadside basins.

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4.2 Multiple-Use Concepts

Specific multi-use alternatives for a retention/detention basin should be appropriate for the size and configuration of the basin, and relate to surrounding land use. Appropriate uses include:

Project Amenity
Active Recreation
Passive Recreation
Urban Open Space
Preservation and enhancement of native plant communities
Water harvesting for recharge and re-use
Wildlife Habitat

4.2.1. Project Amenity

In its simplest form, retention or detention basins should be much more than an engineering facility designed to control stormwater. The ability of a basin to function as a visual amenity or focal point should not be overlooked. As a landscaped space, there are many attractive solutions acceptable under the guidelines set forth in this manual. The basin space can promote feelings of lower density development, add topographic interest to flat terrain, and function as a node or focal point within a community, especially if it is landscaped as an oasis in otherwise desert environs.

4.2.2. Active Recreation

Active recreation involves both structured and unstructured activities requiring physical activity. Active recreation often requires larger basins. These may include:

Jogging
Walking
Bicycling
Playground Activities
Fitness Training
Equestrian Activities
Skate Boarding
Roller Skating
Field Sports
Court Sports
Lawn Sports
Horseshoes
Archery
Golf
Balloon Launching

These activities have specific spatial, orientation, or equipment needs. Site furnishings and recreational equipment may be located in or outside of the flood zone.

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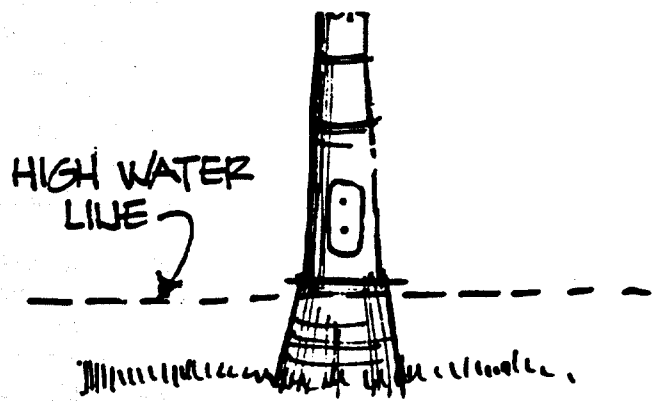
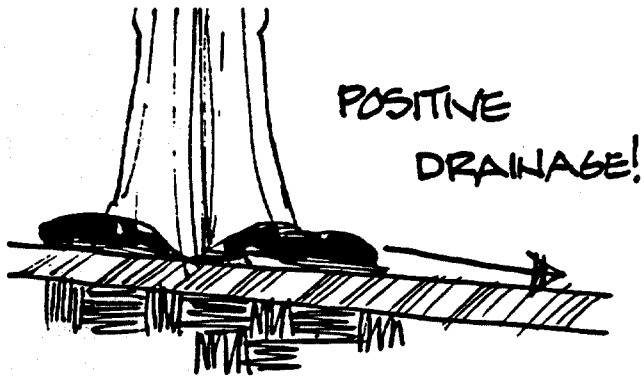
Guidelines: Active Recreation

Provide adequate space, orientation, and groundplane treatments for each desired use.

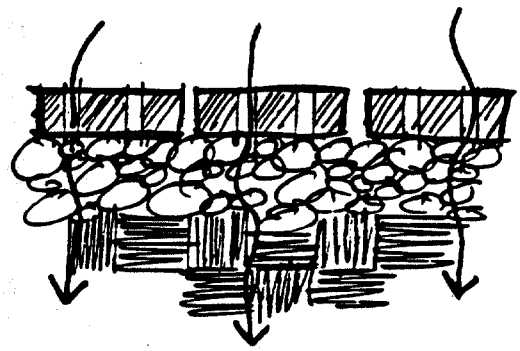
If night use is desired, light poles should have wire connections (and hand-holes) located above the high water mark.



Assure positive drainage for paved surfaces in the flood zone (refer to Chapters II and III of this manual for minimum slope requirements), or



Use porous pavements, where permitted, in the flood zone.



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Use concrete and coated metal products within the flood zone. Avoid the use of wood.

Use vegetation to separate activity areas and provide shade.

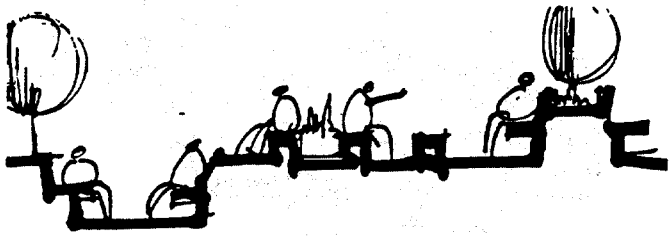
4.2.3. Passive Recreation

Passive recreational use is typically oriented to small groups and individual users. This multi-use concept does not always require special facilities, nor large areas of space. Site design should delineate spaces and provide furnishings or conveniences for users in a relaxed mode. Passive recreational uses include:

- Viewing
- Sitting/Relaxing
- Reading
- Writing or Sketching
- Talking
- Sunbathing
- Board or Card Games
- People Watching
- Concert Going
- Napping
- Picnicking
- Nature Study
- Star Gazing

Guidelines: Passive Recreation

Provide a variety of places, structures or furnishings for people to sit.



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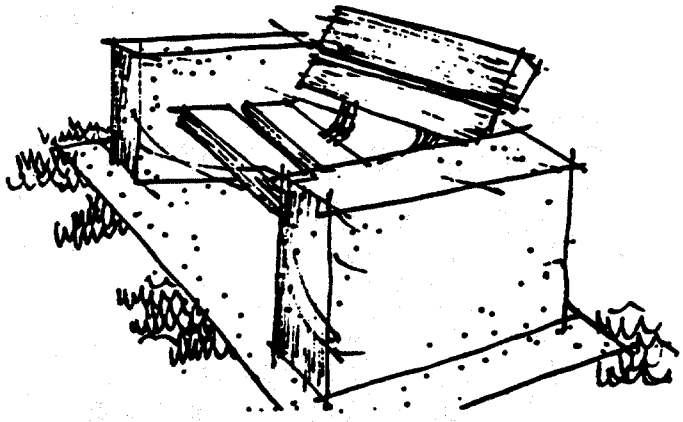
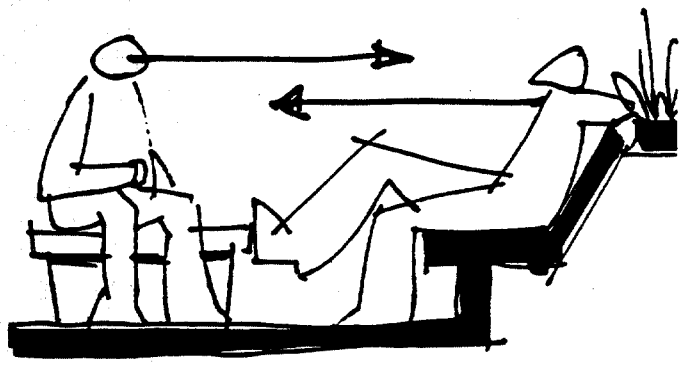
Select all site furnishings for their tolerance to inundation or locate outside of inundated areas.



Locate site furnishings for individual privacy and for small groups.



Use vegetation to shade sitting areas and separate spaces.

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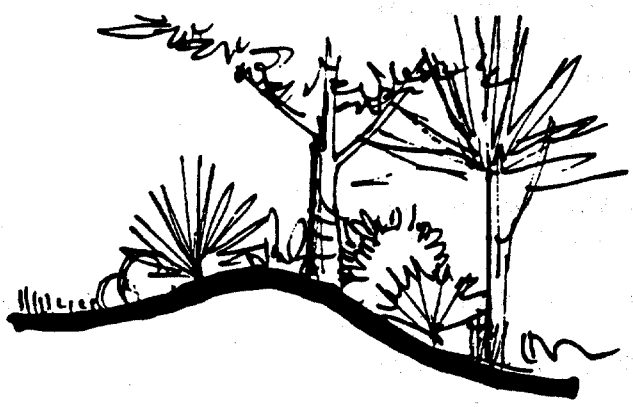
4.2.4. Urban Open Space

The opportunity to use basin sites primarily as open space is strongly urged. Open space within urbanized areas of Pima County is becoming more valuable as growth continues. Open space provides psychological relief from man-made environments and provides potential for city-dwellers to enjoy the out-of-doors. Vegetation also helps filter noxious materials from the air.

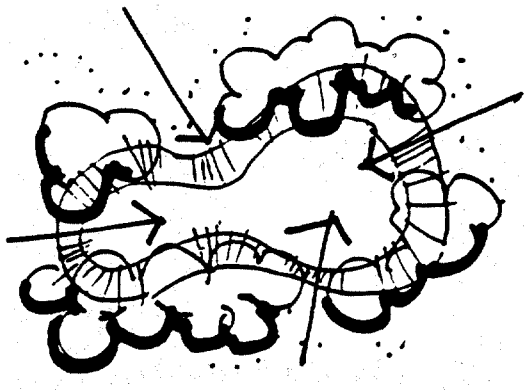
Guidelines: Urban Open Space

Provide a variety of visual sequences from both within and outside the basin.

Emphasize the role of plant materials provide color, contrasting forms and textures.



Provide access to the site from a variety of points.



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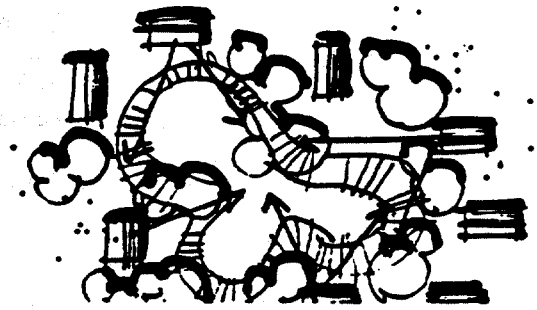
Site basin where it is highly visible and can be enjoyed and used by residents.



4.2.5. Preservation of Native Plant Communities

Tucson's sense of regionalism is often threatened by new development replacing the native landscape with imported materials and exotic plantings. Preservation of native plant communities and topographical features maintains the distinctive character of the Sonoran Desert. This is especially appropriate along scenic routes, or major thoroughfares and business areas. Additional benefits include its wildlife habitat value, low water-use requirements, and lower development costs. This concept includes both preserved and re-established natural environments. It is appropriate at any scale, and may be combined with other uses.

Guidelines: Preservation of Native Plant Communities

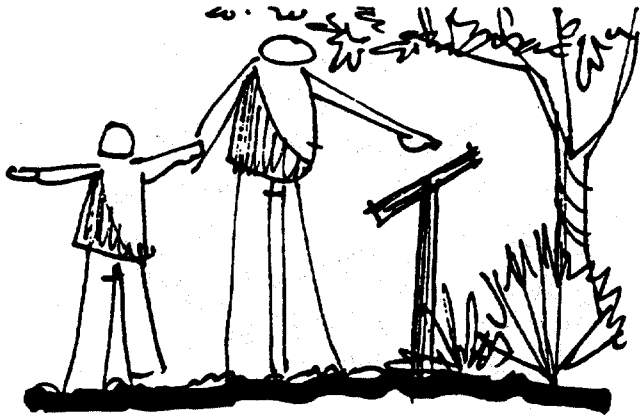
Preserve existing plants and landforms whenever possible. Minimize disturbance of the area during construction.

If revegetating, use existing species at existing densities.

Transplant riparian trees and/or exceptional specimens to new locations if they cannot be preserved.

Provide well-defined pedestrian paths through the site.

Provide educational information about the site in the form of signage or pamphlets, where appropriate.



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4.2.6. Water Harvesting for Recharge and Re-use

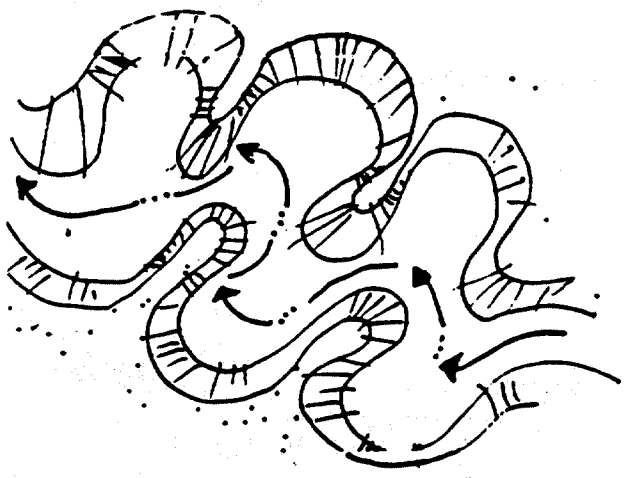
A basic water harvesting system consists of three components: collection, storage, and dispersion. Since stormwater retention/ detention basins will already be designed to collect and store runoff, some simple additions may allow harvesting the water for re-use.

Water may be stored in basins designed specifically to augment the groundwater supply at their locations. These basins should be sited according to the guidelines in Chapters II and III of this manual. No formal dispersion is required other than methods to maximize the potential for water to percolate through the soil and reach the water table. Pima County Health Department requirements must be met in addition to the normal review requirements.

Guidelines: Water Harvesting for Recharge

Site and basin design should allow for maximum surface area contact between stored water and the ground.

At detention basins, use berms perpendicular to direction of flow to slow water and increase contact with soil surface. Minimize sediment accumulation by providing a settling basin at the basin inlet.



Where water is stored for re-use, infiltration is usually prevented, and either passive or active methods of dispersion are provided. Runoff may be utilized en-route to the storage basin, while it is in the basin, or dispersed to off-site locations. Uses include irrigation, recreation and augmenting industrial or commercial water supplies. Comply with all public health regulations regarding the use of stored runoff.

Runoff water stored for recharge or reuse purposes does not meet retention requirements. Adequate basin storage for retention must be provided at all times in addition to the volume provided for harvested water.

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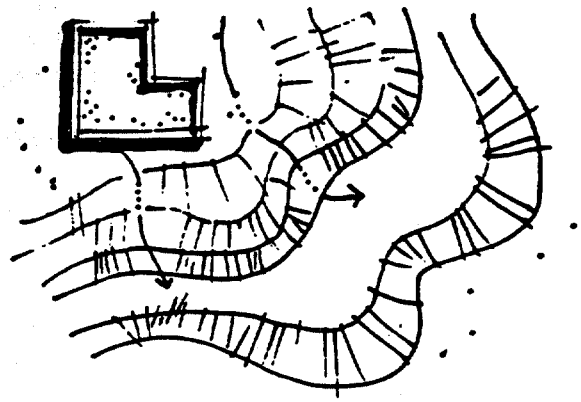
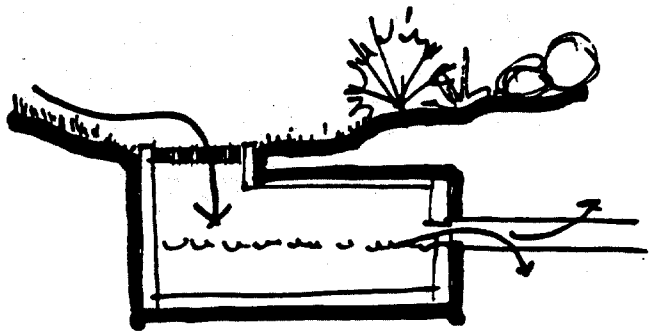
Treat soils to increase impermeability with paraffin, sodium chloride, clay, or use an impermeable membrane liner. Contact Tucson Water and the Pima County Health Department regarding the acceptability of these materials in terms of their effect on water quality.

Site grading should direct the runoff to the storage facility.



Site grading may direct runoff to landscaped areas for direct use prior to collection in a basin.

Underground storage may be used.



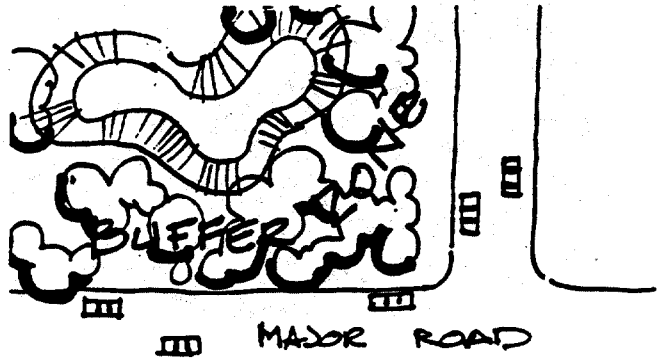
4.2.7. Wildlife Habitat

The three basic requirements for wildlife habitat are food, cover and water. Providing these requirements will attract wildlife. Food plants include grasses and forbs for grazing animals, browse plants such as mesquite, saltbush and hopbush and plants which produce fruits or seeds, such as hackberry, lycium, and jojoba. Cover provides shelter and hiding places for wildlife, and can be provided by placing dense plantings away from heavily used areas.

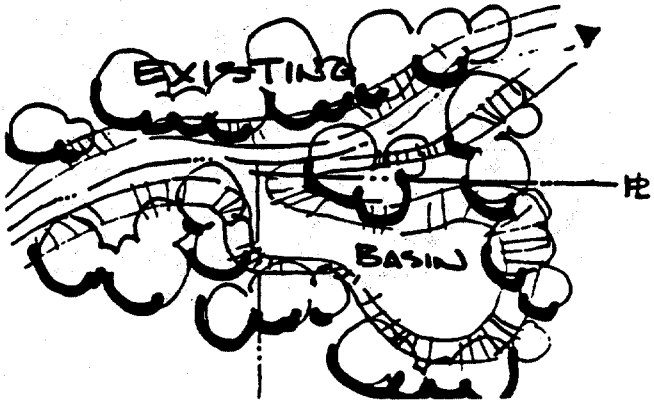
0079

Guidelines: Providing Wildlife Habitat

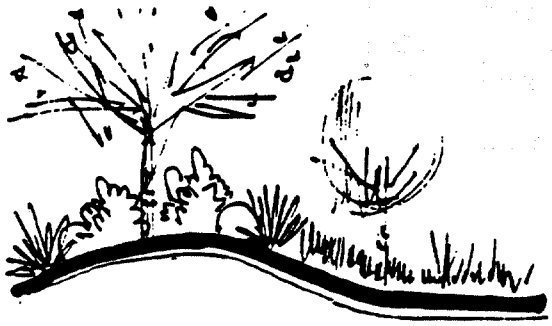
Site basins away from busy roads or noise-producing activities.



Link basin revegetation to heavily vegetated areas off site and densely-vegetated corridors or drainage channels and washes.



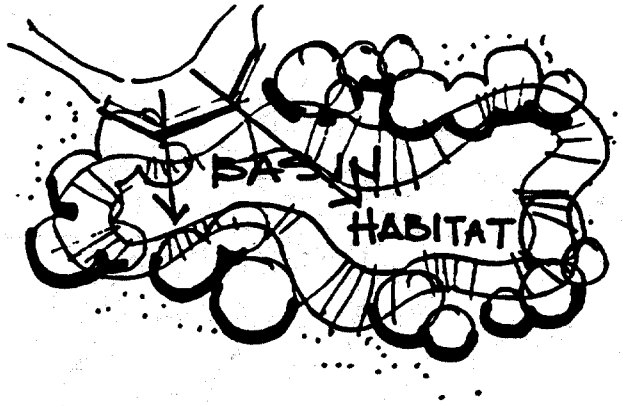
Use predominantly native plants with diversity in species, size and form. Groundcovers, especially range grasses and forbs, provide good grazing. Avoid monocultures of tall trees or grasses — strive for a multi-layered effect.



0080

Control human use of the site by clearly defining trails.

Provide opportunities for people to view wildlife in areas least likely to disturb them.



4.3 Technical Requirements and Guidelines

4.3.1. Basin Configuration

Shape, slope, depth, benching and multiple-basin configurations are the principal considerations of retention/detention basin grading for visual quality. Acceptable grading solutions should reflect the same concerns for proportion and aesthetics as with decorative landform. Contextural factors that influence basin grading and configuration are:

Required floodwater volumes and engineering design

Surrounding land use

Site land use

Surrounding topography

Unique site features or vegetation to be preserved

0081

Availability and cost of additional land, if needed

Intended surface treatments

Points of access

Visibility

Desired visual character

Access for regular maintenance—including landscaping, recreation facilities, floodwater control structures

Safety concerns

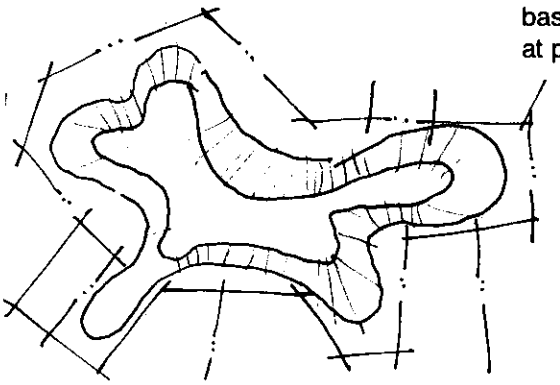
Project budget-including construction and long-term maintenance

Basin Shape

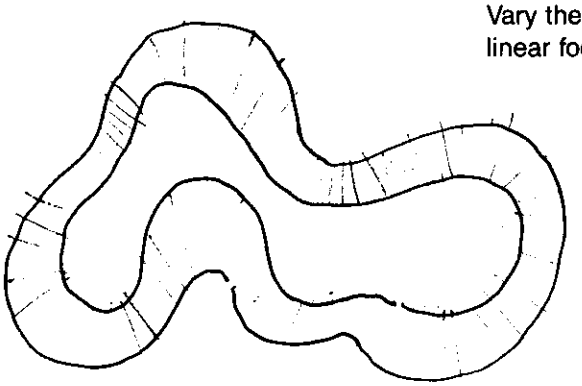
Basin shapes tend to be related to the size and shape of parcel of land dedicated for storm water retention or detention, the desired visual character of the end product—naturalistic or geometric—and the function of the basin, whether only for flood control or multi-use purposes.

Guidelines: Basin Shape

Where possible, dedicate an irregular tract of land for use as a basin site. Use open space areas between building groups and at project edges.

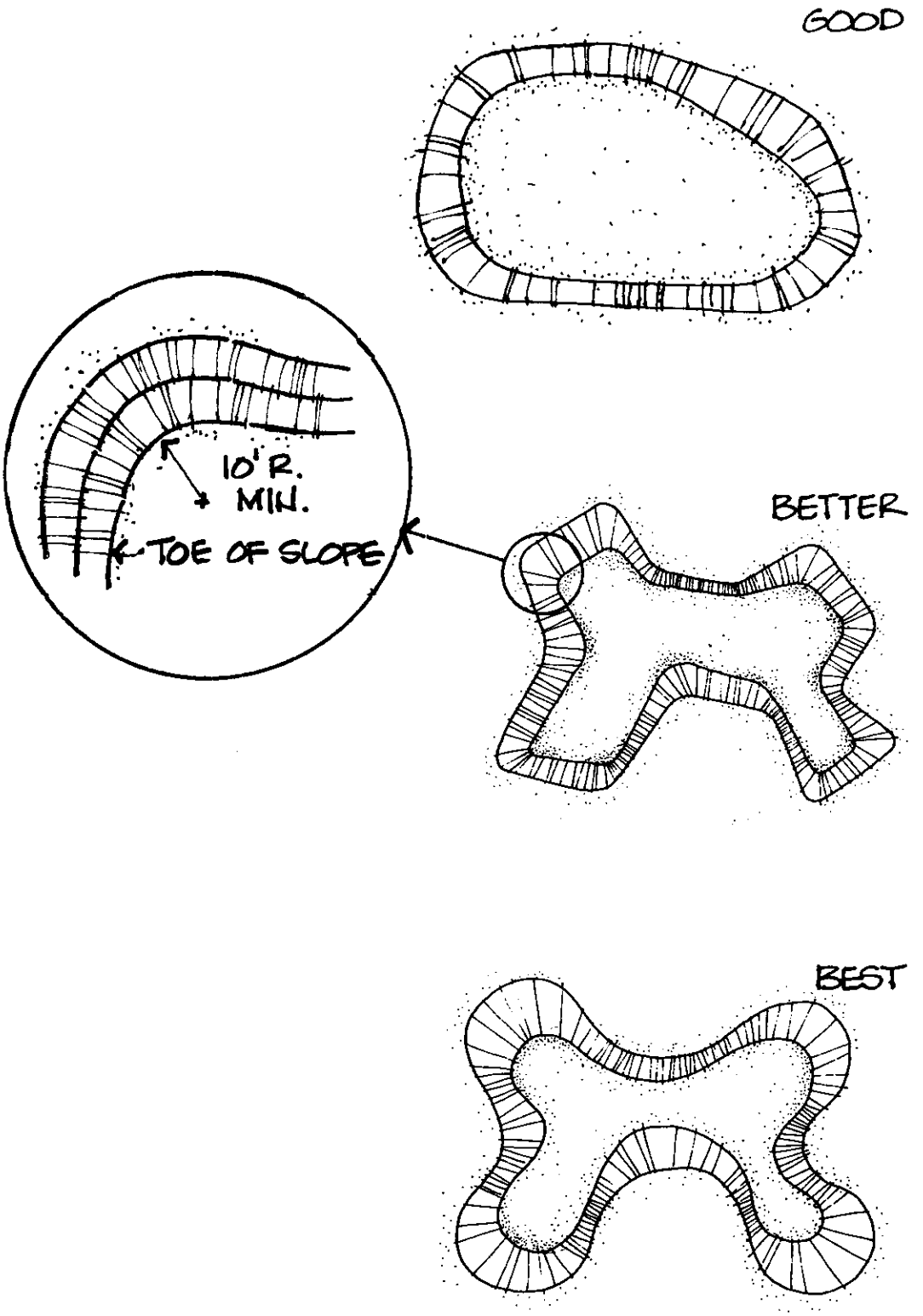


Vary the shape and side slopes of the basin and maximize the linear footage of perimeter.



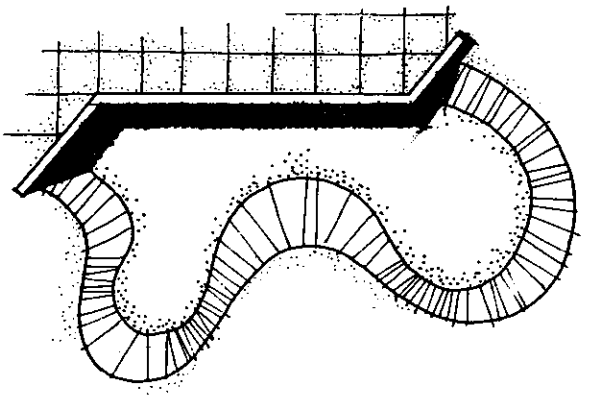
0082

Curvilinear shapes are preferable to geometric ones. If rectilinear or geometric slopes are used, soften the contours with minimum 10-foot radius curves.



0083

Combinations of geometric and curvilinear shapes are acceptable.



Basin Side Slopes

Variation in basin side slopes adds visual interest and enhances the edge quality of the basin. If side slopes are too flat, basin volume is reduced and visual quality is lessened. If too steep, erosion may occur and maintenance may be difficult, in addition to potential safety hazards.

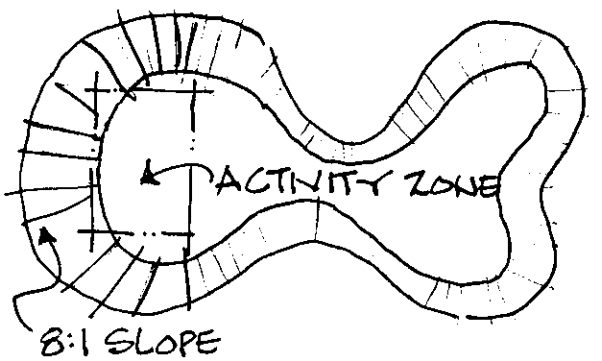
Slope grading should achieve a balance between engineering functions, multi-use factors, and visual attractiveness.

Slope requirements are expressed as a ratio of horizontal to vertical distance.

Requirements: Basin Side Slopes

For basins one acre and larger, use varying side-slope gradients. The recommended minimum horizontal distance for each slope gradient used should vary by at least two feet: example 3:1/5:1/7:1. Provide smooth transitions between grades.

In basins containing human activity zones, access slopes of 8:1 or flatter must be coordinated with these zones for easy exit during flooding. There shall be a maximum of 100 feet either to the base of an access slope or to a 4:1 basin side slope.



0084

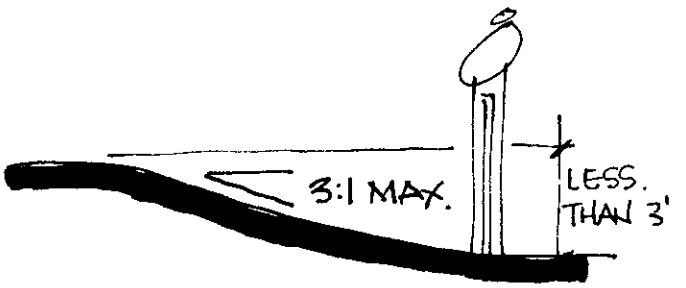
Continuous uniform slopes shall not exceed 20 percent of the basin perimeter.

Transitions from slopes to level ground at top and bottom of basins shall be smooth curves.

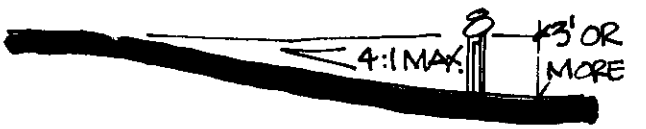
Vertical depth to be measured from top of slope at lowest point on basin rim to toe of slope at lowest point in basin.

Multi-use basins shall be required to conform to the following slope-to-depth ratios.

Less than 3 feet deep:
Maximum 2:1 for protected side slopes and
3:1 for unprotected side slopes.



3 feet deep and greater:
Maximum 4:1



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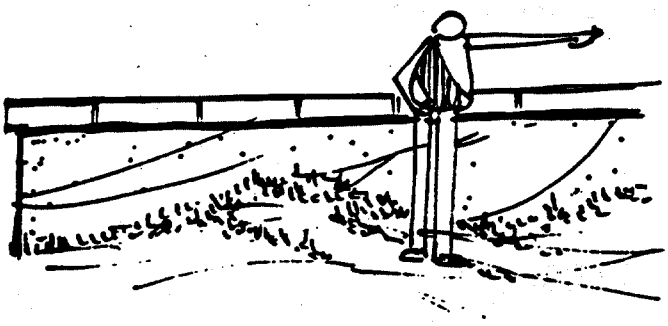
Guidelines:

Curvilinear contours at areas immediately adjacent to walls or structures are encouraged.



Structures such as retaining walls are acceptable for up to 35% of basin perimeter. Refer to the latest edition of the Uniform Building Code for fencing requirements adjacent to building structures.

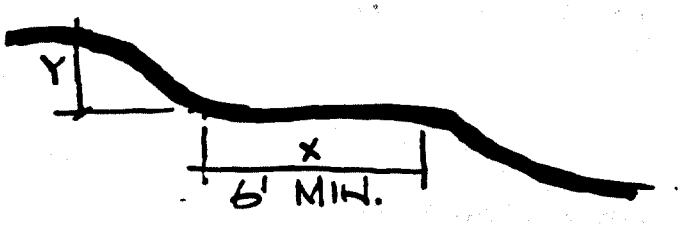
Basin Depth

The depth of retention basins affects the desired visual character, the perceived scale of the facility, safety when stormwater is retained, and visibility into the basin for supervision.

Requirements: Basin Depth

A benched configuration will be required for basins in excess of six feet deep.

Benches within basins shall be proportioned so the bench width is at least three times the height of the slope above it, measured from the lowest point on the top of the slope above the bench. The minimum bench width shall be 6 feet.



0082

Maximum depth to first bench or basin bottom shall conform to the slope-depth ratio of the previous section.

In larger basins greater than one acre in size, avoid one consistent depth where possible unless required for playing fields. Use earth berms to provide topographic interest or islands above the flood level.

PREFERRED

AVOID

Multiple Basins

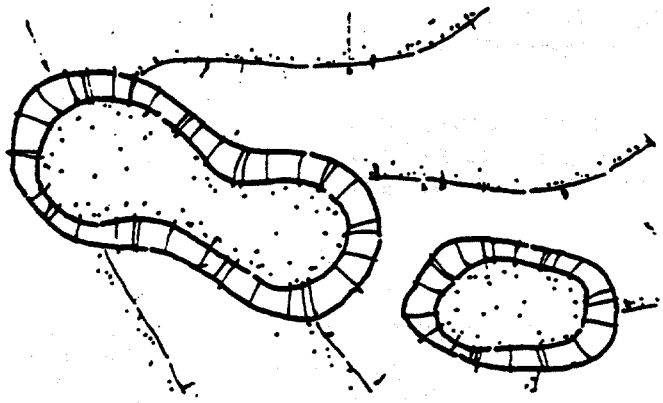
A series of basins is useful on sites with excessive stormwater volumes or a large land area available for retention or detention. Multiple basins can reduce the perceived scale of the facility.

Requirements: Multiple Basins

Where the single-basin depth required exceeds 10 feet or where the basin volume exceeds 50 acre-feet, multiple basins shall be used or guidelines from the manual entitled "Guidelines for the Development of Regional Multiple-Use Retention/Detention Basins in Pima County, Arizona" [76], shall be employed.

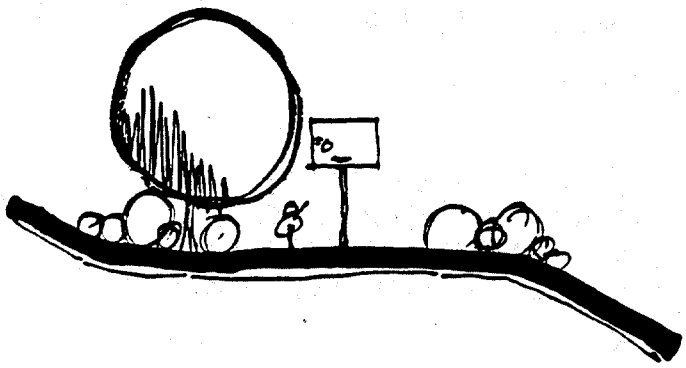
Guidelines:

Arrangement and grading of multiple basin facilities should reflect and enhance local topography. Refer to state dam requirements if appropriate.



Greater perimeter allows for more screening, wildlife cover, visual interest, and shading in use areas outside of the basins.

If recreational use is planned for the site, locate facilities in higher areas of the basin to avoid frequent inundation.



Security Barriers

Because retention/detention basins are designed to hold water for short periods of time, safety precautions must be taken to protect the public. The requirements and guidelines in this manual were developed, in part, to preclude any need for fencing, such as chain link, around retention/detention basins. Some instances may however, require placement of security barriers. Security barriers may be constructed of vegetation, masonry, wood or chain link. **Vegetation, or a combination of vegetation and structural materials, is preferred.**

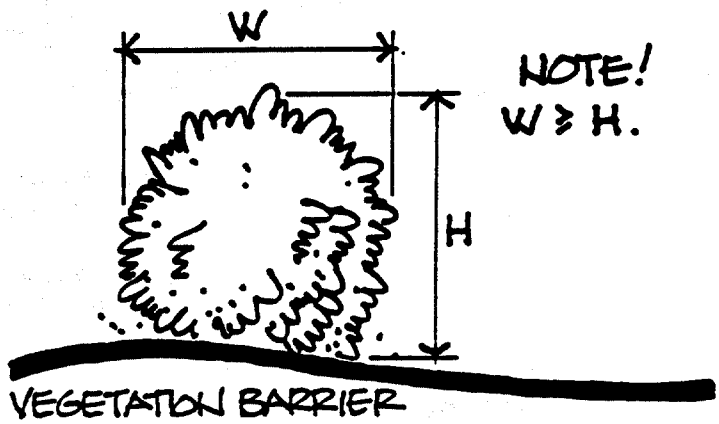
0084

Fencing at inlet and outlet structures, if required, shall not restrict the hydraulic capacity of the structures. Fencing details should be shown on the improvement plans or development plan, where appropriate.

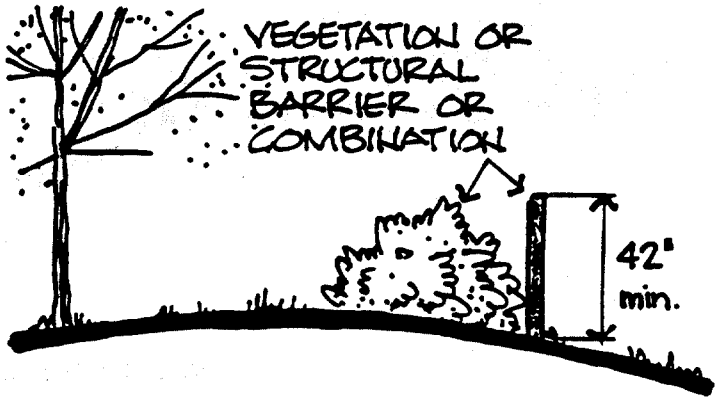
Requirements for Security Barriers

Security barriers must be provided at the top of all basin side slopes steeper than 4:1 where water depths exceed 2 feet.

Vegetative barriers must be of a width equal to or greater than overall height. Density must be sufficient to restrict acccess. Plant selection must be consistent with the Pima County Landscape Ordinance.



A minimum 42-inch barrier height is required for all basins.



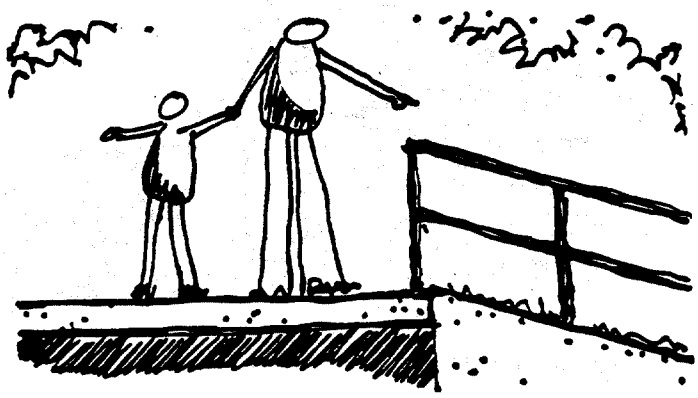
Detail sections of proposed fences, if required, are to be shown on paving and grading plans or development plans as appropriate.

Local private basin fences must be 42 or higher on any side of the basin where buildings or other restrictive structures are within 5 feet of the basin and have no points of exit or entry into the basin area. Combinations of this option with other fencing may be used as appropriate.

0085

If vegetative screening is used, plant materials must be in place and established at the time the occupancy permit is requested.

Provide railings as required by the Uniform Building Code for retaining walls on any inlet and outlet structure headwalls and wingwalls.



Provide signs to inform the public of the purpose of the basin and the potential safety hazard resulting from stormwater retention/detention.

Danger

This basin is designed to collect stormwater runoff.

Do Not Enter

during rainy or threatening weather.

EXAMPLE SIGN

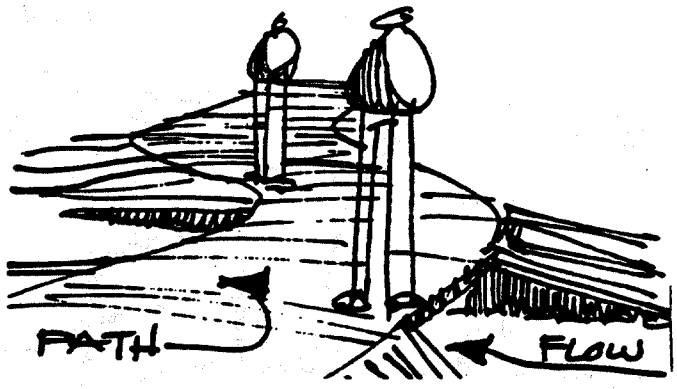
Inlets, Outlets and Spillways

Basin inlet and outlet structures may be at or below grade, or a combination of both. Engineering and safety considerations will play primary roles in the design and sizing of these structures. However, their visual character should be in keeping with overall basin design, landscaping, and multi-use potentials, especially where structures are highly visible.

0084

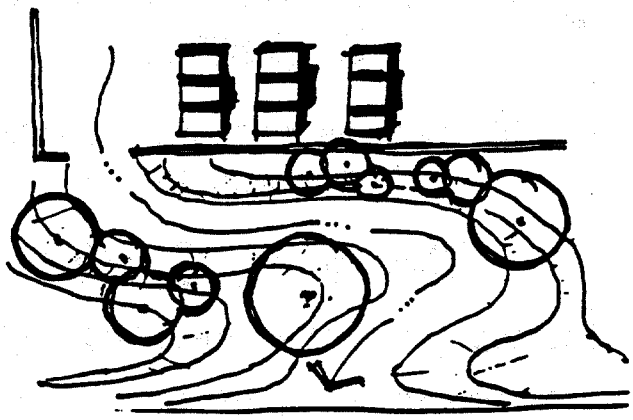
Guidelines for Visible Inlet/Outlet Structures

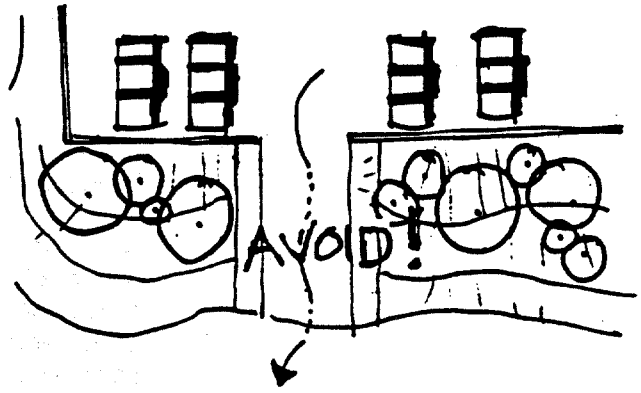
Provide subsurface drainage crossings wherever incoming runoff crosses pedestrian paths or sidewalks.



Stabilize soils around inlet/outlet structures to deter erosion (see Section 3.3.3.)

Avoid placing spillways within major sight lines. If no alternative location is available, meander and screen them from view.





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4.3.2. Basin Landscaping

Retention basin landscaping should respond to the recessed nature of the landform, the scale of the facility, its potential for multi-use, and the occurrence of frequent flooding. Plant materials should perform the following functions, where appropriate:

Define spaces for multi-use activities

Provide shade and wind control

Act as a screen or buffer

Attract wildlife

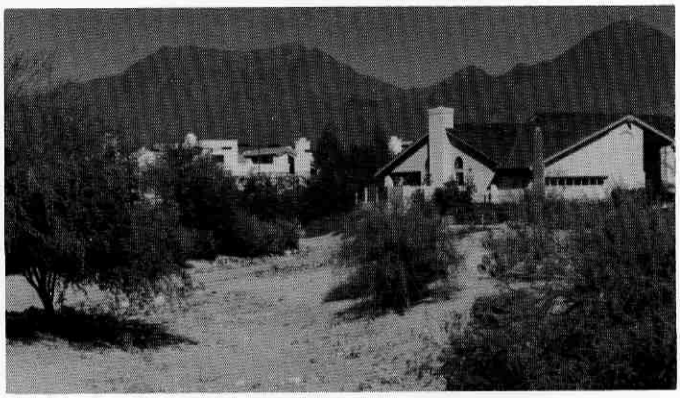
Add visual interest: texture, color, skyline sillouette

Protect the facility from erosion damage

Landscape Themes

Riparian Landscapes are informal and rustic with curving lines, natural materials, and a relatively lush appearance. Densely massed trees and diverse understory growth are important features. Plant forms should be natural and free in shape. Trimming or thinning is done to control the size of plants but there is no shearing or shaping. Both native and introduced plant materials may be used to create riparian landscapes.

Transitional Landscape include plants that look at home with the ornamental landscape and the existing desert vegetation. The main function is to blend two landscape types together to create a uniform whole.



Natural Landscapes include plants native to the site and are not as lush in appearance as riparian landscapes. These areas may be enhanced by the addition of similar non-native drought-tolerant plants. Natural Landscapes are informal and placement of plants is random and should be done as naturally as possible.

Formal Landscapes are created by producing a feeling of geometry, precision and containment. Plants that grow naturally into contained shapes or accept training should be used.

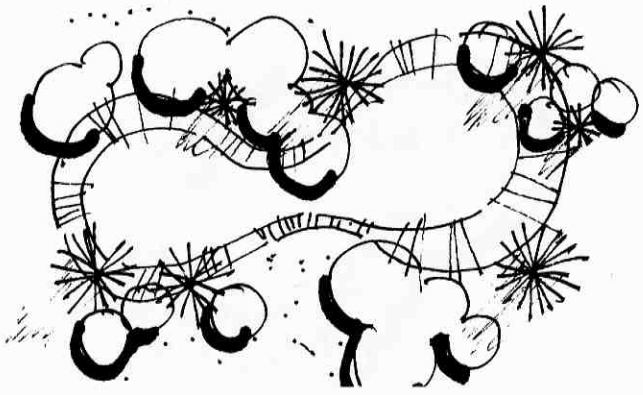
Urban Park Landscapes are informal and open. Large shade trees and useable areas of grass are important features. Trees should be massed to enhance the scale of the space and define activity zones.

Selection and placement of plants must be compatible with flood control, as well. In general, keep vegetation out of flow channels and away from inlets.

Guidelines: General Planting Concepts

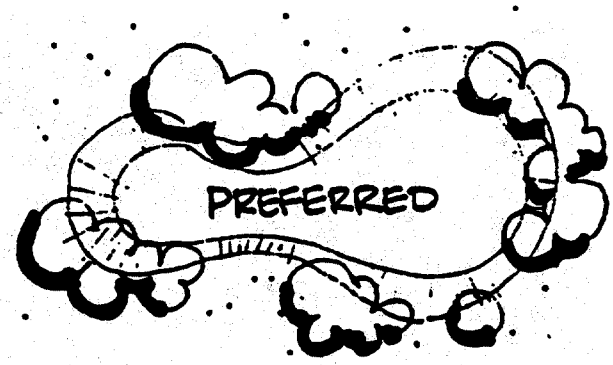
Preserve existing vegetation as much as possible.

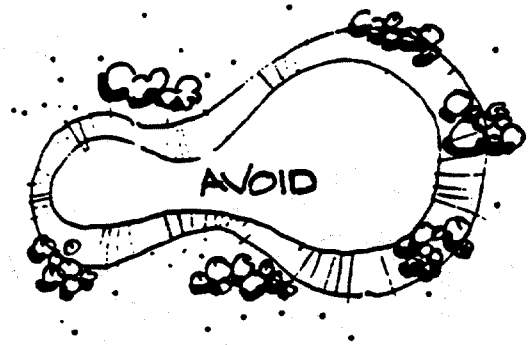
Mass vegetation, varying the degree of diversity, size and texture.



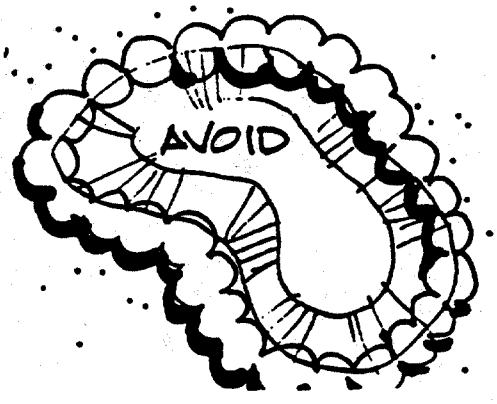
0090

Relate masses of vegetation to scale of basin site.





Avoid homogenous groups of vegetation around basin.



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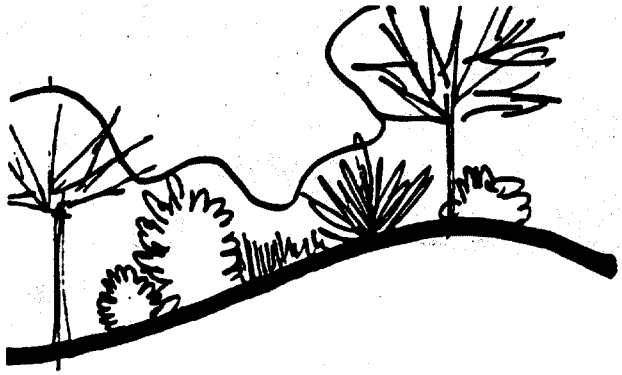
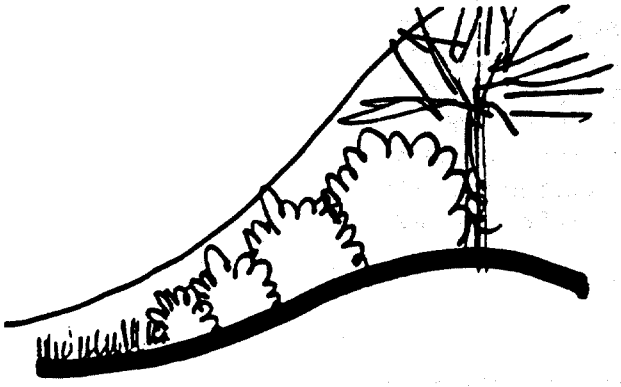
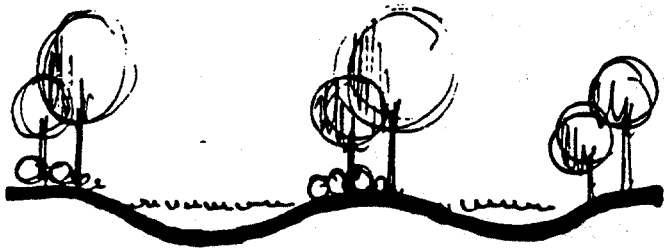
Basin side slopes may be planted to mitigate or accentuate the slope.





For basins located adjacent to arterial thoroughfares, planted areas should account for at least 35% of the total basin area.

Plant materials can be grouped on berms to create an island effect.



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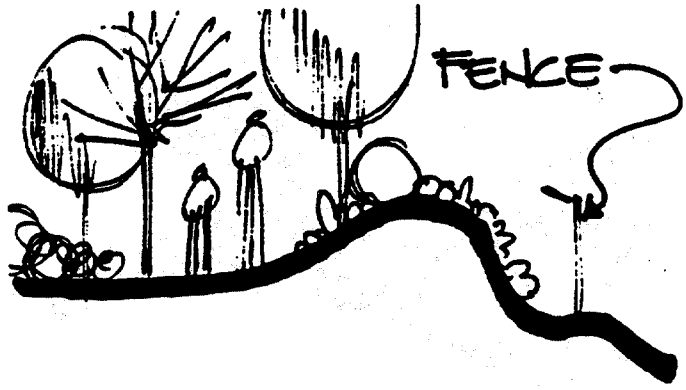
Use vegetation in conjuction with berms to screen fences or flood control structures where used.



Landscape Materials

Plant materials for use in retention/ detention basins should be able to withstand periodic inundation. Landscape design should comply with applicable city and county regulations, ordinances and policies. For non-flooding locations plant materials should be selected from Chapter 18.73, Pima County Zoning Code Landscape Design Manual (October 1985). For locations within the flood zone, use the varieties shown on the lists included in this section, which have been selected for tolerance of inundation. Soils for backfilling planting pits within the flood zone should be appropriately amended for wet and saline soils. Refer to Brooks, 1984. [60]

Guidelines: Soil Preparation for Planting

To prepare soil for turf installation, distribute 400 pounds of granular soil sulphur and 2,000 pounds of agricultural gypsum per acre. Disk thoroughly to a depth of 6 inches. Disking operations should be conducted only when soil is not excessively moist or dry.

Backfill mixes for tree and shrub planting pits should be based on site soil conditions. The following mixes should be used:

Sandy loam soils – 30% wood fiber mulch, nitrogen stablized – 70% site soil

Clay loam soils – 30% wood fiber mulch, nitrogen stabilized – 35% sand – 35% site soil

Add, per cubic yard of mix: – 5 pounds 16-20-0 fertilizer – 3 pounds granular soil sulphur –20 pounds agricultural gypsum

Thoroughly incorporate these items into the soil mix.

Trees

Trees may be used on basin side slopes, bottom, and periphery. They may not be planted in flow channels.

0093

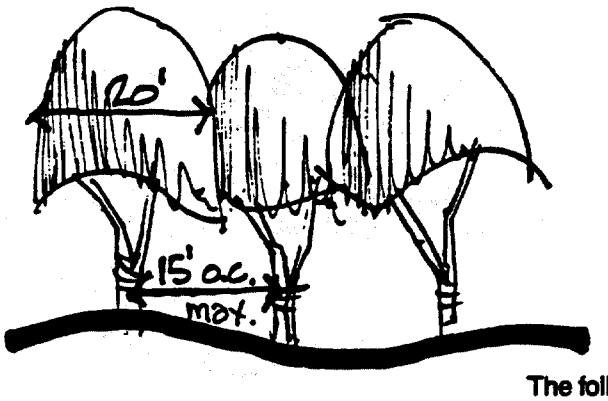
Guidelines: Use of Trees

Provide a minimum of 20 trees per acre.

Minimum tree size should be 15 gallon or an equivalent height and caliper as set forth by the American Association of Nurserymen.

Thirty-three percent of trees on any basin site should be a 24 inch box or larger.

Mass trees in groups consisting of three or more. Distance between trunks of individual trees in any grouping should be no greater than 75% of its mature crown spread.



The following varieties of trees are recommended for use in areas subject to inundation.

Botanical Name	Common Name
Acacia sp.*	Acacia species
Casuarina equisetifolia	Horsetail tree
Casuarina stricta	Beefwood
Celtis reticulata	Canyon hackberry
Cercidium floridum	Blue palo verde
Chilopsis linearis	Desert willow
Eucalyptus microtheca	Coolibah tree
Eucalyptus camaldulensis	River gum
Eucalyptus sideroxylon	Red ironbark
Eucalyptus viminalis	Manna gum
Geijera parviflora	Australian willow
Gleditsia triacanthos "Inermis"	Honey locust
Parkinsonia aculeata	Mexican palo verde
Pithecellobium flexicaule	Texas ebony
Populus fremonti*	Fremont cottonwood
Prosopis sp.*	Mesquite species
Salix gooddingii*	Goodding's willow
Sophora secundiflora	Mescal bean
Tamarix aphylla*	Athel tree tamarisk
Vitex agnus castus	Monk's pepper tree

* Recommended for salt tolerance.

0094

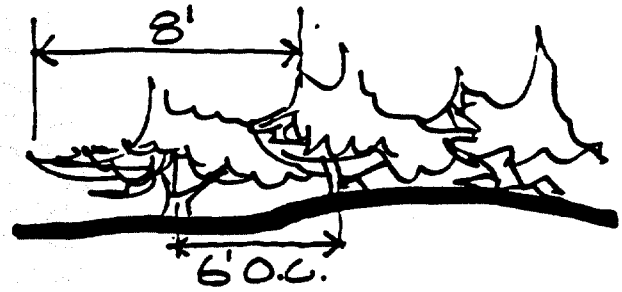
Shrubs

Shrubs may be planted on basin sideslopes (both above and below the flood zone), in the periphery, and with special precautions, in the basin bottom. They may not be planted in flow channels.

Guidelines: Use of Shrubs

Use in masses, reserve single placement for accent specimens. Minimum number of shrubs in any one mass should be five. Vary the number of individual plants from group to group. A minimum of two shrubs for each tree is recommended.

Distance between shrubs in any group should be no greater than 75% of its mature spread.



35% of shrubs should be 5 gallon. The minimum shrub size is 1 gallon.

Avoid placing shrub masses in flow channels.

For location with the flood zone the following varieties, which have been selected for tolerance of inundation, are recommended:

0095

Botanical Name	Common Name
Atriplex lentiformis "Breweri"*	Brewer Saltbush
Bacharis sarothroides*	Desert Broom
Caesalpinia species	Birds of Paradise
Cassia species*	Cassia
Cortaderia selloana	Pampas Grass
Dodonaea viscosa	Hopbush
Elaeagnus ebbingei	Ebbing Silverberry
Larrea tridentata*	Creosote
Ligustrum japonicum*	Japanese Privet
Nerium oleander	Oleander
Xylosma congestum	Xylosma

* Recommended for salt tolerance

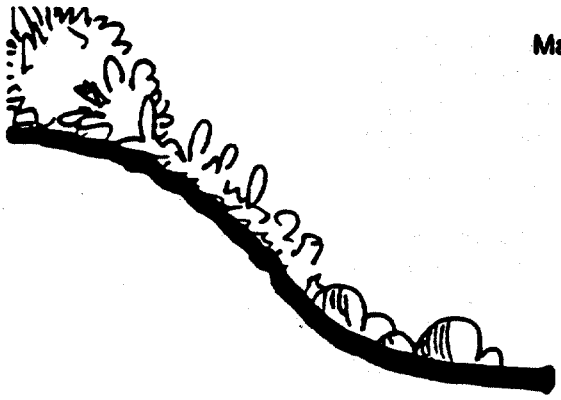
Groundcovers

Organic groundcovers include low-growing shrubs, ground-hugging surface plants, turf grasses, and clumping grasses. They may be used anywhere on the basin site.

Guidelines: Use of Groundcovers

Do not use densely matted groundcovers with heights over eight inches in channels. Design channel capacity must account for this height of groundcover.

May be used where erosion control is necessary.



Plant in masses in scale with size of basin.

The following varieties, which have been selected for tolerance of inundation, are recommended for use in the flood zone:

Acacia redolens	Prostrate Acacia
Atriplex semibaccata*	Australian Saltbush
Oenothera drummondii	Baja Primrose
O. berlandieri	Mexican Evening Primrose
Vinca major	Periwinkle
Cynodon dactylon	Bermuda Grass

*Recommended for salt tolerance.

0094

Bermuda grass may only be used on sports fields or multi-use play fields. The use of Bermuda grass must comply with applicable city and county regulations, policies and ordinances.

Seeding

While the planting of individual trees and shrubs is desirable it is impractical for achieving revegetation over large sites. Groundcover plantings consisting of native grasses and forbs are useful in restoring desert cover and in preventing erosion. Seeding is the most practical way for achieving this type of revegetation.

Guidelines: Seed Application

Use of seeding for revegetation should augment—not replace—container planting.

Seed should be of the latest season's crop of pure live seed and should be delivered in original sealed packages bearing the producer's guaranteed analysis.

Soil preparation and seed scarification should be adequate to insure proper germination.

All seeded areas should be irrigated and kept in a constant state of moisture until germination has begun. After germination irrigate as required to insure proper establishment of plants.

Establishment for grasses and forbs should be to such an extent that the planted seed should yield an average of at least five (5) healthy plants per square foot within a reasonable time after seed application. Establishment of tree and shrub species should relate to the seed supplier's specified germination rate for each species.

The proposed seed mixes will be appropriate for most conditions encountered at retention/detention basins in Pima County. However, other seed mixes can and should be considered.

The following plant materials should be avoided within the flood zone due to disease susceptibility.

Buxus microphylla japonica	Japanese Boxwood
Citrus (all species)	Citrus
Cynodon dactylon hybrids	Hybrid Bermuda grass
Hedera (all species)	Ivy
Leucophyllum frutescens	Texas Ranger
Lolium multiflorum	Annual Rye grass
Rosmarinus officinalis (all varieties)	Rosemary
Washingtonia (all species)	Palms

0097

Inert Materials

Inert groundcover materials are recommended at basin sites for:

Reducing water consumption

Ease of maintenance

Dust control

Erosion control

For general basin landscaping, both riverstone and decomposed granite are appropriate. Sand may be used at playground of fitness facilities where a more resilient material is desired. Overall, inert groundcovers alone should not comprise over 35% of the total basin area.

Decomposed granite provides a fine-textured, walk-on surface. Its drawbacks are that it is easily eroded and washed away, it may stain in areas of standing water, and silt deposits are highly visible on its surface.

Guidelines: Use of Decomposed Granite

Use in areas where people walk, where grass is not required.

Use only on side slopes 4:1 or flatter.

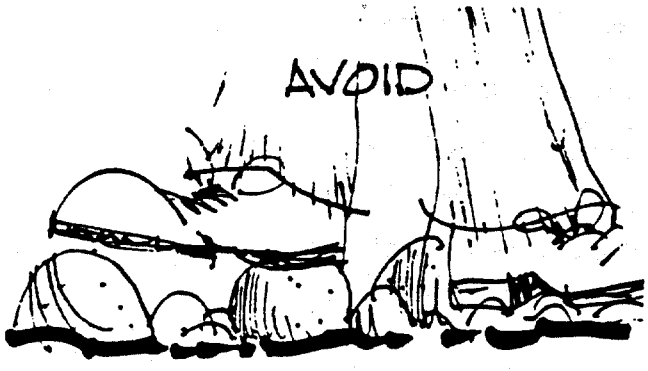
Do not use in basin bottom.

Do not use in flow channels or near inlets.

Large diameter (eg. six to eight inches) river stone as a basin groundcover has exhibited the ability to resist removal by flowing water, control erosion, and accommodate silt and sediments within its void space when placed in basin bottoms.

Guidelines: Use of River Stone

Do not use in activity zones or where people will be frequently walking.



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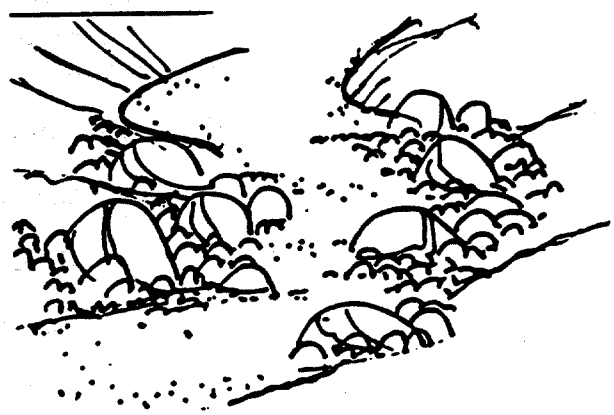
Use large diameter stone (eight inches plus) on surfaces where water will stand.

Vary rock size in areas that represent natural drainage channels.



4.3.3. Erosion Control

Erosion control may be necessary on steep side slopes, along channels, adjacent to inlets, or any other location where flowing water may threaten the stability of ground or embankments. Erosion control may be done through revegetation, use of inert materials, or a combination therof. The use of grasses in flow channels may affect the hydraulic characteristics of the channel. Refer to Chow, 1954 [61] for more detailed information on grassed channel design.

In smaller areas, or at highly visible locations, revegetation for erosion control may be accomplished by planting individual trees, shrubs, and groundcovers. Soils are then protected by foliage absorbing the impact of falling rain and by root systems which hold the soil in place. On larger sites, seeding may be used to augment container planting for revegetation.

Inert material will typically be used where potential for erosion is severe. Use of these materials should be properly engineered and should respond to aesthetic considerations.

0099

Inert material for erosion control include:

Rock rip-rap (6 to 12 inches diameter).

Boulder rip-rap (24 inches and larger).

Gabions

Soil Cement

River Stone

Geotextile mats

Combination methods consist of inert materials with voids that allow vegetation to grow up through or around them. The result is a very durable, attractive method of protection. These include:

Articulated revetment units (ARU's).

Geotextiles

Rip-rap can be vegetated by using soil to partially fill the void spaces and applying a grass seed mix.

4.3.4. Landscape Irrigation

Permanent irrigation systems are required for turf areas and most types of basin revegetation and landscaping. Revegetation efforts (including seeding) with native or drought tolerant species require a temporary system for effective germination and establishment. Whether permanent or temporary, systems within the flood zone must be designed to tolerate inundation and silt accumulations.

Guidelines: For Irrigation System Design

Piping should be zoned in the following manner, with independent control each zone:

basin bottom
basin sides below high water mark
basin sides above high water mark
non-basin areas

Locate valves, controllers, wire connections, and main line outside the flood zone.

Enclose controllers and valves in vandal resistant boxes and screen from view.

In basin bottoms, mount sprinkler heads on swing joints to allow for adjustment to silt accumulations.

0100

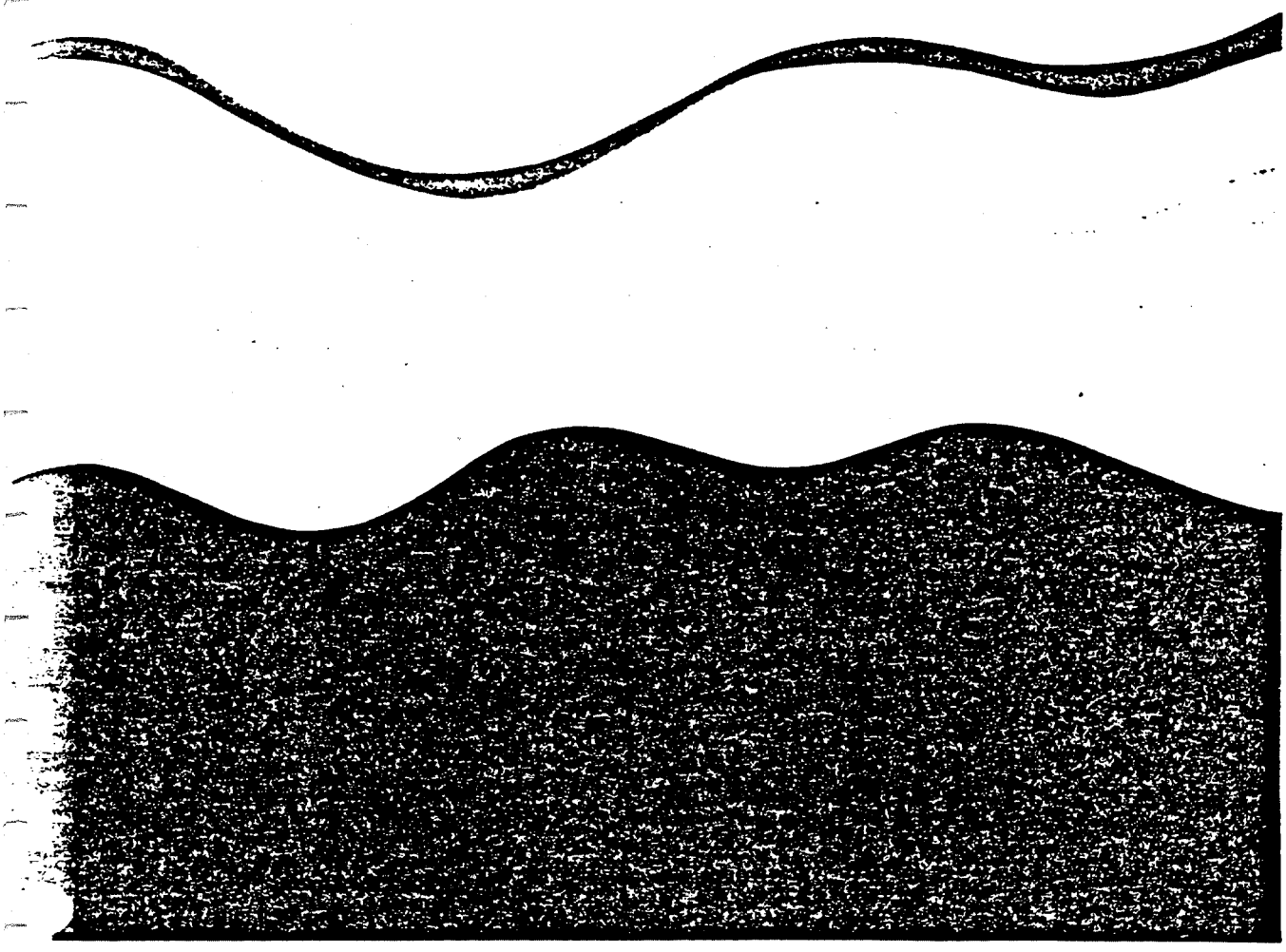
Use gear driven closed case heads in flood zones.

Avoid use of low pressure drip irrigation systems within the flood zone. Low operating pressure and small emitter orifices allow for silt intrusion, clogging, and maintenance problems.

Refer to Pima County Parks and Recreation standard irrigation specifications for further information on irrigation system design.

0101

Report Submittal and Review Requirements



CHAPTER V

V. Report Submittal and Review Requirements

5.1 Submittal Procedure

It is intended that stormwater detention/retention reports will be prepared and submitted in conjunction with the hydrologic and hydraulic report required for each proposed development within Pima County or the City of Tucson. Therefore, the submittal procedure for stormwater detention/retention reports shall be identical to the procedures followed when submitting hydrologic and hydraulic reports to the appropriate reviewing agency (i.e., either Pima County or the City of Tucson).

5.2 Stormwater Detention/Retention Report Requirements

This section provides a list of required items to be included within stormwater detention/retention reports submitted to either Pima County or the City of Tucson in conjunction with development plans, tentative plats, or paving and drainage improvement plans. Detention/retention reports may be submitted as an integral part of the hydrologic and hydraulic report required for all proposed developments, or as a separate, but complete report which addresses only detention/retention. Detention/retention reports may be required by the appropriate reviewing agency at the time detailed engineering analyses are presented for review.

The following items represent the **minimum** requirements for inclusion within a stormwater detention/retention report:

1. Cover Sheet

   Title of report.
   Engineer's name, address, and phone number.
   Client's name and address.
   Date of report completion.
   Seal and signature of the responsible registered professional civil engineer.

2. Table of Contents

   List of tables and illustrations.
   Seal and signature of the responsible registered professional civil engineer.

3. Introduction

   Location map showing the project in relation to adjacent properties, streets, and nearby watercourses.

   A legal description of the project parcel.

   A description of the existing and proposed land uses within the development.

0103

A brief summary of any available existing hydrologic and/or hydraulic studies or information which pertains to the project.

Note: Sections 1-3 will not be required when the detention/retention report is integrated within a hydrologic and hydraulic report which provides the necessary information.

4. Objectives and Procedures Section

A brief summary of the purpose of the report in relation to the project, and a description of the methodology and/or any pertinent assumptions used in preparing the report.

A statement of the applicable detention/retention requirements to which the proposed development must adhere.

5. Hydrology Section

A drainage-basin map which clearly delineates and labels all concentration points and drainage areas which may affect the project.

Hydrologic data sheets for concentration points being considered. These sheets must be clearly labeled such that a correlation may easily be made between the data sheets and the corresponding concentration points on the drainage-basin map.

A summary table with a listing of all concentration points, corresponding drainage areas, the calculated peak-discharge rates for both pre-development and post-development conditions, and the differences in discharges.

6. Detention/Retention Section

A site plan which clearly shows the location of all proposed detention and/or retention systems, including the location, size, and type of inflow and outflow structures. Flow arrows and drainage divides shall also be labeled on the site plan.

A description of how the detention/retention scheme will comply with landscaping requirements and grading criteria. Basin shape, depths, and sideslope variations shall be shown both on the site plan and on typical cross sections.

A statement of the minimum discharge necessary for outflow from the basin to occur, and an estimate of the recurrence interval of this flow.

Reservoir-routing calculation sheets for each detention/retention basin for the 2-, 10-, and 100-year flows. At a minimum, the routing calculation sheets shall consist of a working table for each basin and a routing table for each flow event. These tables shall provide all necessary data, as shown in Tables 3.9 and 3.10 of this

manual. Detailed reservoir-routing calculation sheets shall be required for review at the time that onsite grading plans, development plans, paving and drainage improvement plans, or other final plans are provided to the appropriate agency for review.

Other calculation sheets used in determining the stage-outflow relationships, stage-storage relationships, and other pertinent data used in the basin analysis and design.

Plotted inflow and outflow hydrographs, and water-surface elevations.

A hydraulics section showing details of all inlet and outlet structures, water-surface elevations, limits of ponding, etc. When necessary, free-body diagrams of retaining walls shall be provided which show all forces, moments and calculations required for determining factors of safety against sliding and overturning.

7. Summary and Conclusion

A brief summary of the analyses and conclusions presented within the report.

A brief description of how the proposed development will adhere to applicable stormwater detention/retention regulations.

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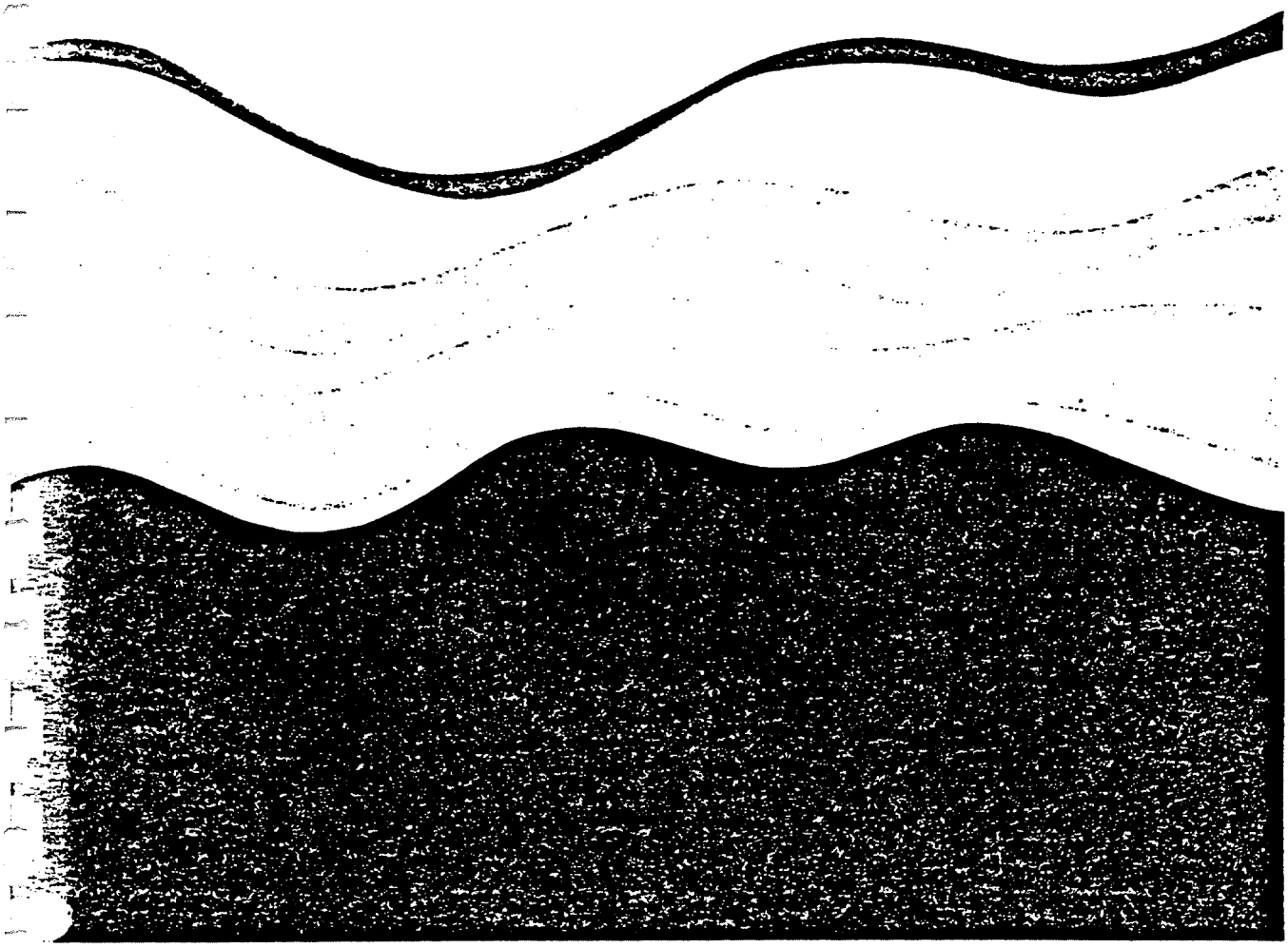
Bibliography



Bibliography

Flood Routing

1. **HEC-1 Flood Hydrograph Package, Users Manual,** U.S. Army Corps of Engineers, January 1985.

2. **SCS National Engineers Handbook,** Section 4, "Hydrology," U.S. Department of Agriculture, Soil Conservation Service, August 1972.

3. **TR-20 Computer Program for Project Formulation, Hydrology,** U.S. Department of Agriculture, Soil Conservation Service, May 1983.

4. Aitken, A.D., A.D. Goyen, **Simplification in Stormwater Detention Design,** Proceedings of the Conference on Stormwater Detention Facilities, American Socity of Civil Engineer, 1982, ed. William DeGroot.

5. Aron, G. & D.F. Lakatos, **Penn State Runoff Model, Users Manual,** Pennsylvania State University, June 1983.

6. Huber, W.C., et al , **Storm Water Management Model, Users Manual,** Verison III, U.S. Environmental Protection Agency, October 1982.

7. Jenscok, E.I., **Hydrologic Design for Highway Drainage in Arizona,** Arizona Department of Transportation (formerly Arizona Highway Department), March 1968.

8. Lakatos, D.F., R.H. Kropp, **Stormwater Detention Downstream Effects on Flood Peaks,** Proceedings of the Conference on Stormwater Detention Facilities, American Socity of Civil Engineers, 1982, ed. William DeGroot.

9. Linsley, R.K., Jr., M.A. Kohler, **Hydrology for Engineers,** McGraw-Hill Book Company, 1982.

10. Malcom, H.R., **Some Detention Design Ideas,** Proceedings of the Conference on Stormwater Detention Facilities, American Society of Civil Engineers, 1982, ed. William DeGroot.

11. Mason, J.M., Jr., E.J. Rhombert, "On-Site Detention Example," **Public Works,** February 1983.

12. Robinson, J.W., **Continuous Models Essential for Detention Design,** Proceedings of the Conference on Stormwater Detention Facilities, American Society of Civil Engineers, 1982, ed. William DeGroot.

13. Urbonas, B., M. Glidden, **Development of Simplified Detention Sizing Relationships,** Proceedings of the Conference on Stormwater Detention Facilities, American Society of Civil Engineers, 1982, ed. William DeGroot.

0107

14. Wycoff, R.L., U.P. Singh, "Preliminary Hydrologic Design of Small Flood Detention Reservoirs," **Water Resources Bulletin**, Vol. 12, No. 2, American Water Resources Association, April 1976.

Soils

15. **Guidelines for Installation of Septic-Tank Systems**, Pima County Health Department Technical Services Division, October 1982.

16. **Santa Cruz San Pedro River Basin, Arizona, Resource Inventory**, U.S. Department of Agriculture, Soil Conservation Service, August 1977.

17. Oppenheimer, J.M., **Depth-to-Bedrock Map, Basin and Range Province, Arizona**, Laboratory of Geophysics, University of Arizona, Tucson, Arizona, 1980.

18. Richardson, M.L., M.L. Miller, **General Soils Map, Pima County, Arizona**, U.S. Department of Agriculture, Soil Conservation Service, March 1974.

Outlet Structures

19. **Design of Small Dams**, U.S. Department of the Interior, Bureau of Reclamation, 1977.

20. **Drainage and Channel Design Standards for Local Drainage**, Pima County Department of Transportation and Flood Control District, May 1984.

21. **Modern Sewer Design**, American Iron and Steel Institute, 1980.

22. French, R.H., **Open-Channel Hydraulics**, McGraw-Hill Book Company, 1985.

23. Herr, L.A., "Capacity Charts for the Design of Highway Culverts," **Hydraulic Engineering Circular No. 10**, U.S. Department of Transportation, Federal Highway Administration, March 1965.

24. Herr, L.A., "Hydraulic Charts for the Selection of Highway Culverts," **Hydraulic Engineering Circular No. 5**, U.S. Department of Transportation, Federal Highway Administration, December 1965.

25. Sandvik, A., "Proportional Weirs for Stormwater Pond Outlets," **Civil Engineering**, Amercian Society of Civil Engineers, March 1985.

26. Urbonas, B.R., **Stormwater Detention Outlet Control Structures**, American Society of Civil Engineers, 1985.

Hydrology

27. **SCS National Engineering Handbook**, Section 4, "Hydrology," U.S. Department of Agriculture, Soil Conservation Service, August 1972.

28. **Urban Stormwater Management**, Special Report No. 49, American Public Works Association.

29. Boughton, W.C., J.J. Stone, "Variations of Runoff With Watershed Area in a Semi-Arid Location," Journal of Arid Environments, 1985.

30. Chow, V.T., **Handbook of Applied Hydrology**, McGraw-Hill Book Company, 1964.

31. Hickok, R.B., R.V. Keppel, B.R. Rafferty, "Hydrograph Synthesis for Small Arid-Land Watersheds," **Agricultural Engineering**, Vol. 10, No. 10, pp. 608-611, October 1959.

32. Linsley, R.K., Jr., M.A. Kohler, **Hydrology for Engineers**, McGraw-Hill Book Company, 1982.

33. Masch, F.D., "Hydrology," **Hydraulic Engineering Circular No. 19**, U.S. Department of Transportation, Federal Highway Administration, October 1984.

34. Miller, J.F., R.H. Frederick, R.J. Tracey, **Precipitation-Frequqency Atlas of the Western United States**, Volume VIII-Arizona, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1973.

35. Osborn, H.B., L.J. Lane, **Point-Area-Frequency Conversions for Summer Rainfall in Southeastern Arizona**, Supplement to proceedings of the Joint Arizona Academy of Sciences Hydrology Section, AWRA, Hydrology and Water Resources in Arizona and the Southwest, 1981.

36. Zehr, R.M., V.A. Myers, **Depth-Area Ratios in the Semi-Arid Southwest United States**, Technical Memorandum NWS Hydro-40, U.S. Deparment of Commerce, National Oceanic and Atmospheric Administration, 1984.

37. Zeller, M.E., **Hydrology Manual for Engineering Design and Floodplain Management Within Pima County, Arizona**, Pima County Department of Transportation and Flood Control District, September 1979.

Water Harvesting

38. Cluff, C.B., "The Compartmented Reservoir: Efficient Water Storage in Flat Terrain Areas of Arizona," **Hydrology and Water Resources in Arizona and the Southwest**, Vol. 8, American Water Resources Association and Arizona Academy of Science, 1978.

0109

39. Cluff, C.B., **Urban Water Harvesting System, Tucson, Arizona,** Water Resources Research Center, June 1984.

40. Cluff, C.B., R.K. Frobel, **Water Harvesting Catchment and Reservoir Construction Methods,** Water Resources Research Center, University of Arizona, 1978.

Groundwater/Water Quality

41. Babcock, J.A., et. al., **Annual Static Water Level Basic Data Report, Tucson Basin,** City of Tucson, Tucson Water, Planning Division, July 1985.

42. Bandeen, R.F., **Case Study Simulations of Dry Well Drainage in the Tucson Basin,** Water Resources Research Center, University of Arizona, Publication #219, September 1984.

43. Davidson, E.S., "Geohydrology and Water Resources of the Tucson Basin, Arizona," **Geological Survey Water Supply Paper 1939-E,** U.S. Geological Survey, 1973.

44. DeCook, K.J., L.G. Wilson, **Ground-Water Recharge from Urban Runoff and Irrigation Returns,** Water Resources Research Center, University of Arizona, Publication #170, May 1980.

45. Hannon, J.B., **Underground Disposal of Stormwater Runoff Design Guidelines Manual,** U.S. Department of Transportation, Federal Highway Administration, February 1980.

46. Murphy, B.A., J.D. Hedley, "Maps Showing Ground-Water Conditions in the Upper Santa Cruz Basin Areas, Pima, Santa Cruz, Pinal and Cochise Counties, Arizona," **Hydrologic Map Series Report No. 11,** Arizona Department of Water Resources, January 1984.

47. Randall, C.W., **Stormwater Detention Ponds for Water Quality Control,** Proceedings of the Conference on Stormwater Detention Facilities, American Society of Civil Engineers, 1982, ed. William DeGroot.

48. Reeter, R.W., C.V. Cady, "Map Showing Ground Water Conditions in Avra/Altar Valley Area, Pima and Santa Cruz Counties, Arizona 1981," **Hydrologic Map Series Report No. 7,** Arizona Department of Water Resources, March 1982.

49. Schmidt, K.D., **Results of Dry Well Monitoring Project for a Commercial Site in the Phoenix Area,** Maricopa Association of Governments, Phoenix, Arizona, July 1985.

50. Smith, W.G., **Water Quality Enhancement Through Stormwater Detention,** Proceeings of the Conference on Stormwater Detention Faciliites, American Society of Civil Engineers, 1982, ed. William DeGroot.

0110

51. Wilson, G.L., **A Case Study of Dry Well Recharge**, Water Resources Researth Center, Publication #202, University of Arizona, September 1983.

Erosion/Sedimentation

52. **Drainage and Channel Design Standards for Local Drainage**, Pima County Department of Transportation and Flood Control District, May 1984.

53. **Santa Cruz San Pedro River Basin, Arizona, Resource Inventory**, U.S. Department of Agriculture, Soil Conservation Service, August 1977.

54. "Design Manual for Engineering Analysis of Fluvial Systems," Simons, Li & Associates, Inc., March 1985.

55. Wischmeier, W.H., D.D. Smith, **Predicting Rainfall Erosion Losses**, Agriculture Handbook No. 437, U.S. Department of Agriculture, Science and Education Administration, 1978.

56. Zeller, M.E., W.T. Fullerton, **A Theoretically-Derived Sediment Transport Equation for Sandbed Channels in Arid Regions**, Proceedings of the D.B. Simons Symopsium on Erosion and Sedimentation, September 1983.

Construction and Design Methods

57. Hannon, J.B., **Underground Disposal of Stormwater Runoff Design Guidelines Manual**, U.S. Department of Transportation, Federal Highway Administration, February 1980.

58. Kropp, R.H., **Water Quality Enhancement Design Techniques**, Proceedings of the Conference on Stormwater Detention Facilities, American Society of Civil Engineers, 1982, ed. William DeGroot.

Landscaping

59. Ankeny, D., Civil Engineer, City of Tempe, Arizona. Personal Communication.

60. Brooks, Margaret, **Physical & Political Parameters Related to Design for Recreation Use at Stormwater Detention Basins in Phoenix**, Thesis, School of Renewable Natural Resources, University of Arizona, 1984.

61. Chow, Ven Te, **Open Channel Hydraulics.** McGraw-Hill Book Company, New York, 1954.

62. Jones, Warren G. and Duffield, Mary Rose, **Plants for Dry Climates**, HP Books, Tucson, 1981.

0111

63. Kivela, Larry, Associate Planner, City of Scottsdale, Arizona. Personal Communication.

64. Natural Vegetation Committee, Arizona Chapter, Soil Conservation Society of America. **Landscaping With Native Arizona Plants,** University of Arizona Press, Tucson, 1973.

65. **Retention Basin Landscape Standards for Arterial Throughfares,** Department of Planning and Development, City of Chandler, Arizona.

66. **Retention Basin Landscaping Criteria,** City of Tempe Parks and Recreation Department.

67. Traylor, Patrice, Planner, City of Chandler, Personal Communication.

Basin Configuration

68. **Drainage Criteria Manual,** Denver, Colorado undated.

69. **Drainage Criteria,** City of Tempe, Public Works Department, March 15, 1980.

70. **Floodplain Management Ordinance no. 1985 FCI for Pima County, Arizona,** May 1985.

71. **Mesa Engineering Procedure Manual,** Mesa, Arizona, June 1983.

72. **Planning Guidelines Landform Grading Manual,** Department of City Planning, Los Angeles, California, 1983.

73. **Residential Storm Water Management: Objectives, Principles, and Design Considerations,** Urban Land Institute, Washington D.C., 1975.

74. **Scottsdale, City Code Requirements,** City of Scottsdale, Arizona.

Multiple Use Concepts

75. Everett, Charles, **Arid/Environmental Water Use Alternatives to Conventional Urban Parkland,** Thesis, School of Renewable Natural Resources, University of Arizona, 1982.

76. Hebel, Susan & McGann, Donald, **Guidelines for the Development of Regional Multiple-Use Retention/Detention Basins in Pima County, Arizona,** Pima County Transportation and Flood Control District, 1986.

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PIMA COUNTY
DEPARTMENT OF TRANSPORTATION AND FLOOD CONTROL DISTRICT

JOHN M. BERNAL
DIRECTOR

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FAX (602) 620-1933

May 17, 1991

To: Stormwater Detention/Retention Manual Users

Subject: Depth to Groundwater

The 1989 Annual Water Level Basic Data Report by Tucson Water indicates the depth to groundwater has increased by approximately 25, and in some cases 50 feet, from that shown on Figure 2.3 of the Stormwater Detention/Retention Manual.

When assessing the feasibility of designing a retention facility, there must be sufficient vertical separation between the point of discharge of the retention facility and the groundwater surface elevation to prevent direct contact between retained water and the groundwater, thereby minimizing the likelihood of adversely affecting the groundwater quality. Because the depth to groundwater has increased in some locations, the revised data will not significantly impact this aspect of assessing retention feasibility.

At this time, the District is not planning on revising the figure in the manual. However, a revised depth to groundwater map can be obtained by calling Tony Tineo of the Mapping and Records Section at Tucson Water, 791-2631.

Sincerely,

Dave Smutzer, Manager
Flood Control Planning and Development Division

DAS:JSH:jh

xc: Brooks Keenan
Mike Ortega
Tim Morrison
Tom Helfrich
Yash Desai, City of Tucson

Board of Supervisors Memorandum

DEPARTMENT OF TRANSPORTATION AND FLOOD CONTROL DISTRICT

Subject: Revised "Balanced and Critical Basin Map for Study Session of January 27, 1987

Recommendation: It is recommended that the Board of Supervisors discuss adoption of a revised "Balanced and Critical Basin Map". Adoption of the Map is proposed for the Public Hearing of February 17, 1987.

Report:

This item complements the "Stormwater Detention/Retention Manual", specifying in map format, those designated areas to which certain provisions of the Manual apply.

On January 19, 1982, the Board of Supervisors approved Resolution No. 1982-FC3 adopting the language and concept of requiring detention/retention of stormwater runoff in those basins designated as "balanced" or "critical". The resolution directed staff to prepare both a map showing such basins, as well as design standards for detention/retention. The purpose of the resolution was to maintain existing conditions for balanced basins by limiting peak discharges from developed sites to values no greater than pre-developed conditions and, for critical basins, to reduce existing flood hazards through detention/retention requirements.

The Balanced and Critical Basin Map was adopted by the Board of Supervisors on April 5, 1982. Since that time, the Department of Transportation and Flood Control District has determined that development occurring in additional basins warrants detention/retention measures. The revised map presented herewith includes both those basins previously adopted by the Board, and those additional basins for which staff supports designation. Table A compares the existing and proposed Balanced and Critical Basin Maps.

The following criteria have been used in determining which basins should be included on the present map:

1. Pursuant to Floodplain Management Ordinance No. 1985-FC1, balanced basins are those where the channels presently convey existing runoff, but in which additional runoff cannot be safely contained. Critical basins are those in which the channels and drainage structures cannot safely convey existing runoff produced by regulatory flows, or where habitable structures constructed prior to the adoption of the Floodplain Management Ordinance are located in flood hazard areas.

2. Basins that have been considered for inclusion are generally those in the metropolitan Tucson area where substantial development is likely to occur within the next decade, or where substantial existing developments may be subjected to flooding.

The following paragraphs discuss each basin and indicate the recommended regulatory designation. The basins are numbered on the map, and categorized within Table A.

1. Tortolita Fan Area: This area has been designated as a critical basin in the Tortolita Fan Area Interim Floodplain Management Guidelines, adopted by the Board of Supervisors on April 8, 1986. A portion of the area had already been designated as critical on the 1982 Balanced and Critical Basin Map. Numerous flood-related hazards have been identified by the Tortolita Fan Area Basin Management Study, including: widespread overbank flooding from natural channels originating on the fan; unpredictable flow paths for major floods originating at the fan apex; potential for flooding to cross watershed boundaries; rapid and spatially unpredictable erosion and deposition along a given stream; flooding due to inadequate culvert drainage capacities under the Southern Pacific Railroad; and impassable roadway dip sections.

2. Loma de Oro Wash: This watershed, located between the Tortolita Fan Area and Highlands Wash, was adopted as a balanced basin by the Board on March 16, 1982. Because an existing channel constructed through the Loma de Oro subdivision is inadequate, staff recommends this basin be designated as critical.

3. Highlands Wash: This watershed was adopted as a critical basin by the Board on April 5, 1982. An undersized channel through a subdivision has resulted in severe flooding. Flood-related complaints are numerous, and because of the inadequate channel, there is a potential for extensive damage during major flood event. Flood hazards are documented in the Highlands Wash Basin Management Study.

4. Catalina Area

   a. Basin to the east of Twenty-seven Mile Wash that drains into the Canada Del Oro Wash. Should be added to the map as a balanced basin because of the potential for development to increase drainage problems.

   b. Drainage flowing easterly into the Canada del Oro Wash. Peak discharges should be limited to existing values because of the severe potential for erosion on extremely steep slopes underlain by erodible materials. This watershed should be added to the map as a balanced basin.

5. Riverside Terrace Area: Includes Pegler, Nanini, Casas Adobes, Citrus, Roller Coaster, and lower Carmack Washes, as well as the West Orange Grove and West Ina basins. Portions of this area were designated as balanced basins by the Board of Supervisors on April 5, 1982. The West Ina basin was designated as critical by the Board because it was included with the North Ranch basin

at that time. All of the basins studied in the Riverside Terrace Basin Management Plan were found to pose flooding problems under conditions of existing development. The Riverside Terrace Basin Management Plan recommends the entire area, with the exception of West Ina basin, be designated critical. Staff proposes that the existing balanced designation be continued and evaluate for each specific development at the time of rezoning for enactment of critical basins requirements under interim floodplain management guidelines. Staff also proposes to withdraw the West Ina Basin from the North Ranch basin into the Riverside Terrace Area.

6. Ruthrauff Road Area: Within this area the overall drainage is extremely poor, and drainage facilities are almost nonexistent. Flooding problems have been documented in the Ruthrauff Road Area Critical Watershed Management Plan, and affect homes, businesses, and access. The basin has already been designated critical by the Board.

7. Friendly Village and Northmanor Washes: Severe drainage problems currently occur in the Northmanor and Friendly Village subdivisions, where constructed drainageways cannot convey the flows with low return intervals. These basins should be added to the map and designated as critical.

8. Finger Rock Wash and Valley View Wash: These washes in the Catalina Foothills area have flooding and erosion problems caused by inadequate channels, diverted floodwaters, and homes located within the floodplain, as documented in the Flecha Caida Improvement Study. These basins should be changed from balanced to critical.

9. Ventana Canyon: Because of the steepness of the terrain, downstream flooding could greatly increase with development unless this basin continues to be designated as a balanced basin.

10. Tres Hombres and Woodland Wash Basins: Several drainage problems have been reported in the vicinity of Rio de Oro Drive and Sierra de Luna Way (Section 28, Township 13 South, Range 15 East) due to natural and man-made channels which lack the capacity to convey present discharges. The Tres Hombres watershed is characterized by poorly defined channels on the fan surface. In addition, there exists the potential for breakout of runoff into Woodland Wash. Both basins should be added to the map and designated as critical.

11. Basin draining into Agua Caliente Wash at Melpomene Way: Natural channels in the vicinity of Limberlost Road and Prospect Lane do not have the capacity to convey discharges greater than existing. The basin should be added to the map and designated as balanced.

12. Watershed entering Tanque Verde Wash at Soldier Trail: This wash should be added to the map and designated critical because of inadequate drainageways and current drainage problems in the Fortyniner's Country Club Estates subdivision.

13. Fortyniner's Wash: Drainageways within Fortyniner's Country Club Estates subdivision cannot convey existing discharges. The watershed should be added to the map and designated as critical.

14. Hidden Hills Wash and small wash at Houghton Road: This two watersheds have already been designated as critical basins upon the request of the City of Tucson. Flood hazards which already exist within the City of Tucson could be worsened by upstream development.

15. Earp Wash: Portions of this watershed upstream of Valencia Road should be reclassified from critical to balanced due to diversion of runoff from part of the Earp Wash watershed into the Rodeo Wash Detention Basin.

16. Airport Wash: Under existing developed conditions there have not been flooding problems in the unincorporated portion of Airport Wash basin, but flood hazards will exist within the City of Tucson if the upstream land is developed. Also, the wash flows across the Tucson International Airport as sheet flow. To prevent downstream flooding and to protect the airport, this basin should continue to be designated as balanced.

17. Julian Wash and Rodeo Wash: These basins have historically had flooding problems, especially near Littletown, Palo Verde/Valencia and along Interstate Highway 10. Flood hazards have been documented for the Julian Wash by the Arizona Department of Water Resources and within the City of Tucson limits by the Federal Emergency Management Agency. As part of the Kolb Corridor Project, Pima County has scheduled improvements and detention basins which will reduce flood peaks to the capacities of existing drainage facilities. However, future upstream development should be required to maintain this improved flood-free condition through the use of balanced basin design criteria.

18. Black Wash Area: This area includes the portion of Black Wash upstream of Ajo Way and associated tributaries. Historically, flooding within a portion of this basin is severe and occurs on an annual basis. Flooding affects major transportation routes and homes and businesses. Especially flood-prone lands near Cardinal and Los Reales, have already been acquired with funding from the 1984 bond program. Drainage improvements are planned in

conjunction with road construction near Bopp Road and Tucson Estates Parkway. Part of the area was designated as critical in 1982. Additional areas upstream of Ajo Way have been added due to existing flooding problems in the vicinity of Postvale Road, and the potential for upstream development to increase flooding.

19. Valencia Wash Area: This area includes Valencia Wash and other tributaries to the West Branch of the Santa Cruz River. These basins lack adequate channels and outlets, but the existing flood problems are not yet severe. The area should continue to be designated as balanced.

20. Tucson Mountains: This area is affected by flooding which severely limits access, due to the numerous roadway dip sections and inadequate culverts. Inadequate culverts, however, may be serving detention needs. The flooding conditions are described in detail within the Tucson Mountain Basin Management Plan. At this time, staff proposes to evaluate each specific development at the time of rezoning for enactment of critical or balanced basin requirements rather than designate the area as either balanced or critical. The formerly balanced Painted Hill basin should be included within the Tucson Mountain management area.

21. Green Valley, drainageways 3, 4, 5, 9, 13, and 17: These basins have been studied by Pima County and the Arizona Department of Transportation. The existing culverts under Interstate Highway 19 are inadequate and cause floodwaters to pond. As a result, neighborhoods are flooded and damage to the Interstate has occurred. Basins 3, 4, 5, and 17 should continue to be designated as critical. Watershed 9 is also characterized by severe erosion, while watershed 13 is subject to flooding which breaks out of the channel. The designation of drainageways 9 and 13 should be changed from balanced to critical.

22. Green Valley: Drainageways 1, 2, 6-8, 10-12, 14-16 and 18-25 in Green Valley currently have adequate capacities to convey runoff, but culverts under Interstate Highway 19 limit the capacity of the system. These watersheds should continue to be designated as balanced to maintain the capacity of the existing system.

23. Ajo, Gibson Arroyo: Should be designated as critical because of existing drainage problems in the Homer Brown subdivision.

Respectfully submitted,

Craig V. McConnell
Director (Acting)

0118

Subject: Revised "Balanced and Critical Basin Map for Study Session of January 27, 1987

TABLE A

BALANCED AND CRITICAL BASINS
As Proposed to the Pima County Board of Supervisors

January 27, 1986

BALANCED BASINS
As Proposed

Loma de Oro Wash
Catalina Area
Ventana Wash
Melpomene Way Area
Earp Wash, upstream of Valencia
Airport Wash
Julian Wash-Rodeo Wash
Valencia Wash
Green Valley #1-2, 6-8, 10-12, 14-16, 18-25.

Previous (1982)

Loma de Oro Wash
Riverside Terrace
Finger Rock/Valley View Wash
Ventana Canyon
Airport Wash
Julian Wash-Rodeo Wash
Valencia Wash
Painted Hill Wash
Green Valley 1-2, 6-16, 18-25

CRITICAL BASINS
As Proposed

Tortolita Fan Area
Highlands Wash
Ruthrauff Road Area
Friendly Village-Northmanor Wash
Finger Rock-Valley View Wash
Tres Hombres-Woodlands Wash
Soldier Trail Area
Fortyniner's Wash
Hidden Hills Area
Earp Wash, downstream of Valencia Road
Black Wash Area
Green Valley #3, 4, 5, 9, 13, 17
Ajo, Gibson Wash

Previous (1982)

Tortolita Fan Area
Highlands Wash
Ruthrauff Road Area
Hidden Hills Area
Earp Wash
Black Wash Area
Green Valley #3, 4, 5, 17

INTERIM GUIDELINES

Riverside Terrace Area (includes West Ina Basin, formerly part of the critical North Ranch Basin)

Tucson Mountain Area (includes Painted Hill Wash, formerly a balanced basin)