Pima County Regional Flood Control District

Design Standards for Stormwater Detention and Retention

Supplement to Title 16, Chapter 16.48,

Runoff Detention Systems

Floodplain and Erosion Hazard Management Ordinance

Pima County Regional Flood Control District
97 E. Congress St., 3rd Floor
Tucson, AZ 85701-1791
(520) 724-4600

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PIMA COUNTY
FLOOD CONTROL

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Symbol	Description
A	Watershed area
A_s	Watershed area flowing to or through stormwater harvesting
A_T	Total watershed area
C_w	Weighted runoff coefficient
C_{w-rp}	Weighted runoff coefficient for the return period
D_{50}	Median diameter of the rock size distribution
H_{rp}	Stormwater harvesting factor
P_{1-rp}	One-hour rainfall depth for the return period
P_t	T-hour rainfall depth
Q_i	Detention basin inflow
Q_o	Peak outflow from detention basin
$Q_{post-rp}$	Post-development peak discharge rate for the return period
Q_{pre-rp}	Pre-development peak discharge rate for the return period
Q_{swh-rp}	Post-development peak discharge rate with stormwater harvesting for the return period
T	Flow travel time
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
$T_{r''}$	Rise time of the 100-year synthetic flood hydrograph for an entire watershed
Δ_t	Length of time interval, minutes
V_{bas}	Volume of proposed stormwater harvesting basin(s)
$V_{post-rp}$	Post development runoff volume for the return period
V_s	Estimate of total required storage volume
V_{swh-rp}	Runoff volume with stormwater harvesting for the return period
W_A	Percent of watershed area draining to stormwater harvesting
X_{rp}	Ratio of stormwater harvesting basin volume to post-development runoff volume

1. INTRODUCTION

1.1 Purpose

The purpose of this manual is to provide guidance, design standards and policy direction when runoff detention and retention systems are required due to development throughout Pima County. This manual is a supplement to, and has the same regulatory authority as, the floodplain management regulations throughout the jurisdictions of Pima County, including:

- Title 16 of the Pima County Code;
- Chapter 26 of the Tucson Code;
- Title 14 of the Sahuarita Town Code;
- Chapter 17 of the Oro Valley Town Code; and
- Title 21 of the Town of Marana Land Development Code.

Throughout the manual, these are collectively referred to as the Ordinances.

Since 1987, the Stormwater Detention/Retention Manual (Pima County Department of Transportation & Flood Control District and City of Tucson) has required the use of runoff detention and retention systems to:

1. Protect adjacent properties from adverse impacts;
2. Preserve watershed-scale peak discharge characteristics; and
3. Retain a portion of stormwater runoff on site for re-use and infiltration.

This manual continues to require protection of adjacent properties and preservation of pre-development peak discharges and also incorporates revisions that:

1. Require first-flush retention that should be located throughout the development. The retained volume may also be used to meet all or part of the project's detention volume requirement;
2. Include sustainability principles and promote early, integrated site planning;
3. Specify acceptable methods of analysis;
4. Provide detailed design standards;
5. Address maintenance responsibilities and expectations;
6. Standardize report and plan content requirements; and
7. Facilitate use of the manual by Floodplain Administrators in both incorporated and unincorporated areas of Pima County.

Upon adoption of this manual by the Board of Supervisors, sitting as the Board of Directors of the Flood Control District (District), the other jurisdiction will begin their respective adoption processes.

1.2 Ordinance Overview and Detention Requirements

The broad goals of the Ordinances are to protect the public health, safety and general welfare of the citizens of Pima County and to protect the natural character of our watercourses, water resources and environment. The Ordinances require the design of all new development to include elements which protect the site from flood damage and which protect adjacent and downstream properties from adverse drainage impacts.

The Ordinances mandate that post-development runoff rates be reduced to pre-development rates. The Ordinances also stipulate that improvements associated with new development are compatible with the existing upstream and downstream drainage conditions and that any grading and/or grade change will not have an adverse impact on surrounding properties. These provisions form the foundation for the requirements presented in this manual.

With a general requirement for no adverse impact, the standards also rely on the more specific requirements in the Ordinances, including:

1. Any new development will include some method of peak discharge and/or volumetric runoff reduction. Detention facilities may be omitted from project design if a waiver is granted by the Floodplain Administrator. A fee may be required. Waivers may be granted when the parcel to be developed is less than 1 acre in size; is located within close proximity to a major watercourse; is of low residential density (less than two residences per acre) and maintains the natural drainage patterns; or when other engineering justification is provided that is acceptable to the Floodplain Administrator. First flush retention will still be required.

2. Within unincorporated Pima County, a watershed is considered a Balanced Basin unless it has been determined to be a Critical Basin. The District's Critical Basin Map is available on the District's web page and shows basin regulated by the District. For watersheds regulated by other jurisdictions within Pima County, other maps may be applicable.

   Unless a Detention Waiver has been granted:
   a. New development located within a Balanced Basin must provide a sufficient combination of retention and detention to reduce the post-developed 2-, 10- and 100-year peak discharge rates to the pre-developed rates.
   b. New development located within a Critical Basin must provide a sufficient combination of retention and detention to reduce the post-developed 2-, 10- and 100-year peak discharge rates to 90% of the pre-developed peak discharge rates. Other reductions may be specified by the Floodplain Administrator.

3. Post-development runoff shall exit the site in approximately the same location(s) as pre-development concentration points, and the Balanced and Critical Basin criteria are applicable at all downstream concentration points.

1.3 Applicability

This manual applies to the planning and design of runoff detention and retention systems when required for private development plans and subdivision plats. These standards do not apply to regional or public detention basins. The use of detention or retention within individual residential parcels to meet or offset any part of the detention or retention requirements for a project site is not allowed, except as described in Section 5.2. For regional basins, where watersheds are greater than 1 square mile, refer to applicable regional basin standards.

1.4 Conflicting Requirements and Use of Alternative Requirements

If any of the requirements in this manual conflict with one another, other Ordinances or other policies, the more restrictive requirement shall apply. Requests to provide designs, analyses, best practices, alternatives or reporting which are different from the requirements stated in this manual shall be made in writing to the Floodplain Administrator prior to submittal. A response to such a request shall be provided in writing to the applicant within 30 days.

1.5 Low Impact Development Practices

This manual introduces the use of Low Impact Development (LID) practices. LID practices model the natural environment with design elements which manage runoff and water use using uniformly-distributed small-scale controls. One goal of LID practices is to mimic a site's pre-development hydrology using methods that effectively capture, detain, infiltrate and evaporate runoff close to its source.

Two components of LID practices are site planning and hydrologic analysis. Traditionally, site development has allowed runoff to be conveyed quickly to a central point, such as a constructed channel or detention basin. This type of development is essentially devoid of natural features, and the result is an increase in runoff volume and peak discharge and an associated decrease in runoff travel time. In contrast, site development using LID practices contains features found in natural watersheds which can increase post-development runoff travel time above that expected with traditional constructed conveyances, while reducing both peak discharge rate and runoff volume.

The use of LID practices accomplishes multiple goals including addressing State and Federal regulations requiring jurisdictions to reduce the contribution of pollutants from urbanized areas, responding to complaints from downstream property owners about the increased frequency and volume of runoff and providing a mechanism to direct runoff to landscape, bufferyards, and riparian areas in a way that also provides some flood control benefit.

Site design which incorporates LID practices will include elements such as water catchments immediately downstream of impervious surfaces and other disturbed or compacted areas and curvilinear flow paths which reduce the velocity of surface flow. An example of a site design incorporating LID practices is the Lester Street site at the University of Arizona. See Figure 1.1.

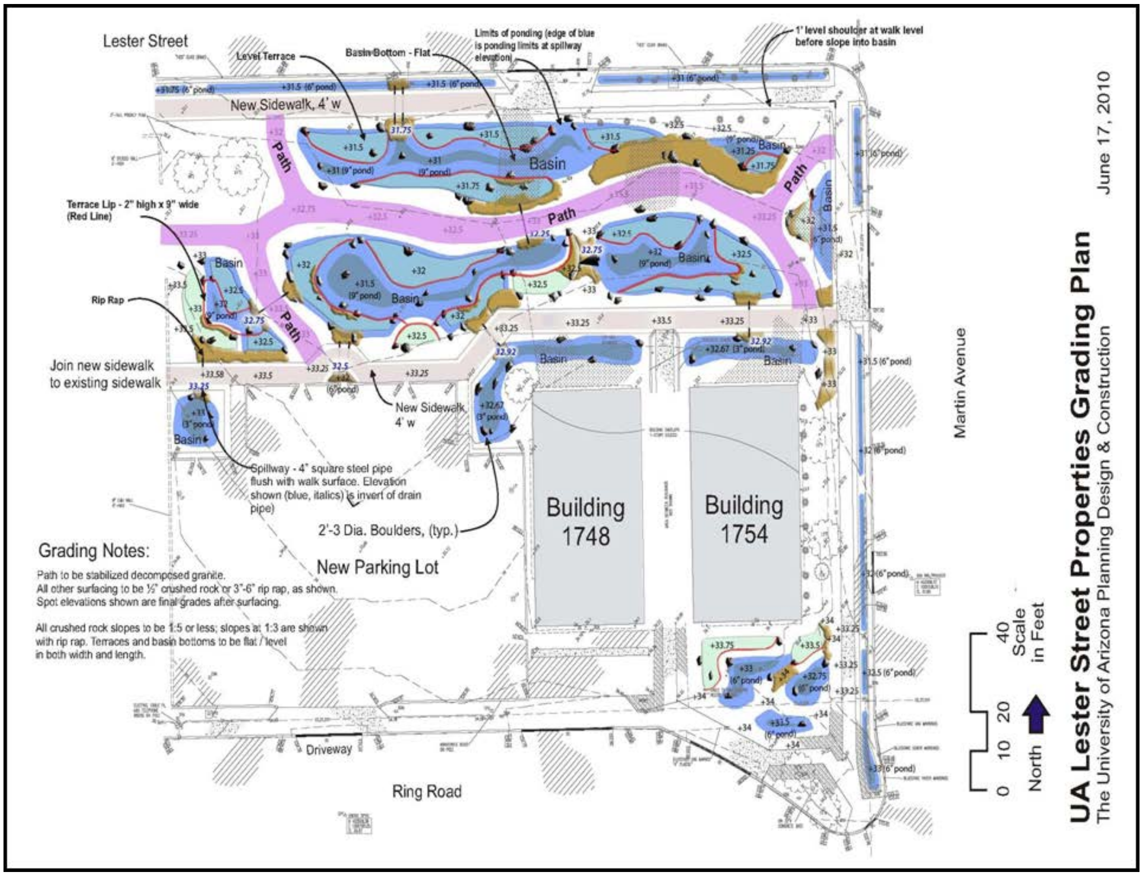


Figure 1.1 An Example LID Site Design
(University of Arizona, Department of Planning, Design & Construction).

In this example design, runoff from roofs and parking areas is directed to a series of shallow basins which are interconnected by pipes or berm spillways which reduce the volume and rate of flow at the downstream boundary of the project.

The requirement, introduced with this manual revision, to provide first-flush retention can be satisfied by site designs which incorporate features similar to the example site design or by providing the retention volume within a detention basin. In addition, landscaping creates aesthetically pleasing runoff paths and increases evapotranspiration. The landscape concept for the Lester Street project is shown in Figure 1.2.

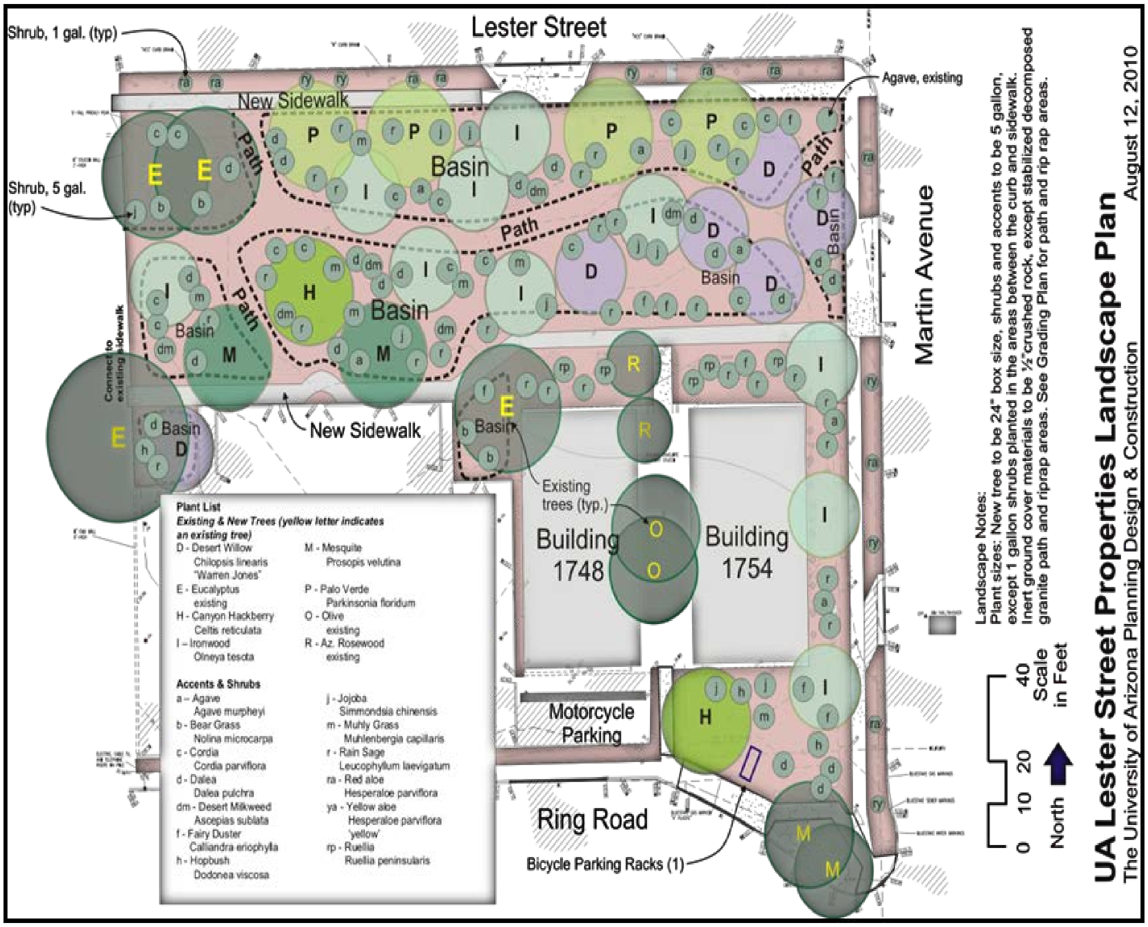


Figure 1.2 An Example LID Landscape Concept Plan
(University of Arizona, Department of Planning, Design & Construction).

First-flush retention is defined as the capturing and retaining of the stormwater runoff volume from 0.5 inch of rainfall on all newly disturbed or impervious areas for new development or redevelopment as defined in Section 2.1. This requirement does not apply to those portions of the project site that are left undisturbed.

To incentivize the use of stormwater harvesting basins, the manual provides a method to reduce the required volume of detention facilities when stormwater harvesting basins are distributed throughout a site. The manual also incentivizes the use other LID practices when quantifiable flood control benefits can be measured, although LID practices other than first flush retention are not required.

Quantifiable flood control benefits include:

1. Optional LID practices that reduce the volume of post-development runoff:
   a. Minimization of disturbed and impervious surfaces. Surfaces designed with pervious pavement systems shall be analyzed as disturbed, rather than impervious, surfaces.
   b. Protection and maintenance of riparian habitat and other high permeability areas; and
   c. Use of stormwater harvesting throughout the site in depressed earthen areas.

2. Other Optional LID practices that increase roughness or lengthen the flow path for watersheds with times of concentration which exceed five minutes:
   a. Disconnection of impervious surfaces;
   b. Maximization of time of concentration through the use of swales, site design and increased lengths of flow paths; and
   c. Use of conveyance systems that mimic natural conditions.

In order to facilitate the use of LID practices, the Floodplain Administrator encourages applicants to satisfy other requirements within LID practice areas. Other requirements which might be satisfied within LID practice areas include landscaping, native plant, and riparian mitigation requirements. Locating mitigation areas within stormwater harvesting basins will maximize the effect of both the LID practice and the success of the mitigation area. Other regulatory requirements that could be met include open space set-aside, bufferyard, and park requirements.

Details and design standards for LID practices are presented in Chapter 5.

1.6 Site Planning

Early review of the project site for opportunities to optimize the use of LID practices, to consider riparian habitat preservation and to reduce the site area devoted to deeply-excavated detention basins is encouraged by the Floodplain Administrator. While this manual provides standards and guidelines for designing, constructing and maintaining detention basins, it also promotes use of alternatives to the construction of deeply-excavated basins or a combination of detention basins and alternative practices to achieve stormwater detention and retention volume requirements.

Site planning during rezoning processes and at the earliest stages of site review will allow for the most appropriate uses of LID practices, stormwater harvesting and riparian habitat and floodplain preservation. Site planners are encouraged to contact the Floodplain Administrator for consultation during preliminary site layout.

1.7 Design Standards

This manual presents the required design standards for detention basins and LID practices. Approval of the use of design standards not in this manual shall be obtained in writing from the Floodplain Administrator prior to submittal of the detention/retention analysis. As new construction methods and materials, environmental regulations and sustainable development practices evolve, new design standards may be incorporated into the manual.

2. FIRST-FLUSH RUNOFF VOLUME REDUCTION

Capturing and retaining stormwater throughout the project site results in a reduction in the size of infrastructure required to convey runoff to a central area. Additionally, it provides permeable area which allows more runoff to infiltrate into the ground. Stormwater retention also addresses water quality protection goals, reduces downstream adverse impacts related to the increased frequency and volume of runoff from development, and mimics natural features which allow for the beneficial re-use of stormwater on site.

2.1 Applicability of First-flush Retention and First-flush Runoff Volume Calculation

The first-flush runoff volume is the volume of stormwater runoff from 0.5 inch of rainfall that is expected to be generated from post-development impervious and disturbed areas. New development shall provide the retention volume necessary to retain the first-flush runoff volume from planned impervious and disturbed areas as determined below:

1. With the following exceptions, when new development is proposed on vacant land, all planned impervious and disturbed areas shall be used to determine the first-flush runoff volume:
    a. Low density residential subdivisions with a development density of 1.2 residence per acre or less (equivalent to CR-1 Zone), unless required by rezoning;
    b. Development that has been platted or received any construction authorization prior to the adoption of this manual;
    c. Individual Blocks within a previously approved Block Plat when an alternative method of stormwater retention has been already been constructed or planned for in the Block Plat.

2. When expansion of existing development occurs, the first-flush runoff volume shall be calculated using:
    a. The total impervious and disturbed areas of the entire site, when more than 1 acre of new development is proposed and the new development is greater than 33% of the entire site.
    b. Only the impervious and disturbed area associated with the proposed expansion, when between 2,000 square feet and 1 acre of new development is proposed, or the new development is less than 33% of the entire site. Expansion area is cumulative over the life of the project.
    c. First-flush retention is not required when an expansion of less than 2,000 square feet is proposed. The 2,000-square-foot threshold is cumulative.

3. A change of use of a property that does not increase impervious surfaces or disturbed area does not require first-flush retention.

4. When known drainage problems exist, the Floodplain Administrator may require mitigation through retention for sites which otherwise would not require first-flush retention.

2.2 First-flush Runoff Volume Calculation

The first-flush runoff volumes required by this Section were determined using the Soil Conservation Service (SCS) Curve Number method with a 0.5-inch rainfall event (Table 2.1).

Appendix A presents supporting data for the use of the 0.5-inch standard.

The first-flush runoff volumes were determined from the difference in runoff volume for post-developed and pre-developed conditions for a 0.5 inch rainfall event. For pre-developed conditions, Natural Resources Conservation Service (NRCS) Hydrologic Group B soils were assumed for areas that were identified as Riparian Habitat on the Board adopted Riparian Classification Maps or other higher permeability areas designated by the Floodplain Administrator. NRCS Hydrologic Group C soils were assumed for other lower permeability areas.

For post-developed conditions, impervious areas proposed within Mapped Riparian Habitat or other higher permeability areas were represented as 0.5 inch of runoff, and the remaining impervious areas were represented as the runoff found from using an NRCS Curve Number of 99. All disturbed areas were assumed to be D soils under post-developed conditions.

Table 2.1 First-flush Retention Volume Required for Each Acre of Impervious or Disturbed Area by Type of Area

	Lower Permeability Area	Mapped Riparian Habitat or Other Higher Permeability Area
Applicable Impervious Area	1440 ft^3/ac	1815 ft^3/ac
Additional Disturbed Area	140 ft^3/ac	245 ft^3/ac

The first-flush retention volume shall be calculated according to the following:

a. The first-flush retention volume requirement shall be calculated separately for the impervious and disturbed areas of each developed watershed associated with flows that exit a project site. The calculation for the required first-flush retention volume shall be in accordance with Table 2.1 above, unless site-specific testing supports use of alternate values.

b. Within each developed watershed, retention areas that are used to meet the first-flush retention requirement shall be located downstream of an impervious area. Sites may contain some impervious or disturbed areas which do not drain to first flush retention.

c. The total first-flush retention volume provided in each developed watershed shall satisfy the first-flush retention requirement for that watershed.
d. Retention volume in stormwater harvesting basins and retention within detention basins may be counted toward the required first-flush volume.

5. First-flush retention areas within stormwater harvesting basins may also be counted for reducing peak discharges as described in Section 3.3. First-flush retention volume within detention basins will be counted as volume within the detention routing procedures described in Section 3.4.

6. Disturbed areas include any areas of the project site which are graded, except for the detention basins and stormwater harvesting basins themselves.

An example to illustrate how first flush volumes are calculated for a site with two post-developed watersheds is presented below. The example includes various combinations of permeability type, constructed surface type and stormwater harvesting basins, both downstream of runoff and non-contributing rainfall only basins.

The example site is 2.3 acres, representing 1 pre-developed watershed of 2.3 acres of undisturbed natural desert flowing generally in a uniformly distributed manner to the downstream limit of the site. The site contains 0.3 acre of Mapped Riparian Habitat.

The proposed development includes a commercial building with parking and landscaped areas. A proposed conditions watershed plan is shown in Figure 2.1.

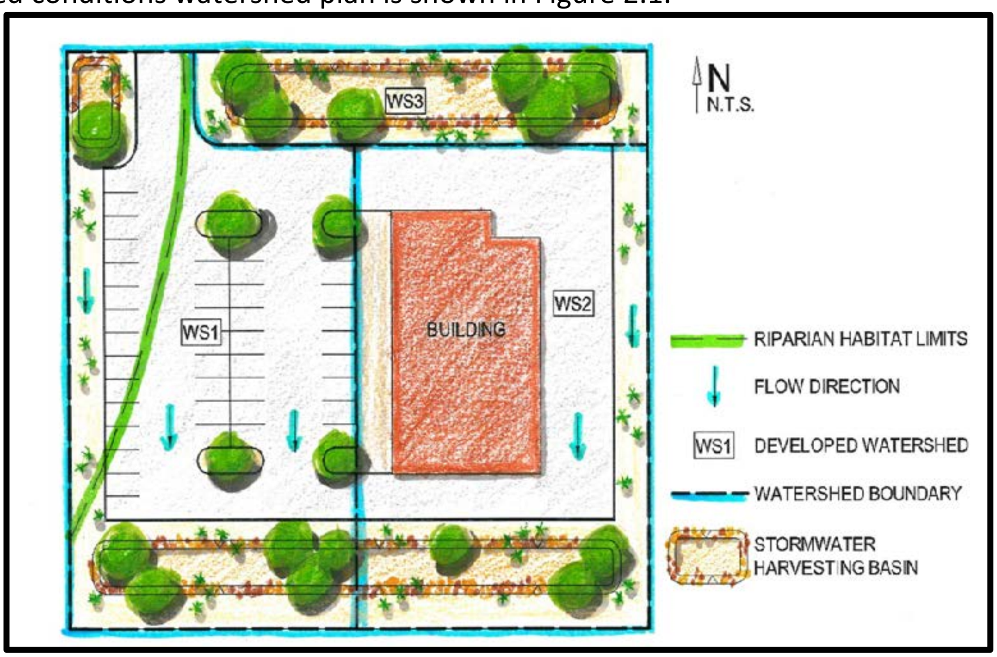


Figure 2.1 First-flush Example Developed Watersheds

WS1 is 1.11 acres and contains both impervious and landscaped areas. Landscaped areas are proposed as stormwater harvesting basins. Stormwater harvesting basin area does not require first-flush and can be considered undisturbed area when evaluating first-flush. Grading that extends outside the limits of the basins is considered as disturbed area when evaluating first-flush. Approximately 0.2 acre of WS1 is stormwater harvesting basins. The Mapped Riparian Habitat of .3 acre is located within WS1.

WS2 is 0.99 acres and also contains impervious and landscaped areas which are evaluated for first-flush for the impervious and disturbed areas only. Approximately 0.1 acre of stormwater harvesting basin is provided.

WS3 is a 0.2 acre Rainfall Only Non-contributing stormwater harvesting basin which is subtracted from the developed area requiring first-flush. Site flows are not directed to Rainfall Only basins; and Rainfall Only basin volume cannot be credited toward first-flush volume.

Example calculations for first-flush volume for the developed on-site watersheds are shown in Table 2.2. Table 2.3 shows the volume of first flush-retention provided by the stormwater harvesting basins, assuming a retention depth of 0.75 feet.

Table 2.2 Example Site First-flush Volume Required

Watershed	*Type of Permeability*	*Constructed Surface Type*	*Watershed Area*	*Table 2.1 Multiplier*	*FF Volume Required*
			acre	ft^3/acre	ft^3
WS1	Higher	Impervious	0.2	1815	363
	Lower	Impervious	0.54	1440	778
	Higher	Disturbed	0.1	245	25
	Lower	Disturbed	0.07	140	10
		Undisturbed	0.2	0	0
WS1 Totals			**1.11**		**1,176**
WS2	Higher	Impervious	0.0	1815	0
	Lower	Impervious	0.63	1440	907
	Higher	Disturbed	0	245	0
	Lower	Disturbed	0.11	140	15
		Undisturbed	0.25	0	0
WS2 Totals			**0.99**		**922**
WS3		Undisturbed	0.2	0	0
WS3 Totals			**0.2**	**0**	**0**

To meet the first-flush requirement for this site, the stormwater harvesting basins in WS1 must retain a minimum of 1,176 cubic feet of stormwater runoff, and the stormwater harvesting basins in WS2 must retain a minimum of 922 cubic feet.

Table 2.3 Example Site Stormwater Harvesting Volume Provided

Watershed	*Basin Bottom Area*	*Basin Top Area*	*Retention Depth*	*Volume Provided*	*FF Volume Required*
	ft^2	ft^2	ft	ft^3	ft^3
WS1	6,700	7,270	.75	5,090	1,176
WS2	4,500	5,620	.75	3,690	922

Each watershed easily retains the required first-flush retention volume. The additional basin volume that is provided can used to reduce the peak discharge and avoid the requirement for additional detention.

2.3 Site Planning and Preliminary Design of LID Practices to Minimize First-flush Volume

Minimizing a development's impervious footprint helps to preserve the natural hydrologic characteristics of a site. The objective of LID is to mitigate the potential for increased runoff due to disturbance. LID practices reduce runoff rates by minimizing the impervious and disturbed surface area and by promoting infiltration through preservation and enhancement of riparian areas and regulatory floodplains. Judicious layout of impervious areas can promote increased infiltration and reduced runoff.

LID practices which minimize impervious and disturbed areas, maximize the preservation/enhancement of riparian areas and regulatory floodplains, and maximize infiltration reduce the required first-flush retention volume. By incorporating these practices in site design during initial planning, an applicant can minimize the amount of first-flush runoff volume required.

During site planning, the following practices which can minimize the first-flush runoff volume shall be considered.

2.3.1 Minimize Disturbed, Compacted and Connected Impervious Surfaces

Fundamental elements of LID are reducing a development's impervious footprint and limiting construction disturbance. By incorporating these elements at the site planning stage, an applicant has the opportunity to reduce the amount post-development runoff volume generated. Table 2.4 summarizes acceptable practices to minimize imperviousness and disturbance.

Table 2.4 Acceptable Techniques to Minimize Disturbed, Compacted, and Impervious Surfaces

Phase	Techniques
Planning	• Consolidate buildings and other impervious areas. • Minimize developed footprint. • Locate impervious surfaces on the site's least permeable soils or previously disturbed areas. • Minimize use of fill and avoid compacting soils.
Design	• Follow the site layout proposed during planning. • Delineate grading limits. • Delimit undisturbed areas which will be fenced during construction. • Maximize use of pervious paving materials.

Disconnecting impervious surfaces provides a greater opportunity for runoff to infiltrate into the ground. At the site planning stage, an applicant has the opportunity to establish flow paths that avoid impervious areas and infiltrate runoff in permeable areas.

Mass-graded, traditional street configuration

Avoidance, loop roads, minimum lot frontages

Figure 2.2 Traditional Layout Compared to Alternative Compact Development Footprint

In addition, pervious pavements can be used to infiltrate or store water. Because pervious pavement systems include a permeable paving surface and a subsurface material that can hold water, they can reduce both runoff peaks and volumes. Pervious pavement systems include porous gravel, concrete grid pavement, permeable interlocking concrete pavement, and pervious concrete. These pavement options are appropriate for low speed vehicular areas, such as parking lots, or for pedestrian areas, such as sidewalks.

2.3.2 Protect/Enhance Riparian Habitat and Other High Permeability Areas

Riparian habitat areas are frequently areas where infiltration rates are higher, where runoff occurs more frequently and at greater rates, and where natural flow paths have been established historically. Disturbance of these areas often causes the greatest impact to the hydrology of a project site. Avoidance of riparian areas and regulatory floodplains retains the site's natural drainage pattern, allows for flow attenuation and additional infiltration due to increased roughness, and provides additional buffer from the impacts of a development on a watercourse. Acceptable techniques for protecting riparian areas and regulatory floodplains are summarized in Table 2.5.

Table 2.5 Acceptable Techniques to Protect/Enhance Regulated Riparian Habitat and Regulatory Floodplains

Phase	Techniques
Planning	• Avoid regulated riparian habitat and regulatory floodplains. • Identify available planting sites adjacent to regulated riparian habitat and regulatory floodplains. • Identify regulated riparian habitat where vegetation has been degraded and propose appropriate plantings.
Design	• Follow the site layout proposed during planning. • Provide limits of regulated riparian habitat and regulatory floodplains. • Delimit avoidance areas and enhanced planting sites. • Avoid channelizing or bank protecting within regulatory floodplains. • Restore degraded stream banks.

At the site planning stage, protection of the regulated riparian habitat and regulatory floodplains will reduce the first-flush runoff volume, provide roughness to attenuate flows, and reduce or negate the requirement for riparian habitat mitigation. In addition, retention basins can be located immediately adjacent to existing riparian habitat in order to enhance this environment by creating a buffer between the developed and riparian areas and by providing supplemental irrigation through stormwater harvesting.

2.3.3 Use of Pervious Pavement

Use of pervious pavements reduces the volume of first-flush retention required because the surfaces paved with permeable materials can be considered disturbed surfaces rather than impervious surfaces. Pavement surfaces should be maintained over the project life to assure permeability remains and reduces runoff to a level less than impervious surfaces.

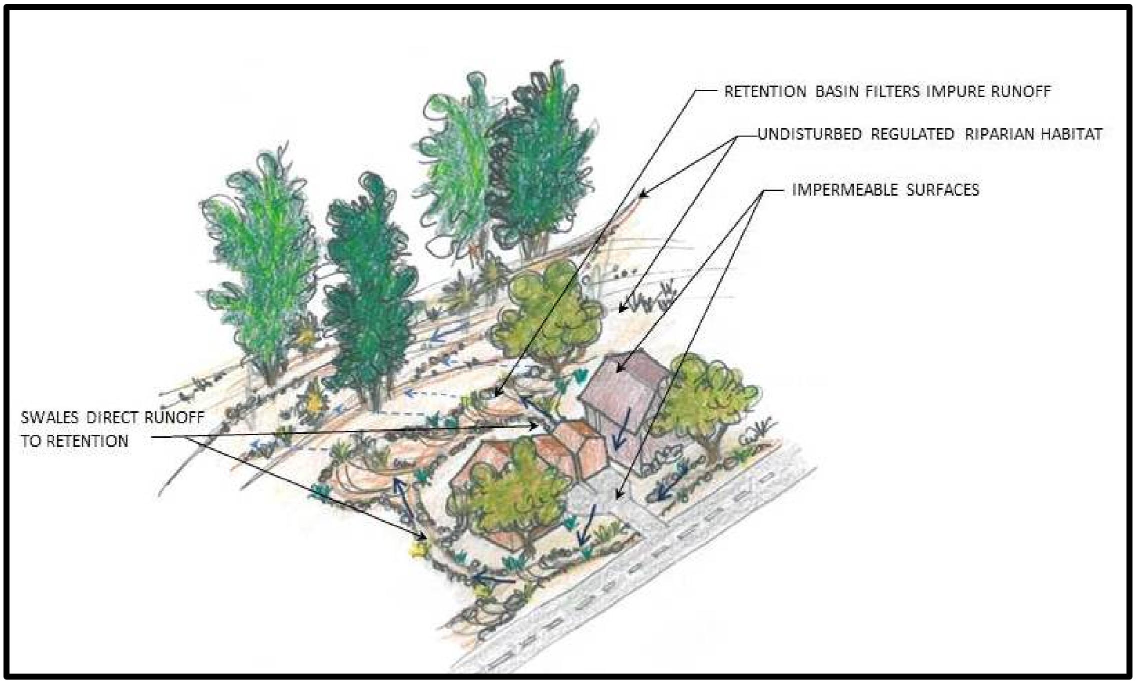


Figure 2.3 Illustration of Protection of Riparian Habitat Adjacent to Development

2.4 Use of LID Practices to Retain the First-flush Runoff Volume

The first-flush retention volume shall be calculated using Table 2.1 and the impervious and disturbed areas of each post-development on-site watershed. The total retention volume provided in each watershed must equal or exceed the required first-flush retention volume within that watershed. Retention areas that are counted towards the first-flush requirement must be located downstream of an impervious or disturbed area. Site grading should route runoff to and/or through the retention areas.

Although their use is encouraged, stormwater or rainwater harvesting facilities provided on individual residential lots shall not be counted toward the project's first-flush retention requirement, except as described in Section 5.2.

The following LID practices can satisfy or reduce the first-flush retention requirement.

2.4.1 Stormwater Harvesting Basins

Stormwater harvesting basins are depressed earthen areas that are located and designed to collect and retain rainfall or runoff from impervious or disturbed areas such as parking lots or rooftops for irrigation of vegetation. If the runoff volume that is directed to a stormwater harvesting basin exceeds the capacity of the basin, an overflow shall be provided with the elevation of the overflow controlling how much water is collected and retained.

Except for basins designed to collect only rainfall, all stormwater harvesting basins shall have an inlet. The discharge rates from stormwater harvesting basins that exit a project site shall not exceed a Balanced or Critical Basin discharge rate.

The maximum effective retention depth is 9 inches. If the basin is sloped, the depressed area may contain internal berms or check dams to pond water in multiple cells with planting areas on the upstream side of the berm. Each cell shall not retain greater than 9 inches of water.

Maximizing stormwater harvesting throughout the site areas reduces the post-developed discharge rates and volumes exiting the site. When stormwater harvesting areas are not large enough to collect all the runoff volume from adjacent impervious areas, overflows will be required. When stormwater collection systems such as storm drains are proposed, engineered features such as elevated grate inlets allow for runoff collection before flows enter the storm drain system. A concept sketch is shown in Figure 2.4.

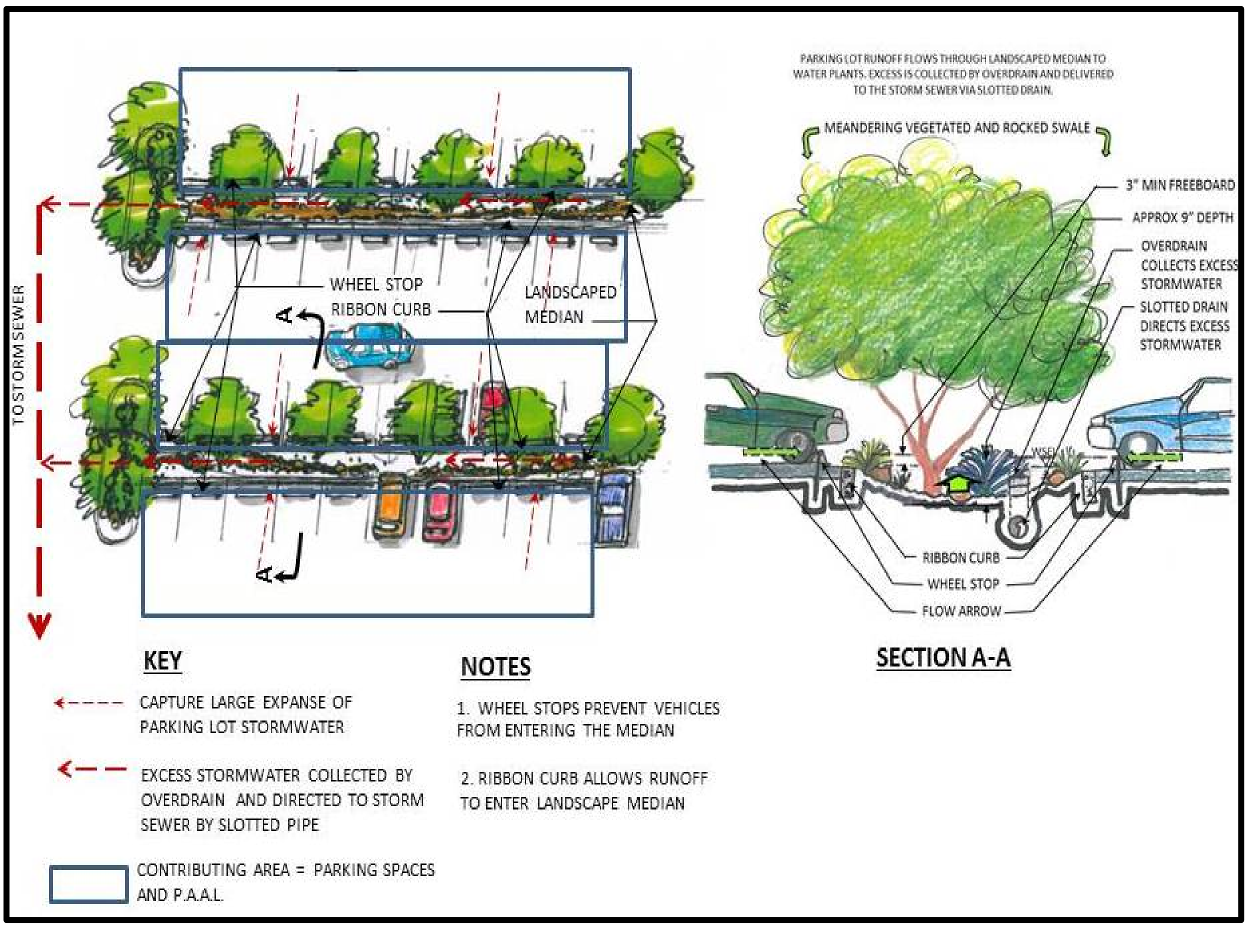


Figure 2.4 Parking Lot with Stormwater Runoff Directed to Basins
Elevated Grate Inlet Maximizes Stormwater Harvesting

2.4.2 Roadside Stormwater Harvesting Basins

Roadside basins collect and retain runoff from impervious areas such as roadways or parking lots. Roadside basins should be located in appropriate areas after considering other factors such as driveway and sidewalk locations, utility locations, site visibility triangles, soil conditions and catchment areas. Safety of pedestrians and vehicles shall be considered when locating roadside basins.

When roadside basins are proposed, they shall not be located at a roadway low point in order to assure continued flow conveyance within the roadway once the basin is full. Roadside basins shall not be located on roads with longitudinal slopes greater than 5% in order to reduce the chance of erosion. Roadside basins require an inlet, but an outlet is not required because flow will follow the roadway slope rather than flowing into a basin when it is full. As shown in Figure 5.2, the design water surface elevation in the basin is set at or above the water surface elevation within the curbed roadway section. A roadside basin at full depth is shown in Photo 2.1.

Photo 2.1 Roadside Stormwater Harvesting Basin at Full Depth

2.4.3 Non-contributing Basins

Non-contributing Basins are stormwater harvesting basins designed to retain the entire 100-year stormwater volume which falls on the basin or on the basin and adjacent area. Non-contributing area basins do not contain any means of disposal other than infiltration or evapotranspiration; therefore, they do not contribute any runoff and should be excluded when determining post-development watersheds.

2.4.3.1 Types of Non-contributing Basins

Non-contributing Basins may be of two types. A Rainfall Only Non-contributing Basin is designed to collect only the rainfall which falls on it, with no contribution from upstream areas. An example of a Rainfall Only Basin is a landscape bufferyard with no inflow from upstream drainage areas. A Rainfall Only Basin must be a minimum of 9 inches in depth to allow a minimum of 3 inches of rainfall from a single event, allow for small variations in the basin bottom for plantings and provide a freeboard of 3 inches. When a Rainfall Only Basin is proposed and designed to the minimum depth, the area of the basin is not included in any peak discharge calculations.

Photo 2.2 Rainfall Only Non-contributing Basin

An Expanded Area Non-contributing Basin is located at a local low point of a project site, such as within a paved or disturbed area of the site. When this type of Non-contributing Basin is proposed, the ratio of the immediately upstream drainage area to the pervious basin bottom area must not exceed 2:1. The Expanded Area Basin shall be 12 inches deep to account for 9 inches of water storage, and 3 inches of freeboard to the top of the adjacent drainage area shall be provided. An Expanded Area Basin and the area draining to it that meet the above criteria are not included in any peak discharge calculations. Figure 5.3 illustrates an application of an Expanded Area Basin within a parking lot median.

2.4.4 Bioretention Basins

Bioretention is the practice of constructing a depressed area specifically to capture and infiltrate water using a constructed soil medium planted with vegetation. Bioretention basins may be used in the same location as stormwater harvesting basins but contain a soil medium that encourages infiltration, soil moisture storage and plant growth. Bioretention basins enhance infiltration characteristics, allowing the same surface planting area to collect more water, potentially reducing the areal extent of stormwater harvesting basins.

The volume captured by a bioretention feature includes both the surface capture volume and the void space of the engineered medium (assumed to be 30%, unless otherwise approved by the Floodplain Administrator).

When bioretention is used, the inlet shall have a sediment trap to capture sediment and organic compounds that may reduce infiltration.

2.5 Retention within Detention Basins

A detention basin also can be designed to retain stormwater, and the volume of the retention within the detention basin can be used to meet the first-flush retention requirement.

Detention basins with uniform side slopes and no terraces may incorporate retention for a maximum depth of 9” below the lowest outlet elevation. The volume provided below the outlet can be counted as retention volume.

Terraces may be proposed within a detention basin in order to meet riparian habitat or native plant requirements. When vegetated terraces and bioretention areas are proposed, the maximum retention depth may be increased to 18 inches. Section 5.8 contains standards for retention within detention basins.

3. PEAK DISCHARGE RATE REDUCTION

3.1 Peak Discharge Rate Reduction Requirements

The required reduction of post-developed 2-, 10- and 100-year peak discharge rates depends on whether the project site is located in a Balanced or Critical Basin.

Within a Balanced Basin, post-developed peak discharge rates shall not exceed pre-developed peak discharge rates at the project boundary.

Within a Critical Basin, post-developed peak discharge rates shall not exceed 90% of pre-developed peak discharge rates at the project boundary, unless a different percentage is specified by the Floodplain Administrator.

A Critical Basin map is available through the Rules and Procedures page of the District's web page. All areas of unincorporated Pima County which are not designated as being located within a Critical Basin are designated as being located within a Balanced Basin.

3.2 Peak Discharge Rate Determination

3.2.1 Pre-Developed Conditions

The pre-developed conditions peak discharge rates for each return period(Q_{pre-rp}) shall be established using the modeling methods described in the District's Technical Policy, *TECH-015*, *Acceptable Methods for Determining Peak Discharges,* and Technical Policy, *TECH-018*, *Acceptable Model Parameterization for Determining Peak Discharges*, and any other technical policies as specified by the Floodplain Administrator. The District's Technical Policies are available through the Rules and Procedures page of the District's web page.

3.2.2 Post-Developed Conditions

Post-developed conditions peak discharge rates for each return period ($Q_{post-rp}$) shall be established using the same methods as for pre-developed conditions.

3.3 Peak Discharge Rate Reduction by Stormwater Harvesting Basins

The optional use of stormwater harvesting basins throughout a project site can reduce the size of or eliminate downstream detention basins. Distributing stormwater retention throughout the site reduces the volume of runoff flowing to a detention basin or other conveyance downstream and may increase the time of concentration.

Where stormwater harvesting basins are proposed, the following method, or other acceptable methods approved by the Floodplain Administrator, shall be used to quantify the peak discharge rate reduction for each return period. Example calculations are presented in Appendix B.

1. Calculate the post-development runoff volumes ($V_{post-rp}$) and peak discharge rates ($Q_{post-rp}$) for the 2-, 10-, and 100- year events (e.g. $V_{post-2}, V_{post-10}, V_{post-100}$) for each watershed. Runoff volume shall be obtained from Equation 3.1.

   $$Equation\ 3.1 \qquad V_{post-rp} = \frac{C_{w-rp}\, P_{1-rp}\, A}{12}$$

   Where:

A	=	Watershed area
C_{w-rp}	=	Weighted runoff coefficient for the return period, dimensionless
P_{1-rp}	=	1-hour rainfall depth for the return period, inches
$V_{post-rp}$	=	Runoff volume for the return period, acre feet

   The solution to Equation 3.1 is the runoff volume reported in the PC-Hydro hydrograph report. The total runoff volume obtained from addition at all-time steps of the PC-Hydro hydrograph is an approximation of the runoff volume obtained from Equation 3.1.

2. Calculate the volume of proposed stormwater harvesting basins (V_{bas}) for each post-developed watershed. Retention volume within a detention basin is not included as stormwater harvesting basin volume because retention volume within a detention basin is incorporated in detention routing calculations.

3. Determine the area of the watershed that will flow to or through stormwater harvesting basins (A_s) and the total watershed area (A_t). Calculate the percent watershed area draining to stormwater harvesting (W_A) by Equation 3.2.

   $$Equation\ 3.2 \qquad W_A = \frac{A_s}{A_t}$$

4. Calculate the ratio (X_{rp}) of the basin volume (V_{bas}) to the post-development runoff volume ($V_{post-rp}$) for each return period by Equation 3.3.

   $$Equation\ 3.3 \qquad X_{rp} = \frac{V_{bas}}{V_{post-rp}}$$

   Or

$X_{rp} = W_A$, whichever is less.

For example, $X_2 = \frac{V_{bas}}{V_{post-2}}$

5. The Stormwater Harvesting Factor (H_{rp}) for each return period is calculated by Equation 3.4. See Appendix C for details on how the Stormwater Harvesting Factor was developed and for a table of factors.

   $$Equation\ 3.4 \qquad y = -0.3843{X_{rp}}^2 + 1.4618X_{rp} - 0.133$$

   For project submittals where stormwater harvesting basins are proposed, a spreadsheet, PC-LID, which automatically returns the correct factor and calculates the peak discharge rate reduction due to stormwater harvesting basins is provided on the Rules and Procedures page of the District's web page.

6. Use H_{rp} to determine the post-development peak discharge rate with stormwater harvesting for the return period, Q_{swh-rp}, by Equation 3.5.

   $$Equation\ 3.5 \qquad Q_{swh-rp} = Q_{post-rp}(1 - H_{rp})$$

   If Q_{swh-rp} is equal to or less than Q_{pre-rp} required for Balanced or Critical Basins for all 3 return periods, then additional detention is not required.

   If Q_{swh-rp} is greater than Q_{pre-rp} required for Balanced or Critical Basins for any return period, then additional detention is required.

   In calculating the required amount of additional detention, an adjusted inflow hydrograph which accounts for the storage volume and attenuation provided by stormwater harvesting basins can be incorporated in the detention basin routing methods of Section 3.4.

   If an adjusted inflow hydrograph is desired, PC-LID shall be used to convert the detention basin inflow hydrographs without stormwater harvesting into detention basin inflow hydrographs with stormwater harvesting. The parameters provided in this section shall be used. The method used by PC-LID to modify a PC-Hydrograph to account for stormwater harvesting is presented in Appendix E.

   In addition to attenuating the peak discharge rate for a given return period, Q_{swh-rp}, stormwater harvesting basins reduce the post-development runoff volume, V_{swh-rp}.

The amount of volume reduction for a given return period can be estimated by Equation 3.6 as:

$$\text{Equation 3.6} \qquad V_{swh-rp} = V_{post-rp}\left(1 - X_{rp}\right)$$

Volume reduction, as well as peak discharge reduction, can be calculated by PC-LID.

3.4 Methods to Calculate the Peak Discharge Rate Reduction by Detention Basins

Incorporation of LID practices and site layout practices can minimize or eliminate the requirement for detention basin volume. When optional LID practices are not included in site design or when LID practices do not reduce peak discharge rates to required levels, detention basins must be included in site design.

The amount of peak discharge rate reduction provided by a detention basin shall be determined by the storage-indication method which calculates change in storage over a time step by Equation 3.7:

$$\text{Equation 3.7} \qquad \frac{(I_{t+1} + I_t)}{2}\Delta t - \frac{(O_{t+1} + O_t)}{2}\Delta t = S_{t+1} - S_t$$

Where:

I_t	=	Inflow at time t
I_{t+1}	=	Inflow at time t + 1
O_t	=	Outflow at time t
O_{t+1}	=	Outflow at time t + 1
S_t	=	Storage volume at time t
S_{t+1}	=	Storage volume at time t + 1

The average inflow over a time step minus the average outflow over a time step equals the change in storage volume during that time step.

Developing a basin design with sufficient storage volume and an outlet design with an appropriate storage-discharge relationship, results in an outflow hydrograph with the target peak discharge. The target discharge will be the pre-developed peak discharge for Balanced Basins or 90% 0of the pre-developed peak discharge for Critical Basins. The Floodplain Administrator may specify a percentage other than 90% for Critical Basins.

The District's PC-Route spreadsheet is recommended for basin routing because results are standardized and consistent across projects. Reviewer proficiency is required and not possible when software not available to the District is utilized. An instruction manual and example are available on the District's web page. HEC-HMS is also acceptable software for basin routing.

Other programs in the public domain may be used if approved by the Floodplain Administrator. Permission to utilize software other than the District's spreadsheet or HEC-HMS must be obtained in writing from the Floodplain Administrator prior to submittal of the detention analysis.

The process of designing a basin and associated outlets is usually iterative. That is, an estimated volume and basin shape are assumed for the first iteration. The estimated basin volume may be obtained from Equation 3.8:

$$Equation\ 3.8 \qquad V_s = \frac{C_w P_t A}{12}\left[1 - \frac{Q_o}{Q_i}\right]$$

Where:

Where:	A	=	Watershed area, acres
	C_w	=	Weighted runoff coefficient reported by PC-Hydro for developed conditions, dimensionless
	P_t	=	1-hour rainfall depth for the design storm under investigation, inches
	Q_i	=	Detention basin inflow, cubic feet per second
	Q_o	=	Detention basin outflow, cubic feet per second
	V_s	=	Estimate of required storage volume, acre feet

Once an initial estimate of the storage volume is obtained, the size of outlet structures is assumed. A trial run gives results which may reach the target for all or none of the 3 design storms. By adjusting the basin and outlet configurations, the designer can successively approximate the design needed to reach regulatory criteria for all 3 design storms. First-flush retention volume, calculated by Table 2.1, when provided within a detention basin should be included in the detention routing calculations.

4. DETENTION BASIN DESIGN STANDARDS

The following design standards apply when detention basins are proposed. Deviation from these standards requires written approval of the Floodplain Administrator. Additional standards or consideration to address specific site conditions may apply. If retention is proposed within a detention basin, design shall also follow the standards in Section 5.8 which supersedes any conflicts with this Chapter.

Requirements for drainage reports are provided in Chapter 10, Drainage Report Content. Requirements for plats, development plans and construction plans are provided in Chapter 11, and Chapter 12 includes required content for as-built plans. Inspection and maintenance requirements are provided in Chapter 7. Typical details required on plans are provided in Appendix E.

4.1 Detention Basin General Requirements

1. Inspection and maintenance are required for all basins. An inspection and maintenance protocol including frequency of inspection, a checklist of items to be inspected and recommended maintenance when an inspection identifies a maintenance requirement shall be prepared by an Arizona registrant. The protocol may be included in the project drainage report or prepared as a separate document. The protocol shall be reviewed and approved by the Floodplain Administrator prior to approval of the tentative plat or development plan. The protocol shall be delivered to the entity responsible for inspection and maintenance. An example of a detention basin inspection and maintenance checklist is provided in Appendix F.

2. To allow performance of inspection and maintenance, basins shall be legally and physically accessible.

3. Upon completion of construction of all basins, an As-built Certification of the basin shall be prepared by an Arizona registrant and submitted to the Floodplain Administrator and entity responsible for basin maintenance. The plan associated with the As-built Certification shall be used by the responsible party when performing periodic inspections and when restoring the basin to design specifications. The Floodplain Administrator may utilize the certification during enforcement actions.

4. Any modification of a basin, other than routine maintenance, that would affect volume or performance requires a Floodplain Use Permit.

5. When detention basins are to be maintained by a private entity, such as a Homeowners Association, this responsibility shall be described in the association's Covenants, Conditions and Restrictions which shall refer to the inspection and maintenance protocol and As-built Certification.

4.2 Detention Basin General Prohibitions

1. Although the use of stormwater and rainwater harvesting facilities on private residential lots is encouraged, any retention volume on private residential lots shall not be counted towards reducing the required detention volume for the project, except as described in Section 5.2.

2. Counting rainwater harvesting cistern volume to reduce the required detention volume is prohibited.

3. On-line detention within regulatory floodplains is prohibited without the approval of the Floodplain Administrator.

4. Walls within detention basins are not allowed without the approval of the Floodplain Administrator.

4.3 Detention Basin Location and Collection

4.3.1 Detention Basin Location and Collection Standards

1. Basins shall be located within the project boundary.

2. Basins shall be located to ensure that post-development flow depth, width and velocity approximate pre-developed flow conditions when flow exits the project boundary.

3. To allow maintenance access, a minimum 4-foot setback from basins and appurtenances, including basin outlets and outer toes of embankments (but not including outlet protection), to the project boundary shall be provided, unless:
   a. A greater setback is required to comply with Section 4.3.1.2, or
   b. Other adequate access space exists adjacent to the basin, such as right-of-way.

   The measurement from the outlet to the property line is illustrated in Figure 4.1.

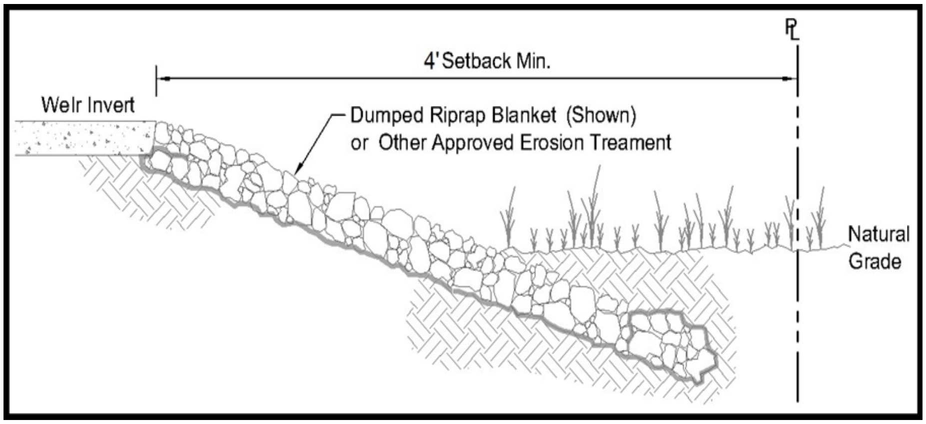


Figure 4.1 Minimum Setback from Property Line

4. In subdivisions, detention basins shall be located in Common Area for Drainage.

5. Basins shall be located to avoid the use of embankments, if possible.

6. When basins are located to accept flows from predominantly natural areas, sediment basins shall be required at inlets. The configuration and volume of the sediment basin shall be determined by an engineer registered in the State of Arizona.

7. When basins are proposed within a regulatory floodplain or erosion hazard area, they shall be designed to withstand all flood and erosion hazards. In addition, it shall be demonstrated that the basin will provide required detention for the 2-, 10- and 100-year on-site flows during a flood event on the regulatory water course.

4.3.2 Detention Basin Location and Collection Prohibitions

1. Inlets or outlets which direct flow to a sidewalk or other paved pedestrian pathway shall include a scupper or other conveyance to prevent sidewalk or pathway overtopping by the 10-year design discharge. Inlets or outlets shall not direct flow over decomposed granite or other erodible pedestrian pathways.

2. Inlets or outlets shall not direct flow through a handicap accessible ramp or handicap parking space.

3. Post-development alterations that affect the function or design of drainage infrastructure are prohibited unless prior approval is obtained from the Floodplain Administrator. Alterations requiring approval include, but are not limited to, alteration of drainage structures, construction of new improvements and post-development site grading which increases flows or causes flows to bypass the basin.

4.4 Detention Basin Depth and Freeboard

4.4.1 Detention Basin Depth and Freeboard Standards

1. Minimum freeboard shall be 6 inches within basins constructed below natural grade and 12 inches within basins designed with an embankment.

2. Freeboard is measured from the 100-year water surface elevation to the lowest top of the basin bank, as shown in Figure 4.2. The freeboard requirement does not apply to weirs or spillways.

3. The water depth is measured from the lowest elevation on the basin floor to the top of the 100-year water surface elevation, as shown in Figure 4.2.

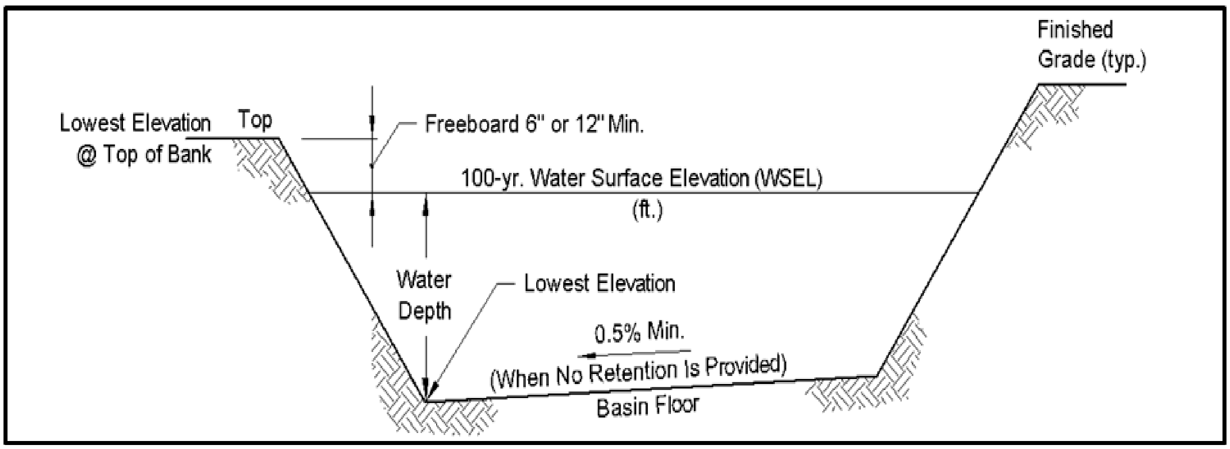


Figure 4.2 Basin Depth and Freeboard Requirements

4. Basins shall have a minimum of 1 sediment level measurement device, which can be incorporated into the weir or the side slope, or constructed as a separate stand-alone device. The device(s) shall be located where sediment is likely to accumulate.

5. Basins designed for 100-year water depths of greater than 2 feet and with side slopes steeper than 4:1 shall have a security barrier at all locations where side slopes are steeper than 4:1. Security barriers shall meet the requirements found in Section 4.11.

4.4.2 Detention Basin Depth Prohibition

1. 100-year water depth shall not exceed 6 feet, unless approved by the Floodplain Administrator.

4.5 Storage Time

4.5.1 Storage Time Standards

1. The maximum storage time for a basin that intercepts runoff from a watershed up to 10 acres in size is 12 hours. The storage time is defined as the time required for stormwater to be removed from the basin.

2. The maximum storage time for a basin that intercepts runoff from a watershed greater than 10 acres in size is 24 hours. The storage time is defined as the time required for stormwater to be removed from the basin.

4.5.2 Storage Time Prohibitions

1. Storage times which exceed the times specified in Section 4.5.1 are prohibited.

2. Ponding times which result in health and safety issues are prohibited, and an enforcement action may be initiated by the Floodplain Administrator for correction of the ponding times.

4.6 Basin Floor

4.6.1 Basin Floor Standards

1. Unless retention is provided in the basin, the basin floor shall be graded to a minimum slope of 0.5% to provide positive drainage to the basin outlet, as illustrated in Figure 4.3.

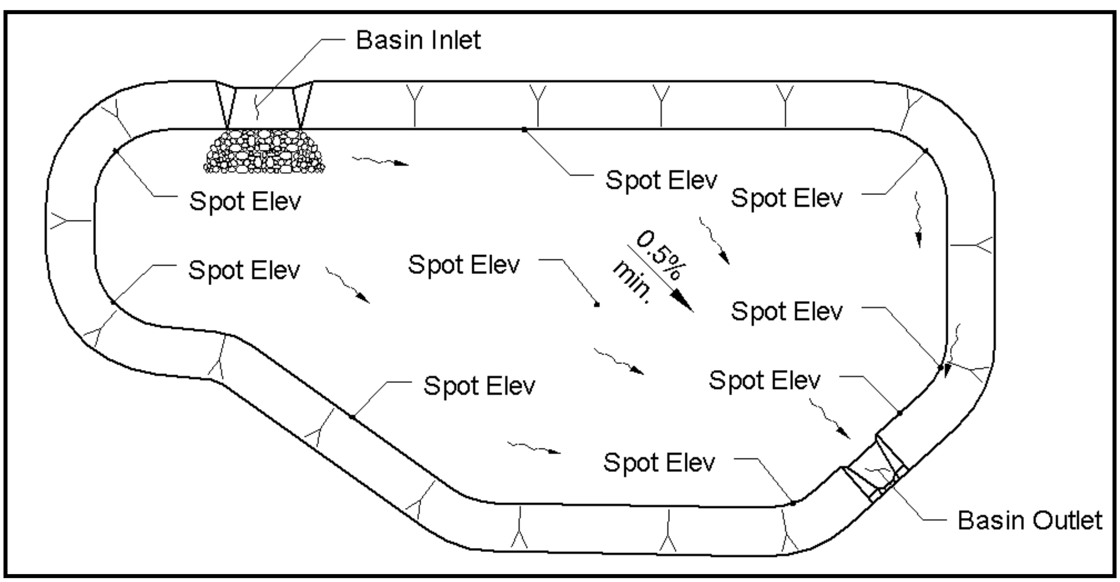


Figure 4.3 Basin Floor Minimum Slope for Positive Drainage

2. The basin floor may be hydroseeded. If hydroseeding is proposed, plant species used in the seed mix shall be selected from the Approved Plant List provided in Appendix B of the Pima County Regulated Riparian Habitat Mitigation Standards and Implementation Guidelines available on the Rules and Procedures page of the District's web page.

3. Other types of vegetation shall comply with Section 4.17.

4.6.2 Basin Floor Prohibitions

1. Except for paths within multi-use basins, the use of decomposed granite or rock less than 4 inches in diameter on the basin floor is prohibited.

2. Invasive non-native plants on the basin floor are prohibited, except for turf grass in multi-use basins.

4.7 Side Slopes

4.7.1 Side Slope Standards

1. Recommended side slope stabilization is presented in Table 4.1, or as otherwise specified in the geotechnical report.

Table 4.1 Side Slope Stabilization

Side Slope Ratio	Stabilization Method
3H:1V or flatter	Approved hydroseed Screened rock with minimal fines Dumped riprap with filter fabric
no steeper than 2H:1V	Hand placed riprap with filter fabric Gabion mattress
no steeper than 1.5H:1V	Articulated revetment units
no steeper than 1H:1V	Grouted riprap Concrete lining with welded wire fabric Gabions
steeper than 1H:1V	Retaining wall

2. The following standards apply to riprap side slope treatments:
   a. Dumped riprap shall have a D_{50} of at least 6 inches and be placed with a blanket thickness of 2 times the D_{50} .

b. Hand placed or dumped riprap shall consist of hard, durable angular stone in erosive environments. In non-erosive environments, non-angular stone is allowed. Gradation shall be provided as described in Table 4.2.

Table 4.2 Dumped or Hand Placed Riprap Gradation

Dumped/Hand Placed Riprap Gradation	
% Passing	Size
100 - 90	2.00 D_{50}
85 - 70	1.50 D_{50}
50 - 30	1.00 D_{50}
15 - 5	0.67 D_{50}
5 - 0	0.33 D_{50}

c. Unless grouted, rock riprap shall be underlain with filter fabric. The filter fabric shall be woven for a minimum of 2 feet into the upper end of the blanket and wrapped for a minimum of 2 feet around the riprap base of the blanket as illustrated in Figure 4.4.

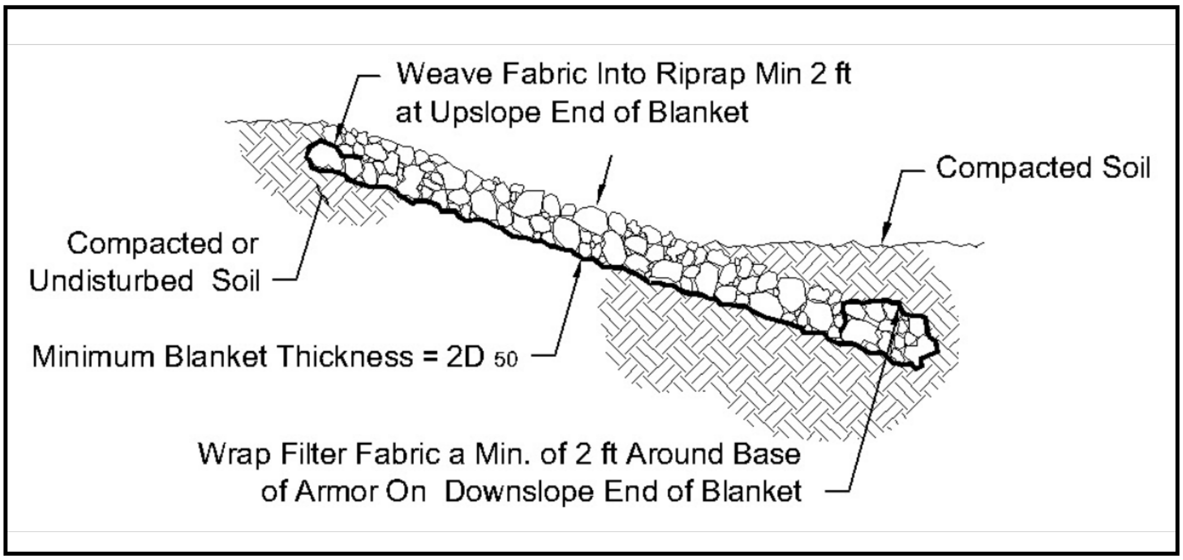


Figure 4.4 Riprap Blanket with Filter Fabric End Treatment

d. Grouted riprap shall be placed on a grout bed at least 6 inches thick. Stones shall be hard, durable and hand-embedded into the grout bed to a minimum depth of one-half the grout depth.

3. When a retaining wall is proposed as a basin side slope, stability design for the retaining wall shall be provided with the development plan or tentative plat. A detail, accompanied by a report clearly stating the assumptions about all soil parameters under saturated conditions, shall be provided and sealed by an Arizona registrant.

4. When hydroseeding is proposed as slope treatment, plant species used in the seed mix shall be selected from the Approved Plant List provided in Appendix B of the Pima County Regulated Riparian Habitat Mitigation Standards and Implementation Guidelines available on the Rules and Procedures page of the District's web page.

4.7.2 Side Slope Prohibitions

1. Free-standing walls are not allowed as a basin side, without prior approval of the Floodplain Administrator.

2. Retaining walls greater than 4 feet measured from the top of the footing are not allowed as a basin side unless prior approval is obtained from the Floodplain Administrator.

3. Riprap that consists of rock that is not hard and durable is not allowed.

4. Invasive non-native plants located on a basin side slope are not allowed. A list of the invasive non-native plants can be found in Appendix E of the Pima County Regulated Riparian Habitat Mitigation Standards and Implementation Guidelines available on the Rules and Procedures page of the District's web page.

4.8 Inlet Structures

4.8.1 Inlet Structure Standards

1. The capacity of an inlet structure shall be determined by methods provided in:
   a. *Drainage and Channel Design Standards for Local Drainage for Flood Plain Management within Pima County, Arizona;*
   b. The *City of Tucson Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona*; or
   c. Other methods accepted by the Floodplain Administrator.

2. When flow crosses a sidewalk or other paved pedestrian pathway, a scupper or other conveyance to prohibit overtopping of the 10-year design discharge shall be used. Inlets shall not direct flow over decomposed granite or other erodible pedestrian pathway.

3. When pipes are used as an inlet, the minimum size allowed is 12 inches.

4. Inlets shall have erosion protection with dimensions determined by the methods provided in the:
   a. *Drainage and Channel Design Standards for Local Drainage for Flood Plain Management within Pima County, Arizona*;
   b. The *City of Tucson Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona*;
   c. *Federal Highway Administration, Hydraulic Engineer Circular No. 14; HEC-14*; or
   d. Other methods accepted by the Floodplain Administrator.

5. The erosion protection shall extend below the finished grade of the basin floor and/or side slope to the appropriate design depth. The surface of the erosion protection shall be level with the finished grade.

6. Unless grouted, rock riprap shall be underlain with filter fabric. The filter fabric shall be woven for a minimum of 2 feet into the upslope end of the blanket and wrapped for a minimum of 2 feet around the riprap base of the blanket on the down-slope end as shown in Figure 4.4.

   Photo 4.1 shows a basin inlet in service which does not exhibit degradation of the basin slopes or floor near the inlet, indicating that an adequate riprap transition was provided. The standards in this manual attempt to provide guidance for designs which will remain well-maintained during the project life.

Photo 4.1 Basin Inlet with Riprap Protection

Photo 4.2 illustrates inadequate riprap placement resulting in erosion extending away from the basin inlet erosion protection.

Photo 4.2 Basin Inlet with Inadequate Riprap Placement

4.8.2 Inlet Structure Prohibitions

1. Inlets shall not direct flow through a handicap accessible ramp or handicap parking space.

2. Ponding exceeding 12 inches in depth at an inlet located in a vehicular use area is prohibited.

4.9 Outlet Structures

4.9.1 Outlet Structure Standards

1. Outlets shall be designed to ensure that flows exiting the project boundary are compatible with the existing downstream drainage conditions and will not have an adverse impact on surrounding properties.

2. Outlets shall be designed to release flow from the basin at rates that do not exceed the 2-, 10- and 100-year pre-development peak discharge rates as determined by the methods specified in Chapter 3. Illustrations of outlet structures indicating that outlets must be

designed for 3 design storms are shown in Figures 4.5 and 4.6 and Photo 4.3. The examples are illustrative only and not intended to be proposed or required designs.

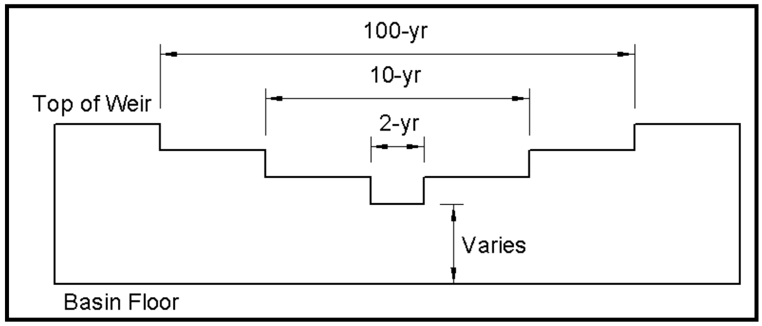
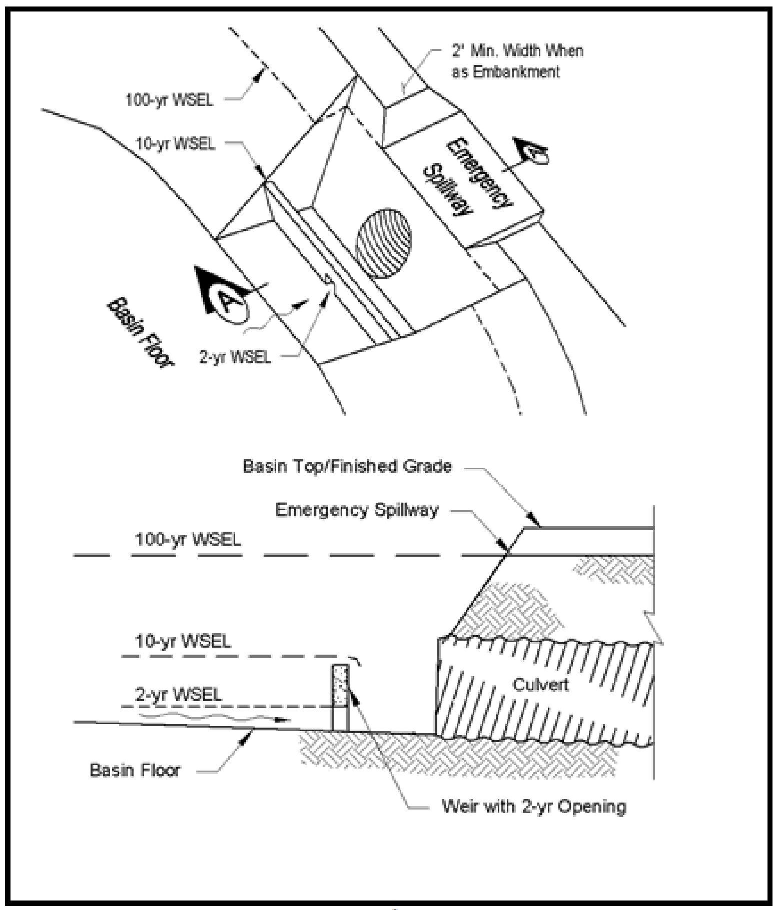


Figure 4.5 Multi-Level Weir Outlet for the 2-, 10-, and 100-year Storms



Cross Section A-A

Figure 4.6 Combination Weir – Culvert Outlet

Photo 4.3 Combination Weir Box

3. The capacity of outlet structures shall be determined using methods provided in:
   a. *Drainage and Channel Design Standards for Local Drainage for Flood Plain Management within Pima County, Arizona*;
   b. The *City of Tucson Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona*; or
   c. Other methods accepted by the Floodplain Administrator.

4. Outlets which direct flow to a sidewalk or other paved pedestrian pathway shall include a scupper or other conveyance to prevent sidewalk or pathway overtopping by the 10-year design discharge. Outlets shall not direct flow over decomposed granite or other erodible pedestrian pathway.

5. Outlets shall have erosion protection with dimensions determined by the methods provided in:
   a. *Drainage and Channel Design Standards for Local Drainage for Flood Plain Management within Pima County, Arizona*;
   b. The *City of Tucson Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona*;
   c. *Federal Highway Administration, Hydraulic Engineer Circular No. 14; HEC-14; or*
   d. Other methods accepted by the District.

6. The erosion protection shall be placed beneath the finished grade of the downstream side of the outlet to the appropriate design depth. The surface of the erosion protection shall be level with the finished grade.

7. Unless grouted, rock riprap shall be underlain with filter fabric. The filter fabric shall be woven a minimum of two feet into the upslope end of the blanket and wrapped for a minimum of two feet around the riprap base of the blanket on the down-slope end as shown in Figure 4.4.

4.9.2 Outlet Structure Prohibition

1. Outlets shall not direct flow to a handicap accessible ramp or handicap parking space.

4.10 Embankments

An embankment, for the purposes of this manual, is a side of a detention basin constructed above natural grade. A typical embankment is illustrated in Photo 4.4.

Photo 4.4 Residential Subdivision Basin with Embankment

4.10.1 Embankment Standards

1. When site constraints prevent a basin from being constructed entirely below grade, an embankment is allowed. Site constraints include topography, existing infrastructure and conflicting code requirements.

2. When an embankment is proposed, the applicant shall include an embankment section in the drainage report describing at least the following:

   a. The physical environment downstream of the embankment, such as natural drainage paths, drainage infrastructure, developed property, and distance to property boundary;
   b. Expected flow conditions in the event of embankment failure; and
   c. Possible effects to public safety and property in the event of embankment failure.

3. Embankments shall have a top width of the 100-year ponding depth or 2 feet, whichever is greater.

4. Embankments shall have at least 1 foot of freeboard above the 100-year water surface elevation in the basin.

5. Embankments shall be compacted to at least 95% of Standard Proctor density.

6. A minimum of 6 inches, or depth recommended by an engineer registered in the State of Arizona, of in-situ soil beneath the embankment base shall be excavated prior to embankment construction.

7. When an outlet is placed through an embankment, an anti-seep collar or equal, shall be provided as specified by an Arizona registered engineer.

8. To allow maintenance access, a minimum 4-foot setback from the outer toes of embankments (not including outlet protection) to the project boundary shall be provided, unless:
   a. A greater setback is required to comply with Section 4.3.1.2; or
   b. Other adequate access space exists adjacent to the basin, such as right-of-way.

   Width, spillway, and setback measurement are illustrated in Figure 4.7.

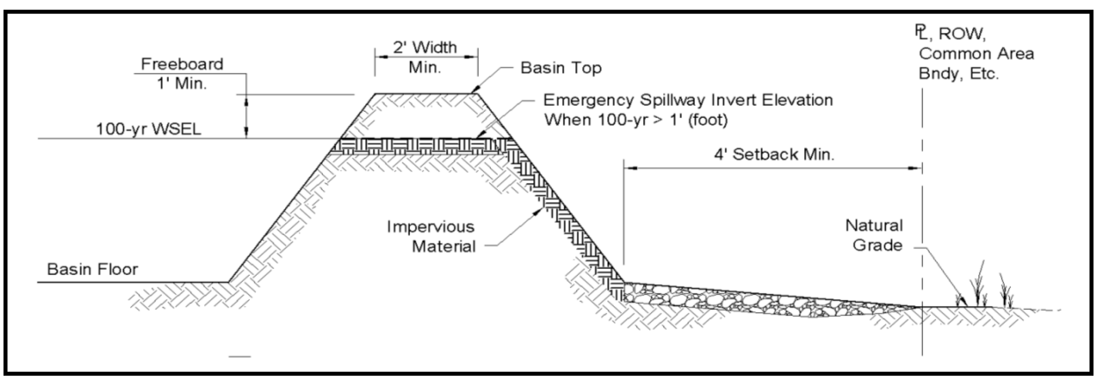


Figure 4.7 Embankment Requirements

9. When embankments are designed to impound greater than 1 foot of water,
   a. An emergency spillway shall be provided;

b. The emergency spillway invert elevation shall be at the 100-year water surface elevation;
c. The invert and the downstream side of the emergency spillway, as shown in Figure 4.7, shall be constructed of impervious material;
d. The design capacity of the emergency spillway shall be the pre-developed 100-year peak discharge outflow rate. The outlet is not included in the routing because it is at the 100-year water surface elevation which is the highest water surface elevation used for routing; or
e. The location of the emergency spillway shall not create any adverse impact to surrounding properties.

10. When an embankment is located within an erosion hazard setback or regulatory sheet flood area, an engineering analysis shall be provided to determine erosion protection requirements which will protect the embankment from lateral migration of the watercourse or other erosion hazards.

11. A separate covenant which specifies, or Conditions, Covenants and Restrictions (CCRs) which include, inspection and maintenance responsibilities shall be recorded when a basin includes an embankment. An example covenant can be found in Appendix G. The covenant or CCRs shall be reviewed and approved by the Floodplain Administrator prior to approval of the development plan or plat. For separate covenants, a properly executed covenant shall be provided to the Floodplain Administrator for recording prior to approval of the development plan. For CCRs, Floodplain Administrator approval is required prior to plat approval, and the CCRs will be recorded by the development services department.

4.10.2 Embankment Prohibition

1. Embankments that are classified as dams pursuant to Arizona Revised Statutes §45-1201 are prohibited.

4.11 Security Barrier

4.11.1 Security Barrier Standards

1. Basins designed for 100-year water depths of more than 2 feet and with side slopes steeper than 4:1 shall have a security barrier at all locations where side slopes are steeper than 4:1.

2. Security barrier shall be a minimum of 42 inches high.

3. The security barrier shall consist of metal, masonry or a combination of the two, meeting the minimum standards in the latest edition of the *City of Tucson/Pima County Standard Details for Public Improvements*.