TAB C-9

SURFACE WATER DESIGN GUIDELINES

Intent

With the continuing development of the campus, the University strives to recognize the long-term inherent value of water by conserving, harvesting, capturing, and reusing it. Within a project's design process, surface water should be an influence on integrated site design promoting proactive solutions that are consistent with or exceed regulatory standards. Given current limited storm sewer and land capacities, combined with a historic reliance on existing streets for surface water conveyance, some of the mitigation of past and future surface water issues at the University of Arizona should occur on a project by project basis. In the interest of fulfilling this intent, two types of design criteria are noted below. The *General Surface Water Guidelines* address issues applicable to all projects while the *Specific Features Guidelines* inform the design intent of specific surface water elements.

General Surface Water Guidelines

- Preliminary siting studies for the project shall consider information related to the existing drainage conditions of the site, using the most recent campus-wide drainage study as a reference. The preliminary siting studies shall consider, at a minimum:
  - The existing site area and adjacent areas within 500 feet of the project, and include areas which may contribute surface water (watershed) to the proposed site.
  - The general area the site is within, for example, the campus historical core, North Campus, South Campus, etc.
  - Evaluation of existing landscapes, plant palette, formal, informal, historic, ornamental – introduced plants.
  - Evaluation of the contextual setting of the site.
  - Utility (below/at grade) corridors, emergency route, pedestrian and automobile electric cart core circulation routes.
  - Identified project building expansion and proposed expansion adjacent to the project site.

- Whenever possible, site development should not diminish the quality or increase the quantity or rate of surface water flow that leaves the site in its existing condition. Potential increased surface water flows should be mitigated on-site if possible.

- Wherever possible, site development should strive to reduce the quantity and rate of flow at or below the original natural condition of the site through the use of landscape swales and water harvesting.

  - Opportunities for water harvesting should be specifically discussed in conceptual narratives in early design stages. *"The City of Tucson Water Harvesting Guidance Manual, 2005"*, and *"Harvesting Rainwater for Landscape Use" by Patricia H. Waterfall (University of Arizona Cooperative Extension)*, should be used as technical references.

- Site development should meet or exceed all applicable regulatory standards. The intent is to meet at a minimum COT stormwater standards (*Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona*), exceed them where possible, and to demonstrate innovative techniques for which the City may not have applicable standards.

- The *Surface Water Report* described in Tab B-11 of these Design and Specifications Standards and prepared for a project will be based on the format and technical standards of the COT (*Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona*) but will be tied to the hydrology model used for the most recent UA campus-wide drainage study. This model is consistent with but more detailed than COT models for the campus.

- All construction activities must be in compliance with the current version of the *University of Arizona Stormwater Management Plan*.

- Wherever possible, site development should occur in a way such that all flows exiting the project site remain in the current watershed sub-basin so as to not impact drainage patterns in adjacent watershed sub-basins.

- Flood Prevention: Proposed building ground floor elevations and any apertures into the building should be 1' or more above the 100 year flood plain (modifying this standard is strongly discouraged, but is an option if appropriate floodproofing can be demonstrated). Sunken access ways or patios leading to building levels below the natural grade of the site are not permitted when adjacent to a 100 year floodplain, and discouraged in other areas. Soil should be graded so that water drains away from the building at a minimum of 2%, subject to other site criteria, such as accessibility. Elevations of underground utilities shall be considered in the grading layout.

- Design and construction activity must be in compliance with the current *University of Arizona Stormwater Management Plan* submitted to Arizona Department of Environmental Quality.

- Site development must be done in a way to avoid the following conditions:
  - Ponding of a duration that may allow mosquito breeding
  - Ponding in access ways which may create a nuisance for pedestrians.
  - Ponding within 10' of building foundations (to prevent infiltration that may cause indoor mold or structural problems)
  - Any water catchment not draining within 24 hours
  - Retention facilities not draining within 12 hours.
  - Surface water that is wasted, e.g., by running down the street.
  - Surface water that is routed in a way which inappropriately distributes sediment or chemicals.
  - Channelized or concentrated water conveyed over sidewalks
  - Water running off of irrigated turf areas.

- A determination is to be made as to whether or not construction activity resulting from site development will disturb 1 acre or more. If 1 acre or more is disturbed a Storm Water Pollution Prevention Plan (SWPPP) will be required and an Environmental Protection Agency AZPDES Storm Water Construction General Permit must be secured. The University of Arizona department of Risk Management and Safety may be contacted for guidance in securing this permit and filing the associated EPA Notice of Intent (NOI).

- Storm Sewer Discharges:
  - Water discharged (e.g., storm water, condensate) from sources that must be pumped to a location for conveyance/disposal should not be directed to roadways/hardscape. Such discharges should be directed to planted areas except when the water quality would be detrimental to plants.
  - Storm and surface waters are not candidates for disposal in the Publicly Owned Treatment Works (POTW) or sewer system. Such disposal would constitute "hydraulic loading" and is considered a prohibited discharge by Pima County Industrial Wastewater Ordinance.
  - Manholes are not allowed in low lying areas and/or known watercourses to prevent waters from infiltrating through perforations in the manhole cover.

- Roof Drainage:
  - Roof drainage outlets and landscape surface materials must be designed to prevent landscape erosion.
  - Ponding within 10' of the building edge is prohibited.
  - Roof leaders/scuppers should be of a small enough diameter so as to divide roof runoff into a series of outlets with a low enough volume/velocity that will allow water to be harvested equally throughout the site (i.e., broken into small volumes for smaller basins/swales). Large diameter outlet pipes convey too much water at too high velocity to capture in small-scale landscape swales. Proper clean outs should be provided to allow necessary maintenance of smaller diameter pipes.
  - Bubbler boxes are strongly discouraged but may be used to dissipate the energy associated with larger volume rain leaders. In such cases, the bubblers should be located at least 10' from building foundations (see specific guidelines for bubblers below).

- Ancillary Water Sources Available On Or Near The Site:
  - Water sources such as mechanical condensate, process water, graywater, drinking fountain water, and other sources identified shall be considered as part of passive and active water harvesting systems.
  - Such water may be used, if deemed appropriate, for landscape irrigation, return to central plant for other uses, supplementing water for pools or water features, or other uses to be determined.

- Soils:
  - Testing
    - If possible, soils testing should be conducted at the time of or prior to preparation of the initial draft of the *Surface Water Report* that will be prepared for a project. Such reports should investigate not only structural characteristics but also percolation rates and agricultural soils analysis as it relates to plant growth. Agricultural soils analysis shall be prepared by a certified soils agronomist.
    - A soil percolation test is required after rough grading of major/regulatory detention and retention facilities to verify that site development activities have not negatively impacted percolation rates. If reduction in percolation rate is identified, mitigation may be required.
  - Subsurface preparation
    - Structural soils should be explored for use under large expanses of hardscape or other areas with limited percolation.
    - Soils beneath/adjacent to french drains, bubbler boxes, and other sub-surface structures should be over-excavated and replaced with an engineered soil designed to absorb or accept water.
  - Compaction
    - Soil beneath the bottoms of all water harvesting areas should be loosened to a depth of at least 18” prior to trenching and installation of irrigation lines.
    - Specified compaction required for buildings, streets, and other structures shall be maintained within specified distances around such structures. Beyond these compaction zones, soil should be loosened to a depth of at least 1’ prior to planting within all landscaped areas.
    - All construction debris and waste material must be removed from the soil within landscape and basin areas.
    - Acceptable limits of compaction must be maintained through completion.

  - Soil Grading: The finished grade of all landscaped areas should be recessed downward from adjacent paved surfaces to create water harvesting catchments. Maximum reveal at edge of pedestrian circulation paving shall be 1" to minimize the risk of injury. A 12" – 18" level shoulder area to the paved surface shall be maintained. The shoulder area shall have a 1% - 2% cross slope away from paving directed to water harvesting/basin areas.

  - Ground Cover Materials:
    - Within areas conveying significant storm flows, ground surfacing should consist of a material that is able to withstand scouring. This includes hardscape paving, rock mulch, graded or sized rock, rip rap, fractured rock, and turf in some situations. Bare soil, decomposed granite, or other loose forms of mulch are not suitable for this application. Filter fabric placed with 12" minimum toe downs at edges shall be used under all rock, mulch, and rip rap within conveyance areas.
    - Rip Rap: Where required, utilize a rough, non-angular, weathered Catalina granite incorporating a spectrum of tan and gray colors. Alternatives will be considered based on justifications for the specific application (samples should be provided by design professionals). Filter fabric should be included under rip rap used for erosion protection in a conveyance channel, and any gaps in rip rap shall be fully filled with pea gravel or sized/graded rock that is swept in the gaps to prevent erosion.
    - Fine grades of decomposed granite should not be used within or adjacent to basins or water harvesting areas. Landscape areas which shed water rather than capture it should receive ½”+ crushed gravel with no fines, preferably with a mixture of sizes and some color variation to reflect the native desert surface.
    - The bottoms of landscaped basins should receive ¼” pea gravel or ½”-1” sized/graded crushed rock that has been washed to remove all fines or organic mulch.
    - Colors samples of all proposed rock types shall be submitted for approval.
    - Organic mulch is encouraged in locations where the vegetation, water collection, erosion, and slope characteristics make it appropriate.

- Turf, as a surface material in large regulatory basins, is only permissible when combined with a low-flow landscaped area which allows a majority of the turf to drain within a short time. It is preferable to utilize turf predominantly on the bottom rather than sides of large basins for ease of irrigation and mowing and to allow the turf to be watered by sheet-flow runoff. Based on project-specific considerations, turf panels may include a shallow retention catchment (6" or less) which shall include a prepared soil bed that will rapidly absorb retained rainfall. Extensive sub surface soil preparation will be required for turf in basins which collect greater volumes.

Specific Features Guidelines for Drainage and Water Harvesting

The following guidelines are intended to inform the design of specific surface water features when they are included in a project. Note that the Design and Specifications Standards (DSS) include specific guidelines for Water Features and for Wells in other sections. This section of the DSS includes guidelines for the following features:

- Water Storage Features
- Water Harvesting Micro-Basins
- Regulatory Detention / Retention Basins
- Sumps
- Dry Wells
- French Drains and other Subsurface Structures
- Structural Soil
- Bubbler Boxes
- Sidewalks
- Storm Sewers
- Area Drains
- Infiltration Chamber
- Permeable Paving

- Water Storage Features

  - Guidelines for all types of water storage cisterns:
    - Access points into the cistern must be secured for safety
    - Openings must be sealed or screened to prevent mosquito breeding
    - Light must be prevented from entering to prevent biological growth
    - A method for using/distributing the water must be designed into the system.
    - Projects which include cisterns are encouraged to explore all available sources of water to be captured, including rainwater, condensate, and other sources unique to the location.

- Underground water storage cisterns:
  - Underground cisterns may be used where a very large volume of water is being stored or where there are no appropriate surface level sites available.
  - Water stored in underground cisterns may be allowed to infiltrate or bleed off, although the preference is for this water to be stored and utilize for landscape irrigation. In such cases, pumping and filtering mechanisms must be included.

- Above ground exterior water storage cisterns:
  - Above ground cisterns are appropriate for smaller volumes of water and where the storage structure may be appropriately integrated into the landscape.

- Water Harvesting Micro-Basins

  - General Guidelines for Design of Water Harvesting Micro-Basins:

- The depth of a micro-basin should be sized according to the anticipated volume of water that will enter the basin, taking into consideration whether the basin will only collect water falling on the basin area or if it will be intercepting flows from adjacent watersheds.
- The edge of any ponding within microbasins should be 10 feet from building foundations. Closer placement may be possible with the approval of a soils professional and may include structural soil backfill with protective liner at the foundation.
- Micro-basins should be designed so that water infiltrates the soil within 12 hours.
- Unpaved or planted areas should be sunken below the grade of adjacent hardscape to create micro-basins wherever possible. Pedestrian circulation should be designed to discourage cutting across basins so as to avoid compaction, erosion, and damage to plants.
- Conveyance swales should incorporate check dams and/or nested micro-basins to slow and harvest water and trap sediment.
- Water should be harvested and slowed near its source to avoid the need for larger catchments downstream.
- The *City of Tucson Water Harvesting Guidance Manual* should be used as a technical reference.
- The design/placement of micro-basins shall "co-evolve" with the planting design so that plantings will take maximum advantage of harvested water.
- In larger, open, landscape areas not constrained by adjacent hardscape, a series of interconnected small basins (5' to 15' wide) terraced into the landform should be included. Additional smaller basins which correspond to planting patterns are generally preferred over fewer large basins. Where included, a concept diagram for such interconnected basins is to be provided in the Surface Water Report.
- The arrangement, contouring, sequence, and form of micro-basins should take on a natural character unless the form of the adjacent hardscape, or an approved overarching artistic concept, suggests more formal or otherwise less-organic forms are appropriate. Earthworks within small, narrow areas should generally include simple, function forms due to the limited area to vary the pattern.
- Plants selected for use in microbasins shall have compatible water needs. Other considerations shall include sun exposure, maintenance requirements, shape, form and aesthetics. Certain plant forms may work better in informal vs. formal planting designs. Consideration shall be given to the area of campus (historical core, AHSC, etc.) when selecting plants. Plants shall be used to create a seamless transition from new improvements/building projects and the existing adjacent landscape. Plants with differing water needs shall be irrigated and controlled separately. Irrigation system shall be capable of monitoring plant water needs through the use of soil moisture gauges and weather station data.

- Drawing Standards for Water Harvesting Micro-Basins:

  - Micro-basin details shall be developed and referenced in all planted or non-paved areas on both the landscape and civil drawings. Below are standards to be used in preparing required drawings which describe in graphic and text form water-harvesting micro-basins.

    - Plans:
      - A 10' setback line from buildings is to be shown on the grading plan indicating the limits of allowable ponding.
      - The design of paved or circulation areas should, wherever possible, slope the hardscape/surface toward micro-basins. All paving adjacent to micro-basins shall be labeled with arrows indicating a slope toward the micro-basins.
      - RipRap shall be indicated on appropriate drawings for micro-basin slopes where required.
      - The level, flat bottoms of micro-basins shall be shown on civil/grading *and* planting plans with a hatch pattern. Spot elevations shall be shown on the grading plan to indicate the elevation of the flat bottom area.
      - The location of any french drains within micro-basins must be indicated on civil/grading plans.
      - For micro-basins accepting water from adjacent watersheds/basins or overflowing into adjacent watersheds/basins, the location of inlets/outlets/spillways shall be indicated on the civil/grading plans along with flow arrows. Rip rap needed for erosion protection shall be shown at inlets/outlets. Volume calculations shall be provided where necessary.

- Details/Notes: A detail or series of details with accompanying notes that reflect the following standards for micro-basins shall be prepared.
- The edge of ponding in micro-basins should be a minimum 10' setback from any building.
- Adjacent to hardscape, there should be a minimum flat area 12" wide of compacted soil before beginning the sideslope of a micro-basin.
- Basin sideslopes should vary, but be no greater than 3:1. Variation in slope is desirable to create undulations in the form of basins.
- Sideslopes and berms which form the edge to micro-basins should be compacted.
- Slopes steeper than 4:1 may require rip rap depending on surface flows, erosion potential, and circulation patterns.
- Micro-basin bottoms should be level, with flat areas as large as possible while not causing sideslopes to exceed 3:1 .
- When proposed planting areas are bound by hardscape at different elevations, micro-basins are to be included for these planting areas as long as a catchment area can be achieved which is at least 1' wide (flat bottom) by 2" deep (while not creating sideslopes steeper than 3:1).
- Micro-basin flat bottoms shall be excavated/loosened to a depth of at least 18" beneath the finished grade of the basin bottom. This shall be done at the time of rough grading and prior to trenching for irrigation lines. Loosened soil should be re-compacted beneath new tree root balls. Note that by following all guidelines in this section, basin bottoms should be far enough away from fixed structures so that minor settling of the soil should not have any negative impacts.
- French drains are encouraged within the bottoms of micro-basin to promote infiltration of water when contributing flows from adjacent watersheds warrants a greater holding capacity. Micro-basin french drains must be longer than they are deep and the bottom of the french drain must be no more than 3' beneath the basin bottom so as to keep the water within the soil root zone of plants. If french drains are proposed, discrete details must be prepared for them.
- For a micro-basin accepting flows from adjacent watersheds, the basin bottom should generally be no deeper than 18" below the basin spillway or rim (greater depth is acceptable if there is an outlet at 18" or less). For a micro-basin only receiving rain falling directly within it, typical depths should range from 4" to 8".
- Rip rap is to be included for erosion protection at spillways.
- The bottoms of micro-basins should receive ¼" pea gravel, or ½"+ crushed gravel that has been washed to remove all fines, including gravel dust. Micro-basin bottoms may also receive organic mulch.
- If a series of small interconnected or terraced basins are included in the design, the horizontal, vertical, and flow relationship between them should be documented in one of the details.
- Typical planting details (shrub, tree) are to be shown in the level bottom and side slope terraces in the micro-basin details, with appropriate grade transitions shown. For trees, indicate the rootball sitting on undisturbed native soil with top of rootball level with a terrace 4"-12" above the finished flat bottom of the basin. Indicate a mulch layer within this terrace which does not bury the trunk. In no circumstances shall there be a low area for water to pond directly around the trunk of the tree.
- Excess soil removed from planting holes must not be spread or disposed of within micro-basins.
- Include a note that all micro-basin grading must be complete and inspected prior to planting and again prior to application of mulch.

- Regulatory Detention / Retention Basins

  - Mitigation of Regulatory Storm Flows with Surface Basins
    - Basins should be designed for multiple-use (i.e. drainage, active and passive recreation, landscape aesthetics, and circulation). Basins should be designed as a collaboration between the project Landscape Architect and the Civil Engineer, with input from other team professionals. The basic land forms and site characteristics should be laid out in concept form by the Landscape Architect. The preliminary basin design will be approved by the University prior to detailed hydrologic modeling by the Civil Engineer.
    - Smaller non-turfed basins can be used for passive type use such as sitting areas. Site amenities such as benches can be built in or incorporated in the design of the basin area.

    - Universal access should be provided to basins to the greatest extent possible using functionally and visually integrated structures.
    - Flows from land uses which are likely to generate pollutants (such as parking lots) should route water in a way that isolates the first flush runoff in discrete catchments so as to limit the spreading of contaminates and to make future clean up easier.
    - Routing of flows between micro-basins or larger basins should be done in a way to slow flows for increased absorption and reduced erosion.
    - The following characteristics should be designed for turf basins to insure quick draining into a landscaped low-collection area.
      - Minimum bottom slope of 1% for turf
      - Sub-surface should be prepared to a minimum of 18” below imported soil for the turf.
      - Low-flow collection areas should not be in the low point of turf. The lowest turf areas should drain to landscaped collection areas, allowing the turf to dry out as soon as possible following the rain.
    - Landscaped (non-turf) basin bottom surface: Round pea gravel or ½” to 1” sized/graded crushed rock is to be used in basin bottoms.
    - Basin form: Single-use storm water catchment basins typically derive their form based on simplified patterns which are easy to translate into a storage volume, and are therefore easy to model. Such forms are generally incompatible with the type of multi-use open space basins desired on the University campus. Therefore, basin side slopes should vary (i.e., the horizontal distance between contours should vary) in response to aesthetic and multi-use design objectives of the project. During concept design, water storage calculations corresponding to desired mitigation goals are to be converted into gross volumetric dimensions and then provided to the project Landscape Architect for use in designing the basin form. The resulting form will then be modeled by the project Hydrologist in order to provide feedback about adjustments which may be needed in the size/form of the basin to achieve storm mitigation goals. Several such iterations of design refinement may be required to achieve a satisfactory result.
    - Basin side slopes: Side slopes should be a maximum of one unit of vertical change for every three units of horizontal change.
    - Retention basins must demonstrate ability to drain within 12 hours, based on soil tests.
    - Low flow metering/outleting to bleed off detained water should be proposed for basins which percolation testing has shown will not drain within 12 hours (otherwise a plan must be proposed for ongoing pumping).
    - Weirs / outlets / inlets should be designed as integral elements of the landscape as opposed to purely functional conveyance structures

  - Mitigation of Regulatory Storm Flows with Subsurface Storage tanks:
    - Subsurface storage tanks include various systems to hold water underground and are conceptually similar to underground cisterns (see above), with the difference being that subsurface storage tanks are sized to accommodate or mitigate flow volumes corresponding to major storm events.
    - Guidelines noted above for underground cisterns apply to subsurface storage tanks.

- Sumps
  - Water collected in site/building sumps: Sumps which collect water running off into courtyards or other non-draining areas should be designed to pump the water into landscaped areas configured for water harvesting, or into an adjacent irrigation system. Sump water which may contain unique pollutants, sediments, or other elements making it unsuitable for irrigation may require special provisions for disposal.
  - Discharge of sump water shall not be to surface streets or storm sewers.

- Dry wells
    - Drywells are defined by the Arizona Department of Environmental Quality (ADEQ) as: "A drywell is a bored, drilled, or driven shaft or hole with a depth that is greater than its width and that is designed and constructed specifically for the disposal of stormwater (Arizona Revised Statutes (A.R.S) 49-331(3)).
    - Drywells shall be considered only as a last resort for the distribution or disposal of surface/storm waters.

- French Drains and other Sub-Surface Structures
  - French drains are encouraged in larger volume harvesting/detention areas where adequate soil percolation may be in question.
  - French drains must be wider than they are deep.
  - Rock backfill in drains may be wrapped with filter fabric depending on the intent of the drain.
  - Perforated pipe may be placed in the trench to facilitate the movement of water throughout the length of the drain.
  - French drains can be routed through planted areas to maximize using rainwater to supplement irrigation.
  - The intent of French drains is to dispose and disperse water throughout soil within the root zone.
  - The bottom is to be no deeper than 10' beneath the finished surface grade. A maximum depth of 3' is desirable in planted areas so as to keep water within plant root zones.
  - Other sub-surface structures intended to disperse water into the soil root zone, such as infiltration chambers shall be evaluated on a case-by-case basis.

- Structural Soil
  - Structural soil is a specialize soil mix involving a coarse aggregate, organic and non-organic soil components, and a binder which creates a structural sub-grade sufficient for heavy load paving, while also providing the air and water flow needed within the soil for root growth.
  - Structural soil shall be utilized to increase the viable root growth zone for trees planted within large expanses of hardscape.
  - Water collected/shed from adjacent hardscape shall be directed into the structural soil via surface flows to planter cut-outs, area or roof drains which empty directly into the soil matrix, or through permeable pavement.

- Bubbler boxes
  - Bubbler boxes are designed to overflow, therefore, they do not meet the definition of a drywell (they are for conveyance, not disposal).
  - All bubbler boxes shall be constructed to have porous, draining bottoms, and the soil beneath bubbler box units must be prepared in such fashion to support percolation.
  - All bubbler box systems shall be constructed to drain their full volume with 24 hours.
  - Bubbler boxes shall be designed to minimize clogging, silting, and calcification, and shall be easy to clean.
  - Bubbler box systems shall drain into one or a combination of recessed turf areas, landscaped water harvesting microbasins, or areas of structural soil.
  - The design shall be configured to allow pumping if needed over the long term. In the event pumping systems are required, pumping durations shall be to be limited so as to not impact landscapes.

- Sidewalk Scuppers/Trench Drains
  - Water from roof drainage outlets, channels and swales must not be routed across sidewalks.
  - Scuppers, drain pipes or trench drains should be used to convey this water beneath walks or paths. Provide rock mulch or rip rap at inlet and outlet as needed to control erosion.
  - It is preferable to route water under walkways in a way that does not interrupt the continuity of the walkway surface material (as happens when steel plate is used). If walkway surface material is interrupted, trench drains may be used as a design element in the hardscape.
  - Sheet flow conveyance across sidewalk surfaces is to be minimized wherever possible by capturing as much runoff as possible in adjacent water harvesting microbasins.

- Storm sewers
  - Campus storm sewers are to be designed using City of Tucson standard details unless alternative direction is provided.

- Area Drains
  - Drains collecting water within confined spaces which do not discharge flows via the natural grade shall be constructed so as to accommodate all flows which may reasonably be expected to enter the drain system during a 100 year storm.

- This shall include consideration of flows originating beyond the extents of the immediate project (e.g., an adjacent 100-year floodplain) which may enter the immediate area during a large storm event.

- Infiltration Chambers
  - Infiltration chambers are recommended in situations where surface catchment is limited or localized flooding is likely due to lack of a natural outflow path. Chambers should be designed to percolate water into the soil root zone.

- Permeable Pavement
  - Permeable paving includes a variety of surfaces which withstand pedestrian and/or vehicular loads and wear, and permit infiltration of water and air into the subgrade.
  - Permeable paving must be installed with an appropriate subgrade which will allow absorption and/or draining of subsurface water to another location. If there is vegetation adjacent to the permeable paving, a Structural Soil subgrade should be used to allow water absorption into the soil. If there is no adjacent vegetation which would benefit by the water being deposited in the soil, a sub-surface drain system should be included which moves the water to adjacent planting areas.

References:

[1]*City of Tucson Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona 1989*

[2]*Stormwater Detention Retention Manual for Pima County Department of Transportation & Flood Control District and the City of Tucson, 1987*

[3]*City of Tucson Water Harvesting Guidance Manual, 2003*

[4]*University of Arizona Master Drainage Study, 1997*

[5] *University of Arizona Stormwater Management Plan*

[6] *Harvesting Rainwater for Landscape Use, 1998*