Appendix D

Surface Water Master Implementation Plan (SWMIP)

Surface Water
Master Implementation Plan

Prepared for

The University of Arizona
Campus and Facilities Planning

February 13, 2009

M3-PN06064

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SURFACE WATER MASTER IMPLEMENTATION PLAN

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1 EXECUTIVE SUMMARY

A positive experience at any learning institution goes far beyond the quality of faculty and curriculum. These experiences are also influenced by the quality and serviceability of various facilities and infrastructure encountered in daily campus life. The projected physical growth of The University of Arizona campus brings with it a greater responsibility for the mitigation of campus flooding due to rainwater and its impact on surrounding neighborhoods. In recognition of this responsibility, The University of Arizona has commissioned an update to the 1997 campus-wide drainage study, *The University of Arizona Campus Master Drainage Plan,* in order to reflect current conditions and investigate future "build-out" conditions.

The following study, in addition to being an update to the 1997 study, is an attempt to address the continuing problems associated with rainfall runoff at The University of Arizona. The analysis and recommendations are primarily focused on the flooding that would result from a 100 year storm event, which is the most extreme storm typically used in design. In Tucson, this event is designated as a storm that produces 3 inches of rain per hour. A 100 year storm can be misinterpreted as a storm that occurs every 100 years. In actuality, a 100 year storm is an event that has a 1% chance of occurring in a single year. This does not imply that a 100 year storm cannot occur two years in a row. Each year has the same probability of experiencing a 100 year storm, 1 in 100. Designing for this recurrence interval can be costly, but with intelligent placement of catchments and water harvesting systems, these costs can possibly be outweighed by the savings that would otherwise be incurred in water consumption.

PURPOSE OF STUDY

The objective of this study is to report on the hydrologic conditions of The University of Arizona and update the floodplain boundaries to reflect the most current state of the campus. In addition to this, future conditions were also investigated to determine the impact of the changes that will be incorporated by The Comprehensive Campus Plan, which identifies the new buildings to be constructed and the physical changes that the campus will experience in the years to come. The results of these investigations are used to locate logical and effective opportunities for rainwater catchment and management throughout flood-prone areas of campus. Another purpose of this study was to develop design guidelines that can be incorporated into future projects throughout the University to address the manner in which rainwater is managed.

SUMMARY OF PRODUCTS

This study has produced many useful hydrologic tools for the future planning of the University of Arizona; these are summarized below.

- The identification of buildings with finish floor elevations that are below the predicted 100 year water surface elevation.
- Many catchment opportunities have been located and analyzed to eliminate or greatly decrease flooding nuisances on campus. Many of these opportunities exist currently, while others will be available as the implementation of the campus plan progresses.
- Volumes at various concentration points along each major flow path were calculated and identified in order to provide a working model in which volumes can easily be modified to reflect changes made to the campus landscape.
- Along with Catchwater Group and Acacia Group, several options for runoff retention/detention, both above and below ground, have been identified for implementation into future campus projects. In addition, Guidelines have been added or modified in The University of Arizona Manual of Design and Specification Standards to reflect the findings and concerns encountered in this study.

CONCLUSIONS AND RECOMMENDATIONS

After the analysis and investigation of the hydrological conditions of the University of Arizona, it has become apparent that an event, such as a 100 year storm, could cause significant flooding problems in both streets and buildings throughout campus and in neighboring communities. This is a costly event that can be avoided by strategically placing runoff catchments throughout the problem areas on campus. M3 Engineering & Technology (M3) is recommending that the catchment opportunities proposed in this study be incorporated and designed to contain 100% of the 100 year flow whenever possible. The contained runoff should then be managed using a combination of deep infiltration and bleed-off into landscape areas or be stored for later use. Due to space and budget constraints, it is unlikely that the 100% level of catchment will be accomplished in all areas of campus, however, proposed catchments were sized to this level in order to insure adequate space is reserved in the event a project becomes feasible, and also in recognition that due to a past lack of mitigation throughout campus that there is a lot of "catch up" to be done, and in many cases this will only be accomplished through very large catchment systems. In the event any given sub-surface catchment facility is designed to hold the entire 100 year storm, it is recommended to be designed such that the volume needed to reduce the peak flows below the level of flooding buildings will be detained and released into landscape areas, thereby freeing up capacity for, although highly unlikely, a subsequent 100 year storm while the remainder of the catchment system will be reserved for direct deep infiltration and/or storage for later use. It is also recommended that guidelines be placed on new construction projects that would require 100 percent of the rainfall for that specific location to be managed onsite. An estimate of the cost for various types of catchments is provided in **Table 3.**

2 INTRODUCTION

This report is organized into two separate documents. The first being the *UA Surface Water Master Implementation Plan* and the one that follows is the *Technical Model Appendix*. The *UA Surface Water Master Implementation Plan* outlines the important points and results found during the study. This includes sections for Inventory and Analysis and Plan Development. The Inventory and Analysis section includes a review of prior studies along with summaries of work completed on design guidelines and technical modeling. The Plan Development section details indentified problem areas and proposed solutions for the indentified problem areas. The *Technical Model Appendix* supplies the technical data to support the study findings and in-depth explanations of this data if the reader requires more information than that provided in the *UA Surface Water Master Implementation Plan*.

The University of Arizona has adopted a Comprehensive Campus Plan (June 2003), which identifies significant growth of campus buildings and open space. With the information provided by the completion of the Comprehensive Campus Plan and the fact that the runoff produced by The University of Arizona affects not only the Campus proper, but also many adjacent neighborhoods on its journey to the Rillito River to the North and the Santa Cruz River to the West (see **Figure 1**), The University recognized the opportunity to update its 1997 campus-wide drainage study, *The University of Arizona Campus Master Drainage Plan.* The technical goals met by the updated document include:

1. Floodplain models to reflect 2005 conditions and an investigation of the impact of the “build-out” conditions of campus as shown in the Comprehensive Campus Plan.

2. The identification of drainage problem areas present in both current and “build-out” conditions and possible projects to mitigate the problems

3. Recommendations of a surface water infrastructure system made up of individual, prioritized / phased projects.

Although the above items are important, the vision of the University, realized by this document, is to provide more than an analysis of current and future build-out conditions, it also:

- Recognizes the long-term inherent value of water by conserving, harvesting, capturing and reusing it.

- Demonstrates good environmental stewardship to both the University community and our neighbors by mitigating the impacts of floodwaters and providing models that may be replicated throughout the community.

- Makes surface water a proactive influence on integrated site design.

- Puts a priority on creative and innovative solutions which keep surface water on campus and put it to beneficial use as close as possible to its source.

- Integrates engineering techniques used for flood prevention with natural ecological techniques used for water harvesting within a framework of designed multi-use landscapes.

- Assists in making informed design and budgeting decisions based on a planned system for managing campus surface water.

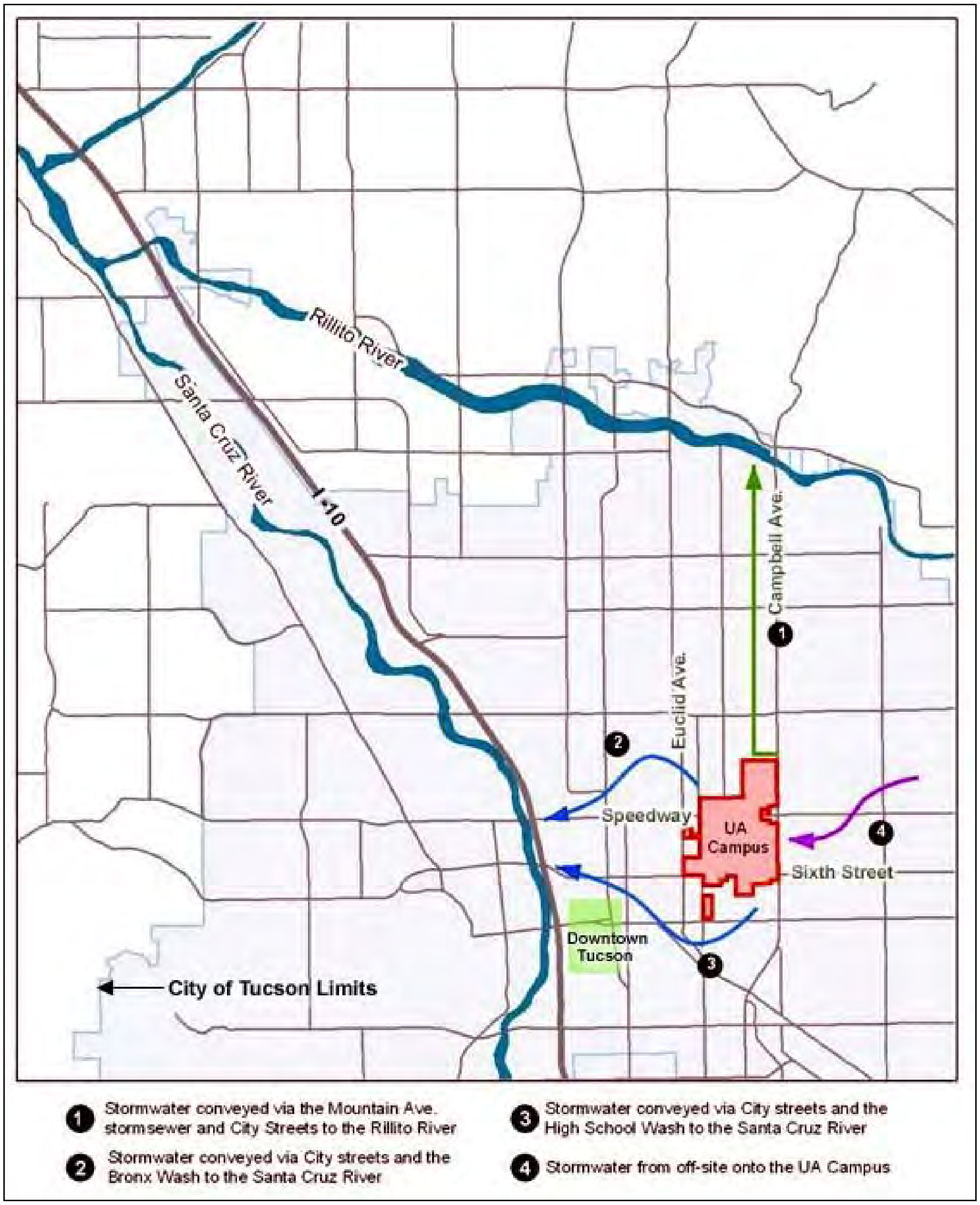


Figure 1 – Location Map showing runoff paths for The University of Arizona. Note the adjacent neighborhoods affected by the run-off leaving the University on its path to the Rillito & Santa Cruz Rivers.

3 INVENTORY AND ANALYSIS

3.1 REVIEW OF EXISTING DOCUMENTS

In order to produce this document, significant external investigation and collaboration was necessary throughout the project. This included multiple site visits to observe campus conditions during storm events, collaborations with the UA Surface Water Working Group, and the review of multiple drafts of the UA Surface Water Implementation Plan. It was also necessary to review previous reports provided by The University of Arizona of past work done on campus. Although the technical information was generally not used for this project, the following drainage reports provided a sense of context and understanding necessary in providing an accurate update as possible.

1. *The University of Arizona Campus Master Drainage Plan,* prepared by Collins/Piña Consulting Engineers, Inc., September 1997.

   The UA Surface Water Implementation Plan is considered an update of this document. The original 1997 document was found to be useful in providing a methodology for analysis and the location of various existing drainage facilities. The analysis procedure in the 1997 Drainage Plan is essentially identical to the one followed for this update. This was helpful in that it provided a similar model to compare current results against to detect and analyze possible errors in assumptions or modeling that could be improved upon or corrected for the current study.

2. *Revised Master Drainage Report for the Arizona Health Science Center Basin Management Plan,* prepared by McGovern, MacVittie Lodge & Dean, Inc., August 1990.

   This report provides an analysis of the impact that would occur due to expansion of the Arizona Health Science Center. It also attempts to create a master drainage plan as a guide for future development.

3. *Cherry Avenue Drainage Study & Conceptual Flood Mitigation Plan: Hydrologic/Hydraulic Analysis & Flood Mitigation Report,* prepared by Urban Engineering, May 1992.

   This study provides a hydraulic and hydrologic analysis of Cherry Avenue between 6th Street and University Boulevard.

4. *Drainage Report for McKale Center Strength & Conditioning Facility & Heritage Hall,* prepared by ENTRANCO, December 1998.

   This report provides a drainage report in preparation for the construction of the McKale Center Strength & Conditioning Facility & Heritage Hall.

5. *Concept Report for Martin Avenue at Mabel Street Drainage Improvement Project,* prepared by Envirotech Southwest, April 1998.

   This report provides recommendations for reducing or eliminating the flooding problems at the intersection of Martin Avenue and Mabel Street. Although this project was never completed, this report was used to compare flows and water surface elevations for this area during a 100 yr storm event.

6. *U of A Student Union Access Roadway Improvements,* prepared by Stantec, March 2000.

   This study provides recommendations for the roadway improvements for the access to the Student Union.

7. *Drainage Investigation & Alternative Analyses for AHSC & Jefferson Park Neighborhood,* prepared by MMLA, November 2001.

   This investigation focuses on drainage problems associated with the Arizona Health Sciences Center and portions of the Jefferson Park neighborhood.

8. *Drainage Statement for L'Aldea,* prepared by Rick Engineering Company, May 2002.

   This statement provides a hydrology summary for the construction of the housing building located at 5th Street & Euclid Avenue.

9. *Design Concept Report Jefferson Park Neighborhood Drainage Improvements,* prepared by MMLA, Inc., October 2002.

   This report used the findings from the above investigation (*Drainage Investigation & Alternative Analyses for AHSC & Jefferson Park Neighborhood,* prepared by MMLA, November 2001) to determine the feasibility of extending the Mountain Avenue storm drain south to mitigate the drainage problems associated with the Jefferson Park neighborhood . This report was helpful in obtaining the location of existing drainage facilities in the northern region of the current study.

10. *Drainage Report for University of Arizona Meinel Optical Sciences Building Expansion*, prepared by KPFF Consulting Engineers, March 2002.

    This report provides drainage recommendations for the construction of the Meinel Optical Sciences Building West Expansion.

11. *University of Arizona Phase VI Open Space Drainage Investigation*, prepared by GLHN Architects & Engineers, Inc., September 2003. (Executive Summary prepared November 2004)

    This Investigation was performed to demonstrate that development related to the University of Arizona's Phase VI Open Space project will not produce additional drainage problems in the Jefferson Park Neighborhood, which is downstream from the project.

12. *University of Arizona Storm Water Management Plan*, prepared by Engineering & Environmental Consultants, Inc., March 2003.

    This plan's intention is to improve the quality of surface runoff by identifying possible causes of and reducing the amount of pollutants that enter storm water. The floodplain maps were very useful for comparison.

3.2 EXISTING INVENTORY SITE TOUR

A site tour was organized to observe existing drainage area improvements throughout campus. The tour included members of the UA Surface Water Working Group, the Catchwater Group (water harvesting and reuse consultant), the Acacia Group (landscape architects), and M3 Engineering & Technology (civil engineers).

The existing stormwater management projects that were visited on the tour included the following:

- Norton School of Family & Consumer Sciences Building
- Highland Avenue Residence Hall Plaza
- New Chemistry Building Area
- McKale Center North Plaza
- Health Sciences Center Retention Basin (east & west side)
- Highland Avenue Parking Garage Retention Basin

These projects are both of recent and older construction and, in general, have addressed some local runoff issues, but have minimal effect on the overall existing flooding problems. However, some of the improvements have the potential to be more effective in managing peak runoff flows. For example, the west detention basin at the Health Sciences Center (shown below) has the potential of reducing peak runoff flows through management of the size of outlet pipe openings. Also, the piped drainage system at the north end of McKale Center has a provision to close off drains to allow runoff to "bubble up" into the terraced landscape area for water harvesting. This system is not currently being utilized but could significantly contribute to alleviating existing flooding issues to the south and east of McKale Center.

These are just a few examples that were observed on the site tour in which a portion of storm runoff issues can be addressed by incorporating existing facilities for a coordinated solution to campus flooding.

3.3 DESCRIPTION OF SITE

The project is located in Township 14 South, Range 14 East of the Gila River Base and Meridian, Pima County, Arizona. The project is bounded by Lester Street to the north, Eighth Street to the south, Campbell Avenue to the East, and Euclid Avenue to the West. More than half of the campus is covered with impervious surfaces, such as roads, sidewalks, buildings, and parking lots.

The campus is situated in a medium density neighborhood within one mile of downtown Tucson. The areas around the campus were developed in the early to mid twentieth century. The project site is contained within the watersheds of the Rillito and Santa Cruz Rivers, both dry wash beds for the greater part of the year. The rainy monsoon season occurs during summer months and can precipitate flash flooding in washes and the flooding of surface streets due to low ground permeability. A small amount of the rainfall onsite is collected in retention/detention basins or storm water sewers, while the majority of runoff is collected by campus roads and conveyed offsite westward on surface streets and in the Bronx and High School Washes to the Santa Cruz River and to a lesser degree, northward across surface streets and in the Mountain Avenue stormwater sewer to the Rillito River (see **Figure 2**).

Since the 1970s the campus has experienced most of its new development at sites north of Speedway Boulevard and south of Sixth Street. These projects displaced previously existing developments, so the impact on drainage from these sites was not significant. The most significant change in drainage patterns from the campus was the construction of the Mountain Avenue stormwater sewer, which has decreased the amount of surface street drainage northward from the campus by collecting stormwater underground and conducting it directly to the Rillito River.

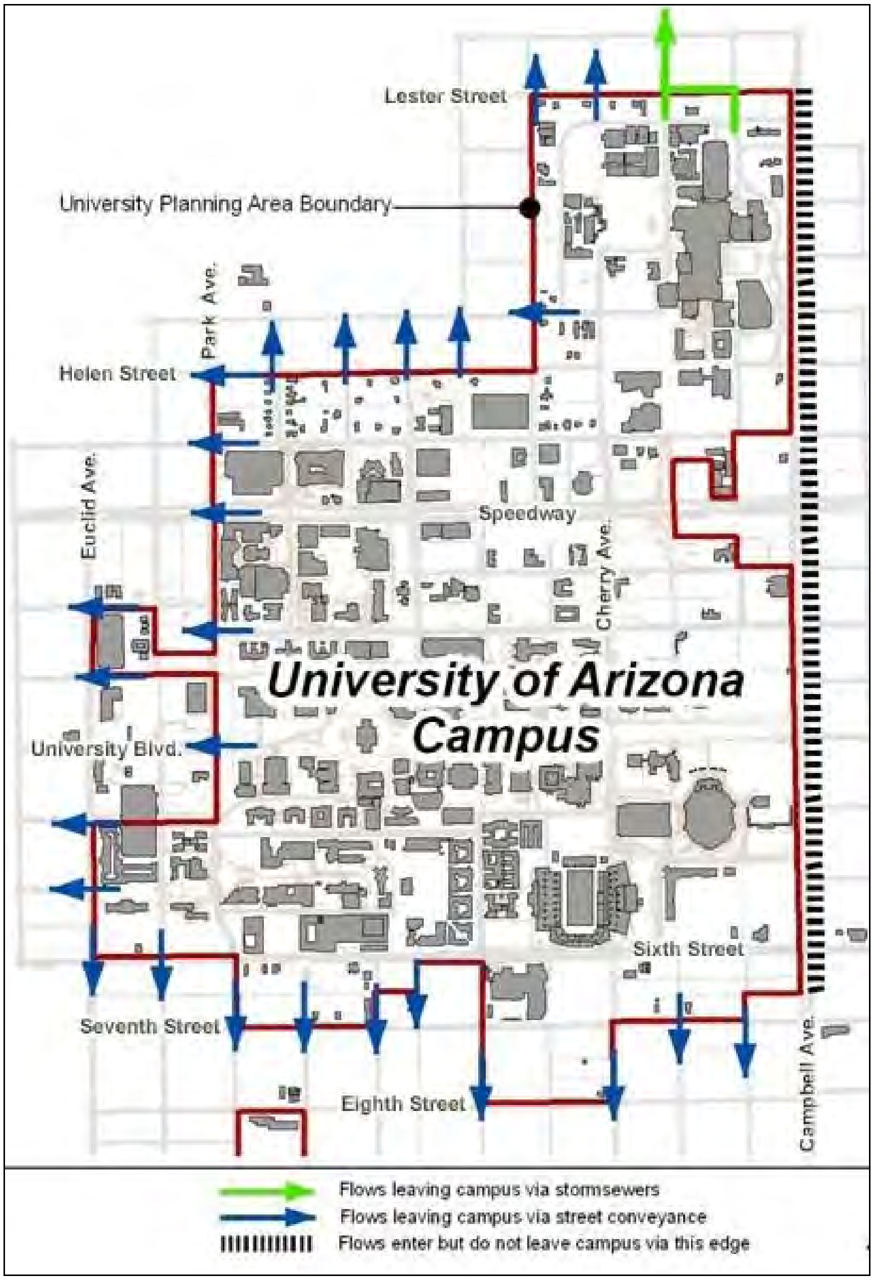


Figure 2 – Map Showing flow paths leaving campus boundary (graphic may not reflect the most current buildings located onsite).

3.4 SURFACE WATER GUIDELINES

The University of Arizona Manual of Design and Specifications Standards (DSS) are meant to be utilized as a guideline for the execution of professional services associated with the design, construction, renovation and maintenance of all facility related projects. The DSS is also the standard of execution for all Job Order Contract work unless specified otherwise.

The principles of water harvesting were incorporated into the Surface Water Procedures (Tab B-11) & Drainage and Surface Water Guidelines (Tab C-9) of the DSS by the Surface Water Working Group prior to the initiation of this project. As part of this plan update, the consultant team reviewed and commented on these guidelines and created graphics intended to provide visual examples of the ideas conveyed in the text. The intent of these guidelines is to help reduce runoff throughout campus and neighboring communities by harnessing, infiltrating, and using runoff as close to the source as possible, as well as to conserve water and to support a more vibrant and sustainable landscape. Several of the graphics developed for the DSS are shown and described below and on the following pages. The graphics do not represent construction details, rather, their purpose is to communicate overall intent, to inspire innovation, and expand the designer's sense of what is possible.

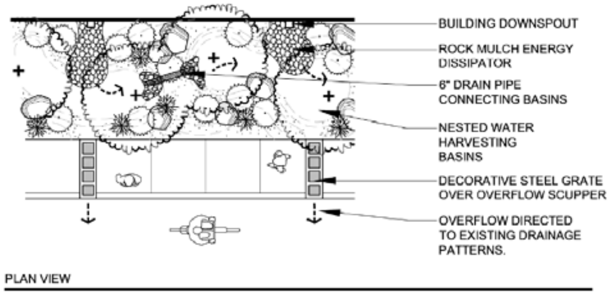


Figure 3

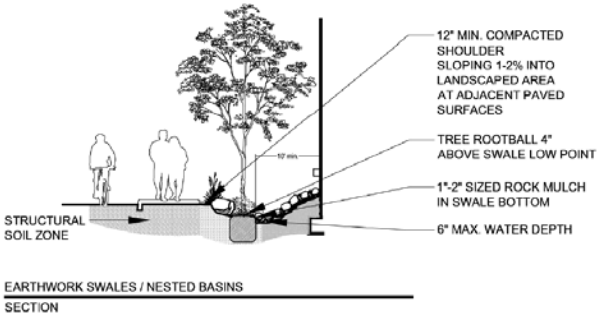


Figure 4

The **Figure 3** and **Figure 4** above and the photo to the left illustrate how roof runoff can be reduced by providing earthwork swales that slow the flow of runoff into the street and provide water for vegetation.

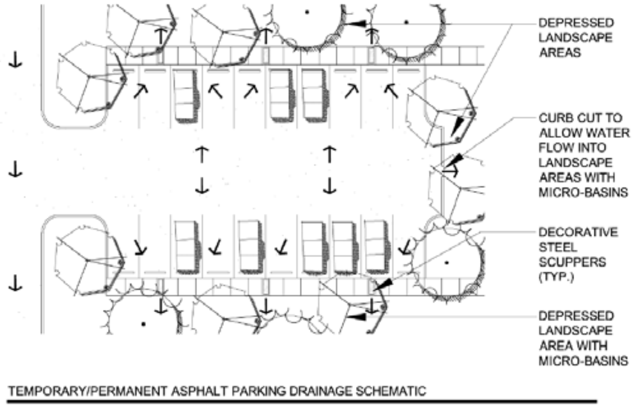


Figure 5

Figure 5 to the upper left illustrates the way in which parking lot runoff can be mitigated. Note how the grading of the lot directs the flow to landscape areas via scuppers or curb cuts. The photo above shows a parking lot that drains into a depressed landscape area via scuppers. The photo to the left shows a parking lot that supplies water to a landscaped area by the use of curb cuts.

Figure 6 and the photo below illustrate the use of depressed tree wells as a way to mitigate runoff and to provide water for landscape foliage. Additional figures illustrating these and other options can be found in the DSS.

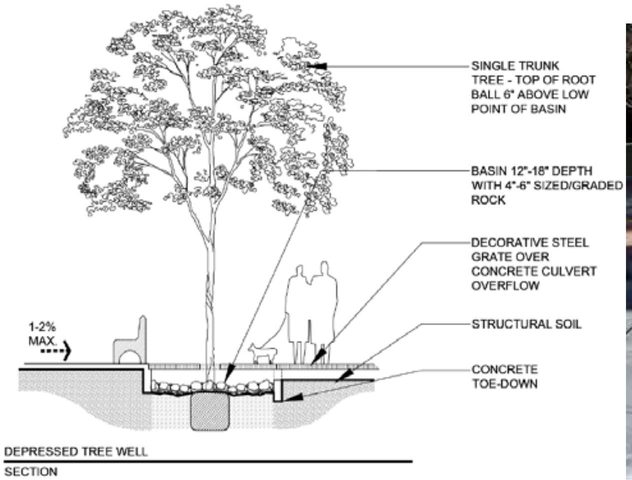


Figure 6

3.5 TECHNICAL MODEL & ANALYSIS

The goal of this section is to provide a non-technical description of the methods and procedures that were required to create this study. A more in-depth description of the analysis can be found in the Technical Model Appendix of this document. The end result of this analysis is to provide easy to understand graphical information which conveys the results of the various conditions explored in this study given the project boundary below (see **Figure 7**).

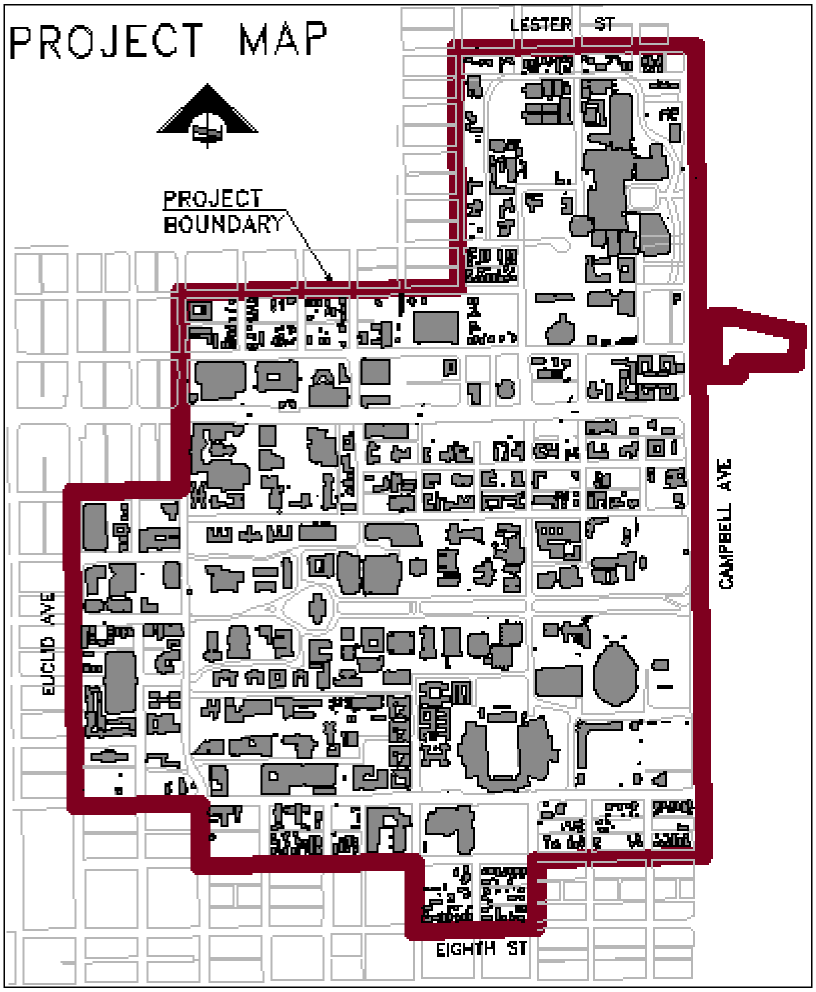


Figure 7 - Project Boundary used for hydrologic analysis

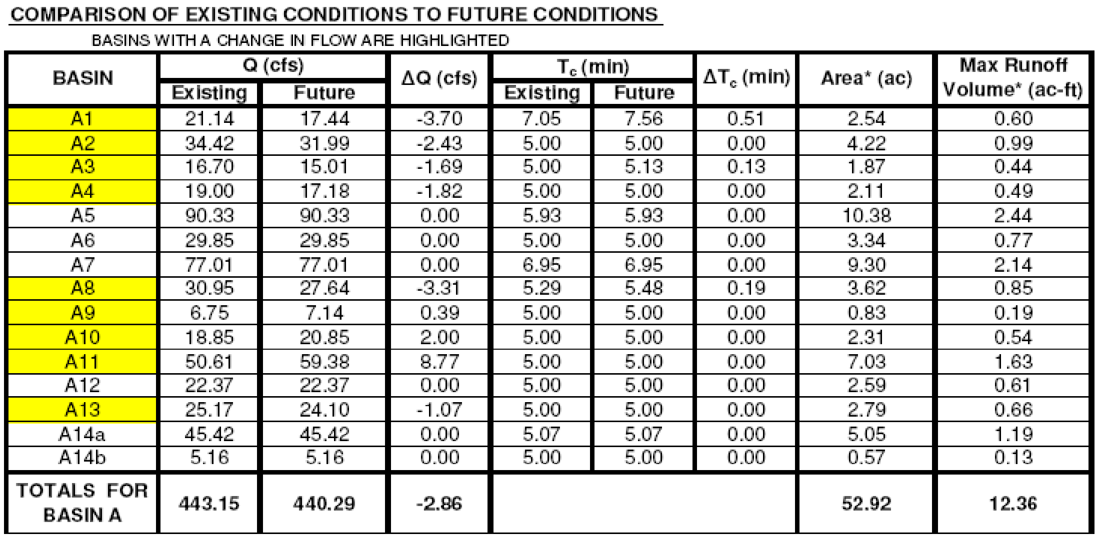
The conditions that were explored in this study include:

1. <u>Existing Conditions</u> – Explored the changes to the 100-yr floodplain originally mapped in *The University of Arizona Campus Master Drainage Plan*, 1997. Also indentified university buildings that are in jeopardy of flooding in the event of a 100-yr storm (See **Figure 13**).

2. Future Conditions – Explored the effects of the "build-out" conditions outlined in *The Comprehensive Campus Plan* on the sites rainwater flows.

3. Future "build-out" Conditions with Improvements – Explored the availability of catchment opportunities and the estimated costs associated with them. Also produced an updated 100-yr floodplain map to reflect the reductions in problem flooding these catchments would provide (See **Figure 15**).

It should be noted that the analysis of the "build-out" conditions revealed that there was not a significant enough increase in flows (the greatest increase in any given subbasin was less than 3.25%) to warrant in-depth modeling of "build-out" conditions. While the perviousness of campus will increase somewhat overall and the routing of flows will change in some areas, the overall hydrology pattern will not change significantly as a result of future development. Instead, the results from current conditions, which are essentially equivalent to future "build-out" conditions from a hydrology standpoint, were utilized in the design of proposed rainwater catchment systems. **Table 1** illustrates the comparison between future "built out" conditions and current conditions. An excerpt of the table is shown below; the complete table can be located in the Surface Water Implementation Plan Appendix at the end of this portion of the document.



COMPARISON OF EXISTING CONDITIONS TO FUTURE CONDITIONS

BASINS WITH A CHANGE IN FLOW ARE HIGHLIGHTED

BASIN	Q (cfs)		ΔQ (cfs)	T_c (min)		ΔT_c (min)	Area* (ac)	Max Runoff Volume* (ac-ft)
	Existing	Future		Existing	Future			
A1	21.14	17.44	-3.70	7.05	7.56	0.51	2.54	0.60
A2	34.42	31.99	-2.43	5.00	5.00	0.00	4.22	0.99
A3	16.70	15.01	-1.69	5.00	5.13	0.13	1.87	0.44
A4	19.00	17.18	-1.82	5.00	5.00	0.00	2.11	0.49
A5	90.33	90.33	0.00	5.93	5.93	0.00	10.38	2.44
A6	29.85	29.85	0.00	5.00	5.00	0.00	3.34	0.77
A7	77.01	77.01	0.00	6.95	6.95	0.00	9.30	2.14
A8	30.95	27.64	-3.31	5.29	5.48	0.19	3.62	0.85
A9	6.75	7.14	0.39	5.00	5.00	0.00	0.83	0.19
A10	18.85	20.85	2.00	5.00	5.00	0.00	2.31	0.54
A11	50.61	59.38	8.77	5.00	5.00	0.00	7.03	1.63
A12	22.37	22.37	0.00	5.00	5.00	0.00	2.59	0.61
A13	25.17	24.10	-1.07	5.00	5.00	0.00	2.79	0.66
A14a	45.42	45.42	0.00	5.07	5.07	0.00	5.05	1.19
A14b	5.16	5.16	0.00	5.00	5.00	0.00	0.57	0.13
TOTALS FOR BASIN A	**443.15**	**440.29**	**-2.86**				**52.92**	**12.36**

Excerpt from Table 1 - The basins highlighted in yellow indicate there is a predicted hydrological change between existing and future conditions. Q is the subbasin peak flow in cubic feet per second (cfs), ΔQ is the change in flow between existing and future conditions, Tc is the subbasin time of concentration in minutes (min), ΔTc is the change in time of concentration between existing and future conditions, the Area is the subbasin area in acres (ac) , and the Max Runoff Volume is the volume produced by each subbasin in acre-feet (ac-ft).

A short summary of the types of analysis methods and software utilized in this study are as follows:

- City of Tucson (COT) Method – This method, obtained from the COT Standards Manual for Drainage Design and Floodplain Management, was used to obtain flows produced on the site due to a specific storm event based on various site parameters, such as soil type (see **Figure 8**), slope of grade, and the amount of impervious cover. The Natural Resource Conservation Service (NRCS) categorizes soils into four hydrologic groups: Group A, Group B, Group C, and Group D. Where Group A soils generally have the lowest runoff potential and Group D soils have the highest. Most of the soil for this project falls into soil Group D with some interspersed areas with soil Group B as seen in the figure below. This indicates that the majority of the site has a high potential for runoff due to the very low infiltration rates of Group D soil.

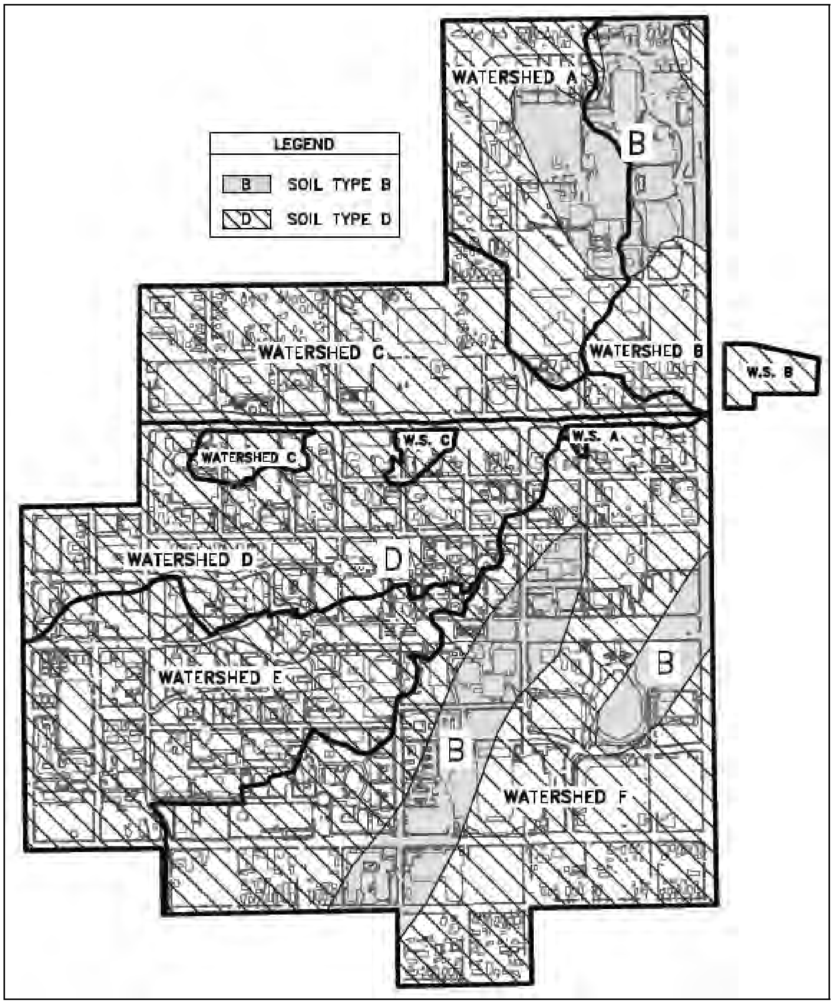


Figure 8 – Hydrologic Soil Groups for The University of Arizona

For this study, the analysis was based upon a 100-yr storm, which produces an average rainfall rate of approximately 3” per hour for the Tucson area. Before the C.O.T. method could be utilized, the site needed to be divided into watersheds. These areas were labeled Watersheds A, B, C, D, E, & F (see **Figure 9**).

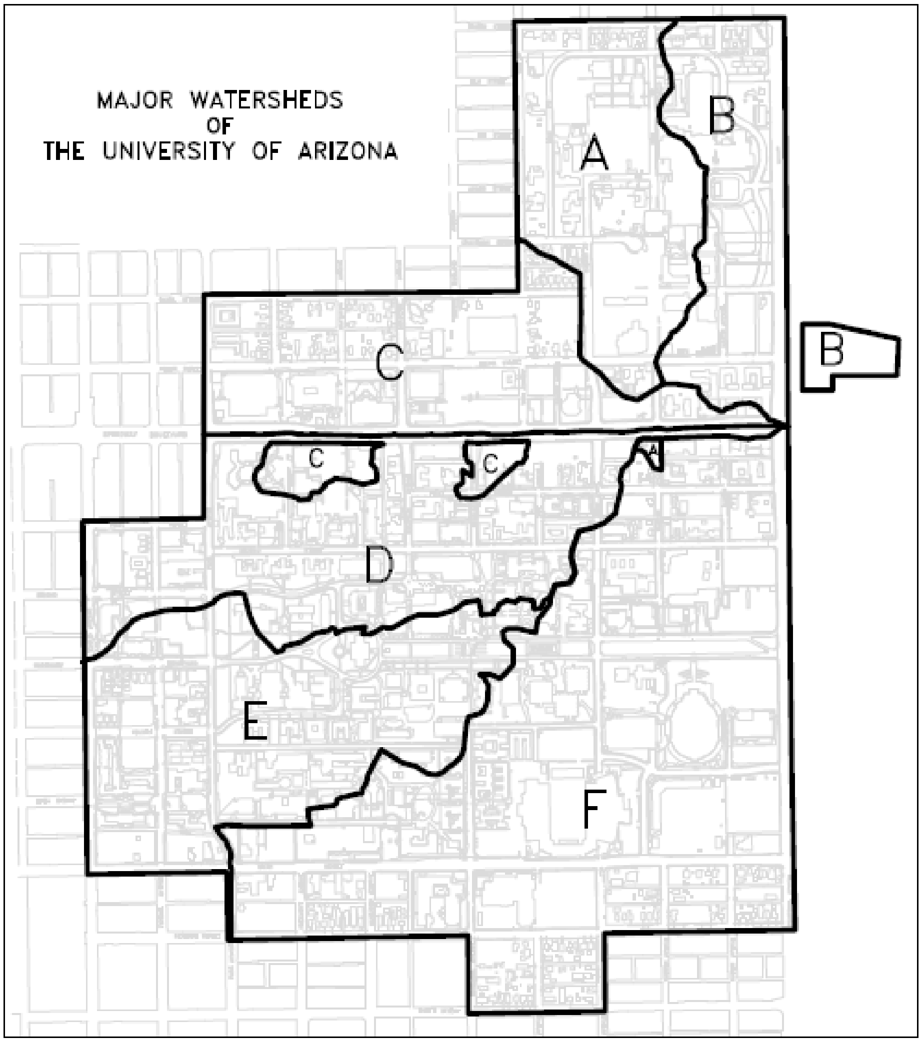
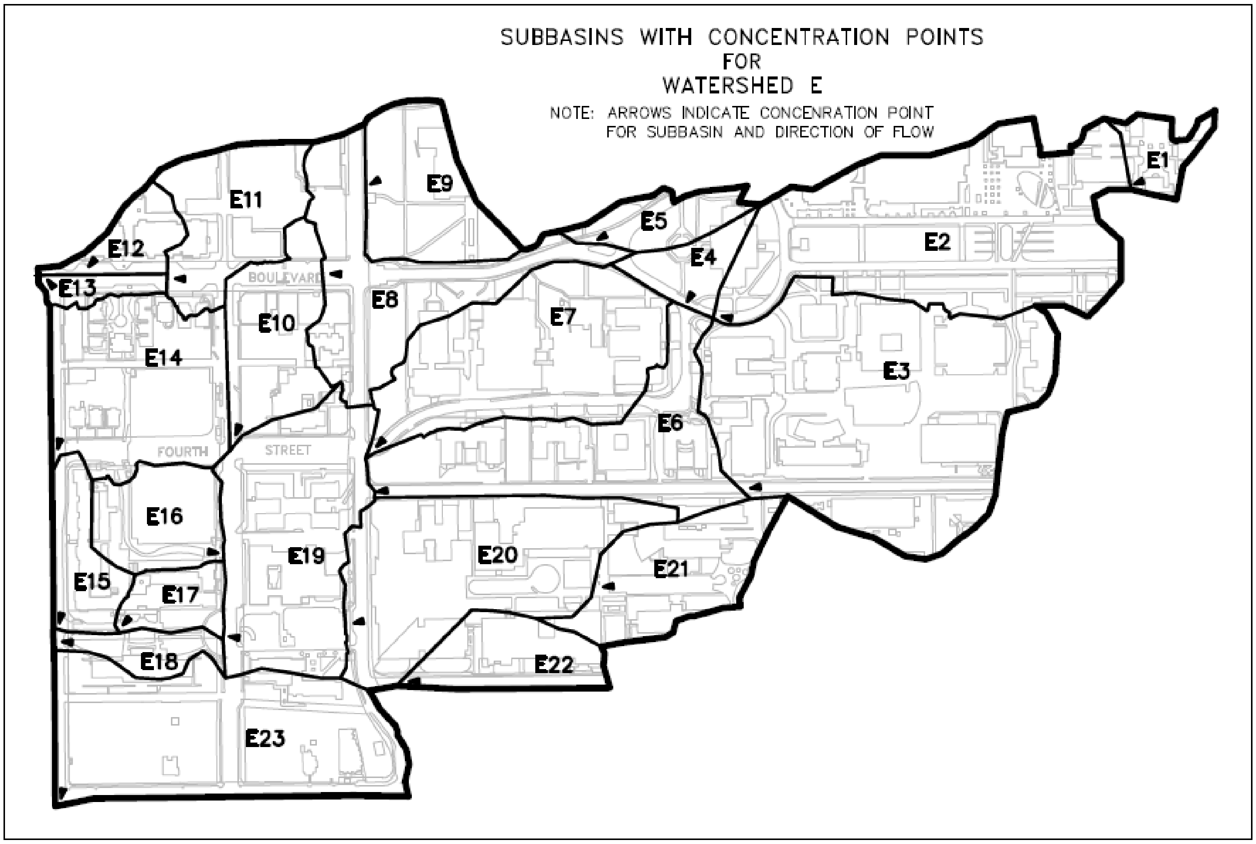


Figure 9

Once this was accomplished, the watersheds were divided into smaller areas called subbasins to obtain peak flows at key positions along various flow-paths on the site for further analysis. **Figure 10,** which can be found in the Surface Water Implementation Plan Appendix at the end of this portion of the document, shows both the subbasins for each watershed and the point at which the flow leaves the subbasin, called a concentration point, for each subbasin; a portion of this figure showing Watershed E only is shown on the following page. The peak flows obtained using the C.O.T. Method only predict the flow produced by each subbasin, not the cumulative that passes through the subbasin.



Excerpt from Figure 10

A peak flow is the maximum volume of water that is transported by a given area in a specific amount of time due to a single storm event; in this report, flows were measured in cubic feet per second. A generic discharge hydrograph is depicted in **Figure 11** to illustrate peak flow. A hydrograph is a useful tool which illustrates how discharge (flow) varies over time after a storm event. Using the data produced by the C.O.T. Method, a hydrograph for each subbasin was created to be used in the routing portion of the analysis.

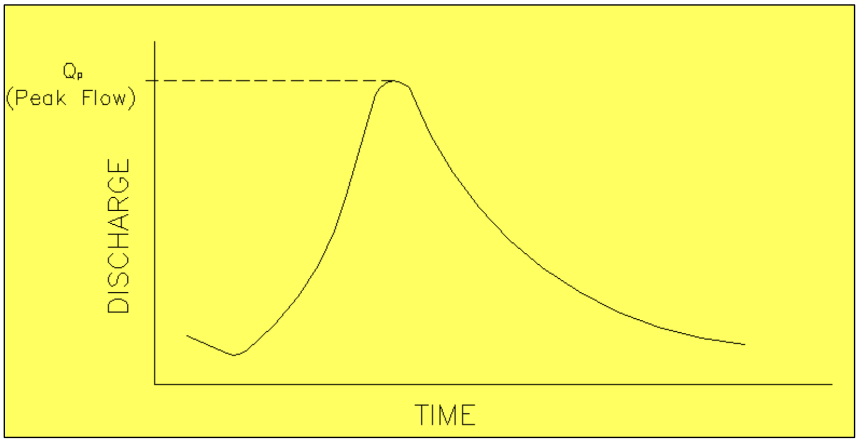
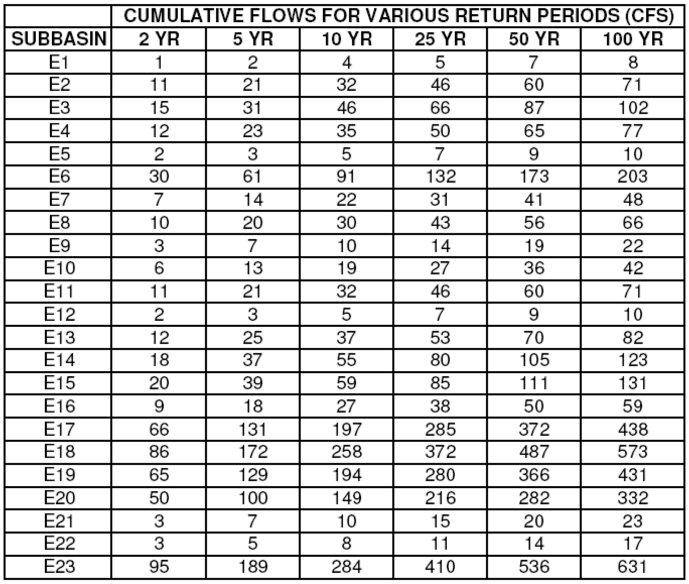


Figure 11 – Hydrograph illustrating peak flow of a given site. Note that the peak flow is the maximum flow which occurs during a precipitation event. The magnitude of the peak flow can be influenced by factors such as slope and roughness of the site and density and length of precipitation.

- Obtained, the rainfall needed to be combined and “routed” through the terrain of the site. Different subbasins of the site experience their respective peak flows at different times during the storm depending on the site parameters listed in the previous section.

The program used in this study to route rainfall throughout the site was the Army Corps of Engineers’ routing program, HEC-HMS. The results from this program provide the cumulative peak flows experienced at key points by taking into consideration the different times of concentration for each subbasin. The predicted cumulative flow values at the concentration points shown in **Figure 10** can be found in **Table 10** for a multiple of storm events**.** Both Figure 10 and Table 10 can be found in the Surface Water Implementation Plan Appendix at the end of this portion of the document; an excerpt of **Table 10** showing only Watershed E is shown below. HEC-HMS also allows rainwater reservoir systems or catchments to be modeled to determine their effects on the rainfall runoff for the site.



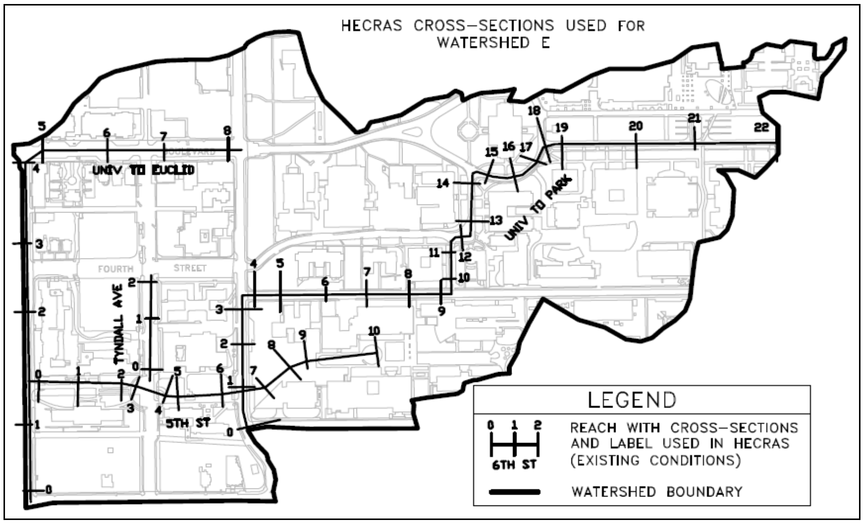
	CUMULATIVE FLOWS FOR VARIOUS RETURN PERIODS (CFS)					
SUBBASIN	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
E1	1	2	4	5	7	8
E2	11	21	32	46	60	71
E3	15	31	46	66	87	102
E4	12	23	35	50	65	77
E5	2	3	5	7	9	10
E6	30	61	91	132	173	203
E7	7	14	22	31	41	48
E8	10	20	30	43	56	66
E9	3	7	10	14	19	22
E10	6	13	19	27	36	42
E11	11	21	32	46	60	71
E12	2	3	5	7	9	10
E13	12	25	37	53	70	82
E14	18	37	55	80	105	123
E15	20	39	59	85	111	131
E16	9	18	27	38	50	59
E17	66	131	197	285	372	438
E18	86	172	258	372	487	573
E19	65	129	194	280	366	431
E20	50	100	149	216	282	332
E21	3	7	10	15	20	23
E22	3	5	8	11	14	17
E23	95	189	284	410	536	631

Excerpt from Table 10

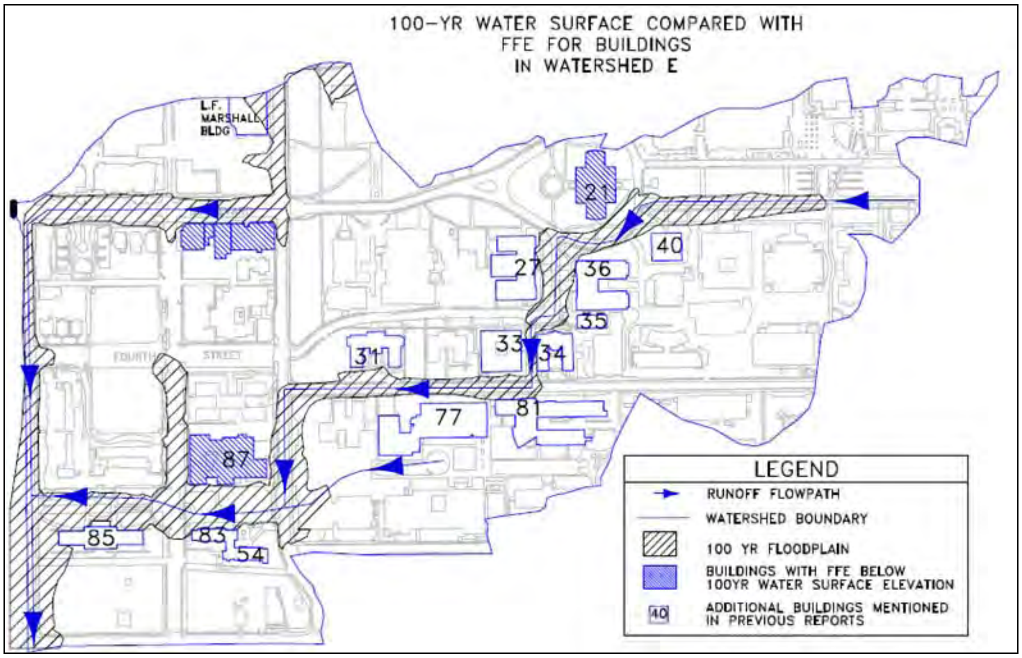
The results were spot checked for accuracy using previous reports. In most cases, the flows matched within an acceptable amount of deviation. Differences in modeling techniques were apparent in cases where discrepancies of greater significance occurred. One discrepancy in modeling occurs at the pedestrian underpasses at Speedway Boulevard. There are portions of the area south of Speedway that drains into the underpass and is then pumped to the subbasins to the north of Speedway. It should also be noted that during a 100 year storm event, the channel that is designed to convey runoff from the parking lot south of the new

Architectural Building to the pedestrian street running north / south in front of the old Architectural Building will lose a significant amount of runoff to the underpass to the north due to overtopping of the channel. This occurrence can be observed in even minor storm events. As noted in a previous report, an area of about 5 acres just east of Campbell Avenue between Mabel Street and Speedway Boulevard also contributes to the hydrology of the University. This area's runoff is released just west of Campbell Avenue near the intersection of Martin Avenue and Helen Street. The Majority of this flow is conveyed to the retention basin at the northeast corner of Martin Avenue and Mabel Street. The flow from this retention basin is carried underground to a storm sewer located north of the site.

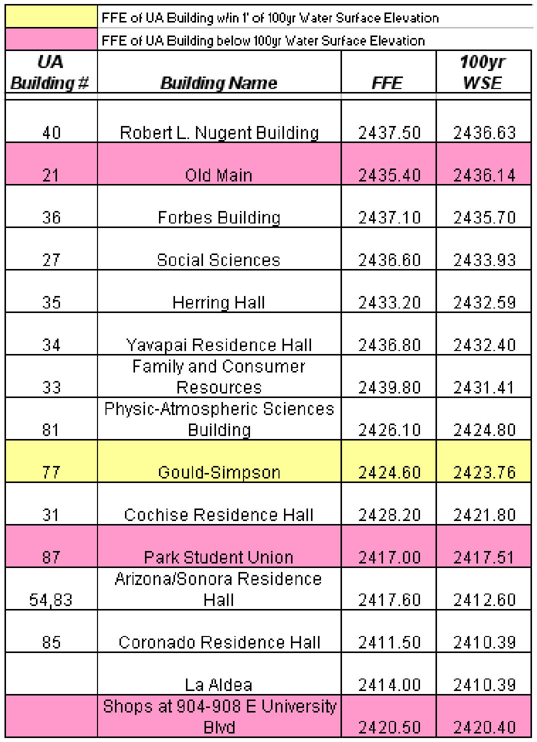
<u>HEC-RAS</u> – The cumulative peak flows produced in HEC-HMS that were greater than 50 cfs, which is the flow that can be contained on a typical two lane street, were then entered into another Army Corps of Engineer program called HEC-RAS. HEC-RAS is a computer program that models the flow of water through channels, or in this study, streets. While this program can provide a wealth of useful information, this study's interest was limited to the output of the water surface elevations (WSE) at pre-defined cross-sections cut perpendicular to the street. A cross-section is a specified point in the street where HEC-RAS can use the geometry and flow input to calculate the WSE at that point in the flow path. These are shown on **Figure 12,** which can be found in the Surface Water Implementation Plan Appendix at the end of this portion of the document. An excerpt of this figure is shown below.



Excerpt from Figure 12



Excerpt from Figure 13



🟨	FFE of UA Building w/in 1' of 100yr Water Surface Elevation
🟥	FFE of UA Building below 100yr Water Surface Elevation

UA Building #	*Building Name*	*FFE*	*100yr WSE*
40	Robert L. Nugent Building	2437.50	2436.63
21	Old Main	2435.40	2436.14
36	Forbes Building	2437.10	2435.70
27	Social Sciences	2436.60	2433.93
35	Herring Hall	2433.20	2432.59
34	Yavapai Residence Hall	2436.80	2432.40
33	Family and Consumer Resources	2439.80	2431.41
81	Physic-Atmospheric Sciences Building	2426.10	2424.80
77	Gould-Simpson	2424.60	2423.76
31	Cochise Residence Hall	2428.20	2421.80
87	Park Student Union	2417.00	2417.51
54,83	Arizona/Sonora Residence Hall	2417.60	2412.60
85	Coronado Residence Hall	2411.50	2410.39
	La Aldea	2414.00	2410.39
	Shops at 904-908 E University Blvd	2420.50	2420.40

Excerpt from Table 2 – FFE vs Predicted Water Surface Elevation

The WSE's from HECRAS were used to produce a floodplain map that was useful in predicting which buildings and areas are subject to flooding. The finish floor elevations (FFE) of the buildings that are at risk were identified using previous reports or by site visits in cases where elevations were unavailable.

A comparison of FFE's to 100 year WSE's is provided in **Table 2** and a graphical representation can be found in **Figure 13**. An excerpt of each depicting Watershed E only is shown above and to the left. The complete versions can be found in the Surface Water Implementation Plan Appendix at the end of this portion of the document.

4 PLAN DEVELOPMENT

4.1 PROBLEM AREAS

Another goal of this project was to identify the most significant problem areas within the project boundaries in order for a priority level to be determined for each proposed project. To focus the scope of this analysis, it was decided to study the top ten problem areas; choosing the appropriate criteria for locating these problem areas was a challenging task. The problem areas were identified by the subbasin's susceptibility to flooding, especially in relation to campus buildings. The susceptibility for an area to flood does not depend solely on the amount of flow passing through a particular subbasin. It is also dependent on the contours of the terrain and the location of buildings and their respective floor elevations.

Figure 14 found on the following page illustrates the top 10 problem flooding areas for current campus conditions; these are represented by a red dot placed at the point of concentration of the subbasin in which the problem area exists. The cumulative 100 year runoff volume is also provided in red for each problem area. This volume represents the volume of water that would need to be stored or diverted if the entire 100 year storm were to be mitigated. This map can be used with **Figure 13** to create a priority list of projects for these areas based on buildings that are in jeopardy of flooding or other factors such as cost and opportunities presented with new projects. In addition to identifying the top 10 problem flooding areas, **Figure 14** compares the maximum cumulative flow routed through each subbasin during a 100 year storm event by color-coding each subbasin according to the following 5 categories: 1.) flows between 0-149 cfs, 2.) flows between 150-299 cfs, 3.) flows between 300-449 cfs, 4.) flows between 450-599 cfs, 5.) flows equal to or greater than 600 cfs. These flows were obtained from the schematics and output from HEC-HMS located in **Chapters 6** & **7** of the *Technical Model Appendix, Volume II.*

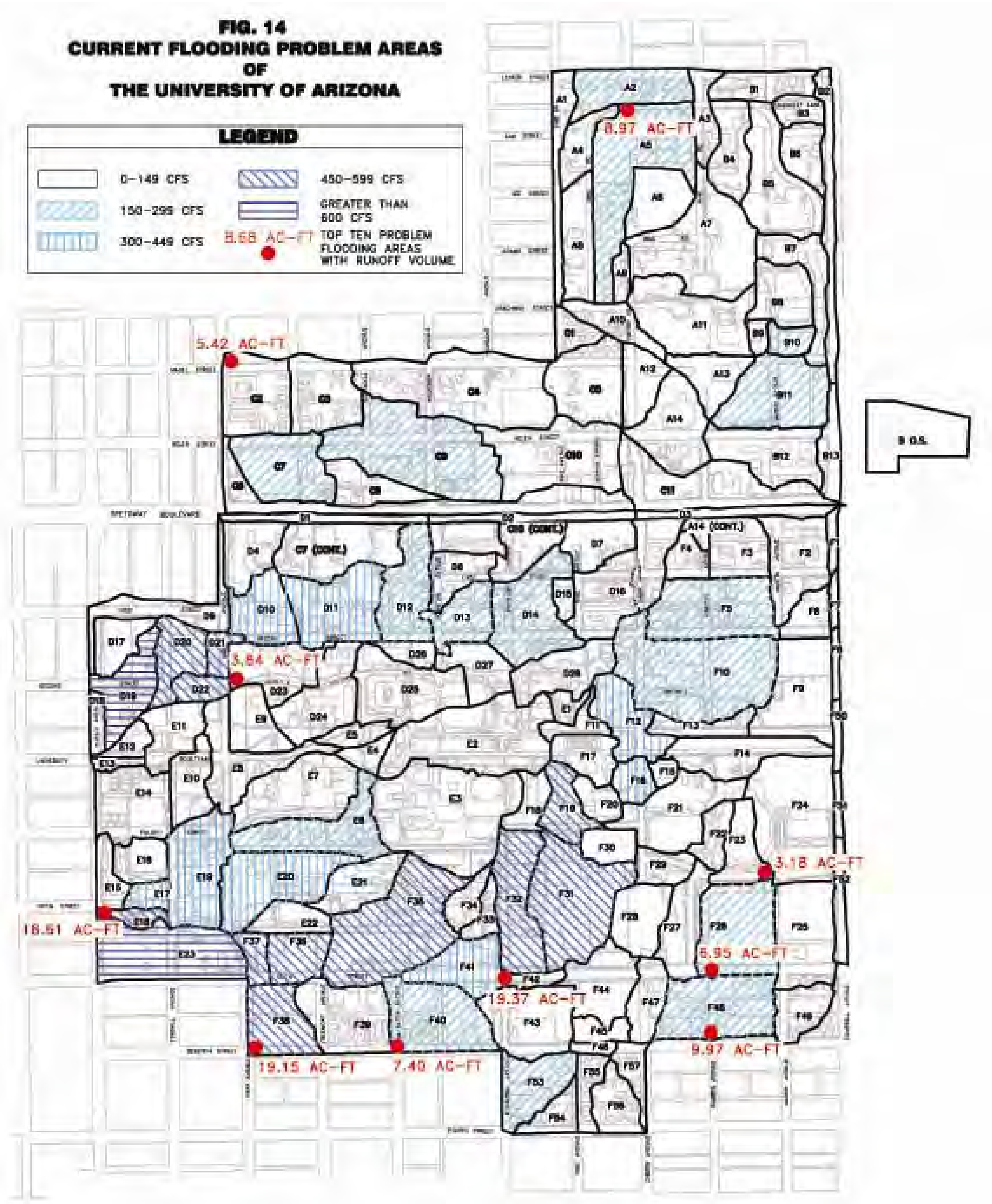


FIG. 14
CURRENT FLOODING PROBLEM AREAS
OF
THE UNIVERSITY OF ARIZONA
LEGEND
0-149 CFS
150-299 CFS
300-449 CFS
450-599 CFS
GREATER THAN 600 CFS
8.68 AC-FT TOP TEN PROBLEM FLOODING AREAS WITH RUNOFF VOLUME
8.97 AC-FT
5.42 AC-FT
3.64 AC-FT
16.61 AC-FT
3.18 AC-FT
6.95 AC-FT
19.37 AC-FT
9.97 AC-FT
19.15 AC-FT
7.40 AC-FT
SPEEDWAY BOULEVARD
9 O.S.

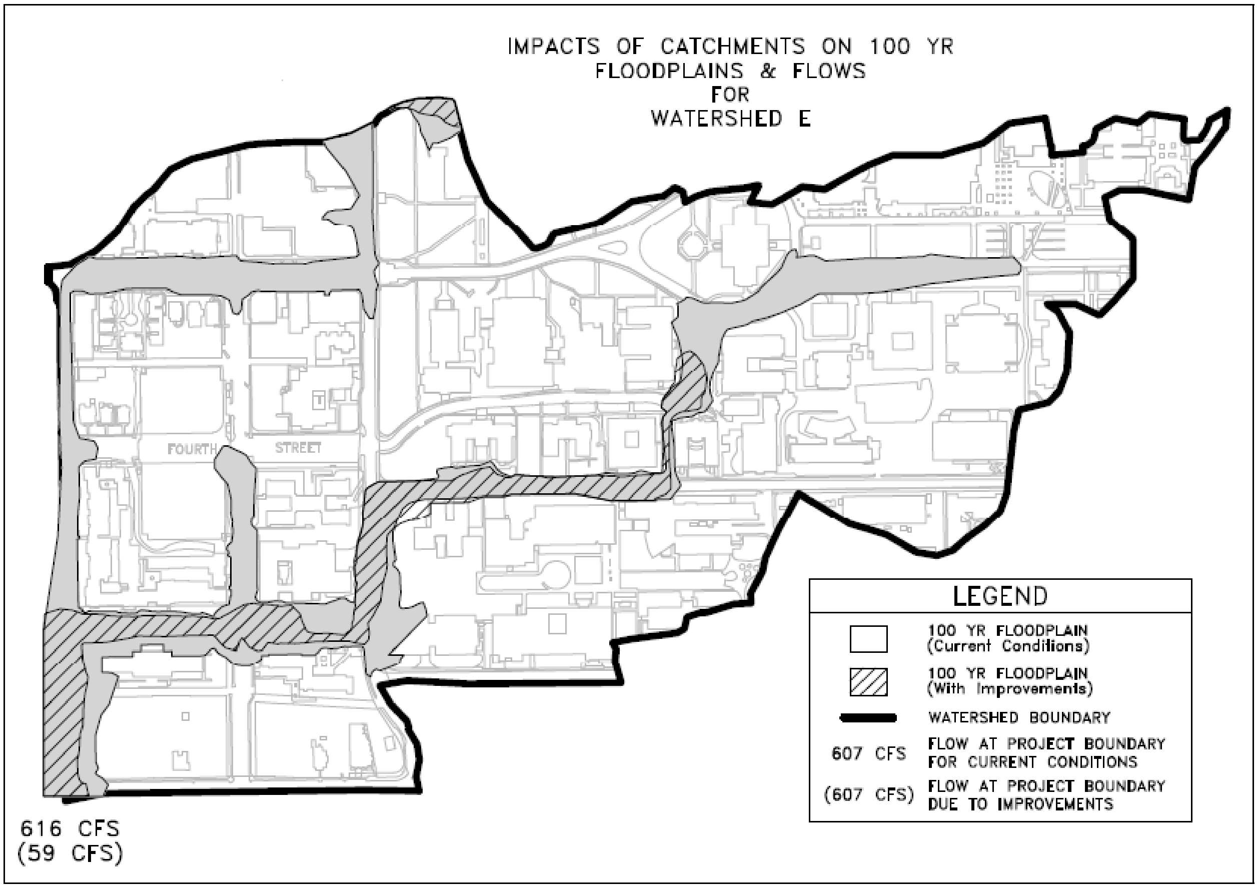
Figure 14

4.2 MAJOR PROJECT PROPOSALS

The campus wide stormwater runoff study indicates significant potential flooding both on the campus and offsite. The main conveying system for the runoff is the campus streets. In general, the capacity of the existing streets is inadequate for the calculated flow and major projects such as storm drain pipes are not a practical or acceptable solution to the stormwater runoff issues. Water harvesting, stormwater retention, and peak runoff reduction would be a more environmentally responsible solution for major projects. These types of projects will transform flooding due to rainwater from a nuisance into a resource by harnessing and reusing stored rainwater for irrigation and industrial needs and by recharging our aquifers through infiltration.

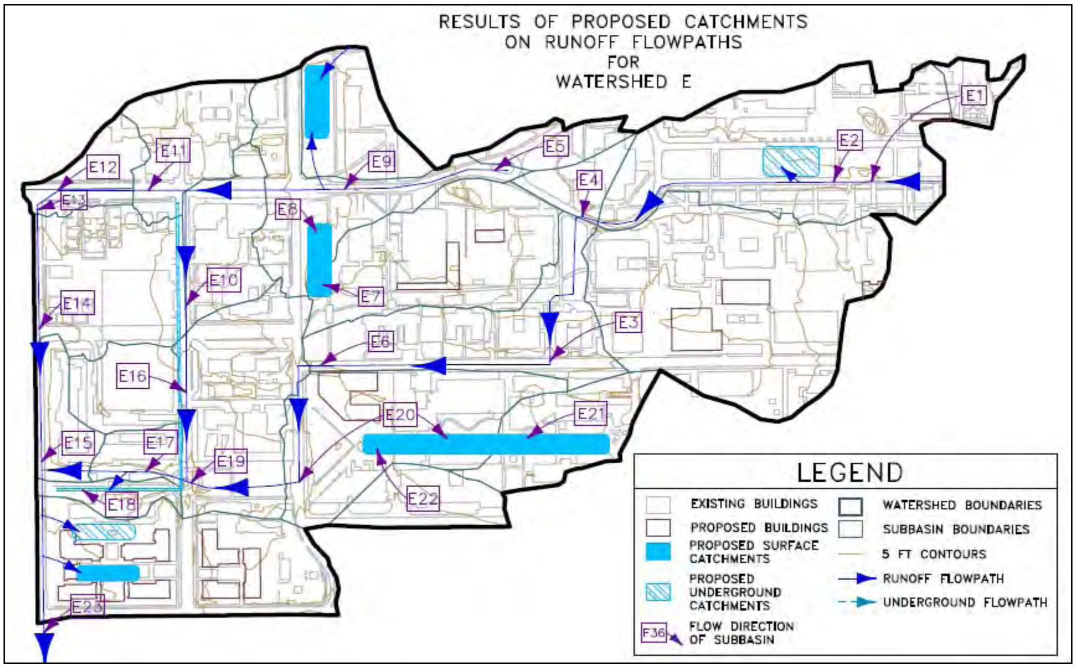
The City of Tucson requires areas like The University of Arizona that are not designated as a balanced or critical basin to provide catchments that can hold the volume produced during a 5 year storm event and show that the 100 year peak runoff leaving the developed site does not exceed the 100 year peak flow for the pre-developed site. The total 100 year storm runoff from the study area in its current state is approximately 121 ac-ft; prior to the development of the campus, the site only produced about 100 ac-ft of runoff. This volume is distributed throughout the campus, so several projects are needed to control the runoff.

The projects proposed for this study were designed to store 100% of the 100 year storm. Although designing for the 100 year storm is typically not financially feasible, this strategy was used to ensure that adequate site areas were reserved and to strive to correct previous development patterns that did not provide adequate mitigation of stormwater runoff. Designing for the 100 year storm event will also allow for storage areas large enough to contain several smaller storm events making the concepts of storage and reuse potentially viable. This study found that the areas available for catchment opportunities were able to significantly reduce or eliminate the 100 year peak flows leaving the site. **Figure 15** illustrates the effects that the proposed catchments will have on the 100 year storm floodplains. An excerpt from **Figure 15** is shown on the following page for Watershed E only; this figure clearly shows the considerable reduction in the floodplains as well as the decrease in the peak flows leaving each watershed due to the proposed projects.



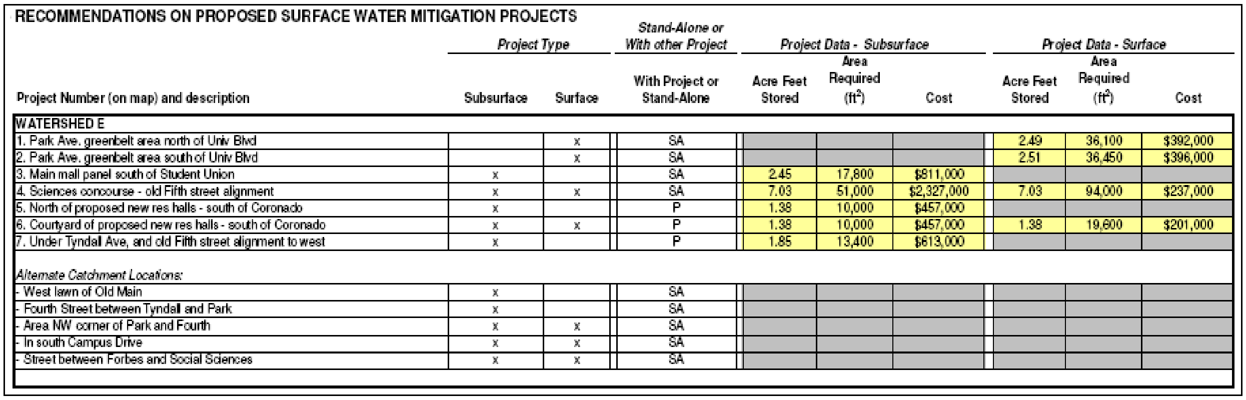
Excerpt from Figure 15

Figure 16 illustrates which subbasins contribute to each flowpath, how each flowpath will be diverted to the proposed projects. This figure will be useful to determine when specific site projects located within a subbasin can be subtracted from the volumes required by a particular catchment. For example, when the new buildings in subbasin E7 are constructed and a portion of the runoff can be utilized or retained within the site, the retained volume can simply be subtracted from the volume shown on **Figure 17** that would have been required for a particular catchment downstream if no site retention was provided. **Figure 17** presents the 100 year stormwater runoff volumes predicted for current campus conditions along the flowpaths and for each subbasin; in addition, it shows the most effective locations for catchment opportunities that will be available in the future build-out conditions and quantifies the required catchment areas and volumes to be retained or attenuated. These basins are numbered to correspond with the project numbers in **Table 3**. **Table 3, Figure 16** and **Figure 17** can be used together for estimating and designing major projects. Portions of **Table 3, Figure 16** and **Figure 17** showing Watershed E only are shown on the following page; the complete table and figures can be found in the Surface Water Master Implementation Plan Appendix at the end of this portion of the document.



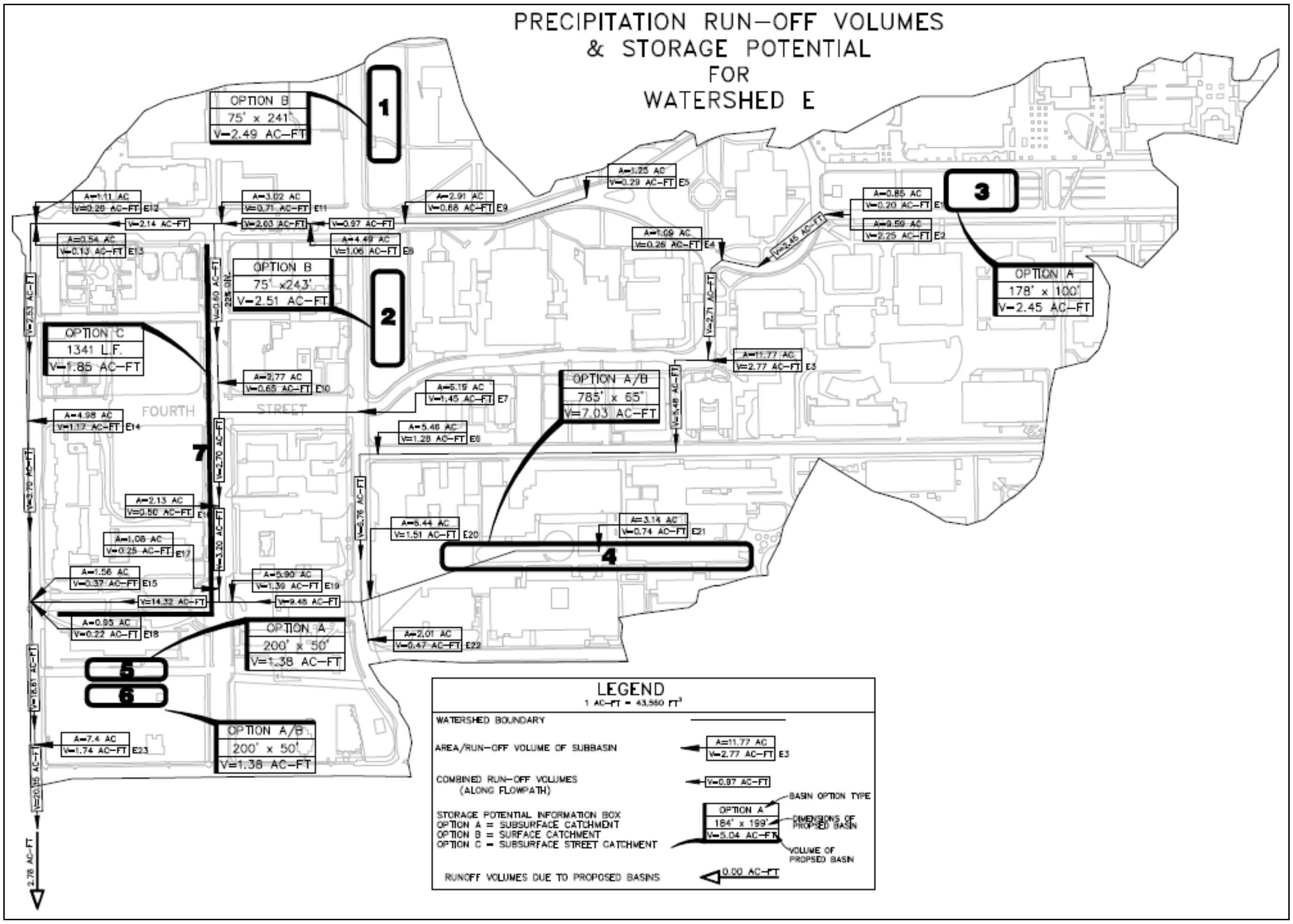
Excerpt from Figure 16 - The symbol labeled in the legend as “flow direction of subbasin” indicates what direction the subbasin runoff is flowing and approximately where it joins the main runoff flowpath (streets having flows greater than 50 cfs). Although not represented in this excerpt, “underground flowpath” is the flow which occurs below grade in storm drains or pipes.

Table 3 lists potential costs for stormwater retention facilities and provides proposed costs and storage volumes for subsurface facilities and/or surface facilities. The subsurface costs were based on a 6' diameter corrugated metal pipe as the storage facility. The costs estimated in **Table 3** are for preliminary estimates and do not include full surface landscape treatment. A more in-depth estimate including turf replacement and landscaping per acre is provided in **Chapter 14** of the Technical Model Appendix Volume II and is intended to be used when specifics of a project have been determined and a more accurate estimation is required. **Table 3** should be used in conjunction with **Figure 17** to determine the locations of proposed and possible storage facilities.



RECOMMENDATIONS ON PROPOSED SURFACE WATER MITIGATION PROJECTS	*Project Type*		*Stand-Alone or With other Project*	*Project Data - Subsurface*			*Project Data - Surface*		
Project Number (on map) and description	Subsurface	Surface	With Project or Stand-Alone	Acre Feet Stored	Area Required (ft^2)	Cost	Acre Feet Stored	Area Required (ft^2)	Cost
WATERSHED E									
1. Park Ave. greenbelt area north of Univ Blvd		x	SA				2.49	36,100	$392,000
2. Park Ave. greenbelt area south of Univ Blvd		x	SA				2.51	36,450	$396,000
3. Main mall panel south of Student Union	x		SA	2.45	17,800	$811,000			
4. Sciences concourse - old Fifth street alignment	x	x	SA	7.03	51,000	$2,327,000	7.03	94,000	$237,000
5. North of proposed new res halls - south of Coronado	x		P	1.38	10,000	$457,000			
6. Courtyard of proposed new res halls - south of Coronado	x	x	P	1.38	10,000	$457,000	1.38	19,600	$201,000
7. Under Tyndall Ave, and old Fifth street alignment to west	x		P	1.85	13,400	$613,000			
Alternate Catchment Locations:									
- West lawn of Old Main	x		SA						
- Fourth Street between Tyndall and Park	x		SA						
- Area NW corner of Park and Fourth	x	x	SA						
- In south Campus Drive	x	x	SA						
- Street between Forbes and Social Sciences	x	x	SA						

Excerpt from Table 3



Excerpt from Figure 17

The function of the proposed catchment facilities is to allow large amounts of water to enter a designated area and utilize the outflow for productive applications such as the fulfillment of the University's irrigation or industrial needs while reducing or eliminating downstream flooding. **Figure 18** on the following page illustrates how a catchment system might function. Once the stormwater runoff is directed to the designated catchment area, it will ideally pass through a sediment chamber to separate out any suspended particles and debris that may clog the system. The sedimentation chamber will require periodic maintenance to remove the collected sludge. Once the water is cleaned of the suspended solids, it can be stored for later use for any irrigation or industrial applications required for that area. In the rare case of consecutive storm events that would create volumes too large to be stored, excess stormwater can overflow into detention chambers or areas designed with permeable bottoms for infiltration into Tucson's precious aquifers. Above ground detention basins must be carefully designed to drain quickly to prevent the area from becoming a breeding ground for mosquitoes that could potentially carry West Nile virus.

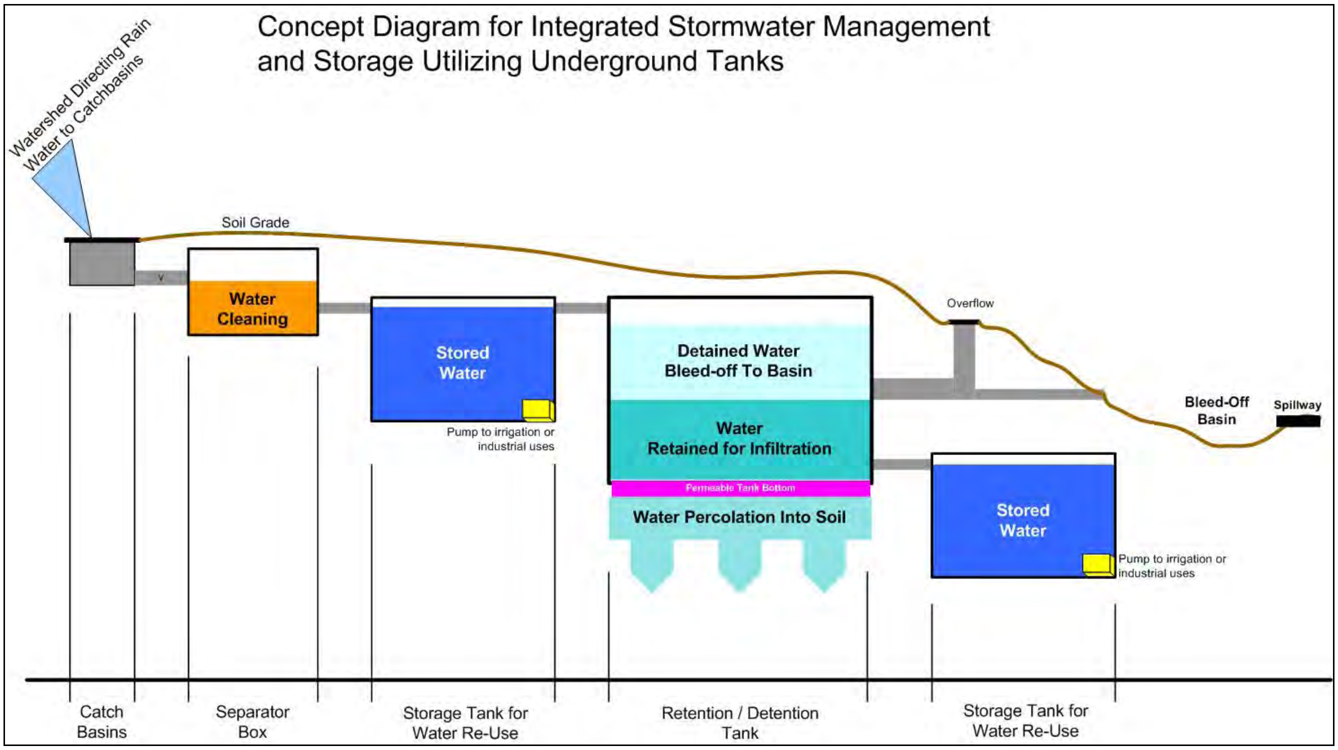


Figure 18

Currently, there are numerous products using various technologies on the market that can be used for subsurface storage and retention. Some of which are listed below; additional vendor information examples on these products can be found in the Surface Water Master Implementation Plan Appendix located at the end of this portion of the document.

- Corrugated metal pipe (CMP) culverts
- Plastic stackable grid systems, such as "Rainstore[3]"
- Concrete pipe
- Pre-cast concrete vaults (cisterns)
- Cast-in-place concrete cisterns

For this study, a CMP system was selected as an economical standard construction technique. The alternate technologies may provide unique advantages for specific projects and should be evaluated on a case-by-case basis.

The CMP system is constructed by excavating a hole six to ten feet deep. The CMP is laid in the excavation, connected to inlet structures and other water handling appurtenances and then buried with compacted backfill. The storage volume obtained by this system is 40% to 50% of the volume excavated. This type of system is proposed where the surface over the storage facility is to be used for other uses such as streets or recreation.

Surface facilities are generally excavated basins that retain the stormwater that drains into it. This method costs significantly less than the subsurface facility. Nearly 100% of the excavated volume can be used for storage. The drawback for a surface facility is that the stormwater may remain in the basin for some time depending of the percolation rate of the soil. This may delay the use of the area for recreation purposes and could also provide breeding areas for insects. The city if Tucson Stormwater Design Manual requires retention basins to drain within 12 hours to minimize the potential for insect nuisance.

The cost estimates found in **Chapter 14** of the Technical Model Appendix is based on three proposed storage facility types:

- Subsurface CMP in a generally square excavated area with active recreation on the surface. Pipe size of 8 feet diameter was assumed.
- Subsurface CMP in a generally rectangular excavation area under a street. Pipe size of 8 feet diameter was assumed.
- Surface excavated area forming a landscaped basin.

These three options are illustrated in **Figures 19-21**.

Figure 19

The two subsurface facilities include allowances for inlet structures, de-silting chambers, and water reuse pumps and piping that can feed existing irrigation systems. Soil percolation can be provided to dispose of excess runoff water that cannot be reused.

Figure 20

The surface facility includes inlet structures. Optional provisions for water reuse pumping facilities are included.

ABOVE GROUND STORMWATER
RETENTION BASIN AT THE
STUDENT RECREATION CENTER

Figure 21

4.3 DISTRIBUTED PROJECT ALTERNATIVE PROPOSALS

In some cases, the construction of the proposed catchment facilities may not be feasible due to cost, location, or disruption of campus activities. In these instances, it is recommended that catchment opportunities take the form of street-side inlets that provide water for campus vegetation in microbasins along the rainfall flow paths. Due to the minimal amount of rainfall run-off that can be mitigated by these structures, these opportunities would be best suited in lower priority flood-zones or would need to be used in conjunction with larger catchment facilities to maximize effectiveness. The placement of the inlets would be most effective at the higher regions of a watershed where the runoff volumes are relatively low and the larger catchments should be placed at the middle to lower portions of the watershed where the cumulative effects would overwhelm the microbasins. Placing the microbasins at the higher elevated regions of a watershed will also help to reduce the required volume that will need to be stored by the more costly larger catchment facilities at the lower elevations of the watershed.

Another approach would be to provide a number of small to medium size detention basins along the flow path to be mitigated. The overall cost may be similar to providing the larger proposed catchment facilities, but the construction of smaller catchment areas would be far less disruptive to localized campus activities and it may be easier to provide suitable locations along the flow path due to the decreased area requirement.

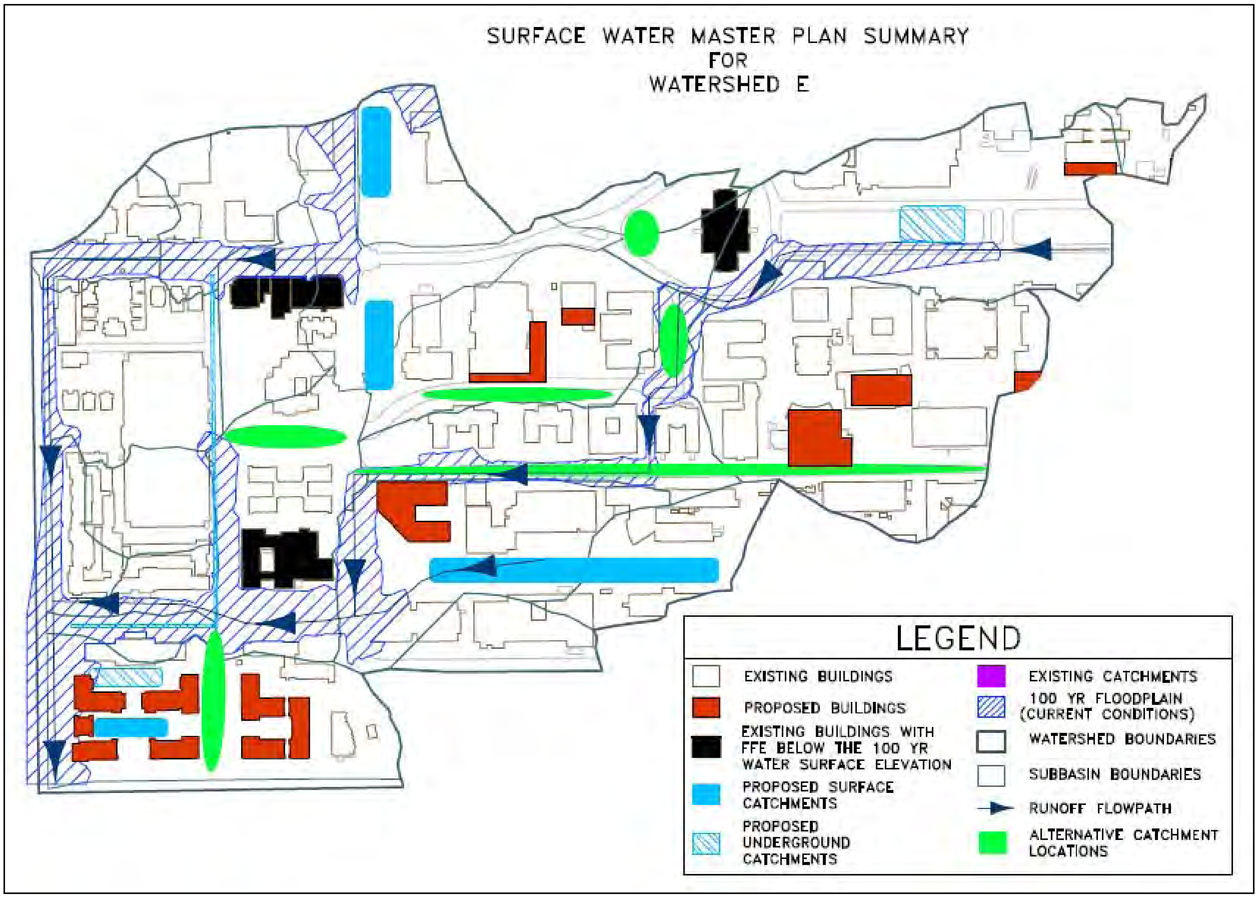
4.4 CONCLUSION

The analysis performed and the results produced for this document are a direct product of The University of Arizona's realization of the need to mitigate the current flooding problems produced from the campus' stormwater runoff both onsite and in the surrounding neighborhoods.

In addition to this, the university has recognized the importance of harnessing and reusing stormwater to produce a more environmentally and financially responsible solution to the current flooding problems. The goal of this document is to provide a platform to bring these insights into action. This was accomplished by first formulating a multidisciplinary consultant team with expertise in areas such as stormwater modeling techniques, the design of stormwater mitigation facilities, water harvesting techniques, and the design of multi-use landscapes which coordinated and collaborated with the University's Surface Water Working Group. The fruit of this collaboration is this document, the Surface Water Master Implementation Plan and its appendices, and the updated version of the University of Arizona Manual of Design and Specifications Standards' (DSS) Tabs B-11 and C-9. In summary, this document provides the analysis and modeling of current and future campus hydrologic conditions, the identification of the location, size, cost, and hydrologic impact of the proposed catchment opportunities. The update to the DSS created construction guidelines and visual examples that are intended to reduce flooding throughout campus and in neighboring communities by harnessing, infiltrating, and reusing runoff as close to its source as possible. Based on this idea, it is recommended that new campus developments utilize a portion of or the total amount of the runoff produced on the development site.

The mitigation plan explained in this document meets or exceeds the hydrological requirements of the City of Tucson. As stated earlier, the City of Tucson requires that the 100 year runoff produced on a new development site not exceed the 100 year runoff calculated for the site before development. It also requires that catchments must have the capacity to store the volume produced during a 5 year storm event.

A graphical summary illustrating the products of this study is shown in **Figure 22,** which can be found in the Surface Water Master Implementation Plan Appendix at the end of this portion of the document. A portion of **Figure 22** showing only Watershed E is shown below. The figure shows not only the existing and proposed catchments, but also the alternate catchment locations that may be available currently or will become available with the construction of new projects. The alternate catchment locations are identified in the case that an area designated as a proposed catchment location is lost or reduced in size and additional capacity is required.



Excerpt from Figure 22

SURFACE WATER MASTER IMPLEMENTATION PLAN
APPENDIX

Table 1

COMPARISON OF EXISTING CONDITIONS TO FUTURE CONDITIONS

BASINS WITH A CHANGE IN FLOW ARE HIGHLIGHTED

BASIN	Q (cfs)		ΔQ (cfs)	T_c (min)		ΔT_c (min)	Area* (ac)	Max Runoff Volume* (ac-ft)
	Existing	Future		Existing	Future			
A1	21.14	17.44	-3.70	7.05	7.56	0.51	2.54	0.60
A2	34.42	31.99	-2.43	5.00	5.00	0.00	4.22	0.99
A3	16.70	15.01	-1.69	5.00	5.13	0.13	1.87	0.44
A4	19.00	17.18	-1.82	5.00	5.00	0.00	2.11	0.49
A5	90.33	90.33	0.00	5.93	5.93	0.00	10.38	2.44
A6	29.85	29.85	0.00	5.00	5.00	0.00	3.34	0.77
A7	77.01	77.01	0.00	6.95	6.95	0.00	9.30	2.14
A8	30.95	27.64	-3.31	5.29	5.48	0.19	3.62	0.85
A9	6.75	7.14	0.39	5.00	5.00	0.00	0.83	0.19
A10	18.85	20.85	2.00	5.00	5.00	0.00	2.31	0.54
A11	50.61	59.38	8.77	5.00	5.00	0.00	7.03	1.63
A12	22.37	22.37	0.00	5.00	5.00	0.00	2.59	0.61
A13	25.17	24.10	-1.07	5.00	5.00	0.00	2.79	0.66
A14a	45.42	45.42	0.00	5.07	5.07	0.00	5.05	1.19
A14b	5.16	5.16	0.00	5.00	5.00	0.00	0.57	0.13
TOTALS FOR BASIN A	**443.15**	**440.29**	**-2.86**				**52.92**	**12.36**
B1	17.27	16.25	-1.02	5.00	5.00	0.00	2.65	0.61
B2	15.87	15.87	0.00	10.46	10.46	0.00	2.84	0.65
B3	8.92	11.15	2.23	5.00	5.00	0.00	1.29	0.30
B4	28.96	28.96	0.00	5.00	5.00	0.00	3.24	0.75
B5	55.37	55.37	0.00	5.00	5.00	0.00	6.27	1.44
B6	18.54	18.54	0.00	5.00	5.00	0.00	2.25	0.52
B7	43.18	43.18	0.00	5.00	5.00	0.00	6.00	1.38
B8	28.47	29.43	0.96	5.00	5.00	0.00	3.33	0.77
B9	3.96	3.96	0.00	5.00	5.00	0.00	0.63	0.15
B10	8.01	8.01	0.00	5.00	5.00	0.00	1.23	0.28
B11	58.00	58.00	0.00	5.00	5.00	0.00	6.43	1.51
B12	43.83	44.80	0.97	5.00	5.00	0.00	5.07	1.19
B13	16.66	15.06	-1.60	5.00	5.00	0.00	1.85	0.43
B.O.S.	44.90	44.90	0.00	6.63	6.63	0.00	5.30	1.25
TOTALS FOR BASIN B	**391.94**	**393.48**	**1.54**				**48.37**	**11.22**
C1	10.55	10.29	-0.26	5.00	5.00	0.00	1.36	0.32
C2	34.57	34.57	0.00	6.42	6.42	0.00	4.23	0.99
C3	32.69	34.43	1.74	5.65	5.55	-0.10	4.31	1.01
C4	73.68	78.50	4.82	7.47	7.30	-0.17	9.92	2.33
C5	42.60	47.11	4.51	5.00	5.00	0.00	5.22	1.23
C6	43.24	43.24	0.00	14.67	14.67	0.00	6.94	1.63
C7a	47.46	49.71	2.25	5.13	5.06	-0.07	5.52	1.30
C7b	49.34	51.53	2.19	5.00	5.00	0.00	5.71	1.34
C8	23.55	23.55	0.00	5.00	5.00	0.00	2.73	0.64
C9	88.94	93.31	4.37	7.23	7.11	-0.12	11.21	2.64
C10a	68.62	68.62	0.00	6.18	6.18	0.00	7.96	1.87
C10b	24.65	23.60	-1.05	5.00	5.00	0.00	2.73	0.64
C11	52.84	52.84	0.00	11.53	11.53	0.00	7.38	1.74
TOTALS FOR BASIN C	**592.73**	**611.30**	**18.57**				**75.23**	**17.68**
D1	13.57	13.57	0.00	7.83	7.83	0.00	1.67	0.39
D2	13.92	13.92	0.00	7.41	7.41	0.00	1.69	0.40
D3	14.51	14.51	0.00	9.09	9.09	0.00	1.87	0.44
D4	28.94	28.94	0.00	5.00	5.00	0.00	3.21	0.75
D5	18.68	18.68	0.00	5.00	5.00	0.00	2.07	0.49
D6	21.73	21.73	0.00	5.00	5.00	0.00	2.41	0.57
D7	25.01	25.01	0.00	5.00	5.00	0.00	2.77	0.65
D8	24.80	25.90	1.10	5.00	5.00	0.00	2.87	0.67
D9	23.04	23.04	0.00	10.12	10.12	0.00	3.08	0.72
D10	31.37	31.37	0.00	5.00	5.00	0.00	3.63	0.85
D11	49.51	51.90	2.39	5.98	5.89	-0.09	5.96	1.40
D12	42.29	42.29	0.00	5.00	5.00	0.00	4.69	1.10
D13	27.65	27.65	0.00	5.00	5.00	0.00	3.06	0.72
D14	53.70	56.28	2.58	5.57	5.48	-0.09	6.36	1.49
D15	6.37	6.37	0.00	5.00	5.00	0.00	0.78	0.18
D16	34.99	34.99	0.00	5.57	5.57	0.00	4.14	0.97
D17	20.52	20.52	0.00	5.00	5.00	0.00	2.27	0.53
D18	7.86	7.86	0.00	5.33	5.33	0.00	0.88	0.21
D19	34.59	34.59	0.00	5.00	5.00	0.00	3.83	0.90
D20	27.66	27.66	0.00	5.00	5.00	0.00	3.07	0.72
D21	9.70	9.70	0.00	5.00	5.00	0.00	1.08	0.25
D22	11.38	11.38	0.00	5.00	5.00	0.00	1.32	0.31
D23	32.52	32.52	0.00	5.00	5.00	0.00	4.18	0.98
D24	38.17	38.17	0.00	5.00	5.00	0.00	4.91	1.15
D25	52.53	52.53	0.00	5.00	5.00	0.00	6.08	1.43
D26	10.13	10.13	0.00	5.00	5.00	0.00	1.17	0.28
D27	24.62	24.62	0.00	6.00	6.00	0.00	2.84	0.67
D28	34.03	34.03	0.00	5.00	5.00	0.00	3.94	0.93
TOTALS FOR BASIN C	**733.79**	**739.86**	**6.07**				**85.82**	**20.17**

* 1 acre = 43,560 ft^2 / 1 acre-foot = 43,560 ft^3

Table 1 (cont.)

COMPARISON OF EXISTING CONDITIONS TO FUTURE CONDITIONS

BASINS WITH A CHANGE IN FLOW ARE HIGHLIGHTED

BASIN	Q (cfs)		ΔQ (cfs)	T_c (min)		ΔT_c (min)	Area (ac)	Max Runoff Volume (ac-ft)
	Existing	Future		Existing	Future			
E1	7.68	7.68	0.00	5.00	5.00	0.00	0.85	0.20
E2	66.42	66.42	0.00	9.44	9.44	0.00	9.59	2.25
E3	102.78	102.78	0.00	5.85	5.85	0.00	11.77	2.77
E4	8.44	8.44	0.00	5.00	5.00	0.00	1.09	0.26
E5	8.44	8.44	0.00	5.00	5.00	0.00	1.25	0.29
E6	10.21	10.21	0.00	7.71	7.71	0.00	5.46	1.28
E7	42.53	42.53	0.00	6.61	6.61	0.00	6.19	1.45
E8	50.2	50.2	0.00	5.00	5.00	0.00	4.49	1.06
E9	36.62	36.62	0.00	5.00	5.00	0.00	2.91	0.68
E10	22.05	22.05	0.00	6.34	6.34	0.00	2.77	0.65
E11	23.72	23.72	0.00	5.53	5.53	0.00	3.02	0.71
E12	26.65	26.65	0.00	5.00	5.00	0.00	1.11	0.26
E13	9.99	9.99	0.00	5.00	5.00	0.00	0.54	0.13
E14	41.5	41.5	0.00	5.90	5.90	0.00	4.98	1.17
E15	12.56	12.56	0.00	5.26	5.26	0.00	1.56	0.37
E16	19.23	19.23	0.00	5.00	5.00	0.00	2.13	0.50
E17	9.63	9.63	0.00	5.21	5.21	0.00	1.08	0.25
E18	7.62	7.62	0.00	5.40	5.40	0.00	0.95	0.22
E19	50.96	50.96	0.00	5.00	5.00	0.00	5.90	1.39
E20	51.01	51.01	0.00	5.73	5.73	0.00	6.44	1.51
E21	24.11	24.11	0.00	6.56	6.56	0.00	3.14	0.74
E22	17.38	17.38	0.00	5.00	5.00	0.00	2.01	0.47
E23	62.83	62.83	0.00	6.56	6.56	0.00	7.40	1.74
TOTAL ΔQ (cfs) FOR BASIN E			**0.00**					
F1	5.42	5.42	0.00	5.00	5.00	0.00	0.60	0.14
F2	42.63	44.53	1.90	5.00	5.00	0.00	4.93	1.16
F3	28.62	28.62	0.00	5.00	5.00	0.00	3.31	0.78
F4	13.24	13.24	0.00	5.00	5.00	0.00	1.53	0.36
F5	59.9	59.9	0.00	5.00	5.00	0.00	6.93	1.63
F6	16.56	16.56	0.00	5.00	5.00	0.00	1.83	0.43
F7	4.2	4.2	0.00	5.00	5.00	0.00	0.47	0.11
F8	4.7	4.7	0.00	5.00	5.00	0.00	0.53	0.12
F9	45.45	45.45	0.00	6.91	6.91	0.00	6.14	1.44
F10	95.4	95.4	0.00	5.92	5.92	0.00	11.71	2.72
F11	9.02	9.02	0.00	6.61	6.61	0.00	1.18	0.28
F12	30.89	30.89	0.00	5.00	5.00	0.00	3.79	0.89
F13	12.62	12.62	0.00	5.34	5.34	0.00	1.83	0.43
F14	28.48	28.48	0.00	7.74	7.74	0.00	4.39	1.03
F15	4.95	4.95	0.00	5.00	5.00	0.00	0.61	0.14
F16	4.90	4.90	0.00	5.00	5.00	0.00	0.60	0.14
F17	17.35	17.35	0.00	6.72	6.72	0.00	2.41	0.56
F18	15.26	15.26	0.00	5.00	5.00	0.00	1.69	0.40
F19	22.83	22.83	0.00	5.00	5.00	0.00	2.56	0.60
F20	5.3	5.3	0.00	5.00	5.00	0.00	0.60	0.14
F21	48.5	48.5	0.00	5.16	5.16	0.00	5.65	1.30
F22	15.64	15.64	0.00	5.00	5.00	0.00	1.73	0.41
F23	23.78	23.78	0.00	5.00	5.00	0.00	2.69	0.62
F24	66.14	61.60	-4.54	6.88	7.05	0.17	9.26	2.15
F25	46.79	44.43	-2.36	5.40	5.49	0.09	5.83	1.37
F26	46.22	46.22	0.00	7.80	7.80	0.00	6.61	1.55
F27	32.58	32.58	0.00	5.00	5.00	0.00	3.61	0.85
F28	30.4	30.4	0.00	5.00	5.00	0.00	3.37	0.79
F29	15.86	15.86	0.00	5.00	5.00	0.00	1.76	0.41
F30	11.13	11.13	0.00	6.91	6.91	0.00	1.71	0.40
F31	67.73	64.47	-3.26	8.34	8.49	0.15	8.60	2.02
F32	46.01	46.01	0.00	6.56	6.56	0.00	5.47	1.27
F33	10.25	10.25	0.00	5.00	5.00	0.00	1.14	0.27
F34	8.58	9.23	0.65	5.00	5.00	0.00	1.13	0.27
F35	87.37	87.37	0.00	7.04	7.04	0.00	10.47	2.46
F36	24.36	24.36	0.00	5.00	5.00	0.00	2.70	0.63
F37	10.85	10.85	0.00	5.00	5.00	0.00	1.26	0.30
F38	35.91	35.91	0.00	5.00	5.00	0.00	3.98	0.94
F39	47.09	49.18	2.09	5.00	5.00	0.00	5.45	1.28
F40	49.46	49.46	0.00	7.22	7.22	0.00	6.23	1.46
F41	31.26	31.26	0.00	5.00	5.00	0.00	3.66	0.85
F42	6.96	6.96	0.00	5.24	5.24	0.00	0.80	0.18
F43	45.32	45.32	0.00	6.76	6.76	0.00	5.43	1.26
F44	37.02	37.02	0.00	5.00	5.00	0.00	4.10	0.96
F45	10.92	10.92	0.00	5.00	5.00	0.00	1.21	0.28
F46	4.58	4.58	0.00	5.00	5.00	0.00	0.51	0.12
F47	21.83	19.59	-2.24	5.50	5.70	0.20	2.47	0.58
F48	59.30	53.62	-5.68	5.00	5.00	0.00	6.57	1.54
F49	22.33	22.33	0.00	5.00	5.00	0.00	2.47	0.58
F50	5.22	5.22	0.00	6.06	6.06	0.00	0.62	0.14
F51	4.58	4.58	0.00	5.76	5.76	0.00	0.52	0.12
F52	10.13	10.13	0.00	10.41	10.41	0.00	1.37	0.32
F53	27.62	27.62	0.00	5.41	5.41	0.00	3.85	0.90
F54	13.58	12.62	-0.96	5.00	5.01	0.01	1.66	0.39
F55	12.15	11.85	-0.30	5.00	5.00	0.00	1.56	0.37
F56	19.23	18.75	-0.48	5.00	5.00	0.00	2.47	0.58
F57	11.55	11.55	0.00	5.05	5.05	0.00	1.49	0.35
TOTAL ΔQ (cfs) FOR BASIN F			**-15.18**					
TOTALS FOR ENTIRE CAMPUS			**8.14**				**718.16**	**168.15**

* 1 acre = 43,560 ft^2 / 1 acre-foot = 43,560 ft^3

Table 2
FFE vs Predicted Water Surface Elevation

🟨	FFE of UA Building w/in 1' of 100yr Water Surface Elevation
🟥	FFE of UA Building below 100yr Water Surface Elevation

Basin A

UA Building #	*Building Name*	*FFE*	*100yr WSE*
241	Research Building	2460.00	2453.39
204	The Herbert K Abrams	2445.50	2441.90
204A, 204B	Campus Health Services Satellite Clinic	2446.70	2440.06
559	Comstock House	2445.00	2441.57
201A	Arizona Health Sciences Library	2446.40	2444.80
201	SW Corner of AHSC	2442.80	2441.57
201	Arizona Respiratory Center	2446.40	2439.71
201	North End of AHSC	2446.20	2437.97
208	1620 N Warren Clinical Research	2439.50	2436.80
226	Department of Orthopaedic Surgery	2440.90	2437.00
220	Faculty Office Building (College of Medicine)	2436.40	2435.60
209	Biomedical Research	2435.90	2436.93
225	1690 N Warren Ave (Facilities Management)	2432.75	2436.41
526B	NA	2438.40	2436.41
526A	NA	2438.30	2435.86
-	Bldg East of Bldg 526	2437.70	2435.50
-	Residence-1700 E Lester St.	2433.90	2434.95
211	Radiology	2432.10	2429.61
-	Residence-1602 E Lester St.	2429.20	2429.61
-	Residence-1550 E Lester St.	2429.50	2429.61

Table 2 (cont.)
FFE vs Predicted Water Surface Elevation

Basin B

UA Building #	***Building Name***	***FFE***	***100yr WSE***
202	Roy P Drachman Hall	2457.00	2453.66
203	College of Nursing	2452.00	2451.55
212	1605 N Cambell Ave (Employee Health / Emergency Services Admin Offices)	2443.50	2441.25
-	Residence- 1802 E Lester St.	2434.60	2432.83
-	Apts. At Lester St and Martin Ave	2434.60	2432.80

Table 2 (cont.)
FFE vs Predicted Water Surface Elevation

Basin C			
UA Building #	***Building Name***	***FFE***	***100yr WSE***
	Poetry Center	2456.27	2455.14
471B	1249 N Mountain Ave.	2437.50	2436.65
429A	1201 E Helen St.	2436.50	2435.21
411A	1103 E Helen St	2433.00	2432.53
415G	1203 N Fremont Ave.	2432.00	2430.97
420	Esquire Bldg	2427.00	2429.24
	1010 E Mabel St. (University Park Apts)	2427.50	2429.24

Table 2 (cont.)
FFE vs Predicted Water Surface Elevation

Basin D			
UA Building #	***Building Name***	***FFE***	***100yr WSE***
	Delta Gamma Sorority	2450.00	2448.00
105	Learning Services Building		2447.37
5023	Sigma Alpha Epsilon Fraternity	2451.40	2446.14
	Gamma Zeta Sorority	2446.10	2446.14
69	Education Building	2445.00	2445.19
114	2nd Street Garage	2438.60	2442.03
	Meyer Agron Student Center	2438.00	2439.23
11,12	Harshbarger/Mines Bldg	2436.00	2437.17
72	Civil Engineering Bldg	2438.50	2437.17
71	Speech/Hearing Sciences Bldg	2439.40	2436.02
23	Cesar E. Chavez Building (Economics)	2438.00	2431.63
10	Yuma Residence Hall	2434.30	2435.06
76	Harvill Bldg	2438.10	2435.06
24	Center for English as a Second Language	2432.50	2429.90
9	Maricopa Residence Hall	2434.30	2432.12
5	Coconino Residence Hall	2435.30	2431.67
6	Slonaker Alumni	2433.00	2430.80
8	Gila Residence Hall	2430.40	2430.3
26	Arizona State Museum North	2432.70	2429.27

Table 2 (cont.)
FFE vs Predicted Water Surface Elevation

Basin E			
UA Building #	***Building Name***	***FFE***	***100yr WSE***
40	Robert L. Nugent Building	2437.50	2436.63
21	Old Main	2435.40	2436.14
36	Forbes Building	2437.10	2435.70
27	Social Sciences	2436.60	2433.93
35	Herring Hall	2433.20	2432.59
34	Yavapai Residence Hall	2436.80	2432.40
33	Family and Consumer Resources	2439.80	2431.41
81	Physic-Atmospheric Sciences Building	2426.10	2424.80
77	Gould-Simpson	2424.60	2423.76
31	Cochise Residence Hall	2428.20	2421.80
87	Park Student Union	2417.00	2417.51
54,83	Arizona/Sonora Residence Hall	2417.60	2412.60
85	Coronado Residence Hall	2411.50	2410.39
	La Aldea	2414.00	2410.39
	Shops at 904-908 E University Blvd	2420.50	2420.40

Table 2 (cont.)
FFE vs Predicted Water Surface Elevation

Basin F			
Building #	***Building Name***	***FFE***	***100yr WSE***
	NOAO 1002 N Warren Ave.	2451.00	2448.77
93C	Hillenbrand Memorial Stadium Facility C	2446.20	2447.77
	NOAO,Bldg Located on SW Corner of 2nd St & Warren Ave	2451.00	2447.77
	NOAO,NW Corner of Hawthorne St & Warren Ave	2448.00	2446.82
92	Gerard P. Kuiper Space Sciences Building	2447.30	2445.66
91	Flandrau Science Center and Planeterium	2444.70	2444.56
63	Sonnett	2443.80	2440.90
55	Main Library	2444.20	2438.60
57	Hopi Lodge Residence Hall	2432.00	2433.32
52	Greenlee Residence Hall	2441.50	2430.82
53	Graham Residence Hall	2551.50	2430.82
118	Colonia De La Paz Residence Hall	2432.70	2430.77
50,50A	Apache/Santa Cruz Residence Hall	2431.60	2430.28
58	Printing and Publishing (S)	2428.70	2427.31
58	Tree Ring Lab (N)	2429.00	2430.77
59	Pinal Residence Hall	2430.00	2426.80
117	Student Recreation Center	2425.20	2425.38
	Mansfield Middle School	2424.50	2424.37
95	Highland Commons	2423.00	2423.24
181	Parking and Transportation Office Building	2420.00	2419.95
180	6th Street Garage	2420.00	2420.18

Table 2 (cont.)
FFE vs Predicted Water Surface Elevation

Basin F (cont.)			
UA Building #	***Building Name***	***FFE***	***100yr WSE***
	Shops Directly South of 6th Street Garage	2417.50	2418.20
120	Dennis DeConcini Environment and Natural Resources	2414.50	2415.90
96	McKale Center	2441.00	2440.93
62	Frank Sancet Field	2441.50	2440.63
62A	Facilities Mgmt Gounds (513 N Martin Ave)	2441.50	2436.28
	1718-1742 E. 6th St.	2436.00	2435.68
	428-430 N. Warren Ave.	2431.00	2429.45

Table 3 - RECOMMENDATIONS ON PROPOSED SURFACE WATER MITIGATION PROJECTS

	Project Type		*Stand-Alone or With other Project*	*Project Data - Subsurface*			*Project Data - Surface*		
Project Number (on map) and description	**Subsurface**	**Surface**	**With Project or Stand-Alone**	**Acre Feet Stored**	**Area Required (ft^2)**	**Cost**	**Acre Feet Stored**	**Area Required (ft^2)**	**Cost**
WATERSHED A									
1. Lester buffer	x	x	SA	8.72	63,300	$2,886,000			
2. Beneath existing turf basin - AHSC library basin	x		SA	3.45	25,050	$1,142,000			
3. Beneath plaza - future development	x		P	1.32	9,580	$437,000			
Alternate Catchment Locations:									
- Landscape buffer along east side of Vine	x	x	SA						
- Courtyard in future building west of existing AHSC Library basin	x		P						
WATERSHED B									
1. Lester buffer	x	x	SA	3.22	23,380	$1,066,000			
2. Under existing Nursing basin.	x		SA	4.81	34,920	$1,592,000			
WATERSHED C									
1. Street-edge buffer along Mabel	x	x	SA	3.58	26,000	$1,185,000	3.58	49,450	$521,000
2. NW quadrangle site	x	x	SA	5.56	40,365	$1,841,000	5.56	78,730	$875,000
3. Open space in Highland alignment between Highland garage and the park	x	x	SA	2.48	18,005	$821,000	2.48	36,680	$391,000
4. Quadrangle on diagonal axis from AHSC to AME	x	x	SA	2.75	20,000	$911,000	2.75	38,300	$400,000
Alternate Catchment Locations:									
- Future courtyards on either side of Santa Rita	x	x	P						
- Below future AME phase II Courtyard	x		P						
- Below Helen Street, Mountain to Park.	x		SA						
WATERSHED D									
1. Park Ave. greenbelt area south of 2nd street		x	SA				2.32	33,700	$366,000
2. Under Second street, Vine to Park	x		P	9.30	67,500	$3,078,000			
3. Under Highland, 2nd to 1st street	x		SA	1.49	11,000	$494,000			
Alternate Catchment Locations:									
- Future plaza space south of Architecture addition	x	x	P	1.34	9,750	$444,000	1.34	21,800	$237,000
- In roadway segments north from 2nd street - Olive, Palm, Vine	x		SA						
- Under courtyards in U. Village town center area (north of 1st, West of Cherry)	x		P						
- Under future Arts Oasis plaza (Olive underpass area)	x		SA						
WATERSHED E									
1. Park Ave. greenbelt area north of Univ Blvd		x	SA				2.49	36,100	$392,000
2. Park Ave. greenbelt area south of Univ Blvd		x	SA				2.51	36,450	$396,000
3. Main mall panel south of Student Union	x		SA	2.45	17,800	$811,000			
4. Sciences concourse - old Fifth street alignment	x	x	SA	7.03	51,000	$2,327,000	7.03	94,000	$237,000
5. North of proposed new res halls - south of Coronado	x		P	1.38	10,000	$457,000			
6. Courtyard of proposed new res halls - south of Coronado	x	x	P	1.38	10,000	$457,000	1.38	19,600	$201,000
7. Under Tyndall Ave, and old Fifth street alignment to west	x		P	1.85	13,400	$613,000			
Alternate Catchment Locations:									
- West lawn of Old Main	x		SA						
- Fourth Street between Tyndall and Park	x		SA						
- Area NW corner of Park and Fourth	x	x	SA						
- In south Campus Drive	x	x	SA						
- Street between Forbes and Social Sciences	x	x	SA						
WATERSHED F									
1. Below Warren from hawthorn to the Mall	x		SA	0.42	3,050	$139,000			
2. Under main mall panel, Cherry to Campbell	x		SA	9.75	70,800	$3,227,000			
3. Under Bear Down field	x		SA	4.71	34,200	$1,559,000			
4. Between La Paz and Arizona Stadium	x	x	SA	4.49	32,600	$1,486,000	4.49	60,200	$653,000
5. Under Sancet field.	x		SA	4.73	34,400	$1,566,000			
6. In future field south of Sixth, between Cherry and Warren	x	x	P	4.34	31,500	$1,437,000	4.34	94,530	$1,025,000
7. In future field south of Sixth, between Vine and Highland	x	x	P	5.04	36,600	$1,668,000	5.04	110,000	$1,190,000
8. Under Sixth Street from Highland to Park	x		SA	2.09	15,200	$691,690			
9. Under courtyard in future devel., south of 6th from Santa Rita to Fremont	x		P	1.00	7,300	$331,000			
10. In Fremont, from Sixth to Seventh	x	x	SA	3.02	22,000	$1,000,000	3.02	32,900	$357,000
11.Under quad in future development, south of Sixth from Park to Fremont.	x	x	P	2.35	17,100	$778,000	2.35	25,600	$278,000
Alternate Catchment Locations:									
- Under lawn area north of current ICA addition	x		SA						
- In Courtyard in future development on NW corner of Inke and Campbell	x		P						
- Under corner plaza in future development on SW corner of Sixth and Cherry	x		P						
- Along Campus buffer - Seventh Street and Eighth Street, Park to Campbell		x	SA						
- Under future field between 7th and 8th streets and Vine and Cherry	x		P						

NOTES:

Plaza, courtyard, quadrangle open spaces: the determination on whether to recommend sufrace or subsurface is subjective, but generally has to do with size - with the smaller spaces there will be less softscape to work with, so subsurface is generally called for.

For most projects where "subsurface" is denoted by itself, the ground level development would accommodate some level of catchment, but likely not enough to model it as part of the flood mitigation.

"Alternate Catchment Locations" refers to other potential project locations which could be a complement or alternateive location to one of the adjacent project sites which was modeled in the study.

"With Project" means that the surface water improvement would be constructed with an adjacent capital project, while "Stand-Alone" means it would be an improvement to be funded and implemented as a stand-alone capital project.

Table 10

	CUMULATIVE FLOWS FOR VARIOUS RETURN PERIODS (CFS)					
SUBBASIN	**2 YR**	**5 YR**	**10 YR**	**25 YR**	**50 YR**	**100 YR**
A1	3	6	9	13	17	20
A2	44	88	131	190	248	292
A3	15	29	44	63	82	97
A4	7	14	21	30	39	46
A5	36	71	107	155	202	238
A6	15	30	45	65	85	100
A7	17	33	50	72	94	110
A8	5	9	14	20	26	31
A9	11	22	32	47	61	72
A10	10	20	29	42	55	65
A11	11	22	33	47	62	73
A12	11	21	32	46	60	71
A13	4	8	11	16	21	25
A14a	7	15	22	32	42	49
A14b	1	2	2	3	4	5

Table 10 (cont.)

	CUMULATIVE FLOWS FOR VARIOUS RETURN PERIODS (CFS)					
SUBBASIN	**2 YR**	**5 YR**	**10 YR**	**25 YR**	**50 YR**	**100 YR**
B1	12	24	36	53	69	81
B2	2	4	6	9	12	14
B3	1	3	4	6	8	9
B4	4	8	13	18	24	28
B5	6	12	18	26	34	40
B6	3	5	8	12	15	18
B7	11	21	32	46	60	70
B8	4	8	13	18	24	28
B9	1	1	2	3	3	4
B10	24	49	73	105	138	162
B11	23	47	70	101	132	155
B12	15	29	44	64	83	98
B13	9	17	26	38	49	58
B.O.S.	6	13	19	27	36	42

Table 10 (cont.)

	CUMULATIVE FLOWS FOR VARIOUS RETURN PERIODS (CFS)					
SUBBASIN	**2 YR**	**5 YR**	**10 YR**	**25 YR**	**50 YR**	**100 YR**
C1	2	3	5	7	9	10
C2	22	44	67	96	126	148
C3	17	35	52	75	99	116
C4	12	25	37	54	71	83
C5	8	16	23	34	44	52
C6	9	19	28	40	53	62
C7a	42	83	125	181	236	278
C7b	7	15	22	32	42	49
C8	3	7	10	15	20	23
C9	26	53	79	114	149	175
C10a	14	28	41	60	78	92
C10b	4	7	11	16	20	24
C11	5	11	16	23	31	36

Table 10 (cont.)

	CUMULATIVE FLOWS FOR VARIOUS RETURN PERIODS (CFS)					
SUBBASIN	**2 YR**	**5 YR**	**10 YR**	**25 YR**	**50 YR**	**100 YR**
D1	3	5	8	12	15	18
D2	3	6	9	14	18	21
D3	2	4	6	9	12	14
D4	5	10	14	21	27	32
D5	3	7	10	14	19	22
D6	6	13	19	28	37	43
D7	7	15	22	32	42	49
D8	4	8	11	16	21	25
D9	7	13	20	29	37	44
D10	55	109	164	237	309	364
D11	51	102	153	221	289	340
D12	45	90	135	194	254	299
D13	39	79	118	170	223	262
D14	26	52	78	112	147	173
D15	1	2	3	4	5	6
D16	14	27	41	59	77	91
D17	3	6	9	13	17	20
D18	1	2	4	5	7	8
D19	94	187	281	406	530	624
D20	80	160	240	346	453	533
D21	74	149	223	322	421	495
D22	76	152	228	329	430	506
D23	19	39	58	84	110	129
D24	15	29	44	64	83	98
D25	9	18	27	40	52	61
D26	2	3	5	7	9	10
D27	4	7	11	16	20	24
D28	5	9	14	20	26	31

Table 10 (cont.)

	CUMULATIVE FLOWS FOR VARIOUS RETURN PERIODS (CFS)					
SUBBASIN	**2 YR**	**5 YR**	**10 YR**	**25 YR**	**50 YR**	**100 YR**
E1	1	2	4	5	7	8
E2	11	21	32	46	60	71
E3	15	31	46	66	87	102
E4	12	23	35	50	65	77
E5	2	3	5	7	9	10
E6	30	61	91	132	173	203
E7	7	14	22	31	41	48
E8	10	20	30	43	56	66
E9	3	7	10	14	19	22
E10	6	13	19	27	36	42
E11	11	21	32	46	60	71
E12	2	3	5	7	9	10
E13	12	25	37	53	70	82
E14	18	37	55	80	105	123
E15	20	39	59	85	111	131
E16	9	18	27	38	50	59
E17	66	131	197	285	372	438
E18	86	172	258	372	487	573
E19	65	129	194	280	366	431
E20	50	100	149	216	282	332
E21	3	7	10	15	20	23
E22	3	5	8	11	14	17
E23	95	189	284	410	536	631

Table 10 (cont.)

	CUMULATIVE FLOWS FOR VARIOUS RETURN PERIODS (CFS)					
SUBBASIN	**2 YR**	**5 YR**	**10 YR**	**25 YR**	**50 YR**	**100 YR**
F1	1	2	2	3	4	5
F2	9	18	27	38	50	59
F3	13	25	38	55	71	84
F4	15	29	44	63	82	97
F5	23	46	69	99	130	153
F6	3	5	8	12	15	18
F7	1	3	4	6	8	9
F8	2	3	5	7	9	11
F9	6	13	19	28	37	43
F10	37	74	111	161	210	247
F11	1	3	4	6	8	9
F12	56	112	167	242	316	372
F13	8	17	25	36	47	55
F14	4	8	13	18	24	28
F15	1	2	2	3	4	5
F16	56	112	168	243	318	374
F17	2	5	7	10	14	16
F18	2	5	7	10	13	15
F19	69	139	208	300	393	462
F20	1	2	2	3	4	5
F21	8	16	24	34	45	53
F22	2	5	7	10	13	15
F23	3	7	10	15	20	23
F24	13	25	38	55	71	84
F25	19	38	56	81	106	125
F26	32	64	96	138	181	213
F27	7	14	21	30	39	46
F28	7	14	20	29	38	45
F29	2	5	7	10	14	16
F30	2	3	5	7	9	11
F31	79	158	238	343	449	528
F32	85	171	256	370	484	569
F33	2	3	5	7	9	10
F34	1	2	4	5	7	8
F35	77	155	232	335	439	516
F36	80	160	239	346	452	532
F37	81	162	243	350	458	539
F38	84	169	253	366	479	563
F39	7	14	21	30	39	46
F40	32	65	97	140	184	216
F41	63	127	190	274	359	422
F42	14	29	43	62	81	95
F43	21	41	62	90	117	138
F44	14	27	41	59	77	91
F45	2	3	5	7	9	11
F46	1	1	2	3	3	4
F47	3	7	10	14	19	22
F48	42	85	127	184	241	283
F49	3	7	10	14	19	22
F50	2	5	7	10	14	16
F51	3	6	9	13	17	20
F52	5	9	14	20	26	30
F53	30	61	91	131	172	202
F54	7	13	20	29	37	44
F55	5	9	14	20	26	31
F56	3	6	9	12	16	19
F57	5	9	14	20	26	31

FIG. 10
SUBBASINS WITH CONCENTRATION POINTS
FOR
THE UNIVERSITY OF ARIZONA

NOTE: ARROWS INDICATE CONCENRATION POINT FOR SUBBASIN AND DIRECTION OF FLOW

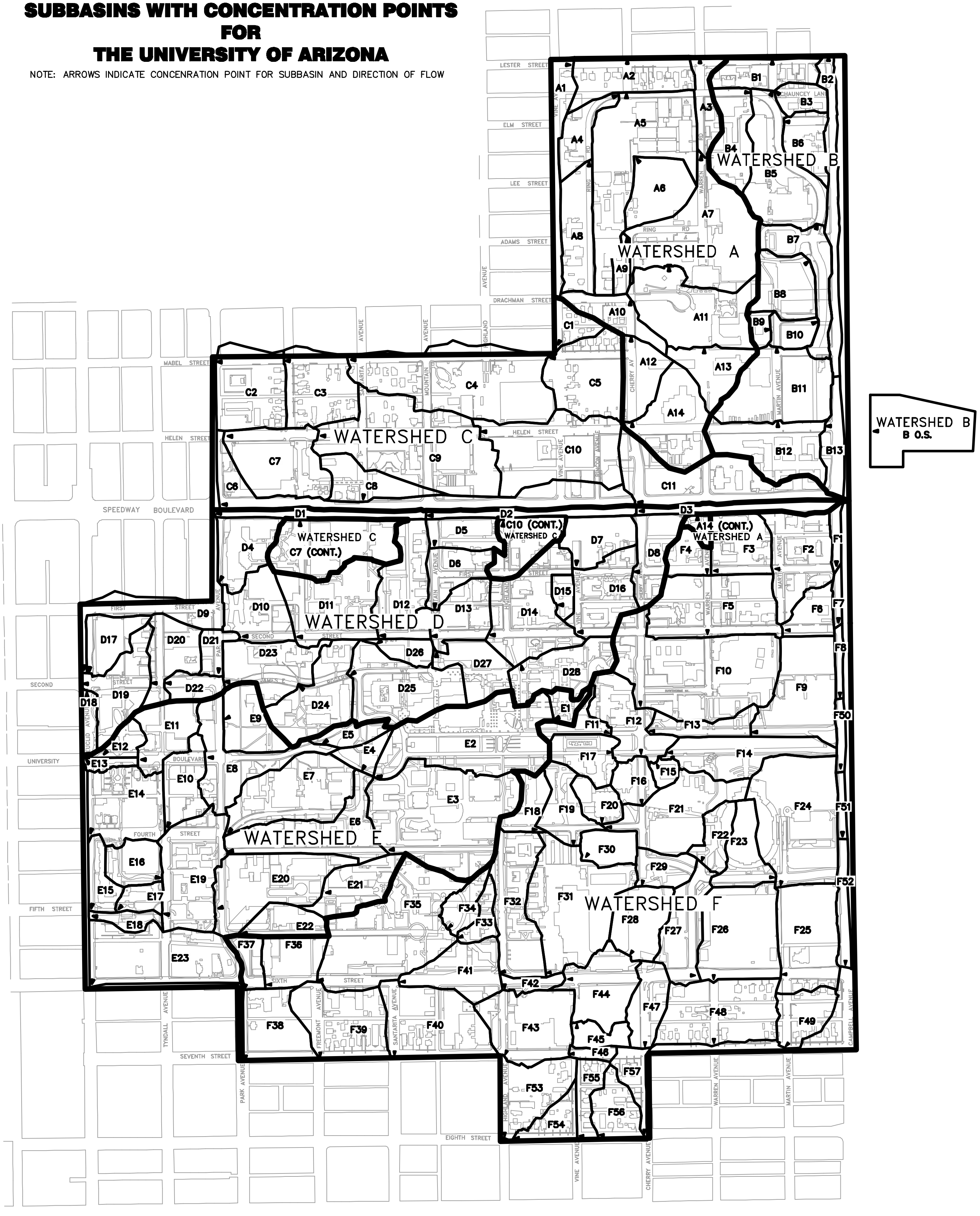


FIG. 12
HECRAS CROSS-SECTIONS
USED IN THE STUDY FOR
THE UNIVERSITY OF ARIZONA

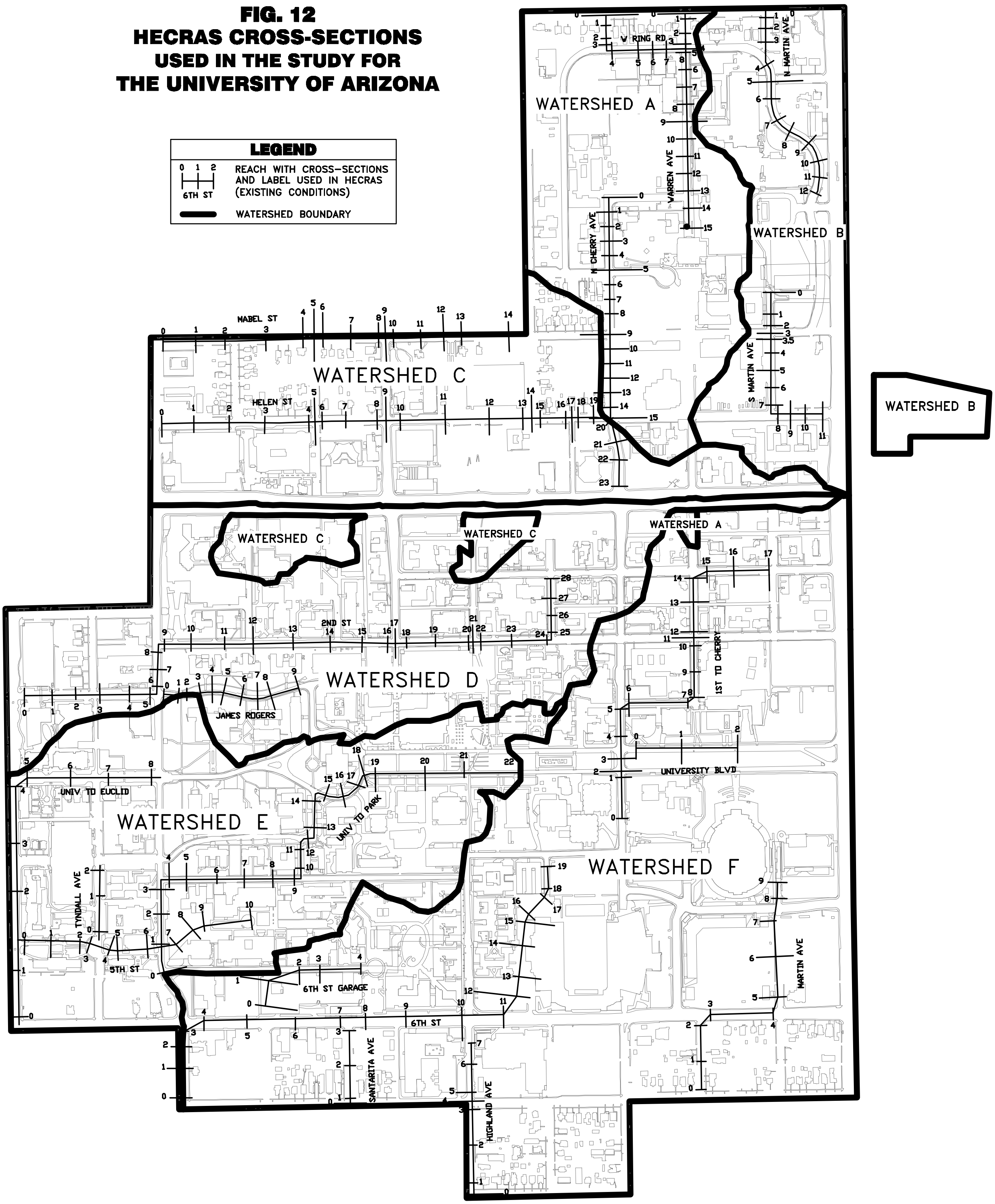
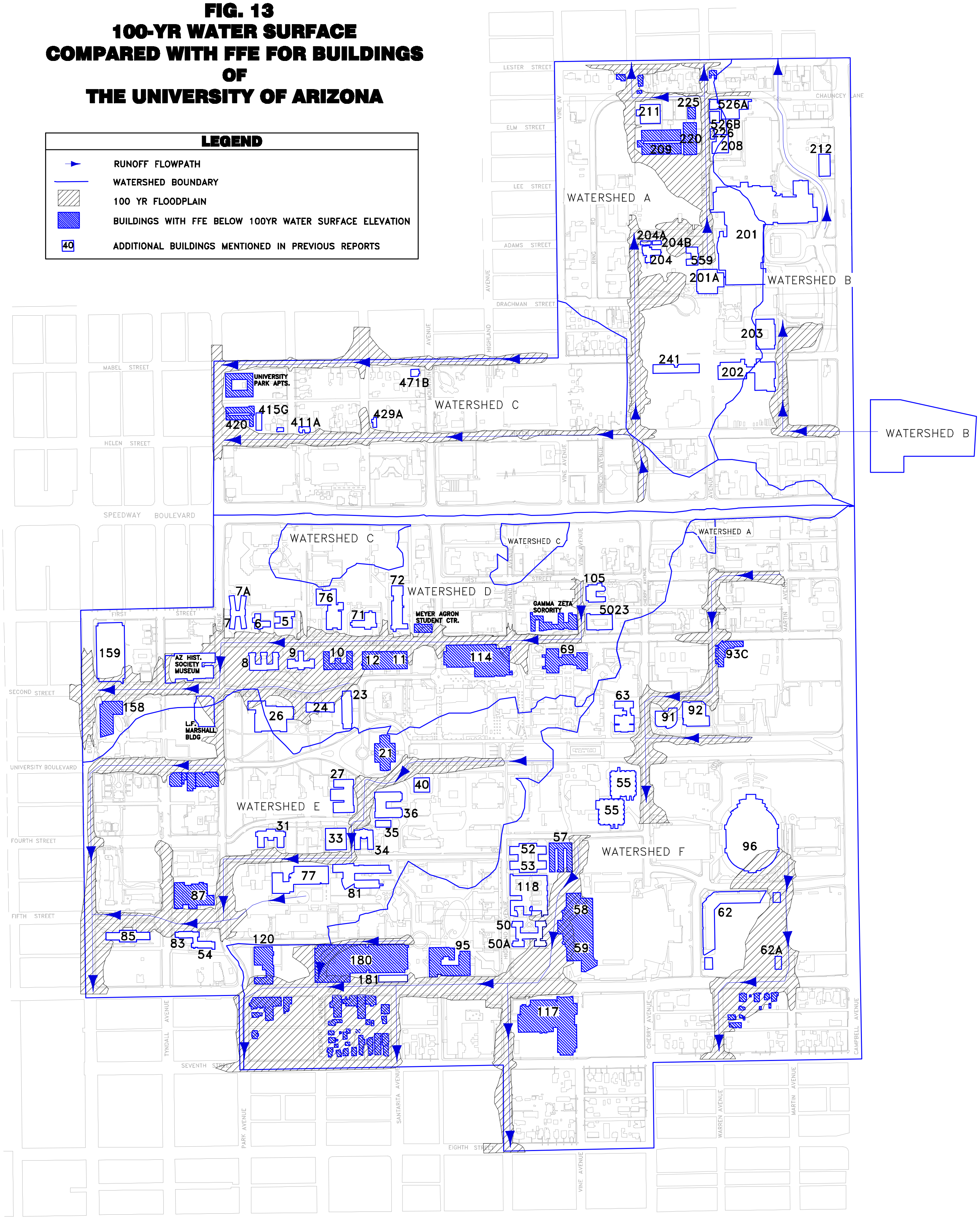


FIG. 13
100-YR WATER SURFACE COMPARED WITH FFE FOR BUILDINGS OF THE UNIVERSITY OF ARIZONA

LEGEND

➤	RUNOFF FLOWPATH
—	WATERSHED BOUNDARY
▨	100 YR FLOODPLAIN
▨	BUILDINGS WITH FFE BELOW 100YR WATER SURFACE ELEVATION
40	ADDITIONAL BUILDINGS MENTIONED IN PREVIOUS REPORTS



SWMIP-7

FIG.15
IMPACTS OF CATCHMENTS ON 100 YR FLOODPLAINS & FLOWS

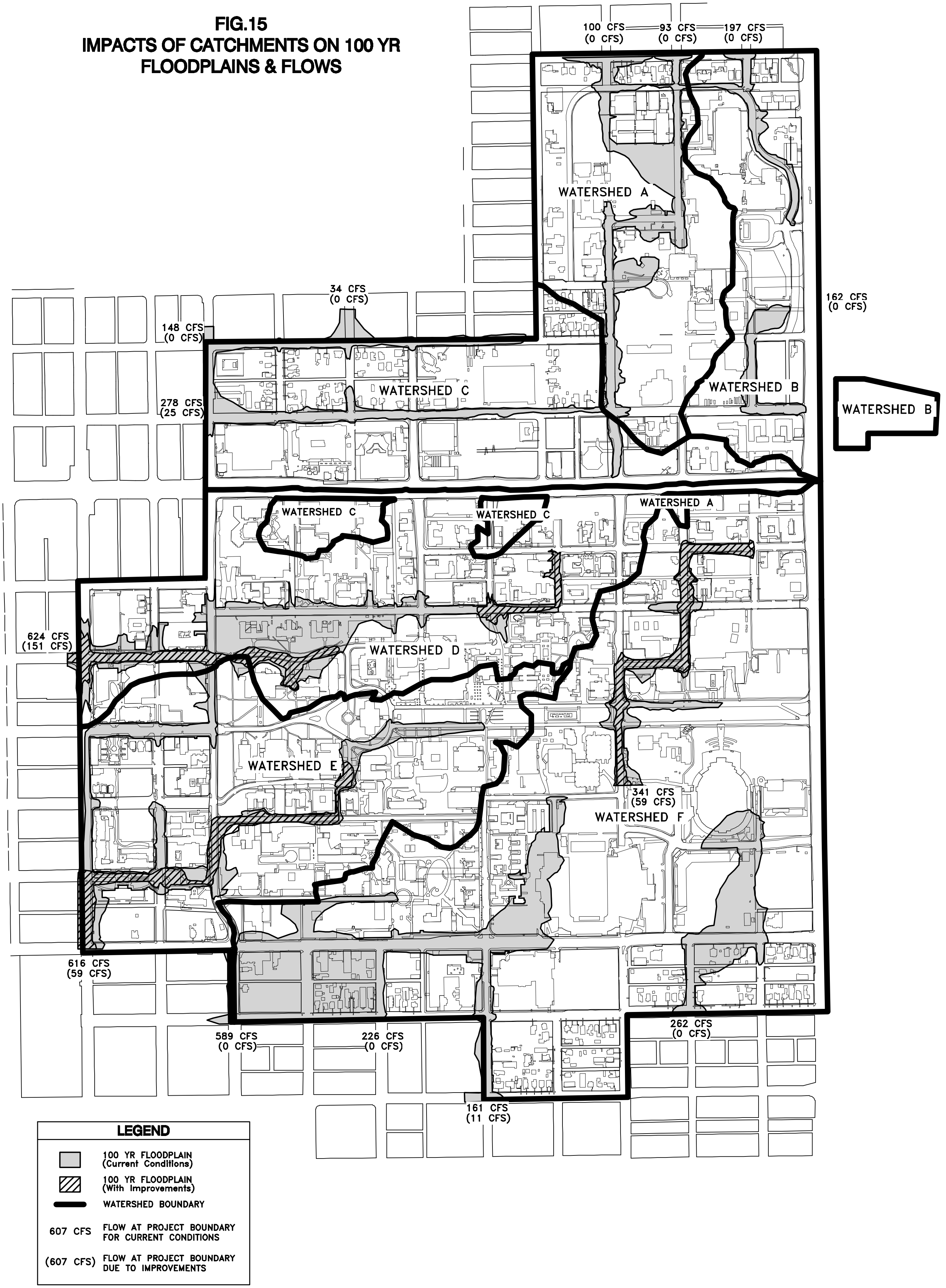


FIG. 16
RESULTS OF PROPOSED CATCHMENTS ON RUNOFF FLOWPATHS FOR THE UNIVERSITY OF ARIZONA

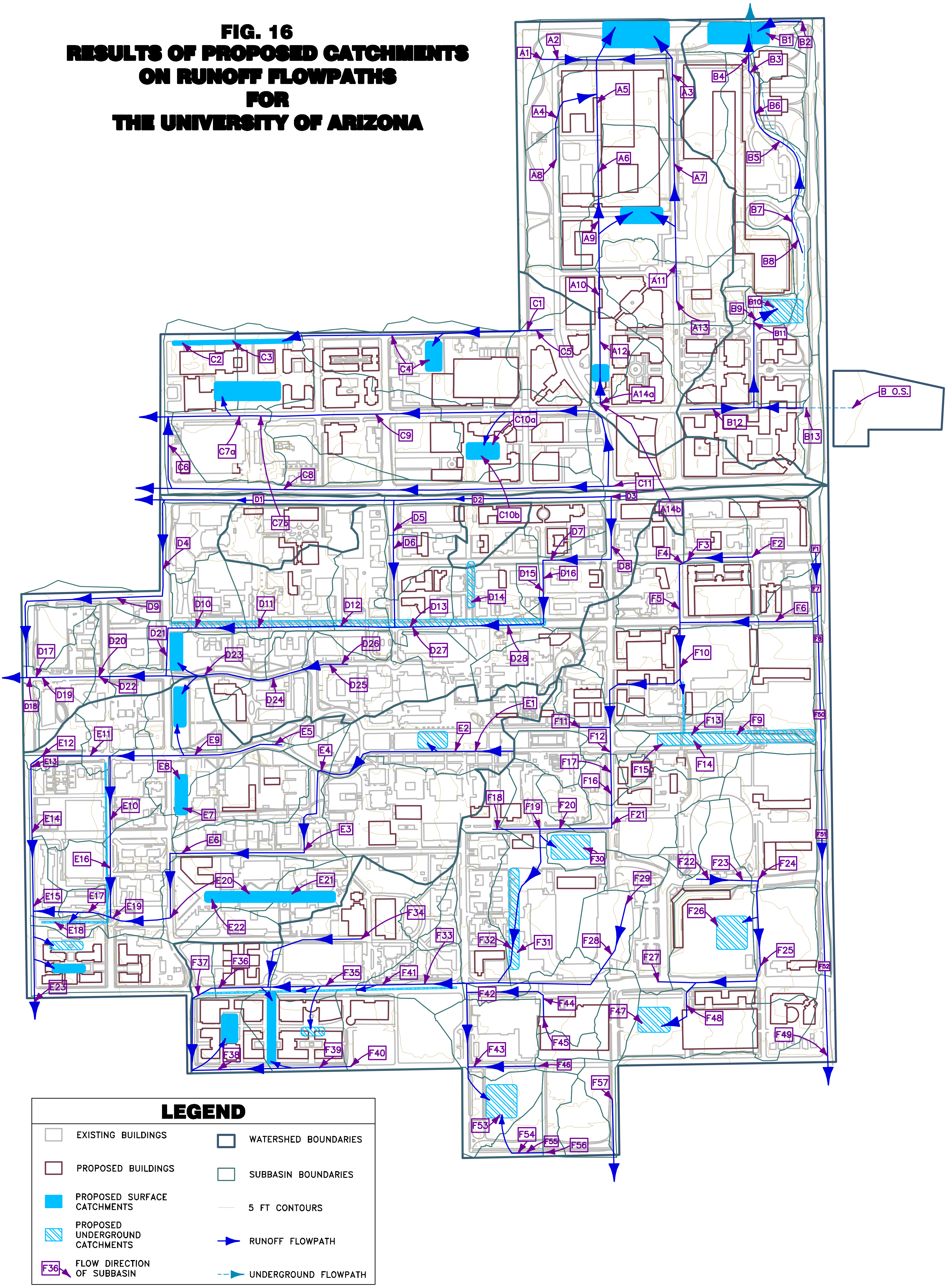
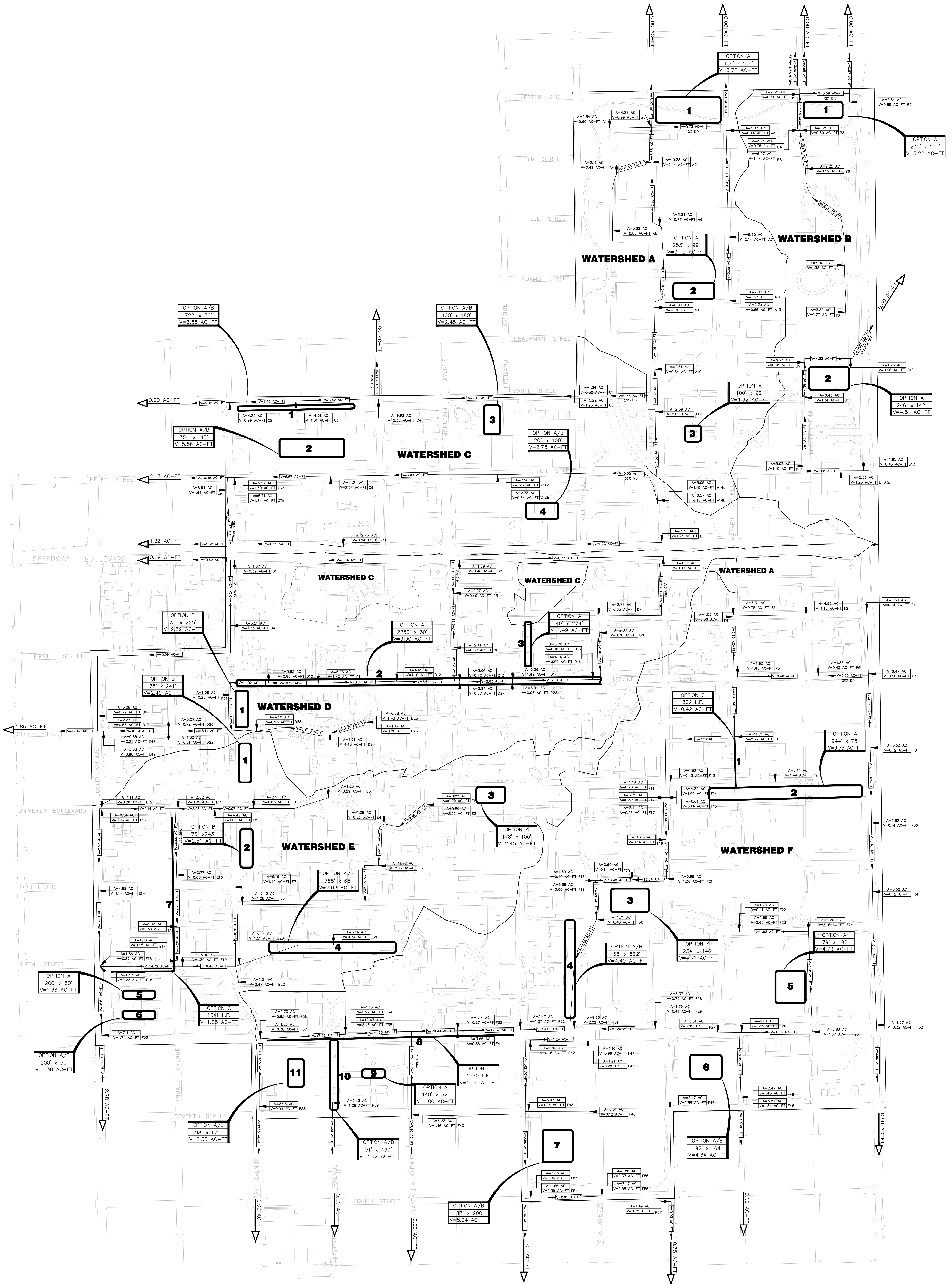


FIG. 17
PRECIPITATION RUN-OFF VOLUMES & STORAGE POTENTIAL FOR THE UNIVERSITY OF ARIZONA

SCALE: 1"=300'



LEGEND

1 AC-FT = 43,560 FT^3

WATERSHED BOUNDARY

AREA/RUN-OFF VOLUME OF SUBBASIN — A=2.84 AC V=0.65 AC-FT B2

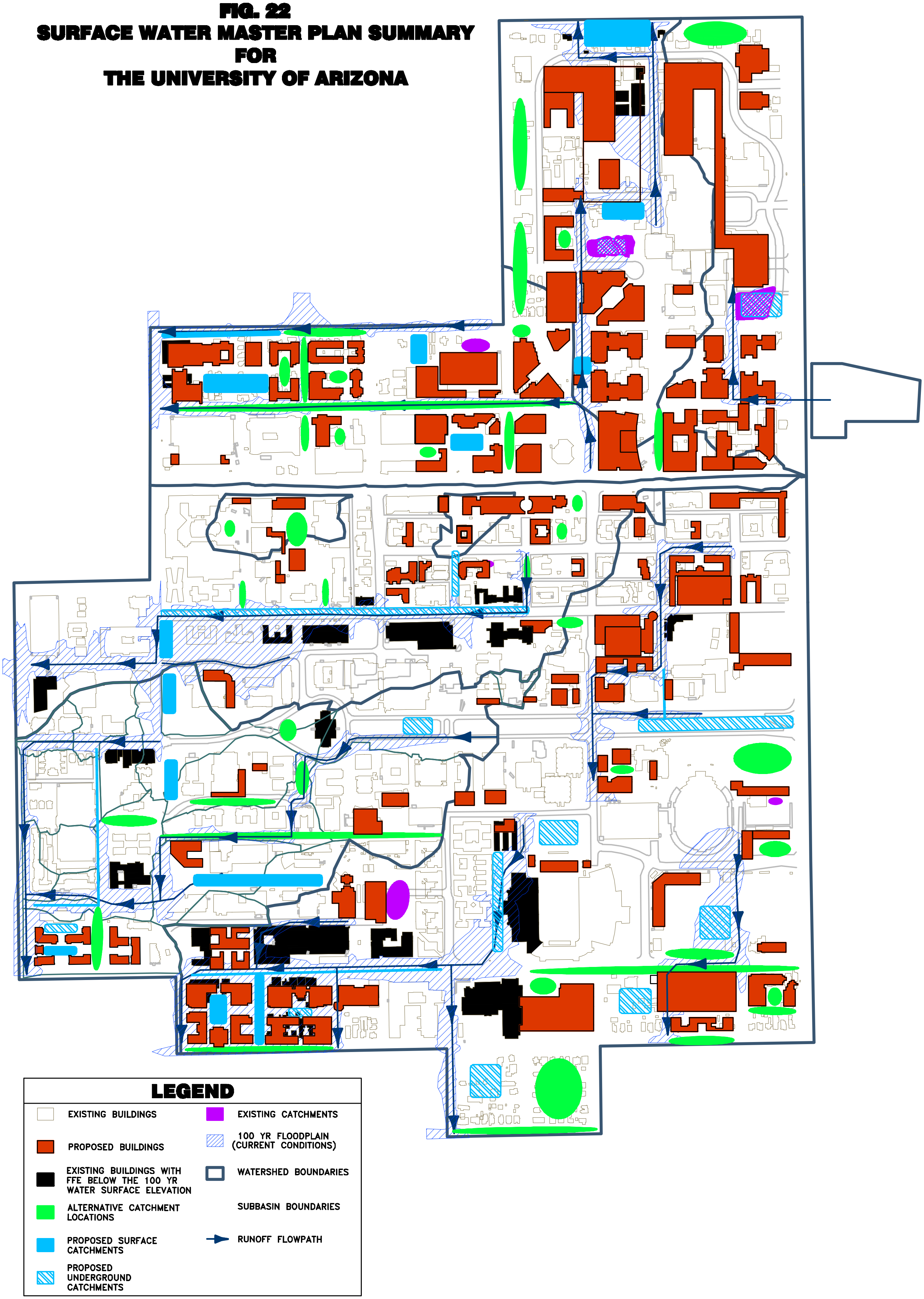
COMBINED RUN-OFF VOLUMES (ALONG FLOWPATH) — V=0.08 AC-FT

STORAGE POTENTIAL INFORMATION BOX — OPTION A 184' x 199' V=5.04 AC-FT
BASIN OPTION TYPE
DIMENSIONS OF PROPSED BASIN
VOLUME OF PROPOSED BASIN

OPTION A = SUBSURFACE CATCHMENT
OPTION B = SURFACE CATCHMENT
OPTION C = SUBSURFACE STREET CATCHMENT

RUNOFF VOLUMES DUE TO PROPOSED BASINS — 0.00 AC-FT

FIG. 22
SURFACE WATER MASTER PLAN SUMMARY FOR THE UNIVERSITY OF ARIZONA



CONTECH® STORMWATER SOLUTIONS INC.

Metal Detention/Retention Products

Optimizer™

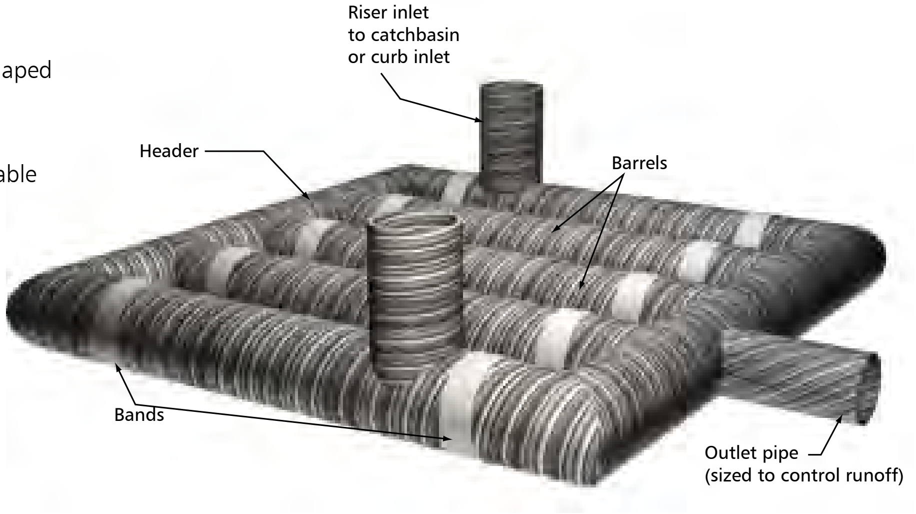
CONTECH® CMP DETENTION SYSTEMS

Corrugated Metal Pipe

CMP Detention Systems

CONTECH CMP detention systems store stormwater runoff exceeding a site's allowable discharge rate and releases it slowly over time. These detention systems work as an integral part of the storm sewer system, and are designed to meet specific water quantity requirements.

CONTECH's CMP detention systems are sized and shaped to fit a site's footprint and storage needs. They are installed below-grade to maximize property usage and lower development costs. The systems are available in all AASHTO M-36 Types.



CMP Retention Systems

CONTECH CMP retention systems allow captured stormwater to percolate into the subsoil, and offer efficient and economical groundwater recharge. In addition to reducing stormwater flows from the site, recharge systems also present water quality benefits through the soil's natural filtering ability.

Perforated CMP is installed and typically enclosed with a high quality, soil-compatible geotextile. This provides long-term infiltration and protects against soil migration. The system is then backfilled with uniformly graded stone. Typically, the same type of material used around subdrainage pipes is excellent for recharge systems.

Standard pipe-wall perforations (3/8" diameter holes meeting AASHTO M-36, Class 2) provide approximately 2.5% open area. This provides adequate recharge flow for most soils. Perforated pipe-arch is also available. Before implementing a retention system it is advisable to consult with a geotechnical engineer to ensure that on site soils are well drained and the water table is at an appropriate elevation to make recharge systems feasible.

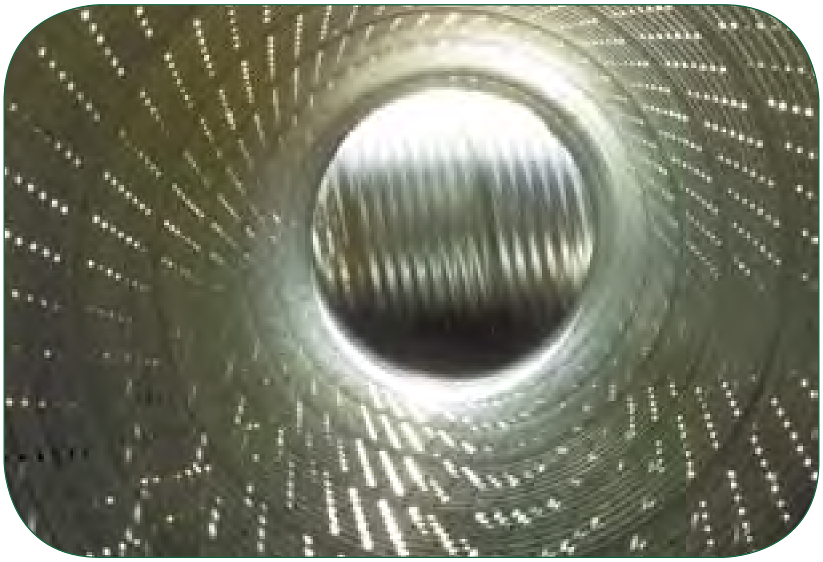


Plate Systems

CONTECH plate systems allow for high volume stormwater storage in small footprint areas. The systems are offered in a wide variety of shapes and sizes in both aluminum and galvanized steel. Full-pipe systems and three-sided structures with open bottoms are utilized for retention.

Typically, CONTECH plate systems are used on high vertical rise applications or in areas where the smallest possible footprint is of the greatest concern. The systems are bolted together in the field, which reduces the number of freight loads. Remote sites or projects with challenging accessibility often utilize plate systems.

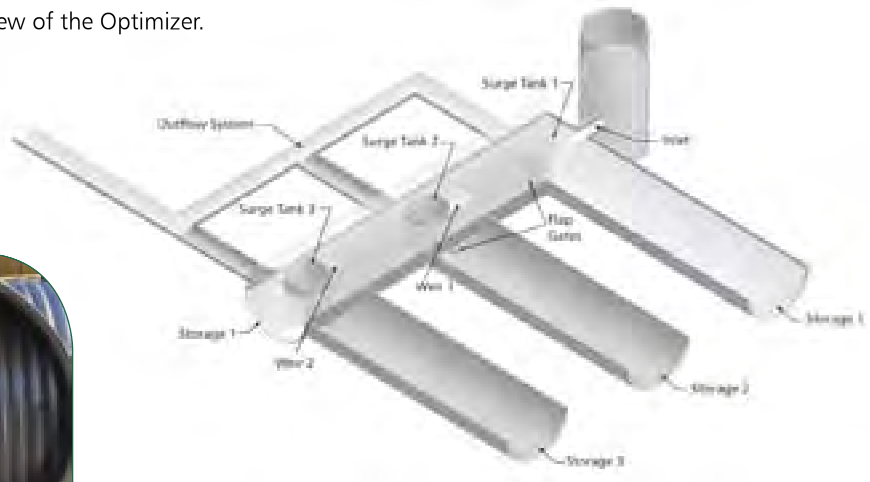
Optimizer™

The Optimizer underground detention technology system is engineered to be the smallest and most efficient stormwater detention solution available in the marketplace today.

Typical detention systems collect and temporarily store excess runoff while discharging up to the maximum allowable release rate. The Optimizer technology utilizes surge tanks that allow head to build rapidly above the outlet orifices so that the maximum allowable release is achieved quickly. Multiple tanks within the system accommodate all required design storms. This process can reduce the size of standard detention systems by up to 50 percent.

The Optimizer process also lowers project installation costs due to less excavation and backfill necessary on the smaller-sized solution, which speeds up installation. Less pipe needs to be installed, so it is ideal for tight sites where larger, traditional systems will not work.

Logon to contechstormwater.com for an animated view of the Optimizer.



CMP Versatility

With versatile layout, material type, coatings, shapes and sizes, CMP solutions provide almost limitless opportunities to match individual site requirements. Variable sizes, material economy, faster installation and durability combine to make CMP detention systems an economical method for controlling stormwater runoff.

Material

Aluminized Steel™ Type 2

Aluminized Steel™ Type 2 provides the ideal mix of economy and durability for most CMP detention systems.

More than 50 years of field testing confirm that Aluminized Steel Type 2 corrugated steel pipe (CSP) offers 75 years or more of maintenance-free service life in a pH range of 5.0 to 9.0 with resistivities as low as 1,500 ohm-cm. When hot-dipped in commercially pure aluminum, a passive aluminum-oxide reaction creates a film that provides excellent protection. Field installations more than 50 years old have shown that this material provides a service life three to 10 times longer than plain galvanized steel.

Galvanized

Galvanizing is a widely used and economical metallic coating for CSP. In addition to forming a physical barrier against corrosion, the zinc coating sacrifices itself slowly by galvanic action to protect the base metal. This sacrificial action continues as long as any zinc remains. Optimal conditions is a pH range of 5.8 to 10 with soil resistivity greater than 2000 ohm-cm and water resistivity in the range of 2000 ohm-cm to 8000 ohm-cm.

CORLIX® (Aluminum Pipe)

Corrugated aluminum pipe is made of rugged core aluminum alloy 3004–H32 or H34 that is clad on both sides with alloy 7072 to protect the pipe physically and electrochemically against corrosion. When backfilled with a free-draining granular material, the pipe can perform well in marine environments. A 75-year service life is expected when the soil and water in contact with the pipe has a pH in the range of 4 to 9 and a resistivity greater than 500 ohm-cm. In addition, the light weight of aluminum makes for an easier and faster installation with longer pipe lengths.

TRENCHCOAT® (Polymer-Coated Steel)

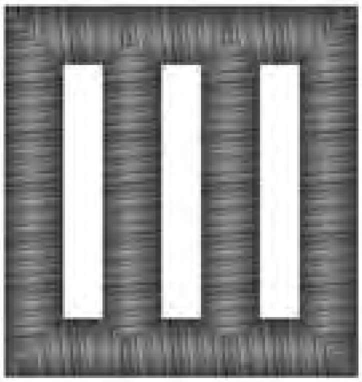
This heavy-gauge protective film offers long–term protection. Even under harsh conditions, it protects against abrasion and corrosion to provide at least 100 years of service life within a pH range of 5.0 to 9.0 with a resistivity greater than 1500 ohm-cm. Bonded to both the inside and outside of CONTECH's galvanized CSP, the film serves as a protective barrier – resisting corrosion from acids, salts, and alkalis found in today's storm sewers and culverts.

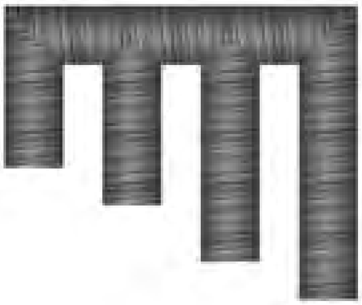
Shape

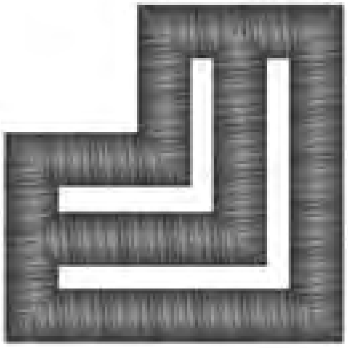
CMP is available in both round pipe and pipe-arch shapes. Pipe-arch provides maximum storage volume in low headroom situations.

Layout

CMP underground detention/retention systems can be sized and shaped to meet most site-specific storage needs. A wide variety of layouts including rectangular, L-shapes and staggered cells are frequently utilized.





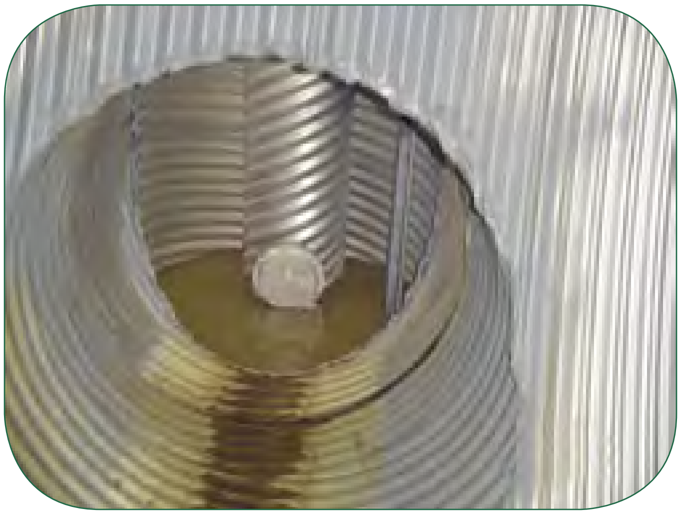


Outlet Control and Maintenance

The versatility of CONTECH CMP systems allows for an outlet control structure to be integrated directly into the piping.

The two most common methods for creating this release structure are through an internal bulkhead and outlet control tee. An internal bulkhead provides a vertical wall, in which openings such as an orifice or overflow weir can be cut to allow for proper release rates. A stand pipe with outlet tee, provides for a low flow orifice in the tee, and an overflow through the top of the standpipe. Integration of either assembly into the CMP detention system eliminates the need for a downstream outlet control structure, reducing costs and maximizing land use.

CMP systems may be equipped with manhole riser sections, complete with ladders, to facilitate any access and scheduled maintenance of the systems.



Sizing

Round Pipe - CMP and Plate (CMP → 12-in to 144-in; Plate → 60-in to 240-in)

Diameter (inches)	Volume (ft^3/ft)	Min. Cover Height	Diameter (inches)	Volume (ft^3/ft)	Min. Cover Height	Diameter (inches)	Volume (ft^3/ft)	Min. Cover Height	Diameter (inches)	Volume (ft^3/ft)	Min. Cover Height
12	.78	12″	60	19.6	12″	120	78.5	18″	180	176	24″
15	1.22	12″	66	23.7	12″	126	86.5	18″	186	188	24″
18	1.76	12″	72	28.2	12″	132	95.0	18″	192	201	24″
21	2.40	12″	78	33.1	12″	138	103.8	18″	198	213	30″
24	3.14	12″	84	38.4	12″	144	113.1	18″	204	227	30″
30	4.9	12″	90	44.1	12″	150	122	24″	210	240	30″
36	7.0	12″	96	50.2	12″	156	132	24″	216	254	30″
42	9.6	12″	102	56.7	18″	162	143	24″	222	268	30″
48	12.5	12″	108	63.6	18″	168	153	24″	228	283	30″
54	15.9	12″	114	70.8	18″	174	165	24″	234	298	30″

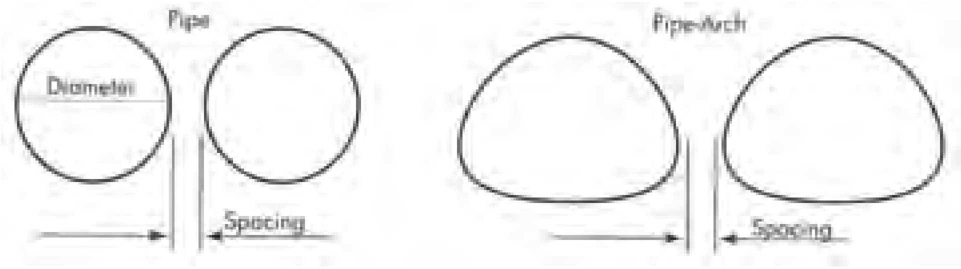
Pipe Arch - CMP

1/2″ Deep Corrugations											
Shape (inches)	Volume (ft^3/ft)	Min. Cover Height	Shape (inches)	Volume (ft^3/ft)	Min. Cover Height	Shape (inches)	Volume (ft^3/ft)	Min. Cover Height	Shape (inches)	Volume (ft^3/ft)	Min. Cover Height
17 x 13	1.1	12″	28 x 20	2.9	12″	49 x 33	8.9	12″	71 x 47	18.1	12″
21 x 15	1.6	12″	35 x 24	4.5	12″	57 x 38	11.6	12″	77 x 52	21.9	12″
24 x 18	2.2	12″	42 x 29	6.5	12″	64 x 43	14.7	12″	83 x 57	26.0	12″
1″ Deep Corrugations											
60 x 46	15.6	15″	81 x 59	27.4	18″	103 x 71	42.4	18″	128 x 83	60.5	24″
66 x 51	19.3	15″	87 x 63	32.1	18″	112 x 75	48.0	21″	137 x 87	67.4	24″
73 x 55	23.2	18″	95 x 67	37.0	18″	117 x 79	54.2	21″	142 x 91	74.5	24″

Pipe Arch - Multi Plate

2″ Deep Corrugations												
	Shape (Inches)	Volume (ft^3/ft)	Min. Cover Height	Shape (Inches)	Volume (ft^3/ft)	Min. Cover Height	Shape (Inches)	Volume (ft^3/ft)	Min. Cover Height	Shape (Inches)	Volume (ft^3/ft)	Min. Cover Height
18-in Corner Radius (Rc)	6-1 x 4-7	22	12″	8-7 x 5-11	41	18″	8-7 x 5-11	41	18″	14-1 x 8-9	97	24″
	6-4 x 4-9	24	12″	8-10 x 6-1	43	18″	8-10 x 6-1	43	18″	14-3 x 8-11	101	24″
	6-9 x 4-11	26	12″	9-4 x 6-3	46	18″	9-4 x 6-3	46	18″	14-10 x 9-1	105	24″
	7-0 x 5-1	29	12″	9-6 x 6-5	49	18″	9-6 x 6-5	49	18″	15-4 x 9-3	109	24″
	7-3 x 5-3	31	12″	9-9 x 6-7	52	18″	9-9 x 6-7	52	18″	15-6 x 9-5	114	24″
	7-8 x 5-5	33	12″	10-3 x 6-9	55	18″	10-3 x 6-9	55	18″	15-8 x 9-7	118	24″
	7-11 x 5-7	36	12″	10-8 x 6-11	58	18″	10-8 x 6-11	58	18″	15-10 x 9-10	122	24″
	8-2 x 5-9	38	18″	10-11 x 7-1	61	18″	10-11 x 7-1	61	18″	16-5 x 9-11	126	30″
							13-11 x 8-7	93	24″	16-7 x 10-1	131	30″
31-in Corner Radius (Rc)	13-3 x 9-4	98	24″	15-4 x 10-4	124	24″	17-2 x 11-4	153	30″	19-3 x 12-4	185	30″
	13-6 x 9-6	102	24″	15-7 x 10-6	129	24″	17-5 x 11-6	158	30″	19-6 x 12-6	191	30″
	14-0 x 9-8	106	24″	15-10 x 10-8	134	24″	17-11 x 11-8	163	30″	19-8 x 12-8	196	30″
	14-2 x 9-10	111	24″	16-3 x 10-10	138	30″	18-1 x 11-10	168	30″	19-11 x 12-10	202	30″
	14-5 x 10-0	115	24″	16-6 x 11-0	143	30″	18-7 x 12-0	174	30″	20-5 x 13-0	208	36″
	14-11 x 10-2	120	24″	17-0 x 11-2	148	30″	18-9 x 12-2	179	30″	20-7 x 13-2	214	36″

Typical Spacing for Multiple Barrels



Diameter	Spacing*	Pipe-Arch Span	Spacing*
Up to 24″	12″	Up to 36″	12″
24″ to 72″	1/2 Diameter of Pipe	36″ to 108″	1/3 Span of Pipe-Arch
72″ +	36″	108″ to 189″	36″

* Spacing shown provides room for proper backfill to enable the structure to develop adequate side support. Spacing with AASHTO M-145, A-1, A-2, A-3 granular fill. Closer spacing is possible depending on quality of backfill and placing and compaction methods.

Design

DYODS™
Design Your Own Detention System

Design Your Own Detention System

Our DYODS (Design Your Own Detention System) sizing calculators, makes it is easier than ever to design the best detention system for your site.

Features

- Sizes system and lays out footprint
- Quantifies construction materials
- Provides graphic plan view layout

Available for our corrugated metal pipe (CMP), concrete, and plastic detention systems.

Available at www.contechstormwater.com/dyods

Installation

Lightweight pipe sections assemble quickly to lower installation costs and shorten site development times.

CMP systems typically include pipe barrels, header pipes, elbows, tees, bulkheads and bands to join pipe segments. Elements are designed to resist a minimum of HS20-44 loading with as little as one foot of cover.

1. Fabrication of pipe materials
2. Excavate and prepare
3. Set, header pipe/manifold
4. Set piping runs
5. Apply bands and joints
6. Connect any piping
7. Backfill and complete








FSC

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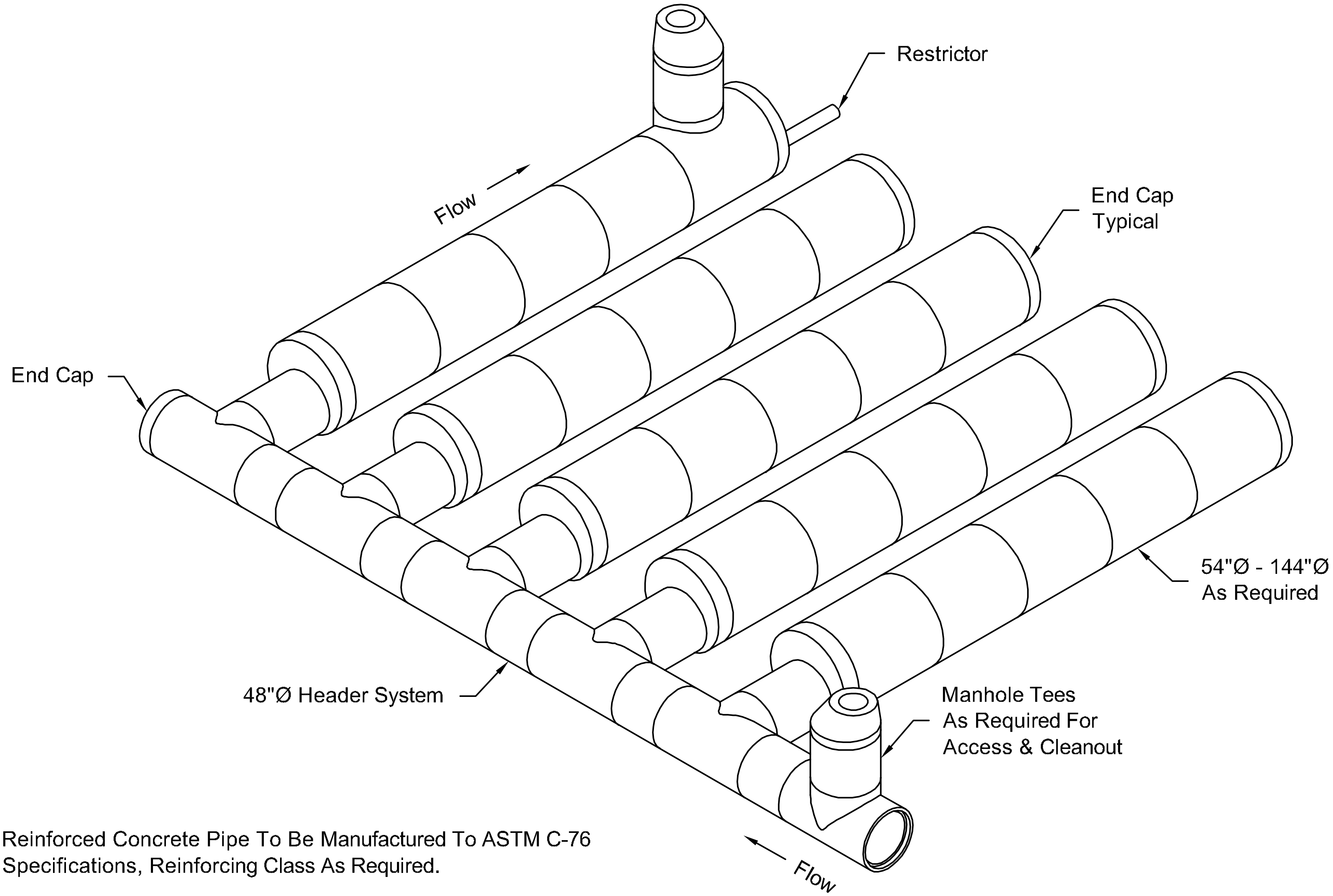
Support

- Drawings and specifications are available at contechstormwater.com.
- Site-specific design support is available from our engineers.

800.925.5240
contechstormwater.com

CONTECH Construction Products Inc. provides site solutions for the civil engineering industry. CONTECH's portfolio includes bridges, drainage, sanitary sewer, stormwater and earth stabilization products. For information on other CONTECH division offerings, visit contech-cpi.com or call 800.338.1122

The product(s) described may be protected by on
6,406,218; 6,641,720; 6,511,595; 6,649,048; 6,991,114; 6,998,038; 7,186,058; related foreign patents or other patents pending.

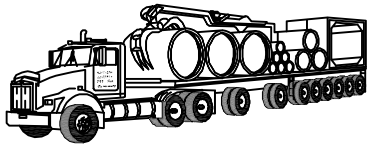


Reinforced Concrete Pipe To Be Manufactured To ASTM C-76 Specifications, Reinforcing Class As Required.

Manhole Tees To Be Manufactured To ASTM C-478 Specifications.

Diameter And Length Of Retention System To Be Determined By Required Capacity.

Restrictor Pipe Location And Size May Be Varied As Needed To Accomodate Specific Requirements.

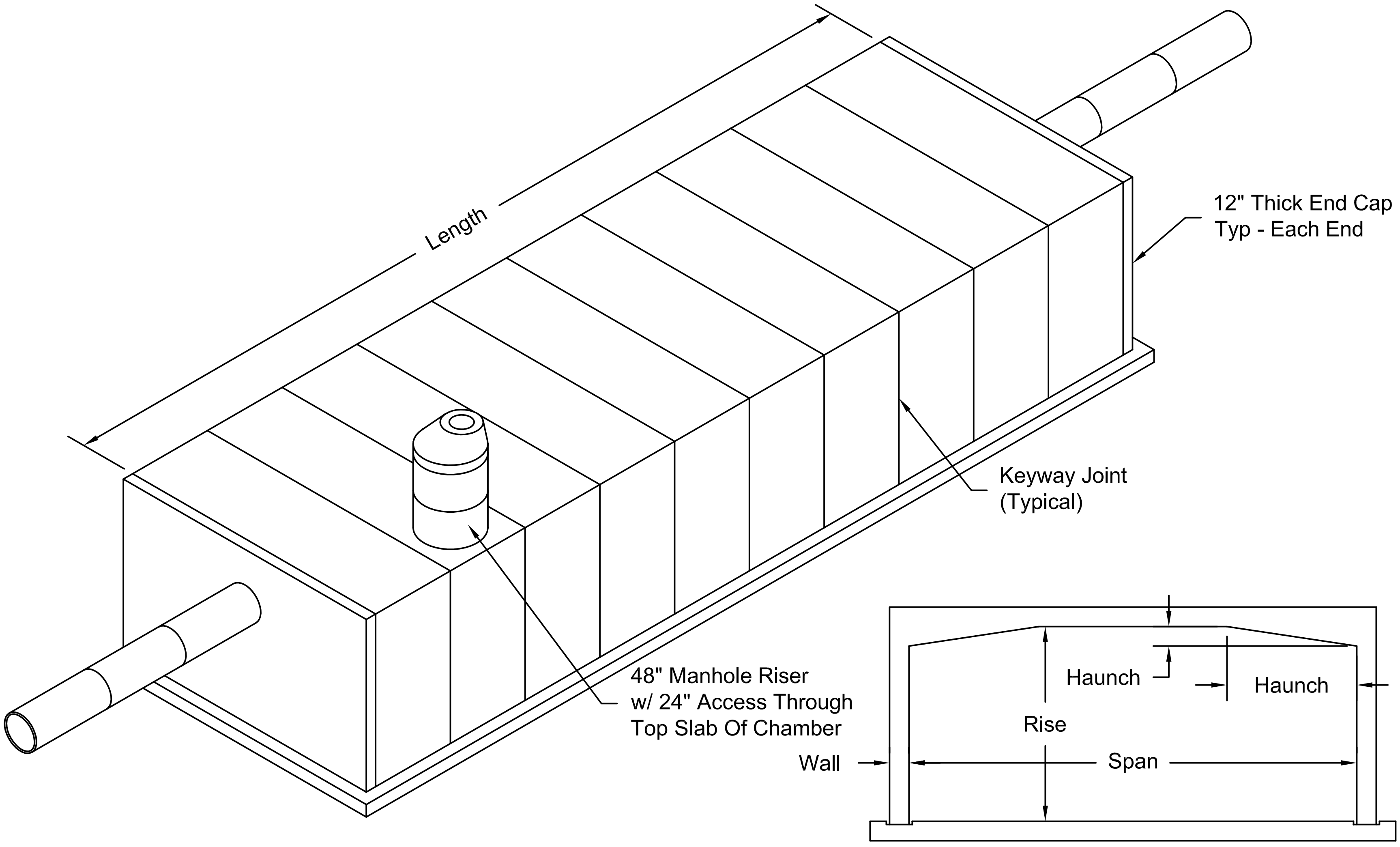


Northern Concrete Pipe, Inc.

401 Kelton Street	5281 Lansing Road
Bay City, MI 48706	Charlotte, MI 48813
1 800 222 9918	1 800 874 9701

High Capacity Precast Concrete Pipe Retention System

Date	Revised	Drawn By	Scale		
15 Aug 03		BmG	NTS		7.2



For Spans Greater Than 24'-0"

Box Culvert Sections Are To Be Manufactured To ASTM C-1433 Specifications As Required.

In Traffic Areas w/ Less Than 2' Of Cover, Non-Shrink Grout Must Be Placed In Top Deck Keyway Only. Joints To Be Sealed w/ Cadillac Wrap Or Equal And Wrapped w/ 22" Wide Filter Fabric.

Inlets And Outlets To Penetrate Through End Caps To Maintain Structural Integrity Of The Box Culvert.

Span, Rise And Length Of Retention Chamber To Be Determined By Required Capacity.

Northern Concrete Pipe, Inc.

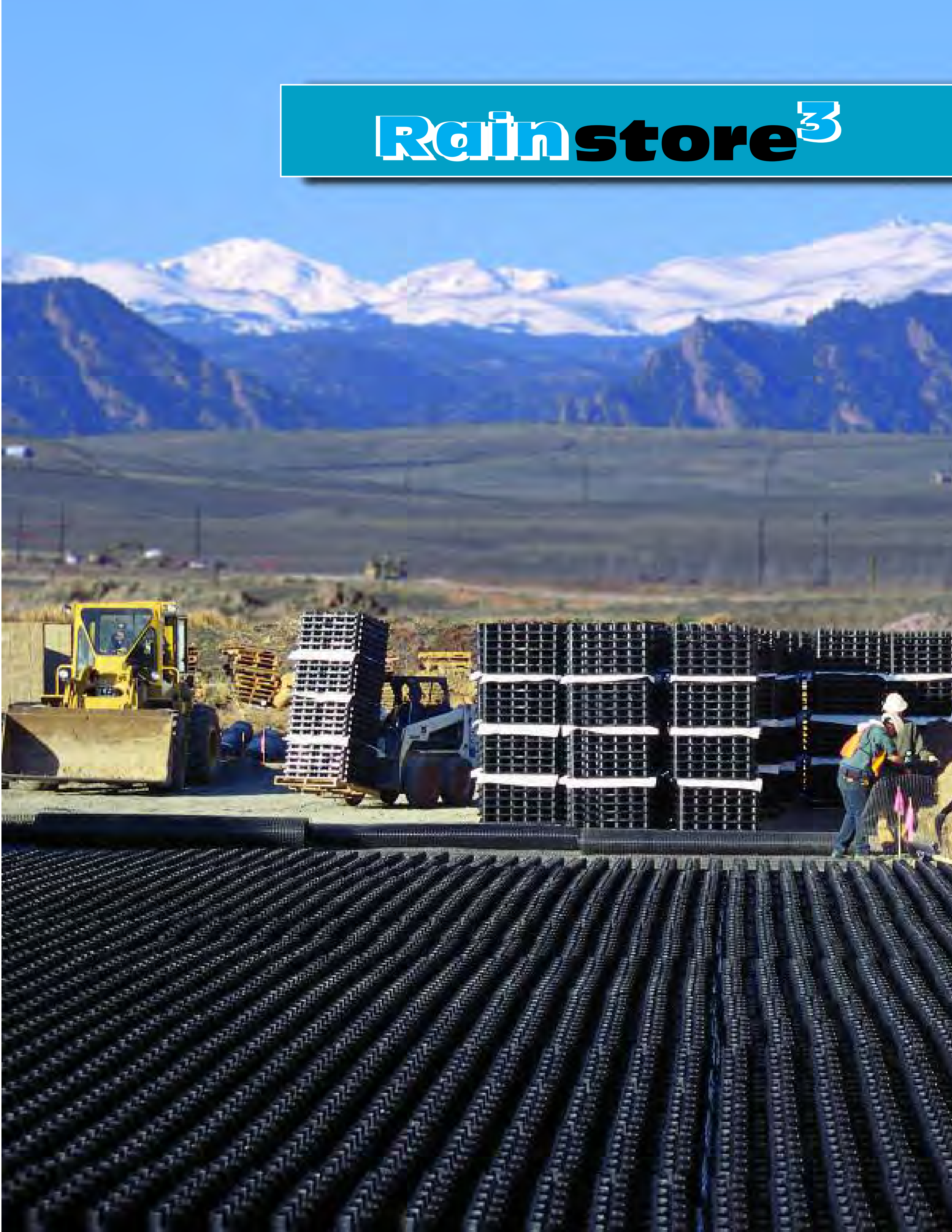
401 Kelton Street
Bay City, MI 48706
1 800 222 9918

5281 Lansing Road
Charlotte, MI 48813
1 800 874 9701

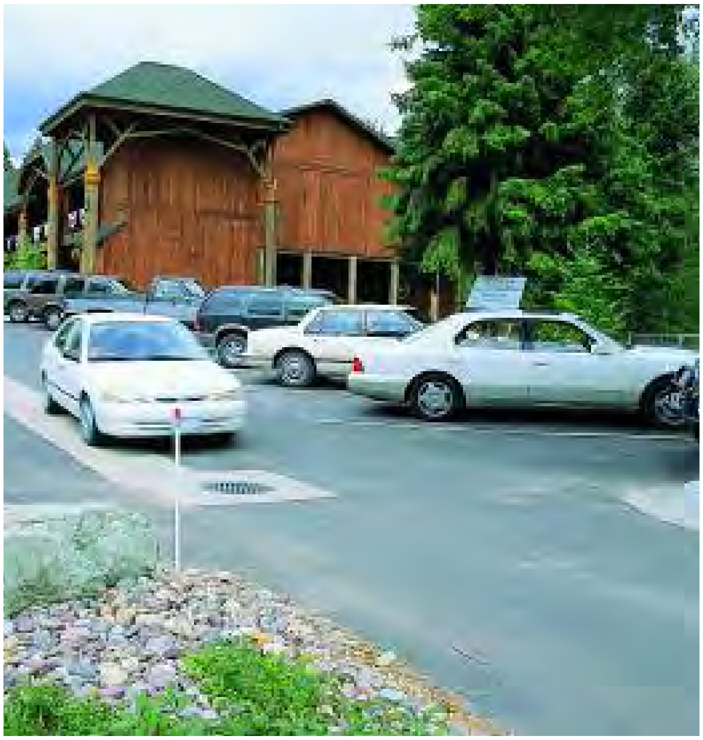
Typical Precast Concrete Hy-Span Retention System

Date	Revised	Drawn By	Scale		
20 Nov 00	12 May 05	BmG	NTS		7.4

Rainstore^3

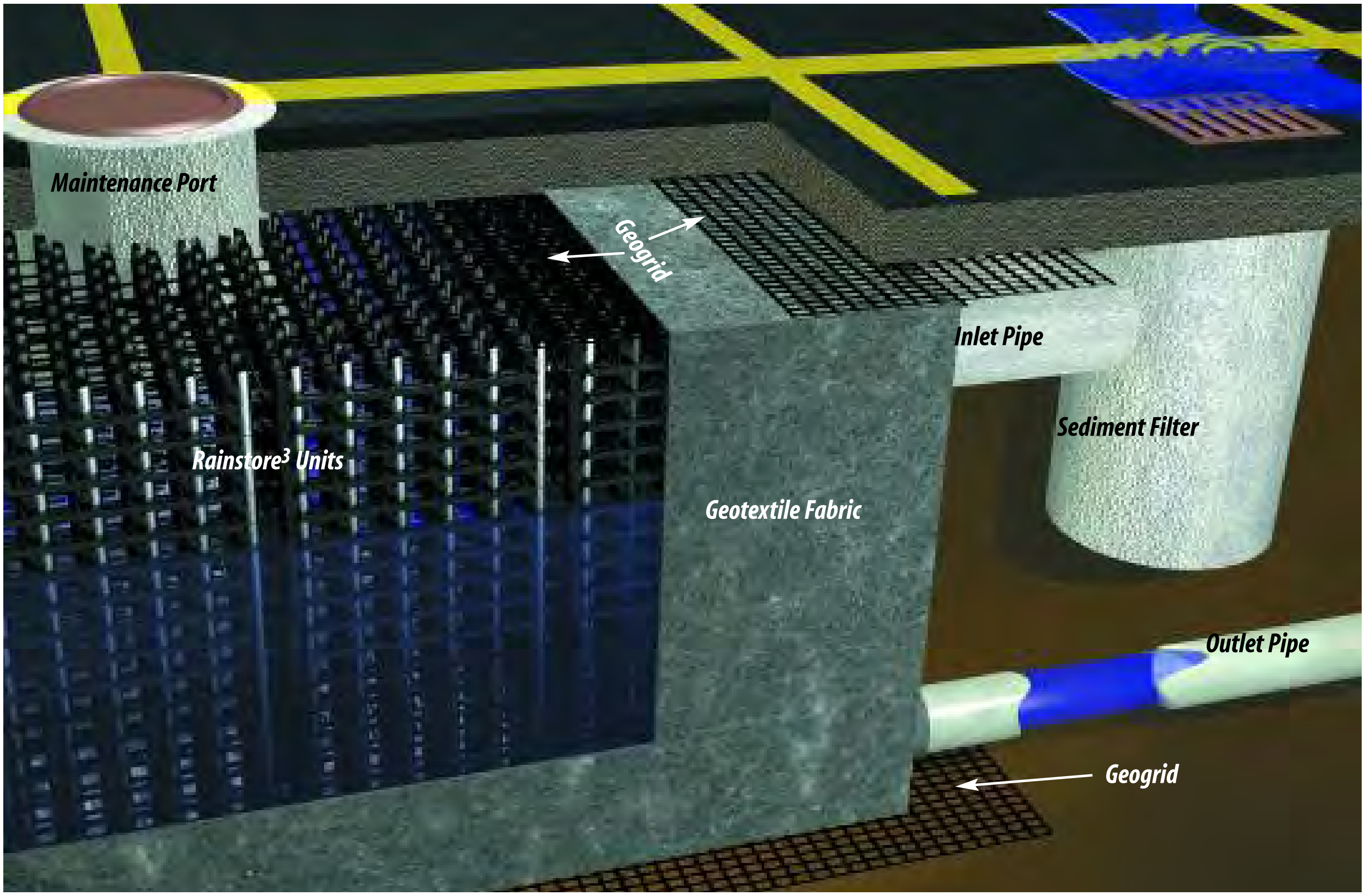


On the cover: Rainstore^3 chamber under parking lot, Broomfield, CO. Without Rainstore^3's high water storage capacity at shallow depths, the flexibility in design, and the convenience of exfiltration, the owners of this site would have been unable to develop this site and would have been forced to find a different location for their new construction.



Above: Two views of a completed RS^3 install under a parking lot in Big Fork, MT. Parking lot and off-street bays for approximately 48 cars, drains into a 26,250-gallon Rainstore^3 stormwater detention structure. Diagonal parking is graded toward the center concrete strip, which drains toward the catch basin.

Below: Graphic representation of asphalt parking lot with Rainstore^3 detention showing individual components. Drawing not to scale.



Version 01/03

NOW IT IS POSSIBLE!

Invisible Structures, Inc., (ISI) has created a new class of subsurface water storage system, Rainstore^3 (RS^3). It is not pipe or arched chamber, but a structure with strength throughout its shape. The unique design places the plastic entirely in compression rather than bending or tension, resulting in an excess of H-20 loading, and high void storage volume of 94%! Minimum cover is only 0.3 meter (12″).

The structure can be as shallow as 0.1 meter (4″) or as deep as 2.5 meters (94″), and with any length and width in 1 m (40″) increments. Rainstore^3 eliminates site restrictions by conforming to custom project requirements.

RS^3 does not require any stone backfill between structures. Calculating the void (storage) volume is as simple as dividing storage demand by 94%. This means significant savings in amount of excavation, soil transport, imported stone, installation time, and labor.

Rainstore^3 can be utilized for long-term water storage for irrigation, fire protection, and potable applications by encasing the structures in an impervious liner.

Porous lining materials around RS^3 offer 100% surface area coverage for water infiltration/exfiltration.

Above: Nearly completed installation of a stormwater detention system at a gas station in Nampa, ID. This site has three separate Rainstore^3 chambers to provide the necessary water storage. This photo shows the catch basin and curbing for one of the chambers. Asphalt will cover the visible gravel base.

Below: Installation of a water harvesting application in Santa Fe, NM at the Santa Fe Greenhouse. Rain water is captured and re-used for irrigating the greenhouse plants - saving on the cost of using city water.

STORMWATER QUALITY IS OLD BUSINESS

Company Background and Product Line

Invisible Structures, Inc., has been in the stormwater management business since 1982 with our porous paving systems Grasspave^2 and Gravelpave^2, ring and grid structures for grass and gravel drivable surfaces. Large rolls sizes cover areas quickly while either protecting grass roots from compaction or containing small gravel to eliminate gravel migration. These products have extensive design brochures that cover all aspects from project photographs to latest technology and specifications. Check our web site www.invisiblestructures.com for a full display of information and downloadable details.

Draincore^2 (DC^2) collects excess irrigation and rainfall from recreational grass surfaces such as lawns, sports fields, and bio-swales, and transports filtered water to RS^3. This water may be recycled for irrigation or other uses. Draincore^2 conveys water in a shallow horizontal plane, eliminating trenching and backfill requirements of pipe.

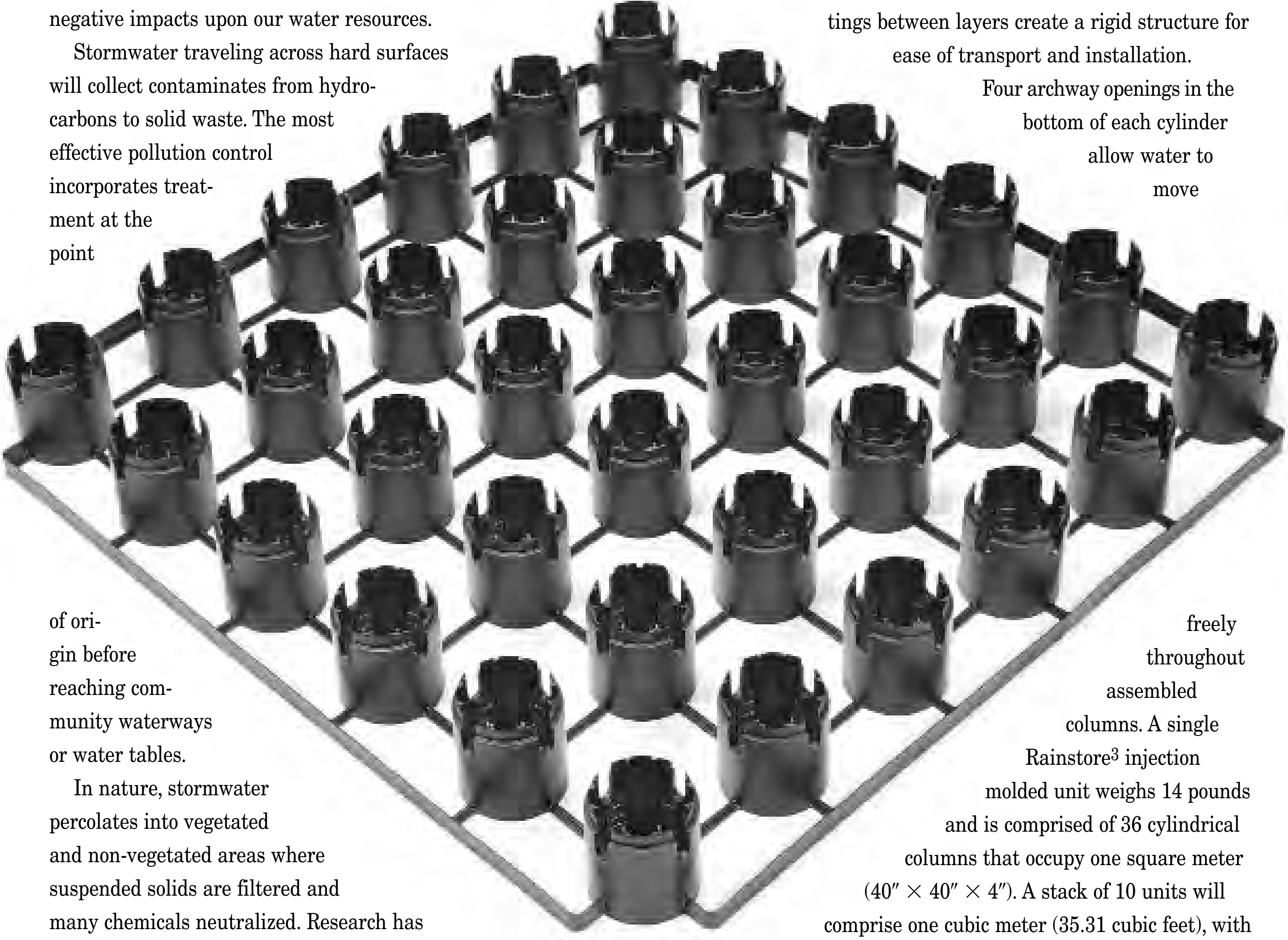
Slopetame^2 (ST^2) is a three dimensional soil, vegetation, pre-vegetation containment mat used to reduce soil loss due to water erosion on slopes, river banks, channels, and bio-swales. Crossbars between rings serve to prevent rill erosion. ST^2 provides support for grasses and a variety of plant material whose roots furnish natural fibrous anchorage. ST^2 bio-swales will help clean debris and pollutants from stormwater prior to entering Rainstore^3.

RS^3 evolved from the ring and grid concept by allowing stackability to greater depths, and increased lateral compressive strength to resist deep soil pressures. The 94% void capacity was attained for RS^3 while satisfying structural criteria.

Water Quality Background

Water quality is critical and must be considered when dealing with stormwater management. In the past, point-source pollution (contaminates from a concentrated source) was of primary concern. Today, non-point source pollution (contaminates from a large area such as a parking lot) is important due to its magnitude and frequency.

The EPA has regulated point source pollution for years and is now implementing strict regulations to control non-point source pollution, which is cumulative and presents long term negative impacts upon our water resources.



Stormwater traveling across hard surfaces will collect contaminates from hydrocarbons to solid waste. The most effective pollution control incorporates treatment at the point of origin before reaching community waterways or water tables.

In nature, stormwater percolates into vegetated and non-vegetated areas where suspended solids are filtered and many chemicals neutralized. Research has shown that hydrocarbons are consumed by bio-organisms found in the root zone without killing the vegetation.

Invisible Structures' porous pavement and bio-swale products provide one of the most effective means of removing pollutants at the source. Refer to Sand-Bio Filter Inlet Detail for ways to reduce or eliminate catch basins and elaborate cleaning systems. Rainstore^3 in combination with ISI's other outstanding products provide a complete stormwater management package.

PRODUCT DESCRIPTION

Basic Structure

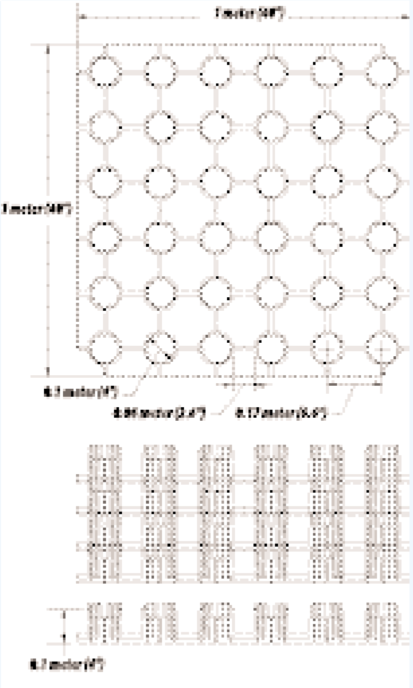
Rainstore^3 is a structure of thin-walled cylindrical columns injection molded of recycled resins of either high impact polypropylene (HIPP), or high density polyethylene (HDPE) plastic for strength, durability, and green industry benefit. For potable water storage, virgin plastic is used. Cylinders are 10 cm (4″) diameter, 5mm (0.2″) average wall thickness, 10 cm (4″) tall, and spaced 16.7 cm (4.6″) apart. T-shaped beams connect the cylinders and resist external lateral soil/water pressure. Compression fittings between layers create a rigid structure for ease of transport and installation.

Four archway openings in the bottom of each cylinder allow water to move freely throughout assembled columns. A single Rainstore^3 injection molded unit weighs 14 pounds and is comprised of 36 cylindrical columns that occupy one square meter (40″ × 40″ × 4″). A stack of 10 units will comprise one cubic meter (35.31 cubic feet), with approximately 250 gallons of net water storage.

RS^3 allows for water containment depths from 10 cm to 2.5 meters (4″ to 94″ or 8.2′). The following standard depths are stocked: *in meters* (0.2, 0.3, 0.4, 0.6, 0.8, 1.2, and 2.4) *in feet* (0.7, 1.0, 1.3, 2.0, 2.6, 4.0, and 7.9). Custom depths are also available.

Side bumpers provide foolproof, accurate spacing. Structures may be moved by hand. A layer of geogrid, below the cells and above the existing subsoil, provides a stable surface and will insure proper alignment.

RS3 withstands repeated freeze-thaw cycles, will not rust, break down, crack, is not affected by chemicals, extremes of pH, oils, salts, or fertilizers. Ethylene plastics have a projected service life in excess of 100 years provided they are not exposed to UV light.



Rainstore³ Unit Detail
Single Rainstore³ injection molded unit geometry and dimensions

Overall System

RS3, wrapped with a geotextile filter fabric or geomembrane, and placed side by side in an excavated void create a variety of water storage structures. Inflow, outflow, visual inspection pipes, catch basins, pumps and water filters are installed as needed. Backfilling and compacting the sides, geogrid, base course, and surfacing complete the system.

STORMWATER MANAGEMENT APPLICATIONS

Land development significantly affects the natural course of stormwater. Prior to development, land is semi-porous enabling rainfall to directly infiltrate, which filters pollutants, recharges subsurface water tables, and reduces flooding. Sealing the earth's surface with parking lots, roads, walks, and roofs, results in rapid runoff to storm sewers and rivers, causing flooding and unacceptable pollution of valuable water resources.

To combat these serious problems, national (EPA) and regional regulatory agencies require all or a portion of stormwater to be managed on site.

Surface detention basins and ponds are common, but often occupy valuable real estate and create safety hazards, insects, weeds, and odor problems. Increasingly, the most economical and convenient solution is an "underground pond," where the water may be stored temporarily before it is released to a storm sewer (detention), stored until it exfiltrates (retention), or stored for reuse (harvesting).

Porous Paving

The most direct stormwater management technique is to allow the rain to penetrate the surface where it falls. This can be done with Grasspave2 or Gravelpave2 porous paving. The base course below these plastic reinforcement structures will typically store at least 2.5″ of rain, or more, if subsoils are porous. Firelanes and overflow parking areas are frequently used as infiltration basins.

Rainstore3 Detention

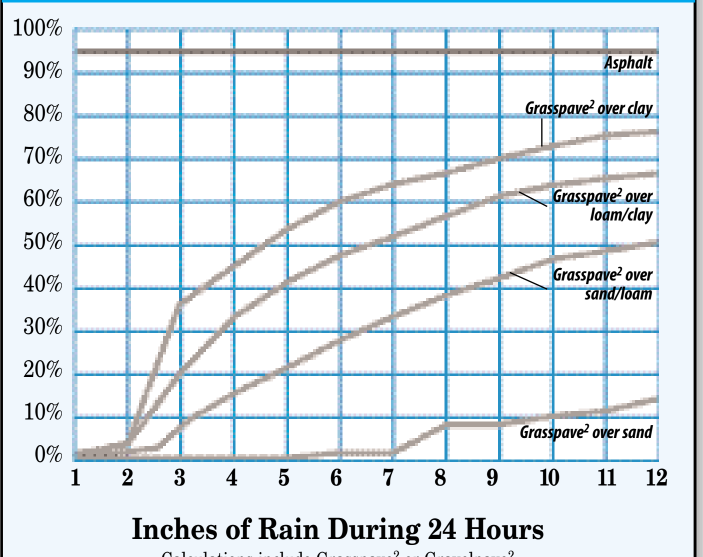
Short term storage and releasing stormwater at a predetermined rate through the use of small outlet pipes or pumps is detention. Downstream stormwater facilities may exist but have a limited flow rate capacity. While the water is held awaiting gradual release, it may or may not be allowed to exfiltrate into the site soils. A porous non-woven geotextile is used to encase RS3. Geomembranes are used when exfiltration must be avoided.

Rainstore3 Retention

When downstream stormwater facilities do not exist or the amount of water released from a site is limited for some other reason, stormwater retention is utilized. Typically, there are no outflow pipes. RS3 is encased in non-woven geotextile and placed above porous soil. Replenishing existing aquifers is a benefit.

Runoff Comparison Chart

Runoff coefficients, Grasspave² or Gravelpave² and sandy gravel base over various soil types.



Calculations include Grasspave² or Gravelpave²
placed over 6″ of sandy gravel base course, laid over native soils indicated.

Corporate Parking Lot, Southborough, MA — Rainstore^3, 1 meter high, 667 m^3, were used as a detention basin underneath asphalt parking. Product was easy to lift with two men. Stacks were placed and adjusted by hand for a close fit with no fasteners required.

Water Harvesting

As population centers expand in arid climates, traditional water sources such as rivers and aquifers have been significantly depleted. With increased water prices, it becomes more economical to harvest rainfall with Rainstore^3. Also, demands upon ground resources are reduced, making some water critical projects possible. The choice for long term storage with Rainstore^3 is influenced by site opportunities and constraints, access to community infrastructure (water, sewer, fire protection), government regulations, and owner principles and guidelines.

Stormwater falling on a site is collected from roofs, bio-swales, and parking areas. A strong impermeable liner surrounding the

Product Performance Analysis

Performance Criteria	Rainstore^3 2.5 meter (8.2′) height	Arched Chambers (34″ × 75″ × 16″)	Corrugated Plastic Pipe (60″ dia.)	Corrugated Metal Pipe (72″ dia.)	Concrete Pipe (72″ dia.) Non-perforated
% of excavated volume available for water storage	~75%*	~40%*	~60%*	~53%*	~38%*
% of storage volume occupied by stone	0%	~59%	~60%	~70%	0%
Maximum water storage volume/ surface area	8.2 ft^3 water storage/ft^2 surface area	~1.4 ft^3 water storage/ft^2 surface area	3.8 ft^3 water storage/ft^2 surface area	4.7 ft^3 water storage/ft^2 surface area	3.2 ft^3 water storage/ft^2 surface area
Chamber depth design flexibility	4″ min., 98″ max., in 4″ increments	12″ min., 30.5″ max.	12″ dia. min., 60″ dia. max., 6″ increments	12″ dia. min., 240″ dia. max., 6″ increments	12″ dia. min., 240″ dia. max., 6″ increments
Cover depth required	12″	18″	12″ – 30″ based on diameter	12″ – 24″ based on diameter	6″
On-site handling and manual installation	Easy	Easy	Difficult	Difficult	Difficult
Maintenance, inspection, clean-out	Moderate	Moderate	Easy	Easy	Easy
% of chamber surface area available for infiltration	100%	~75%, including side cuts	~15%, based on perforation area to pipe surface area	~15%, based on perforation area to pipe surface area	0%

*Calculations based on an average sized (10 meter × 10 meter) footprint installed per manufacturer's specifications.

chamber prevents evaporation and contamination. The water may be used for landscape irrigation, fire protection, potable applications, and industrial processes, such as water for heating and cooling with geothermal energy transfer. For long term storage, water may require chemical treatment or oxygenation to preserve water quality.

PRODUCT PERFORMANCE COMPARISON

Crushed rock wrapped in geotextile, concrete, corrugated metal or plastic pipe, and plastic arch chambers have been historical subsurface water storage options available to designers. Invisible Structures closely studied the performance of these systems and obtained feedback from engineers and contractors as to what they liked and disliked about available solutions.

With this information, ISI designers developed Rainstore3 which boasts a highly efficient excavated volume, economical installation, reduced stone requirements, improved design flexibility, safety, strength, and exceptional longevity.

DESIGNING WITH RAINSTORE3

Design Steps

1. *Choose system application:* Determine whether porous paving, detention, retention, and/or water harvesting methods will be used. Function will determine whether outflow pipes will be needed, and choice of liner to encase the structures.

2. *Determine the location and quantity of storage systems:* Pick the most appropriate site location to minimize excavation, grading, and piping — usually downhill from runoff sources. Use soil boring information to determine subsoil conditions and water table depth. Exfiltration requires porosity. Rainstore3 can be located below most landscaped or paved surfaces. It may be desirable to use more than one location for storage.

3. *Choose surfacing to be placed above storage structure:* RS3 allows for many different surfacing options — parking, green space, recreation, landscaping, and light weight buildings. Landscaping directly above a storage structure should be restricted to shallow rooted materials such as grasses, groundcovers, and low growing shrubs. Long term chemical root barrier materials are available if RS3 must be kept root free.

If parking is the surface use, then choose between porous paving and hard surface options. Grasspave2 and Gravelpave2 filter stormwater directly by allowing percolation through the parking surface and base course into RS3 without the use of pipe.

Typical Soil Permeabilities

Soil Group	Typical Coefficient	Inches /Day	Description	Suitable for Exfiltration
GW	2.5 EE-2	850.4	well graded, clean gravels, gravel-sand mixtures	Yes
GP	5 EE-2	170.1	poorly graded clean gravels, gravel-sand mixtures	Yes
SW	>5 EE-4	17.0	well-graded clean sands, gravelly sands	Yes
SP	>5 EE-4	17.0	poorly graded clean sands, sand-gravel mix	Yes

Note: The following soil groups are not suitable for exfiltration (silty, clayey soils): GM, GC, SM, SM-SC, SC, ML, ML-CL, CL, OL, MH, CH, OH.

4. *Determine required capacity:* Local regulating agencies establish rainfall storage requirements. Calculate by multiplying the hard surface area (roads, parking lots, walks, roofs, etc.) by the "design rainfall" required, then by the runoff coefficient (refer to Runoff Comparison Chart on page 3). Determine supplemental storage requirements for irrigation, process, fire safety, or potable uses, and add to regulated storage demand.

5. *Determine quantity of Rainstore3:* Convert the storage requirement to cubic meters, divide by 0.94 to determine volume of Rainstore3 in cubic meters. Gallon storage reference is 1 m^3 of water = 264 gallons × .94 = 250 gallons/m^3 RS3.

6. *Depth of Rainstore3:* Factors such as depth of water table, bedrock and available excavation area affect the optimal depth of retention/ detention capability. Choose a RS3 bottom elevation that is higher than the water table maximum level. In cases where surface area is very limited and storage volume is great, deeper structures are usually more cost effective. Include 12″ of gravel fill and surfacing cover in the decision. The Rainstore3 cells are assembled to the desired depth prior to shipment. The following depths are available to avoid additional shipping costs: *in meters* (0.2, 0.3, 0.4, 0.6, 0.8, 1.2, and 2.4), *in feet* (0.7, 1.0, 1.3, 2.0, 2.6, 4.0, and 7.9).

Provide an appropriate safety factor when depth of structure is near the maximum water table level because water rising into RS3 reduces storage volume. Please refer to the Product Description section for standard and custom depths.

7. *Choose the length and width of Rainstore3:* Having already chosen RS3 depth, pick the length and width that occupies the required volume of RS3 (L × W = V/height). Adjust length or width as necessary to meet site criteria. The length and width must be in full meter increments.

8. *Determine catch basin and inflow locations:* **All water entering the Rainstore3 structure must be reasonably silt and debris free to minimize maintenance and extend the system's useful life.**

The preferred filtration method is a sand or bio-filter constructed with Gravelpave² or Grasspave² (refer to Sand/Bio-Filter Inflow Detail). A catch basin or other structural means may also be used. Choose an inflow location that best suits site conditions and minimizes waterborne debris. Standard pipe made of PVC, HDPE, steel, concrete, tile, copper, or any other material may be used to convey water to or away from Rainstore³.

9. *Determine outflow locations (if necessary):* For gravity fed outflow, ensure that site topography allows the outflow pipe to travel to a lower elevation stormwater facility. Size the pipe to limit outflow to the desired rate. If gravity outflow is not possible, pumps may be used (refer to Water Harvest or Maintenance Port Details). **A fail safe power supply is essential if outflow pumps are used.**

10. *Select Rainstore³ liner:* First, choose between permeable and impermeable. Non-woven filter fabrics are typically used except when water harvesting or stormwater exfiltration is prohibited by regulation.

Acceptable impermeable liners are at least 40 mil PVC or equal. Permeable liners must be at least 8 ounce non-woven. Properly match fabric pore sizes to surrounding soils to prevent clogging and blinding. **Fabric seams must have a 24″ minimum overlap unless sewn.**

To make pipe connections to geotextile fabric, cut an “X” in the fabric, insert the pipe, gather fabric, and fasten tightly with a pipe clamp. If using a geomembrane, construct a ”boot” of material and bond it to the circular opening. Insert the pipe through the boot and fasten with two pipe clamps (refer to the Water Harvest Detail).

11. *Determine quantity of geogrid:* **Three layers of geogrid (Tensar BX1200, Tenax MS330, Huesker Fornit 30 or equivalent) must be placed. One layer on the soil below the RS³ (see step 12), one layer directly on top of the RS³ cells — to stabilize with adjacent cells and to provide a walking surface — and the final layer placed on fabric-encased chamber and extended 0.5 meter (20″) beyond the sides of the structure.**

12. *Compute length, width, and depth of excavation:* **Excavation must extend at least 0.5 meter (20″) beyond all sides of RS³ structures to allow for ease of product installation and backfill compaction with powered compactor. Soil below RS³ must be leveled with minimal compaction. A layer of geogrid (Tensar BX1200, Tenax MS330, Huesker Fornit 30 or equivalent) must be placed on the subsoil and extended 0.5 meter (20″) beyond the sides of the structure.** Large and deep storage volumes may demand a drivable access route for excavation, leveling, compaction and placing Rainstore³ structures.

0.3 meters (12″) minimum, 0.9 meters (36″) maximum, structural base course (no greater than 1″ particle size) must cover the geogrid and extend past all RS³ sides by 0.5 meter (20″). Compact this layer to a minimum of 95% modified Proctor density.

Native excavated soil or imported structural backfill may be used along the sides of the structure as long as a 95% modified Proctor density is achieved. Compact in lifts as needed to attain proper compaction. Water saturated backfill should not be used as it is difficult to compact and creates excessive hydrostatic pressure on bottom sides of RS³.

Warning: Take extreme care when driving and/or compacting over the chamber and do not drive over exposed Rainstore³ units — wait until ALL the units are installed, the side backfill is complete, fabric and geogrid layers are completed, and an adequate amount of cover material is placed. Mark area to identify chamber location.

13. *Choose maintenance port locations:* Check local regulations proper size and placement of maintenance ports. An inside corner section of Rainstore³ may be removed to create a suitable opening for inspection and inserting cleanout pumps. (Refer to the Maintenance Port Detail.)

MAINTENANCE OF A RAINSTORE³ STORMWATER STORAGE CHAMBER

Invisible Structures, Inc. recommends that stormwater be pretreated prior to discharging into the chambers to avoid foreign matter accumulation inside the chamber. This can be accomplished by a variety of techniques or products. Some examples are:

Short Term Storage (Detention Basin)

“Zero” Maintenance — the Preferred Method

Use a natural, or “Bio-Filter,” inlet device — essentially a porous pavement or swale, to pre-filter trash and sediment laden runoff before capture and conveyance into a Rainstore³ chamber. Use of a simple 10-12″ deep sand, or sand/gravel, filter pavement or swale will provide adequate vertical flow capacity (20 to 35+ inches per hour) and residence time to capture coarse debris and trash at the surface, with sediment and hydrocarbons (and even most traffic generated metals) kept in voids of the section for treatment action by bacteria and oxidation.

Water passing through the filter section can pass directly into the top of a Rainstore³ chamber, or be collected and transported over larger distances via Draincore².

Only super fine sediments will pass through this section and be conveyed into the chamber. With relatively short storage times (24 to 48 hours) most of these sediments shall remain suspended, or be easily re-suspended by the next rain event for removal. Long-term accumulations to a depth affecting exfiltration rates can be measured in decades, not years.

Trash pickup from the surface requires that Zero be in quotes. Also be aware that grass surface porous pavements (Grasspave2) offer greater biological activity, but at a higher surface maintenance cost — mowing, fertilization and irrigation. Gravel surface porous pavements (Gravelpave2) still provide biological activity at a level lower than with grass, but with lower maintenance required.

Short Term Storage (Detention Basin)

Low, but Periodic, Maintenance

Use a structural form of catch basin with a deep sump prior to use of a hooded elbow inlet into the chamber. Whether standard catch basins or sophisticated cyclonic flow devices are used, the objective is to remove any coarse debris and sediment (sand and larger) from entering the Rainstore3 chamber. Periodic maintenance will be required to remove trash and sediment that accumulates in the device. Frequency shall depend upon the physical nature of sediments carried and allowed into the "screening" device.

Fine sediments may still be transported into the chamber via the inlet pipe and will likely be dispersed rather evenly over the entire chamber bottom surface area, where they will then settle to the bottom — depending upon the duration of time water is left in the chamber and the size of the particle. Particles smaller than the AOS of the porous fabric liner will pass through the liner and continue migration until stopped by underlying soils. Particles larger than the AOS shall remain inside the chamber, and can be periodically re-suspended by injecting high-pressure water into a Maintenance Port, with removal of the sediment laden water via sump pump from the same, or other, port.

Below: Taller can be better for your design with 8.2 feet or 2.5 meters high versatility. H-20 loading capability allows use underneath all parking lots and a variety of structures.

Eventually, especially if maintenance is too infrequent, the bottom of the chamber may develop a thick sediment layer sufficient to obstruct exfiltration through the bottom of the chamber. The sides of the chamber shall continue to function, but time for total water evacuation will increase.

This approach is most closely related to more traditional design responses, but is not the best solution long term for the client. Standard catch basins are lowest initial cost, but much higher in maintenance cost. Commercial cyclonic devices may have lower maintenance cost, but offer higher levels of cleaning efficiency at much higher initial investment cost.

Long Term Storage (Water Harvest Basin)

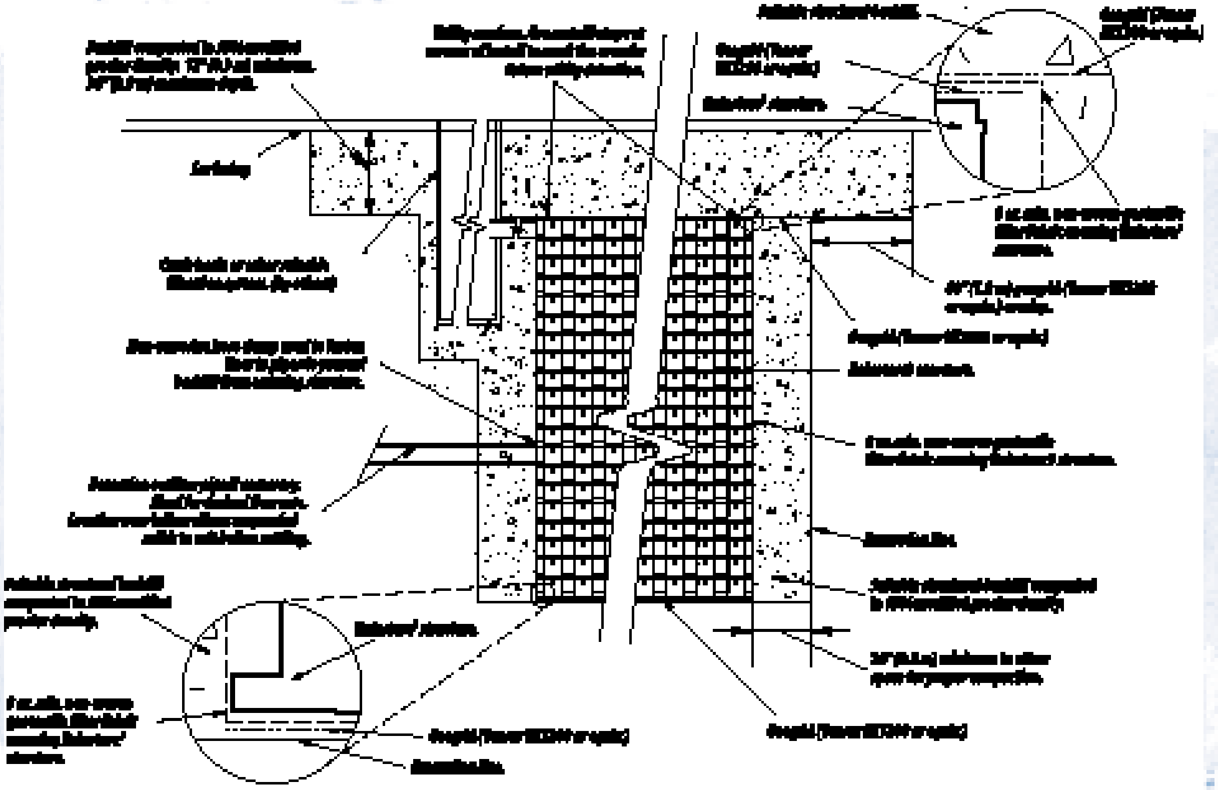
"Zero" Maintenance — the Preferred Method

Again, use a natural, or "Bio-Filter", inlet device – essentially a porous pavement or swale, to pre-filter trash and sediment laden runoff before capture and conveyance into a Rainstore3 chamber. Use of a simple 10-12″ deep sand, or sand/gravel, filter pavement or swale will provide adequate vertical flow capacity (20 to 35+ inches per hour) and residence time to capture coarse debris and trash at the surface, with sediment and hydrocarbons (and even most traffic generated metals) kept in voids of the section for treatment action by bacteria and oxidation.

Water passing through the filter section can pass directly into the top of a Rainstore3 chamber, or be collected and transported over larger distances via Draincore2.

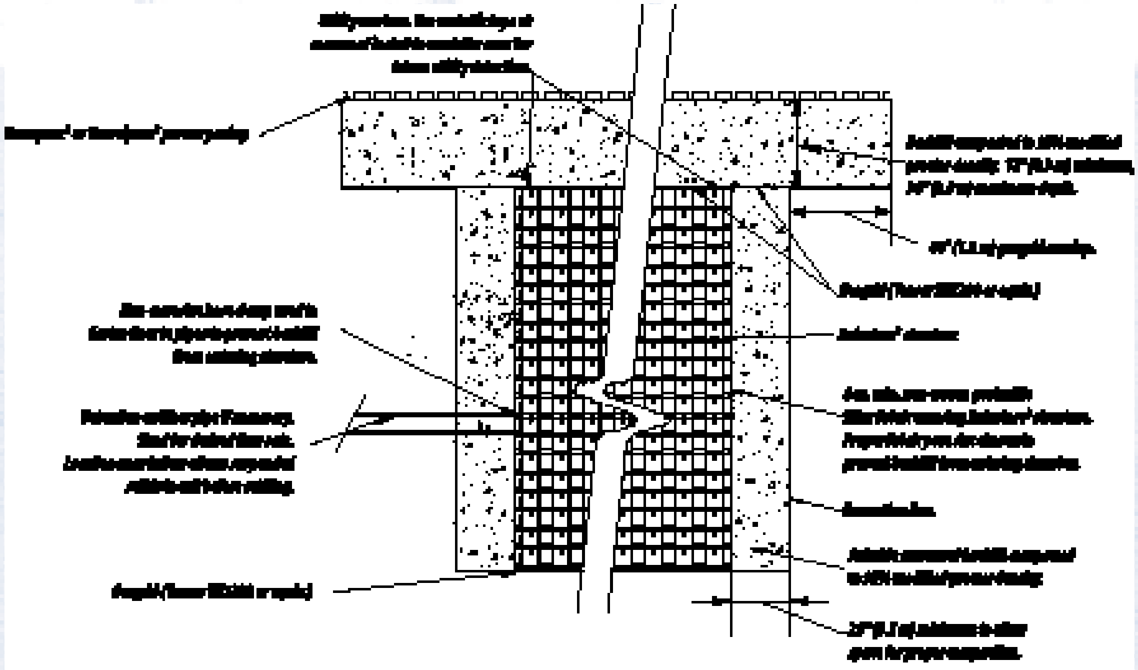
Only super fine sediments will pass through this section and be conveyed into the chamber. With relatively short storage times (24 to 48 hours) most of these sediments shall be easily re-suspended by the next rain event for removal. This level of sediment can be safely captured and transported via pumps for water reuse in irrigation or gray water applications, or further filtered by an automatic sand filter device with "back-flush" capabilities.

DESIGN DETAILS



Rainstore³ System

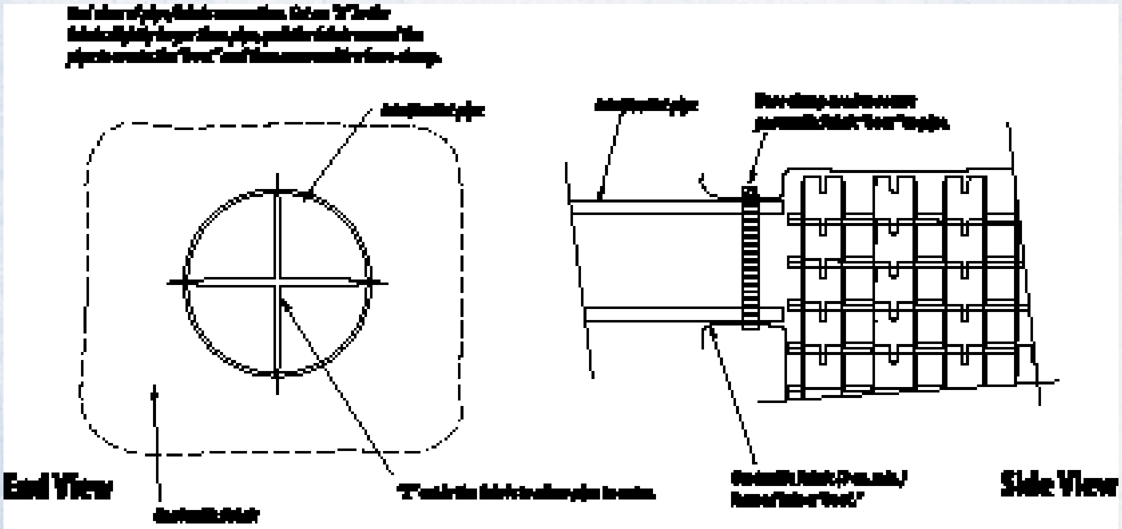
Typical Rainstore³ installation below paving



Porous Paving Inflow Method

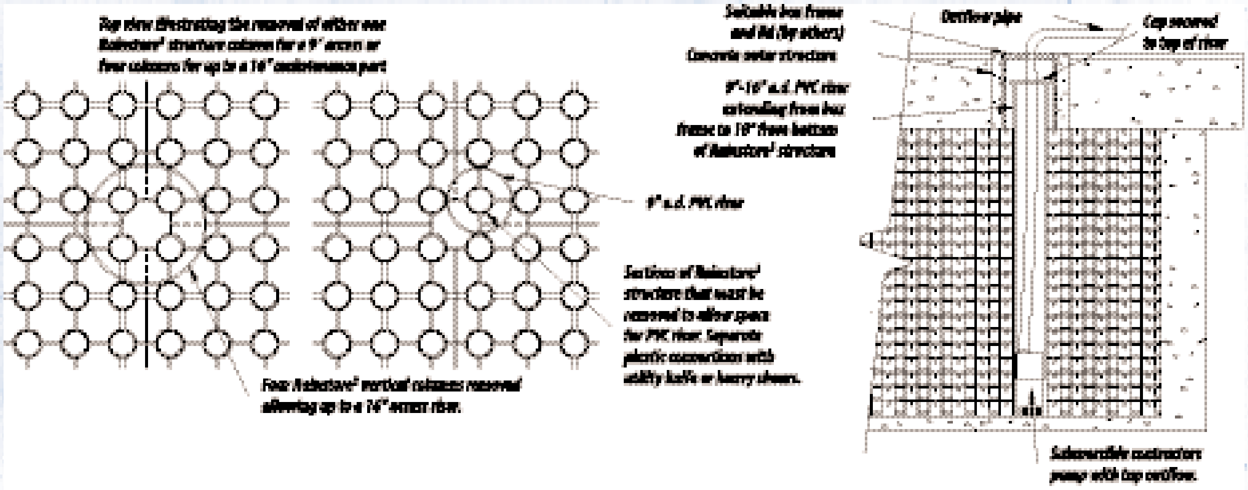
Eliminates structural inlets and provides thorough filtration

DESIGN DETAILS



Rainstore^3 Inlets/Outlets With Fabric

Connecting pipe to the Rainstore^3 structure

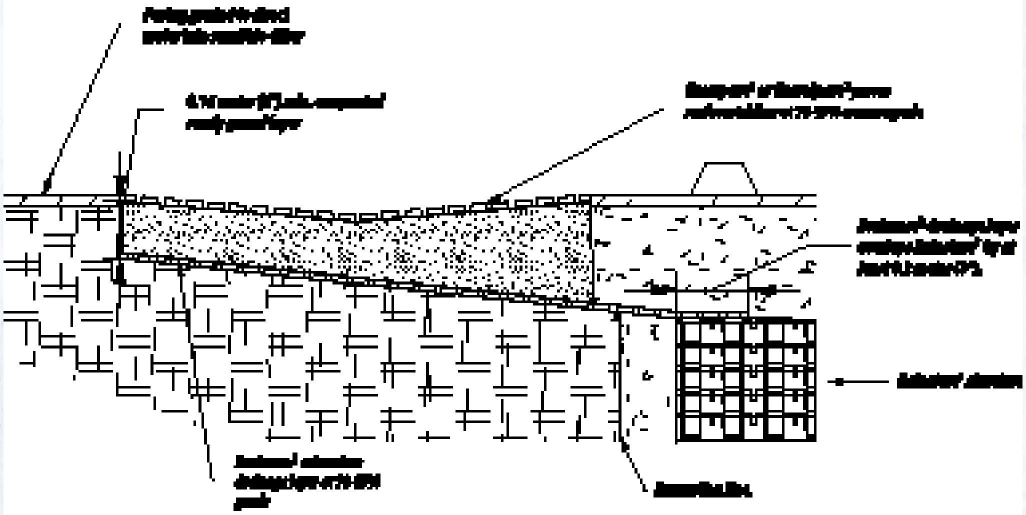


Rainstore^3 Maintenance Port

Method for providing inspection and cleanout access

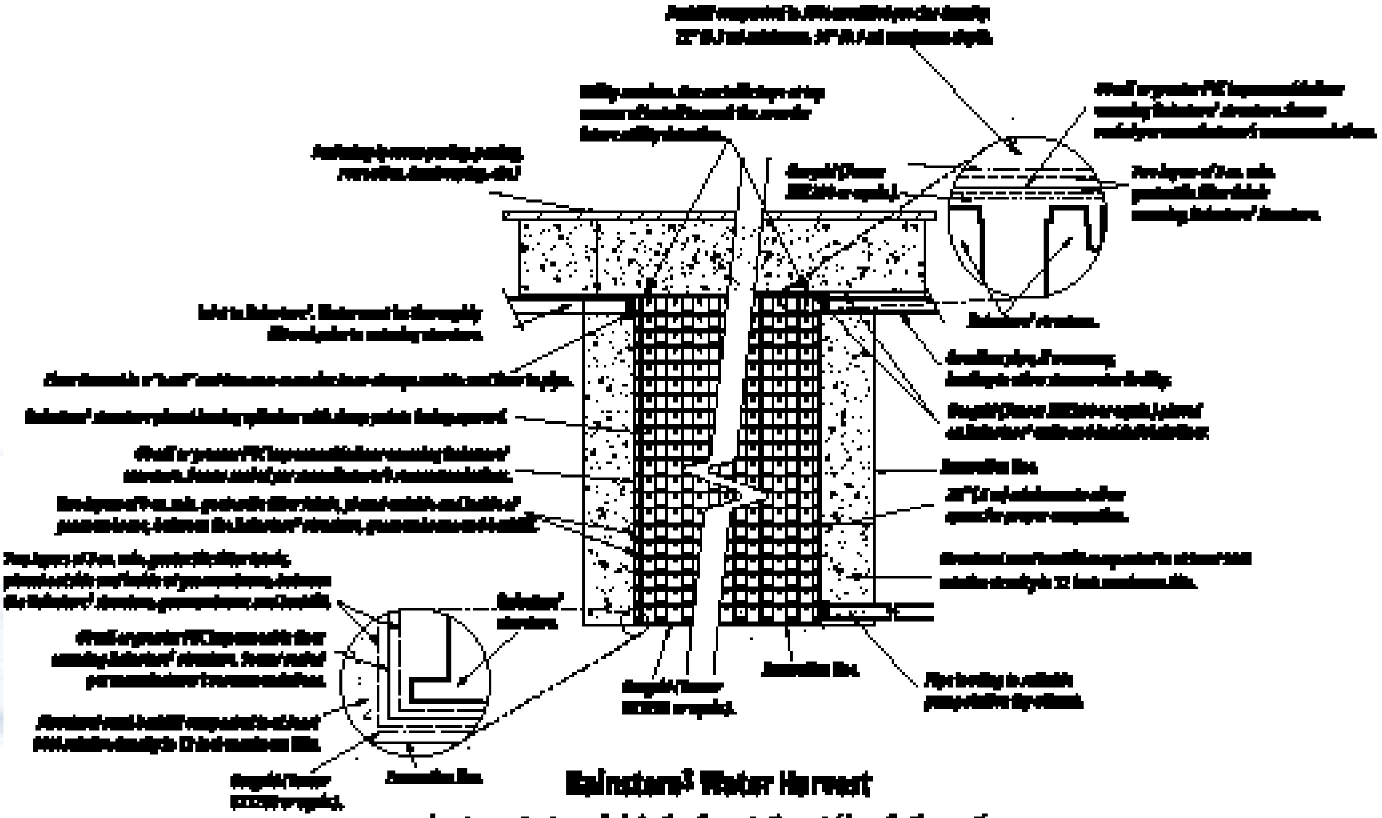
DESIGN DETAILS

[illegible]	[illegible]
8	[illegible]
7	[illegible]
6	[illegible]
5	[illegible]
4	[illegible]
3	[illegible]
2	[illegible]



Rainstore³ Sand-Silo Filter Inlet

[illegible]



Rainstore³ Water Harvest

Long term water storage for irrigation, fire protection, potable applications or other

Rainstore^3 Materials and Budgeting Worksheet

Online version of the materials estimator available at: http://www.invisiblestructures.com/RS3/estimator.htm

Item	Description	Formula	Quantity	Unit	$/Unit	Budget Total $	Notes
1	Required Water Volume (V_w)	–		m^3	N/A	N/A	Minimum agency requirements+client/site requirements
2	RS^3 Storage Volume (V_r)	$V_r = V_w / .94$		m^3			RS^3 is 94% void
3	Depth RS^3 (D)	see note		m	N/A	N/A	in meters (0.2, 0.3, 0.4, 0.6, 0.8, 1.2, and 2.4) in feet (0.7, 1.0, 1.3, 2.0, 2.6, 4.0, and 7.9)
4	Length RS^3 (L)	$L=V_r/H \times W$		m	N/A	N/A	Site dimensions, round up to nearest meter
5	Width RS^3 (W)	$W=V_r/H \times L$		m	N/A	N/A	Site dimensions, round up to nearest meter
6	Geotextile Fabric Area (A_f) for detention†	$A_f=2.1 \times ((L \times W)+(L \times D+W \times D))$		m^2			Top+bottom+sides+5%, 8 oz. min., includes labor
7	Geogrid Area (A_g)	$A_g=((L+1\ m) \times (W+1\ m)/0.95) \times 3)$		m^2			RS^3 area+1 meter on each side+5%, includes labor
8	**Total Materials**	Add items 1-8	N/A	$	N/A		
9	Excavation Volume (V_e)	$V_e=(D+0.4\ m) \times (L+1\ m) \times (W+1\ m)$		m^3			Equipment, labor and hauling included
10	RS^3 installation labor (L_r)	$L_r=V_r/15$		man-hours			Estimation assuming installation of 15m^3/man-hour
11	**Total***	Add items 9-11	N/A	$	N/A		

† For harvesting applications, budget for twice the fabric area (A_f) and include cost for 40 mil PVC liner = A_f

*Overhead and contingency expenses not included

USEFUL CONVERSIONS

1 gallon = .1337 ft^3
1 gallon = .003785 m^3
1 gallon = 3.7854 liters
1 inch = 2.54 cm
1 cm = .3937 inches
1 foot = .3048 m
1 meter = 3.28 ft

1 ft^2 = .0929 m^2
1 m^2 = 10.76 ft^2
1 m^2 = 1.196 yd^2
1 acre = 43,560 ft^2
1 acre = 4,047 m^2
1 acre foot = 1,233.5 m^3
1 ft^3 = .0283 m^3
1 ft^3 = 7.48 gallons

1 m^3 = 264.15 gallons
1 m^3 = 35.314 ft^3
1 m^3 = 1.308 yd^3
1 yd^3 = .8361 m^3
1 ton @ 125/ft^3 = 16 ft^3
1 ton @ 125/ft^3 = .593 yd^3
1 ton @ 125/ft^3 = .453 m^3

DESIGN AND TECHNICAL SUPPORT

Invisible Structures welcomes the opportunity to review project designs and answer technical questions. AutoCAD design details may be downloaded from our website. ISI staff is available for on-site construction guidance.

See a comprehensive list of project profiles with photos, project sizes, descriptions, locations, and designs on the web at www.invisiblestructures.com

CONTACT INFORMATION

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Fax 303-233-8282
www.invisiblestructures.com
e-mail sales@invisiblestructures.com

Rainstore^3 Patent No. 6,095,718. International Patents Apply

LIMITED WARRANTY — RAINSTORE^3

INVISIBLE STRUCTURES, INC., warrants to the Owner the structural integrity of Rainstore^3 structures themselves when installed in accordance with Invisible Structures' written specifications at the time of installation. This warranty applies against defective materials for two (2) years from the date of purchase.

This warranty shall be the sole and exclusive warranty granted by Invisible Structures, Inc., and shall be the sole and exclusive remedy available to Owner. INVISIBLE STRUCTURES, INC., DISCLAIMS ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, THAT ARISE BY THE OPERATION OF LAW, SPECIFICALLY INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. INVISIBLE STRUCTURES, INC., SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES WHICH MAY HAVE RESULTED FROM ANY ALLEGED BREACH OF WARRANTY.

SPECIFICALLY EXCLUDED FROM WARRANTY COVERAGE ARE DAMAGES ARISING FROM ORDINARY WEAR AND TEAR; ALTERATION, ACCIDENT, MISUSE, ABUSE, OR NEGLECT, THE RAINSTORE^3 STRUCTURE BEING SUBJECTED TO USES OTHER THAN THOSE PRESCRIBED IN INVISIBLE STRUCTURES, INC.'S WRITTEN SPECIFICATIONS, OR ANY OTHER EVENT NOT CAUSED BY INVISIBLE STRUCTURES, INC.

Some states do not allow limitations on how long an implied warranty lasts or the exclusion or limitation of incidental or consequential damages, so the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

Neither the sales personnel of the seller nor any other person is authorized to make any warranties other than those described herein or to extend the duration of any warranties beyond the time period described herein on behalf of Invisible Structures, Inc.

Should a defect appear in the warranty period, the Owner must inform Invisible Structures, Inc. of the defect in writing within ten (10) days of the discovery of the defect to the following address:

Kevin F. Wright, President
Invisible Structures, Inc.
1600 Jackson Street, Suite 310
Golden, CO 80401

Invisible Structures, Inc., agrees to supply replacement Rainstore^3 structures for those parts found by Invisible Structures, Inc., to be defective. THE COST OF REMOVAL OR INSTALLATION, OR A COMBINATION THEREOF, OF THE RAINSTORE^3 STRUCTURE IS SPECIFICALLY EXCLUDED FROM THIS WARRANTY. Shipping costs shall be the responsibility of the Owner.

Under no circumstances shall Invisible Structures, Inc. be liable to the Owner or to any third party for claims arising from the design of the Rainstore^3 structure, shipment of the components of the Rainstore^3 structure, or installation of the Rainstore^3 structure.

This warranty may not be amended except by a written instrument signed by an officer of Invisible Structures, Inc., at its corporate headquarters in Golden, Colorado. This warranty does not apply to any party other than to the Owner.

California Industrial Resources, Monroe, WA — Installation of Rainstore^3

Moving stacks of product

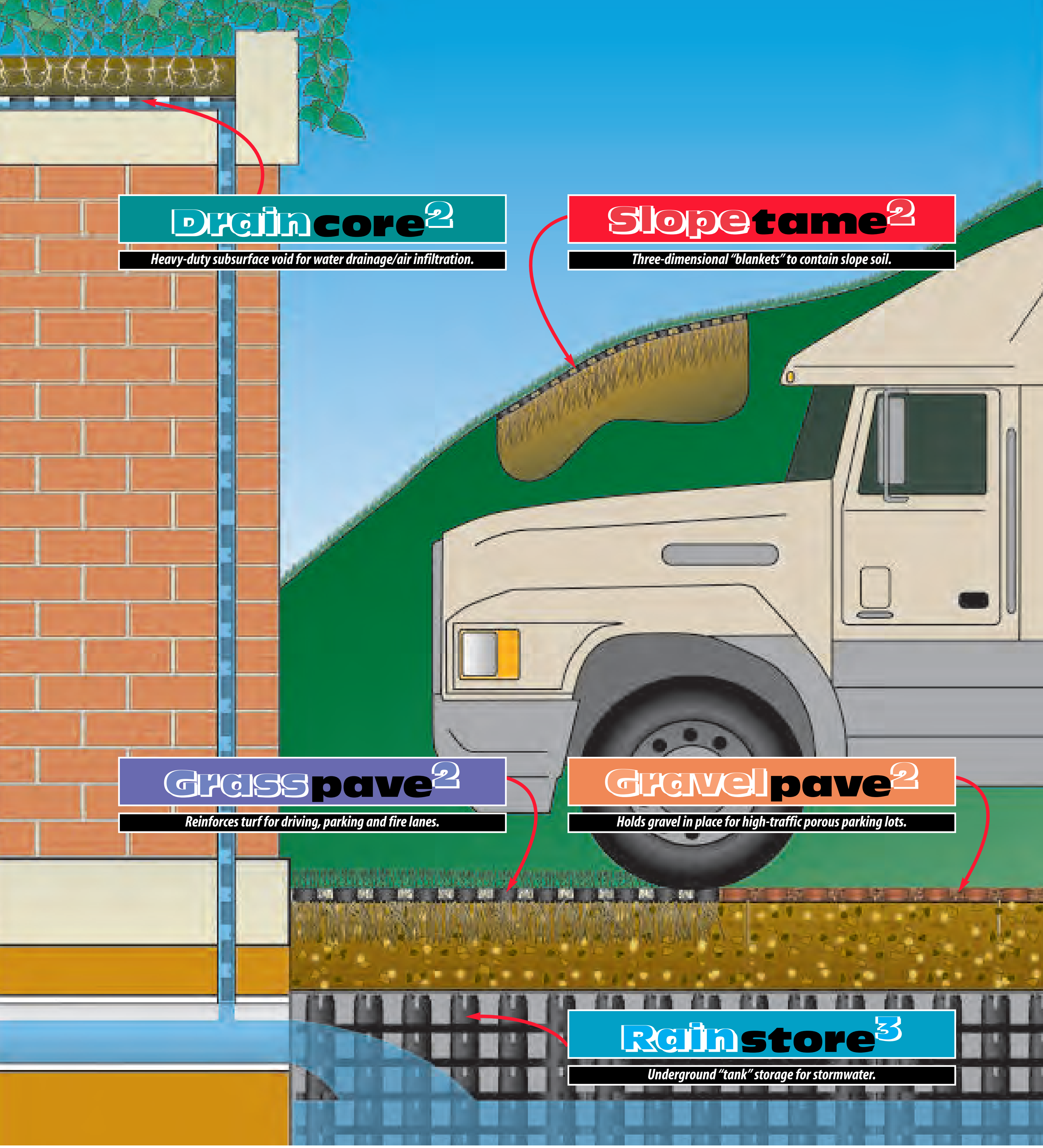
Inlet boot connection detail

Filter fabric with geogrid placed on top

Backfill with roadbase prior to operating heavy machinery on Rainstore^3 units

Left: Heavy equipment begins to put the cover material over an installed Rainstore^3 chamber. Take extreme care when driving and/or compacting over the chamber and do not drive over exposed Rainstore^3 units — wait until ALL the units are installed, the side backfill is complete, fabric and geogrid layers are completed, and an adequate amount of cover material is placed.

Below: A completed Rainstore^3 installation at a chemical plant's loading dock in Chicago Heights, IL. Stormwater drains via multiple inlets to a Rainstore^3 retention area beneath a concrete loading dock pad. The outflow into the city system is controlled by a shut off valve on a single 6" pipe. For safety, if there is a chemical spill, the valve can be closed, the contents can be pumped out, and the spill cleaned up.



Draincore^2

Heavy-duty subsurface void for water drainage/air infiltration.

Slopetame^2

Three-dimensional "blankets" to contain slope soil.

Grasspave^2

Reinforces turf for driving, parking and fire lanes.

Gravelpave^2

Holds gravel in place for high-traffic porous parking lots.

Rainstore^3

Underground "tank" storage for stormwater.

Invisible Structures, Inc.

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CD-ROM
CADD DISK
IECA MEMBER

Rainstore^3 Patent No. 6,095,718.
International Patents Apply