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University Arroyo Flood Control and Enhancement Plan: Summary Report of Hydrologic and Hydrodynamic Conditions and Evaluation of Alternatives.

Prepared for

University of California at Riverside

Prepared by

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October 9, 2001

PWA Ref. # 1418

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1. INTRODUCTION

Hydrologic and hydraulic conditions of the University Arroyo watershed and stream system were analyzed for the University of California at Riverside (UCR) to assist the University in developing a flood control management plan for the arroyo. This current analysis of the University Arroyo system is part of a broader regional planning effort being coordinated by representatives from the University of California, the City of Riverside, and Riverside County.

Existing hydrologic conditions were initially assessed using standard rainfall-runoff modeling methods. However, the complexity of the University Arroyo drainage system, which involves several reaches of linked open channel and pipe flows, required a more rigorous analysis that considered hydrodynamic conditions throughout the system. Models were developed to represent catchment areas, flow routing, pipe capacities, and linked pressure conduit and open channel hydraulic effects. The ultimate goal of these technical studies was to identify alternatives that could reduce the flood hazards through the campus and locations further downstream.

Section 2 of this report presents the methodology and results from the hydrologic studies and also includes a preliminary assessment of proposed detention basins at the Islander Park site to reduce campus flows. Section 3 describes the subsequent hydraulic analysis and presents hydrodynamic modeling results for existing conditions. In Section 4, both regional and on-campus alternatives are presented and evaluated using the baseline hydrodynamic model. Section 4 includes the identification of preferred alternatives. The preferred regional alternative (Alternative A) includes two Islander Park detention ponds, a smaller single detention basin west of the campus botanical garden, and restored channel reaches on the UCR campus. This composite alternative was selected based upon goals of maximizing flood benefits while minimizing environmental impacts and costs. The preferred on-campus alternative (Alternative G) includes an enlarged open channel beginning at the eastern campus entrance at Valencia Hill Dr., a detention pond along the Botanical Garden tributary channel, increased storage capacity at the Campus Glade basin, and a 7’ x 7’ box culvert running from the campus junction to the Gage Basin. The elements of Alternative G are entirely within the UCR campus.

2. HYDROLOGY

2.1 OVERVIEW AND METHODS

Surface runoff analysis of the University Arroyo watershed was conducted in several stages. Initially, an ArcView GIS database was developed to organize data, derive watershed parameters and generate other hydrologic data. Information regarding soil, land-use, vegetation, degree of impervious cover, sub-basin roughness, and runoff curve numbers were obtained, processed, and organized into a spatial database. These data were then used as input to create a synthetic unit hydrograph and rainfall-runoff model to simulate hydrologic conditions in the watershed. The runoff analysis was conducted using CivilCadd-CivilDesign Synthetic Unit Hydrograph (Version 2.2) for estimating rainfall runoff response and the most recent version of U.S. Army Corps of Engineer's HEC-1 to determine channel routing. These software applications follow the recommended procedures of the Riverside County Flood Control and Water Conservation District (RCFCWCD) Hydrology Manual.

To accurately model hydrologic conditions at University Arroyo, it was important to accurately represent runoff contributions from individual sub-basins and to analyze how flow paths and tributaries from these sub-basins function in relation to each other. These flow relationships are important in evaluating the effectiveness of potential flood control alternatives.

2.2 HYDROLOGIC SETTING

The UCR campus is located on westward sloping alluvial deposits at the base of the Box Springs Mountains (Figure 1). Campus elevations along the arroyo range from about 1100 ft (*NGVD*) at the eastern campus entrance at Valencia Hill Drive and descend to about 1000 ft at the Gage Basin near the I-215/SR 60 freeway. East of campus, slopes increase dramatically, as the Box Springs Mountains rise above 2800 feet over a horizontal distance of less than two miles. This mountainous area consists of steep, rocky, and undeveloped hillslopes, which shed precipitation runoff into a few principal canyon streams. These canyon tributaries discharge onto broad, gently sloping, alluvial fans and plains at the western base of the mountain front. The Islander Park site east of Watkins Drive is located within this alluvial corridor at the confluence of two streams that emerge from their steeper canyons (Figures 2 & 3).

Downstream of this confluence at the Islander Park site, surface runoff flows westward towards the UCR campus via Big Springs Road which has a trapezoidal inverted-crown shape. Runoff from residential neighborhoods east of Watkins Drive (and south of the railroad line) is also collected along Big Springs Road and routed westward towards campus. Just east of Watkins Drive, an intake culvert in the center of Big Springs Rd. collects a portion of the surface flow along the street into a 36" sub-surface pipe.

figure 1

University Arroyo Physical Setting

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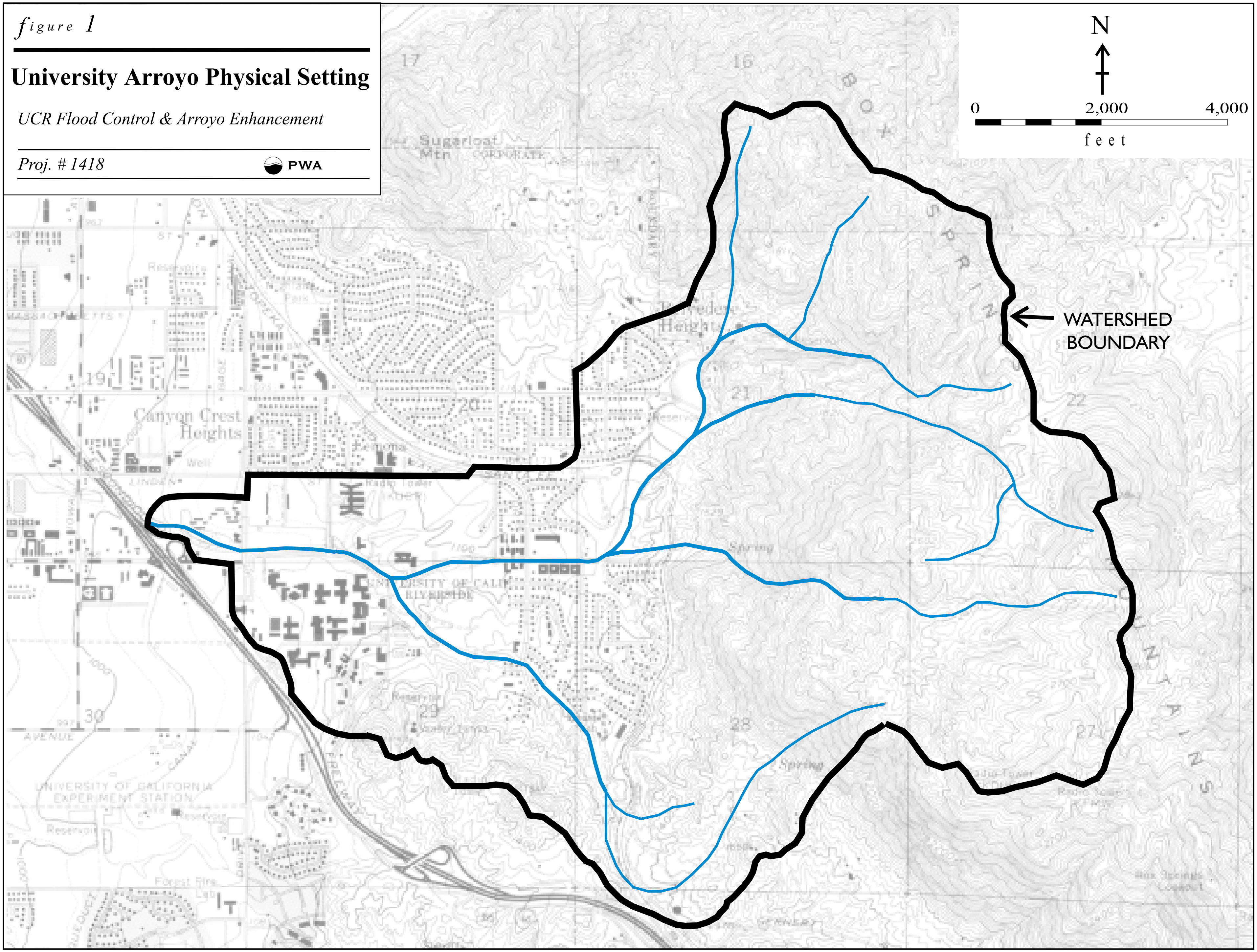

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figure 2

Existing Drainage Conditions

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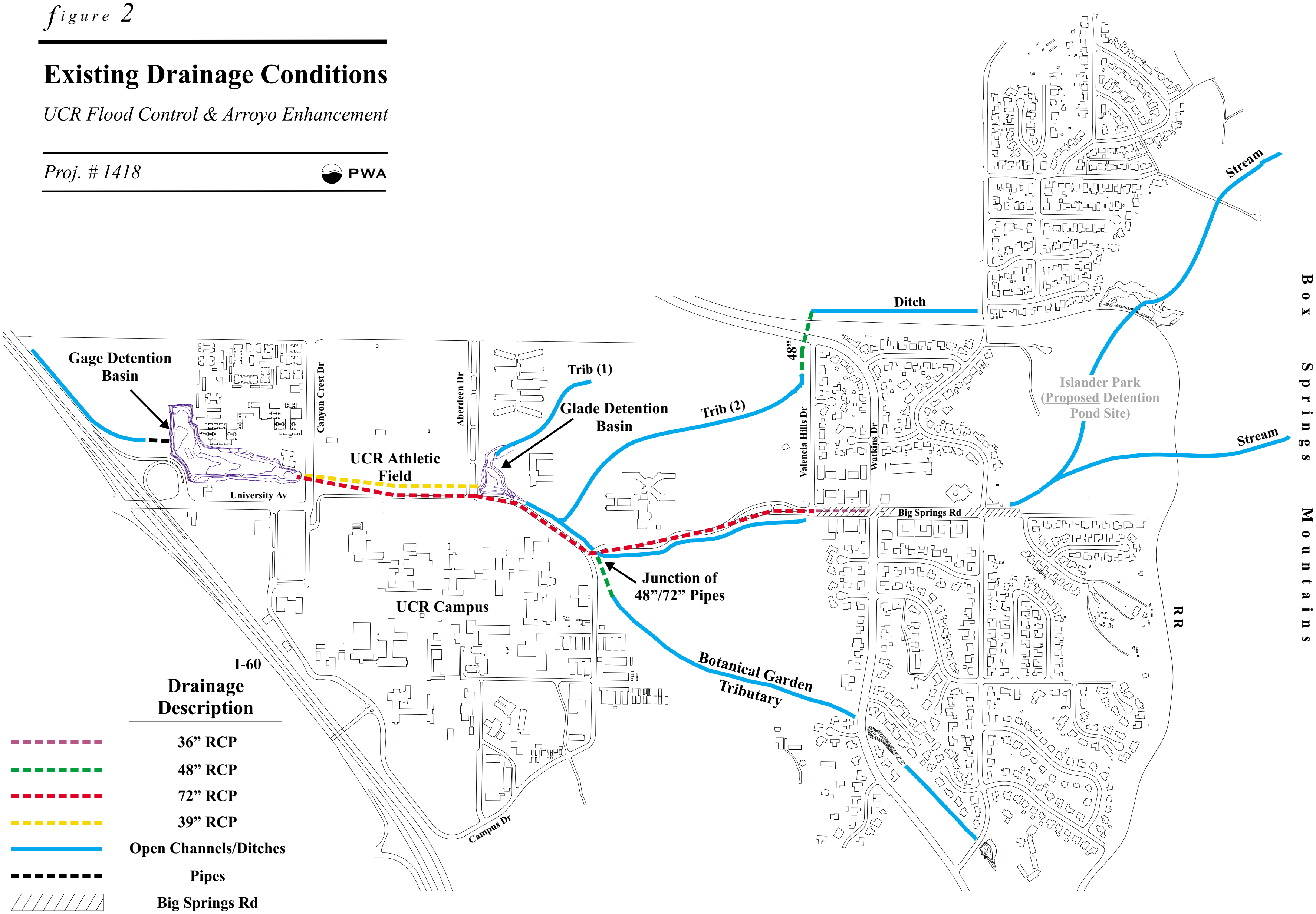

figure 3

Islander Park Site

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Islander Park Site - looking north from Box Springs Road (site of proposed detention basins)

Islander Park Site - looking south from railroad (site of proposed detention basins)

1418 islander park site.cdr

At the eastern campus entrance near Valencia Hill Drive, a series of large road grates on Big Springs Rd. (Figure 4a) direct surface flow into an existing 72” RCP (reinforced concrete pipe). Flows that pass over the grates and do not enter the 72” culvert, remain on the surface and eventually enter an on-campus open channel system (Figure 4b), which parallels North Campus Drive (the western continuation of Big Springs Road). Thus, the main branch of University Arroyo as it passes through the campus is not a single arm, but a complex network of open channel and piped reaches.

Three tributaries, as well as several smaller drainage pipes, join the main drainage branch of University Arroyo watershed through the UCR campus. From the south, a tributary draining the UCR Botanical Garden and contributing areas upstream, joins the main 72” campus pipe through a 48” connecter pipe at the junction of North Campus and East Campus Drives at the northwest corner of Parking Lot 13 (Figure 2). From the north, two tributaries contribute flow to the open campus channel. The more eastern of these northern tributaries collects runoff from a residential neighborhood further upstream, while the more western tributary collects runoff from a more limited on-campus catchment area (Figure 2). Surface flows from the open channel system collect at the Campus Glade, enter a 39” culvert, and then flow westward beneath the campus athletic fields. West of Canyon Crest Drive, both the 39” and 72” culverts daylight into an open channel reach referred to as the Gage Canal Basin. At the western end of the Gage Canal Basin, the open channel enters two parallel 60”x 54” box culverts to pass beneath the Gage Canal and exit the campus area.

2.3 WATERSHED CHARACTERISTICS

This section of the report describes watershed characteristics including topography, soil types, land use, vegetation, impervious cover, antecedent moisture conditions, runoff curve numbers, and design precipitation conditions.

2.3.1 Topography and sub-basin delineations

To examine watershed topography, a 10-meter resolution Digital Elevation Model (DEM) was processed from the USGS Global Land Information System (GLIS). Analysis of the DEM was conducted using ArcView/Spatial Analyst GIS software (ESRI 1996). The DEM was used to delineate watershed and sub-basin boundaries, determine watercourse alignments and tributary flow paths, measure sub-basin geometric properties, estimate channel routing parameters, and calculate watershed time lag parameters.

As mentioned above, one of the key tasks in building a hydrologic model is to allocate flows from individual runoff generating areas (sub-basins). In addition, the spatial arrangement between these sub-basins in the model must accurately reflect actual ground conditions. Sub-basins were delineated utilizing a GIS technique whereby each cell in the DEM was given a flow direction based upon the elevations of surrounding cells. Sub-basin boundaries were mapped where divergences in this flow-direction layer occur. Following the flow-direction layer, a flow-accumulation layer was generated to identify the chain of upstream grid cells for each cell in the DEM. Tributary channels in each sub-basin were then mapped by integrating the flow-accumulation grid with selected stream concentration points.

figure 4

Campus Features of University Arroyo

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(4a) Intake road grates where surface flow conveyed along Big Springs Road enters main 72” campus pipe, view is looking west on Big Springs Road into campus entrance.

(4b) On campus open channel running parallel to Big Springs Road, view is looking east across entrance into Parking Lot 13.

In the Box Springs Mountains, where overland flow paths closely follow the steep terrain and there are no drainage improvements, this GIS procedure is applied directly. In more developed regions with drainage modifications the DEM derived sub-basins were field checked and manually adjusted to represent actual surface conditions. Ultimately, 15 sub-basins were delineated for the UC Riverside watershed (Figure 5). Geometric and hydrologic parameters, including elevational change, area, channel length, and centroid distance, were calculated for each sub-basin for use in the modeling process (Table 1).

2.3.2 Infiltration parameters

Infiltration is the process by which surface water percolates into the sub-surface soil and groundwater column. Infiltration is an important hydrologic process because it governs groundwater recharge, soil moisture storage, and surface water runoff. As modeled by HEC-1, infiltration is one of several processes that represent a withdrawal of a portion of total storm precipitation that could generate surface runoff. Other processes that reduce the amount of storm runoff from the precipitation (cumulatively referred to as "losses" in HEC-1) include vegetation interception, depression storage, and evapotranspiration. Infiltration computations were made using the standard Natural Resource Conservation Service (NRCS) runoff index (RI), or curve number (CN), method. This method incorporates soil characteristics, land use, vegetation, impervious cover and antecedent moisture conditions to estimate loss rates. The RI scale has a range from zero to 100, where higher numbers indicate lower infiltration rates. The mapping division at RCFCWCD compiled and provided the most recent data for hydrologic soil type, vegetation coverage, and land use throughout the watershed.

Soil Characteristics

Soils are classified into four hydrologic soil groups (A, B, C, or D) based on infiltration rates. A-type soils have the highest infiltration rates while D-type soils have the lowest infiltration potential. Table 2 defines each soil type according to the RCFCWCD Hydrology Manual.

Table 2: RCFC & WCD Hydrologic Soil Type Descriptions

Type A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands and gravels. These soils have a high rate of water transmission.
Type B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
Type C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
Type D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The distribution of hydrologic soil types across the University Arroyo watershed is mapped in Figure 6a and listed by sub-basin in Table 1. Poorly infiltrating D-type soils dominate the large sub-basins of the Box Springs Mountains (*VALHIL*, *WATFH*) and represent 62% of total watershed soils. Higher infiltrating B and C-type soils occur in the alluvial valleys downstream of the mountains and through the

figure 5

Sub-basin delineation of University Arroyo watershed used for hydrologic modeling

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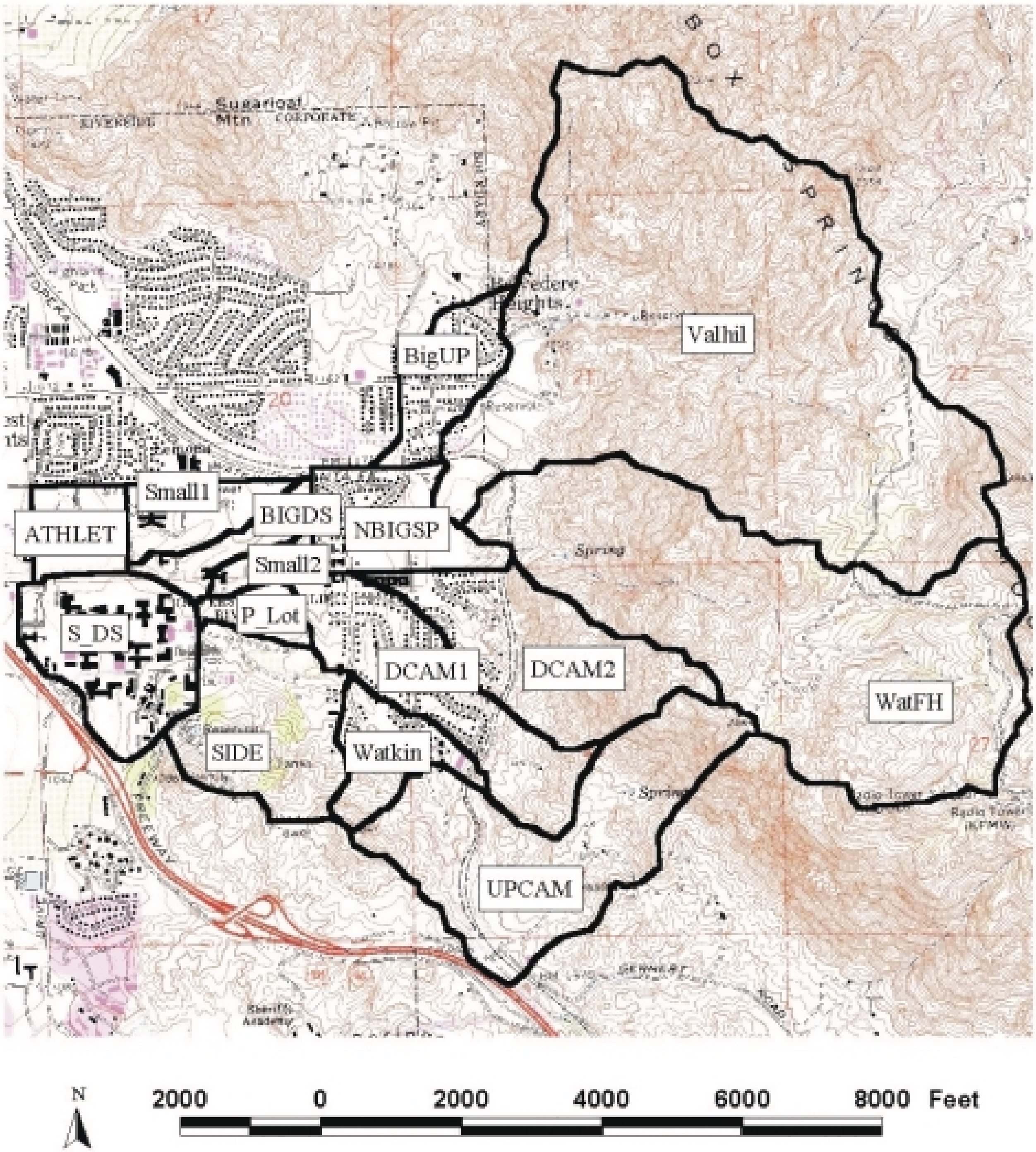

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Table 1: Summary of Geometric and Hydrologic Characteristics, University Arroyo Watershed

Basin ID	Basin Description	Area (acres)	Longest Reach (feet)	Lengh to Centroid (feet)	Δ Elevation (feet)	Percentage of Hydrologic Soil Group					Sub Basin 'n' Values	Runoff Index	% Impervious	S-Hydrograph	Low Loss Rate
						A	B	BC	C	D					
ATHLET	Athletic field area & surrounding campus area	39.34	2730	1272	50	0%	29%	47%	20%	3%	0.05	62.4	75%	Valley	0.3
BIGDS	Sub basin entering ditch opposite Campus Dr. & Big Springs Rd	30.44	3882	1603	101	6%	1%	0%	52%	41%	0.04	73.7	32%	Valley	0.64
BIGUP	Sub basin North of Campus View Dr & train tracks	57.06	8630	6945	261	0%	35%	0%	56%	9%	0.025	77.9	42%	Valley	0.57
DCAM1	Sub basin south of Broadbent Rd	126.02	8619	3371	604	0%	10%	0%	54%	35%	0.035	79.3	29%	Valley	0.67
DCAM2	Sub basin north of Broadbent Rd	142.85	9231	2961	1315	0%	12%	0%	15%	73%	0.035	79.2	16%	Foothills	0.77
NBIGSP	Sub basin north of Big Springs Rd	77.94	2998	1652	163	0%	27%	0%	38%	35%	0.025	82.4	41%	Valley	0.57
PLOT	Sub basin surrounding parking lot	21.77	2519	907	100	0%	41%	0%	33%	26%	0.02	67.9	40%	Valley	0.58
SDS	Main campus drains sub basin	112.58	7249	1480	128	0%	20%	16%	56%	7%	0.025	65.5	75%	Valley	0.3
SIDE	Sub basin between 48" pipe inlet & Watkins Rd	120.81	8866	6656	429	0%	10%	4%	63%	23%	0.035	72.9	32%	Valley	0.64
SMALL1	Sub basin west of Aberdeen Rd	42.77	3684	1726	98	0%	4%	23%	58%	15%	0.04	71.5	40%	Valley	0.58
SMALL2	Sub basin north of Big Springs Rd	17.92	2579	1265	68	0%	9%	0%	77%	14%	0.04	70.9	50%	Valley	0.5
UPCAM	Sub basin upstream of Hyatt School	220.37	7460	3899	1253	0%	4%	1%	57%	39%	0.04	77	3%	Foothills	0.87
VALHIL	Valencia Hills sub basin	767.16	12002	5970	1727	0%	6%	3%	4%	86%	0.045	80	2%	Foothills	0.88
WATFH	Watkins Foothills sub basin	465.97	14553	4849	1850	0%	0%	8%	4%	88%	0.05	80.3	0%	Foothills	0.9
WATKIN	Sub basin between Watkins Rd & Hyatt School	51.47	6654	4109	397	0%	0%	0%	69%	31%	0.035	78.4	32%	Valley	0.64
TOTAL WATERSHED	Entire UCR Watershed	2294.47	-	-	??	0%	8%	5%	25%	62%	0.041	77.86	15%	-	0.775

\projects\1418_UCR_IV\report\tables\1418_Tb_ 1_Geom&Hydroparameters.xls

figure 6a

Hydrologic soil types for the University Arroyo Watershed

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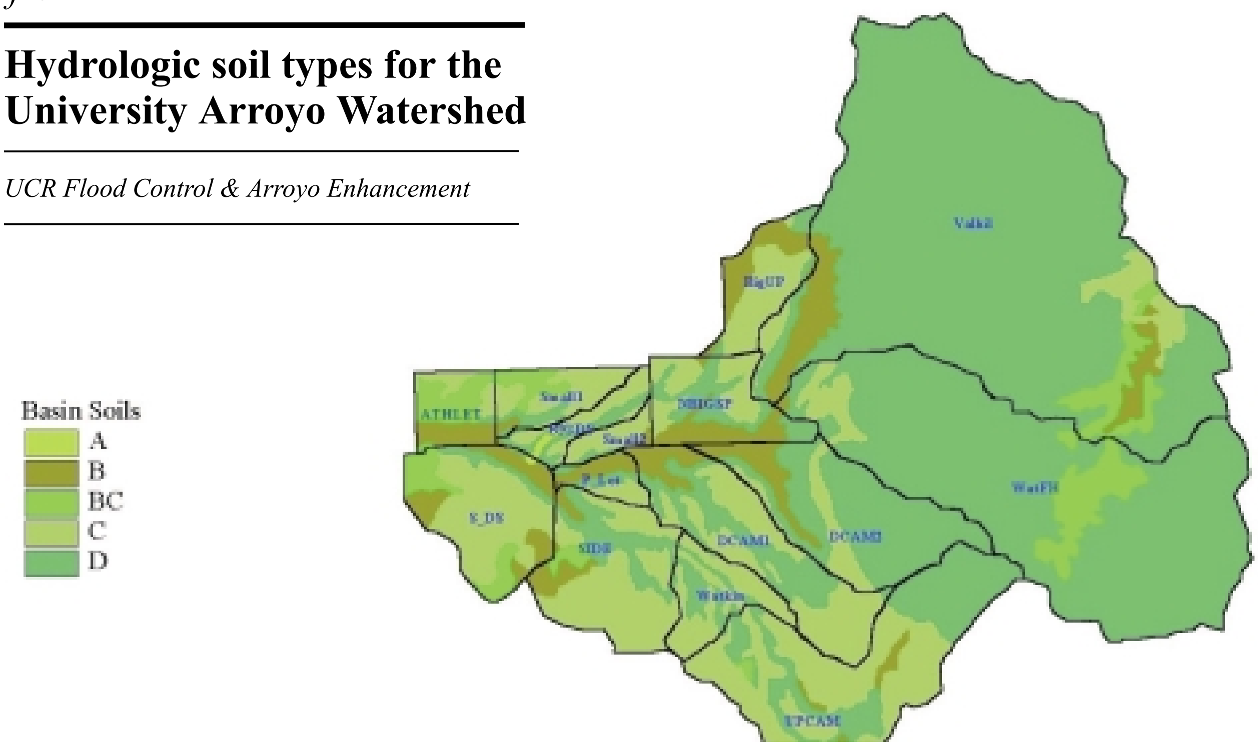

figure 6b

Vegetation description for the University Arroyo Watershed

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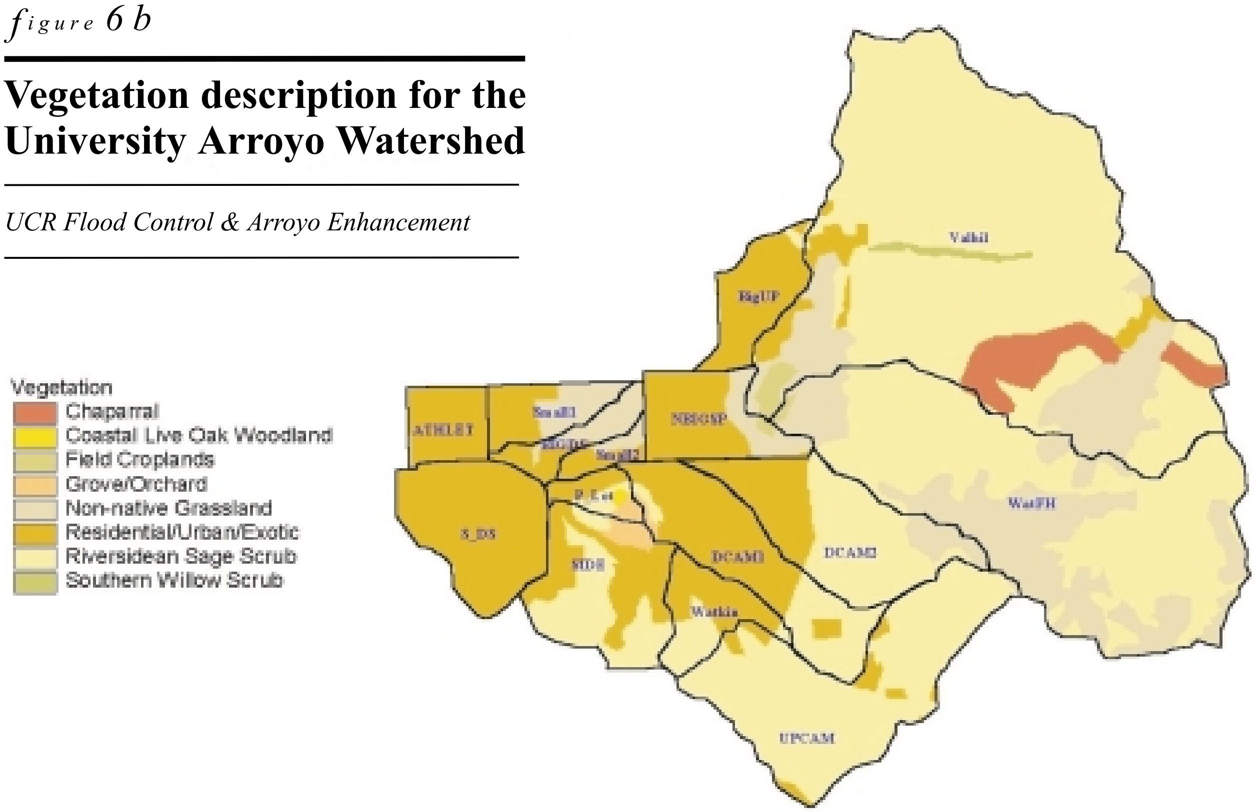

PWA

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campus and surrounding residential neighborhoods some. These moderately infiltrating soils account for 38% of the overall watershed. The highest infiltrating A-type soils are absent in the watershed except for a small floodplain area along one of the northern campus tributaries.

Vegetation and Land Use

In addition to soil properties, the runoff response of the watershed will be strongly affected by vegetation and land use conditions. Figures 6a and 7b include maps showing the distribution of vegetation and land use types within the University Arroyo watershed.

The primary vegetation type found throughout the UCR watershed is Riversidean Sage Scrub, which makes up 55 % of the total area. This vegetation is found on the rugged slopes of the Box Springs Mountains. In developed areas, the composite residential/urban/exotic vegetation type is dominant and covers roughly 25% of the watershed. A few small regions of non-native grasslands and chaparral can also be found in localized areas of the watershed.

Land-use in the University Arroyo watershed was classified into 21 types (Table 3). Vacant/Undifferentiated lands cover roughly 70% of the watershed, while high density single-family residential and the UCR campus account for 12% and 7% respectively. Other varying land uses constitute less than 11% of the entire watershed.

Runoff curve numbers were developed based on vegetation and land use conditions and synthesized as a single GIS layer. This was accomplished by creating a cross-reference matrix (Table 3) and performing a two-layer GIS analysis. Each cell in the GIS database was identified as being *natural, agricultural*, or *developed*. If the ground cover cell was "developed" then the land-use layer (Figure 7a) took precedence and the vegetation layer was ignored. In contrast, if the cell was "natural" or "agricultural", then the assigned vegetative cover from Figure 6b became the active land cover type. In this way, each grid cell in the watershed GIS database was assigned a specific land cover code, a soil type, and a runoff curve number.

The three general land-use distinctions are classified further into specific types (Table 3). Natural (*or undeveloped*) lands are divided into particular plant communities where differences in canopy cover and density influences assigned runoff curve numbers. Developed regions are classified according to the density of their development and given different runoff curve numbers. For example, rural residential areas have lower runoff curve numbers than single-family residential zones (Table 3).

Impervious cover and basin roughness

The extent of impervious surfaces within each sub-basin is an important factor in determining runoff. Percent impervious values were assigned for each land-use class in Table 3 based upon recommendations in the RCFCWCD Hydrology Manual. Subsequently, each grid cell in the GIS database was assigned a percent impervious value (Figure 7b). Average impervious values were then calculated for each sub-basin based upon all of the grid cell values in the sub-basin (Table 1).

figure 7a

Land use description for the University Arroyo Watershed

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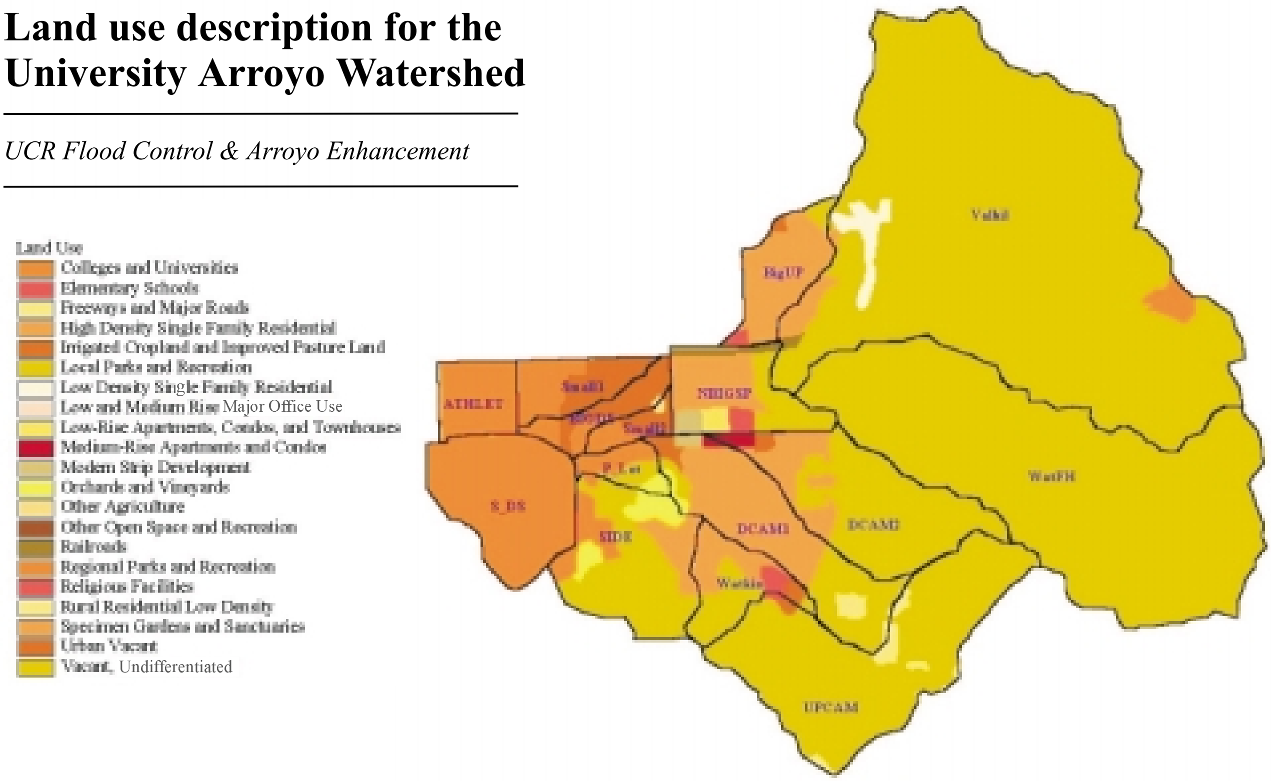
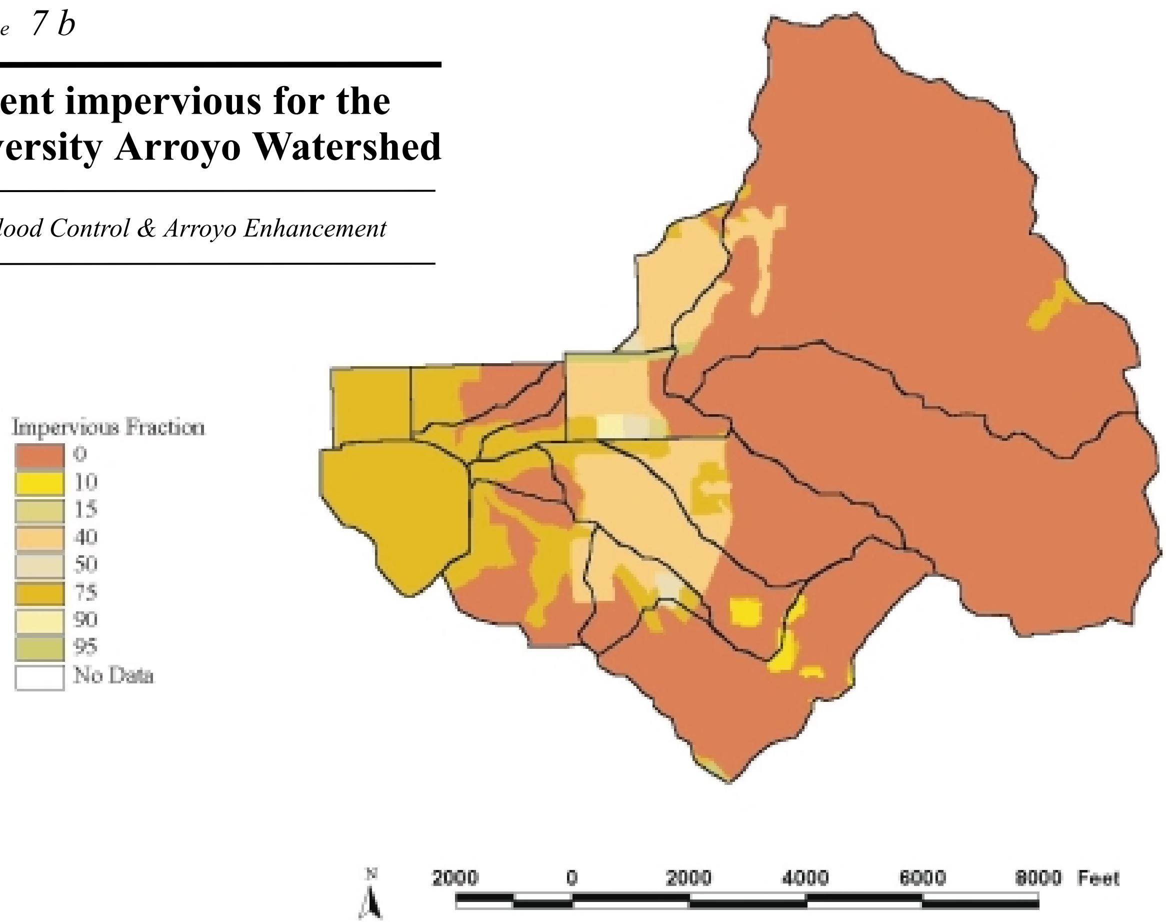


figure 7b

Percent impervious for the University Arroyo Watershed

UCR Flood Control & Arroyo Enhancement



PWA

1418 land use = imperv.cdr

Table 3: Runoff Curve Number Index Table for Various Land Use, Vegetation, and Soil Conditions

PWA Category and Sub-categories			PWA Code	Descriptive Examples	Source Cover Type(s)	Curve Number for Soil Types			
						A	B	C	D
Natural Classification	Dunes	General Dunes	10101	Dune Habitats; S. Coastal Foredunes; S. Dune Scrub	Open Brush - good	41	63	75	81
	Chaparral	General Chaparral	10301	Chaparral Habitats; Southern Mixed Chaparral; Mixed Montane Chaparral; Nolina Chaparral; Toyon-Sumac	Average Broadleaf Chaparral - fair and Narrowleaf Chaparral - fair	48	68	78	84
	Grassland	General Grassland	10401	Grassland Habitats; Annual Grass; Elymus Grassland; Southern Coastal Needlegrass; Mixed Perennial Grass; Ruderal; Deergrass	Grass - average fair and good	44	65	77	82
	Woodland and Forest	Woodland and Riparian Habitat	10501	Riparian Habitats; Riparian Herb; S. Sycamore; S. Coast Live Oak; S. Arroyo Willow; S. Black Willow; S. Cottonwood-Willow; White Alder; Canyon Live Oak; Woodland Habitats	Woodland - average fair and good	31	58	72	78
		Riparian Willow	10502	Southern Willow Scrub; Mulfat Scrub	Average Open Brush - fair and Woodland - fair	41	63	75	81
Agricultural Classification	General Agriculture	General Agriculture	20101	Agriculture; Other Agriculture	Average Fallow, Legumes/Close Seeded, Row Crops, Small Grains	67	78	85	89
	Orchards	General Orchards	20401	Vineyards and Orchards	Orchards/Evergreen - average fair and good	39	62	75	81
Developed Classification	General Developed Areas	General Developed Areas	30101	Developed Areas; Non-urban Industrial/Commercial/Institutional; Other Developed Areas	Residential/Commercial with 50% impervious	65	77	84	87
	Residential	Residential / Commercial	30102	Colleges & Universities	Residential/Commercial with 75% impervious	32	56	69	75
		Rural Residential	30201	Rural residential	Chaparral and Sage with 10% impervious	50	69	79	85
		Single Family Residential	30202	Single Family Residential	Residential/Commercial with 40% impervious	58	73	81	84
		Multiple Family Residential	30203	Duplexes & Triplexes,	Residential/Commercial with 75% impervious	82	88	91	92
	Urban Commercial and Industrial	General Urban Commercial and Industrial	30301	Urban	Residential/Commercial with 90% impervious	91	94	95	96
	Transportation	General Transportation	30401	Transportation	Residential/Commercial with 95% impervious	95	96	97	97
	Parks	General Parks	30501	Parks and Ornamental Plantings	Turf - fair with 15% impervious	52	70	80	84

As illustrated in the map of Figure 7b, impervious fractions for the undeveloped sub-basins of the Box Springs Mountains (*VALHIL*, *WATFH*, *UPCAM*) are low. In contrast, the more developed portions of the western watershed (including the UCR campus) are more impervious. Generally, areas with more impervious surface area generate more runoff. As the runoff curve numbers (RI) in Table 1 indicate, in some instances, factors like soil type, slope, or basin geometry results in different values. For example, even though the *WATFH* sub-basin has 0% impervious surfaces, it has a relatively high runoff curve number due to other basin factors.

An additional parameter listed in Table 1 that is required for runoff modeling is basin roughness (Figure 8a). Like the impervious fraction estimates, basin roughness values vary for each of the land-use classes in Table 3. Basin roughness values were selected according to suggested values in the RCFCWCD Hydrology Manual and reviewed with the Riverside County Flood Control District. (Robert Cullen, RCFCWCD, personnel comm. 2000).

Runoff Index

Following the procedure outlined in the RCFCWCD Hydrology Manual, a runoff curve number (RI) was assigned to each type of surface cover for each of the four hydrologic soil-types (Figure 8b). In undeveloped areas, hydrologic soil type strongly influences runoff generation. For many of the land-uses classes in Table 3, D-type soils often have twice as high of a runoff curve number as the A-type soils. In developed areas with more impervious surfaces the relative influence of soil-type is dampened. In general, “fair” conditions were assumed for the quality of the land coverage in designating the runoff curve values. Where “fair” cover conditions were not available for a particular land type, averages were taken between “good” and “poor” conditions to approximate “fair” cover conditions.

Runoff curve numbers from each cell of the watershed were averaged to provide a singular sub-basin value as input to the hydrologic model (Table 1). Although, spatial detail is lost through this aggregation process, this GIS procedure represents an analytical improvement in the accuracy of the rainfall-runoff modeling. Runoff curve numbers varied from 62.4 to 82.4 for the 15 sub-basins of the watershed.

Design precipitation and antecedent moisture

Following procedures of the RCFCWCD Hydrology Manual, design precipitation events were used to represent 100-year recurrence storm events with durations of 3, 6, and 24 hours. These durations represent periods that would produce both maximum peak flows and maximum flow volumes for use in design. The rainfall distribution used for the 3 and 6-hr events was obtained from the Indio storm of September 24, 1939. The 24-hr hyetograph (graph of precipitation) is based on the storm of March 2-3, 1938. Due to the small size of the University Arroyo watershed, each storm pattern was designed to be distributed uniformly across each sub basin. Intermediate antecedent soil moisture conditions (AMC II) were selected in developing the 100-year runoff model.

figure 8a

Basin Roughness (Manning's n) for the University Arroyo Watershed

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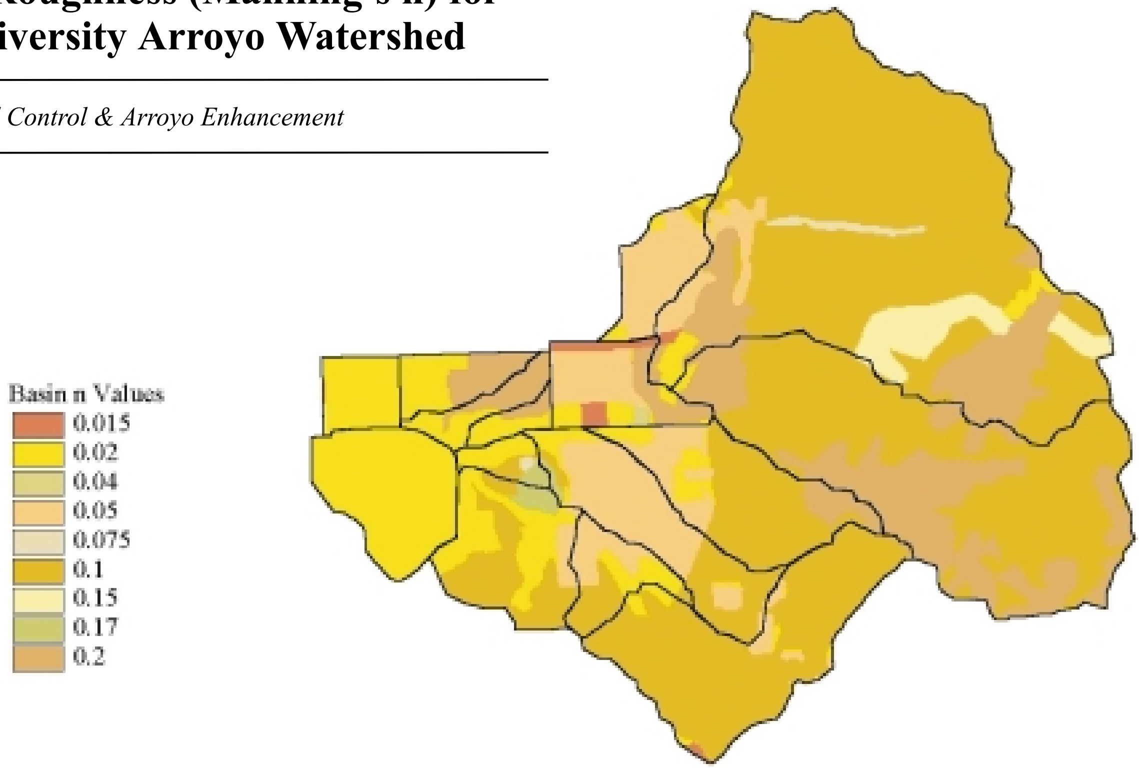
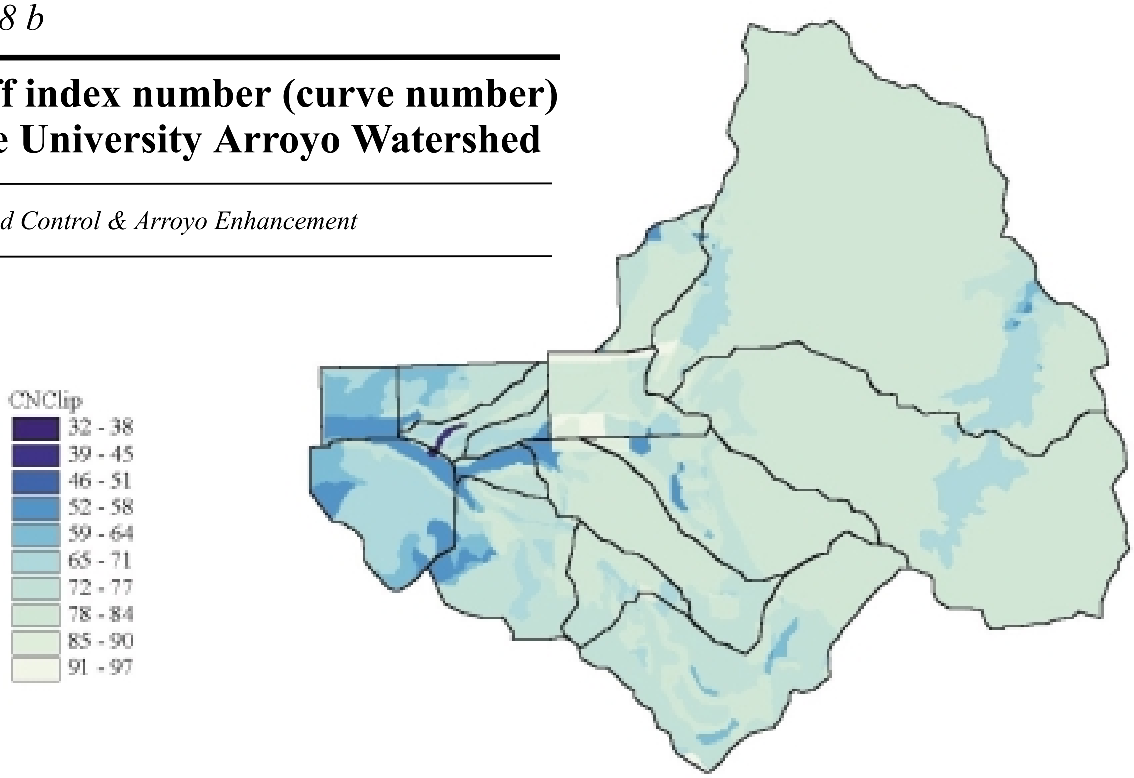


figure 8b

Runoff index number (curve number) for the University Arroyo Watershed

UCR Flood Control & Arroyo Enhancement



N

2000 0 2000 4000 6000 8000 Feet

PWA

1418 mannings + index

2.4 INPUT FOR SYNTHETIC UNIT HYDROGRAPH METHOD

Infiltration (loss) rates were calculated by integrating surface conditions from the GIS analysis with design rainstorm hyetographs. Excess precipitation (runoff) was calculated for each sub-basin at each timestep where rainfall rates exceeded infiltration rates. The unit hydrograph approach was used to convolute the excess precipitation into peak flow, volume, and timing of streamflow at the sub-basin outlet. The model is based on the size, shape, relief, land cover, and channel network of the sub-basin.

The CivilCadd-CivilDesign Synthetic Unit Hydrograph software package includes unit hydrograph data (S-curves) derived from the measured response of a variety of Riverside County watersheds. S-curves are provided according to generic geomorphic provinces. The *valley* and *foothill* S-curves were used for different portions of the University Arroyo watershed depending on topography and slope conditions.

Basin lag time represents an estimate of the response time between the onset of effective precipitation and the time that the summation hydrograph reaches 50% of ultimate discharge. The RCFCWCD time lag computation requires parameters that summarize routing and natural detention characteristics of the basin:

$$t_{lag} = 24n\left(\frac{LL_{ca}}{\sqrt{S}}\right)^{0.38}$$

where, t_{lag} = the lag time in hours
n = the average sub basin Manning's roughness
L = the length of the main channel from outlet to the watershed divide
L_{ca} = the length along the watercourse from the centroid of the watershed to the outlet point in miles
S = the overall slope of the main watercourse in feet/mile

These input parameters describing the size, shape, and slope of the basin were measured from large-scale 4-foot contoured topographic maps. Manning's *n* roughness values for the channels of each sub-basin were based on visual observations and guidelines in the Riverside County Hydrology Manual.

2.5 PRELIMINARY HYDROLOGIC RESULTS

2.5.1 <u>Estimated 100-year discharge under existing conditions</u>

Following the procedure of the *Riverside County Hydrology Manual*, unit hydrographs were calculated for the 100-year rainfall events of 3-hr, 6-hr, and 24-hr storm durations. Of the three storm durations, the 3-hr storm generates maximum peak discharge, while the 24-hr event produces the largest flow volumes. The 6-hr stormflow peaks are only slightly lower than the 3-hr values. Based on this, the 3-hr and 24-hr storms were selected as the design events for analyzing peak flow and maximum flow volume conditions.

The 100-year storm events of 3-hr and 24-hr durations were analyzed using the HEC-1 hydrology model developed for the University Arroyo watershed (Figure 9). Hydrographs for the 3-hr and 24-hr events at four representative locations are shown in Figures 10 and 11. From upstream to downstream, the four locations are: (A) at the Islander Park site (*downstream of the proposed detention basins introduced below*); (B) at the entrance to UCR Campus (*at the junction of Valencia Hill Drive and Big Springs Road*); (C) at the confluence of the main campus channel and the botanical garden tributary (*at the junction of Campus Drive and Big Springs Road*); and (D) at the entrance to the Gage Detention Basin (*just west of Canyon Crest Drive*). These stations were selected because of their hydrologic significance as key locations within the channel network (Figure 12).

Peak discharges from the hydrographs of Figures 10 and 11 are summarized in Table 4. Peak 3-hr flow rates of 1042 cfs at the Islander Park site at the base of the Box Springs mountains increase to 1700 cfs downstream at the Gage Basin. Also shown in Table 4 are estimated reduced peak flows resulting from the proposed Islander Park detention ponds. These structures and their hydrologic impact will be discussed further below.

Table 4: 100-year Peak Discharges at Key Watershed Locations

	Watershed Location	**Existing Conditions**		**With 115 ac-ft detention ponds**	
		3-hr (cfs)	24-hr (cfs)	3-hr (cfs)	24-hr (cfs)
A	Islander Park	1042	500	248	266
B	UCR Campus Entrance	1232	648	554	366
C	Confluence of Botanical and Main Channels	1480	800	795	502
D	Inflow to Gage Detention Basin	1700	940	1080	654

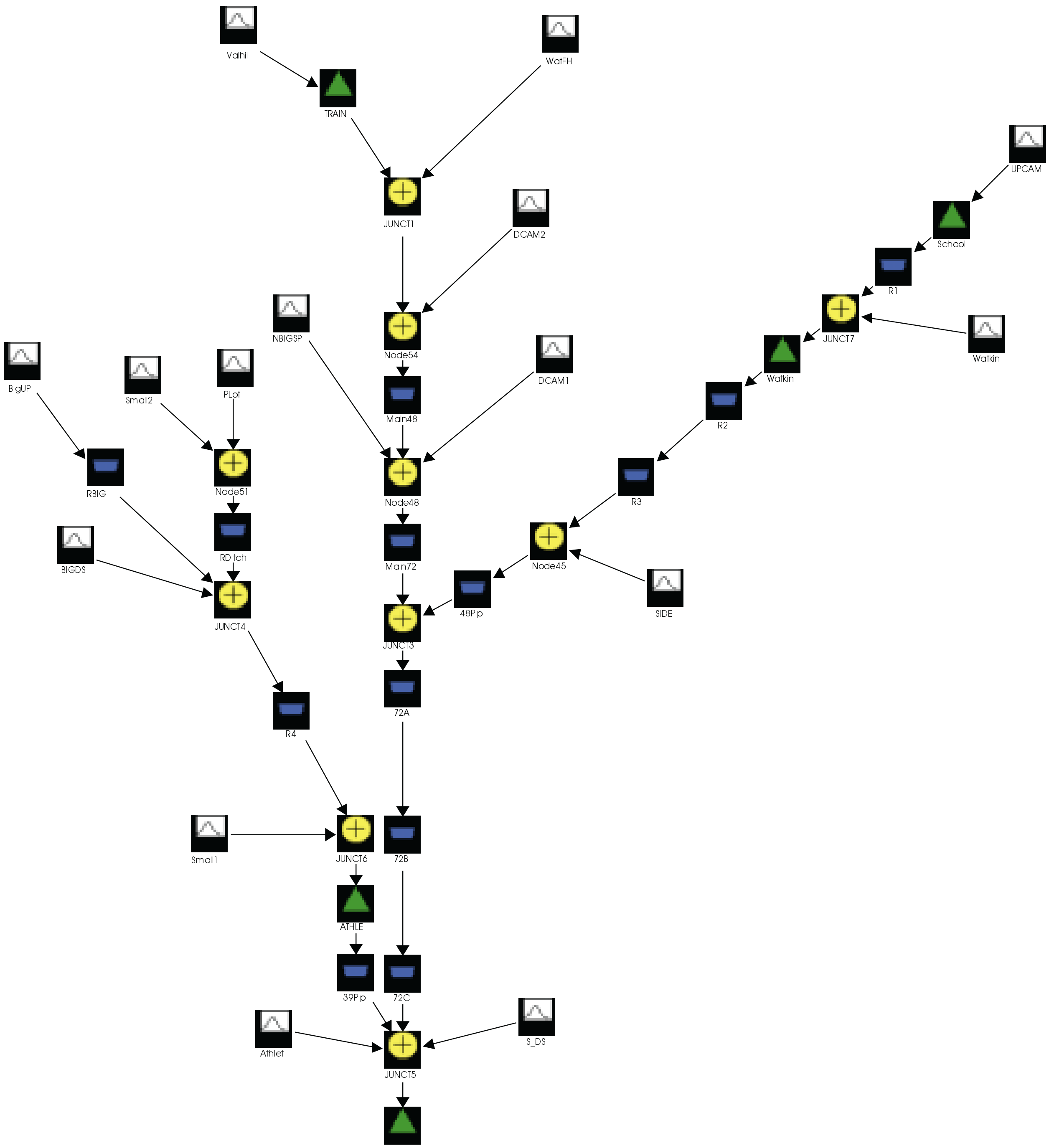
The timing of peak discharge at locations B, C, and D on the UCR campus occurs simultaneously, about 2.8 and 13.6 hours after the onset of effective precipitation for the 3-hr and 24-hr storms (Figures 10 and 11). This identical timing of peak flows results primarily from the design storm's uniform spatial distribution of rainfall across the watershed. Table 5 lists times to peak discharge for the 3-hr and 24-hr design storms under existing conditions and with the proposed detention basins. Flows at the Islander Park site (A) reach their peak slightly later than flows further downstream. This is most likely due to more impervious surfaces and lower roughness values in the downstream sub-basins.

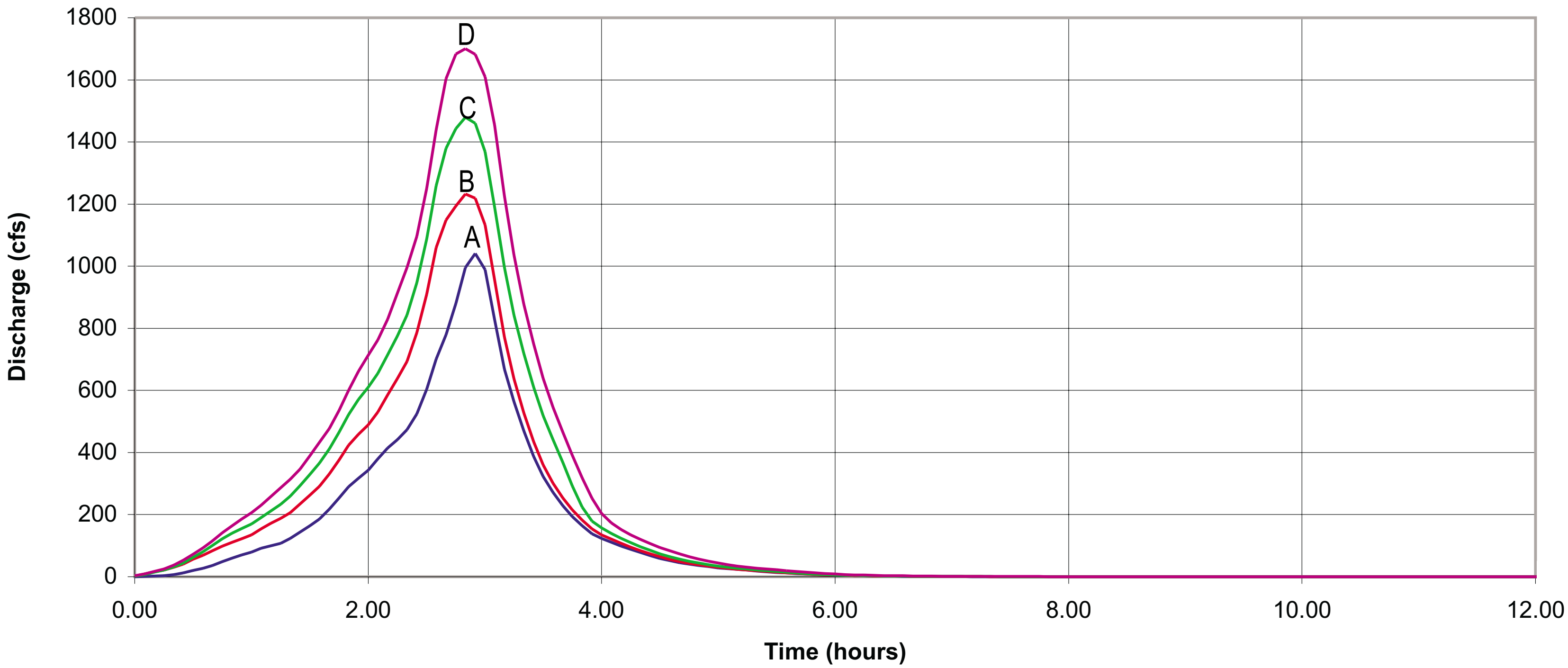
figure 9

HEC-1 Network Map

UCR Flood Control & Arroyo Enhancement

Proj. # 1418 PWA





(A) Islander Park site downstream of proposed detention ponds

(B) Campus entrance at junction of Valencia Hills Drive and Big Springs Road

(C) Confluence of main campus channel and botanical garden tributary

(D) At Gage detention basin west of Canyon Crest Drive

figure 10

3-hr Design Storm Hydrographs
Existing Hydrologic Conditions

UCR Flood Control & Arroyo Enhancement

PWA

PWA#: 1418

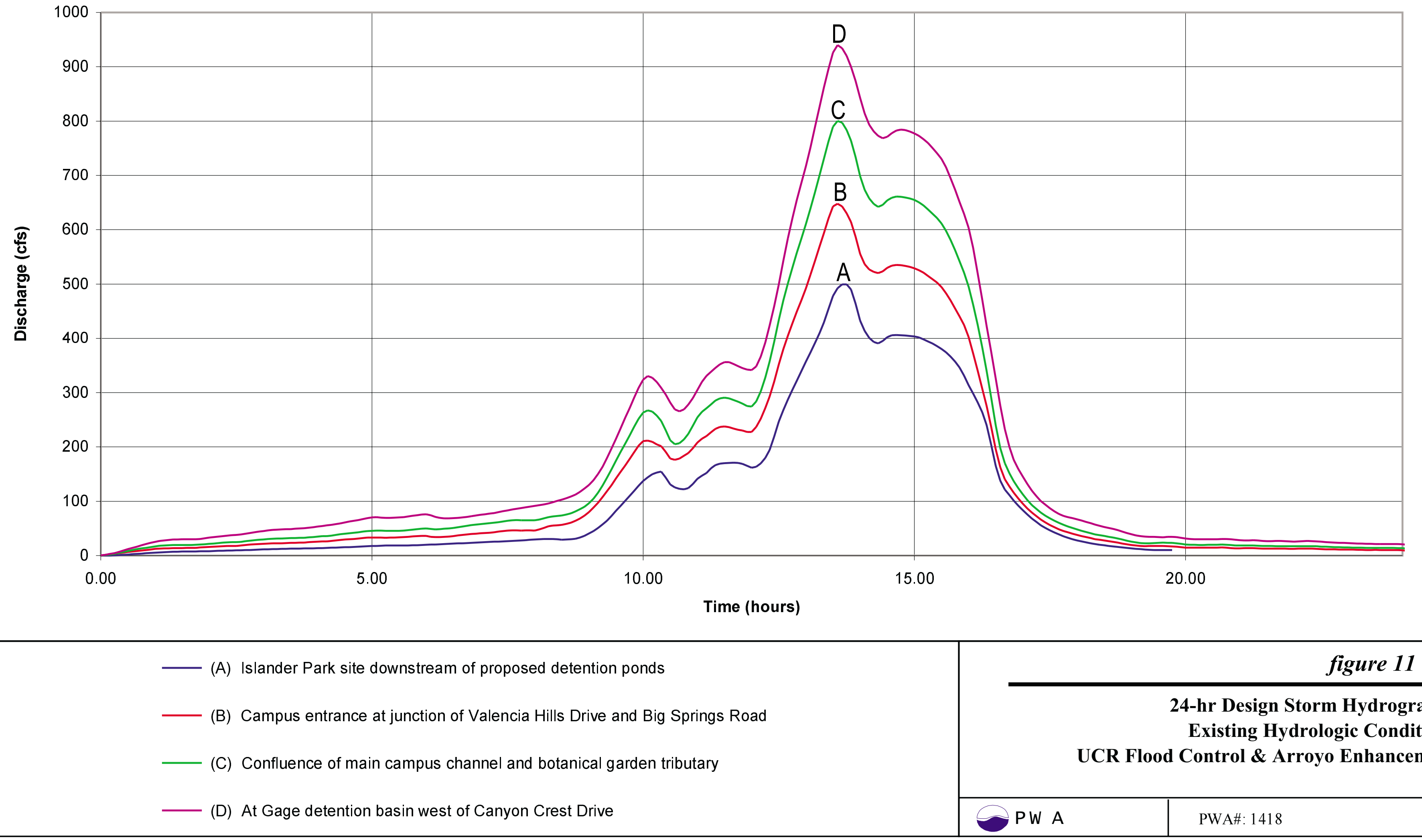


figure 11

24-hr Design Storm Hydrographs
Existing Hydrologic Conditions
UCR Flood Control & Arroyo Enhancement

PWA

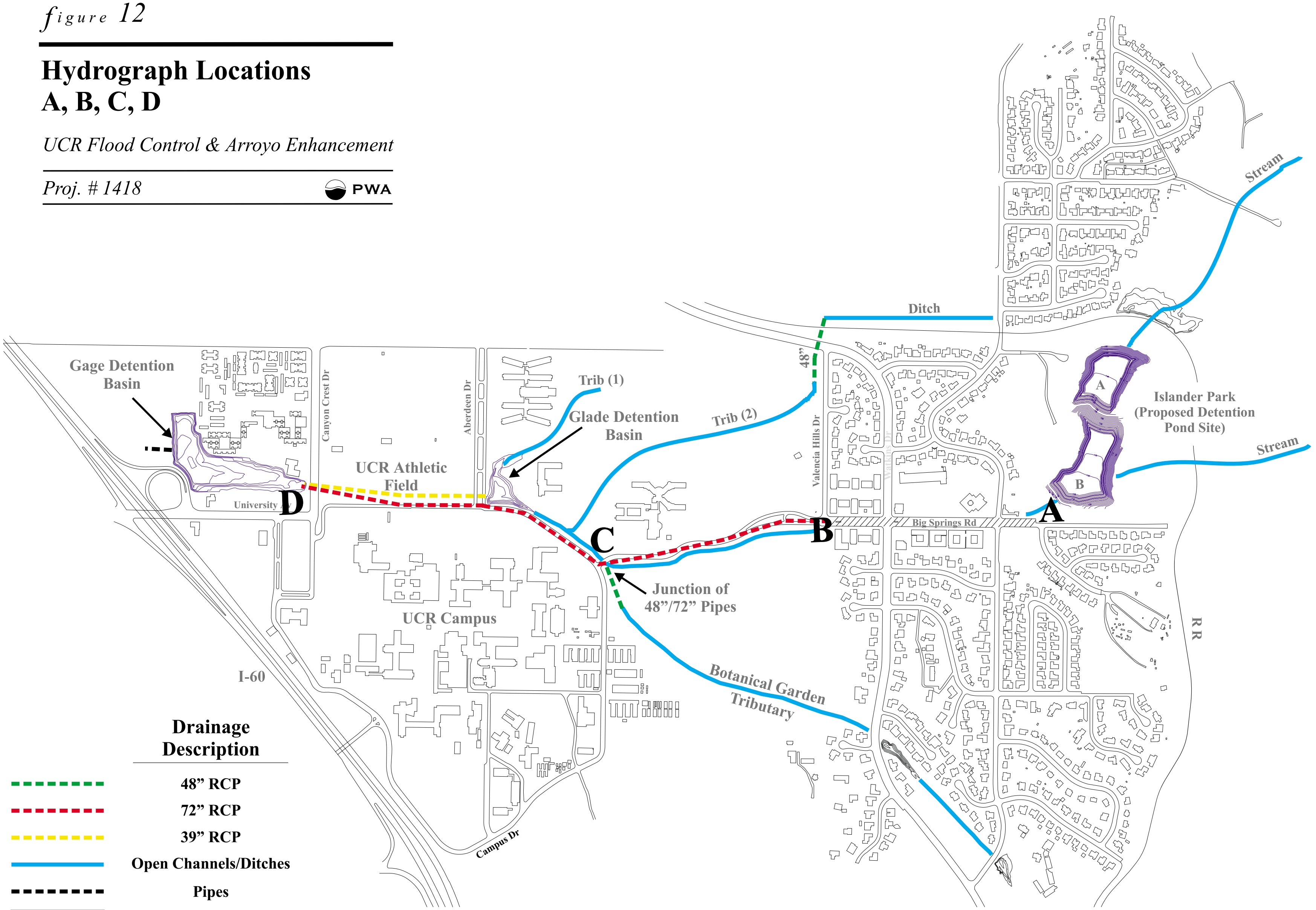
PWA#: 1418

figure 12

Hydrograph Locations A, B, C, D

UCR Flood Control & Arroyo Enhancement

Proj. # 1418 PWA



Drainage Description

green dashed line	48" RCP
red dashed line	72" RCP
yellow dashed line	39" RCP
blue solid line	Open Channels/Ditches
black dashed line	Pipes
hatched bar	Big Springs Rd

Table 5: Time to Peak Discharge

Location	Time (hours) 3-hr Storm	
	Existing Conditions	**With 115 ac-ft detention ponds**
A	2.92	4.25
B	2.83	2.67
C	2.83	2.67
D	2.83	2.75
Location	**Time (hours) 24-hr Storm**	
	Existing Conditions	**With 115 ac-ft detention ponds**
A	13.75	16.50
B	13.58	15.25
C	13.58	13.50
D	13.58	13.50

The hydrographs of Figures 10 and 11 indicate that most of total runoff volume is generated in the Box Springs Mountains upstream of the Islander Park site. The *VALHIL* and *WATFH* sub-basins account for 53% of the total watershed drainage area (Figure 5). Proportional runoff generated by these sub-basins is approximately equal to their aerial proportion, accounting for 51% and 47% of the total runoff volume for the 3-hr and 24-hr storms respectively. The slightly lower runoff volume percentages are attributed to the absence of impervious surfaces within these two sub-basins compared with more developed areas downstream. At the campus entrance, location B downstream of Islander Park, above 70% of total watershed runoff is produced; meanwhile this station represents only 63% of the watershed area. Adding the developed areas of the *DCAM1*, *DCAM2* and *NBIGSP* sub-basins (Figure 7a) results in more proportional runoff than the aerial percentage of these sub-basins to the overall watershed. This notable difference in watershed functioning between locations A and B results from differing human land-use.

In Table 6, the times between the initiation of effective precipitation and the production of 90% of total runoff volume are shown. Under existing conditions, 90% of stormflow volume passes after 3.7 hours for the 3-hr design storm and passes after 16.3 hours for the 24-hr event. Once again, lag times for the undeveloped mountain watersheds upstream of location A are slightly less than at the more developed locations downstream.

2.5.2 Comparison of Results with prior Hydrology Studies

Tables 7 and 8 compare results from the 1998 hydrologic analysis of the University Arroyo Watershed by Webb Associates (Webb), the preliminary PWA feasibility study of July 2000 (which included the proposed detention basins but used the 1998 Webb model as a basis), and the current GIS-based PWA model. Locations along the drainage network identified in these tables can be cross-referenced to the map in Figure 13.

Table 6: Time to 90% of Total Runoff Volume

Location	Time (hours) 3-hr Storm	
	Existing Conditions	**With 115 ac-ft detention ponds**
A	3.67	7.50
B	3.58	7.25
C	3.58	7.00
D	3.58	6.92
Location	**Time (hours) 24-hr Storm**	
	Existing Conditions	**With 115 ac-ft detention ponds**
A	16.25	19.83
B	16.17	19.50
C	16.17	19.25
D	16.25	19.17

Under existing conditions, the Webb and current PWA models are similar; although PWA modeled flows have generally higher peaks. For example, at the entrance to the UCR campus, the Webb (1998) model suggests 1106 cfs whereas the current PWA model estimates 1232 cfs for the 3-hr peak flow. Downstream at the entrance to the Gage Basin the difference between the two studies is more pronounced. Smaller flows from the earlier Webb model result from using higher infiltration rates (nearly double that of the PWA model) during a basin calibration process. The timing of peak flows is also different for the two models due to different predicted lag-time values. Aside from the different infiltration rates, the other principal difference between the two studies is the level of detail at which sub-basins were selected. The Webb model used three large sub-basins to characterize the watershed while the current PWA study delineated the watershed into 15 sub-basins. Using more sub-basins reduces the need to average hydrologic input parameters and allows a more accurate portrayal of flow routing conditions.

2.5.3 Hydrologic effect of proposed Islander Park Detention Ponds

During an earlier feasibility study, engineers from RBF worked with PWA to identify a conceptual detention basin design for the Islander Park site that would maximize flow reduction while minimizing environmental impacts and costs. A two-pond system was selected that has an upper 50 ac-ft basin (Pond A) and a lower 65 ac-ft basin (Pond B) to provide a total of 115 ac-ft of storage (Figure 14). The two principal effects of a detention facility are to reduce peak discharge flow rate and delay the timing of peak discharge.

The hydrologic impact of these two ponds on 100-year flow conditions was evaluated by modifying the existing conditions HEC-1 flow model to include the storage effects of the basins. As described above, approximately 50% of total watershed runoff volume is generated upstream of the Islander Park site (location A) during the 3-hr and the 24-hr design storms.

Table 7: 100-yr 3-hr Storm, PWA and Webb Hydrology Results

Location	Webb (1998) (cfs)	PWA Feasibility Study w/Webb Hydrology (cfs)	Revised PWA Hydrology (cfs)	Revised PWA Hydrology (cfs)	Available Conveyance Capacity (cfs)
	Without Detention	With Detention	Without Detention	With Detention	
(1) Downstream of Proposed Pond B at Big Springs Road (Note 2)	1117	204	1042	248	230 (Note 3)
(2) Campus Entrance at Valencia Hill Drive	1106	203	1232	554	632 (Note 5)
(3) 48” Concrete Pipe Entrance at Base of Botanical Garden Channel	NA	NA	256	256	332 (Note 4)
(4) Campus Junction of 48” and 72” Pipe	1425	562	1480	795	632 (Note 5)
(5) Surface Channel at Glade Detention (Note 8)	NA	NA	179	179	NA
(6) 39” Pipe Exiting the Glade, Running Beneath the Athletic Field to the Gage Basin	NA	NA	155	155	108 (Note 6)
(7) Entrance: Gage Basin	1468	631 (Note 7)	1700	1080	NA
(8) Exit: Gage Basin	442	350	600	524	NA

Notes:

1. More appropriate to use a hydrodynamic model for modeling backwater effects.
2. Discharge values listed for Location 1 for Webb correspond to a watershed area of 1444 ac., while discharge values for PWA correspond to a 1233 ac. Basin (Valhil and WatFH sub-basins only). Therefore, these two flow estimates for Location 1 are not entirely comparable. Also, the PWA flow estimates includes some existing detention at the railroad track (~75 cfs). Basins 7A & B contain significant available storage which will be optimized in preliminary and final design.
3. Pipe capacity estimated assuming normal flow and concrete materials: 48" pipe, n=0.013, s=2.55%
4. Pipe capacity estimated assuming normal flow and concrete materials: 48" pipe, n=0.013, s=5.30%
5. Pipe capacity estimated assuming normal flow and concrete materials: 72" pipe, n=0.013, s=2.26%
6. Pipe capacity estimated assuming normal flow and concrete materials: 39" pipe, n=0.013, s=1.70%
7. Includes ditch, parking lot runoff, BIGUP runoff and BIGDS runoff
8. Earlier bulk models passed all flows through the Glade detention basin

Table 8: PWA Hydrology Results for 100-yr 6-hr and 24-hr Storms

Location	6-hr: Without Detention	6-hr: With Detention	24-hr: Without Detention	24-hr: With Detention	Available Conveyance Capacity (cfs)
(1) Downstream of Proposed Pond B at Big Springs Road (Note 2)	950	251	500	266	230 (Note 3)
(2) Campus Entrance at Valencia Hill Drive	1162	541	648	353	632 (Note 5)
(3) 48" Concrete Pipe Entrance at Base of Botanical Garden Channel	247	247	153	153	332 (Note 4)
(4) Campus Junction of 48" and 72" Pipe	1408	771	800	502	632 (Note 5)
(5) Surface Channel at Glade Detention (Note 8)	167	167	80	80	NA
(6) 39" Pipe Exiting the Glade, Running Beneath the Athletic Field to the Gage Basin	145	145	80	80	108 (Note 6)
(7) Entrance: Gage Basin	1638	1056	940	654	NA
(8) Exit: Gage Basin	603	527	580	522	NA

Notes:
1. More appropriate to use a hydrodynamic model for modeling backwater effects.
2. Basins 7A & B contain significant available storage which will be optimized in preliminary and final design.
3. Pipe capacity estimated assuming normal flow and concrete materials: 48" pipe, n=0.013, s=2.55%
4. Pipe capacity estimated assuming normal flow and concrete materials: 48" pipe, n=0.013, s=5.30%
5. Pipe capacity estimated assuming normal flow and concrete materials: 72" pipe, n=0.013, s=2.26%
6. Pipe capacity estimated assuming normal flow and concrete materials: 39" pipe, n=0.013, s=1.70%
7. Includes ditch, parking lot runoff, BIGUP runoff and BIGDS runoff

figure 13

Hydrograph Locations for comparison in Tables 7 & 8

UCR Flood Control & Arroyo Enhancement

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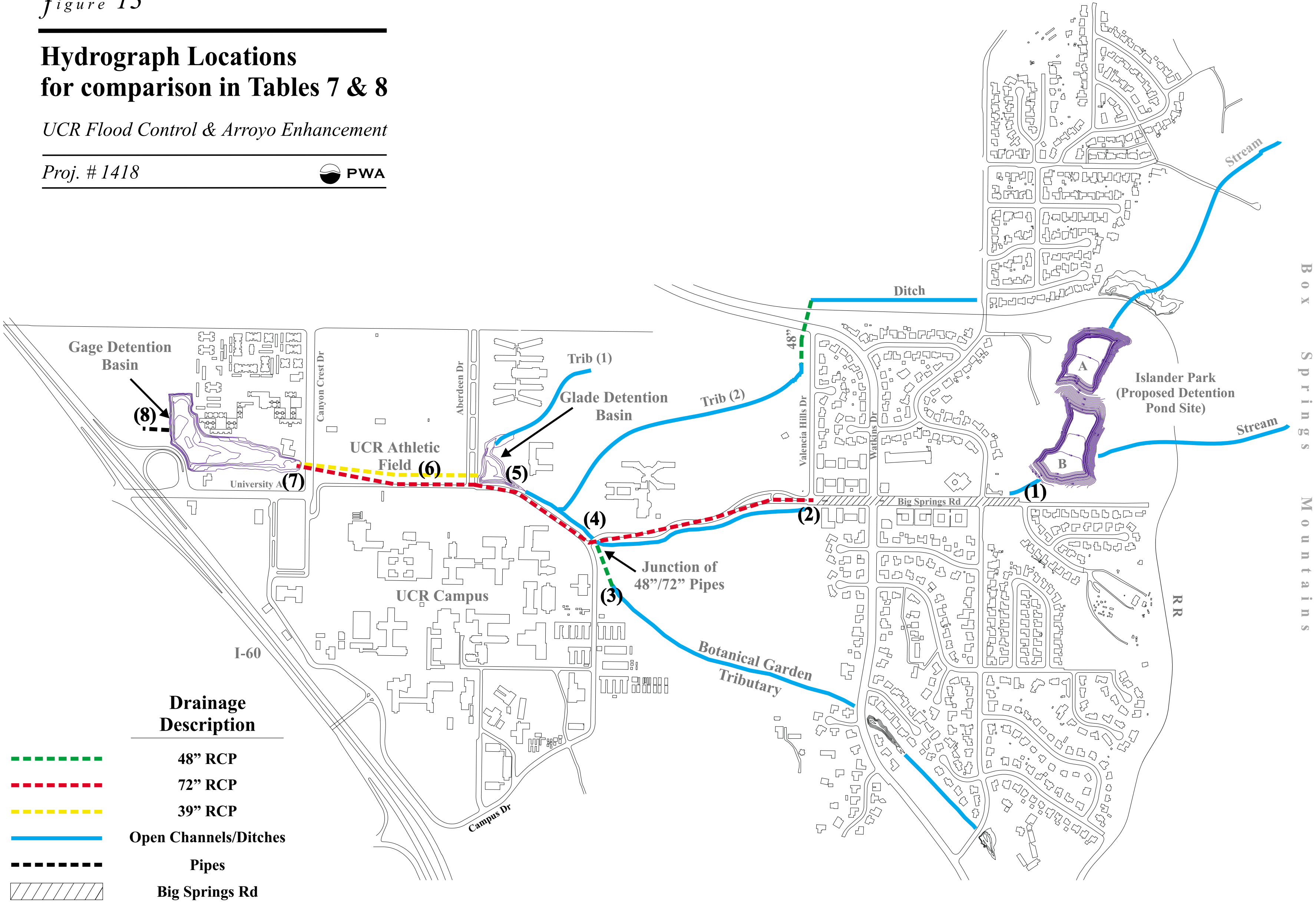

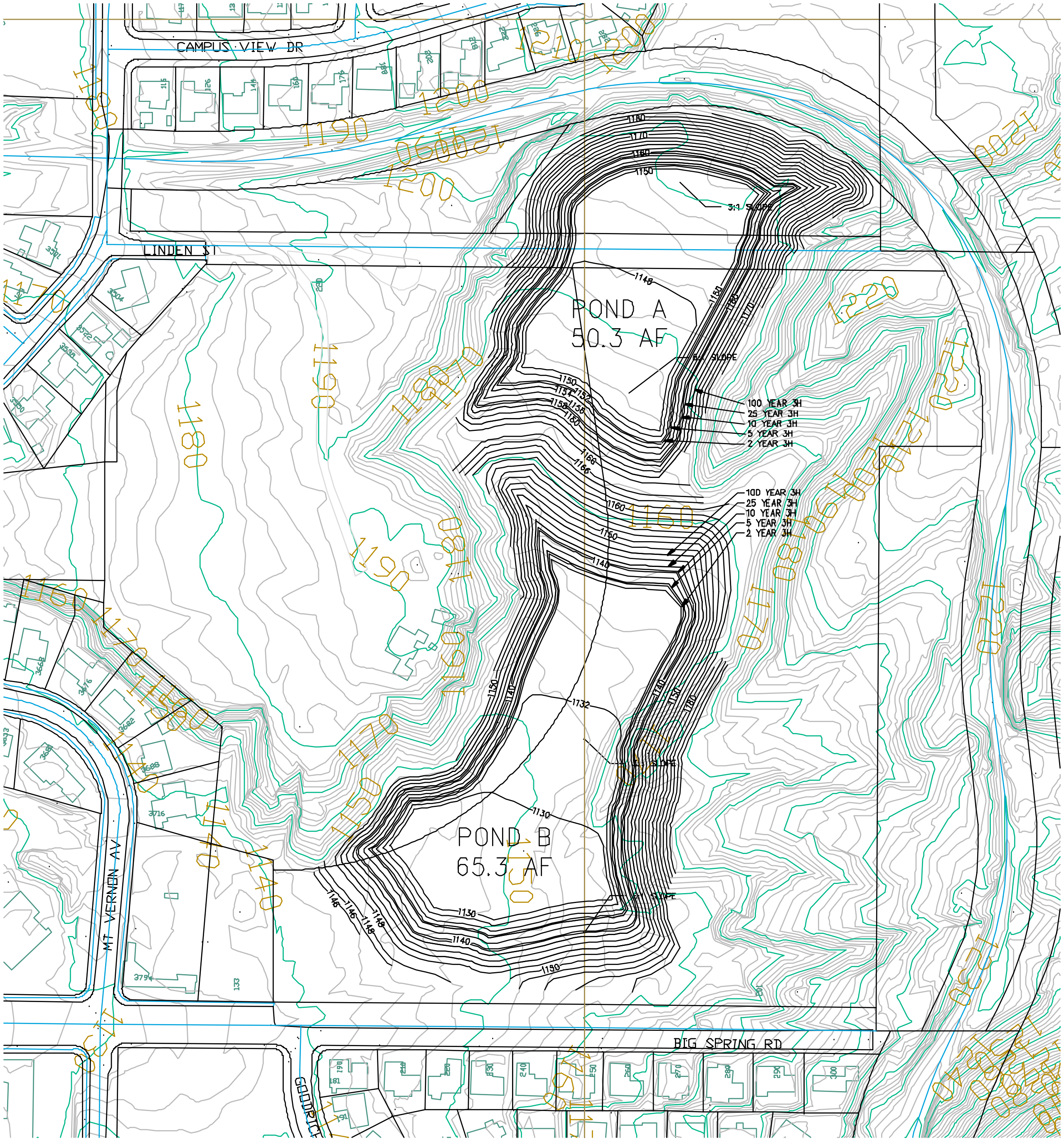

POND A

STORAGE VOLUME = 50.3 AF
AREA (WS) = 4.3 AC
DEPTH = 16 FT

STAGE FT	STORAGE AF
1148	0
1150	3.6
1152	8.8
1154	14.4
1156	20.5
1158	27.1
1160	34.3
1162	42.0
1164	50.3

POND B

STORAGE VOLUME = 65.3 AF
AREA (WS) = 5.8 AC
DEPTH = 16 FT

STAGE FT	STORAGE AF
1130	0
1132	3.6
1134	9.5
1136	17.0
1138	25.2
1140	34.0
1142	43.7
1144	54.1
1146	65.3

STORM	BASIN 7A		BASIN 7B	
	MAX W.S. ELEV.	DRAIN TIME (HR)	MAX W.S. ELEV.	DRAIN TIME (HR)
100Y-3H	1163.9	4.33	1145.9	6.83
25Y-3H	1160.4	3.83	1142.9	6.00
10Y-3H	1158.5	3.50	1141.1	5.42
5Y-3H	1154.3	3.17	1136.8	4.00
2Y-6H	1152.7	3.17	1135.4	3.50

ENCROACHMENT ACROSS PROPERTY LINE = 4.1 AC

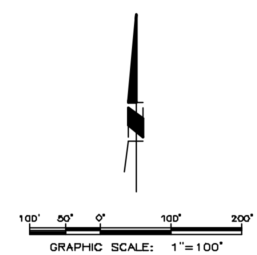

figure 14

Two Pond Design

PWA

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The hydrographs of Figures 15 and 16 illustrate the drastic reduction in peak flows of the 3-hr and 24-hr storms due to the proposed detention ponds. Peak discharge at the Islander Park site (location A**)** is reduced by over 76% from 1042 cfs to 248 cfs for the 3-hr event and lowered 47% from 500 cfs to 266 cfs for the 24-hr event (Table 4). At the Gage Basin downstream (location D), 3-hr peak flows are reduced by 36% from 1700 to 1080 cfs.

Figures 15 and 16 also indicate a delay of 2.75 hours in the timing of peak flows at location A for both the 3-hr and 24-hr events (Table 5). Downstream at location D, peak discharge actually occurs slightly earlier with the detention basins due to the timing of local campus runoff.

Another index of the effectiveness of the detention ponds is the time required for 90% of total runoff volume to pass the outlet. This parameter provides a combined measure of peak flow reduction rates and relative storm volume. Table 6 shows that the time-lag for the passage of 90% runoff volume doubles from about 3 hours to over 7 hours for the 3-hr event and increases by about 20% for the 24-hr event.

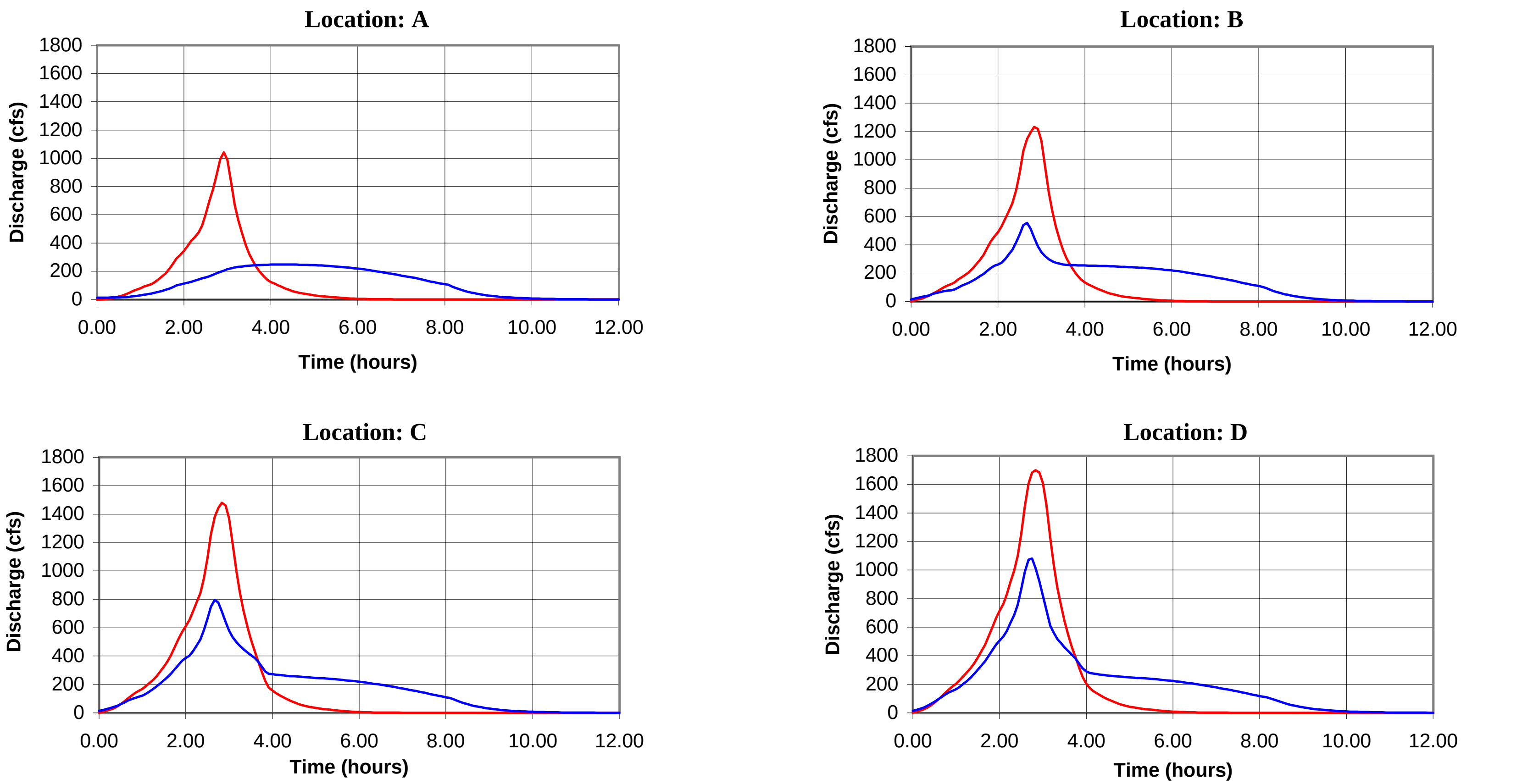
2.5.4 Hydrologic Refinement

The preliminary hydrology results (Tables 7 and 8) indicated that even with the detention basins, peak flow rates still exceeded the available conveyance capacity at the campus junction of the 48” and 72” pipes (Figure 2). The peak flow rate at the pipe junction is approximately 800 cfs, about 160 cfs more then the maximum estimated pipe capacity. At other locations such as the entrance of the 72” pipe at Valencia Hill Drive. and the 48” pipe at the base of the Botanical Garden tributary, peak flow rates were estimated to be less than available conveyance capacities. However, this hydrologic modeling was static and did not consider backwater and other hydraulic effects within the pipe network that may have further reduced conveyance.

In addition the preliminary hydrologic model was not capable of:

- Optimizing the two-pond design to maximize on-site storage conditions, reduce downstream peak flows, and reduce construction costs.
- Correctly modeling flow interactions between the open channel stream system and the piped drainage network.
- Evaluating other alternatives to reduce potential flooding including: re-routing additional tributary flows to the detention basins; bypassing on campus flows from the botanical garden channel directly to the Gage Basin; enlarging the on-campus open channel capacity; and installing an on-campus detention basin along the botanical garden channel.

To address these issues a hydrodynamic analysis of the University Arroyo system was conducted and different project alternatives were evaluated based on their flood reduction impact. These results are presented in Sections 3 and 4 below.



Legend

Existing Hydrologic Conditions

Proposed Hydrologic Conditions (Includes Islander Park Detention Ponds A & B)

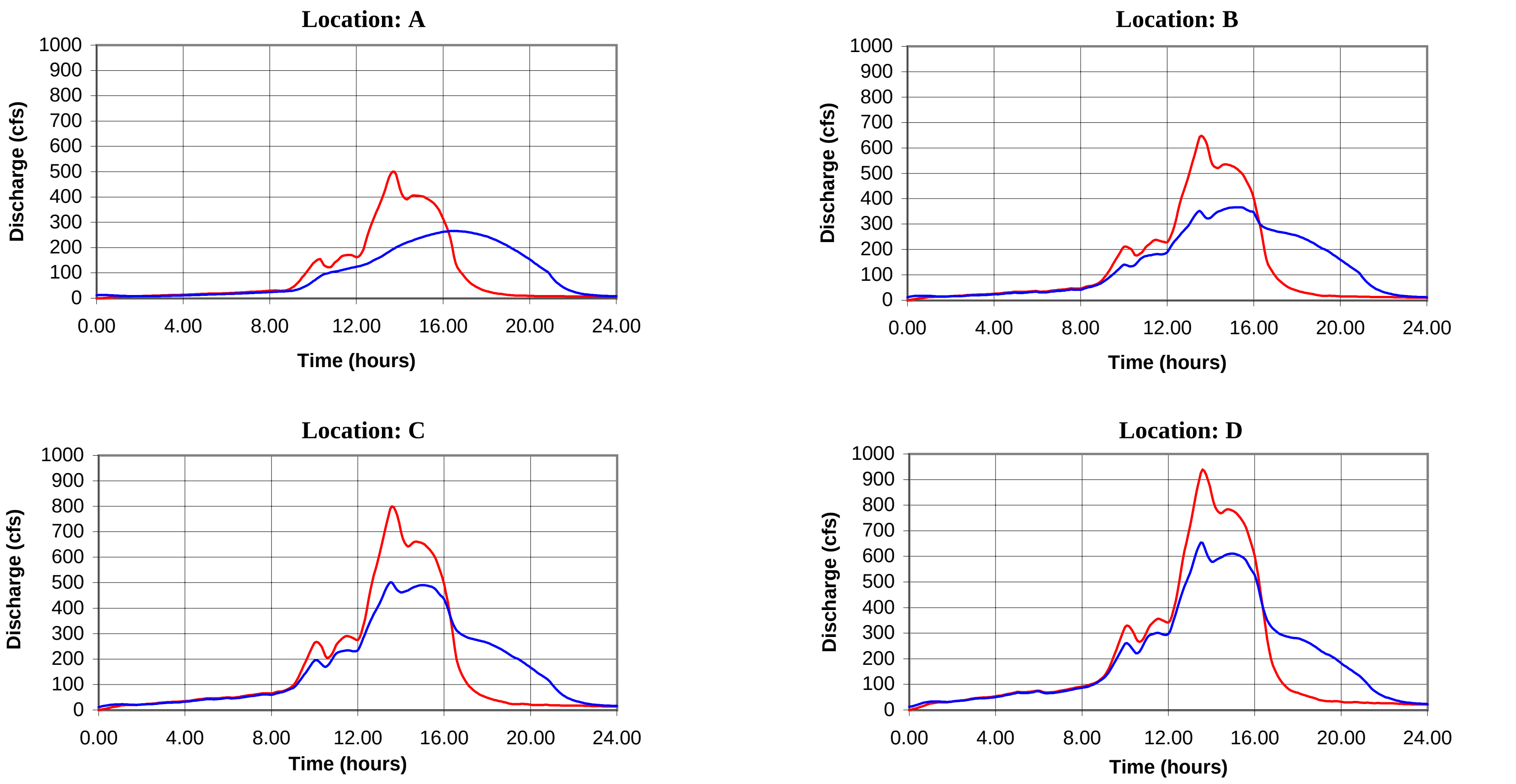
(A) Islander Park site downstream of proposed detention ponds
(B) Campus entrance at junction of Valencia Hills Drive and Big Springs Road
(C) Confluence of main campus channel and botanical garden tributary
(D) At Gage detention basin west of Canyon Crest Drive

figure 15

3-hr Design Storm Hydrographs Existing vs. Proposed Conditions

PWA

PWA#: 1418



Legend

Existing Hydrologic Conditions

Proposed Hydrologic Conditions (Includes Islander Park Detention Ponds A & B)

(A) Islander Park site downstream of proposed detention ponds
(B) Campus entrance at junction of Valencia Hills Drive and Big Springs Road
(C) Confluence of main campus channel and botanical garden tributary
(D) At Gage detention basin west of Canyon Crest Drive

figure 16

24-hr Design Storm Hydrographs
Existing vs. Proposed Conditions

PWA

PWA#: 1418

3. HYDRODYNAMIC MODELING

3.1 INTRODUCTION AND METHODS

In order to address remaining issues from the baseline hydrologic analysis (Section 2) and to also provide a model capable of evaluating project alternatives, a more robust hydrodynamic model was constructed for the University Arroyo drainage system. The US EPA Storm Water Management Model (SWMM) with EXTRAN (Extended Transport) module was selected for this analysis because of its capability to analyze closed conduit and open channels simultaneously. EXTRAN solves the fully dynamic equations for gradually varied flow (St. Venant equations) computing time histories of flow and head throughout the system. The University Arroyo SWMM/EXTRAN model was developed to examine the influence of the proposed Islander Park detention ponds on the current downstream conveyance system and to identify locations with insufficient capacity. The SWMM model was also used to refine the detention basin configuration, examine locations where flooding or capacity limitations were identified by the HEC-1 hydrologic analysis, and test the effectiveness of other alternatives.

3.2 MODEL PARAMETERS

All inflow hydrographs used in the University Arroyo EPA SWMM analysis were developed from the PWA HEC-1 model described in Section 2 of this report. Cross-sectional channel data used in the model was generated from detailed 2-ft contour maps provided by the City of Riverside, where the distance between cross-sections was determined by pipe or culvert locations. On the UCR campus, intervals between channel cross-sections are about 500 feet to maintain topographic accuracy.

Flow structures including pipes, culverts, detention basins, storm drains, and road intake grates were modeled based on plans and specifications provided by RCFCWCD, City of Riverside Department of Public Works, and UCR Office of Design and Construction. PWA verified features of structures and channel conditions in the field. The outlet structure from Gage Basin, (which is the only outfall for the model), was assumed to operate as free outfall (i.e. no backwater influence from downstream). Engineers at the City of Riverside supported this assumption.

Estimates of Manning's roughness coefficient (*n*) for the open channel regions were estimated based on field evaluations and range from 0.2 to 0.5. A Manning's n-value of 0.013 was assumed for all stormwater pipes and culverts and an n-value of 0.016 was applied to water conveying roads. The EXTRAN module does not explicitly address local energy losses associated with pipe manholes, bends, entrances/exits etc, but does allows the modeler/engineer to manually prescribe energy loss values uniquely. Energy loss coefficients were selected based on published values from the Handbook of Hydraulics (Person and Person, 1962).

The University Arroyo SWMM model consists of a number of individual open channel and piped reaches (Figure 17). Stormwater pipes and culverts were included in the model, and manholes are "surface-linked" to ensure water distribution during surcharge and flooding. Engineered detention structures, as well as natural features that provide additional retention, were modeled to depict flow routing conditions.

3.3 EXISTING CONDITIONS HYDRODYNAMIC MODEL

Results from the existing conditions SWMM/EXTRAN model indicate several refinements from the initial hydrologic analysis performed with HEC-1. Table 9 compares discharge and depth estimates from the two models. Locations in Table 9 match the locations listed in Tables 7 and 8 and are shown in Figure 13.

In the SWMM model, flows leaving the proposed Islander Park detention ponds (897 cfs) are lower than HEC-1 estimates (1042 cfs) because the SWMM model more accurately routes a portion of the stormflow from north of the railroad tracks to the west (Figure 17). At the campus entrance, intake grates on Big Springs Rd. limit flow entering the campus main 72" drainage pipe to 236 cfs while surface discharge (784 cfs) inundates the campus entrance road to a depth of 2.3 ft prior to entering the campus open channel. At the base of the Botanical Garden tributary, 100-year stormflows spill over the entrance of the 48" pipe into the adjacent parking lot and road. At the campus junction, surface flows are 3.4 ft deep and flooding is widespread. Downstream, the SWMM model predicts the Campus Glade is filled to capacity with flows spilling over and flooding the athletic field. The 3-hr 100-year event fills the Gage Basin to a depth of 15.6 ft with a peak exit flow of 652 cfs from the basin.

The fully dynamic nature of the SWMM model accounts for pipe pressurization and backwater effects. The HEC-1 results do not reflect this. For example, the HEC-1 model estimates 255 cfs at the entrance to the 48" pipe at the base of the Botanical Garden tributary (Table 9). In contrast, the SWMM model estimates only 215 cfs as a result of backwater effects due to the pressurization of the pipe system further downstream.

The most recent Federal Emergency Management Agency (FEMA) Flood Insurance Study (Aug 2, 1996: #060260) of University Arroyo provides water surface elevations and identifies the estimated 100-year floodplain boundaries along the stream through the UCR campus and surrounding areas (Figure 18). Comparing Figures 2 and 18 indicates that the estimated floodplain occupies much of the proposed Islander Park site, as well as, a broad swath through the central campus area. FEMA's water surface analysis was conducted using the USACOE HEC-2 hydraulic model.

PWA sought to verify its current existing conditions hydrodynamic model by comparing water depth results with the FEMA analysis. Figure 19 compares water surface profiles from the current PWA existing conditions model using SWMM and the earlier FEMA flood study using HEC-2. In general the PWA profile and the FEMA water surface profile were consistent within 0.5 ft. The exact

figure 17

University Arroyo EPA-SWMM Model Network

UCR Flood Control & Arroyo Enhancement

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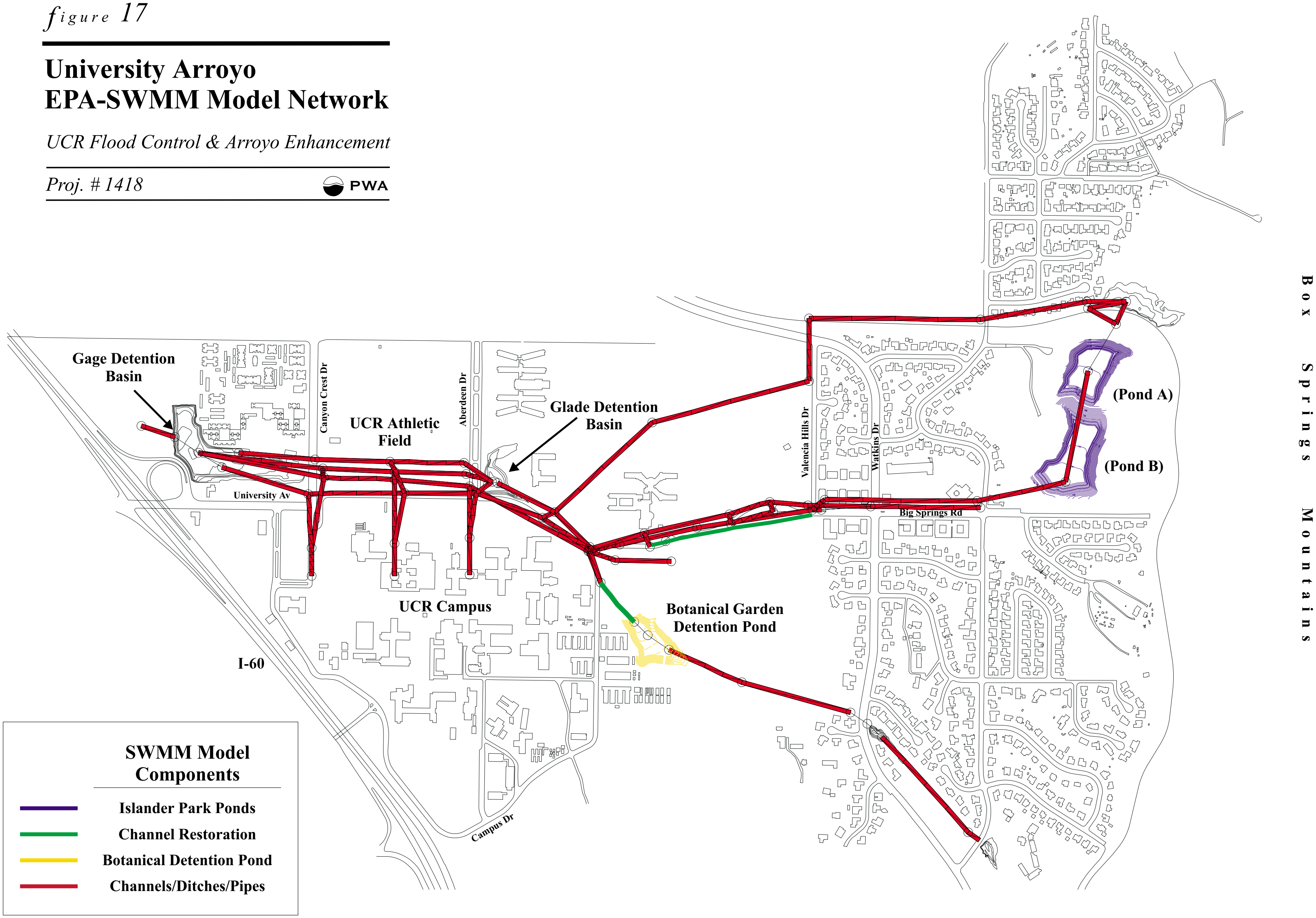


Table 9: Hydrodynamic Modeling Results for Existing Drainage Conditions.

Results from EPA SWMM model are compared to previous HEC-1 results at eight locations across the University Arroyo. Results shown are for the 100-year recurrence interval 3-hour storm event.

Locations		SWMM Hydrodynamic Model Results		HEC-1 Hydrologic Model Results	
		Discharge (cfs)	Depth (ft)	Discharge (cfs)	Depth (ft)
(1) Downstream of the Proposed Islander Park Detention Pond Site	Surface	897	1.1	-	-
	Sub Surface	-	-	-	-
Depth and discharge estimates located at the southeast corner of Islander Park.	*Total*	**897**	**1.1**	**1042**	**N/A**
(2) Campus Entrance: Big Springs Rd & Valencia Hills Dr	Surface	784	2.3	-	-
	Sub Surface	236	-	-	-
Surface measurements made at the eastern entrance of the UCR campus immediately west of the existing surface grate at the junction of Big Springs Road and Valencia Hills Drive. Sub surface flows provided at the entrance to the existing main 72" storm drain. HEC-1 results lump surface and sub surface results togeather.	*Total*	**1022**	**2.3**	**1232**	**N/A**
(3) 48" RCP at the Base of the Botanical Garden Tributary	Surface	40	0.5	-	-
	Sub Surface	184	-	-	-
Surface flows leaving the botanical garden tributary (40 cfs) flow down Campus Drive. Sub surface flows (184 cfs) are conveyed in the exisiting 48" RCP. HEC-1 results lump both surface and sub surface flows togeather.	*Total*	**224**	**0.5**	**256**	**N/A**
(4) Junction of Campus Drive and Big Springs Road	Surface	40 + 754	3.4	-	-
	Sub Surface	429	-	-	-
Surface flows immediately downstream from the junction of Campus Drive and Big Springs Road originate from the road itself (40 cfs) and the ditch running parallel to Big Springs Road (754 cfs). Sub surface flows in the main 72" RCP are 429 cfs. HEC-1 results lump surface and sub surface togeather.	*Total*	**1223**	**3.4**	**1480**	**N/A**
(5) Surface Channel at the Glade Detention Pond	Surface	529 + 392	11.2	-	-
	Sub Surface	-	-	-	-
SWMM results estimate surface flows entering the Glade to be 529 cfs (existing ditch) and 392 cfs (roadway and surrounding area). *HEC-1 results are not linked to the main campus channels and only include surface flows from the northern tributaries. The total depth of the Glade detention pond is roughly 11.2'	*Total*	**921**	**11.2**	**155 ***	**N/A**
(6) Surface channel at the Athletic Field	Surface	756	1.2	-	-
	Sub Surface	-	-	-	-
Discharge and depth predictions for the athletic field. Sub surface flows not included in the SWMM results.	*Total*	**756**	**1.2**	**1042**	**N/A**
(7) Gage Detention Pond Entrance	Surface	38 + 756	15.6	-	-
Surface flows entering the gage detention basin originate from the atheletic field (756 cfs) and the road (38 cfs). Sub surface flows enter gage from the main 72" campus drain (490 cfs) and the smaller 39" conduit draining the Glade detention pond (143 cfs). HEC-1 results lump surface and sub surface results togeather. The total depth of Gage basin is roughly 15.6'	Sub Surface	143 + 490	-	-	-
	Total	**1427**	**15.6**	**1700**	**N/A**
(8) Gage Detention Pond Exit	Surface	-	-	-	-
	Sub Surface	326 + 326	2.5	-	-
Flow estimates taken immediately downstream from the gage basin outlet structure which is controlled by two 54" by 60" rectangular orifices.	*Total*	**652**	**2.5**	**600**	**N/A**

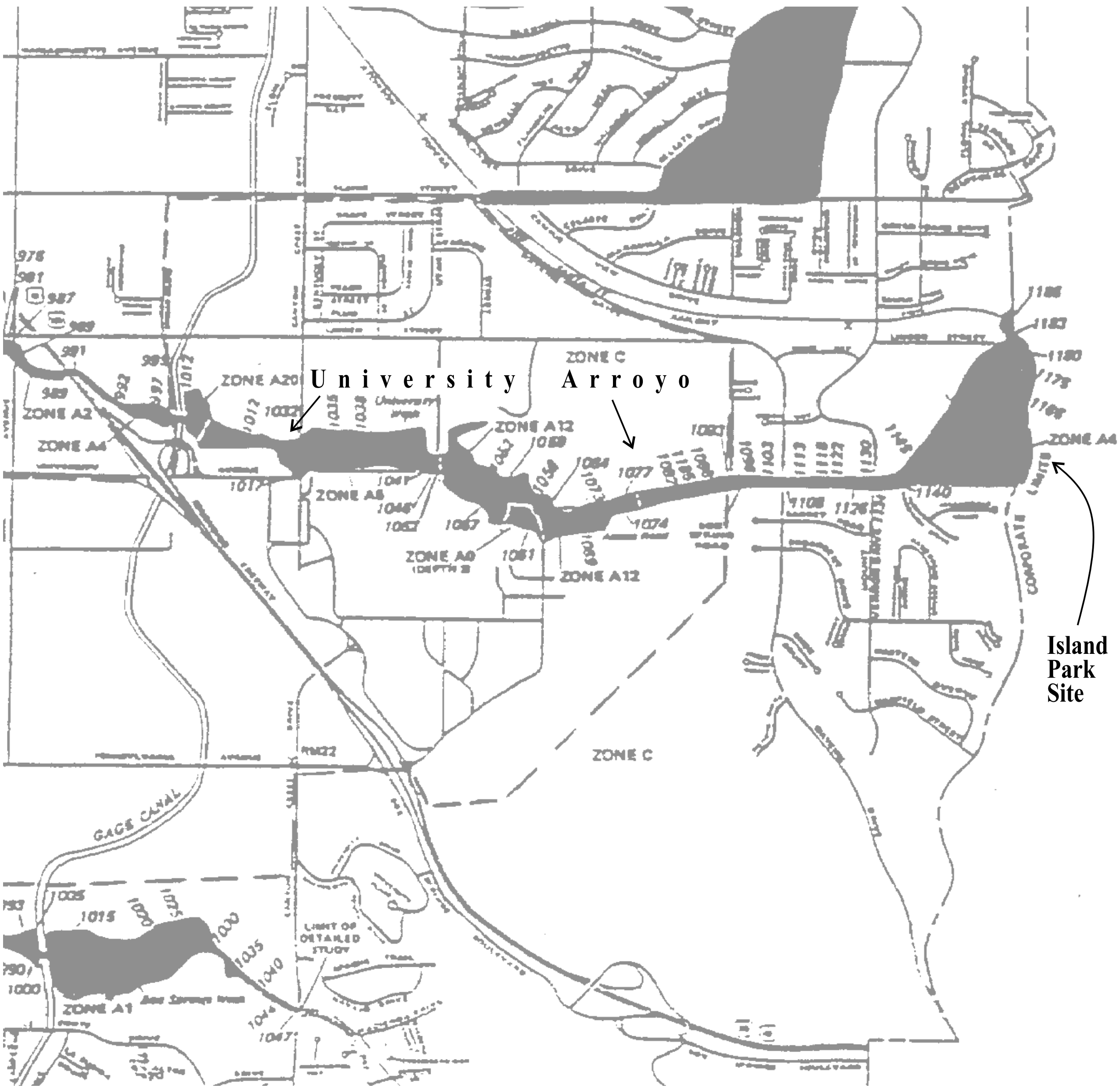
figure 18

FEMA Floodplain Boundaries

UCR Flood Control & Arroyo Enhancement

Proj. # 1418 PWA

= Area inundated during 100-year flood



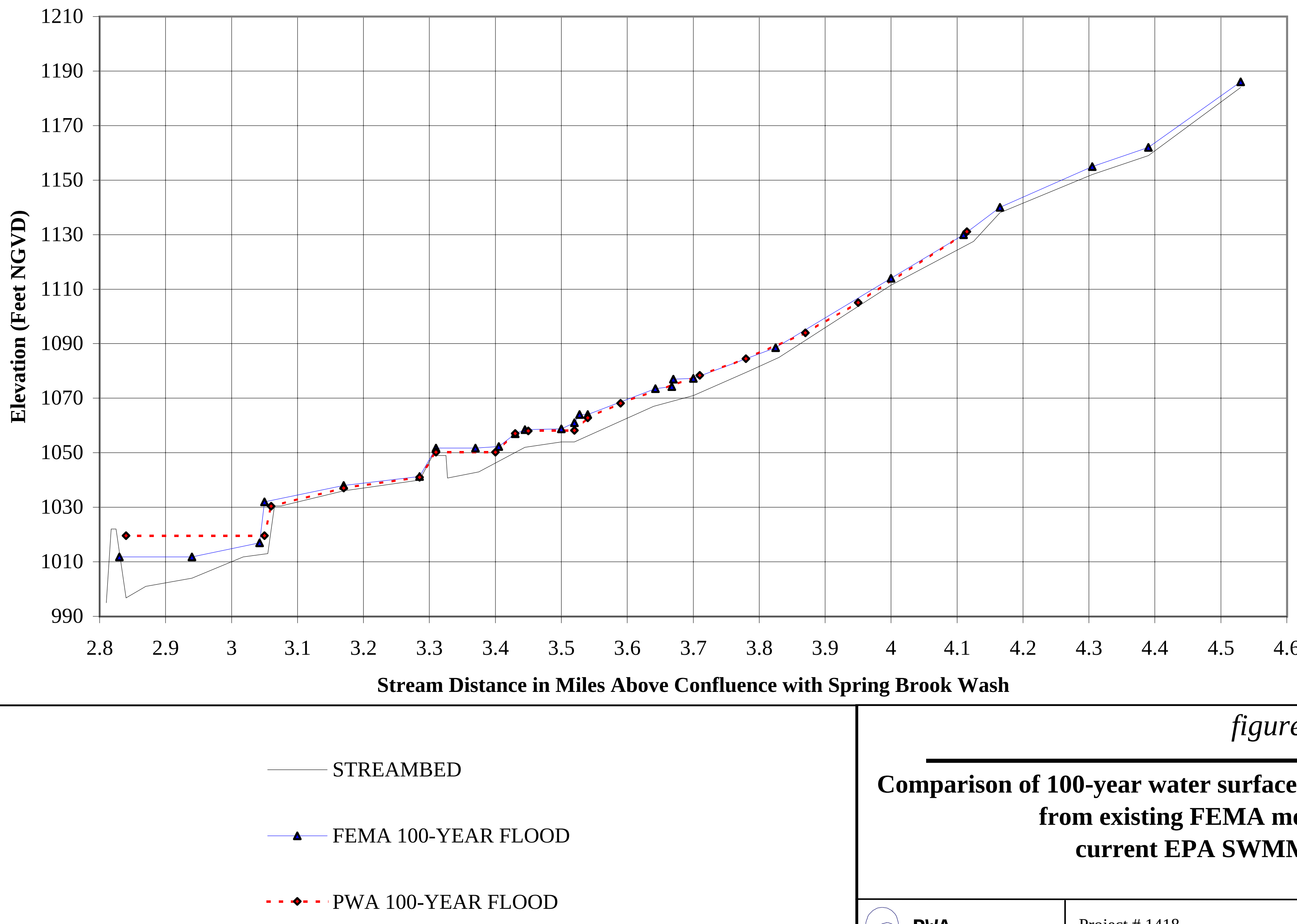


figure ***19***

Comparison of 100-year water surface profiles from existing FEMA model and current EPA SWMM Model

PWA

Project # 1418

matching of water surface profiles from the two models is not expected for several reasons. First, there are several differences in how the models operate in terms of hydraulic calculations; second, there are differences in the hydrologic and geometric input data used to run the models; third, (and perhaps most importantly), the two studies use different representations of the drainage network. The original FEMA HEC-2 model consists of a single branch while the current PWA SWMM model is assembled from 7 major branches (Figure 17). This more detailed PWA representation of the drainage system produces a more refined hydraulic model with more specific results. In Section 4 below, PWA's existing conditions hydrodynamic model is used as a baseline to evaluate the hydrologic effectiveness of various project alternatives to streams, drainage channels, and potential campus and downstream flooding conditions.

4. ALTERNATIVES ANALYSIS

To reduce the existing 100-year flood hazard, project alternatives were proposed and analyzed. Alternatives are grouped into two categories: (1) alternatives which offer both on-campus and broader regional flood management benefits; and (2) on-campus alternatives which reduce the existing 100-year on-campus flood hazard. In total, seven alternatives (A through G) were evaluated.

The four regional alternatives (A through D) include two large detention ponds located at the Islander Park site. In addition to the two common detention ponds, the proposed regional alternatives also include on-campus facilities such as an additional on-campus detention pond, bypass pipe sections, and restored channel reaches. Modifications to the existing outlet structure from the Gage Basin were also considered in the designs. The three on-campus alternatives also include an on-campus detention pond in addition to increased open channel capacity, channel restoration, and new pipe, or culvert, sections. The following sections describe the components and hydrologic impacts of each alternative in more detail. A final section (4.3) discusses the recommendation of the preferred regional and on-campus alternatives.

4.1 REGIONAL ALTERNATIVES

4.1.1 Alternative A

Alternative A consists of two "full-sized" Islander Park detention ponds (Figure 14). The total storage estimated for these ponds is 115.6 ac-ft (50.3 ac-ft for Pond A and 65.3 ac-ft for Pond B). Both ponds will be approximately 18 ft deep with at least 2 ft of freeboard above the predicted 100-yr flood. These ponds are connected to the existing 72" storm pipe at the junction of Big Springs Road and Valencia Hill Drive by a 1600 foot 48" RCP culvert. Alternative A also includes an on-campus detention pond located just downstream of the campus Botanical Garden (Figure 17). A 300 ft open channel reach will link this pond to the existing 48" RCP culvert which flows northward and connects to the main 72" pipe at the campus junction (Figure 2). This open channel reach on the Botanical Garden tributary will be restored to improve geomorphic and hydrologic function. Alternative A also includes restoring 1300 ft of the main campus open channel that runs parallel to Big Springs Road (Figure 4b). The modified channel will be enlarged to convey required flows and enhanced to produce improved riparian habitat conditions. Downstream, the outlet structure from the Gage Basin will be modified to include a single 54 in x 60 in rectangular orifice rather than the existing double orifice.

Hydrologically, Pond A detains approximately 45.1 ac-ft during the 24-hr volume-design storm with 3.3 ft of freeboard. Under maximum pond depth conditions, Pond A discharges about 86 cfs into Pond B. During the 24-hour event, Pond B holds approximately 58.9 ac-ft with 3.2 ft of freeboard. The peak outflow from Pond B is approximately 110 cfs. The outlet structure for each basin was optimized to attain maximum detention and thus minimum outflow discharges.

Discharge exiting Pond B enters a 48” pipe, which flows beneath Big Springs Rd and connects with the main campus 72” pipe. Maximum flow conditions in the main 72” pipe running east to west beneath the campus vary along the length of the pipe as a result of hydrodynamic effects. During the 3-hr storm event, peak flow at the pipe inlet at the eastern campus entrance is approximately 243 cfs, while at the outlet into the Gage Basin discharge increases to about 440 cfs. These flow rates are within the estimated flow conveyance capacity of the 72” pipe. The hydrologic impacts of Alternative A are summarized in Table 10. A restored on-campus main surface channel (running parallel to Big Springs Road) could convey 195 cfs during peak flows of the 3-hr storm event. The 24-hr storm produces peak flow rates of approximately 57 cfs in the surface channel. With the features of Alternative A, the 11.2 ft deep campus Glade fills to maximum depths of 8.8 ft and 4 ft during the 3-hr and 24-hr events respectively, and does not spill over Aberdeen Rd into the campus athletic field. The 39” RCP outlet conduit that connects the Glade to the Gage Basin has peak flows of 111 cfs and 97 cfs under 3-hr and 24-hr conditions respectively. These flow rates are within the estimated flow conveyance capacity of the 39” pipe.

The maximum predicted depth at Gage Basin for Alternative A is roughly 16.9 feet during the 24-hr storm. Under the 100-year 3-hr storm, the maximum water depth is predicted to be approximately 14.4 feet. Peak discharge leaving the modified Gage Basin outlet structure (a single 54” x 60” orifice) is 350 cfs for the 24-hr storm and 300 cfs for the 3-hr event.

Along the Botanical Garden tributary channel, the proposed 14 ft deep detention pond (7.7 ac-ft) is filled to 11.8 ft (2.2 ft freeboard) during the 3-hr event and filled to 9.7 feet (4.3 ft freeboard) during the 24-hr event. The restored open channel tributary reach conveys peak flows of roughly 126 cfs for the 3-hr storm and 115 cfs for the 24-hr event. These flows are within the estimated capacity of the 48” connecting pipe which leads to the main 72” campus drain (Figure 2).

Under Alternative A, the standard analysis shown indicate that surface water flooding during a 100-yr event would be maintained with the capacities of the existing and proposed drainage facilities.

4.1.2 Alternative B

Alternative B is similar to Alternative A in that it includes: two 18 ft deep Islander Park detention ponds with a total storage capacity of 115.6 ac-ft; 1600 feet of 48” RCP to connect Pond B to the existing 72” main campus pipe; 1300 ft of main campus channel restoration; modification of the Gage Basin outlet orifice; and a 7.7 ac-ft on-campus detention pond along the Botanical Garden tributary channel. The primary difference between alternatives A and B is the connection of the on-campus pond with the existing 48” pipe. For Alternative A, this conduit occurred as a 300 ft open channel reach. For Alternative B, this link occurs as 300 feet of additional 48” RCP linked directly to the detention pond.

Table 10: Alternative A

Two full sized Islander Park detention ponds linked to the existing 72" storm sewer at the Junction of Big Springs Road and Valencia Hills Road with 1600 feet of 48" RCP. An on-campus detention pond located immediately downstream from the botanical garden with associated channel restoration. Channel restoration and culvert modifications to the surface channel immediately south of Big Springs Road on campus. Modification of Gage Basin outlet structure to use only a single exit orifice.

		Alternative Features						
		Pond A	**Pond B**	**On-Campus Channel Restoration**	**Detention Pond**		**Bypass Conduit**	
		Full 18' Deep + 300' - 30" RCP	*Full 18' Deep + 1300' - 48" RCP*	*Channel Restormation 1300'*	*Natural Channel Connection & Restoration*	*Direct Pipe Bypass (300' - 48" RCP)*	*~3000' - 54" RCP to Gage Basin*	*~4000' - 54" RCP to Gage Channel*
Locations		Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)
72" Campus Drain: Big Springs Rd & Valencia Hills Dr	3hr	*243 cfs* *NA*	*243 cfs* *NA*	*243 cfs* *NA*	*243 cfs* *NA*			
	24hr	*191 cfs* *NA*	*191 cfs* *NA*	*191 cfs* *NA*	*191 cfs* *NA*			
Restored Surface Channel Parallel to Big Springs Rd	3hr	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*			
	24hr	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*			
Main 72" Conduit at the Juction of Campus Dr & Big Springs Rd	3hr				*365 cfs* *NA*			
	24hr				*300 cfs* *NA*			
Botanical Garden Tributary	3hr				*126 cfs* *1' - 2.5'*			
	24hr				*115 cfs* *1' - 2.4'*			
Glade Detention Basin	3hr				*NA* *8.8'*			
	24hr				*NA* *4.1'*			
Gage Detention Basin	3hr				*300 cfs* *14.4'*			
	24hr				*350 cfs* *16.9'*			

The hydrologic effect of Alternative B is shown in Table 11. Estimated flow conditions are identical for both the A and B alternatives. The differences between the two scenarios are the more favorable ecological and maintenance conditions associated with the open channel reach of Alternative A.

4.1.3 Alternative C

Alternative C is similar to alternatives A and B in that it includes: two 18 ft deep Islander Park to the existing 72" main campus pipe; 1300 ft of main campus channel restoration; and modifying the Gage Basin outlet orifice. However, Alternative C does not involve an additional on-campus detention pond along the Botanical Garden tributary. Rather, flows from the Botanical Garden tributary enter a 3000 ft long 54 in RCP bypass pipe and are diverted through campus directly to the Gage Basin. This bypass prevents non-detained flows from the Botanical Garden tributary from exceeding the conveyance capacities of the existing 48" and 72" campus pipes.

In terms of hydrologic impacts, flow conditions for Alternative C are identical to the A and B alternatives in the upstream reach between the Islander Park detention ponds and the UCR campus (Table 12). Differences in flow conditions between the alternatives occur further downstream. The bypass pipe effectively reduces flow at the campus junction of the 48" and 72" pipes by 100 cfs more than the on-campus detention pond alternative. Flows exiting the Botanical Garden tributary are greater for Alternative C without the additional detention basin. At the Gage Basin, Alternative C results in a greater amount of required storage (17.4 ft) and slightly higher flows exiting the basin.

4.1.4 Alternative D

Alternative D is similar to the other 3 alternatives in that it includes the Islander Park site detention ponds, the connecting 48" pipe from the upstream ponds to the campus 72" pipe, on-campus channel restoration, and modifying the Gage Basin outlet orifice. More specifically, Alternative D is similar to Alternative C in that a bypass channel out of the Botanical Garden tributary is used in place of an on-campus detention pond. The key difference for Alternative D is that the 54" bypass channel is about 1000 ft longer and discharges into the University Arroyo immediately downstream of the Gage Basin. The important hydrologic effect of this routing difference is that less flow is stored in the Gage Basin (11.2 ft depth for Alternative D vs. 17.4 ft depth for Alternative C) and peak flows downstream of the Gage Basin are higher (432 cfs) for Alternative D (Table 13).

4.1.5 Identification of Preferred Regional Alternative

The four regional alternatives were evaluated in terms of their hydrologic effectiveness, environmental consequences, and costs. Based on these criteria, Alternative A was selected as the preferred regional alternative by an advisory team consisting of representatives from the University, City of Riverside, Riverside County Regional Parks, Riverside County Flood Control District, and consultants from PWA and RBF. Alternative A would result in the reduction of the 100-year floodplain as shown in Figure 20, where the predicted 100-yr peak surface and subsurface flows are contained within existing or proposed facilities. A comparison between Figure 20 and the current FEMA floodplain map (Figure 18) indicates a substantial reduction

Table 11: Alternative B

Two full sized Islander Park detention ponds linked to the existing 72” storm sewer at the Junction of Big Springs Road and Valencia Hills Road with 1600 feet of 48” RCP. An on-campus detention pond located immediately downstream from the botanical garden linked to 72" RCP with ~300' of 48" RCP. Channel restoration and culvert modifications to the surface channel immediately south of Big Springs Road on Campus. Modification of Gage Basin outlet structure to use only a single exit orifice.

		Alternative Features						
		Pond A	**Pond B**	**On-Campus Channel Restoration**	**Detention Pond**		**Bypass Conduit**	
		Full 18' Deep + 300' - 30" RCP	*Full 18' Deep + 1300' - 48" RCP*	*Channel Restormation 1300'*	*Natural Channel Connection & Restoration*	*Direct Pipe Bypass (300' - 48" RCP)*	*~3000' - 54" RCP to Gage Basin*	*~4000' - 54" RCP to Gage Channel*
Locations		Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)
72" Campus Drain: Big Springs Rd & Valencia Hills Dr	3hr	*243 cfs* *NA*	*243 cfs* *NA*	*243 cfs* *NA*		*243 cfs* *NA*		
	24hr	*191 cfs* *NA*	*191 cfs* *NA*	*191 cfs* *NA*		*191 cfs* *NA*		
Restored Surface Channel Parallel to Big Springs Rd	3hr	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*		*215 cfs* *Variable ~2.5'*		
	24hr	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*		*57 cfs* *Variable ~1.5'*		
Main 72" Conduit at the Juction of Campus Dr & Big Springs Rd	3hr					*365 cfs* *NA*		
	24hr					*300 cfs* *NA*		
Botanical Garden Tributary	3hr					*126 cfs* *1' - 2.5'*		
	24hr					*115 cfs* *1' - 2.4'*		
Glade Detention Basin	3hr					*NA* *8.8'*		
	24hr					*NA* *4.1'*		
Gage Detention Basin	3hr					*300 cfs* *14.4'*		
	24hr					*350 cfs* *16.9'*		

Table 12: Alternative C

Two full sized Islander Park detention ponds linked to the existing 72" storm sewer at the Junction of Big Springs Road and Valencia Hills Road with 1600 feet of 48" RCP. Direct bypass of botanical garden channel flows via ~3000' of 54" RCP routed through campus to the Gage basin. Channel restoration and culvert modifications to the surface channel immediately south of Big Springs Road on campus. Modification of Gage Basin outlet structure to use only a single exit orifice.

		Alternative Features						
		Pond A	**Pond B**	**On-Campus Channel Restoration**	**Detention Pond**		**Bypass Conduit**	
		Full 18' Deep + 300' - 30" RCP	*Full 18' Deep + 1300' - 48" RCP*	*Channel Restormation 1300'*	*Natural Channel Connection & Restoration*	*Direct Pipe Bypass (300' - 48" RCP)*	*~3000' - 54" RCP to Gage Basin*	*~4000' - 54" RCP to Gage Channel*
Locations		Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)
72" Campus Drain: Big Springs Rd & Valencia Hills Dr	3hr	*243 cfs* *NA*	*243 cfs* *NA*	*243 cfs* *NA*			243 cfs *NA*	
	24hr	*191 cfs* *NA*	*191 cfs* *NA*	*191 cfs* *NA*			*191 cfs* *NA*	
Restored Surface Channel Parallel to Big Springs Rd	3hr	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*			215 cfs *Variable ~2.5'*	
	24hr	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*			*57 cfs* *Variable ~1.5'*	
Main 72" Conduit at the Juction of Campus Dr & Big Springs Rd	3hr						265 cfs *NA*	
	24hr						*209 cfs* *NA*	
Botanical Garden Tributary	3hr						211 cfs *NA*	
	24hr						*140 cfs* *NA*	
Glade Detention Basin	3hr						NA *8.8'*	
	24hr						*NA* *3.5'*	
Gage Detention Basin	3hr						315 cfs *14.9'*	
	24hr						*360 cfs* *17.4'*	

Table 13: Alternative D

Two full sized Islander Park detention ponds linked to the existing 72” storm sewer at the Junction of Big Springs Road and Valencia Hills Road with 1600 feet of 48” RCP. Direct bypass of botanical garden channel flows via ~4000' of 54" RCP routed through campus to be connected beyond the outlet of Gage basin. Channel restoration and culvert modifications to the sufvace channel immediately south of Big Springs Road on campus. Modification of Gage Basin outlet structure to use only a single exit orifice.

		Alternative Features						
		Pond A	**Pond B**	**On-Campus Channel Restoration**	Detention Pond		**Bypass Conduit**	
		Full 18' Deep + 300' - 30" RCP	*Full 18' Deep + 1300' - 48" RCP*	*Channel Restormation 1300'*	*Natural Channel Connection & Restoration*	*Direct Pipe Bypass (300' - 48" RCP)*	*~3000' - 54" RCP to Gage Basin*	*~4000' - 54" RCP to Gage Channel*
Locations		Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)
72" Campus Drain: Big Springs Rd & Valencia Hills Dr	3hr	*243 cfs* *NA*	*243 cfs* *NA*	*243 cfs* *NA*				243 cfs *NA*
	24hr	*191 cfs* *NA*	*191 cfs* *NA*	*191 cfs* *NA*				*191 cfs* *NA*
Restored Surface Channel Parallel to Big Springs Rd	3hr	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*	*215 cfs* *Variable ~2.5'*				215 cfs *Variable ~2.5'*
	24hr	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*	*57 cfs* *Variable ~1.5'*				*57 cfs* *Variable ~1.5'*
Main 72" Conduit at the Juction of Campus Dr & Big Springs Rd	3hr							265 cfs *NA*
	24hr							*209 cfs* *NA*
Botanical Garden Tributary	3hr							211 cfs *NA*
	24hr							*140 cfs* *NA*
Glade Detention Basin	3hr							NA *8.7'*
	24hr							*NA* *2.5'*
Gage Detention Basin	3hr							432 cfs *13.7'*
	24hr							*405 cfs* *11.2'*

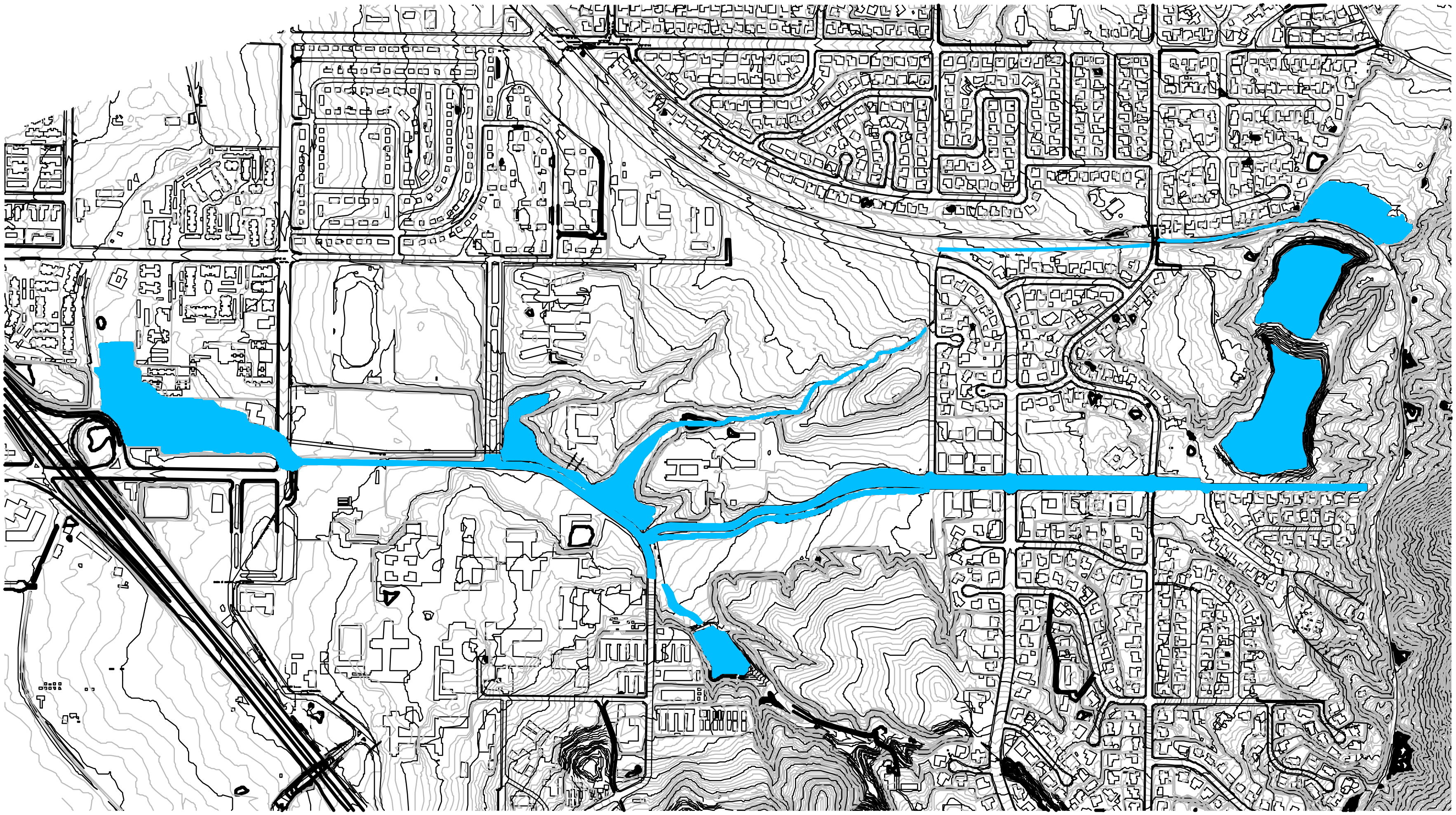


figure 20

New floodplain boundaries as a result of Alternative A modifications

in on-campus flood hazards, particularly between the N. Campus Drive/Big Springs Rd. intersection and Canyon Crest Dr. west of the athletic field. The reduction of the on-campus flood hazard is favorable to potential campus development scenarios. Furthermore, Alternative A results in the reduction of flows exiting the Gage Basin towards target levels (300 cfs for the 3-hr storm, 350 cfs for the 24-hr storm) which aid downstream flood control measures by the City of Riverside.

Of the four regional alternatives, Alternative A is the only plan which includes restoring open channel reaches on both the main campus channel and the Botanical Garden tributary. The goal of these channel restoration efforts (in addition to aspects of the Islander Park and Botanical Garden detention ponds) is to create geomorphically appropriate channels with vegetation that would enhance the habitat quality of these riparian corridors.

Preliminary cost estimates indicate that the four regional alternatives have similar costs. Alternative A is the second most economical option with an estimated cost at $6,100,000. This is $25,000 more than alternative B. Alternatives C and D, which involve 3000/4000 ft of 54" bypass pipe cost $50,000 more than Alternative A. The potential need to replace existing infrastructure along the bypass pipes of alternatives C and D may further increase the total costs associated with these alternatives. More detailed cost estimates for the four alternatives are presented in Appendix A.

4.2 ON-CAMPUS ALTERNATIVES

4.2.1 Alternative E

Alternative E involves adding two additional 72" pipes to the existing 72" main campus storm drain system. Similar to the existing 72" pipe, these new pipes would begin at the eastern campus entrance near Valencia Hill Dr. and continue west to the Gage Basin. An intake/diversion structure near Valencia Hill Dr. would capture flow arriving along Big Springs Rd. Runoff that does not enter the 3-72" pipes is routed to the surface channel on the south side of Big Springs Rd. This open channel would be enlarged, including culvert modifications, to increase flow capacity. The form of this enlarged channel will be designed to improve geomorphic qualities and ecologic function. This alternative also includes an on-campus detention basin along the Botanical Garden tributary channel, with a restored linking channel to the 48" culvert. Alternative E also requires modifying the outlet structure from the Gage Basin, such that the area of the exit orifice is reduced by 5 sq. ft. Flow conditions along stations of the University Arroyo drainage system as a result of Alternative E are shown in Table 14.

4.2.2 Alternative F

Alternative F is similar to Alternative E in that it includes the existing 72" campus drain, two additional 72" pipes and an intake structure, a restored open channel, and a detention pond along the Botanical Garden tributary. Alternative F is different than Alternative E in that it does not involve any modification to the outlet structure from the Gage Basin. Rather, Alternative F requires some re-grading of the Campus Glade, and modification of the Glade's exit structure, to increase storage

Table 14: Alternative E

Addition of two 72" diameter reinforced concrete pipe (RCP) storm drains to connect the eastern campus entrance at Valencia Hills Dr. with the Gage detention basin. An adequate intake/diversion structure at the inlet of the proposed 72" pipes to capture flows arriving along Big Springs Rd, with remaining flows routed into the surface channel south of Big Springs Rd. on campus. This open channel will be enlarged (with culvert modifications) to increase flow capacity and restored to improve ecologic function. An on-campus detention pond located downstream from the botanical garden including a restored channel reach to the 48" connector pipe. The Gage detention pond outlet structure will be altered to reduce the overall exit area by 5 sq. ft.

		Alternative Features					
		Existing 72" Campus Pipe	**Restored Campus Channel**	**Full Campus Bypass Conduit**	**Botanical Garden Detention Basin**	**Campus Glade**	**Gage Basin**
			1300' long two stage channel XX' wide	*2 x ~4500' - 72" RCP*	*7.7 ac-ft pond with 300 ft. of downstream channel restoration*	*no modifications*	*(outlet structure area reduced by 5 sq. ft)*
Locations		Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)		
Campus Entrance at Big Springs Rd & Valencia Hills Dr	3hr	*182 cfs*		*550 cfs* *~3.3'*			
	24hr	*147 cfs*		*332 cfs* *~2'*			
In Restored Surface Channel Parallel to Big Springs Rd	3hr		*249 cfs* *Variable ~2.5'*				
	24hr		*107 cfs* *Variable ~2'*				
Along Botanical Garden Tributary	3hr				*131 cfs* *variable ~2'*		
	24hr				*115 cfs* *variable ~2'*		
At Campus Juction at Big Springs Rd. and Campus Drive	3hr	*315 cfs* *NA*		*550 cfs* *NA*			
	24hr	*257 cfs* *NA*		*332 cfs* *NA*			
Glade Detention Basin	3hr					*NA* *11'*	
	24hr					*NA* *10.8'*	
Exiting Gage Detention Basin	3hr						*626 cfs* *14.2'*
	24hr						*609 cfs* *13.6'*

capacity at this existing campus basin. Flow conditions along stations of the University Arroyo drainage system as a result of Alternative F are shown in Table 15.

4.2.3 Alternative G

Alternative G differs from both Alternatives E and F in that two additional 72" pipes from the Valencia Hill Dr. Campus entrance are not required. Rather, Alternative G involves an enlarged on-campus channel that will capture flows arriving from Big Springs Rd. Elements of Alternative G are shown in the map of Figure 21. The enlarged campus channel will be approximately 70' wide from the campus entrance transition zone to a distance about 350' downstream. Further downstream the campus channel tapers down to a 40' width. Both the 70' and 40' segments of the expanded open channel will include a two-stage design to provide a suitable geomorphic form for low-flow conditions and higher magnitude stormflow conditions (Figure 22). This restored campus channel shall be designed to improve ecologic conditions by providing a vegetated riparian corridor. Conditions from upstream tributaries in the Box Springs Mountains, as well as from the riparian zone of the Gage Basin, can be referenced to create a suitable design. At the campus junction, much of the flows arriving from the Botanical Garden tributary and the enlarged open channel enter into a 7'x7' box culvert which flows to the Gage Basin. A portion of the streamflow remains in the surface channel and is directed towards the Campus Glade. Similar to Alternative F, in Alternative G the Campus Glade is re-graded and modified to increase storage capacity. Alternative G also includes the detention pond along the Botanical Garden tributary. Flow conditions along stations of the University Arroyo drainage system as a result of Alternative G are shown in Table 16.

4.2.4 Identification of Preferred On-Campus Alternative

Alternative G was selected as the preferred on-campus alternative based on hydrologic effectiveness, environmental consequences, and costs. Alternative G would result in the reduction of the 100-year floodplain such that the predicted 100-yr peak surface and subsurface flows are contained within existing or proposed facilities. The reduction of the on-campus flood hazard is favorable to potential campus development scenarios in the western portion of Parking Lot 13 and in the campus athletic field area. In comparing results from Table 16 with Table 9, Alternative G does not alter existing discharge conditions downstream of the Gage Basin (652 cfs for the 3-hr storm, 640 cfs for the 24-hr storm). Of all seven regional and on-campus alternatives, Alternative G includes the greatest amount of channel restoration which is considered a significant environmental benefit. Preliminary cost estimates indicate that Alternative G ($4,340,000) has a similar cost to Alternative E ($4,361,000). Both of these alternatives are about $500,000 less expensive than Alternative F ($4,909,000). More detailed cost estimates for the on-campus alternatives are presented in Appendix A.

Table 15: Alternative F

Addition of two 72" diameter reinforced concrete pipe (RCP) storm drains to connect the eastern campus entrance at Valencia Hills Dr. with the Gage detention basin. An adequate intake/diversion structure at the inlet of the proposed 72" pipes to capture flows arriving along Big Springs Rd, with remaining flows routed into the surface channel south of Big Springs Rd. on campus. This open channel will be enlarged (with culvert modifications) to increase flow capacity and restored to improve ecologic function.   Re-grading the Glade detention pond to increase storage capacity with modifications to the Glade outlet structure. An on-campus detention pond located downstream from the botanical garden including a restored channel reach to the 48" connector pipe.

		Alternative Features					
		Existing 72" Campus Pipe	**Restored Campus Channel**	**Full Campus Bypass Conduit**	**Botanical Garden Detention Basin**	**Enlarged Campus Glade**	**Gage Basin**
			1300' long two stage channel XX' wide	*2 x ~4500' - 72" RCP*	*7.7 ac-ft pond with 300 ft. of downstream channel restoration*	*with modifications to outlet structure*	*(no modifications)*
Locations		Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	
Campus Entrance at Big Springs Rd & Valencia Hills Dr	3hr	*182 cfs*		*550 cfs* *~3.3'*			
	24hr	*147 cfs*		*312 cfs* *~2'*			
In Restored Surface Channel Parallel to Big Springs Rd	3hr		*249 cfs* *Variable ~2.5'*				
	24hr		*107 cfs* *Variable ~2'*				
Along Botanical Garden Tributary	3hr				*131 cfs* *variable ~2'*		
	24hr				*115 cfs* *variable ~2'*		
At Campus Juction at Big Springs Rd. and Campus Drive	3hr	*315 cfs* *NA*		*550 cfs* *NA*			
	24hr	*257 cfs* *NA*		*312 cfs* *NA*			
Glade Detention Basin	3hr					*NA* *9.9'*	
	24hr					*NA* *10.8'*	
Exiting Gage Detention Basin	3hr						*652 cfs* *12.6'*
	24hr						*640 cfs* *12.3'*

Table 16: Alternative G

An enlarged surface channel will be constructed between the campus entrance at Valencia Hills Drive and the junction of Big Springs Road and Campus Drive . The eastern transitional zone of this channel (~ first 350 ft) will be up to 70 ft. wide. The remaining western continuation of the surface channel will taper down to a 42 ft. width. This channel will be designed to improve riparian habitat qualities, offereing an important riparian corridor between Box Springs mountain springs. and Gage Basin wetland. Downstream of the campus junction, majority of the surface flow will be directed from the open channel into a 2500 ft. length of 7' x 7' box culvert which will discharge directly into the Gage Basin. Remaining surface water will flow towards the Campus Glade. The Campus Glade will be enlarged (with modifications to the Glade outlet structure) to offer additional detention and accomodate required flow volumes . Along the Botanical Garden tributary, a detention pond will be built downstream from the botanical garden. The channel which links flows from the Botanical Garden pond to the 48" pipe (at the southwest end of Lot 13) will be improved for both drainage and habitat. The gage detention pond outlet structure will not be altered.

		Alternative Features					
		Existing 72" Campus Pipe	**Restored Campus Channel**	**7'x7' Box Bypass Drain**	**Botanical Garden Detention Basin**	**Enlarged Campus Glade**	**Gage Basin**
			1800' long two stage channel 42' wide, 70' width at eastern transition	*2500 ft. pipe flows from campus junction to Gage Basin*	*7.7 ac-ft pond with 300 ft. of downstream channel restoration*	*with modifications to outlet structure*	*(no modifications)*
Locations		Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	Discharge (cfs) Depth (ft)	
Campus Entrance at Big Springs Rd & Valencia Hills Dr	3hr	*182 cfs*	*1070 cfs* *~ 2'*				
	24hr	*147 cfs*	*556 cfs* *~1.5'*				
In Restored Surface Channel Parallel to Big Springs Rd	3hr		*888 cfs* *~6'*				
	24hr		*409 cfs* *~4'*				
Along Botanical Garden Tributary	3hr				*131 cfs* *variable ~2'*		
	24hr				*115 cfs* *variable ~2'*		
At Campus Juction at Big Springs Rd. and Campus Drive	3hr	*315 cfs* *NA*		*553 cfs*			
	24hr	*257 cfs* *NA*		*332 cfs*			
Glade Detention Basin	3hr					*NA* *10.4*	
	24hr					*NA* *11'*	
Exiting Gage Detention Basin	3hr						*652 cfs* *12.6'*
	24hr						*640 cfs* *12.3'*

figure 21

Alternative G
Proposed Layout

UCR Flood Control & Arroyo Enhancement

Proj. # 1418 PWA

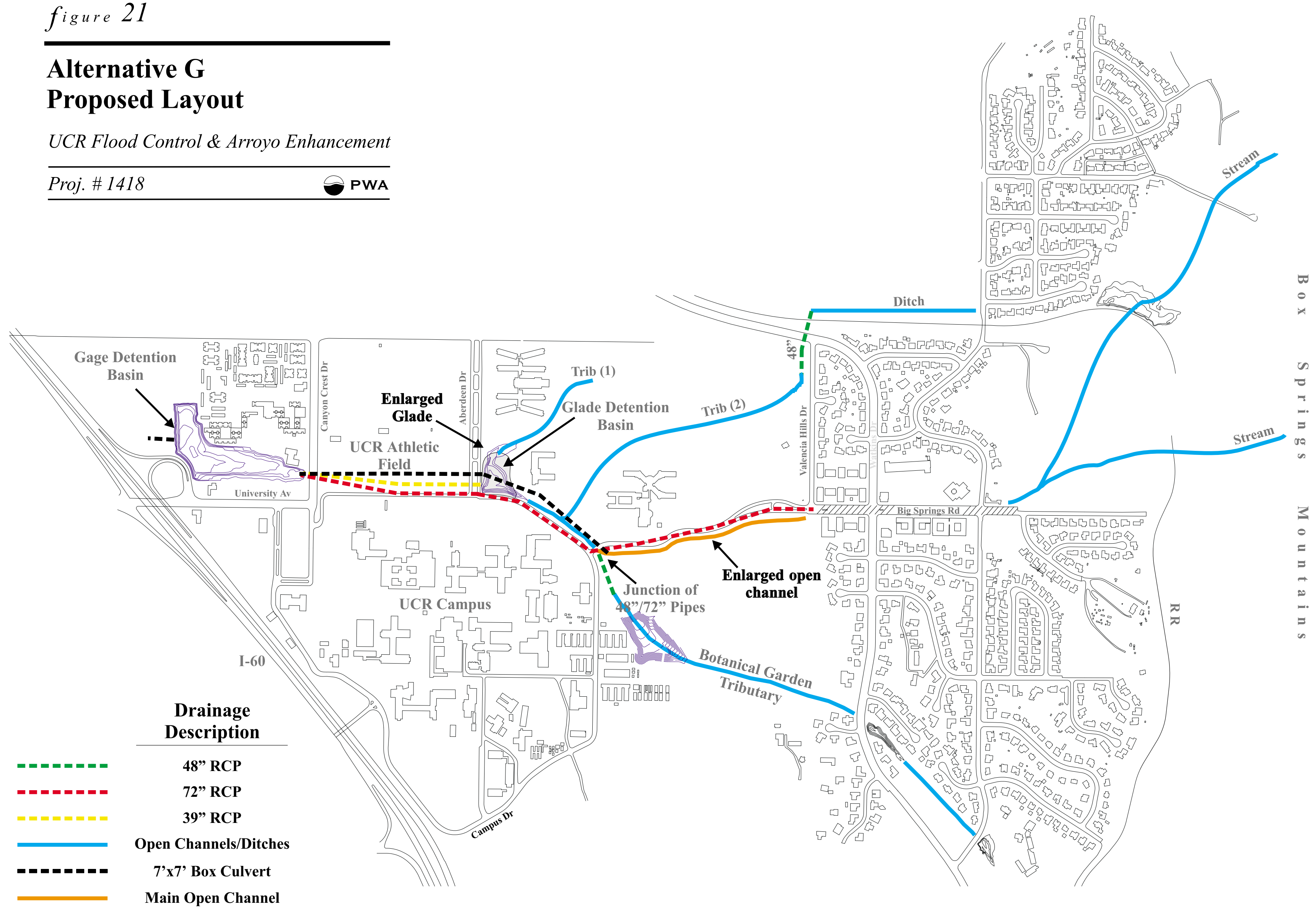
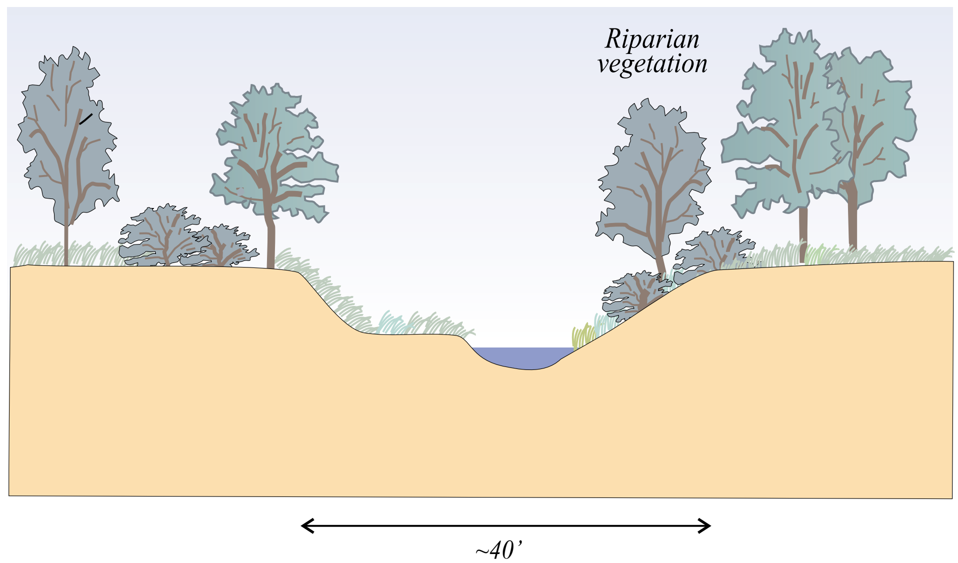


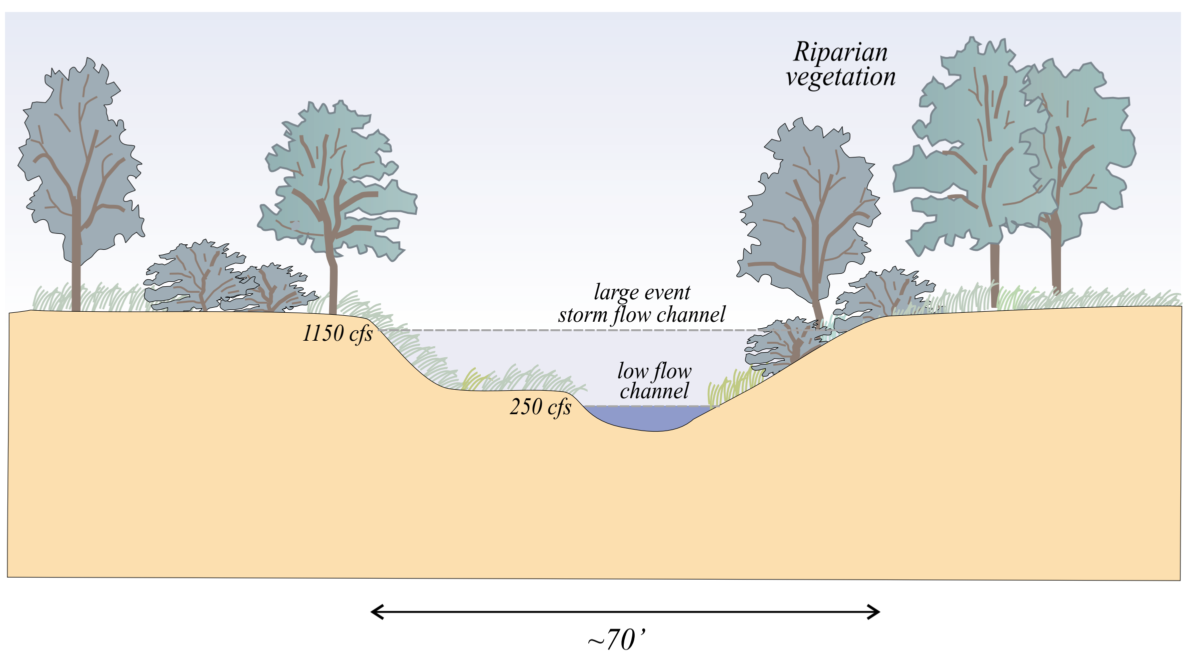
figure 22

Alternative G: Proposed Cross Sections

UCR Flood Control & Arroyo Enhancement

Proj. # 1418 x-sec.cdr PWA





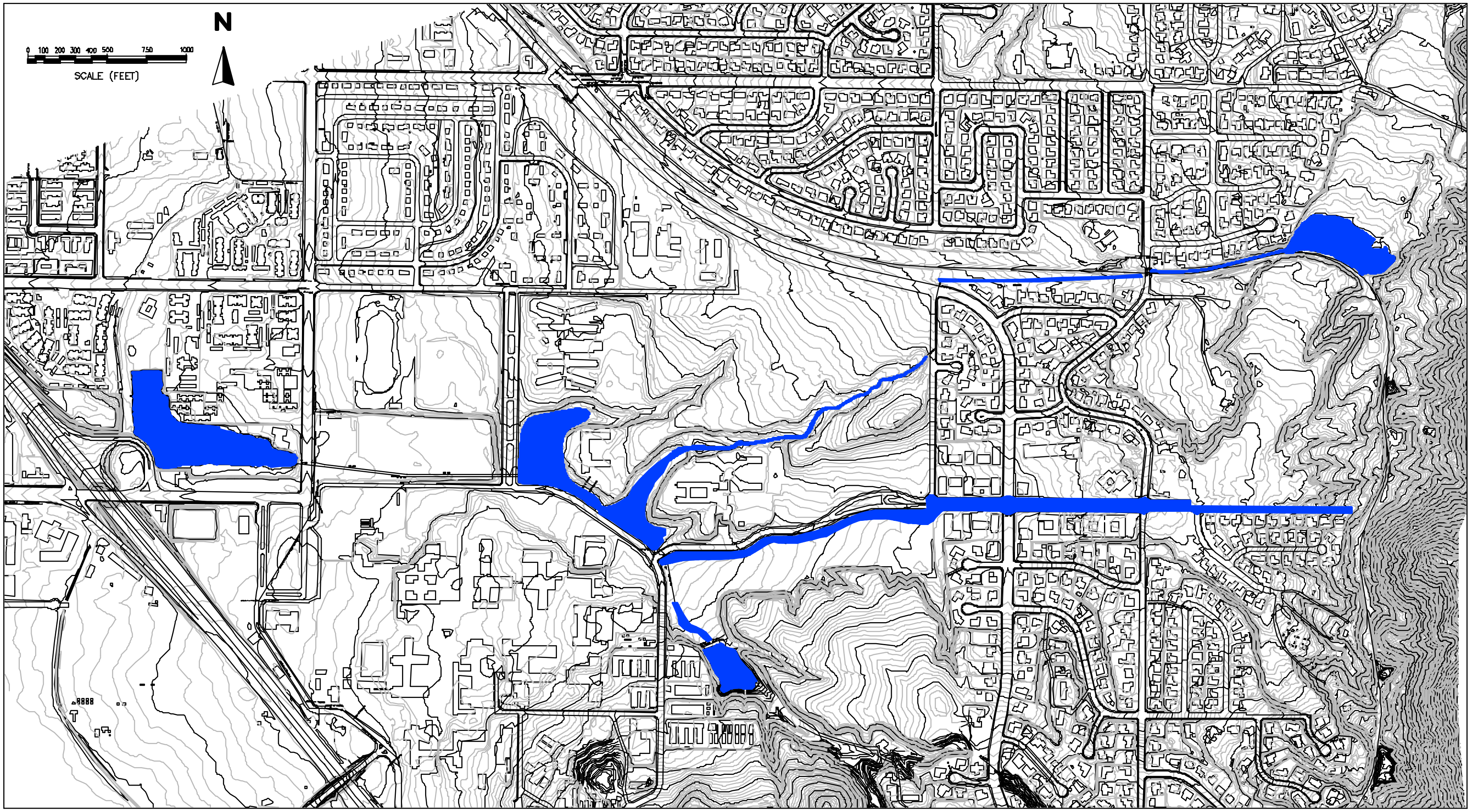


figure 23

New Floodplain boundaries as a result of Alternative G modifications

PWA

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5. LIST OF PREPARERS

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APPENDIX A
Cost Estimates

Alternative A

1: Islander Park Detention Ponds						
Description	***Unit Cost***		***Quantity***	***Unit***	***Cost***	
Grouted Rock Channel	$	65.00	670	CY	$	43,550
Intake Structure	$	100,000.00	1	LS	$	100,000
Settling Basin	$	65.00	2,220	CY	$	144,300
Grouted Rock Spillway	$	65.00	3,300	CY	$	214,500
30" Dia Outlet Culvert (A)	$	150.00	300	FT	$	27,000
36" Dia Outlet Culvert (B)	$	150.00	200	FT	$	20,000
Excavation	$	3.00	337,700	CY	$	1,013,100
Earth Disposal	$	5.00	337,700	CY	$	1,688,500
48" Outflow Culvert	$	130.00	1600	FT	$	208,000
AC Parking Lot	$	2.00	40,000	SF	$	80,000
DG Roadway	$	1.50	38,000	SF	$	57,000
Islander Park Landscaping		-	-	-	$	450,000
					$	***4,045,950***
2: On Campus Features						
Description	***Unit Cost***		***Quantity***	***Unit***	***Cost***	
Grouted Rock Spillway	$	65.00	1,500	CY	$	97,500
Grouted Rock Channel	$	65.00	180	CY	$	11,700
Settling Basin	$	65.00	280	CY	$	18,200
DG Maintenance Road	$	1.50	13,200	SF	$	19,800
36" Dia Outlet Culvert	$	100.00	250	FT	$	25,000
Excavation	$	3.00	21,200	CY	$	63,600
Earth Disposal	$	5.00	21,200	CY	$	106,000
Garden Channel Restoration	$	200.00	300	FT	$	60,000
Main Surface Channel Restoration	$	200.00	1,300	FT	$	260,000
Gage Outlet Modification	$	10,000.00	1	LS	$	10,000
					$	***671,800***
3: Engineering/Permits			10%		***$***	***471,775***
4: Contingency			20%		***$***	***943,550***
				Total:	**$**	**6,133,075**

Alternative B

1: Islander Park Detention Ponds				***$***	***4,045,950***
2: On Campus Features					
Description	***Unit Cost***	***Quantity***	***Unit***	***Cost***	
Grouted Rock Spillway	$ 65.00	1,500	CY	$	97,500
Grouted Rock Channel	$ 65.00	180	CY	$	11,700
Settling Basin	$ 65.00	280	CY	$	18,200
DG Maintenance Road	$ 1.50	13,200	SF	$	19,800
36" Dia Outlet Culvert	$ 100.00	250	FT	$	25,000
Excavation	$ 3.00	21,200	CY	$	63,600
Earth Disposal	$ 5.00	21,200	CY	$	106,000
48" Outflow Conduit	$ 130.00	300	FT	$	39,000
Main Surface Channel Restoration	$ 200.00	1,300	FT	$	260,000
Gage Outlet Modification	$ 10,000.00	1	LS	$	10,000
				$	***650,800***
3: Engineering/Permits		10%		***$***	***469,675***
4: Contingency		20%		***$***	***939,350***
			Total:	**$**	**6,105,775**

Alternative C

1: Islander Park Detention Ponds				***$***	***4,045,950***
2: On Campus Features					
Description	***Unit Cost***	***Quantity***	***Unit***	***Cost***	
54" Bypass Conduit	$ 150.00	3,000	CY	$	450,000
Main Surface Channel Restoration	$ 200.00	1,300	CY	$	260,000
Gage Outlet Modification	$ 10,000.00	1	LS	$	10,000
				$	***720,000***
3: Engineering/Permits		10%		***$***	***476,595***
4: Contingency		20%		***$***	***953,190***
			Total:	**$**	**6,195,735**

Alternative D

1: Islander Park Detention Ponds				***$***	***4,045,950***
2: On Campus Features					
Description	***Unit Cost***	***Quantity***	***Unit***	***Cost***	
54" Bypass Conduit	$ 150.00	4,000	CY	$	600,000
Main Surface Channel Restoration	$ 200.00	1,300	CY	$	260,000
Gage Outlet Modification	$ 10,000.00	1	LS	$	10,000
				$	***870,000***
3: Engineering/Permits		10%		***$***	***491,595***
4: Contingency		20%		***$***	***983,190***
			Total:	**$**	**6,390,735**

Alternative E

a: 2-72" RCP

Description	***Unit Cost***	***Quantity***	***Unit***	***Cost***
72" Storm Drain	$ 137.00	9,000	LF	$ 1,233,000
Remove Asphalt Pavement	$ 1.50	130,500	SF	$ 195,750
Pipe Excavation	$ 6.00	73,400	CY	$ 440,400
Pipe Backfill	$ 7.30	73,400	CY	$ 535,820
Asphalt & Base	$ 1.65	130,500	SF	$ 215,325
Intake Stucture	$ 60,000.00	1	EA	$ 60,000
Subtotal				$ 2,680,295
Engineering/Permits		10	%	$ 268,030
Contingency		20	%	$ 536,059
			Subtotal (a)	**$ 3,484,384**

b: Main Channel Restoration and Gage Outlet Modification

Description	***Unit Cost***	***Quantity***	***Unit***	***Cost***
Main Surface Channel Restoration	$ 200.00	1,300	FT	$ 260,000
Gage Outlet Modification	$ 10,000.00	1	LS	$ 10,000
Subtotal				$ 270,000
Engineering/Permits		10	%	$ 27,000
Contingency		20	%	$ 54,000
			Subtotal (b)	**$ 351,000**

c: Botanical Garden Basin

Description	***Unit Cost***	***Quantity***	***Unit***	***Cost***
Grouted Rock Channel	$65	200	CY	$ 13,000
Settling Basin	$65	300	CY	$ 19,500
DG Roadway	$1.50	13,200	SF	$ 19,800
Grouted Rock Spillway	$65	1,500	CY	$ 97,500
Excavation	$3	21,200	CY	$ 63,600
Earth Disposal	$5	21,200	CY	$ 106,000
36" Outflow Culvert	$100	250	FT	$ 25,000
Garden Channel Restoration	$200	$300	FT	$ 60,000
Subtotal				$ 404,400
Engineering/Permits		10	%	$ 40,440
Contingency		20	%	$ 80,880
			Subtotal (c)	**$ 525,720**
			Total (a, b, c)	**$ 4,361,104**

Alternative F

a: 2-72" RCP

Description	Unit Cost	Quantity	Unit	Cost
72" Storm Drain	$ 137.00	9,000	LF	$ 1,233,000
Remove Asphalt Pavement	$ 1.50	130,500	SF	$ 195,750
Pipe Excavation	$ 6.00	73,400	CY	$ 440,400
Pipe Backfill	$ 7.30	73,400	CY	$ 535,820
Asphalt & Base	$ 1.65	130,500	SF	$ 215,325
Intake Stucture	$ 60,000.00	1	EA	$ 60,000
Subtotal				$ 2,680,295
Engineering/Permits		10	%	$ 268,030
Contingency		20	%	$ 536,059
			Subtotal (a)	**$ 3,484,384**

b: Main Channel Restoration and Gage Outlet Modification

Description	Unit Cost	Quantity	Unit	Cost
Glade Grading Excavation	$ 3.00	52,700	CY	$ 158,100
Earth Disposal	$ 5.00	52,700	CY	$ 263,500
Glade Outlet Modification	$ 10,000.00	1	EA	$ 10,000
Main Surface Channel Restoration	$ 200.00	$1,300	FT	$ 260,000
Subtotal				$ 691,600
Engineering/Permits		10	%	$ 69,160
Contingency		20	%	$ 138,320
			Subtotal (b)	**$ 899,080**

c: Botanical Garden Basin

Description	Unit Cost	Quantity	Unit	Cost
Grouted Rock Channel	$ 65.00	200	CY	$ 13,000
Settling Basin	$ 65.00	300	CY	$ 19,500
DG Roadway	$ 1.50	13,200	SF	$ 19,800
Grouted Rock Spillway	$ 65.00	1,500	CY	$ 97,500
Excavation	$ 3.00	21,200	CY	$ 63,600
Earth Disposal	$ 5.00	21,200	CY	$ 106,000
36" Outflow Culvert	$ 100.00	250	FT	$ 25,000
Garden Channel Restoration	$ 200.00	$300	FT	$ 60,000
Subtotal				$ 404,400
Engineering/Permits		10	%	$ 40,440
Contingency		20	%	$ 80,880
			Subtotal (c)	**$ 525,720**
			Total (a, b, c)	**$ 4,909,184**

Alternative G

a: 7x7 RCB construction

Description	Unit Cost	Quantity	Unit	Cost
7x7 RCB	$ 500.00	2,500	LF	$ 1,250,000
Remove Asphalt Pavement	$ 1.50	38,000	SF	$ 57,000
Pipe Excavation	$ 6.00	18,100	CY	$ 108,600
Pipe Backfill	$ 7.30	7,500	CY	$ 54,750
Asphalt & Base	$ 1.65	38,000	SF	$ 62,700
Intake Structure	$ 60,000.00	1	EA	$ 60,000
Utility Protection/Relocation	$ 1,000.00	14	EA	$ 14,000
Subtotal				$ 1,607,050
Engineering/Permits		10	%	$ 160,705
Contingency		20	%	$ 321,410
			Subtotal (a)	**$ 2,089,165**

b: Campus Glade Modification and Main Channel Restoration

Description	Unit Cost	Quantity	Unit	Cost
Glade Grading Excavation	$ 3.00	52,700	CY	$ 158,100
Earth Disposal	$ 5.00	77,700	CY	$ 388,500
Glade Outlet Modification	$ 10,000.00	1	EA	$ 10,000
2 - 8'x12' RCB Crossings	$ 110,000.00	2	EA	$ 220,000
Channel Excavation	$ 6.00	14,400	CY	$ 86,400
Energy Dissipation Structure	$ 100,000.00	1	EA	$ 100,000
Vegetation (seeded)	$ 0.10	64,000	SF	$ 6,400
Main Surface Channel Restoration	$ 200.00	1,800	FT	$ 360,000
Subtotal				$ 1,329,400
Engineering/Permits		10	%	$ 132,940
Contingency		20	%	$ 265,880
			Subtotal (b)	**$ 1,728,220**

c: Botanical Garden Basin

Description	Unit Cost	Quantity	Unit	Cost
Grouted Rock Channel	$ 65.00	200	CY	$ 13,000
Settling Basin	$ 65.00	300	CY	$ 19,500
DG Roadway	$ 1.50	13,200	SF	$ 19,800
Grouted Rock Spillway	$ 65.00	1,500	CY	$ 97,500
Excavation	$ 3.00	21,200	CY	$ 63,600
Earth Disposal	$ 5.00	21,200	CY	$ 106,000
36" Outflow Culvert	$ 100.00	250	FT	$ 25,000
Garden Channel Restoration	$ 200.00	300	FT	$ 60,000
Subtotal				$ 404,400
Engineering/Permits		10	%	$ 40,440
Contingency		20	%	$ 80,880
			Subtotal (c)	**$ 525,720**
			Total (a, b, c)	**$ 4,343,105**