El Rio Medio - With-Project Alternatives Analyses of the Santa Cruz River from Prince Road to Congress Street along with Current Conditions Analysis and With-Project Alternatives Analyses of the Silvercroft Wash from Grant Road to the Santa Cruz River

Prepared for and in cooperation with the
Pima County Regional Flood Control District

October 2008

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1 Introduction

1.1 Project Purpose

This study has been conducted in support of the El Rio Medio Feasibility Study, F4 Phase for the U.S. Army Corps of Engineers, Los Angeles District.

1.2 Project Location

The El Rio Medio Project encompasses an approximate four and a half (4.5) mile reach of the Santa Cruz River from Congress Street to Prince Road and an approximate one (1.0) mile reach of the Silvercroft Wash from Grant Road to the Santa Cruz River, all within the incorporated boundaries of the City of Tucson. The study area is within Sections 27, 28, 33, and 34 of Township 13 South, Range 13 East, and Sections 2, 3, 11, 12, and 14 of Township 14 South, Range 13 East, Gila and Salt River Base and Meridian. Figure 1 shows the project location within Arizona and shows the study limits locally.

1.3 Previous Studies

The study area was previously discussed within a report titled "El Rio Medio – Pima County Arizona, Santa Cruz River - Prince Road to Congress Street F3 Feasibility Study, Without Project Hydrology and Hydraulic Analysis Report" (referred to as ERM F3 Report from here on) which documented the existing condition hydrology, hydraulics, and sediment transport characteristics of the study area. Additionally, the study area has been modeled and mapped by FEMA.

1.4 Description of Study Area

The study area consists of the Santa Cruz River (channel and 500-year floodplain) within the boundaries of the Congress Street Bridge to the Prince Road alignment. The study area also includes the Silvercroft Wash (channel and 500-year floodplain) within the boundaries of the Grant Road Bridge to the Santa Cruz River confluence. For computational stability and floodplain mapping purposes, the Santa Cruz River modeling is extended an additional one-half mile upstream and downstream of the above mentioned boundaries and the Silvercroft Wash modeling is extended an additional one-half mile upstream of Grant Road.

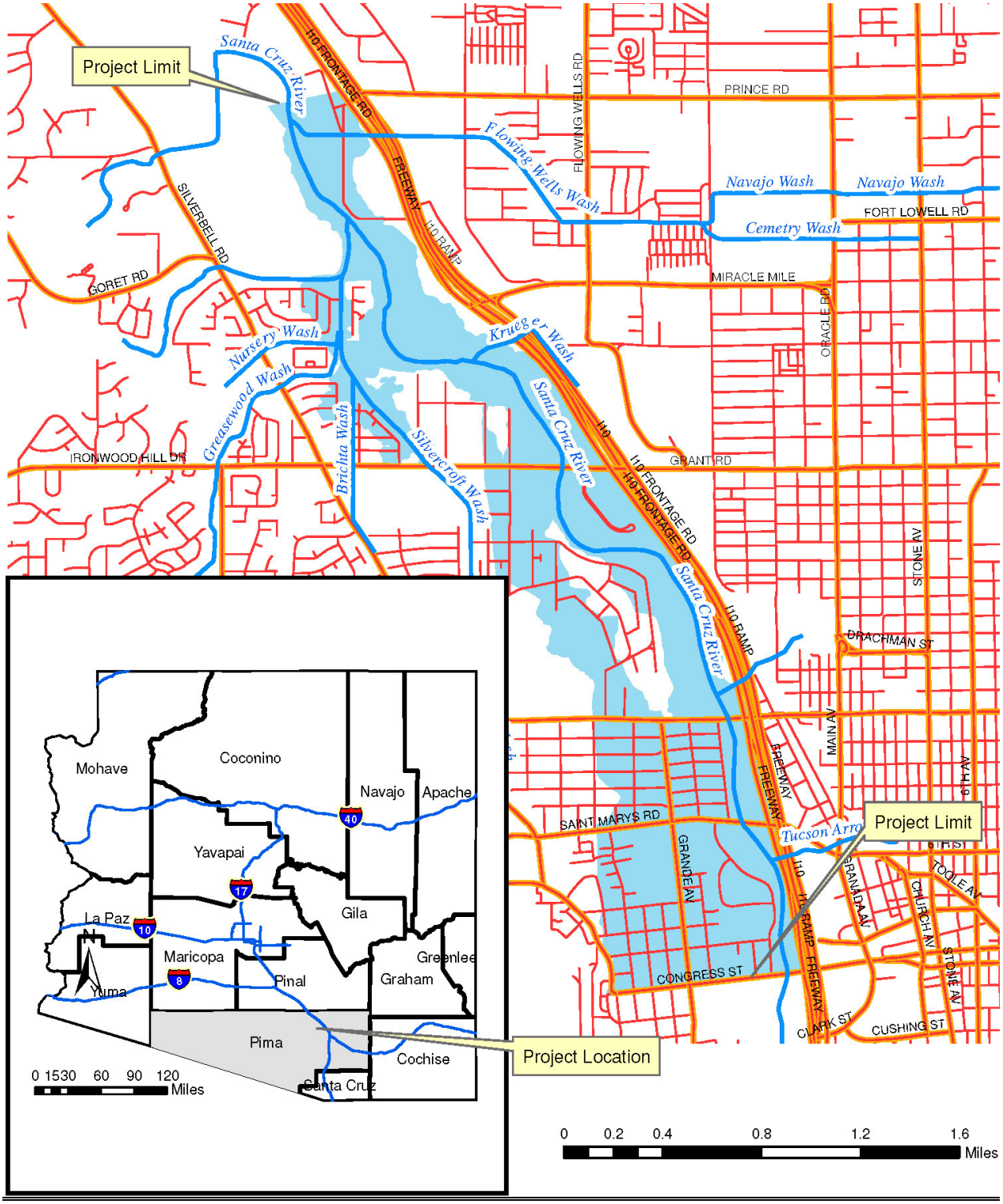

Figure 1 - El Rio Medio Project Location Map with 500-year Flood Limits

1.5 Project Scope

JE Fuller Hydrology and Geomorphology, Inc. (JEF) prepared this report while under contract with the Pima County Regional Flood Control District (PCRFCD). This report documents the study described by the scope of work associated with Requisition Number 0703757: El Rio Medio With-Project Alternative Analyses. This project follows the existing conditions hydrologic, hydraulic, and geomorphic analysis for the main stem of the Santa Cruz River and confluence areas (ERM F3 Report) prepared by Castro Engineering (by the current author) for PCRFCD in December 2005

The project scope is divided into two major tasks. The first is based on the existing conditions HEC-RAS model of the main stem of the Santa Cruz River and includes analyses of several with project alternatives developed by the U.S. Army Corps of Engineers (USACE). This task required JEF to;

- Modify the existing conditions Santa Cruz River HEC-RAS model analysis to represent up to five with-project alternatives and report on the velocities and water surface profiles for the 2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year events and assess project impact. The HEC-RAS models can be found within Appendices F and G and the discussion of the modeling methodology, results, and assessment can be found within Section 5.
- Prepare a comprehensive draft report for review by Pima County and USACE staff. The report was to document assumptions, present the HEC-RAS model and results, and supply qualitative analysis of the hydraulic impacts of the alternatives as compared to the existing condition. The report was also to include suggestions for mitigation of adverse consequences. This report satisfies this sub-task item.
- Respond to USACE Internal Technical Review comments and provide documentation as required. This final version of the report follows USACE review which gave no comments; however some comments were given by PCRFCD and have been responded to here within.

The second task is a hydrologic and hydraulic analysis of the Silvercroft Wash from Grant Road to the Santa Cruz River. This task required JEF to;

- Construct an existing-conditions HEC-RAS model for the Silvercroft Wash from Grant Road to the Santa Cruz River confluence and determine water surface profiles and velocities for the 2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year events. This model can be found within Appendices E and G with a discussion found within Section 8.
- Modify and execute the Silvercroft Wash HEC-RAS model analysis for one with-project alternative and assess project impact on flow hydraulics for the 2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year events. The HEC-RAS models can be found within Appendices E and G and the discussion of the modeling methodology, results, and assessment can be found within Section 6.
- Integrate the above results into the comprehensive draft report prepared for the first task. This report satisfies this sub-task item.

1.6 Description and Organization of Report

This report expands upon the ERM F3 Report. The intent is for the current report to provide sufficient summary information to stand alone and not require the reader to have the ERM F3 Report in hand while reading this report. Following this introductory section, this report has been organized to summarize the ERM F3 Report, followed by the existing condition analysis and research related to the Silvercroft Wash, followed by discussion of alternatives analyses for both the Santa Cruz River and the Silvercroft Wash.

- Section 2 is a synopsis of the ERM F3 Report.
- Section 3 presents as-built plan research and field reconnaissance of the Silvercroft Wash.
- Section 4 discusses the hydrology of the Silvercroft Wash.
- Section 5 discusses the existing condition hydraulic analysis for the Silvercroft Wash.
- Sections 6 and 7 discuss the alternatives analyses for the Santa Cruz River the Silvercroft Wash.
- Section 7 summarizes the project and provides final conclusions and recommendations.

2 Summary of El Rio Medio F3 Report

The ERM F3 Report presented the "methodology and results for a detailed existing condition hydrologic, hydraulic, and sediment transport analysis of the Santa Cruz River" (abstract). The ERM F3 Report included a detailed discussion of field reconnaissance including observations of flow depths and high water marks made during a rare runoff event. The reconnaissance section included photographs documenting field conditions and calculations used to estimate roughness coefficients for the channel and overbank areas.

Hydrology presented within the ERM F3 Report was compiled from research of various sources. Peak discharges were quantified for the main stem of the Santa Cruz River as well as storm drains and open channel tributaries. Peak discharges were included for the 2-, 10-, 20-, 50-, 100-, and 500-year events.

Hydraulic modeling presented within the ERM F3 Report was performed using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) software program. The model was developed using ArcView software by ESRI with USACE HEC Geo-RAS software. Topographic data (2 foot contour interval) was obtained from the Pima Association of Governments (PAG) and was on the North American Vertical Datum of 1988 (NAVD88). The events modeled included the 2-, 10-, 20-, 50-, 100-, and 500-year events. USGS stream gage data, observed flow depths, and observed high water marks were used to verify the models. A risk and uncertainty analysis was included to estimate the effects of modification to roughness coefficients as well as effects of bridge pier obstructions.

The results of the hydraulic modeling indicated that the 2-, 10-, 20-, and 50-year events are entirely contained within the channel. The 100-year event was intermittently contained as expected. Overflow occurred for most cross sections between Congress Street and Saint Mary's Road, for some cross sections between Saint Mary's Road and Speedway, and also for cross sections near the Ft. Lowell Road alignment. The 100-year floodplain computed in the ERM F3 Report exceeded the mapped FEMA floodplain in limited locations due to higher roughness coefficients modeled within the channel. The 500-year event was entirely uncontained with flooding extending as far west as Silverbell Road and east to I-10.

The five tributaries modeled had differing flooding potential. The portions of the Tucson Arroyo, the Bronx Wash, and the Silvercroft Wash which were modeled indicated containment of the 100-year runoff associated with the tributaries. The Krueger Wash and the Flowing Wells Wash exhibited uncontained flow with the Flowing Wells Wash potentially flooding residential structures. The Santa Cruz River was determined to be the primary source of flooding along the modeled tributaries with the exception of the Flowing Wells Wash.

The ERM F3 Report also included a sediment transport analysis of the Santa Cruz River using the USACE HEC-6 software. Sediment data was obtained from bed samples and inflowing sediment load curves were estimated assuming equilibrium conditions. Analyses were performed for the 2-, 10-, 25-, 50-, and 100-year runoff events. The bed elevation changes were quantified on a cross sectional basis and an average annual change in bed elevation was computed. On an average annual basis, the modeling indicated that degradation of less than two-tenths of a foot would occur for all reaches south of Grant Road. The modeling indicated relative equilibrium north of Grant Road. Note that these results are reach averages and individual cross sections had differing results outside of the above reported boundaries.

3 Research and Field Reconnaissance

This section describes research and field investigations primarily related to the Silvercroft Wash with further details found within Appendix B. Research included compilation of design and as-built survey documents. Field investigation was conducted with the following goals;

- Determine if the structures found in the field match the plans.
- Provide an assessment of the channel and overbanks conditions for use in assigning Manning's roughness values.
- Determine if high water marks exist and document their locations.

3.1 Summary of Composite Channel Roughness Values

The composite roughness values are summarized in the following table.

Table 1 – Summary of composite channel roughness values for Silvercroft Wash

Sub-reach	Channel Configuration	Bank Configuration	Composite Roughness Value
Beginning of Modeled Area to Water Street	Earthen	Concrete	0.019
Water Street to Jordan Drive	Earthen	Concrete	0.019
Jordan Drive to Roundwood Place	Concrete	Concrete	0.015
Roundwood Place to Brichta Wash	Earthen	Concrete left, earthen right	0.034
Brichta Wash to Painted Sunset Circle	Earthen	Concrete	0.019
Painted Sunset Circle to Nursery Wash	Earthen	Concrete left, partially lined right	0.029
Nursery Wash to Painted Hills Wash	Earthen	Concrete	0.024
Painted Hills Wash to Santa Cruz River	Earthen	Concrete	0.015

3.2 Floodplain Manning's n Values

The floodplain roughness values were calculated separate of the channel values. The values were previously calculated within the ERM F3 Report and have been verified for use in this study. One additional land use has been delineated, the tributary channel residing in the floodplain. The following values have been used in the current study.

Table 2 - Floodplain roughness values for Silvercroft Wash

Land Use	Land Use Name in HEC-GeoRAS	Roughness Value
Floodplain -Low Vegetation	Obank-LowVeg	0.040
Parks	Obank-Parks	0.050
Urban	Obank-Urban	0.060
Medium Density Residential	Obank-MDResident	0.082
Commercial	Obank-Commercial	0.082
Industrial	Obank-Industrial	0.082
Paved	Obank-Paved	0.025
Tributary Channel	Chan-trib	0.028

4 Silvercroft Wash Hydrology

This section summarizes the hydrology for the Silvercroft Wash and the major tributaries within the study area. The scope of this project required hydraulic modeling of the 2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year series of runoff events for use in steady flow hydraulic models (HEC-RAS).

4.1 Silvercroft Wash Basin Drainage Area

The headwaters for the Silvercroft Wash are in the Tucson Mountain Range, southwest of Star Pass Road. The basin drains towards the north/northeast and terminates at the confluence with the Santa Cruz River, less than 1 mile north or Grant Road. The basin extends almost as far west as Camino de Oeste and is roughly bounded on the east by Grande Avenue. Tributary streams within the basin include the Globeberry Wash, Tucson Park Wash, Maxwell Wash, Pima Community College Wash, Mosaic Wash, "A" Wash, El Rio Wash, Brichta Wash, Greasewood Wash, Nursery Wash, and Painted Hills Wash. The basin contains over 13 square miles of drainage area and the longest flow path is over 6 miles in length.

The Silvercroft Wash is an ephemeral stream which is dry throughout most of the year, although intermittent minor urban runoff is present. Runoff within the basin occurs in response to frontal storms (winter and spring), localized general summer storms (dissipating cyclones), and local convective (monsoonal) storms. Flooding within the Silvercroft Wash is most commonly a result of intense summer thunderstorms.

4.2 Silvercroft Wash Peak Discharges

Appendix C documents preexisting hydrologic studies and populates the 8 event discharge series which is shown in the following table.

Table 3 - 8 Event discharge series

	Silvercroft Wash peak discharge (cfs) by location			
Recurrence Interval (years)	El Rio Wash to Brichta Wash	Brichta Wash to Greasewood Wash Peak	Greasewood Wash to Painted Hills Wash	Painted Hills Wash to Santa Cruz River
2	570	590	690	770
5	1,350	1,380	1,610	1,800
10	2,660	2,730	3,190	3,570
20	3,840	3,940	4,610	5,150
50	5,970	6,130	7,170	8,010
100	7,227	7,423	8,682	9,700
200	9,040	9,280	10,860	12,320
500	11,420	11,730	13,720	16,100

5 Silvercroft Wash Without-Project Hydraulic Model

This section discusses the hydraulic model developed for the Silvercroft Wash. The objectives of this analysis were;

- Develop a one-dimensional hydraulic model of the Silvercroft Wash based upon the existing condition.
- Delineate the floodplain boundaries for the modeled runoff events.
- Provide a description of the overflow areas including location, aerial extent, and average depth of inundation.
- Follow the methodology of and integrate the results with the ERM F3 Report.

5.1 Model Development

Georeferenced HEC-RAS models were developed using the capabilities of HEC-GeoRAS and ArcView. Topography used for developing the model was derived from digital terrain model (DTM) data developed from an aerial survey performed in 2005 by the Pima Association of Governments. The DTM is set to the NAVD 88 datum and includes points and breaklines. The DTM and accompanying aerial photographs encompass the entire study area.

ArcView was used to import the DTM files as well as the aerial images. A triangulated irregular network (TIN) was constructed and two-foot interval contours were developed. A stream centerline and the bank lines were identified with the aid of the aerial images, shape files of the bank protection, as well as the contour lines. An initial model was developed to determine the extent of the 500-year event. This model was extended over 3,600 feet upstream of Grant Road to assure that no significant break over flow would occur. It was found that the 500-year event floodplain could be contained to the Silvercroft Wash floodplain all the way up to Grant Road. This initial model was also used to determine the extent of the floodplain land use delineation. Using existing shape files for zoning areas, land use polygons were delineated for the entire study area and a Manning's n table was developed with each floodplain and channel land use entered.

HEC-GeoRAS was used to generate the basic geometry data file in an iterative manner. A revised 500-year event model was developed with Silver Mountain Place, 700 feet upstream of the El Rio Wash, used as the most upstream limit of the modeling corridor. The model geometry has stationing in River Miles and correlates to the stationing of the ERM F3 Study as well as the Tres Rios del Norte study (located downstream of the El Rio Medio project).

The levee option and the ineffective flow option have been used in the various models. Ineffective flow has been modeled in areas with localized depressions, where water may break out of the main channel locally, or near the drainage crossings. Contraction and expansion coefficients are 0.1 and 0.3 respectively. These values were raised to 0.3 and 0.5 near the culvert and bridge cross sections.

From the 500-year event model, the other models were developed. These include a model for the 2-, 5-, 10-, and 20-year events, a model for the 50-year event, a model for the 100-year event, and a model for the 200-year event. The basic geometry is the same between the models, the difference being placement of infective flow areas and levee stations.

The downstream boundary condition for the Silvercroft Wash was the water surface profile for the Santa Cruz River. The methodology used in the ERM F3 Study for tributary stream boundary conditions was based on time to peak differential of coincidental events. The 50-year and 100-year tributary models used the 20-year Santa Cruz River water surface elevation as a downstream boundary condition, the 10-year and 20-year tributary models used the 10-year Santa Cruz River water surface elevation, and the 2-year model assumed a 2-year Santa Cruz River water surface elevation. The following table outlines the downstream condition used in the current Silvercroft Wash model.

Table 4 - Assumed coincidental events, Silvercroft Wash and Santa Cruz River

Model Runoff Event within Silvercroft Wash	Assumed Coincidental Event within Santa Cruz River	Water Surface Elevation within Santa Cruz River (ft)
2-yr	2-yr	2267.2
5-yr	2-yr	2267.2
10-yr	10-yr	2270.5
20-yr	10-yr	2270.5
50-yr	20-yr	2272.2
100-yr	20-yr	2272.2
200-yr	50-yr	2275.7
500-yr	50-yr	2275.7

5.2 HEC-RAS Model Results

The HEC-RAS model indicates that the 5-, 10-, and 20-year events are contained from Grant Road to the Silvercroft Wash. The 50-year event has a small breakout area upstream of the Brictha Wash while the 100-year event breaks out at this location as well as near W. Silverbell Tree Drive. The 200- and 500-year events are not contained in this reach. See Figure 2 for more details. Plate 2 shows an expanded version of Figure 2. Digital HEC-RAS model files are within Appendix E. Printed versions may be found within Appendix F (summary output for all events) and Appendix G (detailed output for 100-year event).

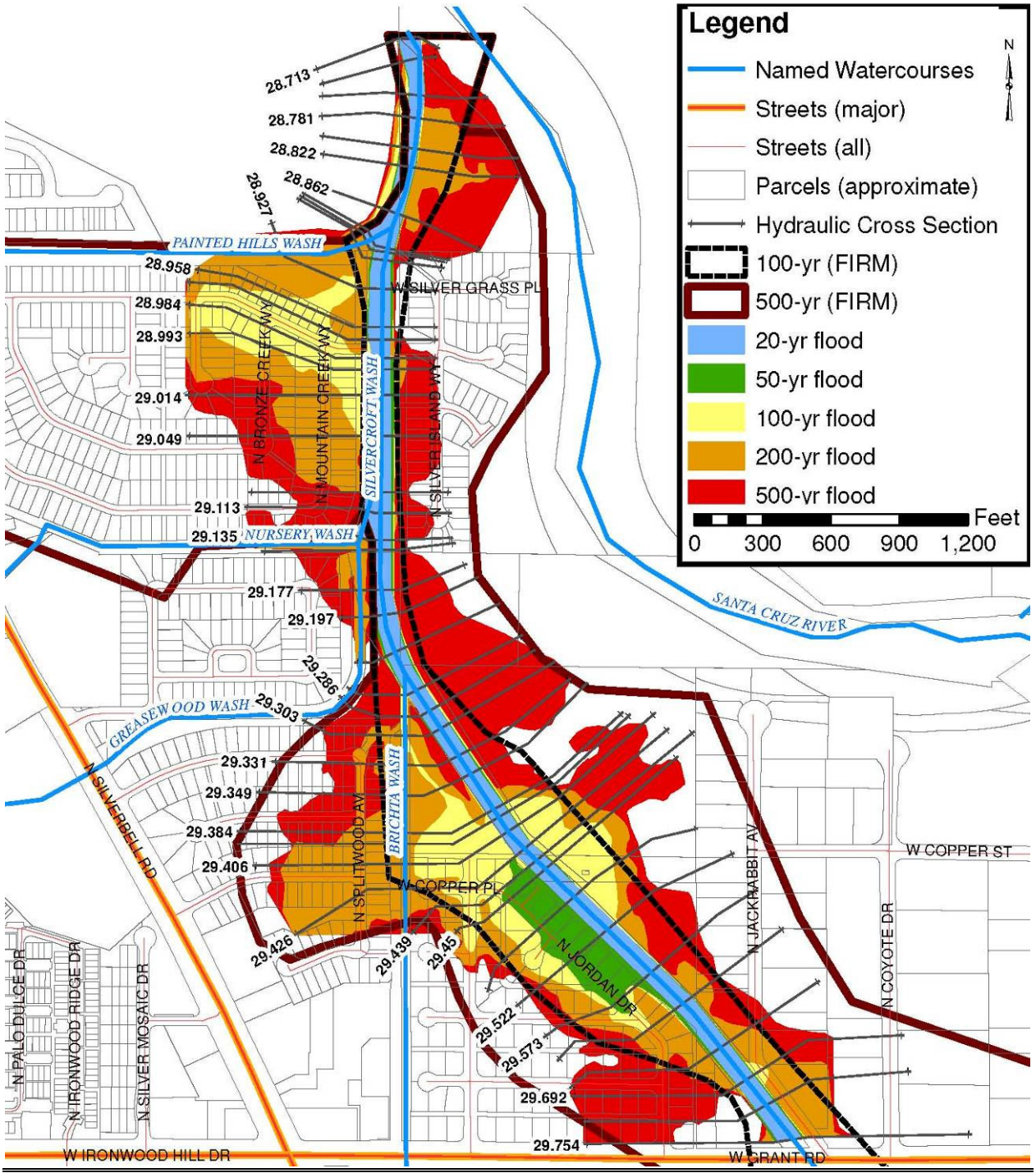

Figure 2 - Without Project Floodplains and FIRM Mapping

5.2.1 Comparison to Effective FEMA Model

Figure 2 shows the uncontained flood limits and compares them to the limits shown on the effective FIRM panels. South of the Brichta Wash, the effective 100-year flood extends beyond that delineated in the current model. The current model indicates a significant ineffective flow area with breakover flow occurring along the west side of the Wash, near and along Silverbell Tree Drive. This is not reflected on the FIRM panel.

Table 5 shows several spot comparisons between the water surface elevations shown on the FIRM and those from the current model. Note that the elevations are on the NAVD 88 datum, NGVD 29 elevations were adjusted by 2.2 feet. Most of the locations compare well but it is not clear why there is such discrepancy at 29.014, 29.658, and 28.822. It may be as simple as changes to topography, which is most likely the cause near the Santa Cruz River considering recent improvements. The original FEMA model has not been reviewed so it is not clear what the original topography looks like.

Table 5 - Comparison of FEMA effective model to current 100-year WSEs

River Mile	Approximate FEMA WSE (adjusted to NAVD 88)	100-year WSE from Current Model
28.822	2282.9	2279.9
29.014	2284.3	2286.7
29.095	2286.2	2287.1
29.177	2288.1	2287.5
29.286	2289.2	2289.1
29.450	2295.2	2295.1
29.658	2299.2	2296.8

6 Methodology for Modeling With-Project Alternatives

The development of with-project HEC-RAS models is summarized in this section and documented in detail within Appendix D. The with-project HEC-RAS models are based upon the original, without-project models but have been modified to reflect the proposed modifications to vegetation and channel grading. In general, the geometry remains the same and the models are only revised to reflect estimated changes to channel and overbank roughness.

6.1 Alternatives Summary

The District provided summaries of three alternatives. Shape files representing the limits of vegetation and grading were provided by the USACE consultant Tetra Tech. The alternatives are labeled LM-HH-MH, ML-ML-ML, and LL-LL-LL.

- The letters L, M, and H signify Low, Medium, or High states.
- The first letter pair in each sequence refers to the main stem (Santa Cruz River), the second pair refers to significant tributaries, and the third pair refers to the overbanks.
- The first letter in each pair refers to the level of planting and watering and the second letter refers to the level of engineering.

6.2 Santa Cruz River Alternative Restoration Features

Review of the Santa Cruz River alternatives indicates that there will be no significant structural changes such as channel realignment but rather smaller, more localized changes such as plantings, notching of the soil cement, placement of boulders, placement of ponds, and placement of point bars. The following table summarizes the main stem restoration features.

Table 6 - Santa Cruz River channel restoration features summary

Feature	LM-HH-MH	ML-ML-ML	LL-LL-LL
Removal of bank protection	2 notches at old bend	none	none
Addition of bank protection	Inside bank of old bend	none	none
Removal of concrete	At the confluence of Silvercroft, Tucson Arroyo, and Flowing Wells Washes		
Excavation	Flowing Wells Wash area	none	none
Grading	Temporary mass grading for PWAAs with large equipment	Temporary mass grading for PWAAs with large equipment	Temporary mass grading for PWAAs with large equipment
Channel sinuosity/topography	100’ x 50’ triangle point bars with 2’ boulders, 1.5’ protruding. 17 bars spaced 1,500’ apart Add few large boulders to allow for natural creation of depressions and scour holes	Create channel topography using boulder/cobble Add few large boulders to allow for natural creation of depressions and scour holes	Create channel topography using boulder/cobble Add few large boulders to allow for natural creation of depressions and scour holes

The HEC-RAS models were modified to reflect with-project conditions by revising the channel roughness values and the overbank roughness values where applicable. Channel roughness increased at all locations where restoration is proposed. Overbank roughness changes were limited to areas with new plantings and roughness values generally increased but did decrease in some areas. The following table summarize the roughness values used in the channel.

Table 7 - Composite channel roughness values within the Santa Cruz River main stem

	Reach composite roughness			
Project reach	Without-project	LM	ML	LL
Congress St. to St. Mary's Rd.	0.032	0.032	0.032	0.032
St. Mary's Rd. to Speedway Blvd.	0.031	0.033	0.033	0.032
Speedway Blvd. to Grant Rd.	0.028	0.030	0.030	0.029
Grant Rd. to Miracle Mile	0.027	0.030	0.029	0.028
Miracle Mile to Prince Road	0.027	0.030	0.029	0.029

Table 8 is a summary of the roughness values applied to each planting for each alternative. Table 9 and Table 10 reflect the composite overbank roughness values on a reach-averaged basis. The values used to calculate an average were those generated by the 500-year HEC-RAS model and are included here for reference.

Table 8 - Santa Cruz River overbanks Manning's roughness values

Planting	MH	ML	LL
Cottonwood-Willow	0.055	0.048	0.040
Mesquite	0.055	0.048	0.040
Riparian	0.060	0.053	0.045

Table 9 - Composite left overbank roughness values for Santa Cruz River main stem

	Reach composite left bank roughness			
Project reach	Without-project	LM	ML	LL
Congress St. to St. Mary's Rd.	0.041	0.041	0.041	0.041
St. Mary's Rd. to Speedway Blvd.	0.067	0.067	0.067	0.065
Speedway Blvd. to Grant Rd.	0.073	0.073	0.070	0.069
Grant Rd. to Miracle Mile	0.047	0.059	0.054	0.049
Miracle Mile to Prince Road	0.039	0.052	0.048	0.043

Table 10 - Composite right overbank roughness values for Santa Cruz River main stem

	Reach composite right bank roughness			
Project reach	Without-project	LM	ML	LL
Congress St. to St. Mary's Rd.	0.063	0.063	0.063	0.063
St. Mary's Rd. to Speedway Blvd.	0.044	0.047	0.045	0.042
Speedway Blvd. to Grant Rd.	0.044	0.044	0.042	0.039
Grant Rd. to Miracle Mile	0.060	0.063	0.060	0.058
Miracle Mile to Prince Road	0.046	0.051	0.050	0.048

6.3 Silvercroft Wash Restoration Features

The Silvercroft Wash restoration features and with-project roughness values are summarized in the following table.

Table 11 -Channel Restoration Features Summary

Feature	LM-HH-MH	ML-ML-ML	LL-LL-LL
Removal of concrete	Yes, invert and banks. Channel widening, lay back and terrace banks for multi-level floodplain	none	none
Grading	Temporary mass grading for PWAAs with large equipment	Temporary mass grading for PWAAs with large equipment	Temporary mass grading for PWAAs with large equipment
Channel sinuosity/topography	40' x 20' triangle point bars with 2' boulders, 1.5' protruding. 20 bars spaced 200' apart Create channel topography using boulder/cobble	Create channel topography using boulder/cobble	Create channel topography using boulder/cobble

The Silvercroft wash HEC-RAS model was revised to reflect the changes to roughness values, similar to the Santa Cruz River methods. In addition, a limited area of channel widening and terracing are proposed downstream of the Brichta Wash. Assumptions were made regarding the depths and areas and the cross sections in the region were revised to reflect terraces.

Table 12 - Summary of composite channel roughness values by reach within the Silvercroft Wash

	Reach composite roughness	
Project reach	Without-project	HH
Beginning of Modeled Area to Water Street	0.019	n/a
Water Street to Jordan Drive	0.019	n/a
Jordan Drive to Roundwood Place	0.015	n/a
Roundwood Place to Brichta Wash	0.034	n/a
Brichta Wash to Painted Sunset Circle	0.019	0.038
Painted Sunset Circle to Nursery Wash	0.029	0.038
Nursery Wash to Painted Hills Wash	0.024	0.038
Painted Hills Wash to Santa Cruz River	0.015	0.038

7 With-Project Results

This section summarizes the results of the with-project analyses for both modeled watercourses.

7.1 Santa Cruz River With Project Conditions

The with-project alternatives all had impacts to the Santa Cruz River hydraulics, see Figure 3.

Figure 3 - Overview of with-project increases to 100-year inundation

All three alternatives have increased roughness and consequently exacerbate 100-year flooding upstream of Speedway Blvd., downstream of Speedway Blvd., and near the Flowing Wells Wash. The reason for increased inundation at the three above mentioned locations is that the channel in the existing condition has minimal containment of 100-year flows. Slight increases to roughness values force breakout of the channel to occur. Alternative LM-HH-MH has an additional increase of flooding due to the notched weir segments, this at the Old Bend" area, north of Grant Road.

Table 13 shows the total increase in 100-year event inundation area from the three alternatives. For the Santa Cruz River, these areas are all outside of the channel.

Table 13 - Santa Cruz River with-project alternatives, 100-year event increased inundation area

Alternative	Increase in 100-year inundation area[1] (acre)
LM-HH-MH	64.8
ML-ML-ML	53.2
LL-LL-LL	41.3

Note 1: Area beyond existing 100-year floodplain

See Plate 1 for more details regarding inundation extent location of PWAA features. The following four tables summarize the average flow depth and velocity for the 6 events reported on in the existing conditions report (page 180). On a reach wide average and for all events, the alternatives increase flow depths and decrease flow velocities.

Table 14 - Existing conditions average hydraulic values for Santa Cruz River

	Average channel depth (ft)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Prince 30.150-28.195	5.14	8.06	9.55	12.68	16.14	24.08
Speedway to Grant 31.523-30.179	5.43	8.87	10.64	14.37	18.48	25.62
St. Mary's to Speedway 31.951-31.542	5.95	9.77	11.69	15.61	20.79	28.71
Congress to St. Mary's 32.608-31.970	6.34	10.47	12.64	17.11	21.59	29.60
Entire Project	5.49	8.86	10.59	14.20	18.20	25.89
	Average channel velocity (ft/sec)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Prince 30.150-28.195	6.53	9.69	11.07	13.59	15.89	16.38
Speedway to Grant 31.523-30.179	6.33	9.37	10.66	12.94	15.02	16.73
St. Mary's to Speedway 31.951-31.542	7.07	10.59	12.10	14.79	15.60	17.11
Congress to St. Mary's 32.608-31.970	7.08	10.19	11.35	12.89	14.04	15.02
Entire Project	6.60	9.75	11.08	13.39	15.29	16.36

Table 15 - Alternative LM-HH-MH average hydraulic values for Santa Cruz River

	Average channel depth (ft)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Prince 30.150-28.195	5.32	8.39	9.95	13.19	16.78	24.37
Speedway to Grant 31.523-30.179	5.57	9.12	10.94	14.75	18.99	25.79
St. Mary's to Speedway 31.951-31.542	6.04	9.97	11.92	15.96	21.68	28.83
Congress to St. Mary's 32.608-31.970	6.35	10.51	12.61	16.80	21.52	29.55
Entire Project	5.63	9.11	10.88	14.53	18.72	26.07
	Increase in average channel depth (ft) (value minus existing value)					
Grant to Prince 30.150-28.195	0.18	0.33	0.39	0.52	0.64	0.28
Speedway to Grant 31.523-30.179	0.15	0.25	0.30	0.38	0.51	0.17
St. Mary's to Speedway 31.951-31.542	0.09	0.19	0.23	0.35	0.89	0.12
Congress to St. Mary's 32.608-31.970	0.01	0.04	-0.03	-0.31	-0.07	-0.05
Entire Project	0.14	0.24	0.28	0.33	0.51	0.18
	Average channel velocity (ft/sec)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Prince 30.150-28.195	6.17	9.17	10.49	12.90	15.11	16.22
Speedway to Grant 31.523-30.179	6.09	9.03	10.29	12.53	14.41	16.70
St. Mary's to Speedway 31.951-31.542	6.95	10.32	11.78	14.37	14.53	16.83
Congress to St. Mary's 32.608-31.970	7.06	10.14	11.38	13.27	14.20	15.13
Entire Project	6.35	9.38	10.68	12.98	14.68	16.28
	Increase in average channel vel (ft/sec) (value minus existing value)					
Grant to Prince 30.150-28.195	-0.36	-0.52	-0.59	-0.69	-0.78	-0.16
Speedway to Grant 31.523-30.179	-0.24	-0.33	-0.37	-0.41	-0.61	-0.03
St. Mary's to Speedway 31.951-31.542	-0.13	-0.27	-0.31	-0.42	-1.07	-0.27
Congress to St. Mary's 32.608-31.970	-0.02	-0.05	0.03	0.38	0.16	0.11
Entire Project	-0.25	-0.36	-0.39	-0.41	-0.61	-0.09

Table 16 - Alternative ML-ML-ML average hydraulic values for Santa Cruz River

	Average channel depth (ft)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Prince 30.150-28.195	5.25	8.26	9.79	12.98	16.52	24.23
Speedway to Grant 31.523-30.179	5.65	9.27	11.12	15.00	19.32	25.96
St. Mary's to Speedway 31.951-31.542	6.04	9.97	11.92	15.96	21.67	28.70
Congress to St. Mary's 32.608-31.970	6.35	10.51	12.61	16.79	21.49	29.46
Entire Project	5.63	9.11	10.87	14.52	18.72	26.04
	Increase in average channel depth (ft) (value minus existing value)					
Grant to Prince 30.150-28.195	0.11	0.20	0.24	0.31	0.39	0.14
Speedway to Grant 31.523-30.179	0.22	0.40	0.48	0.63	0.84	0.34
St. Mary's to Speedway 31.951-31.542	0.09	0.19	0.23	0.35	0.88	-0.02
Congress to St. Mary's 32.608-31.970	0.01	0.04	-0.03	-0.32	-0.10	-0.13
Entire Project	0.13	0.24	0.28	0.32	0.51	0.15
	Average channel velocity (ft/sec)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Prince 30.150-28.195	6.30	9.35	10.70	13.16	15.40	16.38
Speedway to Grant 31.523-30.179	5.99	8.87	10.10	12.30	14.07	16.18
St. Mary's to Speedway 31.951-31.542	6.95	10.32	11.78	14.37	14.54	16.89
Congress to St. Mary's 32.608-31.970	7.06	10.14	11.38	13.28	14.21	15.18
Entire Project	6.37	9.41	10.71	13.01	14.69	16.19
	Increase in average channel vel (ft/sec) (value minus existing value)					
Grant to Prince 30.150-28.195	-0.23	-0.34	-0.37	-0.43	-0.49	0.00
Speedway to Grant 31.523-30.179	-0.35	-0.49	-0.55	-0.64	-0.94	-0.54
St. Mary's to Speedway 31.951-31.542	-0.13	-0.27	-0.31	-0.42	-1.07	-0.21
Congress to St. Mary's 32.608-31.970	-0.02	-0.05	0.03	0.39	0.17	0.16
Entire Project	-0.23	-0.34	-0.37	-0.38	-0.60	-0.18

Table 17 - Alternative LL-LL-LL average hydraulic values for Santa Cruz River

	Average channel depth (ft)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Prince 30.150-28.195	5.22	8.20	9.72	12.89	16.41	24.20
Speedway to Grant 31.523-30.179	5.49	8.98	10.76	14.52	18.73	25.64
St. Mary's to Speedway 31.951-31.542	5.97	9.84	11.77	15.73	21.37	28.63
Congress to St. Mary's 32.608-31.970	6.34	10.49	12.58	16.73	21.34	29.47
Entire Project	5.55	8.97	10.70	14.29	18.42	25.91
	Increase in average channel depth (ft) (value minus existing value)					
Grant to Prince 30.150-28.195	0.08	0.15	0.17	0.21	0.27	0.11
Speedway to Grant 31.523-30.179	0.07	0.11	0.12	0.15	0.25	0.02
St. Mary's to Speedway 31.951-31.542	0.02	0.06	0.09	0.12	0.58	-0.09
Congress to St. Mary's 32.608-31.970	0.00	0.01	-0.06	-0.38	-0.25	-0.12
Entire Project	0.06	0.10	0.11	0.09	0.22	0.03
	Average channel velocity (ft/sec)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Prince 30.150-28.195	6.36	9.45	10.81	13.30	15.56	16.34
Speedway to Grant 31.523-30.179	6.22	9.22	10.50	12.78	14.65	16.68
St. Mary's to Speedway 31.951-31.542	7.03	10.51	11.99	14.65	14.87	16.94
Congress to St. Mary's 32.608-31.970	7.07	10.17	11.42	13.35	14.32	15.08
Entire Project	6.49	9.59	10.92	13.27	15.00	16.33
	Increase in average channel vel (ft/sec) (value minus existing value)					
Grant to Prince 30.150-28.195	-0.17	-0.24	-0.27	-0.29	-0.33	-0.04
Speedway to Grant 31.523-30.179	-0.11	-0.15	-0.16	-0.17	-0.36	-0.04
St. Mary's to Speedway 31.951-31.542	-0.04	-0.09	-0.11	-0.14	-0.73	-0.16
Congress to St. Mary's 32.608-31.970	-0.01	-0.02	0.08	0.46	0.28	0.05
Entire Project	-0.11	-0.16	-0.16	-0.12	-0.29	-0.04

7.2 Silvercroft Wash With Project Conditions

The LM-HH-MH alternative has noticeable impacts to the Silvercroft Wash hydraulics with the most significant change occurring as a result of terracing near the Greasewood Wash confluence. The inundated area is much wider at this location. 100-year flooding is increased throughout as this alternative increases roughness values by a significant amount.

Table 18 shows the increase in 100-year event inundation area for the one modeled alternative. Unlike the Santa Cruz River, just over one-half of this area is within the channel as it is within the planned terrace area.

Table 18 - Silvercroft Wash with-project, 100-year event increased inundation area

Alternative	Increase in 100-year inundation area[1] (acre)
LM-HH-MH	8.0

Note 1: Area beyond existing 100-year floodplain, includes wider terrace area

The following two tables summarize the average flow depth and velocity for the Silvercroft Wash. For all events, the alternative increases flow depths and decrease flow velocities.

Table 19 - Existing conditions average hydraulic values for Silvercroft Wash

	Average channel depth (ft)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Silverbell Tree Dr (29.754-28.984)	2.41	5.60	6.85	8.86	10.00	12.48
Silverbell Tree Dr to River (28.968-28.713)	2.90	6.81	8.27	10.43	11.73	15.95
Entire Project	2.56	5.97	7.28	9.33	10.52	13.53
	Average channel velocity (ft/sec)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Silverbell Tree Dr (29.754-28.984)	5.31	8.35	9.27	10.27	10.44	10.48
Silverbell Tree Dr to River (28.968-28.713)	6.43	9.49	10.53	11.58	11.44	11.14
Entire Project	5.65	8.69	9.65	10.67	10.74	10.68

Table 20 - Alternative LM-HH-MH average hydraulic values for Silvercroft Wash

	Average channel depth (ft)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Silverbell Tree Dr (29.754-28.984)	2.66	6.08	7.47	9.50	10.50	12.76
Silverbell Tree Dr to River (28.968-28.713)	3.65	7.58	9.05	11.38	12.64	16.67
Entire Project	2.96	6.53	7.95	10.07	11.15	13.94
	Increase in average channel depth (ft) (value minus existing value)					
	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Silverbell Tree Dr (29.754-28.984)	0.25	0.48	0.62	0.65	0.50	0.28
Silverbell Tree Dr to River (28.968-28.713)	0.75	0.76	0.78	0.94	0.91	0.72
Entire Project	0.40	0.56	0.67	0.74	0.63	0.41
	Average channel velocity (ft/sec)					
Reach	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Silverbell Tree Dr (29.754-28.984)	4.80	7.65	8.51	9.11	9.63	9.70
Silverbell Tree Dr to River (28.968-28.713)	4.82	8.33	9.10	9.64	10.00	9.39
Entire Project	4.81	7.86	8.69	9.27	9.74	9.61
	Increase in average channel vel (ft/sec) (value minus existing value)					
	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Grant to Silverbell Tree Dr (29.754-28.984)	-0.51	-0.69	-0.75	-1.16	-0.80	-0.77
Silverbell Tree Dr to River (28.968-28.713)	-1.61	-1.17	-1.43	-1.94	-1.45	-1.76
Entire Project	-0.84	-0.84	-0.96	-1.40	-1.00	-1.07

8 Summary and Conclusions

This report expanded upon a previous existing conditions hydrologic, hydraulic, and sediment transport analysis for the El Rio Medio project. The current report presented existing conditions hydrologic and hydraulic analysis of the Silvercroft Wash along with analysis of 3 potential with-project options for the Santa Cruz River and 1 option for the Silvercroft Wash (LM-HH-MH).

8.1 Silvercroft Wash Existing Conditions

External hydrologic studies and models were used to populate the 8 event discharge series at major tributary inflow points. The 100-year discharge is 9,700 cfs at the Santa Cruz River. Hydraulic modeling indicates those events up to and including the 20-year event are contained within the channel. The 50-year event has some breakout at the Brichta Wash which increases in the 100-year event. The 100-year event also breaks out near W. Silverbell Tree Drive. The 200- and 500-year events are not contained.

8.2 Modeled Alternatives

Three with-project alternatives were modeled, LM-HH-MH, ML-ML-ML, and LL-LL-LL. Only the LM-HH-MH had impacts to the Silvercroft Wash. These alternatives included varying degrees of structural measures, plantings, and waterings with LM-HH-MH having the most structural, or engineered improvements in both watercourses.

8.3 Suggestions to Mitigate Adverse Impacts

All Santa Cruz River alternatives increase 100-year flooding potential due to minimal existing conditions containment. It must be pointed out that overbank plantings have no (or minimal) effect on increasing the 100-year flooding. The channel plantings and contour development force water out of the channel, causing the increase in flooding potential. Therefore, it may be best to modify the alternatives so as to include overbank restoration and abandon channel restoration features.

The results of this report were presented to District staff prior to development of the report. In particular, the increase in 100-year flooding was discussed and other alternatives were discussed such as reducing the in-channel plantings to more limited areas. Unfortunately, few areas if any are present where flow is well contained within the channel banks (vertically), where any amount of inflowing runoff is present to maintain vegetation, and where flow conditions are suitable for vegetation to survive most runoff events. Other alternatives would be to increase channel capacity by channel dredging, channel widening, or increasing bank height. All of these options are highly costly and may diminish the restoration benefits by adding more manmade features.

9 References

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Appendix A - Plates and Floodmaps

- *Plate 1 - Santa Cruz River With-project Flooding, 4 sheets*
- *Plate 2- Silvercroft Wash Without- and With-project Flooding, 1 sheet*

Appendix B - Research and Field Reconnaissance

B Research and Field Reconnaissance

Construction and Survey Plans

Several as-built and construction plans were found using the resources of the City of Tucson Department of Transportation online map center as well as the Pima County Department of Transportation online map guide. The following plans were found to be useful to this study:

- Silvercroft Wash Drainage Improvement Project, Santa Cruz River to Grant Road. These as-built plans show the plan view of the constructed channel, bank protection, and channel cross section. These plans document the culvert structure which conveys the Silvercroft Wash flows under Grant Road.
- Silvercroft Wash Drainage Improvements, Grant Road to Speedway Boulevard. These as-built plans show the plan view of the constructed channel, bank protection, and channel cross section upstream of Grant Road.
- Santa Cruz River Bank Protection, Grant Road to Fort Lowell Road. These as-built plans are the most recent plans for the most downstream 1,000 feet of the Silvercroft Wash.
- Silvercroft Wash Pedestrian Bridge. These as-built plans show the construction of a small pedestrian bridge crossing the Silvercroft Wash near the Santa Cruz River.
- Paving, Drainage, and Sewer Improvements for Silvercreek II Lots 289 to 356. These as-built plans show the culvert structure along Silverbell Tree Drive which crosses the Silvercroft Wash.
- Paving, Drainage, and Sewer Improvements for Silvercreek III Lots 29 to 74, 122 to 154, 240 to 271 and Common Areas. These as-built plans show the Silverbell Tree Drive profile west of the Silvercroft Wash culvert structure.
- Grant Road – Silverbell Road to Santa Cruz River, District Paving Improvement. These as-built plans were used to model the profile of Grant Road. These plans represent the earliest obtained record of the Silvercroft Culvert under Grant Road. Per these plans, the 6 cell 10’ x 5.5’ CBC was extended. The extension was a 6 cell 9’-10” x 5’-7.5” CBC. 2 additional cells measuring 9’-10” x 5’-7.5” were placed along side the old culvert.

General Description of Silvercroft Wash

The Silvercroft wash is an urban channel with an engineered channel section throughout the study area. Residential, industrial, and commercial development occupy the historic floodplain with structures built adjacent to the channel. Concentrated runoff from adjacent developments drains to the channel via constructed channels or swales. Some areas of sheet flow drainage along the banks also are found.

There are three confluences where tributaries drain to the Silvercroft Wash within the study area. Some confusion regarding the names of the washes exists as the names vary depending upon the map.

- The northernmost tributary is located approximately 1,200 feet upstream of the Santa Cruz River. The effective FIRM panel, the online Pima County Mapguide, and a set of old City of Tucson flood hazard maps label this as the Speedway Wash. However, this

wash is labeled as the Painted Hills Wash on the City of Tucson online Stormwater Map and on street signage.

- Approximately 2,200 feet upstream of the Santa Cruz River, another tributary drains to the Silvercroft Wash. This tributary is labeled the Painted Hills Wash on the Pima County Mapguide. This wash is labeled the Greasewood Wash on the City of Tucson Stormwater Map, on FIRM panels, and on Street Signage. Just upstream of the tributary of this wash and the Silvercroft Wash, a wash called the Nursery Wash drains into this wash.
- Approximately 3,200 feet upstream of the Santa Cruz River, the Brichta Wash drains to the Silvercroft Wash.

For the purposes of this study, the names of these tributaries will follow the street signage as this would be the source of information that someone in the field would find most reliable. Therefore, the northern tributary is the Painted Hills Wash, the middle tributary is the Greasewood Wash, and the south tributary is the Brichta Wash. The labels of these various watercourses can be found on Figure 2.

The alignment of the Silvercroft Wash is relatively straight with two significant bends. From Grant Road, the wash heads north-northwest. Then at the confluence of the Brichta Wash, the alignment turns approximately 35 degrees to run north. Downstream of the northernmost confluence, the alignment turns approximately 20 degrees towards the northeast, then curves back to run towards the northwest and join the Santa Cruz River. The northernmost bend, just upstream of the Santa Cruz River, has the smallest radius of curvature at 330 feet. The radii of the upstream bends are between 500 and 900 feet.

A limited reach of the Silvercroft Wash was discussed within the field reconnaissance section of the ERM F3 Report with the following discussing:

> The Silvercroft Wash is a concrete lined channel and has a confluence with the Santa Cruz River at approximately 2,500 feet upstream of the Prince Road alignment. The banks of the wash and the river tie into each other with a notch in the left Santa Cruz River bank. The Silvercroft Wash approaches the Santa Cruz River at approximately 70 degrees from normal. The overbanks contain moderately dense, desert vegetation (p 57).

Upstream of the area described previously, the channel section alternates between a fully concrete lined section and a section with lined banks and a natural bottom. Some areas have a section with a channel bottom that is concrete lined across only part of it, covering a sewer pipe. The unlined channel bottom is relatively clear of large vegetation. The channel section upstream of Grant Road has lined banks and an unlined bottom. Vegetation in this reach includes grasses and smaller shrubs.

The channel profile is relatively uniform with the following exceptions:

- A channel drop and cutoff wall are located just upstream of the Painted Hills Wash (northernmost wash) confluence.
- A drop in the profile of the channel is found upstream of the Greasewood Wash tributary. An energy dissipater is located at the drop.
- Cutoff walls are located throughout the reach.

Discussion of Roughness Value Methodology

The HEC-RAS models are developed using Manning's roughness 'n' values following methodology discussed previously in the ERM F3 Report. This methodology references three reports published by the U.S. Geological Survey (USGS);

- "Guide to Selecting Manning's Roughness Coefficients for Natural Channels and Floodplains", U.S. Geological Survey Water-Supply, 2339 Report (USGS WSP-2339).
- "Verification of Roughness Coefficients for Selected Natural and Constructed Stream Channels in Arizona", U.S. Geological Survey Professional Paper 1584 (USGS PP-1584).
- "A method for Adjusting Values of Manning's Roughness Coefficient for Flooded Urban Areas" (Urban Adjustment Guide).

Manning's 'n' values were determined using the methodology presented in the USGS WSP--2339. These values were compared to values derived in the ERM F3 Report. Engineering judgment and experience was applied to determine the variables (namely vegetation pattern, bed material characteristics, degree of irregularity, and obstructions) used in the USGS WSP-2339 procedure.

Per the methodology presented in the USGS WSP-2339, channel roughness values and floodplain roughness values are determined separately, using the same formula and similar constraints.

The equation used to determine the value of n is as follows;

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m \qquad \textit{Equation 1}$$

where;

n_b=the base n value, value for a straight, uniform, smooth channel.

n_1 =surface irregularity correction factor

n_2 =value describing channel cross section shape and size variation

n_3 =value describing obstructions

n_4 =value for vegetation and flow conditions

m =correction factor for channel meandering

The following table summarizes suggested values for each of the coefficients as presented in USGS WSP-2339.

Table B - 1– Channel Roughness Value Adjustment Table

Channel Conditions		Manning's Adjustment	
Channel Material	Concrete	nb	.012-.018
	Firm Soil		.025-.032
	Coarse Sand		.026-.035
	Gravel		.028-.035
	Cobble		.030-.050
	Boulder		.040-.070
Degree of Irregularity	Smooth	n1	0
	Minor		.001-.005
	Moderate		.006-.010
	Severe		.011-.020
Variations in Channel Cross Section	Gradual	n2	0
	Occasionally Alternating		.001-.005
	Frequently Alternating		.010-.015
Effects of Obstruction	Negligible	n3	.000-.004
	Minor		.005-.015
	Appreciable		.020-.030
	Severe		.040-050
Vegetation	Small	n4	.002-.010
	Medium		.010-.025
	Large		.025-050
	Very Large		.050-.100
Degree of Meandering	Minor	m	1
	Appreciable		1.15
	Severe		1.3

Base n Value – n_b

The ERM F3 Report included documentation of sediment mean diameter within the Santa Cruz River and correlation to Base n Values. The Santa Cruz River was classified as a sand channel and based on 8 soil borings the mean diameter ranged from 0.57 mm to 3.2 mm. Soils were classified as 'Poorly Graded Sand' and 'Gravel and Poorly Graded Sand'. The corresponding Base n Values ranged from 0.023 to 0.028.

Based upon inspection, the bed material within the Silvercroft Wash is in the range of sand to firm soil and the wash bottom contains significantly less gravel than the Santa Cruz River with no cobbles. Therefore, the Base n Value can be estimated to be slightly lower than the values

assigned to the Santa Cruz River within the ERM F3 Report. A Base n value of 0.020 has been assigned to all reaches of the Silvercroft Wash, where an unlined channel bottom is present.

The concrete bottom and banks are in relatively good condition. The USGS 2339 report recommends a Base n Value for concrete within the range of 0.012 to 0.018. For the Silvercroft Wash, a Base n value of 0.015 will be used for concrete within the channel.

A composite Base n Value is assigned based upon channel section as follows:

- An entirely concrete lined section has a Base n Value of 0.015.
- A section with an earthen bottom and concrete banks has a Base n Value of 0.018.
- A section with an earthen bottom combined with concrete banks has a Base n Value of 0.021.

Surface Irregularity – n_1

The bed materials within the study reach are found to be generally smooth without irregularities. The transitions between channel sections (concrete to earthen) are smooth. The concrete channel banks are typically in good shape while the earthen channel banks have erosion (yielding scalloped banks) where adjacent overland runoff drains into the channel over the banks. The concrete banks fall under the category of 'smooth' as shown in Table B-1 and no adjustments to the roughness value are made for irregularities for concrete banks within the study reach. The earthen banks fall somewhere in the high end of the minor degree of irregularity to somewhere in the low end of moderate irregularity. An adjustment of 0.006 is used for earthen banks within the study area. Some areas were found with hummocks on the earthen channel floor. An adjustment of 0.005 is used in these areas.

Variation in Channel Cross Section – n_2

The channel cross section does not vary with any significance. The earthen sections of the channel are maintained and flat across the bottom. A low flow channel has not developed. For the entire study area, no adjustments are made to reflect channel cross section variation.

Obstructions – n_3

Obstructions are generally nonexistent within the study reach due to the maintenance of the earthen section and the concrete channel section. An exception would be stilling blocks which are found at the drop structures within the channel. With the exception of the stilling blocks, no adjustments are made to reflect obstructions within the channel.

In reference to Table B-1, the stilling blocks found within the reach have an effect of obstruction which is appreciable. The sphere of influence from each individual block will extend to an adjacent block. An increase to the Manning's n value of 0.025 is made for areas with stilling blocks.

Vegetation – n_4

The impact of vegetation on the Manning's n value is estimated using the procedure outlined in the ERM F3 Report. The value of n_4 is estimated using a best fit equation presented within USGS PP-1584. The relationship is as follows:

n_4=0.0008B-0.0007 Equation 2

where:

B=percentage of flow blocked by vegetation

Channel vegetation is found intermittently within the study area. Most of the channel is well maintained and free of significant vegetation, however some localized areas are found with sizeable vegetation consisting of desert brush and small trees. These areas generally correlate to being near cutoff walls or structures which may prevent the undermining of root structures and/or may provide for surface water ponding or groundwater accumulation, such as near a cutoff wall. Two vegetation scenarios are considered for this study area for sections with earthen bottoms or banks.

1. Low vegetation density. Vegetation is nonexistent or consists of low grasses which occupy a relatively insignificant portion of the channel. A minor adjustment of 0.001 is made to the Manning's n value for these areas. Exhibit 1 shows an aerial view of the channel in an area with little to no vegetation. Photo 1 is a ground shot of a similar area.

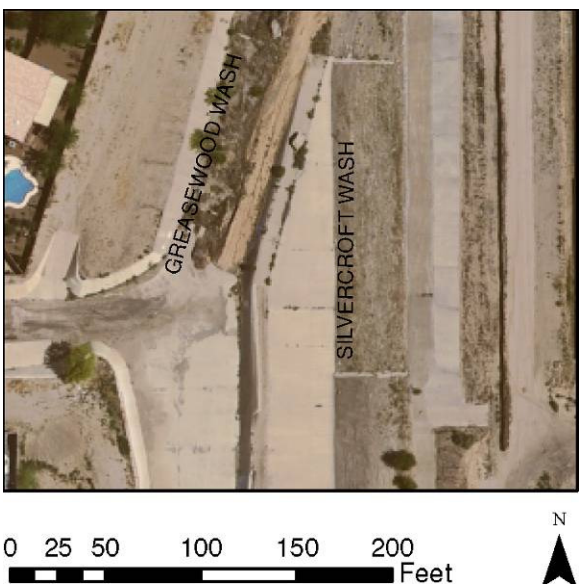

Exhibit 1 – Aerial view of no vegetation to sparse vegetation density area

Photo 1 – Ground view of no vegetation to sparse vegetation density area (LM01-26-01)

2. Medium vegetation density. Vegetation is thick enough to hinder walking through some areas but other areas have rows of vegetation parallel to stream flow paths. Vegetation consists of ground cover, desert shrubs, and sporadic placement of trees. The blocked flow area due to vegetation is approximately 5 to 10 percent. The adjustment to the Manning's n coefficient is 0.007 in these areas. Exhibit 2 shows an aerial view of a medium vegetation density area. Photo 2 shows the ground shot of this area, facing downstream.

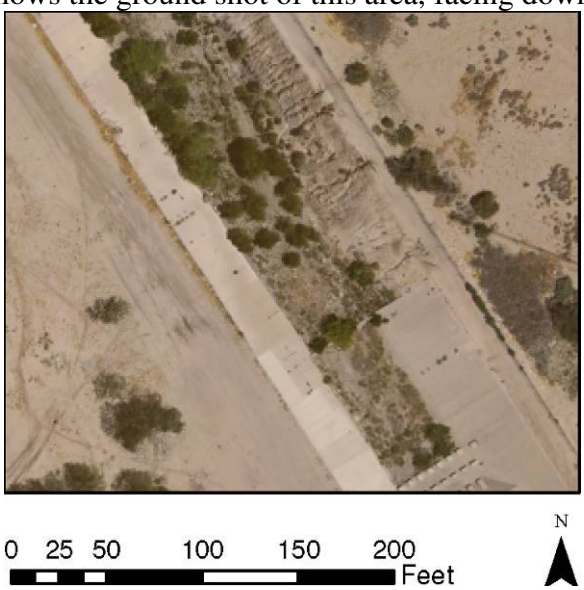

Exhibit 2 – Aerial view of medium vegetation area

Photo 2 – Ground view of medium vegetation area (LM01-31-01)

Meandering – m

The effects due to meandering are minor to negligible for this project and a multiplier of 1.00 is used for this study area.

Channel Manning's n Composite Values

In summary, the composite channel roughness is based on the equation $n = (n_b + n\ 1 + n\ 2 + n\ 3 + n\ 4)m$. The values used for the study area are as follows:

n_b=0.015 for fully concrete lined sections.

n_b=0.018 for earthen bottom (and earthen and partial concrete) and two concrete banks.

n_b=0.020 for earthen bottom, one full concrete bank and one partial concrete bank.

n_b=0.021 for all earthen bottom and one concrete bank.

n_1 =0.000 for channel sections with concrete banks.

n_1 =0.005 for channel sections with hummocks on the earthen floor.

n_1 =0.006 for channel sections with earthen banks.

n_2 =0.000 throughout.

n_3 =0.000 throughout except for areas with stilling blocks.

n_3 =0.025 is used to represent the stilling blocks.

n_4 =0.001 for areas with low vegetation density.

n_4 =0.007 for areas with medium vegetation density.

m =correction factor for channel meandering

The channel roughness coefficient is assigned (as an average value) to individual sub-reaches throughout the extent of the study area. These sub-reaches are defined by geographic landmarks, described from upstream to downstream in the following sections.

Composite Channel Value, Beginning of Modeled Area to Water Street

The channel within this sub-reach has an earthen bottom with concrete banks. Vegetation in the channel bottom is minor and the channel bottom is well maintained. No areas of ponding were found after a runoff event in July of 2007. The following is an aerial view of the sub-reach.

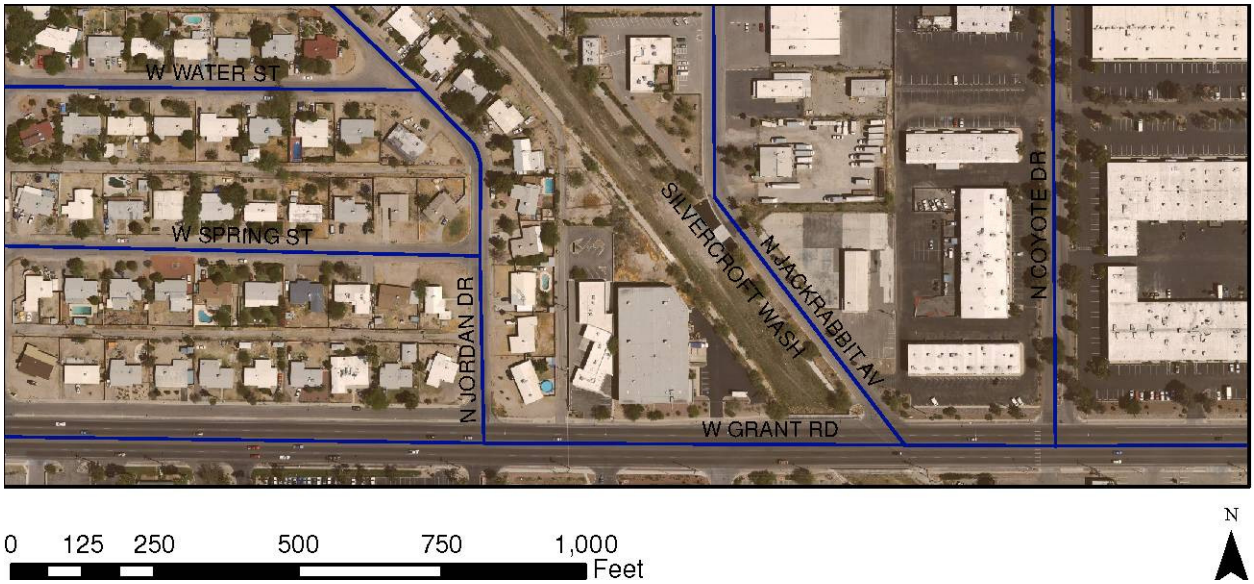

Exhibit 3 – Aerial view of Silvercroft Wash, beginning of modeled area to Water Street

Photo 3 and Photo 4 are typical ground shots within the sub-reach. Note the uniformity within the channel.

Photo 3 – Silvercroft Wash channel, facing downstream, north of Grant Road (ERM01-22-01)

Photo 4 – Silvercroft Wash channel, facing upstream from left bank, south of Grant Road (ERM01-22-01)

The following table summarizes the composite roughness value for the channel within this sub-reach.

Table B - 2 – Determination of Manning's Roughness Value, Beginning of Modeled Area to Water Street

Channel Conditions		Manning's Adjustment	
Channel Material	Earthen bottom, concrete banks	nb	0.018
Degree of Irregularity	Smooth	n1	0.000
Variations in Channel Cross Section	Gradual	n2	0.000
Effects of Obstruction	Negligible	n3	0.000
Vegetation	Small	n4	0.001
Degree of Meandering	Minor	m	1
		n = (nb + n1 + n2 + n3 + n4)m =	0.019

Composite Channel Value, Water Street to Jordan Drive

The channel within this sub-reach has an earthen bottom with concrete banks. There is a strip of concrete along the right side of the channel bottom. Vegetation in the channel bottom is minor and the channel bottom is well maintained. No areas of ponding were found after a runoff event in July of 2007. The following is an aerial view of the sub-reach.

Exhibit 4 – Aerial view of Silvercroft Wash, Water Street to Jordan Drive

Photo 5 shows the channel bottom in this sub-reach. The concrete portion of the channel bottom is found in the lower left side of the photograph.

Photo 5 – Silvercroft Wash channel, facing upstream, south of Jordan Drive (ERM01-25-01)

The following table summarizes the composite roughness value for the channel within this sub-reach.

Table B - 3 – Determination of Manning's Roughness Value, Water Street to Jordan Drive

Channel Conditions		Manning's Adjustment	
Channel Material	Earthen bottom, concrete banks	nb	0.018
Degree of Irregularity	Smooth	n1	0.000
Variations in Channel Cross Section	Gradual	n2	0.000
Effects of Obstruction	Negligible	n3	0.000
Vegetation	Small	n4	0.001
Degree of Meandering	Minor	m	1
		n = (nb + n1 + n2 + n3 + n4)m =	0.019

Composite Channel Value, Jordan Drive to Roundwood Place

The channel within this sub-reach has a concrete bottom and concrete banks. An aerial view is shown on Exhibit 5.

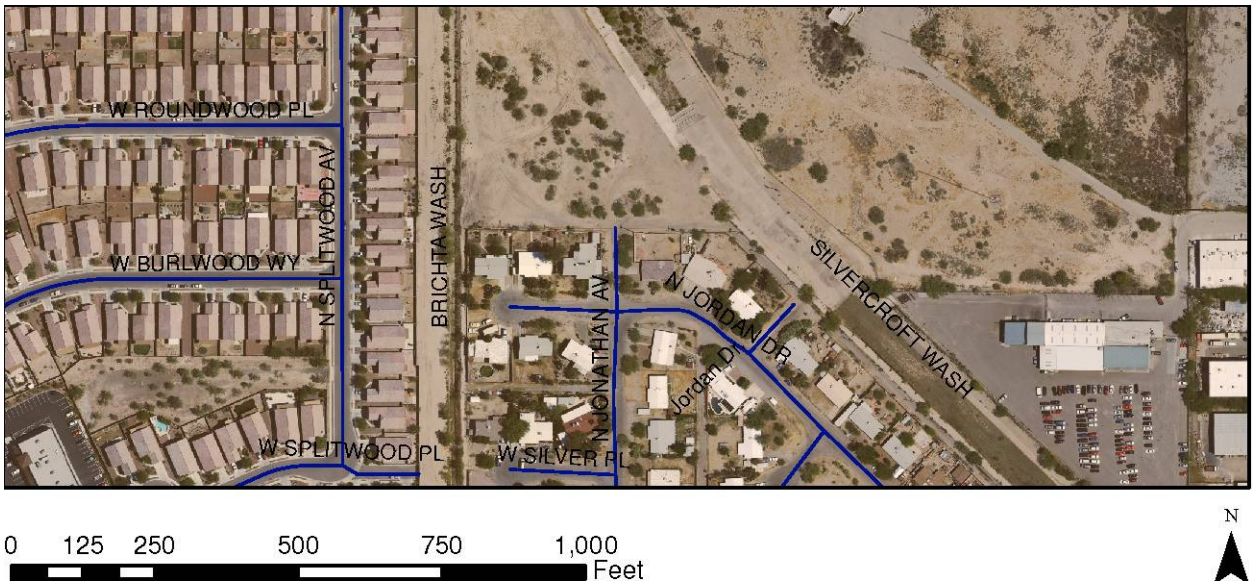

Exhibit 5 – Aerial view of Silvercroft Wash, Jordan Drive to Roundwood Place

Photo 6 shows a typical ground view of the channel in this sub-reach. The channel is uniform in this area.

Photo 6 – Silvercroft Wash channel, facing downstream, south of Roundwood Place (ERM01-29-01)

The following table summarizes the composite roughness value for the channel within this sub-reach.

Table B - 4 – Determination of Manning's Roughness Value, Jordan Drive to Roundwood Place

Channel Conditions		Manning's Adjustment	
Channel Material	Fully concrete lined	nb	0.015
Degree of Irregularity	Smooth	n1	0.000
Variations in Channel Cross Section	Gradual	n2	0.000
Effects of Obstruction	Negligible	n3	0.000
Vegetation	Small	n4	0.000
Degree of Meandering	Minor	m	1
		n = (nb + n1 + n2 + n3 + n4)m =	0.015

Composite Channel Value, Roundwood Place to Brichta Wash

The channel within this sub-reach has an earthen bottom. The left bank is concrete lined while the right bank is earthen. Ponding was found within this reach following a runoff event in July of 2007. The ponding extended from a grade control structure at the end of the sub-reach to about the midpoint of the sub-reach. Ponding was along the left bank near the lower limit of the sub-reach and then mid-channel near the middle of the sub-reach. Exhibit 6 shows an aerial view of the sub-reach.

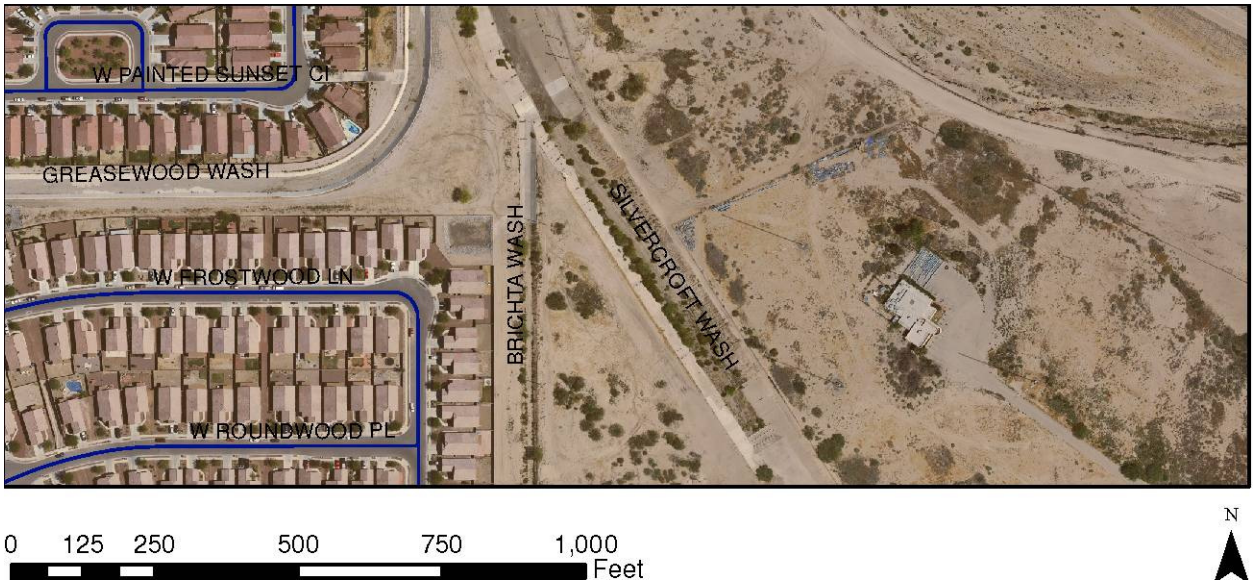

Exhibit 6 – Aerial view of Silvercroft Wash, Roundwood Place to Brichta Wash

The following photographs document the two banks within this sub-reach. Photo 9 shows the scalloping along the right bank due to erosion generated by water flowing over the bank into the channel. Photo 10 shows ponded water observed within this sub-reach.

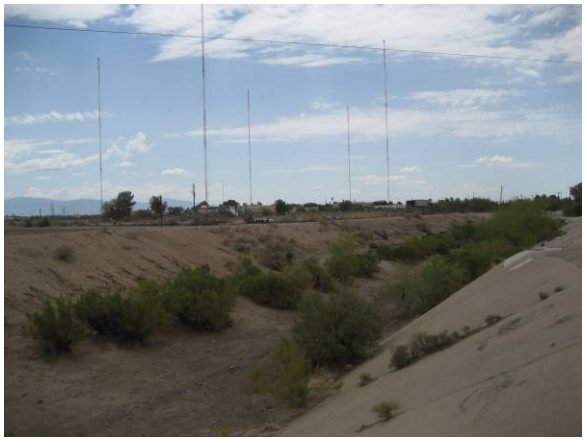

Photo 7 – Silvercroft Wash, facing upstream towards right bank, upstream of Brichta Wash (ERM01-39-01)

Photo 8 – Silvercroft Wash, facing upstream towards left bank, upstream of Brichta Wash (ERM03-20-03)

Photo 9 – Scalloped right bank, upstream of Brichta Wash (ERM03-21-03)

Photo 10 – Ponded water behind grade control structure, upstream of Brichta Wash (ERM03-20-05)

The following table summarizes the composite roughness value for the channel within this sub-reach.

Table B - 5 – Determination of Manning's Roughness Value, Roundwood Place to Brichta Wash

Channel Conditions		Manning's Adjustment	
Channel Material	Earthen bottom, earthen right bank, concrete left bank	nb	0.021
Degree of Irregularity	Moderate	n1	0.006
Variations in Channel Cross Section	Gradual	n2	0.000
Effects of Obstruction	Negligible	n3	0.000
Vegetation	Small	n4	0.007
Degree of Meandering	Minor	m	1
		n = (nb + n1 + n2 + n3 + n4)m =	0.034

Composite Channel Value, Brichta Wash to Painted Sunset Circle

The channel within this sub-reach has an earthen bottom and concrete lined banks. The channel is controlled vertically by grade control structures. Ponding behind the grade control structures was found following a July 2007 runoff event. Exhibit 7 shows the aerial view of the sub-reach.

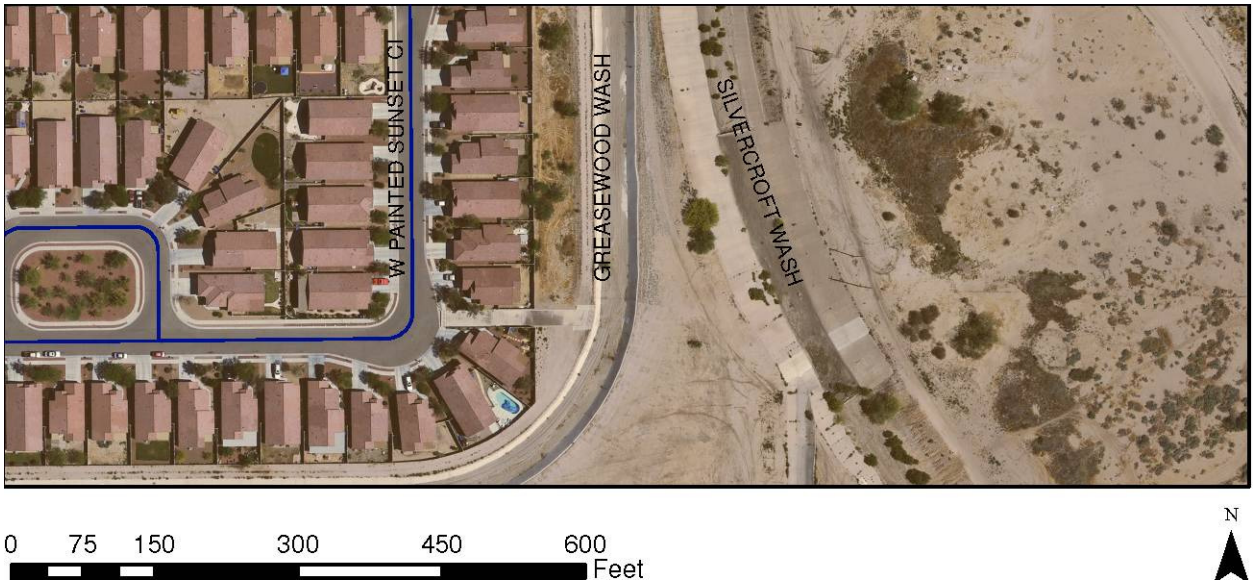

Exhibit 7 – Aerial view of Silvercroft Wash, Brichta Wash to Painted Sunset Circle

Photo 11 and Photo 12 were obtained from on the right bank slope. The first is facing upstream while the second faces downstream. Each photograph shows the earthen bottom and concrete lining on both banks. Note the water ponded behind the grade control structure at the end of this sub-reach.

Photo 11 – Ground view of channel, from right bank facing upstream with Brichta Wash in background (ERM03-16-03)

Photo 12 – Ground view of channel, from right bank facing downstream (ERM03-17-02)

The following table summarizes the composite roughness value for the channel within this sub-reach.

Table B - 6 – Determination of Manning's Roughness Value, Brichta Wash to Painted Sunset Circle

Channel Conditions		Manning's Adjustment	
Channel Material	Earthen bottom, concrete banks	nb	0.018
Degree of Irregularity	Smooth	n1	0.000
Variations in Channel Cross Section	Gradual	n2	0.000
Effects of Obstruction	Negligible	n3	0.000
Vegetation	Small	n4	0.001
Degree of Meandering	Minor	m	1
		n = (nb + n1 + n2 + n3 + n4)m =	0.019

Composite Channel Value, Painted Sunset Circle to Nursery Wash

The channel within this sub-reach has an earthen bottom, a fully lined left bank, and a partially lined right bank. The channel is controlled vertically by grade control structures. Exhibit 8 is an aerial view of the sub-reach.

Exhibit 8 – Aerial view of Silvercroft Wash, Painted Sunset Circle to Nursery Wash

The right bank is lined to about 1/3 of the height of the total bank. The dirt portion of the right bank is scalloped and moderately vegetated. Ponding was observed behind grade control structures. The following photographs are at ground photos from within the channel.

Photo 12 shows a grade control structure within this sub-reach. The image is typical of this sub-reach and the earthen channel bottom sub-reaches elsewhere in the study area.

Photo 13 – Ground view of partially lined right bank, upstream of Nursery Wash, facing upstream (ERM03-12-01)

Photo 14 – Ground view of partially lined right bank, upstream of Nursery Wash, facing upstream (ERM03-14-03)

Photo 15 – Typical ground view of grade control structures in upper sub-reaches of Silvercroft Wash (ERM03-11-02)

Table B - 7 – Determination of Manning's Roughness Value, Painted Sunset Circle to Nursery Wash

Channel Conditions		Manning's Adjustment	
Channel Material	Earthen bottom, earthen/concrete right bank, concrete left bank	nb	0.020
Degree of Irregularity	Moderate	n1	0.006
Variations in Channel Cross Section	Gradual	n2	0.000
Effects of Obstruction	Negligible	n3	0.000
Vegetation	Small	n4	0.003
Degree of Meandering	Minor	m	1
		n = (nb + n1 + n2 + n3 + n4)m =	0.029

Composite Channel Value, Nursery Wash to Painted Hills Wash

The channel within this sub-reach has an earthen bottom and concrete lined banks. This section of the channel appears to be less maintained that the sub-reach below Grant Road. Vegetation is not overly abundant, but it was observed that the channel has hummocks around root structures. Exhibit 9 shows an aerial view of the sub-reach.

Exhibit 9 – Aerial view of Silvercroft Wash, Nursery Wash to Painted Hills Wash

The hummocks observed in the channel bottom are visible in Photo 16. Photo 17 faces downstream towards the Painted Hills Wash. Some standing water was observed behind the top of concrete slope leading down to the confluence.

Photo 16 – Hummocks observed in ground view from right bank of channel south of Painted Hills Wash (ERM03-05-03)

Photo 17 – View downstream towards confluence with Painted Hills Wash (ERM03-05-01)

The channel section and the Silverbell Tree Drive culverts are shown in Photo 18. The channel drop shown in the photograph is 28 inches.

Photo 18 – View upstream from near Painted Hills Wash confluence (ERM03-02-02)

The following table summarizes the composite roughness value for the channel within this sub-reach.

Table B - 8 – Determination of Manning's Roughness Value, Nursery Wash to Painted Hills Wash

Channel Conditions		Manning's Adjustment	
Channel Material	Earthen bottom, concrete banks	nb	0.018
Degree of Irregularity	Minor	n1	0.005
Variations in Channel Cross Section	Gradual	n2	0.000
Effects of Obstruction	Negligible	n3	0.000
Vegetation	Small	n4	0.001
Degree of Meandering	Minor	m	1
		n = (nb + n1 + n2 + n3 + n4)m =	0.024

Composite Channel Value, Painted Hills Wash to Santa Cruz River

The channel within this sub-reach has a fully concrete lined section. An aerial view of the sub-reach along with the confluence with the Santa Cruz River is shown on Exhibit 10. The channel slope in this area is relatively uniform, however some grade breaks are visibly evident. Ponded water was observed from the end of the Silvercroft Wash channel to upstream of the Pedestrian Bridge (which is not visible in Exhibit 10).

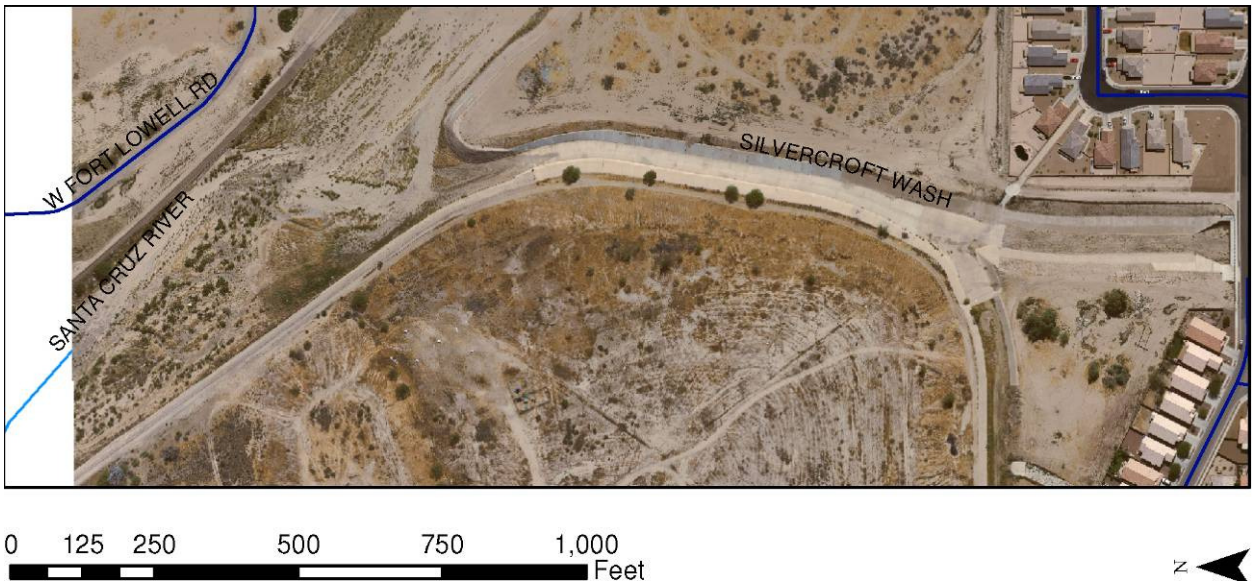

Exhibit 10 – Aerial view of Silvercroft Wash, Painted Hills Wash to Santa Cruz River

Photo 19 shows the channel from on the right bank, facing downstream. Note the ponded water extends upstream of the bridge. Photo 20 shows the confluence of the Painted Hills Wash from on the right bank.

Photo 19 – View of pedestrian bridge from right bank, facing downstream (ERM03-04-02)

Photo 20 – View upstream towards Silvercroft Wash and Painted Hills Wash (ERM02-17-01)

The channel section was photographed from on the pedestrian bridge as shown in the following photographs. Sedimentation at the end of the reach is the cause of backwater observed in Photo 19.

Photo 21 – View from pedestrian bridge, facing downstream (ERM02-15-01)

Photo 22 – View from pedestrian bridge, facing upstream (ERM02-15-02)

The following table summarizes the composite roughness value for the channel within this sub-reach.

Table B - 9 – Determination of Manning's Roughness Value, Painted Hills Wash to Santa Cruz River

Channel Conditions		Manning's Adjustment	
Channel Material	Fully concrete lined	nb	0.015
Degree of Irregularity	Smooth	n1	0.000
Variations in Channel Cross Section	Gradual	n2	0.000
Effects of Obstruction	Negligible	n3	0.000
Vegetation	Small	n4	0.000
Degree of Meandering	Minor	m	1
		n = (nb + n1 + n2 + n3 + n4)m =	0.015

Drainage Crossings and Structures

The drainage crossings and other important drainage structures within the study area (including the model area beyond the project limits) have been examined in the field and as-built plans have been reviewed to determine structure size and arrangement.

As-built plans were generally obtained from the City of Tucson or from Pima County. The City of Tucson as-built plans reference the City of Tucson datum and the Pima County as-built plans reference the NAVD 88 datum. The HEC-RAS modeling is on the NAVD 88 datum, so elevation adjustments are required with the use of City of Tucson datum elevations. The City of Tucson maintains has a benchmark circuit which can be used to make the adjustment.

Following are photographs of the most significant structures as well as brief discussion of modeling assumptions. Pictures were obtained in July of 2007.

Grant Road crossing of the Silvercroft Wash

Table B - 10 – Grant Road Culvert Summary

Structure	8 cell – 9.583' x 5.5' CBC
Skew angle	Approximately 45 degrees to the Grant Road alignment, relatively straight to the Silvercroft Wash alignment.
Condition	Well maintained and not heavily sedimented.
Special assumptions and conditions	The culvert structure has a width in excess of the upstream and downstream channel. The channel transitions near the culverts to accommodate the excess width.
Datum and conversion	As-built plans on COT datum, add 2.2 feet to COT datum to obtain NAVD 88.
Upstream invert	2293.7 NAVD 88
Downstream invert	2292.8 NAVD 88

An aerial view of the alignment is shown on Exhibit 11.

Exhibit 11 – Aerial view of Grant Road culvert crossing of Silvercroft Wash

Photo 23 shows the culverts from within the Silvercroft Wash, facing upstream. Photo 24 and Photo 25 show the culverts from the left (west) bank, upstream of Grant Road. The concrete bottom is visible indicating full capacity is available.

Photo 23 – Grant Road culverts, facing upstream (southeast) (ERM01-21-01)

Photo 24 – West side of Grant Road culverts, facing downstream (ERM02-20-01)

Photo 25 – East side of Grant Road culverts, facing northeast across channel (ERM02-20-01)

Silverbell Tree crossing of the Silvercroft Wash

Table B - 11 – Silverbell Tree Culvert Summary

Structure	6 cell – 12' x 10' CBC
Skew angle	90 degrees to Silverbell Tree Drive and straight to the Silvercroft Wash.
Condition	Well maintained and not heavily sedimented. Some vegetative growth is found within the channel as well as within the crack between the vertical concrete wall and the sloping bank.
Special assumptions and conditions	The culvert structure has a width in excess of the upstream and downstream channel bottom width. The channel bottom was constructed to transition to the width of the culvert structure and the banks transition from 1:1 (H:V) to vertical at the structures. The transition occurs at a rate of 2:1 (longitudinal:lateral).
Datum and conversion	As-built plans on COT datum, add 2.2 feet to COT datum to obtain NAVD 88.
Upstream invert	2272.3 NAVD 88
Downstream invert	2272.2 NAVD 88

The aerial view of the Silverbell Tree culverts is shown on Exhibit 12.

Exhibit 12 – Aerial view of Silverbell Tree Drive culvert crossing of Silvercroft Wash

Ground shots of the Silverbell Tree culvert structure are shown in the following photographs. The transition in bottom width and bank slope can be seen in these photographs.

Photo 26 – Silverbell Tree Culvert structure, from channel facing downstream (north) (ERM01-64-01)

Photo 27 – View of Silverbell Tree Culverts from right (east) bank, facing upstream (south) (ERM02-18-01)

Pedestrian Bridge crossing of the Silvercroft Wash

Table B - 12 – Silvercroft Wash Pedestrian Bridge

Structure	Single Span Prefabricated Truss Bridge
Skew angle	Straight to the Silvercroft Wash.
Condition	Recent construction with no signs of adverse impacts.
Datum and conversion	As-built plans on NAVD 88, no conversion.
Top of deck along bank	2282.5 NAVD 88
Top of deck midspan	2283.9 NAVD 88
Deck thickness	5 inches
Distance from bottom of deck to truss bottom chord	Approximately 28 inches
Bottom chord along bank	2280.2
Bottom chord midspan	2281.6

The aerial view of the Silvercroft Wash pedestrian bridge is shown on

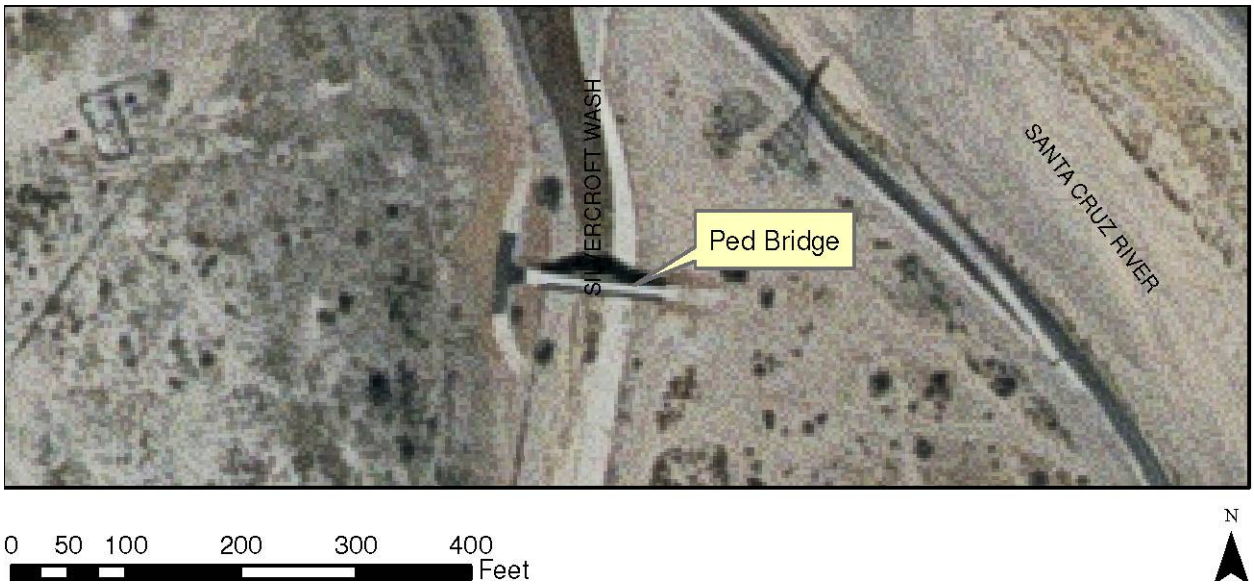

Exhibit 13 – Aerial view of pedestrian bridge crossing of Silvercroft Wash near Santa Cruz River

The pedestrian bridge is shown in Photo 28. Photo 29 shows a close-up view of the upstream face of the bridge.

Photo 28 – Pedestrian bridge, facing downstream (north) from right bank (ERM02-13-01)

Photo 29 – View of pedestrian bridge from right bank across Silvercroft Wash, facing west (ERM02-14-02)

Drop Structure and Energy Dissipater of Brichta Wash

Table B - 13 – Drop Structure near Copper Street Alignment Summary

Structure	Concrete drop structure with baffle blocks in three rows.
Condition	Well maintained.
Special assumptions and conditions	The effects of the blocks can be modeled with a revised roughness value.
Elevation data	Obtained from digital terrain model.

A drop structure with a series of stilling blocks is situated along a profile drop within the Silvercroft Wash, just north of the Copper Street alignment and south of the Brichta Wash. The drop is approximately 5 feet over a distance of approximately 12 feet. Exhibit 14 shows an aerial view of the structure and Photo 30 shows a ground view of the structure, facing downstream and towards the right bank. Photo 31 shows channel below the structure and Photo 32 shows a view of the structure facing upstream. The rod in Photo 31 is 5 feet long. In addition to the composite roughness value calculated for the concrete channel (n-0.015), an adjustment of 0.025 is added to reflect the energy dissipater. The total modeled roughness at the dissipater is 0.050.

Exhibit 14 – Aerial view of drop structure along Copper Street alignment

Photo 30 – Ground view of drop structure, facing northeast (ERM01-33-01)

Photo 31 – View of bed downstream of drop structure (ERM03-24-03)

Photo 32 – Ground view of drop structure, facing upstream (ERM03-24-04)

Appendix C - Silvercroft Wash Hydrology

C Silvercroft Wash Hydrology

Documentation of Peak Discharges

Three sources exist which provide peak discharge estimates for several runoff events.

- The Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) provides discharges for the 10-, 50-, 100-, and 500-year events.
- The Tucson Stormwater Management Study (TSMS) provides discharges all but the 20- and 200-year events.
- Regional regression equations are available for all of the above events except for the 20- and 200-year events.

The following sub-sections discuss the various sources of hydrologic data.

FIS Peak Discharges

The FIS lists the following values for the Silvercroft Wash.

Table C - 1 – FEMA FIS Computed Peak Discharge Values for Silvercroft Wash

Location	DA (sq-ml)	Peak Discharge (cfs) by Runoff Event 10-yr	50-yr	100-yr	500-yr
Silvercroft Wash at Grant Road	8.70	1,700	3,800	5,200	10,000
Silvercroft Wash at Santa Cruz River	13.24	3,500	7,500	9,700	16,100

The FIS provides very little discussion regarding the specific methodology and assumptions applied to the Silvercroft Wash hydrologic model, although it was most like developed using the empirically based flood-prediction model described within the Pima County 'Hydrology Manual for Engineering Design and Flood Plain Management Within Pima County'. The following specific discussion was found related to this watercourse.

> Discharges along Silvercroft Wash were adjusted based on tributary drainage areas. A headwater elevation-discharge relationship was developed for the box culverts under St. Mary's Road. (p 38)

The FIS contains a table documenting the history of flooding. The Silvercroft Wash has one entry, a 1,500 cfs event occurring "at City of Tucson" on July 20, 1970 with an estimated recurrence interval of 25 years. Two other events are listed with no discharges; one on August 17, 1971 and another in August 1969.

TSMS Peak Discharges

The TSMS was conducted by the City of Tucson and is an ongoing study. The City of Tucson maintains detailed HEC-1 models and provides peak discharge estimates and HEC-1 models at specified nodes along studied watercourses. The HEC-1 models reflect contributing and non-contributing areas which are based upon zoning and development densities. The methodology applies aerial reduction in rainfall depth to basins which exceed 1 square mile and adjusts curve numbers in response to rainfall intensity. Two storms are modeled, a 3-hour duration thunderstorm and a 24-hour duration general storm.

The TSMS includes HEC-1 models of the Silvercroft Wash. The following nodes are found near to or within the study area;

- DL-N0180 – Silvercroft Wash at El Rio Wash (upstream of the study area).
- DL-N0200 – Silvercroft Wash at Brichta Wash.
- DL-N0260 – Silvercroft Wash at Greasewood Wash.
- DL-N0320 – Silvercroft Wash at Santa Cruz River.
- DL-N0310 – Silvercroft Wash at Painted Hills Wash.

Detailed discharge data for all available events for both the Silvercroft Wash and the tributaries would be preferable. However, this would require 7 events to be modeled at 5 nodes with 3 models for each node, a total of 105 models. Each event, each tributary, and each confluence require a separate model due to the methodology of aerial reduction and curve number adjustment based upon contributing area. Three models can be generated at each node because a node includes a basin area for the Silvercroft Wash upstream of the confluence, a basin area for the tributary, and a basin area for the two combined streams. The City of Tucson was short staffed at the time of this study so the request was reduced to the downstream side (including tributary area) of nodes 200, 260, and 320 with the 500-year only supplied at 320. Additionally, 100-year peak discharge values can be obtained online for any TSMS Node from the City of Tucson Map Guide. Therefore, the 100-year discharge for Node 180 and Node 310 have also been obtained as well as the upstream side (excluding tributary area) discharges for each node.

The Silvercroft Wash peak discharge values computed by the TSMS at the above locations are summarized in Table C - 2. The peak discharge values reported by the TSMS represent the results of the 3-hour thunderstorm model as this model computed a higher peak discharge at these locations than the 24-hour general storm model.

Table C - 2 – TSMS Computed Peak Discharge Values for Silvercroft Wash

TSMS Node	DA (sq-ml)	Peak Discharge (cfs) by Runoff Event 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
DL-N0180 (w/ trib) [1]	8.29	not reported	not reported	not reported	not reported	not reported	7,176	not reported
DL-N0200 (w/out trib) [1]	8.75	not reported	not reported	not reported	not reported	not reported	7,227	not reported
DL-N0200 (w/ trib) [2]	9.06	572	1,430	2,780	4,388	6,190	7,407	not reported
DL-N0260 (w/out trib) [1]	9.69	not reported	not reported	not reported	not reported	not reported	7,423	not reported
DL-N0260 (w/ trib) [2]	11.53	707	1,610	3,206	5,117	7,193	8,679	not reported
DL-N0310 (w/out trib) [1]	11.69	not reported	not reported	not reported	not reported	not reported	8,682	not reported
DL-N0310 (w/ trib) [2]	13.15	not reported	not reported	not reported	not reported	not reported	9,292	not reported
DL-N0320 [2]	13.18	723	1,651	3,312	5,311	7,540	9,290[3]	12,590

Note 1: Obtained from online City of Tucson Stormwater Map.
Note 2: Obtained from HEC-1 models supplied by City of Tucson for this project.
Note 3: Reduction in discharge from N0310 to N0320 a result of computed attenuation in channel.

Regional Regression Equation Peak Discharges

A USGS publication by Eychaner (USGS 84-4142) presents a method for estimating peak discharges on ungaged streams in Pima County. Following the procedures outlined within Table 4 of USGS 84-8142, a basin development factor of 7 has been assigned to the Silvercroft Wash basin. Peak discharges computed with this method near Grant Road and at the Santa Cruz River can be found within Table C - 3.

Table C - 3 – Regional Regression Peak Discharge Estimates for Silvercroft Wash

Location	DA (sq-ml)	Peak Discharge (cfs) by Runoff Event						
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
Regression Est. – at Grant Rd.	8.70	710	1,585	2,285	3,315	4,370	5,640	8,880
Regression Est. – at El Rio Wash	8.29	690	1,545	2,220	3,230	4,255	5,490	8,630
Regression Est. – at SC River	13.24	910	2,020	2,895	4,195	5,535	7,155	11,295

Comparison of Peak Discharges

The peak discharges are compared for the three sources within Table C-4 and on Figure C-1. With the exception of the 500-year event, the TSMS and FIS discharge values are comparable at the Santa Cruz River. It is not clear why the FIS discharge is so great at this location nor is it clear why the ratio of the 500-year to 100-year discharge (FIS) is so great at this location (see the following sub-section).

The TSMS discharge values exceed the FIS discharge values by a significant margin near Grant Road. It is noted that the reported TSMS drainage area exceeds the FIS drainage area near Grant Road, but the 100-year discharge upstream of Grant Road (at the El Rio Wash) is also in excess of 7,000 cfs. The regression equation discharges for the frequent events tend to exceed both the FIS and TSMS data while the regression equation discharges for the less frequent events tend to be lower than the FIS and TSMS data. Review of Figure C-1 shows that the TSMS data has the least linear relationship of the sources, a reflection of the complex assumptions and variable input associated with the methodology.

Table C - 4 – Comparison of Peak Discharge Estimates

Source – Location	DA (sq-ml)	Peak Discharge (cfs) by Runoff Event						
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
FIS – at Grant Rd.	8.70	not reported	not reported	1,700	not reported	3,800	5,200	10,000
TSMS – Brichta Wash	9.06	572	1,430	2,780	4,388	6,190	7,407	not reported
Regression – at Grant Rd.	8.70	710	1,585	2,285	3,315	4,370	5,640	8,880
FIS – at SC River	13.24	not reported	not reported	3,500	not reported	7,500	9,700	16,100
TSMS – at SC River	13.18	723	1,651	3,312	5,311	7,540	9,290	12,590
Regression – at SC River	13.24	910	2,020	2,895	4,195	5,535	7,155	11,295

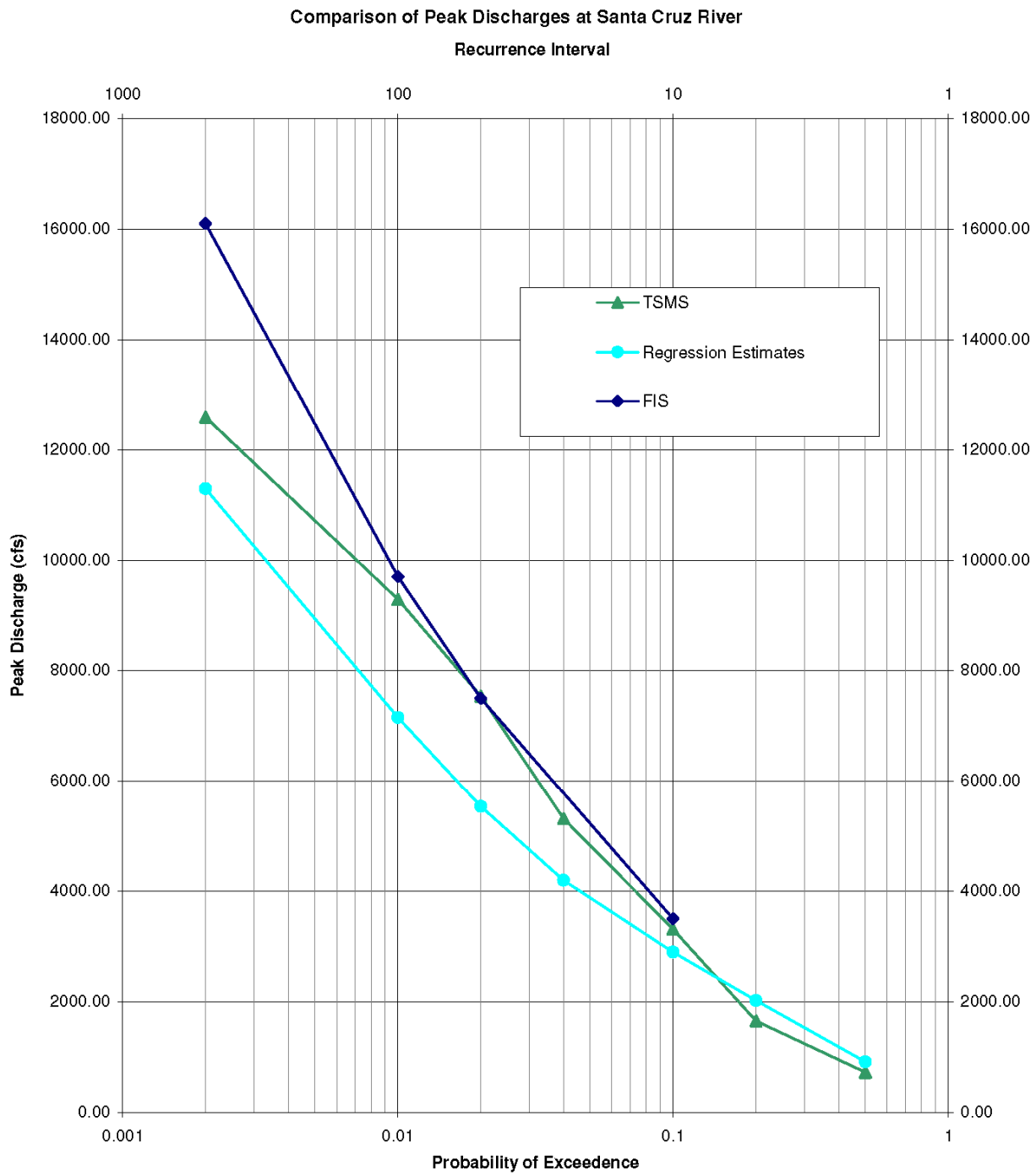

Figure C - 1 - Graph of discharges at Santa Cruz River

Peak Discharge Ratios

Table C - 5 documents the ratio of the supplied peak discharge values to the 100-year value (Q-100 ratio). The individual TSMS nodes had almost identical Q-100 ratios so an average is reported in Table C - 5. This table also documents computed Q-100 ratios from the FIS discharges and regression estimates as well as recommended Q-100 ratios provided within the Pima County Hydrology Manual. Some of the values shown within Table C - 5 are shown graphically within Figure C-2. From the graph shown on C-2, the 20- and 200-year Q-100 ratios have been interpolated for the TSMS and regression data as well as the 200-year Q-100 ratios for the FIS data.

Consistency is found between the FIS, TSMS, and regression estimate for the 10-year and 50-year event Q-100 ratios. The greatest variation in the Q-100 ratios is found in the 500-year event and the 2-year event.

Table C - 5 – Ratio of TSMS Computed Peak Discharge Values to the 100-year Event

		Ratio of Discharge Value to 100-year Event							
(1)	Source - Location	2-yr	5-yr	10-yr	20-yr	25-yr	50-yr	200-yr	500-yr
(2)	FIS - Silvercroft Wash at Grant Road	n/a	n/a	0.33	n/a	n/a	0.73	*1.38*[1]	1.92
(3)	FIS - Silvercroft Wash at Santa Cruz River	n/a	n/a	0.36	n/a	n/a	0.77	*1.27*[1]	1.66
(4)	TSMS – Average	0.079	0.19	0.37	*0.53*[1]	0.58	0.83	*1.16*[1]	1.36
(5)	Regression Estimates, Drainage Area of 8.3 – 13.3 sq-ml	0.13	0.28	0.40	*0.54*[1]	0.59	0.77	*1.25*[1]	1.58
(6)	PC Hydrology Manual – Moderately Urban Conditions	0.20	n/a	0.45	n/a	0.65	0.85	n/a	n/a
(7)	PC Hydrology Manual – Highly Urban Conditions	0.25	n/a	0.50	n/a	0.70	0.85	n/a	n/a

Note 1: Values estimated by interpolation from semi-log plot of known table values.

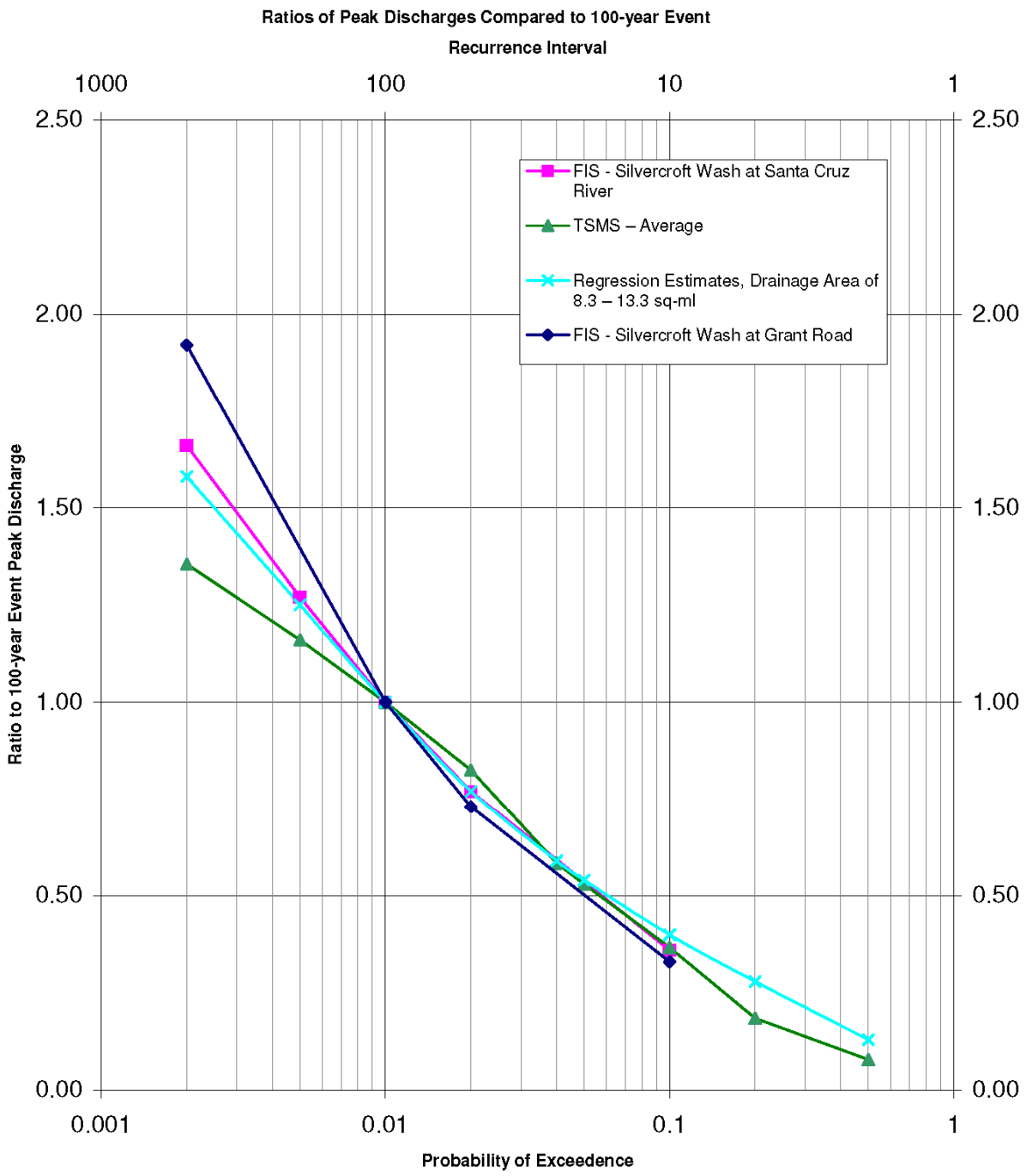

Figure C - 2 – Graphical comparison of discharge ratios

Assignment of Peak Discharges

With multiple sources available for discharge data, a logical approach must be developed to assign project specific discharges for use in the modeling. The discharges used in the tributary hydraulic modeling, within the ERM F3 Report, were based upon an assigned 100-year event discharge with the lesser events scaled by acceptable ratios. The portion of the Silvercroft Wash modeled within the ERM F3 Report used the discharge series shown in Table C - 6.

Table C - 6 – Silvercroft Wash Peak Discharges Used in El Rio Medio F3 Report

	Peak Discharge (cfs) by Event				
Location	2-yr	10-yr	20-yr	50-yr	100-yr
Silvercroft Wash at Santa Cruz River	490	3,210	4,850	7,760	9,700

The above values were based upon the FIS discharge of 9,700 cfs because the effective FIRM panels used this discharge and it is a regulatory discharge. The four lesser events were scaled based on Q-100 ratios extracted from TSMS data. Review of these values against the peak discharges documented within Table C - 6 shows that the 2-year discharge is slightly low while the remaining discharges are consistent with those documented within Table C-4.

A similar approach has been used in this current study. Except for at the Santa Cruz River, the 100-year discharge from the TSMS data exceeds the FIS discharge. The greater of the two discharges is used as the basis for determining all other discharges (except for the 500-year discharge at the Santa Cruz River). The 2- through 50-year runoff event discharges are scaled from the 100-year event using the average TSMS Q-100 ratio. At the Santa Cruz River, the 200-year event is scaled using the FIS Q-100 ratio at this location. Upstream of this location, the 200- and 500-year events are scaled from the 100-year event using the regional regression equation Q-100 ratios as these are more conservative than the TSMS data with more available data points. Further details can be found in the following 4 tables where the 8 event discharge series has been defined for the sub-reaches. The discharges can be seen graphically in Figure C-3.

Table C - 7 – El Rio Wash to Brichta Wash Peak Discharge Series

Source of 100-year Discharge: TSMS Node 200, upstream of Brichta Wash

Recurrence Interval (years)	Probability of Exceedence	Source of Discharge	Source of Q-100 Ratio	Q-100 Ratio	Peak Discharge (cfs)
2	0.5	Ratio to Q-100	TSMS Data	0.08	570
5	0.2	Ratio to Q-100	TSMS Data	0.19	1,350
10	0.1	Ratio to Q-100	TSMS Data	0.37	2,660
20	0.05	Ratio to Q-100	TSMS Data	0.53	3,840
50	0.02	Ratio to Q-100	TSMS Data	0.83	5,970
100	0.01	TSMS Data	n/a	n/a	7,227
200	0.005	Ratio to Q-100	Regression Data	1.25	9,040
500	0.002	Ratio to Q-100	Regression Data	1.58	11,420

Table C - 8 – Brichta Wash to Greasewood Wash Peak Discharge Series

Source of 100-year Discharge: TSMS Node 260, upstream of Greasewood Wash

Recurrence Interval (years)	Probability of Exceedence	Source of Discharge	Source of Q-100 Ratio	Q-100 Ratio	Peak Discharge (cfs)
2	0.5	Ratio to Q-100	TSMS Data	0.08	590
5	0.2	Ratio to Q-100	TSMS Data	0.19	1,380
10	0.1	Ratio to Q-100	TSMS Data	0.37	2,730
20	0.05	Ratio to Q-100	TSMS Data	0.53	3,940
50	0.02	Ratio to Q-100	TSMS Data	0.83	6,130
100	0.01	TSMS Data	n/a	n/a	7,423
200	0.005	Ratio to Q-100	Regression Data	1.25	9,280
500	0.002	Ratio to Q-100	Regression Data	1.58	11,730

Table C - 9 – Greasewood Wash to Painted Hills Wash Peak Discharge Series

Source of 100-year Discharge: TSMS Node 310, upstream of Painted Hills Wash

Recurrence Interval (years)	Probability of Exceedence	Source of Discharge	Source of Q-100 Ratio	Q-100 Ratio	Peak Discharge (cfs)
2	0.5	Ratio to Q-100	TSMS Data	0.08	690
5	0.2	Ratio to Q-100	TSMS Data	0.19	1,610
10	0.1	Ratio to Q-100	TSMS Data	0.37	3,190
20	0.05	Ratio to Q-100	TSMS Data	0.53	4,610
50	0.02	Ratio to Q-100	TSMS Data	0.83	7,170
100	0.01	TSMS Data	n/a	n/a	8,682
200	0.005	Ratio to Q-100	Regression Data	1.25	10,860
500	0.002	Ratio to Q-100	Regression Data	1.58	13,720

Table C - 10 – Painted Hills Wash to Santa Cruz River Peak Discharge Series

Source of 100-year Discharge: FIS at Santa Cruz River

Recurrence Interval (years)	Probability of Exceedence	Source of Discharge	Source of Q-100 Ratio	Q-100 Ratio	Peak Discharge (cfs)
2	0.5	Ratio to Q-100	TSMS Data	0.08	770
5	0.2	Ratio to Q-100	TSMS Data	0.19	1,800
10	0.1	Ratio to Q-100	TSMS Data	0.37	3,570
20	0.05	Ratio to Q-100	TSMS Data	0.53	5,150
50	0.02	Ratio to Q-100	TSMS Data	0.83	8,010
100	0.01	FIS Data	n/a	n/a	9,700
200	0.005	Ratio to Q-100	FIS Data	1.27	12,320
500	0.002	FIS Data	n/a	n/a	16,100

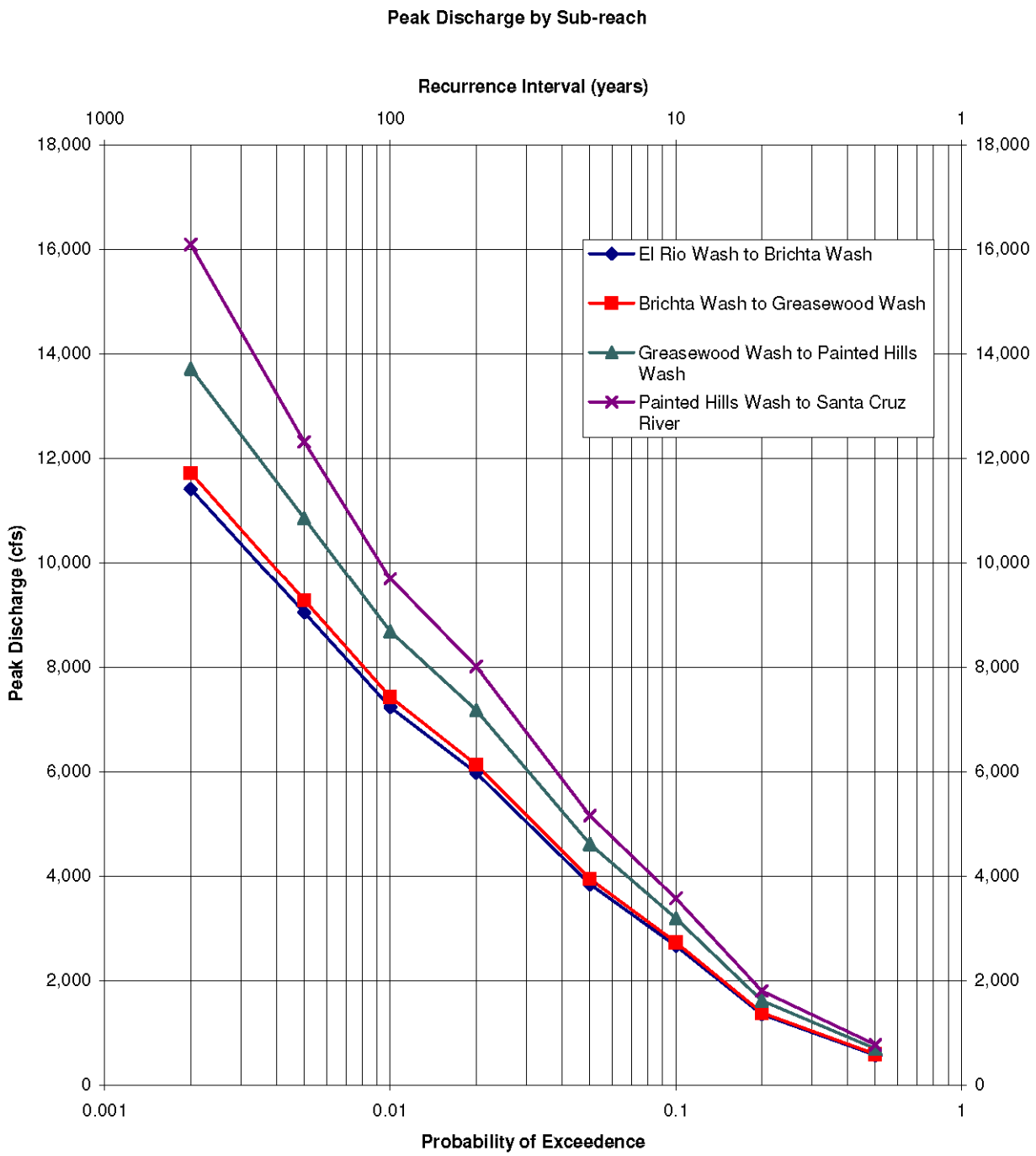

Figure C - 3 – Silvercroft Wash discharge series graph

Appendix D - Methodology for Modeling Alternatives

D Methodology for Modeling Alternatives

Methodology

The assumptions and methodology followed in the without-project analysis limit how the with-project alternatives are analyzed. This is in order to provide an appropriate comparison between without- and with-project conditions. The shape files provided by the USACE consultant detail the extent of the primary wetland assessment areas (PWAAs). Therefore, the goal was to assign specific roughness values to each PWAA within the channel then develop reach composite roughness values within the same reaches as were used in the without-project assessment.

The overbanks were previously modeled with more detail than the channel and can consequently be modeled in more detail in the with-project conditions than the channel. In addition to the above, it is also important to determine with-project roughness values considering the values used in the original without-project study to provide continuity in the comparison.

One final consideration is that the without-project analysis did not account for any discharge based roughness values; the 2-year event and 500-year event assume the same roughness values. The roughness values were determined considering the 100-year event and therefore the values are likely underestimated for more frequent events.

Impact of Santa Cruz River Channel Restoration on Roughness

Of the features listed, only grading and rocky point bars will have an appreciable, project-wide impact on the roughness values. The following summarizes methodology for addressing the roughness adjustments for the individual restoration features:

- Grading for PWAAs reflects temporary grading done to increase roughness in low flow portion of channel and should have the impact of increasing the roughness value which will be reflected by increasing the value of n_3
- The rocky point bars will have the impact of increasing roughness by adding obstructions and by forcing the low flow invert to meander through the reach. This will have the most significant impact on low flow events; however, the absence of a discharge based roughness analysis in the without-project assessment precludes the use of such analysis for the rocky point bars. Rocky point bars are addressed by increasing n_2 and n_3.
- Placement of boulders/cobbles for channel topography may be addressed by increasing n_3.
- Large boulders placed for creating depressions and scour holes will be addressed by increasing the value of n_3. .
- The combined impacts of the individual impacts to the roughness values may not necessarily be additive. In other words, the total increase to n_2 and n_3 may likely be less than the sum total of the increases due to combined impacts and some rounding of values.
- The excavation area at the Flowing Wells Wash may be modeled by adjusting the local cross section to reflect the grading, but this will have little impact on the flow hydraulics as this is likely ineffective flow. The excavation will not be modeled in the Flowing Wells Wash as this was not a part of the project scope.

The above are summarized in Rows H through M in Tables D-1 through D-3

Santa Cruz River Channel Roughness Adjustments

In the without-project assessment, the adjustments to the channel roughness value (added to a base roughness of 0.023 to 0.026) for vegetation were based upon a best fit equation in the form of n_4=0.0008B-0.0007; where n_4 is the roughness adjustment for vegetation and B is percentage of flow blocked by vegetation. The blocked area ranged from 0 to 50 percent and the resulting vegetation adjustment ranged from 0.000 for no or sparse vegetation, to 0.001 for low vegetation density, to 0.007 for medium vegetation density, to 0.039 for high vegetation density. An adjustment for obstructions of 0.002 was included for all cross sections. Boulders and similar objects may be modeled using this component.

In order to estimate vegetation roughness for the alternatives, several assumptions were made such as blocked flow area without inputs such as irrigation as well as the impacts that each input would have on the blocked area. This is shown as Rows A through F in Tables D-1 through D-3.

With-project Santa Cruz River Channel Roughness Values

The following tables estimate roughness adjustment values in the main stem for the three alternatives.

Table D-1 -Santa Cruz River Channel roughness adjustment values for main stem alternative LM

		LM Level of Planting/Water - L, Level of Engineering - M			
				n_4	
			Cottonwood-willow	Mesquite	Riparian Shrub
A	Vegetation Community	Xeroriparian dominant with mesoriparian	20	15	3
B	Vegetation	Pole plantings; small container trees, shrubs, & grasses, plus native seeding	0%	0%	0%
C	Water	Temporary ponds supplied using stormwater only; irrigation for establishment only; drought contingency irrigation	15%	5%	10%
D	Water harvesting/retention features	Install new structures for water catchment purposes, clay lens behind new and existing grade control structures, micro-grading and addition of few large boulders to create depressions, scour holes	10%	10%	20%
E	*Sum of added increase in vegetation, B+C+D*		25%	15%	30%
F	*Estimated blocked flow area with added inputs, A*(1+E)*		25	17	3.7
G	*n_4*		**0.021**	**0.015**	**0.004**
			n_1	n_2	n_3
H	Soil Cement & Bank Treatments				
I	Channel sinuosity/topography	Construct sandy point bars, create low flow meander, add boulders/cobble		0.001	0.001
J	Grading for PWAA				0.000
K	Based conditions value	n/a	0.000	0.000	0.002
L	Subtotal, N_1, N_2, N_3		**0.000**	**0.001**	**0.003**
M	**Total, N_1 through N_3**			**0.004**	
N	**Sum of N_1 through N_4, G+M**		**0.025**	**0.019**	**0.008**

Row A values are assumed minimum blocked flow area (%) with no other inputs.
Rows B through D estimate the improvement to the vegetation from the listed input, Row E sums B through D, and Row F adjusts the Row A value by the Row E value.
Row G applies the Row F n_4 value to n_4=0.0008B-0.0007 equation with F_i=B.
Rows H through L estimate the n_1 through n_3 adjustments for each input.
Row N is the total adjustment to be added to the base roughness value.

Table D-2 - Santa Cruz River Channel roughness adjustment values for main stem alternative ML

	ML Level of Planting/Water - M, Level of Engineering - L				
				n_4	
			Cottonwood-willow	Mesquite	Riparian Shrub
A	Vegetation Community	Xeroriparian and mesoriparian dominant, no hydroriparian	20	15	3
B	Vegetation	Container trees, shrubs & grasses, plus native seeding	10%	10%	0%
C	Water	Temporary ponds supplied using stormwater and effluent, permanent periodic irrigation in select areas	50%	15%	30%
D	Water harvesting/retention features	Add few large boulders to allow for natural creation of depressions and scour holes	2%	2%	2%
E	*Sum of added increase in vegetation, B+C+D*		62%	27%	32%
F	*Estimated blocked flow area with added inputs, A*(1+E)*		32	19	4.0
G	*n_4*		**0.027**	**0.016**	**0.004**
			n_1	n_2	n_3
H	Soil Cement & Bank Treatments				
I	Channel sinuosity/topography	Add boulders/cobble, create depressions and scour holes		0.000	0.001
J	Grading for PWAA				0.000
K	Based conditions value	n/a	0.000	0.000	0.002
L	Subtotal, N_1, N_2, N_3		**0.000**	**0.000**	**0.003**
M	**Total, N_1 through N_3**			**0.003**	
N	**Sum of N_1 through N_4, G+M**		**0.030**	**0.019**	**0.007**

Row A values are assumed minimum blocked flow area (%) with no other inputs.
Rows B through D estimate the improvement to the vegetation from the listed input, Row E sums B through D, and Row F adjusts the Row A value by the Row E value.
Row G applies the Row F n_4 value to n_4=0.0008B-0.0007 equation with F_i=B.
Rows H through L estimate the n_1 through n_3 adjustments for each input.
Row N is the total adjustment to be added to the base roughness value.

Table D-3 - Santa Cruz River Channel roughness adjustment values for main stem alternative LL

		LL Level of Planting/Water - L, Level of Engineering - L			
				n_4	
			Cottonwood-willow	Mesquite	Riparian Shrub
A	Vegetation Community	Xeroriparian dominant with mesoriparian	20	15	3
B	Vegetation	Pole plantings; small container trees, shrubs, & grasses, plus native seeding	0%	0%	0%
C	Water	Temporary ponds supplied using stormwater only; irrigation for establishment only; drought contingency irrigation	15%	5%	10%
D	Water harvesting/retention features	Add few large boulders to allow for natural creation of depressions and scour holes	2%	2%	2%
E	*Sum of added increase in vegetation, B+C+D*		17%	7%	12%
F	*Estimated blocked flow area with added inputs, A*(1+E)*		23	16	3.4
G	*n_4*		**0.019**	**0.014**	**0.003**
			n_1	n_2	n_3
H	Soil Cement & Bank Treatments				
I	Channel sinuosity/topography	Add boulders/cobble, create depressions and scour holes		0.000	0.001
J	Grading for PWAA				0.000
K	Based conditions value	n/a	0.000	0.000	0.002
L	Subtotal, N_1, N_2, N_3		**0.000**	**0.000**	**0.003**
M	**Total, N_1 through N_3**			**0.003**	
N	**Sum of N_1 through N_4, G+M**		**0.022**	**0.017**	**0.006**

Row A values are assumed minimum blocked flow area (%) with no other inputs.
Rows B through D estimate the improvement to the vegetation from the listed input, Row E sums B through D, and Row F adjusts the Row A value by the Row E value.
Row G applies the Row F n_4 value to n_4=0.0008B-0.0007 equation with F_i=B.
Rows H through L estimate the n_1 through n_3 adjustments for each input.
Row N is the total adjustment to be added to the base roughness value.

The following table summarizes the previous computations, shows the estimated values of total roughness for each of the proposed vegetative conditions. For example, if an area of Mesquite is planted for the LM alternative between Speedway Blvd. and Grant Road, the roughness for just that area may be 0.043. Composite roughness values take these values into account.

Table D-4 - Summary of Santa Cruz River channel roughness adjustments for with-project alternatives

Summary of roughness adjustment values in main stem			
Vegetation	LM	ML	LL
Cottonwood-willow	0.025	0.030	0.022
Mesquite	0.019	0.019	0.017
Riparian Shrub	0.008	0.007	0.006
Bare River Bottom	0.004	0.003	0.003

Summary of total roughness values in main stem by reach

Cottonwood-willow				
Project reach	Base n value	LM	ML	LL
Congress St. to St. Mary's Rd.	0.023	0.048	0.053	0.045
St. Mary's Rd. to Speedway Blvd.	0.026	0.051	0.056	0.048
Speedway Blvd. to Grant Rd.	0.024	0.049	0.054	0.046
Grant Rd. to Miracle Mile	0.023	0.048	0.053	0.045
Miracle Mile to Prince Road	0.023	0.048	0.053	0.045
Prince Road to End of Project	0.023	0.048	0.053	0.045

Mesquite				
Project reach	Base n value	LM	ML	LL
Congress St. to St. Mary's Rd.	0.023	0.042	0.042	0.040
St. Mary's Rd. to Speedway Blvd.	0.026	0.045	0.045	0.043
Speedway Blvd. to Grant Rd.	0.024	0.043	0.043	0.041
Grant Rd. to Miracle Mile	0.023	0.042	0.042	0.040
Miracle Mile to Prince Road	0.023	0.042	0.042	0.040
Prince Road to End of Project	0.023	0.042	0.042	0.040

Riparian Shrub				
Project reach	Base n value	LM	ML	LL
Congress St. to St. Mary's Rd.	0.023	0.031	0.030	0.029
St. Mary's Rd. to Speedway Blvd.	0.026	0.034	0.033	0.032
Speedway Blvd. to Grant Rd.	0.024	0.032	0.031	0.030
Grant Rd. to Miracle Mile	0.023	0.031	0.030	0.029
Miracle Mile to Prince Road	0.023	0.031	0.030	0.029
Prince Road to End of Project	0.023	0.031	0.030	0.029

Bare River Bottom				
Project reach	Base n value	LM	ML	LL
Congress St. to St. Mary's Rd.	0.023	0.027	0.026	0.026
St. Mary's Rd. to Speedway Blvd.	0.026	0.030	0.029	0.029
Speedway Blvd. to Grant Rd.	0.024	0.028	0.027	0.027
Grant Rd. to Miracle Mile	0.023	0.027	0.026	0.026
Miracle Mile to Prince Road	0.023	0.027	0.026	0.026
Prince Road to End of Project	0.023	0.027	0.026	0.026

Composite Channel Roughness Values

The data in the above tables were used to support the final composite channel roughness values shown in the following table. This was done via analysis with arcview polygon shape files of the proposed land uses, tabulation, and engineering judgment.

Table D-5

Reach	Description	RM Range			n-ex	LM	ML	LL
1	Congress to St. Mary's	32.608	-	31.970	0.032	***0.032***	***0.032***	***0.032***
2	St. Mary's to Speedway	31.951	-	31.542	0.031	***0.033***	***0.033***	***0.032***
3	Speedway to Grant	31.523	-	30.179	0.028	***0.030***	***0.030***	***0.029***
4	Grant to Miracle Mile	30.150	-	29.334	0.027	***0.030***	***0.029***	***0.028***
5	Miracle Mile to End	29.235	-	28.019	0.027	***0.030***	***0.029***	***0.029***

Structural Changes

Two 100-foot long by 10-feet deep notches are included within the LM-HH-MH alternative. These notches are at the "Old Bend" area, north of Grant Road between RM 29.3 and 29.1 and were assumed to be at RM 29.334 and 29.136.

Santa Cruz River Overbanks Roughness Adjustments

Four vegetation types were delineated in the without-project analysis;

- Floodplains with low vegetation, open desert areas with low vegetation density and minor surface irregularities. n=0.040
- Floodplains with high vegetation, open desert areas with high vegetation density or parks with thick brush and trees. More surface irregularities and obstructions than low vegetation areas. n=0.055
- Crop and pasture. n=0.050
- Parks, linear parks on and near the banks. n=0.050

The following values may be appropriate for the overbank roughness values based upon comparison to those values used in the without-project analysis

Table D-6 - Santa Cruz River overbanks Manning's roughness values

Planting	min n	max n	MH	ML	LL
Cottonwood-Willow	0.040	0.060	0.055	0.048	0.040
Mesquite	0.040	0.060	0.055	0.048	0.040
Riparian	0.045	0.065	0.060	0.053	0.045

With-project Silvercroft Wash Channel Roughness Values

The following table estimates roughness adjustment values in the Silvercroft Wash channel for the LM-HH-MH alternative. It is assumed that all concrete is removed from RM 29.3 to the end of the project, and the composite n value is therefore determined by adding the values of n_1, n_2, n_3, and n_4 to an assumed n_b value.

Table D-7 -Channel roughness adjustment values for Silvercroft Wash Alt. HH

		HH Level of Planting/Water - H, Level of Engineering - H			
				n_4	
A	Vegetation Community	Xeroriparian and mesoriparian dominant with hydroriparian		10	
B	Vegetation	Box trees; container trees, shrubs, & grasses; plus native seeding		10%	
C	Water	Periodically flood irrigate channel and widened areas & acequias, drip irrigation (top of bank & widened areas)		20%	
D	Water harvesting/retention features	Subsurface aquatard basins; location unlimited, completely re-naturalize trapezoidal/cement-lined channel discharges, add grade control structures to prevent headcut, clay lens behind new grade control structures		5%	
E	*Sum of added increase in vegetation, B+C+D*			35%	
F	*Estimated blocked flow area with added inputs, A*(1+E)*			14	
G	*n_4*			**0.012**	
			n_1	n_2	n_3
H	Soil Cement & Bank Treatments	Remove invert and banks. Channel widening, lay back and terrace banks for multi-level floodplain.	Resets n to n_b = 0.022 (all other inputs added to this value)		
I	Channel sinuosity/topography	40' x 20' triangle point bars with 2' boulders, 1.5' protruding. 20 bars spaced 200' apart Create channel topography using boulder/cobble		0.001	0.002
J	Grading for PWAA				0.001
K	Based conditions value	n/a	n/a	n/a	n/a
L	Subtotal, N_1, N_2, N_3		**0.000**	**0.001**	**0.003**
M	**Total, N_1 through N_3**			**0.004**	
N	**Sum of N_1 through N_4, G+L**			**0.016**	

Row A values are assumed minimum blocked flow area (%) with no other inputs.
Rows B through D estimate the improvement to the vegetation from the listed input, Row E sums B through D, and Row F adjusts the Row A value by the Row F value.
Rows H through L estimate the n_1 through n_3 adjustments for each input.
Row N is the total adjustment to be added to the base roughness value.

Appendix E - Digital Files

- HEC-RAS models
- PDF version of this report and appendices
- PDF version of plates