Sweetwater Wash Letter of Map Revision Technical Data Notebook

Prepared for:

Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701

Prepared by:

Akitsu Kimoto, Ph.D., C.F.M, Principal Hydrologist.
Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701

Approved by

Suzanne Shields, PE
Director

Registered Professional Engineer (Civil)
CERTIFICATE NO.
15610
SUZANNE J.
SHIELDS
DATE SIGNED
ARIZONA U.S.A.

Pima County Regional Flood Control District
97 E Congress Street
Tucson Arizona, 85701

List of Tables

List of Figures

Exhibit

Section 1 Introduction

1.1 Propose

This Technical Data notebook (TDN) has been prepared for a Letter of Map Revision (LOMR) application for a portion of the Sweetwater Wash (SWT) located in Pima County, Arizona. The objective of the TDN and LOMR submission is provide regulatory discharge rates and floodplain limits along the Sweetwater Wash using better topographic, hydrologic, and hydraulic data.

This TDN was prepared in accordance with the "Instructions for Organizing and Submitting Technical Documentation for Flood Studies" prepared by the Arizona Department of Water Resources, Flood Mitigation Section (Arizona State Standard, SSA 1-97) and FEMA Guideline. FEMA LOMR forms are included in this TDN.

1.2 Project Authority

The State of Arizona has delegated the responsibility to each county flood control district to adopt floodplain regulations designed to promote the public health, safety and general welfare of its citizenry as provided under the Arizona Revised Statutes, Title 48, Chapter 21, Article 1, Sections 48-3601 through 3627. More specifically, A.R.S. 3609 directs county flood control districts to adopt floodplain regulations that:

> A. Regulate all development of land, construction of residential, commercial or industrial structures or uses of any kind which may divert, retard or obstruct flood water and threaten public health or safety or the general welfare; and
> B. Establish minimum flood protection elevations and flood damage prevention requirements for uses, structures and facilities which are vulnerable to flood damage; and
> C. Comply with state and local land use plans and ordinances, if any.
> In conformance with A.R.S. 3609, this ordinance provides for protection of the public health safety and welfare by regulation of flood and erosion hazard areas to control flood hazards and prevent repetitive loss from flood damage.
> D. The flood hazard areas of Pima County are subject to periodic inundation which may result in loss of life and property, create health and safety hazards, disrupt commerce and governmental services, require extraordinary public expenditures for flood protection and relief, and impair the tax base, all of which adversely affect the public health, safety, and general welfare.
> E. These flood losses are caused by the cumulative effect of obstructions in areas of special flood hazards which increase flood heights, flow velocities, and cause flood and erosion damage. Uses that are inadequately flood-proofed, elevated, or otherwise protected from flood damage, also contribute to the flood loss. (Ord. 2005 FC-2 § 2 (part), 2005).

Section 16 of the Pima County Ordinance describes the provisions for floodplain regulation in Pima County.

This study has been prepared by the Pima County Regional Flood Control District (RFCD):

Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701

The project was prepared by:

Akitsu Kimoto, Ph.D., C.F.M., Principal Hydrologist.
Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701

1.3 Project Location

The study reach of the Sweetwater Wash (SWT) is located within a Federal Emergency Management Agency (FEMA)-designated "Zone A" flood-hazard area, as depicted on FIRM Map Panel Numbers 04019C1616K and 1618K (February 8, 1999). No documented hydraulic analyses were found to determine the "Zone A", and the existing "Zone A" depiction is not consistent with current topography. The objective of the TDN and LOMR submission is provide regulatory discharge rates and floodplain limits along the Sweetwater Wash using better topographic, hydrologic, and hydraulic data.

The study reach of the Sweetwater Wash is located primarily west of Silverbell Rd. Section 19 and 20, Township 13 South, Range 13 East, Pima County, Arizona (Fig. 1.1). The Sweetwater Wash enters study limit from the west and flows east until it converges with the Santa Cruz River. The study limit for the Sweetwater Wash is from Sweetwater Dr. to the confluence with the Santa Cruz River in Section 19 of Township 13 South, Range 13 East.

1.3 Hydrologic and Hydraulic Methods

Hydrologic analysis was preformed to determine proposed regulatory discharge rate at Silverbell Rd using U.S. Army Corps of Engineers Computer Hydrologic Modeling System, HEC-HMS. Parameterization followed guidelines developed by Pima County Regional Flood Control District and described in Technical Policy 018 (Tech 018, Appendix A). The proposed regulatory discharge is a flow rate that has a 1-percent chance of being equaled or exceeded each year ("100-year" discharge rates). Hydraulic analysis was performed to delineate floodplain limit along the study reach of the Sweetwater Wash using U.S. Army Corps of Engineers Computer Backwater Model, HEC-RAS and FLO-2D. A flow split occurs approximately 1500 feet upstream of the

Silverbell Rd. The flow becomes distributary after crossing Silverbell Rd. FLO-2D was used to delineate a floodplain limit in the distributary area (approximately 1700 feet from Silverbell Rd. to a confluence with the Santa Cruz River). HEC-RAS was used to map a floodplain at the upstream of the distributary area.

1.4 Acknowledgment

This study relied on assistance of RFCD GIS staff, who were integral to the development of the models and maps.

1.5 Study Results

The regulatory peak discharge rate was calculated at Silverbell Rd (CP A; Fig. 1.3). The estimated regulatory discharge rate is 5622 cubic feet per second (cfs) with a drainage area of 4.8 square mile at CP A (at Silverbell Rd.). The discharge at CP A was used for the steady flow analysis with HEC-RAS. The hydrograph at CP A input to the FLO-2D model. The HEC-RAS and FLO-2D results showed that the existing FEMA floodplain (Zone A) is narrower than a floodplain limit proposed in this study.

Figure 1.1
Watershed Map
Sweetwater Wash

SWT CP

River

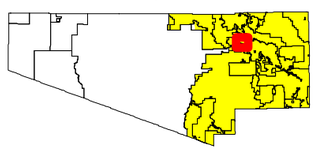
contour 40 feet

SWT Subbasins

- SWT A
- SWT B
- SWT C
- SWT D
- SWT E
- SWT F
- SWT G
- SWT H

Aerial Photo: 2008 Pima Association of Government

Pima County Index Map



Index Map Scale 1:5,250,000

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control Department makes no claims regarding the accuracy of the information depicted herein.

This product is subject to the Department of Transportation Technical Services Division's Use Restriction Agreement.

Pima County Regional Flood Control District

Pima County Regional FLOOD CONTROL DISTRICT

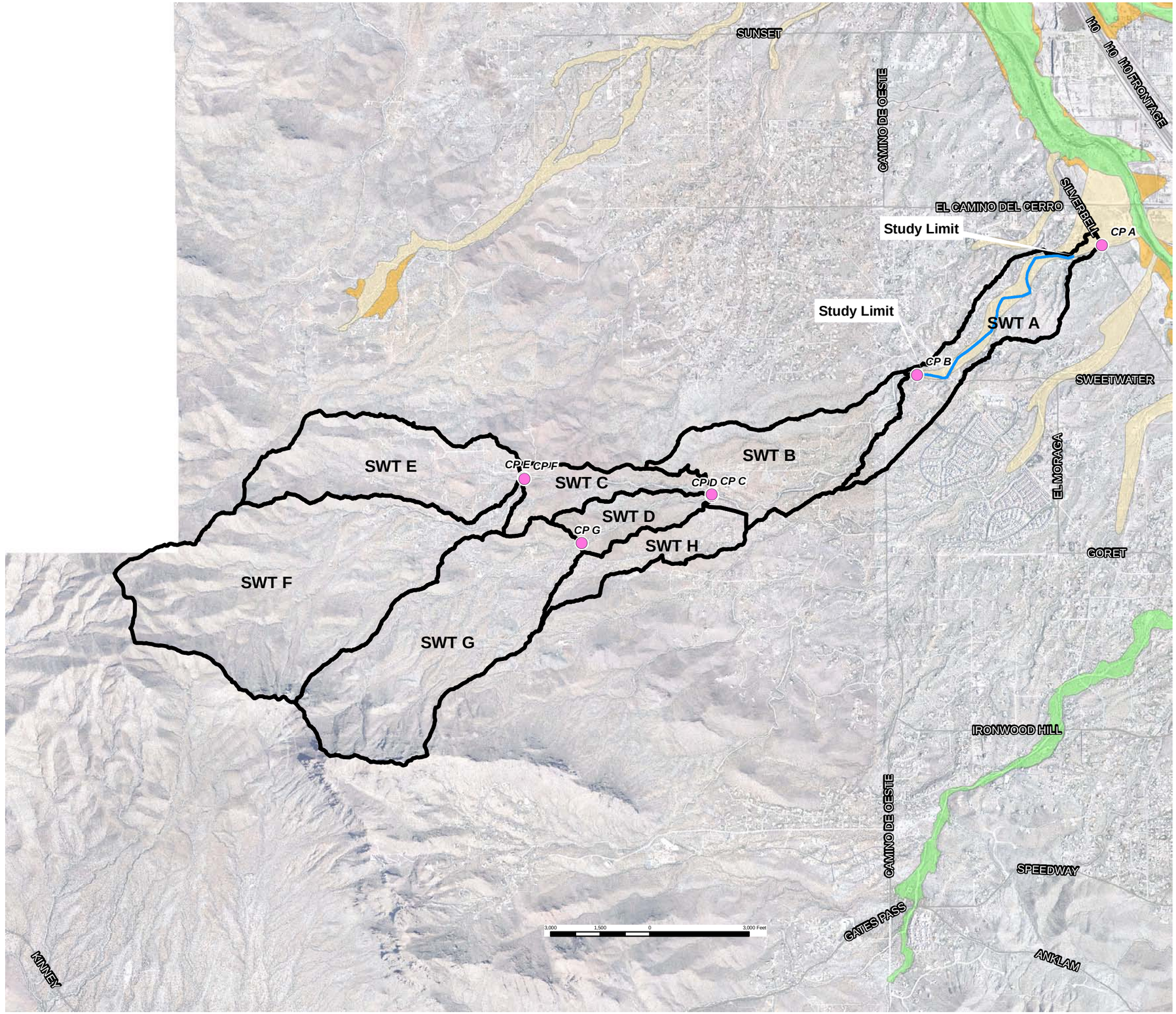
N

Scale 1:3000

04/2010

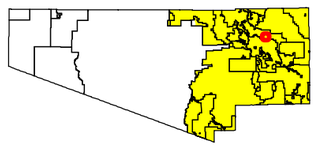
\\gislib\rfcd\projects\imd\xavi\mxd\AKITSU\Swetwater_wash_Watershed_Fig1_1.mxd

Figure 1.2
Study Limit Map
Sweetwater Wash



SWT CP
River
SWT Subbasins2
Existing Floodplain
ZONE A
ZONE AE
ZONE X - SHADED
2008PAGclr01ft.ecw

Pima County Index Map



Index Map Scale 1:5,250,000

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control Department makes no claims regarding the accuracy of the information depicted herein.

This product is subject to the Department of Transportation Technical Services Division's Use Restriction Agreement.

Pima County Regional Flood Control District

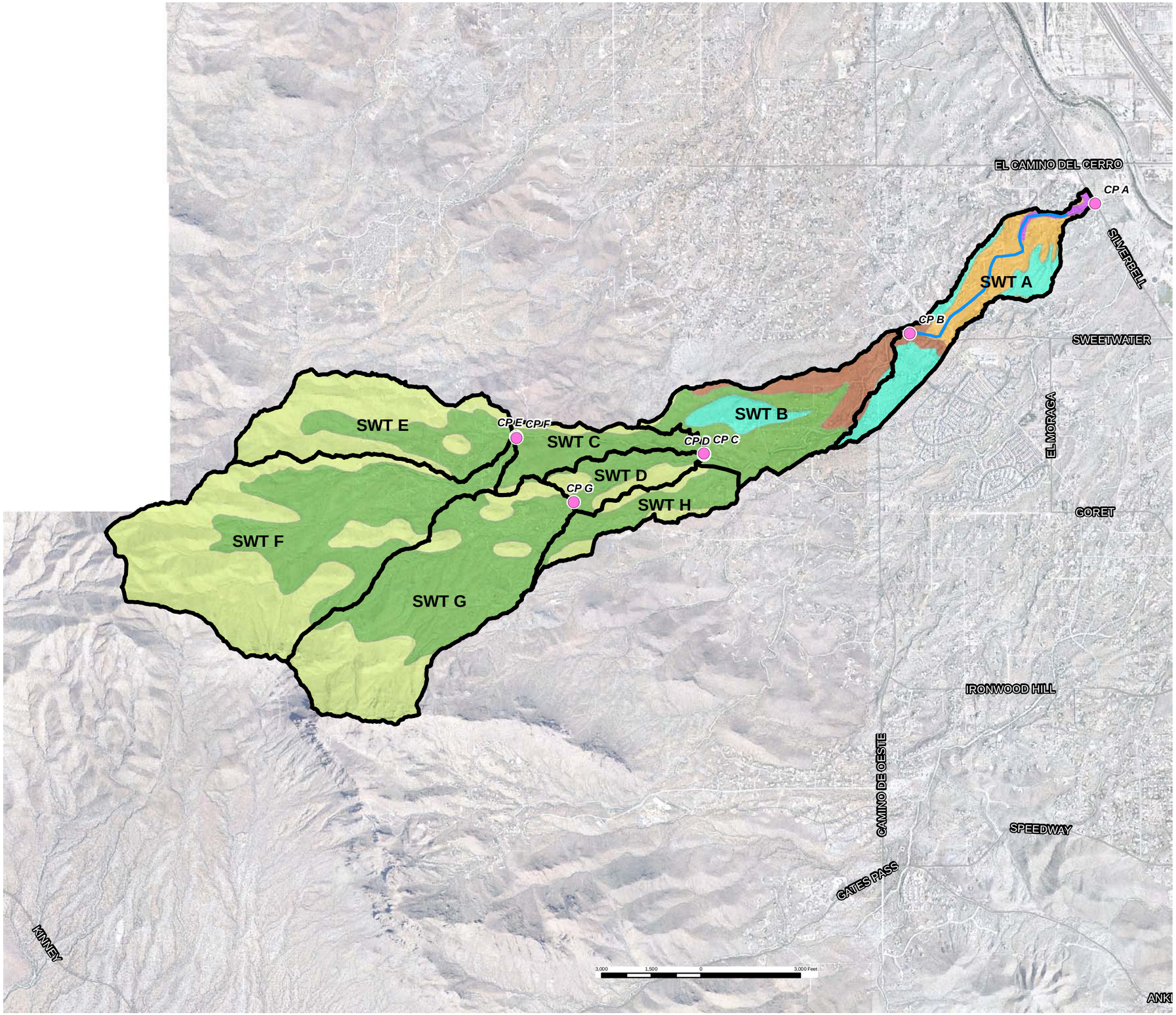
Pima County Regional FLOOD CONTROL DISTRICT

Scale 1:3000'

03/2010

\\gislib\rfcd\projects\imd\xavi\mxd\AKITSU\Sweetwater_wash_Watershed_Fig1_2.mxd

Figure 1.3
Soil Classification
Sweetwater Wash



SWT CP

River

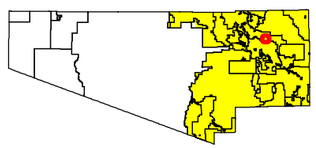
SWT Subbasins2

Soil Classification

- Soil Group: B (100%), ANTHONY FINE SANDY LOAM, 0 TO 3 PERCENT SLOPES
- Soil Group: B (100%), ANTHONY GRAVELLY SANDY LOAM,1 TO 3 PERCENT SLOPES
- Soil Group: B (100%), PINALENO VERY COBBLY SANDY LOAM, 1 TO 8 PERCENT SLOPES
- Soil Group: B (100%), PINALENO-STAGECOACH COMPLEX, 5 TO 16 PERCENT SLOPES
- Soil Group: B (82%) C (18%), PINALENO-STAGECOACH-PALOS VERDES COMPLEX, 10 TO 35 PERCENT SLOPES
- Soil Group: C (47%) D (53%), PANTANO-GRANOLITE COMPLEX, 5 TO 25 PERCENT SLOPES
- Soil Group: D (100%), ANKLAM-CELLAR-ROCK OUTCROP COMPLEX, 15 TO 55 PERCENT SLOPES

2008PAGclr01ft.ecw

Pima County Index Map



Index Map Scale 1:5,250,000

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control Department makes no claims regarding the accuracy of the information depicted herein.

This product is subject to the Department of Transportation Technical Services Division's Use Restriction Agreement.

Pima County Regional Flood Control District

Pima County Regional FLOOD CONTROL DISTRICT

N

Scale 1:3000'

03/2010

\\gislib\rfcd\projects\imd\xavi\mxd\AKITSU\Sweetwater_wash_Watershed_Fig1_3.mxd

Section 2 FEMA Forms

2.1 Study Documentation Abstract for FEMA submittals

2.1.1 Date Study Accepted: _____

2.1.2 Study Contractor:

Planning and Development Division,
Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701
(520) 243-1800

Prepared by Akitsu Kimoto, Ph.D, C.F.M., Principal Hydrologist.

2.1.3 Local Technical Reviewer:

Terry Hendricks, C.F.M, Chief Hydrologist
Planning and Development Division,
Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701
(520) 243-1800

2.1.4 Reach Description

The study reach of the Sweetwater Wash is located within a Federal Emergency Management Agency (FEMA)-designated "Zone A", as depicted on FIRM Map Panel Numbers 04019C1616 K and 1618K (February 8, 1999). The study reach of the Sweetwater Wash is located primarily west of Silverbell Rd., Pima County, Arizona (Fig. 1.1). The study reach of the Sweetwater Wash is primarily composed of a channel with cobble, and the bottom of the reach is relatively clean with vegetation cover. The overbank of the reach is covered with desert brush.

2.1.5 USGS Quad Sheets

Not available for this study

2.1.6 Unique Conditions and Problems

Hydrograph at Silverbell Rd. was generated with HEC-HMS. Flow in the distributary flow area at the downstream of Silverbell Rd. was modeled with FLO-2D. Flow at the upstream of the distributary area was modeled with HEC-RAS.

2.1.7 Coordination of Peak Discharges

The 100-year regulatory discharge rate at the Silverbell Rd. was computed using HEC-HMS, assuming no base flow in the watersheds and no transmission loss within the reaches. The hydraulic data used to derive parameters for HEC-HMS was obtained using HEC-RAS. The discharge rate was acceptable per Suzanne Shield, Director of the Pima County Regional Flood Control District.

2.2 FEMA Forms

The FEMA MT-2 forms are included in Appendix B.

Section 3 Survey and Mapping Information

3.1 Field Survey Information

None.

3.2 Mapping

The topographic data was obtained using HEC-GeoRAS and ArcGIS. Digital Elevation Model (DEM) derived from 2008 Light Detection and Ranging (LiDAR) data was used for the HEC-RAS analysis (approximately 1700 feet upstream of Silverbell Rd. to the upstream end of the existing FEMA Zone A), while Digital Terrain Model (DTM) derived from 2005 LiDAR was used for the FLO-2D analysis (from a confluence with the Santa Cruz River to approximately 1700 feet upstream of the Silverbell Rd.). The DTM with the 2005 LiDAR was developed by HDR in the Silverbell Road, Grant Road to Ina Road Design Concept Report (2009). It includes break lines, which is considered to be more accurate topographic data set. The sealed document for the field survey of the break lines is included in Appendix C. The DTM is available only in the downstream area of the Sweetwater Wash. The documentation showing that 2008 Lidar data set is FEMA-compliant is included in Appendix C.

The following data was used in this TDN;

The aerial photo: 2008 PAG aerial photo
Projection: UTM, Zone 12
Units: International feet

The contour interval of the topographic map is 2 feet.

Section 4 Hydrology

4.1 Method Description

The 100-year peak discharges for the eight subbasins of the Sweetwater Wash (SWT A, B, C, D, E, F, G, and H; Fig. 1.3) were calculated using U.S. Army Corps of Engineers Computer Hydrologic Modeling System, (HEC-HMS) version 3.4. The HEC-HMS model requires the parameters regarding rainfall, topography, soil, vegetation, and channel characteristics to determine runoff volume and peak discharge. Those parameters were determined by following the Pima County Regional Flood Control District Technical Policy 018 (Tech-018). Tech-018 is included in Appendix A. The HEC-HMS model is included in Appendix D.

4.2 Parameter Estimation

4.2.1 Drainage Area

Subbasin boundaries were delineated using the hydrology function of ArcGIS with 2008 LiDAR Data. A 5-ft contour map derived from 2008 LiDAR was used to make sure if the subbasin delineation was reasonable.

4.2.2 Watershed Work Map

A watershed work map is included in Exhibit 1. Eight subbasins were delineated for the HEC-HMS hydrologic analysis. A 100-yr peak discharge at CP A (at Silverbell Rd.) was estimated in this study. The peak discharge was used as input for the HEC-RAS and FLO-2D analysis.

4.2.3 Gage Data

No gage data were used in this TDN.

4.2.4 Spatial Parameters

No spatial parameters were used in this TDN.

4.2.5 Precipitation

According to the Tech-018, the 3-hour storm shall be used as rainfall data in the HEC-HMS model in case that a time of concentration (Tc) is equal or less than three hours. A 3-hour storm was selected for a peak discharge calculation for the Sweetwater Wash, since Tc was less than 3 hours in all the subbasins.

A point 3-hour rainfall depth at the coordinates of the centroid of the watershed was obtained from NOAA Atlas 14, upper 90% confidence interval precipitation frequency estimate (NOAA 14 rainfall). Areal reduction factor was applied to watersheds larger than 1 square mile, as described in Tech-018. The 3-hour rainfall depth for the Sweetwater Wash watershed is 2.69 inches. The areal reduction factor of 0.87 was applied to CP A.

4.2.6 Physical Parameters

The physical parameters for the subbasins and reaches of the HEC-HMS model were summarized in Tables 1 and 2. As mentioned in 4.1, all the methods and parameters were determined following Tech-018. Table 1 summarizes the method used for a HEC-HMS analysis.

Table 1 Methods used for a HEC-HMS analysis

	Selected Method
Rainfall Depth	NOAA 14, upper 90% Confidence Interval
Rainfall Distribution	3-hr SCS Type II Storm
Rainfall Loss	SCS Curve number
Time of Concentration	SCS Segmental Method
Transform	SCS Unit Hydrograph
Routing	Modified-Puls

The SCS Curve Number (CN) method was utilized as a rainfall loss method in the HEC-HMS model. The CN was determined using the Curve Number table associated with the PC Hydro User Guide (Arroyo Engineering, 2007) and a Hydrologic Soils Group map. The CN was not adjusted for rainfall intensity or antecedent moisture conditions in the HEC-HMS model. The SCS Unit Hydrograph method was used as a transform method. Impervious cover was determined using the 2008 PAG aerial photograph and Table 3 in the PC Hydro User Guide (Arroyo Engineering, 2007). The combination of the kinematic wave method and the U.S. Natural Resources Conservation Service (NRCS) segmented Time of Concentration (Tc) calculation method (USDA-NRCS, 1986) was used to determine Tc, following the recommendation on Tech-018. The Tc was calculated by summing the travel time for sheet flow, shallow concentrated flow and channel flow. The Tc for sheet flow was estimated using the kinematic wave equation. Manning's roughness coefficient for sheet flow was obtained using Table 3-1 in Technical Release

55, Urban Hydrology for Small Watersheds (USDA-NRCS, 1986). HEC-GeoRAS and HEC-RAS were used to estimate average velocity of channels. The detail of the Tc calculation is included in Appendix D.

Table 2 Physical Parameters for the Sub-Basins

Sub-Basin	Area (sq mi)	CN	Vegetation Cover (%)	Lag Time (min)
SWT A	0.45	82.9	30	16.1
SWT B	0.55	86.3	30	18.7
SWT C	0.22	88.9	30	13.6
SWT D	0.18	89.2	30	12.7
SWT E	0.62	89.8	30	12.8
SWT F	1.49	89.2	35	16.8
SWT G	1.05	89.0	35	15.5
SWT H	0.24	89.3	30	17.7

Runoff from subbasins was routed using the Modified-Puls method. Storage discharge tables for the channel routing were developed using HEC-GeoRAS and HEC-RAS. Six different discharges were used for storage-discharge relations. The number of subreaches was calculated using the following method:

$$V_w = 1.5 * V_{ave} \text{.....} eq.1$$

$$K = \frac{L}{V_w} \text{.....} eq.2$$

Therefore,

$$N = \frac{K}{\Delta t} \text{.....} eq.3$$

where V_{ave} is average flow velocity, L is reach length, V_w is velocity of flood wave (a conversion factor of 1.5 is used for natural channels), K is hydrograph travel time, Δt is the time interval for computations in the model, and N is the number of steps in the reach routing. Eq.4 was obtained from eq.1, 2, and 3. The detail of the calculation of the number of subreach is included in Appendix D.

4.3 Problems Encountered During the Study

4.3.1 Special Problems and Solutions

There were no problems with the hydrologic modeling.

4.3.2 Modeling Warning and Error Messages

The time interval of the rainfall data used in this study is 5 minutes, while the simulation time interval is 1 minute. The HEC-HMS model interpolated the 5-minute time interval of the rainfall data to 1-minute time interval.

4.4 Calibration

No calibration was conducted in this study.

4.5 Final Results

4.5.1 Hydrologic Analysis Results

The 100-year peak discharges for the Sweetwater Wash subbasins and at CP A were determined using the HEC-HMS. The results are summarized Tables 3 and 4.

Table 3 Summary of the Hydrologic Analysis Results for Sub-Basins

Sub-Basin	Area (sq mi)	Rainfall Depth (in)	Runoff Volume (in)	Peak Discharge (cfs)
SWT A	0.45	3.11	1.53	680.3
SWT B	0.55	3.11	1.78	882.8
SWT C	0.22	3.11	1.99	478.5
SWT D	0.18	3.11	2.01	410.3
SWT E	0.62	3.11	2.07	1443.9
SWT F	1.49	3.11	2.01	2904.8
SWT G	1.05	3.11	2.00	2128.7
SWT H	0.24	3.11	2.03	456.2

Table 4 Summary of the Hydrologic Analysis Results at the Concentration Points

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q100 HMS (cfs)	Time to Peak
CP A	at Silverbell Rd.	4.8	2.69	1.57	5622	2:07

4.5.2 Verification results

Peak discharge estimated using a HEC-HMS model was compared with an existing 100-year regulatory discharge at CP A (Table 5). The comparison shows that the 100-year peak discharge estimated with a HMS model is in relatively good agreement with the accepted regulatory discharge of 6011 cfs. The HMS-derived peak discharge was also compared with the peak discharge obtained from USGS Regression Equation 13 (RRE;

Thomas et al., 1997) (Table 5). The comparison showed that the HMS-derived peak discharge was higher than the one derived from the Regression Equation. The higher HMS-derived peak discharge compared to the RRE-derived peak discharge would be expected, because these steep watersheds could be expected to produce higher than average at the sub-basin scale.

Table 5 Comparison of a peak discharge

Concentration Point	Location	Area (sq mile)	Q100 HMS (cfs)	Q100 RRE (cfs)	Existing Regulatory Discharge (cfs)
CP A	at Silverbell Rd.	4.8	5622	3275	6011

RRE: USGS Regression Equation 13

Section 5 Hydraulics

5.1 Method Description

The hydraulic modeling for the Sweetwater was performed using HEC-RAS, Version 4.0 (HEC-RAS), HEC-GeoRAS, Version 4.1.1 (HEC-GeoRAS), ArcGIS, Version 9.3, and FLO-2D (Version 2007-6). Hydraulic analysis was performed in the area currently mapped as FEMA Zone A. Corrected model is proposed in this study. The model name is SWT, and the plan name is Plan 01.

Steady flow analysis was performed using HEC-RAS in order to determine a floodplain limit for the upstream of the Sweetwater Wash (from the upstream end of the existing FEMA Zone A to approximately 1700 feet upstream of the Silverbell Rd). The locations of the stream centerline, flowpath, and cross sections of the Sweetwater Wash were determined using a 2-ft contour map and 2008 PAG aerial photos. The physical attributes of the wash were digitized in ArcGIS using the HEC-GeoRAS extension and exported to HEC-RAS to create geospatially referenced geometric data (cross section, reach profile). Other parameters for the steady-state analysis, such as Manning's n-values, expansion and contraction coefficients, boundary condition, and ineffective flow areas were manually input into HEC-RAS. Normal-depth with a slope of 0.013 was assumed for the downstream boundary condition. The hydraulic data obtained from HEC-RAS were imported into HEC-GeoRAS to delineate a floodplain boundary for the Sweetwater Wash.

FLO-2D was used for the downstream distributary area (from approximately 1700 feet upstream of the Silverbell Rd to a confluence with the Santa Cruz River). Geometric data for the FLO-2D model were derived from the 2005 Lidar data. Grid cell size of 20 feet was used to map a floodplain in the distributary area. The time interval used for the computation was 5 minutes. The FLO-2D model includes floodplain cross sections at immediately upstream of Silverbell Rd to estimate discharge crossing the road. The model does not include infiltration or rainfall. A hydrograph from the HMS at CP A (at Silverbell Rd.) was used as inflow data at a cell located at the upstream of the flow split.

5.2 Work Study Maps

The work study map for the Sweetwater Wash is included in Exhibit 2.

5.3 Parameter Estimation

5.3.1 Roughness Coefficients

Manning's n values were determined by a combination of a site visit and 2008 PAG aerial photo. In the HEC-RAS model, Manning's n value of 0.06 was assigned for the overbank with desert brush, and the value of 0.045-0.05 was assigned to a channel. In the FLO-2D model, selected Manning's n values are 0.045-0.05 for a channel, 0.035 for roads (Camino del Cerro and Silverbell Rd.), and 0.05-0.065 for the other area.

5.3.2 Expansion and Contraction Coefficients

In the HEC-RAS model, the channel of the Sweetwater Wash is assumed to have generally gradual transitions with minimum curvature. The expansion coefficient of 0.30 and contraction coefficient of 0.10 were used for the entire reach.

5.4 Cross-Section Description

For the HEC-RAS model, a 5-foot interval contour map was used to select the location of cross sections. Cross-section locations were determined primarily based on the channel topography. The cross-section lines were drawn to be perpendicular to flow paths in HEC-GeoRAS.

In the FLO-2D model, two cross sections were placed at immediately upstream of Silverbell Rd to obtain peak discharge crossing the road.

5.5 Modeling Consideration

5.5.1 Hydraulic Jump and Drop Analysis

No hydraulic, drop analyses or adjustment of the floodplain was conducted in this study.

5.5.2. Bridges and Culverts

None.

5.5.3 Levees and Dikes

There are no levees or dikes located within the study limit.

5.5.4 Island and Flow Splits

At approximately 1500 feet upstream of Silverbell Rd., the flow splits into two major flow paths. The flow becomes distributary at the downstream of Silverbell Rd.

5.5.5 Ineffective Flow Areas

In the HEC-RAS model, ineffective flow option was modeled in the following situations. In general these ineffective flow areas were disconnected overbank areas that would not convey flow to the next downstream cross-section.

5.6 Floodway Modeling

No floodway modeling was performed in this study.

5.7 Problems Encountered

5.7.1 Special Problems and Solutions

Flow in the distributary flow area at the downstream of Silverbell Rd. was modeled with FLO-2D. For a floodplain mapping with FLO-2D, shallow flow depth less than 0.2 feet is considered to be negligible and cells with flood depth less than 0.2 feet were removed from a 100-year flood hazard area. In other words, cells with flow depth deeper than 0.2 feet were considered as a floodplain in this study. Flow at the upstream of the distributary area was modeled with HEC-RAS.

5.7.2 Model Warnings and Errors

No errors occurred. The following warning messages occurred in the HEC-RAS model:

Divided flow
Energy loss greater than 1.0
Energy equation could not be balanced and defaulted to critical.
Cross-section extended vertically.
Multiple critical depths calculated.
Conveyance ratio is less than 0.7 or greater than 1.4.

Inspection indicated that the modeling is accurate given the steep channel conditions. Most of these errors force a critical solution which is reasonable for these steep watercourses. A summary of the HEC-RAS errors is available in Appendix E.

5.8 Calibration

The model was not calibrated in this study.

5.9 Final Results

5.9.1 Hydraulic Analysis Results

The HEC-RAS and FLO-2D modeling results are shown in Exhibit 2.

5.9.2 Verification of Results

The floodplain limit produced in this Sweetwater Wash LOMR study was compared to the existing FEMA floodplain limit. The proposed floodplain limit tends to follow the existing floodplain limit in the upstream area, while the proposed floodplain limit is wider in south and narrower in north. The results suggest that the proposed floodplain limit is reasonable based on the topography.

Section 6 Erosion and Sediment Transport

No erosion or sediment transport analysis was conducted in this study.

Section 7 Draft FIS Report Data

7.1 Summary of Discharges

Peak discharges at CP A (Silverbell Rd.) was used for the hydraulic analysis in this study. The estimated regulatory discharge rates are 5622 cubic feet per second (cfs) with a drainage area of 4.8 square mile.

7.2 Floodway Data

Not applicable.

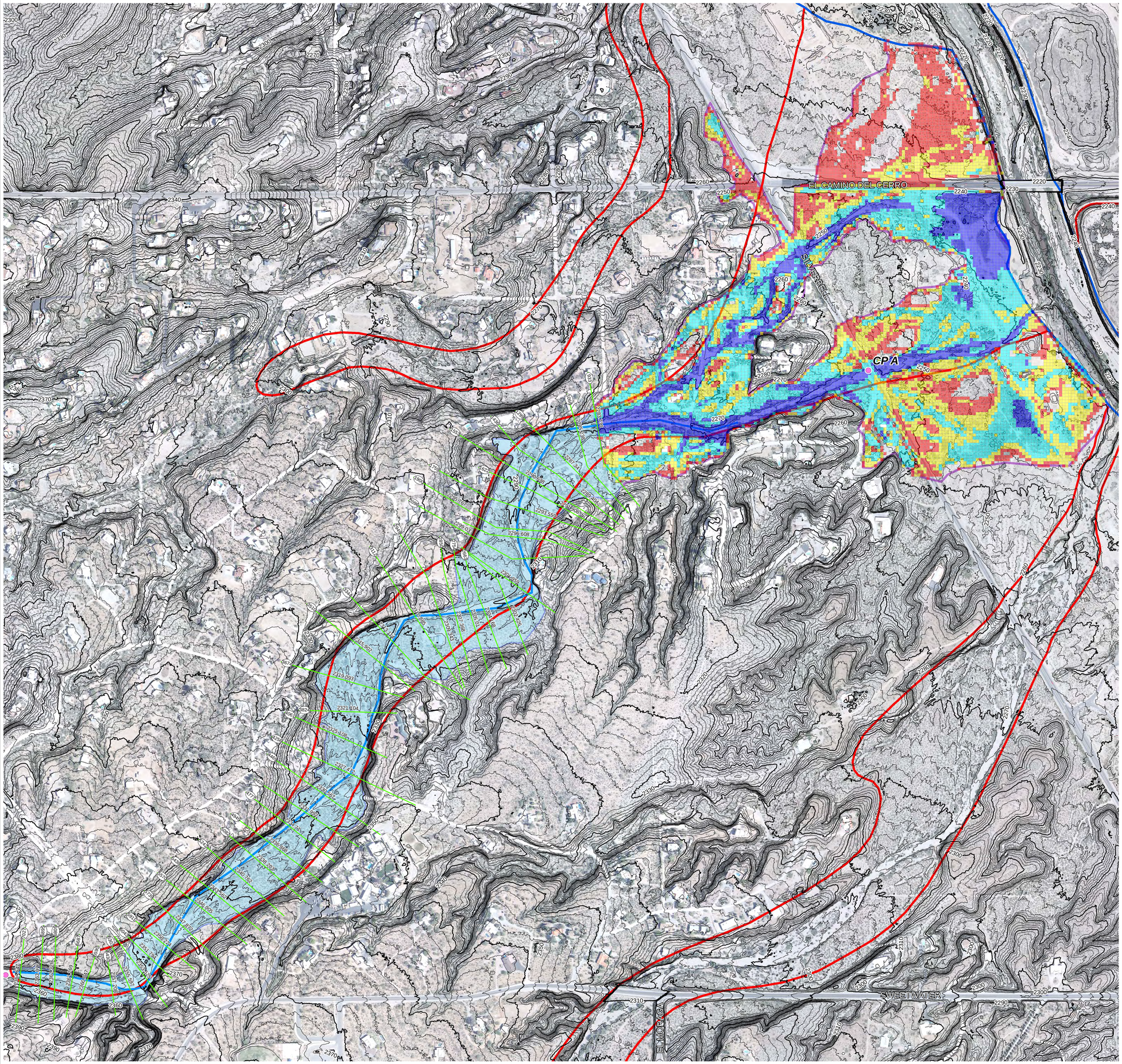
7.3 Annotated Flood Insurance Rate Map

An annotated Flood Insurance Rate Map (FIRM) is included in Exhibits 2.

7.4 Flood Profiles

Flood profile for the upstream area is included in the HEC-RAS model in Appendix E.

Exhibit 1
100-year Floodplain
with Cross Sections & Flow Depth
Sweetwater Wash



- Discharge Points
- Xsections
- Contour 2ft
- Contour 10ft
- River

Proposed Floodplain
- Downstream
- Upstream

Existing Zone AE

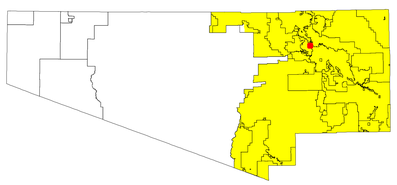
ZONE
- ZONE A
- ZONE AE

Flow Depth at Cell

Feet
- => 0.200
- => 0.500
- => 1.000
- => 2.000

Aerial: 2008 Pima Arizona Government
Topo: 2008 Pima Arizona Government
vertical Datum: NAVD 1988

Pima County Index Map



Index Map Scale 1:1,500,000

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Department of Transportation Technical Services Division makes no claims regarding the accuracy of the information depicted herein.

This product is subject to the Department of Transportation Technical Services Division's Disclaimer and Use Restrictions.

Pima County Regional Flood Control District

N

200 100 0 200 Feet

Pima County Regional FLOOD CONTROL DISTRICT

Pima County Regional Flood Control
97 East Congress Street - 3rd Floor
Tucson, Arizona 85701-1207
(520)243-1800 - FAX (520)243-1821
http://www.rfcd.pima.gov

THE SEAL OF PIMA COUNTY ARIZONA

04/2010

gislib\rfcd\projects\imd\xavi\mdx\AKITSU\Sweetwater\Sweetwater_watershed_FINALexh3.mxd

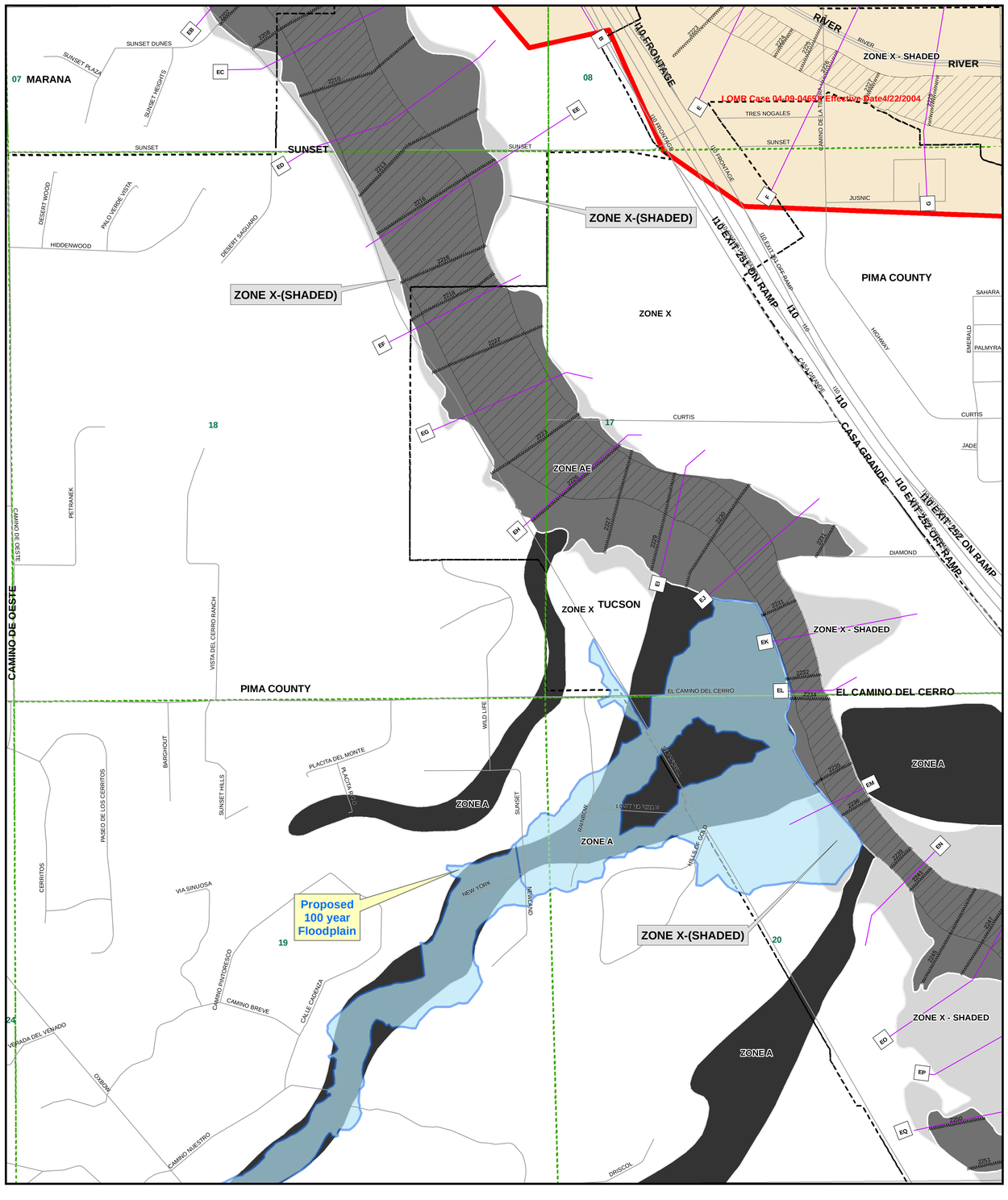


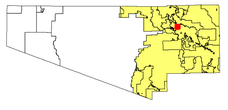
Exhibit 2
Annotated Flood Insurance Rate Map
04019C1616 K
Sweetwater Wash

- Streets
- FIRM X-Sections
- Base Flood Elevations
- Proposed Floodplain
- LOMR Case Studies
- FIRM - Flood Insurance Rate Map
- Floodways
- Sections
- Jurisdictions

Existing Floodplain Zone

- A
- AE
- AO
- X
- X - (SHADED)

Pima County Index Map



The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Department of Transportation Technical Services Division makes no claims regarding the accuracy of the information depicted herein.

This product is subject to the Department of Transportation Technical Services Division's Disclaimer and Use Restrictions.

490 245 0 490 Feet

Pima County Regional Flood Control
97 East Congress Street - 3rd Floor
Tucson, Arizona 85701-1207
(520)243-1800 - FAX (520)243-1821
http://www.rfcd.pima.gov

gislib\rfcd\projects\iimd\xavi\mdx\AKITSU\Sweetwater\Sweetwater_watershed_Anno_FIRM28x40.mxd

A.1 Data Collection Summary

Aldridge, B. and J. Garrett. 1973. Roughness Coefficients for Stream Channels in Arizona. US Department of the Interior Geological Survey. Tucson, AZ.

Arizona Department of Water Resources, Flood Mitigation Section
"Instruction for Organization and Submitting Technical Document for Flood Studies" SSA1-97, November 1997

Arizona Department of Water Resources, Flood Mitigation Section
"Requirements for Flood Study Technical Documentation" SS1-97, November 1997

Arroyo Engineering. 2007. PC-Hydro User Guide. Pima County Regional Flood Control District

City of Tucson (COT), Department of Transportation, 1989. Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona. Revised in 1998.

National Weather Service. 1984. Depth-Area Ratios in the Semi-Arid Southwest United States, NOAA Technical Memorandum NWS Hydro-40

Phillips, J., and S. Tadayon. 2006. Selection of Manning's roughness coefficient for natural and constructed vegetated and non-vegetated channels, and vegetation maintenance plan guidelines for vegetated channels in central Arizona: U.S. Geological Survey Scientific Investigations Report 2006–5108, 41 p.

Phillips, J., and T. Ingersoll. 1998. Verification of Roughness Coefficients for Selected Natural and Constructed Stream Channels in Arizona. U.S. Geological Survey Professional Paper 1584.

Pima County Regional Flood Control District
"Pima County Mapguide Map", 2008

U.S. Army Corps of Engineers (COE). 1998. HEC-1 Flood Hydrograph Package, Users Manual, CPD-1A, Hydraulic Engineering Center, Davis, CA.

U.S. Army Corps of Engineers (COE). 2001. HEC-RAS, River Analysis System, Hydraulic
Reference Manual, CPD-69, Hydraulic Engineering Center, Davis, CA.

U.S. Army Corps of Engineers (COE). 2003. Geospatial Hydrologic Modeling Extension HEC-GeoHMS, (v 1.1) CPD-77, Hydraulic Engineering Center, Davis, CA.

U.S. Army Corps of Engineers (COE). 2006. HEC-HMS, Hydrologic Modeling System User's Manual, (v. 3.1.0) CPD-74A, Hydraulic Engineering Center, Davis, CA.

U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), 1986. Urban Hydrology for Small Watersheds, Technical Release 55. Washington, DC.

A 2. Referenced Documents

Arroyo Engineering. 2007. *PC-Hydro User Guide*. Pima County Regional Flood Control District

Eychaner, J.H., 1984. Estimation of magnitude and frequency of floods in Pima County, Arizona, with comparisons of alternative methods: U.S. Geological Survey Water-Resources Investigations Report 84-4142, 69 p.

Haan, C.T., Barfield, B.J., Hayes, J.C. 1994. Design Hydrology and Sedimentology for Small Catchments, Academic Press.

Thomas, B.E., H.W. Hjalmarson, and S.D. Waltemeyer. 1997. Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States. USGS Water Supply Paper 2433. 195 p.

U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), 1986. Urban Hydrology for Small Watersheds, Technical Release 55. Washington, DC.

Appendix C: Survey Field Notes

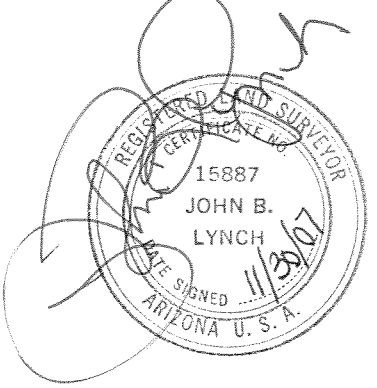
TETRA TECH, INC.

The accuracy of the lidar data was verified using the methods described in sections A.3, A.4 and A.8 of the *FEMA Guidelines and Specifications for Flood Hazard Mapping Partners* (April, 2003). Ground cover categories (1) bare-earth and low grass and (5) urban area, roadways were evaluated. A total of 493 points were compared. The difference was determined to be 0.2 feet (median value).

A total of 506 points were collected throughout the area defined by the 100yr flood limit (TetraTech Job 0939-FVW-LOMR) plus an additional 300 feet, from Stone Loop northeasterly to North 1st Avenue, all within Section 13, T13S, R13E and Section 18, T13S, R14E. The survey utilized a GPS/RTK base and receiver, localized on survey monuments with Arizona State Plane, Central Zone NAD83 coordinates (horizontal) and orthometric heights relative to NAVD88, published by the Pima Association of Governments (PAG). The field survey was conducted in October and November of 2007. A total of 13 points were discarded due to man-made changes in the ground surface or insufficient satellite reception.

The surface used for this survey was provided by Pima County Flood Control as lidar point file (13S13E13) using LAS format and a XYZ point cloud covering the approximate same area. A TIN was created using ArcGIS 9.2 3D Analyst and elevations extracted at locations as determined per the field survey and differences between the two were calculated.

It was found that accuracy of the lidar surface was within the two-foot equivalent contour interval ($accuracy_z$ = 1.2 foot at the 95-percent confidence level) criteria specified by FEMA. The actual ground elevation was higher then the lidar surface by an average of 0.2 feet, with a min/max range of 1.1 feet. The verification demonstrates that the lidar surface meets the criteria for lidar compliance specified in sections A.3, A.4 and A.8 of FEMA Guidelines and Specifications for Flood Hazard Mapping Partners.



Tetra Tech Job Number: 0939 Friendly Village Wash LOMR

33 N. Stone Avenue, Suite 1500, Tucson, AZ 85701-1413
520.623.7980 • FAX 520.884.5278
www.tetratech.com

From: Kenneth Maits
Sent: Monday, May 03, 2010 12:20 PM
To: Evan Canfield
Subject: FW: PAG 2008 Orthos/Lidar

Evan,

I think this is the right email....

From: Terry Hendricks
Sent: Thursday, November 12, 2009 8:30 AM
To: Bill Zimmerman; Kenneth Maits; Evan Canfield; Chris Cawein
Subject: FW: PAG 2008 Orthos/Lidar

Read Ed Curtis's email below. It appears that FEMA accepts the 2008 LiDAR HOWEVER it looks in some places we may need to provide "additional ground survey data where necessary"

From: Manny M. Rosas [mailto:MRosas@pagnet.org]
Sent: Tuesday, November 10, 2009 4:26 PM
To: 'Curtis, Edward'
Cc: Terry Hendricks; 'Don Freeman'; 'Lucero, Andrew'
Subject: RE: PAG 2008 Orthos/Lidar

Thanks Ed,

Good news!!

Manny

From: Curtis, Edward [mailto:Edward.Curtis@dhs.gov]
Sent: Tuesday, November 10, 2009 2:44 PM
To: Manny M. Rosas
Cc: Terry Hendricks; Lucero, Andrew; Caldwell, Jason; Akl, Pascal
Subject: RE: PAG 2008 Orthos/Lidar

Mr. Rosas –

I apologize for the delay in responding to you regarding the Sanborn LiDAR report. Pascal Akl of Michael Baker, Jr. reviewed the updated July 2009 report on behalf of FEMA and advised me that all of the concerns raised in his May 18, 2009 memorandum titled “Pima County, CA [sic] Sanborn LiDAR Report Items” were addressed in the updated report except the comment that the original report lacked a sufficient number of checkpoints in urban areas and dense vegetation areas. No additional checkpoints were surveyed in such arease to permit analysis of data accuracy in

these land cover categories. However, in the data voids analysis section of the updated report (p. 16), Sanborn states the following: "Specific areas, dense vegetation or undergrowth near small streams, for example, prevents the LiDAR pulses to fully penetrate to the true ground surface. Thus, for mapping products such as floodplain or contour mapping, LiDAR data must often be manually supplemented with breaklines and mass-points to accurately model the terrain surface." As long as the data is used with caution and supplemented with additional ground survey data where necessary in accordance with this statement, I am satisfied that the terrain data meets FEMA standards for use in detailed flood studies.

Please contact me if you have any questions regarding our review and comments.

Ed Curtis, P.E., CFM

Risk Analysis Branch

FEMA Region IX

(510) 627-7207 - office

(510) 295-5249 - mobile

From: Manny M. Rosas [mailto:MRosas@pagnet.org]
Sent: Tuesday, November 10, 2009 7:29 AM
To: 'Lucero, Andrew'; 'Caldwell, Jason'
Cc: 'Terry Hendricks'; Curtis, Edward
Subject: PAG 2008 Orthos/Lidar

Hi Andy,

I resent Sanborn’s Version 3 document produced in July 2009 and yet to receive any comments from FEMA, Pima County and Michael Baker Inc. therefore

please proceed with direct communications with Michael Baker Inc (Pascal Akl) to resolve all issues regarding the FEMA guidelines

Thank You

Manny

Manny M. Rosas Jr.

GIS Administrator

177 N Church Ave. Suite 405

Tucson, Arizona 85701

520-792-1093 (tel)

520-620-6981 (fax)

Property of HDR ENG. INC.

5210 E. WILLIAMS CIR.

Address STE. 530

TUCSON, AZ. 85711

Phone 520-584-3611

This Book is manufactured of a High Grade 50% Rag Ledger Paper having a Water Resistant Surface, and is sewed with Nylon Waterproof Thread.

Made in U. S. A.

815275

INDEX PAGE

JOB NO.	PROJECT	PAGE NUMBER
112279	SILVERBELL RD, GRANT RD TO INA RD. (C.O.T.) (REF. JOB NO. 15794 IN HDR F.B. 201)	ALL
	COT FB # 2255	
	I HEREBY CERTIFY THAT THE SURVEY CONTAINED HEREIN WAS CONDUCTED UNDER MY DIRECT SUPERVISION BETWEEN MAY, 2009 AND MAY, 2010. I FURTHER CERTIFY THAT THIS SURVEY WAS CONDUCTED AS A CONTROL AND DESIGN SURVEY FOR SILVERBELL RD. FROM GRANT RD. TO INA RD. THE INFORMATION CONTAINED HEREIN IS TRUE, ACCURATE AND SUFFICIENT TO RETRACE THIS SURVEY. THIS SURVEY MEETS OR EXCEEDS THE MINIMUM STANDARDS FOR SURVEYS IN ARIZONA.	

REGISTERED LAND SURVEYOR CERTIFICATE NO. 18211 FRANK D. ABELL Date Signed 5.6.10 ARIZONA U.S.A.

Terry Hendricks

From: Curtis, Edward [mailto:Edward.Curtis@dhs.gov]
Sent: Tuesday, November 10, 2009 2:44 PM
To: Manny M. Rosas
Cc: Terry Hendricks; Lucero, Andrew; Caldwell, Jason; Akl, Pascal
Subject: RE: PAG 2008 Orthos/Lidar

Mr. Rosas –

I apologize for the delay in responding to you regarding the Sanborn LiDAR report. Pascal Akl of Michael Baker, Jr. reviewed the updated July 2009 report on behalf of FEMA and advised me that all of the concerns raised in his May 18, 2009 memorandum titled “Pima County, CA [sic] Sanborn LiDAR Report Items” were addressed in the updated report except the comment that the original report lacked a sufficient number of checkpoints in urban areas and dense vegetation areas. No additional checkpoints were surveyed in such arease to permit analysis of data accuracy in these land cover categories. However, in the data voids analysis section of the updated report (p. 16), Sanborn states the following: "*Specific areas, dense vegetation or undergrowth near small streams, for example, prevents the LiDAR pulses to fully penetrate to the true ground surface. Thus, for mapping products such as floodplain or contour mapping, LiDAR data must often be manually supplemented with breaklines and mass-points to accurately model the terrain surface.*" As long as the data is used with caution and supplemented with additional ground survey data where necessary in accordance with this statement, I am satisfied that the terrain data meets FEMA standards for use in detailed flood studies.

Please contact me if you have any questions regarding our review and comments.

Ed Curtis, P.E., CFM
Risk Analysis Branch
FEMA Region IX
(510) 627-7207 - office
(510) 295-5249 - mobile