Tucson Mountain Watercourse Studies:
Technical Data Notebook for Hydrologic and Hydraulic Mapping of the Unnamed 02 and 03 Washes,
Pima County Arizona.

FEMA FIRM Panel 04019C-1655L

Prepared by

Akitsu Kimoto
Principal Hydrologist

Approved by

Registered Professional Engineer (Civil) CERTIFICATE NO. 15510 SUZANNE J. SHIELDS DATE SIGNED 11/25/15 ARIZONA U.S.

Suzanne Shields, PE
Director

Pima County Regional FLOOD CONTROL DISTRICT

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

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Section 1 Introduction

1.1 Purpose

The objective of this Technical Data Notebook (TDN) is to provide 100-yr peak discharges at a Concentration Point (CP A) for the Unnamed 02 and 03 Washes, 100-yr floodplain boundary and erosion hazard information, using the most up-to-date 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 Guidelines. This is a local study and has not been submitted to FEMA.

1.2 Project Authority

The State of Arizona has delegated the responsibility to each county flood control district to delineate or require the delineation of floodplains and to regulate development within floodplains (ARS § 48-3609):

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

1.3 Project Location

The study was performed to provide drainage information for Unnamed 02 and 03 Washes. The site includes Sections 02 and 03 of Township 13 South, Range 12 East, Pima County, Arizona. The entire watershed of the Unnamed 02 and 03 Washes is in FEMA Zone X, as shown on the current Flood Insurance Rate Map (FIRM) number 04019C-1655L.

The study area for the Unnamed 02 Wash is from Ina Rd. to Stable TR. (Fig.1.1). The study watershed is 0.25 square miles (Fig.1.2). The study area for the Unnamed 03 Wash

is from Silverbell Rd. to ~700 feet east of Paddock Pl. (Fig.1.1). The study watershed is 0.25 square miles (Fig.1.2).

1.4 Hydrologic and Hydraulic Methods

A hydrologic analysis was performed to estimate regulatory discharge rates at Ina Rd. using PC-Hydro Version 5.4.2 (PC-Hydro). The parameters for PC-Hydro, such as soil, vegetation, slope, flow path length and roughness were selected in accordance with the PC-Hydro User Guide (Arroyo Engineering, 2007). The proposed regulatory discharges are flow rates that have a 1-percent chance of being equaled or exceeded each year ("100-year" discharge rates). A hydraulic analysis was performed to determine a 100-yr floodplain boundary using HEC-GeoRAS, Version 10 (HEC-GeoRAS) and HEC-RAS Version 4.1 (HEC-RAS).

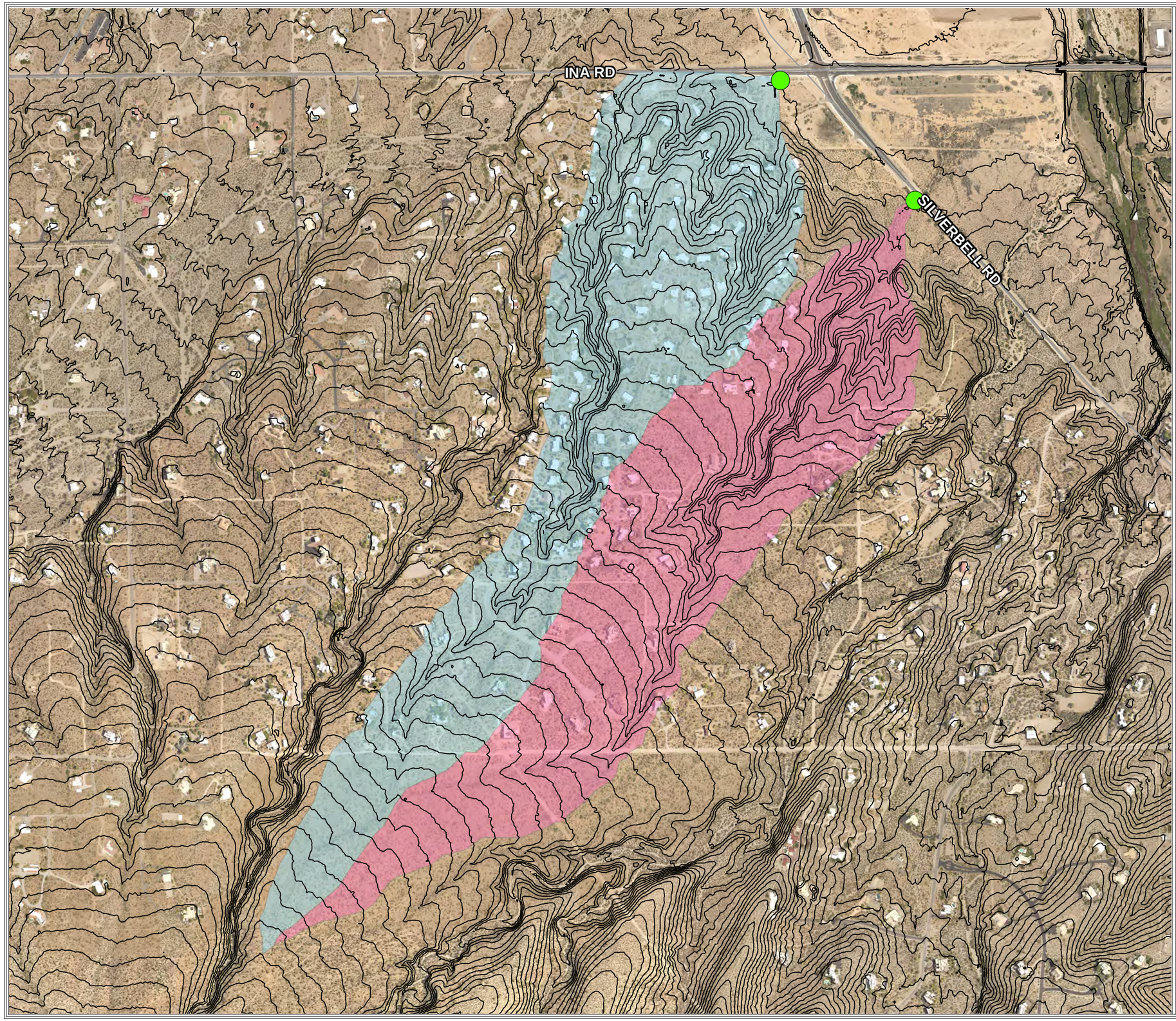
1.5 Acknowledgment

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

1.6 Study Results

The 100-yr discharges were calculated for the Unnamed 02 and 03 Washes. Subbasin boundaries and corresponding CPs are illustrated in Figure 1.2. Hydrologic characteristics for the studied subbasins are presented in Table 2. Calculated discharges are summarized in Table 3. The calculated discharges are compared with the USGS Regional Regression Equation (Table 4). The comparison shows that the peak discharges calculated in this study are reasonable. This study found one home in the Unnamed 02 Wash watershed at risk for flooding during the 100-yr flood.

Figure 1.1
Watershed Map
Unnamed 2 Wash
Unnamed 3 Wash



Discharge Points

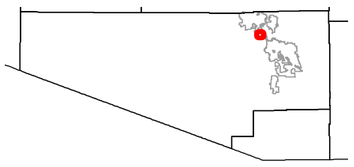
Contour 5ft.

Watersheds

Unnamed 2

unnamed 3

Aerial : 2012 Pictometry Orthophoto Imagery©
Topo: 2008 Pima Association of Governments
Datum: NAVD 1988



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Pima County Regional Flood Control District

Pima County Regional FLOOD CONTROL DISTRICT

THE SEAL OF PIMA COUNTY ARIZONA

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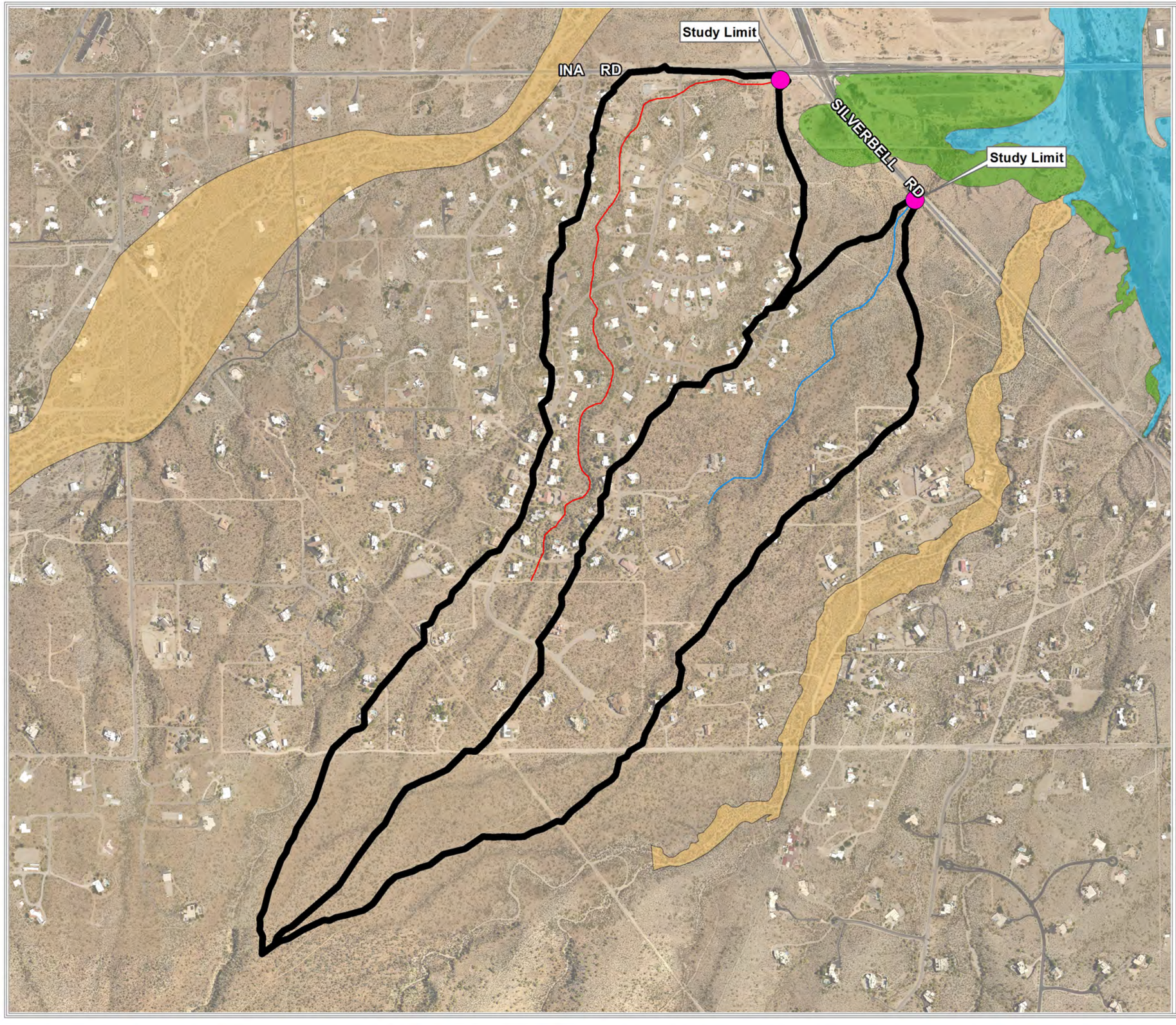

Figure 1.2
Study Limit
Unnamed 2 Wash
Unnamed 3 Wash

Discharge Points

River Unnamed 2

River Unnamed 3

Watersheds

Existing FEMA Floodplain

ZONE A

ZONE AE

ZONE X - SHADED

Aerial : 2012 Pictometry Orthophoto Imagery ©

Pima County Index Map

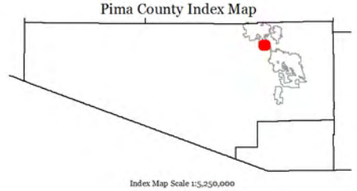

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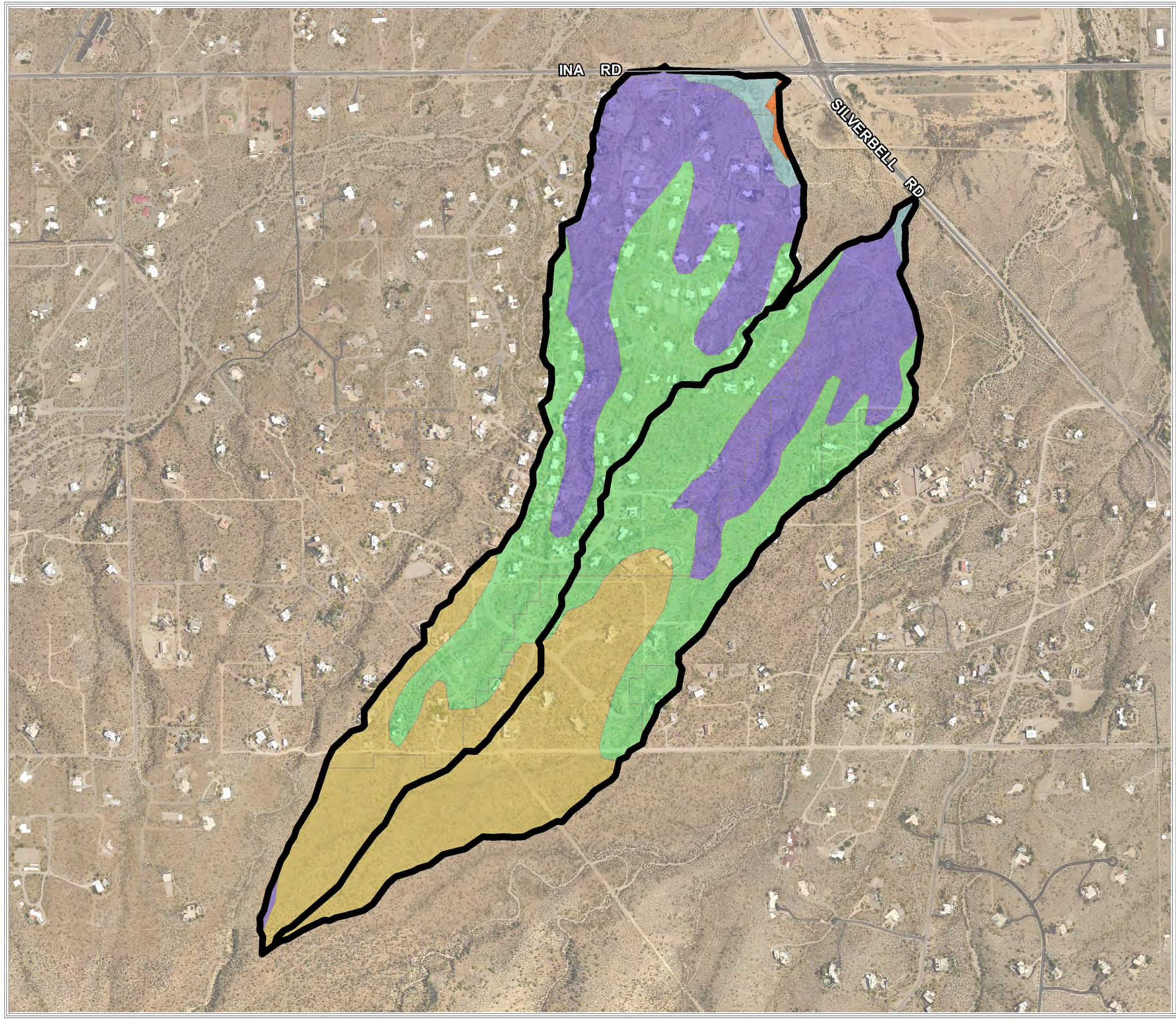
Figure 1.3
Soil Classification
Unnamed 2 Wash
Unnamed 3 wash



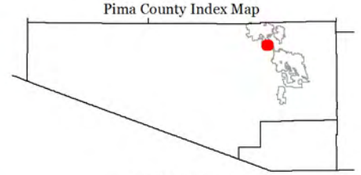
Watersheds

Soil Classification

- Soil Group: B (100%), ANTHONY FINE SANDY LOAM, 0 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 (100%), STAGECOACH-SAHUARITA ASSOCIATION, 1 TO 8 PERCENT SLOPES
- Soil Group: C (100%), TUBAC GRAVELLY LOAM, 1 TO 8 PERCENT SLOPES

Aerial : 2008 Pima Association of Governments

Pima County Index Map



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Pima County Regional FLOOD CONTROL DISTRICT

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Section 2 Local Government Abstract

2.1 Project Contact Information

Contact Information:
Akitsu Kimoto
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Local Technical Reviewer:
Terry Hendricks
Pima County Regional Flood Control District
97E Congress, Tucson, AZ 85705
Terry.Hendricks@pima.gov

Date Study Submitted: _____

Date Study Approved: _____

2.2 General Information

Community: Pima County Regional Flood Control
County: Pima County
River or Stream Name: Tucson Mountain Unnamed 02/03 Wash
Reach Description: Wash in Tucson Mountain
Study Type: Hydrology and Hydraulics study of a Riverine System
Purpose of the Study: To provide regulatory discharges and map floodplain boundaries
Summary of Hydrology and Hydraulic Methods:
Brief Summary Description of the Study Results:
Acknowledgements:

2.3 Survey and Mapping Information

Digital Projection Information: NAD 1983 HARN State Plane Arizona Central
USGS Quad Sheets if available:
Mapping for Hydrologic Study: LiDAR based on 2008 flight used to derive 2-ft contour interval maps using ArcGIS 10.0, PAG 2012 orthophotos
Mapping for Hydraulic Study: LiDAR based on 2008 flight used to derive a DEM (20-ft cell size) for use with HEC-GeoRAS, PAG 2012 orthophotos

2.4 Hydrology

Model or Method Used: PC-Hydro Version 5.4.2
Storm Duration: Based on 1-hr Rainfall Depth
Hydrograph Type: NA
Frequencies Determined: 100 yr
List of Gages used in Frequency Analysis or Calibration: None
Rainfall Amounts and Reference: NOAA 14 Upper 90% Confidence Interval
Unique Conditions and Problems: None
Coordination of Q's: Comparison with a USGS Regression Equation

2.5 Hydraulics

Model or Method Used: HEC-GeoRAS, Version 10 (HEC-GeoRAS) and HEC-RAS Version 4.1 (HEC-RAS)
Regime: Modeled as subcritical
Frequencies for which Profiles were computed: 100 yr
Method of Floodway Calculation: Floodway Not Determined in this Study
Unique Conditions and Problems: None

2.6 Erosion, Sediment Transport and Geomorphic Analysis

Summary of Method: NA
Issues Encountered During Study: NA
Summary of Findings: NA

2.7 Additional Study Information

None

Section 3 Survey and Mapping Information

3.1 Digital Projection Information

The data below are included in this TDN (see "GIS" folder)
Projection: State Plane, Arizona Central Zone
Horizontal Datum: NAD 83 HARN
Vertical Datum: NAVD 88
Units: International Feet
Aerial Photo: PAG 2012 Orthophotos
Contour: 2 feet interval
Topographic Data: 20-ft DEM

3.2 Field Survey Information

A survey was not necessary for this study.

3.3 Mapping

A Digital Elevation Model (DEM) derived from 2008 Light Detection and Ranging (LiDAR) data was used for the HEC-RAS analysis. The contour interval of the topographic map is 2 feet.

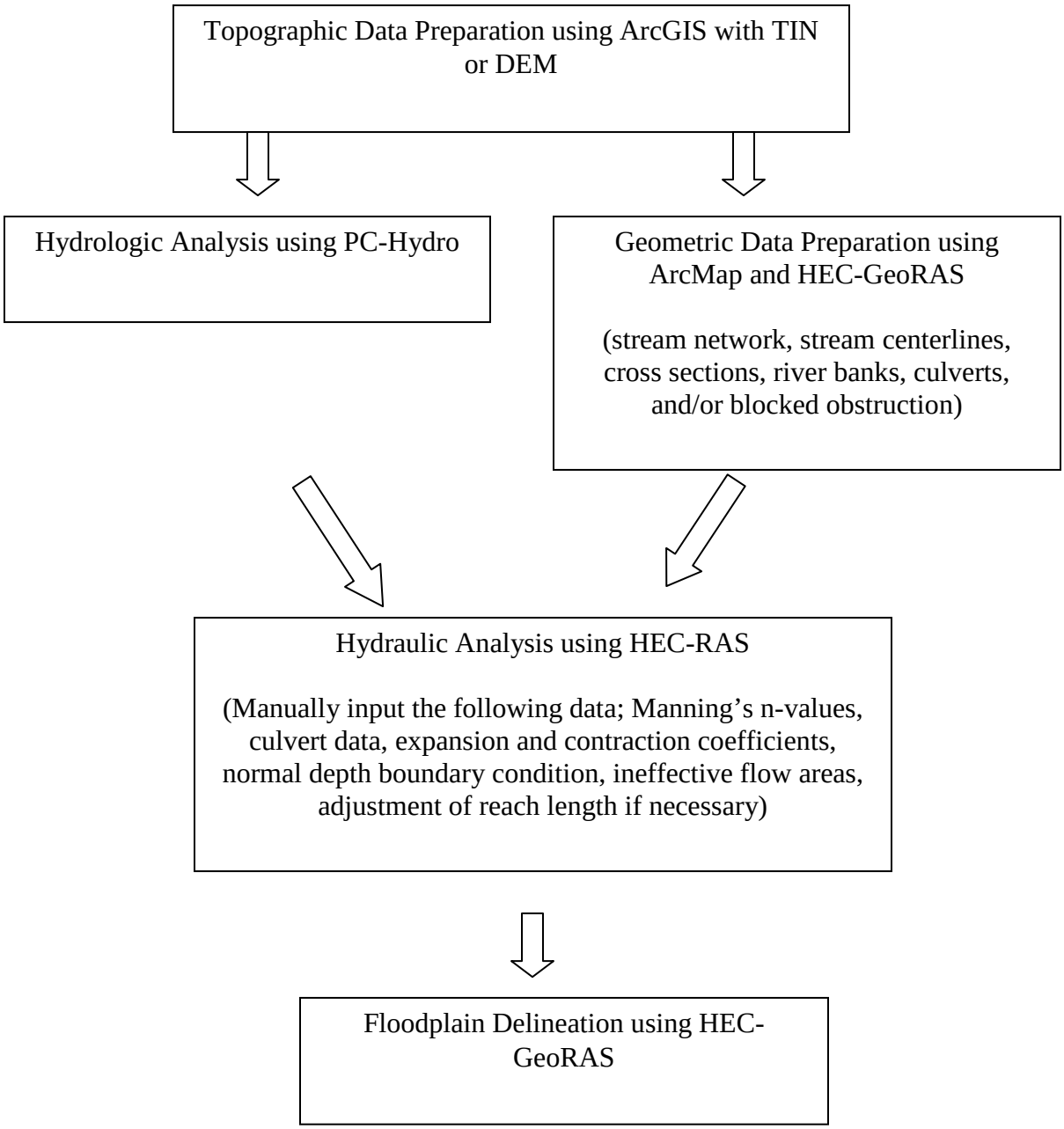
Following data are included in this TDN (see "GIS" folder):
Aerial Photo: PAG 2012 Orthophotos
Contour: 2 feet interval
Topographic Data: 5-ft DEM

Section 4 Hydrology

4.1 Method Description

Hydrologic analysis was performed using PC-Hydro Version 5.4.3 (PC-Hydro). The PC-Hydro uses a semi-empirical method, which is similar to the Rational Formula. The method is unique to Pima County. Pima County has been using the Pima County Hydrology Procedures (PC-Hydro method) for over 30 years for a floodplain management. The PC-Hydro method has been accepted by FEMA for prediction of 100-yr peak discharges in Pima County (i.e. Friendly Village LOMR, Case # 08-09-0473P). The PC-Hydro method produces conservative discharge on smaller watersheds and PC-Hydro is the accepted method for watersheds less than one square mile in Pima County Regional Flood Control District Technical Policy 018 (Tech-018, Appendix A). The PC-Hydro model requires the parameters regarding rainfall, topography, soil, and vegetation to determine peak discharge. Those parameters were determined following the PC-Hydro User Guide (Arroyo Engineering, 2007). The PC-Hydro output is included in Appendix D.

Figure 4.1 Flow Chart of Mapping Process



4.2 Parameter Estimation

4.2.1 Drainage Area Boundaries

The Unnamed 02 and 03 Washes watersheds are located within FEMA Zone X. The study area for the Unnamed 02 Wash is from Ina Rd. to Stable TR. (Fig.1.1). The study watershed is 0.25 square miles (Fig.1.2). The study area for the Unnamed 03 Wash is from Silverbell Rd. to ~700 feet east of Paddock Pl. (Fig.1.1). The study watershed is 0.25 square miles (Fig.1.2).

4.2.2 Watershed Work Maps

A watershed work map is included in Exhibit 1. The work map includes subbasin boundaries, concentration points, flow center lines and cross sections with station numbers and water surface elevations. Soil group boundaries are shown for the drainage area in Figure 1.3. Concentration point was named as Un_02 CP A for the Tucson Mountain Unnamed 02 Wash, and Un_03 CP A for the Tucson Mountain Unnamed 03 Wash.

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

The NOAA 14 Atlas 90% upper confidence rainfall data was used. The rainfall intensity at the time of concentration is 5.2 in/hr for the Unnamed 02 Wash watershed, and 5.27 in/hr for the Unnamed 03 Wash watershed. No area reduction factor was applied. 1-hr, 100-year storm rainfall is 3.27 in/hr for Unnamed 02 Wash and 3.46 in/hr for Unnamed 03 Wash.

4.2.6 Physical Parameters

The methods used in this study are summarized in Table 1. The PC-Hydro model calculates runoff coefficients using an adjusted Curve Number (CN) method, which has been developed based on the results of the USDA-ARS research. This procedure assumes that high intensity, short duration storms result in raindrop impacts causing the

surface of soils to seal up, resulting in reducing infiltration (Caliche Effect). The CN in the PC-Hydro model increases with increasing rainfall depth and intensity. The detail of the method is described in PC-Hydro User Guide (Arroyo Engineering, 2007).

Table 1 Methods used for a PC-Hydro analysis

	Selected Method
Rainfall Depth	NOAA 14, upper 90% Confidence Interval
Rainfall Loss	Adjusted SCS Curve number
Time of Concentration	Pima County Hydrology Procedure

Table 2 Watershed Characteristics

CP Name	Area (Acre)	Impervious Area (%)	Vegetation Cover (%)
Un_02 CP A	0.23	15	25
Un_03 CP A	0.25	25	25

4.3 Issues 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

None

4.4 Calibration

No calibration was conducted in this study.

4.5 Final Results

4.5.1 Hydrologic Analysis Results

The 100-year peak discharge at CP A (near Ina Rd.) was determined using the PC-Hydro. The result is summarized Table 3.

Table 3 Summary of the Hydrologic Analysis

CP Name	Location	Area (acre)	Rainfall Intensity at Tc (in/hr)	Time of Concentration (min)	Q100 (cfs)
Un_02 CP A	Silverbell Rd.	147	5.2	20	485

Un_03 CP A	Near Ina Rd.	160	5.27	19.5	558

4.5.2 Verification of results

The estimated peak discharge at CP A was also compared with the peak discharge obtained from USGS Regression Equation 13 (Thomas et al., 1997) (Table 4). The comparison showed that the PC-Hydro-derived peak discharge is 12.8% higher than the one derived from the Regression Equation for the Unnamed 02 Wash, while 21.5% for the Unnamed 03 Wash.

Table 4 Comparison of a peak discharge

Concentration Point	Location	Area (sq mile)	Q100 PC-Hydro(cfs)	Q100 RRE (cfs)
Un_02 CP A	Silverbell Rd.	0.23	485	430
Un_03 CP A	Near Ina Rd.	0.25	558	459

RRE: USGS Regression Equation 13

Section 5 Hydraulics

5.1 Method Description

Steady flow analysis with HEC-RAS, Version 4.1 was performed to delineate a 100-year floodplain of the Unnamed 02 and 03 Washes. Normal depth was used as a downstream boundary condition. Parameters for the hydraulic analysis were selected following the District Tech Policy 019.

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 0.021 was assumed for the downstream boundary condition for the Unnamed 02 Wash, while 0.135 was used for the Unnamed 03 Wash. The hydraulic data obtained from HEC-RAS were imported into HEC-GeoRAS to delineate a floodplain boundary for the Unnamed 02 and 03 Washes.

5.2 Work Study Maps

A work study map is shown in Exhibit 1.

5.3 Parameter Estimation

5.3.1 Roughness Coefficients

Manning's n values were determined by a combination of a site visit and 2012 PAG aerial photo. Manning's n value of 0.065 was assigned for the overbank with desert brush along the Unnamed 02 Wash. The value of 0.06 was used for the Unnamed 03 Wash. The value of 0.035 was assigned to a channel for the both washes.

5.3.2 Expansion and Contraction Coefficients

The expansion coefficient of 0.3 and contraction coefficient of 0.1 were used for the entire study reach, except immediately upstream and downstream of the three culverts. The expansion coefficient of 0.5 and contraction coefficient of 0.3 were used at the upstream and downstream of the culverts along the Unnamed Wash 03.

5.4 Cross-Section Description

A 2-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. The locations of cross sections and channels used for this study are shown in Exhibit 1.

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

There are three culverts along the Unnamed 03Wash.

5.5.3 Levees and Dikes

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

5.5.4 Non-Levee Embankments

None.

5.5.5 Island and Flow Splits

There were no islands or flow splits modeled.

5.5.5 Ineffective Flow Areas

Ineffective flow option was modeled in the HEC-RAS model. 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

There are no special problems in the study limit.

5.7.2 Model Warnings and Errors

No errors occurred. The following warning messages occurred:

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.

5.8 Calibration

The model was not calibrated in this study.

5.9 Final Results

5.9.1 Hydraulic Analysis Results

The HEC-RAS model is included in Appendix E.

5.9.2 Verification of Results

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 was used for the hydraulic analysis in this study. The estimated regulatory discharge rates are summarized in Table 3.

7.2 Floodway Data

Not applicable.

7.3 Annotated Flood Insurance Rate Map

Not applicable.

7.4 Flood Profiles

Flood profiles are included in the HEC-RAS model in Appendix E.

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 B FEMA MT-2 Form, General Documentation and Correspondence

None

Appendix C: Survey Field Notes

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

Appendix D: Hydrologic Analysis Supporting Documentation

(models, spreadsheets and supporting information is provided digitally in the TDN disk)

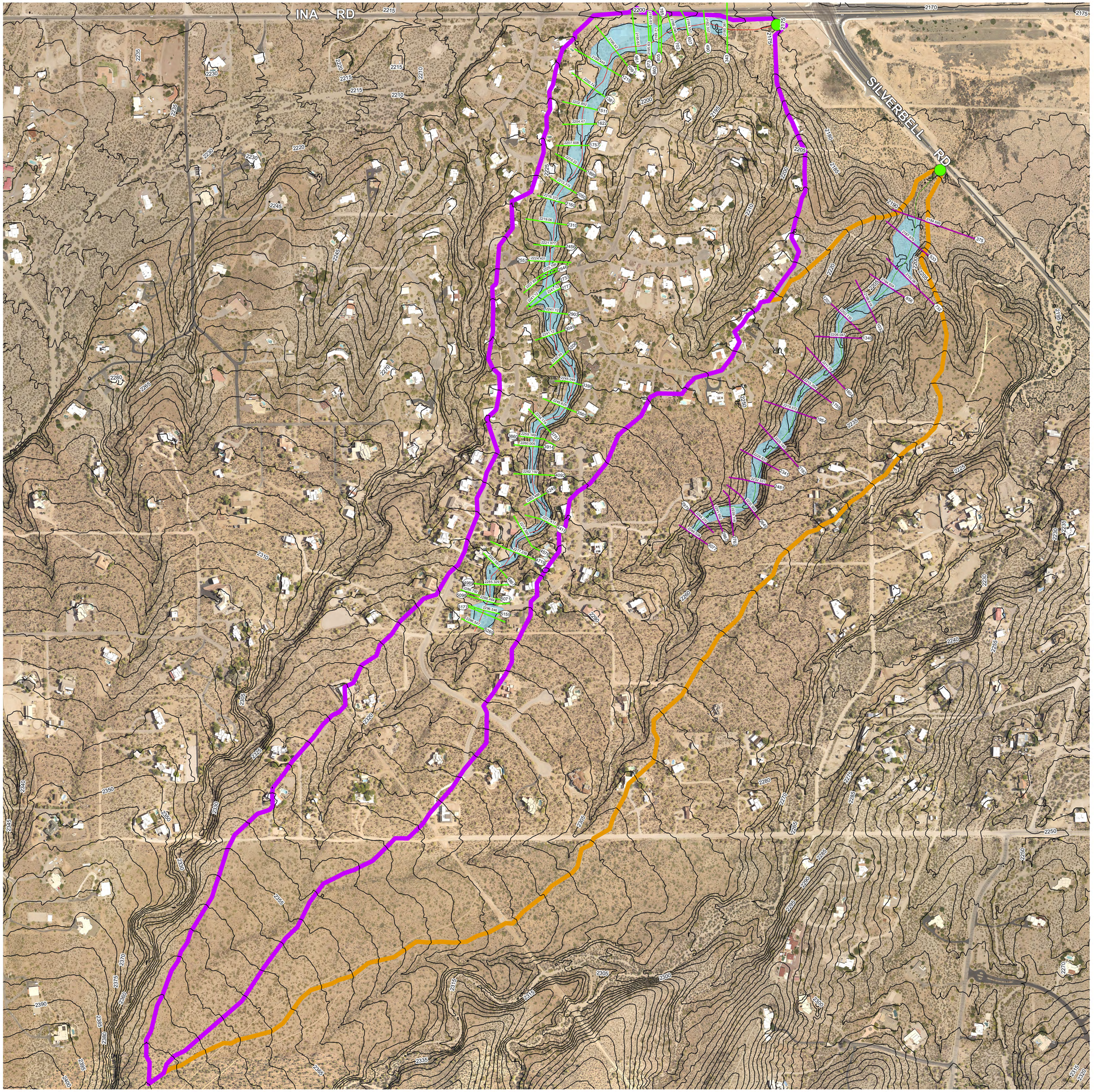
Appendix E: Hydraulic Analysis and As-Built Drawings for Hydraulic Structures

(models, spreadsheets and supporting information is provided digitally in the TDN disk)

Appendix F: Erosion and Sediment Transport Analysis Supporting Documentation

None

Exhibit 1
100-year Floodplain with cross sections for Unnamed 2 Wash & Unnamed 3 Wash



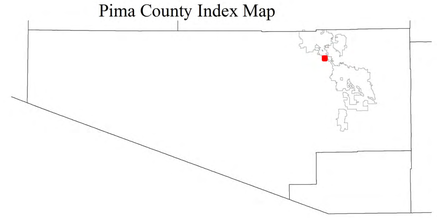
- Discharge Points
- Contour 5ft.
- River Unnamed 2
- River Unnamed 3
- Cross Section Unnamed 2
- Cross Section Unnamed 3
- Floodplain

Watersheds

- Unnamed 2
- Unnamed 3

Aerial : 2012 Pictometry Orthophoto Imagery ©
Topo: 2008 Pima Association of Governments
Datum: NAVD 1988

Pima County Index Map



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