Trails End Wash Technical Data Notebook

Prepared for:

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

Prepared by:

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Approved by

5/6/2010

Suzanne Shields, PE
Director
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97 E Congress Street
Tucson Arizona, 85701

List of Tables

List of Figures

Exhibit
Exhibit 1 100-yr floodplain limits for the Trails End Wash
Exhibit 2 Annotated Flood Insurance Rate Map for the Trails End Wash

Attached CD Trails End Wash TDN with supporting models and GIS data.

Section 1 Introduction

1.1 Purpose

This Technical Data notebook (TDN) has been prepared for a Letter of Map Revision (LOMR) application for a portion of the Trails End Wash (TRA) located in Pima County, Arizona. The objective of the TDN and LOMR submission is to provide regulatory discharge rates and floodplain limits along the Trails End 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:

Dave Stewart, EIT, Civil Engineering Assistant.
Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701

1.3 Project Location

The study reach of the Trails End Wash (TRA) is located within a Federal Emergency Management Agency (FEMA)-designated "Zone A" flood-hazard area, as depicted on FIRM Map Panel Numbers 04019C1618K and 04019C1619K (February 8, 1999). The objective of the TDN and LOMR submission is to provide regulatory discharge rates and floodplain limits along the Trails End Wash using better topographic, hydrologic, and hydraulic data.

The study reach of the Trails End Wash is located primarily west of N. Silverbell Rd. and extends from Section 20 of Township 13 South, Range 13 East into Section 29 of Township 13 South, Range 13 East, in Pima County, Arizona.

1.4 Hydrologic and Hydraulic Methods

The hydrologic analysis was performed to determine proposed regulatory discharge rates at concentration points along the Trails End Wash using the U.S. Army Corps of Engineers Hydrologic Modeling System, HEC-HMS. The proposed regulatory discharges are flow rates that have a 1-percent chance of being equaled or exceeded each year ("100-year" discharge rates). Hydraulic analysis was performed to delineate floodplain limits along the study reach of the Trails End Wash using the Hydrologic Engineering Center's River Analysis System (HEC-RAS).

No duplicate effective model is being provided because the area of the proposed map revision represents a complete replacement of the Trails End Wash existing model based on better topographical data and revised hydrology. The revised hydrology is based on the newer rainfall values from NOAA Atlas 14.

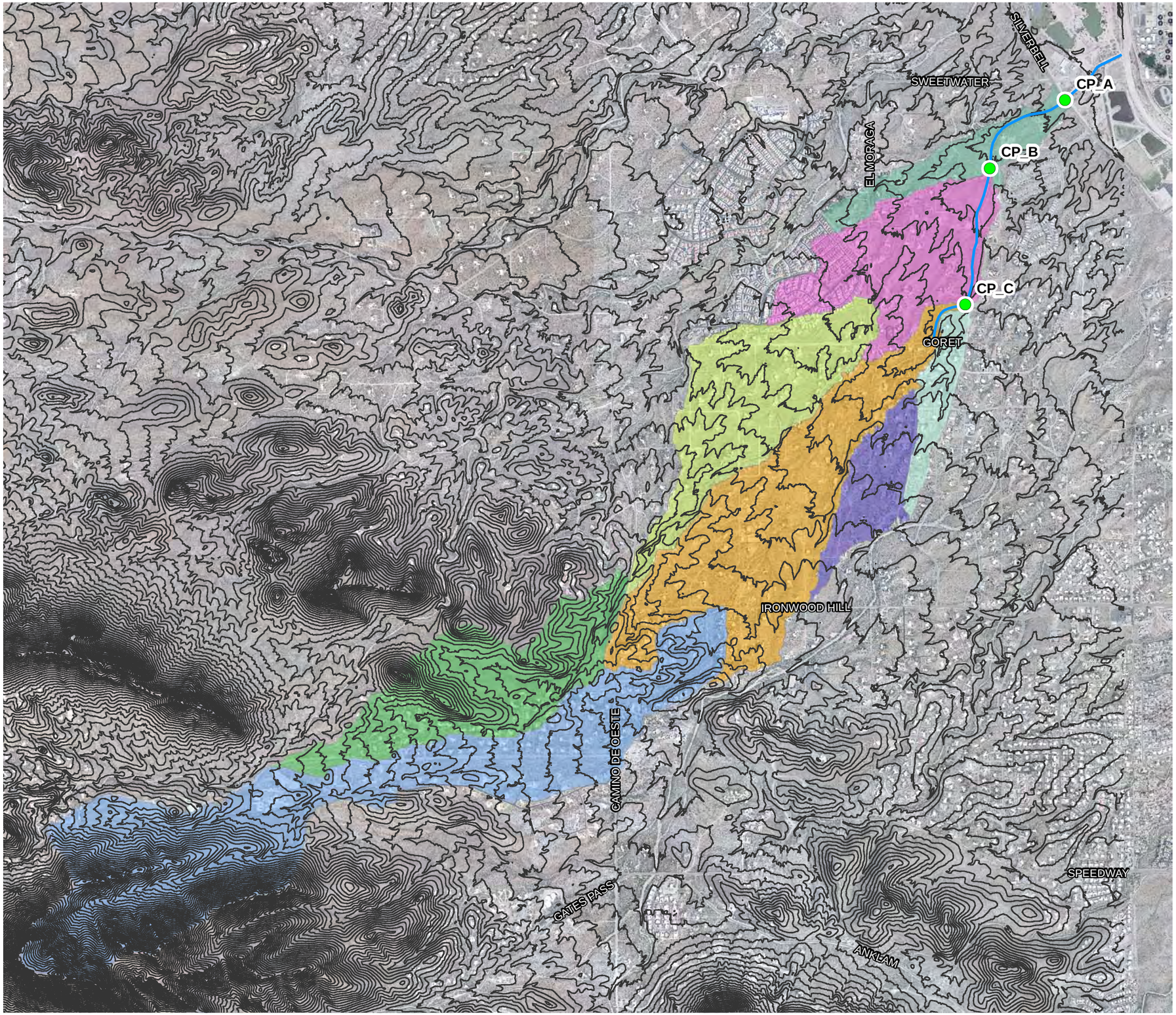
1.4 Acknowledgments

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

1.5 Study Results

The regulatory discharges were calculated for floodplain mapping at three concentration points along the Trails End Wash (TRA A, B, and C). The 100-yr discharge of the Trails End Wash at N. Silverbell Rd. (TRA A) was found to be 2546.0 cfs with a drainage area of 2.84 mi^2.

Figure 1.1
Watershed Map
Trails End Wash



TrailsEnd_ConcPoints

TrailsEnd_MainStream

TRE_contour20ft

Trails End_subbasins

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

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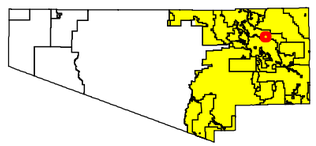
Pima County Index Map



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Pima County Regional Flood Control District

Scale 1:2000'

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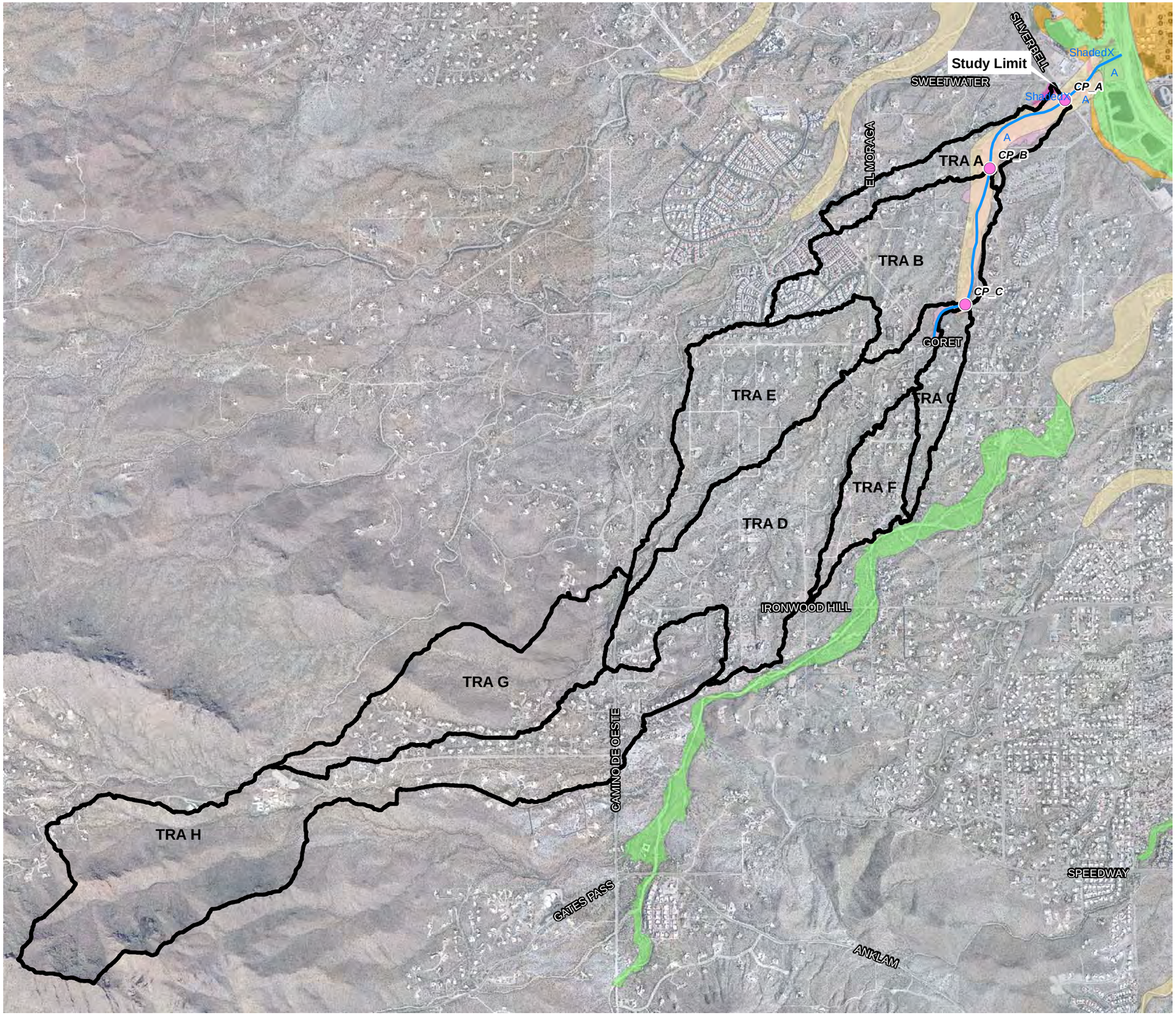
Figure 1.2
Study Limit Map
Trails End Wash



TrailsEnd_ConcPoints
TrailsEnd_MainStream
Subbasin
Existing Floodplain
ZONE A
ZONE AE
ZONE X - SHADED
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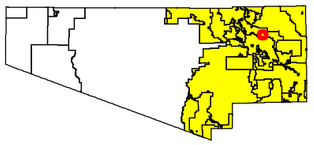
Pima County Index Map



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Pima County Regional Flood Control District

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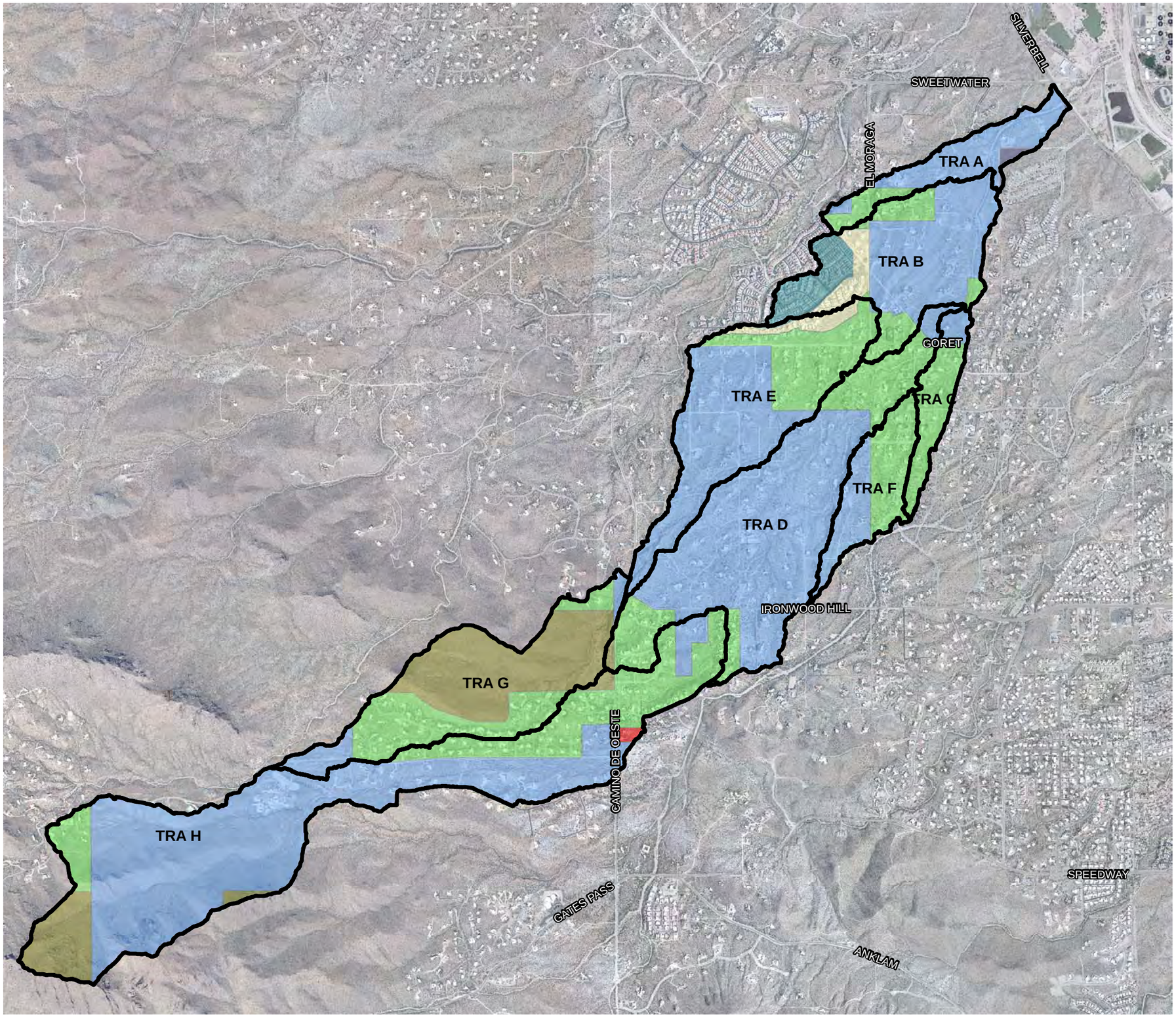
Figure 1.3
Zoning Classification Map
Trails End Wash



Subbasin

Pima County Zoning

- CB-1
- CR-1
- CR-2
- CR-3
- IR
- SR
- TUC

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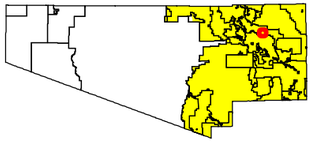
Pima County Index Map



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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 Dave Stewart, Civil Engineering Assistant.

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 Trails End Wash (TRA) is located within a Federal Emergency Management Agency (FEMA)-designated "Zone A" flood-hazard area, as depicted on FIRM Map Panel Numbers 04019C1618K and 04019C1619K (February 8, 1999). The study reach of the TRA is located primarily west of N. Silverbell Rd. and extends from Section 20 of Township 13 South, Range 13 East into Section 29 of Township 13 South, Range 13 East, in Pima County, Arizona.

The study reaches of the Trails End Wash contain coarse sand and cobble beds. Small shrubs and trees grow in some areas of the channel bed, and desert brush dominates the overbanks.

2.1.5 USGS Quad Sheets

Not available for this study.

2.1.6 Unique Conditions and Problems

There were no unique conditions or problems.

2.1.7 Coordination of Peak Discharges

The 100-year regulatory discharge rates at the concentration points along the study reach were computed using HEC-HMS, assuming no base flow in the watersheds and no transmission loss within the reaches. All reaches were modeled with HEC-RAS. The discharge rates were acceptable per Suzanne Shields, Director of the Pima County Regional Flood Control District and Andrew Dinauer, Engineering Administrator of the City of Tucson.

2.2 FEMA Forms

The FEMA MT-2 forms are included in Appendix B at the end of this TDN.

Section 3 Survey and Mapping Information

3.1 Field Survey Information

3.2 Mapping

The topographic data for the hydrology was obtained using 2008 Pima Associations of Governments (PAG) Light Detection and Ranging (LiDAR) data in Geo-RAS and ArcGIS. A raster was created from the 2008 LiDAR data with 5' cells and used with Geo-RAS.

For the hydraulic analysis, the triangular irregular network (TIN) developed by HDR in the Silverbell Road, Grant Road to Ina Road Design Concept Report (2009) was used. The TIN was developed from 2005 Lidar (Appendix C) and supplemented with field survey methods that provide equal or better precision and accuracy to the Lidar data.

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 5 feet.

Section 4 Hydrology

4.1 Method Description

The 100-year peak discharges for the Trails End Wash were modeled using the U.S. Army Corps of Engineers Computer Hydrologic Modeling System, (HEC-HMS) version 3.2. The Trails End Wash basin upstream of N. Silverbell Rd. was split into eight sub-basins.

The HEC-HMS model requires parameters for rainfall, topography, soil, vegetation, and channel characteristics to determine runoff volume and peak discharge. Those parameters were determined according to 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

The topographic data was obtained from a 5-ft cell raster created from 2008 PAG LiDAR data. ArcGIS was used to delineate watersheds from the raster and determine the drainage areas of each sub-basin. The composite watershed map is included in Exhibit A.

4.2.2 Watershed Work Map

Eight sub-basins were delineated for the Trails End Wash basin. The 100-year peak discharge was calculated for three concentration points (CP A, B, C) and used in the HEC-RAS hydraulic analysis for the floodplain maps (Exhibit A).

4.2.3 Gage Data

No gage data were used in this TDN.

4.2.4 Statistical Parameters

No data record was available for the Trails End Wash and therefore no Bulletin 17B analysis was used for this TDN.

4.2.5 Precipitation

According to Tech-018, the design storm should be used that produces the higher discharge between the 100-yr 3-hour SCS Type II distribution and the 100-yr 24-hr SCS Type I distribution. The 100-yr 3-hour SCS Type II distribution was found to produce the higher discharge on the Trails End Wash.

NOAA Atlas 14, upper 90% confidence interval precipitation frequency estimate values (NOAA 14 rainfall) were used to determine 3-hour and 24-hour point rainfall depths for the watershed. The point rainfall depth for the 3-hour storm was obtained for the coordinates of the watershed centroid (Latitude 32.2506°, Longitude -111.0607°). An areal reduction factor was applied to watersheds larger than 1 square mile as noted in Tech-018.

4.2.6 Physical Parameters

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

Table 1 Methods used for the 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 tables and Hydrologic Soils Group maps associated with the PC Hydro User Guide (Arroyo Engineering, 2007). The CN was not adjusted for rainfall intensity or antecedent moisture conditions.

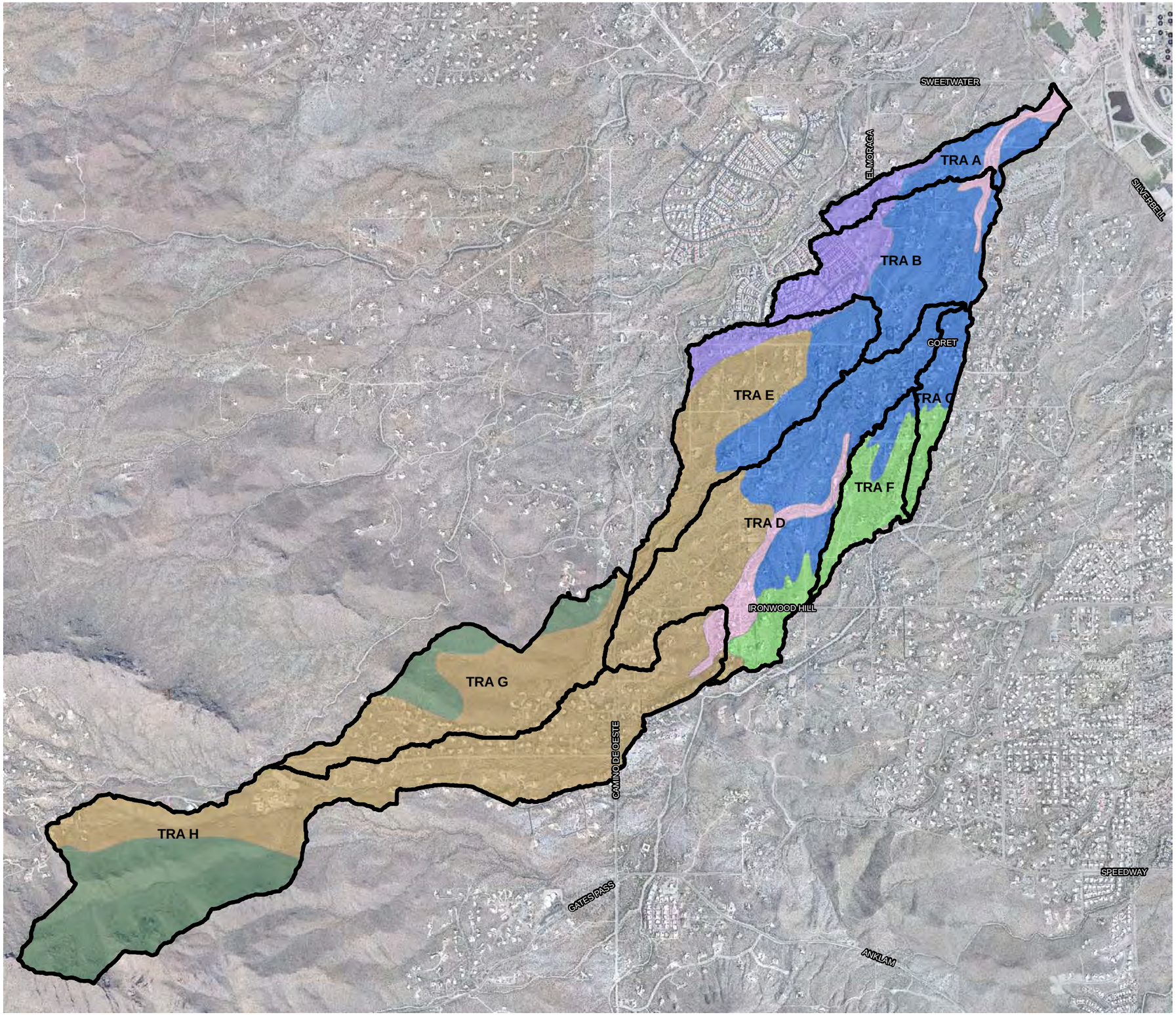
The SCS Unit Hydrograph method was used as a transform method. Impervious cover was determined using 2008 PAG aerial photographs. The combination of the kinematic wave time of concentration method and the U.S. Natural Resources Conservation Service (NRCS) segmented Time of Concentration (Tc) calculation (USDA-NRCS, 1986) was used to determine Tc, based on 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). The velocity for channel was calculated using Manning's equation. 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	Impervious Area (%)	Vegetation Cover (%)	Lag Time (min)
TRA A	0.125	86.0	8.0	20	19.0
TRA B	0.316	88.4	24.1	20	14.3
TRA C	0.079	86.0	18.6	20	15.7
TRA D	0.562	88.6	23.4	20	22.9
TRA E	0.364	90.3	25.2	20	16.9
TRA F	0.124	87.0	24.8	20	18.3
TRA G	0.372	90.8	9.2	20	18.5
TRA H	0.899	90.9	10.2	20	27.8

Runoff from sub-basins was routed using the Modified-Puls method. A storage discharge table for the channel routing was developed using the cross sections and slopes derived from HEC-HMS. The number of sub-reaches was calculated using the following method:

Figure 4.2
Soil Classification Map
Trails End Wash



Subbasin

Soil Classification

- Soil Group: A (100%), ARIZO-RIVERWASH COMPLEX, 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: C (47%) D (53%), PANTANO-GRANOLITE COMPLEX, 5 TO 25 PERCENT SLOPES
- Soil Group: C (53%) D (47%), PALOS VERDES-JAYNES COMPLEX, 2 TO 8 PERCENT SLOPES
- Soil Group: D (100%), ANKLAM-CELLAR-ROCK OUTCROP COMPLEX, 15 TO 55 PERCENT SLOPES

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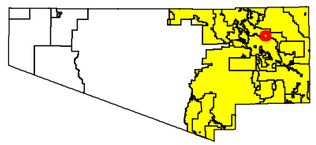
Pima County Index Map



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

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

Therefore,

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

where V_{ave} is the average flow velocity, L is the reach length, V_w is the velocity of the flood wave (a conversion factor of 1.5 is used for natural channels), K is the 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 sub-reach 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.

The following warnings were produced in the HEC-HMS;

- The “3-hr SCS Type II” gage with data interval of 5 minutes was interpolated to a simulation time interval of 1 minute.

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 at the concentration points along the Trails End Wash were determined using HEC-HMS. The results are summarized in Tables 3 and 4. CP B 2

refers to the junction in the HEC-HMS model that receives flow from only the reach included in the hydraulic analysis and the TRA B sub-basin. The junction labeled CP B is the same location as CP B 2 but includes all incoming reaches at concentration point B and the TRA B sub-basin. The discharge at CP B 2 was used for the hydraulic analysis of the study reach above concentration point B.

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)
TRA A	0.125	3.16	1.80	201.3
TRA B	0.316	3.16	2.00	671.3
TRA C	0.079	3.16	1.80	143.1
TRA D	0.562	3.16	2.01	891.8
TRA E	0.364	3.16	2.16	756.8
TRA F	0.124	3.16	1.88	214.0
TRA G	0.372	3.16	2.20	746.2
TRA H	0.899	3.16	2.21	1377.2

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

Concentration Point	Location	Area (Sq mi)	Rainfall Depth (in)	Runoff Volume (in)	100-yr Peak Discharge (cfs)	Time to Peak
CP A	At Silverbell Rd.	2.84	2.91	1.87	2546.0	2:21
CP B		2.72	2.92	1.89	2543.5	2:16
CP B 2		1.98	2.92	1.86	1749.5	2:17
CP C		1.46	3.03	2.02	1645.7	2:09

4.5.2 Verification results

The modeled discharges were found to be relatively close to the Regional Regression Equation 13 (RRE) (Thomas et al., 1997) peak discharges (Table 5).

Table 5. Comparison of modeled 100-yr peak discharges to Regional Regression Equation 13 peak discharges.

CP	Location	Area (mi^2)	Q_{p100} HMS (cfs)	Q_{p100} RRE (cfs)
CP A	At Silverbell Rd.	2.84	2546.0	2426.5
CP B		2.72	2543.5	2362.6
CP B 2		1.98	1749.5	1951.6
CP C		1.46	1645.7	1612.7

Section 5 Hydraulics

5.1 Method Description

The hydraulic modeling for the Trails End Wash was performed using HEC-RAS, Version 4.0, HEC-GeoRAS, Version 4.1.1, and ArcGIS, Version 9.2.

The topographic data was obtained using a triangular irregular network (TIN) developed by HDR in the Silverbell Road, Grant Road to Ina Road Design Concept Report (2009) (Appendix C). The locations of the stream centerlines were determined using ArcGIS with the contour lines from the topographic data and 2008 PAG aerial photos.

The physical attributes of the wash were digitized in ArcGIS using the HEC-GeoRAS extension and then exported to HEC-RAS to create geospatially referenced geometric data (cross sections, reach lengths). Other parameters for the steady-state analysis, such as the Manning's n-values, obstructions, and ineffective flow areas were manually entered into HEC-RAS. The hydraulic data obtained from HEC-RAS were exported to ArcGIS to delineate the floodplain in the study area. The downstream boundary condition for the reach was assumed to be normal depth with a slope estimated as the bed slope between the two farthest downstream cross sections.

The hydraulic analysis was performed in the area currently mapped as FEMA Zone A. A steady flow analysis was performed to determine 100-year water surface elevations in the study area by using HEC-RAS. The HEC-RAS data and shape files (contour lines, flow path, cross section lines, study watersheds, concentration points, sub-watersheds, hydrologic soil groups, proposed floodplain limit) used in the analysis are included in Appendix D with an attached CD.

5.2 Work Study Maps

The work study map for the Trails End Wash is included in Exhibit B.

5.3 Parameter Estimation

5.3.1 Roughness Coefficients

Manning's n values were determined in the field and using 2008 PAG aerial photo based on USGS publications for Manning's n values in southern Arizona (Phillips and Tadayon, 2006). A Manning's n value of 0.045 was assigned for the channel based on the sand and cobble bed material with dense vegetation in some areas, and a value of 0.060 was assigned for the overbanks based on the desert brush (Figures 5.1 and 5.2).

Figure 5.1. Trails End Wash Photo 1. A location of the Trails End Wash containing cobbles and dense vegetation at Lloyd Bush Rd., farther upstream in the watershed than Silverbell Rd.

Figure 5.2. Trails End Wash Photo 2. A location of the Trails End Wash with a primarily sand channel and scattered vegetation immediately downstream of Silverbell Rd.

5.3.2 Expansion and Contraction Coefficients

The Trails End Wash is assumed to have relatively gradual transitions, and the default values for the expansion and contraction coefficient of 0.30 and 0.10 were used respectively.

5.4 Cross-Section Description

Cross-section locations were determined primarily based on the channel topography from the TIN and 2008 PAG LiDAR data. Cross sections were placed at a spacing of approximately 100 ft. The cross-section lines were drawn to be perpendicular to flow paths in ArcGIS.

5.5 Modeling Consideration

5.5.1 Hydraulic Jump and Drop Analysis

No hydraulic jumps or hydraulic drops were modeled in this study.

5.5.2. Bridges and Culverts

There are no bridges located in the floodplain study reach of the Trails End Wash.

5.5.3 Levees and Dikes

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

5.5.4 Island and Flow Splits

No islands or split flows were modeled in the study.

5.5.5 Ineffective Flow Areas

Ineffective flow option was modeled in situations where:

- The floodplain areas are not hydraulically connected
- There is a contraction or expansion of the effective flow area.

5.6 Floodway Modeling

No floodway modeling was performed in this study.

5.7 Problems Encountered

5.7.1 Special Problems and Solutions

At three locations along the Trails End Wash near Silverbell Rd., the 100-yr discharge was not contained in the channel and a discharge could leave the channel without returning to the main flow path. As a result, River Stations 2093, 1030, and 684 have "hanging" cross sections. These locations were modeled in HEC-RAS using lateral structures along the overbank of the channel. The discharge leaving the channel was determined using the optimization feature in HEC-RAS for the lateral structures. The "break out" flow paths were modeled as separate reaches of the Trails End Wash using the discharge determined from the optimization feature. Two of these "break out" flow paths (River Station 2200 "Breakout 1," and River Station 830 "Breakout 2") are proposed as a Shallow 100 yr Flooding Zone where flow depth is less than one foot.

The third location of a break out leads to a depression in the floodplain of the Santa Cruz (River Station 1430, "Overbank Ponding"). The stage-storage relationship for this depression was determined in a GIS using the 2-ft contour lines and the area measurement tool. The volume of the depression was calculated by assuming a conical volume change for increases in elevation and area (Table 6). The volume of flow leaving the channel was found by calculating the area of the top of the hydrograph that was determined to leave the channel by the lateral structure optimization feature. The peak discharge in the channel at Silverbell Rd. was determined as 2546.04 cfs, and the peak discharge leaving the channel into the depression was found as 20.28 cfs. The volume leaving the channel was calculated as 0.079 ac-ft by finding the area of the hydrograph with discharge exceeding 2525.76 cfs, or 20.28 cfs lower than the maximum discharge. The depth of the flow stored in the depression was determined as 1.24 ft from the calculated volume and the stage-storage relationship. The depression was found to contain the volume of flow leaving the channel and the depression was added to the floodplain map as a proposed Zone A.

Table 6. Stage-storage relationship for overbank ponding located at River Station 1430.

Elevation	Depth (ft)	Area (ac)	Increase in Volume (ac-ft)	Total Volume (ac-ft)
2254	0	0.003	0.000	0.000
2256	2	0.192	0.128	0.128
2258	4	0.749	0.870	0.998
2260	6	1.229	1.461	2.459

River Station 495 is a “hanging” cross section with an ineffective area that extends over a wastewater treatment pond near the Santa Cruz river and no right bank extending above the water surface elevation ; however, the cross section is within the current FEMA Zone A for the Santa Cruz River and should not affect the proposed Zone A for the Trails End Wash.

5.7.2 Model Warnings and Errors

The FEMA guidelines require hydraulic models to simulate subcritical flow conditions. The HEC-RAS modeling produced warnings at some cross sections stating that:

- The energy equation could not be balanced within the specified number of iterations
- The energy loss was greater than 1.0 ft between cross sections
- The conveyance ratio is less than 0.7 or greater than 1.4
- Multiple critical depths were found
- Divided flow was computed and
- The program defaulted to critical depth when the water surface was calculated below critical depth
- Cross sections end points were extended vertically for the computed cross section

A summary of 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 modeling results are summarized in Appendix E.

5.9.2 Verification of Results

The floodplain limit produced in this LOMR study was compared to the existing FEMA floodplain limit. The proposed limits are similar to the existing FEMA floodplain limit, but provide additional detail. This similarity to the existing FEMA floodplain limit suggests that the results are reasonable.

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

The peak discharge at Silverbell Rd. (CP A) was determined as 2546 cfs for the drainage area of 2.84 square miles. The discharges along the flow path upstream of Silverbell Rd., CP B 2 and CP C, were found to be 1749.5 and 1645.7 respectively with drainage areas of 1.98 and 1.46 square miles.

7.2 Floodway Data

Not applicable.

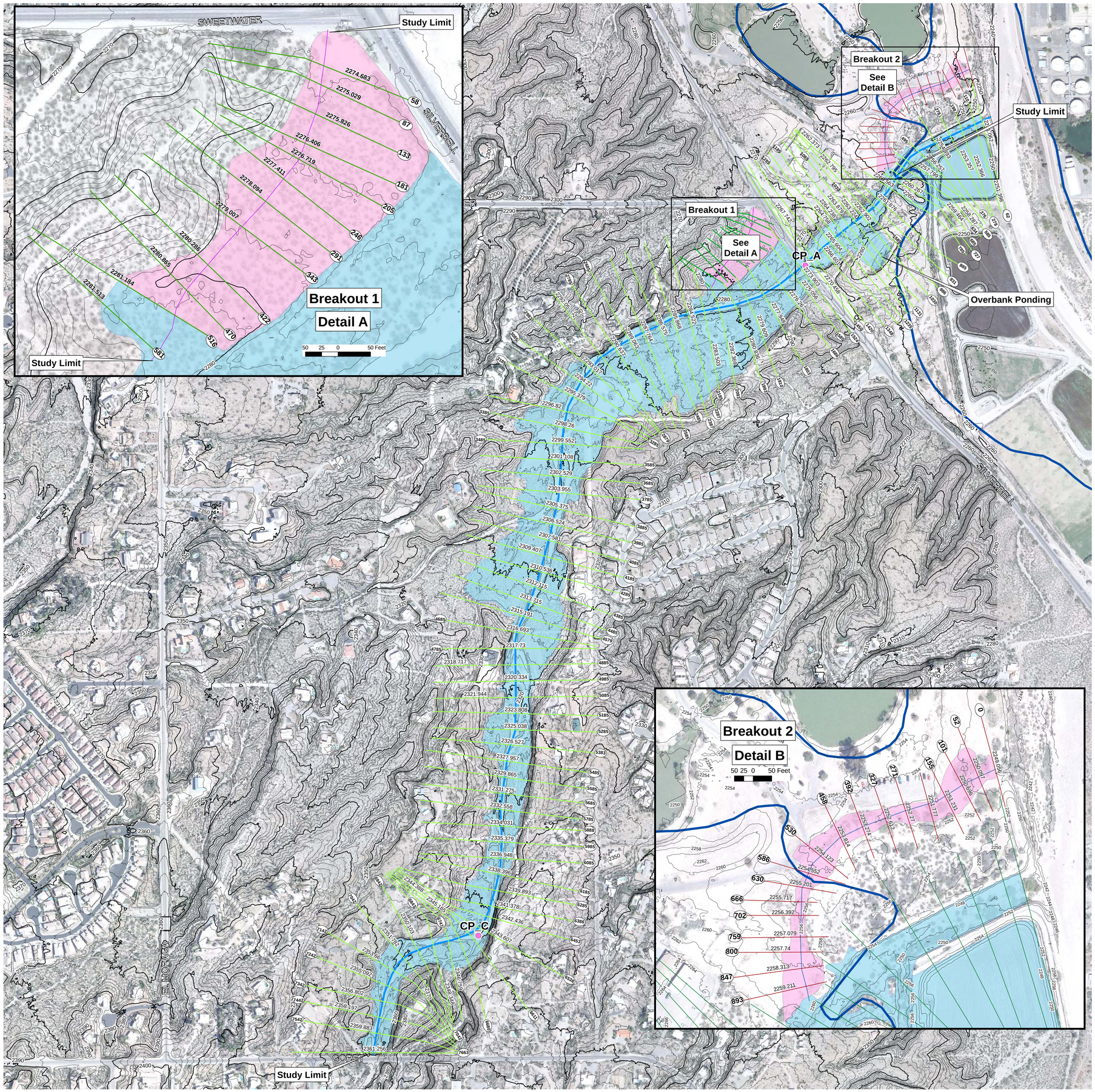
7.3 Annotated Flood Insurance Rate Map

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

7.4 Flood Profiles

Flood profiles are included in Appendix E.

Exhibit 1
100-year Floodplain with cross sections Trails End Wash



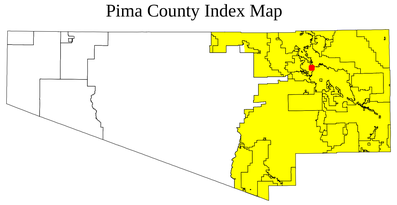
- Discharge Points
- Trails End Main XS
- Trails End Main Stream
- Trails End Breakout1 XS
- Trails End Breakout1 Stream
- Trails End Breakout2 XS
- Trails End Breakout2 Stream
- Contour2ft
- Contour 10ft.
- Existing Zone AE

Proposed 100yrFloodplain

- Proposed Shallow 100 yr Flooding
- Proposed Zone A

Aerial Photo:2008 Pima Association of Government
Topo: 2008 Pima Association of Government
Vertical Datum: NAVD 1988

Pima County Index Map



Index Map Scale 1:1,500,000

Pima County Regional Flood Control District

N

200 100 0 200 Feet

04/2010

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\imd\xavi\mdx\AKITSU\Trails_End_watershed_100yrFINALexh1.mxd

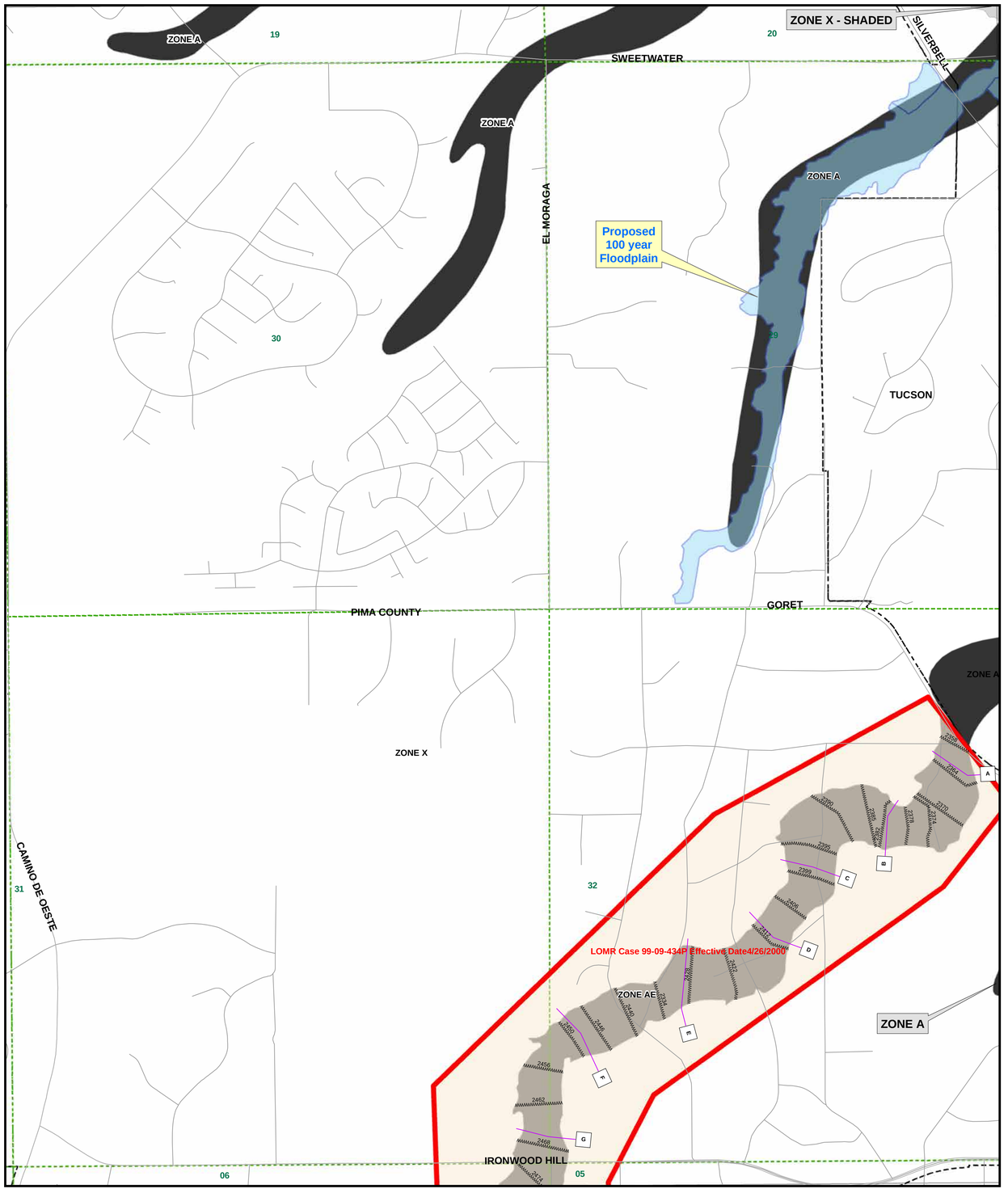


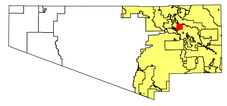
Exhibit 2
Annotated Flood Insurance Rate Map
04019C1618 K
Trails End Wash

- FIRM X-Sections
- Base Flood Elevations
- Streets
- Proposed 100yr 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.

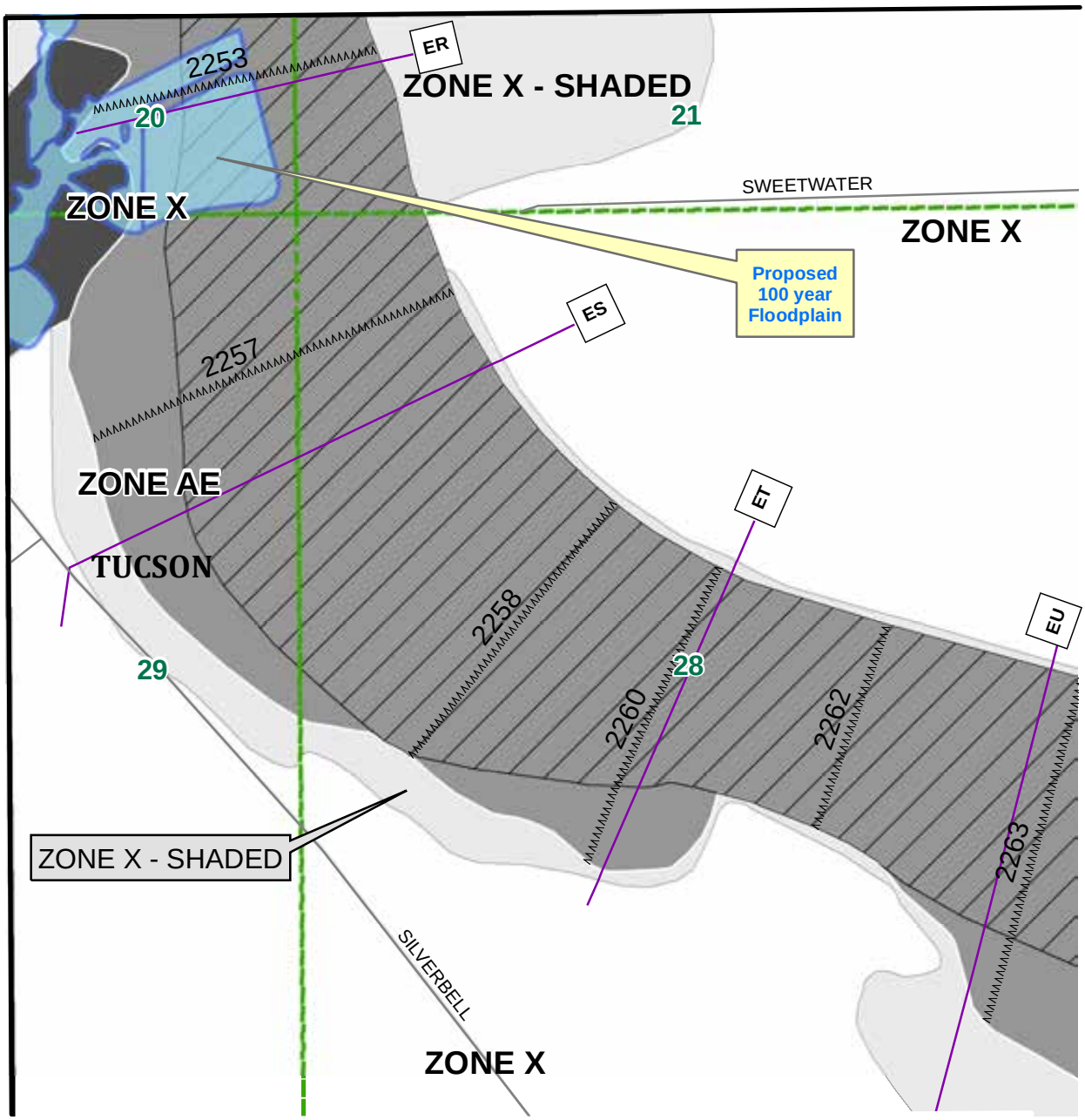
N

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\imd\xavi\mdx\AKITSU\Trails_End\Trails_End_watershed_Anno_FIRM28x40.mxd

Exhibit 2
Annotated Flood Insurance Rate Map
04019C1619 K
Trails End Wash



Pima County Regional Flood Control
97 East Congress Street - 3rd Floor
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- Streets
- FIRM X-Sections
- Base Flood Elevations
- Proposed Floodplain
- LOMRs
- FIRM - Flood Insurance Rate Map
- Sections
- Jurisdictions

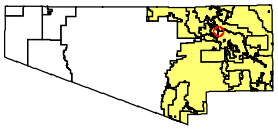
Existing Floodplain Zone

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

0 125 250 500 Feet

N

Pima County Index Map



gislib\rfcd\projects\imd\xavi\mdx\AKITSU\Trails_End\Trails_End_watershed_Anno_FIRM8X11.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
"Requirements for Flood Study Technical Documentation" SS1-97, November 1997

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.

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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

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 General Documentation and Correspondence

U.S. DEPARTMENT OF HOMELAND SECURITY - FEDERAL EMERGENCY MANAGEMENT AGENCY

OVERVIEW & CONCURRENCE FORM

O.M.B No. 1660-0016
Expires: 12/31/2010

PAPERWORK BURDEN DISCLOSURE NOTICE

Public reporting burden for this form is estimated to average 1 hour per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, U.S. Department of Homeland Security, Federal Emergency Management Agency, 500 C Street, SW, Washington DC 20472, Paperwork Reduction Project (1660-0016). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

A. REQUESTED RESPONSE FROM DHS-FEMA

This request is for a (check one):

☐ CLOMR: A letter from DHS-FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision, or proposed hydrology changes (See 44 CFR Ch. 1, Parts 60, 65 & 72).

☒ LOMR: A letter from DHS-FEMA officially revising the current NFIP map to show the changes to floodplains, regulatory floodway or flood elevations. (See 44 CFR Ch. 1, Parts 60, 65 & 72)

B. OVERVIEW

1. The NFIP map panel(s) affected for all impacted communities is (are):

Community No.	Community Name	State	Map No.	Panel No.	Effective Date
Ex: 480301	City of Katy	TX	480301	0005D	02/08/83
480287	Harris County	TX	48201C	0220G	09/28/90
040073	Pima County	AZ	04019C	1618K 1619K	02/08/99
040078	City of Tucson	AZ	04019C	1619K	02/08/99

2. a. Flooding Source: Trails End Wash

b. Types of Flooding: ☒ Riverine ☐ Coastal ☐ Shallow Flooding (e.g., Zones AO and AH)

☐ Alluvial fan ☐ Lakes ☐ Other (Attach Description)

3. Project Name/Identifier: Trails End Wash

4. FEMA zone designations affected: A (choices: A, AH, AO, A1-A30, A99, AE, AR, V, V1-V30, VE, B, C, D, X)

5. Basis for Request and Type of Revision:

a. The basis for this revision request is (check all that apply)

☐ Physical Change ☒ Improved Methodology/Data ☐ Regulatory Floodway Revision ☐ Base Map Changes

☐ Coastal Analysis ☐ Hydraulic Analysis ☐ Hydrologic Analysis ☐ Corrections

☐ Weir-Dam Changes ☐ Levee Certification ☐ Alluvial Fan Analysis ☐ Natural Changes

☐ New Topographic Data ☐ Other (Attach Description)

Note: A photograph and narrative description of the area of concern is not required, but is very helpful during review.

b. The area of revision encompasses the following structures (check all that apply)

Structures: ☐ Channelization ☐ Levee/Floodwall ☐ Bridge/Culvert

☐ Dam ☐ Fill ☐ Other (Attach Description)

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☐ Yes Fee amount: $_____

☒ No, Attach Explanation

Please see the DHS-FEMA Web site at http://www.fema.gov/plan/prevent/fhm/frm_fees.shtm **for Fee Amounts and Exemptions.**

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Dave Stewart, E.I.T.	Company: Pima County Regional Flood Control	
Mailing Address: 97 E. Congress, Tucson AZ, 85701	Daytime Telephone No.: 520 243 1800	Fax No.: 520 243-1821
	E-Mail Address: Dave.Stewart@rfcd.pima.gov	
Signature of Requester (required): Dave Stewart	Date: 5/5/2010	

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirement that no fill be placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Andrew Dinauer, Engineering Administrator	Community Name: City of Tucson	
Mailing Address: P.O. Box 27210 Tucson, AZ 85726-7210	Daytime Telephone No.: 520-791-4251	Fax No.:
	E-Mail Address: adinaue1@ci.tucson.az.us	
Community Official's Signature (required):	Date: 5/4/10	

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information data, hydrologic and hydraulic analysis, and any other supporting information as per NFIP regulations paragraph 65.2(b) and as described in the MT-2 Forms Instructions. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Howard Evan Canfield	License No.: 41917	Expiration Date: 3/31/2011
Company Name: Pima County Regional Flood Control	Telephone No.: 520-243-1836	Fax No.:
Signature: H. Evan Canfield		Date: 5/5/10

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☐ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

Seal (Optional)

U.S. DEPARTMENT OF HOMELAND SECURITY - FEDERAL EMERGENCY MANAGEMENT AGENCY

OVERVIEW & CONCURRENCE FORM

O.M.B No. 1660-0016
Expires: 12/31/2010

PAPERWORK BURDEN DISCLOSURE NOTICE

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☒ LOMR: A letter from DHS-FEMA officially revising the current NFIP map to show the changes to floodplains, regulatory floodway or flood elevations. (See 44 CFR Ch. 1, Parts 60, 65 & 72)

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1. The NFIP map panel(s) affected for all impacted communities is (are):

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040078	City of Tucson	AZ	04019C	1619K	02/08/99

2. a. Flooding Source: Trails End Wash

b. Types of Flooding: ☒ Riverine ☐ Coastal ☐ Shallow Flooding (e.g., Zones AO and AH)

☐ Alluvial fan ☐ Lakes ☐ Other (Attach Description)

3. Project Name/Identifier: Trails End Wash

4. FEMA zone designations affected: A (choices: A, AH, AO, A1-A30, A99, AE, AR, V, V1-V30, VE, B, C, D, X)

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☐ Coastal Analysis ☐ Hydraulic Analysis ☐ Hydrologic Analysis ☐ Corrections

☐ Weir-Dam Changes ☐ Levee Certification ☐ Alluvial Fan Analysis ☐ Natural Changes

☐ New Topographic Data ☐ Other (Attach Description)

Note: A photograph and narrative description of the area of concern is not required, but is very helpful during review.

b. The area of revision encompasses the following structures (check all that apply)

Structures: ☐ Channelization ☐ Levee/Floodwall ☐ Bridge/Culvert

☐ Dam ☐ Fill ☐ Other (Attach Description)

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☐ Yes Fee amount: $_____

☒ No, Attach Explanation

Please see the DHS-FEMA Web site at http://www.fema.gov/plan/prevent/fhm/frm_fees.shtm **for Fee Amounts and Exemptions.**

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Dave Stewart, E.I.T.	Company: Pima County Regional Flood Control	
Mailing Address: 97 E. Congress, Tucson AZ, 85701	Daytime Telephone No.: 520-243-1800	Fax No.: 520 243-1821
	E-Mail Address: Dave.Stewart@rfcd.pima.gov	
Signature of Requester (required): Dave Stewart	Date: 5/5/2010	

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirement that no fill be placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Suzanne Shields, PE, Chief Engineer	Community Name: Pima County Flood Control	
Mailing Address: 97 E Congress St. Tucson, AZ 85701	Daytime Telephone No.: 520-243-1800	Fax No.:
	E-Mail Address: suzanne.shields@rfcd.pima.gov	
Community Official's Signature (required): Suzanne Shields	Date: 5/5/10	

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information data, hydrologic and hydraulic analysis, and any other supporting information as per NFIP regulations paragraph 65.2(b) and as described in the MT-2 Forms Instructions. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Howard Evan Canfield	License No.: 41917	Expiration Date: 3/31/2011
Company Name: Pima County Regional Flood Control	Telephone No.: 520-243-1836	Fax No.:
Signature: H. Evan Canfield		Date: 5/5/10

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
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☐ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

Registered Professional Engineer (Civil) CERTIFICATE NO. 41917 HOWARD EVAN CANFIELD Date Signed 5/5/10 Seal (Optional) ARIZONA U.S.A.

Expires 3/31/2011

U.S. DEPARTMENT OF HOMELAND SECURITY - FEDERAL EMERGENCY MANAGEMENT AGENCY

RIVERINE HYDROLOGY & HYDRAULICS FORM

O.M.B No. 1660-0016
Expires: 12/31/2010

PAPERWORK REDUCTION ACT

Public reporting burden for this form is estimated to average 3.25 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, U.S. Department of Homeland Security, Federal Emergency Management Agency, 500 C Street, SW, Washington DC 20472, Paperwork Reduction Project (1660-0016). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

Flooding Source: Trails End Wash
Note: Fill out one form for each flooding source studied

A. HYDROLOGY

1. Reason for New Hydrologic Analysis (check all that apply)

☐ Not revised (skip to section B) ☐ No existing analysis ☒ Improved data
☐ Alternative methodology ☐ Proposed Conditions (CLOMR) ☐ Changed physical condition of watershed

2. Comparison of Representative 1%-Annual-Chance Discharges

Location	Drainage Area (Sq. Mi.)	Effective/FIS (cfs)	Revised (cfs)
Silverbell Rd.	2.84	N/A	2546.0
Near N. Grannen Rd.	2.72	N/A	2543.5
Near Wilma Dell Rd.	1.46	N/A	1645.7

3. Methodology for New Hydrologic Analysis (check all that apply)

☐ Statistical Analysis of Gage Records ☒ Precipitation/Runoff Model HEC-HMS
☐ Regional Regression Equations ☐ Other (please attach description)

Please enclose all relevant models in digital format, maps, computations (including computation of parameters) and documentation to support the new analysis.

4. Review/Approval of Analysis

If your community requires a regional, state, or federal agency to review the hydrologic analysis, please attach evidence of approval/review.

5. Impacts of Sediment Transport on Hydrology

Was sediment transport considered? ☐ Yes ☒ No If yes, then fill out Section F (Sediment Transport) of Form 3. If No, then attach your explanation for why sediment transport was not considered.

B. HYDRAULICS

1. Reach to be Revised

	Description	Cross Section	Water-Surface Elevations (ft.)	
			Effective	Proposed/Revised
Downstream Limit	Confluence with the Santa Cruz River	St#62.17		
Upstream Limit	Goret Rd.	St# 7662.95		

2. Hydraulic Method/Model Used

HEC-RAS

B. HYDRAULICS (CONTINUED)

3. Pre-Submittal Review of Hydraulic Models

DHS-FEMA has developed two review programs, CHECK-2 and CHECK-RAS, to aid in the review of HEC-2 and HEC-RAS hydraulic models, respectively. These review programs may help verify that the hydraulic estimates and assumptions in the model data are in accordance with NFIP requirements, and that the data are comparable with the assumptions and limitations of HEC-2/HEC-RAS. CHECK-2 and CHECK-RAS identify areas of potential error or concern. **These tools do not replace engineering judgment.** CHECK-2 and CHECK-RAS can be downloaded from http://www.fema.gov/plan/prevent/fhm/frm_soft.shtm. We recommend that you review your HEC-2 and HEC-RAS models with CHECK-2 and CHECK-RAS. Review of your submittal and resolution of valid modeling discrepancies may result in reduced review time.

4. Models Submitted

Models Submitted	Natural Run	Floodway Run	Datum
Duplicate Effective Model*	File Name: N/A Plan Name: N/A	File Name: N/A Plan Name:	
Corrected Effective Model*	File Name: TrailsEnd_FP Plan Name: Plan 1	File Name: Plan Name:	NAVD 88
Existing or Pre-Project Conditions Model	File Name: N/A Plan Name:	File Name: Plan Name:	
Revised or Post-Project Conditions Model	File Name: N/A Plan Name:	File Name: Plan Name:	
Other - (attach description)	File Name: N/A Plan Name:	File Name: Plan Name:	

* For details, refer to the corresponding section of the instructions.

☒ Digital Models Submitted? (Required)

C. MAPPING REQUIREMENTS

A **certified topographic map** must be submitted showing the following information (where applicable): the boundaries of the effective, existing, and proposed conditions 1%-annual-chance floodplain (for approximate Zone A revisions) or the boundaries of the 1%- and 0.2%-annual-chance floodplains and regulatory floodway (for detailed Zone AE, AO, and AH revisions); location and alignment of all cross sections with stationing control indicated; stream, road, and other alignments (e.g., dams, levees, etc.); current community easements and boundaries; boundaries of the requester's property; certification of a registered professional engineer registered in the subject State; location and description of reference marks; and the referenced vertical datum (NGVD, NAVD, etc.).

☒ Digital Mapping (GIS/CADD) Data Submitted

Note that the boundaries of the existing or proposed conditions floodplains and regulatory floodway to be shown on the revised FIRM and/or FBFM must tie-in with the effective floodplain and regulatory floodway boundaries. Please attach **a copy of the effective FIRM and/or FBFM,** annotated to show the boundaries of the revised 1%- and 0.2%-annual-chance floodplains and regulatory floodway that tie-in with the boundaries of the effective 1%- and 0.2%-annual-chance floodplain and regulatory floodway at the upstream and downstream limits of the area of revision.

☒ Annotated FIRM and/or FBFM (Required)

D. COMMON REGULATORY REQUIREMENTS*

1. For LOMR/CLOMR requests, do Base Flood Elevations (BFEs) increase? ☐ Yes ☒ No

   a. For CLOMR requests, if either of the following is true, please submit **evidence of compliance with Section 65.12 of the NFIP regulations**:
   - The proposed project encroaches upon a regulatory floodway and would result in increases above 0.00 foot.
   - The proposed project encroaches upon a SFHA with or without BFEs established and would result in increases above 1.00 foot.

   b. For LOMR requests, does this request require property owner notification and acceptance of BFE increases? ☐ Yes ☒ No
   If Yes, please attach **proof of property owner notification and acceptance (if available)**. Elements of and examples of property owner notification can be found in the MT-2 Form 2 Instructions.

2. Does the request involve the placement or proposed placement of fill? ☐ Yes ☒ No

   If Yes, the community must be able to certify that the area to be removed from the special flood hazard area, to include any structures or proposed structures, meets all of the standards of the local floodplain ordinances, and is reasonably safe from flooding in accordance with the NFIP regulations set forth at 44 CFR 60.3(a)(3), 65.5(a)(4), and 65.6(a)(14). Please see the MT-2 instructions for more information.

3. For LOMR requests, is the regulatory floodway being revised? ☐ Yes ☒ No

   If Yes, attach **evidence of regulatory floodway revision notification**. As per Paragraph 65.7(b)(1) of the NFIP Regulations, notification is required for requests involving revisions to the regulatory floodway. (Not required for revisions to approximate 1%-annual-chance floodplains [studied Zone A designation] unless a regulatory floodway is being added. Elements and examples of regulatory floodway revision notification can be found in the MT-2 Form 2 Instructions.)

4. For LOMR/CLOMR requests, does this request have the potential to impact an endangered species? ☐ Yes ☒ No

   If Yes, please submit documentation to the community to show that you have complied with Sections 9 and 10 of the Endangered Species Act (ESA). Section 9 of the ESA prohibits anyone from "taking" or harming an endangered species. If an action might harm an endangered species, a permit is required from U.S. Fish and Wildlife Service or National Marine Fisheries Service under Section 10 of the ESA.

   For actions authorized, funded, or being carried out by Federal or State agencies, please submit documentation from the agency showing its compliance with Section 7(a)(2) of the ESA.

* Not inclusive of all applicable regulatory requirements. For details, see 44 CFR parts 60 and 65.

Appendix C: Survey Field Notes

Pima County Regional
FLOOD CONTROL
DISTRICT

PIMA COUNTY
REGIONAL FLOOD CONTROL DISTRICT
97 EAST CONGRESS STREET, THIRD FLOOR
TUCSON, ARIZONA 85701-1797

SUZANNE SHIELDS, P.E.
DIRECTOR

(520) 243-1800
FAX (520) 243-1821

January 2, 2009

Craig S. Kennedy, CFM, Program Specialist
Engineering Management Branch
Mitigation Directorate
FEMA
500C Street SW
Washington, DC 20472

Re: Re: Acceptability of LiDAR

Dear Mr. Kennedy:

The Pima Association of Governments (PAG) has contracted with Sanborn to generate ortho rectified aerial photography and LiDAR. Figure 1 shows the extent of the LiDAR coverage for Pima County and the FIRM Special Flood Hazard Areas. The next version of Flood Insurance Rate Maps for Pima County will be converted to the North American Vertical Datum of 1988 (NAVD88). Attached to this letter you will find a draft letter from Sanborn indicating the vertical accuracy of the LiDAR meets FEMA's Map Modernization requirements.

The Pima County Regional Flood Control District (District) requests that the documentation in the draft letter be examined by FEMA to verify the LiDAR and topography created from this data would meet FEMA's vertical requirements for mapping to the NAVD88 Datum. If acceptable, the District will request PAG to have Sanborn seal the documentation so that it may be used in FEMA re-mapping processes. The District understands the digital maps generated from the LiDAR would need to be re-projected to FEMA's UTM coordinate system for LOMR applications.

Please call me at 520-243-1800, should you have any questions with this request.

Sincerely,

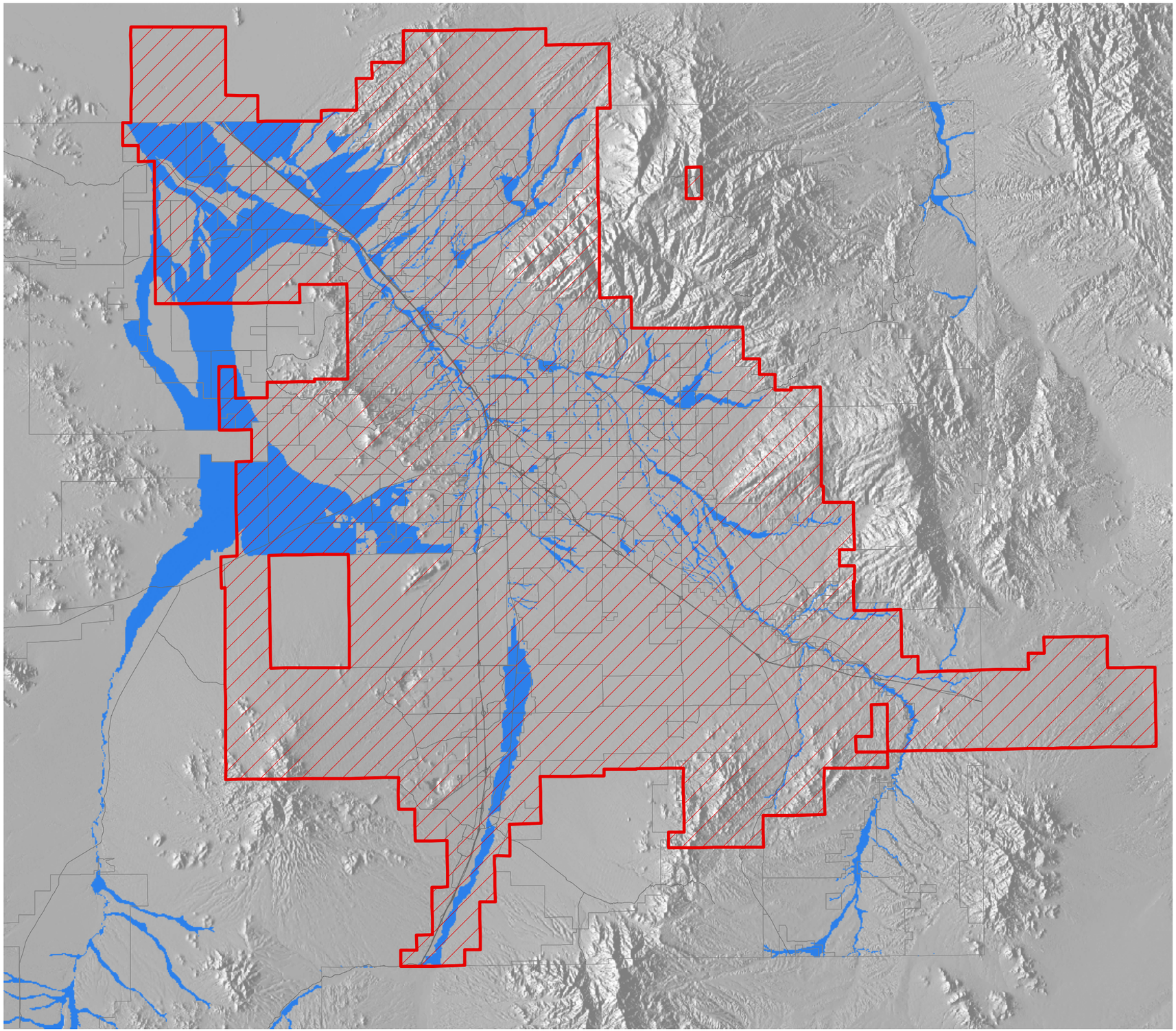
R. "Terry" Hendricks, CFM, Chief Hydrologist
Planning and Development Division

RTH/cd

Cc: Steve Whitney, GIS Manager, Pima County Department of Transportation
Kenneth Maits, Senior GIS Analyst, PC Regional Flood Control District
Manny M. Rosas, GIS Administrator, Pima Association of Governments.

Enclosures

Exhibit 1:
2008 LiDAR Coverage and FEMA Special Flood Hazard Areas



2008 LiDAR Coverage

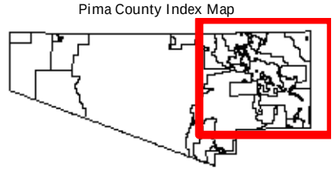
FEMA Floodplains

Major Streets

Jurisdiction Lines

Not Shown: Western Pima County, including Ajo and LiDAR coverage on Tohono O'dham Nation.

Pima County Index Map



Index Map Scale 1:5,250,000

Pima County Regional Flood Control District

Scale 1:415,000

\\gislib\rfcd\projects\imd\ken\lidar08\fema_08cov.mxd km

Corporate Headquarters:
Colorado Springs
Colorado

Ann Arbor
Michigan

Charlotte
North Carolina

Ft. Collins
Colorado

Pelham
New York

Portland
Oregon

Sacramento
California

St. Louis
Missouri

Sanborn
Middle East

Mumbai
India

30 December 2008

Manny Rosas, GIS Administrator
Pima Association of Governments
177 N. Church Ave.
Suite 405
Tucson, AZ 85701

Re: FEMA Results for the PAG 2008 Ortho Project (Contract – 08-5951-01)

Dear Mr. Rosas,

Attached you will find the results of the FEMA checkpoints for PAG 2008 LiDAR data. Sanborn's contracted Arizona State Registered Land-Surveyor, Greg Thompson, performed a review of the report and is in agreement with the results.

Background

To ensure the accuracy of the PAG 2008 LiDAR data, Sanborn was contracted to implement a project plan that included the integration of FEMA checkpoints as part of the QA/QC process. To support this initiative, Sanborn collected 69 checkpoints as part of the control survey effort. This meets the minimum standards for vertical accuracy testing and reporting as defined in FEMA's map modernization requirements. FEMA recommends 20 checkpoints in each of the major land cover categories representative of floodplains being mapped; this normally requires a minimum of 60 checkpoints for at least three land cover categories. The three categories surveyed were:

1. Bare Earth and Low Grass
2. High Grass, Weeds, and Crops
3. Brush lands/low trees

Field data was acquired using GPS equipment and static surveying methods. Sanborn team surveyed all checkpoint following the procedures in NOAA Technical Memorandum NOS NGS-58, "Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm)" and use NGS' latest Geoid Model to compute NAVD88 orthometric heights accurate to 5-cm at the 95% confidence level. (The x and y coordinates of checkpoints will be accurate to 2-cm at the 95% confidence level.)

Final adjusted results were adjusted to Arizona State Plane Coordinates, Central Zone NAD83-92 (HARN), NAVD88, in units of International Foot.

Testing Methodology

As stated in the Guidelines and Specifications for Flood Hazard Mapping Partners (April 2003), Section A.87.6.1, "The Root Mean Square Error (RMSE) is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points…TINs (and DEMs derived therefrom) should normally have a maximum RMSE of 18.5 centimeters, equivalent to

2-foot contours, in flat terrain. The following are the results from the PAG 2008 Ortho Program.

Bare Earth:

Number	Easting	Northing	Known Z	Laser Z	Dz ----------
1	1001837.162	410093.611	2587.031	2587.530	+0.499
7	999345.782	449442.944	2441.401	2441.640	+0.239
20	933721.166	412981.849	2439.091	2439.310	+0.219
17	933650.558	412993.658	2438.451	2438.660	+0.209
15	897369.501	552863.803	1937.257	1937.430	+0.173
3	1159921.689	349431.234	4294.062	4294.210	+0.148
8	1005806.086	434836.185	2509.196	2509.340	+0.144
9	1000927.946	448200.185	2446.309	2446.400	+0.091
13	994444.372	503631.914	2655.984	2656.070	+0.086
11	994513.846	503595.055	2658.012	2658.090	+0.078
18	955798.751	425094.504	2540.814	2540.880	+0.066
2	906521.919	540616.247	1946.585	1946.640	+0.055
12	987338.200	503575.338	2542.972	2542.930	-0.042
14	965580.705	519074.819	2667.182	2667.120	-0.062
21	955893.647	425085.496	2541.302	2541.240	-0.062
5	1021871.892	457772.536	2472.149	2472.080	-0.069
6	1033139.499	445741.877	2610.656	2610.580	-0.076
16	939704.593	416728.203	2432.726	2432.640	-0.086
10	985754.835	454784.703	2313.130	2312.980	-0.150
19	939508.793	416651.451	2432.802	2432.630	-0.172
22	1027485.930	416573.872	2740.833	2740.650	-0.183
4	1156429.917	365109.827	4055.003	outside	*

Average dz	+0.053
Minimum dz	-0.183
Maximum dz	+0.499
Average magnitude	0.139
Root mean square	**0.171 (foot)**
Std deviation	0.166

Medium Vegetation:

Number	Easting	Northing	Known Z	Laser Z	Dz ----------
1	1187028.525	351518.925	4080.561	4080.540	-0.021
2	1117108.620	363592.785	3587.077	3586.940	-0.137
3	1073972.909	383419.761	3240.515	3240.590	+0.075
4	1010832.502	410849.441	2643.786	2643.990	+0.204
5	1005445.314	419156.617	2579.495	2579.880	+0.385
6	1045092.088	435136.157	2724.009	2724.050	+0.041

7	1069748.640	446273.392	2760.125	2760.050	-0.075
8	1033371.126	464364.855	2518.606	2518.310	-0.296
9	1054207.161	418935.174	2886.854	2886.950	+0.096
10	955203.805	487660.945	2178.734	2179.130	+0.396
11	997532.713	434803.804	2460.164	2460.250	+0.086
12	979509.921	492673.940	2417.792	2418.190	+0.398
13	995655.491	465569.990	2344.777	2344.690	-0.087
14	997550.935	482620.376	2598.648	2598.550	-0.098
15	1001334.429	474026.061	2493.153	2493.240	+0.087
16	990196.690	487542.780	2546.083	outside	*
17	990519.334	490352.801	2559.039	2559.110	+0.071
18	998219.739	493708.248	2936.804	2937.080	+0.276
19	996795.607	504234.682	2727.497	2727.370	-0.127
20	988245.902	501104.027	2560.988	2560.870	-0.118
21	985960.009	501595.086	2553.169	2553.130	-0.039
22	997446.853	506178.000	2694.613	2695.140	+0.527
23	987398.768	503506.302	2546.335	2546.410	+0.075
24	985971.797	501493.493	2552.516	2552.570	+0.054
25	997540.656	506124.929	2707.864	2708.230	+0.366
26	991206.370	506306.455	2518.406	2518.250	-0.156
27	978945.698	519233.465	2782.405	2782.330	-0.075
28	978935.642	519272.398	2784.006	2784.080	+0.074
29	965555.375	519044.382	2666.260	2666.260	+0.000
30	897298.425	552978.606	1937.352	1937.730	+0.378
31	910066.011	514280.384	2003.658	2003.840	+0.182

Average dz	+0.085
Minimum dz	-0.296
Maximum dz	+0.527
Average magnitude	0.167
Root mean square	**0.217 (foot)**
Std deviation	0.203

High Vegetation:

Number	Easting	Northing	Known Z	Laser Z	Dz
1	1041505.790	408998.331	2868.881	2869.410	+0.529
4	1007421.616	441240.211	2501.880	2502.270	+0.390
9	988302.547	500937.045	2557.959	2558.170	+0.211
10	993323.041	504876.742	2616.818	2616.900	+0.082
3	944799.536	483176.205	2406.404	2406.480	+0.076
6	993338.640	505132.410	2616.096	2616.130	+0.034
13	995168.385	519848.931	2773.051	2773.040	-0.011
8	996811.199	504124.980	2733.504	2733.470	-0.034
14	995094.857	519807.072	2771.624	2771.590	-0.034
5	995053.089	492295.493	2741.552	2741.500	-0.052
7	986911.443	504348.439	2463.848	2463.780	-0.068

11	986965.447	504425.310	2458.159	2458.090	-0.069
12	993296.411	506167.522	2598.730	2598.640	-0.090
16	919968.908	521623.590	2003.520	2003.130	-0.390
15	909979.986	514314.158	2004.186	2003.740	-0.446
2	988498.629	488163.006	2506.243	outside	*

Average dz	+0.009
Minimum dz	-0.446
Maximum dz	+0.529
Average magnitude	0.168
Root mean square	**0.240 (foot)**
Std deviation	0.248

Sanborn concludes that the overall RMSE of the LiDAR data is within PAG 2008 Ortho project requirements, as it meets the +/- 15.0 cm (0.492 foot) RMSE at 95% confidence for all three categories. RMSE is an indicator of overall accuracy of the product and is not used for individual point accuracy.

Please contact me at (719) 593-0093 extension 5645 or Jamie Young (General Manager – ext. 5602) if you have any question regarding the report.

Sincerely,

Andrew Lucero
Sanborn
Senior Project Manager