Catalina Foothills Watercourse Studies:
Technical Data Notebook for Hydrologic and Hydraulic Mapping of the Old Grandad Tank Wash,
Pima County Arizona.

FEMA FIRM Panel 04019C-1690 and 2280 K

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11/16/2011

June 2013

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

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Exhibit

Attached CD

Old Grandad Tank TDN with supporting models and GIS data.

Section 1: Introduction

1.1 Purpose

The purpose of this study is to provide flood and erosion hazard information for the Old Grandad Tank Wash for use by the Pima County Regional Flood Control District (District) in floodplain use permitting and floodplain management. More specifically, it provides:

- discharge values for sub-basins and important concentration points;
- hydrographs for use with floodplain mapping;
- floodplain mapping for channels with contributing areas greater than 1 square mile, and channels with 100-yr discharges greater than 2000 cfs, which are treated differently under the Pima County Ordinance.

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.

1.3 Project Location

The study was performed to provide drainage information for the Old Grandad Tank Wash. The site includes Sections 24, 25, 26, 27, 34, and 35 of Township 13 South, Range 16 East, Sections 3 of Township 14 South, Range 16 East, Pima County, Arizona. The Old Grandad Tank Wash watershed is in FEMA Zone X and Zone D, as shown on the current Flood Insurance Rate Map (FIRM) number 04019C-1690 and 2280K.

The watershed is 2.02 square mile. The study watershed was divided into four sub-basins (Fig.1.1). The study limits for the Old Grandad Tank Wash extends from a confluence with Tanque Verde Creek to the upstream end of Subbasin A (Fig.1.2).

1.4 Methodologies Used for Hydrology and Hydraulics

Topographic, hydrologic and hydraulic analyses were performed to determine drainage conditions in the Old Grandad Tank Wash. ArcGIS, Version 9.3.1, HEC-HMS Version 3.4 (HEC-HMS), Hec-RAS Version 4.0 (HEC-RAS), and HEC-GeoRAS, Version 4.2.93 (HEC-GeoRAS) were used for the analyses.

1.5 Acknowledgements

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

1.6 Study Results

The modeled discharge for the Old Grandad Tank Wash at the confluence with the Tanque Verde Creek is 3942 cfs, where the area is 2.02 square miles.

The Old Grandad Tank Wash watershed is partially located within Federal land (national forest, FEMA Zone D). The floodplain was mapped in the downstream area of the Old Grandad Tank Wash.

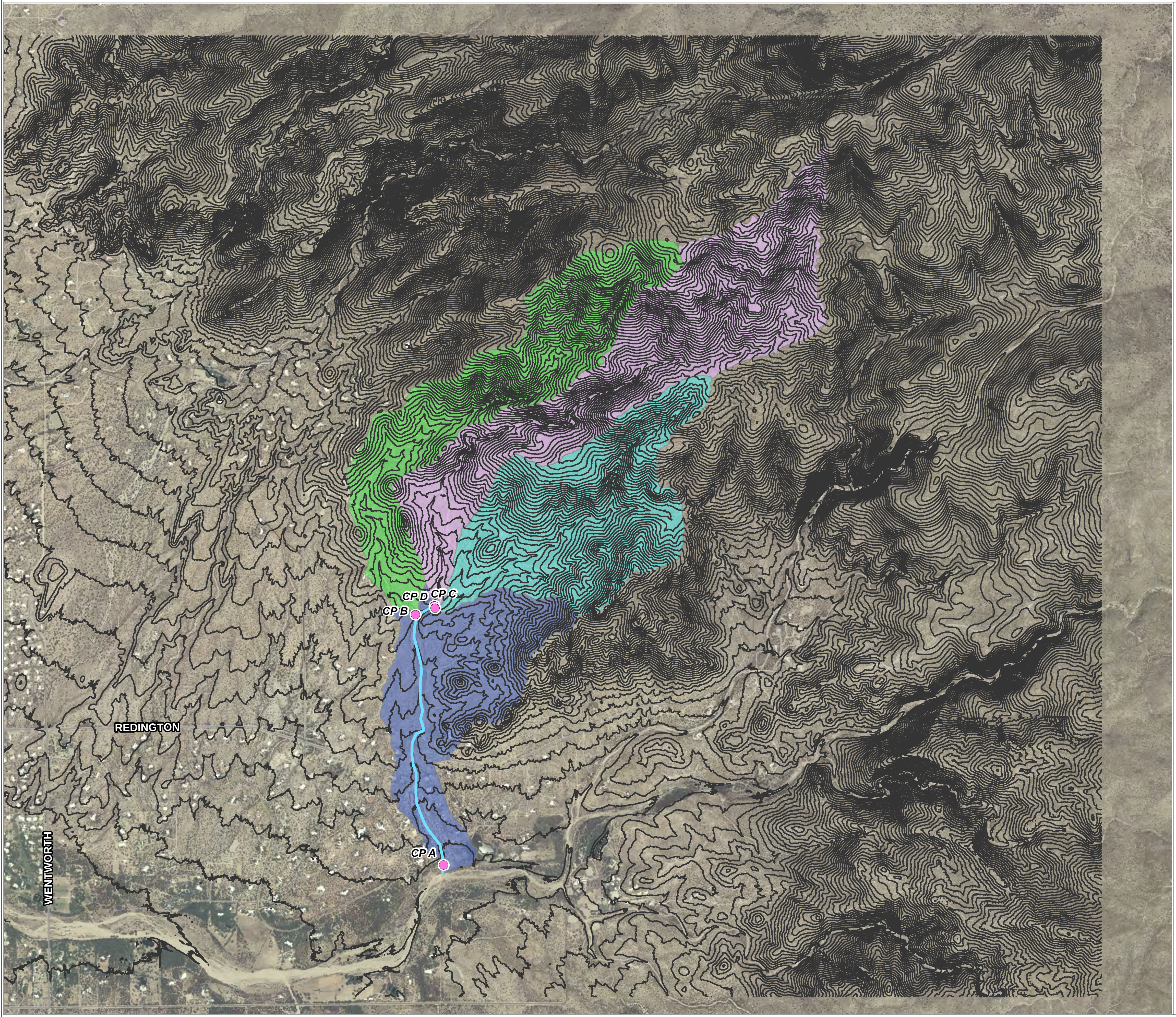

Figure 1.1
Watershed Map
Old Grandad Tank Wash

Discharge Point
River
Contour 20 foot

Subbasins

OLG A
OLG B
OLG C
OLG D

Photo: Pima Arizona Governmens 2007
Topo: Pima Arizona Government 2008

Pima County Index Map

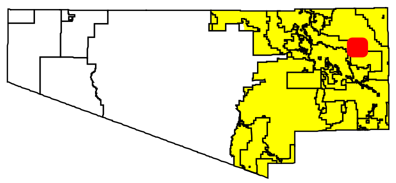

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Figure 1.2
Study Limit
Old Grandad Tank Wash

Discharge Point

River

Subbasins

Existing FEMA Floodplain

ZONE A

ZONE AE

ZONE X - SHADED

Aerial Photo: 2007 Pima Association of Governments

Pima County Index Map

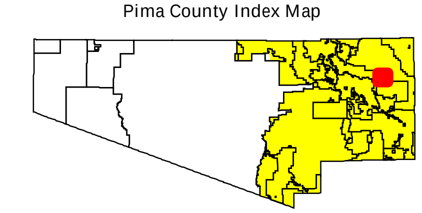

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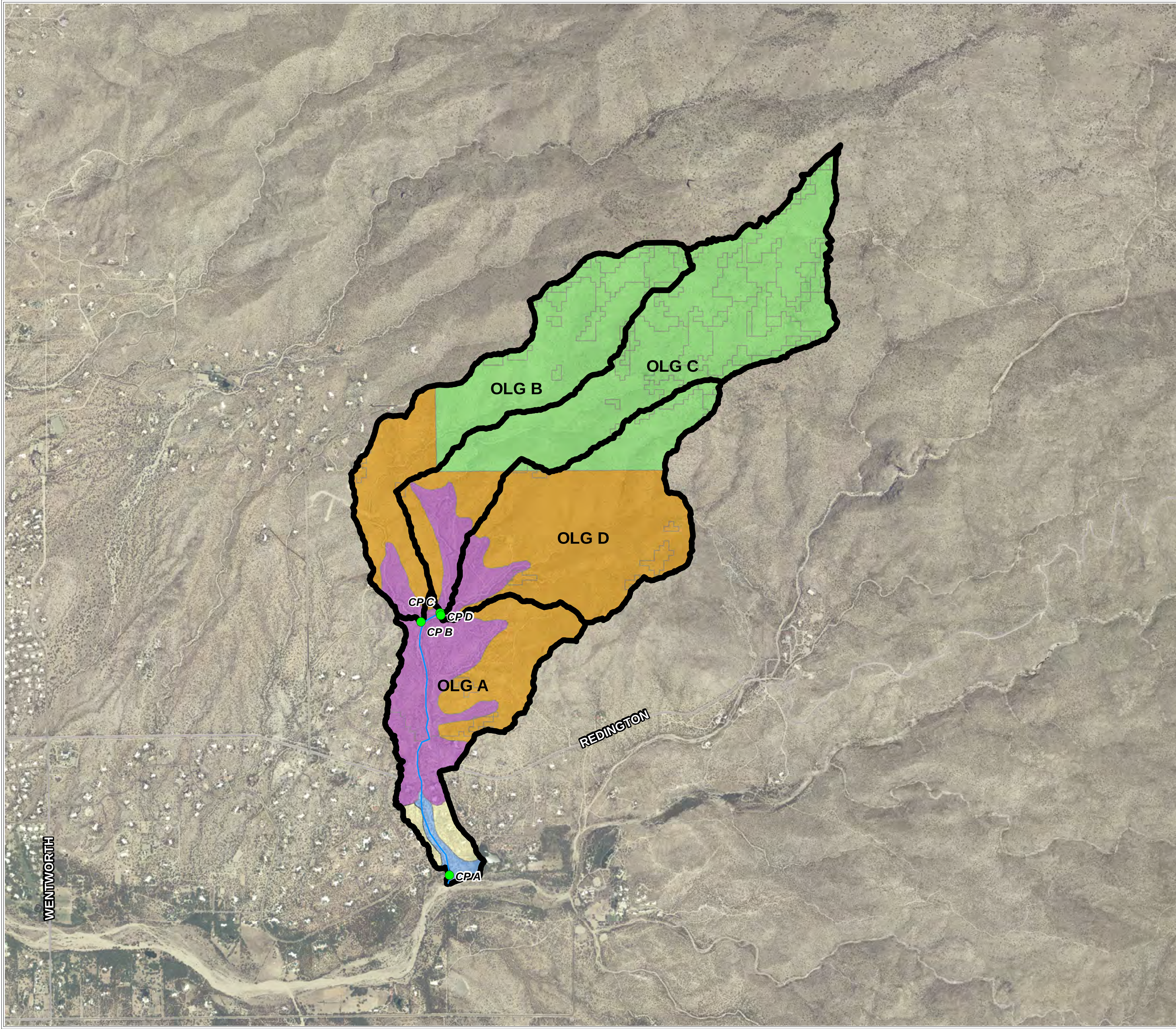
Figure 1.3
Soil Classification
Old Grandad Tank Wash



Discharge Point

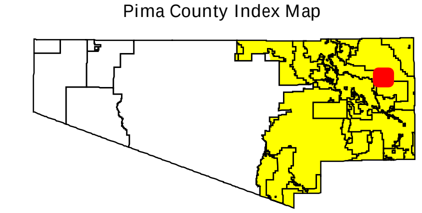
Subbasins

Soil Classification

- Soil Group: A (100%), ARIZO-RIVERWASH COMPLEX, 0 TO 3 PERCENT SLOPES
- Soil Group: B (50%) C (50%), PALOS VERDES -SAHUARITA COMPLEX, 2 TO 8 PERCENT SLOPES
- Soil Group: C (50%), D (50%)
- Soil Group: D (100%), CELLAR-LAMPSHIRE-ROCK OUTCROP COMPLEX, 15 TO 60 PERCENT SLOPES
- Soil Group: D (100%), CELLAR-LEHMANS COMPLEX, 5 TO 25 PERCENT SLOPES

Aerial Photo: 2007 Pima Association of Governments

Pima County Index Map



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Section 2.0 Summary of Key Facts

Section 2.1: General Information

2.1.1 Community: Pima County Regional Flood Control
2.1.2 Community Number: NFIP Community Number 04019C
2.1.3 County: Pima
2.1.4 State: Arizona
2.1.5 Date Study Accepted: Not Accepted
2.1.6 Study Contractor: Pima County Regional Flood Control District – Akitsu Kimoto
2.1.7 State Technical Reviewer: Not Applicable
2.1.8 Local Technical Reviewer: Suzanne Shields
2.1.9 River or Stream Name: Old Grandad Tank Wash
2.1.10 Reach Description: Old Grandad Tank Wash
2.1.11 Study Type: Hydrology and Hydraulics study of a Riverene System

Section 2.2: Mapping Information

2.2.1 FIRM Panels: 04019C-1690 and 2280K
2.2.2 Mapping for Hydrologic Study: Lidar based on 2008 flight used to derive 2' contour interval maps using ARC-GIS 9.3.1
2.2.3 Mapping for Hydraulic Study: Lidar based on 2008 flight used to derive a DEM (5-ft cell size) for use with GeoRAS

Section 2.3: Hydrology

2.3.1 Model or Method Used: HEC-HMS (v. 3.4) model parameterized using methods of RFCD Draft Tech Policy 018 (October 10, 2008)
2.3.2 Storm Duration: 3-hr
2.3.3 Hydrograph Type: SCS Unit Hydrograph
2.3.4 Frequencies Determined: 100 yr
2.3.5 List of Gages used in Frequency Analysis or Calibration: None
2.3.6 Rainfall Amounts and Reference: SCS Type II, NOAA 14 Upper 90% Confidence Interval
2.3.7 Unique Conditions and Problems: None
2.3.8 Coordination of Q's: Comparison with previous studies on file with RFCD and discharge estimates

Section 2.4: Hydraulics

2.4.1 Model or Method Used: HEC-RAS 4.0, GeoRAS to parameterize
2.4.2 Regime: Modeled as subcritical
2.4.3 Frequencies for which Profiles were computed: 100 yr
2.4.4 Method of Floodway Calculation: No Floodway
2.4.5 Unique Conditions and Problems: Boundary set at normal depth.

Section 2.5: Additional Study Information:

None

Section 3: Survey and Mapping Information

3.1 Field Survey Information

No field survey was used.

3.2 Mapping

The 2008 Light Detection and Ranging (LiDAR) data was used for the analysis. Coordinates were in Pima County projection:

Projection = State Plane, Arizona Central Zone
Datum = NAD83 HARN
Units = International Feet
North American Vertical Datum of 1988 (NAVD, 1988)

The LiDAR was used to derive a Digital Elevation Model (DEM) and a contour map. DEM derived on 5’ centers provided the basis for delineating the watershed and sub-basins. DEM was also used to characterize the topography along channels used for the floodplain mapping process. Contour map derived from the DEM allowed modelers to visualize topographic differences in making decisions on how to model different areas.

Section 4: Hydrology

4.1 Method description.

The 100-year peak discharges for the nine subbasins of the Old Grandad Tank Wash (OLG A, B, C and D; Figure 1.1) were calculated using U.S. Army Corps of Engineers Computer Hydrologic Modeling System, (HEC-HMS) version 3.4. The HEC-HMS model requires parameters regarding 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.

Methods are summarized in Table 4.1. The data processing methods are summarized in Fig. 4

Table 4.1 - 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

4.2.1 Drainage area boundaries.

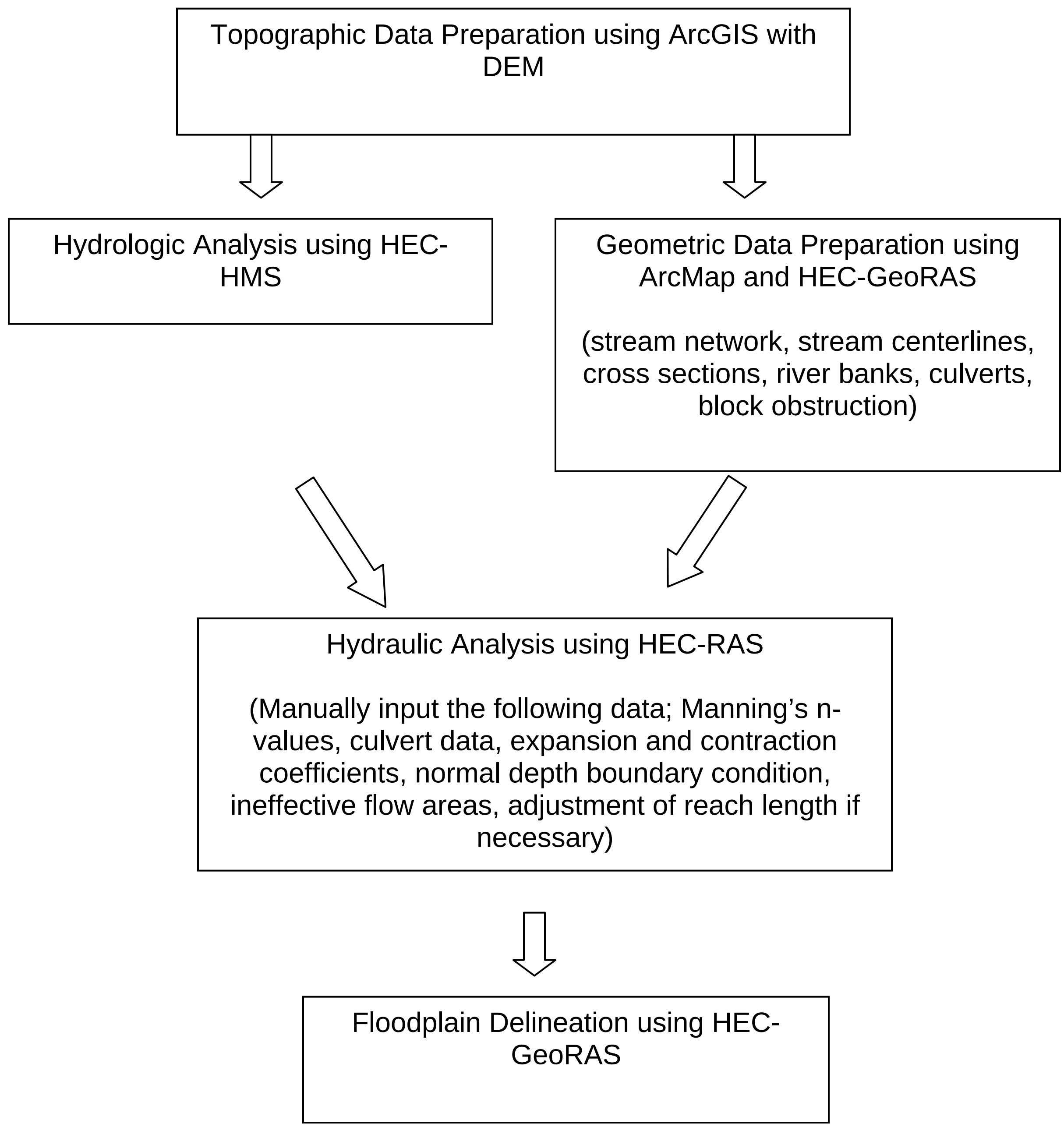
The limits of this study are shown in Fig.1.2. The Old Grandad Tank Wash watershed is partially located within Federal land (national forest, FEMA Zone D), as shown on the current Flood Insurance Rate Map (FIRM) number 04019C-1690 and 2280K.

The study watershed was divided into four sub-basins (Fig.1.1). The upstream mapping limits is the upstream end of the Subbasin A, while the downstream limit is the upstream end of FEMA Zone X-shaded (Fig.1.2).

4.2.2 Watershed work maps

The boundary of the watershed and internal sub-basins were determined using Hydrology function in ArcGIS with DEM derived from the 2008 Lidar. The sub-basins reflected predominant topographic, soils, cover and development conditions, so that the sub-basins would represent hydrologic response from the sub-basin. The locations of the stream centerline, cross-sections, culverts, and other physical attributes of the wash were determined by using the 10-ft interval contour map and 2008 aerial photo.

Figure 4.1 – Flow Chart of Mapping Process



4.2.3 Gage Data.

None Available

4.2.4 Statistical parameters

None Available

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 Roger 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.

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.

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. 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 4.2 - Sub-basin Characteristics

Sub-Basin	Area (sq mi)	CN	Impervious Area (%)	Vegetation Cover (%)	Lag Time (min)
OLG A	0.38	90.6	7	30	13.1
OLG B	0.47	89.5	5	30	15.9
OLG C	0.68	89.3	5	30	19.3
OLG D	0.49	90.4	5	30	12.5

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:

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

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

Therefore,

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

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.

Table 4.3 - Sub-basin discharges

Sub-Basin	Area (sq mi)	Rainfall Depth (in)	Runoff Volume (in)	Peak Discharge (cfs)
OLG A	0.38	3.44	2.37	1001
OLG B	0.47	3.44	2.35	1105
OLG C	0.68	3.44	2.32	1402
OLG D	0.49	3.44	2.41	1341

4.3 Problems encountered during the study.

None

4.3.1 Special problems and solutions

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

4.5 Final results

4.5.1 Hydrologic analysis results

As described above, this study mainly focuses on drainage information in the downstream of the Old Grandad Tank Wash (Subbasin A). The 100-year peak discharge at CP A was determined using the HEC-HMS. Six hours were simulated on a 1 minute time step with rainfall occurring in the first three hours. The following discharges were obtained from the hydrologic analysis:

Table 4.4 – Summary of 100-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q100 HMS (cfs)	Time to Peak
CP A	Confluence with Tanque Verde Creek	2.02	3.25	2.18	3942	1:45

Table 4.5 – Summary of 25-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q25 HMS (cfs)	Q25 RRE (cfs)	Time to Peak
CP A	Confluence with Tanque Verde Creek	2.02	2.52	1.5	2723	1119	1:46

Table 4.6 – Summary of 500-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q500 HMS (cfs)	Time to Peak
CP A	Confluence with Tanque Verde Creek	2.02	4.22	3.09	5575	1:44

4.5.2 Verification of results.

Results are reasonable when compared with USGS Regression Equation 13 (Thomas et al, 1997, Table 4.7). The equation 13 results were generally lower than the HMS results, which would be expected, because these steep watersheds could be expected to produce higher than average discharge on average. No regulatory discharge point data is available along the Old Grandad Tank Wash.

Table 4.7 – Comparison of 100-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Q100 HMS (cfs)	Q100 RRE (cfs)
CP A	**Confluence with Tanque Verde Creek**	2.02	3942	1976

Section 5: Hydraulics

5.1 Method description.

The hydraulic modeling for the Old Grandad Tank Wash was performed using Hec-RAS, Version 4.0 (HEC-RAS), HEC-GeoRAS, Version 4.2.93 (HEC-GeoRAS), and ArcGIS, Version 9.3.1. Normal-depth with a slope of 0.021 was assumed for a downstream boundary condition.

The locations of the stream centerline, cross-sections, and bank of the Old Grandad Tank Wash were determined using the 5-ft contour map and 2008 PAG aerial photos. The geometric data, including stream centerline, flow paths and cross-sections, were digitized in HEC-GeoRAS. The digitized data was exported to create geospatially referenced geometric data (cross section, reach profile) in HEC-RAS. Other parameters for the steady-state analysis in HEC-RAS, such as Manning's n-values, expansion and contraction coefficients, boundary condition, and ineffective flow areas were manually input into HEC-RAS. The hydraulic data obtained from HEC-RAS were imported into HEC-GeoRAS to delineate a floodplain boundary for the Old Grandad Tank Wash.

5.2 Work study maps

The work study map for the Old Grandad Tank Wash is included in Exhibit 2.

5.3 Parameter estimation.

The watershed was modeled using methods consistent with District Tech Policy 019.

5.3.1 Roughness coefficients.

Manning's roughness coefficients for the channel and the over-bank areas were determined by using a 2008 aerial photo. Manning's n value of 0.05-0.055 was assigned to overbank with desert brush along the Old Grandad Tank Wash, while 0.035-0.045 was assigned to a channel.

5.3.2 Expansion and contraction coefficients.

Default HEC RAS expansion (0.3) and contraction (0.1) coefficients were used for the most cross sections.

5.4 Cross section description.

A 5-foot interval contour map derived from 2008 LiDAR data 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 Geo-RAS and ArcGIS.

5.5 Modeling considerations.

5.5.1 Hydraulic Jump and drop analysis.

No hydraulic jumps were encountered.

5.5.2 Bridges and culverts.

There are no culverts along the study reaches of the Old Grandad Tank Wash.

5.5.3 Levees and dikes.

None.

5.5.4 Islands and flow splits.

None.

5.5.5 Ineffective flow areas.

Ineffective flow areas were noted on the study reach of the Old Grandad Tank Wash. In general these ineffective flow areas were disconnected overbank areas that would not convey flow to the next downstream cross-section.

5.5.6 Supercritical flow.

No supercritical reaches.

5.6 Floodway modeling

No encroachment calculations were performed.

5.7 Problems encountered during the study.

5.7.1 Special problems and solutions.

None.

5.7.2 Modeling warning and error messages.

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.

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 errors is available in Appendix E.

5.8 Calibration.

None.

5.9 Final results.

5.9.1 Hydraulic analysis results.

The HEC-RAS modeling results were summarized in Appendix E.

5.9.2 Verification of results.

Existing floodplain maps are not available along the Old Grandad Tank Wash. The new map tends to follow the floodplain topography. The results suggest that the mapping is reasonable.

Section 6: Erosion and Sediment Transport

6.1 Method description.
None – not applicable
6.2 Parameter estimation.
None – not applicable
6.4 Modeling considerations.

None – not applicable

6.5 Problems encountered during the study.

6.5.1 Special problems and solutions.

None – not applicable

6.5.2 Modeling warning and error messages.

None – not applicable

6.6 Calibration.

None – not applicable.

6.7 Final results.

6.7.1 Erosion and sediment transport analysis results.

None – not applicable

6.7.2 Verification of results.

None – not applicable

Section 7: Ratio of the top width of 100-yr and 25-yr floodplain

A map showing the cross sections with the ratio of the topwidth less than 1.25 is included in Addendum 1. The average ration of 100-yr to 25-yr floodplain topwidth for the study reach of the Old Grandad Tank Wash is 1.22.

Exhibit 1
100-year Floodplain with cross sections Old Grandad Tank Wash

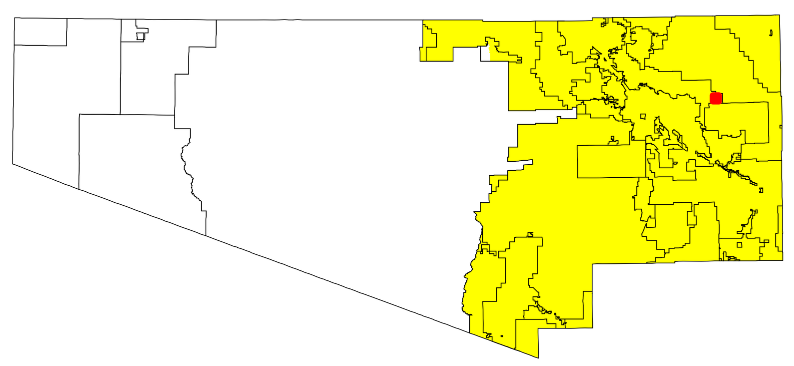
- Discharge Point
- Cross Sections
- Contour 2 foot
- Contour 10 foot
- Proposed Floodplain

Floodplain Zone

- ZONE A
- ZONE AE

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

Pima County Index Map



Index Map Scale 1:1,500,000

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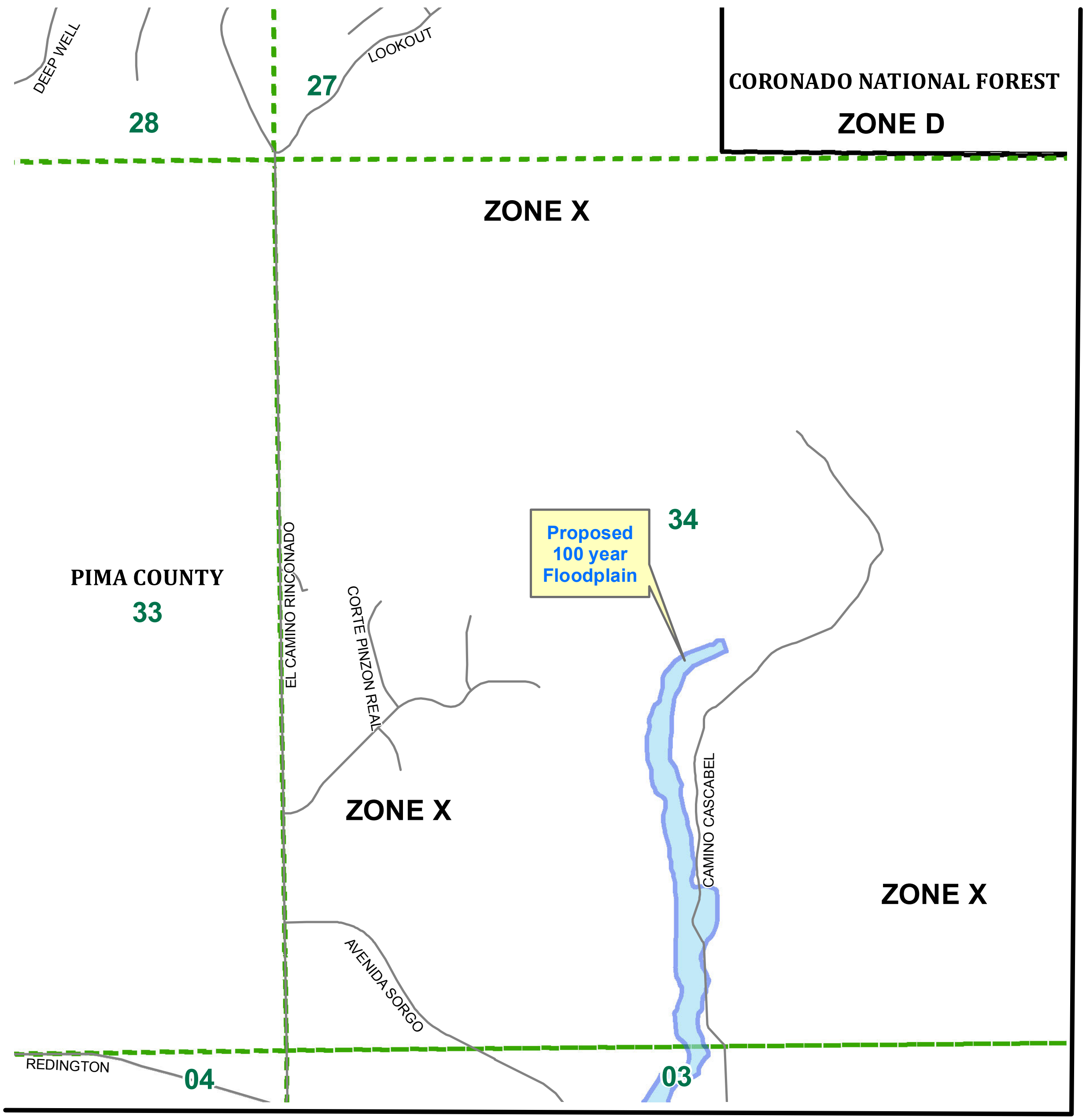
Exhibit 2
Annotated Flood Insurance Rate Map
04019C1690 K
Old Grandad Tank Wash



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- Streets
- FIRM X-Sections
- Base Flood Elevations
- Proposed Floodplain
- LOMRs
- Sections
- FIRM - Flood Insurance Rate Map
- Jurisdictions

Existing Floodplain Zone
- A
- AE
- AO
- X
- X (SHADED)

0 275 550 1,100 Feet

N

Pima County Index Map

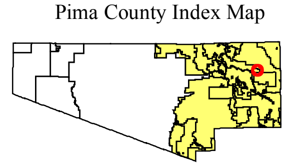

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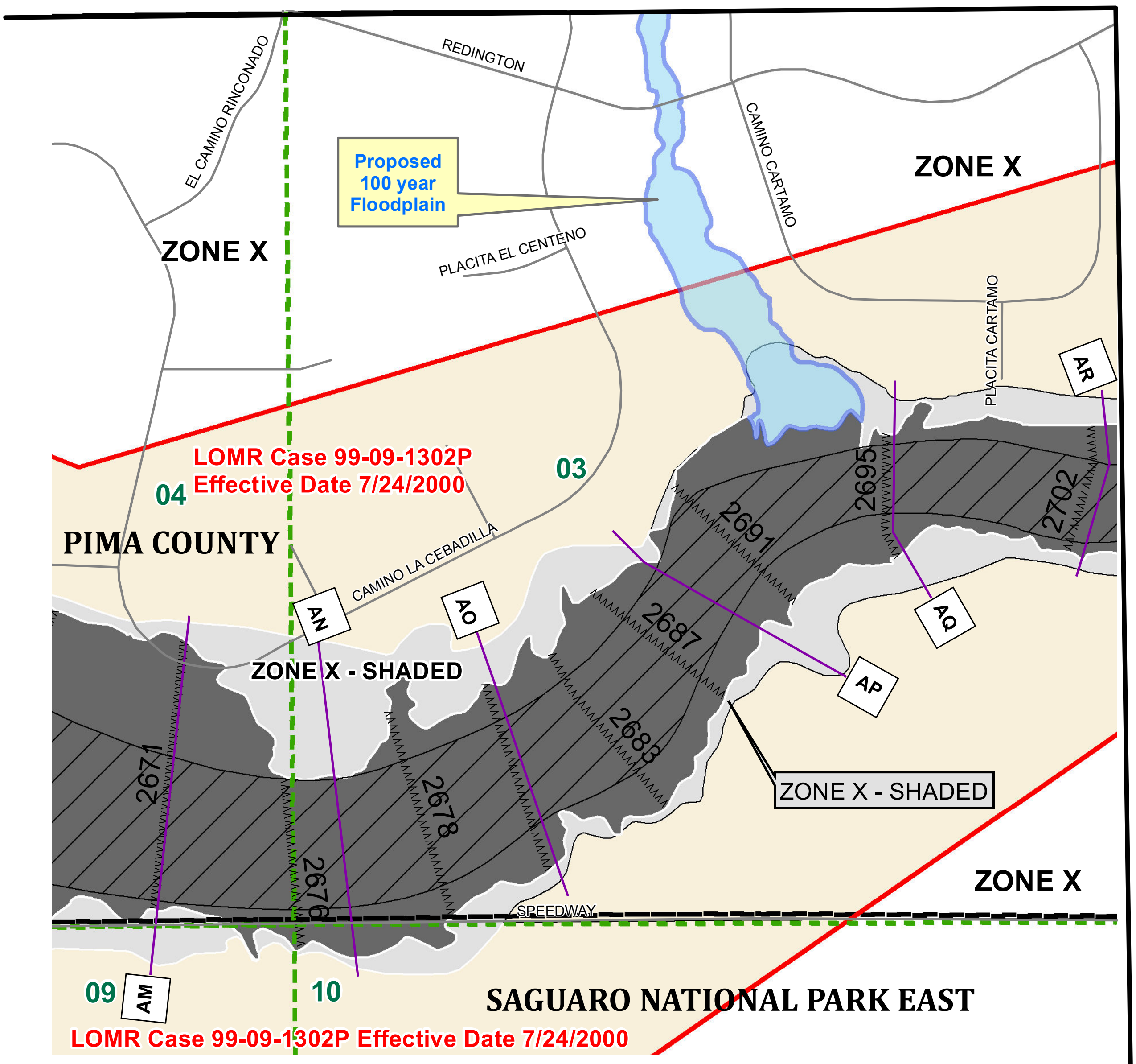
Exhibit 2
Annotated Flood Insurance Rate Map
04019C 2280K
Old Grandad Tank Wash



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- FIRM X-Sections
- Base Flood Elevations
- Proposed Floodplain
- LOMRs
- Sections
- FIRM - Flood Insurance Rate Map
- Jurisdictions

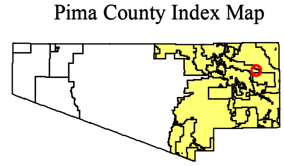
Existing Floodplain Zone

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

0 280 560 1,120 Feet

N

Pima County Index Map



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Appendix A: References

A.1 Data collection summary.

Include a list of previous studies, other applicable studies, published and unpublished historical
flood information, and research contacts.

A.2 Referenced documents.

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