Catalina Foothills Watercourse Studies:
Technical Data Notebook for Hydrologic and Hydraulic Mapping of the Castle Wash and its Tributary,
Pima County Arizona.

FEMA FIRM Panel 04019C-1670K

Prepared by

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June 2013

Approved by

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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Exhibit

Attached CD

Castle Wash 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 Castle 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;
- floodplain mapping for channels with contributing areas greater than 20 acre

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 Castle Wash. The site includes Sections 25, 26, 34, 35 and 36 of Township 13 South, Range 15 East, Sections 2 and 3 of Township 14 South, Range 15 East, Pima County, Arizona. Entire watershed of the Castle Wash is in FEMA Zone X, as shown on the current Flood Insurance Rate Map (FIRM) number 04019C-1670K.

The Castle Wash watershed is partially located within the City of Tucson. This study focused on an area located outside of the city limit, upstream of Tanque Verde Rd. The study area was divided into twelve subbasins (Fig.1.1). Per Section 16 of the Pima County Ordinance, regulatory floodplain is an area where the 100-year peak discharge is 100 cfs or greater. Regulatory floodplains along the Castle Wash and its tributaries were mapped in this study, assuming watersheds greater than 20 acre produce 100-year peal discharge of 100 cfs or greater. The study limits extends from Tanque Verde Rd. to Kleindale Rd. (Fig.1.2).

1.4 Methodologies Used for Hydrology and Hydraulics

Hydrologic analysis was preformed to estimate regulatory discharge rate at the Concentration Points (CPs) using PC-Hydro Version 5.4.2 (PC-Hydro). The parameters for PC-Hydro, such as rainfall intensity and subbasin characteristics (e.g. soil, vegetation, slope, flow distance, roughness), were selected using 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). Hydraulic analysis was performed to delineate floodplain limit along the study reach of the Unnamed Wash 1 using U.S. Army Corps of Engineers Computer Backwater Model, HEC-RAS.

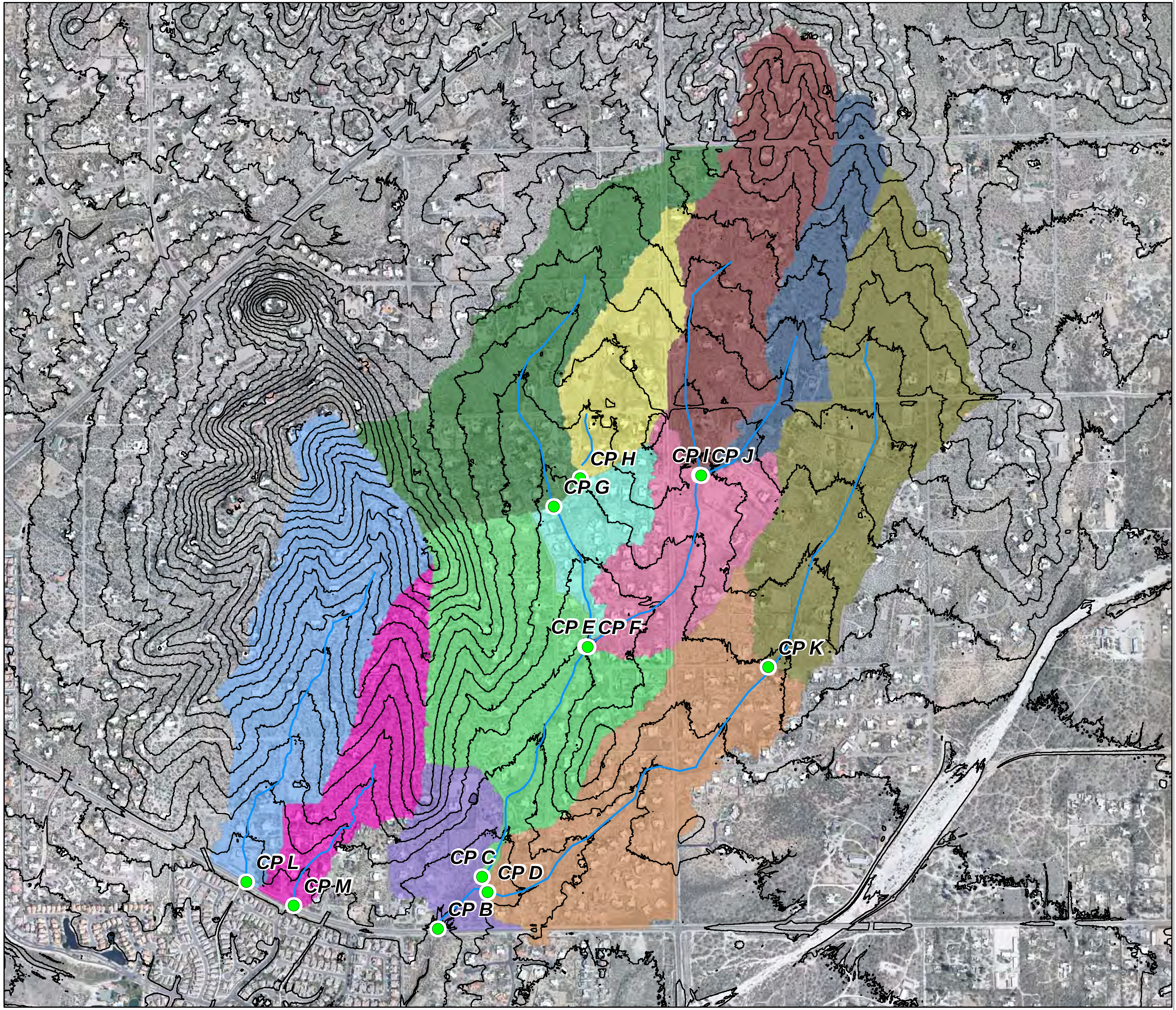
1.5 Acknowledgements

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 at the downstream end of the Castle Wash (on Tanque Verde Rd.) is 2559 cfs, where the contributing area is 772 acre. The 100-year peak discharges at the CPs were compared to the peak discharge computed using USGS Regression Equation. The comparison showed that the PC-Hydro produced higher discharges. Regulatory floodplains along the Castle wash and its tributaries were mapped in this study. The study found many homes are at risk for flooding during the 100-yr flood.

Figure 1.1
Watershed Map
Castle Wash



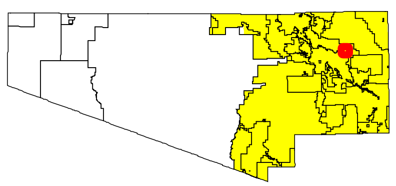
- Discharge Point
- CST_River
- Contour 10 foot

Castle Wash Subbasins

- CST B
- CST C
- CST D
- CST E
- CST F
- CST G
- CST H
- CST I
- CST J
- CST K
- CST L
- CST M

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

Pima County Index Map



Index Map Scale 1:5,250,000

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Pima County Regional FLOOD CONTROL DISTRICT

THE SEAL OF PIMA COUNTY ARIZONA

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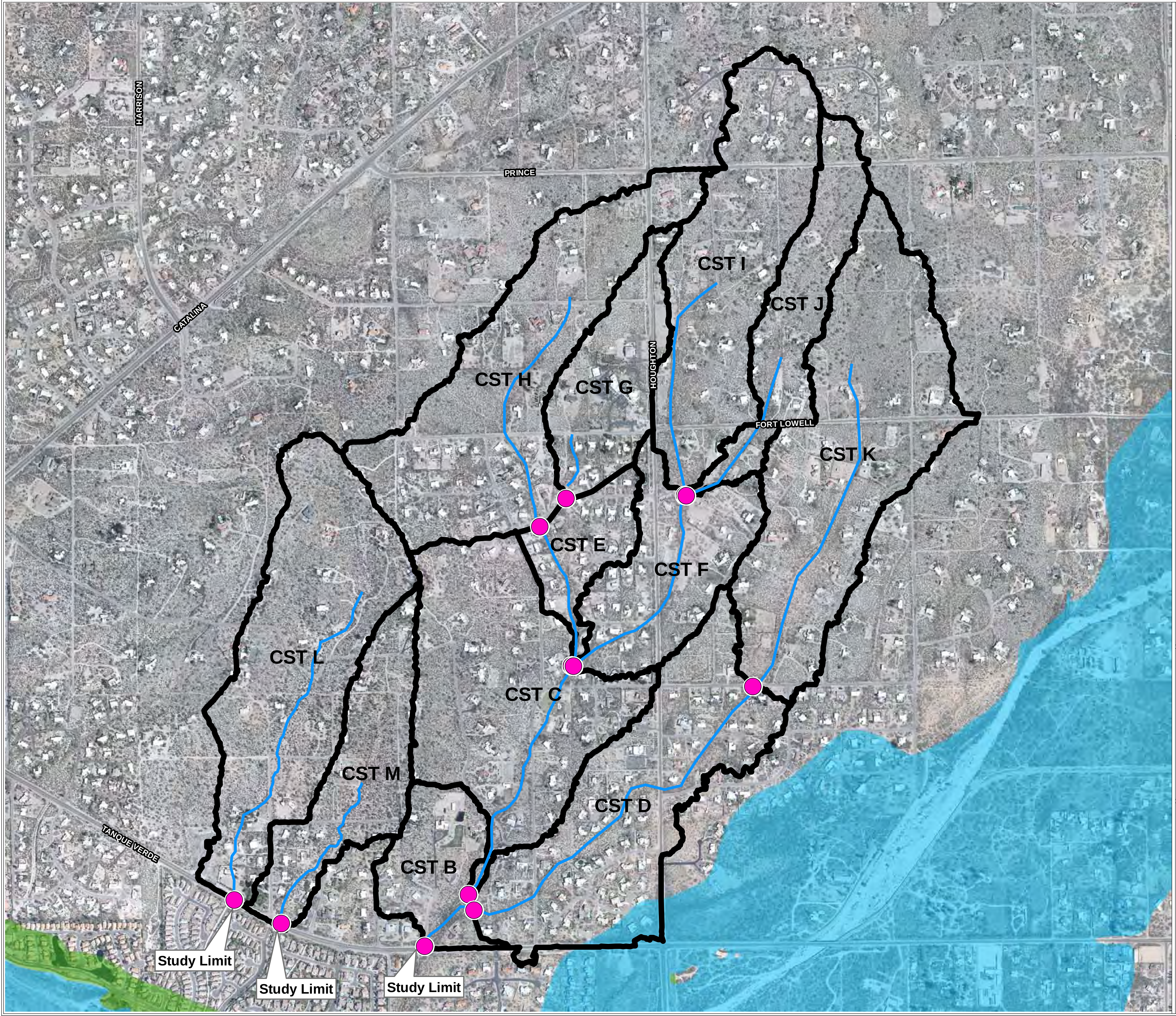
Figure 1.2
Study Limit
Castle Wash



Discharge Point

River

Subbasins

Existing FEMA Floodplain

ZONE A

ZONE AE

ZONE X - SHADED

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

Pima County Index Map

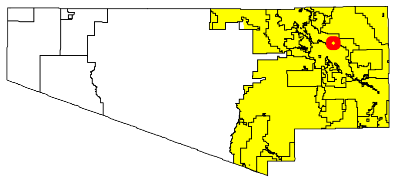


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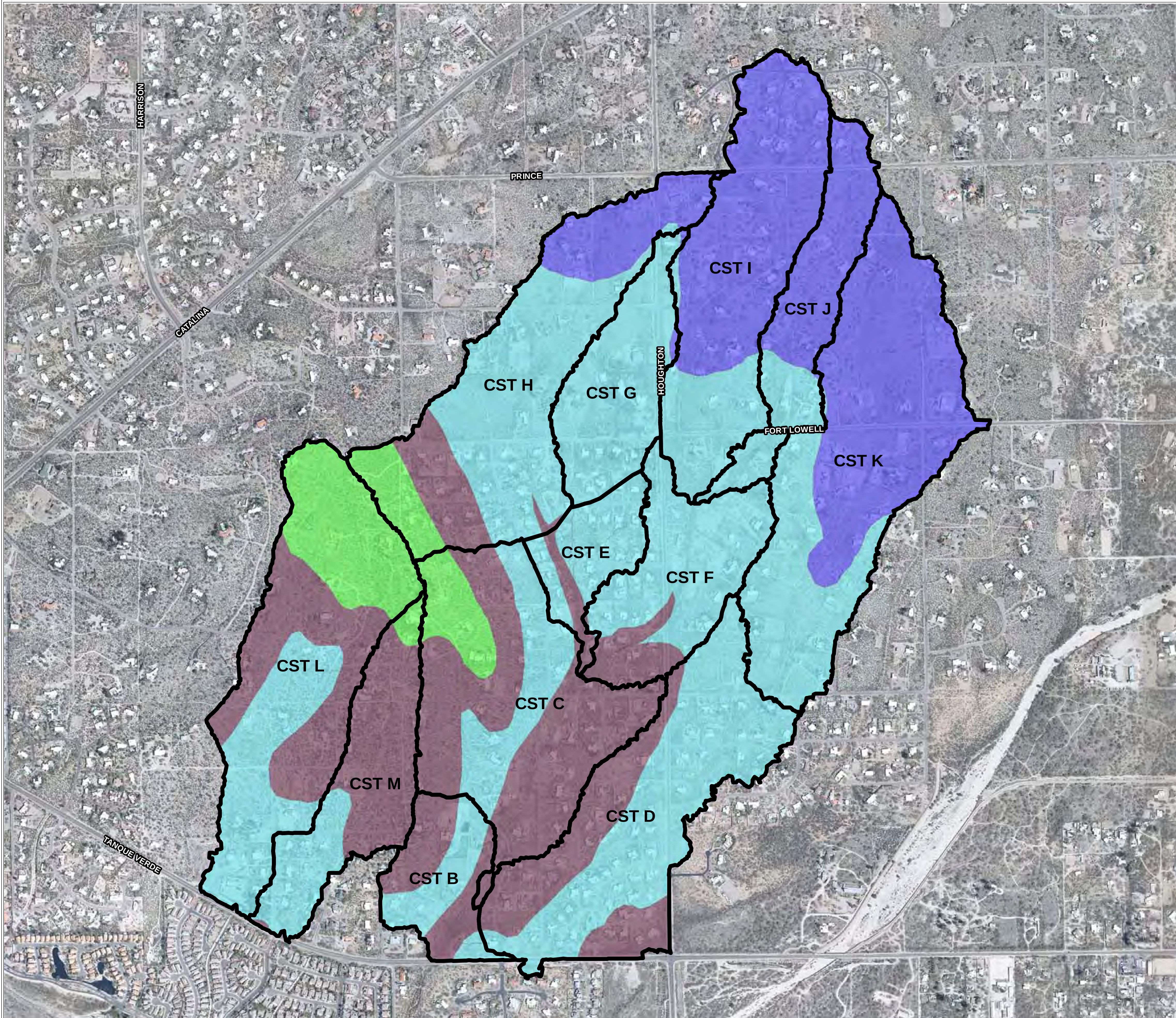
Figure 1.3
Soil Classification
Castle Wash



Subbasins

Soil Classification

Soil Group: B (100%)

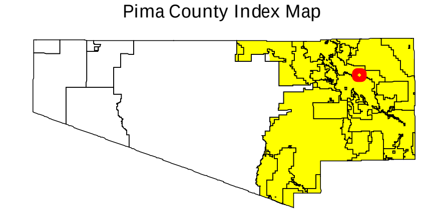
Soil Group: B (82%) C (18%)

Soil Group: C (47%) D (53%)

Soil Group: C (53%) D (47%)

Aerial : 2008 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: Castle Wash
2.1.10 Reach Description: Castle 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-1670K
2.2.2 Mapping for Hydrologic Study: Lidar based on 2008 flight used to derive 2' contour interval maps using ARC-GIS 9.2
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: PC-Hydro, version 5.3.1
2.3.2 Storm Duration: NA
2.3.3 Hydrograph Type: NA
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: 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.

For the floodplain mapping, a 100-yr discharge is required. The 100-year peak discharges at the CPs of the Castle Wash and its tributaries (CP B to CP M; Figure 3) were calculated using PC-Hydro, version 5.3.1. 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 method has been deemed as a FEMA-accepted hydrologic method for prediction of 100-yr peak discharge in Pima County. The method was used for the Friendly Village LOMR (case# 08-09-0473P) and it was approved by FEMA. The PC-Hydro method generally produces higher discharge values compared to HEC-HMS or USGS Regression equations. Peak discharge values produced by the PC-Hydro would be conservative, compared to using HEC-HMS or USGS Regression equations. In general, PC-hydro program is applied determine peak discharge for watersheds with areas less than 1 square mile. HEC-HMS is applied to watersheds with areas greater than 1 square mile. The study area of the Castle Wash main channel is 1.2 square mile. This study only used PC-Hydro to estimate the 100-year peak discharges for the Castle Wash and its tributaries. Therefore, the estimated peak discharge at the downstream end of the study area is expected to be conservative.

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 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. The PC-Hydro uses adjusted Curve Number (CN), which has been developed based on the results of the USDA-ARS research. The PC-Hydro procedure assumes that high intensity, short duration storms result in raindrop impacts causing the surface of soils to real up, resulting in reducing infiltration (Caliche Effect). The CN in the PC-Hydro procedure increases with increasing rainfall depth and intensity. The detail of the method was described in PC-Hydro User Guide (Arroyo Engineering, 2007).

Table 4.1 - 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

4.2.1 Drainage area boundaries.

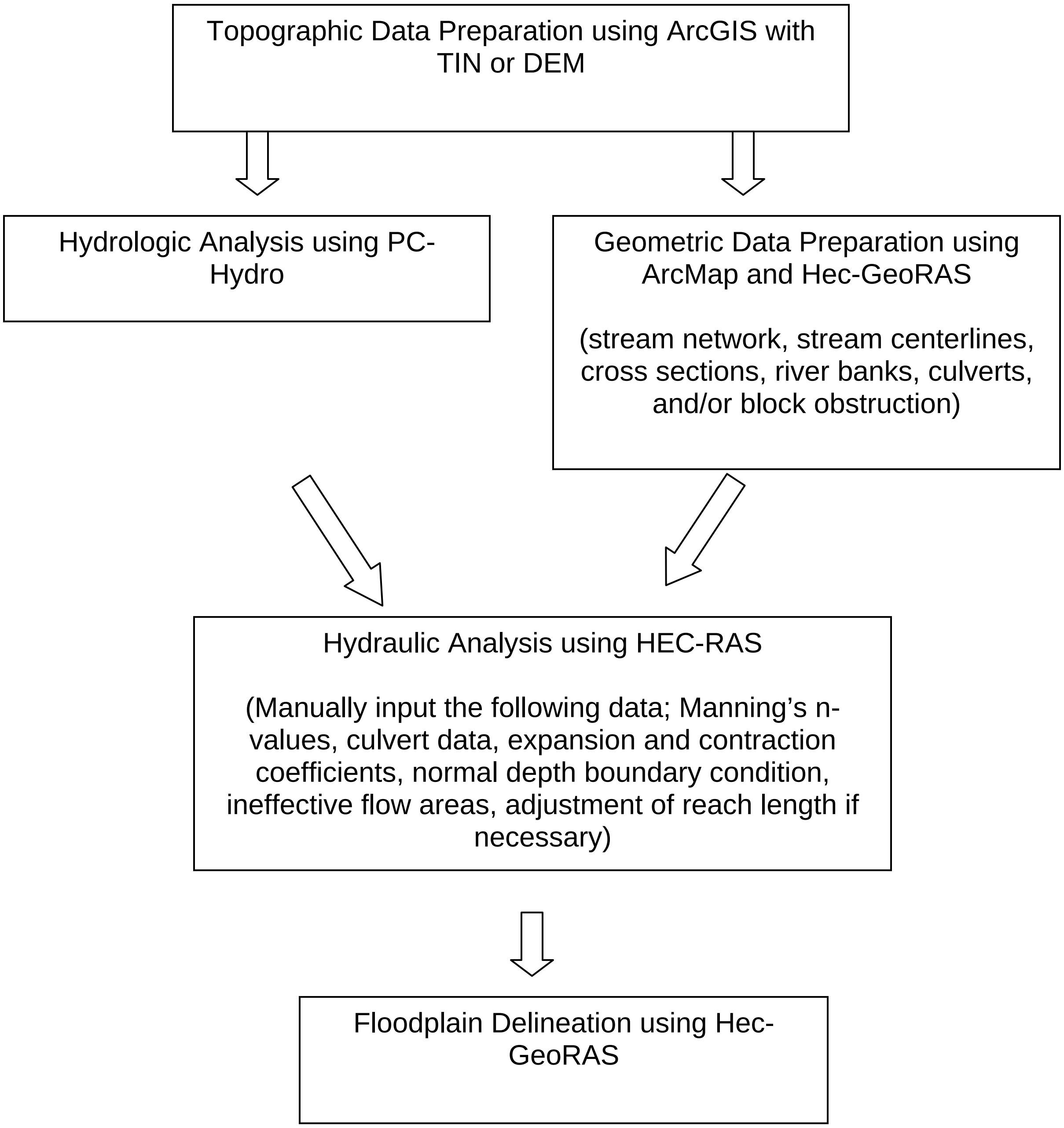
The limits of this study are shown in Fig.1.2. The study site includes Sections 25, 26, 34, 35 and 36 of Township 13 South, Range 15 East, Sections 2 and 3 of Township 14 South, Range 15 East, Pima County, Arizona. Entire study area is in FEMA Zone X, as shown on the current Flood Insurance Rate Map (FIRM) number 04019C-1670K.

The Castle Wash watershed is partially located within the City of Tucson. This study focused on an area located outside of the city limit, upstream of Tanque Verde Rd. The study area was divided into twelve subbasins (Fig.1.1). Per Section 16 of the Pima County Ordinance, regulatory floodplain is an area where the 100-year peak discharge is 100 cfs or greater. The study limits extends from Tanque Verde Rd. to Kleindale Rd. (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 (Fig.1.1) 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 2-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.

Rainfall depth was selected from the NOAA 14 Upper 90% rainfall data used in PC Hydro.

4.2.6 Physical parameters.

The entire study area is covered with Desert brush. Hydrologic Soil Groups C and D are the dominant soil types in the Castle Wash watershed.

The Pima County Hydrology Procedure uses the Curve Number (CN) adjustment procedure. The CN adjustment procedure was developed based on the research at the USDA-ARS Walnut Gulch experimental watershed near Tombstone. 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 (know as “Caliche Effect”, Mike Zeller, personal communication, 2006). Adjusted CN increased with increasing rainfall depth and intensity. The CN charts in the PC Hydro Manual (Arroyo Engineering, 2007) were the basis for original CN selection. A vegetation cover density of 30% was used to select the SCS Curve Number for the hydrologic calculation of the mountainous watersheds. Impervious cover percentage from 10-15%, were selected using the 2008 aerial photo and the tables in the PC Hydro manual. The detail of the CN calculation is included in Appendix D.

The hydraulically most distant point on the sub-basin and slope break points along the longest water course were identified using a contour map. The length between slope break points was measured using ArcGIS.

Table 4.2 - Watershed Characteristics

Concentration Points	Area (acre)	Impervious Area (%)	Vegetation Cover (%)	Weighted Runoff Coefficient
CP B	772	15.0	30	0.7
CP C	499	15.0	30	0.7
CP D	241	15.0	30	0.7
CP E	187	15.0	30	0.7
CP F	200	13.0	30	0.7
CP G	45	10.0	30	0.7
CP H	116	10.0	30	0.7
CP I	97	10.0	30	0.7
CP J	47	10.0	30	0.7
CP K	133	10.0	30	0.7
CP L	117	10.0	30	0.6
CP M	53	10.0	30	0.6

4.3 Problems encountered during the study.

None

4.3.1 Special problems and solutions

4.3.2 Modeling warning and error messages

None

4.4 Calibration.

No Calibration

4.5 Final results.

4.5.1 Hydrologic analysis results

The 100-year peak discharges at the concentration points along the Castle Wash and its tributaries were estimated using PC-Hydro. The 100-year peak discharges are summarized in Table 4.3.

Table 4.3 – Summary of 100-yr Peak Discharge Values

Concentration Points	Area (acre)	Time of Concentration (Tc) (min)	Rainfall Intensity at Tc (in/hr)	Runoff Supply Rate at Tc (in/hr)	Peak Discharge (cfs)
CP B	772	28.9	4.67	3.29	2554
CP C	499	27.9	4.74	3.33	1674
CP D	241	27.9	4.74	3.39	823
CP E	187	19.3	5.82	4.14	780
CP F	200	19.3	5.81	4.19	844
CP G	45	10.8	7.91	5.66	257
CP H	116	15.4	6.68	4.61	539
CP I	97	13.9	7.03	5.06	495
CP J	47	13.1	7.22	5.19	246
CP K	133	17.7	6.13	4.41	591
CP L	117	12.1	7.48	4.81	567
CP M	53	10	8.16	5.18	277

4.5.2 Verification of results.

Computed 100-year peak discharges were compared to the discharge calculated using USGS Regression Equation 13 (Thomas et al, 1997) and existing regulatory discharge values. The equation 13 results were generally lower than the PC-Hydro results, which would be expected, because these steep watersheds could be expected to produce higher than average discharge. Existing regulatory discharge is slightly higher than the PC-Hydro discharge.

Table 4.4 – Comparison of 100-yr Peak Discharge Values

Concentration Points	Loaction	Area (sq mile)	Q100 PC-Hydro (cfs)	Q100 RRE (cfs)	Regulatory Q100 (cfs)
CP B	**Tanque Verde Rd.**	1.21	2554	1425	2148
CP C	**Around 530 ft north of Tanque Verde Rd.**	0.78	1674	1063	NA
CP D	**Around 370 ft north of Tanque Verde Rd.**	0.38	823	630	NA
CP E	**South of Placita Cresta Verde**	0.29	780	519	NA
CP F	**South of Placita Cresta Verde**	0.31	844	546	NA
CP G	**East of Placita Cresta Mia**	0.07	257	156	NA
CP H	**East of Placita Cresta Mia**	0.18	539	354	NA
CP I	**South of Fort Lowell Rd.**	0.15	495	306	NA
CP J	**South of Fort Lowell Rd.**	0.07	246	162	NA
CP K	**Glenn St.**	0.21	591	396	NA
CP L	**Tanque Verde Rd.**	0.18	567	357	NA
CP M	**Tanque Verde Rd.**	0.08	277	181	NA

Section 5: Hydraulics

5.1 Method description

The hydraulic modeling for the Castle Wash 1 was performed using Hec-Ras, Version 4.0 (HEC-RAS), HEC-GeoRAS, Version 4.1.1 (HEC-GeoRAS), and ArcGIS, Version 9.3. Corrected model is proposed in this study.

As previously mentioned, DEM derived from 2008 LiDAR data was used to create a 5-foot contour map. The locations of the stream centerline, cross-sections, and bank of the Castle Wash were determined using the contour map 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 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 added in the HEC-RAS model. The hydraulic data obtained from HEC-RAS were then imported into HEC-GeoRAS to delineate a floodplain boundary of the Castle Wash.

Steady flow analysis was performed to determine 100-year water surface elevations in the study area by using HEC-RAS with the discharge obtained from PC-Hydro.

5.2 Work study maps

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

5.3 Parameter estimation.

5.3.1 Roughness coefficients.

Manning's roughness coefficients for the channel and the over-bank areas were determined based on a 2008 aerial photo and a site visit. Bank stations were determined based on the topography and a 2008 aerial photo. The roughness used in this study is 0.035 for channel and 0.055 for overbank areas. Differentiation of channel and overbank 'n' values should be done only when channel flow is at least twice as deep as overbank flow (Phillips and Tadayon, 2006). There are many reaches that are wide with several flow paths. Rather than assign a channel and overbank Manning's n, an average n for the whole cross-section of 0.045 was assigned.

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. The expansion coefficient of 0.5 and contraction coefficient of 0.3 were used for the cross sections immediately upstream or downstream of culverts.

5.4 Cross section description.

A 2-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 HEC-GeoRAS.

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 four culverts along the study reach of the Castle Wash and its tributaries. The photos of the culverts are included in Appendix E.

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 Castle Wash and its tributaries. In general these ineffective flow areas were disconnected overbank areas that would not convey flow to the next downstream cross-section or immediately upstream or downstream of culverts. Contraction rate of 1:1 and expansion rate of 1:3 were used to determine ineffective areas immediately upstream and downstream of road crossings.

5.5.6 Supercritical flow.

No super critical flow

5.6 Floodway modeling

No encroachment calculations were performed.

5.7 Problems encountered during the study.

5.7.1 Special problems and solutions.

Lateral structures were used in HEC-RAS where flows breakout over banks. The breakout flow was calculated using an optimization function of lateral structures in HEC-RAS. The peak rates for the breakouts are shown in the Exhibit 1.

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 Castle 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

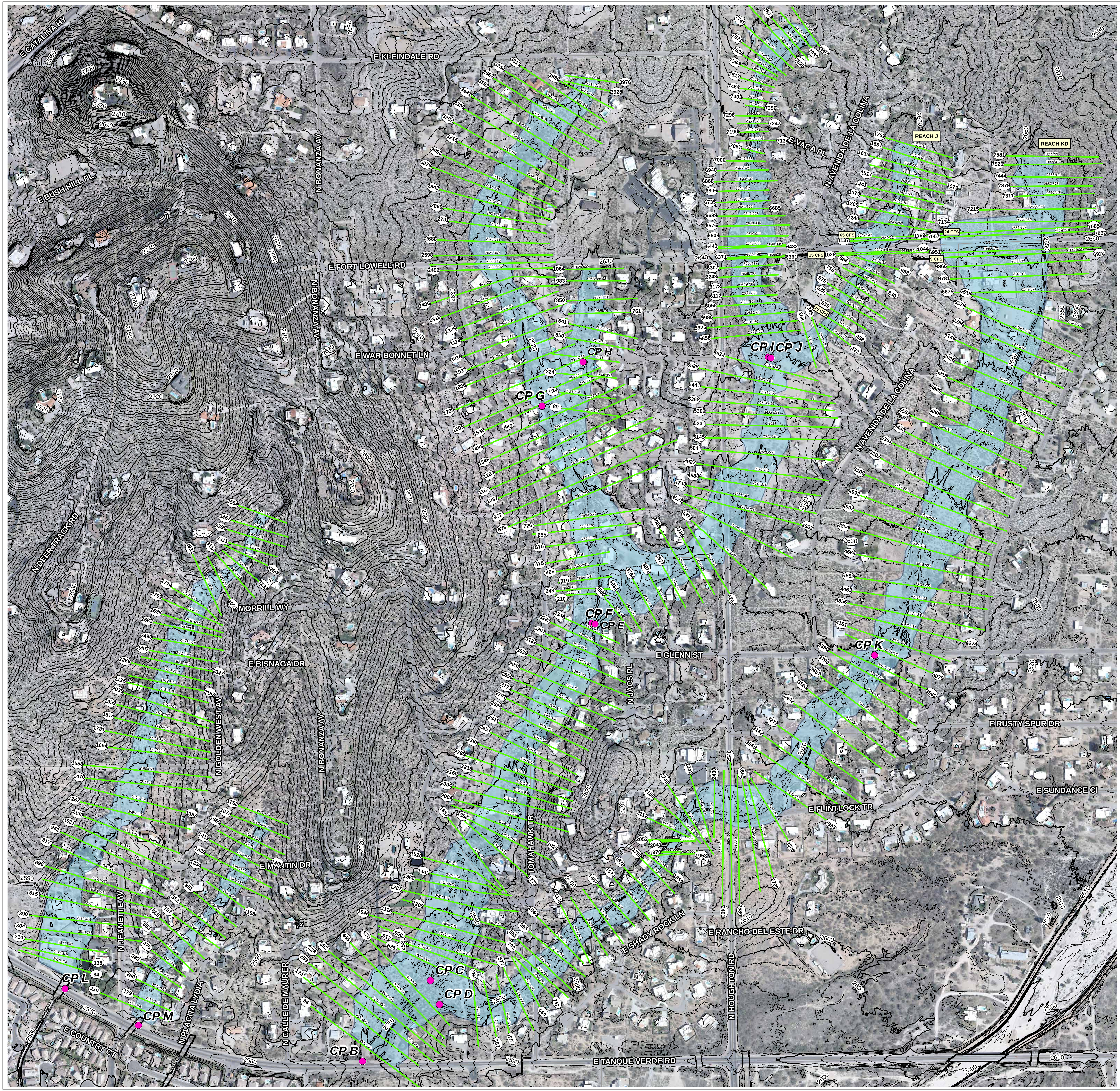
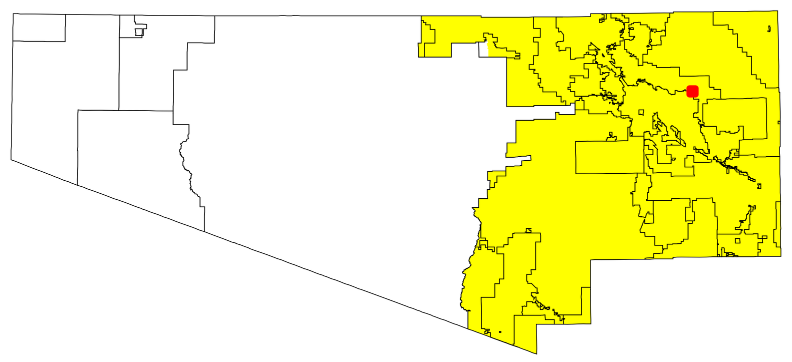


Exhibit 1
100-yearFloodplain
with cross sections
Castle Wash

- Discharge Point
- Cross Sections
- Contour 2 foot
- Contour 10 foot
- Proposed 100-yr Floodplain

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

Pima County Index Map



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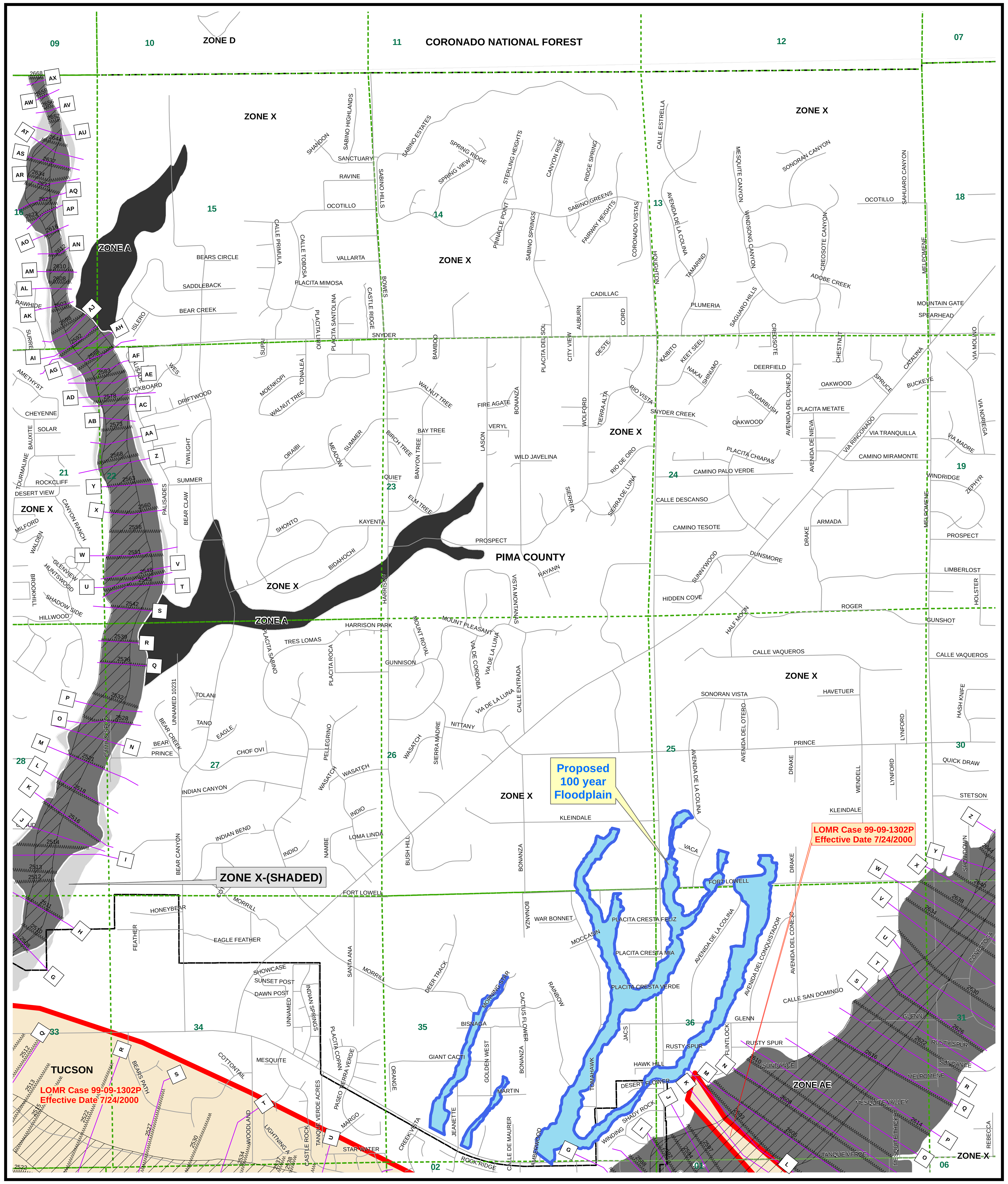


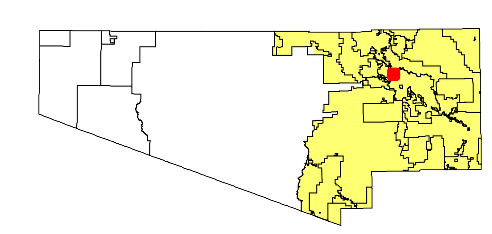
Exhibit 2
Annotated Flood Insurance Rate Map
04019C1670 K
Castle Wash

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

Existing Floodplain Zone

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

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.

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

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.

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

NOAA, 2006. NOAA Atlas 14, Precipitation Frequency Atlas for the United States: Volume 1 - Version 4.0 The Semiarid Southwest. National Weather Service, Hydrometeorological Design Studies Center. Available on the internet at: http://hdsc.nws.noaa.gov/ hdsc/pfds/sa/az_pfds.html

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.

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. 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). 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.