Wickenburg Area Drainage Master Study/Plan

FCD 2009C030 - HYDROLOGY REPORT

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EXPIRES 3/31/2015

Expire 6/30/15

1 INTRODUCTION

Hoskin•Ryan Consultants, Inc. (HRC), has been contracted by the Flood Control District of Maricopa County (District) to prepare the Wickenburg Area Drainage Master Study (WADMS) (Figure 1). The study is an update of the Wickenburg Area Drainage Master Study (WADMS-94), completed in 1994. Since the WADMS-94, there have been advancements in the technology used to identify flood hazards, precipitation data has changed, and more recent and accurate digital topography is available. Growth, development, and other factors have modified drainage patterns in some areas, causing potential changes to the flood hazards.

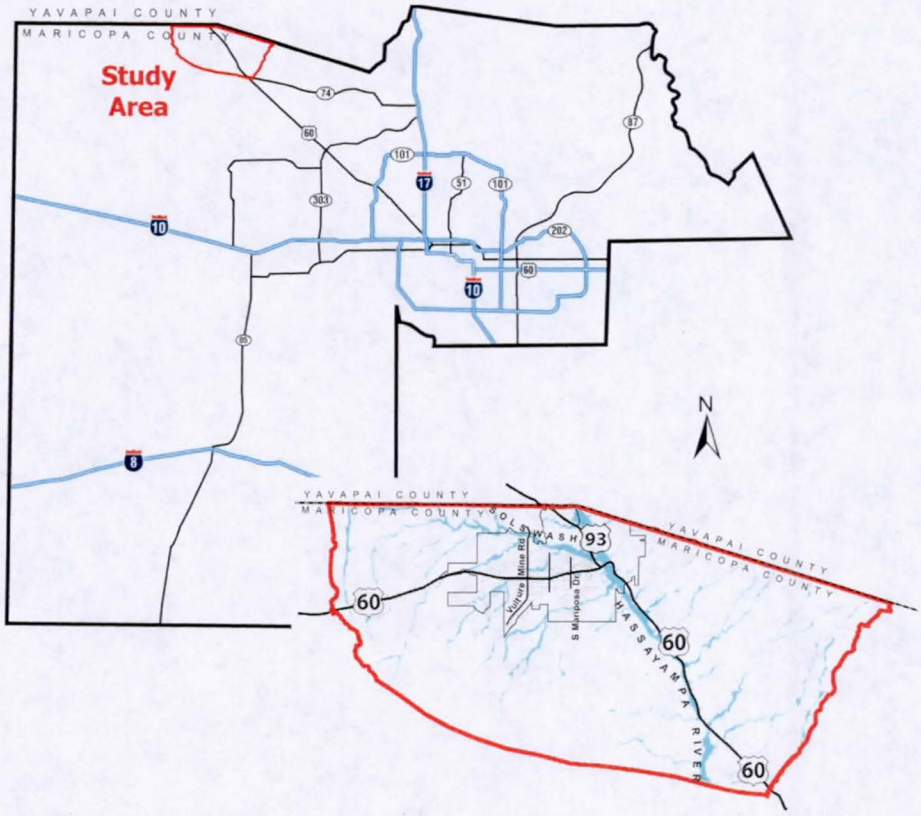

FIGURE 1 –VICINITY AND STUDY AREA

The study was performed in three phases (Figure 2). The first phase identifies the current floodplain and flood hazards for Sunset Wash and Sunnycove Wash. The second phase delineates the

floodplains for Sols Wash and Hassayampa River tributary washes that occur within, or in close proximity to, the Town of Wickenburg (Town) limits. The third phase includes floodplain delineations for select washes outside the Town's jurisdictional limits. See Figure 2 for the location of each phase.

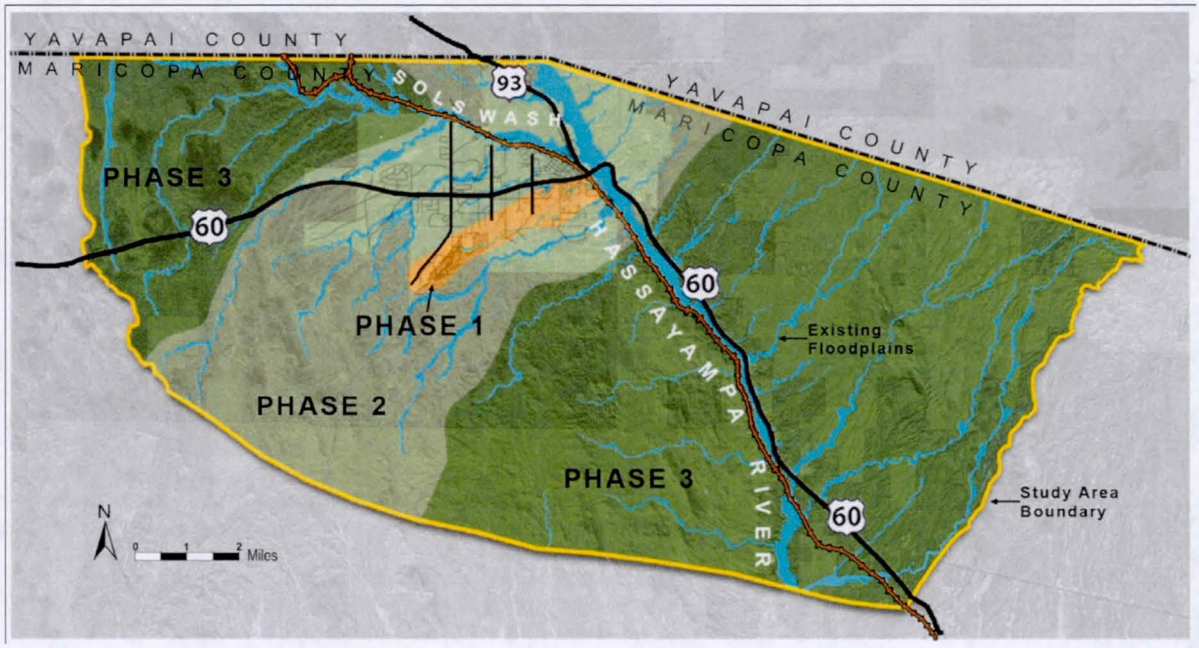

FIGURE 2 – STUDY PHASES

1.1 Purpose of Report

The purpose of the Hydrology Report is to present and summarize the methodology and results of the hydrologic work effort for the WADMS. The Scope of Work (SOW) Section 5.0 (Ref. 2) documents the District's general procedures, and methodologies for producing hydrologic models and reports. There is some latitude discussed in the SOW for the WADMS team, with District approval, to adjust the recommended methodologies. Therefore, this report documents these adjustments and their impact to the hydrology modeling.

1.2 Project Team

This study was performed under the authority of the District, in cooperation with the Town. The HRC Consultant Team comprised of firms of various disciplines required to complete all aspects of the project. HRC was the Prime Consultant responsible for all aspects of the study. Dewberry and Coe & Van Loo Consultants, Inc., assisted HRC with data collection, hydrology, hydraulics, and floodplain delineation and EPG assisted with data collection, existing conditions analysis, and flood hazard assessment. Bender Consulting Services assisted with Public Involvement and Del Sol Group provided environmental analysis. Geological Consultants, Inc. provided soils and bedrock analysis and Alpha Geotechnical provided soils sampling and testing.

1.3 Methodology and Results Summary

Hydrologic analysis and storm water modeling was performed using the US Army Corps of Engineer's computer program; HEC-1, Version 4.1, Flood Hydrograph Package. The models were developed following the procedures recommended in the District's *Drainage Design Manual for Maricopa County, Volume I, Hydrology* (Ref. 4). The soil losses were estimated using the Green & Ampt method and excess rainfall runoff was generated for sub-basins using the Phoenix Mountain and Desert Rangeland S-graphs.

This study updates the WADMS-94 and incorporates advancements in the methodologies used to identify flood hazards. Since the completion of the WADMS-94, many areas within the study area have experienced growth. Development and other factors have resulted in changes to drainage patterns, creating new flood hazards. New and more accurate data is available, including digital topography, soil survey data and land-use data. Recent changes in development on the watershed area are reflected in this study.

Recently, the District adopted the use of point precipitation values from the NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 1, Arizona (Ref. 26). For the majority of Maricopa County, this has resulted a decrease in precipitation values; however, for the WADMS watershed areas there has generally been an increase. NOAA Atlas 14 rainfall data is available in DDMSW version 4.6.0 (Ref. 3) for the 10-, 50-, and 100-year events. The 500-year precipitation is available from the NOAA website.

Results indicate the peak runoff for the 100-year, 24-hour event has increased, over the WADMS-94, for most areas within the study area. For some of the more remote and undeveloped areas little has changed since the WADMS-94. The increase for the peak runoff in these areas may be attributable to the higher precipitation from NOAA 14. For the areas closer to or within the Town limits increased development, coupled with precipitation changes, may have led to the increase in runoff.

The 6-hour rainfall Pattern No.1 (Ref. 4) for drainage areas of less than 0.5 square miles, which is expected at the "eye" of a local storm, usually results in higher rates of runoff than the 24-hour SCS type II. The 6-hour rainfall Patterns 2, 3 and 4 (Ref. 4) are less concentrated than Pattern 1, and were applied for a range of drainage areas. The rainfall pattern for a watershed is interpolated between these rainfall patterns according to the size of the watershed. Within Maricopa County the SCS Type II distribution is used for the 24-hour storm distribution and is typically used for drainage areas larger than 20 square miles, modeling more of a generalized storm. Watersheds in the WADMS ranged in size from 21 to 0.1 square miles. The 100-year 6-hour storm and the 100-year 24-hour storm were compared to determine if either a localized or a general storm produces a larger discharge. For smaller watersheds, the 100-year 6-hour storm peak discharge was typically higher than the 100-year 24-hour model. Table 1 provides a summary of watershed areas and max discharges by wash. These discharges were used for floodplain delineations.

Table 1: Watershed Properties

Wash Name	Watershed Area (sq mi)	Duration of Storm for Max Q	Number of Subbasins	Max Q (cfs)
Phase 1 Washes				
Sunset Wash	1.08	6 - Hour	3	1146*
Sunnycove Wash	1.51	6 - Hour	6	326**
Phase 2 Washes West				
Hartman Wash	9.53	24 - Hour	10	5398
Sols Wash Tributary 1S	1.00	6 - Hour	1	1354
Sols Wash Tributary 2S	0.77	6 - Hour	1	907
Flying E Wash	3.75	24 - Hour	15	8249
Basin FE26	0.20	6 - Hour	1	439
Yucca Flat Wash	5.26	24 - Hour	6	4347**
Twin Peak Wash	2.44	24 - Hour	4	2158
Casandro Wash	1.66	6 - Hour	8	401***
Wash AG	0.25	6 - Hour	2	453
Cemetery Wash	9.17	24 - Hour	21	8089
Wash Q	0.38	6 - Hour	2	705
Phase 2 Washes East				
Amir Wash Watershed	2.18	24 - Hour	7	1827
Wash P	0.85	6 - Hour	3	1239
Blue Tank Wash	10.89	24 - Hour	5	4899
Wash N	0.34	6 - Hour	2	865
Powder House Wash Watershed	1.95	24 - Hour	6	2652
Wash AF	0.31	6 - Hour	2	881
Calmity Wash	4.28	24 - Hour	4	3544
Phase 3 Washes West				
Sols Wash Tributary	1.23	6 - Hour	3	984
Sols Wash Tributary AH2	8.96	24 - Hour	11	4395
Sols Wash Tributary AH3	7.16	24 - Hour	9	3395
Sols Wash Tributary AH4	0.94	6 - Hour	1	1254
Sols Wash Tributary AH5	2.76	24 - Hour	3	2613
Turtleback Wash	9.17	24 - Hour	6	5601
Vulture Mountain Wash 1	1.40	6 - Hour	3	1729
Vulture Mountain Wash 2	1.56	6 - Hour	2	1765

Table 1: Watershed Properties (Continued)

Wash Name	Watershed Area (sq mi)	Duration of Storm for Max Q	Number of Subbasins	Max Q (cfs)
Vulture Mountain Wash 3	3.61	24 - Hour	4	3636
Vulture Mountain Wash 4	2.68	6 - Hour	3	2523
Hassayampa Tributary West 1	0.24	6 - Hour	1	624
Hassayampa Tributary West 2	0.63	6 - Hour	1	1165
Hassayampa Tributary West 3	0.68	24 - Hour	1	1004
Hassayampa Tributary West 4	0.48	6 - Hour	1	1056
Hassayampa Tributary West 5	1.31	6 - Hour	1	1771
Hassayampa Tributary West 6	0.24	6 - Hour	1	656
Hassayampa Tributary West 7	0.11	6 - Hour	1	330
Hassayampa Tributary West 8	0.47	6 - Hour	1	962
Hassayampa Tributary West 9	0.21	6 - Hour	1	490
Hassayampa Tributary West 10	0.67	6 - Hour	1	1100
Phase 3 Washes East				
Wash O	2.94	24 - Hour	3	2412
Mockingbird Wash	6.50	24 - Hour	10	5482
Wash M	0.32	6 - Hour	1	679
Wash L	0.80	6 - Hour	1	1072
Wash K	3.08	24 - Hour	4	2988
Wash J	0.41	6 - Hour	1	721
Wash I	2.31	24 - Hour	3	2139
Monarch	10.65	24 - Hour	10	5357
Wash H	1.76	6 - Hour	1	1480
Wash G	0.41	6 - Hour	1	620
Wash F	0.26	6 - Hour	1	577
HT07	0.89	6 - Hour	1	1063
San Domingo	20.49	24 - Hour	19	8993
Ox Wash	8.47	24 - Hour	9	5734
Little San Domingo Wash	8.76	24 - Hour	13	4456

** Flow includes Sunnycove Wash*

*** Flow includes Twin Peaks Wash*

**** Flow reduced by dam upstream*

2 MAPPING AND SURVEY

2.1 Aerial Mapping

The Wickenburg Mapping project (FCD 03-66), produced 2-foot and 4-foot contour interval mapping (Ref. 7) with a vertical datum of NAVD88 and projected on the State Plane Arizona Central (NAD83). This mapping did not include the southern portions of Little San Domingo Wash, therefore, new 2-foot contour interval mapping was prepared under this study for this area (Ref.8) Aerial photography, with a pixel resolution of 0.8-foot and a pixel depth of 8-bit (Ref. 9), was flown in between 2007 and 2010.

2.2 Survey

Aerial topographic mapping was supplemented with field survey of major existing drainage and embankment structures. All structures surveyed are documented in the Phase 1, 2 and 3 Survey Reports (Refs. 21-23). Control Points were provided by the National Geodetic Survey, via the Maricopa County Department of Transportation (MCDOT) website.

Surveys of the impoundment areas behind Sunset, Sunnycove and Casandro Dams were performed by the District in 2010 and provided for this study (Refs. 12 & 16). Dam storage volumes were computed using the field and aerial topographic mapping and compared (Appendix C). The results were similar and therefore, the 2004 aerial mapping was selected for all computations.

3 METHODOLOGY

Hydrologic analyses were performed using the US Army Corps of Engineer's computer program HEC-1, Version 4.1, Flood Hydrograph Package in accordance with procedures and parameters recommended in the District's *Drainage Design Manual for Maricopa County, Volume I, Hydrology* (Ref. 4). Hydrologic Models completed for each watershed include:

- 500-year; 6-hour and 24-hour Existing Condition
- 100-year; 6-hour and 24-hour Existing Condition
- 100-year; 6-hour and 24-hour Future Condition
- 50-year; 6-hour and 24-hour Existing Condition
- 10-year; 6-hour and 24-hour Existing Condition

Each model uses the Green and Ampt methodology to estimate rainfall losses. Most basins are located within the upper, mountainous reaches and thus used the Phoenix Mountain S-graph for the unit hydrograph. Basins in the in the lower, flatter areas of the northeastern watersheds of Phase 3 used the Desert/Rangeland S-graph. Flow is routed using the Normal Depth routing option and ponding and storage is modeled for the dams and culvert backups using level pool reservoir routing. The watershed sub-basins and the flow routing schematic for the runoff model are shown on Exhibits 1-6.

The 6-hour and 24-hour peak discharges were computed for each wash and the highest discharges was selected as summarized in Table 1.

The 250-year model was created for Casandro Dam and was used along with the 500-year storms to model the emergency spillway overflow from Casandro Dam. The 500-year storm was used to model the emergency spillway overflow from the Sunset and the Sunnycove Dams.

4 WATERSHED

4.1 Drainage Area Boundary

The watershed basin and sub-basin boundaries are shown on Exhibits 1-6 and Exhibits 7.A1 thru F2, along with a schematic of the HEC-1 sub-basins and routings. Flow concentration points were placed at the natural confluence of tributaries, split flow locations, and where manmade drainage facilities or structures appeared likely to affect flow characteristics. Concentration points were also

located at existing developments that have been, or could be impacted by flooding. The total number of sub-basins used for each wash and watershed areas are summarized in Table 1 (Page 8).

Washes with dams are partially impounded, reducing the contributing area used in the modeling downstream of the dams.. The combined un-impounded watershed for Sunset and Sunnycove watersheds is 2.5 square miles and for Casandro Wash is 1.66 square miles at the confluence with the Hassayampa River. The watershed contributing areas used in the modeling are summarized in Table 1.

4.2 Watershed Work Maps

4.2.1 Watershed Map

An ArcGIS terrain model, created from the 2004 topographic mapping, was used to delineate the watershed basin and sub-basin boundaries. Adjustments were made to the basin boundaries, as necessary, based on aerial photography and field observations. The resulting boundaries, overlaid on the 2004 and 2013 topographic map, are shown on the Routing Maps (Exhibits 7.A1 thru 7.F2).

Sub-basins are named after the main watershed. Subbasins outside of a main watershed are named as tributaries to Sols Wash or the Hassayampa River. The first two to three characters identify the wash and watershed that the sub-basin is located within (e.g. Basin HA1 is located within the Hartman watershed). The remaining characters are numeric values that start at the upstream end of the sub-basin and increase in the downstream direction.

Channel routes are identified by an "R" followed by the wash name initials and the downstream operation. Storage Routings are identified by the word "DAM" followed by the wash name initials. Diversions are identified by the word "DIV" followed by the wash name

initials and temporary stock tanks are identified by the word "TNK" followed by the wash name initials and tank number.

4.2.2 Soils Map

Detailed soils survey data from the Natural Resources Conservation Service (NRCS), formerly known as the Soil Conservation Services (SCS), was provided from the District's GIS database. The Soils Maps (Exhibits 8.A1 thru 7.F2) list the soil types within the WADMS study area.

4.2.3 Land Use Map – Existing Conditions

The Maricopa Association of Governments (MAG) landuse file (Ref. 10), prepared in 2009, represents the existing conditions land use. This file, which became effective in 2010, replaces the 2004 draft existing land use dataset. Since the 2010 dataset does not provide MAG land use codes that are readable within the DDMSW program, it was edited to incorporate the MAG land use codes from 2004. The 2009 dataset was further refined using aerial photography and field observation and the results presented on the Existing Land Use Maps (Exhibits 9.A1 thru 9.F2).

4.2.4 Land Use Map – Future Conditions

The Maricopa Association of Governments (MAG) future land use file (Ref. 11), prepared in 2007, was used to define future developments on vacant lands. The product is presented in the Future Land Use Maps (Exhibits 10.A1 thru 10.F2).

4.3 Gage Data

Phase 1

There are two impoundment and precipitation gages within the Phase 1 study area; one at Sunset Dam and the other at Sunnycove Dam, both maintained by the District. Both gages have 21 years of records.

Phase 2

There are four streamflow and rainfall gage stations within the Phase 2 study area. Three stations along US 60 have record flows for Hartman Wash, Flying E Wash and Casandro Wash since 1994. A streamflow and rainfall gage station at Vulture Mine Road and South Casandro Wash was erected in 2005 and has limited data. One impoundment and precipitation gage at Casandro Dam has been in service since 1996. There are three rainfall gage stations within the west study area; one at the Wickenburg Airport Station (since 1994), one at Flying E Tank Station (since 1995) and one along Twin Peaks (since 2003) though it has poor records. In the east study area, there is a streamflow gage station along Powder House wash (since 1995), and a rainfall gage station northeast of US 60 and US 93 (since 1994).

Phase 3

There are two rainfall gage stations within Phase 3; one near Little San Domingo Wash (since 1992) and the other north of Sols Wash Tributary AH3 and US 60 (since 1994).

All gages are maintained by the District and their rainfall and impoundment data are available on the District's website. Calibration of hydrologic models was not within the scope of this study.

4.4 Statistical Parameters

It was beyond the scope of this study to perform a statistical analysis for washes with gage data. The runoff models are compared with those from the WADMS-94 (see Table 2). Further

comparison was also made with the results from USGS and regional regression equations (see Section 8.2 and Appendix D).

5 HYDROLOGY MODELING INPUT

5.1 Precipitation

The District has adopted the Mean Partial Duration Time Series point precipitation values from NOAA Atlas 14 (Ref. 26). This has resulted in a decrease in precipitation values for most of Maricopa County, however for the ADMS watershed, the precipitation values have increased by approximately ten percent.

Isopluvial maps of rainfall intensities published in the NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 1, Arizona (Ref. 26) were used for this study. DDMSW was used to develop hydrologic models for the 10, 50, and 100-year events using the District's rainfall data that is embedded within. Since DDMSW does not include the 500-year rainfall intensities, the precipitations for the 500-year event were developed using NOAA 14 table and graphs. The information was obtained from the NOAA website (http://hdsc.nws.noaa.gov/hdsc/pfds/sa/az_pfds.html) based on the geographic coordinates of the centroids of the study areas. The precipitation tables and graphs are provided in Appendix A.

This study compares the peak discharge results from the 6- and 24-hour storm events for the 10-, 50-, 100- and 500-year storm events. Typically, the 6-hour storm distribution is used for drainage areas less than 20-square miles with the option of checking the 24-hour storm for a higher discharge. (Ref. 5). The Maricopa County 6-hour local storm distributions consist of five dimensionless storm patterns, as shown in Table 2.4 of the *Hydrology Manual* (Ref. 4). Pattern 1 has the greatest peak rainfall intensities that can be expected in the eye of a local storm, and is applied to drainage areas

less than 0.5 square miles. Pattern 2, 3, 4 and 5 have less concentrated peaks and are applicable to larger watersheds. For each concentration point or sub-basin in the HEC-1 model, the 6-hour rainfall distribution was interpolated from these five patterns.

The SCS Type II distribution is used to model the 24-hour duration storm event. For watersheds up to 100-square miles, it is compared with the 6-hour peak discharges to determine the larger peak discharge. This distribution is encoded in the DDMSW software and is listed in Table 5 of the District's *Hydrology Manual* (Ref. 4). An areal reduction is applied using the JD record option of HEC-1 and is based on the curves presented in, Table 2.1 and 2.2 of the *Hydrology Manual* (Ref. 4). The DDMSW program has these curves embedded in it.

5.2 Soils and Land Use

As noted in Section 5.2, detailed digital soil survey data is available from the NRCS. The soil maps and data for the Wickenburg ADMS were compiled from this source, as provided by the District.

As previously noted, the existing 2010 land use dataset developed by MAG was refined for use in the hydrologic analysis. There are 68 different MAG land use categories that do not directly correlate to the 17 shown in Table 4.2 of the District's *Hydrology Manual* (Ref. 4). Since the DDMSW program provides Green and Ampt parameters for each MAG land use category, these were used instead of Table 4.2.

The soil texture and land use data provide information regarding rainfall infiltration, which is discussed in the next section.

5.3 Rainfall Losses – Green-Ampt Infiltration

Two phases were used to apply the Green-Ampt infiltration equation to calculate rainfall losses. The first phase of surface retention loss is represented by a parameter called initial abstraction (IA) in

HEC-1 which is a function of land use. The DDMSW program provides initial abstraction values for each category of land use.

The second phase simulates the infiltration of rainfall into soil. The Green-Ampt equation, which is represented as follows, takes into account the soil suction head, porosity, hydraulic conductivity and time.

$$f = XKSAT\left(1 + \frac{PSIF \cdot DTHETA}{F}\right)$$

$$f = \frac{dF}{dt}$$

where f = infiltration rate (inches/hour)

XKSAT=saturated hydraulic conductivity (inches/hour)

PSIF=wetting front capillary suction (inches)

DTHETA=soil moisture deficit, pre-condition

F=accumulated infiltration depth (inches)

The saturated hydraulic conductivity (XKSAT) for bare ground conditions varies with soil texture. The DDMSW program provides this parameter for each soil texture and adjusts it according to vegetation cover and land use to calculate the average XKSAT for each sub-basin. The wetting front capillary suction (PSIF) is also a function of soil texture and decreases with XKSAT. The DDMSW program calculates the PSIF from XKSAT based on the relationship depicted in Figure 4.3 of the District's Hydrology Manual (Ref. 4). The soil moisture deficit (DTHETA) is a function of land use. The DDMSW program provides a default DTHETA value for each land use type. However, based on the observation of the aerial photographs, some land use types within the study area exhibit different soil moisture deficits from these default values. Adjustments were made by adding new land use categories with reasonable DTHETA values. These new categories could be found in Appendix B.

Within the impervious area of a sub-basin, no infiltration occurs. A default percentage of impervious area (RTIMP) for each land use type is provided in the DDMSW program. However, some land use types within the study area exhibit different impervious percentages from these default values. Adjustments were made by adding new land use categories with reasonable RTIMP values (Appendix B).

5.4 Unit Hydrograph – S-Graphs

The four S-graphs appropriate for use within Maricopa County are Phoenix Mountain, Phoenix Valley, Desert/Rangeland, and Agricultural S-graphs. Given the terrain of the study area, the Phoenix Mountain S-graph was selected to generate the unit hydrographs for most sub-basins. The Phoenix Desert-Rangeland S-graph was selected for flatter portions of the northeastern part of Phase 3 as it better represented the terrain. The lag time is required to obtain the unit hydrograph from the S-graph.

The lag time was calculated per the District's Hydrology Manual using the following equation:

$$Lag = 24K_n\left(\frac{L \cdot Lca}{S^{0.5}}\right)^{0.38}$$

where,

Lag=basin lag in hours

Kn = mean Manning's n for channels within the basin

L= length of the longest watercourse in miles

Lca=length along the watercourse to a point opposite the centroid in miles

S=watercourse slope in feet per mile

The DDMSW program calculates the Kn for the drainage basins based on the land use types within the sub-basin. The Kn values added to the DDMSW program were estimated using aerial photography and terrain mapping.

The longest watercourses for each sub-basin were traced using the terrain model produced from the 2004 and 2013 mapping. Lca values for all sub-basins were calculated by identifying their centroids. The watercourse slopes were calculated using ArcGIS tools.

5.5 Reach Routing

The Normal Depth Routing Method was used for routing hydrographs within the WADMS. It is the preferred method for most applications in Maricopa County and can be used for natural and artificial channels, in both urbanized and non-urbanized watersheds. This method simulates attenuation due to overbank storage.

NSTPS: A spreadsheet was prepared to estimate the time steps for the 100-year controlling storm event using the following equation:

$$NSTPS = \frac{Reach\ Length}{Celerity \times Time\ Step \times 60}$$

where,

NSTPS= time steps
Reach Length= reach routing length
Celerity= $\partial Q/\partial A$, for a rectangular channel it is 5/3 of normal velocity. This ratio is also used to estimate the celerity in the spreadsheet.
Time Step=3 (for smaller watershed) or 5 (for larger watershed) minutes

Calculated NSTPS were used except in locations of low slopes and long reach routes where the calculated result caused greater attenuation than appeared reasonable. In these cases, NSTPS were modified manually to reduce the attenuation. The resulting values are noted in the HEC-1 models and included in Appendix C.

NSTPS Tool version 1.0.0 from the District (Ref.6) was used to calculate NSTPs for all future conditions modeling. The program runs the HEC-1 model several times, until the NSTPS values converge. The program automatically generates a HEC-1 model containing the refined NSPS values.

Geometry: The channel cross-sections used for the routing are from field observations and the 2004/2013 terrain data. Typical channel cross-sections are identified in the Field Reconnaissance Notes (Ref. 17 thru 20), however, for more remote reaches, they were determined using the terrain data. A summary of the selected cross-sections and their corresponding descriptions are included in Appendix C.

Slopes and "n" Values: Longitudinal slopes and Manning's "n" values for the routing reaches were estimated based on the topographic mapping, aerial photographs, and field observations. Worksheets for "n" value calculations are located in the Field Reconnaissance Notes (Ref. 17 thru 20). These worksheets show tabulated reach routing parameters and cross-section sketches with "n" value estimations. The selected "n" values were not varied for each storm duration or for development conditions because the roughness for well-defined channels does not change appreciably with varying depths of flow. The tabulated reach routing parameters are included in Appendix C.

5.6 Storage Routing

Typically, the capacity of existing roadway culverts do not have capacity for the 100-year or even smaller flood events. In most cases the roadway crossings do not have much upstream storage capacity and, therefore, there is minimalized effect on the peak flows downstream. As a result, most roadway crossings were not modeled for storage routing in the HEC-1 models, and flow was assumed to continue downstream unimpeded, except as noted below.

The HEC-1 models include JD records so that the area-depth relationships are computed. These models do not calculate the water surface elevations for storage routings, therefore, a separate HEC-1 models were developed without the JD records, to route the hydrographs through the dams. The resulting hydrographs were retrieved through a DSS data file and used to determine the flood pool elevations of each storage area.

5.6.1 Casandro Flood Retarding Structure

Two data sources were available for developing the stage-storage relationship of Casandro Dam, the 2004 aerial mapping, and the 2009 volume survey conducted by the District. The stage-storage curves derived from these two data sources are very similar (Appendix C), however, since the 2009 survey data only provides storage volumes below the Emergency Spillway crest, the stage-storage rating curve from the 2004 aerial mapping was selected.

Per the as-built construction plans (Ref. 13), the Principal Spillway of Casandro Dam is an outlet pipe controlled by a 16-inch diameter orifice with an invert of 2137.19-feet (NAVD 88). The 36-inch reinforced concrete pipe outlet pipe is 147-foot long at a slope of 0.0303-ft/ft. The outlet pipe crosses the dam and releases flow at the concrete Emergency Spillway. The Emergency Spillway is controlled by an ogee crest at an elevation of 2157.19-feet (NAVD 88) and was designed following the procedures in *Design of Small Dams* (Ref. 35).

In 2004, the District surveyed the dam. The crest of the Emergency Spillway was identified to be at an elevation of 2157.03-feet (NAVD 88), indicating a subsidence of 0.16 feet since the construction of the dam. To be consistent with the 2004 aerial mapping used for the stage-storage rating curve, the subsidence of 0.16-feet was applied to the spillway elevations on the as-built plans allowing for a 2004 condition stage-discharge rating curve. The calculations for the stage-discharge rating curve are provided in Appendix C.

5.6.2 Sunset and Sunnycove Flood Retarding Structures

The stage-storage relationships provided for both Sunnycove and Sunset Dams are derived from the 2004 topographic mapping. Construction plans for each dam and outflow

pipe are the basis for the stage-discharge relationship prepared in the SITES (Ref. 34) models (discussed in Section 5.8).

Per the construction plans (Ref. 28, 29, 30) and the structural reports (Ref. 24, 25), the Principal Spillway of each dam has an un-gated orifice, that allows the floodwaters above the sediment pool elevations to discharge into the outlet pipeline, and a gated orifice at the reservoir bottom to drain the sediment pool. The sediment pools are anticipated to be dry at the beginning of a rainfall. If at any time the low-stage orifice were to become clogged, the gated sediment pool drain could be opened.

According to the NRCS, Sunnycove Dam and Sunset Dam are classified as Class C structures. A Class C structures is defined as one where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

Sunset Dam

Sunset Dam was designed and constructed by the NRCS, formerly the Soil Conservation Services (SCS), to protect portions of the Town from flooding. The Dam is located within the Town on Sunset Wash, a tributary to the Hassayampa River, and was completed in April 1975.

The dam is an earth-fill structure with a crest length of 488-feet and a crest width of 14-feet. The embankment has an upstream slope of 3:1, a downstream slope of 2:1 and a height of 30.5-feet. The dam reservoir has a capacity of 80.53-acre-feet at the emergency spillway crest elevation of 2133.2-feet (NAVD88), as determined from the 2004 mapping data. It also provides 10.81-acre-feet of sediment storage for the 100-year life of the structure. The

dam reservoir does not have a permanent pool and is designed only to detain the 100-year runoff.

The Principal Spillway structure is an intake tower (two-way riser) attached with a perforated gate well. The flow into the intake tower is controlled by a 9-inch by 9-inch low stage orifice at elevation 2122.2-feet (NAVD88) and a high stage spillway weir at elevation 2133.2-feet. The orifice was designed to drawdown the 100-year reservoir pool in less than ten days to the sediment pool elevation of-2122.2 feet. The perforated gate well is a 60-inch corrigated metal Pipe (CMP) with its top flush with the sediment pool.

An 18-inch diameter gated orifice, at the reservoir bottom of 2113.5-feet, controls flow from the gate well into the intake tower and was designed to drain the sediment pool. The intake tower connects to a 30-inch outlet pipe. Discharge through the 30-inch pipe conduit enters the relief manhole immediately downstream of the toe of the dam and is then conveyed through a pipeline system, jointly used by Sunnycove Dam, to an outfall in the Hassayampa River approximately 1.5 miles downstream. Flow in excess of the pipeline capacity can leave the relief manhole and travel as surface flow.

The emergency spillway is a 40-feet wide, uncontrolled reinforced concrete structure constructed on top of the dam embankment with a crest elevation of 2133.2-feet. It consists of an entrance control structure, a straight chute and a stilling basin with baffle blocks. The emergency spillway conveys the runoff to a discharge point just downstream of the dam. The emergency spillway has a discharge capacity of 3,400 cfs and can pass 3,907 cfs of the PMF with 0.3-feet of freeboard (Ref. 25).

Sunnycove Dam

Sunnycove Dam was designed and constructed by the NRCS to protect the downstream areas of the Town. Construction of the dam was completed in September 1976.

The dam embankment is an earth-fill structure with a crest length of 714-feet, crest width of 14-feet, upstream slope of 3:1, downstream slope is 2:1 and a maximum height of 48.5-feet (Ref. 24).

The Principal Spillway structure is an intake tower (two-way riser) attached with a perforated gate well. The flow into the intake tower is controlled by an 8-inch by 8-inch low stage orifice at 2150.2-feet (NAVD88) and a high stage spillway weir at 2171.7-feet. The orifice was designed to drawdown the 100-year reservoir pool to the sediment pool elevation of 2150.2-feet in less than ten days (Ref. 24). The perforated gate well is a 60-inch CMP with its crown flush with the sediment pool at 2150.2-feet.

The 18-inch diameter gated orifice, at the reservoir bottom elevation of 2130.2 feet, controls flow from the gate well into the intake tower and was designed to drain the sediment pool. The intake tower connects to a 30-inch outlet pipe. Discharge through the 30-inch pipe conduit enters the relief manhole immediately downstream toe of the dam and is then conveyed through the same pipeline system as Sunset Dam to an outfall in the Hassayampa River. Any flow in excess of the pipeline capacity can exit the relief manhole and travel as surface flow.

The emergency spillway is a 100-feet wide uncontrolled earth-lined channel, which was constructed though a narrow ridge located 200-feet north of the abutment. The emergency spillway conveys the runoff to a discharge point several hundred feet below the

downstream toe of the dam. The emergency spillway has a discharge capacity of 6,300 cfs and can pass the PMF of 7709 cfs with 0.7-feet of freeboard (Ref. 24).

The dam reservoir capacity is 216.92-acre-feet at the emergency spillway crest elevation, calculated from the 2004 mapping data. In addition, it provides 19.28-acre-feet of sediment storage for the 100-year life of the structure. The dam reservoir does not have a permanent pool and is designed to detain the 100-year runoff. The principal spillway is designed to empty the accumulated 100-year runoff within ten days.

5.6.3 Flying E Railroad Crossing Storage Area

Flying E Wash crosses the Burlington Northern Santa Fe (BNSF) Railroad just upstream of its convergence with the Hassayampa River. This bridge structure does not have sufficient capacity for the 100-year 24-hour flow, and could cause upstream ponding in two areas. Ponding would initially occur at the bridge, spreading to the west and east. Once ponding reaches an elevation of 2141-feet, water would begin to spill to the east into a second ponding area and over the top of the railroad.

A second ponding area is created by inflow from the first ponding area, plus local flows, with an outflow through a 42-inch x 46-inch oval concrete pipe under the railroad. This pipe does not have capacity for the 100-year 24-hour flows, and overtopping will occur when ponding exceeds an elevation of 2127-feet.

The stage-storage relationships for both ponding areas were created using aerial topography supplemented with field survey along the top of the railroad. Weir and culvert capacity calculations were used to determine the outflow (Appendix C).

5.6.4 Flying E Wash Tank 1 & 2

Within the Flying E Wash Watershed, there are two man-made stock tanks that retain flow from the contributing watershed. The first storage area, located at the base of Yucca Flats Wash Reach 2, will hold approximately 24-acre-feet and overflows at an elevation of 2504-feet into Yucca Flat Wash. The second storage area (a.k.a. George's Tank), located at the base of Flying E Wash Reach 1, will contain approximately 68-acre-feet at an overflow elevation of 2452-feet. There is no primary discharge for the second tank, however, if the storage area fills, it will overflow northwest into Flying E Wash Tributary 3. Flying E Wash continues to the northeast of the tank eventually reconnecting with Tributary 3. Neither of these structures are FEMA certified and, therefore, cannot be assumed to remain intact during a major event. To understand the worst flooding scenario, two sets of HEC-1 models were created for the Flying E Watershed, one with and one without the tanks. The model that includes the tanks routes the overflow from the second storage area to the northwest, rather than along the natural channel. The model without the tanks routes the flow that would enter the second storage area through the natural water path to the northeast.

5.7 Flow Splits and Diversions

5.7.1 Sunset and Sunnycove Pipeline System

The Principal Spillways of Sunnycove and Sunset Dams connect to a pipeline system that outlets into Sunset Wash at the railroad, just upstream of the Hassayampa River. Information collected from the pipeline as-built plans (Ref. 30) is schematically depicted in Figure 3. A datum difference of +2.2 feet was added to the elevations on the as-built plans to convert from NGVD 29 to NAVD 88.

As shown on Figure 3, the two-way riser Principal Spillways, are connected to relief manholes immediately downstream of the dams through 30-inch conduits. Pipelines collect flow from the two relief manholes and then combine at a joint manhole, before releasing to an outlet manhole located at Sunset Wash south of the railroad.

The pipeline system is composed of pipes ranging in size from 15-inch to 30-inch in diameter. When the Principal Spillway outflow exceeds the capacity of the pipeline system, the excess flow is released at the relief manhole. The downstream pipe capacity was calculated by assuming the upstream ends of hydraulic grade lines are exactly at the crests of the two relief manholes. It is estimated that the pipeline capacities are 17.1 cfs for Sunset Dam and 19.5 cfs for Sunnycove Dam (Appendix C).

In the HEC-1 models, the capacity of the pipeline system is diverted to the confluence with the Hassayampa River using Kinematic Wave routing. The remaining flow, consisting of the combination of the excess flow from the relief manhole and the flow from the emergency spillway, was routed along the existing washes using Normal Depth Routing.

5.7.2 Casandro Wash Pipe System

The natural portion of Casandro Wash is intercepted at Navajo Street by two 48-inch which convey the flow to Sols Wash. These pipes have a capacity of 247 cfs whereas the 100-year 6-hour flow is 330 cfs. Excess flow crosses overland on Jackson and Mohave Streets before reaching Sols Wash (see Exhibit 7.C2 for location of pipes and flow split).

In the hydrology models, the flow conveyed by the pipeline system is diverted to its confluence with Sols Wash using Kinematic Wave routing while the overflow is routed along Jackson and Mohave Streets using Normal Depth Routing.

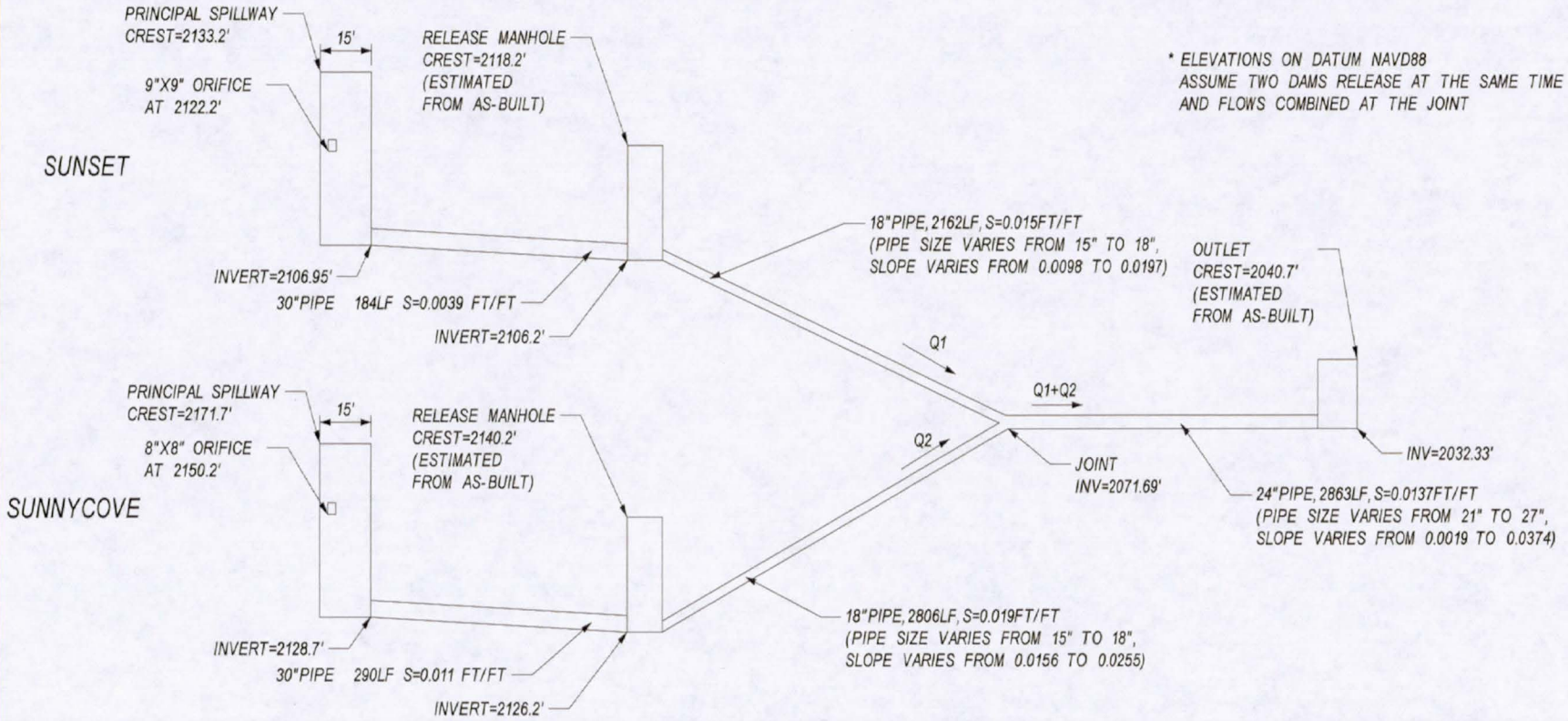

Figure 3 - Schematic of Sunset and Sunnycove Principal Spillways and Pipelines

5.8 SITES Model

The SITES Water Resource Site Analysis program (Ref. 34) was developed by NRCS to analyze the hydrology and hydraulics for design of NRCS dams and ponds. The program estimates watershed runoff using curve numbers, develops unit hydrographs based on the dimensionless curve documented in the National Engineering Handbook (NEH), Chapter 16 (Ref. 32) and analyzes the stability and integrity of emergency spillways. The program determines principal spillway rating curves by standard weir, orifice and pipe flow formulas documented in the NEH, Section 5 (Ref. 33). The program can also develop emergency spillway rating curves using one of four encoded methods (Ref. 34).

The riser hydraulics and stage-storage curves for Sunset and Sunnycove Dams were developed by the District using the SITES model. As the water surface elevation rises above the principle outlet structure, the friction of the 30-inch outlet conduit increases dramatically, controlling the outlet flows and the capacities of the principal spillways for Sunset and Sunnycove Dams. Detailed calculations simulated using the SITES models and were provided by the District.

6 SPECIAL PROBLEMS AND SOLUTIONS

No special problems or errors were encountered. The following are warnings identified in the HEC-1 models.

**** WARNING *** MODIFIED PULS ROUTING MAY BE NUMERICALLY UNSTABLE FOR OUTFLOWS BETWEEN 728 TO 4238. THE ROUTED HYDROGRAPH SHOULD BE EXAMINED FOR OSCILLATIONS OR OUTFLOWS GREATER THAN PEAK INFLOWS. THIS CAN BE CORRECTED BY DECREASING THE TIME INTERVAL OR INCREASING STORAGE (USE A LONGER REACH.)*

This warning occurs wherever Courant-Friedrichs-Levy (CFL)principle is not met within a specific range of outflows. The CFL principle is as follows:

$$C = \beta V \frac{\Delta t}{\Delta x} \leq Cmax \quad \textit{Where Cmax is usually} = 1$$

T = time step

X = length

V = velocity

C= Courant number

This principle insures that the relationship between the amount of change within the hydrograph and the timestep over which it is calculated is such that irregularities are not present in the resulting hydrograph. When this principle is not met, possible instabilities in the hydrograph could arise. In most locations, the computed outflow was not in the range of flows given in the warning. If the computed outflow was within this range, the output hydrograph was examined to ensure that irregularities were not present.

WARNING EXCESS AT PONDING LESS THAN ZERO FOR PERIOD. EXCESS SET TO ZERO

This warning occurs in subbasin calculations where the initial abstraction is greater than the initial rainfall depth, which can cause runoff to be less than zero. To avoid negative runoff, the model sets the runoff to zero at that timestep.

7 CALIBRATION

A lack of accurate discharge data for all of the washes prevented calibration of the hydrology models. Calibration was not included with the scope of this study.

8 RESULTS

8.1 Model Outputs – 100 Year Event

Hydrologic models were prepared for the 100-year, 6-hour and the 100-year, 24-hour storm events for the existing condition using the NOAA 14 precipitation results for each. The peak flow rates from the current study were compared with the peak rates from the WADMS-94.

Complete results of the hydrologic analysis, including the HEC-1 input and output files, are included on the CD. In general, the flow obtained is higher than the WADMS-94. Table 2 shows the increase in flow at selected concentration points. The increase in flow can be attributed to the increased precipitation from NOAA 14 in comparison with NOAA 2 and increased development in the area.

As expected, for smaller watersheds, such as Wash M or Sunnycove Watershed, the 6-hour storm produces the higher peak discharges, and is therefore recommended to be used for the floodplain delineations. For larger watersheds, like Hartman Watershed or Powder House Watershed, the 24-hour storm produces the higher peak discharges, and is therefore recommended to be used for the floodplain delineations.

Table 2. Peak Discharges – Current Study vs. WADMS-94

Location	WADMS-94 Study		Current Study				
			Existing Condition			Future Condition	
	CP	100-Year 24-Hour	CP	100-Year 6-Hour	100-Year 24-Hour	100-Year 6-Hour	100-Year 24-Hour
Sunset and Sunnycove Watershed							
Sunset and Sunnycove Washes							
Upstream of Sunset Dam	SAD2	740	SN1	927	777	929	779
Upstream of Sunnycove Dam	SAE10	1232	C3	1542	1454	1621	1530
Confluence at the Hassayampa River	CAD16	600	C7	1146	953	1147	954
Phase 2 Washes West							
Hartman Wash							
Confluence at Hartman Wash Tributary 1	CAI157	3395	C4	3601	4328	6730	7776
Confluence at Sols Wash	CAI171	3802	C8	4633	5398	9572	10710
Sols Wash Tributary 1S							
Confluence at Sols Wash	SAJ175	1058	ST4	1424	1354	2001	1858
Sols Wash Tributary 2S							
Confluence at Sols Wash	SAH125	840	ST1	988	907	1607	1450
Flying E Wash							
Confluence at Sols Wash	CAB211	7820	C19*	6961	8249	13145	15926
Yucca Flat Wash							
Confluence at Flying E Wash	N/A		C10*	3911	4347	8009	8528
Twin Peak Wash							
Confluence at Yucca Flat Wash	CAB186	2099	C4	2066	2158	4095	4019
Casandro Wash							
Casandro Wash South Branch	CS235**	386	C2	754	603	923	727
Upstream of Casandro Dam	DAMIN**	1265	C4	1637	1570	1946	1885
Confluence with Sols Wash	DAC242**	147	RRDET	326	279	361	308
Wash AG							
Confluence at the Hassayampa River	SAG2	272	AG1	452	354	466	363
Cemetery Wash							
DS of Confluence with Tributary R2	CR34	6308	C13	5844	6969	6436	7514
Confluence at the Hassayampa River	CR52	7251	C20	6643	7821	7221	8272
Wash Q							
Confluence at the Hassayampa River	SQ2	584	CQ1	843	705	921	762
Phase 2 Washes East							
Amir Wash Watershed							
Confluence at the Hassayampa River	SA	1500	C3	1699	1827	1932	1974

Table 2. Peak Discharges – Current Study vs. WADMS-94 (Continued)

Location	WADMS-94 Study		Current Study				
			Existing Condition			Future Condition	
	CP	100-Year 24-Hour	CP	100-Year 6-Hour	100-Year 24-Hour	100-Year 6-Hour	100-Year 24-Hour
Phase 2 Washes East *(Continued)*							
Wash P							
Confluence at the Hassayampa River	SP	898	PC2	1239	1146	1355	1251
Blue Tank Wash							
Confluence at the Hassayampa River	CC22	4071	BTC4	2863	4899	3906	6407
Wash N							
Confluence at the Hassayampa River	SN	429	NC1	865	708	971	788
Powder House Wash Watershed							
Confluence at the Hassayampa River	CAA17	2114	PHC4	2321	2652	2570	2868
Wash AF							
Confluence at the Hassayampa River	SAF	420	AFC1	881	718	939	762
Calamity Wash							
Confluence at the Hassayampa River	CB12	3098	CLC3	2757	3544	3137	3904
Sols Wash Tributaries							
Sols Wash Tributary							
Confluence at Sols Wash	N/A		C20	984	1013	1156	1796
Sols Wash Tributary AH2							
Confluence at Sols Wash	SAH65	6031	C9	4776	5075	8063	7793
Sols Wash Tributary AH3							
Confluence at Sols Wash	CAH96	4046	C16	3560	3577	6380	6730
Sols Wash Tributary AH4							
Confluence at Sols Wash	SAH100	907	ST32	1254	1212	2293	2135
Sols Wash Tributary AH5							
Confluence at Sols Wash	SAH120	2129	C18	2511	2613	3632	3571
Vulture Mountain and Turtleback Washes							
Turtleback Wash							
Confluence at the Hassayampa River	CW22	5180	T6	4872	5124	4934	5115
Vulture Mountain Wash 1							
Confluence at the Hassayampa River	N/A		V2	1988	1889	2105	1992
Vulture Mountain Wash 2							
Confluence at the Hassayampa River	N/A		V3	1949	1819	2065	1927
Vulture Mountain Wash 3							
Confluence at the Hassayampa River	N/A		V6	3730	3864	3870	4109

Table 2. Peak Discharges – Current Study vs. WADMS-94 (Continued)

Location	WADMS-94 Study		Current Study				
			Existing Condition			Future Condition	
	CP	100-Year 24-Hour	CP	100-Year 6-Hour	100-Year 24-Hour	100-Year 6-Hour	100-Year 24-Hour
Vulture Mountain and Turtleback Washes *(Continued)*							
Vulture Mountain Wash 4							
Confluence at the Hassayampa River	N/A		V8	2589	2612	2750	2685
Phase 3 Washes East							
Wash O							
Confluence at the Hassayampa River	SO	1995	CO3	2284	2412	2467	2745
Mockingbird Wash							
Confluence at the Hassayampa River	CE22	3459	CMB07	4282	5482	4458	5445
Wash M							
Confluence at the Hassayampa River	SM	390	M01	679	545	724	583
Wash L							
Confluence at the Hassayampa River	SL	802	L01	1072	931	1184	1035
Wash K							
Confluence at the Hassayampa River	CK17	2508	CK04	2803	2988	2998	3230
Wash J							
Confluence at the Hassayampa River	SJ	488	J01	721	581	793	635
Wash I							
Confluence at the Hassayampa River	CI17	1795	CI03	2097	2139	2204	2255
Monarch							
Confluence at the Hassayampa River	CD24	3832	CMW08	4236	5357	4270	5213
Wash H							
Confluence at the Hassayampa River	CH8	1631	H01	1480	1375	1659	1557
Wash G							
Confluence at the Hassayampa River	SG2	526	G01	620	493	696	553
Wash F							
Confluence at the Hassayampa River	SF2	345	F01	577	460	602	478
HT07							
Confluence at the Hassayampa River	N/A		HT07	1063	944	1177	1054
San Domingo							
Confluence at the Hassayampa River	CT30	12760	CSD10	8993	12949	9192	12492
Ox Wash							
Confluence at the Hassayampa River	CV24	4447	COX7	5213	5734	5588	6137

Table 2. Peak Discharges – Current Study vs. WADMS-94 (Continued)

Location	WADMS-94 Study		Current Study				
			Existing Condition			Future Condition	
	CP	100-Year 24-Hour	CP	100-Year 6-Hour	100-Year 24-Hour	100-Year 6-Hour	100-Year 24-Hour
Phase 3 Washes East *(Continued)*							
Little San Domingo Wash							
Confluence at the Hassayampa River	CS22	3403	CLS09	3943	4456	4301	4576

* Current study flows are from the models that do not include tanks TNKFE1 or TNKFE2

** Values from Casandro Wash LOMR (1996)

8.2 Verification of Results-

The District has adopted a chart to describe the general relationship between peak discharges and watershed size for Maricopa County based on USGS studies (Ref. 4). For this study, the estimated peak discharges were plotted on the charts adopted by the District for comparison. Figures 4.1 thru 19.4 contain the verification of results and are included in Appendix D.

The USGS regional regression figures include the Log-Pearson Type 3 (LP3) regression curve developed by USGS. The remaining figures include the curve developed from the Region 12 Regression Equation. The LP3 Regression, as shown in the Hydrology Manual, is a function of drainage area. The 75% Confidence Limits are taken from the data used to generate this LP3 Regression Curve. This data contains 314 continuous or partial record gage stations throughout Arizona and is provided in the Hydrology Manual. The Region 12 Regression Equations, as found in the Hydrology Manual, is a function of drainage area and elevation. Based on the terrain model, the average elevation for the project areas are listed below and were used in the regional regression calculations.

Watershed	Average Elevation (NAVD88)
Sols Wash Tributaries	2554.79'
Turtleback Watershed	2357.35'
Vulture Mountain Watersheds	2208.17'
Ph. 3 East Watersheds	2488.51'
Amir Wash Watershed	2252.51'
Ph. 2 East Watersheds	2377.95'
Wash Q	2200.00'
Cemetery Wash Watershed	2400.00'
Wash AG	2131.83'
Casandro Wash Watershed	2209.60'
Flying E Wash Watershed	2492.60'
Hartman Wash Watershed	3756.90'
Sunset & Sunnycove Watershed	2227.80'

Generally the HEC-1 outputs appear to be within the 75th percentile confidence limits when examining the USGS regression equations. For most watersheds, the HEC-1 output results are significantly higher than the regional regression results for the 10-year event, but are reasonably close for the 50-year and 100-year events (See Appendix D).

8.3 Flood Frequency Analysis

Streamflow gage stations are maintained by the District and their data is available on the District's website. Flood frequency analysis is not covered under the scope of this study.

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T8N R7W

T8N R6W

SOLS WASH

ST18
898 cfs

SOLS WASH TRIBUTARY AH2
UNNAMED TRIBUTARY

SOLS WASH TRIBUTARY AH 2

SOLS WASH TRIBUTARY AH2

ST19
998 cfs

ST21
414 cfs

ST17
1385 cfs

ST16
1623 cfs

ST20
1330 cfs

ST22
1368 cfs

C4
2004 cfs

C5A
3687 cfs

C5
2963 cfs

C6
4208 cfs

RC4C6
1912 cfs

R5AC6
3531 cfs

RC3C5
2691 cfs

BNSF Railroad

MATCH SHEET 11-A2

MATCH SHEET 11-B1

LEGEND

- Sols Wash Tributary AH4 Subbasins
- Sols Wash Tributary AH2 Subbasins
- Sols Wash Tributary AH3 Subbasins
- Sols Wash Tributary AH5 Subbasins
- Wash SWT Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Casandro Wash Subbasins
- Flying E Wash Subbasins
- Hartman Wash Subbasins
- Amir Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
- 2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

	A	B	C	D	E	F
1	11-A1	11-B1	11-C1	11-D1	11-E1	11-F1
2	11-A2	11-B2	11-C2	11-D2	11-E2	11-F2
3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

US60

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FLOW MAP
FIGURE 11-A1

MATCH SHEET 11-A1

T8N R7W
T7N R7W
T8N R6W
T7N R6W

SOLS WASH TRIBUTARY AH2

ST16
1623 cfs

RC3C5
2691 cfs

ST20
1330 cfs

C3
2866 cfs

C2
2463 cfs

ST14
1087 cfs

RC1C2
2213 cfs

ST15
836 cfs

C1
2403 cfs

ST26
1740 cfs

ST13
1433 cfs

ST12
1272 cfs

ST23
1106 cfs

US 60

MATCH SHEET 11-A3

MATCH SHEET 11-B2

LEGEND

- Sols Wash Tributary AH4 Subbasins
- Sols Wash Tributary AH2 Subbasins
- Sols Wash Tributary AH3 Subbasins
- Sols Wash Tributary AH5 Subbasins
- Wash SWT Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Casandro Wash Subbasins
- Flying E Wash Subbasins
- Hartman Wash Subbasins
- Amir Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
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- Township and Range
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- 11 — Section Line and ID
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3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-A2

MATCH SHEET 11-A2

MATCH SHEET 11-B3

LEGEND

- Sols Wash Tributary AH4 Subbasins
- Sols Wash Tributary AH2 Subbasins
- Sols Wash Tributary AH3 Subbasins
- Sols Wash Tributary AH5 Subbasins
- Wash SWT Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Casandro Wash Subbasins
- Flying E Wash Subbasins
- Hartman Wash Subbasins
- Amir Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
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0 500 1,000 2,000 Feet

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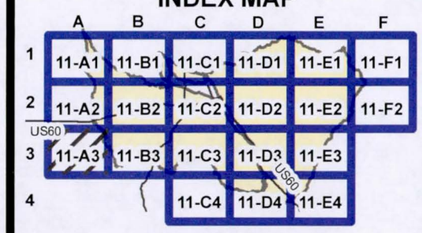
INDEX MAP



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FLOW MAP
FIGURE 11-A3

MATCH SHEET 11-A1

MATCH SHEET 11-C1

T8N R6W

T8N R5W

US 89

US 93

BNSF Railroad

SOLS WASH

SOLS WASH TRIBUTARY AH2

SOLS WASH TRIBUTARY AH3

SOLS WASH TRIBUTARY

ST21 414 cfs

ST20 330 cfs

RC6C7 4009 cfs

C7 4701 cfs

RC7C8 4685 cfs

C8 4823 cfs

RC8C9 4550 cfs

C9 5075 cfs

ST22 1368 cfs

ST20 1330 cfs

ST27 1258 cfs

R12C13 3133 cfs

C14 2130 cfs

C15 3685 cfs

C13 3348 cfs

ST30 955 cfs

R15C16 3518 cfs

C16 3577 cfs

ST37 782 cfs

ST38 104 cfs

C19 857 cfs

ST39 406 cfs

R19C20 875 cfs

MATCH SHEET 11-B2

LEGEND

- Sols Wash Tributary AH4 Subbasins
- Sols Wash Tributary AH2 Subbasins
- Sols Wash Tributary AH3 Subbasins
- Sols Wash Tributary AH5 Subbasins
- Wash SWT Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Casandro Wash Subbasins
- Flying E Wash Subbasins
- Hartman Wash Subbasins
- Amir Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
- 2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

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3	11_A3	11_B3	11_C3	11_D3	11_E3	
4			11_C4	11_D4	11_E4	

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FLOW MAP
FIGURE 11-B1

MATCH SHEET 11-B1

MATCH SHEET 11-A2

MATCH SHEET 11-C2

MATCH SHEET 11-B3

ST22 1368 cfs
ST30 955 cfs
T8N R6W
T8N R5W
C18 2613 cfs
BNSF Railroad
SOLS WASH
ST31 454 cfs
R12C13 3133 cfs
ST27 1258 cfs
T7N R6W
T7N R5W
C12 3214 cfs
ST29 1464 cfs
R28C14 984 cfs
ST33 424 cfs
ST2 148 cfs
ST32 1254 cfs
ST36 1398 cfs
R17C18 1738 cfs
ST3 481 cfs
ST1 988 cfs
SOLS WASH TRIBUTARY AH3 UNNAMED TRIBUTARY
SOLS WASH TRIBUTARY AH5
SOLS WASH TRIBUTARY AH3
HA10 984 cfs
RC7C8 5180 cfs
C7 5359 cfs
ST28 1236 cfs
C17 2254 cfs
ST4 1424 cfs
R11C12 2317 cfs
ST35 1326 cfs
RC6C7 4944 cfs
ST26 1740 cfs
C6 5226 cfs
HA9 1474 cfs
FE22 731 cfs
R34C17 1342 cfs
HARTMAN WASH
FE20 869 cfs
YUCCA FLAT WASH
C11 2627 cfs
US 60
HA8 1253 cfs
RC5C6 4573 cfs
C9 4315 cfs
RC9C10 4154 cfs
ST34 1464 cfs
C4 2158 cfs
FE11 633 cfs
C3 2110 cfs
C8 2853 cfs
FE18 705 cfs
TWIN PEAKS WASH
R10C11 1697 cfs
ST13 1433 cfs
RC3C4 2058 cfs
R11C14 74 cfs
R11C13 965 cfs
C5 4914 cfs
FE4 882 cfs
RC2C3 1848 cfs
FE5 966 cfs
FE19 789 cfs
ST25 1202 cfs
C2 2145 cfs
FE14 444 cfs
C10 1953 cfs
YUCCA FLAT WASH
FE10 1076 cfs
RC7C8 2278 cfs
FLYING 'E' WASH TRIBUTARY 3
C11 1024 cfs
FE17 970 cfs
ST23 1106 cfs
ST24 1121 cfs
HA7 1629 cfs
RC4C5 4043 cfs
FE3 840 cfs
RC1C2 1650 cfs
C7 2636 cfs
FE7 765 cfs
FLYING 'E' WASH
FE13 776 cfs

LEGEND

- Sols Wash Tributary AH4 Subbasins
- Sols Wash Tributary AH2 Subbasins
- Sols Wash Tributary AH3 Subbasins
- Sols Wash Tributary AH5 Subbasins
- Other Sols Wash Tributary Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Casandro Wash Subbasins
- Flying E Wash Subbasins
- Hartman Wash Subbasins
- Amir Wash Subbasins

FE3 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
C3 — Concentration Point
RC6C7 — Routing Reach ID
Routing Reach
Flow Path
Railroad
Township and Range
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3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
EXHIBIT 11-B2

MATCH SHEET 11-B2

MATCH SHEET 11-A3

MATCH SHEET 11-C3

HARTMAN WASH

HARTMAN WASH TRIBUTARY 2

HARTMAN WASH TRIBUTARY 1

TWIN PEAKS WASH

YUCCA FLAT WASH

YUCCA FLAT WASH TRIBUTARY 1

FLYING E WASH

HOLLY WASH

Vulture Mine Rd

T7N R6W

T7N R5W

T6N R6W

T6N R5W

HA1 1152 cfs

HA2 769 cfs

HA3 886 cfs

HA4 601 cfs

HA5 1489 cfs

HA6 1111 cfs

HA7 1629 cfs

ST23 1106 cfs

ST24 1121 cfs

ST25 1202 cfs

FE1 1342 cfs

FE2 1140 cfs

FE3 840 cfs

FE6 1424 cfs

FE7 765 cfs

FE8 1037 cfs

FE9 924 cfs

FE10 1076 cfs

FE12 724 cfs

FE13 776 cfs

FE15 669 cfs

FE16 615 cfs

FE17 970 cfs

FE19 789 cfs

CM1 1277 cfs

CM2 911 cfs

CM3 1085 cfs

CM6 1064 cfs

CM7 1169 cfs

C1 2237 cfs

C1 1893 cfs

C2 2293 cfs

C3 2103 cfs

C4 4328 cfs

C5 1429 cfs

C6 1478 cfs

C12 1142 cfs

RC1C2 1995 cfs

RC1C2 1650 cfs

RC2C3 1351 cfs

RFE1C1 1148 cfs

RFE6C5 1086 cfs

RFE8C6 780 cfs

R12C11 505 cfs

R15C12 607 cfs

LEGEND

- Sols Wash Tributary AH4 Subbasins
- Sols Wash Tributary AH2 Subbasins
- Sols Wash Tributary AH3 Subbasins
- Sols Wash Tributary AH5 Subbasins
- Wash SWT Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Casandro Wash Subbasins
- Flying E Wash Subbasins
- Hartman Wash Subbasins
- Amir Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
- 2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

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4			11-C4	11-D4	11-E4	

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FLOW MAP
EXHIBIT 11-B3

MATCH SHEET 11-B1

MATCH SHEET 11-D1

MATCH SHEET 11-C2

T8N R5W

T8N R4W

AMIR WASH

WASH P

BLUE TANK WASH

HASSAYAMPA RIVER

US 93

US60

AM01 826 cfs

AM21 453 cfs

AM07 430 cfs

AM31 201 cfs

AM11 446 cfs

AM04 1044 cfs

AM03 508 cfs

HT01 445 cfs

C20 1013 cfs

C1 1004 cfs

C2A 1041 cfs

C1A 805 cfs

C2 1415 cfs

C3 1827 cfs

RM1C1 803 cfs

RC1C2 887 cfs

RC2C3 1150 cfs

P01 991 cfs

P02 573 cfs

P03 325 cfs

PC1 1123 cfs

PC2 1239 cfs

RP1C1 951 cfs

RPC1C2 1113 cfs

BT04 1854 cfs

BTC3 4910 cfs

BT05 854 cfs

RBC2C3 3606 cfs

RBC3C4 4870 cfs

HT02 383 cfs

N02 366 cfs

N01 594 cfs

PH21 342 cfs

LEGEND

- Wash HT Subbasins
- Sunnycove Wash Subbasins
- Sunset Wash Subbasins
- Wash SWT Subbasins
- Amir Wash Subbasins
- Wash HA Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Wash AF Subbasins
- Blue Tank Wash Subbasins
- Calamity Wash Subbasins
- Wash HT Subbasins
- Wash N Subbasins
- Wash P Subbasins
- Powder House Wash Subbasins

FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)

C3 — Concentration Point

RC6C7 — Routing Reach ID

Routing Reach

Flow Path

Railroad

Township and Range

Streets

11 — Section Line and ID

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0 500 1,000 2,000 Feet

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3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-C1

MATCH SHEET 11-C1

MATCH SHEET 11-B2

MATCH SHEET 11-D2

MATCH SHEET 11-C3

AMIR WASH

BLUE TANK WASH

WASH N

POWDER HOUSE WASH

WASH AF

WASH Q

HARTMAN WASH

FLYING E WASH

SOLS WASH

CASSANDRO WASH

SUNSET WASH

CALAMITY WASH

YUCCA FLAT WASH

SUNNYCOVE WASH

CEMETERY WASH

HOLLY WASH

CEMETERY WASH TRIBUTARY R2

CEMETERY WASH TRIBUTARY R1

TURTLEBACK WASH

BNSF Railroad

US 93

US 60

Tegner St

Constellation Rd

Madison St

Vulture Mine Rd

HASSAYAMPA RIVER

T8N R4W

T8N R5W

T7N R5W

T7N R4W

AM04 1044 cfs

RC2C3 1150 cfs

HT02 383 cfs

BT05 854 cfs

BTC4 4899 cfs

RBC3C4 4870 cfs

N01 594 cfs

N02 366 cfs

HT03 153 cfs

PHC2 1527 cfs

PH03 260 cfs

RN1C1 541 cfs

PHC2C3 1494 cfs

PH04 1323 cfs

NC1 865 cfs

HT04 824 cfs

PH05 339 cfs

PHC3C4 2577 cfs

HT05 754 cfs

AF01 486 cfs

AF01C1 445 cfs

AF02 436 cfs

CL07 742 cfs

CLC2C3 3463 cfs

CLC3 3544 cfs

ST2 148 cfs

C8 5398 cfs

ST3 481 cfs

RC7C8 5180 cfs

HA10 984 cfs

ST5 193 cfs

R26C19 501 cfs

C19 8249 cfs

C19a 8209 cfs

C20 1954 cfs

FE26 530 cfs

ST6 234 cfs

ST4 1424 cfs

ST8 465 cfs

ST9 116 cfs

C6 251 cfs

C7 493 cfs

CA8 271 cfs

PHC4 2652 cfs

ST11 242 cfs

FE25 1040 cfs

R18C19 8064 cfs

GA6 318 cfs

C5 330 cfs

RC5C6 40 cfs

FE23 509 cfs

ST7 567 cfs

C4 1637 cfs

RCASC5 28 cfs

ST10 154 cfs

CA7 215 cfs

R101 1147 cfs

C8 384 cfs

C17 8008 cfs

C18a 8040 cfs

R17C18 7996 cfs

C18 8203 cfs

SN3 557 cfs

RC1C3 1046 cfs

CA5 399 cfs

RC3C4 1429 cfs

AFC1 881 cfs

FE22 731 cfs

C16 7563 cfs

C15 7026 cfs

C1 1080 cfs

C3 1560 cfs

C5 493 cfs

AG2 51 cfs

FE20 869 cfs

FE21 310 cfs

FE24 621 cfs

RCA1C1 772 cfs

CA4 437 cfs

SN1 927 cfs

SN2 493 cfs

SC6 326 cfs

C4 326 cfs

C10 4347 cfs

CA2 401 cfs

AG1 452 cfs

C20 7821 cfs

FE11 833 cfs

RCA3C2 380 cfs

FE19 789 cfs

FE18 705 cfs

CA1 773 cfs

CA3 406 cfs

SC5 372 cfs

SC4 663 cfs

CM21 766 cfs

R1920 7804 cfs

C19 7976 cfs

Q2 153 cfs

CQ1 843 cfs

R1819 7958 cfs

RQ2 148 cfs

C13 2546 cfs

R13C14 2355 cfs

C13a 1645 cfs

C14a 1084 cfs

SC2 288 cfs

C18 8089 cfs

C17 7587 cfs

CM20 755 cfs

Q1 740 cfs

CM18 943 cfs

R1617 7438 cfs

CM15 405 cfs

C16 7571 cfs

C14 6917 cfs

C15 980 cfs

RTB06 5009 cfs

T6 5124 cfs

TB6 804 cfs

T5 5044 cfs

T4 4709 cfs

SC3 427 cfs

C4 3057 cfs

C13 6969 cfs

C12 4047 cfs

RCM16 803 cfs

CM19 1064 cfs

TB5 1148 cfs

HTW01 626 cfs

SC1 1005 cfs

R12C13 973 cfs

RC3C4 2455 cfs

R1112 3864 cfs

CM17 433 cfs

CM5 1063 cfs

CM14 640 cfs

TB4 1395 cfs

RTB04 4062 cfs

TB2 1387 cfs

VM0103 802 cfs

LEGEND

- Wash HT Subbasins
- Sunnycove Wash Subbasins
- Sunset Wash Subbasins
- Amir Wash Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Wash AG Subbasins
- Casandro Wash Subbasins
- Flying E Wash Subbasin
- Hartman Wash Subbasins
- Wash AF Subbasins
- Blue Tank Wash Subbasins
- Calamity Wash Subbasins
- Wash N Subbasins
- Powder House Wash Subbasins
- Wash HTW Subbasins
- Turtleback Wash Subbasins
- Vultuure Mountain Wash Subbasins

FE3 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)

C3 — Concentration Point

RC6C7 — Routing Reach ID

Routing Reach

Flow Path

Railroad

Township and Range

Streets

11 — Section Line and ID

2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

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4			11-C4	11-D4	11-E4	

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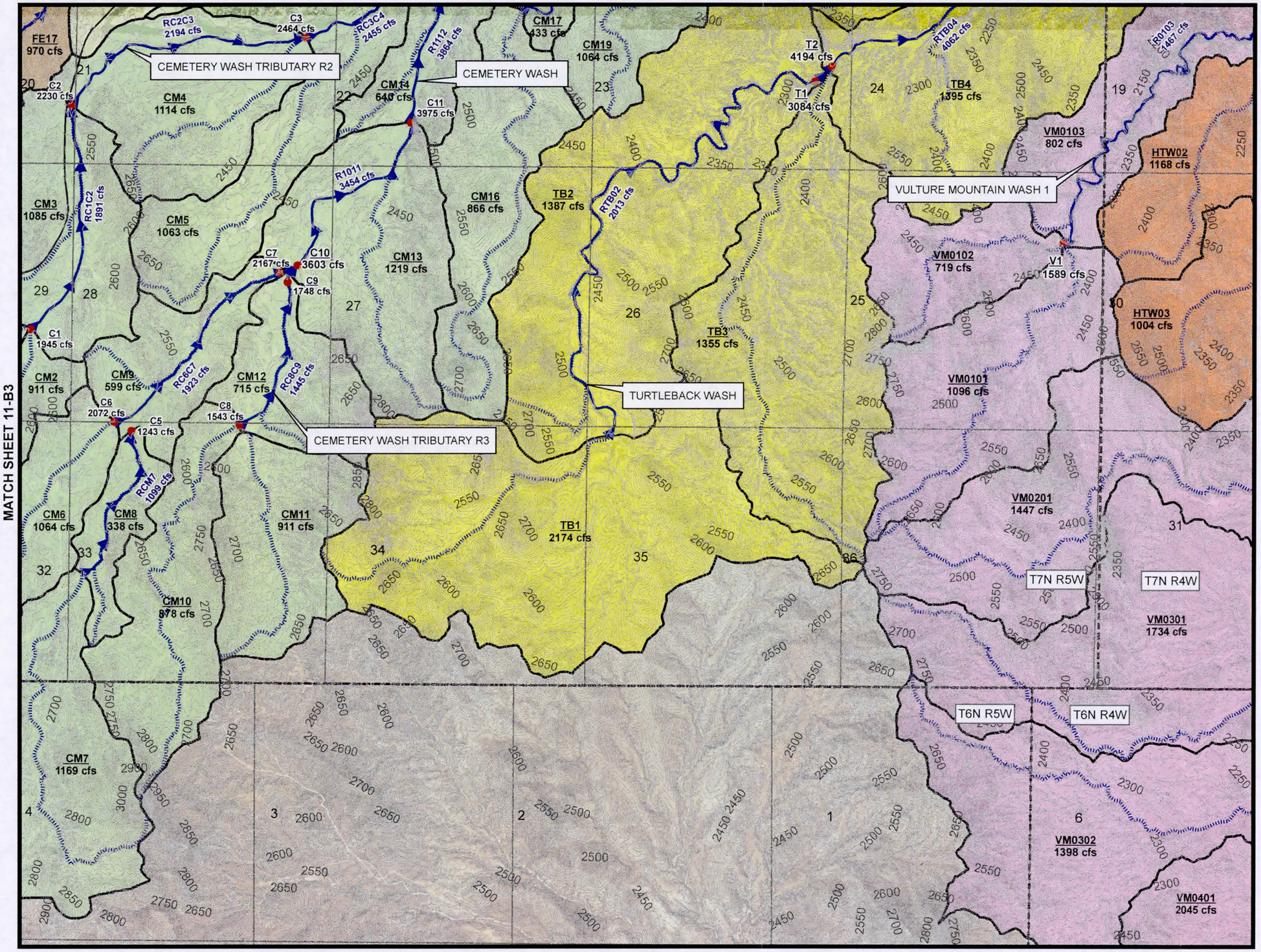
FLOW MAP
FIGURE 11-C2

MATCH SHEET 11-C2

MATCH SHEET 11-B3

MATCH SHEET 11-D3

MATCH SHEET 11-C4



LEGEND

- Wash HT Subbasins
- Sunnycove Wash Subbasins
- Sunset Wash Subbasins
- Wash SWT Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Flying E Wash Subbasins
- Wash HT Subbasins
- Wash N Subbasins
- Wash P Subbasins
- Powder House Wash Subbasins
- Wash HTW Subbasins
- Turtleback Wash Subbasins
- Vulture Mountain Wash Subbasins

FE3 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)

C3 — Concentration Point

RC6C7 — Routing Reach ID

Routing Reach

Flow Path

Railroad

Township and Range

Streets

11 — Section Line and ID

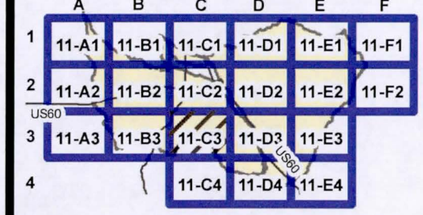
2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP



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FLOW MAP
FIGURE 11-C3

MATCH SHEET 11-C3

MATCH SHEET 11-B4

MATCH SHEET 11-D4

VM0302
1398 cfs

VM0401
2045 cfs

T6N R5W

T8N R6W

LEGEND

- Wash HT Subbasins
- Sunnycove Wash Subbasins
- Sunset Wash Subbasins
- Wash SWT Subbasins
- Cemetery Wash Subbasins
- Wash Q Subbasins
- Flying E Wash Subbasins
- Wash HT Subbasins
- Wash N Subbasins
- Wash P Subbasins
- Powder House Wash Subbasins
- Wash HTW Subbasins
- Turtleback Wash Subbasins
- Vulture Mountain Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
- 2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

	A	B	C	D	E	F
1	11-A1	11-B1	11-C1	11-D1	11-E1	11-F1
2	11-A2	11-B2	11-C2	11-D2	11-E2	11-F2
3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-C4

MATCH SHEET 11-C1

MATCH SHEET 11-E1

T8N R4W

BLUETANK WASH

CALAMITY WASH

MOCKINGBIRD WASH TRIBUTARY

BT03
1956 cfs

BTC2
3994 cfs

BT04
1854 cfs

RBC1C2
2379 cfs

RBC2C3
3606 cfs

CL01C1
910 cfs

CL01
1017 cfs

CL03
2126 cfs

CL05
1225 cfs

MB01
1899 cfs

MB02
793 cfs

MB03
1359 cfs

MB05
1189 cfs

RMB01
1768 cfs

CMB02
2233 cfs

CMB03
3477 cfs

MB21
749 cfs

MW04
836 cfs

O1
1257 cfs

O2
1014 cfs

P01
991 cfs

PH01
1143 cfs

PH04
1323 cfs

PH11
300 cfs

PH21
342 cfs

MATCH SHEET 11-D2

LEGEND

- WASH AF SUBBASINS
- BLUE TANK WASH SUBBASINS
- CALAMITY WASH SUBBASINS
- POWDER HOUSE WASH SUBBASINS
- WASH F SUBBASINS
- WASH G SUBBASINS
- WASH H SUBBASINS
- WASH I SUBBASINS
- WASH J SUBBASINS
- WASH K SUBBASINS
- WASH M SUBBASINS
- MOCKINGBIRD WASH SUBBASINS
- MONARCH WASH SUBBASINS
- WASH O SUBBASINS
- WASH P SUBBASINS
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
- 2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

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1	11-A1	11-B1	11-C1	11-D1	11-E1	11-F1
2	11-A2	11-B2	11-C2	11-D2	11-E2	11-F2
3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-D1

MATCH SHEET 11-D1

MATCH SHEET 11-C2

MATCH SHEET 11-E2

MATCH SHEET 11-D3

POWDERHOUSE WASH
CALAMITY WASH
WASH O
MOCKINGBIRD WASH
WASH K
MONARCH WASH TRIBUTARY
MONARCH WASH
WASH I
HASSAYAMPA RIVER
BNSF Railroad
US 60
Constellation Rd
T8N R4W
T7N R4W

PHC1 1324 cfs
PH01 1143 cfs
PH03 260 cfs
PH04 1323 cfs
CL03 2126 cfs
CL01C1 910 cfs
CLC1 2926 cfs
HT05 754 cfs
CL05 1225 cfs
O1 1257 cfs
AF01 486 cfs
CLC1C2 2834 cfs
O2 1014 cfs
MB21 749 cfs
CL07 742 cfs
CLC2C3 3463 cfs
C027 2118 cfs
MB06 836 cfs
O3 1215 cfs
HT01 449 cfs
RO2 1846 cfs
MB23 604 cfs
RMB21 699 cfs
MB22 849 cfs
HT02 549 cfs
C03 2412 cfs
CMB22 1052 cfs
CMB23 1492 cfs
HT03 452 cfs
RMB22 405 cfs
CMB05 4402 cfs
CMB07 5494 cfs
RMB06 4587 cfs
MB07 295 cfs
HT04 503 cfs
M01 679 cfs
L01 1072 cfs
HTW01 626 cfs
V2 1988 cfs
VM0103 802 cfs
J01 721 cfs
MB04 425 cfs
RMB02 3444 cfs
CMB04 3585 cfs
CMB05 4402 cfs
RMB04 4050 cfs
K02 1139 cfs
K03 614 cfs
RK01 1042 cfs
CK02 2291 cfs
CK03 1432 cfs
RK02 1786 cfs
K04 1461 cfs
I02 1313 cfs
RI01 1116 cfs
MB03 1359 cfs
MB05 1189 cfs
MW04 836 cfs
MW03 863 cfs
CMW04 1343 cfs
MW05 786 cfs
RMW03 1224 cfs
K01 1152 cfs
RMW01 1143 cfs
MW02 895 cfs
CMW05 3262 cfs
RMW02 2839 cfs
MW06 955 cfs
I01 1211 cfs
MW22 1228 cfs
RMW21 1179 cfs
SD43 1755 cfs
H01 1480 cfs
MW08 761 cfs

LEGEND

- Wash HT Subbasins
- Wash AF Subbasins
- Calamity Wash Subbasins
- Powder House Wash Subbasins
- Wash HTW Subbasins
- Vulture Mountain Wash Subbasins
- Wash H Subbasins
- Wash I Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Wash M Subbasins
- Mockingbird Wash Subbasins
- Monarch Wash Subbasins
- Wash O Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash HT Subbasin
- Wash L
- FE3 / 430 cfs / C3 — Subbasin ID / Subbasin 100-yr Q (cfs) / Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
- 2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

	A	B	C	D	E	F
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2	11-A2	11-B2	11-C2	11-D2	11-E2	11-F2
3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-D2

MATCH SHEET 11-D2

MATCH SHEET 11-C3

MATCH SHEET 11-E3

MATCH SHEET 11-D4

VM0103 882 cfs
L01 072 cfs
K04 1461 cfs
WASH K
US 60
RK02 1786 cfs
CK04 2988 cfs
J01 721 cfs
I02 1313 cfs
CI02 2096 cfs
RI01 1116 cfs
CMW09 3319 cfs
RMW02 2839 cfs
RMW21 1179 cfs
CMW06 5230 cfs
CMW22 1936 cfs
SD43 1755 cfs
RSD41 1483 cfs
HTW02 1168 cfs
VULTURE MOUNTAIN WASH 1
HASSAYAMPA RIVER
WASH I
RI02 2046 cfs
CSD41 2954 cfs
CSD08 12651 cfs
CSD08A 10780 cfs
HTW03 1004 cfs
I03 615 cfs
MW07 1176 cfs
RMW06 5144 cfs
MW08 761 cfs
CI03 2139 cfs
MONARCH WASH
SAN DOMINGO WASH
H01 1480 cfs
RSD33 10666 cfs
HT08 233 cfs
HTW04 1056 cfs
CMW07 5241 cfs
CMW08 5357 cfs
RMW08 754 cfs
VM0202 955 cfs
R0202 1411 cfs
V3 1949 cfs
HT310 459 cfs
SD09 1352 cfs
VULTURE MOUNTAIN WASH 2
VM0201 1447 cfs
BNSF Railroad
G01 620 cfs
HT07 1063 cfs
HTW05 1771 cfs
HT06 361 cfs
SD11 1069 cfs
RSD08 12273 cfs
VM0301 1734 cfs
T7N R4W
V4 2879 cfs
VULTURE MOUNTAIN WASH 3
HTW06 656 cfs
F01 577 cfs
OX4 1925 cfs
T6N R4W
SD10 1164 cfs
CSD11 12961 cfs
CSD09 12649 cfs
VM0302 1398 cfs
V5 3703 cfs
R0303 2789 cfs
VM0303 1804 cfs
RSD09 12926 cfs
V6 3864 cfs
VM0304 622 cfs
R0304 3662 cfs
OX5 1767 cfs
ROX1 2754 cfs
OX3 747 cfs
COX4 4624 cfs
CSD10 12949 cfs
OX WASH
VM0401 2045 cfs
HTW07 330 cfs
ROX4 4529 cfs
COX1 3319 cfs
OX21 1487 cfs
HTW08 962 cfs

LEGEND

- Wash HT Subbasins
- Powder House Wash Subbasins
- Wash HTW Subbasins
- Vulturte Mountain Wash Subbasins
- Wash H Subbasins
- Wash I Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Wash M Subbasins
- Monarch Wash Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash HT Subbasins
- Wash F Subbasins
- Wash G Subbasins
- Ox Wash Subbains
- Wash L

FE3 — Subbasin ID
430 cfs — Subbasin 100-yr Q (cfs)
C3 — Concentration Point
RC6C7 — Routing Reach ID
Routing Reach
Flow Path
Railroad
Township and Range
Streets
11 — Section Line and ID
2000 — Elevation in Feet

0 500 1,000 2,000 Feet
1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

	A	B	C	D	E	F
1	11-A1	11-B1	11-C1	11-D1	11-E1	11-F1
2	11-A2	11-B2	11-C2	11-D2	11-E2	11-F2
3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-D3

MATCH SHEET 11-D3

MATCH SHEET 11-C4

MATCH SHEET 11-E4

VM0303 1804 cfs
HTW08 962 cfs
VM0402 897 cfs
VM0401 2045 cfs
HTW09 490 cfs
HTW10 1100 cfs
V7 2377 cfs
VM0403 589 cfs
R0403 2341 cfs
V8 2612 cfs
VULTURE MOUNTAIN 4 WASH
HASSAYAMPA RIVER
BNSF Railroad
US 60
ROX4 4529 cfs
COX5 4722 cfs
OX5 1767 cfs
OX WASH
ROX5 4720 cfs
OX6 11 360 cfs
COX6 4726 cfs
ROX6 5733 cfs
COX22 5742 cfs
COX7 5734 cfs
QX7 273 cfs
OX22 904 cfs
1230 cfs
OX21 1487 cfs
LS21 791 cfs
LS11 486 cfs
LS22 787 cfs
RLS11 424 cfs
LITTLE SAN DOMINGO WASH
RLS21 723 cfs
LS12 378 cfs
LS08 1050 cfs
CLS12 595 cfs
CLS07 3314 cfs
CLS10 3466 cfs
RLS12 592 cfs
CLS22 4089 cfs
CLS08 3360 cfs
CLS06 3281 cfs
RLS22 4001 cfs
RLS07 3310 cfs
LS09 1163 cfs
RLS08 3356 cfs
CLS09 4456 cfs
HT319 532 cfs
T6N R4W

LEGEND

- Wash HT Subbasins
- Powder House Wash Subbasins
- Wash HTW Subbasins
- Vulturte Mountain Wash Subbasins
- Wash H Subbasins
- Wash I Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Wash M Subbasins
- Monarch Wash Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash HT Subbasins
- Wash F Subbasins
- Wash G Subbasins
- Ox Wash Subbains

FE3 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
C3 — Concentration Point
RC6C7 — Routing Reach ID
Routing Reach
Flow Path
Railroad
Township and Range
Streets
11 — Section Line and ID
2000 — Elevation in Feet

0 500 1,000 2,000 Feet
1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

	A	B	C	D	E	F
1	11-A1	11-B1	11-C1	11-D1	11-E1	11-F1
2	11-A2	11-B2	11-C2	11-D2	11-E2	11-F2
3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-D4

T8N R4W

T8N R3W

BLUE TANK WASH

MONARCH WASH

RBC1C2
2379 cfs

BT03
1956 cfs

BTC1
2405 cfs

RBT1C1
1653 cfs

BT02
1535 cfs

MB01
1899 cfs

BT01
1840 cfs

MB03
1359 cfs

MW04
836 cfs

MW03
863 cfs

MW01
1323 cfs

MW02
895 cfs

RMW01
1143 cfs

C20
1013 cfs

MW21
1410 cfs

SD21
1054 cfs

SD03
1224 cfs

SD01
821 cfs

SD02
1083 cfs

SD04
1656 cfs

CSD02
1531 cfs

MATCH SHEET 11-D1

MATCH SHEET 11-F1

MATCH SHEET 11-E2

LEGEND

- Wash HT Subbasins
- Blue Tank Wash Subbasins
- Powder House Wash Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Little San Domingo Wash Subbasins
- Wash M Subbasins
- Mockingbird Wash Subbasins
- Monarch Wash Subbasins
- Wash O Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash P Subbasins
- Ox Wash Subbasins

FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)

C3 — Concentration Point

RC6C7 — Routing Reach ID

Routing Reach

Flow Path

Railroad

Township and Range

Streets

11 — Section Line and ID

2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

	A	B	C	D	E	F
1	11-A1	11-B1	11-C1	11-D1	11-E1	11-F1
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3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-E1

MATCH SHEET 13-E1

MATCH SHEET 11-D2

MATCH SHEET 11-F2

MATCH SHEET 11-E3

MW03 863 cfs
MW05 786 cfs
MW02 895 cfs
MW06 955 cfs
MW22 1228 cfs
MW21 1410 cfs
SD21 1054 cfs
SD03 1224 cfs
SD04 1656 cfs
SD31 1801 cfs
SD22 1217 cfs
SD32 931 cfs
SD41 1111 cfs
SD05 1500 cfs
SD33 1263 cfs
SD06 1907 cfs
SD42 868 cfs
SD43 1755 cfs
SD07 1489 cfs
OX1 1618 cfs
LS01 1026 cfs
LS02 929 cfs
RMW01 1143 cfs
RMW21 1179 cfs
RSD01 1426 cfs
RSD21 986 cfs
RSD03 3910 cfs
RSD31 1495 cfs
RSD05 6916 cfs
RSD06 7731 cfs
RSD41 1483 cfs
CSD03 4164 cfs
CSD04 2984 cfs
CSD22 1919 cfs
CSD05 7137 cfs
CSD05A 5247 cfs
CSD06 8019 cfs
CSD42 1681 cfs
T8N R4W
T8N R3W
T7N R4W
T8N R6W
MONARCH WASH
SAN DOMINGO WASH

LEGEND

- Wash HT Subbasins
- Blue tank Wash Subbasins
- Powder House Wash Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Little San Domingo Wash Subbasins
- Wash M Subbasins
- Mockingbird Wash Subbasins
- Monarch Wash Subbasins
- Wash O Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash P Subbasins
- Ox Wash Subbasins

FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
C3 — Concentration Point
RC6C7 — Routing Reach ID
Routing Reach
Flow Path
Railroad
Township and Range
Streets
11 — Section Line and ID
2000 — Elevation in Feet

0 500 1,000 2,000 Feet
1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

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3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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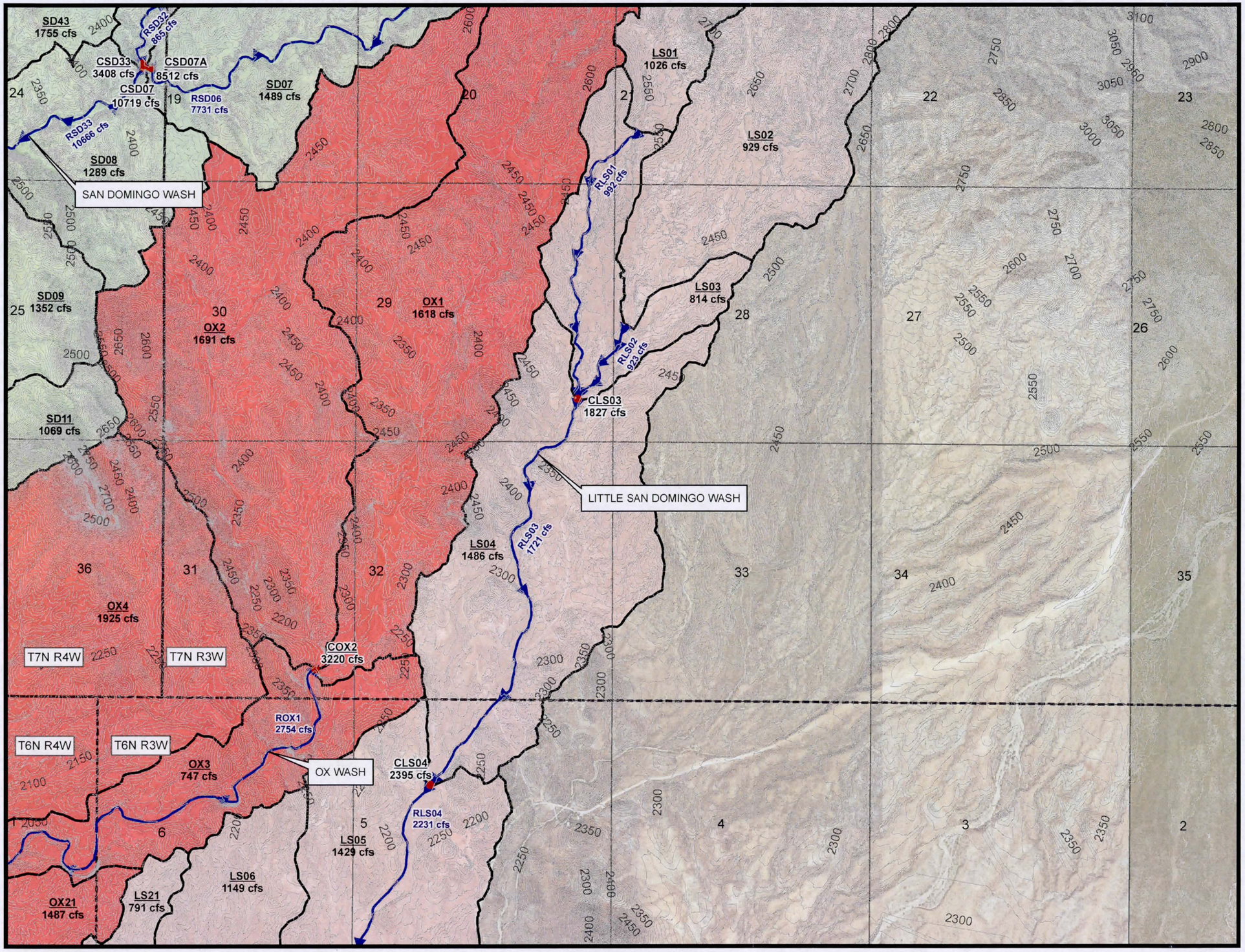
FLOW MAP
FIGURE 11-E2

MATCH SHEET 13-E2

MATCH SHEET 11-D3



MATCH SHEET 11-E4

LEGEND

- Wash HT Subbasins
- Blue Tank Wash Subbasins
- Powder House Wash Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Little San Domingo Wash Subbasins
- Wash M Subbasins
- Mockingbird Wash Subbasins
- Monarch Wash Subbasins
- Wash O Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash P Subbasins
- Ox Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
- 2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

	A	B	C	D	E	F
1	11-A1	11-B1	11-C1	11-D1	11-E1	11-F1
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3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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FLOW MAP
FIGURE 11-E3

MATCH SHEET 11-E3

MATCH SHEET 11-D4

QX21
1487 cfs

LS21
791 cfs

RLS04
2231 cfs

LS06
1149 cfs

LS05
1429 cfs

LS11
486 cfs

LS07
910 cfs

CLS05
2882 cfs

RLS06
1107 cfs

LITTLE SAN DOMINGO WASH

SR 74

US 60

BNSF Railroad

T6N R4W

T6N R3W

LEGEND

- Wash HT Subbasins
- Blue Tank Wash Subbasins
- Powder House Wash Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Little San Domingo Wash Subbasins
- Wash M Subbasins
- Mockingbird Wash Subbasins
- Monarch Wash Subbasins
- Wash O Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash P Subbasins
- Ox Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
- C3 — Concentration Point
- RC6C7 — Routing Reach ID
- Routing Reach
- Flow Path
- Railroad
- Township and Range
- Streets
- 11 — Section Line and ID
- 2000 — Elevation in Feet

0 500 1,000 2,000 Feet

1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

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3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

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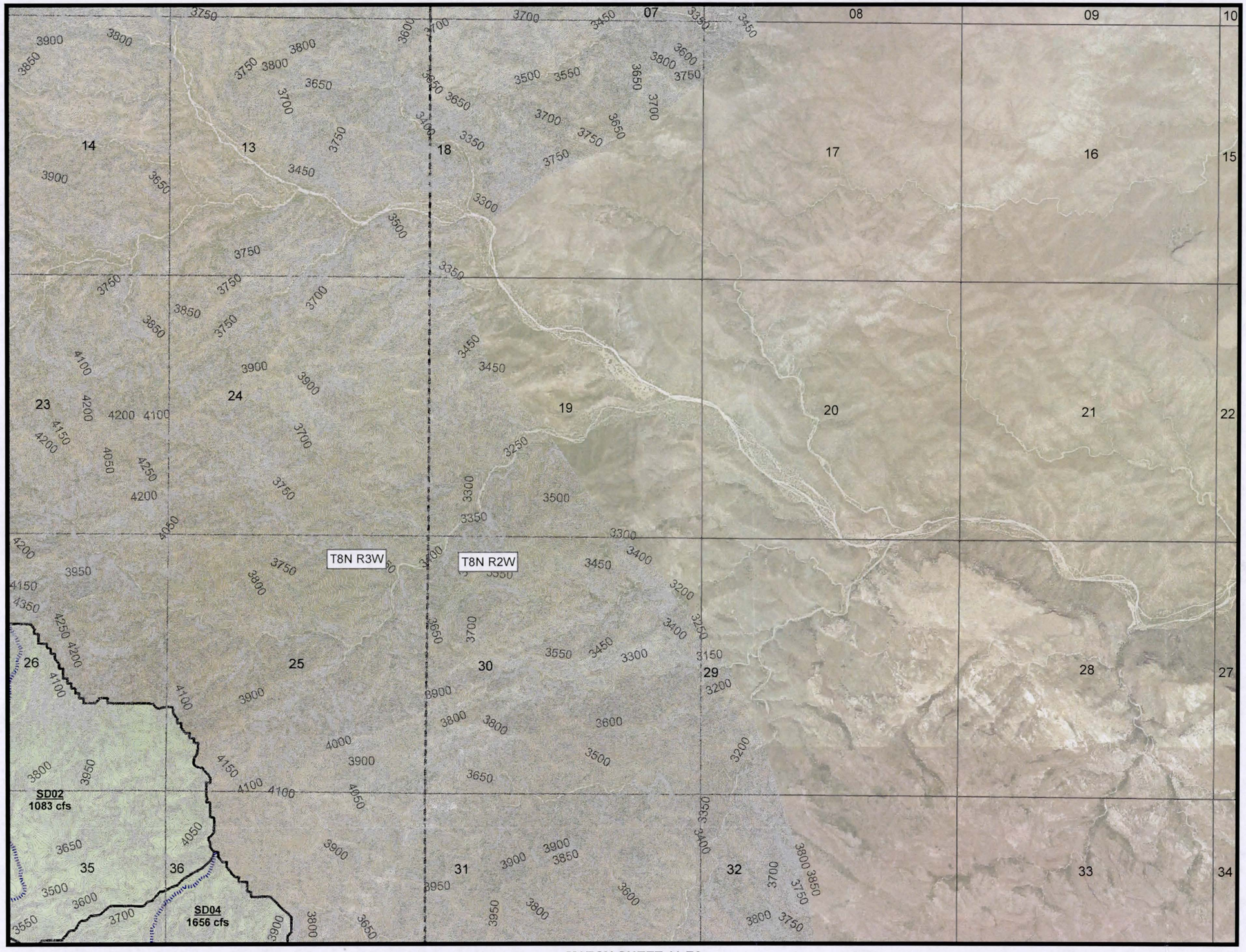
FLOW MAP
FIGURE 11-E4

MATCH SHEET 11-E1



MATCH SHEET 11-F2

LEGEND

- Wash HT Subbasins
- Blue Tank Wash Subbasins
- Powder House Wash Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Little San Domingo Wash Subbasins
- Wash M Subbasins
- Mockingbird Wash Subbasins
- Monarch Wash Subbasins
- Wash O Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash P Subbasins
- Ox Wash Subbasins

FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
C3 — Concentration Point
RC6C7 — Routing Reach ID
Routing Reach
Flow Path
Railroad
Township and Range
Streets
11 — Section Line and ID
2000 — Elevation in Feet

0 500 1,000 2,000 Feet
1 in = 2,000 ft

Note:
Flows correspond to the greater of the 100 Year-24 Hour or the 100 Year-6 Hour.

INDEX MAP

	A	B	C	D	E	F
1	11-A1	11-B1	11-C1	11-D1	11-E1	11-F1
2	11-A2	11-B2	11-C2	11-D2	11-E2	11-F2
3	11-A3	11-B3	11-C3	11-D3	11-E3	
4			11-C4	11-D4	11-E4	

US60

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

Hoskin • Ryan Consultants, Inc.
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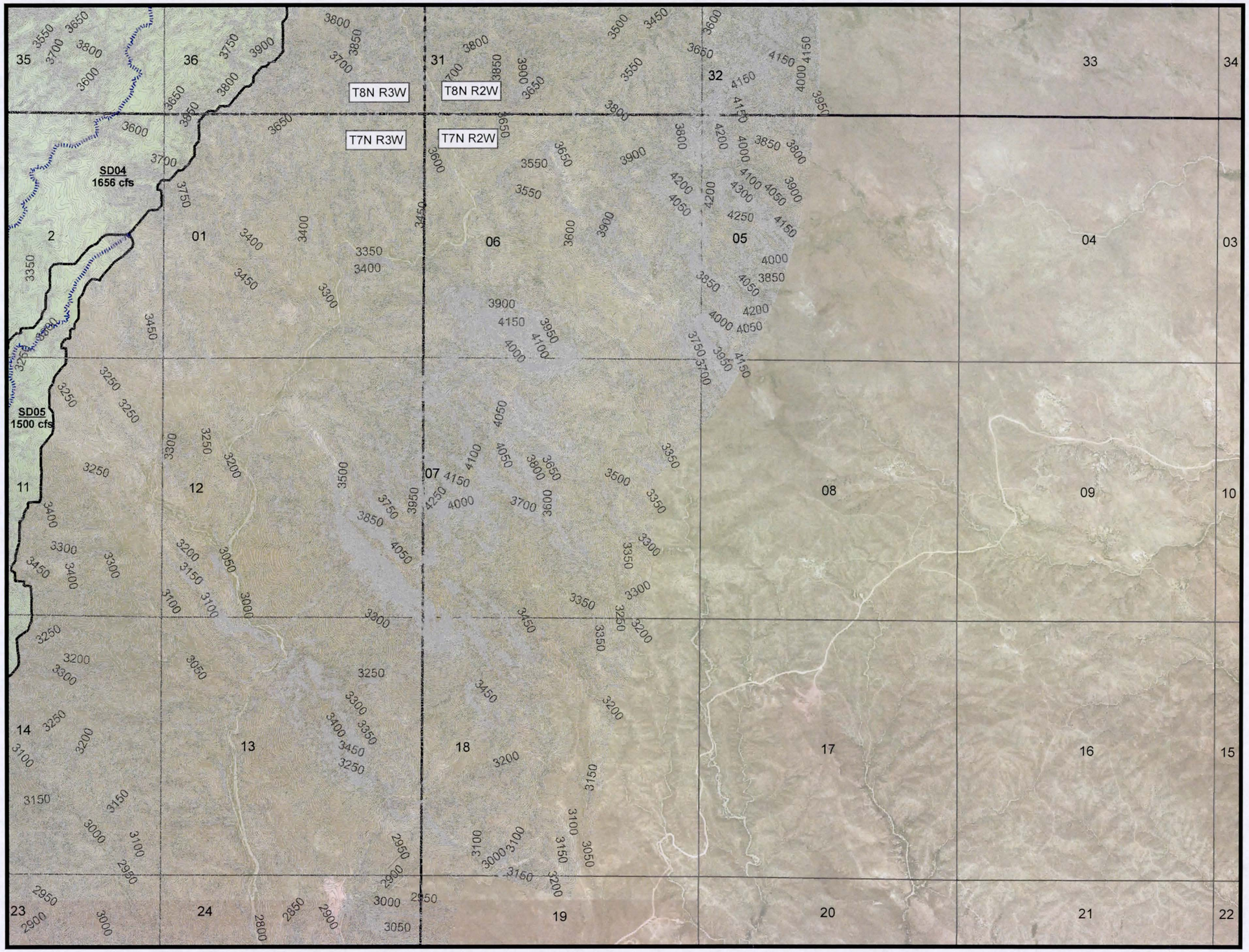
WICKENBURG
AREA DRAINAGE MASTER STUDY / PLAN

F.C.D. Contract No. 2009-C030

FLOW MAP
FIGURE 11-F1

MATCH SHEET 11-F1

MATCH SHEET 11-E2



LEGEND

- Wash HT Subbasins
- Blue Tank Wash Subbasins
- Powder House Wash Subbasins
- Wash J Subbasins
- Wash K Subbasins
- Little San Domingo Wash Subbasins
- Wash M Subbasins
- Mockingbird Wash Subbasins
- Monarch Wash Subbasins
- Wash O Subbasins
- San Domingo Wash Subbasins
- Vulture Mountain Wash Subbasins
- Wash P Subbasins
- Ox Wash Subbasins
- FE3 / 430 cfs — Subbasin ID / Subbasin 100-yr Q (cfs)
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0 500 1,000 2,000 Feet

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Note:
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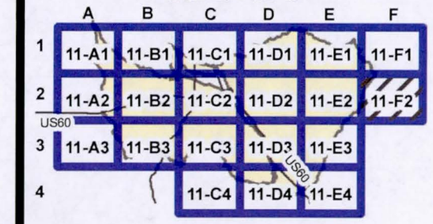
INDEX MAP



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FLOW MAP
FIGURE 11-F2