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ENGINEER | PLAN | SURVEY | MANAGE

HORSESHOE DRAW FLOOD CONTROL, RESTORATION AND EROSION MITIGATION STUDY AND DESIGN PROJECT

VOLUME 1

EXISTING CONDITIONS HYDROLOGIC STUDY

COCHISE COUNTY, ARIZONA

Prepared for:

Herford Natural Resource Conservation District
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April 2015
HilgartWilson Project No. 1472

DRAFT

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FINAL DRAINAGE REPORT
GATEWAY AT SONORAN PRESERVE

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1. INTRODUCTION

1.1. PURPOSE

The purpose of this study is to provide a hydrologic analysis for Horseshoe Draw (the Project), which is a tributary to the San Pedro River. Hydrologic analysis of the 100-year event has been prepared for the Project using HEC-HMS and will be used for future hydraulic analyses and the proposed flood control, restoration and erosion mitigation solution detailed below.

1.2. PROJECT LOCATION AND DESCRIPTION

The study area spans the border between the United States and Mexico roughly 7 miles west of Naco, Arizona/Sonora. The section of the study area located in the US lies within Township 24 South, Range 22 East of the Gila and Salt River Base and Meridian in Cochise County, Arizona. The Project's location is highlighted in the Vicinity Map in Appendix A, Figure 1.

This study has been prepared for the Herford Natural Resource Conservation District (NRCD), who has identified the need for a project which will reduce significant flooding, erosion and soil loss, as well as road and property damage in and adjacent to Horseshoe Draw. In order to complete such a project, the Herford NRCD reached out to the Arizona Department of Water Resources (ADWR) for funding. ADWR has reviewed the application and awarded the Hereford NRCD a grant through the Arizona Water Protection Fund Program. In turn, the Hereford NRCD contracted HILGARTWILSON for professional engineering services.

This study and corresponding report are the first in a series of reports under the cover of the awarded grant. The ultimate objective of these studies is the design and construction of a water impoundment structure which will mitigate flooding damage. This existing conditions hydrologic study will be used as the basis for subsequent tasks outlined within the grant. These future tasks include; hydraulic analyses, geotechnical investigation, sediment transport analysis, analysis of aquifer recharge potential, and final design. Financing for the final phase of the Project, construction, is not included in the grant.

1.3. FLOOD HAZARD IDENTIFICATION

As shown in Figure 2 of Appendix A, there is a Zone A floodplain associated with Horseshoe Draw, shown on FEMA Flood Insurance Rate Map 04003C2780F, dated August 28, 2008. Flood Zone A is defined as:

> "Areas subject to inundation by the 1-percent-annual-chance flood event generally determined using approximate methodologies. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply."

2. HYDROLOGY OVERVIEW

Horseshoe Draw conveys runoff from roughly 17 square miles of undeveloped rangeland to the San Pedro River. The watershed of the Project originates in the Sierra San Jose mountains in Mexico and extends to the confluence of Horseshoe Draw and the San Pedro River, located just south of Highway 92.

HEC-HMS was used for the hydrologic analysis of the Project. Due to the size of the watershed, both, the 100-year, 6-hour and 100-year, 24-hour storm events were modeled to compare flow rates. The methodology and design parameters utilized in the HEC-HMS hydrologic modeling of the Project are described herein.

3. WATERSHED DESCRIPTION

As mentioned above, the study area of the watershed for Horseshoe Draw extends from the Sierra San Jose Mountains in Sonora Mexico to Paloma Trail near the San Pedro River. The watershed was divided into 21 different sub basins. Sub basins were divided according to points of interest within the overall watershed, such as, junctions of the various wash branches. They were also separated at mountainous as low lying areas and were divided to be similar in area and flow path length.

Data for the delineation of the drainage sub basins was obtained from 2 sources. The first source was a flown topographical survey performed by Kenny Aerial Mapping in October, 2014. The second was a surface and corresponding image obtained from Google Earth. These sub basin boundaries are shown in the Hydrology Exhibit - Figure 2, Appendix A with further description of each sub basin included in Appendix B.

3.1. SOILS

Soil data and classifications for the site were gathered from the Natural Resources Conservation Services (NRCS) soil survey. The soil classifications found within the custom soil report for the area were used in in the HEC-HMS model while estimating infiltration losses. Excerpts from the soil report have been included in Appendix B.

Soils characteristics for the portion of the watershed located in Mexico were estimated using the FAO/UNESCO Soil Map of the World. The Soil Map of the World described the soils in this area to be, soils with strong accumulation of clay and not dark in color.

3.1.1. LOSS METHOD

Rainfall losses are a result of natural infiltration and surface retention. In the HEC-HMS modeling program, the SCS Curve Number loss method was used to estimate infiltration losses and determine sub basin runoff. The SCS Curve Number method is based off of several variables; these are soil type, which is used to estimate hydraulic conductivity, vegetation type and coverage, and the time of concentration within each sub basin. Curve numbers for the various sub basins were determined as follows.

- Sub basins 1-4: From the NRCS TR-55 Manual - Using Table 2-2d – Runoff Curve Numbers for Arid and Semiarid Rangelands. Assuming Pinyon-juniper cover type and estimating fair hydrologic condition vegetation coverage type

(30 to 70% ground cover). Soil Group C was chosen for these sub basins based from FAO/UNESCO soil data. Soil Group C represents soils with a low rate of water transmission. The curve number corresponding to the conditions above is 73.

- Sub basins 5-21: Also using Table 2-2d of the NRCS TR-55, but estimating herbaceous vegetation cover type and assuming poor coverage (less than 30%). The predominate soil group derived from the NRCS Soil Report for each sub basin (either B or C) is shown in the attached Sub Basin Summary Table included in Appendix B.

3.2. RAINFALL DATA

Site specific rainfall data for the Project was obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Hydrometeorological Design Studies Center. The 100-year, 6-hour and 100-year, 24-hour precipitation depths were used to compute peak flow rates in the HEC-HMS model.

The 6 and 24 hour rainfall distribution patterns were assigned to the precipitation depths based on rainfall data for the western United States. Precipitation values were entered into the HEC-HMS model at five minute intervals in order to match the time interval at which hydrograph values were calculated in the model. The five minute rainfall distribution table is included in Appendix D. Precipitation values between the percentages listed in the distribution table were interpolated.

3.3. TIME OF CONCENTRATION

In accordance with the HEC-HMS Technical Reference Manual, Equation 39 was used for determining the time of concentration within each sub basin; this is the, "Segmental Time of Concentration Method". This equation is written as;

$$t_c = t_{sheet} + t_{shallow} + t_{channel}$$

Where t_{sheet} equals the sum of travel time over sheet flow segments of the watershed land surface; $t_{shallow}$ equals the sum of travel time in shallow flow segments; and $t_{channel}$ equals the sum of travel time in channel segments. Time of concentration calculations for each sub basin are included in Appendix C.

The surface runoff calculations for each sub basin are performed by the transform method within the HEC-HMS program. In this case, the SCS Unit Hydrograph Transform method was chosen. This method uses the "lag time" of each sub basin in determining surface runoff. The standard lag is defined as, "the length of time between the centroid of precipitation mass and the peak flow of the resulting hydrograph". The Technical Reference Manual advises that lag time can be approximated by taking 60% of the time of concentration.

4. REACH ROUTING

Routing of hydrograph flows from one junction point to the next was accomplished using the Muskingum-Cunge routing method in HEC-HMS. This method was selected based on the routing slope as well as the guidelines set forth in Table 19 of the Technical Reference Manual. Inputs for the Muskingum-Cunge method include the following characteristics of the routing flow path:

- Length
- Slope
- Manning's n
- Channel Bottom Width
- Channel Side Slope

Manning's n values were applied based on general observations from aerial photography, and estimated to be 0.03 for all routing reaches. Lengths and slopes were calculated using CAD with the elevations based on the aforementioned flown topography and google earth surface. The routing channel side slopes were assumed to be 8:1 for all channels with the bottom width of each estimated using aerial imaging. A summary table of the routing data is included in Appendix B.

5. MODEL RESULTS

The 100-year, 6-hour model produced a flow rate of 13,356 CFS at the Paloma Trail wet crossing of Horseshoe Draw. The 100-year, 24-hour model returned a 12,604 CFS flow rate at this same point. At Junction-6, the likely location of the future impoundment structure, the calculated flow rates were 10,248 CFS and 10,285 CFS for the 6 and 24 hour models respectively. HEC-HMS model results have been included in Appendix E and electronic copies of the two models are also included on the CD included with this submittal. These results are to be used as a starting point for the future analyses and studies outlined in the water protection fund grant.

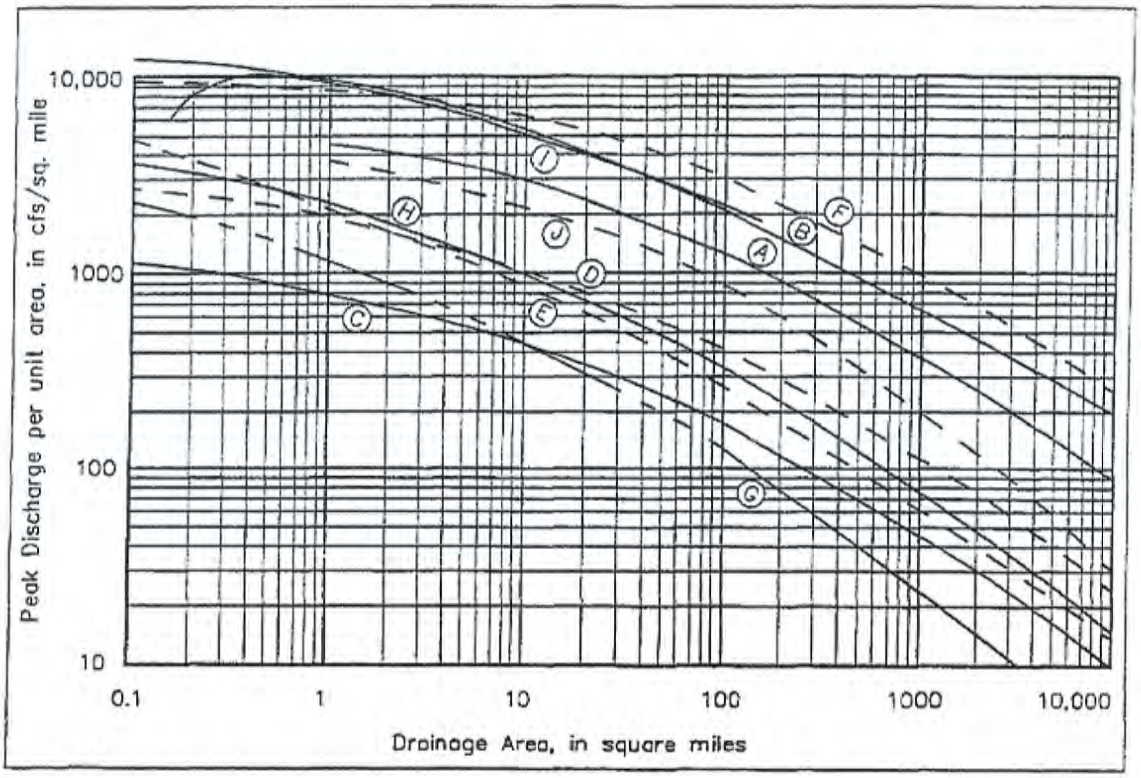
6. INDIRECT METHODS OF DISCHARGE VERIFICATION

The peak discharges using the analytic HEC-HMS methods are based on various estimated parameters and assumptions. The Flood Insurance Study for the area does not list flow rates within Horseshoe Draw. In absence of this, for ungagged watersheds, peak discharge estimates can be checked using indirect methods. The *Highway Drainage Design Manual-Hydrology* by the Arizona Department of Transportation (ADOT) provides various indirect methods for peak discharge verification.

6.1. INDIRECT METHOD 1 – UNIT PEAK DISCHARGE CURVES

Figure 6.1 shows unit peak discharge curves developed from various data sets for different hydrologic regions throughout Arizona. The ADOT Highway Drainage Design Manual states that, "The curves of most interest in evaluating 100-year peak discharges for Arizona are C, G, and H. Both curves G and H were developed for Southeastern Arizona, and as such, were the two used to check the HEC-HMS discharge values for reasonableness. In particular, Curve H yielded values similar to those obtained in HEC-HMS.

Figure 6.1



6.2. INDIRECT METHOD 2 – USGS DATA FOR ARIZONA

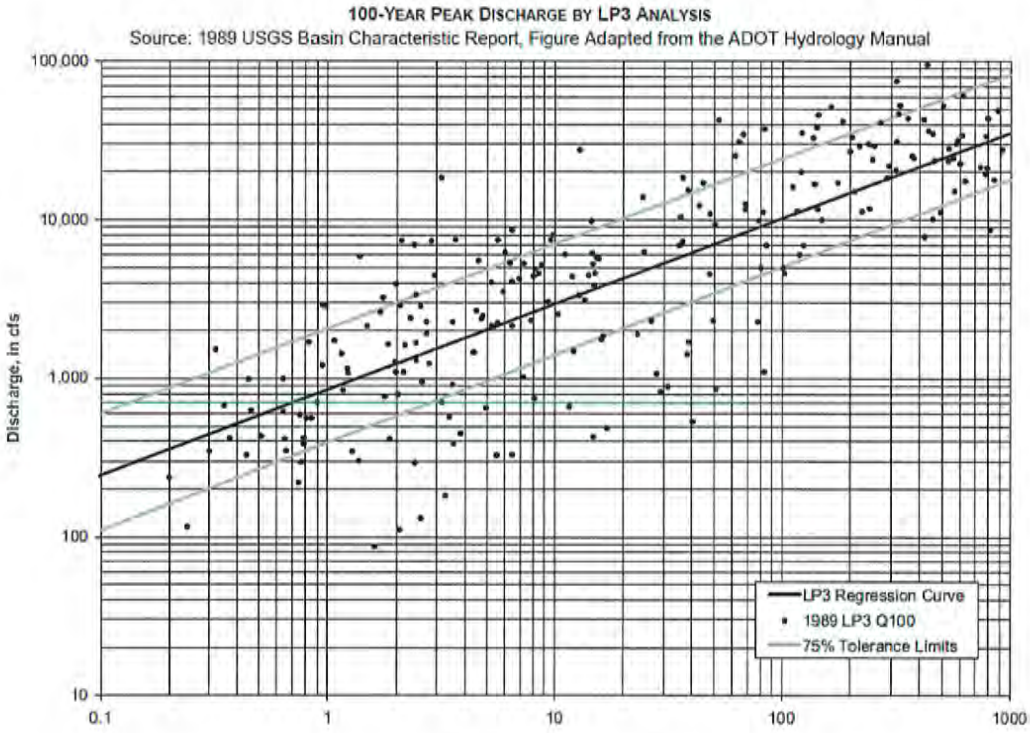
The U.S. Geological Survey (USGS) provides streamflow data for numerous gaging stations throughout Arizona. The data has been analyzed using a Log-Pearson Type 3 analysis (LP3). Figure 6.2 is a plot of the 100-year peak discharge from the analysis verses drainage area. Lines were fit to the data by least-squares of the log transformed data and an equation was developed for the 100-year peak discharge line.

$$Q_{100} = 850A^{0.54}$$

Where Q_{100} = The 100-year event peak discharge
A = Drainage Area in square miles

Results from the equation revealed results much lower than those determined in the HEC-HMS model; however, as shown in Figure 6.2, the HEC-HMS discharge values align closely with the 75% tolerance limits of the LP3 Regression Curve.

Figure 6.2



6.3. INDIRECT METHOD 3 – REGIONAL REGRESSION EQUATIONS

We have evaluated regional regression equations developed by Thomas et al. (1997) which was based off of stream flow data for a study area comprised of Arizona, Nevada, Utah, and parts of New Mexico, Colorado, Wyoming, Texas, Idaho, Oregon and California. Upon doing so, problems were encountered when applying them to Horseshoe Draw; few small drainages in Southern Arizona have gaging records, and as a result, are poorly represented in the Thomas regression equations. In contrast, the regional regression relations for flood frequency developed by Roeske (1978), use Arizona data exclusively. We therefore selected to use the regional regression equations published by Roeske. The Roeske regional regression equation for the study area is written as:

$$Q_{100} = 553A^{0.61} * E^{-1.3} * P^{0.915}$$

Where:

Q_{100} = Peak discharge in cubic feet per second
Area = Drainage area in square miles
E = Mean Elevation of the Watershed
P = Average Annual Precipitation

The Roeske regression equation for the area has yielded flow rates that are roughly half of those determined with the HEC-HMS model. This is undesirable for verification of the flows determined using HEC-HMS, however, the average standard error of model in percent for the regression equation is 48%. In light of this, the delta between peak flow rates can be expected. Regional regression calculations are included in Appendix F in the Indirect Methods Comparison Table.

REFERENCES

Arizona Department of Transportation (March, 1993). *Highway Drainage Design Manual-Hydrology*. Phoenix, Arizona.

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Roeske, R.H., (1978). *Methods for estimating the magnitude and frequency of floods in Arizona*. Phoenix, Arizona.

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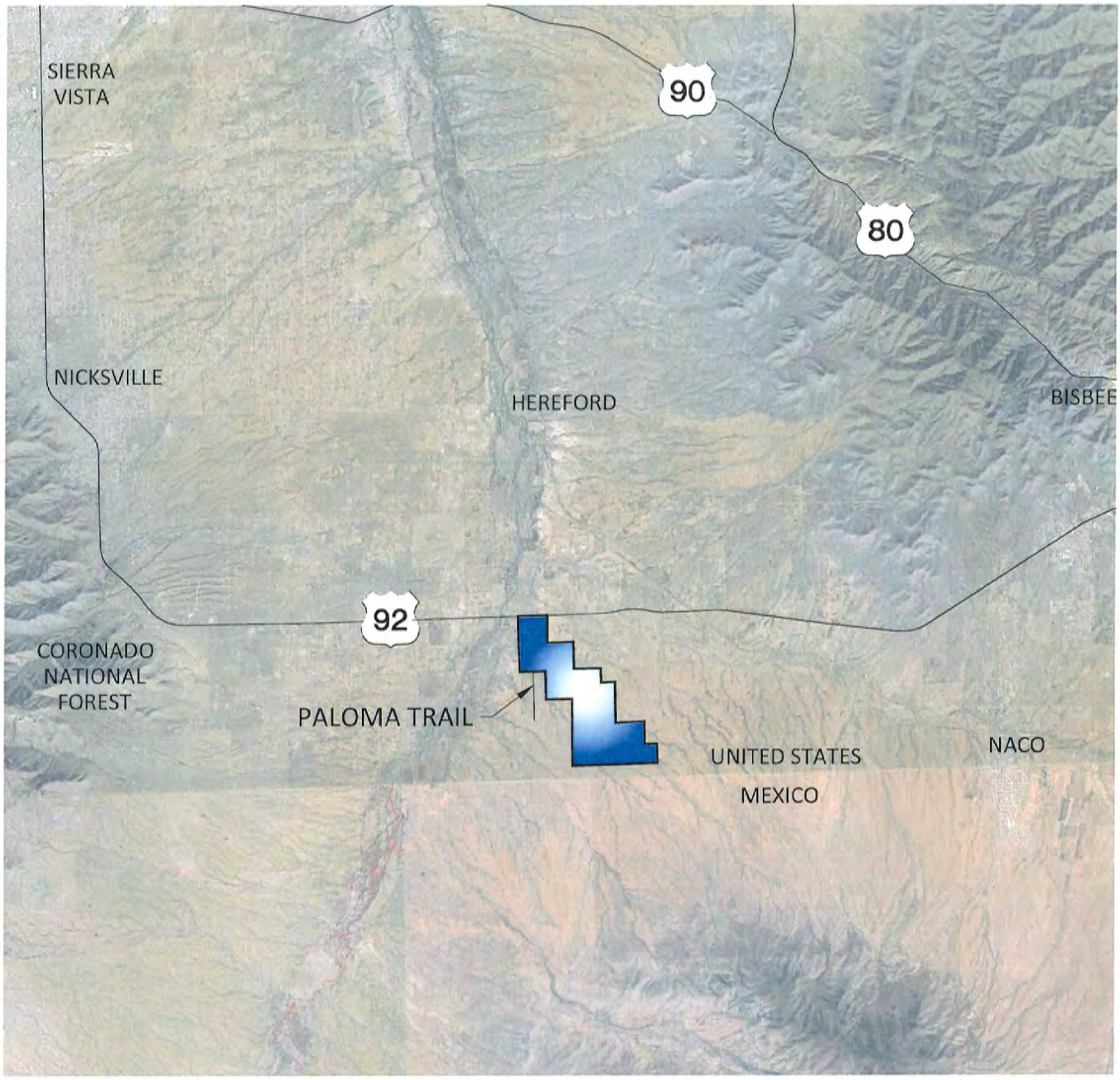
APPENDIX A
FIGURES



LEGEND

PROJECT LOCATION

N

PROJ.NO.:	1472
DATE:	APR. 2015
SCALE:	1"=15,000'
DRAWN BY:	JPG
CHECKED BY:	AT

HORSESHOE DRAW

COCHISE COUNTY, ARIZONA

FIG 1: VICINITY MAP

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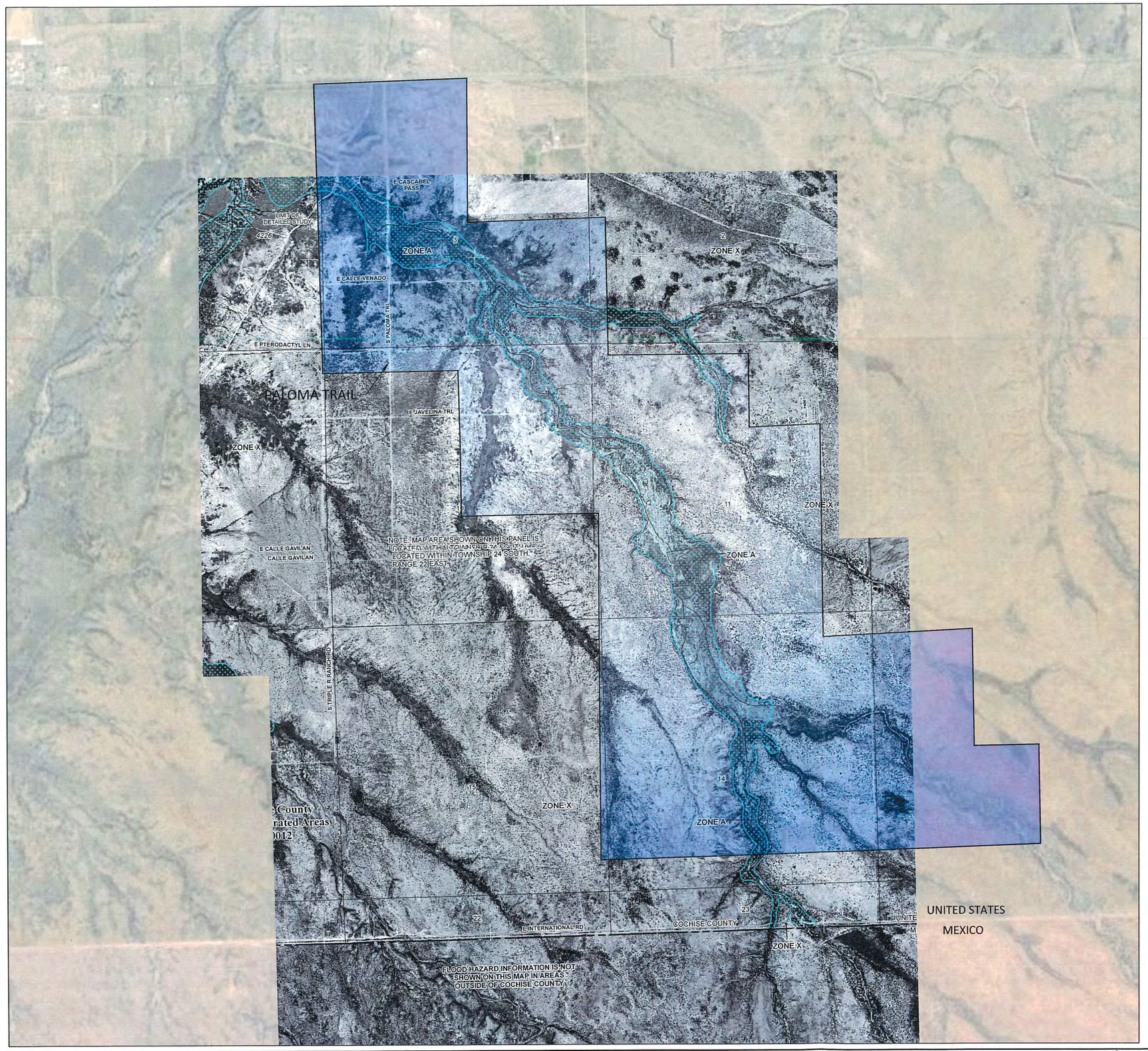
U:\1400\1472\REPORTS\DRAINAGE\Exhibits\1472 FIG 1 - Vicinity Map.dwg 4/27/2015 8:18 AM



LEGEND

PROJECT LOCATION

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 2780F

FIRM

FLOOD INSURANCE RATE MAP

COCHISE COUNTY, ARIZONA AND INCORPORATED AREAS

PANEL 2780 OF 3000

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
COCHISE COUNTY	040012	2780	F

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
04003C2780F

EFFECTIVE DATE
AUGUST 28, 2008

Federal Emergency Management Agency

N

2000 1000 0 2000 4000

SCALE FEET

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HORSESHOE DRAW

COCHISE COUNTY ARIZONA

FIG 2 FEMA MAP

PROJ. NO.:	1472
DATE:	APR, 2015
SCALE:	
DRAWN BY:	JM
CHECKED BY:	AT

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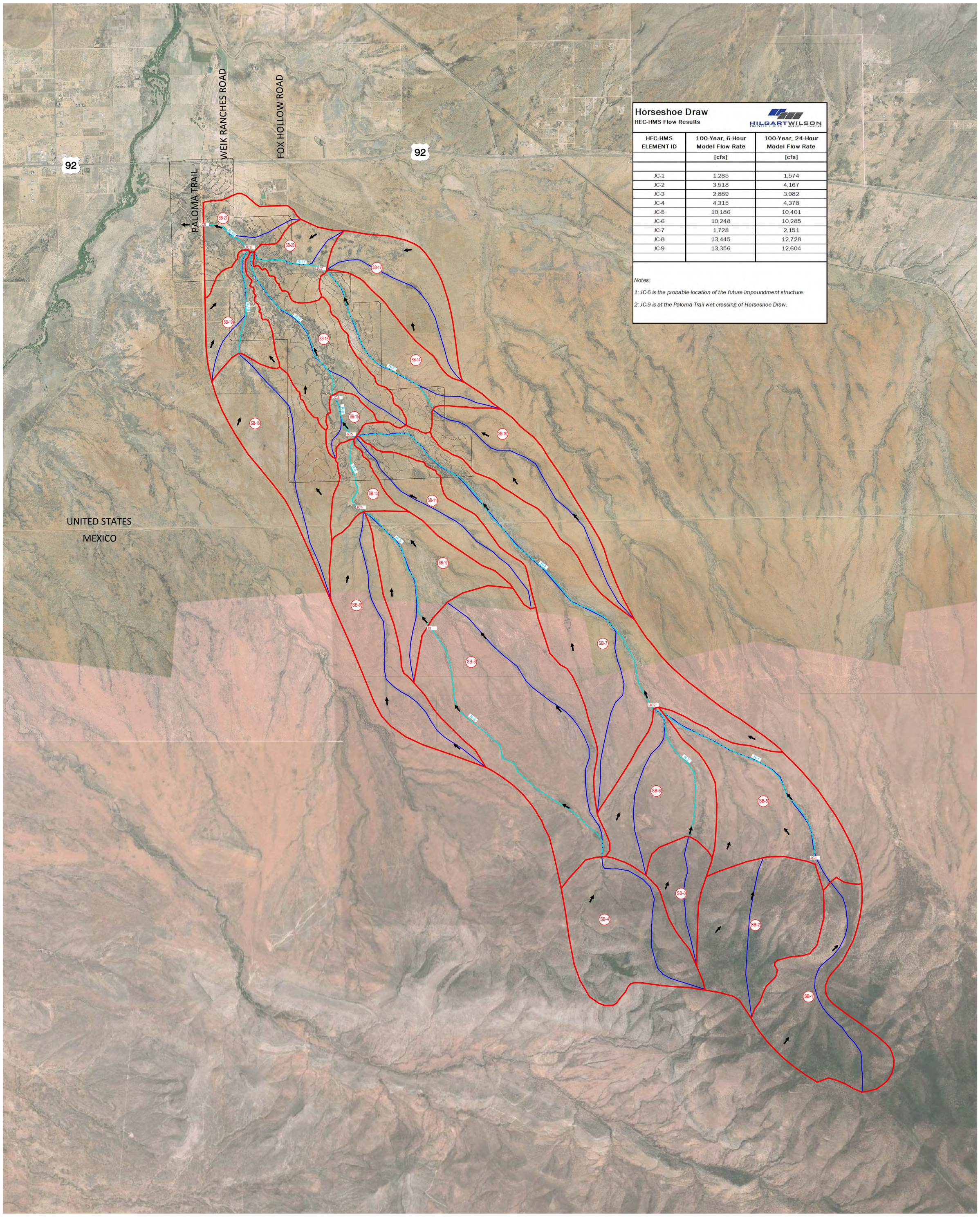

Horseshoe Draw

HEC-HMS Flow Results

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HEC-HMS ELEMENT ID	100-Year, 6-Hour Model Flow Rate [cfs]	100-Year, 24-Hour Model Flow Rate [cfs]
JC-1	1,285	1,574
JC-2	3,518	4,167
JC-3	2,889	3,082
JC-4	4,315	4,378
JC-5	10,186	10,401
JC-6	10,248	10,285
JC-7	1,728	2,151
JC-8	13,445	12,728
JC-9	13,356	12,604

Notes:

1: JC-6 is the probable location of the future impoundment structure.

2: JC-9 is at the Paloma Trail wet crossing of Horseshoe Draw.

LEGEND

SUB BASIN BOUNDARY

SUB BASIN LABEL (SB-4)

LONGEST FLOW PATH

ROUTING (R-3)

FLOW ARROW

JUNCTION (JC9)

100-YEAR FLOWRATE $Q_{100,\ 6\text{-HOUR}}$ =850 CFS, $Q_{100,\ 24\text{-HOUR}}$ =902 CFS

N

2000 1000 0 2000 4000

SCALE FEET

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HILGARTWILSON

SHT. OF

DWG. NO.

PROJ NO.: 1472

DATE: APR. 2015

SCALE: 1" = 2000'

DRAWN: JM

DESIGNED: HW

APPROVED: AT

HORSESHOE DRAW

COCHISE COUNTY, ARIZONA

FIG 3. HYDROLOGY EXHIBIT

REV.:

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APPENDIX B
SUB BASIN
PARAMETERS

SUB-BASIN SUMMARY TABLE

Project: Horseshoe Draw

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Drainage Subarea ID(s)	Predominate Hydrologic Soil Group	Total Area [ft^2]	Total Area [mi^2]	Total Area [ac]	Length of Longest Flowpath [ft]	Length of Longest Flowpath [mi]	Top Elevation [ft]	Bottom Elevation [ft]	Change in Elevation [ft]	Slope [ft/ft]	Slope [ft/mi]
SB-1	C	28,628,306	1.027	657.2	11043	2.091	7518	5143	2375	0.2151	1,136
SB-2	C	29,648,861	1.064	680.6	7265	1.376	7183	5152	2031	0.2796	1,476
SB-3	C	8,997,106	0.323	206.5	5809	1.100	6832	5120	1712	0.2947	1,556
SB-4	C	27,966,687	1.003	642.0	9005	1.705	6927	5042	1885	0.2093	1,105
SB-5	C	31,027,653	1.113	712.3	11394	2.158	5141	4701	440	0.0386	204
SB-6	C	23,808,355	0.854	546.6	8088	1.532	5344	4697	647	0.0800	422
SB-7	C	58,342,108	2.093	1339.4	24051	4.555	4856	4411	445	0.0185	98
SB-8	C	61,042,166	2.190	1401.3	14498	2.746	5037	4525	512	0.0353	186
SB-9	C	23,795,361	0.854	546.3	13919	2.636	4682	4437	245	0.0176	93
SB-10	C	23,021,392	0.826	528.5	13811	2.616	4614	3992	622	0.0450	238
SB-11	C	15,030,672	0.539	345.1	11438	2.166	4569	4380	189	0.0165	87
SB-12	C	20,350,581	0.730	467.2	8479	1.606	4563	4438	125	0.0147	78
SB-13	B	6,947,274	0.249	159.5	3576	0.677	4458	4408	50	0.0140	74
SB-14	B	20,431,303	0.733	469.0	8448	1.600	4433	4312	121	0.0143	76
SB-15	B	3,930,067	0.141	90.2	3094	0.586	4415	4344	71	0.0229	121
SB-16	B	26,965,887	0.967	619.1	12250	2.320	4498	4325	173	0.0141	75
SB-17	C	17,881,140	0.641	410.5	9174	1.738	4430	4320	110	0.0120	63
SB-18	B	20,569,038	0.738	472.2	11042	2.091	4419	4272	147	0.0133	70
SB-19	C	11,305,937	0.406	259.5	6472	1.226	4362	4270	92	0.0142	75
SB-20	C	8,816,726	0.316	202.4	4895	0.927	4363	4272	91	0.0186	98
SB-21	C	1,012,091	0.036	23.2	4747	0.899	4345	4243	102	0.0215	113
Totals		469,518,711	16.84	10,778.7							

HEC-HMS ROUTING DATA

Project: Horseshoe Draw

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ROUTING REACH ID	Length	Top Elevation	Bottom Elevation	Change in Elevation	Slope	Bottom Width	Side Slopes
	[ft]	[ft]	[ft]	[ft]	[ft/ft]	[ft]	[H:V]
R-1	10,045	5,085	4,702	383	0.038	20	8
R-2	5,927	5,114	4,702	412	0.070	15	
R-3	13,900	5,037	4,533	504	0.036	35	
R-4	19,549	4,696	4,381	315	0.016	40	
R-5	6,065	4,532	4,438	94	0.015	50	
R-6	3,611	4,437	4,377	60	0.017	250	
R-7	8,194	4,399	4,312	87	0.011	100	
R-8	2,167	4,380	4,344	36	0.017	600	
R-9	7,812	4,344	4,272	72	0.009	600	
R-10	4,822	4,325	4,270	55	0.011	300	
R-11	3,505	4,321	4,272	49	0.014	350	
R-12	2,405	4,268	4,243	25	0.010	700	

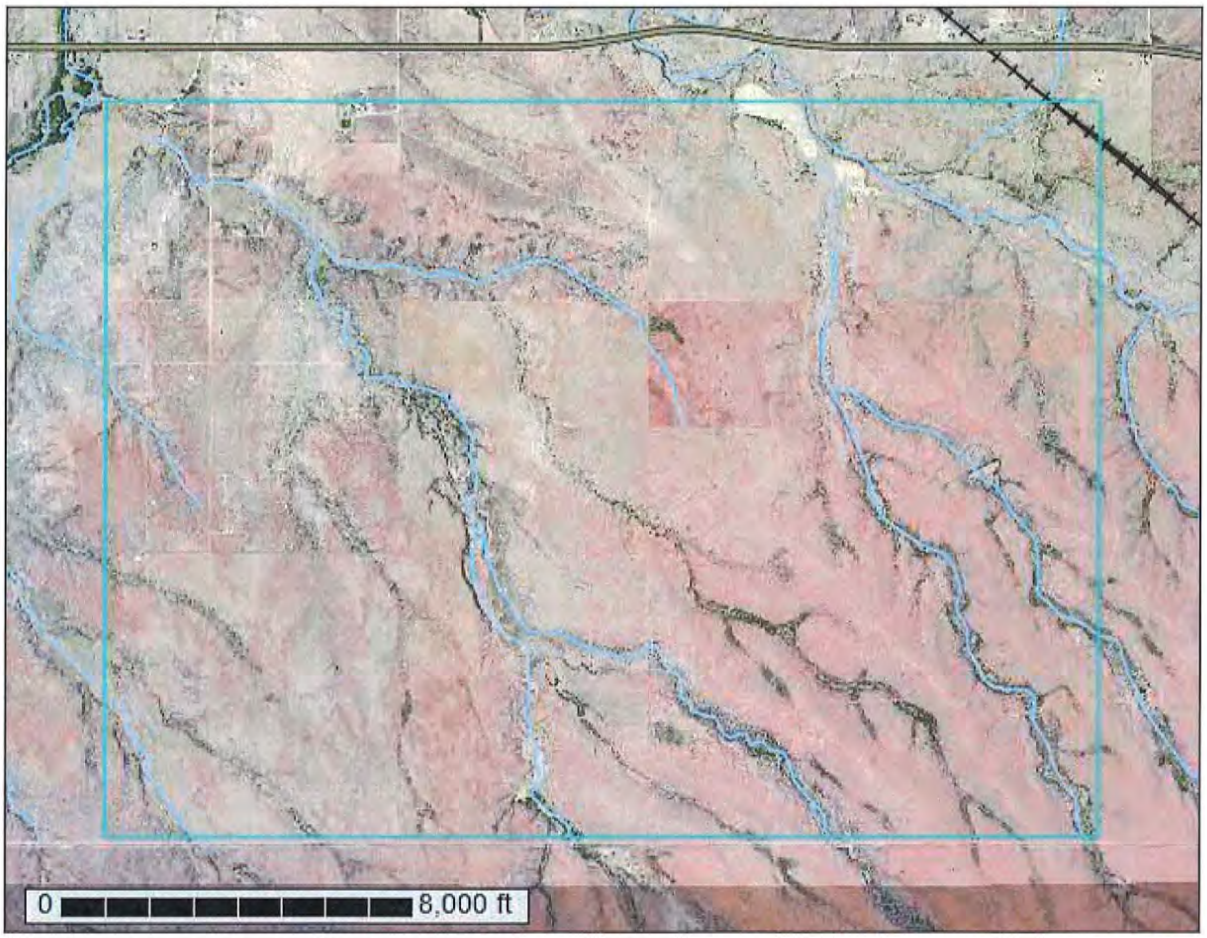
United States Department of Agriculture

NRCS

Natural Resources Conservation Service

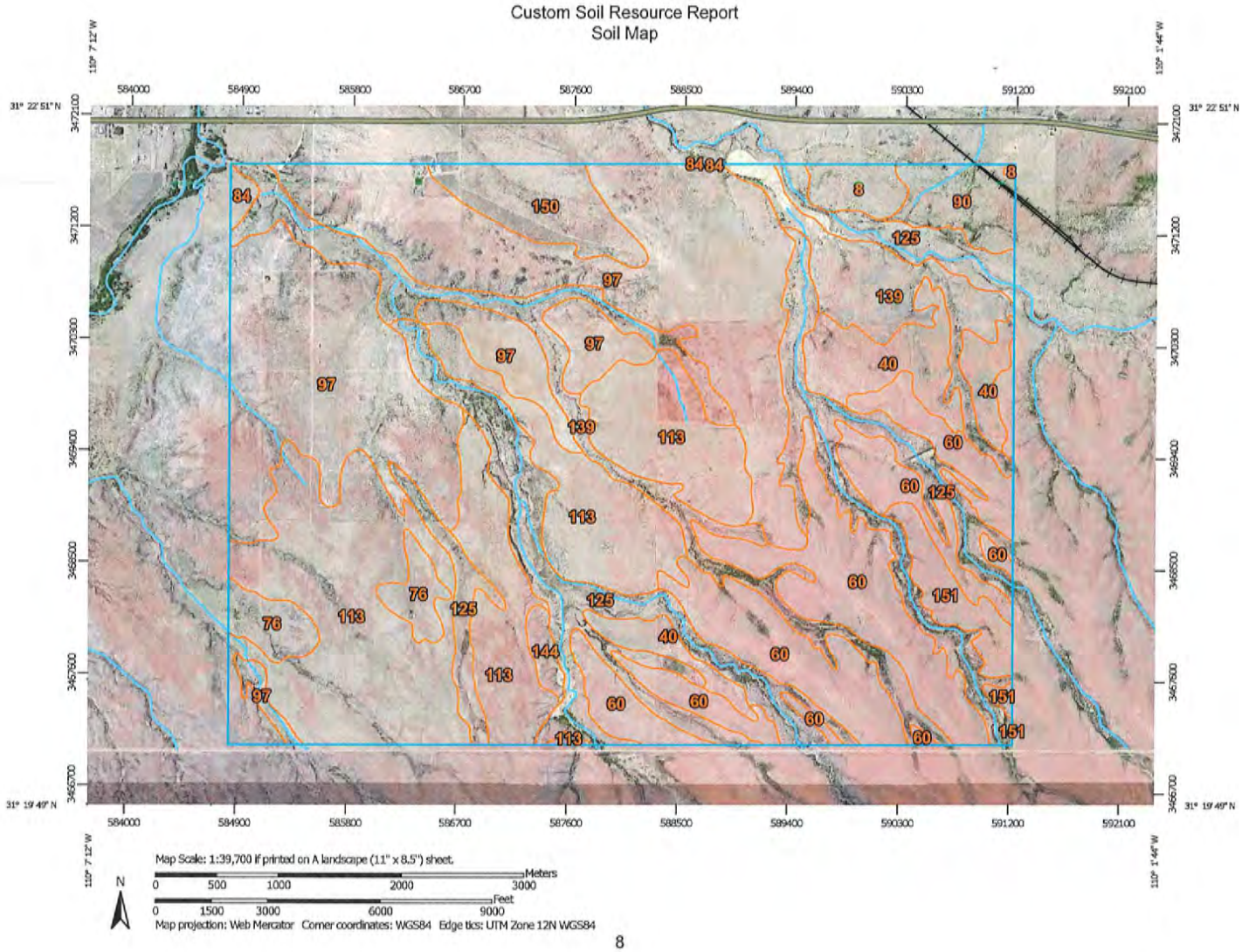
A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Cochise County, Arizona, Douglas-Tombstone Part



April 2, 2015

Custom Soil Resource Report
Soil Map



Cochise County, Arizona, Douglas-Tombstone Part

8—Blakeney-Luckyhills complex, 3 to 15 percent slopes

Map Unit Setting

National map unit symbol: 1v7q
Elevation: 3,900 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Blakeney and similar soils: 65 percent
Luckyhills and similar soils: 25 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Blakeney

Setting

Landform: Fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 11 inches: fine sandy loam
Bkm - 11 to 18 inches: cemented material
2Bk - 18 to 41 inches: fine sandy loam
2Btkb - 41 to 60 inches: loam

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: 6 to 20 inches to petrocalcic
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 20 percent
Gypsum, maximum in profile: 1 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 1.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: D
Ecological site: Limy upland 12-16" p.z. (R041XC309AZ)

Description of Luckyhills

Setting

Landform: Fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed calcareous fan alluvium

Typical profile

A - 0 to 3 inches: fine sandy loam
Bk1 - 3 to 13 inches: fine sandy loam
Bk2 - 13 to 38 inches: loam
Bk3 - 38 to 60 inches: loam

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 30 percent
Gypsum, maximum in profile: 1 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 9.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: A
Ecological site: Limy upland 12-16" p.z. (R041XC309AZ)

40—Courtland-Sasabe-Diaspar complex, 1 to 8 percent slopes MLRA 41

Map Unit Setting

National map unit symbol: 2rs92
Elevation: 4,200 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Sasabe and similar soils: 35 percent
Courtland and similar soils: 35 percent
Diaspar and similar soils: 20 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Courtland

Setting

Landform: Fan piedmonts
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Fan alluvium derived from mixed

Typical profile

A - 0 to 2 inches: sandy loam
Bt1 - 2 to 6 inches: sandy loam
Bt2 - 6 to 24 inches: sandy clay loam
Bt3 - 24 to 36 inches: gravelly clay loam
Bt4 - 36 to 60 inches: clay loam

Properties and qualities

Slope: 1 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 10.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Sandy loam upland 12-16" p.z. (R041XC319AZ)

Description of Sasabe

Setting

Landform: Fan piedmonts
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Fan alluvium derived from mixed

Typical profile

A - 0 to 2 inches: sandy loam
Bt1 - 2 to 26 inches: clay
Bt2 - 26 to 50 inches: sandy clay
Btk - 50 to 60 inches: sandy clay

Properties and qualities

Slope: 1 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Very low

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 13 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 0.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Loamy upland 12-16" p.z. (R041XC313AZ)

Description of Diaspar

Setting

Landform: Fan piedmonts
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Fan alluvium derived from mixed

Typical profile

A - 0 to 2 inches: sandy loam
Bt - 2 to 20 inches: sandy loam
2Btb1 - 20 to 41 inches: sandy clay loam
2Btb2 - 41 to 60 inches: gravelly sandy clay loam

Properties and qualities

Slope: 1 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Sandy loam upland 12-16" p.z. (R041XC319AZ)

60—Eloma-Caralampi-White House complex, 1 to 15 percent slopes MLRA 41

Map Unit Setting

National map unit symbol: 2svvh
Elevation: 4,200 to 4,800 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Eloma and similar soils: 40 percent
Caralampi and similar soils: 30 percent
White house and similar soils: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Eloma

Setting

Landform: Fan remnants
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 1 inches: very gravelly sandy loam
Bt1 - 1 to 10 inches: very gravelly clay loam
Bt2 - 10 to 27 inches: very gravelly clay
Bt3 - 27 to 60 inches: extremely cobbly clay

Properties and qualities

Slope: 1 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 4.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c

Hydrologic Soil Group: C
Ecological site: Clay loam upland 12-16" p.z. (R041XC305AZ)

Description of Caralampi

Setting

Landform: Fan remnants
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 1 inches: sandy loam
Bt1 - 1 to 12 inches: gravelly clay loam
Bt2 - 12 to 50 inches: very cobbly clay loam
Bk - 50 to 60 inches: very gravelly coarse sandy loam

Properties and qualities

Slope: 1 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Gypsum, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 6.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Loamy upland 12-16" p.z. (R041XC313AZ)

Description of White House

Setting

Landform: Fan remnants
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 1 inches: sandy loam
Bt1 - 1 to 5 inches: sandy clay loam
Bt2 - 5 to 35 inches: clay
Bt3 - 35 to 60 inches: extremely gravelly clay

Properties and qualities

Slope: 1 to 15 percent

Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Gypsum, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 6.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Loamy upland 12-16" p.z. (R041XC313AZ)

76—Graveyard-Sierravista complex, 0 to 8 percent slopes

Map Unit Setting

National map unit symbol: 1v7f
Elevation: 4,200 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Graveyard and similar soils: 45 percent
Sierravista and similar soils: 35 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Graveyard

Setting

Landform: Stream terraces, fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed alluvium

Typical profile

A - 0 to 3 inches: fine sandy loam
Bk - 3 to 9 inches: sandy loam
Bkc - 9 to 16 inches: very gravelly sandy loam
Bky - 16 to 34 inches: extremely gravelly sandy loam

B'kyc - 34 to 56 inches: very gravelly sandy loam
B'ky - 56 to 60 inches: extremely gravelly sandy loam

Properties and qualities

Slope: 0 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat excessively drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 40 percent
Gypsum, maximum in profile: 5 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Low (about 4.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: A
Ecological site: Limy upland 12-16" p.z. (R041XC309AZ)

Description of Sierravista

Setting

Landform: Fan terraces, stream terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 3 inches: fine sandy loam
Bt - 3 to 21 inches: very gravelly sandy clay loam
Btc - 21 to 42 inches: very gravelly sandy clay loam
Bkc - 42 to 60 inches: extremely gravelly sandy loam

Properties and qualities

Slope: 0 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 40 percent
Gypsum, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Low (about 4.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c

Hydrologic Soil Group: C
Ecological site: Loamy upland 12-16" p.z. (R041XC313AZ)

84—Guest-Riveroad association, 0 to 1 percent slopes

Map Unit Setting

National map unit symbol: 1v7n
Elevation: 4,000 to 4,300 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Guest and similar soils: 40 percent
Riveroad and similar soils: 40 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Riveroad

Setting

Landform: Flood plains, alluvial fans
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed stream alluvium

Typical profile

Ap - 0 to 14 inches: fine sandy loam
Cy1 - 14 to 22 inches: silt loam
Cy2 - 22 to 33 inches: silty clay loam
Cy3 - 33 to 53 inches: silty clay
Cy4 - 53 to 60 inches: sandy loam

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: 49 to 57 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Gypsum, maximum in profile: 4 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Loamy bottom 12-16" p.z. (R041XC312AZ)

Description of Guest

Setting

Landform: Flood plains
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed alluvium

Typical profile

Apy1 - 0 to 1 inches: clay loam
Apy2 - 1 to 10 inches: clay
Cy1 - 10 to 38 inches: clay
Cy2 - 38 to 60 inches: clay

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Gypsum, maximum in profile: 4 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 2.0
Available water storage in profile: High (about 9.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Clayey swale 12-16" p.z. (R041XC302AZ)

90—Kahn complex, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 1v7r
Elevation: 3,800 to 4,600 feet
Mean annual precipitation: 12 to 16 inches

Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Kahn, fine sandy loam, and similar soils: 45 percent
Kahn, silt loam, and similar soils: 40 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Kahn, Fine Sandy Loam

Setting

Landform: Alluvial fans
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 8 inches: fine sandy loam
Bw - 8 to 18 inches: loam
Bk - 18 to 60 inches: clay loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 45 percent
Gypsum, maximum in profile: 4 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 10.5 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Limy fan 12-16" p.z. (R041XC320AZ)

Description of Kahn, Silt Loam

Setting

Landform: Alluvial fans
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 1 inches: silt loam

Bw - 1 to 15 inches: loam
Bk - 15 to 43 inches: clay loam
Btkb - 43 to 60 inches: clay loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 45 percent
Gypsum, maximum in profile: 4 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 10.9 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Limy fan 12-16" p.z. (R041XC320AZ)

97—Libby-Gulch complex, 0 to 10 percent slopes

Map Unit Setting

National map unit symbol: 1v6z
Elevation: 3,900 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Libby and similar soils: 45 percent
Gulch and similar soils: 35 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Libby

Setting

Landform: Stream terraces, basin floors, fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread, dip
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed alluvium

Typical profile

A - 0 to 1 inches: very gravelly sandy loam
Bt - 1 to 13 inches: clay
2Btyc1 - 13 to 25 inches: gravelly clay
2Btyc2 - 25 to 60 inches: very gravelly clay loam

Properties and qualities

Slope: 0 to 10 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 40 percent
Gypsum, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (2.0 to 4.0 mmhos/cm)
Available water storage in profile: Moderate (about 7.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Clay loam upland 12-16" p.z. (R041XC305AZ)

Description of Gulch

Setting

Landform: Basin floors, fan terraces, stream terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread, dip
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed calcareous alluvium

Typical profile

A - 0 to 1 inches: gravelly fine sandy loam
Btk1 - 1 to 3 inches: sandy loam
Btk2 - 3 to 10 inches: sandy clay loam
Btky1 - 10 to 24 inches: clay loam
Btky2 - 24 to 40 inches: gravelly clay loam
2Btk - 40 to 60 inches: gravelly clay loam

Properties and qualities

Slope: 0 to 10 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 55 percent

Gypsum, maximum in profile: 4 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 9.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Limy upland 12-16" p.z. (R041XC309AZ)

113—Nolam-Libby-Buntline complex, 1 to 10 percent slopes

Map Unit Setting

National map unit symbol: 1v7s
Elevation: 3,900 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Nolam and similar soils: 40 percent
Libby and similar soils: 25 percent
Buntline and similar soils: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Nolam

Setting

Landform: Fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 1 inches: fine sandy loam
Bt - 1 to 19 inches: very cobbly sandy clay loam
Btk - 19 to 38 inches: extremely cobbly sandy loam
Bk - 38 to 60 inches: extremely cobbly sandy loam

Properties and qualities

Slope: 1 to 10 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None

Frequency of ponding: None
Calcium carbonate, maximum in profile: 40 percent
Gypsum, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Low (about 3.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Loamy upland 12-16" p.z. (R041XC313AZ)

Description of Libby

Setting

Landform: Fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 1 inches: gravelly fine sandy loam
Bt - 1 to 8 inches: loam
Btkyc1 - 8 to 23 inches: clay
Btkyc2 - 23 to 60 inches: clay loam

Properties and qualities

Slope: 1 to 10 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 40 percent
Gypsum, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (2.0 to 4.0 mmhos/cm)
Available water storage in profile: High (about 10.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Loamy upland 12-16" p.z. (R041XC313AZ)

Description of Buntline

Setting

Landform: Fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex

Parent material: Mixed fan alluvium

Typical profile

A - 0 to 1 inches: gravelly fine sandy loam
Btk - 1 to 8 inches: sandy loam
Bkm - 8 to 23 inches: cemented material
Ck - 23 to 47 inches: extremely cobbly sandy loam
2Btkb - 47 to 60 inches: sandy clay loam

Properties and qualities

Slope: 1 to 10 percent
Depth to restrictive feature: 5 to 15 inches to petrocalcic
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 30 percent
Gypsum, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 0.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: D
Ecological site: Limy upland 12-16" p.z. (R041XC309AZ)

125—Riveroad and Ubik soils, 0 to 5 percent slopes

Map Unit Setting

National map unit symbol: 1v7p
Elevation: 3,900 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Riveroad and similar soils: 0 percent
Ubik and similar soils: 0 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ubik

Setting

Landform: Alluvial fans, flood plains
Landform position (two-dimensional): Summit

Landform position (three-dimensional): Tread, dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed alluvium

Typical profile

A - 0 to 5 inches: loam
C1 - 5 to 16 inches: silt loam
C2 - 16 to 60 inches: fine sandy loam

Properties and qualities

Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 3 percent
Gypsum, maximum in profile: 3 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Moderate (about 8.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: A
Ecological site: Loamy swale 12-16" p.z. (R041XC311AZ)

Description of Riveroad

Setting

Landform: Alluvial fans, flood plains
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread, dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed stream alluvium

Typical profile

A - 0 to 1 inches: silt loam
C1 - 1 to 21 inches: silt loam
C2 - 21 to 60 inches: silty clay loam

Properties and qualities

Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent

Gypsum, maximum in profile: 4 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 11.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Loamy bottom 12-16" p.z. (R041XC312AZ)

139—Tenneco fine sandy loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 1v7k
Elevation: 3,800 to 4,700 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Tenneco and similar soils: 80 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Tenneco

Setting

Landform: Flood plains, alluvial fans
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread, dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 2 inches: fine sandy loam
Bw - 2 to 11 inches: sandy clay loam
Bk - 11 to 41 inches: loam
C - 41 to 60 inches: sandy loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent

Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 8.6 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: B
Ecological site: Loamy swale 12-16" p.z. (R041XC311AZ)

144—Ubik complex, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 1v71
Elevation: 3,900 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

Ubik, silt loam, and similar soils: 50 percent
Ubik, fine sandy loam, and similar soils: 30 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ubik, Silt Loam

Setting

Landform: Flood plains, alluvial fans
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread, dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed alluvium

Typical profile

C1 - 0 to 10 inches: silt loam
C2 - 10 to 32 inches: loam
C3 - 32 to 60 inches: fine sandy loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Gypsum, maximum in profile: 3 percent
Sodium adsorption ratio, maximum in profile: 13.0

Available water storage in profile: Moderate (about 8.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: B
Ecological site: Loamy bottom 12-16" p.z. (R041XC312AZ)

Description of Ubik, Fine Sandy Loam

Setting

Landform: Alluvial fans, flood plains
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread, dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed alluvium

Typical profile

C1 - 0 to 8 inches: fine sandy loam
C2 - 8 to 30 inches: loam
C3 - 30 to 60 inches: fine sandy loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Gypsum, maximum in profile: 3 percent
Sodium adsorption ratio, maximum in profile: 13.0
Available water storage in profile: Moderate (about 8.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: A
Ecological site: Loamy swale 12-16" p.z. (R041XC311AZ)

150—Vana-Moco complex, 1 to 5 percent slopes

Map Unit Setting

National map unit symbol: 1v63
Elevation: 4,200 to 4,800 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days

Farmland classification: Not prime farmland

Map Unit Composition

Vana and similar soils: 50 percent
Moco and similar soils: 40 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Vana

Setting

Landform: Fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 2 inches: sandy loam
Bt - 2 to 8 inches: sandy clay loam
Btky - 8 to 13 inches: clay loam
Bkym - 13 to 18 inches: cemented material
Bky - 18 to 60 inches: gravelly loam

Properties and qualities

Slope: 1 to 5 percent
Depth to restrictive feature: 10 to 20 inches to petrocalcic
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 70 percent
Gypsum, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 2.2 inches)

Interpretive groups

Land capability classification (irrigated): 4s
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: D
Ecological site: Limy upland 12-16" p.z. (R041XC309AZ)

Description of Moco

Setting

Landform: Basin floors
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Dip
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 1 inches: fine sandy loam

Btk - 1 to 10 inches: clay loam
Btky - 10 to 20 inches: clay loam
Bky - 20 to 60 inches: clay loam

Properties and qualities

Slope: 1 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 55 percent
Gypsum, maximum in profile: 20 percent
Salinity, maximum in profile: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 10.3 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Limy fan 12-16" p.z. (R041XC320AZ)

151—White House complex, 1 to 30 percent slopes

Map Unit Setting

National map unit symbol: 1v79
Elevation: 4,500 to 4,800 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days
Farmland classification: Not prime farmland

Map Unit Composition

White house, gravelly loam, and similar soils: 40 percent
White house, gravelly sandy loam, and similar soils: 35 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of White House, Gravelly Loam

Setting

Landform: Fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 2 inches: gravelly loam
Bt1 - 2 to 18 inches: clay
Bt2 - 18 to 29 inches: gravelly clay loam
2Bb - 29 to 33 inches: loamy sand
3Btkb - 33 to 60 inches: clay loam

Properties and qualities

Slope: 1 to 30 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Available water storage in profile: High (about 9.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Loamy upland 12-16" p.z. (R041XC313AZ)

Description of White House, Gravelly Sandy Loam

Setting

Landform: Fan terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Mixed fan alluvium

Typical profile

A - 0 to 5 inches: gravelly loam
Bt1 - 5 to 25 inches: clay
Bt2 - 25 to 45 inches: gravelly clay loam
Bt3 - 45 to 60 inches: clay loam

Properties and qualities

Slope: 1 to 30 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Available water storage in profile: High (about 9.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: Sandy loam upland 12-16" p.z. (R041XC319AZ)

APPENDIX C
TIME OF CONCENTRATION
CALCULATIONS

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-1

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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	300	2.90	0.210	**8.6**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2900	0.210	7.4	**6.5**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
11,043	12.6	**14.6**

C	b	d	z	R	S	n
1.49	20	0.50	8	0.43	0.200	0.03

t_{sheet} = **8.6 min**
$t_{shallow}$ = **6.5 min**
$t_{channel}$ = **14.6 min**
t_c = **29.8 min**

Lag Time = $0.6t_c$ = **17.9**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-2

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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	300	2.90	0.410	6.6

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2043	0.320	9.1	3.7

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
4,270	14.5	4.9

C	b	d	z	R	S	n
1.49	10	0.50	8	0.39	0.300	0.03

t_{sheet} = 6.6 min
$t_{shallow}$ = 3.7 min
$t_{channel}$ = 4.9 min
t_c = 15.3 min Lag Time = $0.6t_c$ = 9.2

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-3

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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	300	2.90	0.450	**6.4**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
3136	0.320	9.1	**5.7**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
11,043	13.1	**14.0**

C	b	d	z	R	S	n
1.49	5	0.50	8	0.34	0.290	0.03

t_{sheet} = **6.4 min**
$t_{shallow}$ = **5.7 min**
$t_{channel}$ = **14.0 min**
t_c = **26.1 min** Lag Time = $0.6t_c$ = **15.7**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-4

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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	300	2.90	0.360	**7.0**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2006	0.310	9.0	**3.7**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
6,639	11.4	**9.7**

C	b	d	z	R	S	n
1.49	12	0.50	8	0.40	0.180	0.03

t_{sheet} = **7.0 min**
$t_{shallow}$ = **3.7 min**
$t_{channel}$ = **9.7 min**
t_c = **20.4 min** Lag Time = $0.6t_{tc}$ = **12.2**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-5

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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	300	2.90	0.066	**13.7**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2322	0.056	3.8	**10.1**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
9,027	10.8	**13.9**

C	b	d	z	R	S	n
1.49	15	2.00	8	1.31	0.033	0.03

t_{sheet} = **13.7 min**
$t_{shallow}$ = **10.1 min**
$t_{channel}$ = **13.9 min**
t_c = **37.8 min**

Lag Time = $0.6t_c$ = 22.7

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-6

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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	300	2.90	0.28	**7.7**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
1923	0.20	7.2	**4.4**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
5,622	5.2	**18.0**

C	b	d	z	R	S	n
1.49	30	0.50	8	0.45	0.032	0.03

t_{sheet} = **7.7 min**
$t_{shallow}$ = **4.4 min**
$t_{channel}$ = **18.0 min**
t_c = **30.2 min** Lag Time = $0.6t_c$ = **18.1**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-7

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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.047	**9.0**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2710	0.031	2.8	**15.9**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
21,037	29.8	**11.8**

C	b	d	z	R	S	n
1.49	40	2.00	8	1.55	0.200	0.03

t_{sheet} = **9.0 min**
$t_{shallow}$ = **15.9 min**
$t_{channel}$ = **11.8 min**
t_c = **36.7 min** Lag Time = $0.6t_c$ = **22.0**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-8

HILGARTWILSON
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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.093	**6.9**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2571	0.072	4.3	**9.9**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
11,588	11.0	**17.6**

C	b	d	z	R	S	n
1.49	50	2.00	8	1.60	0.026	0.03

t_{sheet} = **6.9 min**
$t_{shallow}$ = **9.9 min**
$t_{channel}$ = **17.6 min**
t_c = **34.4 min** Lag Time = $0.6t_c$ = **20.6**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-9

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.040	9.6

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
3145	0.024	2.5	21.0

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
10,440	8.2	21.3

C	b	d	z	R	S	n
1.49	30	2.00	8	1.48	0.016	0.03

t_{sheet} = 9.6 min
$t_{shallow}$ = 21.0 min
$t_{channel}$ = 21.3 min
t_c = 51.9 min Lag Time = $0.6t_c$ = 31.2

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-10

HILGARTWILSON
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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.017	**13.5**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2921	0.016	2.0	**23.9**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
10,580	8.4	**21.0**

C	b	d	z	R	S	n
1.49	40	2.00	8	1.55	0.016	0.03

t_{sheet} = **13.5 min**
$t_{shallow}$ = **23.9 min**
$t_{channel}$ = **21.0 min**
t_c = **58.4 min** Lag Time = $0.6t_c$ = **35.0**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-11

HILGARTWILSON
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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.023	**12.0**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
1980	0.018	2.2	**15.2**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
9,184	8.6	**17.8**

C	b	d	z	R	S	n
1.49	50	2.00	8	1.60	0.016	0.03

t_{sheet} = **12.0 min**
$t_{shallow}$ = **15.2 min**
$t_{channel}$ = **17.8 min**
t_c = **45.0 min** Lag Time = $0.6t_c$ = **27.0**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-12

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.013	**15.1**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2740	0.014	1.9	**23.9**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
5,614	7.9	**11.9**

C	b	d	z	R	S	n
1.49	30	2.00	8	1.48	0.015	0.03

t_{sheet} = **15.1 min**
$t_{shallow}$ = **23.9 min**
$t_{channel}$ = **11.9 min**
t_c = **50.9 min**

Lag Time = $0.6t_c$ = 30.5

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-13

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.010	**16.8**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
1776	0.096	5.0	**5.9**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
2,898	9.9	**4.9**

C	b	d	z	R	S	n
1.49	50	2.00	8	1.60	0.021	0.03

t_{sheet} = **16.8 min**
$t_{shallow}$ = **5.9 min**
$t_{channel}$ = **4.9 min**
t_c = **27.6 min**

Lag Time = $0.6t_c$ = 16.5

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-14

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Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.026	**11.4**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
3756	0.016	2.0	**30.7**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
6,795	7.1	**16.0**

C	b	d	z	R	S	n
1.49	30	2.00	8	1.48	0.012	0.03

t_{sheet} = **11.4 min**
$t_{shallow}$ = **30.7 min**
$t_{channel}$ = **16.0 min**
t_c = **58.1 min** Lag Time = $0.6t_c$ = **34.9**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-15

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.020	**12.7**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
1,174	0.032	2.9	**6.8**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectanguiar cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
1,752	9.1	**3.2**

C	b	d	z	R	S	n
1.49	50	2.00	8	1.60	0.018	0.03

t_{sheet} = **12.7 min**
$t_{shallow}$ = **6.8 min**
$t_{channel}$ = **3.2 min**
t_c = **22.7 min**

Lag Time = $0.6t_c$ = 13.6

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-16

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.013	**15.1**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
3509	0.013	1.8	**31.8**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
8,634	7.9	**18.3**

C	b	d	z	R	S	n
1.49	40	2.00	8	1.55	0.014	0.03

t_{sheet} = **15.1 min**
$t_{shallow}$ = **31.8 min**
$t_{channel}$ = **18.3 min**
t_c = **65.2 min** Lag Time = $0.6t_c$ = **39.1**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-17

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.015	**14.2**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
4013	0.014	1.9	**35.0**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
4,702	7.3	**10.7**

C	b	d	z	R	S	n
1.49	30	2.00	8	1.48	0.013	0.03

t_{sheet} = **14.2 min**
$t_{shallow}$ = **35.0 min**
$t_{channel}$ = **10.7 min**
t_c = **59.9 min**

Lag Time = $0.6t_c$ = 36.0

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-18

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.026	**11.4**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2694	0.018	2.2	**20.7**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
8,176	7.6	**18.0**

C	b	d	z	R	S	n
1.49	60	2.00	8	1.65	0.012	0.03

t_{sheet} = **11.4 min**
$t_{shallow}$ = **20.7 min**
$t_{channel}$ = **18.0 min**
t_c = **50.1 min**

Lag Time = $0.6t_c$ = **30.1**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-19

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.016	**13.9**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
2181	0.016	2.0	**17.8**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
4,401	7.6	**9.7**

C	b	d	z	R	S	n
1.49	40	2.00	8	1.55	0.013	0.03

t_{sheet} = **13.9 min**
$t_{shallow}$ = **17.8 min**
$t_{channel}$ = **9.7 min**
t_c = **41.4 min** Lag Time = $0.6t_c$ = **24.8**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-20

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.013	**15.1**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
1689	0.028	2.7	**10.4**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
3,032	7.3	**7.0**

C	b	d	z	R	S	n
1.49	60	2.00	8	1.65	0.011	0.03

t_{sheet} = **15.1 min**
$t_{shallow}$ = **10.4 min**
$t_{channel}$ = **7.0 min**
t_c = **32.5 min** Lag Time = $0.6t_c$ = **19.5**

TIME OF CONCENTRATION
Project: Horseshoe Draw
SUBBASIN-21

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

Segmental Time of Concentration Method

$t_c = t_{sheet} + t_{shallow} + t_{channel}$

t_{sheet}

$t_{sheet} = (0.007(NL)^{0.8})/((P2)^{0.5}S^{0.4})$

where:
N = Overland-flow roughness coefficient (Table 14, Technical Reference Manual)
L = flow length, (ft)
P_2 = 2-year, 24-hour rainfall depth, (in)
S = Land slope

N	L	P_2	S	t_{sheet}
0.13	150	2.90	0.023	**12.0**

$t_{shallow}$

$t_{shallow} = L/V$

where:
L = channel length, (ft)
V = 16.1345*(S)^1/2
S = channel slope

L	S	V	$t_{shallow}$
1312	0.023	2.4	**8.9**

$t_{channel}$

$t_{channel} = L/V$

$V = (CR^{2/3}S^{1/2})/n$

where:
L = channel length, (ft)
V = Velocity, (ft/sec)
C = conversion constant (1.49)
R = hydraulic radius (ft)
assuming a rectangular cross section $R = (bd+zd^2)/(b + 2d(z^2+1)^{.5})$
where: b = top width
d = hydraulic depth
z = side slope
S = channel bed slope
n = Manning's roughness coefficient

L	V	$t_{channel}$
3,381	9.8	**5.8**

C	b	d	z	R	S	n
1.49	60	2.00	8	1.65	0.020	0.03

t_{sheet} = **12.0 min**
$t_{shallow}$ = **8.9 min**
$t_{channel}$ = **5.8 min**
t_c = **26.7 min**

Lag Time = $0.6t_c$ = **16.0**

APPENDIX D
RAINFALL
DISTRIBUTION

NOAA Atlas 14, Volume 1, Version 5
Location name: Hereford, Arizona, US*
Latitude: 31.3394°, Longitude: -110.0788°
Elevation: 4395 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.273 (0.242-0.311)	0.350 (0.309-0.398)	0.456 (0.401-0.517)	0.534 (0.469-0.604)	0.640 (0.557-0.724)	0.720 (0.621-0.817)	0.800 (0.683-0.913)	0.881 (0.742-1.01)	0.987 (0.813-1.14)	1.07 (0.866-1.25)
10-min	0.416 (0.368-0.472)	0.533 (0.471-0.606)	0.694 (0.611-0.787)	0.813 (0.714-0.920)	0.974 (0.848-1.10)	1.10 (0.946-1.24)	1.22 (1.04-1.39)	1.34 (1.13-1.54)	1.50 (1.24-1.74)	1.62 (1.32-1.90)
15-min	0.515 (0.456-0.586)	0.660 (0.584-0.751)	0.860 (0.757-0.975)	1.01 (0.885-1.14)	1.21 (1.05-1.37)	1.36 (1.17-1.54)	1.51 (1.29-1.72)	1.66 (1.40-1.91)	1.86 (1.53-2.16)	2.01 (1.63-2.35)
30-min	0.693 (0.613-0.789)	0.889 (0.786-1.01)	1.16 (1.02-1.31)	1.36 (1.19-1.53)	1.63 (1.42-1.84)	1.83 (1.58-2.08)	2.03 (1.74-2.32)	2.24 (1.88-2.56)	2.51 (2.07-2.90)	2.71 (2.20-3.17)
60-min	0.858 (0.759-0.976)	1.10 (0.973-1.25)	1.43 (1.26-1.63)	1.68 (1.48-1.90)	2.01 (1.75-2.28)	2.26 (1.95-2.57)	2.52 (2.15-2.87)	2.77 (2.33-3.17)	3.10 (2.56-3.59)	3.36 (2.72-3.92)
2-hr	0.982 (0.869-1.11)	1.25 (1.10-1.41)	1.61 (1.42-1.82)	1.89 (1.66-2.13)	2.27 (1.99-2.56)	2.58 (2.23-2.92)	2.90 (2.47-3.29)	3.22 (2.71-3.69)	3.66 (3.02-4.23)	4.01 (3.25-4.69)
3-hr	1.04 (0.922-1.17)	1.31 (1.16-1.48)	1.66 (1.48-1.88)	1.96 (1.73-2.20)	2.35 (2.06-2.65)	2.67 (2.32-3.02)	3.01 (2.58-3.41)	3.36 (2.83-3.84)	3.84 (3.16-4.44)	4.23 (3.41-4.95)
6-hr	1.18 (1.05-1.34)	1.48 (1.31-1.68)	1.87 (1.66-2.11)	2.19 (1.94-2.47)	2.65 (2.32-2.98)	3.02 (2.61-3.40)	3.41 (2.91-3.87)	3.82 (3.21-4.37)	4.40 (3.60-5.09)	4.88 (3.91-5.70)
12-hr	1.30 (1.16-1.46)	1.63 (1.45-1.83)	2.04 (1.82-2.29)	2.38 (2.11-2.66)	2.85 (2.50-3.18)	3.22 (2.81-3.61)	3.62 (3.11-4.08)	4.02 (3.40-4.58)	4.59 (3.80-5.29)	5.06 (4.11-5.88)
24-hr	1.50 (1.39-1.65)	1.88 (1.73-2.06)	2.33 (2.14-2.55)	2.68 (2.46-2.93)	3.16 (2.88-3.45)	3.52 (3.20-3.84)	3.89 (3.52-4.25)	4.26 (3.83-4.66)	4.74 (4.23-5.35)	5.11 (4.53-5.94)
2-day	1.69 (1.55-1.84)	2.10 (1.93-2.30)	2.59 (2.37-2.83)	2.98 (2.73-3.25)	3.51 (3.19-3.83)	3.92 (3.55-4.28)	4.34 (3.91-4.75)	4.76 (4.26-5.24)	5.33 (4.72-5.89)	5.77 (5.07-6.40)
3-day	1.85 (1.70-2.02)	2.30 (2.11-2.51)	2.83 (2.60-3.09)	3.26 (2.99-3.56)	3.84 (3.51-4.20)	4.29 (3.90-4.70)	4.76 (4.30-5.21)	5.23 (4.69-5.75)	5.86 (5.20-6.47)	6.35 (5.58-7.05)
4-day	2.01 (1.85-2.19)	2.50 (2.30-2.73)	3.08 (2.83-3.36)	3.54 (3.25-3.87)	4.18 (3.82-4.56)	4.67 (4.25-5.11)	5.18 (4.69-5.67)	5.69 (5.12-6.26)	6.39 (5.68-7.06)	6.93 (6.10-7.70)
7-day	2.39 (2.20-2.58)	2.97 (2.74-3.23)	3.66 (3.37-3.96)	4.20 (3.87-4.54)	4.93 (4.51-5.33)	5.48 (5.00-5.93)	6.04 (5.48-6.55)	6.60 (5.96-7.18)	7.34 (6.56-8.03)	7.90 (7.01-8.68)
10-day	2.77 (2.56-2.99)	3.45 (3.18-3.73)	4.24 (3.91-4.57)	4.85 (4.47-5.22)	5.65 (5.20-6.09)	6.26 (5.73-6.75)	6.86 (6.27-7.43)	7.46 (6.78-8.10)	8.24 (7.42-8.99)	8.82 (7.88-9.67)
20-day	3.77 (3.48-4.06)	4.70 (4.34-5.08)	5.73 (5.30-6.19)	6.50 (6.00-7.01)	7.46 (6.87-8.04)	8.15 (7.49-8.81)	8.82 (8.08-9.55)	9.46 (8.63-10.3)	10.2 (9.30-11.2)	10.8 (9.76-11.8)
30-day	4.64 (4.30-4.99)	5.78 (5.35-6.22)	7.00 (6.49-7.52)	7.88 (7.31-8.46)	8.97 (8.31-9.63)	9.74 (8.99-10.5)	10.5 (9.64-11.3)	11.1 (10.2-12.0)	12.0 (10.9-12.9)	12.5 (11.4-13.6)
45-day	5.60 (5.20-5.99)	6.95 (6.47-7.45)	8.34 (7.76-8.92)	9.32 (8.67-9.96)	10.5 (9.76-11.2)	11.3 (10.5-12.1)	12.0 (11.2-12.9)	12.7 (11.8-13.7)	13.5 (12.5-14.5)	14.0 (12.9-15.1)
60-day	6.54 (6.10-6.99)	8.12 (7.57-8.69)	9.70 (9.05-10.4)	10.8 (10.1-11.6)	12.1 (11.3-13.0)	13.0 (12.1-13.9)	13.8 (12.8-14.8)	14.6 (13.5-15.7)	15.4 (14.2-16.6)	16.0 (14.7-17.3)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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Maps & aerials

Small scale terrain

Large scale terrain

RAINFALL DISTRIBUTION

Project: Horseshoe Draw

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100-Year, 6-Hour Model					100-Year, 24-Hour Model				
100-Yr, 6-Hr Precipitation Depth [in]	Time [Hr]	Percent of Rainfall Depth	Cumulative Precipitation Depth [in]	Incremental Precipitation Depth	100-Yr, 24-Hr Precipitation Depth	Time [Hr]	Percent of Rainfall Depth	Cumulative Precipitation Depth [in]	Incremental Precipitation Depth
	0	0	0.000	0.017		0.000	0	0	0.003
3.41	0.083		0.02	0.017	3.89	0.08		0.00	0.003
↓	0.167		0.03	0.017	↓	0.17		0.01	0.003
	0.25	1.5	0.05	0.006		0.25	0.2	0.01	0.004
	0.333		0.06	0.006		0.33		0.01	0.004
	0.417		0.06	0.006		0.42		0.02	0.004
	0.50	2.0	0.07	0.011		0.50	0.5	0.02	0.004
	0.58		0.08	0.011		0.58		0.02	0.004
	0.67		0.09	0.011		0.67		0.03	0.004
	0.75	3.0	0.10	0.020		0.75	0.8	0.03	0.004
	0.83		0.12	0.020		0.83		0.04	0.004
	0.92		0.14	0.020		0.92		0.04	0.004
	1.00	4.8	0.16	0.017		1.00	1.1	0.04	0.004
	1.08		0.18	0.017		1.08		0.05	0.004
	1.17		0.20	0.017		1.17		0.05	0.004
	1.25	6.3	0.21	0.015		1.25	1.4	0.05	0.004
	1.33		0.23	0.015		1.33		0.06	0.004
	1.42		0.24	0.015		1.42		0.06	0.004
	1.50	7.6	0.26	0.016		1.50	1.7	0.07	0.004
	1.58		0.28	0.016		1.58		0.07	0.004
	1.67		0.29	0.016		1.67		0.07	0.004
	1.75	9.0	0.31	0.017		1.75	2.0	0.08	0.004
	1.83		0.32	0.017		1.83		0.08	0.004
	1.92		0.34	0.017		1.92		0.09	0.004
	2.00	10.5	0.36	0.016		2.00	2.3	0.09	0.004
	2.08		0.37	0.016		2.08		0.09	0.004
	2.17		0.39	0.016		2.17		0.10	0.004
	2.25	11.9	0.41	0.018		2.25	2.6	0.10	0.004
	2.33		0.42	0.018		2.33		0.11	0.004
	2.42		0.44	0.018		2.42		0.11	0.004
	2.50	13.5	0.46	0.019		2.50	2.9	0.11	0.004
	2.58		0.48	0.019		2.58		0.12	0.004
	2.67		0.50	0.019		2.67		0.12	0.004
	2.75	15.2	0.52	0.026		2.75	3.2	0.12	0.004
	2.83		0.54	0.026		2.83		0.13	0.004
	2.92		0.57	0.026		2.92		0.13	0.004
	3.00	17.5	0.60	0.053		3.00	3.5	0.14	0.004
	3.08		0.65	0.053		3.08		0.14	0.004
	3.17		0.70	0.053		3.17		0.14	0.004
	3.25	22.2	0.76	0.093		3.25	3.8	0.15	0.004

3.33		0.85	0.093
3.42		0.94	0.093
3.50	30.4	1.04	0.191
3.58		1.23	0.191
3.67		1.42	0.191
3.75	47.2	1.61	0.225
3.83		1.83	0.225
3.92		2.06	0.225
4.00	67.0	2.28	0.143
4.08		2.43	0.143
4.17		2.57	0.143
4.25	79.6	2.71	0.082
4.33		2.80	0.082
4.42		2.88	0.082
4.50	86.8	2.96	0.050
4.58		3.01	0.050
4.67		3.06	0.050
4.75	91.2	3.11	0.039
4.83		3.15	0.039
4.92		3.19	0.039
5.00	94.6	3.23	0.016
5.08		3.24	0.016
5.17		3.26	0.016
5.25	96.0	3.27	0.015
5.33		3.29	0.015
5.42		3.30	0.015
5.50	97.3	3.32	0.016
5.58		3.33	0.016
5.67		3.35	0.016
5.75	98.7	3.37	0.015
5.83		3.38	0.015
5.92		3.40	0.015
6.00	100.0	3.41	

3.33		0.15	0.004
3.42		0.16	0.004
3.50	4.1	0.16	0.004
3.58		0.16	0.004
3.67		0.17	0.004
3.75	4.4	0.17	0.005
3.83		0.18	0.005
3.92		0.18	0.005
4.00	4.8	0.19	0.005
4.08		0.19	0.005
4.17		0.20	0.005
4.25	5.2	0.20	0.005
4.33		0.21	0.005
4.42		0.21	0.005
4.50	5.6	0.22	0.005
4.58		0.22	0.005
4.67		0.23	0.005
4.75	6.0	0.23	0.005
4.83		0.24	0.005
4.92		0.24	0.005
5.00	6.4	0.25	0.005
5.08		0.25	0.005
5.17		0.26	0.005
5.25	6.8	0.26	0.005
5.33		0.27	0.005
5.42		0.27	0.005
5.50	7.2	0.28	0.005
5.58		0.29	0.005
5.67		0.29	0.005
5.75	7.6	0.30	0.005
5.83		0.30	0.005
5.92		0.31	0.005
6.00	8.0	0.31	0.006
6.08		0.32	0.006
6.17		0.32	0.006
6.25	8.5	0.33	0.006
6.33		0.34	0.006
6.42		0.34	0.006
6.50	9.0	0.35	0.006
6.58		0.36	0.006
6.67		0.36	0.006
6.75	9.5	0.37	0.006
6.83		0.38	0.006
6.92		0.38	0.006
7.00	10.0	0.39	0.006
7.08		0.40	0.006
7.17		0.40	0.006
7.25	10.5	0.41	0.006
7.33		0.41	0.006
7.42		0.42	0.006
7.50	11.0	0.43	0.006
7.58		0.43	0.006

7.67		0.44	0.006
7.75	11.5	0.45	0.006
7.83		0.45	0.006
7.92		0.46	0.006
8.00	12.0	0.47	0.008
8.08		0.47	0.008
8.17		0.48	0.008
8.25	12.6	0.49	0.009
8.33		0.50	0.009
8.42		0.51	0.009
8.50	13.3	0.52	0.009
8.58		0.53	0.009
8.67		0.54	0.009
8.75	14.0	0.54	0.009
8.83		0.55	0.009
8.92		0.56	0.009
9.00	14.7	0.57	0.010
9.08		0.58	0.010
9.17		0.59	0.010
9.25	15.5	0.60	0.010
9.33		0.61	0.010
9.42		0.62	0.010
9.50	16.3	0.63	0.012
9.58		0.65	0.012
9.67		0.66	0.012
9.75	17.2	0.67	0.012
9.83		0.68	0.012
9.92		0.69	0.012
10.00	18.1	0.70	0.013
10.08		0.72	0.013
10.17		0.73	0.013
10.25	19.1	0.74	0.016
10.33		0.76	0.016
10.42		0.77	0.016
10.50	20.3	0.79	0.019
10.58		0.81	0.019
10.67		0.83	0.019
10.75	21.8	0.85	0.023
10.83		0.87	0.023
10.92		0.89	0.023
11.00	23.6	0.92	0.027
11.08		0.95	0.027
11.17		0.97	0.027
11.25	25.7	1.00	0.034
11.33		1.03	0.034
11.42		1.07	0.034
11.50	28.3	1.10	0.135
11.58		1.24	0.135
11.67		1.37	0.135
11.75	38.7	1.51	0.358
11.83		1.86	0.358

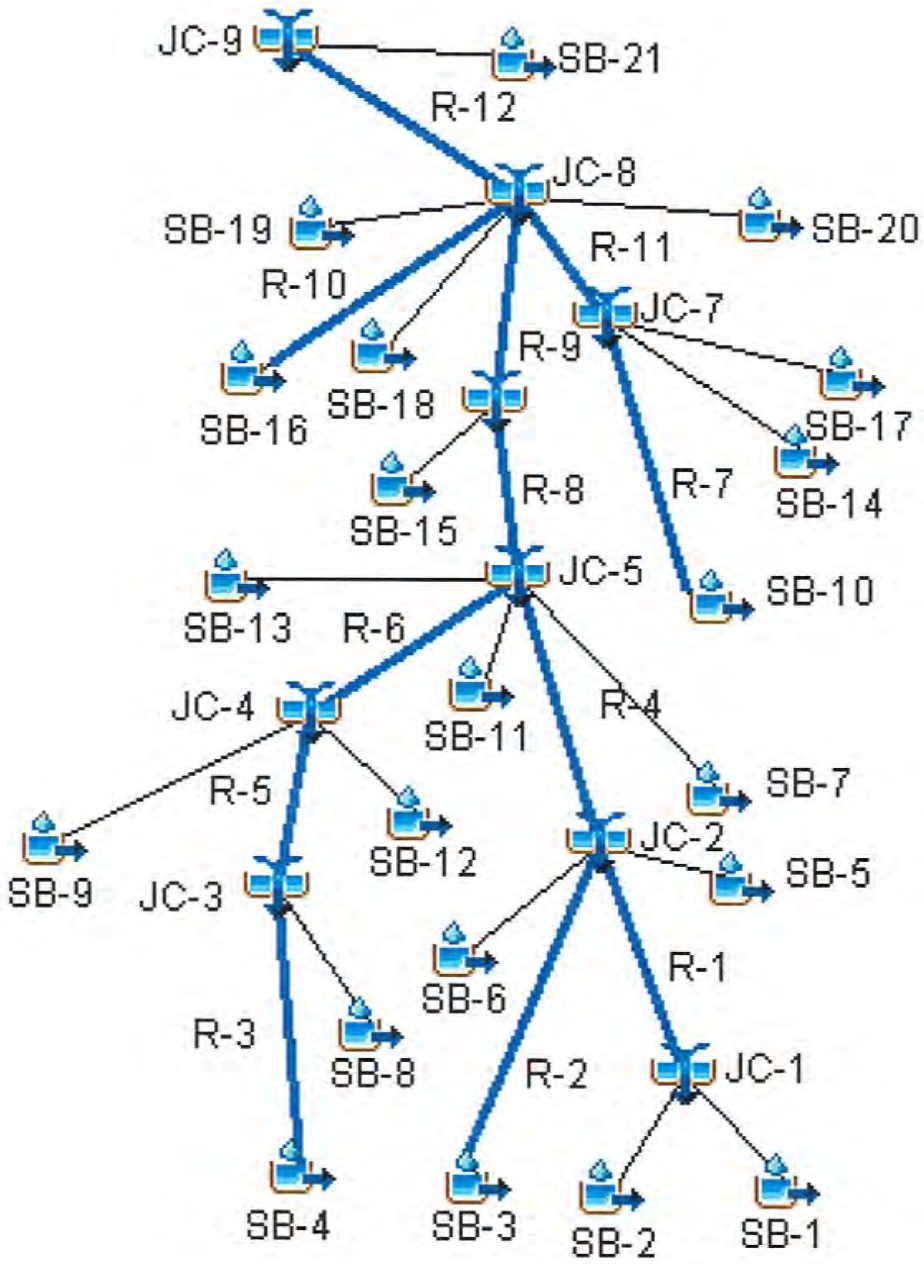
11.92		2.22	0.358
12.00	66.3	2.58	0.057
12.08		2.64	0.057
12.17		2.69	0.057
12.25	70.7	2.75	0.036
12.33		2.79	0.036
12.42		2.82	0.036
12.50	73.5	2.86	0.030
12.58		2.89	0.030
12.67		2.92	0.030
12.75	75.8	2.95	0.023
12.83		2.97	0.023
12.92		3.00	0.023
13.00	77.6	3.02	0.019
13.08		3.04	0.019
13.17		3.06	0.019
13.25	79.1	3.08	0.017
13.33		3.09	0.017
13.42		3.11	0.017
13.50	80.4	3.13	0.014
13.58		3.14	0.014
13.67		3.16	0.014
13.75	81.5	3.17	0.013
13.83		3.18	0.013
13.92		3.20	0.013
14.00	82.5	3.21	0.012
14.08		3.22	0.012
14.17		3.23	0.012
14.25	83.4	3.24	0.010
14.33		3.25	0.010
14.42		3.27	0.010
14.50	84.2	3.28	0.009
14.58		3.28	0.009
14.67		3.29	0.009
14.75	84.9	3.30	0.009
14.83		3.31	0.009
14.92		3.32	0.009
15.00	85.6	3.33	0.009
15.08		3.34	0.009
15.17		3.35	0.009
15.25	86.3	3.36	0.008
15.33		3.36	0.008
15.42		3.37	0.008
15.50	86.9	3.38	0.008
15.58		3.39	0.008
15.67		3.40	0.008
15.75	87.5	3.40	0.008
15.83		3.41	0.008
15.92		3.42	0.008
16.00	88.1	3.43	0.008
16.08		3.44	0.008

16.17		3.44	0.008
16.25	88.7	3.45	0.008
16.33		3.46	0.008
16.42		3.47	0.008
16.50	89.3	3.47	0.006
16.58		3.48	0.006
16.67		3.49	0.006
16.75	89.8	3.49	0.006
16.83		3.50	0.006
16.92		3.51	0.006
17.00	90.3	3.51	0.006
17.08		3.52	0.006
17.17		3.53	0.006
17.25	90.8	3.53	0.006
17.33		3.54	0.006
17.42		3.55	0.006
17.50	91.3	3.55	0.006
17.58		3.56	0.006
17.67		3.56	0.006
17.75	91.8	3.57	0.005
17.83		3.58	0.005
17.92		3.58	0.005
18.00	92.2	3.59	0.005
18.08		3.59	0.005
18.17		3.60	0.005
18.25	92.6	3.60	0.005
18.33		3.61	0.005
18.42		3.61	0.005
18.50	93.0	3.62	0.005
18.58		3.62	0.005
18.67		3.63	0.005
18.75	93.4	3.63	0.005
18.83		3.64	0.005
18.92		3.64	0.005
19.00	93.8	3.65	0.005
19.08		3.65	0.005
19.17		3.66	0.005
19.25	94.2	3.66	0.005
19.33		3.67	0.005
19.42		3.67	0.005
19.50	94.6	3.68	0.004
19.58		3.68	0.004
19.67		3.69	0.004
19.75	94.9	3.69	0.005
19.83		3.70	0.005
19.92		3.70	0.005
20.00	95.3	3.71	0.004
20.08		3.71	0.004
20.17		3.71	0.004
20.25	95.6	3.72	0.004
20.33		3.72	0.004
20.42		3.73	0.004

20.50	95.9	3.73	0.004
20.58		3.73	0.004
20.67		3.74	0.004
20.75	96.2	3.74	0.004
20.83		3.75	0.004
20.92		3.75	0.004
21.00	96.5	3.75	0.004
21.08		3.76	0.004
21.17		3.76	0.004
21.25	96.8	3.77	0.004
21.33		3.77	0.004
21.42		3.77	0.004
21.50	97.1	3.78	0.004
21.58		3.78	0.004
21.67		3.78	0.004
21.75	97.4	3.79	0.004
21.83		3.79	0.004
21.92		3.80	0.004
22.00	97.7	3.80	0.004
22.08		3.80	0.004
22.17		3.81	0.004
22.25	98.0	3.81	0.004
22.33		3.82	0.004
22.42		3.82	0.004
22.50	98.3	3.82	0.004
22.58		3.83	0.004
22.67		3.83	0.004
22.75	98.6	3.84	0.004
22.83		3.84	0.004
22.92		3.84	0.004
23.00	98.9	3.85	0.004
23.08		3.85	0.004
23.17		3.85	0.004
23.25	99.2	3.86	0.004
23.33		3.86	0.004
23.42		3.87	0.004
23.50	99.5	3.87	0.004
23.58		3.87	0.004
23.67		3.88	0.004
23.75	99.8	3.88	0.003
23.83		3.88	0.003
23.92		3.89	0.003
24.00	100.0	3.89	

Note: Ranfall distribution percentages were obtained from Tables 2.4 and 2.5 of the Drainage Design Manual for Maricopa County, Volume 1, Hydrology.

APPENDIX E
HEC-HMS
MODEL OUTPUT


JC-9
SB-21
R-12
JC-8
SB-19
SB-20
R-11
R-10
JC-7
R-9
SB-16
SB-18
SB-17
SB-14
SB-15
R-8
R-7
JC-5
SB-10
SB-13
R-6
JC-4
SB-11
R-4
SB-7
R-5
JC-2
SB-9
SB-12
SB-5
JC-3
SB-6
R-1
R-3
SB-8
R-2
JC-1
SB-4
SB-3
SB-2
SB-1

Horseshoe Draw

HEC-HMS Flow Results

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

HEC-HMS ELEMENT ID	100-Year, 6-Hour Model Flow Rate	100-Year, 24-Hour Model Flow Rate
	[cfs]	[cfs]
JC-1	1,285	1,574
JC-2	3,518	4,167
JC-3	2,889	3,082
JC-4	4,315	4,378
JC-5	10,186	10,401
JC-6	10,248	10,285
JC-7	1,728	2,151
JC-8	13,445	12,728
JC-9	13,356	12,604

Notes:

1: JC-6 is the probable location of the future impoundment structure.

2: JC-9 is at the Paloma Trail wet crossing of Horseshoe Draw.

APPENDIX F
INDIRECT METHOD CALCULATIONS

INDIRECT METHOD COMPARISON TABLE

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INDIRECT METHOD	Drainage Area at JC-6 (mi^2)	Drainage Area at JC-9 (acres)	Mean Elevation (ft/1000)	Mean Annual Precipitation (in)	Discharge at JC-6 (cfs)	Discharge at JC-9 (cfs)
Method 1 Curve G	12.2	16.8			4,880	5,880
Method 1 Curve H					10,980	13,440
USGS Data for AZ					3,278	3,905
Roeske Regression Equation			4	16.0	5,106	6,221
HEC-HMS, 6-Hour Model					10,248	13,356
HEC-HMS, 24-hour Model					10,285	12,604

USGS DATA - $Q_{100} = 850A^{0.54}$

Regional Regression - $Q_{100} = 10^{(5.52 - 2.42AREA^{(-0.12)})}$

Notes:
1: JC-6 is the probable location of the future impoundment structure.
2: JC-9 is at the Paloma Trail wet crossing of Horseshoe Draw.