60% DRAINAGE REPORT

FOR

MONTEZUMA CASTLE NATIONAL MONUMENT

NPS Project No. NM-05-112018-16

Located in
Yavapai County Parcel No. 800-09-001D
Northeast of the City of Camp Verde

Prepared for
National Park Services
Montezuma Castle RD
Camp Verde, AZ 86322

Prepared by
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April 27, 2018
Revised: March 16, 2018
Job #51118

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APPENDICES

INTRODUCTION

Montezuma Castle National Monument (MCNM) is a National Monument under National Park Service jurisdiction. The site is known for the cliff dwellings and is also known for the large amount of rooms this dwelling has. The site is used for educational and destination visits from local and tourists. The site is located 5 miles north from the City of Camp Verde and is located along Beaver Creek. The access to the site is on a single two lane road that comes from the east and south into the current parking lot. National Park Services is proposing a new parking lot to the south of the current drive and parking lot. Site improvements for this project will include a new parking lot, picnic area, sidewalks and water mitigation.

This site currently drains to the south and west and is channeled into Beaver Creek. The hydrology basins are smaller than 200 acres and the existing structures show no sign of lack of efficiency. The proposed drainage will follow the existing drainage patterns.

This project site is located within Zone X of FEMA FIRM Map #04025C2180H effective October 16, 2015. Zone X is described as areas determined to be outside the 0.2% annual chance floodplain. The FEMA map is provided in Appendix A.

OBJECTIVE

The objective of this drainage report is to determine the impact the proposed parking lot will have on the runoff characteristics of the site. Mitigation measures will be provided for adverse impacts to the runoff conditions per the Federal Highway Administration Urban Design Manual (FHAUDM).

PROCEDURE

The Rational Method was used to determine peak discharge rates for the pre and post-development conditions. Topographic and boundary information was provided by Yavapai County Geographic Information Systems, dated in 2014, were used for analysis. Rainfall data was taken from National Oceanic and Atmospheric Administration (NOAA). Soil information was taken from the NRCS Web Soil Survey website and is proved in Appendix B. The site plan is prepared by Multicultural Technical Engineers and was used to determine the additional impervious areas proposed with the development. Appendix C includes a drainage exhibit which illustrates the drainage patterns and proposed site improvements.

Pre-Development Conditions

The existing runoff is concentrated through two concentration points. Drainage Basin A (DB-A) is located north of the access road and is approximately 5 acres. The Concentration Point A (CP-A) is concentrated through a 15 inch CSP culvert (N/S) that crosses the access road (E/W) and is allowed to naturally run to Beaver Creek to the southwest. This has provided a natural stream to form and deposit water in a low sloped ground where the channel disappears and allows the water to seep into the ground prior to reaching Beaver Creek. Drainage Basin B (DB-B) is located south of the access road and is approximately 8 acres and has a Concentration Point B (CP-B) that sheet flows and natural channels to Beaver Creek to the southwest. There is no definite channel to Beaver Creek but the existing topography shows that the

water flows to it. Both of these basins and points were used to determine the pre-development peak flow rates.

There is no evidence that water flows making it from the most upper part of the basin to Beaver Creek. This was determined by extensive topography review and a site walk. There was also no evidence that the existing infrastructure was underperforming or required maintenance.

Post-Development Conditions

The proposed site grading in the post-development condition will not change the size of either drainage basins. DB-A will be unchanged in size and in surface types. DB-B will be unchanged in size but will have an increase in impervious area due to the addition of a parking lot with associated sidewalks. The drainage with not change within the parking lot with the proposed picnic area because the addition of sidewalk is minimal considered the overall size of the drainage basin and will be mitigated through the addition of landscape and proper grading. The overall post-development peak runoff will be increased due to the addition of impervious area with no change in the overall drainage base size.

DB-A is routed under the access road via CSP and will be routed through DB-B with an open channel to Beaver Creek. The open channel will include the runoff from DB-A and DB-B.

The Federal Highway Administration Urban Design Manual does not provide applicable moments when a detention basin is required. If the site was located in a municipality a detention pond would be heavily designed and be required for implementation. Multicultural Technical Engineers recommends an implementation of a Low Impact Development basin or a detention basin. We will provide a simple and conceptual detention basin that will be required to be heavily analyzed.

RESULTS

Multicultural Technical Engineers used the Rational Method provided from the design manual to calculate total runoff in DB-A and DB-B. The Rational Method was used because each Drainage Basin meets the requirements provided by the FHAUDM.

Pre-Development Conditions

DB-A has a net area of 5.51 acres. The Weighted C was calculated by taking the area (4.89 acres) of natural landscape (C = 0.3) and the area (0.62 acres) of impervious area (C = 0.95) and giving a weighted average of 0.373 because there is significantly more natural landscape than impervious area. The flow from DB-A for the 100-year storm is 7.80 CFS. When analyzing CP-A the use of CulvertMaster was used. With a flow of 7.80 CFS through a 15 inch corrugated steel pipe (CSP) provides an exit velocity of 13.3 FPS. The velocity exiting the CSP is significant and is considered to be an extreme scour velocity that has the potential of destroying landscapes/ property.

DB-B has a net area of 12.98 acres. The Weighted C was calculated by taking the area (12.73 acres) of natural landscape (C = 0.3) and the area (0.25 acres) of impervious area (C = 0.95) and giving a weighted

average of 0.31 because there is significantly more natural landscape than impervious area. The flow from DB-B for the 100-year storm is 5.30 CFS.

Post-Development Conditions

DB-A did not change in size or in surface types. The amount of flow through CP-A is 7.80 CFS with 13.3 FPS.

DB-B did not change in size but there was an increase of impervious area by 1.45 acres. Using the Rational Method again the net flow with additional impervious area is increased to 7.00 CFS.

DB-A and DB-B will be drained into a single open channel and deposited through CP-B at Beaver Creek. FlowMaster was used to determine the normal depth and velocity of the channel. In Appendix C includes the generated reports for each section of the channel including the culvert. The amount of freeboard through the channel is 1 to 3 feet. The depth is between 0.28 and .9 feet. The velocities are between 10.66 to 3.0 FPS. The channel flow was increased from 7.8 CFS to 10.8 CFS as the channel moves southeast to Beaver Creek.

The proposed parking lot will be graded to drain to the open channel. There is locations where water will be graded to drain within proposed green spaces to help alleviate the amount of water to the channel but the channel will be designed to hold the entire amount. The green spaces will include existing vegetation or vegetation the client believes will survive. MTE does not hold responsibility or liability for plant specifications/ locations and types for the area of the green spaces.

The detention basin was sized by using Bentley PondPack as running a pre- and post-development Modified Rational Method for the 100-year storm.

CONCLUSION

The peak discharge for the 100-year storm event were determined for the proposed parking lot site for both the pre- and post-development conditions. The proposed lot has been designed to discharge runoff into the proposed channel and then into Beaver Creek. The design concepts in this report will ensure that the drainage integrity of the site is maintained as a National Monument. The proposed drainage plan provides a low maintenance system but may require clearing large debris and any grass/ shrubs inside the channel and parking lot basins. Refer to the construction plans by MTE for grades, locations, and notes of design.

REFERENCES

FEMA Floodplain Maps

https://msc.fema.gov/portal/search?AddressQuery=montezuma%20castle%20national%20monument#searchresultsanchor

Soil Map:

https://www.nps.gov/im/sodn/images/soilmapMOCA_1.png?maxwidth=650&autorotate=false

Appendix HA

FEMA Floodplain Map

National Flood Hazard Layer FIRMette

FEMA

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth
- Regulatory Floodway *Zone AE, AO, AH, VE, AR*

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 2/28/2018 at 11:51:19 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures.** Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 12. The **horizontal datum** was NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum.** For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC–3, #9202
1315 East–West Highway
Silver Spring, MD 20910–3282

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713–3242**, or visit its website at http://www.ngs.noaa.gov/.

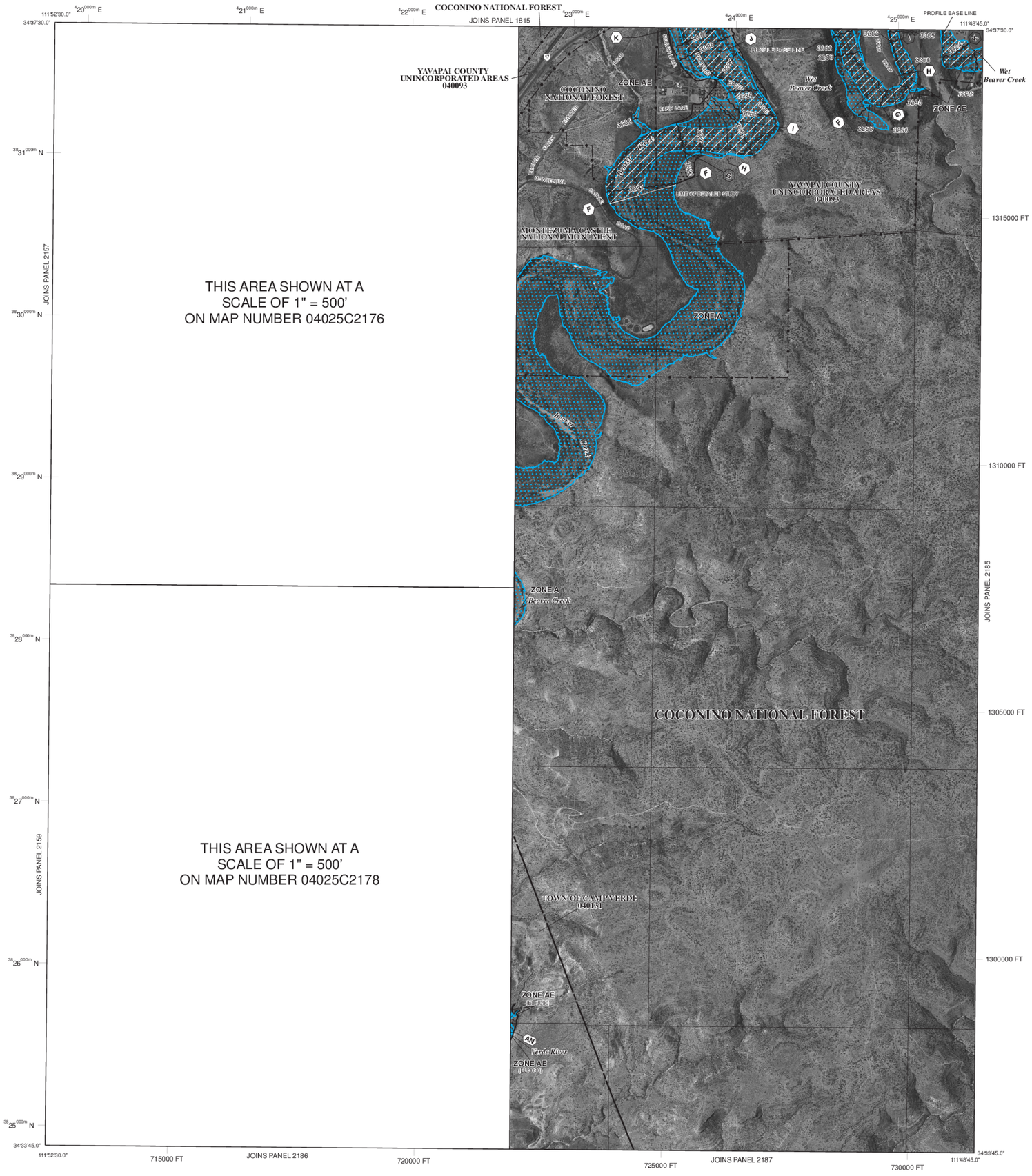
Base map information shown on this FIRM was derived from Arizona Digital Orthophoto Quadrangles (DOQs) with a resolution of 1 ft. per pixel from the USDA Aerial Photography Field Office dated 2010.

This map may reflect more detailed or up to date stream channel configurations than those shown on the previous FIRM. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations and improved topographic data. The profile baselines depicted on this map represent the hydraulic modeling baselines that match the flood profiles and Floodway Data Tables if applicable, in the FIS report. As a result, the profile baselines may deviate significantly from the new base map channel representation and may appear outside of the floodplain.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de–annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

For information and questions about this map, available products associated with this FIRM including historic versions of this FIRM, how to order products or the National Flood Insurance Program in general, please call the FEMA Map Information eXchange at 1-877-FEMA-MAP (1–877–336–2627) or visit the **FEMA Map Service Center** website at http://msc.fema.gov. Available products may include previously issued Letters ofMap Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the website. Users may determine the current map date for each FIRM panel by visiting the **FEMA Map Service Center** website or by calling the FEMA Map Information eXchange.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A No Base Flood Elevations determined.

ZONE AE Base Flood Elevations determined.

ZONE AH Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.

ZONE AO Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.

ZONE AR Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.

ZONE A99 Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.

ZONE V Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.

ZONE VE Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X Areas determined to be outside the 0.2% annual chance floodplain.

ZONE D Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

- 1% annual chance floodplain boundary
- 0.2% annual chance floodplain boundary
- Floodway boundary
- Zone D boundary
- CBRS and OPA boundary
- Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
- 513 — Base Flood Elevation line and value; elevation in feet*
- (EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

- A — A — Cross section line
- 23 — 23 — Transect line
- 97°07'30", 32°22'30" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
- 4275000mN — 1000-meter Universal Transverse Mercator grid ticks, zone 12
- 6000000 FT — 5000-foot grid ticks: Arizona State Plane coordinate system, central zone (FIPSZONE 0202), Transverse Mercator
- DX5510 — Bench mark (see explanation in Notes to Users section of this FIRM panel)
- M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP
June 6, 2001
EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL
September 3, 2010
October 16, 2015 –to change Special Flood Hazard Areas, to change Base Flood Elevations, and to reflect updated topographic information.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1–800–638–6620.

MAP SCALE 1" = 1000'
500 0 1000 2000 FEET
300 0 300 600 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 2180H

FIRM
FLOOD INSURANCE RATE MAP

YAVAPAI COUNTY, ARIZONA

AND INCORPORATED AREAS

PANEL 2180 OF 3900
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
YAVAPAI COUNTY	040093	2180	H
CAMP VERDE, TOWN OF	040131	2180	H

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
04025C2180H

MAP REVISED
OCTOBER 16, 2015

Federal Emergency Management Agency

Appendix HB

NRCS Soil Map

Soil Map—Beaver Creek Area, Arizona
(Montezuma Castle National Monument)

111° 50' 15" W — 111° 50' 8" W
34° 36' 42" N — 34° 36' 32" N
423200 — 423230 — 423260 — 423290 — 423320 — 423350 — 423380
3830310 — 3830280 — 3830250 — 3830220 — 3830190 — 3830160 — 3830130 — 3830100 — 3830070 — 3830040 — 3830010

Re

Gu

Soil Map may not be valid at this scale.

Map Scale: 1:862 if printed on B portrait (11" x 17") sheet.

N

Meters: 0 10 20 40 60

Feet: 0 40 80 160 240

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:31,700.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Beaver Creek Area, Arizona
Survey Area Data: Version 7, Sep 11, 2017

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 28, 2014—Feb 13, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Gu	Guest clay	5.7	90.1%
Re	Retriever loam	0.6	9.9%
Totals for Area of Interest		**6.3**	**100.0%**

Appendix HC

FlowMaster Channel Analysis

Worksheet for 00+00.00 to 00+10.00

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	46.5000	%
Left Side Slope	2.00	ft/ft (H:V)
Right Side Slope	2.00	ft/ft (H:V)
Bottom Width	2.00	ft
Discharge	7.80	ft³/s

Results

Normal Depth	0.28	ft
Flow Area	0.73	ft²
Wetted Perimeter	3.27	ft
Hydraulic Radius	0.22	ft
Top Width	3.14	ft
Critical Depth	0.63	ft
Critical Slope	0.02530	ft/ft
Velocity	10.66	ft/s
Velocity Head	1.77	ft
Specific Energy	2.05	ft
Froude Number	3.89	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.28	ft
Critical Depth	0.63	ft
Channel Slope	46.5000	%

Worksheet for 00+00.00 to 00+10.00

GVF Output Data

Critical Slope	0.02530	ft/ft

Worksheet for 00+10.00 to 00+51.85

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	13.2600	%
Left Side Slope	2.00	ft/ft (H:V)
Right Side Slope	2.00	ft/ft (H:V)
Bottom Width	2.00	ft
Discharge	7.80	ft³/s

Results

Normal Depth	0.40	ft
Flow Area	1.13	ft²
Wetted Perimeter	3.80	ft
Hydraulic Radius	0.30	ft
Top Width	3.61	ft
Critical Depth	0.63	ft
Critical Slope	0.02530	ft/ft
Velocity	6.89	ft/s
Velocity Head	0.74	ft
Specific Energy	1.14	ft
Froude Number	2.17	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.40	ft
Critical Depth	0.63	ft
Channel Slope	13.2600	%

Worksheet for 00+10.00 to 00+51.85

GVF Output Data

Critical Slope	0.02530	ft/ft

Worksheet for 00+51.85 to 02+46.70

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	6.1900	%
Left Side Slope	2.00	ft/ft (H:V)
Right Side Slope	2.00	ft/ft (H:V)
Bottom Width	2.00	ft
Discharge	10.80	ft³/s

Results

Normal Depth	0.59	ft
Flow Area	1.87	ft²
Wetted Perimeter	4.63	ft
Hydraulic Radius	0.40	ft
Top Width	4.36	ft
Critical Depth	0.75	ft
Critical Slope	0.02424	ft/ft
Velocity	5.77	ft/s
Velocity Head	0.52	ft
Specific Energy	1.11	ft
Froude Number	1.55	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.59	ft
Critical Depth	0.75	ft
Channel Slope	6.1900	%

Worksheet for 00+51.85 to 02+46.70

GVF Output Data

Critical Slope	0.02424	ft/ft

Worksheet for 02+46.70 to 05+19.98

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	2.7100	%
Left Side Slope	2.00	ft/ft (H:V)
Right Side Slope	2.00	ft/ft (H:V)
Bottom Width	2.00	ft
Discharge	10.80	ft³/s

Results

Normal Depth	0.73	ft
Flow Area	2.52	ft²
Wetted Perimeter	5.26	ft
Hydraulic Radius	0.48	ft
Top Width	4.92	ft
Critical Depth	0.75	ft
Critical Slope	0.02424	ft/ft
Velocity	4.28	ft/s
Velocity Head	0.28	ft
Specific Energy	1.01	ft
Froude Number	1.05	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.73	ft
Critical Depth	0.75	ft
Channel Slope	2.7100	%

Worksheet for 02+46.70 to 05+19.98

GVF Output Data

Critical Slope	0.02424	ft/ft

Culvert Designer/Analyzer Report
Under Maintenance Road
05+19.98 to 05+49.98

Analysis Component			
Storm Event	Design	Discharge	10.80 cfs

Peak Discharge Method: User-Specified			
Design Discharge	10.80 cfs	Check Discharge	7.80 cfs

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	10.80 cfs	Bottom Elevation	0.00 ft
Depth	0.66 ft	Velocity	3.09 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	2-18 inch Circular	10.80 cfs	1.34 ft	3.06 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Under Maintenance Road
05+19.98 to 05+49.98

Component:Culvert-1

Culvert Summary					
Computed Headwater Elev	1.34	ft	Discharge	10.80	cfs
Inlet Control HW Elev.	1.27	ft	Tailwater Elevation	0.66	ft
Outlet Control HW Elev.	1.34	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.90				

Grades					
Upstream Invert	0.00	ft	Downstream Invert	-1.50	ft
Length	30.00	ft	Constructed Slope	5.0000	%

Hydraulic Profile					
Profile	CompositePressureProfileS1S2		Depth, Downstream	2.16	ft
Slope Type	N/A		Normal Depth	0.47	ft
Flow Regime	N/A		Critical Depth	0.90	ft
Velocity Downstream	3.06	ft/s	Critical Slope	0.5064	%

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	Corrugated HDPE (Smooth Interior)		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	1.34	ft	Upstream Velocity Head	0.37	ft
Ke	0.20		Entrance Loss	0.07	ft

Inlet Control Properties					
Inlet Control HW Elev.	1.27	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	3.5	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Worksheet for 05+49.98 to 07+05.00

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	3.3800	%
Left Side Slope	2.00	ft/ft (H:V)
Right Side Slope	2.00	ft/ft (H:V)
Bottom Width	2.00	ft
Discharge	10.80	ft³/s

Results

Normal Depth	0.69	ft
Flow Area	2.33	ft²
Wetted Perimeter	5.08	ft
Hydraulic Radius	0.46	ft
Top Width	4.76	ft
Critical Depth	0.75	ft
Critical Slope	0.02424	ft/ft
Velocity	4.64	ft/s
Velocity Head	0.33	ft
Specific Energy	1.02	ft
Froude Number	1.17	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.69	ft
Critical Depth	0.75	ft
Channel Slope	3.3800	%

Worksheet for 05+49.98 to 07+05.00

GVF Output Data

Critical Slope	0.02424	ft/ft

Appendix HD

Bentley PondPack – Detention Basin Analysis

Appendix HE

Modified Rational Method

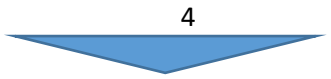
North Watershed into Proposed Lot

Flow Segment	Length (ft)	Beginning Elevation (ft)	End Elevation (ft)	Slope (ft/ft)	Manning's Coefficient (n)
Sheet Flow	145	3320.43	3300.00	0.14089655	0.2
Shallow	None - Straight into Roadside Channel				
Channel	876	3300.00	3228.50	0.081621	

Channel Analysis

$V = (K_u/n)\, R^{2/3}\, S^{1/2}$

		Units/ Location Found
V	13.501	Ft/s
K_u	1.49	Known
n	0.02	Table 3-4
R	0.45	--->
S	0.0952	From Topo



in Feet

$T_{t3} = L/(60\,V)$

T_t3	0.6	Minute(s)
L	450	From Topo

Shallow Flow Analysis

$V = K_u\, k\, S_p^{0.5}$

V	0.2258	ft/s
K_u	3.28	Given
k	0.46	Table 3-3
S_p	15%	%, Topo

$T_{t2} = L/(60\,V)$

T_t2	6.6425	Minutes
L	90	

Sheet Flow $T_{ti} = \frac{K_u}{I^{0.4}} \left(\frac{n\,L}{\sqrt{S}} \right)^{0.6}$ 3.2.2.3 FHA Code Book Equ 3-3

Tsf	11.119	Minutes
K_u	0.933	Given
I	2.03	in/hr (NOAA) 50Y1HR
n	0.2	Table 3-2
L	215	ft,Topo
S	0.186	ft/ft, Topo

Total, Tc	18.3	Minutes

North Watershed into Proposed Lot

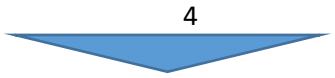
$Q = (CIA)/K_u$		Weighted C	0.373	/
		I_10Y30M	2.21	in/hr
		I_25Y30M	2.78	
		I_50Y30M	3.26	
		I_100Y30M	3.78	
		Area	5.51	acres
		K_u	1	Unit adjustment
Q_10Y30M	4.5438	CFS		
Q_25Y30M	5.7157	CFS		
Q_50Y30M	6.7026	CFS		
Q_100Y30M	7.7717	CFS		

South Watershed Pre-Development

Channel Analysis

$V = (K_u/n)\, R^{2/3}\, S^{1/2}$

		Units/ Location Found
V	13.501	Ft/s
K_u	1.49	Known
n	0.02	Table 3-4
R	0.45	--->
S	0.0952	From Topo



in Feet

$T_{t3} = L/(60\ V)$

T_t3	0.0	Minute(s)
L	0	From Topo

Reason to believe there is no dedicated or topographic channel displayed for water to run through.

Shallow Flow Analysis

$V = K_u\, k\, S_p^{0.5}$

V	0.0813	ft/s
K_u	3.28	Given
k	0.46	Table 3-3
S_p	5.4%	%, Topo

$T_{t2} = L/(60\ V)$

T_t2	95.349	Minutes
L	465	

Sheet Flow $T_{ti} = \frac{K_u}{I^{0.4}} \left(\frac{n\ L}{\sqrt{S}} \right)^{0.6}$ 3.2.2.3 FHA Code Book Equ 3-3

Tsf	20.756	Minutes
K_u	0.933	Given
I	2.03	in/hr (NOAA) 50Y1HR
n	0.2	Table 3-2
L	475	ft,Topo
S	0.1134	ft/ft, Topo

Total, Tc	116.1	Minutes

South Watershed Pre-Development

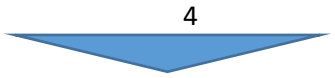
$Q = (CIA)/K_u$		Weighted C	0.31	/
		I_10Y120M	0.777	in/hr
		I_25Y120M	0.972	
		I_50Y120M	1.13	
		I_100Y120M	1.31	
		Area	12.98	acres
		K_u	1	Unit adjustment
Q_10Y120M	3.157	CFS		
Q_25Y120M	3.949	CFS		
Q_50Y120M	4.591	CFS		
Q_100Y120M	5.322	CFS		

South Watershed Post-Development

Channel Analysis

$V = (K_u/n)\, R^{2/3}\, S^{1/2}$

		Units/ Location Found
V	13.501	Ft/s
K_u	1.49	Known
n	0.02	Table 3-4
R	0.45	--->
S	0.0952	From Topo



in Feet

$T_{t3} = L/(60\,V)$

T_t3	0.0	Minute(s)
L	0	From Topo

Reason to believe there is no dedicated or topographic channel displayed for water to run through.

Shallow Flow Analysis

$V = K_u\, k\, S_p^{0.5}$

V	0.0813	ft/s
K_u	3.28	Given
k	0.46	Table 3-3
S_p	5.4%	%, Topo

$T_{t2} = L/(60\,V)$

T_t2	95.349	Minutes
L	465	

Sheet Flow $T_{ti} = \frac{K_u}{I^{0.4}} \left(\frac{n\,L}{\sqrt{S}} \right)^{0.6}$ 3.2.2.3 FHA Code Book Equ 3-3

Tsf	20.756	Minutes
K_u	0.933	Given
I	2.03	in/hr (NOAA) 50Y1HR
n	0.2	Table 3-2
L	475	ft,Topo
S	0.1134	ft/ft, Topo

Total, Tc	116.1	Minutes

South Watershed Post-Development

$Q = (CIA)/K_u$		Weighted C	0.39	/
		I_10Y120M	0.777	in/hr
		I_25Y120M	0.972	
		I_50Y120M	1.13	
		I_100Y120M	1.31	
		Area	12.98	acres
		K_u	1	Unit adjustment
Q_10Y120M	3.889	CFS		
Q_25Y120M	4.865	CFS		
Q_50Y120M	5.656	CFS		
Q_100Y120M	6.557	CFS		

Parking Lot Influence

$Q = (CIA)/K_u$		Weighted C	0.95	/
		I_10Y120M	5.26	in/hr
		I_25Y120M	6.62	
		I_50Y120M	7.75	
		I_100Y120M	8.99	
		Area	1.45	acres
		K_u	1	Unit adjustment
Q_10Y120M	7.241	CFS		
Q_25Y120M	9.113	CFS		
Q_50Y120M	10.668	CFS		
Q_100Y120M	12.375	CFS		

Channel Characteristics

				Upstream	Downstream				
		Station	Length (ft)	Elevation (ft)		Slope (%)	Flows (CFS)	Flow (FT/s)	Normal Depth (ft)
Surface Elevations	1	00+00.00	10.00	3216.52		33.40	7.8	9.51	0.31
		00+10.00			3213.18				
	2	00+10.00	41.85	3213.18		13.02	7.8	6.84	0.41
		00+51.85			3207.73				
	3	00+51.85	194.85	3207.73		6.10	10.8	5.74	0.59
		02+46.70			3195.84				
	4	02+46.70	258.64	3195.84		2.26	10.8	4.01	0.76
		05+19.98			3190				
	5	05+19.98	30.00	3190		0.00	10.8	3.06	0.9
		05+49.98			3190				
	6	05+49.98	155.02	3190		5.16	10.8	5.40	0.62
		07+05.00			3182				

				Upstream	Downstream					
		Station	Length (ft)	Elevation (ft)		Slope (%)	Flows (CFS)	Flow (FT/s)	Normal Depth (ft)	Freeboard (FT)
Channel Elevations	1	00+00.00	10.00	3216.52		46.50	7.8	10.66	0.28	1.03
		00+10.00			3211.87					
	2	00+10.00	41.85	3211.87		13.26	7.8	6.89	0.4	1.01
		00+51.85			3206.32					
	3	00+51.85	194.85	3206.32		6.19	10.8	5.77	0.59	1
		02+46.70			3194.25					
	4	02+46.70	258.64	3194.25		2.71	10.8	4.28	0.73	2.03
		05+19.98			3187.24					
	5	05+19.98	30.00	3187.24		5.00	10.8	3.06	0.9	3.36
		05+49.98			3185.74					
	6	05+49.98	155.02	3185.74		3.38	10.8	4.64	0.69	0.81
		07+05.00			3180.5					

Appendix HF

CulvertMaster Analysis

Culvert Analysis Report
Culvert under Montezuma Castle Road (Into Proposed Parking Lot)

Analysis Component			
Storm Event	Design	Discharge	7.80 cfs

Peak Discharge Method: User-Specified			
Design Discharge	7.80 cfs	Check Discharge	6.70 cfs

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	N/A ft

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-15 inch Circular	7.80 cfs	3,223.44 ft	13.31 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
Culvert under Montezuma Castle Road (Into Proposed Parking Lot)

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	3,223.44	ft	Discharge	7.80	cfs
Inlet Control HW Elev.	3,223.44	ft	Tailwater Elevation	N/A	ft
Outlet Control HW Elev.	3,223.37	ft	Control Type	Inlet Control	
Headwater Depth/Height	1.80				

Grades					
Upstream Invert	3,221.19	ft	Downstream Invert	3,208.61	ft
Length	56.00	ft	Constructed Slope	22.4643	%

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.60	ft
Slope Type	Steep		Normal Depth	0.60	ft
Flow Regime	Supercritical		Critical Depth	1.11	ft
Velocity Downstream	13.31	ft/s	Critical Slope	4.4482	%

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.25	ft
Section Size	15 inch		Rise	1.25	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	3,223.37	ft	Upstream Velocity Head	0.72	ft
Ke	0.50		Entrance Loss	0.36	ft

Inlet Control Properties					
Inlet Control HW Elev.	3,223.44	ft	Flow Control	N/A	
Inlet Type	Headwall		Area Full	1.2	ft²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

Culvert Analysis Report
Under Maintenance Road

Analysis Component			
Storm Event	Design	Discharge	10.80 cfs

Peak Discharge Method: User-Specified			
Design Discharge	10.80 cfs	Check Discharge	7.80 cfs

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	10.80 cfs	Bottom Elevation	0.00 ft
Depth	0.66 ft	Velocity	3.09 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	2-18 inch Circular	10.80 cfs	1.34 ft	3.06 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
Under Maintenance Road

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	1.34	ft	Discharge	10.80	cfs
Inlet Control HW Elev.	1.27	ft	Tailwater Elevation	0.66	ft
Outlet Control HW Elev.	1.34	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.90				

Grades					
Upstream Invert	0.00	ft	Downstream Invert	-1.50	ft
Length	30.00	ft	Constructed Slope	5.0000	%

Hydraulic Profile					
Profile	CompositePressureProfileS1S2		Depth, Downstream	2.16	ft
Slope Type	N/A		Normal Depth	0.47	ft
Flow Regime	N/A		Critical Depth	0.90	ft
Velocity Downstream	3.06	ft/s	Critical Slope	0.5064	%

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	Corrugated HDPE (Smooth Interior)		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	1.34	ft	Upstream Velocity Head	0.37	ft
Ke	0.20		Entrance Loss	0.07	ft

Inlet Control Properties					
Inlet Control HW Elev.	1.27	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	3.5	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				