11607

Hydrological Analysis

Supplemental Information For Lake and Streambed Alteration Agreement

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Humboldt County
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Prepared for:

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MOTHER EARTH ENGINEERING

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1. Purpose

The purpose of this report is to evaluate an existing stream crossings for adequacy in conveying the peak flows of the 100-year storm event. Additionally, four rocked fords are proposed, and the hydrological analysis was used to predict the expected peak flows at these rocked fords for the 100-year storm event. These analyses were done by completing a watershed analysis and analyzing field data.

2. Project Description

The project site is located on Humboldt County APN 522-023-001. The following tables provide the locations, descriptions, and brief summaries of the stream crossings on the property.

Table 1: Inventory of stream crossings on property.

Map ID	Description	Latitude	Longitude
CV-1/Project 1	Existing 18" corrugated metal culvert. 6.8% slope. Clogging at inlet, signs of previous overtopping of road prism.	40.9855	-123.7212
RF-1/Project 2	Proposed rocked ford due to lack of defined channel upstream of crossing..	40.9930	-123.7208
RF-2/Project 3	Proposed rocked ford due to lack of defined channel upstream of crossing.	40.9933	-123.7203
RF-3/ Project 4	Proposed rocked ford due to lack of defined channel upstream of crossing.	40.9940	-123.7203
RF-4/Project 5	Proposed rocked ford due to lack of defined channel upstream of crossing.	40.9934	-123.7202

3. Field Work

Mother Earth Engineering staff conducted a site visit in April of 2020 to map out the locations of the stream crossings, and other relevant drainage features.

4. Hydrological Analysis

A hydrological analysis was conducted by Mother Earth Engineering staff to verify the sizing of the stream crossing and its ability to meet 100-year storm design standards. A full documentation of the analyses conducted may be found in Attachment A: Hydrological Analysis.

Calculating Contributing Watershed Area

The contributing watershed area for each drainage feature was hand delineated using a topographic map with 80 ft. contours on the Humboldt County WebGIS Portal. Table 2 below summarizes the

contributing watershed areas of each feature. Further detail of these delineations may be found in Attachment A: Hydrological Analysis.

Table 2: Contributing watershed areas for each documented drainage feature.

Map ID	Contributing Watershed Area (acres)
CV-1/Project 1	8.22
RF-1/Project 2	1.70
RF-2/Project 3	1.72
RF-3/Project 4	1.19
RF-4/Project 5	0.46

The Rational Method was then used to find the peak flow of the 100-year design storm for each of the projects contributing watershed.

Rational Method

The Rational Method for calculating the peak flow of the 100-year storm in a watershed is determined by the runoff coefficient, the rainfall intensity, and the contributing area in acres for the drainage feature.

Runoff Coefficient

The runoff coefficient (C) used for the Rational Method is based off the values given by Pacific Watershed Associate's *Handbook for Forest, Ranch & Rural Roads* (Weaver, 2014). The loamy soil type and woodland land type provides a *C* value of 0.30.

Calculating the time of concentration, t_c

The time of concentration was calculated using the modified Kirpich equation as outlined in "Designing Watercourse Crossings for Passage of 100-Year Flood Flows, Wood, and Sediment" (Cafferata, 2017). Contributing watershed areas for each drainage feature as well as the length and average slope of the longest flow paths were calculated using topographic data and used to calculate the time of concentration. If a time of concentration value is calculated to be less than 10 minutes, the t_c value is rounded up to 10 minutes (Cafferata, 2017). These time of concentration values were then used to find the runoff intensity.

Calculating the runoff intensity, i:

The runoff intensity was determined by using the NOAA's National Weather Service Precipitation Frequency Data Server (NOAA, accessed 2020). The 100 year return frequency was used along with the time of concentration to find the runoff intensity.

Stream Crossing Sizing:

The Federal Highway Administrations Hydraulic Toolbox, which utilizes Manning's Equation for open channel flow, was used to verify the required sizing of each culvert. The following table documents the variables used for this method.

Table 3: Parameters for stream crossing design in Hydraulic Toolbox.

Variable	Variable Source
Diameter of Culvert	Measured at Site Visit
Material of Culvert	Observed at Site Visit
Roughness Coefficient	Manning Roughness Coefficient based on observed material of culvert
Slope	Measured at Site Visit
Water Depth	Using a headwater-to-culvert diameter ratio (HW/D) of 0.67 to allow woody debris.
Design Flow	Rational Method/USGS Magnitude and Frequency Method Calculation

In addition to the Hydraulic Toolbox application, the Federal Highway Association's Nomograph was used to check the culvert sizing results (FHWA, 1965). This method however has limitations in that it does not consider the slope of the installed culvert and how that affects the flow regime. The nomograph in certain instances recommends a culvert diameter that is orders of magnitude larger than is recommended by the Hydraulic Toolbox because of these aforementioned limitations. The rate of flow that can be conveyed by a culvert varies directly with the slope of the culvert, as shown in Table 4.

Table 4: Expected flow capacity of a 36" CMP culvert with a headwater to depth ratio of 0.67 as slope varies (FHWA, Hydraulic Toolbox).

Culvert Slope (%)	**Flow** (cfs)
0.5	22.00
1.8	41.73
2.4	48.19
3.0	53.88
3.6	59.02
4.0	62.22
6.0	76.20
8.0	88.00
10.0	98.37

5. Results

The Tables below summarize the results of the hydrologic study for each stream crossing.

Table 5: 100-Year Storm peak flows calculated for each stream crossing.

Map ID	100-Year Storm Peak Flow (cfs)
CV-1/Project 1	12.8
RF-1/Project 2	2.7
RF-2/Project 3	2.7
RF-3/Project 4	1.9
RF-4/Project 5	0.7

Table 6: Results of hydrologic analysis for existing stream crossing.

Stream Crossing I.D.	Existing Culvert Diameter (inches)	Calculated Peak Flow (Q_{100}) at Stream Crossing (cfs)	Calculated Culvert Flow Capacity (cfs)	Sized Correctly (Y/N)
CV-1/Project 1	18	12.8	12.7	N

CV-1:

The hydrological analysis showed that CV-1 was not sized appropriately and that the culvert would not allow the passage of the peak flows from the 100 year design storm. These results corroborate with the observed clogging at the inlet and overtopping of the road during the site visit. It is recommended that a 24 inch corrugated metal culvert be installed at a slope of 6.8%. The calculated flow capacity of a new, 24 inch CMP culvert would be 27.5 cfs, which exceeds the 100-year design storm peak flow of 12.8 cfs.

6. Recommendation

- CV-1 is not sized correctly to convey the peak flows of the 100-year design storm. It is recommended that the culvert be upgraded to a 24 inch CMP culvert, installed at a slope of 6.8%.
- Rocked fords shall be installed at Map ID's RF-1, RF-2, RF-3, and RF-4. Road surface at the stream crossings shall be armored with uniformly graded 4" minus diameter rock at a slope of 3 to 5%. Rock armoring (Class 1 riprap minimum) at the outlet shall be installed to return watercourse to native streambed channel slope.

7. References

Cafferata, P., Lindsay, D., Splittlet, T., Wopat, M., Bundros, G., Flanagan, S., Coe, D., Short, W. (2017). "Designing Watercourse Crossings for Passage of 100-year Flood Flows, Wood, and Sediment (Updated 2017)". California Natural Resource Agency Department of Forestry and Fire Protection. Sacramento, CA.

Federal Highway Administration. (1965). Hydraulic charts for the selection of highway culverts, HEC 5, Hydraulic Engineering Circular No. 5, U.S. Department of Commerce. Available at: <http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec05.pdf>.

HawsEDC. (2009). "Manning Formula: Uniform Pipe Flow at Given Slope and Depth". Available online: http://www.hawsedc.com/engcalcs/Manning-Pipe-Flow.php

NOAA. (2017). 'Precipitation Frequency Data Server'. National Weather Service: Hydrometeorological Design Studies Center. Available online: https://hdsc.nws.noaa.gov/hdsc/pfds/

Weaver, W.E., Weppner, E.M. and Hagans, D.K.. (2014). Handbook for Forest, Ranch and Rural Roads: A Guide for Planning, Designing, Constructing, Reconstructing, Upgrading, Maintaining and Closing Wildland Roads, Mendocino County Resource Conservation District, Ukiah, California, 416 p.

Hydrological Analysis

Project:	Cuevas - 16016	
Analysis Location:	40.9855	-123.7212
Map ID:	CV-1	
Analysis Method:	Rational Method	

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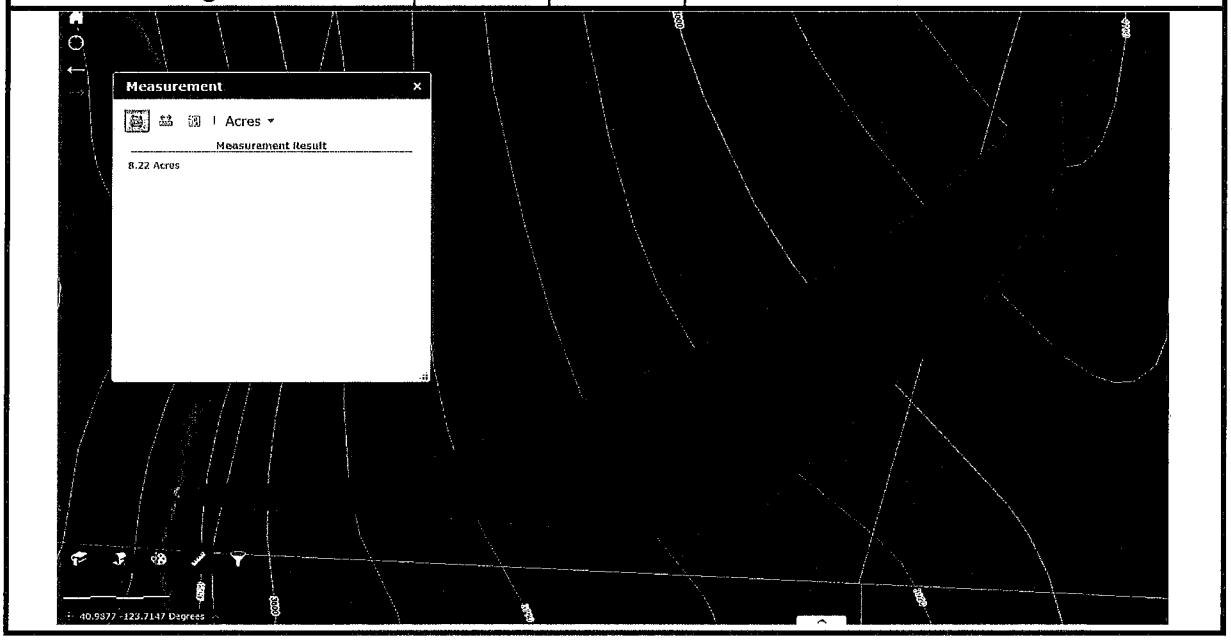
Description: Existing 18" corrugated metal culvert on an unnamed Class III watercourse. Set at 6.8% slope. Culvert inlet blocked at time of observation.

		Units	Variable Source
C Value:	0.30	-	Dunne and Leopold (1978)
I Value	5.21	in/hr	NOAA Precipitation Freq. Estimate
Drainage Area:	8.22	acres	Arc GIS Delineation

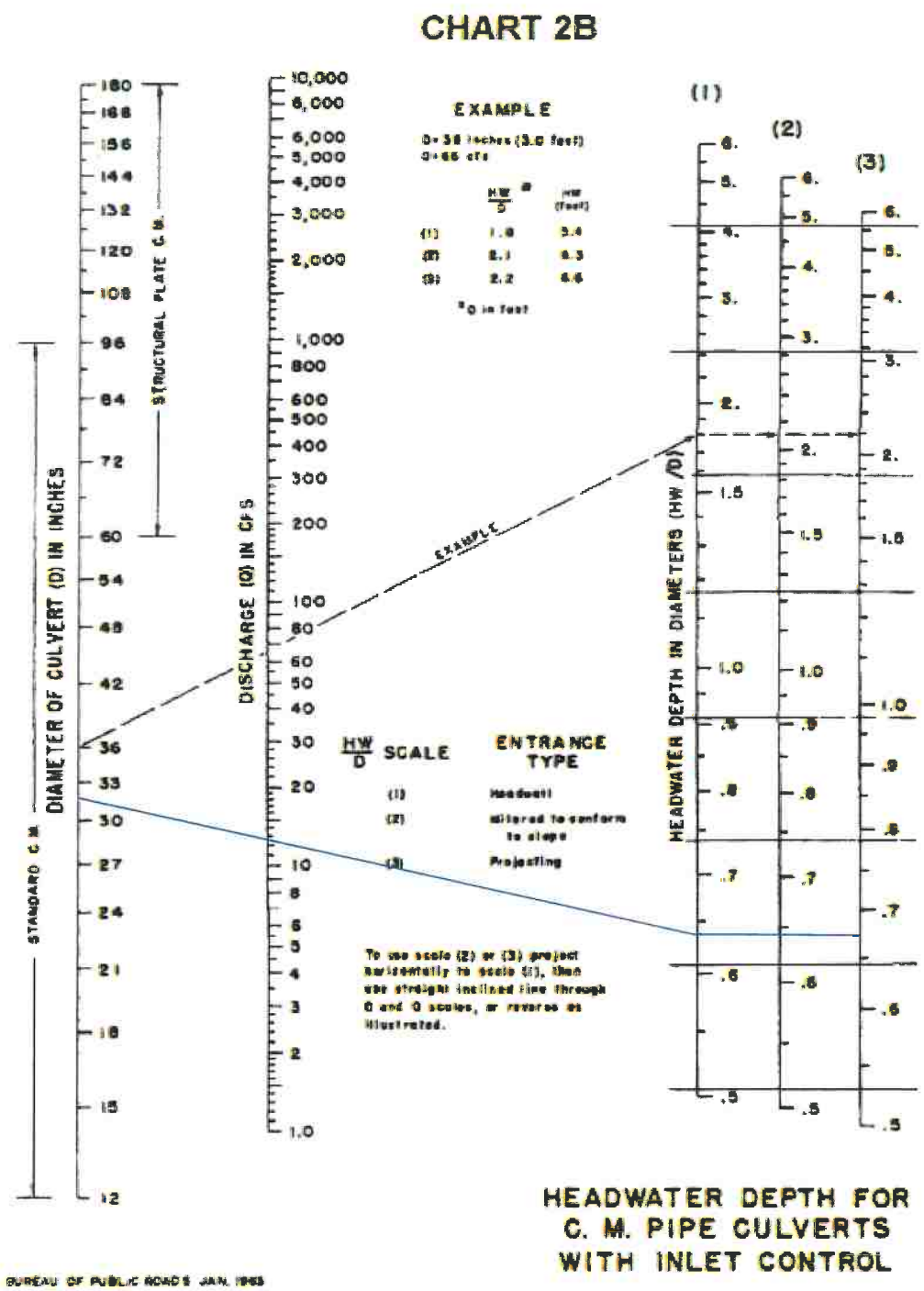


		Units	Additional Information
Inlet Type:	Projecting		Projecting/Mitered/Headwall
HW/D:	0.67	-	Headwater depth in diameters
Elevation Differential:	680	feet	From crossing to high point of basin
Drainage Distance:	0.4	miles	From crossing to high point of basin
Concentration Time:	4.4	min	Use I value assoc'd w/this if > 10 mins
Design Flow:	12.8	cfs	Rational Method
Culvert Diameter:	33	inches	Using FHWA Nomograph Method
Culvert Diameter:	24	inches	Using FHWA Hydraulic Toolbox

Conclusion: The existing 18 inch diameter culvert is NOT sized appropriately to convey the peak flows of the 100 year design storm. It is recommended that the culvert be upgraded to a 24 inch diameter corrugated metal culvert.

Hydrological Analysis

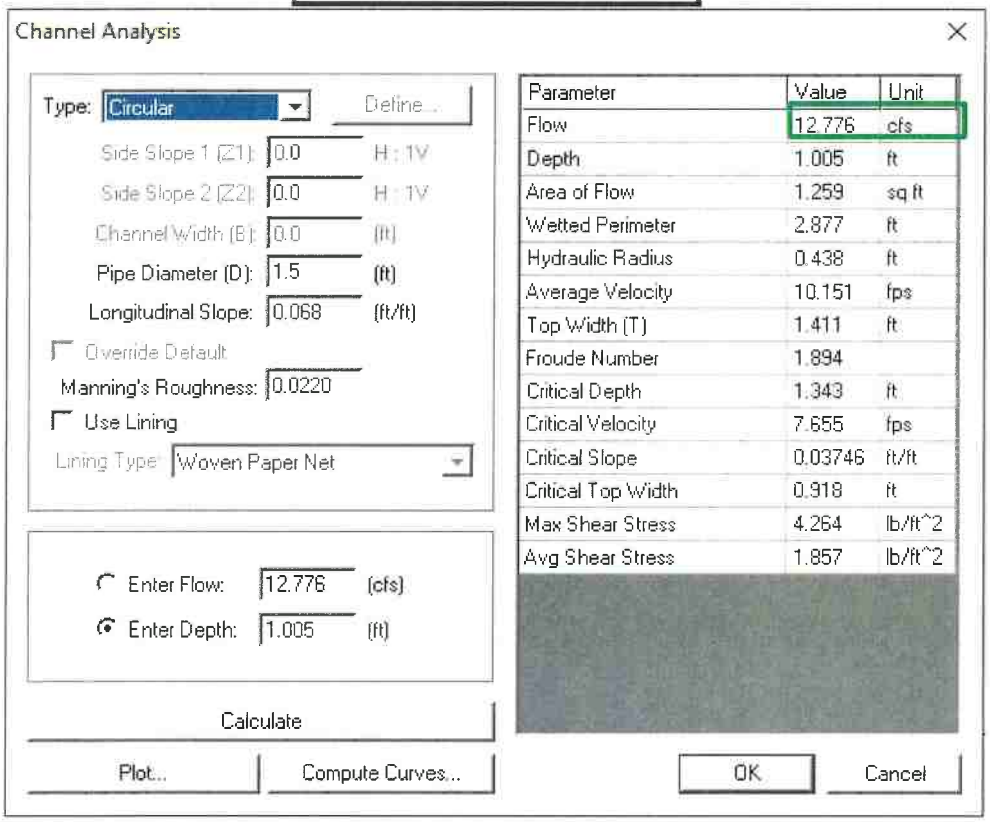
CV-1 Nomograph Results



Hydrological Analysis

Hydraulic Toolbox Analysis

Existing CV-1 Dimensions



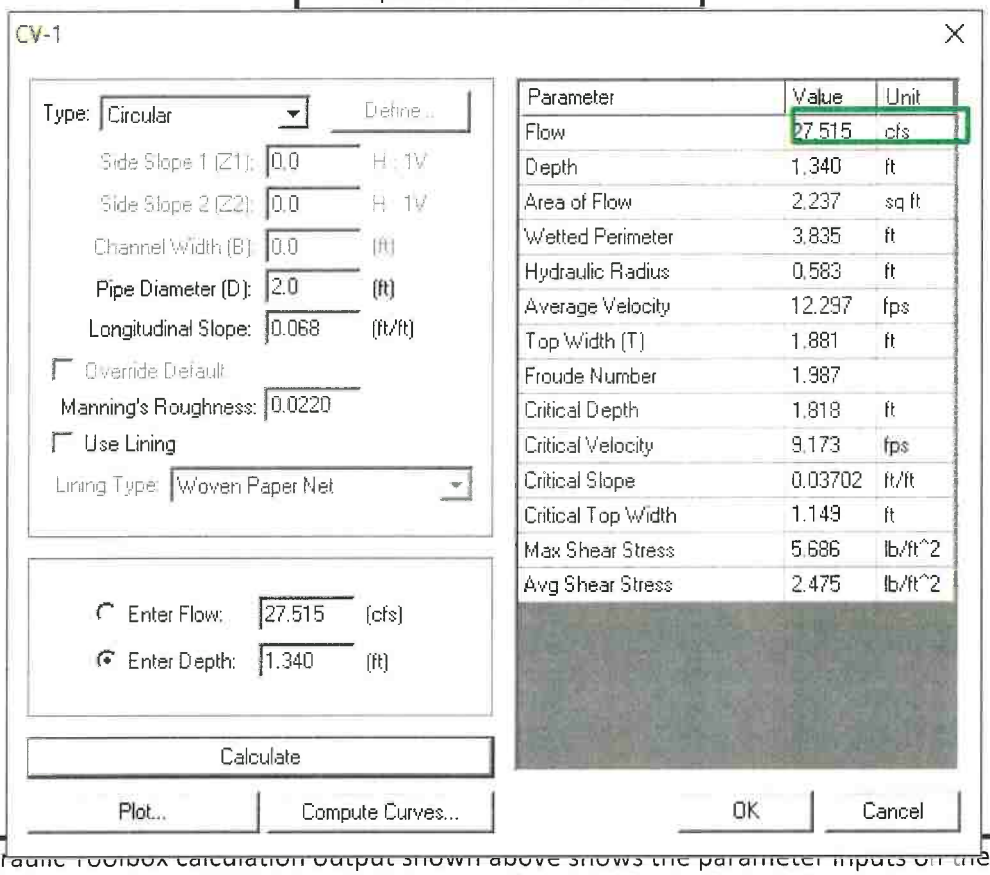
The Hydraulic Toolbox calculation output shown above shows the parameter inputs on the left side of the screen. The culvert diameter is input as 1.5 feet (18") and the slope is input as 0.068, or 6.8%. The Manning's Roughness coefficient for corrugated metal pipes is 0.022. Finally, the flow depth is entered as 1.005 feet, which is 67% of the culvert diameter. This allows for the 0.67 headwater to depth ratio to be considered in the calculation. With these input parameters, the flow capacity is calculated.

Hydraulic Toolbox shows a number of calculated outputs based on the input variables, however the flow capacity of the culvert is shown in the box on the top right of the output screen. With a calculated flow capacity of 12.7 cfs, this culvert cannot convey the peak flow of the 100-year design storm of 12.8 cfs calculated using the Rational Method.

Hydrological Analysis

Hydraulic Toolbox Analysis

Proposed CV-1 Dimensions



The Hydraulic Toolbox calculation output shown above shows the parameter inputs on the left side of the screen. The culvert diameter is input as 2 feet (24") and the slope is input as 0.068, or 6.8%. The Manning's Roughness coefficient for corrugated metal pipes is 0.022. Finally, the flow depth is entered as 1.34 feet, which is 67% of the culvert diameter. This allows for the 0.67 headwater to depth ratio to be considered in the calculation. With these input parameters, the flow capacity is calculated.

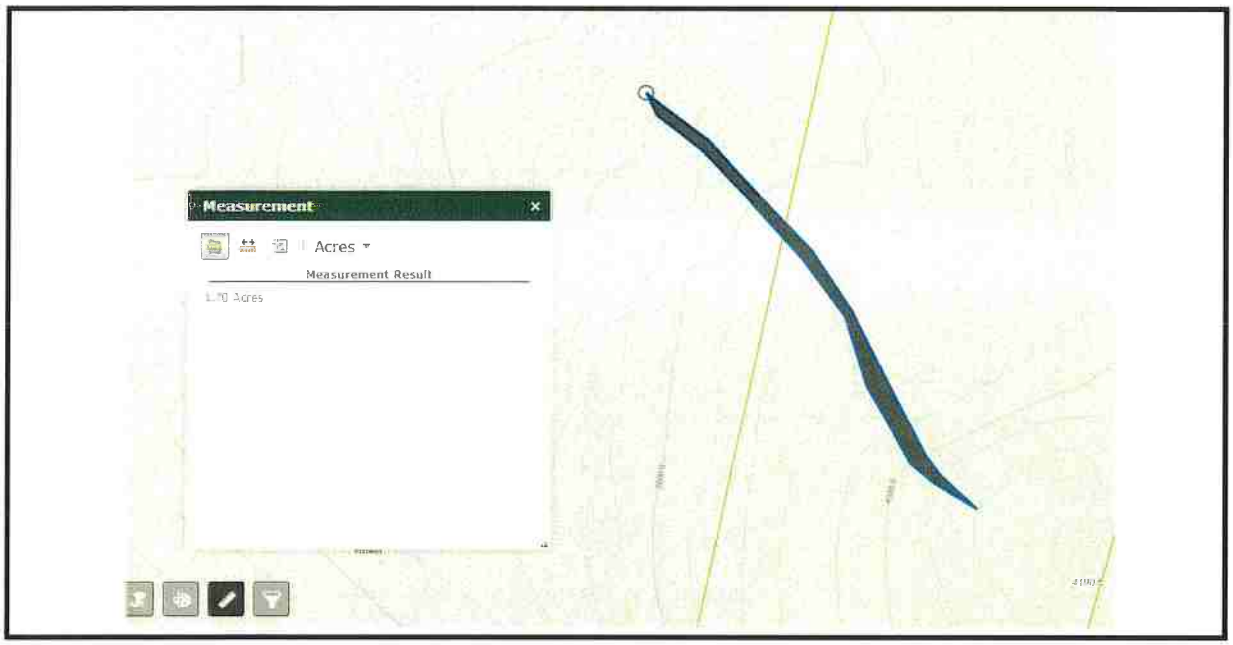
Hydraulic Toolbox shows a number of calculated outputs based on the input variables, however the flow capacity of the culvert is shown in the box on the top right of the output screen. With a calculated flow capacity of 27.5 cfs, this culvert can convey a peak flow that exceeds the 100-year design storm peak flow of 12.8 cfs calculated using the Rational Method.

Hydrological Analysis

Project:	Cuevas - 16016	
Analysis Location:	40.993	-123.7208
Map ID:	RF-1	
Analysis Method:	Rational Method	

Description: No existing drainage features. Stream crossing that has been filled over with road prism.

		Units	Variable Source
C Value:	0.3	-	Dunne and Leopold (1978)
I Value	5.21	in/hr	NOAA Precipitation Freq. Estimate
Drainage Area:	1.7	acres	Arc GIS Delineation



		Units	Additional Information
Inlet Type:	Projecting	-	Projecting/Mitered/Headwall
HW/D:	0.67	-	Headwater depth in diameters
Elevation Differential:	760	feet	From crossing to high point of basin
Drainage Distance:	0.34	miles	From crossing to high point of basin
Concentration Time:	3.5	min	Use I value assoc'd w/this if > 10 mins
Design Flow:	2.7	cfs	USGS Magnitude and Frequency Method

Conclusion: A rocked ford shall be installed at this location. Road surface at the stream crossing shall be armored with uniformly graded 4" minus diameter rock at a slope of 3 to 5%. Rock armoring (Class 1 riprap minimum) at the outlet shall be installed to return watercourse to native streambed channel slope.

Hydrological Analysis

Project:	Cuevas - 16016	
Analysis Location:	40.9933	-123.7203
Map ID:	RF-2	
Analysis Method:	Rational Method	

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Description: No existing stream crossing facilities. Stream crossing has been filled over with road prism.

		Units	Variable Source
C Value:	0.3	-	Dunne and Leopold (1978)
I Value	5.21	in/hr	NOAA Precipitation Freq. Estimate
Drainage Area:	1.72	acres	Arc GIS Delineation

		Units	Additional Information
Inlet Type:	Projecting	-	Projecting/Mitered/Headwall
HW/D:	0.67	-	Headwater depth in diameters
Elevation Differential:	800	feet	From crossing to high point of basin
Drainage Distance:	0.38	miles	From crossing to high point of basin
Concentration Time:	3.9	min	Use I value assoc'd w/this if > 10 mins
Design Flow:	2.7	cfs	USGS Magnitude and Frequency Method

Conclusion: A rocked ford shall be installed at this location. Road surface at the stream crossing shall be armored with uniformly graded 4" minus diameter rock at a slope of 3 to 5%. Rock armoring (Class 1 riprap minimum) at the outlet shall be installed to return watercourse to native streambed channel slope.

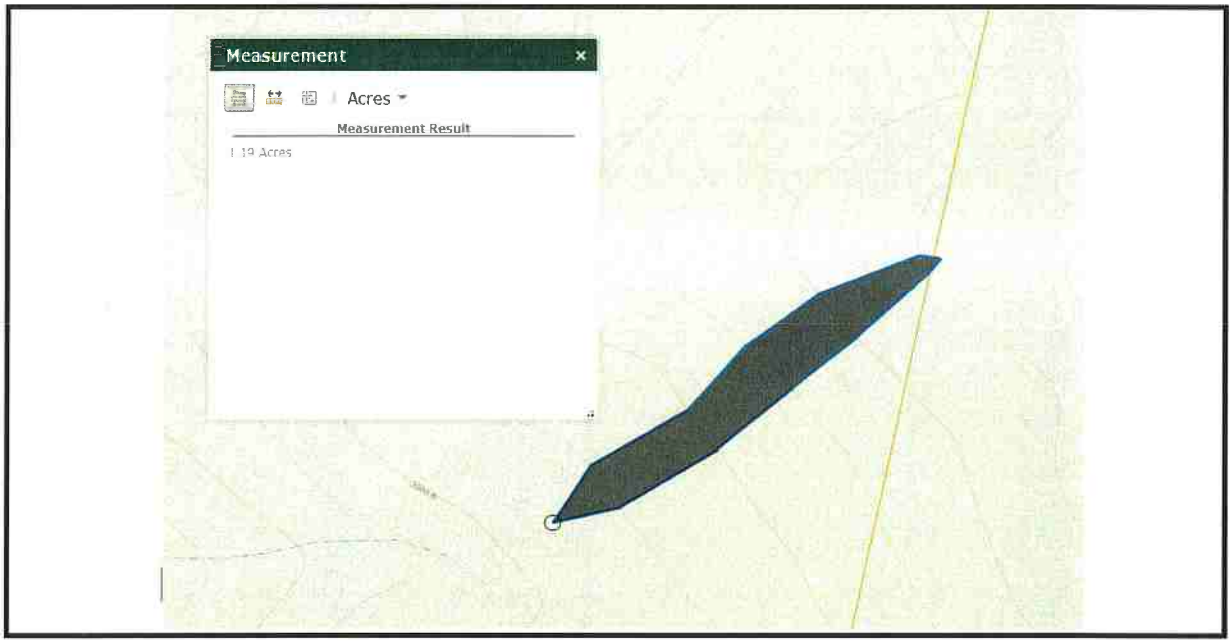
Hydrological Analysis

Project:	Cuevas - 16016	
Analysis Location:	40.994	-123.7203
Map ID:	RF-3	
Analysis Method:	Rational Method	

MOTHER EARTH ENGINEERING

Description: No existing stream crossing facilities. Stream crossing has been filled over with road prism.

		Units	Variable Source
C Value:	0.3	-	Dunne and Leopold (1978)
I Value	5.21	in/hr	NOAA Precipitation Freq. Estimate
Drainage Area:	1.19	acres	Arc GIS Delineation



		Units	Additional Information
Inlet Type:	Projecting	-	Projecting/Mitered/Headwall
HW/D:	0.67	-	Headwater depth in diameters
Elevation Differential:	790	feet	From crossing to high point of basin
Drainage Distance:	0.44	miles	From crossing to high point of basin
Concentration Time:	4.6	min	Use I value assoc'd w/this if > 10 mins
Design Flow:	1.9	cfs	USGS Magnitude and Frequency Method

Conclusion: A rocked ford shall be installed at this location. Road surface at the stream crossing shall be armored with uniformly graded 4" minus diameter rock at a slope of 3 to 5%. Rock armoring (Class 1 riprap minimum) at the outlet shall be installed to return watercourse to native streambed channel slope.

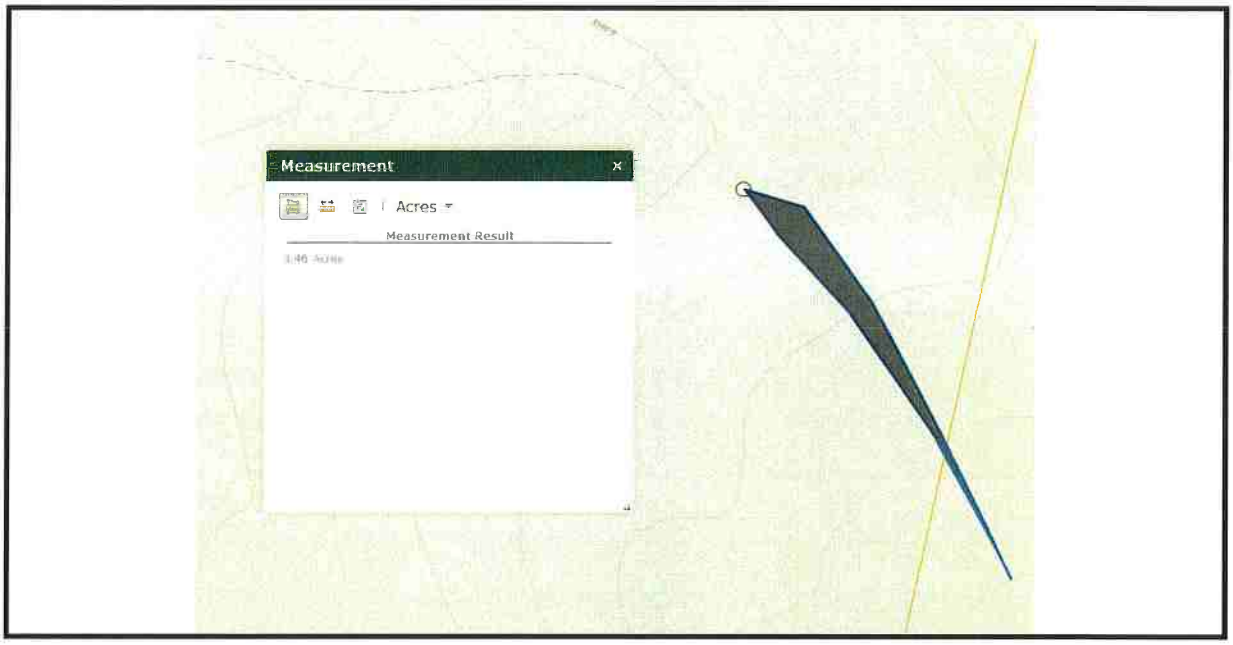
Hydrological Analysis

Project:	Cuevas - 16016	
Analysis Location:	40.9934	-123.7202
Map ID:	RF-4	
Analysis Method:	Rational Method	

MOTHER EARTH ENGINEERING

Description: No existing stream crossing facilities. Stream crossing has been filled over with road prism.

		Units	Variable Source
C Value:	0.3	-	Dunne and Leopold (1978)
I Value	5.21	in/hr	NOAA Precipitation Freq. Estimate
Drainage Area:	0.46	acres	Arc GIS Delineation



		Units	Additional Information
Inlet Type:	Projecting	-	Projecting/Mitered/Headwall
HW/D:	0.67	-	Headwater depth in diameters
Elevation Differential:	800	feet	From crossing to high point of basin
Drainage Distance:	0.38	miles	From crossing to high point of basin
Concentration Time:	3.9	min	Use I value assoc'd w/this if > 10 mins
Design Flow:	0.7	cfs	USGS Magnitude and Frequency Method

Conclusion: A rocked ford shall be installed at this location. Road surface at the stream crossing shall be armored with uniformly graded 4" minus diameter rock at a slope of 3 to 5%. Rock armoring (Class 1 riprap minimum) at the outlet shall be installed to return watercourse to native streambed channel slope.