HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

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

VOLUME 4

EXISTING CONDITIONS RECHARGE POTENTIAL ANALYSIS

COCHISE COUNTY, ARIZONA

Prepared for:

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Registered Professional Engineer (Civil)
CERTIFICATE NO. 49011
AUBREY J. THOMAS
Date Signed 12/7/15
ARIZONA, U.S.A.
Expires 12/31/17

December, 2015
HilgartWilson Project No. 1472

HILGARTWILSON

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TABLE OF CONTENTS

APPENDICES

FIGURES

TABLES

1. INTRODUCTION

1.1. PROJECT DESRIPTION

This study has been prepared for the Hereford Natural Resource Conservation District (NRCD), who has identified the need for a project which will significantly reduce flooding, erosion and soil loss, as well as road and property damage in and adjacent to Horseshoe Draw (the Project). In order to complete such a project, the Hereford NRCD was awarded a grant from the Arizona Department of Water Resources (ADWR) through the Arizona Water Protection Fund Program. In turn, HILGARTWILSON has been contracted under the Water Protection Fund grant for professional engineering services. This study and corresponding report make up Volume 4 in a series of reports that will be prepared under the awarded grant.

1.2. LOCATION

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 within the Upper San Pedro Basin in Cochise County, Arizona. The Project's location is highlighted in the Vicinity Map in Figure 1 of Appendix A.

1.3. PURPOSE

This study provides existing conditions groundwater recharge potential analyses which will be used as a baseline comparison for the future recharge potential analysis that will be prepared for the proposed water impoundment structure. The ADWR website states that water level trends in the aquifer of the Upper San Pedro Basin have declined over recent years due to a growing population and increases in water consumption. ADWR also cites that the principle sources of recharge occur through mountain front recharge and beds of ephemeral stream infiltration (ADWR 2014). The proposed impoundment structure will effectively slow the rate of discharge to downstream waters by detaining surface water runoff and subsequently, increase groundwater recharge to the aquifer located within the Upper San Pedro Basin.

This study analyzes the volume of stormwater that could potentially recharge the underground aquifer during the theoretical 2-year, 25-year, 50-year, and 100-year storm events through infiltration of the channel bottom. The design of the water impoundment structure is discussed in further detail below. The design flow rates utilized within this study were obtained from the *Horseshoe Draw Flood Control, Restoration and Mitigation Study and Design Project Volume 1 – Existing Conditions Hydrologic Study Report* (Volume 1) (HILGARTWILSON 2015a) and *Volume 2 – Existing Conditions Hydraulic Study Report* (Volume 2) (HILGARTWILSON 2015b).

The groundwater recharge potential analysis for the Project has been prepared using HEC-HMS version 4.0 with results being compared to a less complex area/infiltration rate volume calculation for validation. The methodology and design parameters used for these analyses are detailed below.

2. HYDROLOGIC STUDY OVERVIEW

HEC-HMS was used for the hydrologic analysis of the Project which was detailed within Volume 1 of this report series. 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.

Due to the size of the watershed, both, the 100-year, 6-hour and 100-year, 24-hour storm events were modeled to compare the calculated flow rates. Based on the hydrologic modeling results, the flows determined during the 100-year, 6-hour storm exceeded those determined using the 100-year, 24-hour storm; therefore, the flowrates from the 100-year, 6-hour model have been utilized in this aquifer recharge potential analysis. Subsequently, the 2-year, 25-year, and 50-year flow rates with the 6-hour storm duration were determined using the same methodology outlined in Volume 1.

3. HYDRAULIC STUDY OVERVIEW

Hydraulic analysis for Horseshoe Draw was performed utilizing HEC-RAS version 4.1.0 detailed in Volume 2 of this report series. Cross sections within the model were exported from a digital terrain model (DTM) from AutoCAD Civil 3D. The DTM was built based on a topographic aerial survey performed by Kenny Aerial Mapping, Inc. in October, 2014. The aerial mapping contains detailed topography at 2-foot intervals using the North American Vertical Datum of 1988 (NAVD 88). Channel parameters and cross sections from the HEC-RAS model were referenced for the HEC-HMS model of this report and can be found in Appendix B.

4. GEOTECHNICAL EVALUATION

In October 2015, geotechnical analysis for the Project was conducted by Ninyo & Moore, and reported in the *Geotechnical Evaluation, Horseshoe Draw Basin* (Ninyo & Moore 2015). The purpose of the geotechnical evaluation was to assess the subsurface conditions at the project site in order to provide geotechnical recommendations for design and construction of the impoundment structure. The geotechnical evaluation included shallow field infiltration tests, soil borings, and laboratory testing evaluating the soil properties such as; moisture content, dry density, gradation, and Atterberg limits.

The infiltration rates determined within the geotechnical evaluation were used in the methods of estimating recharge volumes. Pertinent excerpts from the geotechnical evaluation report have been included in Appendix C.

5. RECHARGE POTENTIAL MODELING METHODOLOGY

This section describes the methods used in the analysis of the groundwater recharge potential estimate and related data for the study. Hydrologic and hydraulic parameters were referenced from the Volume 1 HEC-HMS model and the Volume 2 HEC-RAS model. Other parameters required for the analysis include a revised routing method for select portions of the basin model network and percolation rate data.

5.1. REACH ROUTING

The original Volume 1 hydrologic analysis was accomplished using the Lag routing method and calculated lag time as the sole input parameter with no infiltration losses accounted for. To analyze the effects of percolation, HEC-HMS uses a constant infiltration rate in combination with the inundated area in the reach to compute channel losses. However, the HEC-HMS percolation loss rate parameter is only an option using the modified Puls and Muskingum-Cunge routing methods. Therefore, the main wash routing of Horseshoe Draw was modified to the Muskingum-Cunge method while all other reaches within the HEC-HMS model remained the same. The Muskingum-Cunge method requires channel parameter data including length, slope, Manning's n, and cross-section geometry for each reach. Representative cross section data was referenced from the Volume 2 HEC-RAS model and are summarized in Table 1 below. The Eight Point channel cross sectional geometry for the four main reaches of Horseshoe Draw can be found in Appendix B. The limits of these four reaches are shown and labeled on Figure 2 of Appendix A.

Table 1: Channel Parameters						
Reach	Reach Cross-Section Span	Length [ft]	Slope [ft/ft]	Manning's n		Shape Geometry Method
				Main	Sides	
R-6	165+20.00-149+31.77	3612	0.006	0.030	0.035	Eight Point
R-8	146+92.54-125+56.85	2167	0.017	0.030	0.035	Eight Point
R-9	123+29.17-46+95.55	7812	0.009	0.030	0.035	Eight Point
R-12	44+62.68-21+18.63	2405	0.010	0.030	0.035	Eight Point

To ensure results from the revised routing method were comparable to the original model, total volumes generated from the 2-year, 25-year, 50-year, and 100-year, storm events were compared for both methods with no infiltration losses modeled. The results were nearly identical which can be seen in Table 2 below.

Table 2: HEC-HMS Routing Method Results Comparison								
Reach	Volume [acre-feet]							
	2-Year		25-Year		50-Year		100-Year	
	Lag	Muskingum-Cunge	Lag	Muskingum-Cunge	Lag	Muskingum-Cunge	Lag	Muskingum-Cunge
R-6	112	112	324	324	400	400	483	483
R-8	259	259	774	774	960	960	1163	1164
R-9	261	261	781	781	969	970	1175	1175
R-12	358	358	1078	1078	1339	1339	1624	1624

5.2. PERCOLATION RATE

Percolation rates were tested at two locations during the field geotechnical investigation performed by Ninyo & Moore (2015) detailed in Appendix C. The investigation concluded that the test locations near the proposed embankment had an average 0.5-$ft^3/hr/ft^2$ (6.1 cubic feet per second (cfs)/acre) percolation rate. Due to limited field data, that average rate was applied throughout all four modified reaches. Supporting the assumption, inspection of the National Resource Conservation Service (NRCS) Soil Resource Map (included as Appendix D) showed that soils throughout the entire Horseshoe Draw wash were consistent to those found at the test locations. To further justify the use of the percolation rate specified by Ninyo and Moore (2015), two journal papers published by the USGS were located through the Upper San Pedro Partnership's website (www.usppartnership.com) which discuss infiltration rates near the Project and are summarized below.

The first paper referenced with reported percolation rates, published in the USGS Professional Paper 1703, titled, *Ephemeral-Stream Channel and Basin-Floor Infiltration and Recharge in the Sierra Vista Subwatershed of the Upper San Pedro Basin, Southeastern Arizona* (Coes and Pool 2007) found that infiltration rates near the Project ranged from 4.0–32.5 cfs/acre with an average of 32.5 cfs/acre. The second report published in the USGS Scientific Investigations Report 2006-5228 from 2007, titled, *Ground-Water Flow Model of the Sierra Vista Subwatershed and Sonoran Portions of the Upper San Pedro Basin, Southeastern Arizona, United States, and Northern Sonora, Mexico* (Dickinson and Pool 2007) stated that that infiltration rates near the Project ranged from 4.1–20.7 cfs/acre with an average of 8.2 cfs/acre. The percolation rate used in this report falls on the lower end but within the ranges reported in both papers. Based on the information discussed in this section, it can be assumed that a percolation rate of 6.1 cfs/acre (0.5-$ft^3/hr/ft^2$) is reasonable for this Project.

5.3. HEC-HMS MODEL RECHARGE VOLUME ANALYSIS

In order to determine the volume of infiltration for 2-year, 25-year, 50-year, and 100-year storm events, two HEC-HMS scenarios were modeled; 1) without percolation losses which serves as a baseline for the analysis and 2) with percolation losses. The model output returns flow hydrographs in five minute increments over a 23-hour period. The difference between the two flow hydrographs is then used to calculate the total recharge volume into the aquifer.

6. 2-DIMENSIONAL AREA/INFILTRATION CALCULATION

The recharge volumes, determined using HEC-HMS, are based on various parameters and assumptions; therefore, some comparison of results is needed. To calculate the estimated aquifer recharge, inundated floodplain areas and the duration of inundation for the 2-year, 25-year, 50-year, and 100-year storm events are required, used in combination with the established percolation rate of 0.5-$ft^3/hr/ft^2$. Floodplain extents have previously been determined in the Volume 2 HEC-RAS analysis (shown in Figure 2) for the various storm events. Floodplain inundation durations are referenced from the HEC-HMS hydrograph outputs of this study. Calculation tables for this method are included in Appendix E.

7. RESULTS

The groundwater recharge HEC-HMS model and the area/infiltration calculation parameters used, along with results from the various storm events have been included in Appendix E. Comparison of the HEC-HMS models and the area/infiltration calculations show that the results are similar with an average relative percent difference of 18.5%. This discrepancy can be attributed to the HEC-HMS model being a more robust method that accounts for depth to determine a wetted perimeter which is then combined with the reach length to calculate a total surface area in a given reach. R-12 has a significantly deeper main channel segment compared to upstream channel reaches which is why the discrepancy is more pronounced at smaller storm events. Comparatively, the area/infiltration calculation method uses a 2-dimensional area determined by floodplain limits in AutoCAD yielding smaller volumes of infiltration. Table 3 below summarizes the total volume of infiltration for the given storm events calculated by HEC-HMS. It should be noted that the estimated infiltration calculated occurs at the channel bottom and some, but not all, of the volume will truly be recharged to the aquifer.

Table 3: HEC-HMS Results Summary

Reach	Infiltration [acre-feet]			
	2-Year	25-Year	50-Year	100-Year
R-6	50	72	76	80
R-8	90	130	139	147
R-9	119	181	197	235
R-12	124	188	205	245
Total	**382**	**570**	**618**	**708**

8. CONCLUSION

This study has been prepared in order to provide an existing conditions groundwater recharge potential analysis for Horseshoe Draw using HEC-HMS and will be used as a basis of comparison for future groundwater recharge potential analyses accounting for the proposed water impoundment structure. Since the volumes determined in both the model and the calculation are relatively similar at the given percolation rate, it can be assumed that the volume of groundwater recharge estimated in HEC-HMS will serve as a useful baseline comparison for the future recharge potential analysis.

A groundwater recharge potential model with the impoundment structure will be prepared after the managed flow rates leaving the proposed impoundment structure have been determined. The future model will show the beneficial impact that the structure will have on the increased groundwater recharge into the Upper San Pedro Basin.

9. REFERENCES

ADWR, (2014). *Upper San Pedro Groundwater Conditions.* Retrieved December 2, 2015, http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/SEArizona/Groundwater/UpperSanPedro.htm

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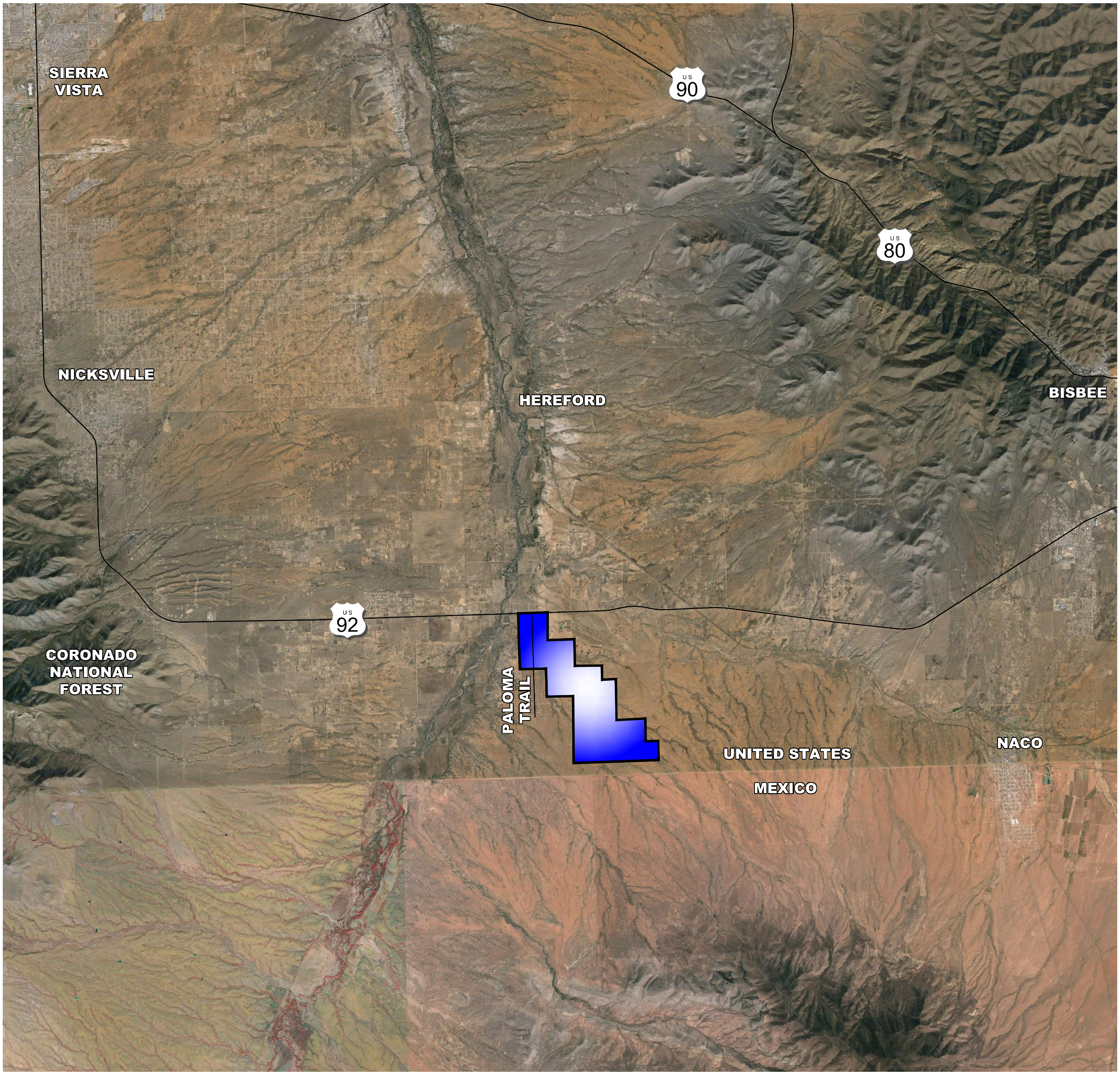
HILGARTWILSON, (2015b). *Horseshoe Draw Flood Control, Restoration and Erosion Mitigation Study and Design Project, Volume 2, Existing Conditions Hydraulic Report.* October 2015. Phoenix, Arizona.

Ninyo & Moore, (2015). *Geotechnical Evaluation Horseshoe Draw Basin*. October 2015 Phoenix, Arizona.

Pool, D.R., Coes, A.L., (2007). *Ephemeral-Stream Channel and Basin-Floor Infiltration and Recharge in the Sierra Vista Subwatershed of the Upper San Pedro Basin, Southeastern Arizona*. USGS Professional Paper 1703, Chapter J.

Pool, D.R., and Dickinson, J.E., (2007). *Ground-Water Flow Model of The Sierra Vista Subwatershed and Sonoran Portions of the Upper San Pedro Basin, Southeastern Arizona. United States and Northern Sonora*, Mexico: U.S Geological Survey Scientific Investigations Report 2006-5228. 48 p.

APPENDIX A
FIGURES



LEGEND

PROJECT LOCATION

N

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CHECKED BY:	AT		

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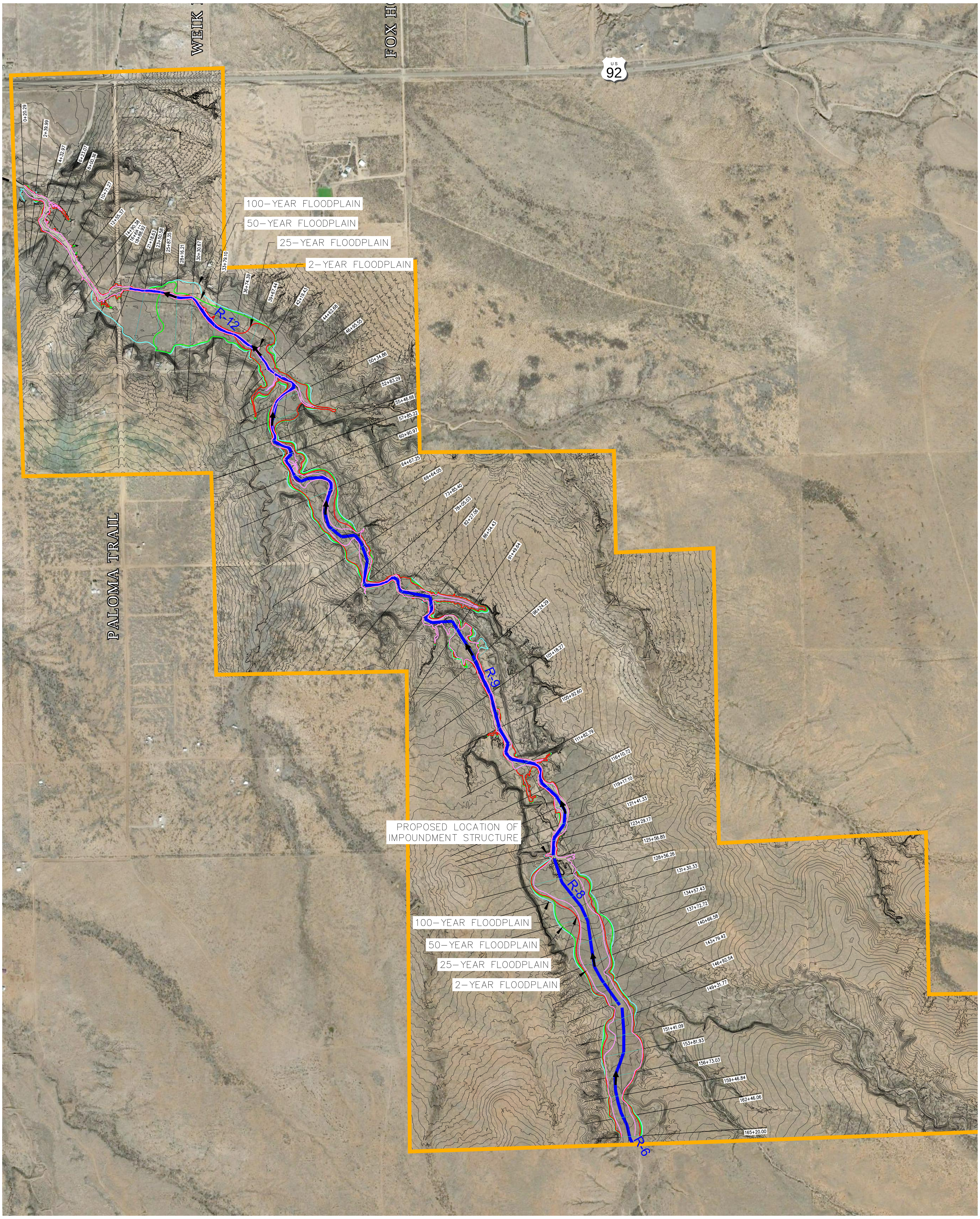

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- PROJECT BOUNDARY
- ROUTING REACH
- 2–YEAR FLOODPLAIN
- 25–YEAR FLOODPLAIN
- 50–YEAR FLOODPLAIN
- 100–YEAR FLOODPLAIN
- FLOW ARROW

N

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SCALE FEET

HILGARTWILSON	HORSESHOE DRAW	HILGARTWILSON ENGINEER | PLAN | SURVEY | MANAGE	REV.:
PROJ NO.: 1472	COCHISE COUNTY, ARIZONA	2141 E. HIGHLAND AVE., STE. 250 PHOENIX, AZ 85016	
DATE: OCT. 2015		P: 602.490.0535 / F: 602.368.2436 www.hilgartwilson.com	
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DESIGNED: HW			
APPROVED: AT			

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DWG. NO.

APPENDIX B

REACH AND CHANNEL CROSS SECTIONS

HEC-HMS CHANNEL CROSS SECTIONS

HEC-HMS CROSS-SECTION EIGHT POINT GEOMETRY

Project: Horseshoe Draw

Prepared by: HW

Date: Dec 2015

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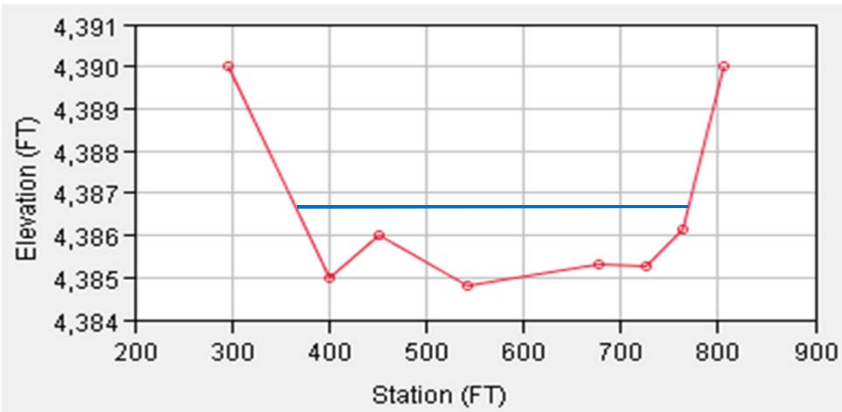
R-6



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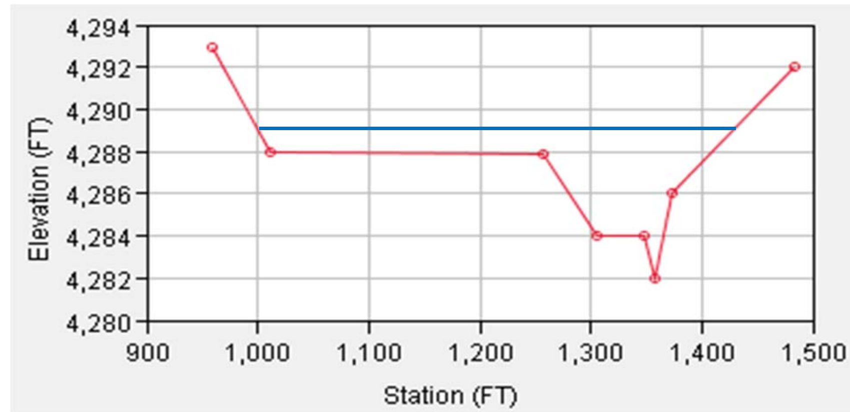

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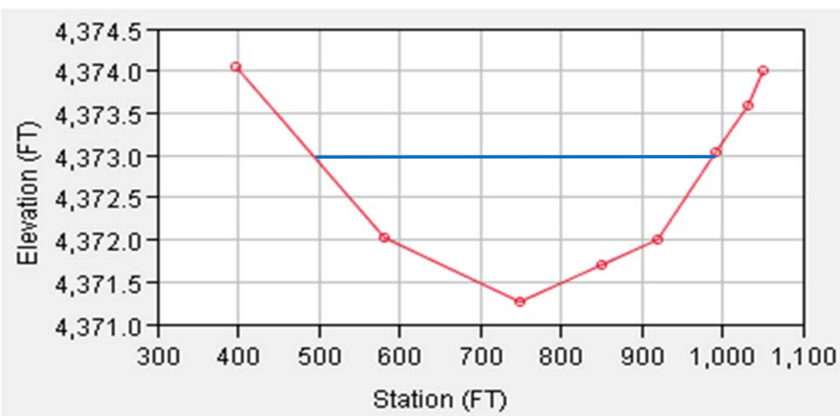

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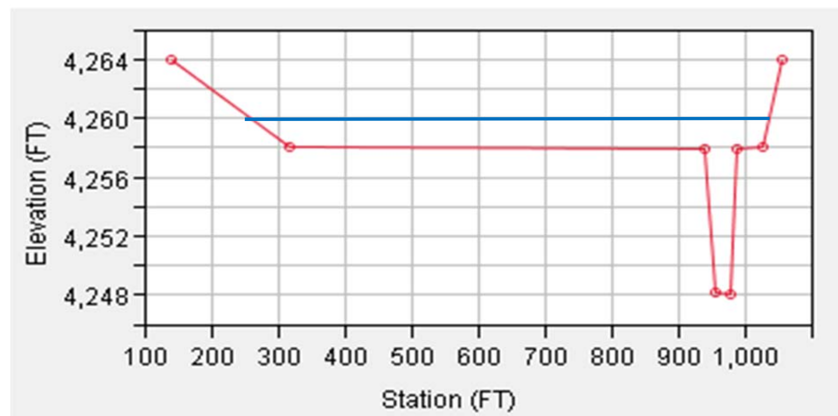
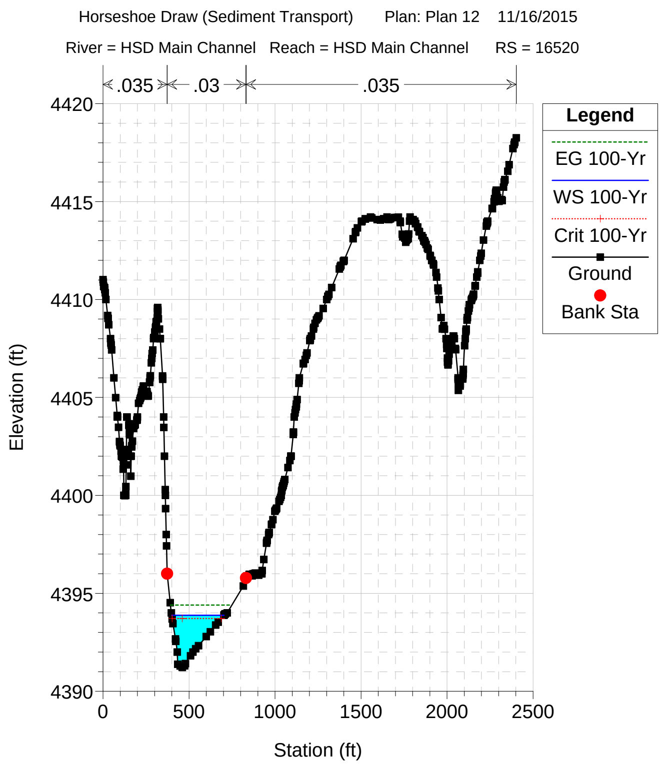


HEC-RAS CHANNEL CROSS SECTIONS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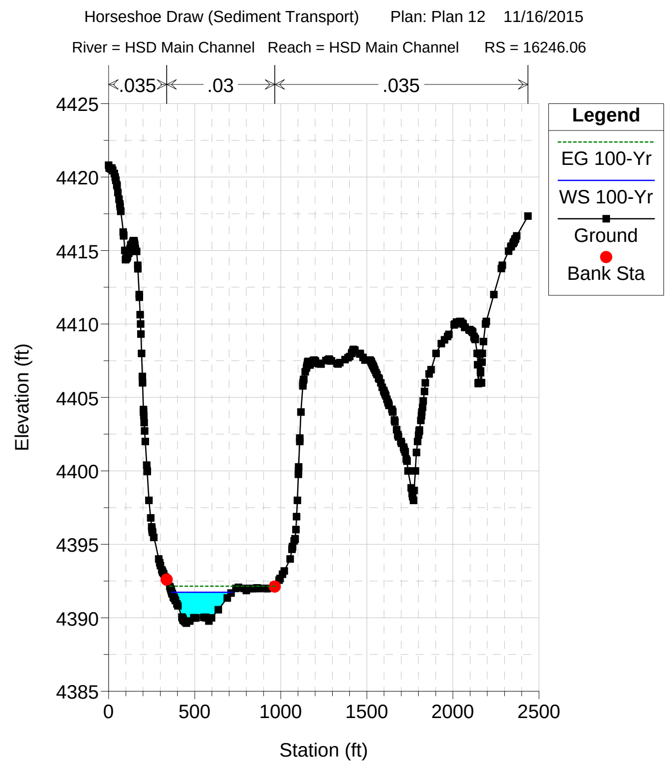
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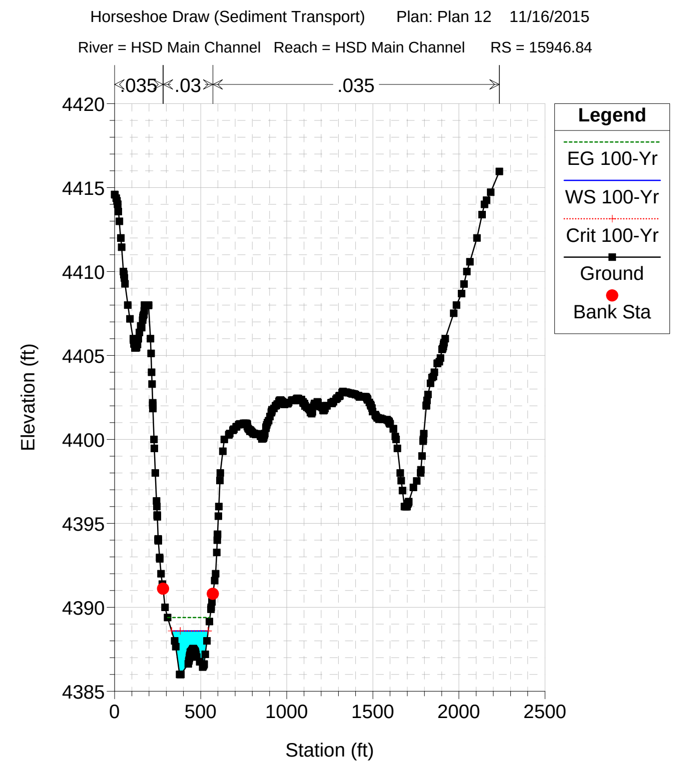
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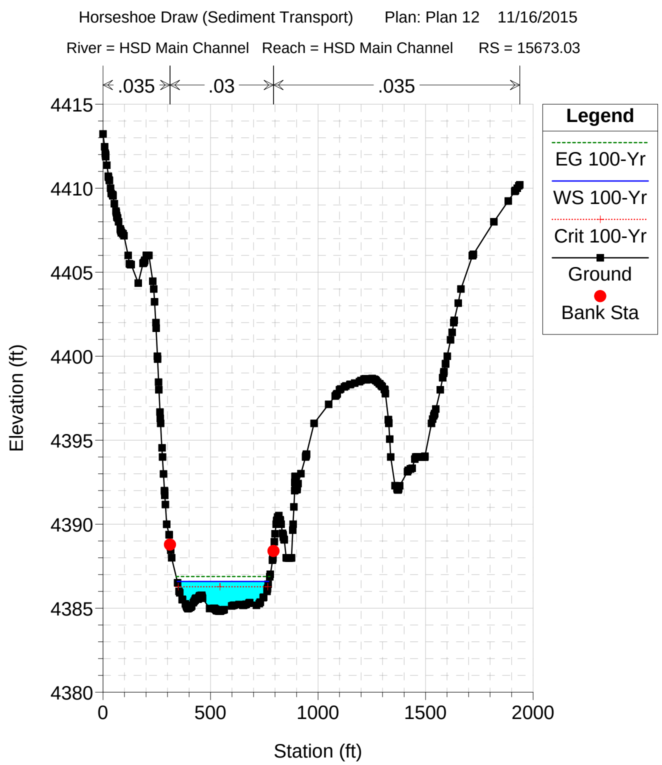
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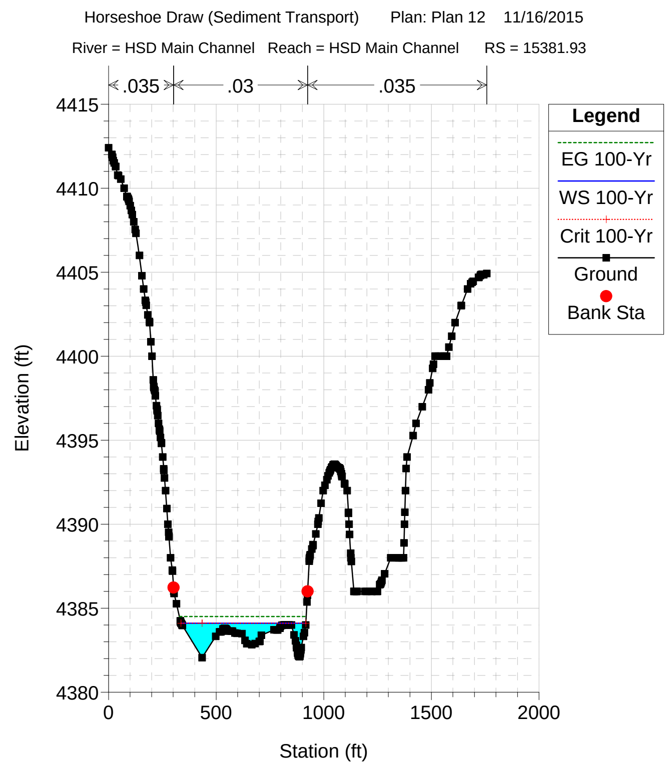
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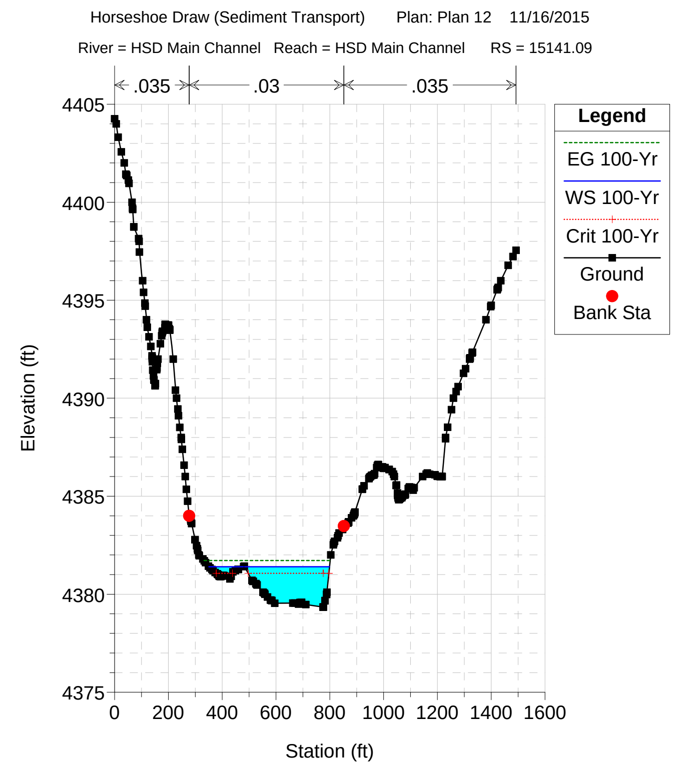
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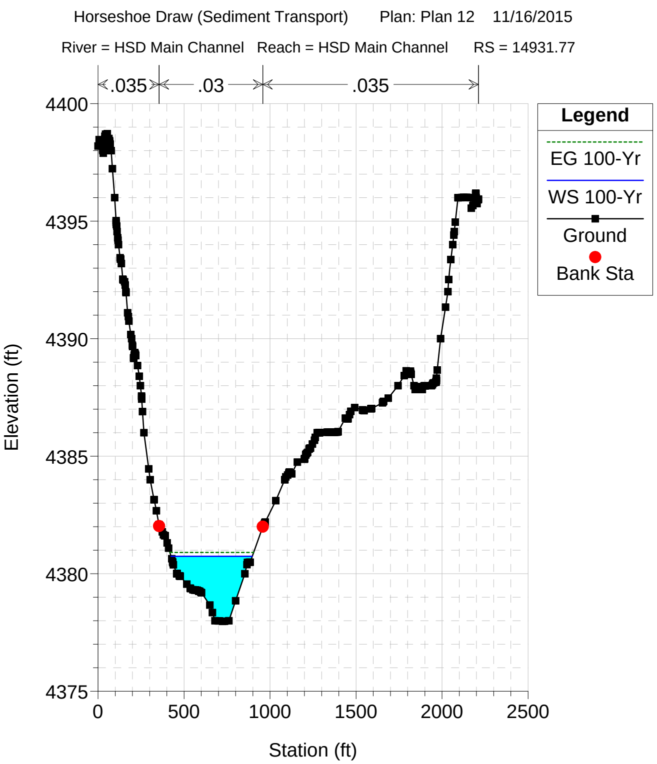
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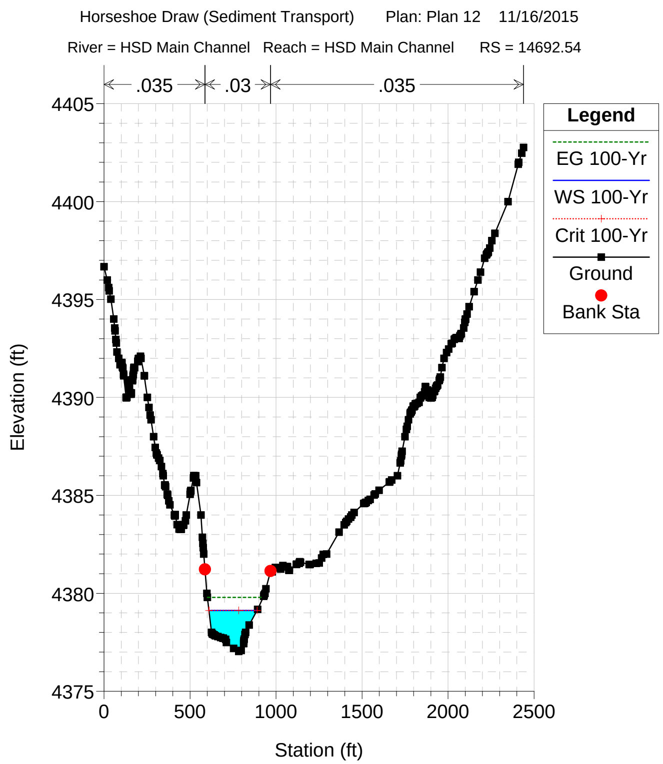
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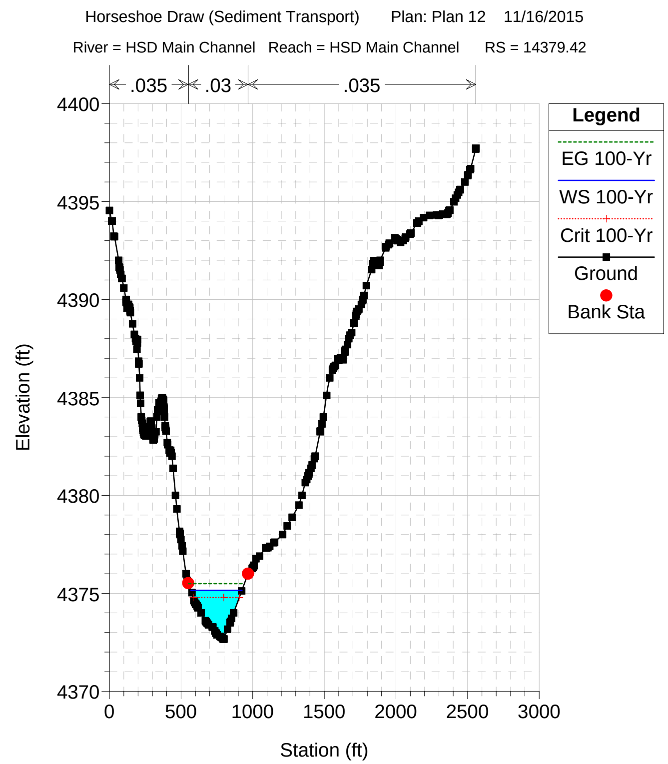
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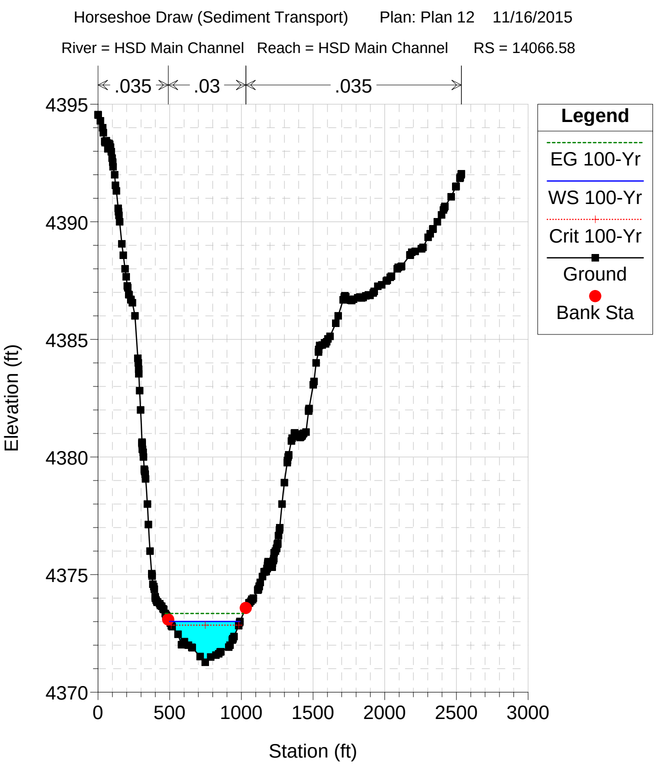
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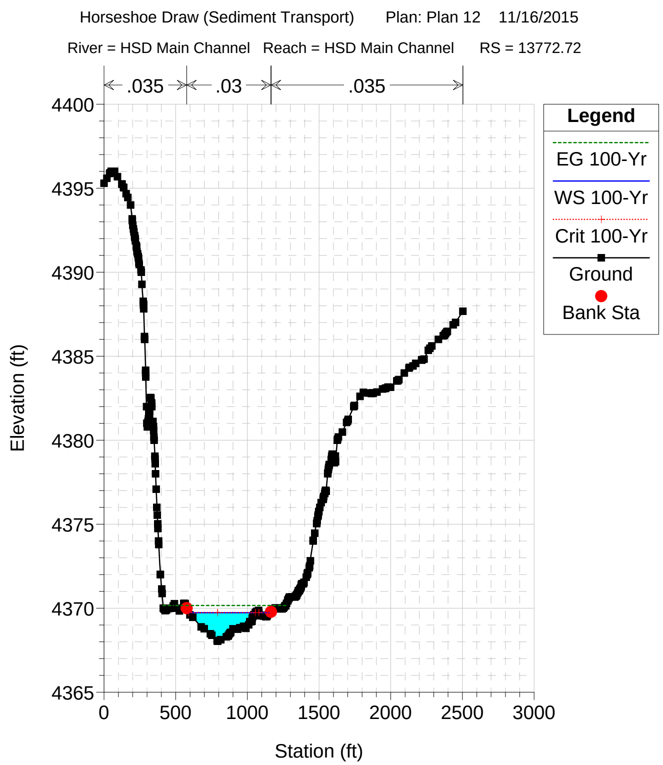
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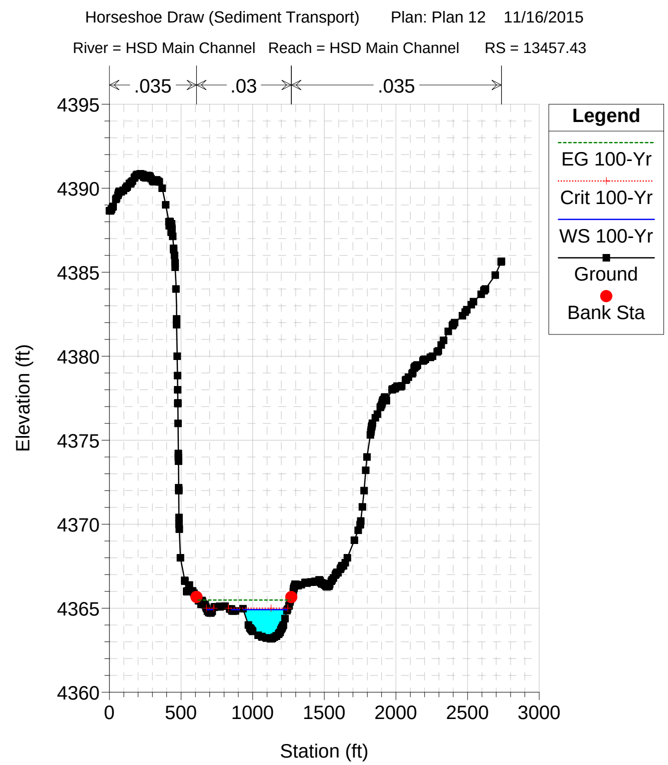
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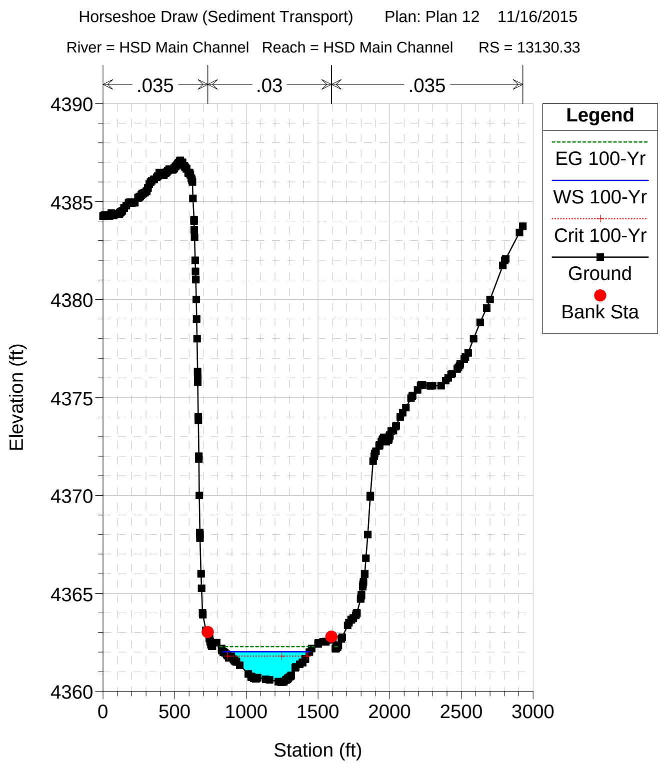
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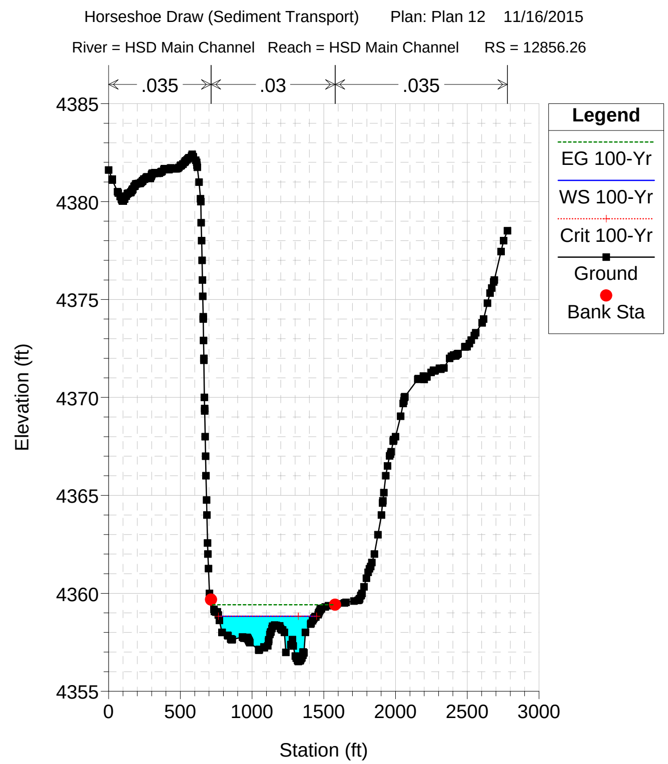
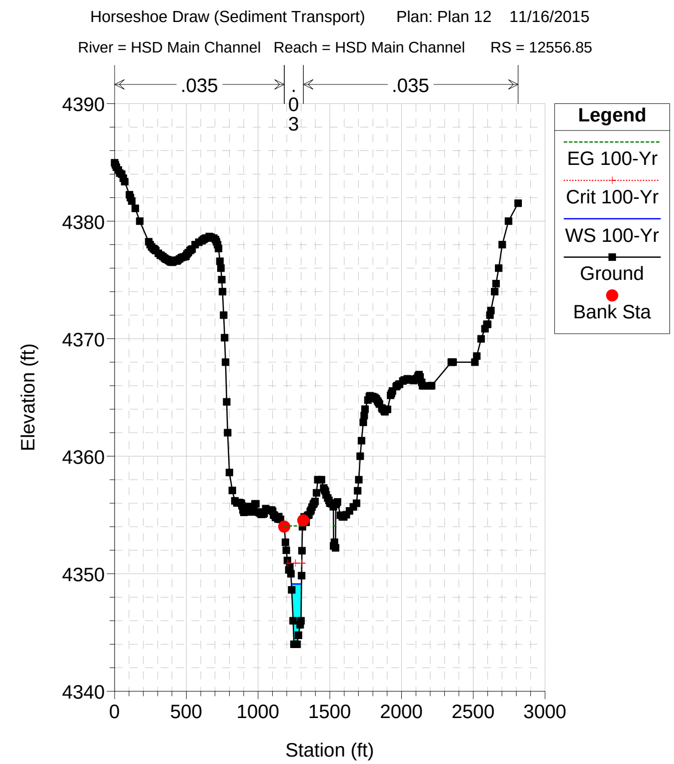
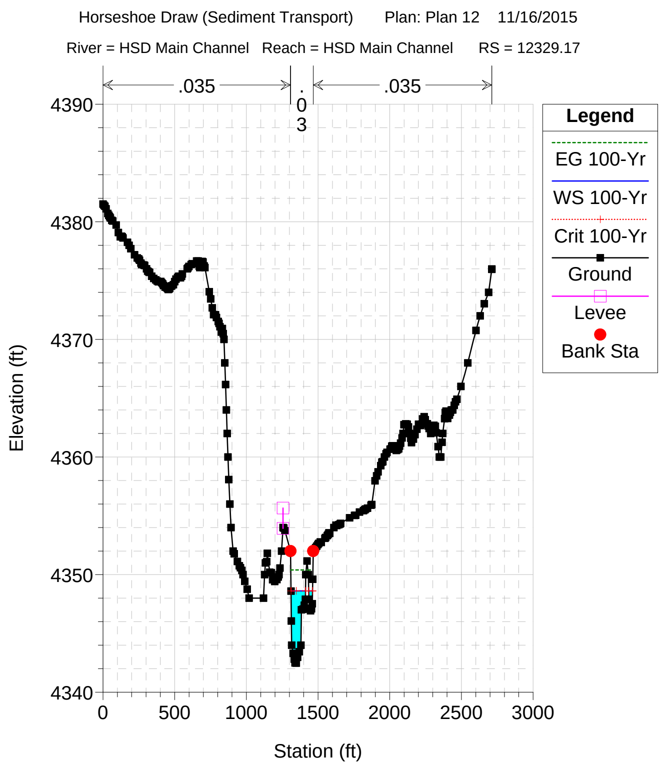
Bank Sta
Elevation (ft)
Station (ft)
4360 4365 4370 4375 4380 4385 4390
0 500 1000 1500 2000 2500 3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 12856.26
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
4355 4360 4365 4370 4375 4380 4385
0 500 1000 1500 2000 2500 3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 12556.85
.035 .03 .035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
4340 4350 4360 4370 4380 4390
0 500 1000 1500 2000 2500 3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 12329.17
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)
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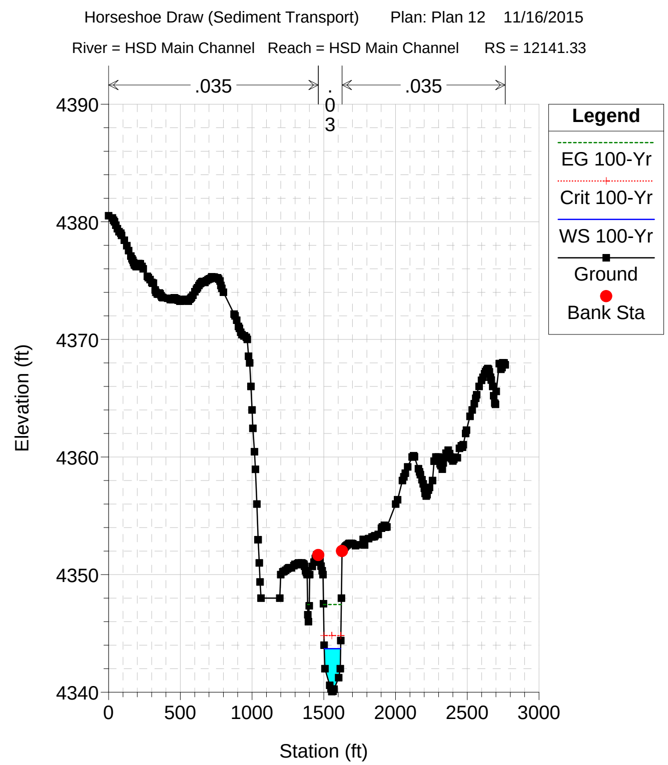
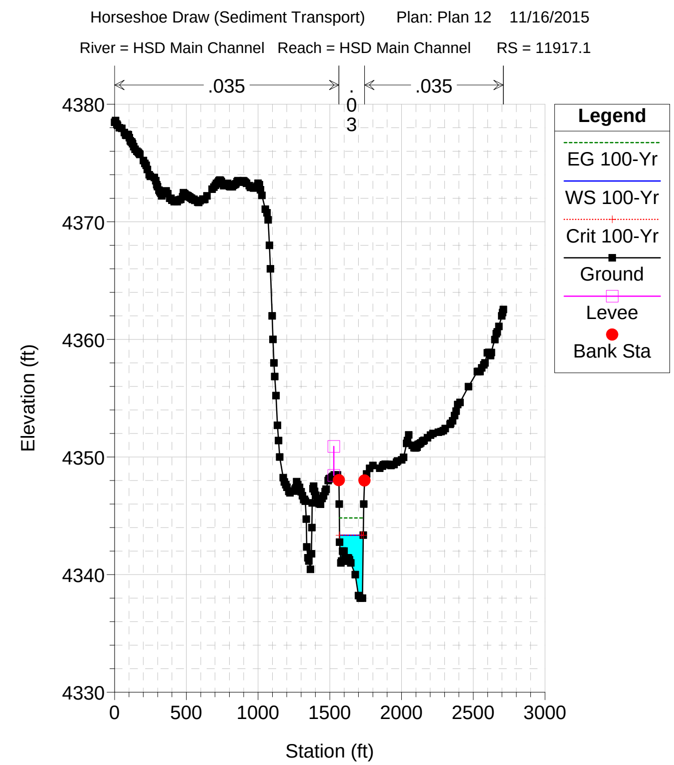
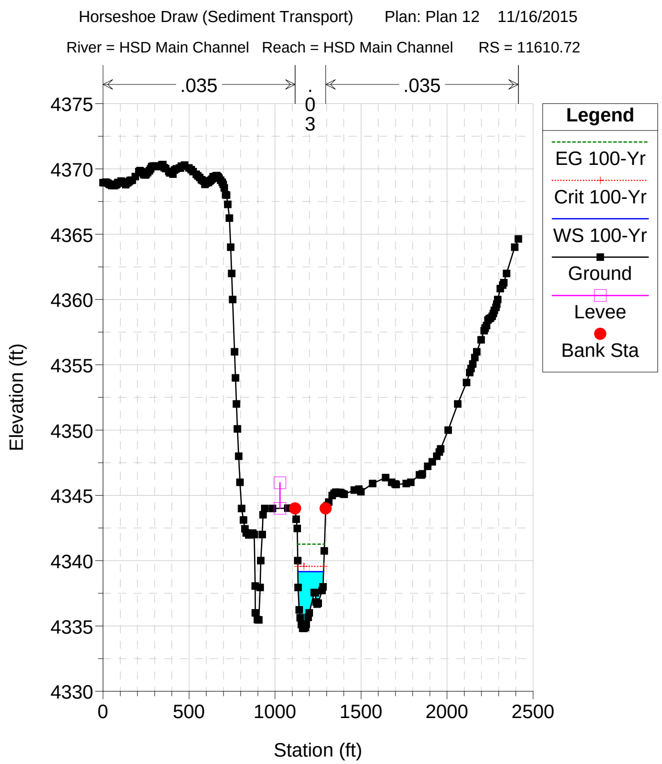
0 500 1000 1500 2000 2500 3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 12141.33
.035 .03 .035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
4340 4350 4360 4370 4380 4390
0 500 1000 1500 2000 2500 3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 11917.1
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)
4330 4340 4350 4360 4370 4380
0 500 1000 1500 2000 2500 3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 11610.72
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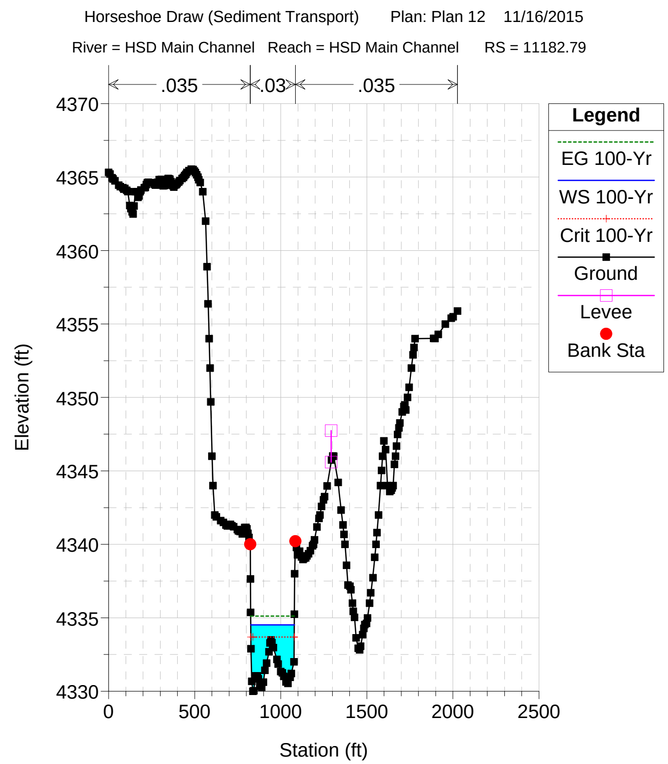
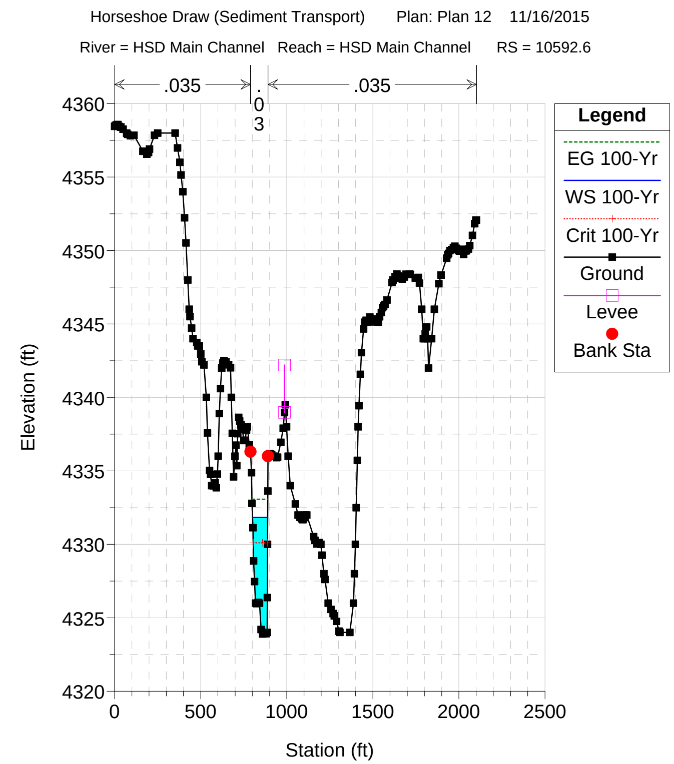
.03
.035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 11182.79
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 10592.6
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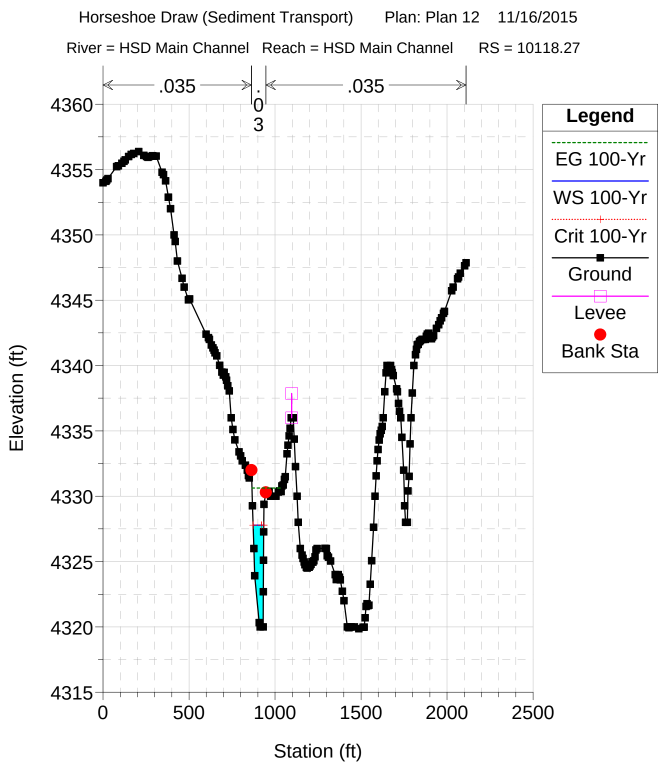
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 10118.27
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.03
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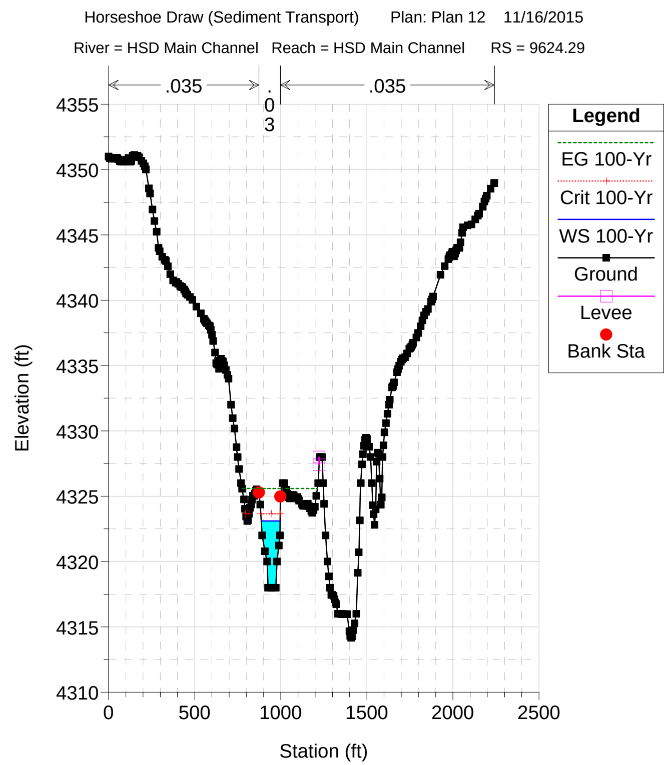
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 9624.29
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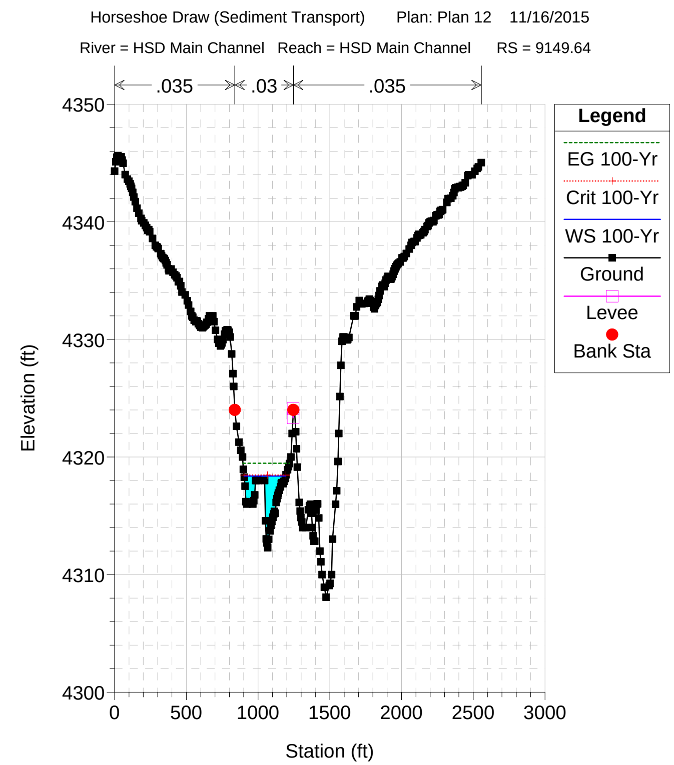
.03
.035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 9149.64
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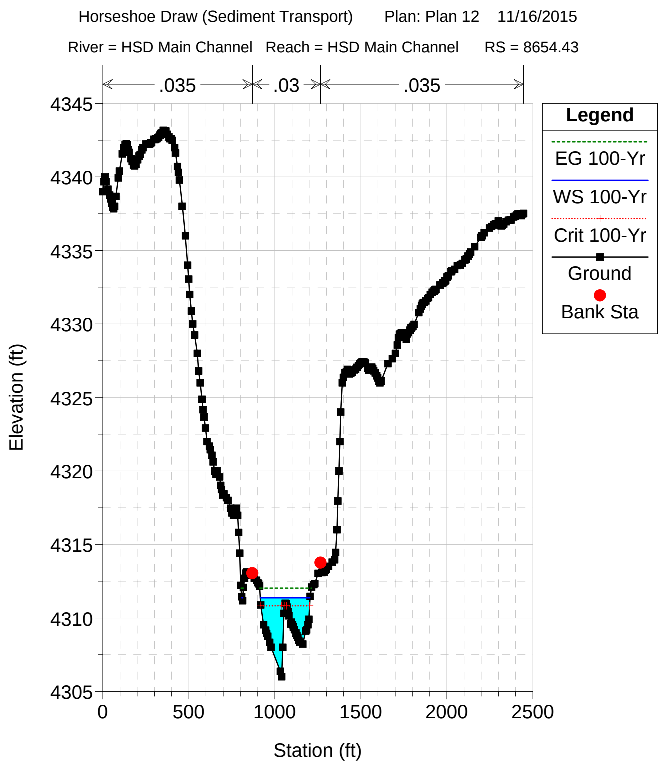
.03
.035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 8654.43
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
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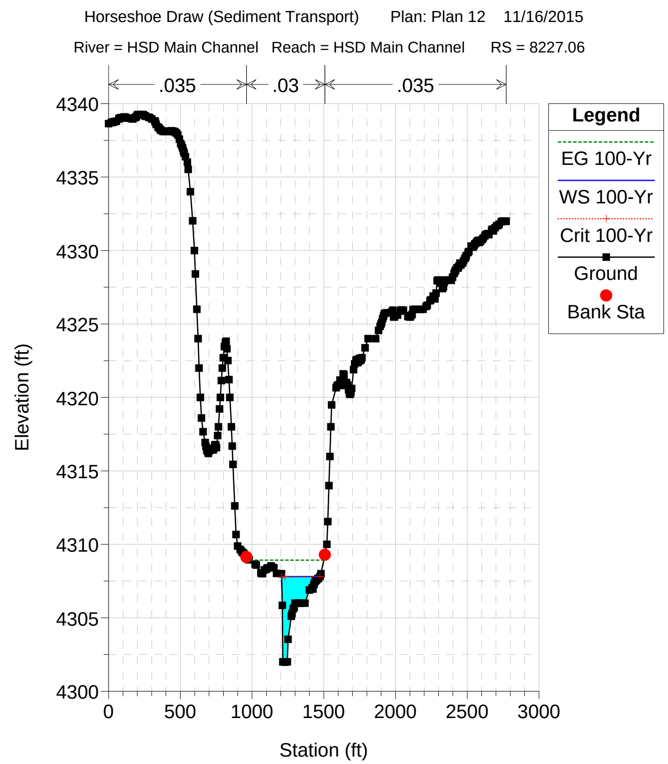
4340
4335
4330
4325
4320
4315
4310
4305
0
500
1000
1500
2000
2500


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 8227.06
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
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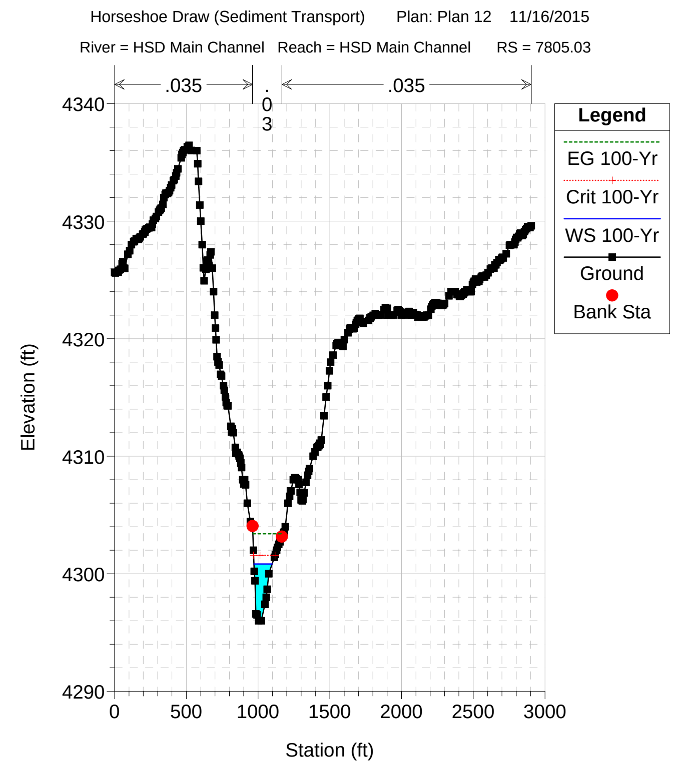
4330
4325
4320
4315
4310
4305
4300
0
500
1000
1500
2000
2500
3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 7805.03
.035
.
0
3
.035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
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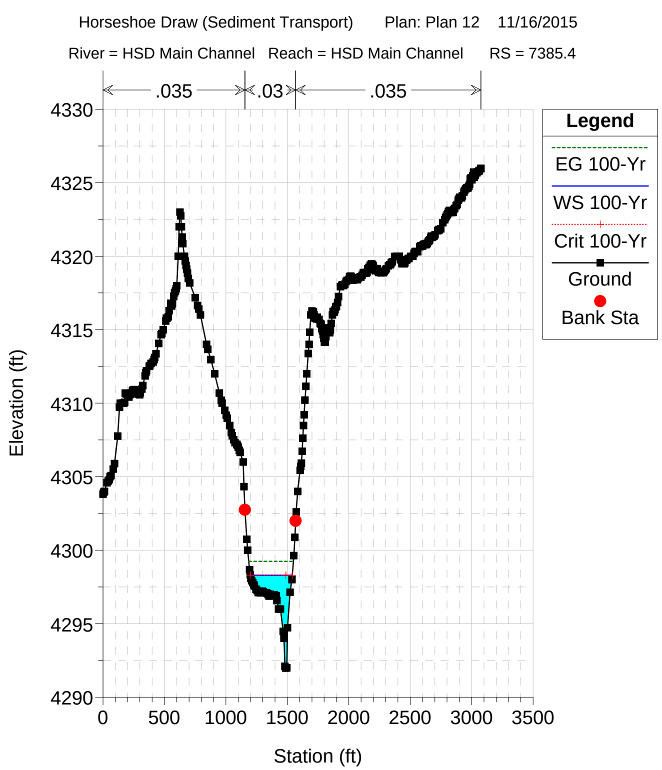
4330
4320
4310
4300
4290
0
500
1000
1500
2000
2500
3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 7385.4
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
4330
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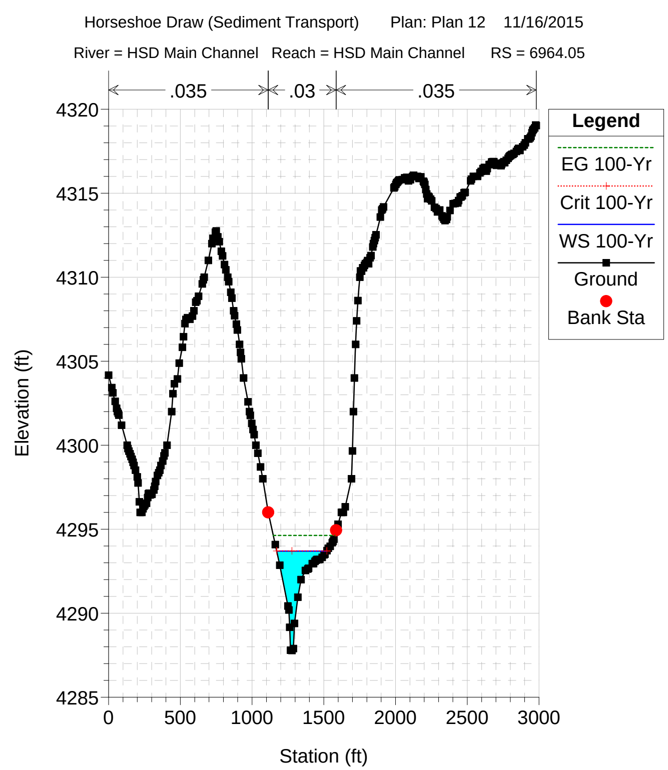
4315
4310
4305
4300
4295
4290
0
500
1000
1500
2000
2500
3000
3500


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 6964.05
.035
.03
.035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
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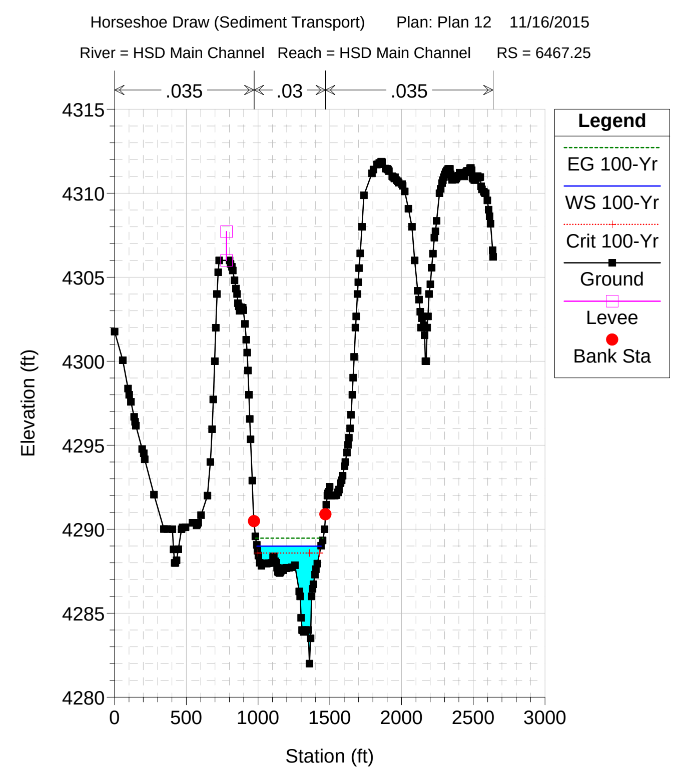
4315
4310
4305
4300
4295
4290
4285
0
500
1000
1500
2000
2500
3000


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 6467.25
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)
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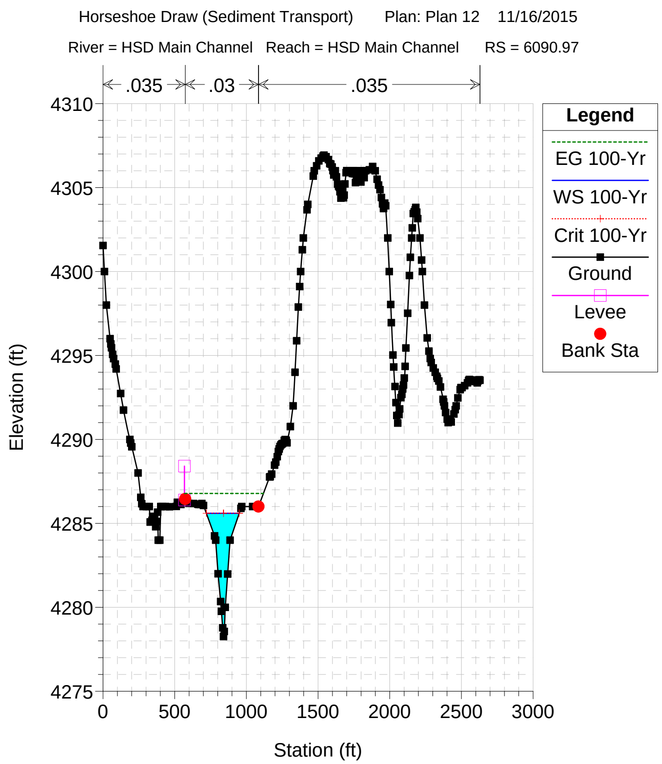
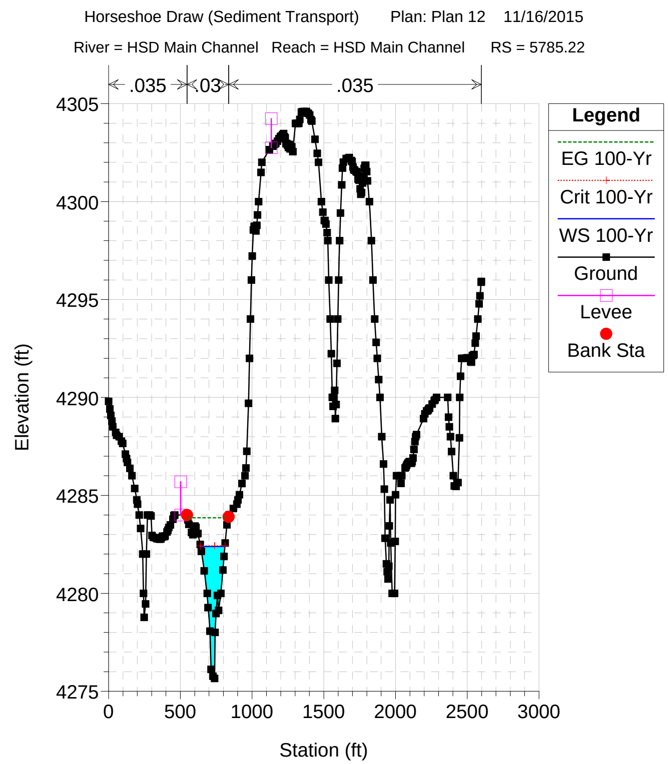
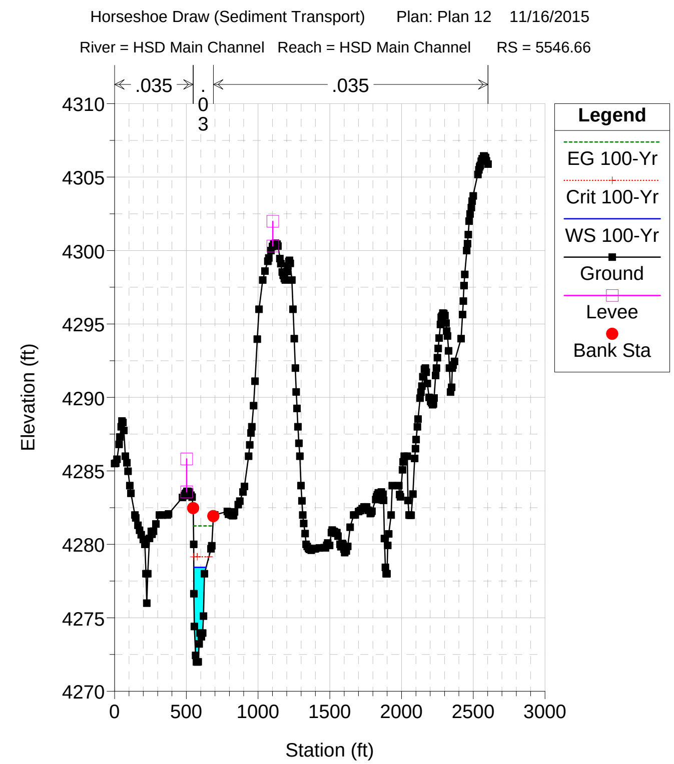
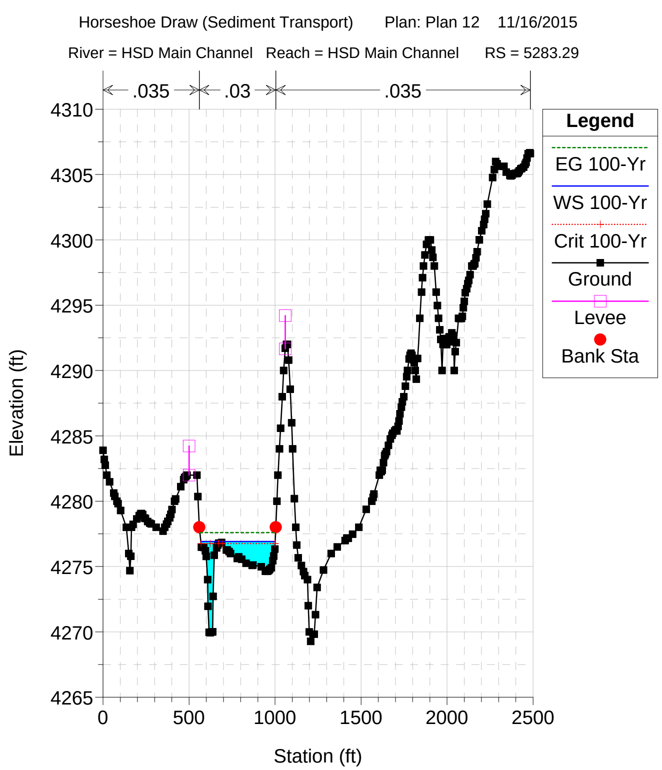
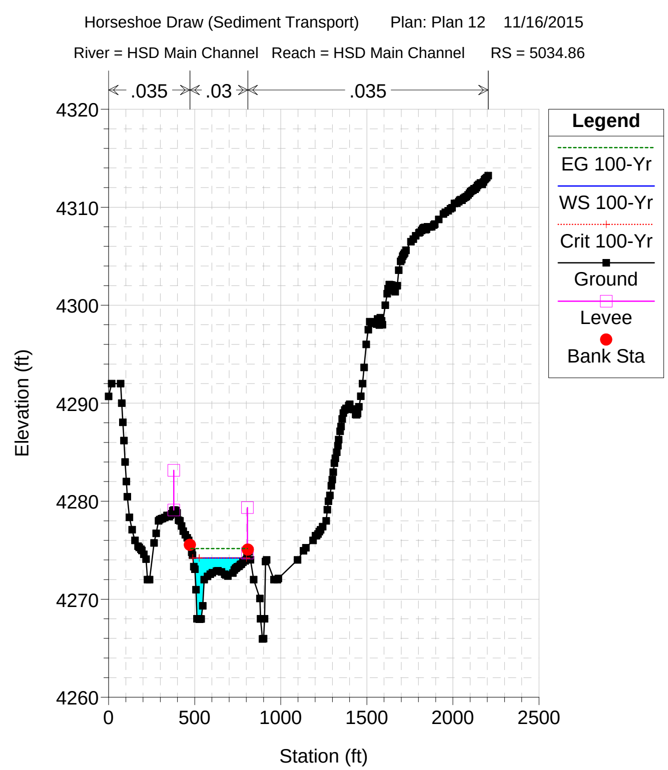
4310
4305
4300
4295
4290
4285
4280
0
500
1000
1500
2000
2500
3000

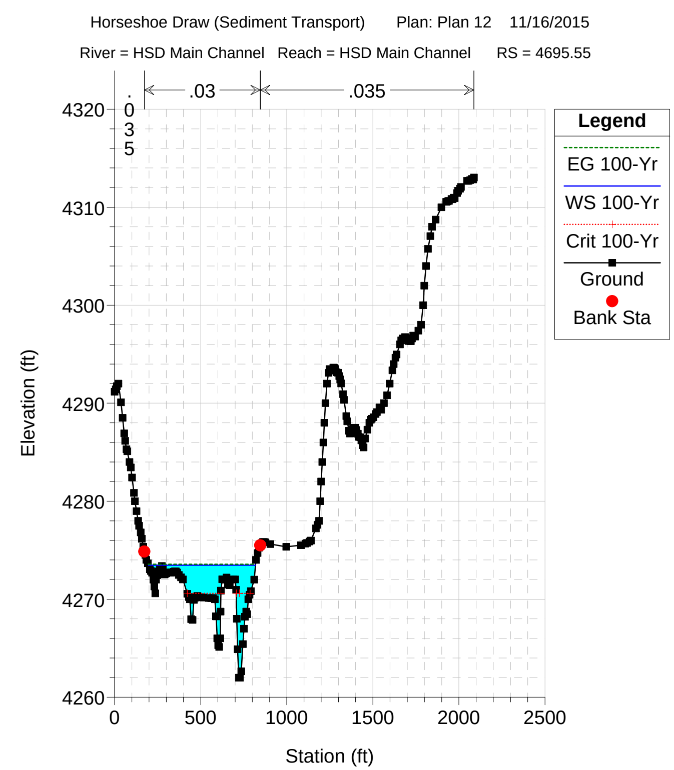

Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 6090.97
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)

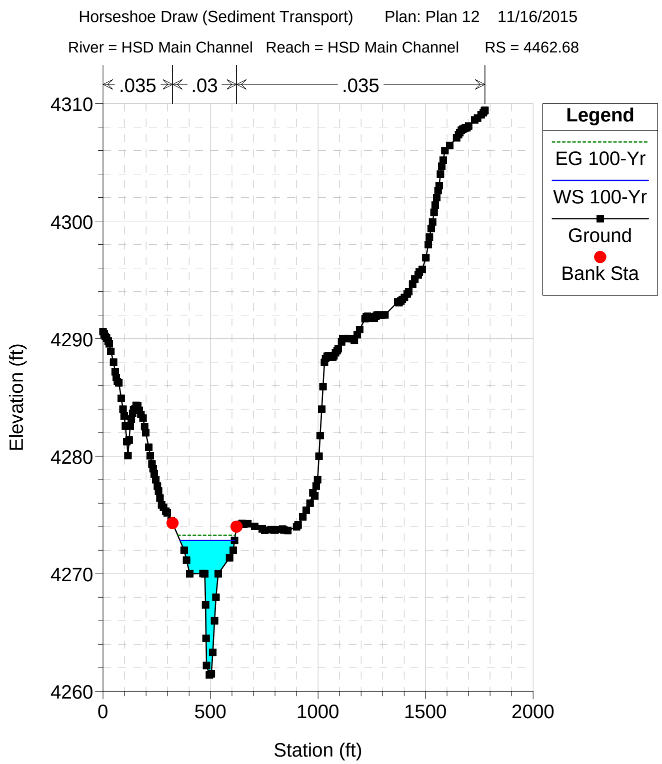

Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 5785.22
.035 .03 .035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)

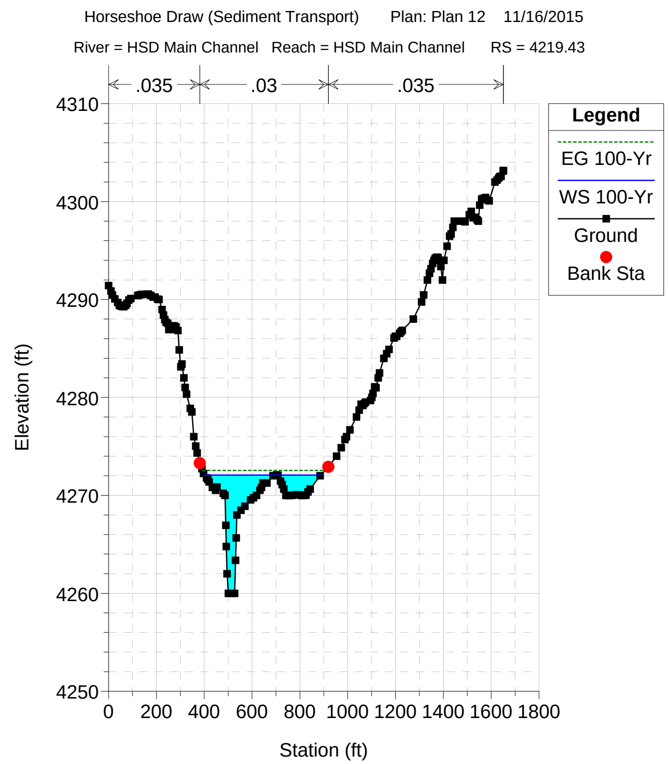

Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 5546.66
.035 .03 .035
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)

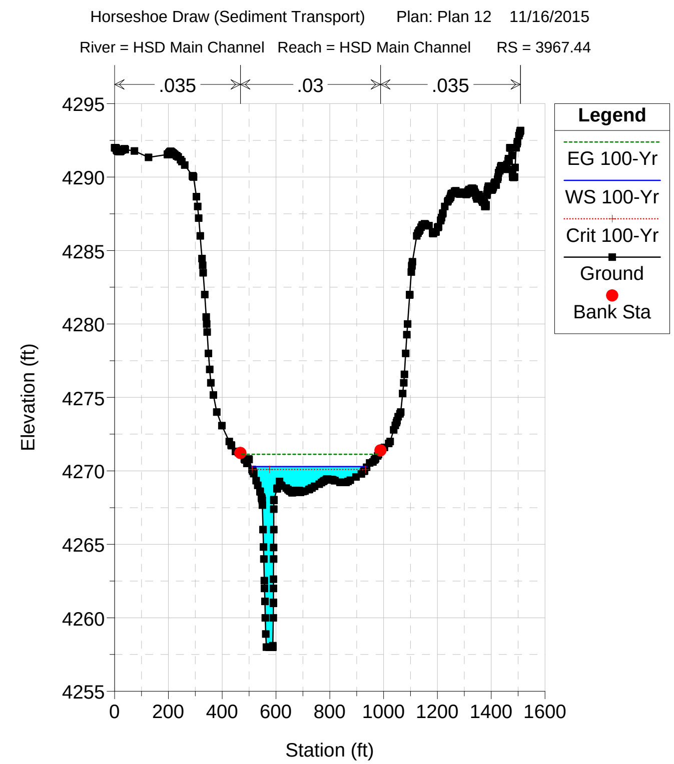

Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 5283.29
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 5034.86
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 4695.55
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 4462.68
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 4219.43
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 3967.44
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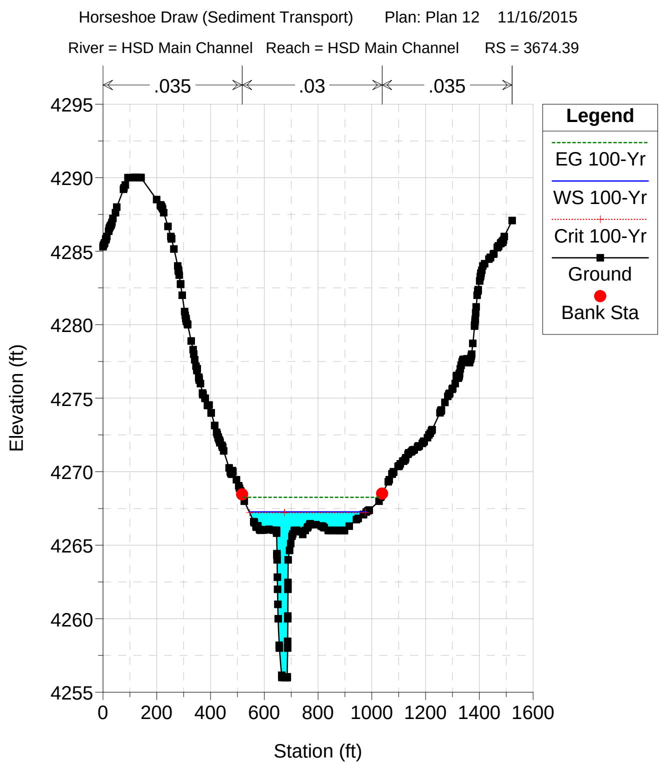
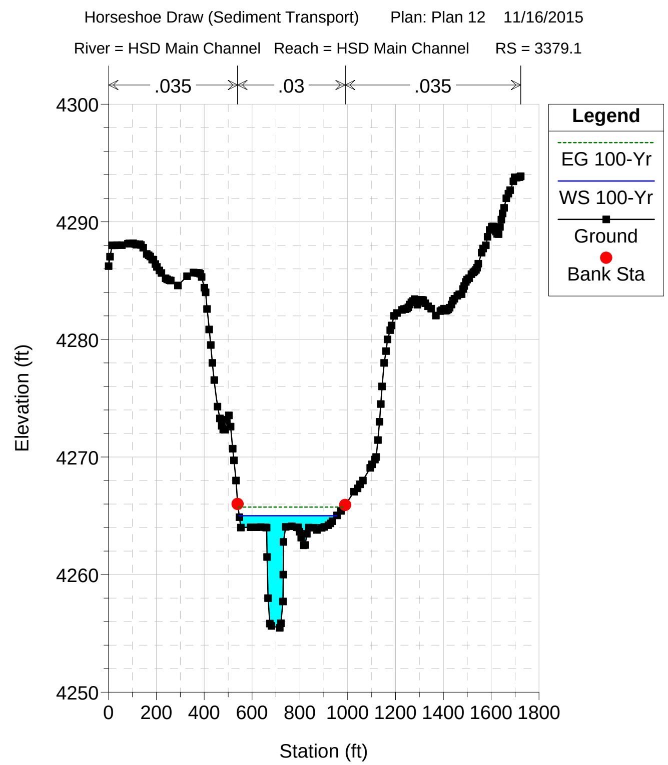
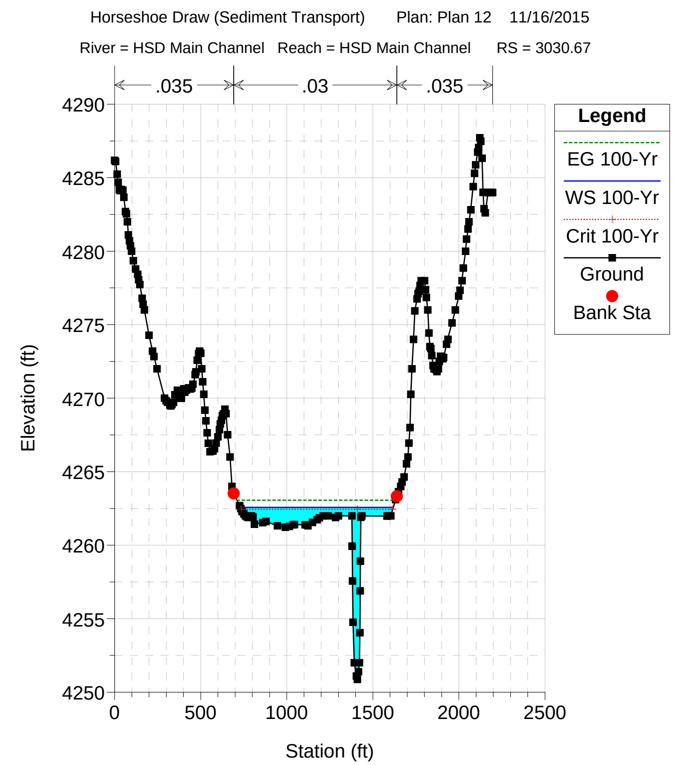
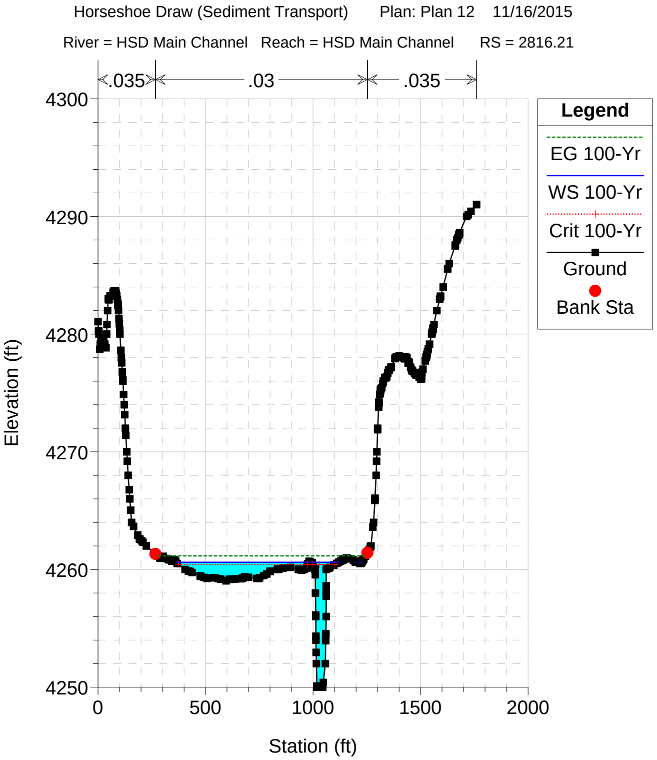
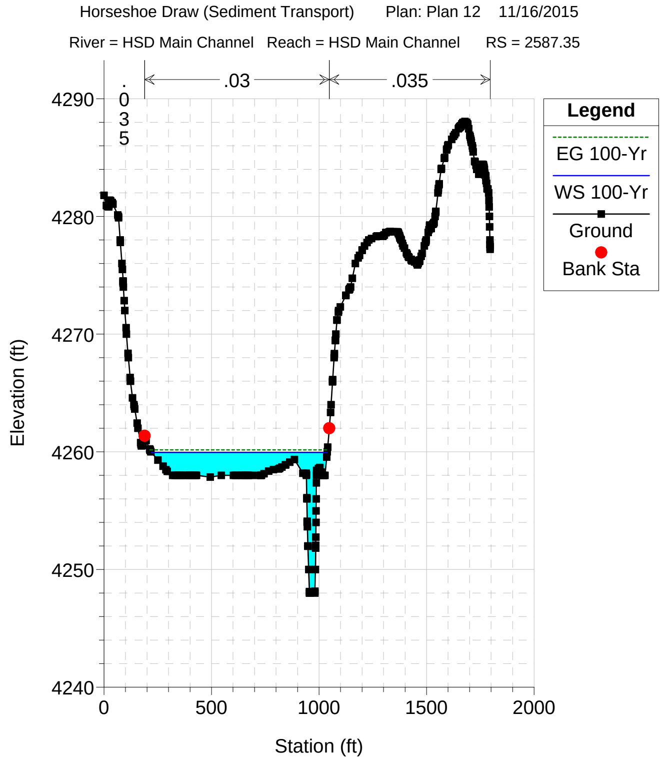
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 3674.39
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 3379.1
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 3030.67
.035 .03 .035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 2816.21
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 2587.35
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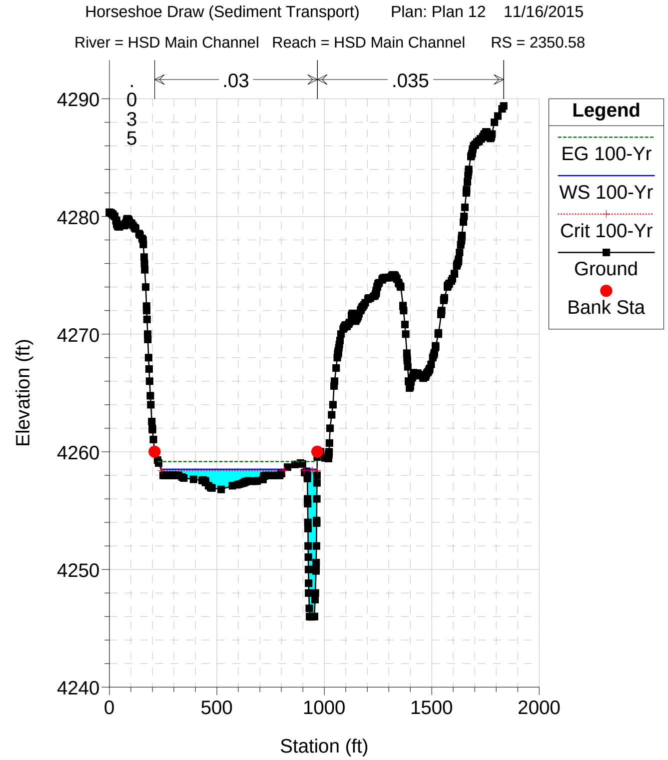
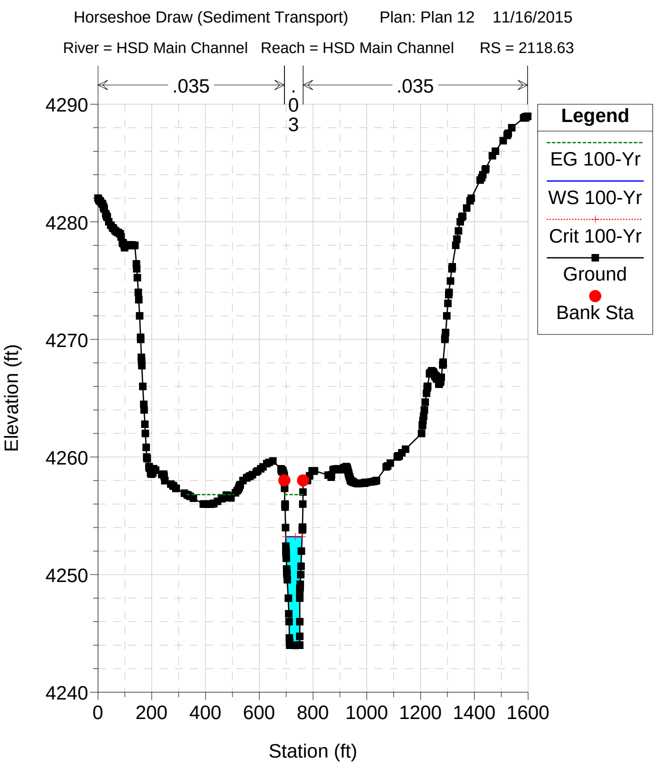
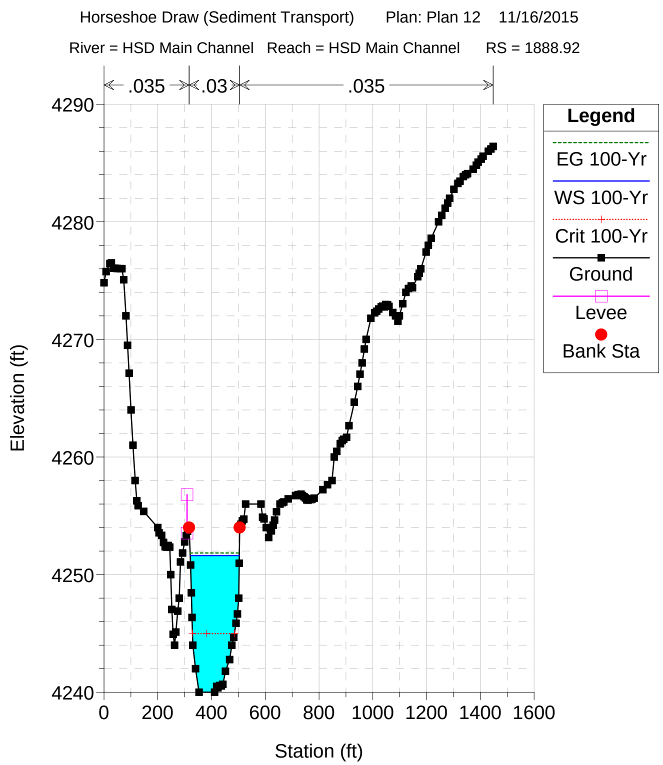
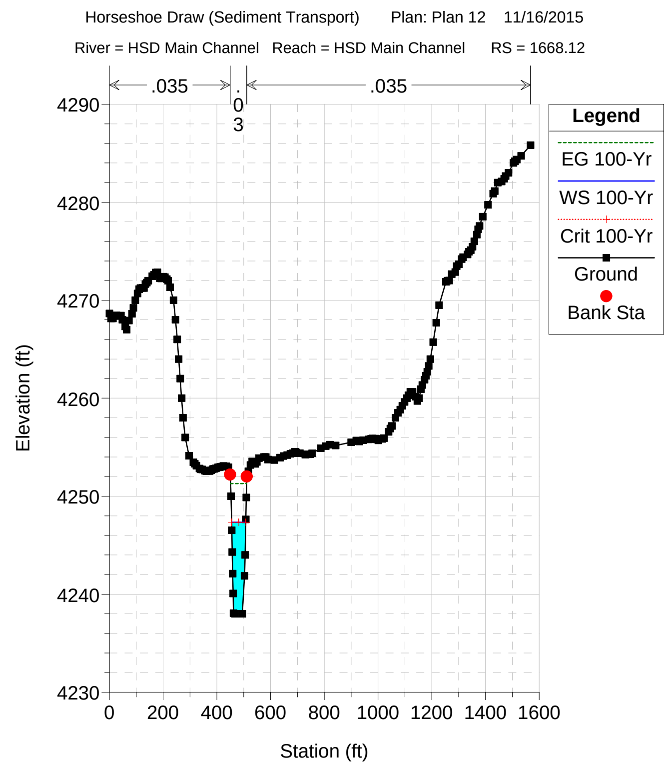
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 2350.58
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 2118.63
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 1888.92
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 1668.12
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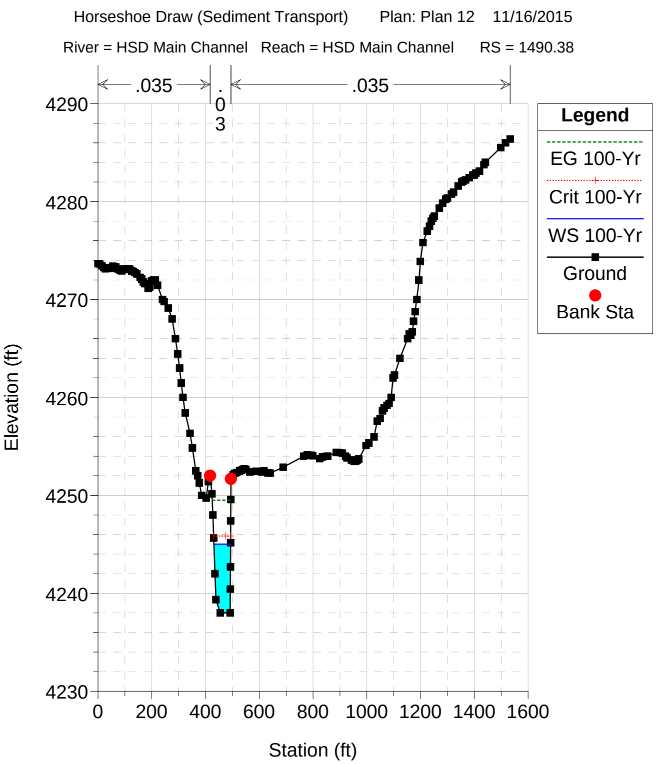
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 1490.38
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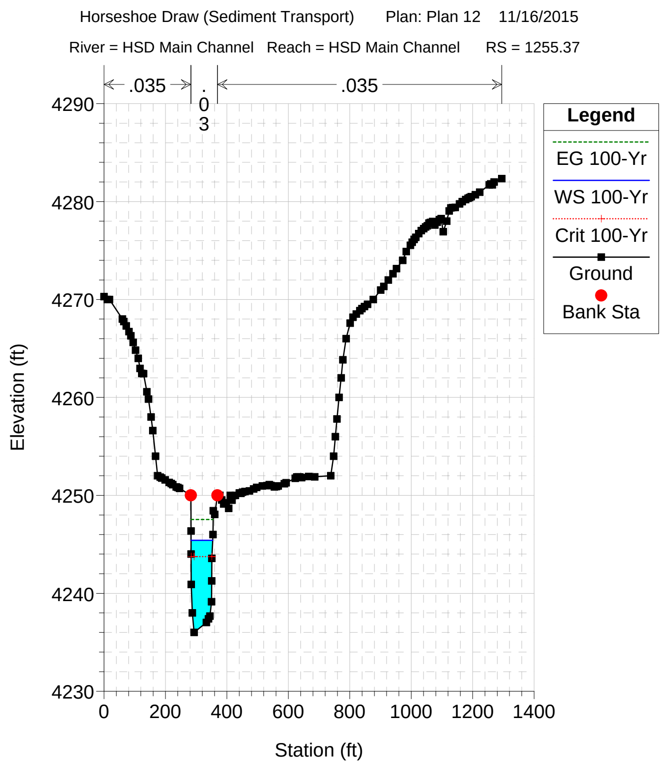
Legend
EG 100-Yr
Crit 100-Yr
WS 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 1255.37
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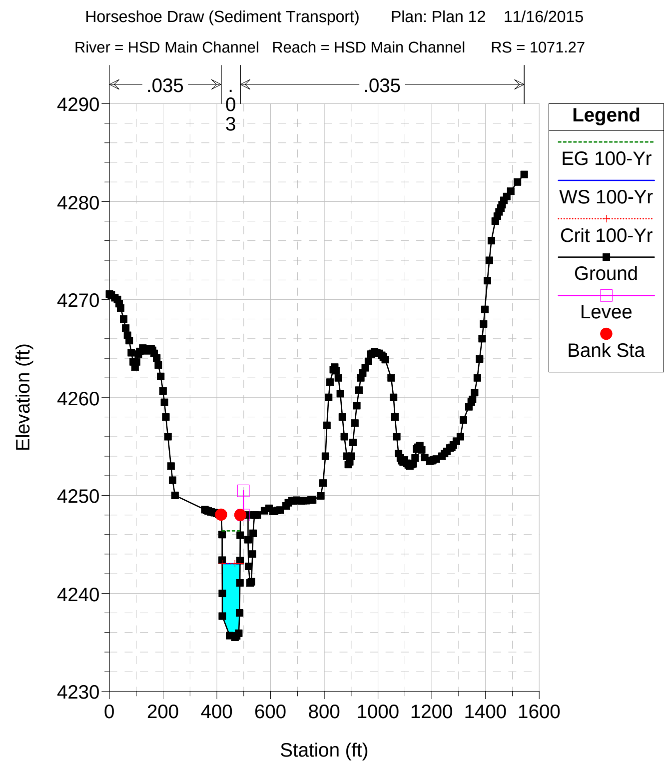
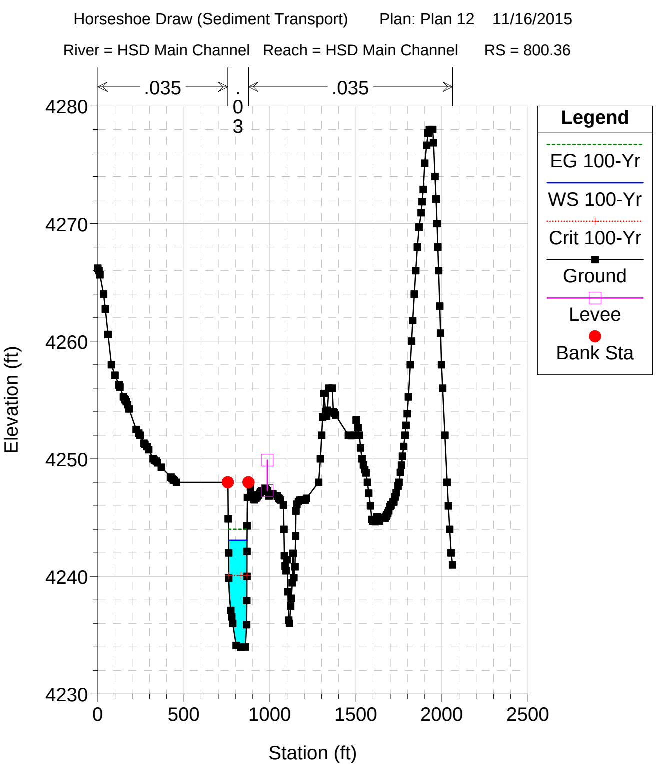
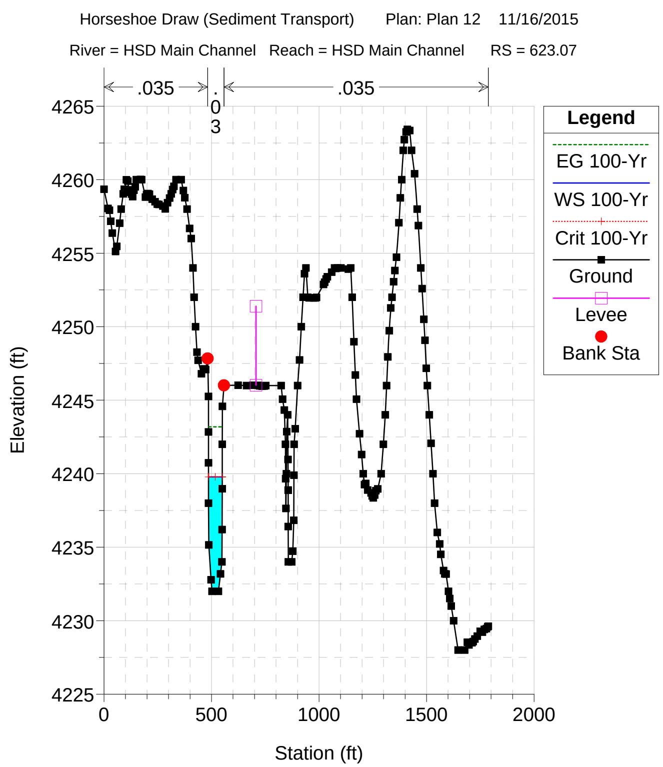
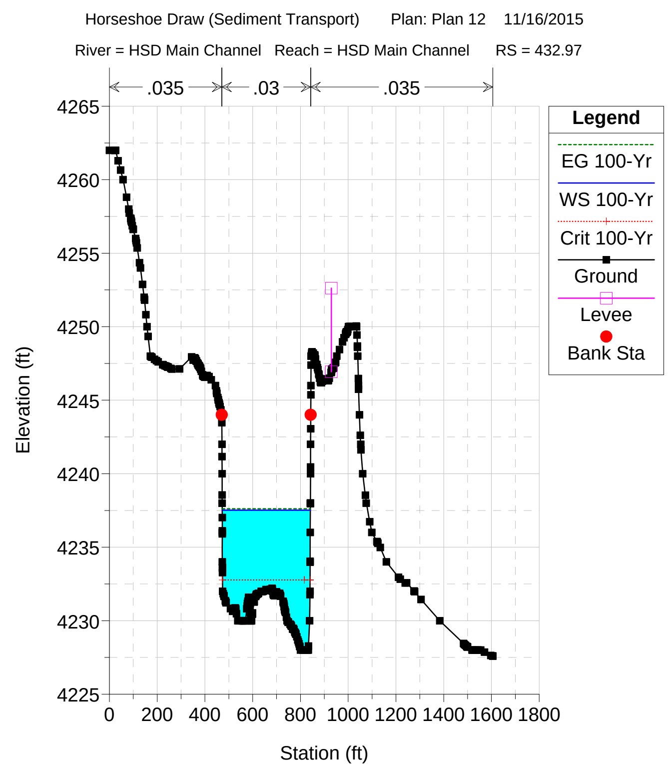
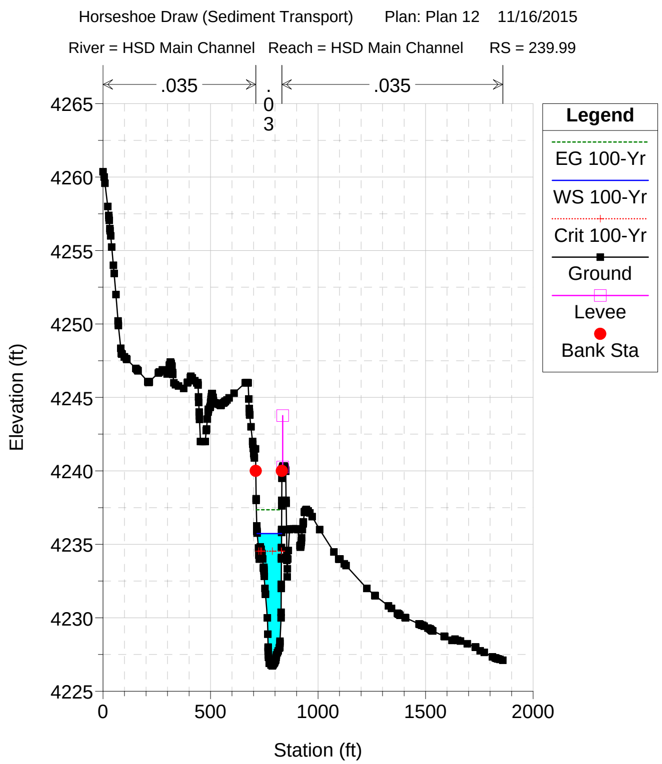
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 1071.27
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)

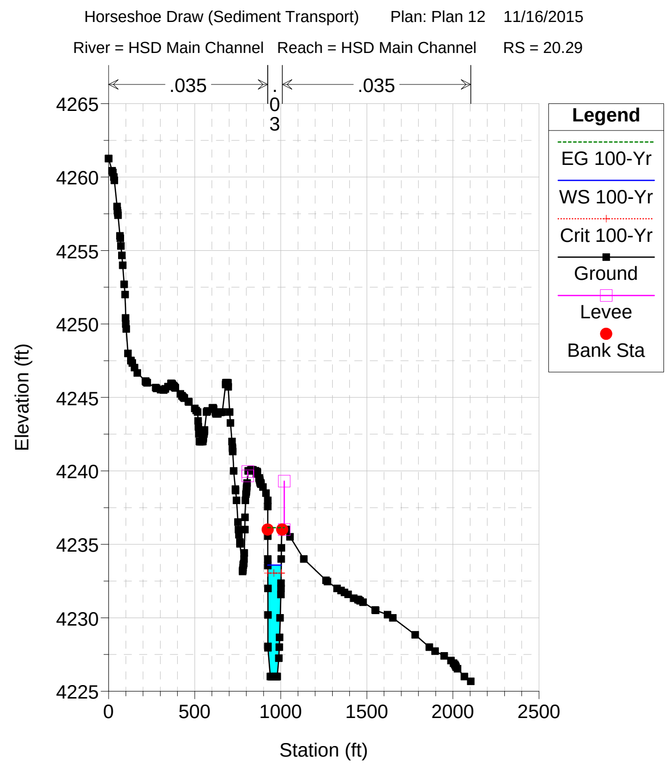

Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 800.36
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 623.07
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)


Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 432.97
.035
.03
.035
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)



Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 239.99
.035
.035
.03
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
4265
4260
4255
4250
4245
4240
4235
4230
4225
0
500
1000
1500
2000
Station (ft)



Horseshoe Draw (Sediment Transport) Plan: Plan 12 11/16/2015
River = HSD Main Channel Reach = HSD Main Channel RS = 20.29
.035
.035
.03
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Levee
Bank Sta
Elevation (ft)
4265
4260
4255
4250
4245
4240
4235
4230
4225
0
500
1000
1500
2000
2500
Station (ft)

APPENDIX C

GEOTECHNICAL EVALUATION EXCERPTS

The soil samples collected from our drilling activities were transported to the Ninyo & Moore laboratory for geotechnical laboratory testing. The testing included in-situ moisture content and dry density, gradation, Atterberg limits, consolidation (response-to-wetting), and corrosivity characteristics (including pH, minimum electrical resistivity, and soluble sulfate and chloride contents). The results of the in-situ moisture content and dry density testing are presented on the excavation logs in Appendix A. A description of each laboratory test method and the remainder of the test results are presented in Appendix B.

In order to assist in obtaining percolation rate information, Ninyo & Moore conducted two shallow percolation tests within the proposed retention basin. The procedures utilized for the percolation test consisted of the insertion of an open-ended, 10-inch diameter casing into undisturbed soil, to a depth of about 5 feet, followed by pre-wetting of the soil. The test continued after the pre-wetting period by refilling the casing and monitoring the drop in water level as a function of time until steady-state conditions were achieved. The test locations are depicted on Figure 2, and the results of the tests are presented in Appendix C.

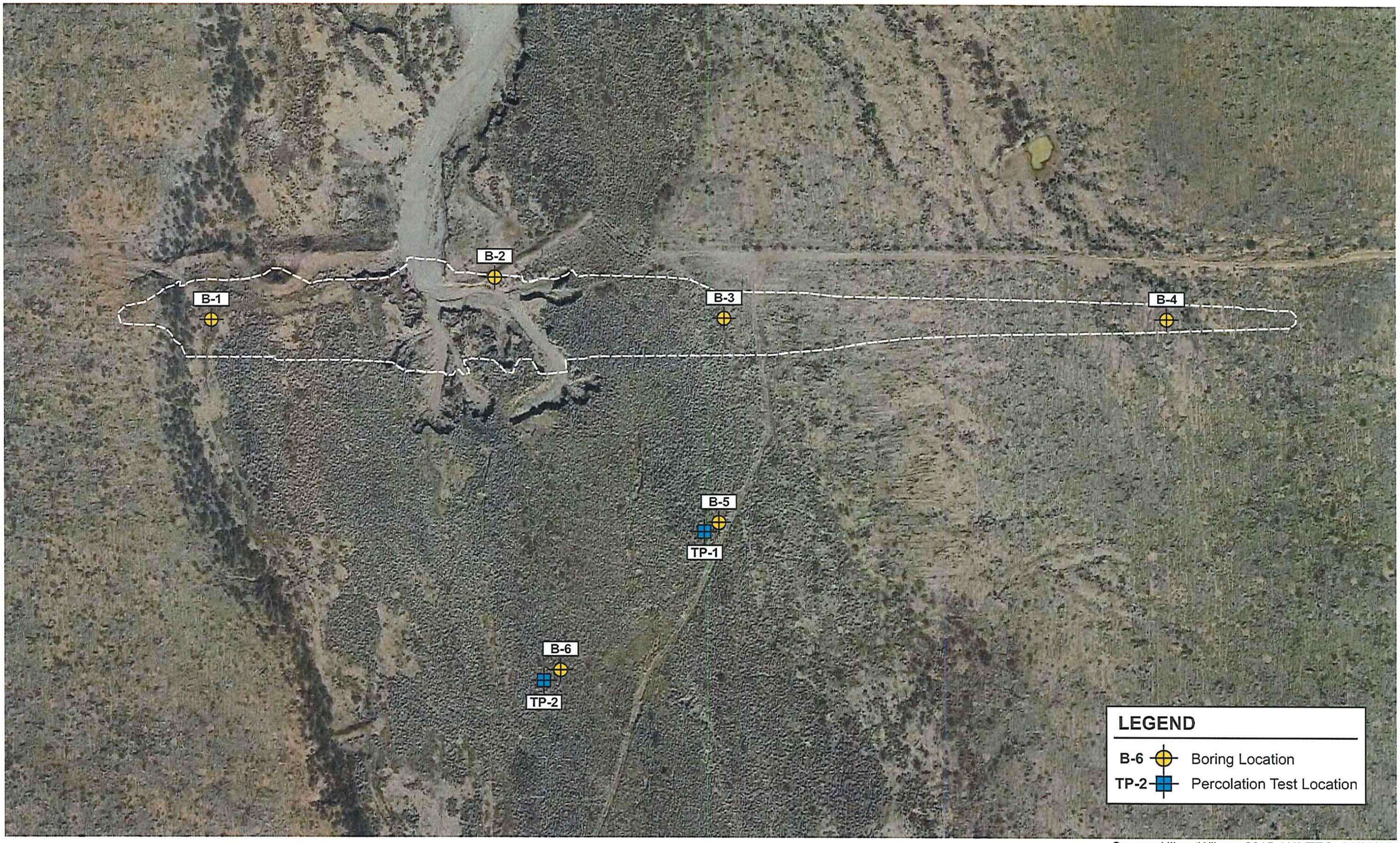
6. GEOLOGY AND SUBSURFACE CONDITIONS

The following sections describe the geologic conditions at the site.

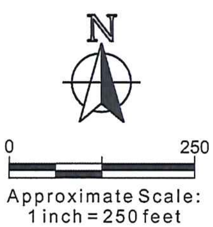
6.1. Geologic Setting

The project site is located in the Southern San Pedro Valley Section of the Basin and Range physiographic province, which is typified by broad alluvial valleys separated by steep, discontinuous subparallel mountain ranges. The mountain ranges generally trend north-south and northwest-southeast. The basins consist of alluvium with thicknesses extending to several thousands of feet.

The basins and surrounding mountains were formed approximately 10 to 18 million years ago during the mid- to late-Tertiary. Extensional tectonics resulted in the formation of horsts (mountains) and grabens (basins) with vertical displacement along high-angle normal faults. Intermittent volcanic activity also occurred during this time. The surrounding basins filled



Source: HilgartWilson, 2015, NAVTEQ, 01/03/15.



Note: Dimensions, directions, and locations are approximate.

Ninyo & Moore		EXPLORATION LOCATIONS	FIGURE 2
PROJECT NO: 604915001	DATE: 10/15	HORSESHOE DRAW BASIN COCHISE COUNTY, ARIZONA	

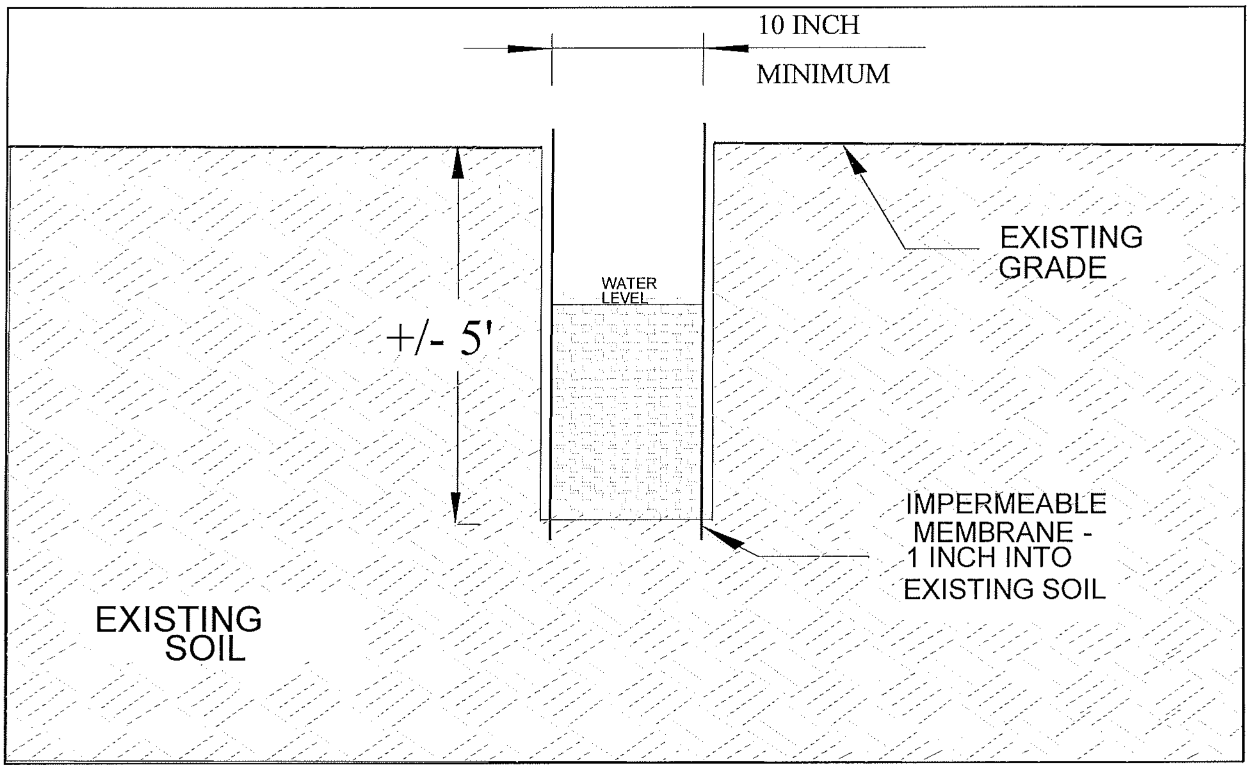
file no: 4915blm1015

Ninyo & Moore

SUMMARY OF PERCOLATION TEST RESULTS

PROJECT: HORSESHOE DRAW BASIN, COCHISE COUNTY, ARIZONA PROJECT NO.: 604915001

TECHNICIAN: NAG DATE: 10/07/05 LOCATION: TP-1



START TIME (Hr:Min)	ENDING TIME (Hr:Min)	ELAPSED TIME (Hr:Min)	INITIAL READING (Feet)	FINAL READING (Feet)	CHANGE IN WATER LEVEL (Feet)	PERCOLATION RATE*
13:03	13:13	0:10	1	1.1	0.1	0.60
13:13	13:23	0:10	1.1	1.2	0.1	0.60
13:23	13:33	0:10	1.2	1.3	0.1	0.60

* Note: Percolation Rate is reported in Cubic Feet per Hour per Square Foot of percolation area.

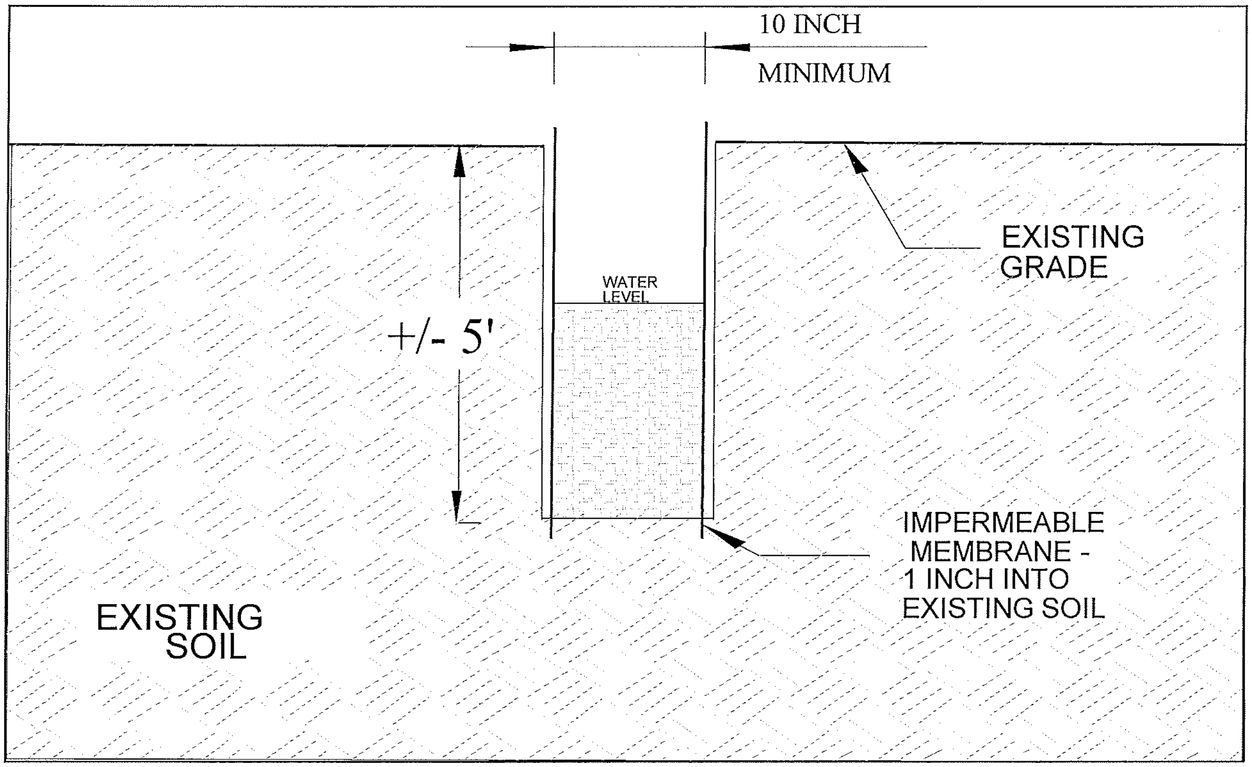
AVERAGE PERCOLATION RATE FOR LAST THREE READINGS	**0.60**	$FT^3/HOUR/FT^2$

Ninyo & Moore

SUMMARY OF PERCOLATION TEST RESULTS

PROJECT: HORSESHOE DRAW BASIN, COCHISE COUNTY, ARIZONA PROJECT NO.: 604915001

TECHNICIAN: NAG DATE: 10/07/05 LOCATION: TP-2



START TIME (Hr:Min)	ENDING TIME (Hr:Min)	ELAPSED TIME (Hr:Min)	INITIAL READING (Feet)	FINAL READING (Feet)	CHANGE IN WATER LEVEL (Feet)	PERCOLATION RATE*
14:17	14:27	0:10	1	1	0	0.00
14:27	14:37	0:10	1.1	1.2	0.1	0.60
14:37	14:47	0:10	1.2	1.3	0.1	0.60

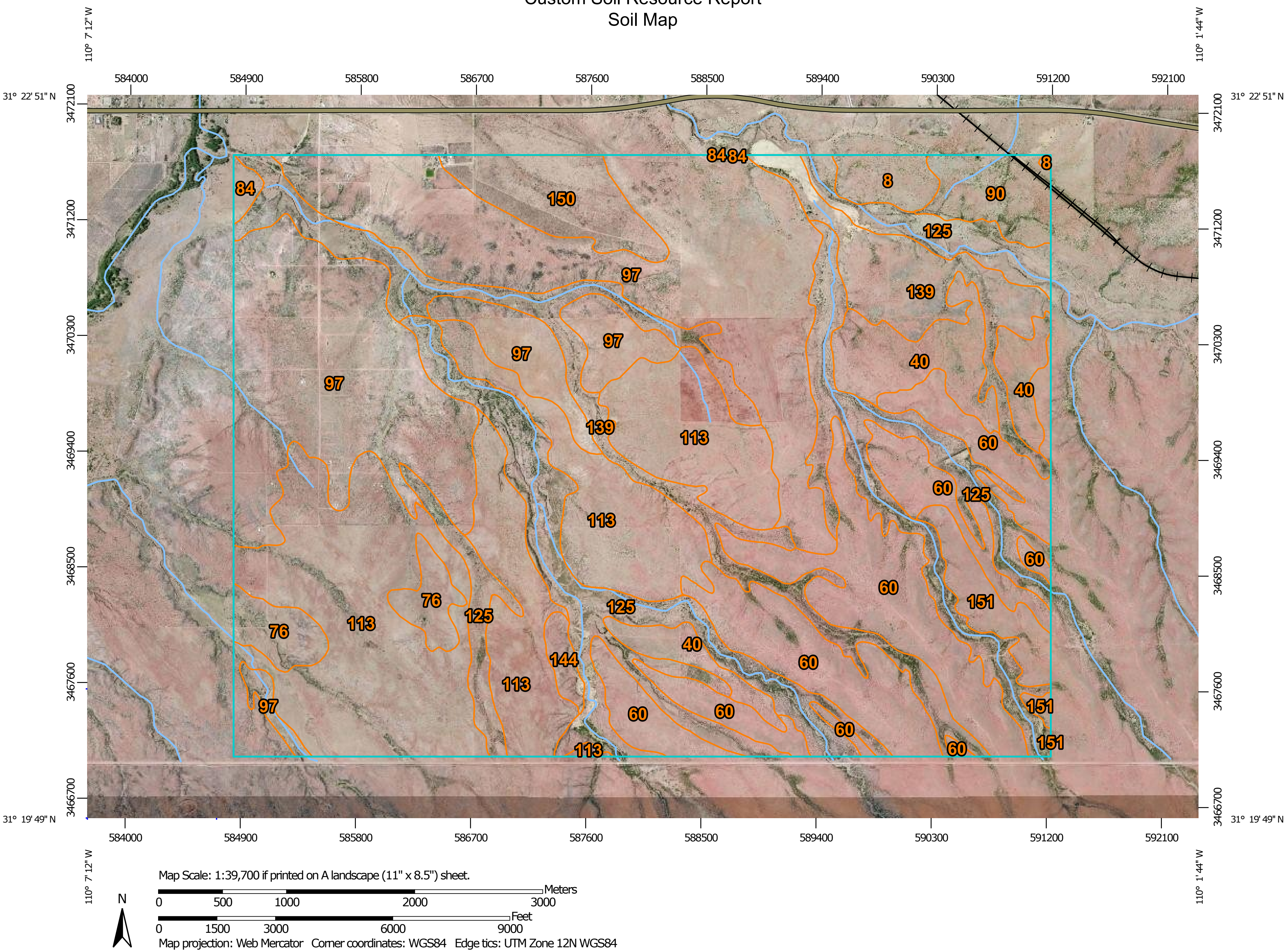
* Note: Percolation Rate is reported in Cubic Feet per Hour per Square Foot of percolation area.

AVERAGE PERCOLATION RATE FOR LAST THREE READINGS	**0.40**	$FT^3/HOUR/FT^2$

APPENDIX D

NRCS SOIL RESOURCE MAP AND REPORT

Soil Map


110° 7' 12" W
110° 1' 44" W
31° 22' 51" N
31° 19' 49" N
584000
584900
585800
586700
587600
588500
589400
590300
591200
592100
3472100
3471200
3470300
3469400
3468500
3467600
3466700
84
8
150
90
125
97
139
40
113
60
76
144
151
Map Scale: 1:39,700 if printed on A landscape (11" x 8.5") sheet.
Meters
0 500 1000 2000 3000
Feet
0 1500 3000 6000 9000
N
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

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

APPENDIX E

HEC-HMS AND AREA/INFILTRATION CALCULATION RESULTS AND COMPARISON

GROUNDWATER RECHARGE POTENTIAL RESULTS COMPARISON

Project: Horseshoe Draw

Prepared by: HW

Date: Dec 2015

HILGARTWILSON
ENGINEER | PLAN | SURVEY | MANAGE

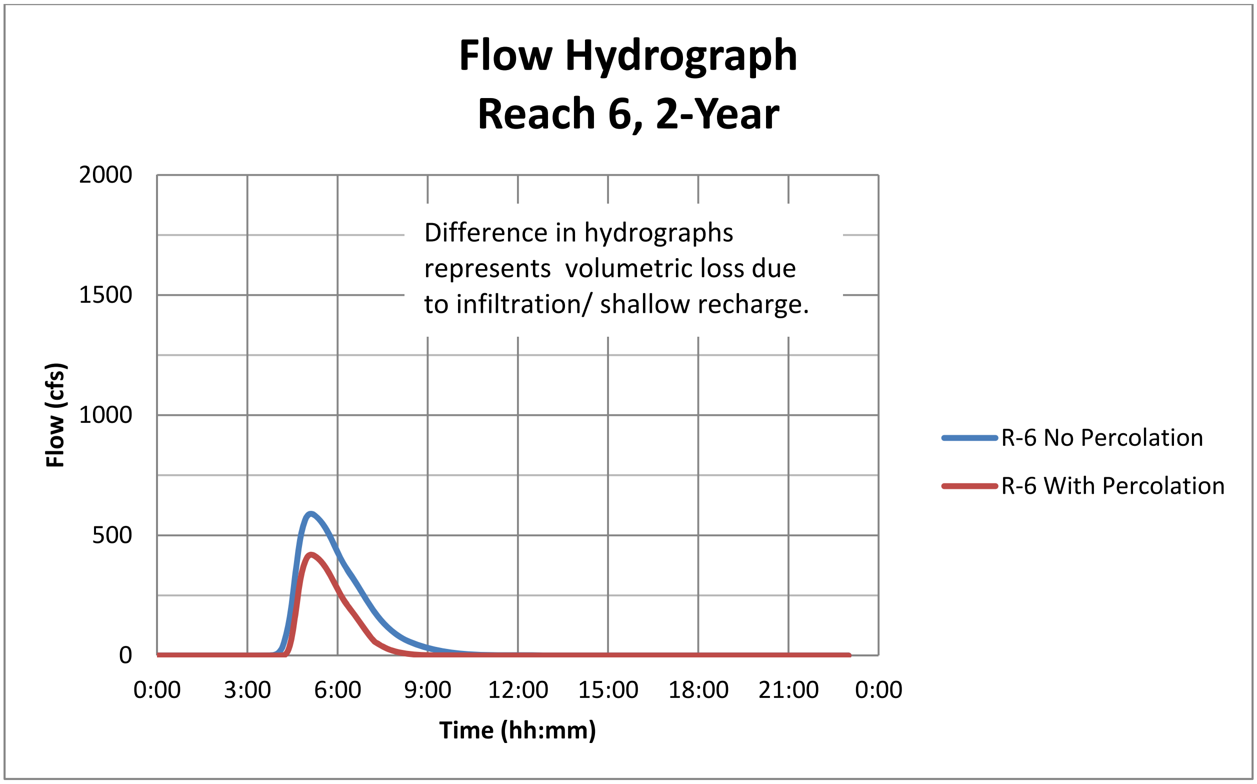
Storm Event	Reach	Floodplain Area [A] [ft^2]	Inudation Duration [t] [hrs]	Area/Infiltration		HEC-HMS	
				Volume [acre-feet]	Total Volume [acre-feet]	Volume [acre-feet]	Total Volume [acre-feet]
2-Year	R-6	526,512	9.3	56	**258**	50	**382**
	R-8	730,204	10.2	85		90	
	R-9	869,649	10.3	103		119	
	R-12	107,155	10.5	13		124	
25-Year	R-6	640,173	10.7	78	**459**	72	**570**
	R-8	906,996	11.4	119		130	
	R-9	1,634,605	11.5	216		181	
	R-12	347,699	11.6	46		188	
50-Year	R-6	665,638	10.9	83	**608**	76	**618**
	R-8	1,080,093	11.7	145		139	
	R-9	1,779,495	11.8	240		197	
	R-12	1,027,385	11.8	140		205	
100-Year	R-6	690,882	11.2	89	**709**	80	**708**
	R-8	1,150,561	11.8	156		147	
	R-9	1,890,104	11.9	259		235	
	R-12	1,480,716	12.1	205		245	

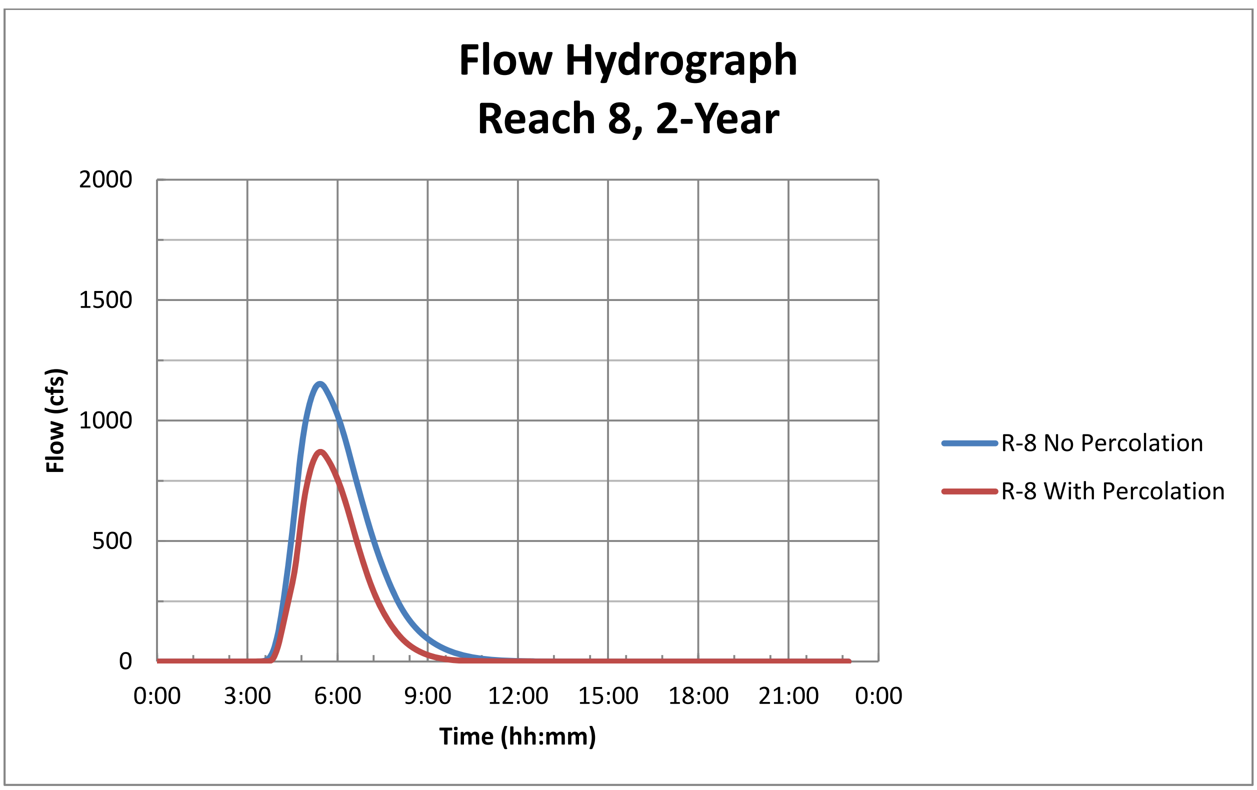
Notes:

Percolation rate (i) = 0.5 $ft^3/hr/ft^2$

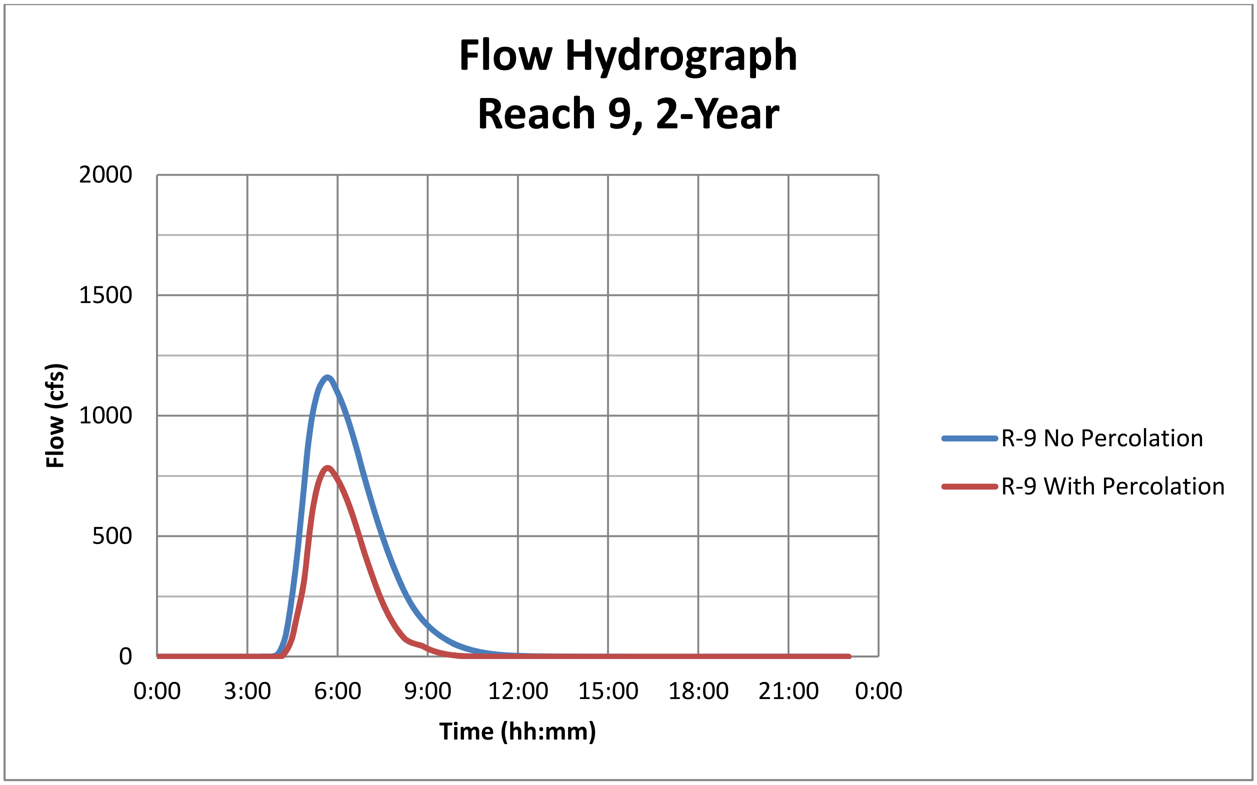
Calculation Volume = (A)*(i)*(t)

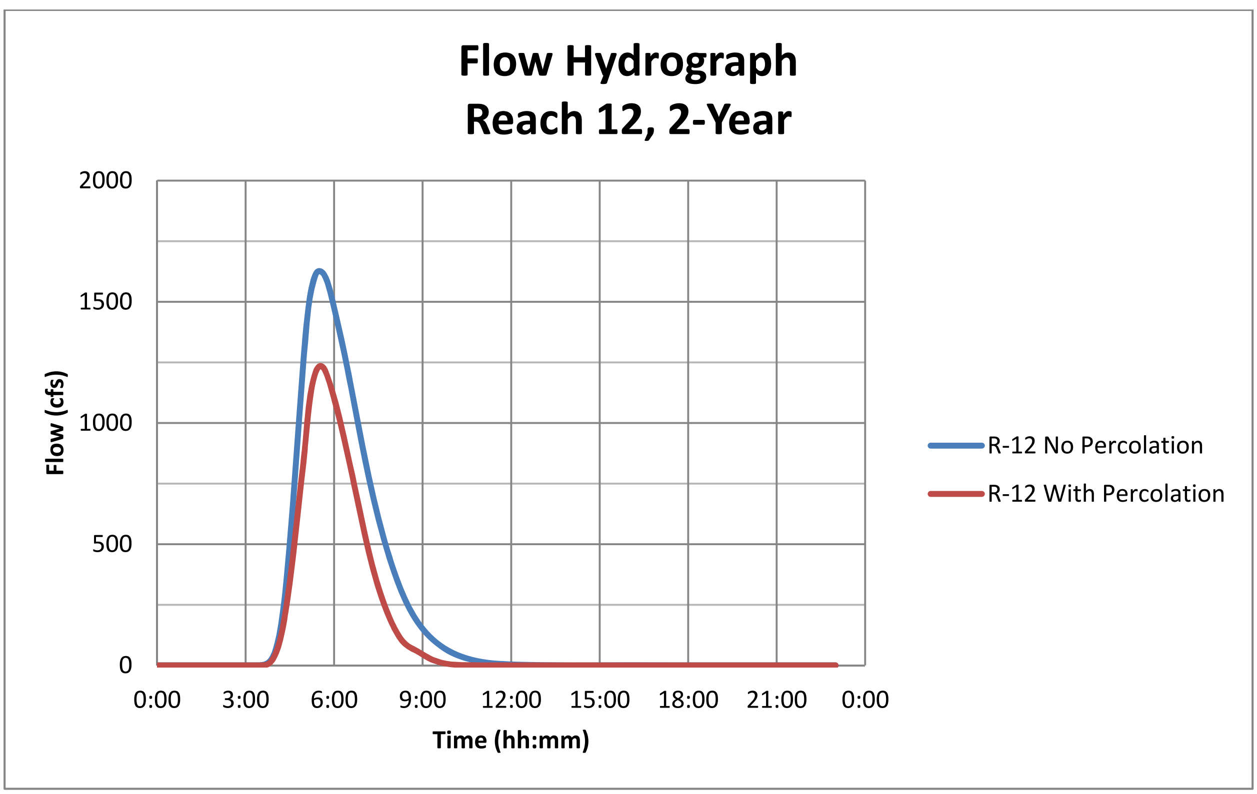
Horseshoe Draw HEC-HMS Model Flow Output



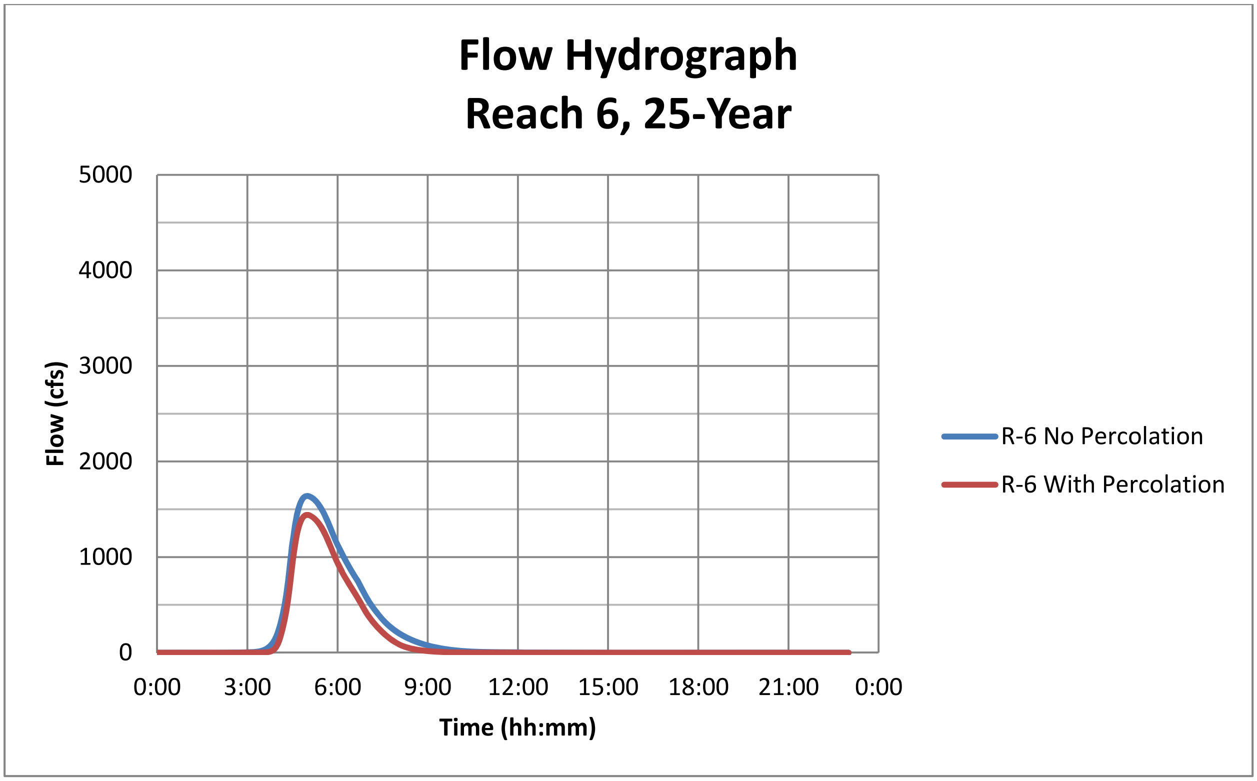


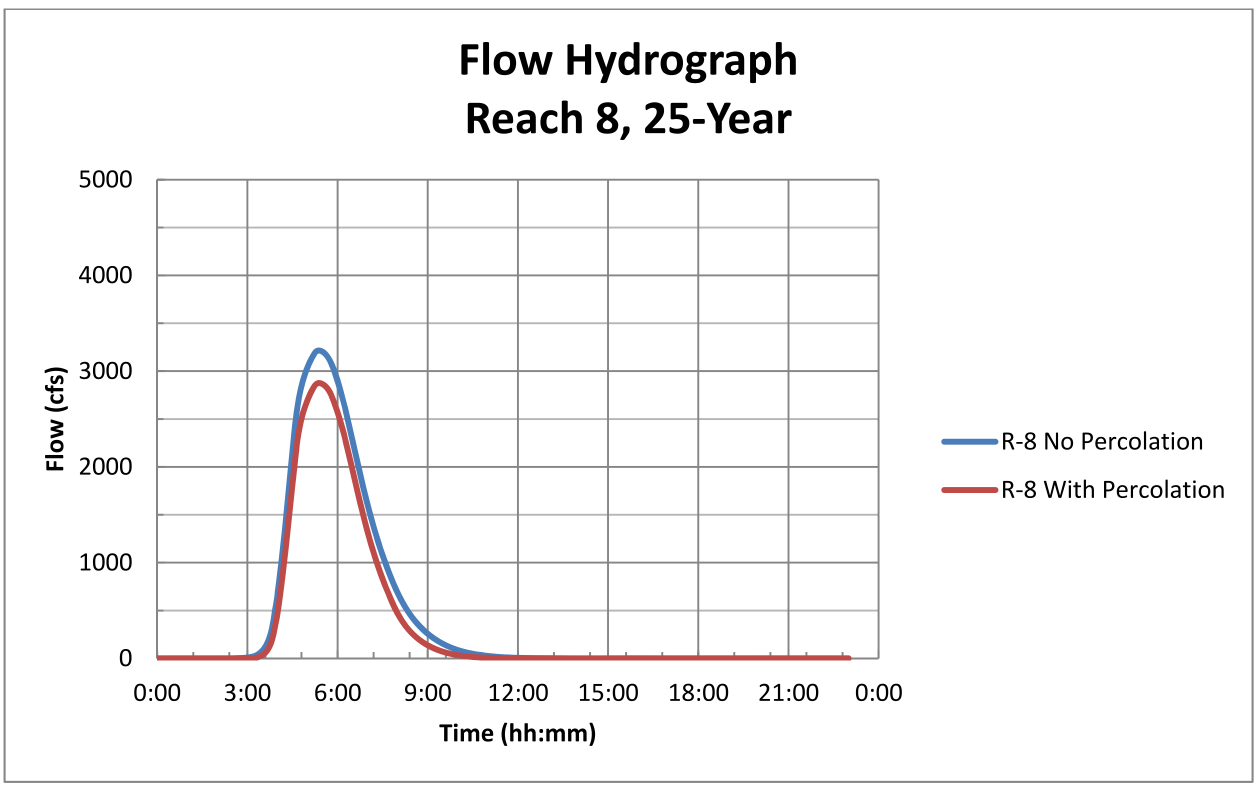
Horseshoe Draw HEC-HMS Model Flow Output



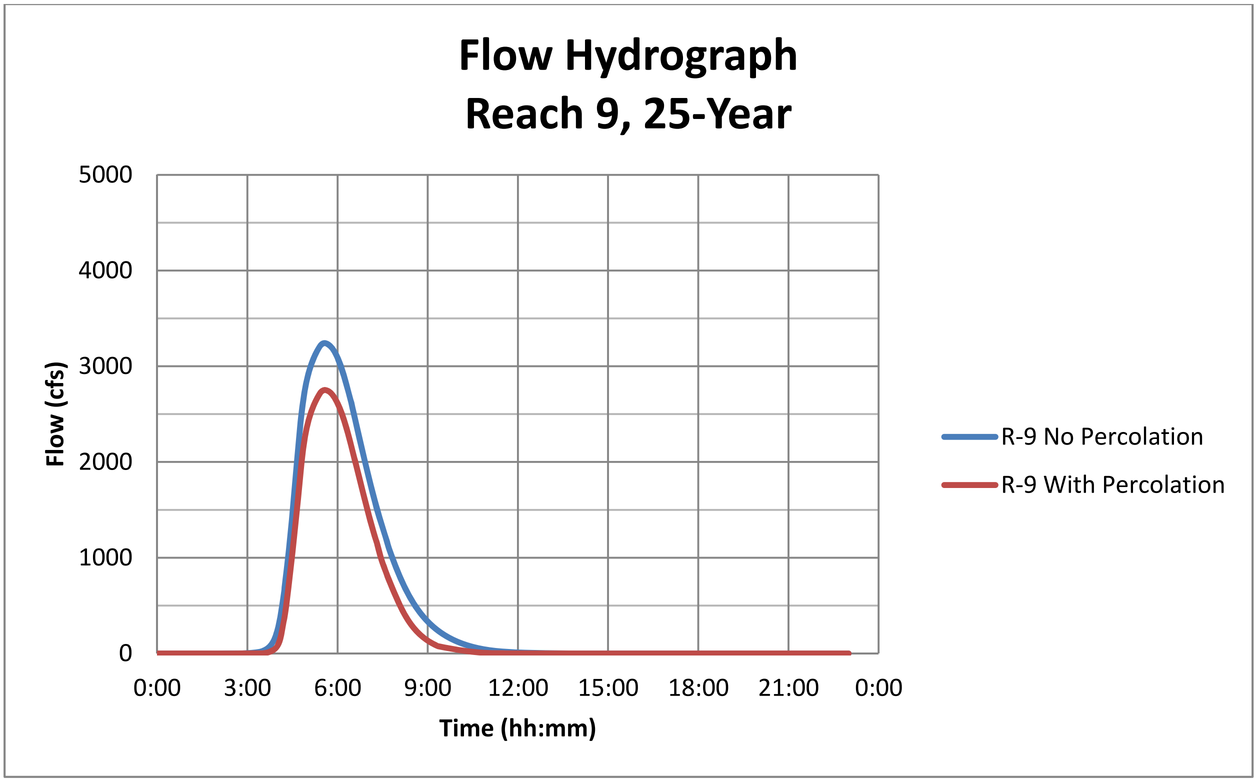


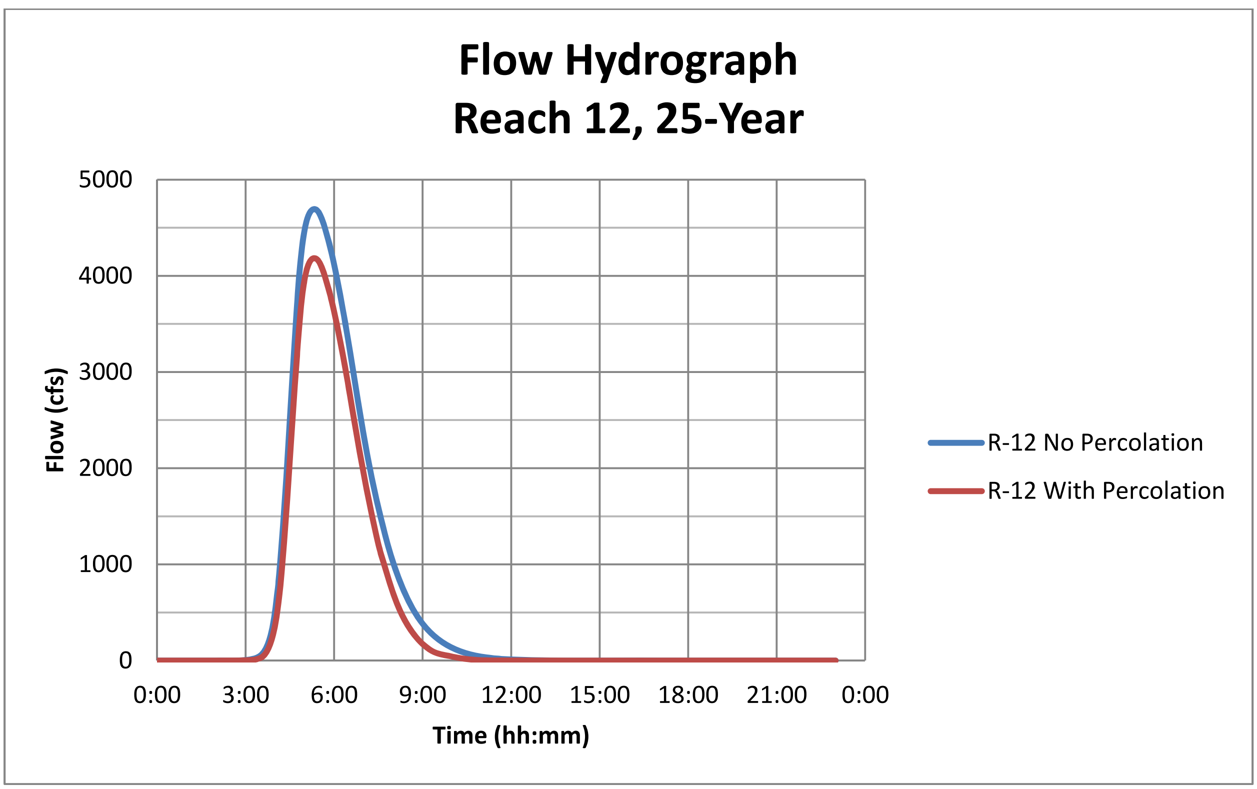
Horseshoe Draw HEC-HMS Model Flow Output



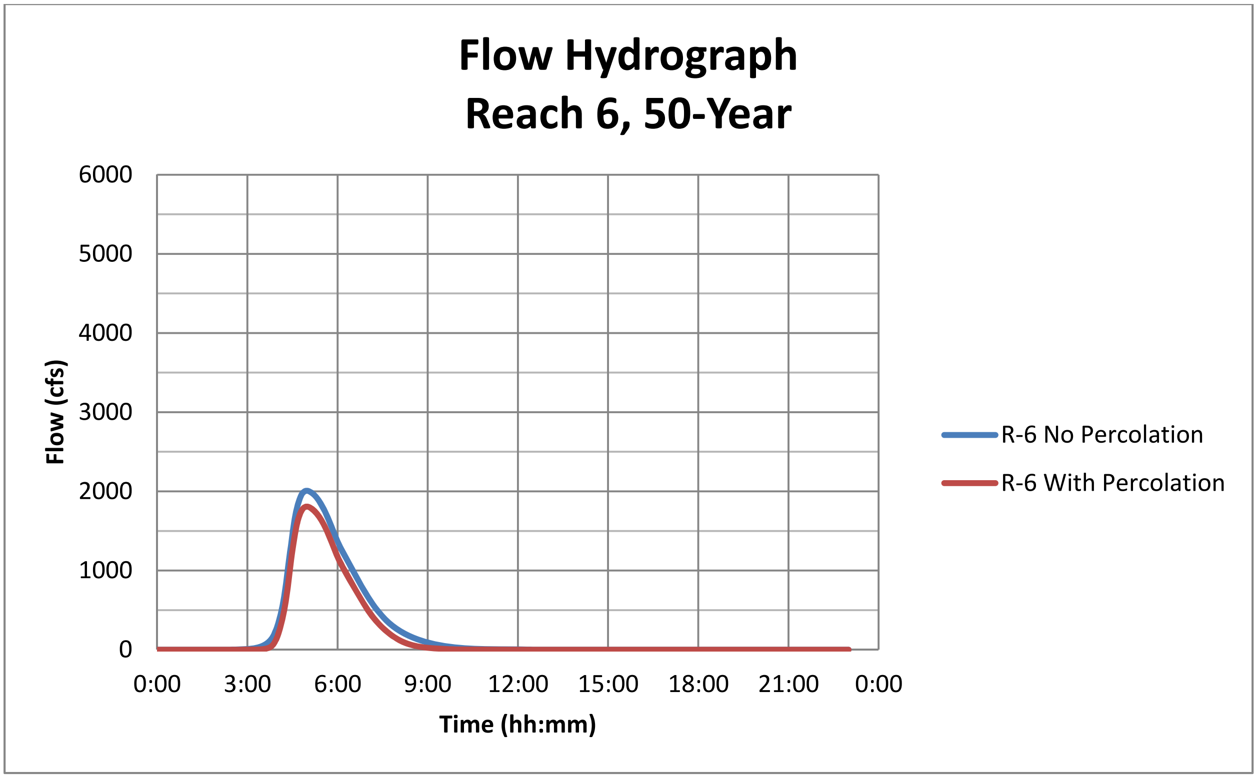


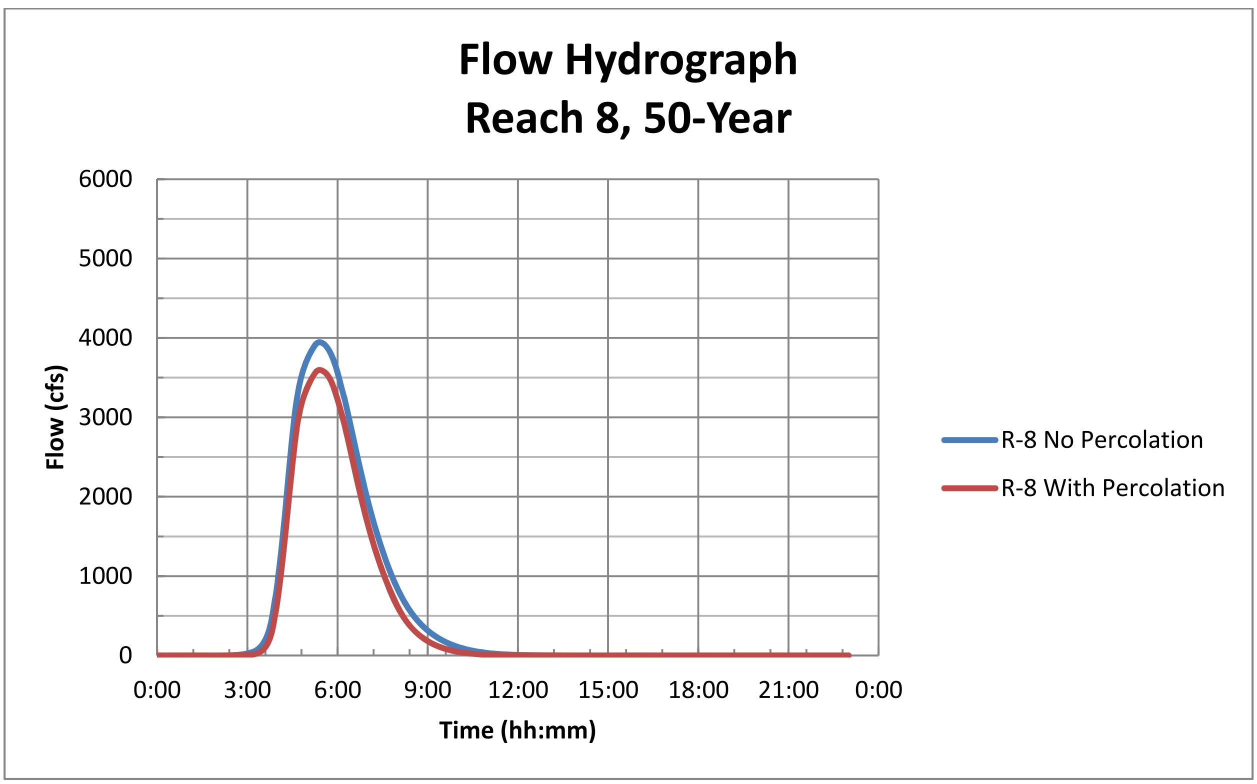
Horseshoe Draw HEC-HMS Model Flow Output



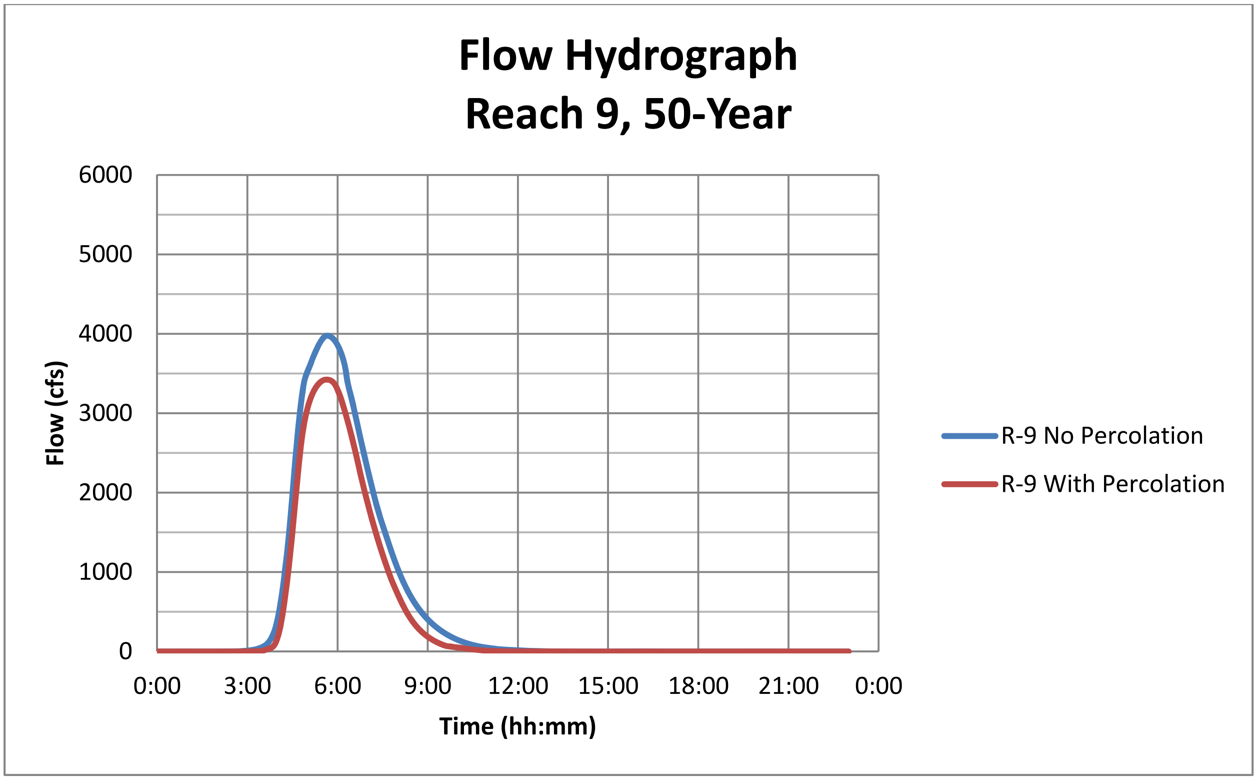


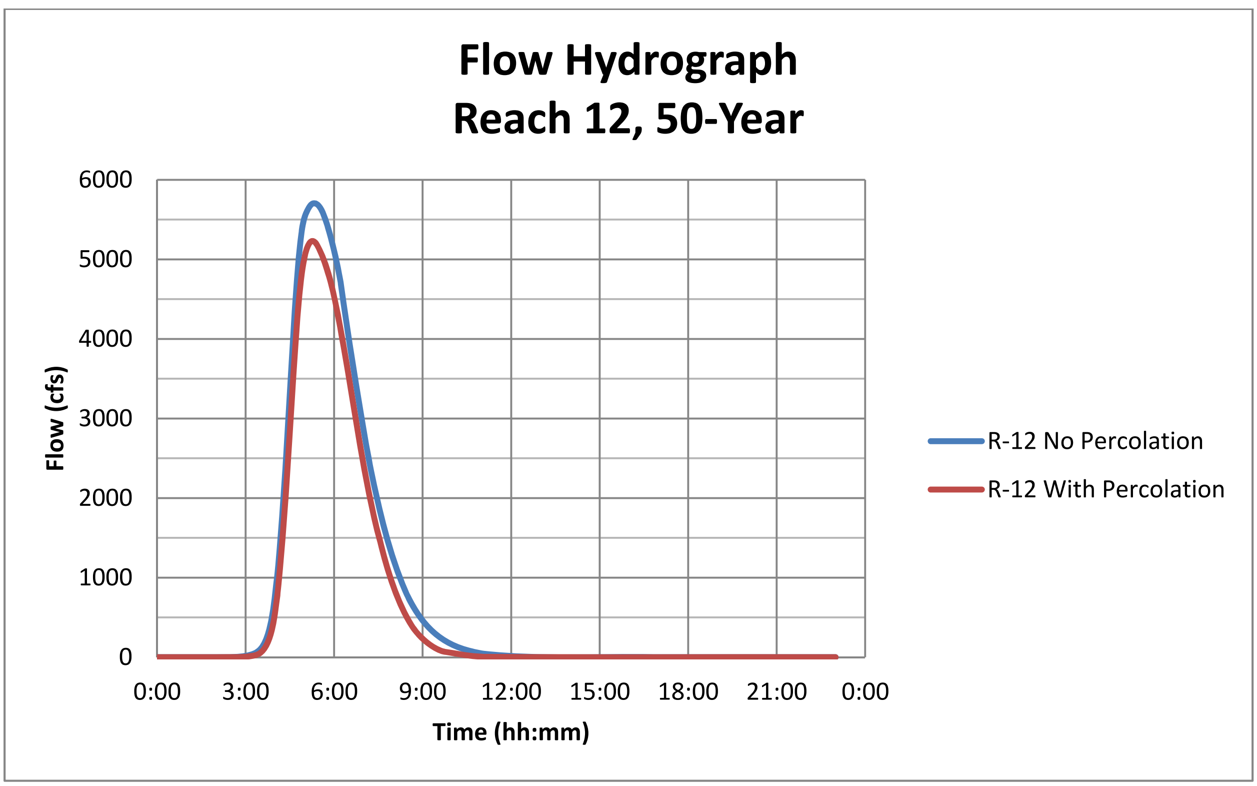
Horseshoe Draw HEC-HMS Model Flow Output



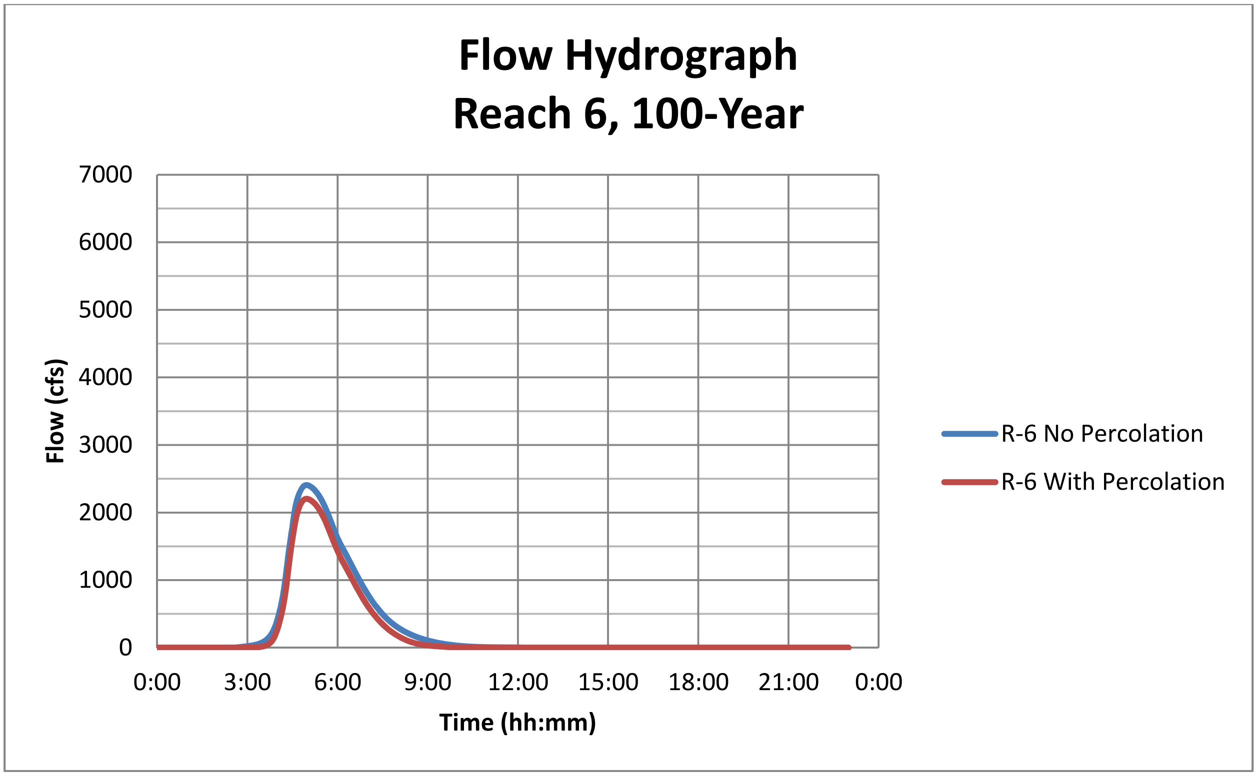


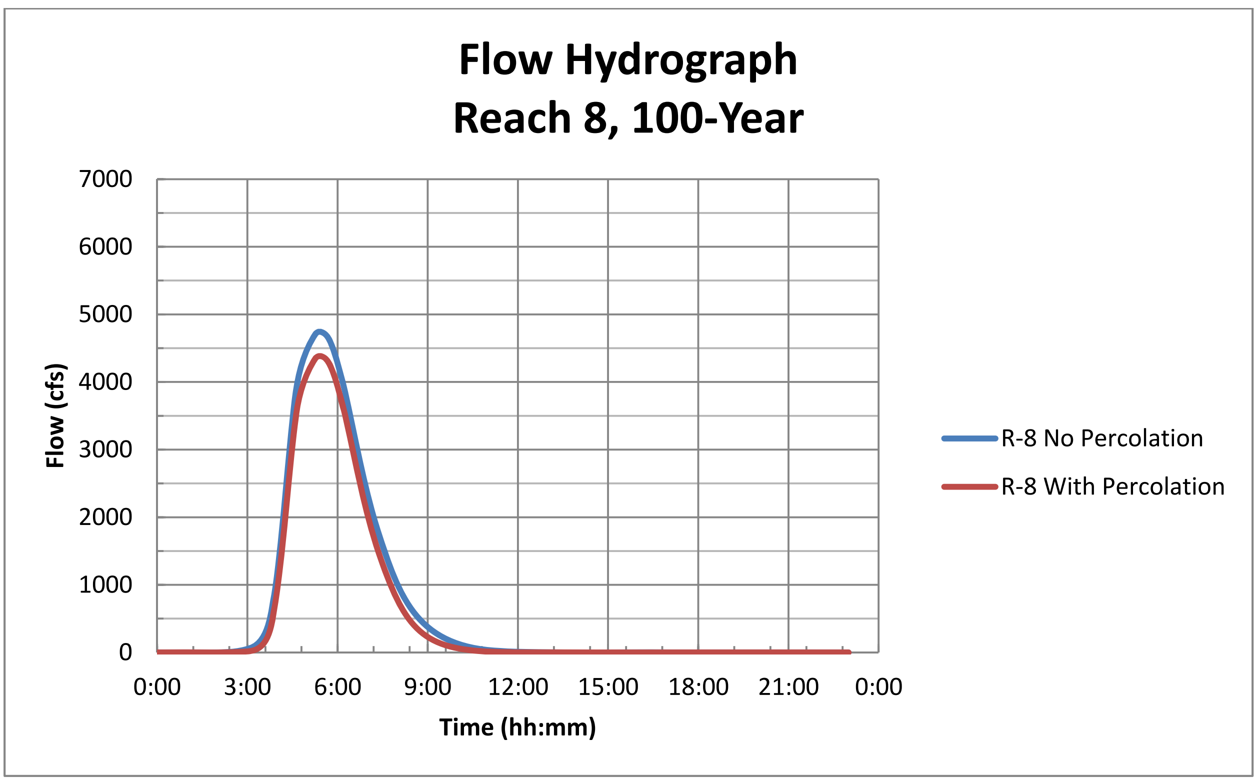
Horseshoe Draw HEC-HMS Model Flow Output





Horseshoe Draw HEC-HMS Model Flow Output





Horseshoe Draw HEC-HMS Model Flow Output