RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

Nucla Station Ash Disposal Facility

Submitted To: Tri-State Generation and Transmission
P.O. Box 33695
Denver, Colorado 80233

Submitted By: Golder Associates Inc.
44 Union Boulevard, Suite 300
Lakewood, Colorado 80228

COLORADO LICENSED
MICAH BRIAN RICHEY
45429
10/14/16
PROFESSIONAL ENGINEER

October 2016 **1657746**

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1.0 INTRODUCTION

This run-on and run-off control system (ROROCS) plan has been prepared by Golder Associates Inc. (Golder) on behalf of Tri-State Generation and Transmission Association, Inc. (Tri-State) for the Nucla Station Ash Disposal Facility (the Facility), which is located in Montrose County, Colorado. This ROROCS plan documents the Facility's run-on and run-off control system design and its compliance with the requirements of 40 CFR 257.81, including appropriate engineering calculations. This ROROCS plan is included in the Facility's operating record as required under 40 CFR 257.105(g)(3).

2.0 REGULATORY REQUIREMENTS

As required under 40 CFR 257.81, the owner or operator of a coal combustion residuals (CCR) landfill must design, construct, operate, and maintain a run-on and run-off control system to appropriately manage surface water generated from a 25-year, 24-hour storm event. This includes the following:

- A run-on control system to prevent flow onto the active portion of the CCR landfill during the peak discharge from a 25-year, 24-hour storm event.
- A run-off control system from the active portion of the CCR landfill to collect and control the water volume resulting from the 25-year, 24-hour storm event.

In the context of the CCR Rule, "active portion" refers to constructed areas of a CCR landfill within the limit of waste on which a final cover system has not been constructed. The limit of waste for the Facility encompasses approximately 61 acres. Currently, an area of the sideslopes totaling approximately 22 acres has received final cover and an area totaling approximately 17 acres on the top surface of the northern half of the Facility has received final cover. These areas are shown on Figure 1.

3.0 DESIGN METHODOLOGY

3.1 Design Storm

The Facility's run-on and run-off control system is designed for hydraulic capacity to manage at least the 25-year, 24-hour storm event. A site-specific precipitation estimate corresponding to the design event was obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 at the Facility location. The 25-year, 24-hour storm event generates 2.11 inches of precipitation at the Facility. Design calculations utilizing this design storm or larger are included in Appendices A and B.

3.2 Rainfall Abstractions

Rainfall abstractions are water losses that occur before run-off begins. Losses may consist of infiltration, depression storage, and other factors. Rainfall abstractions can be estimated using the Soil Conservation Service (SCS) Method as presented in the following series of equations:

$$S = \frac{1000}{CN} - 10$$ [Equation 1]

$$I_a = 0.2S$$ [Equation 2]

Therefore:

$$I_a = \frac{200}{CN} - 2$$ [Equation 3]

Where:
S = potential maximum retention after run-off begins (in)
CN = curve number
I_a = initial abstraction (in)

The initial abstraction is a function of the land use conditions as represented by the composite curve number for the tributary drainage area.

3.3 Routing Methodology

Stormwater calculations were performed using computer software (HEC-HMS) that employs the SCS Method to estimate run-on and run-off volumes. The routing methodology is described for the various engineering calculations in Appendices A and B.

4.0 RUN-ON CONTROL PLAN

Run-on is stormwater that may route towards the active portion of the Facility. Based on a review of the topography surrounding the Nucla Station Ash Disposal Facility, as shown on Figure 1, run-on only has the potential to enter the active portion from the northeast. A perimeter channel system has been constructed to intercept run-on and prevent flow onto the active portion. Based on topographic information and site observations, the minimum perimeter channel section is 2 feet deep with no bottom width and 3 (horizontal) to 1 (vertical) sideslopes. The perimeter channels are grass-lined or riprap-lined. The perimeter channel system is capable of conveying run-on from the 25-year, 24-hour storm event, as well as run-off from the landfill sideslopes for the same storm event, as demonstrated by the engineering calculations in Appendix A.

The calculations in Appendix A were carried out based on existing topographic conditions, which reflect the highest contributing area for run-on. As fill sequencing progresses and the Facility height increases, the contributing area for run-on that could route onto to the active portion will decrease and eventually be eliminated. Therefore, the existing condition represents the maximum run-on condition for the remaining life of the Facility.

5.0 RUN-OFF CONTROL PLAN

5.1 Active Portion of the Facility

Run-off from the active portion of the Facility (and other contributing areas) is contained within the ash placement area by a containment berm maintained around its perimeter. The containment berm has a minimum height of 2 feet. The depth of water resulting from the design storm across the active portion (and other contributing areas) is controlled behind the containment berm with ample freeboard, as demonstrated by the engineering calculations in Appendix A.

The calculations in Appendix A were carried out based on existing topographic conditions, which reflect the highest contributing area for run-off. As fill sequencing progresses and the Facility height increases, the contributing area for run-off will decrease. Therefore, the existing condition represents the maximum run-off condition for the remaining life of the Facility.

5.2 Closed Portion of the Facility

During operation, the exterior sideslopes of the Facility are raised gradually as needed to contain the volume of CCRs being generated. The landfill height is increased through the use of earthen containment berms that are periodically constructed around the perimeter of the landfill in areas of active filling. Each individual containment berm, typically about five feet in height, is constructed atop and slightly inside ("upstream") of the previous (underlying) containment berm (i.e., closer to the center of the landfill) to cumulatively form the landfill sideslopes. At approximate 20-foot vertical intervals, the containment berms are inwardly offset an additional 10 feet to establish benches with terrace channels for run-off control. Terrace channels convey run-off to riprap-lined rundown channels (i.e., downchutes) and into the perimeter channel system described in Section 4.0. The terrace channels, rundown channels, and perimeter channel system are capable of conveying run-off from the 100-year, 24-hour storm event, as demonstrated by the engineering calculations in Appendix B.

The calculations in Appendix B were carried out based on topographic conditions after a possible 20-foot-high vertical expansion above the currently permitted grades. This possible future condition represents the maximum run-off condition for the remaining life of the Facility.

6.0 CLOSING

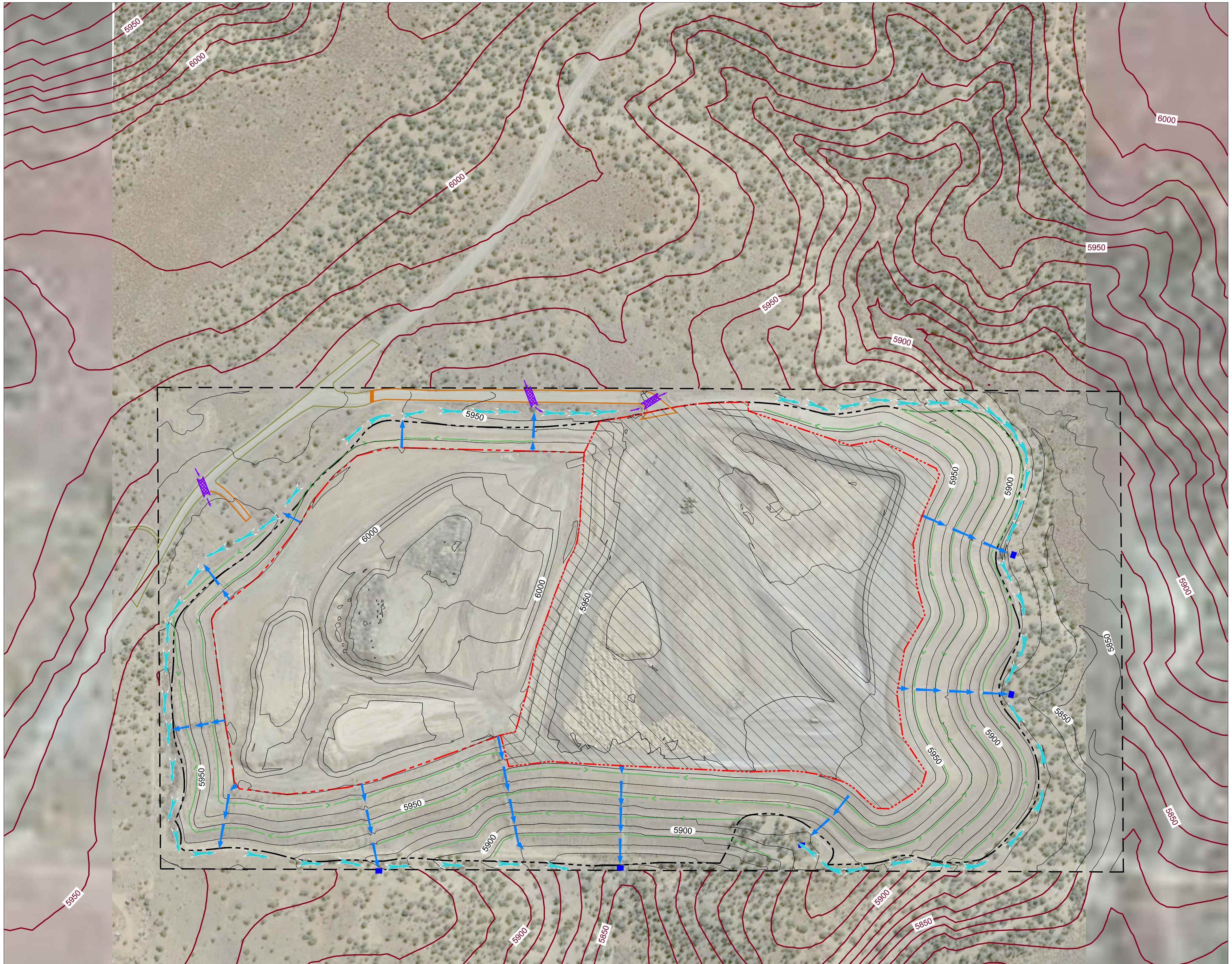
As required under 40 CFR 257.81, the run-on and run-off control system for the Nucla Station Ash Disposal Facility is designed to prevent flow onto the active portion of the CCR landfill during the peak discharge from a 25-year, 24-hour storm and to collect and control the water volume resulting from a 25-year, 24-hour storm.

GOLDER ASSOCIATES INC.

Micah Richey, PE
Project Engineer

Jason Obermeyer, PE
Associate and Senior Engineer

FIGURE



LEGEND

- EXISTING SITE TOPOGRAPHY (SEE REFERENCE 1)
- SURROUNDING TOPOGRAPHY (SEE REFERENCE 2)
- ACTIVE PORTION OF THE FACILITY
- PUBLIC ROADS
- TRI-STATE PRIVATE ROADS
- PROPERTY BOUNDARY
- EXISTING TERRACE CHANNEL
- EXISTING RUNDOWN CHANNEL
- LIMITS OF CLOSED PORTIONS OF THE FACILITY
- APPROXIMATE ASH DISPOSAL FOOTPRINT LIMIT (PROVIDED BY TRI-STATE) (61 ACRES)
- STORMWATER DISCHARGE POINT
- EXISTING PERIMETER CHANNEL
- CULVERT WITH FLOW DIRECTION

NOTES

1. THE LOCATIONS OF RUNDOWN CHANNELS ARE APPROXIMATE AND ARE BASED ON EXISTING GROUND TOPOGRAPHY AND AERIAL IMAGERY.

REFERENCES

1. EXISTING SITE TOPOGRAPHY WAS PROVIDED BY TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION, INC. TOPOGRAPHY IS A COMPOSITE BASED ON SURVEYS PERFORMED BY DEL-MONT CONSULTANTS BETWEEN 2008 AND 2015.
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TRI-STATE GENERATION AND TRANSMISSION
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PROJECT
NUCLA STATION ASH DISPOSAL FACILITY
RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

TITLE
RUN-ON AND RUN-OFF CONTROL SYSTEM
EXISTING CONDITIONS

PROJECT NO. 103-81938 | REV. 0 | FIGURE 1

File Name: Existing Conditions H&H With USGS Topo JEO.dwg

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APPENDIX A
STORMWATER RUN-OFF AND RUN-ON CALCULATIONS – ACTIVE PORTION

CALCULATIONS

Date:	October 13, 2016	**Made by:**	MBR
Project No.:	1657746	**Checked by:**	CPB
Site Name:	Nucla Station Ash Disposal Facility	**Reviewed by:**	JEO
Subject	**STORMWATER RUN-OFF AND RUN-ON CALCULATIONS – ACTIVE PORTION**		

1.0 OBJECTIVES

These calculations have been carried out to meet the following objectives:

1. Determine the run-off water volume generated from the 25-year, 24-hour storm across the active portion of the Nucla Station Ash Disposal Facility (and other contributing areas) and verify that the containment berms maintained around the perimeter of the active portion will contain the design storm volume and prevent run-off.
2. Estimate the run-on volume generated from the 25-year, 24-hour storm that could route towards the active portion of the Nucla Station Ash Disposal Facility and verify that the existing perimeter channels have been designed and constructed to prevent run-on from flowing onto the active portion.

2.0 METHODOLOGY

2.1 Control of Run-off from the Active Portion of the Landfill

Basins contributing to the active portion of the landfill were delineated based on existing topography, as shown in Figure A-1. The United States Soil Conservation Service (USSCS) Curve Number Method was used to calculate the run-off volume due to the design storm. The depth of surface water resulting from the design storm was compared against the containment berm height to determine whether the containment berms maintained around the perimeter of the active portion are sufficient to prevent run-off from the active portion.

2.2 Prevention of Run-on to the Active Portion of the Landfill

Basins contributing to the perimeter channels preventing run-on to the active portion of the facility were delineated based on existing topography, as shown in Figure A-1. These basins include the existing landfill sideslopes. Times of concentration for basins contributing to the perimeter channels were calculated using the methodology described in TR-55 (USSCS 1986) for sheet, shallow concentrated flow and Manning's equation for channel flow. HEC-HMS modeling software (United States Army Corps of Engineers Hydrologic Engineering Center 2010) was used to simulate routing of the run-off from the landfill slopes and run-on from areas outside the landfill footprint through the perimeter channels. Peak flows were used to analyze channels, assuming normal depth using Manning's equation.

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Project No.:	1657746	Made by:	MBR
Site Name:	Nucla Station Ash Disposal Facility	Checked by:	CPB
Date:	October 13, 2016	Reviewed by:	JEO

3.0 ASSUMPTIONS

The following assumptions were made in carrying out the calculations:

- A design storm event of 2.11 inches was used in this analysis. This event is the 25-year-frequency, 24-hour-duration storm event from "NOAA Atlas 14" (Hydrometeorological Design Studies Center 2013), as shown in Attachment A-1.
- The 2-year-frequency, 24-hour-duration storm depth, which is used in the TR-55 time of concentration method, is 1.20 inches (Hydrometeorological Design Studies Center 2013), as shown in Attachment A-1.
- The design storm is distributed in time as an SCS Type II synthetic distribution.
- Lag time is equal to 60% of the time of concentration.
- The minimum lag time is 3.0 minutes (a time of concentration of 5 minutes per TR-55).
- Maximum length of sheet flow is 100 feet.
- Kinematic wave methodology was used to route peak flows in the HEC-HMS model.
- An SCS curve number of 70 was assumed for all basins, except contributing areas within the landfill footprint, reflecting a condition with established native vegetation (assumed to be Piñon-Juniper in good condition, based on site observations) and hydrologic soil group (HSG) D. The active portion and other contributing areas within the landfill footprint were assumed to be impervious (CN=99) for conservatism.
- A Manning's roughness coefficient of 0.035 (for capacity) was assumed for the vegetated perimeter channels.
- Stormwater that falls on the area of final cover on the top surface of the northern half of the facility was assumed to route to the southern half of the facility, which is topographically lower.
- Perimeter channels are grass-lined and were idealized as 2 feet deep with no bottom width and 3H:1V sideslopes, based on topographic information and site observation of the smallest perimeter channels.

4.0 RESULTS AND CONCLUSIONS

4.1 Control of Run-off from the Active Portion of the Landfill

Basin delineations are identified on Figure A-1. The run-off water volume routing onto the active potion of the landfill due to the design storm will decrease over time. This is because the active portion of the facility will decrease in size as the top surface elevation increases with additional waste placement and as additional final cover is placed. Thus, the existing condition represents the maximum run-off condition for the remaining life of the facility.

The run-off water volume routing onto the active portion of the facility due to the design storm and the resulting depth of water requiring containment for the existing condition are calculated in Table A-1. The depth of water requiring containment on the active portion of the facility due to the design storm

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Site Name:	Nucla Station Ash Disposal Facility	Checked by:	CPB
Date:	October 13, 2016	Reviewed by:	JEO

is 3.4 inches. The minimum 2-foot-high containment berms maintained around this area are sufficient to contain this depth of water with ample freeboard.

4.2 Prevention of Run-on to the Active Portion of the Landfill

Basin delineations are identified on Figure A-1. The surface area of basins that potentially contribute run-on to the facility (in the absence of perimeter channels) will decrease over time. This is because the top surface on the southern half of the facility will increase in elevation and the basin areas will correspondingly reduce in size. Thus, the existing condition represents the maximum run-on condition for the remaining life of the facility.

For run-on calculations, hydrologic parameters for the basins (Tables A-1 and A-2) and reaches were entered into the HEC-HMS modeling software and routed to calculate peak flows contributing to each perimeter channel (Table A-3). The HEC-HMS model inputs are included as Attachment A-2. The perimeter channels were analyzed using Manning's equation, as shown in Table A-4. The perimeter channels will convey the combined peak flow from the existing landfill sideslopes and areas routing towards the active portion of the facility, as delineated in Figure A-1, with more than 1 foot of freeboard.

5.0 REFERENCES

Hydrometeorological Design Studies Center. 2013. Precipitation Frequency Data Server. National Oceanic and Atmospheric Administration (NOAA). Washington D. C.: NOAA.

United States Soil Conservation Service. 1986. Urban hydrology for small watersheds. Washington D. C.: United States Department of Agriculture.

United States Army Corps of Engineers Hydrologic Engineering Center. 2010. Hydrologic Modeling System (HEC-HMS). Version 3.5. Davis, California USA: United States Army Corps of Engineers.

TABLES

Table A-1. Subbasin Summary Table

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
Apprvd:	JEO

Design Storm 25 -Year Reccurence Interval

Storm Duration (hours)	2-Year Depth (inches)	25 -Year Depth (inches)	Storm Distribution
24	1.2	2.1	II

Subbasin ID	Subbasin Area (ft^2)	Subbasin Area (acres)	Subbasin Area (sq mile)	CN = 70 Sagebrush with grass understory HSG D, fair condition (acres)	CN = 99 Impervious (acres)	Composite SCS Curve No.	$S = \frac{1000}{CN} - 10$	Unit Runoff Q (in)	Runoff Volume (ac-ft)	Runoff Volume (ft^3)	Run-off Depth (in)
AF	1,006,506	23.11	0.0361		23.11	CN = 99	0.10	1.99	3.84	167,201	3.4
SA	689,013	15.82	0.0247		15.82	CN = 99	0.10	1.99	2.63	114,459	
RE	847,942	19.47	0.0304	19.47		CN = 70	4.29	0.28	0.46	20,026	N/A
RN	399,210	9.16	0.0143	9.16		CN = 70	4.29	0.28	0.22	9,428	
SP1	75,473	1.73	0.0027	1.73		CN = 70	4.29	0.28	0.04	1,782	
SP2	253,629	5.82	0.0091	5.82		CN = 70	4.29	0.28	0.14	5,990	
SP3	172,532	3.96	0.0062	3.96		CN = 70	4.29	0.28	0.09	4,075	
NP	389,751	8.95	0.0140	8.95		CN = 70	4.29	0.28	0.21	9,205	
Total:	3,834,056	88.02	0.14						7.63	332,166	

Golder Associates

Table A-2. Basin Time of Concentration Calculations

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
Apprvd:	JEO

					Flow Segment 1							Flow Segment 2						
Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Total Lag (0.6*Tc) (min)	Total Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition[1]		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition[1]		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
RE	0.0304	70	14.1	23.4	Sheet	100	0.020	H	Range		14.3	Shallow	910	0.066	U	Unpaved		3.7
RN	0.0143	70	12.7	21.2	Sheet	100	0.020	H	Range		14.3	Shallow	500	0.068	U	Unpaved		2.0
SP1	0.0027	70	11.5	19.1	Sheet	90	0.200	H	Range		5.2	Channel	475	0.005	E	Earth-lined	0.05	13.9
SP2	0.0091	70	7.2	11.9	Sheet	50	0.200	H	Range		3.3	Channel	1125	0.010	E	Earth-lined	0.22	8.7
SP3	0.0062	70	6.2	10.4	Sheet	50	0.174	H	Range		3.4	Channel	870	0.010	E	Earth-lined	0.21	6.9
NP	0.0140	70	13.9	23.1	Sheet	65	0.277	H	Range		3.5	Channel	2190	0.042	E	Earth-lined	0.06	19.6

Note:
(1) Refer to Attachment A for Roughness Condition descriptions and Tc Coeffiecients.

Table A-2. Basin Time of Concentration Calculations

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
Apprvd:	JEO

			Flow Segment 3							Flow Segment 4						
Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition[(1)]		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition[(1)]		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
RE	0.0304	70	Channel	475	0.005	E	Earth-lined	0.20	5.5							
RN	0.0143	70	Channel	190	0.074	E	Earth-lined	0.07	1.2	Channel	245	0.005	E	Earth-lined	0.13	3.8
SP1	0.0027	70														
SP2	0.0091	70														
SP3	0.0062	70														
NP	0.0140	70														

Note:
(1) Refer to Attachment A for Roughness Condition descriptions and Tc Coeffiecients.

Table A-3. Flow Results from HEC-HMS

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
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HEC-HMS Basin Model:	Nucla
HEC-HMS Met. Model:	25-yr, 24-hr
HEC-HMS Control Specs:	48-hr, 1-min

Hydrologic Element	Drainage Area (sq mile)	Peak Discharge (cfs)	Time of Peak	Total Volume (ac-ft)
RE	0.030	3.68	02Jun2525, 01:11	0.5
SP1	0.003	0.375	02Jun2525, 01:08	0
Junction-SP1-RE	0.033	4.035	02Jun2525, 01:10	0.5
Reach-SP2	0.033	4.002	02Jun2525, 01:21	0.5
SP2	0.017	3.126	02Jun2525, 01:03	0.3
SP3	0.006	1.186	02Jun2525, 01:02	0.1
Sink-1	0.057	5.299	02Jun2525, 01:20	0.8
RN	0.014	1.861	02Jun2525, 01:09	0.2
Reach-NP	0.014	1.851	02Jun2525, 01:13	0.2
NP	0.014	1.712	02Jun2525, 01:10	0.2
Sink-2	0.028	3.504	02Jun2525, 01:12	0.4

Table A-4. Channel Hydraulic Calculations

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
Apprvd:	JEO

			Channel Design Geometry						Channel Roughness Parameters			
Reach Designation	Q25 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Approximate Channel Length (ft)	Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Minimum Channel Depth (ft)	Design Channel Lining		Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)
North Perimeter	3.5	Sink-2		0.025	3.0	3.0	0	2.0	G	Grass-lined	0.035	0.030
South Perimeter	5.3	Sink-1		0.015	3.0	3.0	0	2.0	G	Grass-lined	0.035	0.030
SW Perimeter	1.2	SP3		0.010	3.0	3.0	0	2.0	G	Grass-lined	0.035	0.030

Table A-4. Channel Hydraulic Calculations

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
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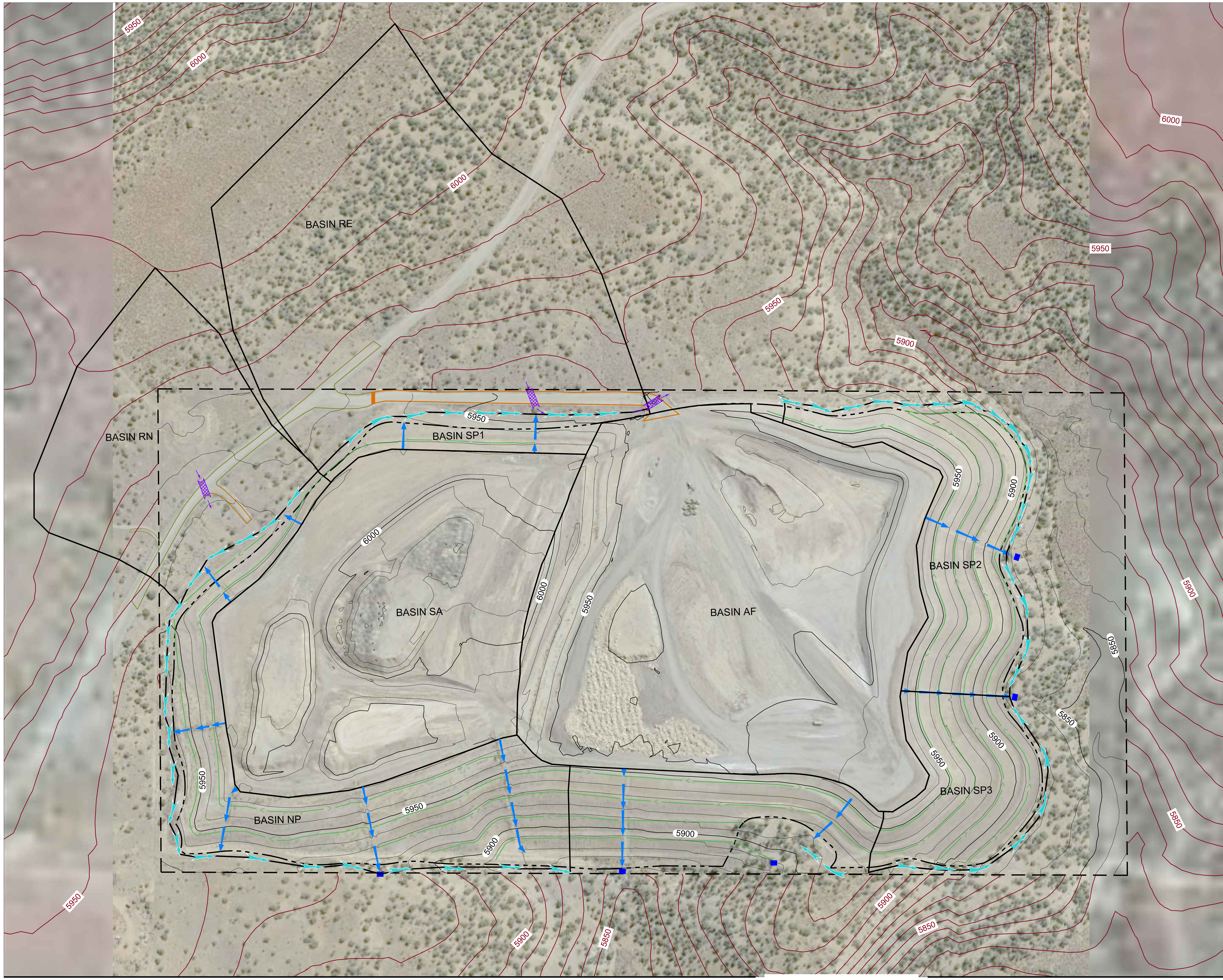
			Hydraulic Calculations							Channel Evaluations	
Reach Designation	Q25 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Froude Number	Normal Depth Shear Stress (lb/ft^2)	Stream Power (W/m^2)	Top Width of Flow (ft)	Top Width of Channel (ft)	Available Freeboard (ft)	
North Perimeter	3.5	Sink-2	3.4	0.62	1.09	0.97	47.49	3.7	12.0	1.4	OK
South Perimeter	5.3	Sink-1	3.1	0.80	0.88	0.75	33.53	4.8	12.0	1.2	OK
SW Perimeter	1.2	SP3	1.8	0.49	0.66	0.31	8.13	3.0	12.0	1.5	OK

FIGURE



LEGEND

- 5900 — EXISTING SITE TOPOGRAPHY (SEE REFERENCE 1)
- 6000 — SURROUNDING TOPOGRAPHY (SEE REFERENCE 2)
- PUBLIC ROADS
- TRI-STATE PRIVATE ROADS
- PROPERTY BOUNDARY
- EXISTING TERRACE CHANNEL
- EXISTING RUNDOWN CHANNEL
- BASIN BOUNDARY
- APPROXIMATE ASH DISPOSAL FOOTPRINT LIMIT (PROVIDED BY TRI-STATE) (61 ACRES)
- STORMWATER DISCHARGE POINT
- EXISTING PERIMETER CHANNEL
- CULVERT WITH FLOW DIRECTION

NOTES

1. THE LOCATIONS OF RUNDOWN CHANNELS ARE APPROXIMATE AND ARE BASED ON EXISTING GROUND TOPOGRAPHY AND AERIAL IMAGERY.

REFERENCES

1. EXISTING SITE TOPOGRAPHY WAS PROVIDED BY TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION, INC. TOPOGRAPHY IS A COMPOSITE BASED ON SURVEYS PERFORMED BY DEL-MONT CONSULTANTS BETWEEN 2008 AND 2015.
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SCALE FEET

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0	2016-10-14	ISSUED FOR RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN	ELH	ELH	MAY	JEO

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PROJECT
NUCLA STATION ASH DISPOSAL FACILITY
RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

TITLE
BASIN DELINEATIONS

PROJECT NO. 1657746 | REV. 0 | FIGURE A-1

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

ATTACHMENT A-1
NOAA ATLAS 14 DATA FOR NUCLA STATION ASH DISPOSAL FACILITY

NOAA Atlas 14, Volume 8, Version 2
Location name: Redvale, Colorado, US*
Latitude: 38.2043°, Longitude: -108.4841°
Elevation: 5956 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

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

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.132 (0.103-0.171)	0.162 (0.127-0.210)	0.220 (0.172-0.286)	0.275 (0.213-0.359)	0.361 (0.276-0.507)	0.437 (0.323-0.619)	0.519 (0.370-0.757)	0.611 (0.417-0.919)	0.743 (0.487-1.15)	0.853 (0.540-1.33)
10-min	0.193 (0.151-0.250)	0.237 (0.186-0.308)	0.322 (0.251-0.419)	0.402 (0.312-0.526)	0.529 (0.404-0.743)	0.639 (0.473-0.906)	0.760 (0.542-1.11)	0.894 (0.610-1.35)	1.09 (0.713-1.69)	1.25 (0.790-1.95)
15-min	0.235 (0.185-0.305)	0.290 (0.227-0.376)	0.392 (0.306-0.511)	0.491 (0.381-0.642)	0.645 (0.492-0.906)	0.780 (0.577-1.10)	0.927 (0.661-1.35)	1.09 (0.744-1.64)	1.33 (0.869-2.06)	1.52 (0.964-2.38)
30-min	0.332 (0.261-0.430)	0.409 (0.321-0.530)	0.552 (0.431-0.718)	0.688 (0.534-0.900)	0.900 (0.686-1.26)	1.08 (0.800-1.53)	1.28 (0.914-1.87)	1.50 (1.02-2.26)	1.82 (1.19-2.83)	2.08 (1.32-3.25)
60-min	0.421 (0.330-0.545)	0.516 (0.405-0.669)	0.689 (0.538-0.897)	0.849 (0.659-1.11)	1.09 (0.830-1.52)	1.30 (0.960-1.83)	1.53 (1.08-2.21)	1.77 (1.21-2.65)	2.12 (1.39-3.28)	2.41 (1.52-3.76)
2-hr	0.510 (0.404-0.652)	0.623 (0.494-0.798)	0.826 (0.653-1.06)	1.01 (0.794-1.31)	1.29 (0.986-1.76)	1.52 (1.13-2.11)	1.77 (1.27-2.53)	2.04 (1.40-3.01)	2.42 (1.60-3.69)	2.73 (1.74-4.21)
3-hr	0.567 (0.453-0.720)	0.685 (0.547-0.871)	0.894 (0.711-1.14)	1.08 (0.855-1.39)	1.36 (1.05-1.85)	1.59 (1.19-2.19)	1.84 (1.33-2.61)	2.11 (1.46-3.09)	2.48 (1.65-3.76)	2.78 (1.79-4.27)
6-hr	0.684 (0.553-0.858)	0.818 (0.660-1.03)	1.05 (0.842-1.32)	1.25 (0.999-1.58)	1.54 (1.20-2.06)	1.78 (1.35-2.42)	2.04 (1.48-2.84)	2.30 (1.61-3.32)	2.67 (1.79-3.99)	2.97 (1.93-4.50)
12-hr	0.848 (0.693-1.05)	0.997 (0.814-1.24)	1.25 (1.02-1.56)	1.48 (1.20-1.85)	1.81 (1.43-2.39)	2.09 (1.60-2.79)	2.38 (1.75-3.28)	2.68 (1.89-3.83)	3.11 (2.11-4.59)	3.45 (2.27-5.16)
24-hr	1.04 (0.862-1.27)	1.20 (0.992-1.47)	1.48 (1.22-1.82)	1.73 (1.42-2.14)	2.11 (1.68-2.74)	2.42 (1.87-3.20)	2.75 (2.05-3.75)	3.10 (2.22-4.37)	3.60 (2.47-5.25)	4.00 (2.66-5.92)
2-day	1.25 (1.05-1.51)	1.42 (1.19-1.72)	1.72 (1.43-2.09)	1.99 (1.65-2.43)	2.39 (1.93-3.07)	2.73 (2.14-3.56)	3.08 (2.33-4.15)	3.46 (2.50-4.82)	4.00 (2.77-5.76)	4.43 (2.98-6.47)
3-day	1.39 (1.17-1.66)	1.58 (1.33-1.89)	1.91 (1.60-2.30)	2.21 (1.84-2.67)	2.63 (2.13-3.35)	2.99 (2.35-3.86)	3.36 (2.55-4.47)	3.75 (2.73-5.17)	4.30 (3.00-6.14)	4.74 (3.21-6.87)
4-day	1.50 (1.27-1.79)	1.71 (1.45-2.04)	2.07 (1.74-2.48)	2.38 (1.99-2.87)	2.83 (2.30-3.57)	3.20 (2.53-4.10)	3.58 (2.73-4.74)	3.99 (2.91-5.46)	4.54 (3.18-6.44)	4.99 (3.39-7.19)
7-day	1.78 (1.52-2.10)	2.02 (1.73-2.38)	2.42 (2.06-2.87)	2.77 (2.34-3.30)	3.26 (2.67-4.05)	3.65 (2.91-4.62)	4.06 (3.12-5.30)	4.48 (3.29-6.06)	5.05 (3.56-7.08)	5.50 (3.77-7.85)
10-day	2.03 (1.74-2.37)	2.29 (1.97-2.68)	2.72 (2.33-3.19)	3.09 (2.63-3.65)	3.61 (2.97-4.44)	4.02 (3.22-5.04)	4.44 (3.43-5.75)	4.87 (3.60-6.54)	5.46 (3.88-7.59)	5.92 (4.08-8.39)
20-day	2.70 (2.35-3.12)	3.02 (2.63-3.49)	3.55 (3.08-4.11)	3.98 (3.43-4.64)	4.59 (3.81-5.55)	5.06 (4.10-6.24)	5.53 (4.32-7.05)	6.01 (4.49-7.93)	6.65 (4.76-9.10)	7.13 (4.97-9.98)
30-day	3.25 (2.85-3.72)	3.63 (3.18-4.16)	4.25 (3.71-4.88)	4.75 (4.13-5.50)	5.44 (4.55-6.52)	5.96 (4.87-7.29)	6.48 (5.09-8.18)	7.00 (5.26-9.15)	7.67 (5.53-10.4)	8.17 (5.74-11.3)
45-day	3.92 (3.47-4.45)	4.39 (3.88-5.00)	5.15 (4.53-5.88)	5.75 (5.03-6.61)	6.56 (5.51-7.77)	7.16 (5.88-8.66)	7.74 (6.12-9.66)	8.30 (6.27-10.7)	9.01 (6.53-12.1)	9.53 (6.73-13.1)
60-day	4.48 (3.99-5.06)	5.05 (4.48-5.71)	5.93 (5.25-6.73)	6.63 (5.83-7.57)	7.55 (6.37-8.87)	8.21 (6.77-9.86)	8.84 (7.02-11.0)	9.45 (7.17-12.1)	10.2 (7.42-13.6)	10.7 (7.60-14.7)

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

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

Please refer to NOAA Atlas 14 document for more information.

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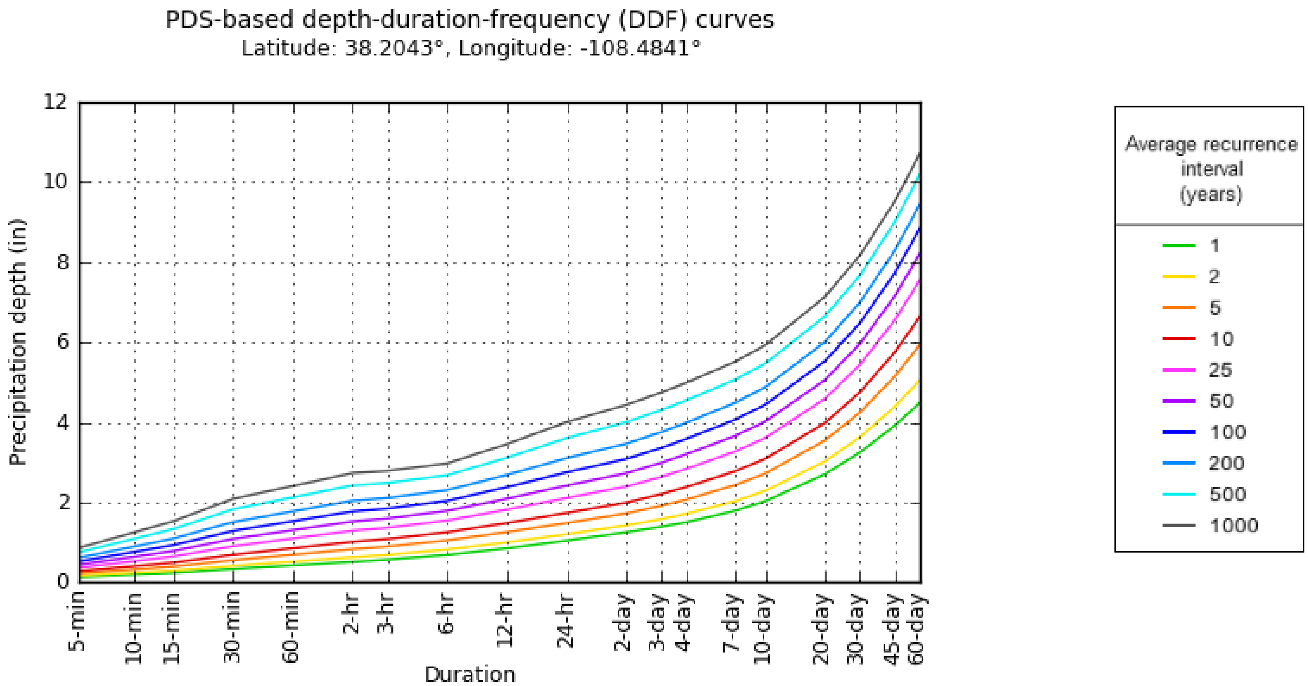
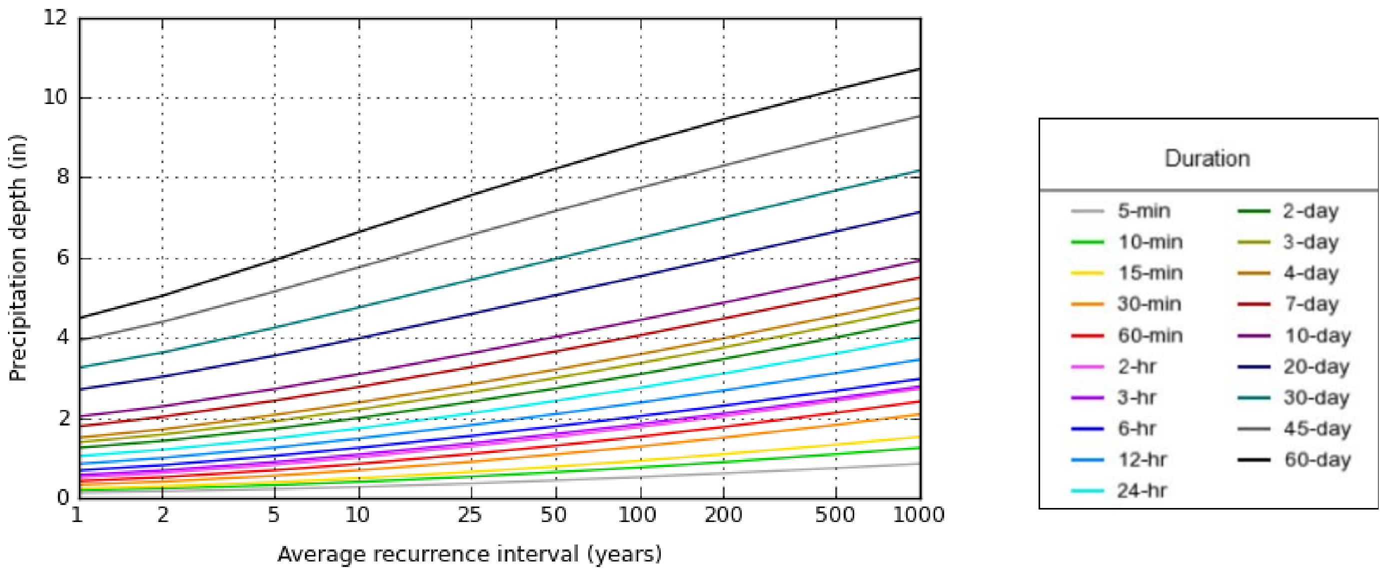
PF graphical





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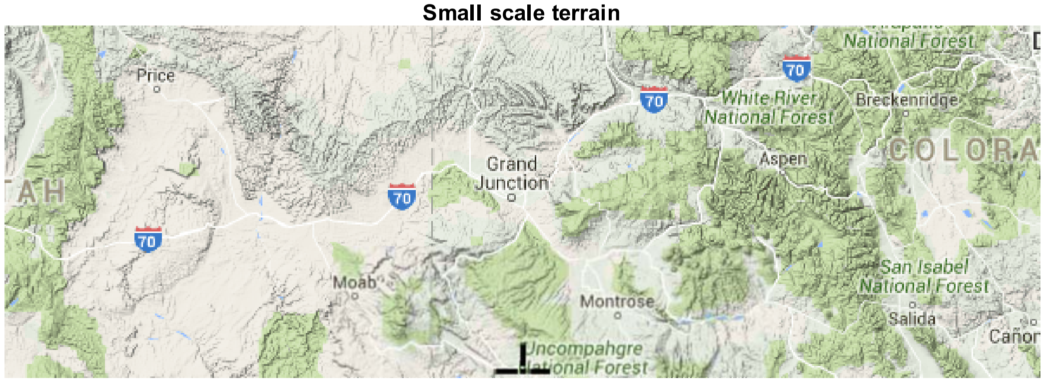
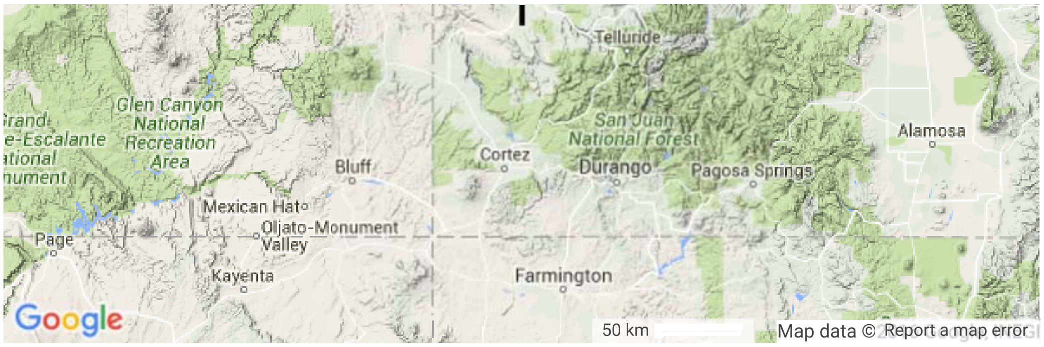
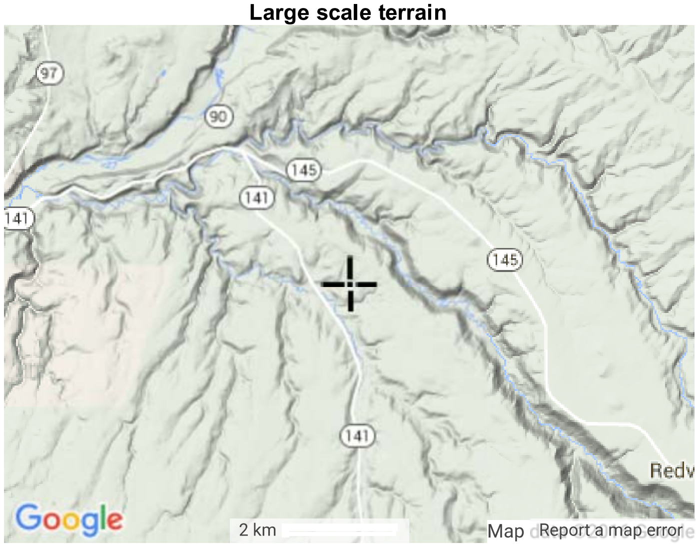
Maps & aerials

Small scale terrain



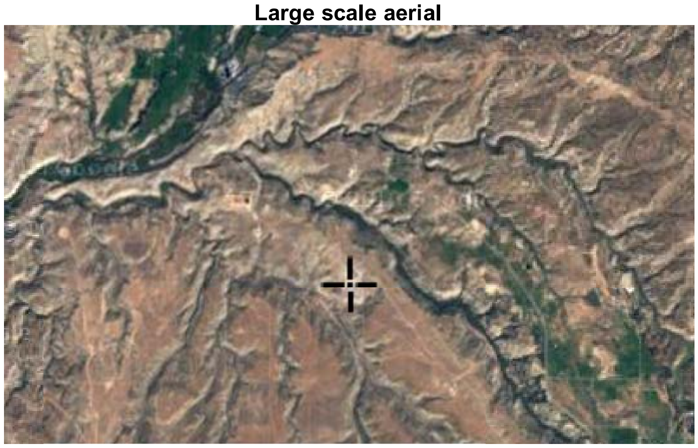


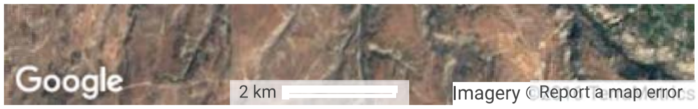
Large scale terrain



Large scale map

Large scale aerial





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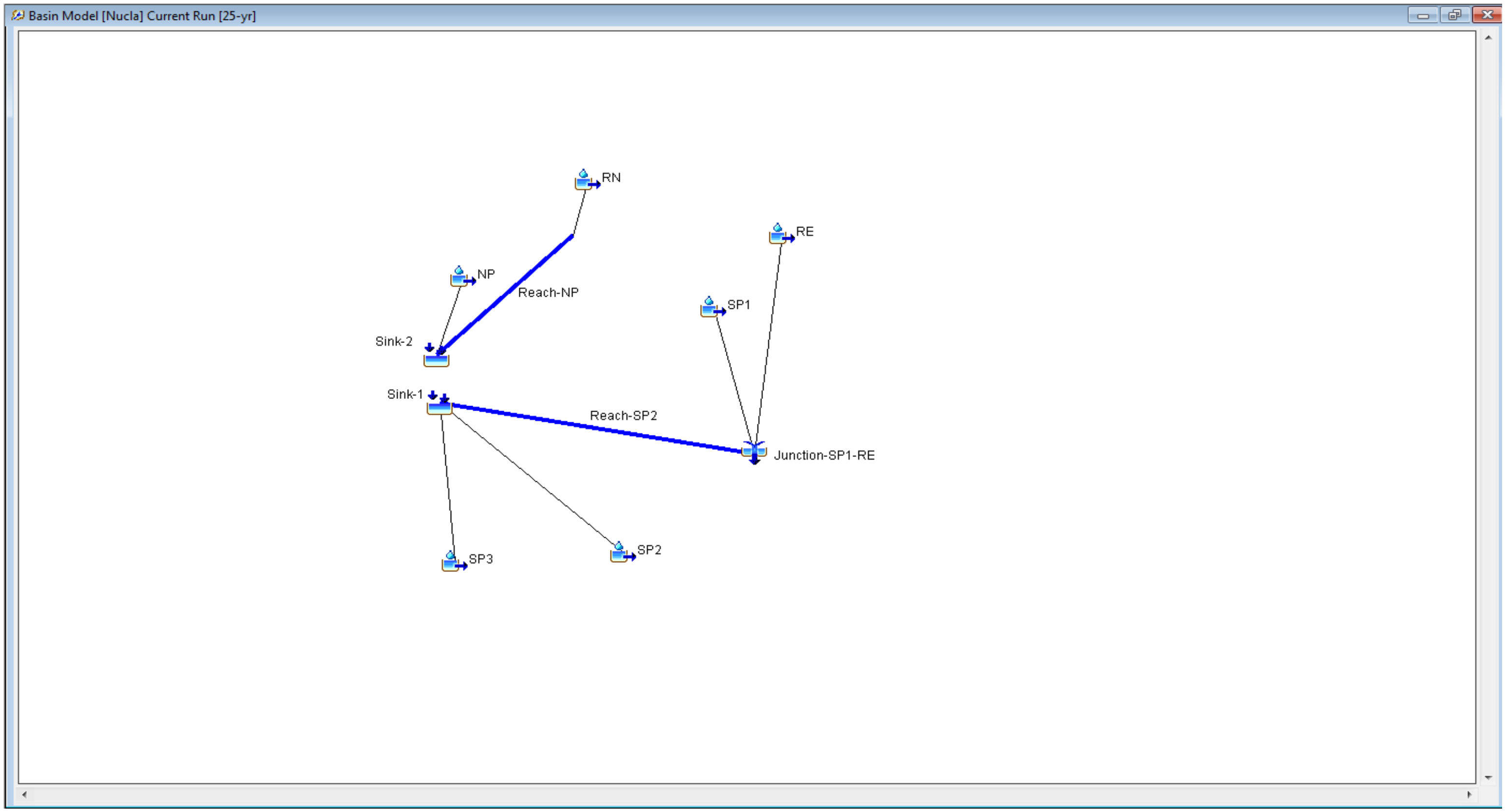
ATTACHMENT A-2
HEC-HMS MODEL INPUTS

HEC-HMS Basin Model Schematic



Sub Basin Area	
Subbasin	Area (mi^2)
RE	0.0304
SP1	0.0027
SP2	0.0174
SP3	0.0062
RN	0.0143
NP	0.0080

Loss SCS Curve Number			
Subbasin	Initial Abstraction (in)	Curve Number	Impervious (%)
RE		70	0
SP1		70	0
SP2		70	0
SP3		70	0
RN		70	0
NP		70	0

Transform SCS Unit Hydrograph		
Subbasin	Graph Type	Lag Time (min)
RE	Standard	14.1
SP1	Standard	11.5
SP2	Standard	7.2
SP3	Standard	6.2
RN	Standard	12.7
NP	Standard	13.9

Routing Kinematic Wave Channel								
Reach	Length (ft)	Slope (ft/ft)	Manning's n	subreaches	Shape	Diameter (ft)	Width (ft)	Side Slope (xH:1V)
Reach-SP2	2930	0.015	0.022	2	Triangle			3
Reach-NP	1270	0.024	0.022	2	Triangle			3

APPENDIX B
STORMWATER RUN-OFF CALCULATIONS – CLOSURE CONDITIONS

CALCULATIONS

Date:	October 13, 2016	**Made by:**	MBR
Project No.:	1657746	**Checked by:**	CPB
Site Name:	Nucla Station Ash Disposal Facility – Montrose County, Colorado	**Reviewed by:**	MAY
Subject:	**STORMWATER RUN-OFF CALCULATIONS**		

1.0 OBJECTIVE

Determine the 100-year, 24-hour (design storm) peak stormwater flows for the Nucla Station Ash Disposal Facility and the possible future vertical expansion. Verify that the stormwater drainage features (terrace channels and downchutes) can convey the design storm peak flow rates.

2.0 METHODOLOGY

Basins for the surface water control system were delineated based on existing and possible future channels and topography, shown in Figure B-1. Times of concentration were calculated using the methodology described in TR-55 (US SCS 1986) for sheet flow, shallow concentrated flow, and channel flow. HEC-HMS modeling software (US CoE Hydrologic Engineering Center 2013) was used to simulate the routing of surface run-off from the final cover system slopes and the resulting peak flows that will occur. Peak flows were used to analyze terrace channels and downchutes, assuming normal depth using Flowmaster software (Bentley Systems 2009).

3.0 ASSUMPTIONS

- A design storm event of 2.75 inches was used in this analysis. This event is the 24-hour duration, 100-year frequency storm event from "NOAA Atlas 14" (HDSC 2013).
- The 2-year frequency, 24-hour duration storm depth, which is used in the TR-55 time of concentration method, is 1.20 inches (HDSC 2013).
- The design storm is distributed in time as an SCS Type II synthetic distribution.
- Lag time is equal to 60% of the time of concentration.
- The minimum lag time is 3.0 minutes (a time of concentration of 5 minutes per TR-55).
- Maximum length of sheet flow is 100 feet.
- Kinematic wave methodology was used to route peak flows in the HEC-HMS model; some reaches did not include routing for conservatism and simplicity.
- An SCS curve number of 70 was assumed for all basins, reflecting a post-closure, covered condition with native vegetation, which is assumed to be "Sagebrush with grass understory, fair condition" and a hydrologic soil group (HSG) D.
- A Manning's roughness coefficient of 0.035 (for capacity) was assumed for riprap-lined downchutes. A Manning's roughness coefficient of 0.030 (for capacity) was assumed for the grass-lined terrace channels.

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Project No.:	1657746	Made by:	MBR
Site Name:	Nucla Station Ash Disposal Facility	Checked by:	CPB
Date:	October 13, 2016	Reviewed by:	MAY

4.0 CALCULATIONS

Channel reach locations and basin delineations are identified in Figure B-1. Hydrologic parameters for the basins (Tables B-1 and B-2) and reaches were entered into the HEC-HMS modeling software and routed to calculate peak flows for each basin and channel (Table B-3). Channels were checked for the ability to accommodate the peak flow (Attachment B-1). The HEC-HMS model inputs are included as Attachment B-2.

5.0 RESULTS/CONCLUSIONS

The downchute reaches are summarized in Attachment B-1, with peak flows, depths, and velocities associated with the design storm event. The downchutes are parabolic, 1 foot deep, and 10 feet wide. The hydraulics for the worst-case terrace channel was evaluated; this is the terrace channel that captures the run-off from subbasins WS5-A and WS4-B. The terrace channels are formed by the 10-foot-wide terrace sloping back toward the landfill sideslope at 5%, which makes the channels 0.5 feet deep.

All downchutes and the worst-case terrace channel (and therefore all terrace channels) were found to have adequate capacity to convey the 100-year, 24-hour peak flow event without overtopping.

6.0 REFERENCES

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Hydrometeorological Design Studies Center (HDSC). 2013. Precipitation Frequency Data Server. National Oceanic and Atmospheric Administration (NOAA). Washington D.C.: NOAA.

United States Soil Conservation Service (US SCS). 1986. Urban Hydrology for Small Watersheds. Washington D.C.: United States Department of Agriculture.

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Robinson, K.M., C.E. Rice, & K.C. Kadavy. 1997. Design of Rock Chutes. Presented at the 1997 ASAE Annual International Meeting, ASAE Paper No. 972062. St. Joseph, MI: ASAE.

TABLES

Table B-1. Subbasin Summary Table

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
Apprvd:	MAY

Design Storm 100 -Year Reccurence Interval

Storm Duration (hours)	2-Year Depth (inches)	100 -Year Depth (inches)	Storm Distribution
24	1.20	2.75	II

Subbasin ID	Subbasin Area (ft^2)	Subbasin Area (acres)	Subbasin Area (sq mile)	CN = 70 Sagebrush with grass understory HSG D, fair condition (acres)	Composite SCS Curve No.	S = 1000/CN - 10	Unit Runoff Q (in)	Runoff Volume (ac-ft)	Runoff Volume (ft^3)
WS1-A	20033.307	0.46	0.0007	0.46	CN = 70	4.29	0.58	0.02	968
WS1-B	46715.873	1.07	0.0017	1.07	CN = 70	4.29	0.58	0.05	2,258
WS1-C	9445.265	0.22	0.0003	0.22	CN = 70	4.29	0.58	0.01	456
WS1-D	11861.436	0.27	0.0004	0.27	CN = 70	4.29	0.58	0.01	573
WS2-A	45835.218	1.05	0.0016	1.05	CN = 70	4.29	0.58	0.05	2,215
WS2-B	56927.783	1.31	0.0020	1.31	CN = 70	4.29	0.58	0.06	2,751
WS2-C	10417.4	0.24	0.0004	0.24	CN = 70	4.29	0.58	0.01	503
WS2-D	6308.162	0.14	0.0002	0.14	CN = 70	4.29	0.58	0.01	305
WS3-A	42232.682	0.97	0.0015	0.97	CN = 70	4.29	0.58	0.05	2,041
WS3-B	62826.295	1.44	0.0023	1.44	CN = 70	4.29	0.58	0.07	3,036
WS3-C	12002.564	0.28	0.0004	0.28	CN = 70	4.29	0.58	0.01	580
WS3-D	9864.942	0.23	0.0004	0.23	CN = 70	4.29	0.58	0.01	477
WS4-A	69157.271	1.59	0.0025	1.59	CN = 70	4.29	0.58	0.08	3,342
WS4-B	91631.222	2.10	0.0033	2.10	CN = 70	4.29	0.58	0.10	4,428
WS4-C	14131.424	0.32	0.0005	0.32	CN = 70	4.29	0.58	0.02	683
WS4-D	10485.549	0.24	0.0004	0.24	CN = 70	4.29	0.58	0.01	507
WS5-A	164331.63	3.77	0.0059	3.77	CN = 70	4.29	0.58	0.18	7,941
WS5-B	26382.382	0.61	0.0009	0.61	CN = 70	4.29	0.58	0.03	1,275
WS5-C	26420.856	0.61	0.0009	0.61	CN = 70	4.29	0.58	0.03	1,277
WS6-A	124487.91	2.86	0.0045	2.86	CN = 70	4.29	0.58	0.14	6,016
WS6-B	58645.015	1.35	0.0021	1.35	CN = 70	4.29	0.58	0.07	2,834
WS6-C	44192.141	1.01	0.0016	1.01	CN = 70	4.29	0.58	0.05	2,136
WS6-D	94644.877	2.17	0.0034	2.17	CN = 70	4.29	0.58	0.10	4,574
WS7-A	91244.47	2.09	0.0033	2.09	CN = 70	4.29	0.58	0.10	4,409
WS7-B	150193.62	3.45	0.0054	3.45	CN = 70	4.29	0.58	0.17	7,258
WS8-A	124949.24	2.87	0.0045	2.87	CN = 70	4.29	0.58	0.14	6,038
WS8-B	51903.297	1.19	0.0019	1.19	CN = 70	4.29	0.58	0.06	2,508
WS8-C	49562.959	1.14	0.0018	1.14	CN = 70	4.29	0.58	0.05	2,395
WS9-A	81699.4	1.88	0.0029	1.88	CN = 70	4.29	0.58	0.09	3,948
WS9-B	114401.63	2.63	0.0041	2.63	CN = 70	4.29	0.58	0.13	5,528
WS9-C	87245.508	2.00	0.0031	2.00	CN = 70	4.29	0.58	0.10	4,216
WS9-D	51231.371	1.18	0.0018	1.18	CN = 70	4.29	0.58	0.06	2,476
WS9-E	17277.719	0.40	0.0006	0.40	CN = 70	4.29	0.58	0.02	835
WS9-F	20326.595	0.47	0.0007	0.47	CN = 70	4.29	0.58	0.02	982
WS10-A	110581.19	2.54	0.0040	2.54	CN = 70	4.29	0.58	0.12	5,344
WS10-B	79138.961	1.82	0.0028	1.82	CN = 70	4.29	0.58	0.09	3,824
WS10-C	55675.412	1.28	0.0020	1.28	CN = 70	4.29	0.58	0.06	2,690
WS10-D	51105.047	1.17	0.0018	1.17	CN = 70	4.29	0.58	0.06	2,470
WS11-A	43778.854	1.01	0.0016	1.01	CN = 70	4.29	0.58	0.05	2,116
WS11-B	62143.68	1.43	0.0022	1.43	CN = 70	4.29	0.58	0.07	3,003
WS11-C	40152.645	0.92	0.0014	0.92	CN = 70	4.29	0.58	0.04	1,940
WS11-D	18345.659	0.42	0.0007	0.42	CN = 70	4.29	0.58	0.02	887
WS12-A	19907.536	0.46	0.0007	0.46	CN = 70	4.29	0.58	0.02	962
WS12-B	23837.608	0.55	0.0009	0.55	CN = 70	4.29	0.58	0.03	1,152
WS12-C	31497.818	0.72	0.0011	0.72	CN = 70	4.29	0.58	0.03	1,522
WS13-A	24305.99	0.56	0.0009	0.56	CN = 70	4.29	0.58	0.03	1,175
WS13-B	53831.318	1.24	0.0019	1.24	CN = 70	4.29	0.58	0.06	2,601
		0.00	0.0000						
		0.00	0.0000						
Total:	2,513,319	57.70	0.09					2.79	121,455

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Table B-2. Basin Time of Concentration Calculations

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
Apprvd:	MAY

					Flow Segment 1							Flow Segment 2						
Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Total Lag (0.6*Tc) (min)	Total Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition[1]		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition[1]		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
WS1-A	0.0007	70	10.9	18.1	Sheet	100	0.02	H	Range		14.3	Shallow	30	0.02	U	Unpaved		0.2
WS1-B	0.0017	70	10.8	18.0	Sheet	100	0.02	H	Range		14.3	Shallow	140	0.02	U	Unpaved		1.0
WS1-C	0.0003	70	3.2	5.3	Sheet	40	0.4	H	Range		2.1	Channel	150	0.005	E	Earth-lined	0.08	3.2
WS1-D	0.0004	70	4.3	7.2	Sheet	45	0.4	H	Range		2.3	Channel	230	0.005	E	Earth-lined	0.08	4.9
WS2-A	0.0016	70	10.6	17.6	Sheet	100	0.02	H	Range		14.3	Shallow	145	0.02	U	Unpaved		1.1
WS2-B	0.0020	70	11.5	19.2	Sheet	100	0.02	H	Range		14.3	Shallow	275	0.02	U	Unpaved		2.0
WS2-C	0.0004	70	3.9	6.5	Sheet	35	0.4	H	Range		1.9	Channel	215	0.005	E	Earth-lined	0.08	4.6
WS2-D	0.0002	70	2.9	4.9	Sheet	40	0.4	H	Range		2.1	Channel	120	0.005	E	Earth-lined	0.07	2.8
WS3-A	0.0015	70	10.6	17.7	Sheet	100	0.02	H	Range		14.3	Shallow	280	0.02	U	Unpaved		2.0
WS3-B	0.0023	70	11.5	19.1	Sheet	100	0.02	H	Range		14.3	Shallow	245	0.02	U	Unpaved		1.8
WS3-C	0.0004	70	3.7	6.1	Sheet	40	0.4	H	Range		2.1	Channel	190	0.005	E	Earth-lined	0.08	4.1
WS3-D	0.0004	70	3.5	5.8	Sheet	35	0.4	H	Range		1.9	Channel	185	0.005	E	Earth-lined	0.08	4.0
WS4-A	0.0025	70	11.1	18.4	Sheet	100	0.02	H	Range		14.3	Shallow	245	0.02	U	Unpaved		1.8
WS4-B	0.0033	70	11.6	19.3	Sheet	100	0.02	H	Range		14.3	Shallow	240	0.02	U	Unpaved		1.8
WS4-C	0.0005	70	4.0	6.6	Sheet	45	0.4	H	Range		2.3	Channel	220	0.005	E	Earth-lined	0.09	4.3
WS4-D	0.0004	70	3.4	5.6	Sheet	40	0.4	H	Range		2.1	Channel	165	0.005	E	Earth-lined	0.08	3.5
WS5-A	0.0059	70	12.6	21.0	Sheet	100	0.02	H	Range		14.3	Shallow	275	0.02	U	Unpaved		2.0
WS5-B	0.0009	70	6.0	10.1	Sheet	40	0.4	H	Range		2.1	Channel	435	0.005	E	Earth-lined	0.10	8.0
WS5-C	0.0009	70	6.3	10.5	Sheet	40	0.4	H	Range		2.1	Channel	460	0.005	E	Earth-lined	0.10	8.5
WS6-A	0.0045	70	12.8	21.3	Sheet	100	0.02	H	Range		14.3	Shallow	250	0.02	U	Unpaved		1.8
WS6-B	0.0021	70	6.2	10.3	Sheet	50	0.4	H	Range		2.5	Channel	535	0.005	E	Earth-lined	0.14	7.9
WS6-C	0.0016	70	3.7	6.1	Sheet	40	0.4	H	Range		2.1	Channel	275	0.005	E	Earth-lined	0.14	4.0
WS6-D	0.0034	70	4.8	8.1	Sheet	55	0.4	H	Range		2.7	Channel	280	0.005	E	Earth-lined	0.18	3.5
WS7-A	0.0033	70	4.3	7.1	Sheet	55	0.4	H	Range		2.7	Channel	205	0.005	E	Earth-lined	0.18	2.5
WS7-B	0.0054	70	5.1	8.5	Sheet	45	0.4	H	Range		2.3	Channel	540	0.005	E	Earth-lined	0.20	6.3
WS8-A	0.0045	70	12.4	20.7	Sheet	100	0.02	H	Range		14.3	Shallow	250	0.02	U	Unpaved		1.8
WS8-B	0.0019	70	4.6	7.6	Sheet	45	0.4	H	Range		2.3	Channel	300	0.005	E	Earth-lined	0.14	4.4
WS8-C	0.0018	70	4.5	7.5	Sheet	50	0.4	H	Range		2.5	Channel	340	0.005	E	Earth-lined	0.14	5.0
WS9-A	0.0029	70	11.2	18.7	Sheet	100	0.02	H	Range		14.3	Shallow	205	0.02	U	Unpaved		1.5
WS9-B	0.0041	70	12.2	20.3	Sheet	100	0.02	H	Range		14.3	Shallow	245	0.02	U	Unpaved		1.8
WS9-C	0.0031	70	4.5	7.6	Sheet	45	0.4	H	Range		2.3	Channel	300	0.005	E	Earth-lined	0.17	3.9
WS9-D	0.0018	70	3.9	6.5	Sheet	45	0.4	H	Range		2.3	Channel	185	0.005	E	Earth-lined	0.15	2.6
WS9-E	0.0006	70	5.2	8.7	Sheet	100	0.16	H	Range		6.2	Channel	215	0.02	E	Earth-lined	0.07	2.5
WS9-F	0.0007	70	4.0	6.7	Sheet	100	0.4	H	Range		4.3	Channel	290	0.04	E	Earth-lined	0.07	2.4
WS10-A	0.0040	70	11.3	18.8	Sheet	100	0.02	H	Range		14.3	Shallow	230	0.02	U	Unpaved		1.7
WS10-B	0.0028	70	11.0	18.3	Sheet	100	0.02	H	Range		14.3	Shallow	205	0.02	U	Unpaved		1.5
WS10-C	0.0020	70	4.0	6.7	Sheet	50	0.4	H	Range		2.5	Channel	185	0.005	E	Earth-lined	0.15	2.6
WS10-D	0.0018	70	4.1	6.8	Sheet	50	0.4	H	Range		2.5	Channel	190	0.005	E	Earth-lined	0.15	2.7
WS11-A	0.0016	70	10.7	17.8	Sheet	100	0.02	H	Range		14.3	Shallow	130	0.02	U	Unpaved		0.9
WS11-B	0.0022	70	11.1	18.5	Sheet	100	0.02	H	Range		14.3	Shallow	225	0.02	U	Unpaved		1.6
WS11-C	0.0014	70	3.9	6.6	Sheet	45	0.4	H	Range		2.3	Channel	200	0.005	E	Earth-lined	0.13	3.1
WS11-D	0.0007	70	3.2	5.4	Sheet	55	0.4	H	Range		2.7	Channel	150	0.005	E	Earth-lined	0.15	2.1
WS12-A	0.0007	70	11.1	18.5	Sheet	100	0.02	H	Range		14.3	Shallow	125	0.02	U	Unpaved		0.9
WS12-B	0.0009	70	3.3	5.5	Sheet	50	0.4	H	Range		2.5	Channel	105	0.005	E	Earth-lined	0.11	1.8
WS12-C	0.0011	70	4.2	7.1	Sheet	55	0.4	H	Range		2.7	Channel	270	0.005	E	Earth-lined	0.12	4.4
WS13-A	0.0009	70	3.6	5.9	Sheet	50	0.4	H	Range		2.5	Channel	200	0.005	E	Earth-lined	0.11	3.5
WS13-B	0.0019	70	3.7	6.1	Sheet	50	0.4	H	Range		2.5	Channel	195	0.005	E	Earth-lined	0.15	2.7

Golder Associates

Table B-2. Basin Time of Concentration Calculations

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
Apprvd:	MAY

			Flow Segment 3							Flow Segment 4						
Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition[1]		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition[1]		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
WS1-A	0.0007	70	Shallow	50	0.400	U	Unpaved	0.35	0.1	Channel	165	0.005	E	Earth-lined	0.08	3.5
WS1-B	0.0017	70	Shallow	45	0.400	U	Unpaved	0.47	0.1	Channel	160	0.005	E	Earth-lined	0.12	2.6
WS1-C	0.0003	70														
WS1-D	0.0004	70														
WS2-A	0.0016	70	Shallow	45	0.400	U	Unpaved		0.1	Channel	130	0.005	E	Earth-lined	0.11	2.2
WS2-B	0.0020	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	175	0.005	E	Earth-lined	0.12	2.9
WS2-C	0.0004	70														
WS2-D	0.0002	70														
WS3-A	0.0015	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	75	0.005	E	Earth-lined	0.11	1.3
WS3-B	0.0023	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	195	0.005	E	Earth-lined	0.13	3.0
WS3-C	0.0004	70														
WS3-D	0.0004	70														
WS4-A	0.0025	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	150	0.005	E	Earth-lined	0.13	2.3
WS4-B	0.0033	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	230	0.005	E	Earth-lined	0.15	3.2
WS4-C	0.0005	70														
WS4-D	0.0004	70														
WS5-A	0.0059	70	Shallow	35	0.400	U	Unpaved		0.1	Channel	375	0.005	E	Earth-lined	0.18	4.7
WS5-B	0.0009	70														
WS5-C	0.0009	70														
WS6-A	0.0045	70	Shallow	35	0.400	U	Unpaved		0.1	Channel	380	0.005	E	Earth-lined	0.16	5.1
WS6-B	0.0021	70														
WS6-C	0.0016	70														
WS6-D	0.0034	70	Channel	330	0.330	R	Riprap	0.05	1.9							
WS7-A	0.0033	70	Channel	375	0.330	R	Riprap	0.06	1.9							
WS7-B	0.0054	70														
WS8-A	0.0045	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	340	0.005	E	Earth-lined	0.16	4.6
WS8-B	0.0019	70	Channel	135	0.330	R	Riprap	0.04	0.9							
WS8-C	0.0018	70														
WS9-A	0.0029	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	195	0.005	E	Earth-lined	0.14	2.9
WS9-B	0.0041	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	310	0.005	E	Earth-lined	0.16	4.2
WS9-C	0.0031	70	Channel	245	0.330	R	Riprap	0.05	1.4							
WS9-D	0.0018	70	Channel	245	0.330	R	Riprap	0.04	1.6							
WS9-E	0.0006	70														
WS9-F	0.0007	70														
WS10-A	0.0040	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	210	0.005	E	Earth-lined	0.16	2.8
WS10-B	0.0028	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	170	0.005	E	Earth-lined	0.14	2.5
WS10-C	0.0020	70	Channel	250	0.330	R	Riprap	0.04	1.7							
WS10-D	0.0018	70	Channel	250	0.330	R	Riprap	0.04	1.7							
WS11-A	0.0016	70	Shallow	45	0.400	U	Unpaved		0.1	Channel	145	0.005	E	Earth-lined	0.11	2.5
WS11-B	0.0022	70	Shallow	40	0.400	U	Unpaved		0.1	Channel	160	0.005	E	Earth-lined	0.13	2.5
WS11-C	0.0014	70	Channel	150	0.330	R	Riprap	0.03	1.2							
WS11-D	0.0007	70	Channel	90	0.330	R	Riprap	0.04	0.6							
WS12-A	0.0007	70	Shallow	45	0.400	U	Unpaved		0.1	Channel	150	0.005	E	Earth-lined	0.08	3.2
WS12-B	0.0009	70	Channel	155	0.330	R	Riprap	0.03	1.3							
WS12-C	0.0011	70														
WS13-A	0.0009	70														
WS13-B	0.0019	70	Channel	140	0.330	R	Riprap	0.04	0.9							

Table B-3. Flow Results from HEC-HMS

Tri-State Generation and Transmission Association
Nucla Station Ash Disposal Facility
Project Number: 1657746

Date:	10/13/16
By:	MBR
Chkd:	CPB
Apprvd:	MAY

HEC-HMS Basin Model:	Nucla
HEC-HMS Met. Model:	100-yr, 24-hr
HEC-HMS Control Specs:	48-hr, 1-min

Hydrologic Element	Drainage Area (sq mile)	Peak Discharge (cfs)	Time of Peak	Total Volume (ac-ft)
J-WS10-AB	0.007	2.5	02Jun2525, 01:06	0.2
J-WS10-CD	0.011	4	02Jun2525, 01:02	0.3
J-WS11-AB	0.004	1.4	02Jun2525, 01:06	0.1
J-WS11-CD	0.006	2.2	02Jun2525, 01:02	0.2
J-WS12-BC	0.003	1.3	02Jun2525, 00:59	0.1
J-WS9-CD	0.005	2.6	02Jun2525, 00:59	0.2
J-WS9-EF	0.013	4.9	02Jun2525, 01:02	0.4
J_WS1-AB	0.002	0.9	02Jun2525, 01:06	0.1
J_WS1-CD	0.003	1.1	02Jun2525, 01:03	0.1
J_WS2-AB	0.004	1.4	02Jun2525, 01:06	0.1
J_WS2-CD	0.004	1.5	02Jun2525, 01:05	0.1
J_WS3-AB	0.004	1.4	02Jun2525, 01:06	0.1
J_WS3-CD	0.005	1.6	02Jun2525, 01:04	0.1
J_WS4B	0.009	3.2	02Jun2525, 01:08	0.3
J_WS4C	0.001	0.7	02Jun2525, 01:02	0
J_WS4-AB	0.012	4.1	02Jun2525, 01:08	0.4
J_WS4-CD	0.014	4.6	02Jun2525, 01:07	0.4
J_WS6-AB	0.007	2.3	02Jun2525, 01:04	0.2
J_WS6-CD	0.012	4.6	02Jun2525, 01:01	0.4
J_WS8-BC	0.008	3	02Jun2525, 01:02	0.3
J_WS9-AB	0.007	2.5	02Jun2525, 01:07	0.2
RWS1	0.002	0.9	02Jun2525, 01:06	0.1
RWS10	0.007	2.5	02Jun2525, 01:06	0.2
RWS11	0.004	1.4	02Jun2525, 01:06	0.1
RWS12	0.001	0.3	02Jun2525, 01:06	0
RWS2	0.004	1.3	02Jun2525, 01:06	0.1
RWS3	0.004	1.4	02Jun2525, 01:06	0.1
RWS4	0.012	4.1	02Jun2525, 01:08	0.4
RWS4B	0.006	2	02Jun2525, 01:09	0.2
RWS4C	0.001	0.4	02Jun2525, 01:04	0
RWS6	0.007	2.3	02Jun2525, 01:04	0.2
RWS8	0.005	1.6	02Jun2525, 01:07	0.1
RWS9	0.007	2.5	02Jun2525, 01:08	0.2
Sink-WS1	0.003	1.1	02Jun2525, 01:03	0.1
Sink-WS10	0.011	4	02Jun2525, 01:02	0.3
Sink-WS11	0.006	2.2	02Jun2525, 01:02	0.2
Sink-WS12	0.003	1.3	02Jun2525, 00:59	0.1
Sink-WS13	0.003	1.5	02Jun2525, 00:59	0.1
Sink-WS2	0.004	1.5	02Jun2525, 01:05	0.1
Sink-WS3	0.005	1.6	02Jun2525, 01:04	0.1
Sink-WS4	0.014	4.6	02Jun2525, 01:07	0.4
Sink-WS5	0.001	0.4	02Jun2525, 01:01	0
Sink-WS6	0.012	4.6	02Jun2525, 01:01	0.4
Sink-WS7	0.009	4.5	02Jun2525, 01:00	0.3
Sink-WS8	0.008	3	02Jun2525, 01:02	0.3
Sink-WS9	0.013	4.9	02Jun2525, 01:02	0.4
WS1-A	0.001	0.3	02Jun2525, 01:06	0
WS1-B	0.002	0.6	02Jun2525, 01:06	0.1
WS1-C	0.000	0.2	02Jun2525, 00:58	0
WS1-D	0.000	0.2	02Jun2525, 00:59	0
WS10-A	0.004	1.5	02Jun2525, 01:06	0.1
WS10-B	0.003	1.1	02Jun2525, 01:06	0.1
WS10-C	0.002	1.1	02Jun2525, 00:59	0.1
WS10-D	0.002	1	02Jun2525, 00:59	0.1
WS11-A	0.002	0.6	02Jun2525, 01:06	0
WS11-B	0.002	0.8	02Jun2525, 01:06	0.1
WS11-C	0.001	0.8	02Jun2525, 00:59	0
WS11-D	0.001	0.4	02Jun2525, 00:58	0
WS12-A	0.001	0.3	02Jun2525, 01:06	0
WS12-B	0.001	0.5	02Jun2525, 00:58	0
WS12-C	0.001	0.6	02Jun2525, 00:59	0
WS13-A	0.001	0.5	02Jun2525, 00:59	0
WS13-B	0.002	1	02Jun2525, 00:59	0.1
WS2-A	0.002	0.6	02Jun2525, 01:06	0
WS2-B	0.002	0.7	02Jun2525, 01:06	0.1
WS2-C	0.000	0.2	02Jun2525, 00:59	0
WS2-D	0.000	0.1	02Jun2525, 00:58	0
WS3-A	0.002	0.6	02Jun2525, 01:06	0
WS3-B	0.002	0.8	02Jun2525, 01:06	0.1
WS3-C	0.000	0.2	02Jun2525, 00:59	0
WS3-D	0.000	0.2	02Jun2525, 00:58	0
WS4-A	0.003	0.9	02Jun2525, 01:06	0.1
WS4-B	0.003	1.2	02Jun2525, 01:07	0.1
WS4-C	0.001	0.3	02Jun2525, 00:59	0
WS4-D	0.000	0.2	02Jun2525, 00:58	0
WS5-A	0.006	2.1	02Jun2525, 01:08	0.2
WS5-B	0.001	0.4	02Jun2525, 01:01	0
WS5-C	0.001	0.4	02Jun2525, 01:01	0
WS6-A	0.005	1.6	02Jun2525, 01:08	0.1
WS6-B	0.002	1	02Jun2525, 01:01	0.1
WS6-C	0.002	0.9	02Jun2525, 00:59	0
WS6-D	0.003	1.8	02Jun2525, 01:00	0.1
WS7-A	0.003	1.8	02Jun2525, 00:59	0.1
WS7-B	0.005	2.8	02Jun2525, 01:00	0.2
WS8-A	0.005	1.6	02Jun2525, 01:07	0.1
WS8-B	0.002	1	02Jun2525, 01:00	0.1
WS8-C	0.002	1	02Jun2525, 01:00	0.1
WS9-A	0.003	1.1	02Jun2525, 01:06	0.1
WS9-B	0.004	1.5	02Jun2525, 01:07	0.1
WS9-C	0.003	1.6	02Jun2525, 01:00	0.1
WS9-D	0.002	1	02Jun2525, 00:59	0.1
WS9-E	0.001	0.3	02Jun2525, 01:00	0
WS9-F	0.001	0.4	02Jun2525, 00:59	0

FIGURE

LEGEND

(hatched box)	EXISTING GROUND TOPOGRAPHY	(teal dashed line)	PROPOSED TERRACE CHANNEL
(hatched box)	PROPOSED GROUND TOPOGRAPHY	(green dashed line)	EXISTING TERRACE CHANNEL
(blue arrow)	DOWNCHUTE LOCATION	(thin blue line)	SUBBASIN BOUNDARY
(orange line)	BASIN BOUNDARY	D	SUBBASIN LABELS
WS11	BASIN LABELS		

0 80 160
1" = 80' FEET

CLIENT
TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION
P.O. BOX 33695
DENVER, CO 80233

PROJECT
NUCLA ASH DISPOSAL FACILITY
RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-07-09
DESIGNED	MBR
PREPARED	MBR
REVIEWED	CPB
APPROVED	MAY

TITLE
STORMWATER SUBBASINS

PROJECT NO.	REV.	FIGURE
1657746	0	B-1

ATTACHMENT B-1

Worksheet for Terrace

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.00500	ft/ft
Left Side Slope	2.50	ft/ft (H:V)
Right Side Slope	20.00	ft/ft (H:V)
Discharge	3.20	ft^3/s

Results

Normal Depth	0.46	ft
Flow Area	2.43	ft^2
Wetted Perimeter	10.56	ft
Hydraulic Radius	0.23	ft
Top Width	10.46	ft
Critical Depth	0.35	ft
Critical Slope	0.02382	ft/ft
Velocity	1.32	ft/s
Velocity Head	0.03	ft
Specific Energy	0.49	ft
Froude Number	0.48	
Flow Type	Subcritical	

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	0.46	ft
Critical Depth	0.35	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.02382	ft/ft

Worksheet for DC WS1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	1.10	ft^3/s

Results

Normal Depth	0.11	ft
Flow Area	0.25	ft^2
Wetted Perimeter	3.37	ft
Hydraulic Radius	0.08	ft
Top Width	3.36	ft
Critical Depth	0.19	ft
Critical Slope	0.04243	ft/ft
Velocity	4.34	ft/s
Velocity Head	0.29	ft
Specific Energy	0.41	ft
Froude Number	2.79	
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	0.11	ft
Critical Depth	0.19	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.04243	ft/ft

Worksheet for DC WS2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	1.50	ft^3/s

Results

Normal Depth	0.13	ft
Flow Area	0.31	ft^2
Wetted Perimeter	3.63	ft
Hydraulic Radius	0.09	ft
Top Width	3.62	ft
Critical Depth	0.22	ft
Critical Slope	0.04050	ft/ft
Velocity	4.77	ft/s
Velocity Head	0.35	ft
Specific Energy	0.48	ft
Froude Number	2.85	
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	0.13	ft
Critical Depth	0.22	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.04050	ft/ft

Worksheet for DC WS3

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	1.60	ft^3/s

Results

Normal Depth	0.13	ft
Flow Area	0.33	ft^2
Wetted Perimeter	3.69	ft
Hydraulic Radius	0.09	ft
Top Width	3.67	ft
Critical Depth	0.23	ft
Critical Slope	0.04010	ft/ft
Velocity	4.87	ft/s
Velocity Head	0.37	ft
Specific Energy	0.50	ft
Froude Number	2.87	
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	0.13	ft
Critical Depth	0.23	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.04010	ft/ft

Worksheet for DC WS4

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	4.60	ft³/s

Results

Normal Depth	0.22	ft
Flow Area	0.68	ft²
Wetted Perimeter	4.71	ft
Hydraulic Radius	0.15	ft
Top Width	4.68	ft
Critical Depth	0.39	ft
Critical Slope	0.03417	ft/ft
Velocity	6.74	ft/s
Velocity Head	0.70	ft
Specific Energy	0.92	ft
Froude Number	3.11	
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	0.22	ft
Critical Depth	0.39	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.03417	ft/ft

Worksheet for DC WS5

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	0.40	ft^3/s

Results

Normal Depth	0.07	ft
Flow Area	0.13	ft^2
Wetted Perimeter	2.68	ft
Hydraulic Radius	0.05	ft
Top Width	2.67	ft
Critical Depth	0.11	ft
Critical Slope	0.04954	ft/ft
Velocity	3.18	ft/s
Velocity Head	0.16	ft
Specific Energy	0.23	ft
Froude Number	2.58	
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	0.07	ft
Critical Depth	0.11	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.04954	ft/ft

Worksheet for DC WS6

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	4.60	ft³/s

Results

Normal Depth	0.22	ft
Flow Area	0.68	ft²
Wetted Perimeter	4.71	ft
Hydraulic Radius	0.15	ft
Top Width	4.68	ft
Critical Depth	0.39	ft
Critical Slope	0.03417	ft/ft
Velocity	6.74	ft/s
Velocity Head	0.70	ft
Specific Energy	0.92	ft
Froude Number	3.11	
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	0.22	ft
Critical Depth	0.39	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.03417	ft/ft

Worksheet for DC WS7

Project Description

Friction Method	Manning Formula		
Solve For	Normal Depth		

Input Data

Roughness Coefficient		0.035	
Channel Slope		0.33000	ft/ft
Constructed Depth		1.00	ft
Constructed Top Width		10.00	ft
Discharge		4.50	ft^3/s

Results

Normal Depth		0.22	ft
Flow Area		0.67	ft^2
Wetted Perimeter		4.68	ft
Hydraulic Radius		0.14	ft
Top Width		4.66	ft
Critical Depth		0.38	ft
Critical Slope		0.03428	ft/ft
Velocity		6.69	ft/s
Velocity Head		0.70	ft
Specific Energy		0.91	ft
Froude Number		3.10	
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		0.22	ft
Critical Depth		0.38	ft
Channel Slope		0.33000	ft/ft
Critical Slope		0.03428	ft/ft

Worksheet for DC WS8

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	3.00	ft³/s

Results

Normal Depth	0.18	ft
Flow Area	0.51	ft²
Wetted Perimeter	4.26	ft
Hydraulic Radius	0.12	ft
Top Width	4.24	ft
Critical Depth	0.31	ft
Critical Slope	0.03645	ft/ft
Velocity	5.91	ft/s
Velocity Head	0.54	ft
Specific Energy	0.72	ft
Froude Number	3.01	
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	0.18	ft
Critical Depth	0.31	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.03645	ft/ft

Worksheet for DC WS9

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	4.90	ft³/s

Results

Normal Depth	0.23	ft
Flow Area	0.71	ft²
Wetted Perimeter	4.78	ft
Hydraulic Radius	0.15	ft
Top Width	4.75	ft
Critical Depth	0.40	ft
Critical Slope	0.03384	ft/ft
Velocity	6.87	ft/s
Velocity Head	0.73	ft
Specific Energy	0.96	ft
Froude Number	3.12	
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	0.23	ft
Critical Depth	0.40	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.03384	ft/ft

Worksheet for DC WS10

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	4.00	ft³/s

Results

Normal Depth	0.21	ft
Flow Area	0.62	ft²
Wetted Perimeter	4.56	ft
Hydraulic Radius	0.14	ft
Top Width	4.53	ft
Critical Depth	0.36	ft
Critical Slope	0.03489	ft/ft
Velocity	6.45	ft/s
Velocity Head	0.65	ft
Specific Energy	0.85	ft
Froude Number	3.08	
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	0.21	ft
Critical Depth	0.36	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.03489	ft/ft

Worksheet for DC WS11

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	2.20	ft^3/s

Results

Normal Depth	0.16	ft
Flow Area	0.41	ft^2
Wetted Perimeter	3.96	ft
Hydraulic Radius	0.10	ft
Top Width	3.95	ft
Critical Depth	0.27	ft
Critical Slope	0.03819	ft/ft
Velocity	5.37	ft/s
Velocity Head	0.45	ft
Specific Energy	0.60	ft
Froude Number	2.94	
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	0.16	ft
Critical Depth	0.27	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.03819	ft/ft

Worksheet for DC WS12

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	1.30	ft^3/s

Results

Normal Depth	0.12	ft
Flow Area	0.28	ft^2
Wetted Perimeter	3.50	ft
Hydraulic Radius	0.08	ft
Top Width	3.49	ft
Critical Depth	0.21	ft
Critical Slope	0.04136	ft/ft
Velocity	4.57	ft/s
Velocity Head	0.32	ft
Specific Energy	0.45	ft
Froude Number	2.82	
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	0.12	ft
Critical Depth	0.21	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.04136	ft/ft

Worksheet for DC WS13

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.33000	ft/ft
Constructed Depth	1.00	ft
Constructed Top Width	10.00	ft
Discharge	1.50	ft³/s

Results

Normal Depth	0.13	ft
Flow Area	0.31	ft²
Wetted Perimeter	3.63	ft
Hydraulic Radius	0.09	ft
Top Width	3.62	ft
Critical Depth	0.22	ft
Critical Slope	0.04050	ft/ft
Velocity	4.77	ft/s
Velocity Head	0.35	ft
Specific Energy	0.48	ft
Froude Number	2.85	
Flow Type	Supercritical	

GVF Input Data

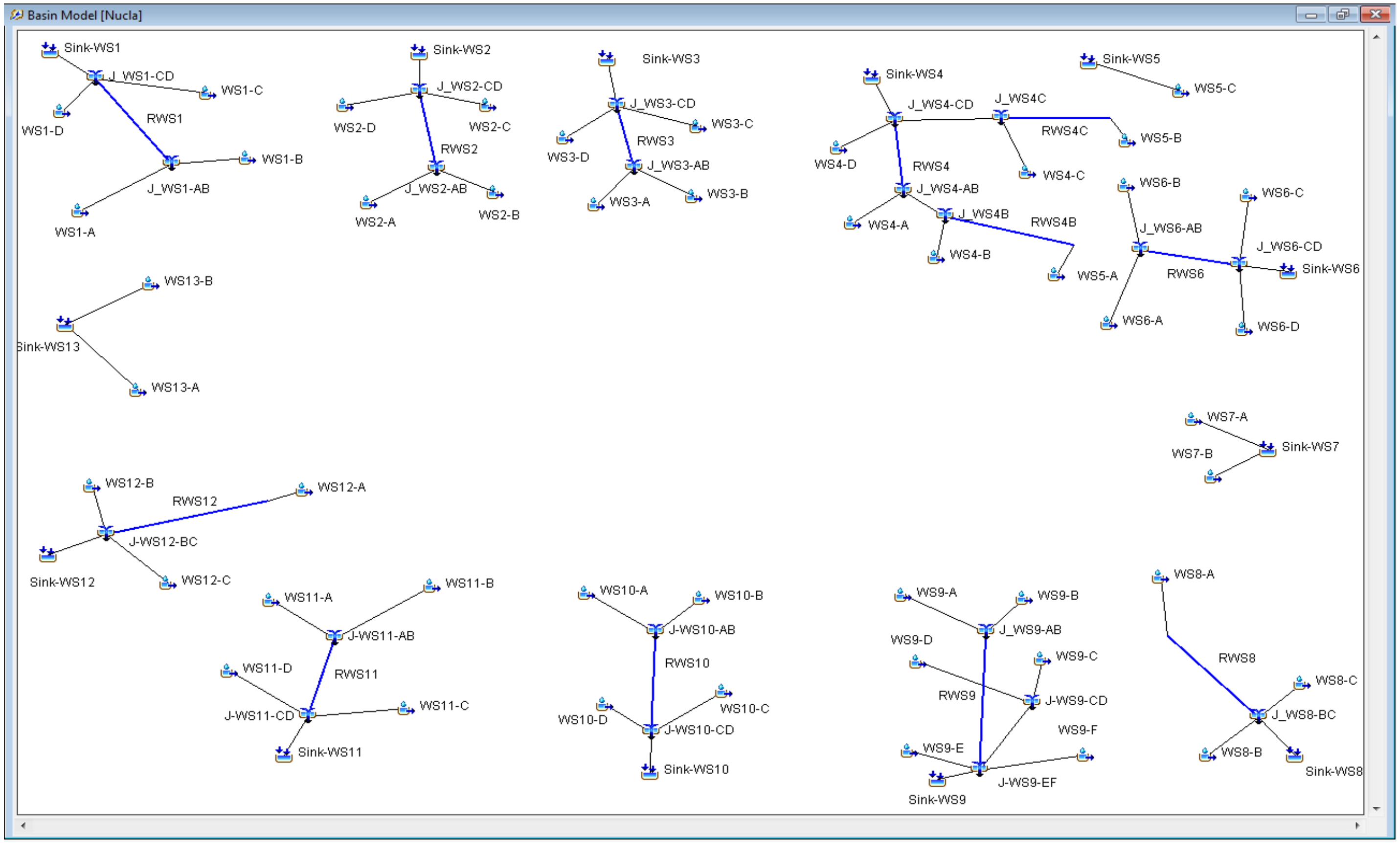
Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

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	0.13	ft
Critical Depth	0.22	ft
Channel Slope	0.33000	ft/ft
Critical Slope	0.04050	ft/ft

ATTACHMENT B-2

HEC-HMS Basin Model Schematic



Sub Basin Area	
Subbasin	Area (mi^2)
WS9-B	0.0041
WS9-A	0.0029
WS9-C	0.0031
WS9-D	0.0018
WS9-F	0.0007
WS9-E	0.0006
WS3-B	0.0023
WS3-A	0.0015
WS3-C	0.0004
WS3-D	0.0004
WS2-B	0.0020
WS2-A	0.0016
WS2-C	0.0004
WS2-D	0.0002
WS1-B	0.0017
WS1-A	0.0007
WS1-D	0.0004
WS1-C	0.0003
WS5-A	0.0059
WS4-B	0.0033
WS4-A	0.0025
WS5-B	0.0009
WS4-C	0.0005
WS4-D	0.0004
WS7-B	0.0054
WS7-A	0.0033
WS6-A	0.0045
WS6-B	0.0021
WS6-D	0.0034
WS6-C	0.0016
WS8-A	0.0045
WS8-B	0.0019
WS8-C	0.0018
WS13-B	0.0019
WS13-A	0.0009
WS12-C	0.0011
WS12-B	0.0009
WS12-A	0.0007
WS11-B	0.0022
WS11-A	0.0016
WS11-C	0.0014
WS11-D	0.0007
WS10-A	0.0040
WS10-B	0.0028
WS10-C	0.0020
WS10-D	0.0018
WS5-C	0.0009

Loss SCS Curve Number			
Subbasin	Initial Abstraction (in)	Curve Number	Impervious (%)
WS9-B		70	0
WS9-A		70	0
WS9-C		70	0
WS9-D		70	0
WS9-F		70	0
WS9-E		70	0
WS3-B		70	0
WS3-A		70	0
WS3-C		70	0
WS3-D		70	0
WS2-B		70	0
WS2-A		70	0
WS2-C		70	0
WS2-D		70	0
WS1-B		70	0
WS1-A		70	0
WS1-D		70	0
WS1-C		70	0
WS5-A		70	0
WS4-B		70	0
WS4-A		70	0
WS5-B		70	0
WS4-C		70	0
WS4-D		70	0
WS7-B		70	0
WS7-A		70	0
WS6-A		70	0
WS6-B		70	0
WS6-D		70	0
WS6-C		70	0
WS8-A		70	0
WS8-B		70	0
WS8-C		70	0
WS13-B		70	0
WS13-A		70	0
WS12-C		70	0
WS12-B		70	0
WS12-A		70	0
WS11-B		70	0
WS11-A		70	0
WS11-C		70	0
WS11-D		70	0
WS10-A		70	0
WS10-B		70	0
WS10-C		70	0
WS10-D		70	0
WS5-C		70	0

Transform SCS Unit Hydrograph		
Subbasin	Graph Type	Lag Time (min)
WS9-B	Standard	12.2
WS9-A	Standard	11.2
WS9-C	Standard	4.5
WS9-D	Standard	3.9
WS9-F	Standard	4.0
WS9-E	Standard	5.2
WS3-B	Standard	11.5
WS3-A	Standard	10.6
WS3-C	Standard	3.7
WS3-D	Standard	3.5
WS2-B	Standard	11.5
WS2-A	Standard	10.6
WS2-C	Standard	3.9
WS2-D	Standard	2.9
WS1-B	Standard	10.8
WS1-A	Standard	10.9
WS1-D	Standard	4.3
WS1-C	Standard	3.2
WS5-A	Standard	12.6
WS4-B	Standard	11.6
WS4-A	Standard	11.1
WS5-B	Standard	6.0
WS4-C	Standard	4.0
WS4-D	Standard	3.4
WS7-B	Standard	5.1
WS7-A	Standard	4.3
WS6-A	Standard	12.8
WS6-B	Standard	6.2
WS6-D	Standard	4.8
WS6-C	Standard	3.7
WS8-A	Standard	12.4
WS8-B	Standard	4.6
WS8-C	Standard	4.5
WS13-B	Standard	3.7
WS13-A	Standard	3.6
WS12-C	Standard	4.2
WS12-B	Standard	3.3
WS12-A	Standard	11.1
WS11-B	Standard	11.1
WS11-A	Standard	10.7
WS11-C	Standard	3.9
WS11-D	Standard	3.2
WS10-A	Standard	11.3
WS10-B	Standard	11.0
WS10-C	Standard	4.0
WS10-D	Standard	4.1
WS5-C	Standard	6.3

Routing Kinematic Wave Channel									
Reach	Length (ft)	Slope (ft/ft)	Manning's n	subreaches	Invert (ft)	Shape	Diameter (ft)	Width (ft)	Side Slope (xH:1V)
RWS9	350	0.330	0.035	2		Trapezoid		10	3
RWS3	60	0.330	0.035	2		Trapezoid		10	3
RWS2	50	0.330	0.035	2		Trapezoid		10	3
RWS1	60	0.330	0.035	2		Trapezoid		10	3
RWS4B	230	0.005	0.025	2		Triangle			5
RWS4	60	0.330	0.035	2		Trapezoid		10	3
RWS4C	220	0.005	0.025	2		Triangle			5

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