Stantec

Stantec Consulting Services Inc.
1409 North Forbes Road, Lexington KY 40511-2024

October 5, 2016
File: rpt_001_let_175555007
Revision 0

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

RE: **Initial Run-on and Run-off Control System Plan**
Consolidated Waste Dry Stack
EPA Final Coal Combustion Residuals (CCR) Rule
TVA Shawnee Fossil Plant
West Paducah, Kentucky

1.0 PURPOSE

This letter documents Stantec's certification of the run-on and run-off control system plan for the TVA Shawnee Fossil Plant's (SHF) Consolidated Waste Dry Stack. Based on this assessment, the Consolidated Waste Dry Stack is in compliance with the run-on and run-off control system requirements in the EPA Final CCR Rule at 40 CFR 257.81.

2.0 RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

As described in 40 CFR 257.81(c), a run-on and run-off control system plan must be prepared to document how the run-on and run-off control system has been designed and constructed to manage the 25-year, 24-hour storm.

3.0 SUMMARY OF FINDINGS

The attached plan presents the analysis of the run-on and run-off control system for the Consolidated Waste Dry Stack. The results show that the landfill meets the requirements set forth in 40 CFR 257.81(a) and (b).

4.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Don W. Fuller II, being a Professional Engineer in good standing in the Commonwealth of Kentucky, do hereby certify, to the best of my knowledge, information, and belief:

1. that the information contained in this certification is prepared in accordance with the accepted practice of engineering;

2. that the information contained herein is accurate as of the date of my signature below; and

3. that the run-on and run-off control system plan for the TVA Shawnee Fossil Plant's Consolidated Waste Dry Stack meets the requirements specified in 40 CFR 257.81(a), (b), and (c)(1).

RE: **Initial Run-on and Run-off Control System Plan**
Consolidated Waste Dry Stack
EPA Final Coal Combustion Residuals (CCR) Rule
TVA Shawnee Fossil Plant
West Paducah, Kentucky

SIGNATURE [signature] DATE 10/5/2016

STATE OF KENTUCKY
DON W. FULLER, II
18142
LICENSED
PROFESSIONAL ENGINEER

ADDRESS: Stantec Consulting Services Inc.
1409 North Forbes Road
Lexington, Kentucky 40511-2024

TELEPHONE: (859) 422-3000

ATTACHMENTS: Initial Run-on and Run-off Control System Plan

Initial Run-On and Run-Off Control System Plan

Shawnee Fossil Plant –
Consolidated Waste Dry Stack
West Paducah, Kentucky

Prepared for:
Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:
Stantec Consulting Services Inc.

October 5, 2016
Revision 0

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1.0 BACKGROUND

1.1 INTRODUCTION

On April 17, 2015 the Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities (RIN-2050_AE81; FRL-9149-4) (EPA Final CCR Rule) was published in the Federal Register. Stantec Consulting Services Inc. (Stantec) was contracted by the Tennessee Valley Authority (TVA) to perform a run-on and run-off analysis on the Shawnee Fossil Plant's (SHF) CCR Landfill and evaluate compliance relative to §257.81 of the EPA Final CCR Rule.

The SHF is a coal-fired, electric generating plant located in McCracken County Kentucky, approximately 10 miles northwest of Paducah. The plant is located near the south bank of Ohio River. Little Bayou Creek flows around the southwest perimeter of SHF. The Consolidated Waste Dry Stack (CWDS) Landfill is an Existing CCR Landfill as defined by the EPA Final CCR Rule. The CWDS is subject to the EPA Final CCR Rule and consists of approximate the boundary area denoted in Figure 1.

Figure 1 Shawnee Fossil Plant

1.2 OBJECTIVE

This Run-on and Run-off Control System Plan documents the design and structures used to meet the requirements of §257.81 of the EPA Final CCR Rule. It addresses run-on and run-off controls for the CWDS. The objective of the analysis described herein is to evaluate compliance related to §257.81, specifically the following:

1. Run-off: The CWDS run-off control system must collect and control the water volume resulting from a 25-year, 24-hour storm event

2. Run-off (permitted discharge): Run-off point sources that discharge into waters of the United States must discharge through a permitted outfall, in this case the Kentucky Pollutant Discharge Elimination System (KPDES)

3. Run-on: The run-on control system must prevent flow onto the CWDS during the peak discharge from a 25-year, 24-hour storm event.

1.3 PLAN ELEMENTS

Specific Run-on and Run-off Control System Plan elements include:

- A description of stormwater control design and structures

- Appropriate hydrological engineering calculations related to run-on and run-off flows

- Amendments to the plan whenever there is a change in conditions that would substantially affect the plan

- A professional engineer's certification stating that the Run-on and Run-off Control System Plan meets the requirements of §257.81 of the EPA Final CCR Rule.

The plan shall be revised every five years, and is considered complete when placed in the facility's operating record.

2.0 EXISTING CONDITIONS

The CWDS is located to the west of the electrical generating facility and receives fly ash and bottom ash. A portion of the CWDS has been previously closed using cap-in-place methods. Fly ash at SHF is handled dry and is taken from silos to the CWDS, where it is placed and compacted. Bottom ash is conveyed in a slurry to the Ash Pond 2 complex, where the majority settles out of suspension in the sluice trench and Ash Pond 2 area. Bottom ash is excavated regularly from the Ash Pond complex and placed along the banks of the sluice trench where it is allowed to partially dewater. The bottom ash is then placed in trucks and hauled to the CWDS where it is placed and compacted.

Stormwater run-off from the CWDS flows to Ash Pond 2 through a combination of ditches, culverts, detention basins, sheet flow and a pump, as detailed below. Appendix A, Figure 1 illustrates the drainage areas and ditches described below.

Run-off from the north portion of the CWDS (Area 1 in Appendix A, Figure 1) flows directly into Ash Pond 2. Run-off is controlled by settlement in Ash Pond 2. Area 1 includes all the un-capped areas and a portion of the capped area.

Run-off from the west half of the CWDS's capped area (Area 2) is conveyed to Ash Pond 2 through the CWDS Stormwater Ditch located at the north corner of the CWDS. Run-off from the CWDS is conveyed through a series of benches and riprap-lined channels to the west main ditch (Ditch 100), which flows around the west side of the CWDS. Ditch 100 flows into the CWDS Stormwater Ditch before being pumped to Ash Pond 2.

Run-off from the east half of the CWDS (Area 3) is conveyed to the east main ditch (Ditch 101) through a series of benches and channels before discharging into Ash Pond 2. Run-off from Area 3 flows east and is conveyed to Ditch 101 and Ditch 102 via a system of ditches located on the east slope of Area 3. Ditch 101 conveys run-off to the northeast and into Ash Pond 2.

Ash Pond 2 discharges through a spillway structure to a drainage ditch that flows clockwise around the Ash Pond 2 complex and into the Ohio River. Flow through the Ash Pond 2 spillways is subject to an active KPDES permit (permit number: KY0004219).

The CWDS does not have run-on flow as it is at an elevation above adjacent ground.

3.0 METHODS AND DESIGN CRITERIA

Criteria listed in the EPA Final CCR Rule were used to evaluate the performance of the CWDS run-on and run-off control system. The following methods were used to evaluate requirements for the existing stormwater conveyance system and methods used to address them:

1. Run-off: Collect and control the run-off water volume of a 25-year, 24-hour design storm event.

    - **Area 1:** Run-off from Area 1 is conveyed directly to Ash Pond 2, and Ash Pond 2 acts as the run-off control. Previously completed calculations documented in 2010 report "Spillway Replacement Project Pond B (Ash Stilling Pond) Ash Disposal Area No. 2 Shawnee Fossil Plant" states that Ash Pond 2 can convey the 6-hour, Probable Maximum Precipitation storm (approximately 35 inches of rainfall in 6 hours). Since this storm is significantly larger than the 25-year, 24-hour storm, Ash Pond 2 meets the run-off control requirements.

    - **Area 2:** Calculations were completed to demonstrate that the conveyance system (Ditch 100, the CWDS Stormwater Ditch) will not leave the site before flowing into Ash Pond 2. A hydrologic analysis was conducted to estimate stormwater run-off peak flow rates and a hydraulic analysis was conducted to evaluate the capacity of Ditch 100 and the high water elevation of the CWDS Stormwater Ditch during the 25-year, 24-hour storm.

    - **Area 3:** A hydrologic analysis was conducted to estimate stormwater run-off peak flow rates and a hydraulic analysis was conducted to evaluate the capacity of Ditches 101 and 102 to verify they can convey the 25-year, 24-hour storm to Ash Pond 2.

2. Run-off (permitted discharge): Run-off discharging into waters of the United States must flow through a permitted outfall.

    - All run-off from the site flows to Ash Pond 2, which flows through active KPDES permit (KY0004219).

3. Run-on: A run-on control system must be in place to prevent the peak discharge from the 25-year, 24-hour storm event onto the CCR Landfill.

    - No run-on discharges onto the CWDS. Therefore, no analysis was performed.

Details of the run-off hydrology and hydraulics are provided in the following sections.

3.1 HYDROLOGY

The Soil Conservation Services (SCS) Technical Release 55 (TR-55) method was used within U.S. Army Corps of Engineers' Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) Version 4.0 software to estimate the peak flows for the 25-year, 24-hour storm event.

3.1.1 Rainfall Runoff and Distribution

The precipitation depth for the 25-year, 24-hour storm event is 6.8 inches and was obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14. Appendix B displays the NOAA precipitation data. The SCS Type II storm distribution was applied to develop a rainfall hyetograph.

3.1.2 Curve Number (CN)

The land use cover on the CWDS includes capped ash, road and riprap.

In general, capped areas were assumed to consist of a 12-24 inch clay layer below the 6-12 inches of vegetated top soil. The capped areas were assumed to behave as "Cover Type: Open Space (lawns, parks, etc.)" per NRCS TR-55, Table 2-2a. Due to the clay layer, the capped area was classified as HSG D. This analysis assumes good grass cover conditions and a CN of 80 for capped areas.

Road and gravel surfaces were also present. The riprap areas were assumed to behave as "Gravel". Due to the anticipated dense compaction and capped area, a CN of 89 and 91 were used for road and riprap areas, respectively.

Table 1 below summarizes the CN used for specific soil and land use combinations. Also, Figure 2 in Appendix C depicts the CN boundaries.

Table 1 CN Summary

Soil and Land Use	NRCS TR-55 Table 2-2a Cover Type	HSG	CN
Capped Ash and Grass	Open Space (lawns, parks, etc.), assume "good" grass cover	D	80
Road	Street and Roads, "Dirt"	D	89
Gravel/Riprap	Street and Roads, "Gravel"	D	91

3.1.3 Subwatershed Delineation

Subwatersheds were delineated in AutoCAD 2015. The watershed delineations were based on topographic data provided by TVA dated February 2014. Figure 3 in Appendix D depicts the watersheds.

3.1.4 Lag Time

The time of concentration for each subwatershed was calculated using the NRCS segmental approach described in TR-55. The longest hydraulic flow path in each subwatershed was delineated using topographic data and aerial imagery data (dated February 2014 and April 2013, respectively). The flowpaths were subdivided into sheet, shallow-concentrated and open-channel flow components. The following methods were used to calculate flow velocities (time of concentration was then found by dividing flow length by velocity) for each flow component:

- Sheet Flow: Sheet flow velocity was computed based on methodology presented in TR-55. This equation calculates time of concentration based on Manning's roughness coefficient for sheet flow, flow length (up to a maximum distance of 100 feet) slope, and the 2-year, 24-hour rainfall depth.
- Shallow Concentrated Flow: Shallow concentrated flow velocity was calculated based on methodology presented in TR-55. This equation calculates average velocity based on the slope and surface of the watercourse.
- Open Channel Flow: Open channel flow velocities were calculated by an iterative process. An initial velocity was assumed and compared to the predicted velocities calculated by HEC-HMS. Successive iterations were calculated until velocities converged.

The time of concentration was multiplied by 0.6 to calculate lag time based on the SCS Lag Time equation.

3.1.5 Reach Routing

Reach routings of subwatersheds through the ditches were analyzed using the Muskingum-Cunge reach routing method.

3.2 HYDRAULIC ANALYSIS

Hydraulic calculations were performed to evaluate whether Ditches 100, 101, 102 and the CWDS Stormwater Ditch are able to convey run-off from the 25-year, 24-hour storm to Ash Pond 2 without leaving the site.

3.2.1 Ditch Capacity

The capacity of the ditches was analyzed using Manning's equations for open channel flow. The ditch geometry was retrieved from a cross section of the ditch generated in AutoCAD using the topographic data provided by TVA, dated February 2014. The ditches used to convey run-off are grassed-lined. A Manning's "n" value of 0.03 was applied. The peak flows for the 25-year 24-hour storm event were retrieved from the HEC-HMS model. Table 2 shows the ditch dimensions.

Table 2 Ditch Geometry

Ditch Identification	Ditch Type	Bottom Width (ft)	Side Slope 1 (H:V)	Side Slope 2 (H:V)	Longitudinal Slope(ft/ft)	Depth (ft)
100 – R1	Triangular	0	9	14	0.0003	2.6
100 – R2	Triangular	0	9	14	0.0034	2.6
100 – R3	Triangular	0	9	14	0.0002	2.85
100 – R4	Triangular	0	9	14	0.0039	2.85
101 – R1	Trapezoidal	10	4	4	0.0001	1.5
101 – R2	Trapezoidal	10	4	4	0.0021	1.5
101 – R3	Trapezoidal	10	4	4	0.0031	3.0
101 – R4	Trapezoidal	10	4	4	0.0213	3.0
101 – R5	Trapezoidal	11	2	2	0.001	4.0
102 – R1	Trapezoidal	10	2	3	0.0001	4.4
102 – R2	Trapezoidal	10	2	2	0.001	4.0

3.2.2 Detention Basin Stage Storage

Storage volume for the CWDS Stormwater Ditch was computed by HEC-HMS. HEC-HMS detention basin input data is displayed in in Table 3 below. Areas for each respective contour were computed in AutoCAD based on the 2014 topographic data.

Table 3 Basin Storage Data

Item No.	Basin Elevation (feet)	Surface Area (acre)
1	340.0	0.38
2	341.0	0.51
3	342.0	0.95
4	343.0	1.55
5	344.0	1.94
6	345.0	2.44
7	346.0	3.21
8	347.0	4.01
9	348.0	4.92
10	349.0	5.40

3.3 MODELING ASSUMPTIONS

Assumptions related to the hydrologic and hydraulic calculations were as follows:

- The CWDS Stormwater Ditch and two adjacent ditches on the northwest corner of the CWDS are assumed to behave as one detention basin.
- Detail information was not available for the pumping facility at the CWDS Stormwater Ditch, therefore it was assumed that the detention basin's pump connects to an 8 inch pipe, flows at a velocity of 10 feet per second and is operating during the entire storm event at a constant flow rate as assumed in the "Spillway Replacement Project Pond B (Ash Stilling Pond) Ash Disposal Area No. 2, Shawnee Fossil Plant" design report developed by Stantec on May 4, 2010.
- The East Ditch located outside of the project limits was assumed to be sized to convey the Ditch 101 discharge (East Ditch is anticipated to be modeled separately). The East Ditch discharge flows counter-clockwise around the CWDS via a detention basin and existing ditch before discharging into Ash Pond 2. Figure 1 in Appendix A depicts the East Ditch.

4.0 CALCULATION RESULTS

The calculation results were reviewed to evaluate performance relative to the EPA Final CCR Rule criteria.

4.1 RUN-OFF

Table 4 displays the peak run-off and ditch capacity in cubic feet per second (cfs) for sub-reaches along Ditches 101, 101 and 102. Appendices E, F and G show the location of the ditches, the HMS model output, and the hydraulic calculations, respectively.

Table 4 Ditch Capacity

Ditch Identification	Discharge (25-year, 24-hour) (cfs)	Ditch Capacity (cfs)
100 – R1	29.6	79
100 – R2	63.2	266
100 – R3	68.4	83
100 – R4	105.1	365
101 – R1	5.9	12
101 – R2	5.9	57
101 – R3	19.6	280
101 – R4	32.3	735
101 – R5	166.9	226
102 – R1	80.1	89
102 – R2	106.8	212

Table 4 illustrates that the ditches are able to convey discharge from the 25-year, 24-hour storm event.

In addition, the HEC-HMS model indicated the peak water elevation in the CWDS Stormwater Ditch was 346.9 feet. The offsite over-flow elevation is 349.5 feet, therefore the CWDS Stormwater Ditch is able to store and convey run-off from the 25-year, 24-hour storm event.

4.2 CONCLUSION

Based on the calculations included in this report, the SHF CWDS meets the requirements of §257.81 of the EPA Final CCR Rule for Run-on and Run-off Controls. The following summarizes compliance with EPA Final CCR Rule criteria:

1. Run-off: Area 1 run-off discharges into Ash Pond 2. Area 2's Ditch 100 and the CWDS Stormwater Ditch and Area 3's Ditches 101 and 102 are capable of conveying run-off for the 25-year, 24 hour storm event before discharging into Ash Pond 2. The "Spillway Replacement Project Pond B (Ash Stilling Pond) Ash Disposal Area No. 2 Shawnee Fossil Plant" report states that Ash Pond 2 can convey the 6-hour, Probable Maximum Precipitation storm, which is significantly larger than the 25-year, 24-hour storm event. Therefore, the run-off control system collects and controls the water volume resulting from a 25-year, 24-hour storm.

2. Run-off (permitted discharge): Run-off from the CWDS flows to Ash Pond 2. Ash Pond 2 discharges through an active KPDES permitted outfall and is therefore handled in accordance with the surface water requirements under §257.3-3.

3. Run-on: The CWDS does not have run-on discharge since it is at an elevation above adjacent ground. Therefore, the run-on control system prevents flow onto the active portion of the CCR unit during the peak discharge from a 25-year, 24-hour storm.

5.0 REFERENCES

1. Brater, E.F. and H.W. King (1976), Handbook of Hydraulics, McGraw-Hill, New York.

2. Chow, V.T. (1959), Open-Channel Hydraulics, McGraw-Hill, 680 p.

3. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities (RIN-2050-AE81; FRL-9149-4) (EPA Final CCR Rule), April 2015.

4. Federal Highway Administration, HY-8 Culvert Hydraulic Analysis Program, Version 7.3, August 18, 2014.

5. KYAPED Kentucky From Above! Program (2013). "Site aerial imagery." Prepared for Tennessee Valley Authority, March-April.

6. NOAA Atlas 14, Precipitation Frequency Atlas of the United States, Volume 2, Version 3, 2006.

7. Stantec (2010). "Spillway Replacement Project Pond B (Ash Stilling Pond) Ash Disposal Area No. 2. Shawnee Fossil Plant." Prepared for Tennessee Valley Authority, May.

8. United States Department of Agriculture (1986). "Urban Hydrology for Small Watersheds, TR-55."June.

9. United States Army Corps of Engineers, Hydrologic Modeling System (HEC-HMS), Version 4.0, December 31, 2013.

10. "175555007_01_sitex_eg01_current.dwg, Topographic data." Provided by Tennessee Valley Authority, February-August 2014.

APPENDIX A
DRAINAGE PATTERNS

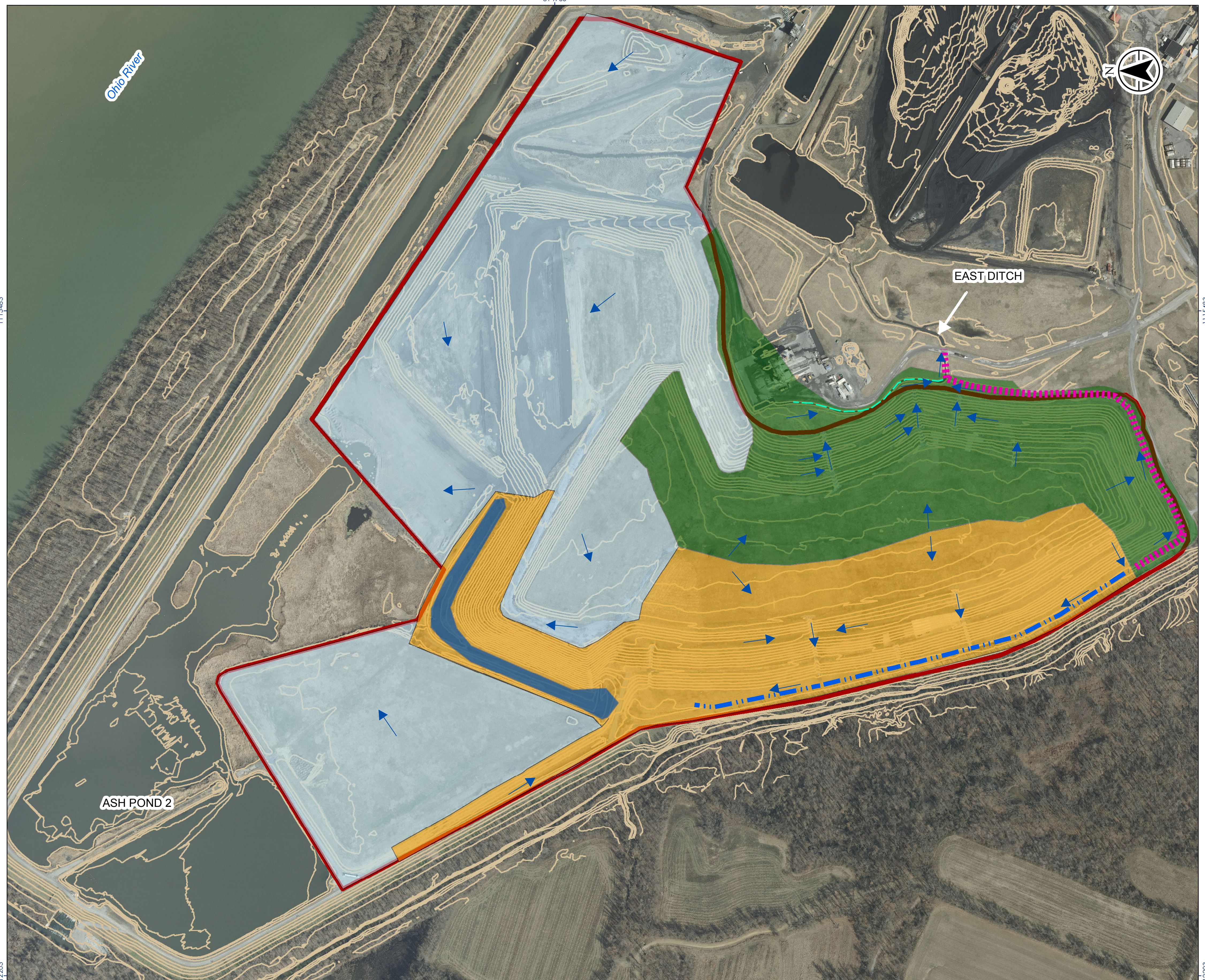

Figure No.
1

Title
DRAINAGE PATTERNS
SHF - CONSOLIDATED WASTE DRY STACK

Client/Project
Tennessee Valley Authority
Run-On/Run-Off Control Plan
175555007

Project Location:
T11N, R12E, S05
McCracken County, Kentucky

Prepared by mmm on 2015-09-22
Technical Review by jr on 2015-09-22
Independent Review by mam on 2015-09-22

0 600 1,200 Feet
1:6,085 (At Original document size of 11x17)

Legend

Approximate CCR Unit Boundary
Topographic Mapping
CWDS Stormwater Ditch

Watersheds

Area 1
Area 2
Area 3

Ditches

Ditch 100
Ditch 101
Ditch 102
Flow Arrow

Notes
1. Coordinate System: NAD 1927 StatePlane Kentucky South FIPS 1602
2. Topographic Data dated February, 2014.
3. Aerial Imagery dated April, 2013.

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APPENDIX B
NOAA RAINFALL DEPTHS

www.nws.noaa.gov

NOAA's National Weather Service
Hydrometeorological Design Studies Center
Precipitation Frequency Data Server (PFDS)

Home Site Map News Organization

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FAQ
Glossary

Precipitation Frequency (PF)
PF Data Server
- PF in GIS Format
- PF Maps
- Temporal Distr.
- Time Series Data
- PFDS Perform.

PF Documents

Probable Maximum Precipitation (PMP)
PMP Documents

Miscellaneous
Publications
AEP Storm Analysis
Record Precipitation

Contact Us
Inquiries
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USA.gov

NOAA ATLAS 14 POINT PRECIPITATION FREQUENCY ESTIMATES: KY

DATA DESCRIPTION

Data type: precipitation depth **Units:** english **Time series type:** partial duration

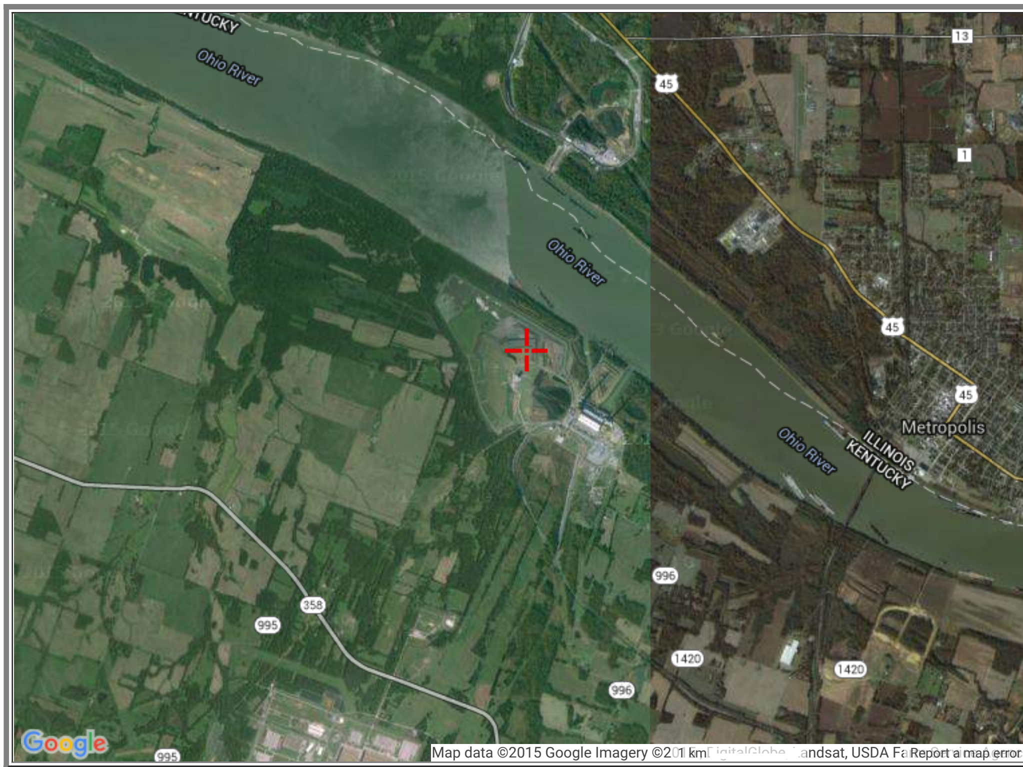
SELECT LOCATION

1. Manually:

a) Enter location (decimal degrees, use "-" for S and W): latitude: 37.1569 longitude: -88.7915 submit

b) Select station (click here for a list of stations used in frequency analysis for KY): select station

2. Use map:



a) Select location
(move crosshair or double click)
b) Click on station icon
(show stations on map)

LOCATION INFORMATION:
Name: Kevil, Kentucky, US*
Latitude: 37.1591°
Longitude: -88.7855°
Elevation: 395 ft*

* source: Google Maps

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 2, Version 3

PF tabular | PF graphical | Supplementary information | Print Page

PDS-based 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	0.422 (0.389-0.460)	0.498 (0.459-0.542)	0.579 (0.533-0.629)	0.644 (0.592-0.698)	0.724 (0.663-0.785)	0.783 (0.715-0.848)	0.841 (0.765-0.909)	0.901 (0.816-0.975)	0.978 (0.880-1.06)	1.04 (0.926-1.12)
10-min	0.658 (0.606-0.717)	0.779 (0.718-0.847)	0.905 (0.832-0.983)	0.998 (0.918-1.08)	1.11 (1.02-1.21)	1.20 (1.09-1.30)	1.28 (1.16-1.38)	1.36 (1.23-1.47)	1.46 (1.31-1.57)	1.53 (1.36-1.66)
15-min	0.809 (0.745-0.880)	0.958 (0.883-1.04)	1.12 (1.03-1.21)	1.23 (1.14-1.34)	1.38 (1.26-1.50)	1.49 (1.36-1.61)	1.59 (1.45-1.72)	1.69 (1.53-1.83)	1.82 (1.64-1.97)	1.91 (1.71-2.07)
30-min	1.08 (0.991-1.17)	1.29 (1.19-1.40)	1.54 (1.42-1.67)	1.73 (1.59-1.87)	1.97 (1.80-2.13)	2.14 (1.96-2.32)	2.32 (2.11-2.51)	2.49 (2.26-2.70)	2.73 (2.45-2.95)	2.90 (2.59-3.14)
60-min	1.32 (1.22-1.44)	1.59 (1.46-1.73)	1.94 (1.78-2.10)	2.20 (2.03-2.39)	2.56 (2.34-2.77)	2.84 (2.59-3.07)	3.12 (2.83-3.37)	3.40 (3.08-3.68)	3.79 (3.41-4.10)	4.09 (3.66-4.44)
2-hr	1.58 (1.45-1.72)	1.90 (1.74-2.07)	2.33 (2.13-2.54)	2.67 (2.44-2.90)	3.12 (2.84-3.40)	3.48 (3.16-3.79)	3.86 (3.48-4.19)	4.24 (3.81-4.61)	4.77 (4.25-5.19)	5.19 (4.59-5.65)
3-hr	1.72 (1.57-1.88)	2.06 (1.89-2.27)	2.54 (2.32-2.78)	2.91 (2.66-3.19)	3.42 (3.11-3.74)	3.84 (3.47-4.19)	4.26 (3.84-4.65)	4.71 (4.22-5.14)	5.34 (4.74-5.82)	5.84 (5.14-6.37)
6-hr	2.12 (1.94-2.34)	2.55 (2.33-2.81)	3.13 (2.85-3.44)	3.59 (3.27-3.94)	4.23 (3.83-4.64)	4.75 (4.28-5.20)	5.29 (4.75-5.79)	5.86 (5.23-6.41)	6.67 (5.88-7.30)	7.32 (6.41-8.01)

12-hr	**2.56** (2.34-2.81)	**3.07** (2.81-3.38)	**3.78** (3.45-4.14)	**4.34** (3.95-4.76)	**5.11** (4.63-5.59)	**5.74** (5.18-6.27)	**6.39** (5.72-6.98)	**7.07** (6.30-7.73)	**8.03** (7.08-8.80)	**8.81** (7.71-9.66)
24-hr	**3.09** (2.88-3.32)	**3.72** (3.47-3.99)	**4.57** (4.26-4.90)	**5.21** (4.85-5.59)	**6.08** (5.64-6.51)	**6.75** (6.25-7.24)	**7.44** (6.87-7.97)	**8.14** (7.48-8.72)	**9.09** (8.31-9.75)	**9.83** (8.95-10.6)
2-day	**3.66** (3.41-3.93)	**4.40** (4.10-4.72)	**5.39** (5.02-5.77)	**6.14** (5.71-6.58)	**7.13** (6.61-7.63)	**7.89** (7.31-8.45)	**8.66** (8.00-9.28)	**9.44** (8.70-10.1)	**10.5** (9.62-11.3)	**11.3** (10.3-12.1)
3-day	**3.87** (3.61-4.15)	**4.65** (4.33-4.99)	**5.68** (5.29-6.09)	**6.46** (6.01-6.93)	**7.49** (6.95-8.02)	**8.29** (7.68-8.88)	**9.09** (8.39-9.73)	**9.89** (9.11-10.6)	**11.0** (10.1-11.8)	**11.8** (10.8-12.7)
4-day	**4.08** (3.80-4.38)	**4.91** (4.57-5.26)	**5.98** (5.57-6.41)	**6.79** (6.32-7.28)	**7.86** (7.30-8.42)	**8.68** (8.04-9.30)	**9.51** (8.78-10.2)	**10.3** (9.52-11.1)	**11.4** (10.5-12.3)	**12.3** (11.2-13.2)
7-day	**4.75** (4.42-5.10)	**5.69** (5.30-6.12)	**6.95** (6.46-7.47)	**7.92** (7.35-8.51)	**9.21** (8.53-9.89)	**10.2** (9.44-11.0)	**11.2** (10.3-12.1)	**12.3** (11.2-13.2)	**13.7** (12.5-14.7)	**14.7** (13.4-15.9)
10-day	**5.30** (4.94-5.68)	**6.33** (5.91-6.80)	**7.68** (7.17-8.25)	**8.71** (8.11-9.34)	**10.1** (9.35-10.8)	**11.1** (10.3-11.9)	**12.1** (11.2-13.0)	**13.2** (12.2-14.2)	**14.6** (13.4-15.7)	**15.6** (14.3-16.8)
20-day	**7.20** (6.76-7.67)	**8.56** (8.04-9.12)	**10.2** (9.56-10.9)	**11.4** (10.7-12.1)	**13.0** (12.1-13.8)	**14.2** (13.2-15.1)	**15.3** (14.3-16.3)	**16.4** (15.3-17.5)	**17.9** (16.6-19.1)	**19.0** (17.6-20.3)
30-day	**8.79** (8.29-9.34)	**10.4** (9.84-11.1)	**12.3** (11.6-13.0)	**13.7** (12.9-14.5)	**15.4** (14.5-16.4)	**16.7** (15.7-17.8)	**18.0** (16.9-19.2)	**19.3** (18.0-20.5)	**20.9** (19.5-22.3)	**22.2** (20.6-23.6)
45-day	**11.0** (10.4-11.7)	**13.1** (12.3-13.9)	**15.3** (14.4-16.2)	**16.9** (15.9-17.9)	**18.9** (17.7-20.0)	**20.4** (19.1-21.6)	**21.9** (20.4-23.2)	**23.3** (21.7-24.7)	**25.1** (23.3-26.6)	**26.4** (24.5-28.1)
60-day	**13.1** (12.4-13.8)	**15.4** (14.6-16.3)	**17.9** (17.0-18.9)	**19.8** (18.7-20.8)	**22.0** (20.8-23.2)	**23.7** (22.4-25.0)	**25.3** (23.8-26.7)	**26.8** (25.2-28.4)	**28.8** (27.0-30.5)	**30.3** (28.3-32.1)

[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.

Estimates from the table in csv format: precipitation frequency estimates ▼ Submit

Main Link Categories:
Home | OHD

US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Office of Hydrologic Development
1325 East West Highway
Silver Spring, MD 20910
Page Author: HDSC webmaster
Page last modified: August 27, 2014

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Credits
Glossary

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Abo
Career Opportu

APPENDIX C
CURVE NUMBER BOUNDARIES

Figure No.
2

Title
CURVE NUMBER BOUNDARIES
SHF - CONSOLIDATED WASTE DRY STACK

Client/Project
Tennessee Valley Authority
Run-On/Run-Off Control Plan
175555007

Project Location:
T11N, R12E, S05
McCracken County, Kentucky

Prepared by mmm on 2015-09-22
Technical Review by jjr on 2015-09-22
Independent Review by mam on 2015-09-22

0 600 1,200 Feet
1:6,000 (At Original document size of 11x17)

Legend

- Approximate CCR Unit Boundary
- Topographic Mapping

Land Use & Curve Number (CN)

- Capped Ash & Grass CN= 80
- Road CN = 89
- Gravel/Riprap CN = 91

Notes

1. Coordinate System: NAD 1927 StatePlane Kentucky South FIPS 1602
2. Aerial Imagery dated April, 2013.

Stantec

\\Us1276-f02\shared_projects\175555007_nbader\SHF Mapping\fig_cn\figure2.mxd Revised: 2016-09-27 By: jureyes

APPENDIX D
WATERSHEDS

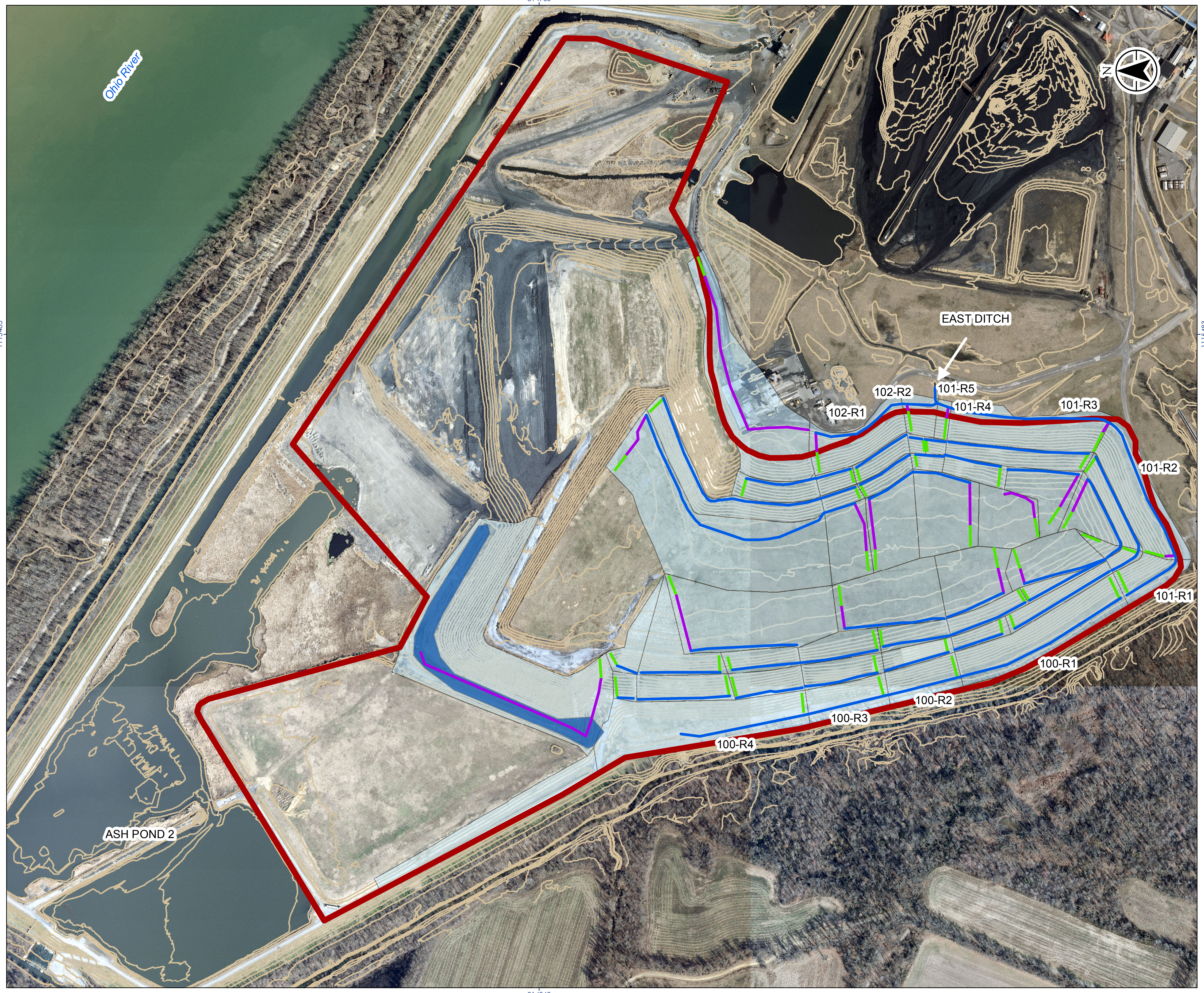


Figure No.
3

Title
WATERSHED
SHF - CONSOLIDATED WASTE DRY STACK

Client/Project
Tennessee Valley Authority
Run-On/Run-Off Control Plan
175555007

Project Location:
T11N, R12E, S05
McCracken County, Kentucky

Prepared by mmm on 2015-09-22
Technical Review by jjr on 2015-09-22
Independent Review by mam on 2015-09-22

0 600 1,200 Feet
1:6,000 (At Original document size of 11x17)

Legend

Approximate CCR Unit Boundary
Watersheds
CWDS Stormwater Ditch
Topographic Mapping

Flowpaths

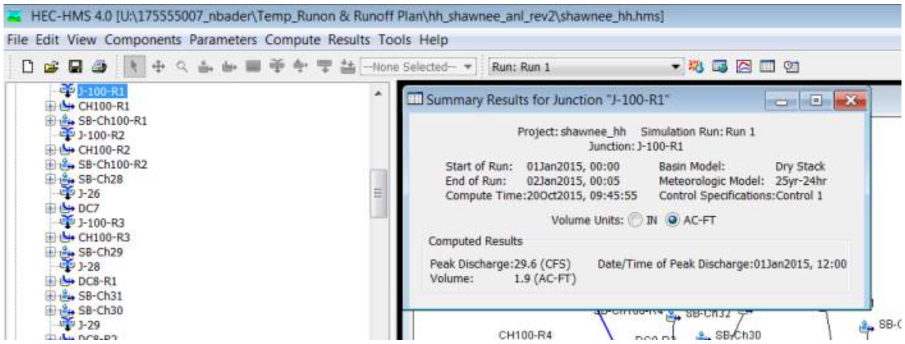
Sheet Flow
Shallow Concentrated Flow
Ditch/Channel Flow
101-R1 Ditch Identification

Notes
1. Coordinate System: NAD 1927 StatePlane Kentucky South FIPS 1602
2. Topographic Data dated February, 2014.
3. Aerial Imagery dated April, 2013.

Stantec

\\Us1276-f02\shared_projects\175555007_nbader\SHF Mapping\fig_drainage_ptrns_and_watersheds\figure3.mxd Revised: 2016-10-05 By: jureyes

APPENDIX E
HYDROLOGY RESULTS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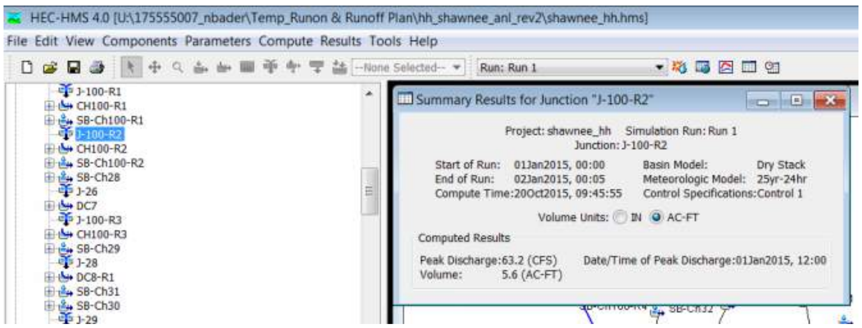
File Edit View Components Parameters Compute Results Tools Help
Run: Run 1
Summary Results for Junction "J-100-R1"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-100-R1
Start of Run: 01Jan2015, 00:00
End of Run: 02Jan2015, 00:05
Compute Time:20Oct2015, 09:45:55
Basin Model: Dry Stack
Meteorologic Model: 25yr-24hr
Control Specifications:Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge:29.6 (CFS)
Volume: 1.9 (AC-FT)
Date/Time of Peak Discharge:01Jan2015, 12:00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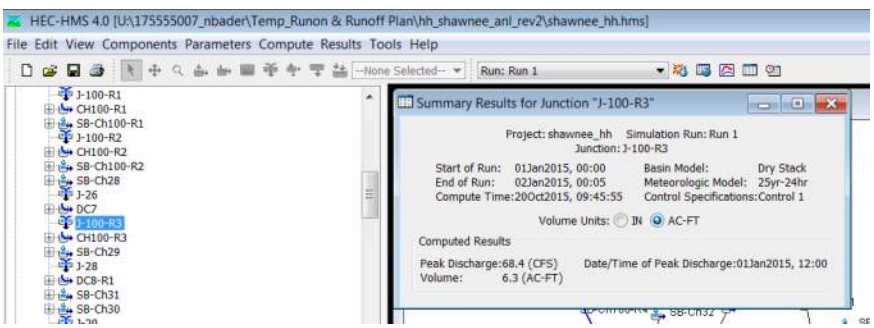
File Edit View Components Parameters Compute Results Tools Help
Run: Run 1
Summary Results for Junction "J-100-R2"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-100-R2
Start of Run: 01Jan2015, 00:00
End of Run: 02Jan2015, 00:05
Compute Time:20Oct2015, 09:45:55
Basin Model: Dry Stack
Meteorologic Model: 25yr-24hr
Control Specifications:Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge:63.2 (CFS)
Volume: 5.6 (AC-FT)
Date/Time of Peak Discharge:01Jan2015, 12:00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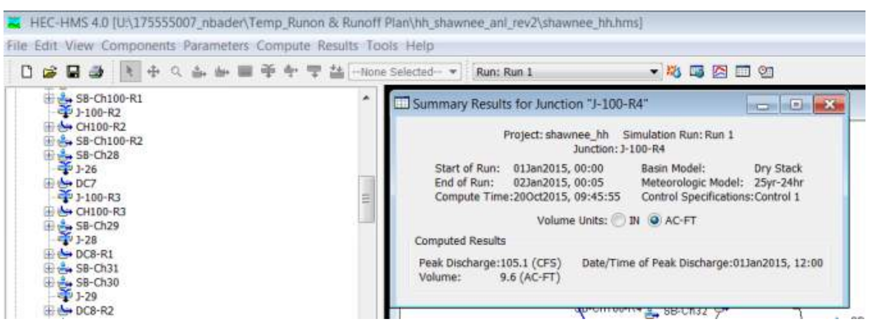
File Edit View Components Parameters Compute Results Tools Help
Run: Run 1
Summary Results for Junction "J-100-R3"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-100-R3
Start of Run: 01Jan2015, 00:00
End of Run: 02Jan2015, 00:05
Compute Time:20Oct2015, 09:45:55
Basin Model: Dry Stack
Meteorologic Model: 25yr-24hr
Control Specifications:Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge:68.4 (CFS)
Volume: 6.3 (AC-FT)
Date/Time of Peak Discharge:01Jan2015, 12:00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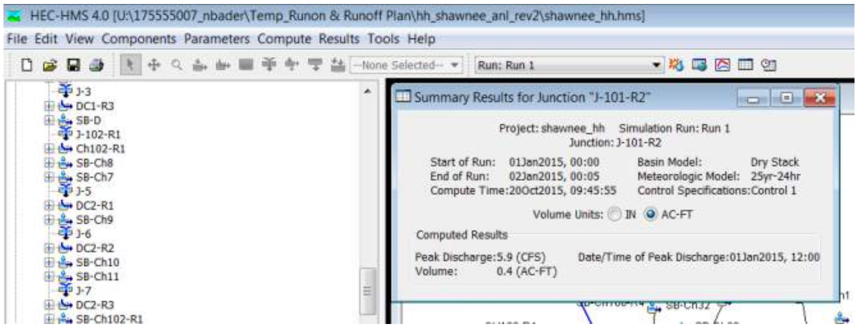
File Edit View Components Parameters Compute Results Tools Help
Run: Run 1
Summary Results for Junction "J-100-R4"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-100-R4
Start of Run: 01Jan2015, 00:00
End of Run: 02Jan2015, 00:05
Compute Time:20Oct2015, 09:45:55
Basin Model: Dry Stack
Meteorologic Model: 25yr-24hr
Control Specifications:Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge:105.1 (CFS)
Volume: 9.6 (AC-FT)
Date/Time of Peak Discharge:01Jan2015, 12:00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File Edit View Components Parameters Compute Results Tools Help
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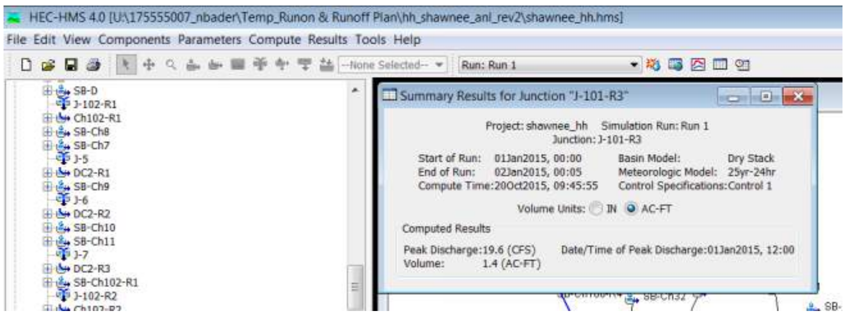
Run: Run 1
J-3
DC1-R3
SB-D
J-102-R1
Ch102-R1
SB-Ch8
SB-Ch7
J-5
DC2-R1
SB-Ch9
J-6
DC2-R2
SB-Ch10
SB-Ch11
J-7
DC2-R3
SB-Ch102-R1
Summary Results for Junction "J-101-R2"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-101-R2
Start of Run: 01Jan2015, 00:00 Basin Model: Dry Stack
End of Run: 02Jan2015, 00:05 Meteorologic Model: 25yr-24hr
Compute Time: 20Oct2015, 09:45:55 Control Specifications: Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge: 5.9 (CFS) Date/Time of Peak Discharge: 01Jan2015, 12:00
Volume: 0.4 (AC-FT)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File Edit View Components Parameters Compute Results Tools Help
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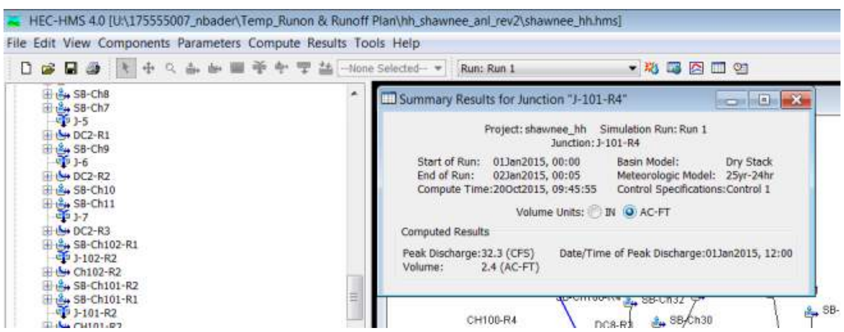
Run: Run 1
SB-D
J-102-R1
Ch102-R1
SB-Ch8
SB-Ch7
J-5
DC2-R1
SB-Ch9
J-6
DC2-R2
SB-Ch10
SB-Ch11
J-7
DC2-R3
SB-Ch102-R1
J-102-R2
Summary Results for Junction "J-101-R3"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-101-R3
Start of Run: 01Jan2015, 00:00 Basin Model: Dry Stack
End of Run: 02Jan2015, 00:05 Meteorologic Model: 25yr-24hr
Compute Time: 20Oct2015, 09:45:55 Control Specifications: Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge: 19.6 (CFS) Date/Time of Peak Discharge: 01Jan2015, 12:00
Volume: 1.4 (AC-FT)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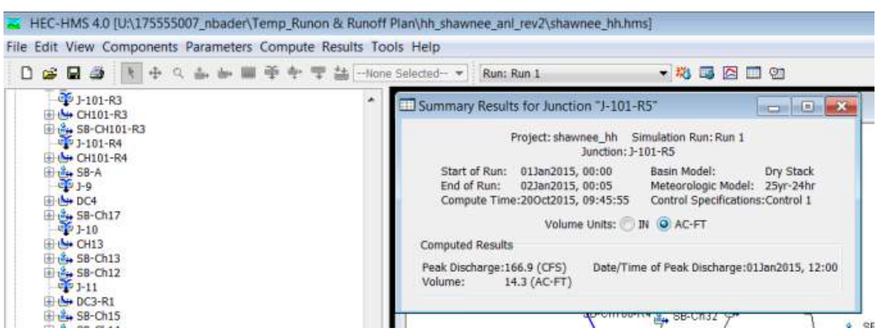
File Edit View Components Parameters Compute Results Tools Help
--None Selected--
Run: Run 1
SB-Ch8
SB-Ch7
J-5
DC2-R1
SB-Ch9
J-6
DC2-R2
SB-Ch10
SB-Ch11
J-7
DC2-R3
SB-Ch102-R1
J-102-R2
Ch102-R2
SB-Ch101-R2
SB-Ch101-R1
J-101-R2
Summary Results for Junction "J-101-R4"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-101-R4
Start of Run: 01Jan2015, 00:00 Basin Model: Dry Stack
End of Run: 02Jan2015, 00:05 Meteorologic Model: 25yr-24hr
Compute Time: 20Oct2015, 09:45:55 Control Specifications: Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge: 32.3 (CFS) Date/Time of Peak Discharge: 01Jan2015, 12:00
Volume: 2.4 (AC-FT)
CH100-R4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File Edit View Components Parameters Compute Results Tools Help
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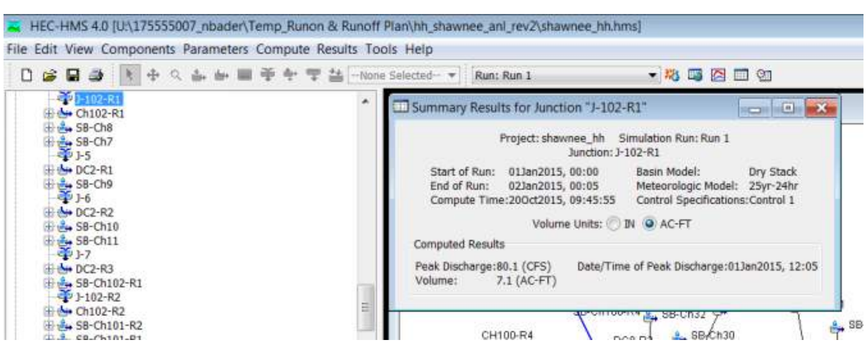
Run: Run 1
J-101-R3
CH101-R3
SB-CH101-R3
J-101-R4
CH101-R4
SB-A
J-9
DC4
SB-Ch17
J-10
CH13
SB-Ch13
SB-Ch12
J-11
DC3-R1
SB-Ch15
Summary Results for Junction "J-101-R5"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-101-R5
Start of Run: 01Jan2015, 00:00 Basin Model: Dry Stack
End of Run: 02Jan2015, 00:05 Meteorologic Model: 25yr-24hr
Compute Time: 20Oct2015, 09:45:55 Control Specifications: Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge: 166.9 (CFS) Date/Time of Peak Discharge: 01Jan2015, 12:00
Volume: 14.3 (AC-FT)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File Edit View Components Parameters Compute Results Tools Help
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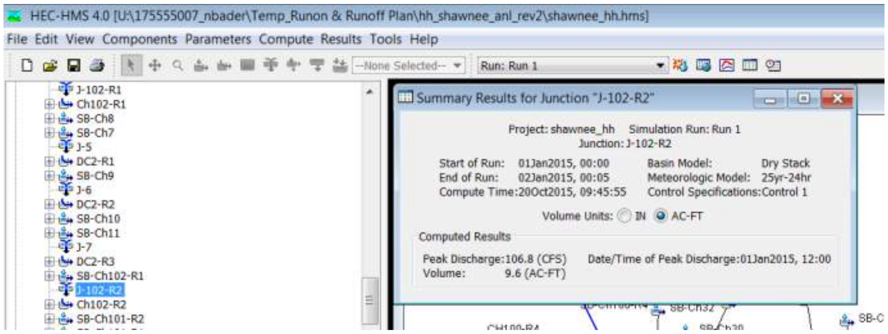
Run: Run 1
J-102-R1
Ch102-R1
SB-Ch8
SB-Ch7
J-5
DC2-R1
SB-Ch9
J-6
DC2-R2
SB-Ch10
SB-Ch11
J-7
DC2-R3
SB-Ch102-R1
J-102-R2
Ch102-R2
SB-Ch101-R2
Summary Results for Junction "J-102-R1"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-102-R1
Start of Run: 01Jan2015, 00:00 Basin Model: Dry Stack
End of Run: 02Jan2015, 00:05 Meteorologic Model: 25yr-24hr
Compute Time: 20Oct2015, 09:45:55 Control Specifications: Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge: 80.1 (CFS) Date/Time of Peak Discharge: 01Jan2015, 12:05
Volume: 7.1 (AC-FT)
CH100-R4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File Edit View Components Parameters Compute Results Tools Help
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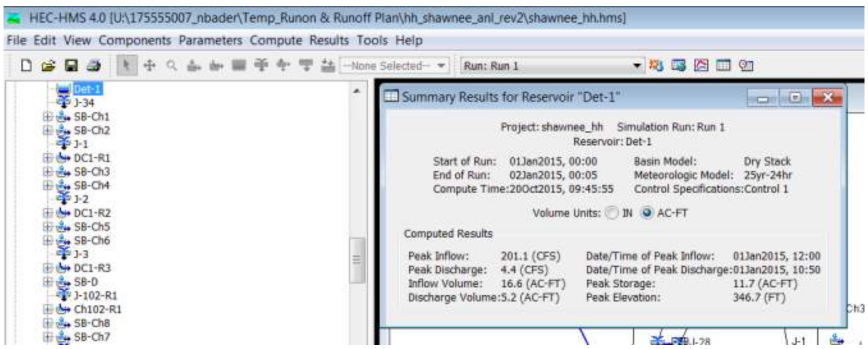
Run: Run 1
J-102-R1
Ch102-R1
SB-Ch8
SB-Ch7
J-5
DC2-R1
SB-Ch9
J-6
DC2-R2
SB-Ch10
SB-Ch11
J-7
DC2-R3
SB-Ch102-R1
J-102-R2
Ch102-R2
SB-Ch101-R2
Summary Results for Junction "J-102-R2"
Project: shawnee_hh Simulation Run: Run 1
Junction: J-102-R2
Start of Run: 01Jan2015, 00:00
End of Run: 02Jan2015, 00:05
Compute Time: 20Oct2015, 09:45:55
Basin Model: Dry Stack
Meteorologic Model: 25yr-24hr
Control Specifications: Control 1
Volume Units: IN AC-FT
Computed Results
Peak Discharge: 106.8 (CFS)
Volume: 9.6 (AC-FT)
Date/Time of Peak Discharge: 01Jan2015, 12:00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File Edit View Components Parameters Compute Results Tools Help
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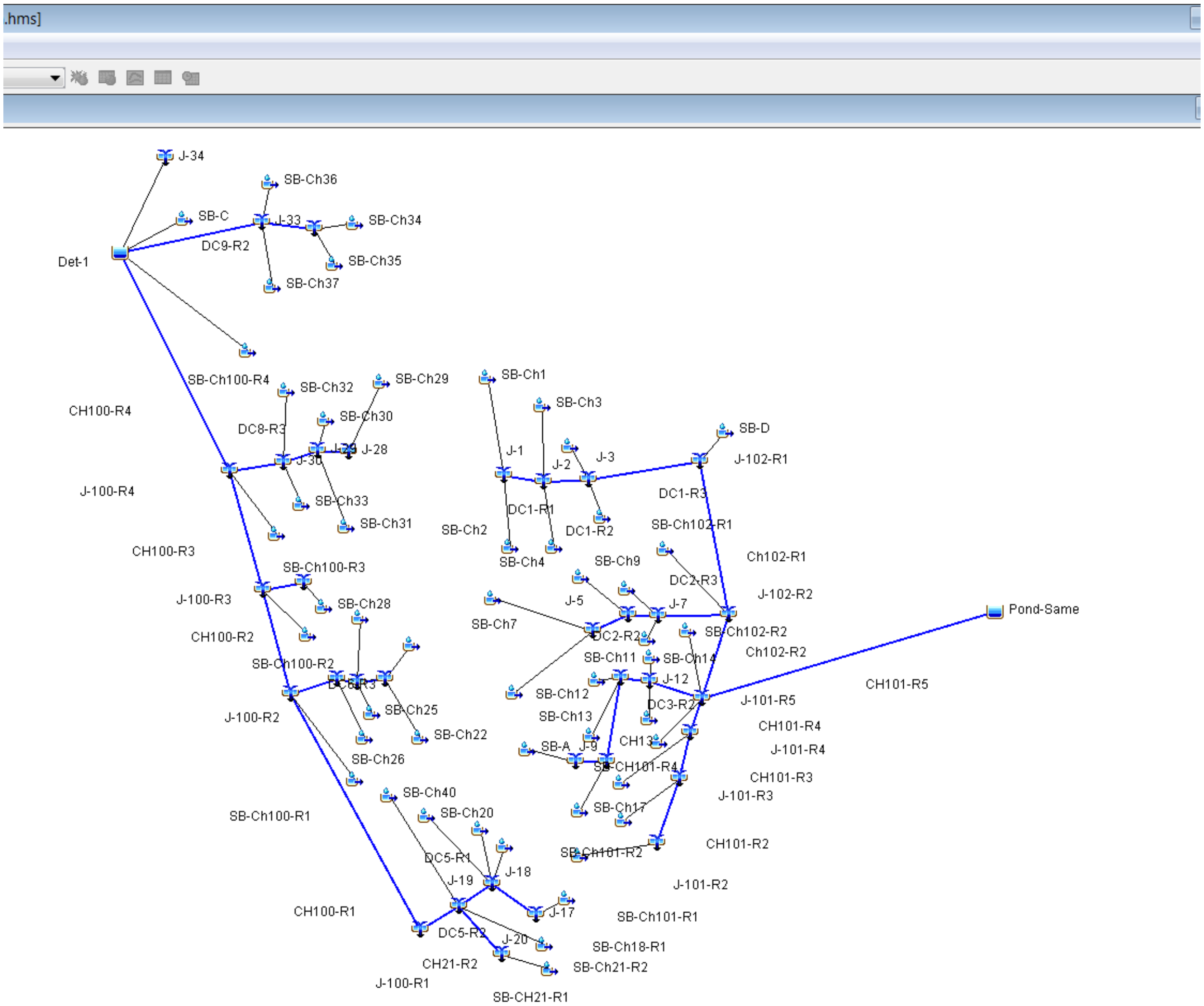
Run: Run 1
Det-1
J-34
SB-Ch1
SB-Ch2
J-1
DC1-R1
SB-Ch3
SB-Ch4
J-2
DC1-R2
SB-Ch5
SB-Ch6
J-3
DC1-R3
SB-D
J-102-R1
Ch102-R1
SB-Ch8
SB-Ch7
Summary Results for Reservoir "Det-1"
Project: shawnee_hh Simulation Run: Run 1
Reservoir: Det-1
Start of Run: 01Jan2015, 00:00
End of Run: 02Jan2015, 00:05
Compute Time: 20Oct2015, 09:45:55
Basin Model: Dry Stack
Meteorologic Model: 25yr-24hr
Control Specifications: Control 1
Volume Units: IN AC-FT
Computed Results
Peak Inflow: 201.1 (CFS)
Peak Discharge: 4.4 (CFS)
Inflow Volume: 16.6 (AC-FT)
Discharge Volume: 5.2 (AC-FT)
Date/Time of Peak Inflow: 01Jan2015, 12:00
Date/Time of Peak Discharge: 01Jan2015, 10:50
Peak Storage: 11.7 (AC-FT)
Peak Elevation: 346.7 (FT)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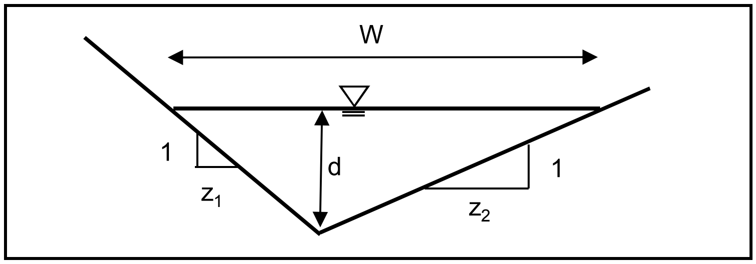
J-34
SB-Ch36
SB-C
J-33
SB-Ch34
DC9-R2
Det-1
SB-Ch35
SB-Ch37
SB-Ch100-R4
SB-Ch32
SB-Ch29
SB-Ch1
CH100-R4
SB-Ch3
SB-Ch30
DC8-R3
SB-D
J-28
J-30
J-1
J-2
J-3
J-102-R1
J-100-R4
DC1-R3
SB-Ch33
DC1-R1
SB-Ch31
SB-Ch102-R1
SB-Ch2
DC1-R2
CH100-R3
SB-Ch4
SB-Ch9
Ch102-R1
SB-Ch100-R3
DC2-R3
J-5
J-102-R2
J-100-R3
SB-Ch28
J-7
Pond-Same
SB-Ch7
DC2-R2
SB-Ch102-R2
CH100-R2
SB-Ch11
Ch102-R2
SB-Ch14
SB-Ch100-R2
J-12
CH101-R5
SB-Ch12
DC3-R2
J-101-R5
SB-Ch25
SB-Ch13
J-100-R2
CH101-R4
SB-Ch22
CH13
SB-A
J-9
J-101-R4
SB-Ch26
SB-CH101-R4
CH101-R3
SB-Ch40
J-101-R3
SB-Ch17
SB-Ch20
SB-Ch100-R1
CH101-R2
SB-Ch101-R2
DC5-R1
J-18
J-19
J-101-R2
J-17
CH100-R1
SB-Ch101-R1
DC5-R2
J-20
SB-Ch18-R1
CH21-R2
SB-Ch21-R2
J-100-R1
SB-CH21-R1

APPENDIX F
HYDRAULIC CALCULATIONS

Channel Section 100-R1

4. Non-Symmetrical Triangular Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0003	ft/ft
Design Discharge - Q	79.0	ft^3/s - cfs

Channel Geometry Data:

Side Slope(s)

z_1 or z	9.0	z H:1V
z_2	14.0	z H:1V

Governing Geometry Equations

$$W = d(z_1 + z_2)$$

$$A = \frac{d^2}{2}(z_1 + z_2)$$

$$W_P = d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

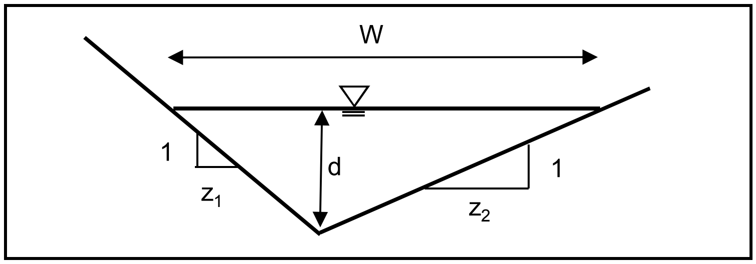
Calculated Depth - d	**2.60**	feet
Calculated Top Width - W	**59.69**	feet
Calculated Area - A	77.44	ft^2
Calc. Wetted Perimeter - Wp	59.92	feet
Calc. Hydr. Radius - R	1.29	feet
Calculated Discharge - Q'	79.04	ft^3/s - cfs
Convergence	0.04	ft^3/s - cfs
Calculated Velocity	**1.02**	ft / s
Calculated Shear Stress - τ_d	**0.05**	lb / ft^2

$$Q = \frac{1.49}{n} AR^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Channel Section 100-R2

4. Non-Symmetrical Triangular Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0034	ft/ft
Design Discharge - Q	266.0	ft^3/s - cfs

Channel Geometry Data:

Side Slope(s)

z_1 or z	9.0	z H:1V
z_2	14.0	z H:1V

Governing Geometry Equations

$$W = d(z_1 + z_2)$$

$$A = \frac{d^2}{2}(z_1 + z_2)$$

$$W_P = d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

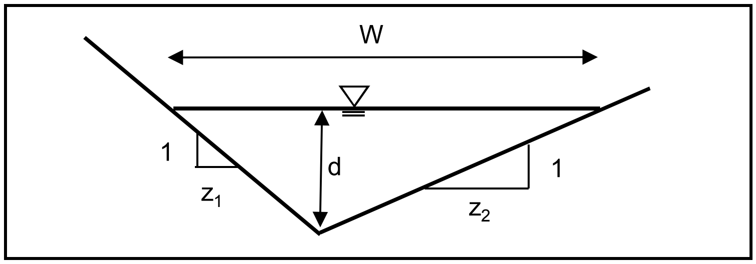
Calculated Depth - d	**2.60**	feet
Calculated Top Width - W	**59.69**	feet
Calculated Area - A	77.44	ft^2
Calc. Wetted Perimeter - Wp	59.92	feet
Calc. Hydr. Radius - R	1.29	feet
Calculated Discharge - Q'	266.10	ft^3/s - cfs
Convergence	0.10	ft^3/s - cfs
Calculated Velocity	**3.44**	ft / s
Calculated Shear Stress - τ_d	**0.55**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Channel Section 100-R3

4. Non-Symmetrical Triangular Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0002	ft/ft
Design Discharge - Q	83.0	ft^3/s - cfs

Channel Geometry Data:

Side Slope(s)

z_1 or z	9.0	z H:1V
z_2	14.0	z H:1V

Output Data:

Calculated Depth - d	**2.85**	feet
Calculated Top Width - W	**65.60**	feet
Calculated Area - A	93.54	ft^2
Calc. Wetted Perimeter - Wp	65.86	feet
Calc. Hydr. Radius - R	1.42	feet
Calculated Discharge - Q'	83.02	ft^3/s - cfs
Convergence	0.02	ft^3/s - cfs
Calculated Velocity	**0.89**	ft / s
Calculated Shear Stress - τ_d	**0.04**	lb / ft^2

Governing Geometry Equations

$$W = d(z_1 + z_2)$$

$$A = \frac{d^2}{2}(z_1 + z_2)$$

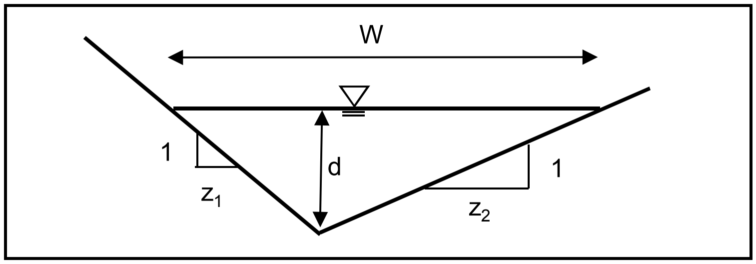
$$W_P = d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Channel Section 100-R4

4. Non-Symmetrical Triangular Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0039	ft/ft
Design Discharge - Q	365.0	ft^3/s - cfs

Channel Geometry Data:

Side Slope(s)

z_1 or z	9.0	z H:1V
z_2	14.0	z H:1V

Governing Geometry Equations

$$W = d(z_1 + z_2)$$

$$A = \frac{d^2}{2}(z_1 + z_2)$$

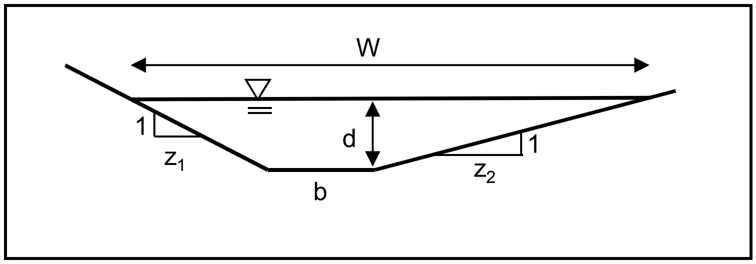
$$W_P = d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

Calculated Depth - d	**2.85**	feet
Calculated Top Width - W	**65.50**	feet
Calculated Area - A	93.28	ft^2
Calc. Wetted Perimeter - Wp	65.76	feet
Calc. Hydr. Radius - R	1.42	feet
Calculated Discharge - Q'	365.23	ft^3/s - cfs
Convergence	0.23	ft^3/s - cfs
Calculated Velocity	**3.92**	ft / s
Calculated Shear Stress - τ_d	**0.69**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$



Channel Section 101R1

2. Non-symmetrical Trapezoidal Section

Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0001	ft/ft
Design Discharge - Q	12.0	ft^3/s - cfs

Channel Geometry Data:

Bottom Width(s)		
b_1 or b	10	feet
Side Slope(s)		
z_1 or z	4.0	z H:1V
z_2	4.0	z H:1V

Governing Geometry Equations

$$W = b + d(z_1 + z_2)$$

$$A = bd + \frac{d^2}{2}(z_1 + z_2)$$

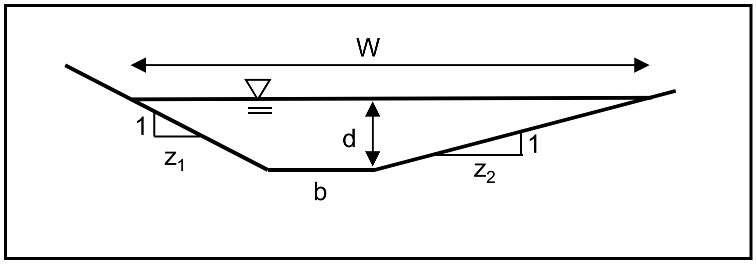
$$W_P = b + d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

Calculated Depth - d	**1.5**	feet
Calculated Top Width - W	**21.75**	feet
Calculated Area - A	23.32	ft^2
Calc. Wetted Perimeter - Wp	22.11	feet
Calc. Hydr. Radius - R	1.05	feet
Calculated Discharge - Q'	12.00	ft^3/s - cfs
Convergence	0.00	ft^3/s - cfs
Calculated Velocity	**0.51**	ft / s
Calculated Shear Stress - τ_d	**0.01**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$



Channel Section 101R2

2. Non-symmetrical Trapezoidal Section

Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0021	ft/ft
Design Discharge - Q	57.0	ft^3/s - cfs

Channel Geometry Data:

Bottom Width(s)		
b_1 or b	10	feet
Side Slope(s)		
z_1 or z	4.0	z H:1V
z_2	4.0	z H:1V

Governing Geometry Equations

$$W = b + d(z_1 + z_2)$$

$$A = bd + \frac{d^2}{2}(z_1 + z_2)$$

$$W_P = b + d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

Calculated Depth - d	**1.5**	feet
Calculated Top Width - W	**21.98**	feet
Calculated Area - A	23.93	ft^2
Calc. Wetted Perimeter - Wp	22.34	feet
Calc. Hydr. Radius - R	1.07	feet
Calculated Discharge - Q'	57.03	ft^3/s - cfs
Convergence	0.03	ft^3/s - cfs
Calculated Velocity	**2.38**	ft / s
Calculated Shear Stress - τ_d	**0.20**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

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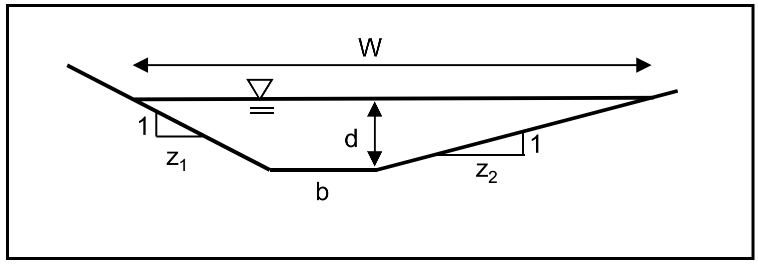
Channel Section 101R3

2. Non-symmetrical Trapezoidal Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0031	ft/ft
Design Discharge - Q	280.0	ft^3/s - cfs

Channel Geometry Data:

Bottom Width(s)		
b_1 or b	10	feet
Side Slope(s)		
z_1 or z	4.0	z H:1V
z_2	4.0	z H:1V

Governing Geometry Equations

$$W = b + d(z_1 + z_2)$$

$$A = bd + \frac{d^2}{2}(z_1 + z_2)$$

$$W_P = b + d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

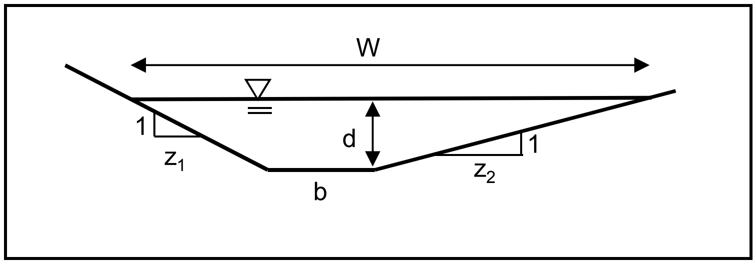
Calculated Depth - d	**3.0**	feet
Calculated Top Width - W	**34.01**	feet
Calculated Area - A	66.03	ft^2
Calc. Wetted Perimeter - Wp	34.75	feet
Calc. Hydr. Radius - R	1.90	feet
Calculated Discharge - Q'	280.17	ft^3/s - cfs
Convergence	0.17	ft^3/s - cfs
Calculated Velocity	**4.24**	ft / s
Calculated Shear Stress - τ_d	**0.58**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Channel Section 101R4

2. Non-symmetrical Trapezoidal Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0213	ft/ft
Design Discharge - Q	735.0	ft^3/s - cfs

Channel Geometry Data:

Bottom Width(s)		
b_1 or b	10	feet
Side Slope(s)		
z_1 or z	4.0	z H:1V
z_2	4.0	z H:1V

Governing Geometry Equations

$$W = b + d(z_1 + z_2)$$

$$A = bd + \frac{d^2}{2}(z_1 + z_2)$$

$$W_P = b + d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

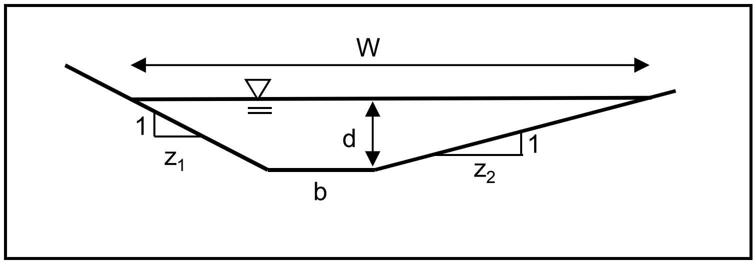
Calculated Depth - d	**3.0**	feet
Calculated Top Width - W	**34.02**	feet
Calculated Area - A	66.10	ft^2
Calc. Wetted Perimeter - Wp	34.76	feet
Calc. Hydr. Radius - R	1.90	feet
Calculated Discharge - Q'	735.41	ft^3/s - cfs
Convergence	0.41	ft^3/s - cfs
Calculated Velocity	**11.13**	ft / s
Calculated Shear Stress - τ_d	**3.99**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Channel Section 101R5

2. Non-symmetrical Trapezoidal Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0010	ft/ft
Design Discharge - Q	226.0	ft^3/s - cfs

Channel Geometry Data:

Bottom Width(s)

b_1 or b	11	feet

Side Slope(s)

z_1 or z	2.0	z H:1V
z_2	2.0	z H:1V

Governing Geometry Equations

$$W = b + d(z_1 + z_2)$$

$$A = bd + \frac{d^2}{2}(z_1 + z_2)$$

$$W_P = b + d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

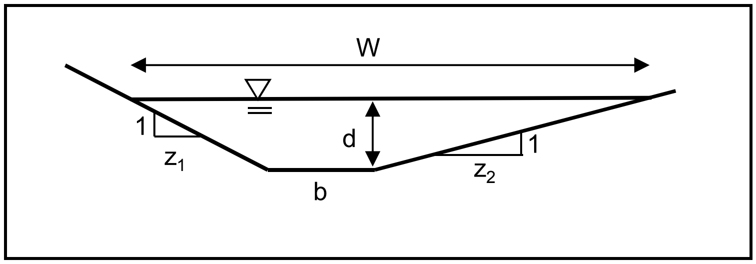
Calculated Depth - d	**4.0**	feet
Calculated Top Width - W	**26.95**	feet
Calculated Area - A	75.65	ft^2
Calc. Wetted Perimeter - Wp	28.83	feet
Calc. Hydr. Radius - R	2.62	feet
Calculated Discharge - Q'	226.03	ft^3/s - cfs
Convergence	0.03	ft^3/s - cfs
Calculated Velocity	**2.99**	ft / s
Calculated Shear Stress - τ_d	**0.25**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Channel Section 102R1

2. Non-symmetrical Trapezoidal Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0001	ft/ft
Design Discharge - Q	89.0	ft^3/s - cfs

Channel Geometry Data:

Bottom Width(s)

b_1 or b	10	feet

Side Slope(s)

z_1 or z	2.0	z H:1V
z_2	3.0	z H:1V

Governing Geometry Equations

$$W = b + d(z_1 + z_2)$$

$$A = bd + \frac{d^2}{2}(z_1 + z_2)$$

$$W_P = b + d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

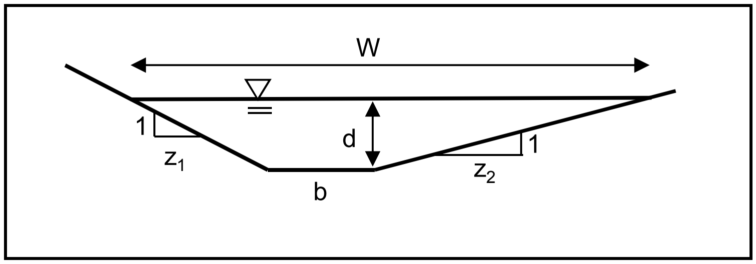
Calculated Depth - d	**4.4**	feet
Calculated Top Width - W	**31.91**	feet
Calculated Area - A	91.79	ft^2
Calc. Wetted Perimeter - Wp	33.65	feet
Calc. Hydr. Radius - R	2.73	feet
Calculated Discharge - Q'	89.01	ft^3/s - cfs
Convergence	0.01	ft^3/s - cfs
Calculated Velocity	**0.97**	ft / s
Calculated Shear Stress - τ_d	**0.03**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Channel Section 102R2

2. Non-symmetrical Trapezoidal Section



Input Data:

Manning's "n" value	0.03	
Longitudinal Slope - S_o	0.0010	ft/ft
Design Discharge - Q	212.0	ft^3/s - cfs

Channel Geometry Data:

Bottom Width(s)

b_1 or b	10	feet

Side Slope(s)

z_1 or z	2.0	z H:1V
z_2	2.0	z H:1V

Governing Geometry Equations

$$W = b + d(z_1 + z_2)$$

$$A = bd + \frac{d^2}{2}(z_1 + z_2)$$

$$W_P = b + d\left(\sqrt{z_1^2 + 1} + \sqrt{z_2^2 + 1}\right)$$

Output Data:

Calculated Depth - d	**4.0**	feet
Calculated Top Width - W	**25.97**	feet
Calculated Area - A	71.82	ft^2
Calc. Wetted Perimeter - Wp	27.86	feet
Calc. Hydr. Radius - R	2.58	feet
Calculated Discharge - Q'	212.08	ft^3/s - cfs
Convergence	0.08	ft^3/s - cfs
Calculated Velocity	**2.95**	ft / s
Calculated Shear Stress - τ_d	**0.25**	lb / ft^2

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$