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September 30, 2016

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

Initial Inflow Design Flood Control System Plan
Gypsum Disposal Area and Stilling Ponds 1 & 2
EPA Final CCR Rule
TVA Paradise Fossil Plant
Drakesborow, Kentucky

1.0 PURPOSE

This letter documents AECOM's certification of the initial inflow design flood control system plan for the TVA Paradise Fossil Plant's Gypsum Disposal Area and Stilling Ponds 1 & 2. Based on the assessment, the Gypsum Disposal Area and Stilling Ponds 1 & 2 comply with the inflow design flood control requirements in the Final CCR Rule 40 CFR 257.82.

2.0 INFLOW DESIGN FLOOD CONTROL SYSTEM PLAN

As described in 40 CFR 257.82(c), an inflow design flood control system plan must be prepared to document how the inflow design flood control system has been designed and constructed to manage the design storm required by the hazard classification. Based on the Hazard Potential Classification, the Gypsum Disposal Area and Stilling Ponds 1 & 2 have been assigned a Significant hazard potential classification rating. Thus, the 1,000 year storm event was selected from §257.82(a)(3) as the inflow design storm flood event based upon the hazard potential classification.

3.0 SUMMARY OF FINDINGS

The attached plan presents the analysis of the inflow design flood control system for the Gypsum Disposal Area and Stilling Ponds 1 & 2. The resulting water surface elevations are shown in the following table. The plan and results show that the impoundments meet the requirements set forth in 40 CFR 257.82(a) and (b).

Plant	Facility	Inflow Design Storm	Water Surface Elevation (feet)	Minimum Embankment Elevation (feet)
PAF	Stilling Pond 1	1,000-year storm	481.3	484.0
	Stilling Pond 2	1,000-year storm	452.7	456.0

4.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Nicholas S. Golden PE, being a Professional Engineer in good standing in the State 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 inflow design flood control system plan for the TVA Paradise Fossil Plant's Gypsum Disposal Area and Stilling Ponds 1 & 2 meets the requirements specified in 40 CFR 257.82(a), (b), and (c)(1).

SIGNATURE ______________________ DATE 9/30/16

ADDRESS: AECOM
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TELEPHONE: (330) 836-9111
ATTACHMENTS: Initial Inflow Design Flood Control System Plan

STATE OF KENTUCKY
NICHOLAS
GOLDEN
30816
LICENSED
PROFESSIONAL ENGINEER

COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

TENNESSEE VALLEY AUTHORITY – GYPSUM DISPOSAL AREA AND STILLING PONDS 1 AND 2
PARADISE FOSSIL PLANT
DRAKESBORO, KENTUCKY

INITIAL INFLOW DESIGN FLOOD CONTROL SYSTEM PLAN (40 CFR §257.82) FOR COAL COMBUSTION RESIDUALS (CCR)

EXISTING SURFACE IMPOUNDMENT

Prepared for

TVA

Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402-2801

September 30, 2016 - Rev0

STATE OF KENTUCKY
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30816
LICENSED PROFESSIONAL ENGINEER

9/30/16

Prepared by

AECOM

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1.0 BACKGROUND

This plan outlines compliance to **Rule § 257.82** of the EPA Final CCR Rule.

The owner or operator of an existing CCR surface impoundment must design, construct, operate, and maintain an inflow design flood control system as specified in **Rule §257.82 (a),** which is directly stated below for clarity.

Rule §257.82(a)(1): The inflow design flood control system must adequately manage flow into the CCR unit during and following the peak discharge of the inflow design flood.

Rule §257.82(a)(2): The inflow design flood control system must adequately manage flow from the CCR unit to collect and control the peak discharge resulting from the inflow design flood.

Rule §257.82(a)(3): The inflow design flood is:

- **(i):** For a high hazard potential CCR surface impoundment, the probable maximum flood;
- **(ii):** For a significant hazard potential CCR surface impoundment, the 1,000-year flood;
- **(iii):** For a low hazard potential CCR surface impoundment, the 100-year flood; or
- **(iv):** For an incised CCR surface impoundment, the 25-year flood.

According to **Rule §257.82(b)**, discharge from the CCR unit must be handled in accordance with the surface water requirements under **§257.3-3.**

Section **§257.82(c)(1)** states that the owner or operator must prepare initial and periodic inflow design flood control system plans for the CCR unit according to the timeframes specified in paragraphs **(c)(3)** and **(4)**. The plans must document how the inflow design flood control system has been designed and constructed to meet the requirements of the section. Each plan must be supported by appropriate engineering calculations. The owner or operator of the CCR unit has completed the inflow design flood control system plan when the plan has been placed in the facility's operating record.

Section **§257.82(c)(2)** allows amendments to the written inflow design flood control system plan at any time and requires amendments to the written inflow design flood control system plan whenever there is a change in conditions that would substantially affect the written plan in effect. The revised plan must be placed in the facility's operating record.

Section **§257.82(c)(3)** requires that the initial inflow design flood control system plan be completed no later than October 17, 2016.

Section **§257.82(c)(4)** states that the owner or operator must prepare periodic inflow design flood control system plans every five years.

Section **§257.82(c)(5)** requires a certification from a qualified professional engineer stating that the initial and periodic inflow design flood control system plans meet the requirements of **Rule §257.82**.

According to **Rule §257.82(d)**, the owner or operator must comply with recordkeeping, notification, and internet requirements specified elsewhere in the Rule.

1.1 SITE LOCATION

Tennessee Valley Authority (TVA) owns and operates the Paradise Fossil Plant (PAF) in Drakesboro, Kentucky. The plant is located along the southwestern side of the Green River along State Route 176. The Gypsum Disposal Area manages process water flows and CCR waste during power generation. The Gypsum Disposal Area has two stilling ponds called Stilling Ponds 1 & 2. These ponds receive process water and stormwater drainage from the Gypsum Disposal Area and the surrounding drainage area. This area is located west of the PAF plant. It is bordered by hilly and grassy areas on all four sides. Stilling Pond 1 drains to Stilling Pond 2, which discharges to a surface water channel that eventually leads to the Peabody Ash Pond, which is located on the southeast side of the site.

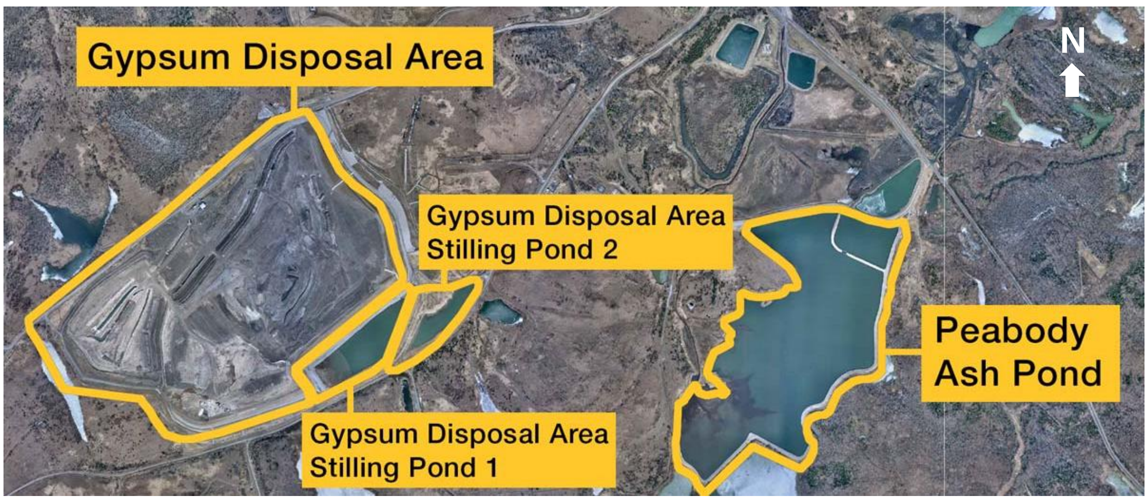


Figure 1: Site Overview

1.2 SITE HISTORY

The Gypsum Disposal Area has been used for gypsum disposal since 1986. The facility was initially operated as a gypsum pond until 1996 when the complex was converted to a wet stacking facility (Gypsum Disposal Area) which involves mechanical stacking on top of hydraulically placed gypsum/ash deposits. Some fly ash from Units 1 and 2 was introduced into the sluice flows beginning in the late 1990s. In 2002, all fly ash from Units 1 and 2 were combined with the gypsum sluice flows to the Gypsum Disposal Area.

More information on the construction history of the Gypsum Disposal Area can be found in the History of Construction document prepared for CCR Certification.

2.0 Existing Conditions - §257.82(a)(1)

Under existing conditions, the drainage area for the Gypsum Disposal Area Stilling Ponds and outlet ditch is approximately 394 acres, based on 2014 aerial survey. The contributing drainage area to the Stilling Ponds is approximately 267 acres. In addition, to analyze for potential backwater conditions at the outlet of Stilling Pond 2, the model incorporated an additional area approximately 127 acres in size which drains directly to the outlet ditch at the discharge of Stilling Pond 2.

3.0 Methods / Design Criteria

AECOM conducted a hydrologic and hydraulic modeling analysis of the Gypsum Disposal Area Stilling Ponds for compliance with the new Federal Register Coal Combustion Residual regulations (40 CFR Part 257.82). A Hazard Potential Classification Assessment was previously completed on the Gypsum Disposal Area and associated Stilling Ponds. This impoundment was determined to be a “significant” hazard. These regulations require that the ponds safely store and convey the 1000-yr storm event in addition to normal process flow conditions (40 CFR Part 257.82(a)(3)(ii)). This report documents the development of the H&H model, including data sources and assumptions, and findings from the model results.

To assess the capacity of the ponds to store and convey the storm flows, a hydraulic model was created in HEC-HMS. HEC-HMS is a deterministic model and as such, assumes boundary conditions, initial conditions, and parameters of the model elements are well defined. The model incorporates model element characteristics and meteorological data to calculate infiltration losses, runoff, reservoir storage and flow conditions. HEC-HMS computes each element’s routing calculations for the entire simulation time window before proceeding to the next element. This ensures the simulations run quickly while still producing accurate and precise results, making the program an efficient tool for this evaluation. The model was developed based upon Aerial LiDAR data and plans provided by TVA, field data collected by TVA Surveying personnel, and observations made during a site visit by AECOM Personnel.

The following table shows the storms that were analyzed. The 6-hour, 1000-year precipitation depth was obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 2, Version 3.

Table 1: Rainfall Depth for Analyzed Storms

Reoccurrence Interval	Storm Duration	Rainfall Depth	Storm Distribution
1000 year	6 hour	7.14 inches	SCS Type II

The Soil Conservation Service (SCS) Type II distribution for average conditions was selected for Paradise Fossil Plant in Drakesboro, Kentucky. SCS Curve Number method was used for estimating infiltration losses. SCS Unit Hydrograph was used to transform precipitation into runoff for each subbasin. The pond routing method used was an outflow curve for Stilling Pond 1 and outlet structure characteristics for Stilling Pond 2.

A base flow of 5.55 MGD or 8.58 cfs is considered for normal operating conditions, according to TVA Paradise Fossil Plant Wastewater Flow Schematic Rev 9-11. This flow is a combination of process flows from Units 1, 2, and 3 at the plant. Units 1 and 2 drain to dikes on the northeast side of the Gypsum Disposal Area, while Unit 3 drains to the dikes on the northwest. This base flow was applied to Stilling Pond 1.

Stormwater from the site flows through two stormwater management areas that allow for runoff sediments to settle before water flows into the perimeter ditches (1R and 3R) on the south and east sides of the Gypsum Disposal Area. The perimeter ditches drain to Stilling Pond 1, which outlets to Stilling Pond 2, then out to a ditch, eventually draining to the Peabody Ash Pond. An alternate outlet from Stilling Pond 2 was identified in the instance that the pond crests the roadway to the east and discharges to an unnamed pond, here identified as the Ancillary Pond. Additional subbasins were added to the model to incorporate surface runoff from the areas outside the Gypsum Disposal Area that surround the stilling ponds and perimeter drainage ditches. Also, the surface areas of the normal pond elevation were added to capture precipitation falling directly onto the pond surfaces. The general site configuration as set up in HEC-HMS is presented in **Figure 2**.

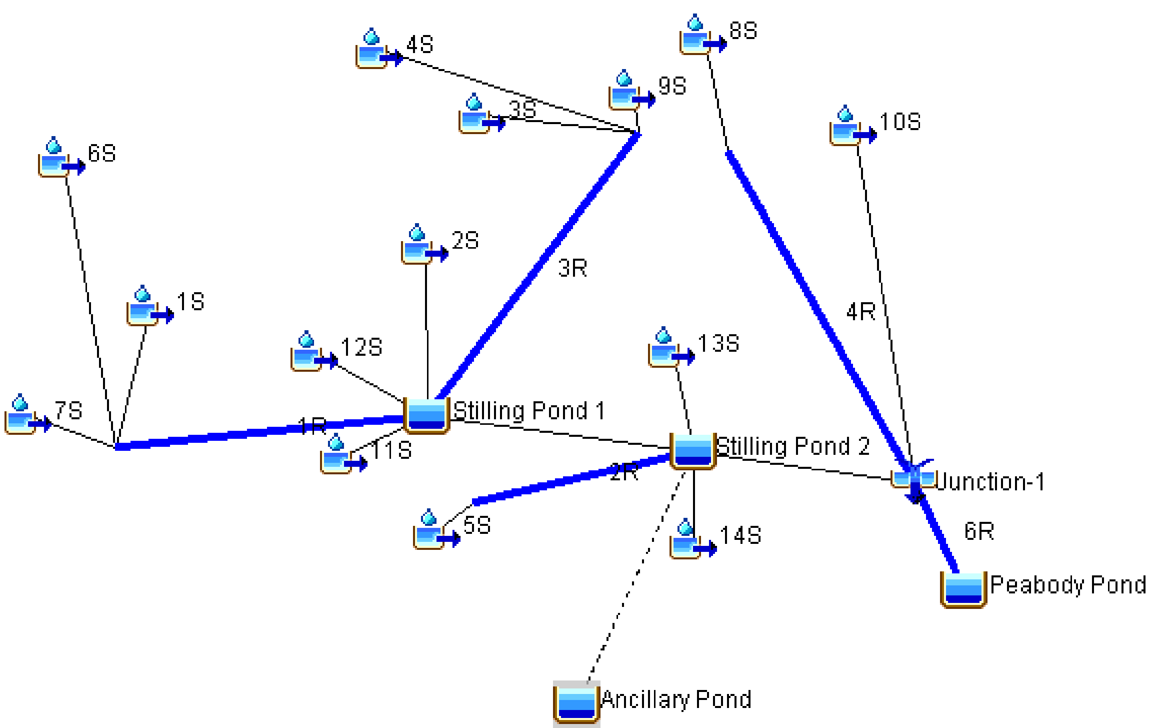


Figure 2: HEC-HMS model schematic

3.1 Watershed Delineation and Runoff Variables

The drainage area of the stilling ponds was delineated into subbasins based on LiDAR contour data. Data inputs such as area, runoff curve number, percent impervious area, and lag time were entered into the model for each subbasin. Curve numbers were assigned to each subbasin based on the type of land cover present. For the subbasins located within the Gypsum Disposal Area a curve number for “newly graded area” was given. For the subbasins located outside of the Gypsum Disposal Area a curve number for “Open space, grass cover > 75%” or “Open space, grass cover 50% to 75%” was given based on observations of aerial imagery. Due to the lack of more specific soil characterization data, Type C Hydraulic Soil Group characteristics were used for all of the subbasins in the model based on general understanding of Gypsum Disposal Area residual characteristics and compaction of the site.

Runoff from subbasins was routed to reaches or directly to a pond. Five subbasins (1S-4S and 6S) were identified within the Gypsum Disposal Area that drain to Stilling Pond 1. Seven subbasins were identified outside of the Gypsum Disposal Area that drain to the perimeter ditches or to the ponds. Finally, two subbasins for the ponds themselves were included in the model (11S & 14S). Each subbasin was defined by the contouring presented in the most recent available LiDAR data for the site. Area of each subbasin was calculated in AutoCAD Civil 3D, a runoff curve number was applied to each, and the hydraulic length and average slope of the subbasin and subsequent time of concentration were used to calculate the lag time for each subbasin.

Subbasins that do not directly drain to either pond drain to ditches located along the perimeter of the Gypsum Disposal Area. These ditches were defined in the model as reaches. Reaches within HEC-HMS are defined by channel type (pipe, rectangular or trapezoidal channel, etc). The perimeter ditches surrounding the Gypsum Disposal Area were defined as trapezoidal channels with 2:1 side slopes. Channel dimensions were entered, as well as slope, length, inverts and outlet discharge criteria. These reaches were then routed to the ponds. Four reaches were defined in the model. A perimeter ditch along the southeast side of the Gypsum Disposal Area receives runoff discharge from subbasins 1S and 6S. The perimeter ditch to the northeast receives discharge from subbasins 4S and 3S. One ditch draining directly to Pond 2 receives runoff from sub catchment 5S. Finally, the fourth reach runs on the other side of a service drive from the east perimeter ditch and receives overland flow from subbasin 8S and drains into the outlet ditch, 6R.

3.2 Pond Hydraulics and Routing

Ponds were defined with stage storage information. For this model, stage - storage and stage – area relationships were used to define the storage for the ponds. This was done by noting the surface area of each contour line within the ponded area in AutoCAD Civil 3D and entering these values into the model. Outlet structures or outlet discharge curves were entered for each pond and included culvert sizes, weir lengths, and designation of main versus auxiliary overflow structures. Stilling Pond 1 was originally equipped with a 48” circular riser structure connected into a 36” pipe draining to Stilling Pond 2. In 2016, this structure was replaced with a spillway structure consisting of a main outlet structure of a 10 foot long weir flowing to three 24-inch double broken back culverts that discharge to Stilling Pond 2 at an elevation of 452.3’ (See **Figure 3**). Using this new configuration, an outlet discharge curve was entered into the model.

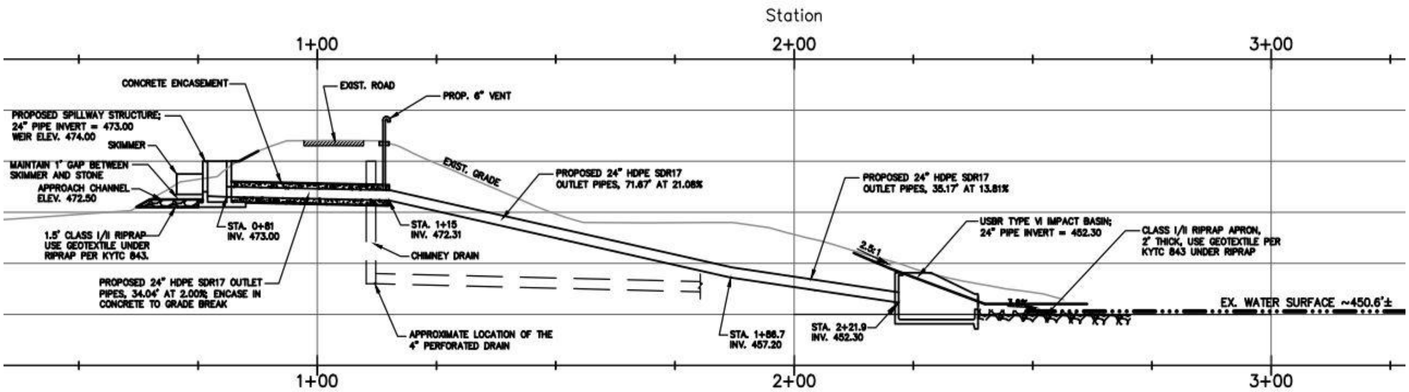


Figure 3: Stilling Pond 1 Outlet Structure Design

The Stilling Pond 2 outlet structure consists of two (2) 42-inch steel pipes discharging to an open channel drainage ditch that runs along a service drive. This drainage ditch eventually drains to the Peabody Ash Pond, which is the main detention pond on site that discharges to Jacob’s Creek. If Stilling Pond 2 were to overflow, water would over top the berm on its southeast side as a broad-crested weir at an elevation of 456’ and flow over the service drive and down the road embankment into an ancillary pond.

Starting water surface elevation of Stilling Pond 1 is 474.41 ft and 450.32 ft for Stilling Pond 2 based on the normal operating water surface elevation under baseflow conditions. All structure dimensions, and invert elevations are modeled using the best available information under current baseflow operating conditions of the PAF Plant. Existing topographic and survey information for the PAF Gypsum Disposal Area was provided by TVA. Drainage areas, volumes, and other site geometry were determined using the AutoCAD Civil 3D 2013 software package in conjunction with survey data provided by TVA.

A detailed H&H modeling summary of the Gypsum Disposal Area Stilling Ponds is provided in **Appendix A**. Computer model outputs are provided for the existing drainage conditions with the replacement spillway structure at Stilling Pond 1 and dual 42-inch outlet culverts at Stilling Pond 2.

3.3 Assumptions

Based on the existing information available the following assumptions were made when preparing the HEC-HMS model:

- Knowing that the deposits and placement of material within the Gypsum Disposal Area is constantly changing, aerial LiDAR was used for watershed delineation within the Gypsum Disposal Area. The two most recent LiDAR sets from 2015 were used.
- Conveyance structures with no known information, but visible in aerial imagery (Google Earth) were omitted from the model and flows were directly routed to the Stilling Ponds to be conservative.
- Runoff from the northwest corner of the Gypsum Disposal Area flows to the west and does not flow into the Stilling Ponds.

4.0 Calculation Results - §257.82(a)(2)

Tables 2 and **3** show estimated peak pond inflows for the 1,000-yr storm analyzed under existing conditions as well as the estimated peak pool elevations for Stilling Ponds 1 and 2, respectively. The tables also show the estimated amount of freeboard remaining at the time of peak pool elevation.

The principal outlet structure for Stilling Pond 1 consists of a 10 ft. long weir set at elevation 474' that drains to three 24-inch broken back pipes that discharge to Stilling Pond 2 at elevation 452.3'. The pond berm height is 484'.

The principal outlet structure for Stilling Pond 2 consists of two 42-inch diameter steel culverts approximately 112-ft long. The culverts drain to an outlet ditch that eventually drains to Peabody Ash Pond and out to Jacob's Creek. The pond berm height is at 456'.

Table 2: Stilling Pond 1 Estimated Peak Inflows and Peak Pool Elevations

Reoccurrence Interval (year)	Storm Duration	Peak Inflow	Peak Pool Elev.	Notes
1,000	6 hour	736.0 cfs	481.3 ft	2.7 ft. of freeboard remaining

Table 3: Stilling Pond 2 Estimated Peak Inflows and Peak Pool Elevations

Reoccurrence Interval (year)	Storm Duration	Peak Inflow	Peak Pool Elev.	Notes
1,000	6 hour	150.8 cfs	452.7 ft	3.3 ft. of freeboard remaining

5.0 CONCLUSIONS

The modeling results indicate the ponds would not overtop during a 1000-year, 6-hour design storm. The inflow design flood control system adequately manages flow into the CCR unit during and following the peak discharge of the inflow design flood. Discharge is handled in accordance with the surface water requirements under Final CCR Rule 40 CFR 257.82.

6.0 REFERENCES

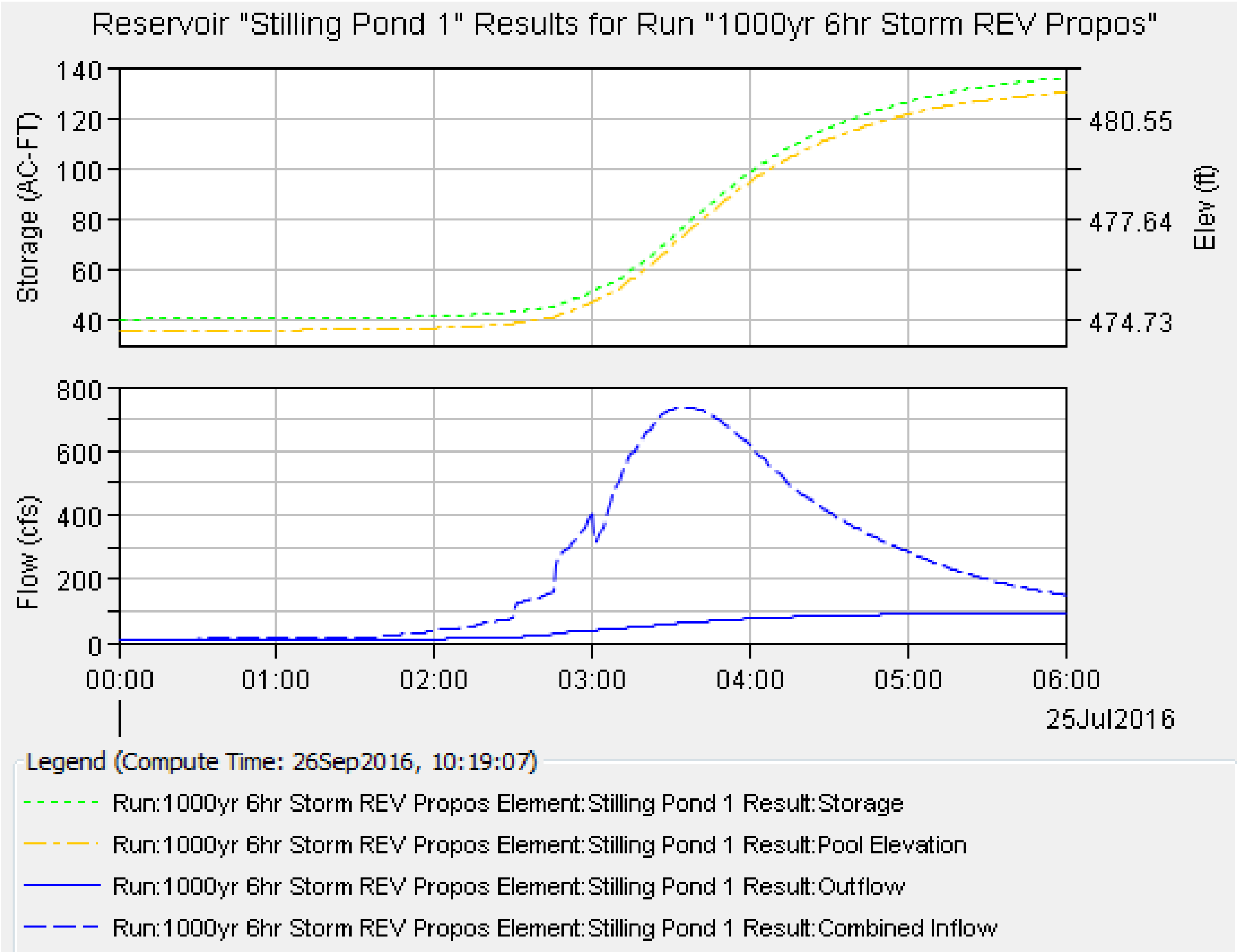
1. Environmental Protection Agency, “Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities”, Federal Register, April 17, 2015.
2. AECOM, Gypsum Disposal Area, History of Construction 257.73(c)(1) prepared for CCR Certification, 2016
3. Stantec Consulting Services Inc., Hazard Potential Classification Assessment, Gypsum Disposal Area, 2016
4. National Oceanic and Atmospheric Administration, Atlas 14, Volume 2, Version 3; 2016
5. TVA, Paradise Fossil Plant Permit No. KY0004201 Wastewater Flow Schematic Rev 9-2011.
6. United States Army Corps of Engineers, Hydrologic Modeling System (HEC-HMS), Version 4.0, 2016.

APPENDIX A
HEC-HMS OUTPUT

Project: TVA PAF Gypsum Disposal Area		Simulation Run:	1000yr 6hr Storm REV Proposed
Start of Run:	25JUL2016, 00:00	Basin ModeL:	Gypsum Disposal Area
End of Run:	25JUL2016, 06:00	Meteorologic Model:	1000yr 6hr
Compute Time:	23SEP2016, 11:27:00	Control Specifications:	6hr

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
6S	0.0816	202.1	25Jul2016, 03:38	5.71
1S	0.0723	181.9	25Jul2016, 03:37	5.72
7S	0.0165	79.8	25Jul2016, 03:04	4.65
1R	0.1704	395.1	25Jul2016, 03:42	5.52
2S	0.10453	156.2	25Jul2016, 04:25	4.83
3S	0.04	113.4	25Jul2016, 03:30	5.79
4S	0.029141	111.4	25Jul2016, 03:16	5.91
9S	0.0135	43.7	25Jul2016, 03:15	4.57
3R	0.082641	251.1	25Jul2016, 03:23	5.57
11S	0.0238	179.4	25Jul2016, 02:49	10.5
12S	0.014375	39.8	25Jul2016, 03:21	4.53
Stilling Pond 1	0.395746	94.4	25Jul2016, 06:00	1.1
5S	0.005	19.4	25Jul2016, 03:07	4.09
2R	0.005	19.3	25Jul2016, 03:08	4.06
14S	0.0096	68.9	25Jul2016, 02:49	7.14
13S	0.0069	33.4	25Jul2016, 03:04	4.65
Stilling Pond 2	0.417246	80.2	25Jul2016, 06:00	0.73
8S	0.0672	233.3	25Jul2016, 03:10	4.07
4R	0.0672	232.6	25Jul2016, 03:20	3.88
10S	0.1313	168.7	25Jul2016, 04:05	3.57
Junction-1	0.615746	334.5	25Jul2016, 03:22	1.68
6R	0.615746	333.5	25Jul2016, 03:32	1.6
Peabody Ash Pond	0.615746	61.9	25Jul2016, 06:00	0.23
Ancillary Pond	0	0	25Jul2016, 00:00	n/a

Stilling Pond 1
1000yr 6hr



Stilling Pond 1
1000yr 6hr

Project: TVA_Paradise_Gypsum_Stack_B   Simulation Run: 1000yr 6hr Storm REV Propos
Reservoir: Stilling Pond 1

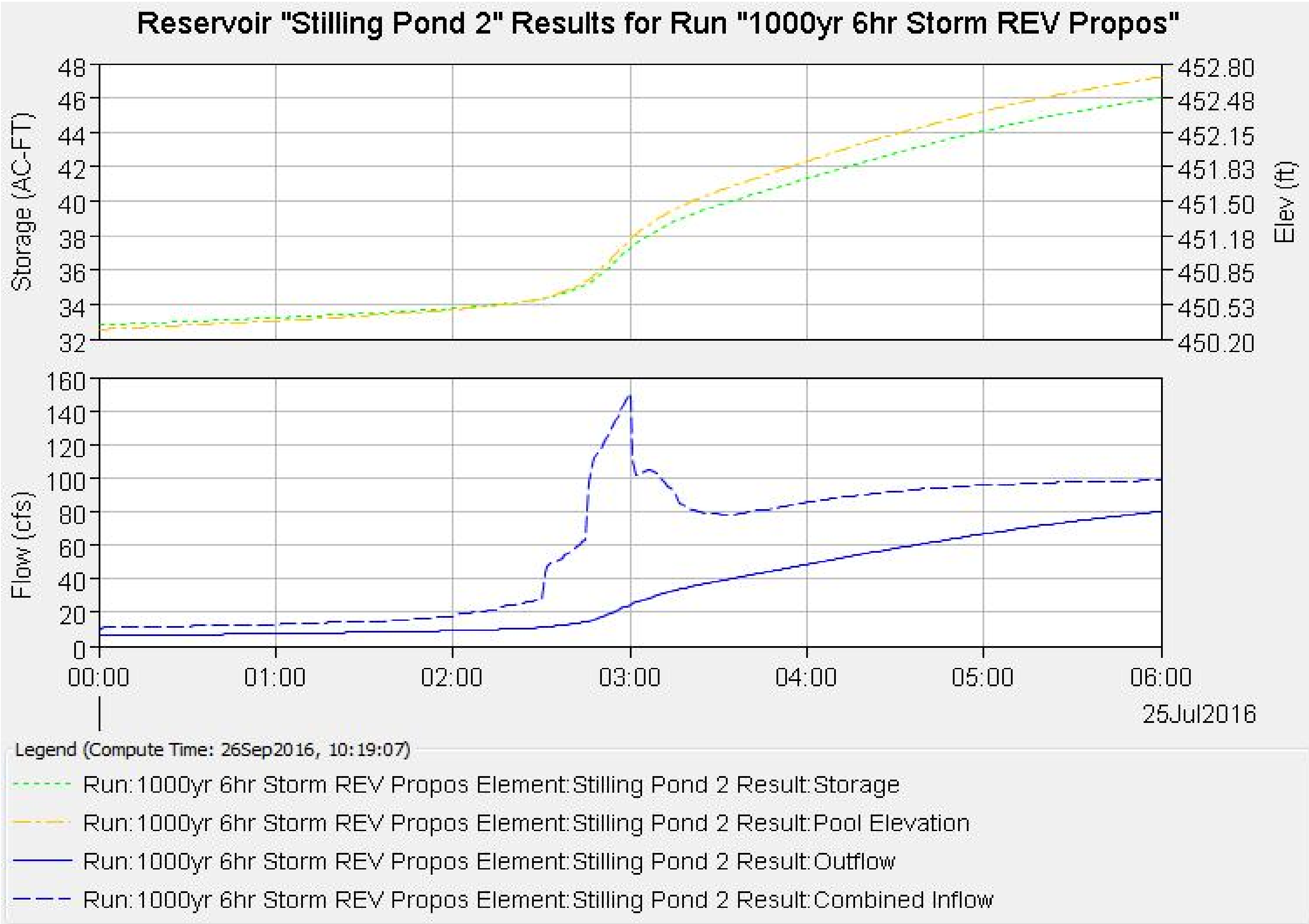
Start of Run:	25Jul2016, 00:00	Basin Model:	Gypsum Disposal Area
End of Run:	25Jul2016, 06:00	Meteorologic Model:	1000yr 6hr
Compute Time:	26Sep2016, 10:19:07	Control Specifications:	6hr

Volume Units: (●) IN ( ) AC-FT

Computed Results

Peak Inflow:	736.0 (CFS)	Date/Time of Peak Inflow:	25Jul2016, 03:35
Peak Discharge:	94.4 (CFS)	Date/Time of Peak Discharge:	25Jul2016, 06:00
Inflow Volume:	5.61 (IN)	Peak Storage:	135.7 (AC-FT)
Discharge Volume:	1.10 (IN)	Peak Elevation:	481.3 (FT)

Stilling Pond 2
1000yr 6hr



Stilling Pond 2
1000yr 6hr

Project: TVA_Paradise_Gypsum_Stack_B   Simulation Run: 1000yr 6hr Storm REV Propos
Reservoir: Stilling Pond 2

Start of Run:	25Jul2016, 00:00	Basin Model:	Gypsum Disposal Area
End of Run:	25Jul2016, 06:00	Meteorologic Model:	1000yr 6hr
Compute Time:	26Sep2016, 10:19:07	Control Specifications:	6hr

Volume Units: (●) IN ( ) AC-FT

Computed Results

Peak Inflow:	150.8 (CFS)	Date/Time of Peak Inflow:	25Jul2016, 03:00
Peak Discharge:	80.2 (CFS)	Date/Time of Peak Discharge:	25Jul2016, 06:00
Inflow Volume:	1.33 (IN)	Peak Storage:	46.0 (AC-FT)
Discharge Volume:	0.73 (IN)	Peak Elevation:	452.7 (FT)