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# Coal Combustion Residuals Unit History of Construction

## Richmond Power & Light
## Whitewater Valley Station
## Surface Impoundment
## Wayne County, Indiana

GAI Project Number: C151119.07

April 2018

RICHMOND POWER & LIGHT

Prepared by: GAI Consultants, Inc.
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Prepared for: Richmond Power & Light
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P.O. Box 908
Richmond, Indiana 47374

# Table of Contents

# Certification/Statement of Professional Opinion

This History of Construction (HOC) for the Whitewater Valley Power Station Surface Impoundment was prepared by GAI Consultants, Inc. (GAI). The Report may contain findings and determinations that are based on certain information that, other than for information GAI originally prepared, GAI has relied on but not independently verified. This Certification/Statement of Professional Opinion is therefore limited to the information available to GAI at the time the Assessment was written. On the basis of and subject to the foregoing, it is my professional opinion as a Professional Engineer licensed in the State of Indiana that the Assessment has been prepared in accordance with good and accepted engineering practices as exercised by other engineers practicing in the same discipline(s), under similar circumstances, at the same time, and in the same locale. It is my professional opinion that the Assessment was prepared consistent with the requirements of § 257.73(c)(1) of the United States Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments," published in the Federal Register on April 17, 2015 with an effective date of October 19, 2015 (40 CFR 257 Subpart D), and meeting the provisions of the "Extension of Compliance Deadlines for Certain Inactive Surface Impoundments: Response to Partial Vacatur," effective October 4, 2016.

The use of the words "certification" and/or "certify" in this document shall be interpreted and construed as a Statement of Professional Opinion and is not and shall not be interpreted or construed as a guarantee, warranty or legal opinion.

GAI Consultants, Inc.

Charles F. Straley, P.E.
Senior Engineering Manager

Date Apr 17, 2018

## Acronyms

| | |
|---|---|
| CCR | Coal Combustion Residuals |
| CCR Rule | "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" 40 CFR 257 Subpart D (2015) |
| CCR Unit | Whitewater Valley Power Station Surface Impoundment |
| CFR | Code of Federal Regulations |
| CL | Clay of low plasticity, lean clay |
| EPA | United States Environmental Protection Agency |
| GAI | GAI Consultants, Inc. |
| HOC | Coal Combustion Residuals CCR History of Construction |
| Impoundment | Surface Impoundment |
| IN | Indiana |
| ML | Inorganic Silts |
| RP&L | Richmond Power & Light |
| SC | Clayey Sand |
| SM | Silty Sand |
| Station | Whitewater Valley Station |
| SWM | Stormwater Management |
| USGS | United States Geological Survey |

# 1.0 Introduction

The Whitewater Valley Station (Station) is owned by Richmond Power & Light (RP&L) and is located in Richmond, Indiana (IN). The Station consists of two generating units, which are capable of producing a combined 100 megawatts of electricity.

Coal Combustion Residuals (CCR) generated at the Station were placed in the CCR Surface Impoundment Disposal Impoundment (Impoundment), which is located on the western side of the Station's property (center coordinates 39° 48' 12.9" North and 84° 53' 54.8" West). The Impoundment location is shown on the United States Geological Survey (USGS) 7.5-Minute Topographic Quadrangle Map (see Drawing A2-001).

The Impoundment is currently inactive. The original purpose of the Impoundment was to receive CCR generated at the Station and waste materials collected primarily because of general house-cleaning maintenance and/or repair at the Station. The state identification number for the Impoundment is 89-UP-04.

The Impoundment is regulated as an existing CCR surface impoundment under the Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" [40 CFR 257 Subpart D] published in the Federal Register on April 17, 2015 with an effective date of October 19, 2015 (CCR Rule), and meeting the provisions of the "Extension of Compliance Deadlines for Certain Inactive Surface Impoundments: Response to Partial Vacatur," effective October 4, 2016.

# 2.0 Purpose

This History of Construction (HOC) is prepared pursuant to § 257.73(c)(1) of the CCR Rule [40 CFR § 257.73(c)(1)]. In this document the CCR Unit is identified as the Impoundment.

# 3.0 History of Construction

As required by § 257.73(c)(1), this HOC includes, to the extent feasible:

- The name and address of the person(s) owning or operating the CCR Unit; the name associated with the CCR Unit; and the identification number of the CCR Unit if one has been assigned by the state;
- The location of the CCR Unit identified on the most recent USGS 7-1/2 minute or 15 minute topographic quadrangle map, or a topographic map of equivalent scale if a USGS map is not available;
- A statement of the purpose for which the CCR Unit is being used;
- The name and size in acres of the watershed within which the CCR Unit is located;
- A description of the physical and engineering properties of the foundation and abutment materials on which the CCR Unit is constructed;
- A statement of the type, size, range, and physical and engineering properties of the materials used in constructing each zone or stage of the CCR Unit; the method of site preparation and construction of each zone of the CCR Unit; and the approximate dates of construction of each successive stage of construction of the CCR Unit;
- At a scale that details engineering structures and appurtenances relevant to the design, construction, operation, and maintenance of the CCR Unit, detailed dimensional drawings of the CCR Unit, including a plan view and cross sections of the length and width of the CCR Unit, showing all zones, foundation improvements, drainage provisions, spillways, diversion ditches,

outlets, instrument locations, and slope protection, in addition to the normal operating pool surface elevation and the maximum pool surface elevation following peak discharge from the inflow design flood, the expected maximum depth of CCR within the CCR surface impoundment, and any identifiable natural or manmade features that could adversely affect operation of the CCR Unit due to malfunction or mis-operation;

- A description of the type, purpose, and location of existing instrumentation;
- Area-capacity curves for the CCR Unit;
- A description of each spillway and diversion design features and capacities and calculations used in their determination;
- The construction specifications and provisions for surveillance, maintenance, and repair of the CCR Unit; and
- Any record or knowledge of structural instability of the CCR Unit.

The above requirements are addressed in Sections 3.1 through 3.12 of this HOC.

## 3.1 Impoundment (CCR Unit)

The Impoundment, located at the Station, is owned and maintained by Richmond Power & Light:

Richmond Power & Light
2000 U.S. Highway 27 South
P.O. Box 908
Richmond, Indiana 47374

The contact information for RP&L is:

Mr. Randall W. Baker
General Manager
Richmond Power & Light
2000 U.S. Highway 27 South
P.O. Box 908
Richmond, Indiana 47374

The Station is operated by:

Indiana Municipal Power Agency
2000 U.S. Highway 27 South
Richmond, Indiana 47374

The Surface Impoundment discharge is permitted as a Non-categorical industrial discharge through the Richmond Sanitary District. The Indiana Department of Environmental management (IDEM) identification number for the Impoundment is 89-UP-04.

## 3.2 Location Map

The Impoundment location is shown on 2016 US Geological Survey (USGS) mapping and is included in this HOC (see Drawing A2-001).

## 3.3 Purpose of Impoundment (CCR Unit)

The Impoundment was originally constructed to receive CCR material generated at the Station along with waste materials collected primarily because of general house-cleaning maintenance and/or repair at the Station. The Impoundment is currently inactive, meaning no new CCR materials are added to the Impoundment. The Impoundment does receive stormwater runoff from adjacent upgradient areas.

## 3.4 Watershed

The Impoundment is located in the Whitewater Watershed (USGS Hydrologic Unit Code 05080003). The watershed area is 1,474 square miles (United States Department of Agriculture, 2013). This corresponds to 943,108 acres. The current direct contributory watershed to the Impoundment is approximately 26 acres.

## 3.5 Foundation and Abutment Materials

The Impoundment is underlain by Ordovician-aged bedrock of the Whitewater Formation, which consists primarily of rubbly blue-gray limestone and interbedded calcareous shale. The formation is located along the Whitewater River in Wayne County (GAI Consultants, August 2016).

According to the United States Department of Agriculture, Natural Resources Conservation Service's Web Soil Survey, loamy orthents are the primary surficial soils situated in the Impoundment vicinity. Loamy orthents are considered to be a skeletal soil (GAI Consultants, August 2016). The surficial soil at the interface between the Impoundment embankment and natural ground (abutment) is expected to be of this type.

Boring data show that the material beneath and adjacent to the Impoundment consists of clays, sands, and gravels classified as Inorganic Silts (ML), Silty Sand with Inorganic Silts (SM-ML), and Silty Sand (SM). Bedrock was encountered at an approximate elevation range of 908.5 feet to 956.5 feet at the project location. The top of underlying bedrock varies in depth of approximately 14 to 72 feet below the ground surface (GAI Consultants, September 2016).

Table 1 indicates the properties for the material beneath the Impoundment, which is a generalization of available information gathered (GAI Consultants, August 2016).

**Table 1**
**Impoundment Foundation Soil Properties**

| Soil Name | Classification | Moist Unit Weight (pounds per cubic foot) | Cohesion (pounds per square foot) | Drained Friction Angle (degrees) |
|---|---|---|---|---|
| Silty Sand | SM | 125 | 0 | 28 |

## 3.6 Impoundment (CCR Unit) Properties and Construction Details

Portions of the Impoundment embankment were constructed from surficial soils situated in the area of the Impoundment, which have been classified as loamy orthents (GAI Consultants, August 2016). Additional information was obtained from a subsurface investigation (GAI Consultants, August 2016). The investigation indicated that the Impoundment's western embankment was constructed partially with CCR. The CCR material found below soil fill is an indication that the impoundment may have been increased in size in the past by raising the impoundment dike at least partially on top of the previously placed CCR material. Table 2 presents the embankment fill properties as determined from the investigation.

**Table 2**
**Impoundment Embankment Fill Properties**

| Soil Name | Classification | Moist Unit Weight (pounds per cubic foot) | Cohesion (pounds per square foot) | Drained Friction Angle (degrees) |
|---|---|---|---|---|
| Sandy Lean Clay | CL | 130 | 50 | 28 |
| CCR Material | SM* | 90 | 0 | 19 |

* - Based on Grain Size

The Station was constructed beginning in 1953 and began generating electricity in 1955. Aerial photography from 1955 depicts the Impoundment, which appears to be partially incised. As of 1955, the Impoundment footprint appears smaller than that of the present day. Little detailed information is available on the Impoundment design and construction, including that of the embankment.

GAI estimated the impoundment bottom was between approximate elevations 975 and 965 feet above mean sea level, depending on the location within the Impoundment (GAI Consultants, September 2016). The embankment crest elevation is approximately 985 feet above mean sea level (Beals and Moore, 2016). The Impoundment area is approximately 14 acres.

A stormwater management (SWM) pond was constructed in the northern portion of the Impoundment, with an internal embankment constructed to separate the SWM pond from the Impoundment. Gravel drains were constructed within the internal embankment to direct Impoundment flow to the SWM pond.

## 3.7 Detailed Drawings

Detailed drawings of the site are provided in this HOC. The drawings include:

- Plan View; and
- Cross Sections based on Boring information

## 3.8 Existing Instrumentation

No instrumentation is present at the Impoundment.

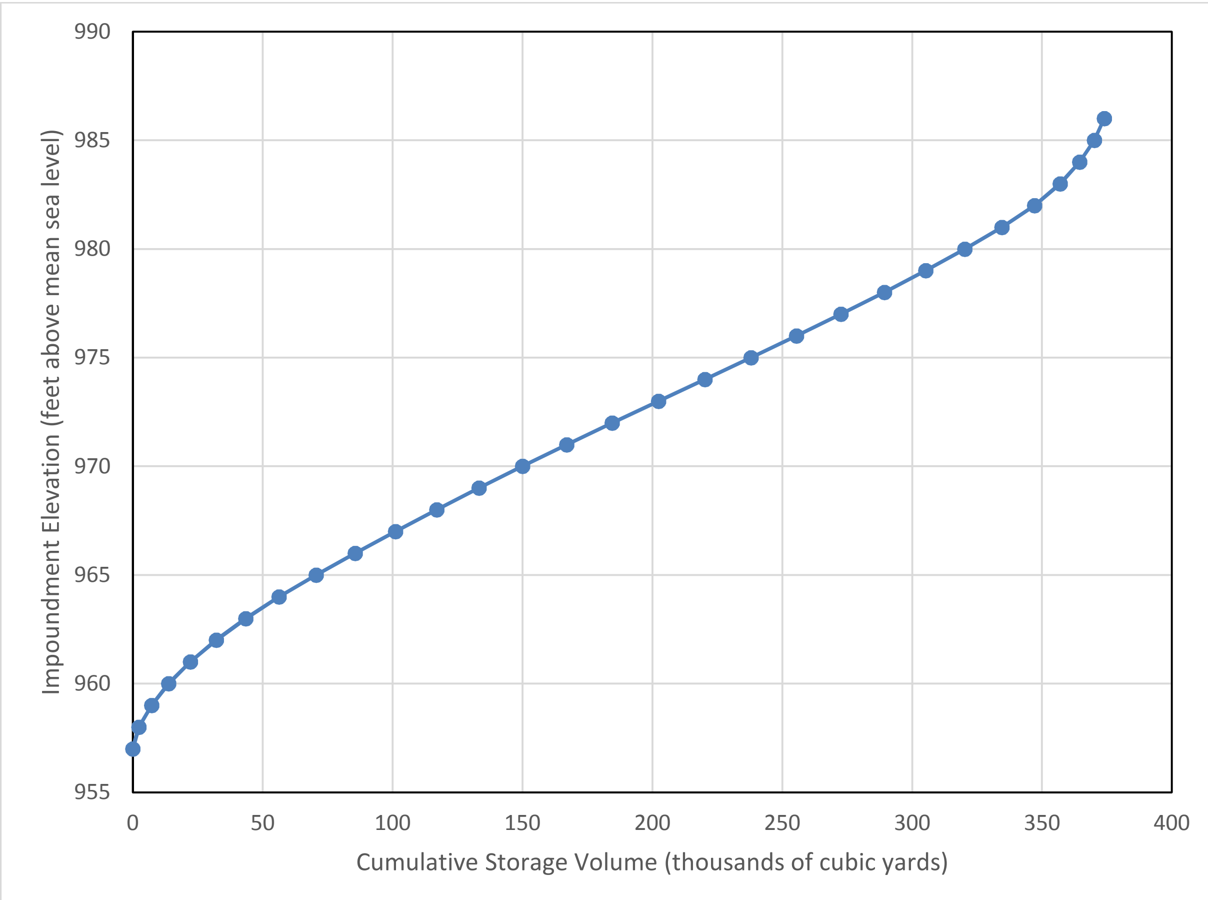
## 3.9 Area Capacity Curves

Based on the historical documentation reviewed, the stage-storage for the Impoundment was not available. The stage-storage was estimated based on the depth of CCR measured in borings (GAI Consultants, August 2016) and the current Impoundment topography. As the Impoundment has been inactive since 2015, no further CCR placement is anticipated, and therefore this represents the estimated maximum volume of disposed CCR.

**Figure 1**

**Impoundment Stage-Storage Capacity Curve**

**(based on limited available information)**




## 3.10 Spillway and Diversion Features

No diversion features are currently in place for the Impoundment. Runon from adjacent watersheds is limited to the immediately upgradient areas (approximately 8 acres).

Discharge from the Impoundment occurs via three gravel drains that discharge into the SWM Pond (stormwater can also overflow the internal embankment to the SWM Pond during high flow events). The water collected in the SWM Pond will then travel over a Spillway and into Station Pond P4. From Pond P4, the water is discharged to the local municipality-owned Richmond Sanitary District.

Spillway and other internal hydraulic structures capacity calculations are included within Appendix A.

## 3.11 Construction Specifications and Provisions for Surveillance, Maintenance, and Repair

No construction specifications are available for the Impoundment.

RP-L performs weekly, monthly, and annual inspections of the Impoundment in accordance with the requirements of the CCR Rule. Repairs are addressed if needed based on the inspection observations.

## 3.12 Record or Knowledge of Structural Instability

There is no record or knowledge at this time that would suggest structural instability.

# 4.0 References

Beals-Moore and Associates, Inc. 2016. *Beals and Moore Impoundment Survey*.

GAI Consultants, Inc. August 2015. *Plan of Borings – As Drilled.*

GAI Consultants, Inc. September and October 2015. *Field Boring Logs.*

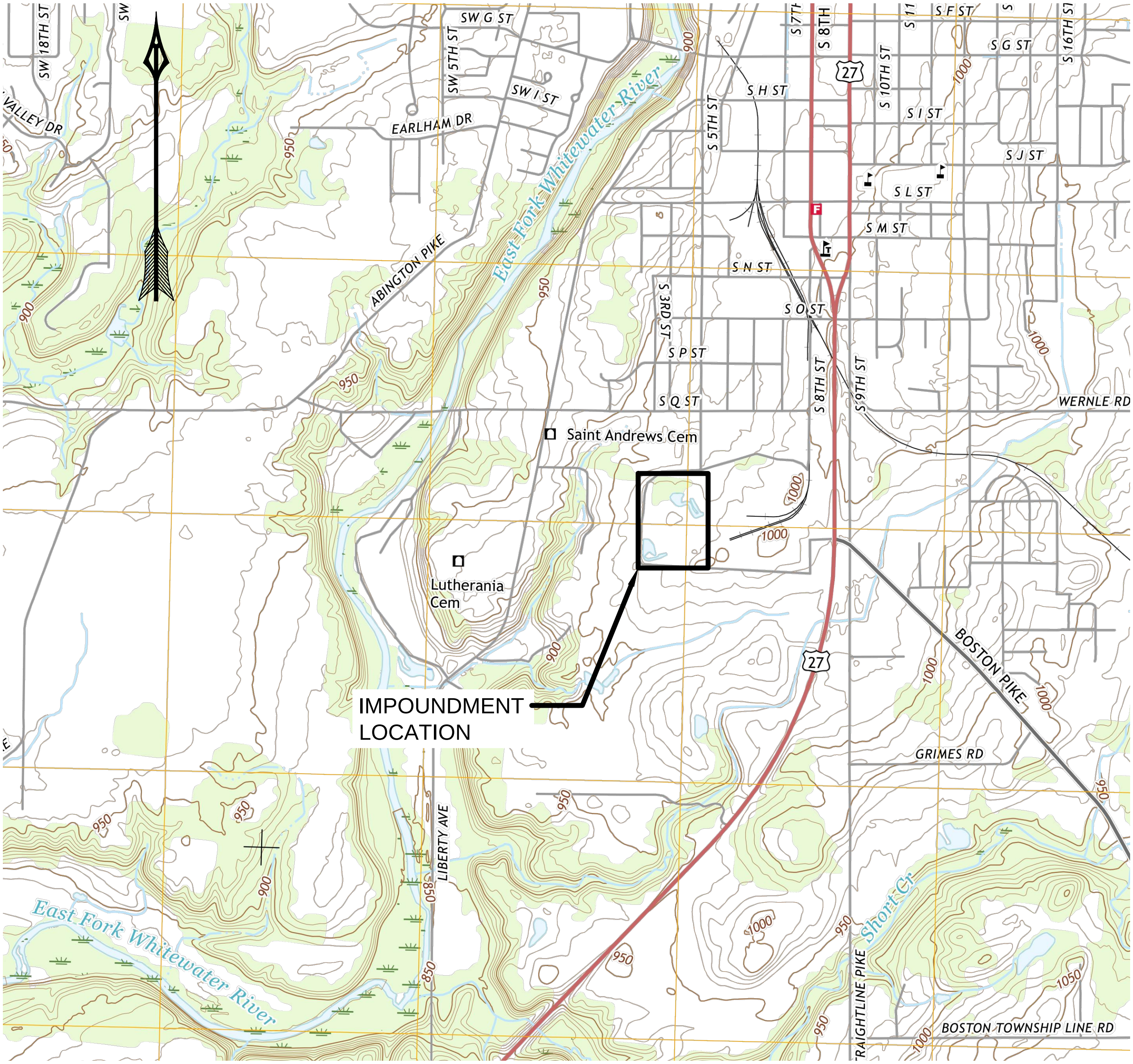
GAI Consultants, Inc. August 2016. *Geotechnical Summary Report.*

GAI Consultants, Inc. September 2016. *Groundwater Characterization Report.*

NPDES Permit No. IN0063151. *Authorization to Discharge Under the National Pollutant Discharge Elimination System*, July 2013.

United States Department of Agriculture, Natural Resources Conservation Service. Winter 2013. *Whitewater Watershed 12 Digit HUCs.*

# DRAWINGS




MAP REFERENCE:
RICHMOND, IN 7.5 MINUTE
QUADRANGLE DATED 2014
PHOTO REVISED 2016

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2000 0 2000 4000

DRAWING TITLE
## SITE LOCATION MAP

PROJECT
**WHITEWATER VALLEY IMPOUNDMENT**
**HISTORY OF CONSTRUCTION**

CLIENT
**RICHMOND POWER AND LIGHT COMPANY**
**RICHMOND, INDIANA**

gai consultants

GAI DRAWING NUMBER: **A2-001**

GAI FILE NUMBER: **C151119-07-002-001-A2-001**

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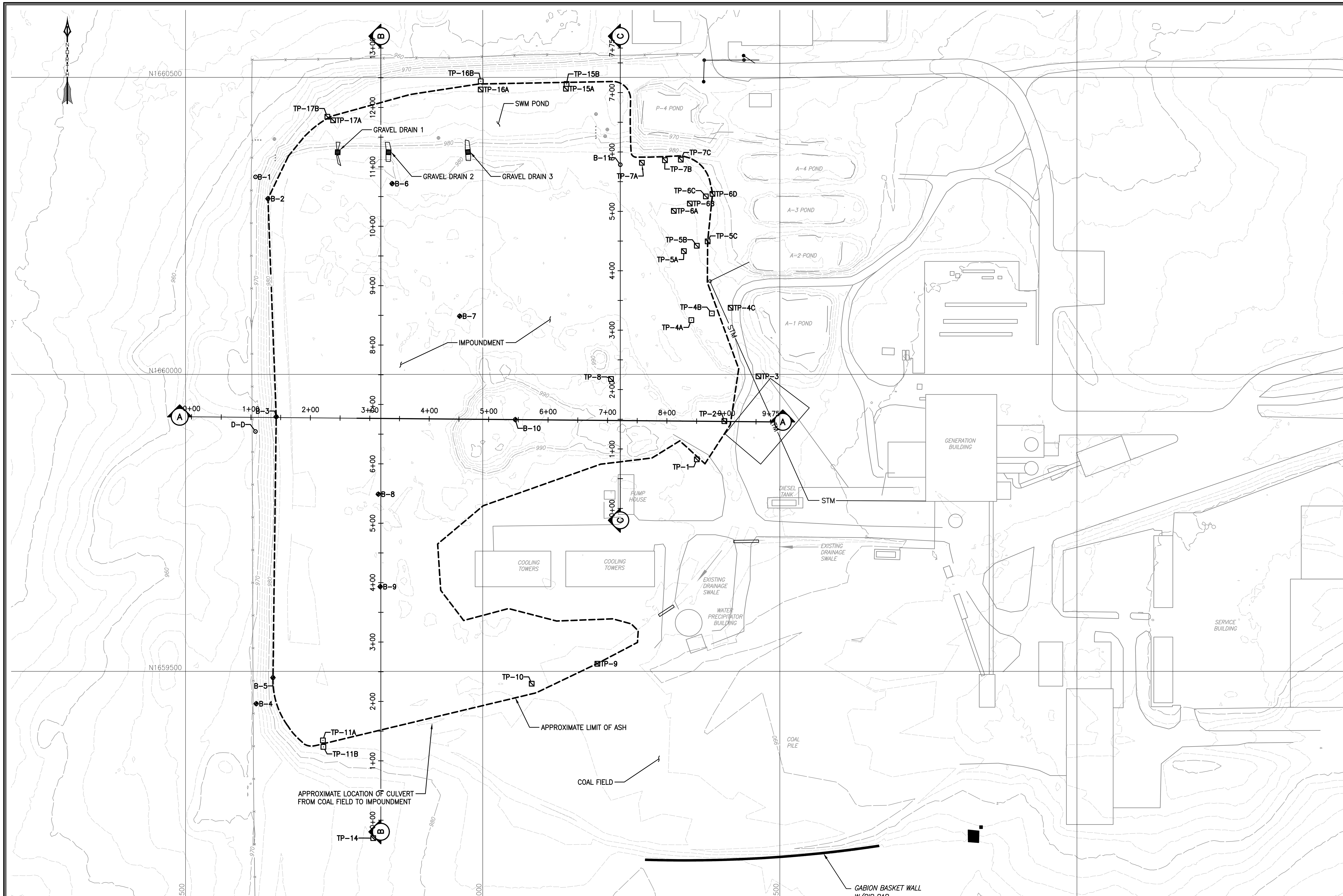


REFERENCE:
2012 INDIANA STATEWIDE IMAGERY AND LIDAR PROGRAM
1-FOOT PIXEL RESOLUTION ORTHOIMAGERY; AND
2-FOOT CONTOUR INTERVALS LINES DEVELOPED FROM 1.5 METER NPS BARE EARTH LIDAR.

SURVEY PROVIDED BY BEALS-MOORE & ASSOCIATES,INC. DATED JANUARY 17TH 2016

LEGEND:

- APPROXIMATE LIMIT OF ASH
- TP-2 SURVEYED TEST PIT LOCATION
- TP-11 APPROXIMATE TEST PIT LOCATION
- B-3 SURVEYED BORING LOCATION
- B-1 APPROXIMATE BORING LOCATION

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REVISION RECORD
SHEET NO.: 1 OF 4
ALT./CLIENT DRAWING NUMBER:
REVISION

DRAWING TITLE
IMPOUNDMENT PLAN VIEW

CLIENT
RICHMOND POWER AND LIGHT
RICHMOND, INDIANA

gai consultants

PROJECT
CCR RULE COMPLIANCE-RP&L
WHITEWATER VALLEY STATION
WAYNE COUNTY
RICHMOND, INDIANA 47374

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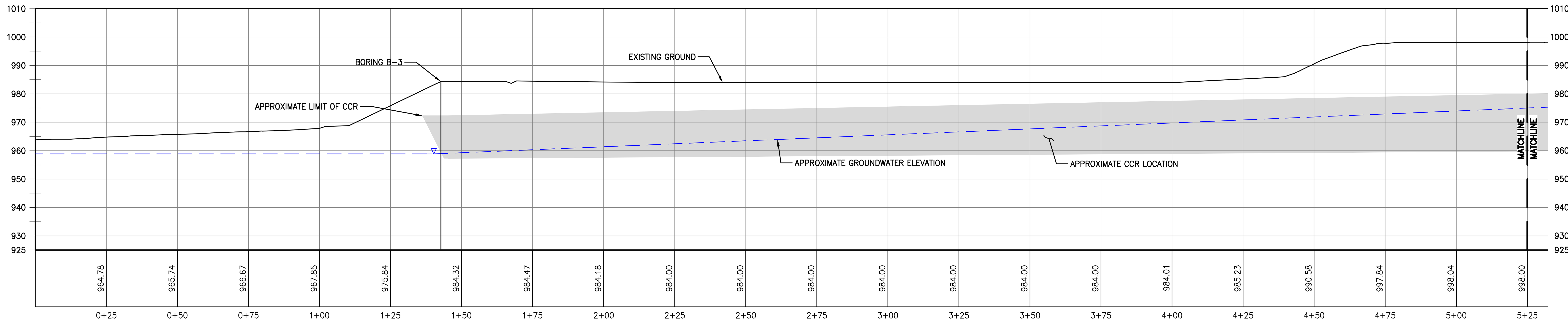


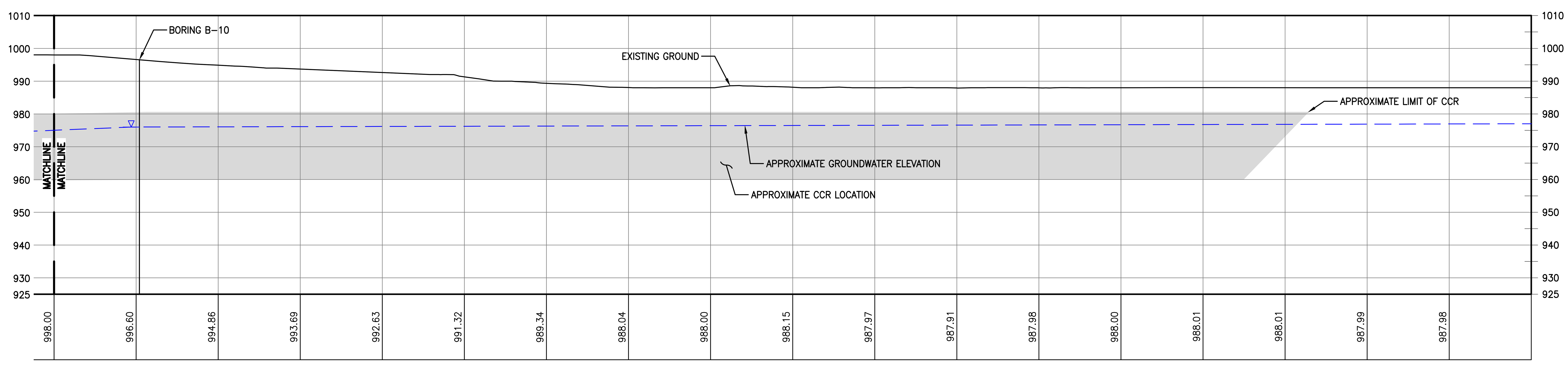


## SECTION A

NOTES:

1. INFORMATION SHOWN IS APPROXIMATED FROM EXISTING TOPOGRAPHY, TEST PIT DATA, AND BORING DATA. BORINGS ARE FROM SEPTEMBER AND OCTOBER 2015.
2. THE APPROXIMATE CCR LOCATION SHOWN REPRESENTS THE MAXIMUM CCR PLACEMENT THAT WILL OCCUR IN THE IMPOUNDMENT.

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REVISION RECORD

REVISION

ALT./CLIENT DRAWING NUMBER:

SHEET NO.: 2 OF 4

GAI FILE NUMBER: C151119-07-002-C-D1-001

DRAWING TITLE
**CROSS SECTIONS**

CLIENT
**RICHMOND POWER AND LIGHT**
**RICHMOND, INDIANA**

gai consultants

PROJECT
**CCR RULE COMPLIANCE-RP&L**
**WHITEWATER VALLEY STATION**
**WAYNE COUNTY**
**RICHMOND, INDIANA 47374**

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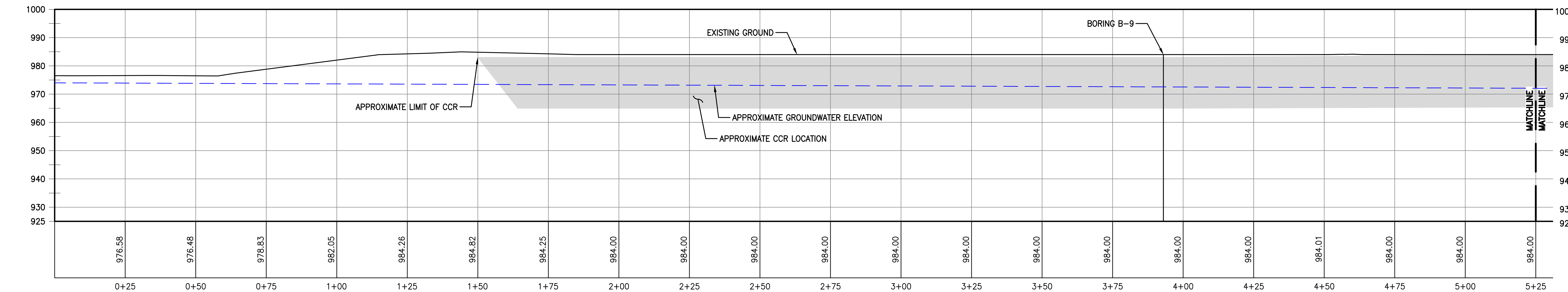


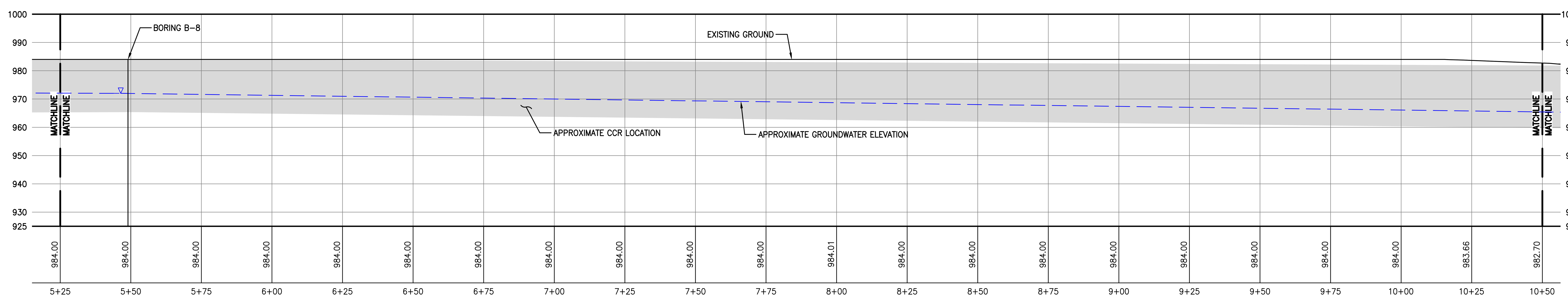


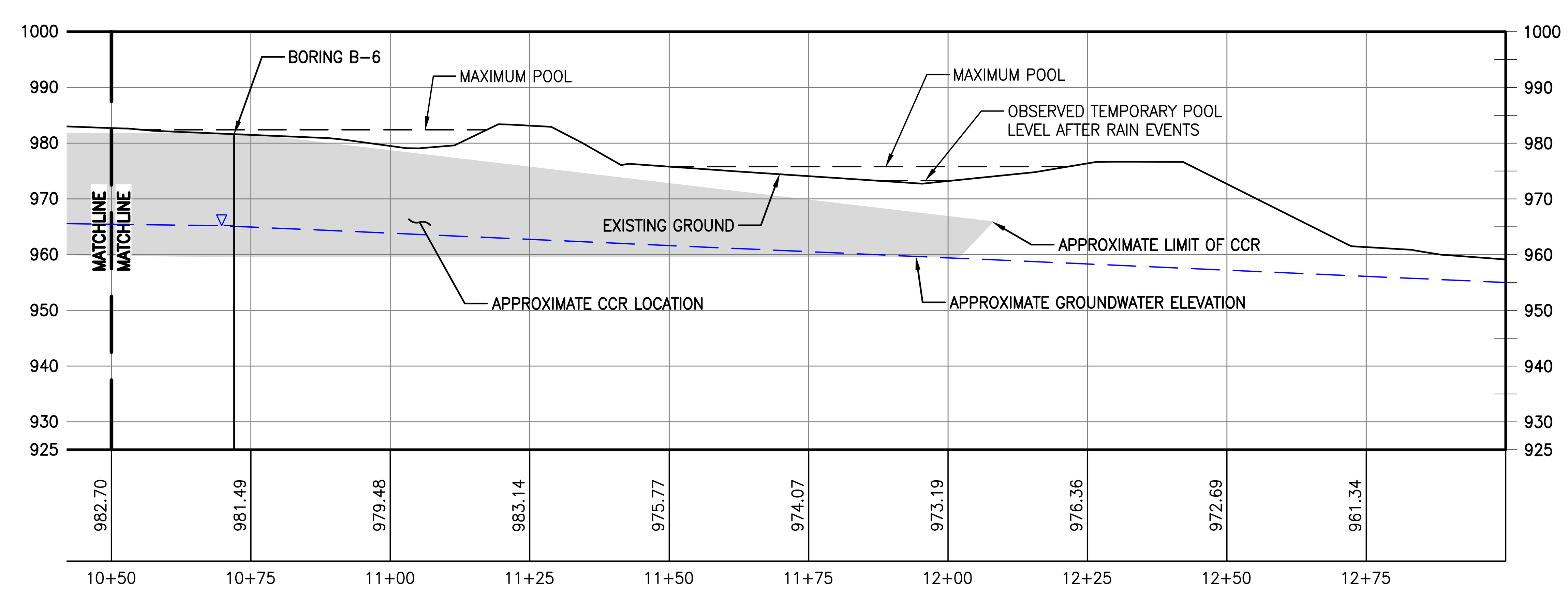


SECTION B

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PROJECT

CCR RULE COMPLIANCE-RP&L
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WAYNE COUNTY
RICHMOND, INDIANA 47374

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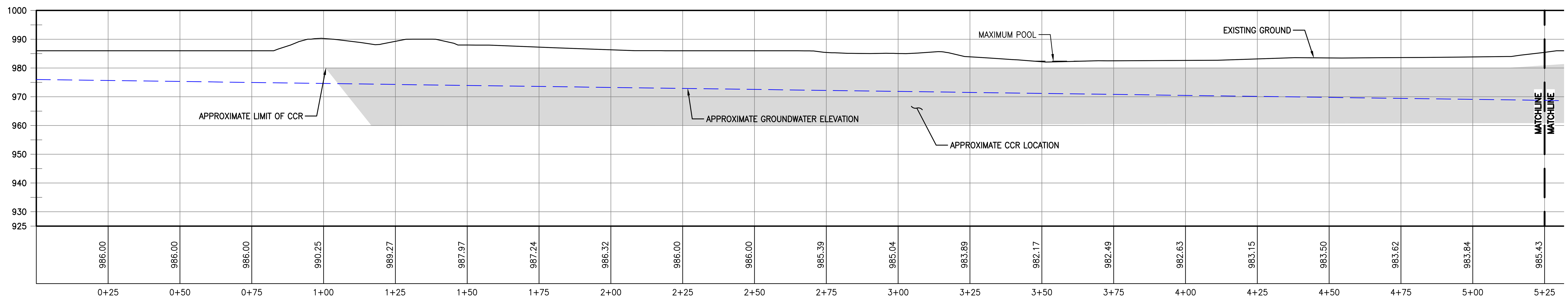


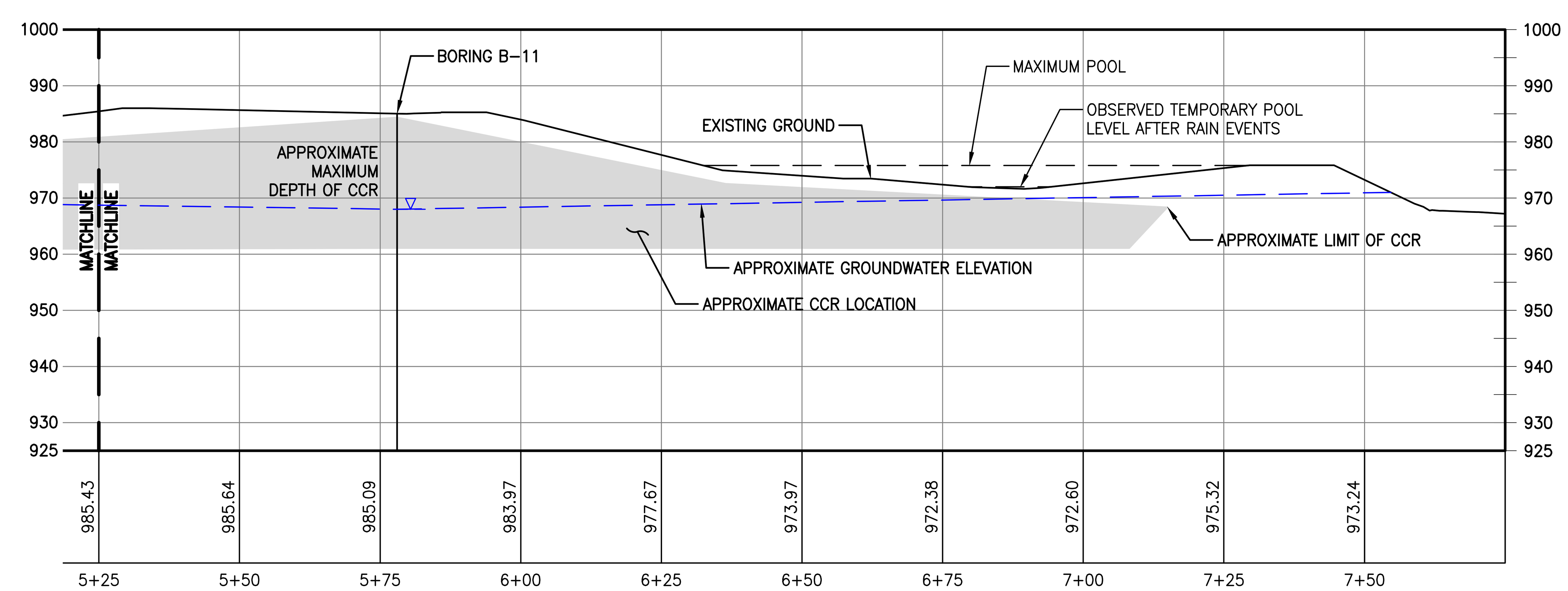


SECTION C

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1. INFORMATION SHOWN IS APPROXIMATED FROM EXISTING TOPOGRAPHY, TEST PIT DATA, AND BORING DATA. BORINGS ARE FROM SEPTEMBER AND OCTOBER 2015.

2. THE APPROXIMATE CCR LOCATION SHOWN REPRESENTS THE MAXIMUM CCR PLACEMENT THAT WILL OCCUR IN THE IMPOUNDMENT.

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REVISION RECORD

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ALT./CLIENT DRAWING NUMBER:

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GAI FILE NUMBER: C151119-07-002-C-D1-001

DRAWING TITLE

CROSS SECTIONS

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RICHMOND POWER AND LIGHT

RICHMOND, INDIANA

gai consultants

PROJECT

CCR RULE COMPLIANCE-RP&L
WHITEWATER VALLEY STATION
WAYNE COUNTY
RICHMOND, INDIANA 47374

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# APPENDIX A
## Spillway Capacity Calculations

**OBJECTIVE**

The purpose of this calculation is to determine the hydraulic and hydrologic capacity of flow into and from the existing coal combustion residuals (CCR) Surface Impoundment (Impoundment) at the Whitewater Valley Power Station in Richmond, Indiana during the Impoundment's inflow design flood event.

**METHODOLOGY**

Runoff from the contributing watersheds was calculated using methodology from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Urban Hydrology for Small Watersheds Technical Release 55 (TR-55) Type II Soil Conservation Service (SCS) 24-hour storm. Peak flow rates and hydrologic routing were calculated using Hydraflow Hydrographs 2004.

Flow through the Impoundment's internal gravel drains was calculated using Hazen's empirical formula for coefficient of permeability based on the effective grain size, and Darcy's law for flow through porous media.

**REFERENCES**

1. Beals-Moore and Associates, Inc. *Beals and Moore Survey*; 2016.
2. United States Department of Agriculture. *Urban Hydrology for Small Watersheds Technical Release 55*; June 1986.
3. United States Department of Agriculture. *Web Soil Survey - Hydrologic Soil Group Report*; retrieved March 6, 2018.

**BACKGROUND**

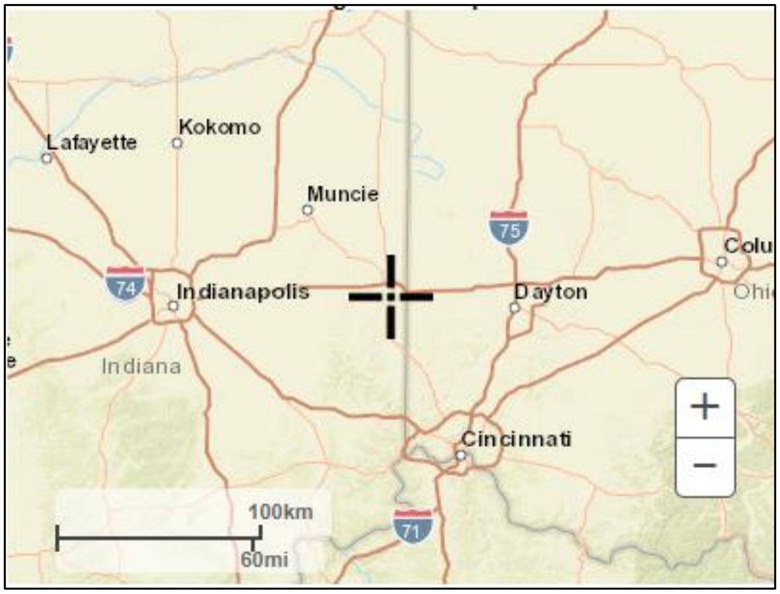
Section 257.82 of the Coal Combustion Residuals (CCR) Rule requires an Inflow Design Flood Control Plan that documents that the Impoundment adequately manages the peak discharge of the inflow design flood event. The Impoundment is classified as a significant hazard, and is therefore assigned an inflow design flood event of the 1,000-year flood by the CCR Rule.

In addition to direct rainfall within the Impoundment area, the Impoundment is incised on the southeastern side, and therefore stormwater runoff is conveyed to the Impoundment via grass swales and culverts from adjacent surfaces including vegetated areas, impervious areas, and a coal field. The Impoundment discharges to a stormwater management (SWM) pond (SWM Pond) at the northern end of the Impoundment, and ultimately to an outfall permitted as a non-categorical discharge. See Appendix A for a Watershed Map.

## CALCULATIONS

### Precipitation

From the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, the Impoundment is located at approximately the marked location:




Precipitation data for this location is as follows:

**NOAA Precipitation Data**

| PDS-based point precipitation frequency estimates with 90% confidence interval (in inches) | | | | | | |
|---|---|---|---|---|---|---|
| Duration (in hours) | Average recurrence intervals (in years) | | | | | |
| | 2 | 5 | 10 | 25 | 100 | 1000 |
| 24 | 2.82 | 3.44 | 3.92 | 4.56 | 5.56 | 7.26 |

**Site Soils and Curve Numbers**

Hydrologic soil groups were determined using data from the Web Soil Survey (USDA). The soil map is shown here:


Based on the Hydrologic Soil Group report, the "Or" symbol indicates loamy orthents, and the hydrologic soil group was not rated by the USDA. The coal field is the only area evaluated outside of the loamy orthents, and the curve number is not dependent on the hydrologic soil group. Based on the USDA's description of the Orthents in the area, the soil is well-drained. The hydrologic soil group C was assigned to vegetated areas based on the USDA drainage description combined with the overall industrial site designation.

The curve number (CN) for the watersheds was determined by using:

- CN = 98 for impervious areas
- CN = 88 for the coal field area (equivalent to "raw spoils" for disturbed surface mine areas)
- CN = 74 for good condition open vegetated space (grass cover greater than 75%) in fully developed urban areas (hydrologic soil group C)
- CN = 65 for the Impoundment and SWM Pond, approximately equivalent to poor condition brush (hydrologic soil group B) and used due to the visual observation of infiltration within the Impoundment and SWM Pond area

**Watershed Analysis**

Contributing watersheds to the Impoundment include:

- Grassy Swale (Eastern): Runoff from the coal field, grassy, and impervious areas conveyed via a grass swale to the western portion of the grassy swale;
- Grassy Swale (Western): Grassy and impervious areas runoff;
- Coal field runoff conveyed via a culvert which discharges into the Impoundment;
- Grassy and impervious areas runoff conveyed directly into the Impoundment; and
- Runoff conveyed directly into the SWM pond.

The sub-watersheds are evaluated individually. The collection swale is split into two sections, eastern and western: the eastern section collects runoff from the coal field, grassy areas, and impervious areas, and discharge via a culvert to the western section, which collects additional runoff from grassy and impervious areas and discharges via a culvert to the Impoundment.

The composite curve numbers are shown here:

| | Drainage Area | Grassy Swale (Eastern) | | Grassy Swale (Western) | | Coal Field | | Impoundment (Direct Runoff) | | SWM Pond (Direct Runoff) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cover Description | Runoff CN | Area (Acres) | Product of CN x Area | Area (Acres) | Product of CN x Area | Area (Acres) | Product of CN x Area | Area (Acres) | Product of CN x Area | Area (Acres) | Product of CN x Area |
| Impervious Surfaces | 98 | 0.46 | 44.83 | 0.13 | 12.98 | 0.00 | 0.00 | 1.66 | 162.75 | 0.00 | 0.00 |
| Coal Field | 88 | 1.23 | 108.04 | 0.00 | 0.00 | 5.34 | 469.91 | 0.00 | 0.00 | 0.00 | 0.00 |
| Vegetated Space (Soil Group C) | 74 | 0.70 | 51.79 | 0.32 | 23.47 | 0.00 | 0.00 | 2.10 | 155.59 | 0.00 | 0.00 |
| Impoundment | 65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12.47 | 810.83 | 1.53 | 99.24 |
| | **TOTALS** | **2.39** | **204.66** | **0.45** | **36.45** | **5.34** | **469.91** | **16.24** | **1129.18** | **1.53** | **99.24** |
| | **CN (WEIGHTED)** | **85.8** | | **81.1** | | **88.0** | | **69.5** | | **65.0** | |

**Time of Concentration (Flow Path)**

For the sub-watersheds that are relatively small, assume a time of concentration of 5 minutes, the minimum required for the TR-55 method. The calculated times of concentration for the coal field and impoundment sub-watersheds are shown on the following pages. The approximate physical dimensions of the channel is based on aerial photography.

Coal Field

| Check one: | ■ Present | ❑ Developed | ❑ Developed (Undist |
|---|---|---|---|
| **Sheet Flow** | | | |
| | Segment ID | A | |
| Surface Description (Table 3-1)........ | | Gravel | |
| Manning's Roughness Coefficient, n (table 3-1)........ | | 0.011 | |
| Flow Length, L (max. 100 feet), (ft)........ | | 100 | |
| Two-year 24-hour Rainfall, $P_2$ (in)........ | | 2.82 | |
| Land Slope, s (ft/ft)........ | | 0.04 | |
| Travel Time, $T_t = (0.007*(n*L)^{0.8}) / (P_2^{0.5}*s^{0.4})$, (hrs)..... | | **0.0163** | |
| **Shallow Concentrated Flow** | | | |
| | Segment ID | B | |
| Surface Description (Paved (P) / Unpaved (U))........ | | Unpaved | |
| Surface Description Coefficient, C (P: 20.3282, U: 16.1345 | | 16.1345 | |
| Flow Length, L (ft)........ | | 229 | |
| Watercourse Slope, s (ft/ft)........ | | 0.01 | |
| Average Velocity, V = C*s^0.5 (ft/sec)........ | | 1.85 | |
| Travel Time, Tt = (L) / (3600*V), (hrs)........ | | **0.0345** | |
| **Channel Flow** | | | |
| | Segment ID | C | |
| Section Base, b........ | | 1 | |
| Section Depth, d........ | | 1 | |
| Section Side Slope, z........ | | 1.5 | |
| Cross Sectional Flow Area, $a = b*d + z*d^2$........ | | 2.5 | |
| Wetted Perimeter, $p_w = b + (2*d)*(z^2 + 1)^{0.5}$........ | | 4.61 | |
| Hydraulic Radius, $r = a / p_w$........ | | 0.54 | |
| Channel Slope, s........ | | 0.01 | |
| Manning's Roughness Coefficient, n........ | | 0.033 | |
| Average Velocity, $V = (1.49*r^{2/3}*s^{1/2}) / (n)$, (ft/sec)........ | | 3.02 | |
| Flow Length, L (ft)........ | | 605 | |
| Travel Time, $T_t$ = (L) / (3600*V), (hrs)........ | | **0.0558** | |
| **Time of Concentration** | | | |
| Sheet Flow $T_t$........ | | 0.0163 | hrs |
| Shallow Concentrated Flow $T_t$........ | | 0.0345 | hrs |
| Channel Flow $T_t$........ | | 0.0558 | hrs |
| Time of Concentration, $T_c$........ | | **0.1066** | **hrs** |
| | | **6.4** | **mins** |

For the impoundment, the time of concentration is taken using an existing, observed drainage path within the impoundment. The path is assumed to be a channelized flow feature split into two segments due to changes in channel slope: Segment A conveys stormwater into and through a small pool area, and Segment B conveys stormwater from the pool area to the gravel drains. The approximate physical dimensions of the channels are based on aerial photography.

Impoundment

| Check one: | ■ Present | ❑ Developed | ❑ Developed (Undist |
|---|---|---|---|

**Sheet Flow**

| | | |
|---|---|---|
| Segment ID | - | |
| Surface Description (Table 3-1)........................................ | Gravel | |
| Manning's Roughness Coefficient, n (table 3-1)................ | 0 | |
| Flow Length, L (max. 100 feet), (ft)................................. | 0 | |
| Two-year 24-hour Rainfall, $P_2$ (in)................................... | 2.82 | |
| Land Slope, s (ft/ft)........................................................ | 0.00 | |
| Travel Time, $T_t = (0.007*(n*L)^{0.8}) / (P_2^{0.5}*s^{0.4})$, (hrs)..... | **0.0000** | |

**Shallow Concentrated Flow**

| | | |
|---|---|---|
| Segment ID | - | |
| Surface Description (Paved (P) / Unpaved (U)).................. | Unpaved | |
| Surface Description Coefficient, C (P: 20.3282, U: 16.1345 | 16.1345 | |
| Flow Length, L (ft)........................................................... | 0 | |
| Watercourse Slope, s (ft/ft)............................................ | 0.00 | |
| Average Velocity, V = C*s^0.5 (ft/sec)............................ | 0.00 | |
| Travel Time, Tt = (L) / (3600*V), (hrs)............................ | **0.0000** | |

**Channel Flow**

| | | |
|---|---|---|
| Segment ID | A | B |
| Section Base, b................................................................ | 1.5 | 4 |
| Section Depth, d.............................................................. | 1 | 1 |
| Section Side Slope, z........................................................ | 1.5 | 1.5 |
| Cross Sectional Flow Area, $a = b*d + z*d^2$...................... | 3 | 5.5 |
| Wetted Perimeter, $p_w = b + (2*d)*(z^2 + 1)^{0.5}$.................. | 5.11 | 7.61 |
| Hydraulic Radius, $r = a / p_w$............................................. | 0.59 | 0.72 |
| Channel Slope, s.............................................................. | 0.003 | 0.012 |
| Manning's Roughness Coefficient, n................................. | 0.05 | 0.05 |
| Average Velocity, $V = (1.49*r^{2/3}*s^{1/2}) / (n)$, (ft/sec)......... | 1.10 | 2.63 |
| Flow Length, L (ft)........................................................... | 1471 | 322 |
| Travel Time, $T_t = (L) / (3600*V)$, (hrs)............................ | **0.3710** | **0.0340** |

**Time of Concentration**

| | | |
|---|---|---|
| Sheet Flow $T_t$.................................................................. | 0.0000 | hrs |
| Shallow Concentrated Flow $T_t$........................................... | 0.0000 | hrs |
| Channel Flow $T_t$............................................................... | 0.4050 | hrs |
| Time of Concentration, $T_c$.................................................. | **0.4050** | **hrs** |
| | **24** | **mins** |

**Coal Field Conveyance**

Flow from the majority of the coal field is conveyed to the Impoundment through a culvert, with flow in excess of the culvert capacity directed both into the Impoundment and to a slope to the southwest. A natural swale/channel is formed along this slope by the existing ground/Impoundment embankment and shown below:


The capacity of this channel was assessed to determine its ability to convey stormwater without eroding. The existing channel dimensions (area, wetted perimeter) were taken from survey data provided by Beals-Moore and Associates, Inc. (2016) and used to determine capacity and shear stress at the 1000-year storm depth:

| Channel | Southwest Channel |
|---|---|
| Design Storm | 1000-year, 24-hour |
| Protective Lining | Grass |
| Flow Depth (ft) | 0.37 |
| Area (square feet) | 18.9 |
| Wetted Perimeter (ft) | 85.1 |
| Hydraulic Radius (ft) | 0.22 |
| Slope | 0.034 |
| Vegetative Lining Retardance | N/A |
| Manning's n | 0.0350 |
| Velocity at Flow Depth (ft/s) | 2.87 |
| Flow at Flow Depth (cfs) | 54.2 |
| Required Capacity (cfs) | 53.2 |
| Minimum Required Freeboard (ft) | 0.00 |
| Total Depth Required (ft) | 0.37 |
| Actual Depth (ft) | 0.34 |
| Allowable Velocity (ft/s) | 5.00 |
| Actual Velocity (ft/s) | 2.87 |
| Shear Stress at Flow Depth (lb /sf) | 0.78 |
| Safety Factor | 1.00 |
| Shear Stress with SF (lb/sf) | 0.78 |
| Max. Allowable Shear Stress (lb/sf) | 1.00 |
| Froude Number | 0.47 |
| Lining OK? | YES |

The channel is capable of conveying the overflow from the coal field within the allowable velocity and shear stress, and therefore is not anticipated to erode during the 1000-year storm event.

For the purposes of modeling the Impoundment, it is assumed all stormwater collected within the coal field is conveyed to the Impoundment by overtopping the road.

**Impoundment Storage and Conveyance**

The Impoundment stage-storage is based on survey data provided by Beals-Moore and Associates, Inc. (2016). Stage-storage is as follows:

| Impoundment | | | |
|---|---|---|---|
| Elevation (ft) | Area (sq ft) | Incremental Volume (cu ft) | Cumulative Volume (cu ft) |
| 978 | 150 | - | - |
| 979 | 200 | 175 | 175 |
| 980 | 1,656 | 928 | 1,103 |
| 981 | 4,757 | 3,207 | 4,310 |
| 982 | 16,416 | 10,587 | 14,896 |
| 983 | 58,854 | 37,635 | 52,531 |
| 984 | 132,936 | 95,895 | 148,426 |

The Impoundment drains to the SWM Pond through three gravel drains in the northern embankment. The crest at the northern embankment is lower than at the rest of the Impoundment, allowing runoff overtopping the drains to be controlled and conveyed to the SWM Pond.

The calculations for conveyance through the gravel drains are included below. The coefficient of permeability for the stone for all gravel drains is based on the equation by Hazen for relating coefficient of permeability to effective grain size. For constant C, the average value was used (1), and based on photographs of the area, gradation is assumed to be similar to AASHTO No. 8:

| **Coefficient of Permeability - Stone** | | | |
|---|---|---|---|
| Equation: | k = C * (D10)^2 | | |
| | | | |
| Values: | C (constant) | 1 | - |
| | D10 (10% particles less than this diameter) | 4.76 | mm |
| | | | |
| Result: | k (Permeability) | 22.7 | cm/s |

The flow through the gravel drains is based on Darcy’s law for flow through porous media. The length is measured from the upstream midpoint to the downstream midpoint (except for Gravel Drain 1, where gravel is washed out upstream and the point is from the grate location to the downstream midpoint). The width of the drains is based on the width at the narrowest location as delineated by the surveyors. No discharge is assumed at the lowest elevation of the gravel drain as observed on the mapping.

## Gravel Drain 1 - Flow

| **Flow Through Gravel Drain** | | | |
|---|---|---|---|
| Equation: | q = k * (delta H)/L * A | | |
| | | | |
| Values: | k (Permeability) | 22.7 | cm/s |
| | L (length of french drain) | 14 | ft |
| | Width of french drain | 2.6 | ft |
| | Downstream invert (elevation) | 975.9 | el. (ft) |
| | | | |
| Results: | | | |
| Elevation (ft) | Head over invert (ft) | Area (sq ft) | Flow (cfs) |
| 978 | 2.1 | 5.5 | 0.6 |
| 979 | 3.1 | 8.1 | 1.3 |
| 980 | 4.1 | 10.7 | 2.3 |
| 981 | 5.1 | 13.3 | 3.6 |
| 982 | 6.1 | 15.9 | 5.1 |
| 983 | 7.1 | 18.5 | 7.0 |
| 983.2 | 7.3 | 19.0 | 7.4 |
| 983.4 | 7.5 | 19.5 | 7.8 |
| 983.6 | 7.7 | 20.0 | 8.2 |
| 983.8 | 7.9 | 20.5 | 8.6 |
| 984 | 8.1 | 21.1 | 9.1 |

## Gravel Drain 2 - Flow

| **Flow Through Gravel Drain** | | | |
|---|---|---|---|
| Equation: | q = k * (delta H)/L * A | | |
| | | | |
| Values: | k (Permeability) | 22.7 | cm/s |
| | L (length of french drain) | 20 | ft |
| | Width of french drain | 7 | ft |
| | Downstream invert (elevation) | 975.67 | el. (ft) |
| | | | |
| Results: | | | |
| Elevation (ft) | Head over invert (ft) | Area (sq ft) | Flow (cfs) |
| 978 | 2.3 | 16.3 | 1.4 |
| 979 | 3.3 | 23.3 | 2.9 |
| 980 | 4.3 | 30.3 | 4.9 |
| 981 | 5.3 | 37.3 | 7.4 |
| 982 | 6.3 | 44.3 | 10.4 |
| 983 | 7.3 | 51.3 | 14.0 |
| 983.2 | 7.5 | 52.7 | 14.8 |
| 983.4 | 7.7 | 54.1 | 15.5 |
| 983.6 | 7.9 | 55.5 | 16.4 |
| 983.8 | 8.1 | 56.9 | 17.2 |
| 984 | 8.3 | 58.3 | 18.1 |

**Gravel Drain 3 - Flow**

| Flow Through Gravel Drain | | | |
|---|---|---|---|
| Equation: | q = k * (delta H)/L * A | | |
| | | | |
| Values: | k (Permeability) | 22.7 | cm/s |
| | L (length of french drain) | 21 | ft |
| | Width of french drain | 7 | ft |
| | Downstream invert (elevation) | 976.2 | el. (ft) |
| | | | |
| Results: | | | |
| Elevation (ft) | Head over invert (ft) | Area (sq ft) | Flow (cfs) |
| 978 | 1.8 | 12.6 | 0.8 |
| 979 | 2.8 | 19.6 | 1.9 |
| 980 | 3.8 | 26.6 | 3.6 |
| 981 | 4.8 | 33.6 | 5.7 |
| 982 | 5.8 | 40.6 | 8.3 |
| 983 | 6.8 | 47.6 | 11.5 |
| 983.2 | 7.0 | 49.0 | 12.1 |
| 983.4 | 7.2 | 50.4 | 12.8 |
| 983.6 | 7.4 | 51.8 | 13.6 |
| 983.8 | 7.6 | 53.2 | 14.3 |
| 984 | 7.8 | 54.6 | 15.1 |

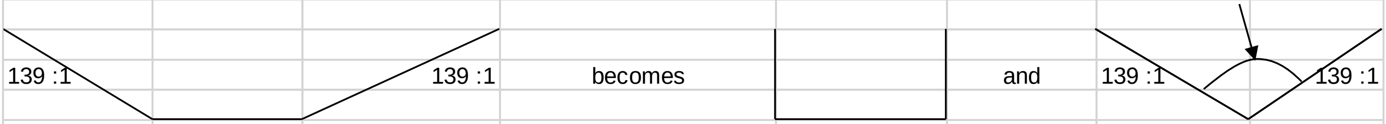
The northern embankment acts as a spillway between the Impoundment and the SWM Pond. The embankment has a low elevation 983 and extends at a shallow slope to the east (276:1), and provides containment up to elevation 984. The calculations for overflow of the northern embankment are as follows:

Evaluate the stage-discharge characteristics of the emergency spillway for the Surface Impoundment.

| | |
|---|---|
| Spillway elevation | 983 |
| Bottom width | 0 |
| Weir coefficient C | 2.8 |
| Coefficient of discharge $C_d$ | 0.622 |
| Side Slopes | 139 :1 |
| $\theta$ (degrees) | 179.18 |

Note: 276H:1V on the east; assume 2H:1V on the west.

The spillway will be divided as follows:




Flor through the rectangular section can be defined by the rectangular weir equation: $Q = C\ L\ H^{3/2}$

Flor through the triangular section can be defined by the triangular weir equation: $Q = C_d\ (8/15)\ (2g)^{1/2}\ \tan(\theta/2)\ h^{5/2}$

| Elevation (ft) | Head over spillway (ft) | Rectangular section flow (cfs) | Triangular section flow (cfs) | Total flow (cfs) | Flow Area (sf) | Spillway Velocity (ft/s) |
|---|---|---|---|---|---|---|
| 983 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| 983.2 | 0.2 | 0 | 7 | 7 | 5.6 | 1.2 |
| 983.4 | 0.4 | 0 | 38 | 38 | 22.2 | 1.7 |
| 983.6 | 0.6 | 0 | 104 | 104 | 50.0 | 2.1 |
| 983.8 | 0.8 | 0 | 213 | 213 | 89.0 | 2.4 |
| 984 | 1 | 0 | 372 | 372 | 139.0 | 2.7 |

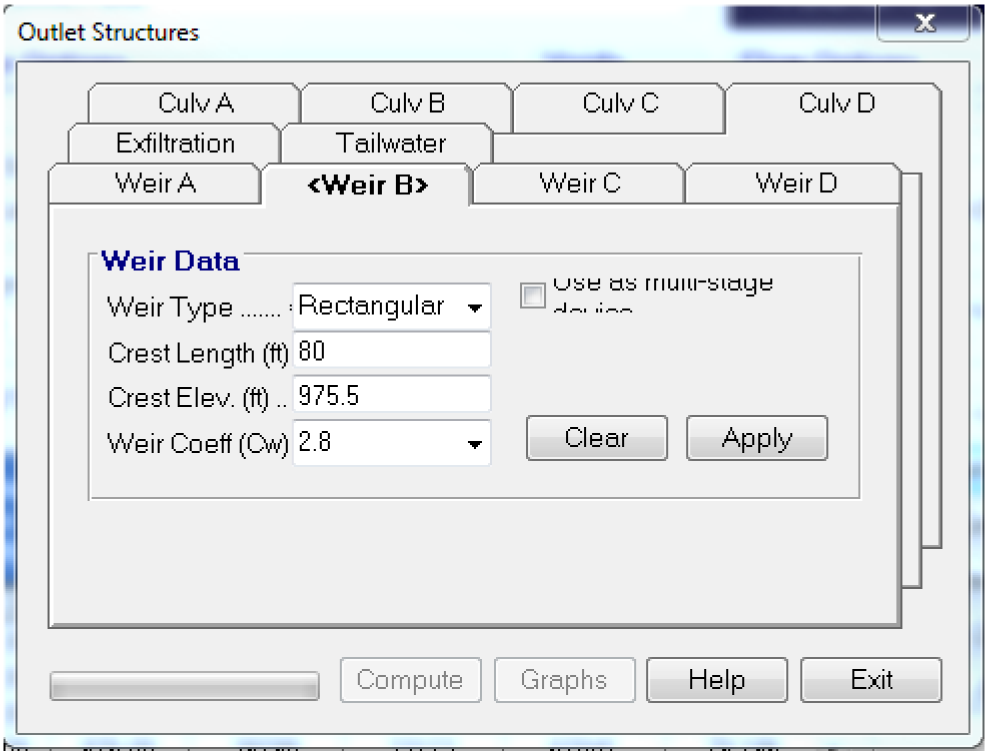
The discharge rate from the Impoundment will consist of the three gravel drains and embankment overflow.

**SWM Pond Storage and Conveyance**

The SWM Pond stage-storage is based on survey data provided by Beals-Moore and Associates, Inc. (2016). Stage-storage is as follows:

| SWM Pond (P Pond) | | | |
|---|---|---|---|
| Elevation (ft) | Area (sq ft) | Incremental Volume (cu ft) | Cumulative Volume (cu ft) |
| 972 | 118 | - | - |
| 973 | 2,731 | 1,424 | 1,424 |
| 974 | 12,654 | 7,693 | 9,117 |
| 975 | 26,948 | 19,801 | 28,918 |
| 976 | 39,298 | 33,123 | 62,041 |

The SWM Pond discharges into site Pond P4 via an overflow spillway. The spillway is approximately 80 feet wide at elevation 975.5 feet:




*The SWM Pond spillway was evaluated in Hydrographs 2004 as a rectangular weir.*

The SWM Pond is downstream of the gravel drain discharge, and the embankment height surrounding the SWM Pond (elevation 976.0 feet) is lower than the main Impoundment area. The maximum water level contained within the SWM Pond is not anticipated to affect the main Impoundment.

**Routing**

Hydrographs 2004 was used to model the stormwater runoff based on precipitation, watershed areas and curve numbers, times of concentration, calculated stage-storage, and discharge. Based on results from Hydrographs 2004, the peak flows are as follows:

| Watershed | Peak Flow, 1000-Year Storm (cfs) |
|---|---|
| Grassy Swale (Eastern) | 23.1 |
| Grassy Swale (Western) | 27.2 |
| Coal Pile | 53.2 |
| Impoundment Discharge | 65.1 |
| SWM Pond Discharge | 65.5 |

The pool levels for the 1,000-year storm are:

| Pond Name | Pool Level, 1000-Year Storm (feet above mean sea level) |
|---|---|
| Impoundment | 983.4 |
| SWM Pond | 976.0 |

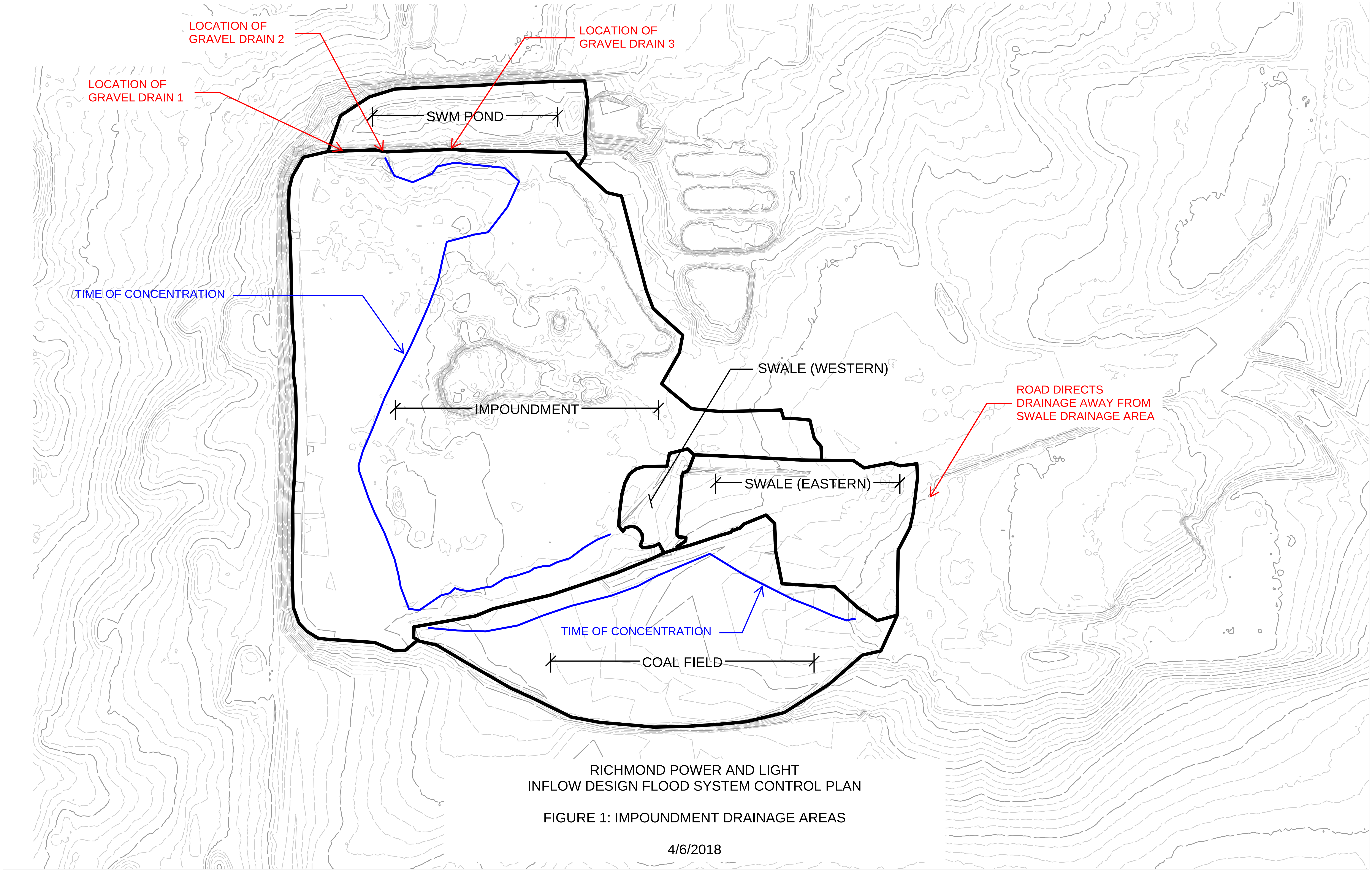
The Hydrographs 2004 report is attached.

**CONCLUSIONS**

The Impoundment is capable of conveying and controlling runoff collected from the contributing watersheds through the spillway and SWM Pond. The hydraulic ratings of conveyance structures including spillways have adequate capacity to control the peak flow from the runoff without overtopping.

gai consultants

**FIGURE 1**
**WATERSHED MAP**




RICHMOND POWER AND LIGHT
INFLOW DESIGN FLOOD SYSTEM CONTROL PLAN

FIGURE 1: IMPOUNDMENT DRAINAGE AREAS

4/6/2018

gai consultants

**ATTACHMENT 1**
**HYDROGRAPHS 2004 REPORT**

# Hydrograph Summary Report

| Hyd. No. | Hydrograph type (origin) | Peak flow (cfs) | Time interval (min) | Time to peak (min) | Volume (cuft) | Inflow hyd(s) | Maximum elevation (ft) | Maximum storage (cuft) | Hydrograph description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SCS Runoff | 23.13 | 1 | 717 | 50,040 | ---- | ------ | ------ | Swale-E |
| 2 | SCS Runoff | 4.04 | 1 | 717 | 8,522 | ---- | ------ | ------ | Swale-W |
| 3 | Combine | 27.18 | 1 | 717 | 58,562 | 1, 2 | ------ | ------ | Swale |
| 4 | SCS Runoff | 53.20 | 1 | 717 | 116,868 | ---- | ------ | ------ | Coal Pile |
| 5 | SCS Runoff | 62.55 | 1 | 728 | 222,946 | ---- | ------ | ------ | Impoundment |
| 6 | Combine | 119.08 | 1 | 718 | 398,375 | 3, 4, 5 | ------ | ------ | Impoundment Combine |
| 7 | Reservoir | 65.12 | 1 | 733 | 398,375 | 6 | 983.35 | 77,723 | Impound Route |
| 8 | SCS Runoff | 9.41 | 1 | 718 | 18,929 | ---- | ------ | ------ | SWM Pond |
| 9 | Combine | 66.42 | 1 | 733 | 417,304 | 7, 8 | ------ | ------ | SWM Pond Combine |
| 10 | Reservoir | 65.53 | 1 | 736 | 371,824 | 9 | 975.94 | 60,036 | SWM Pond Route |

| Inflow-RPL_P4 berm.gpw | Return Period: 1 Year | Tuesday, Apr 17 2018, 12:32 PM |
|---|---|---|

# Hydrograph Plot

Hydraflow Hydrographs by Intelisolve

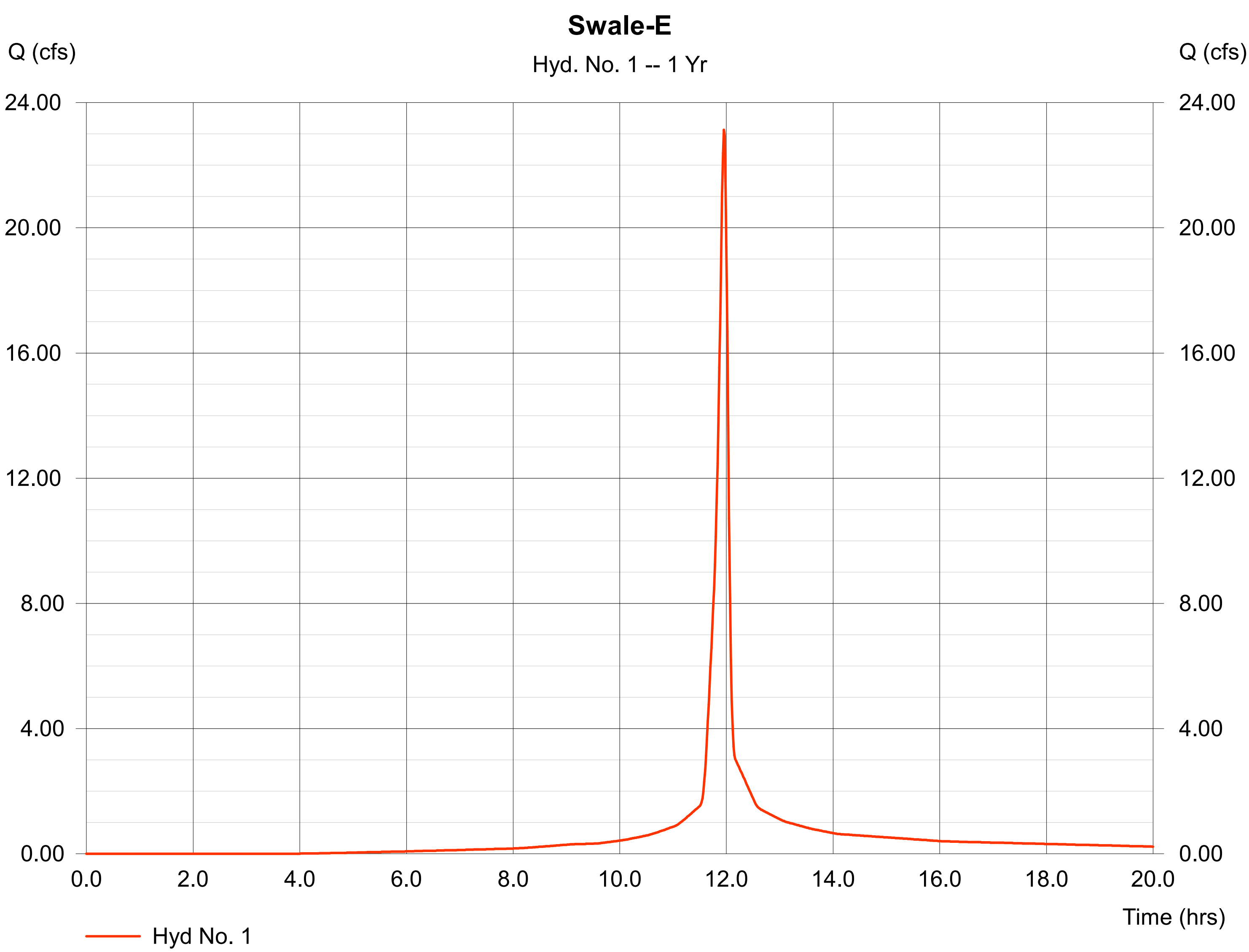
Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 1

Swale-E

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 23.13 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Drainage area | = 2.390 ac | Curve number | = 85.8 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = USER | Time of conc. (Tc) | = 5.00 min |
| Total precip. | = 7.26 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

Hydrograph Volume = 50,040 cuft



# Hydrograph Plot

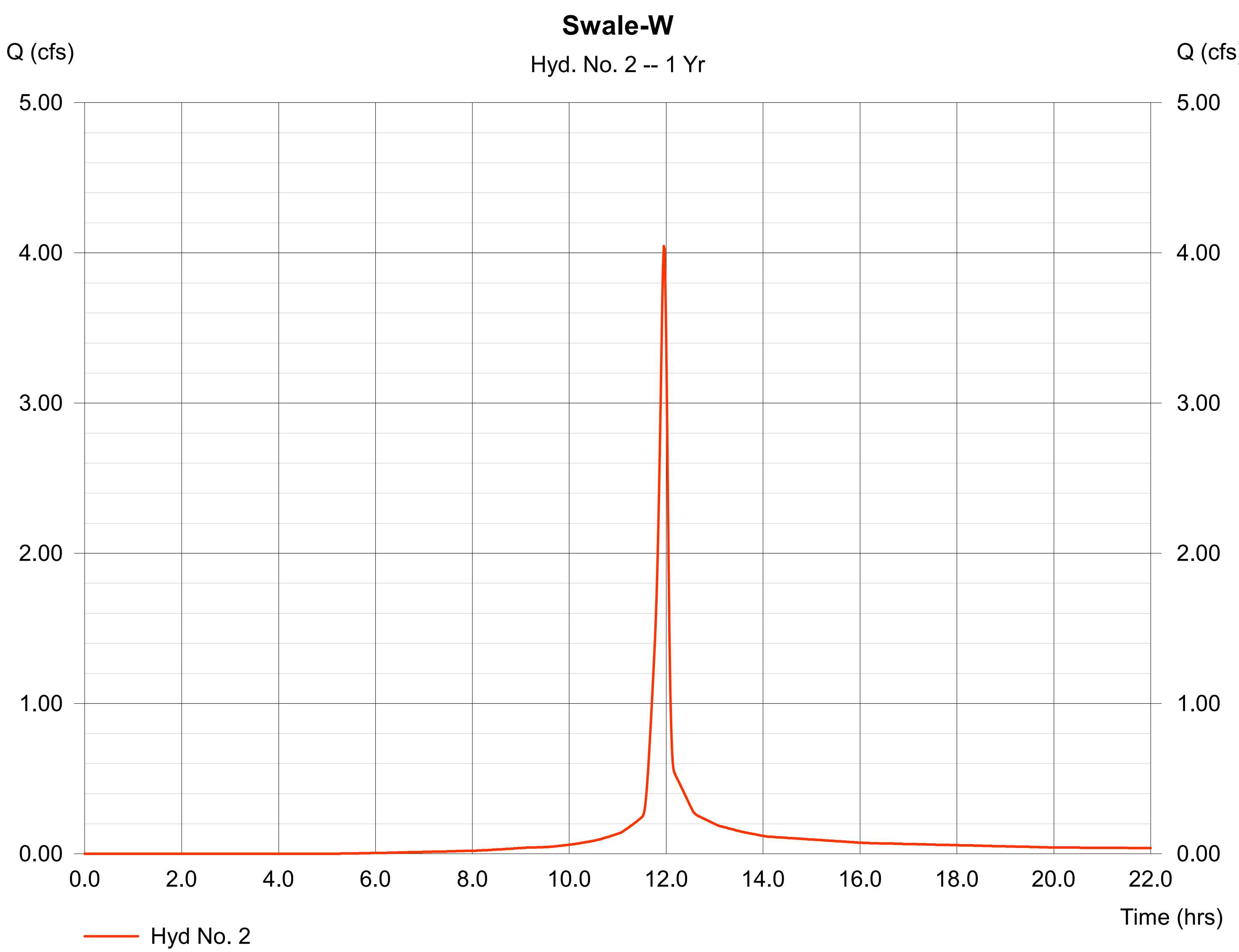
Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 2

Swale-W

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 4.04 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Drainage area | = 0.450 ac | Curve number | = 81.1 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = USER | Time of conc. (Tc) | = 5.00 min |
| Total precip. | = 7.26 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

Hydrograph Volume = 8,522 cuft



# Hydrograph Plot

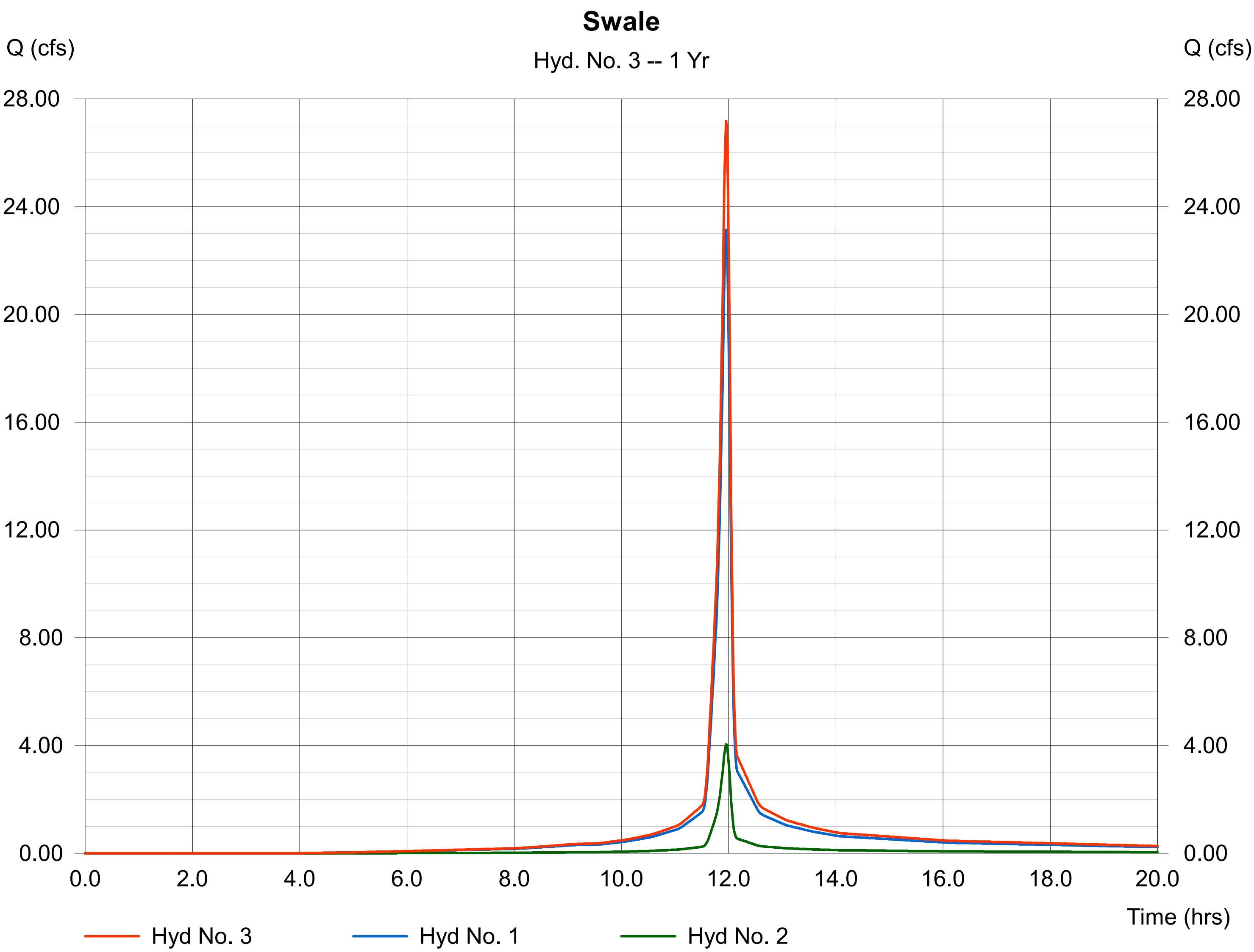
Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 3

Swale

| | | | |
|---|---|---|---|
| Hydrograph type | = Combine | Peak discharge | = 27.18 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Inflow hyds. | = 1, 2 | | |

Hydrograph Volume = 58,562 cuft



# Hydrograph Plot

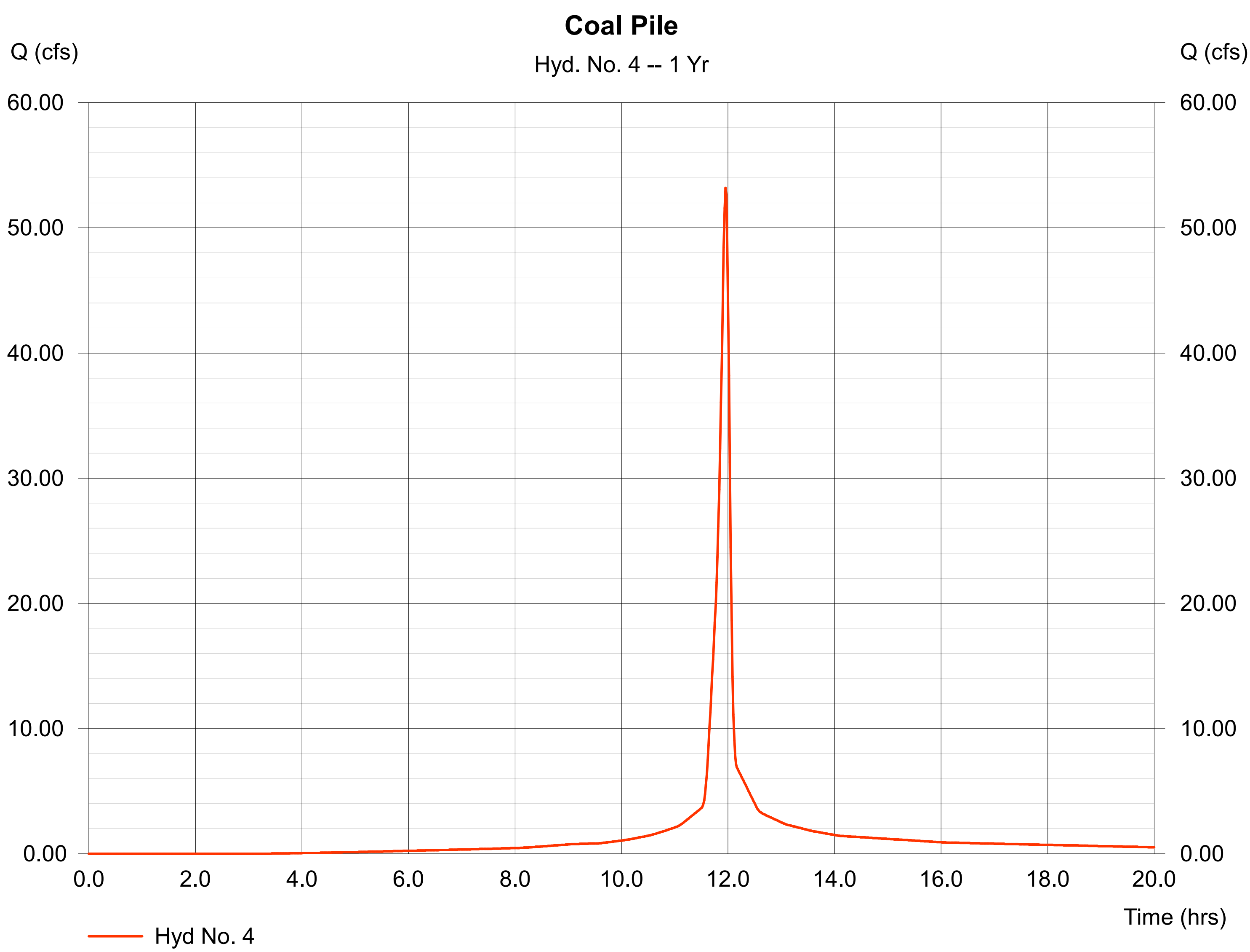
Hydraflow Hydrographs by Intelisolve — Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 4

Coal Pile

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 53.20 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Drainage area | = 5.340 ac | Curve number | = 88 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = USER | Time of conc. (Tc) | = 6.40 min |
| Total precip. | = 7.26 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

Hydrograph Volume = 116,868 cuft



# Hydrograph Plot

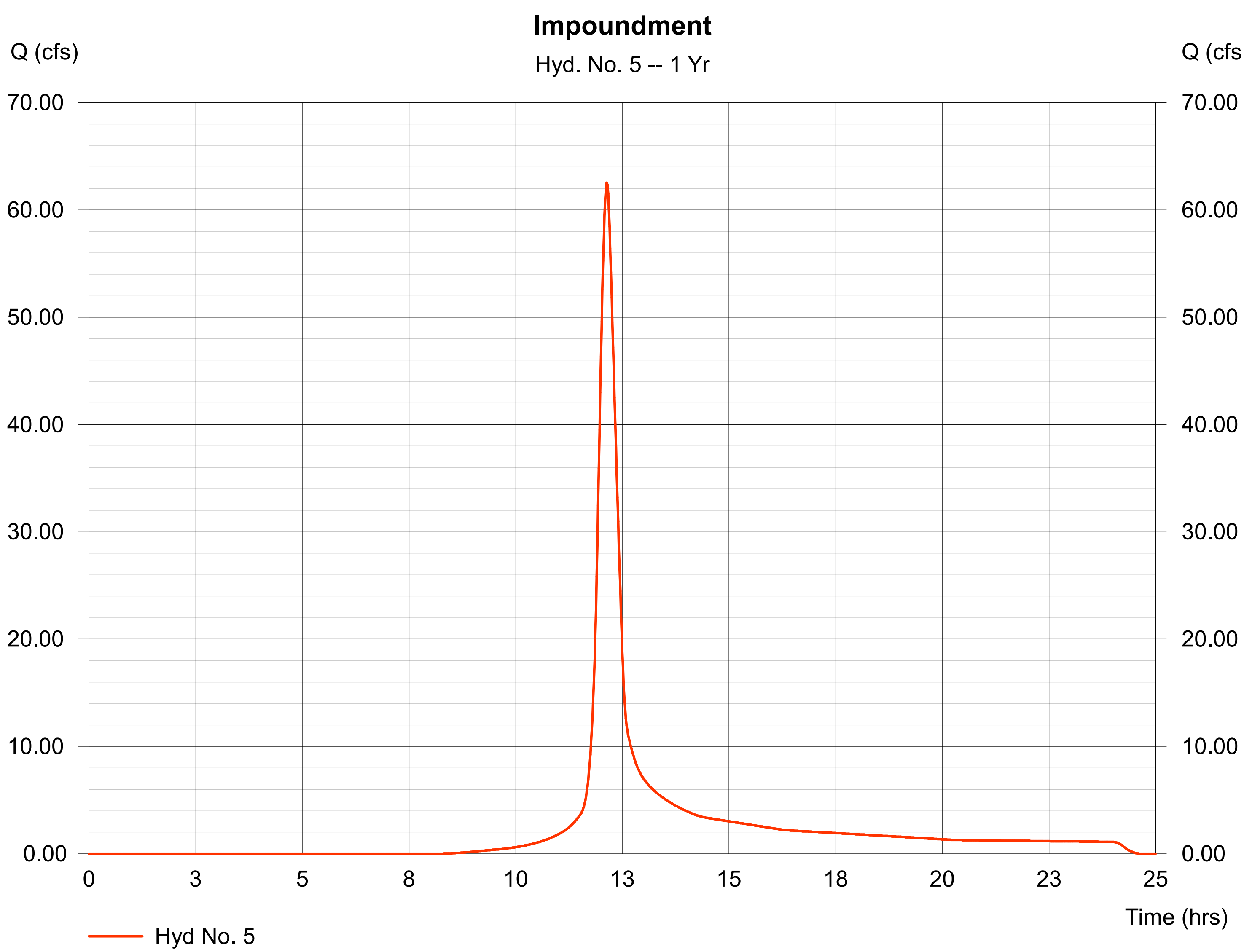
Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 5

Impoundment

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 62.55 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Drainage area | = 16.240 ac | Curve number | = 69.5 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = USER | Time of conc. (Tc) | = 24.00 min |
| Total precip. | = 7.26 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

Hydrograph Volume = 222,946 cuft



# Hydrograph Plot

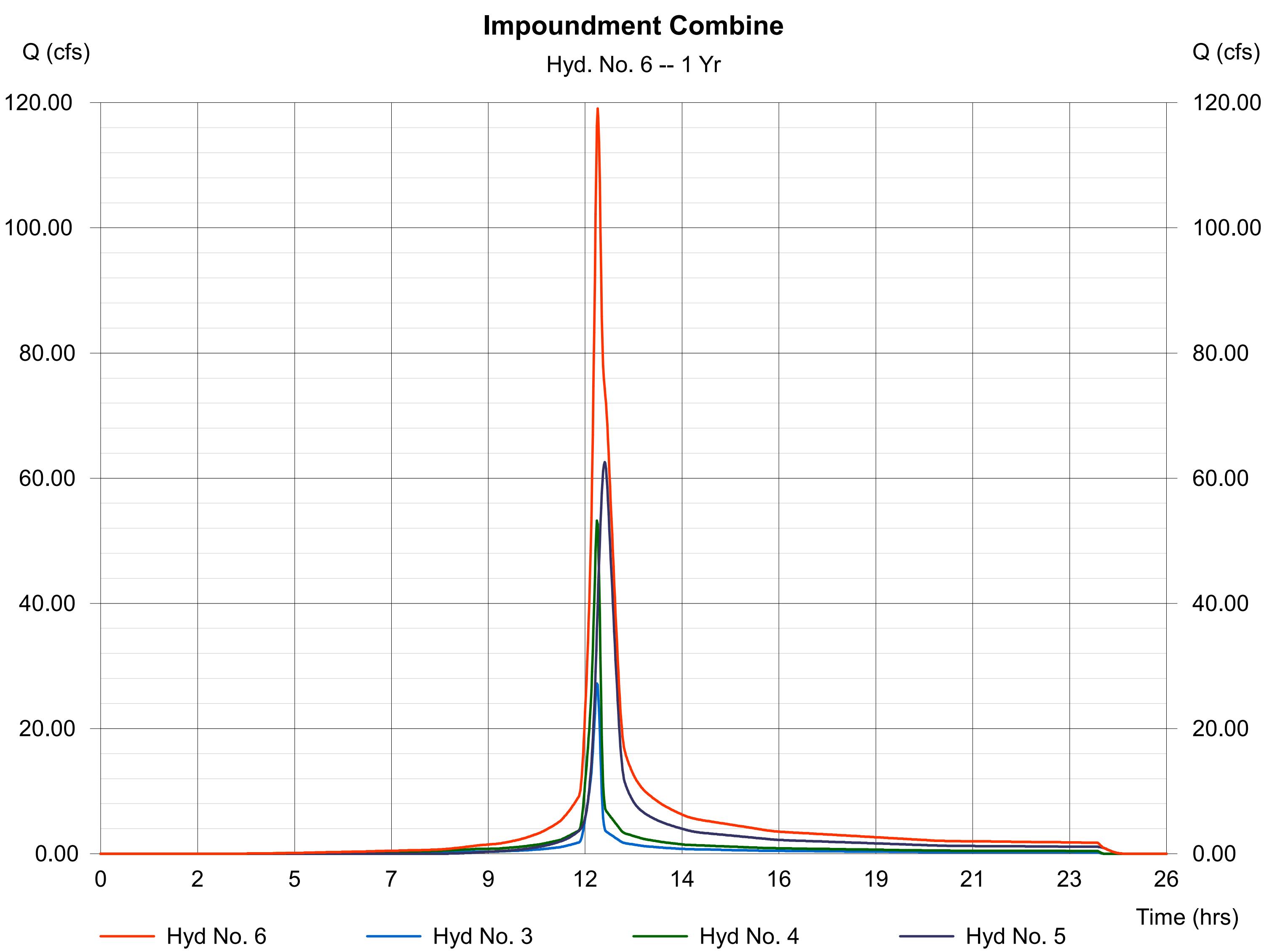
Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 6

Impoundment Combine

| | | | | | |
|---|---|---|---|---|---|
| Hydrograph type | = | Combine | Peak discharge | = | 119.08 cfs |
| Storm frequency | = | 1 yrs | Time interval | = | 1 min |
| Inflow hyds. | = | 3, 4, 5 | | | |

Hydrograph Volume = 398,375 cuft



# Hydrograph Plot

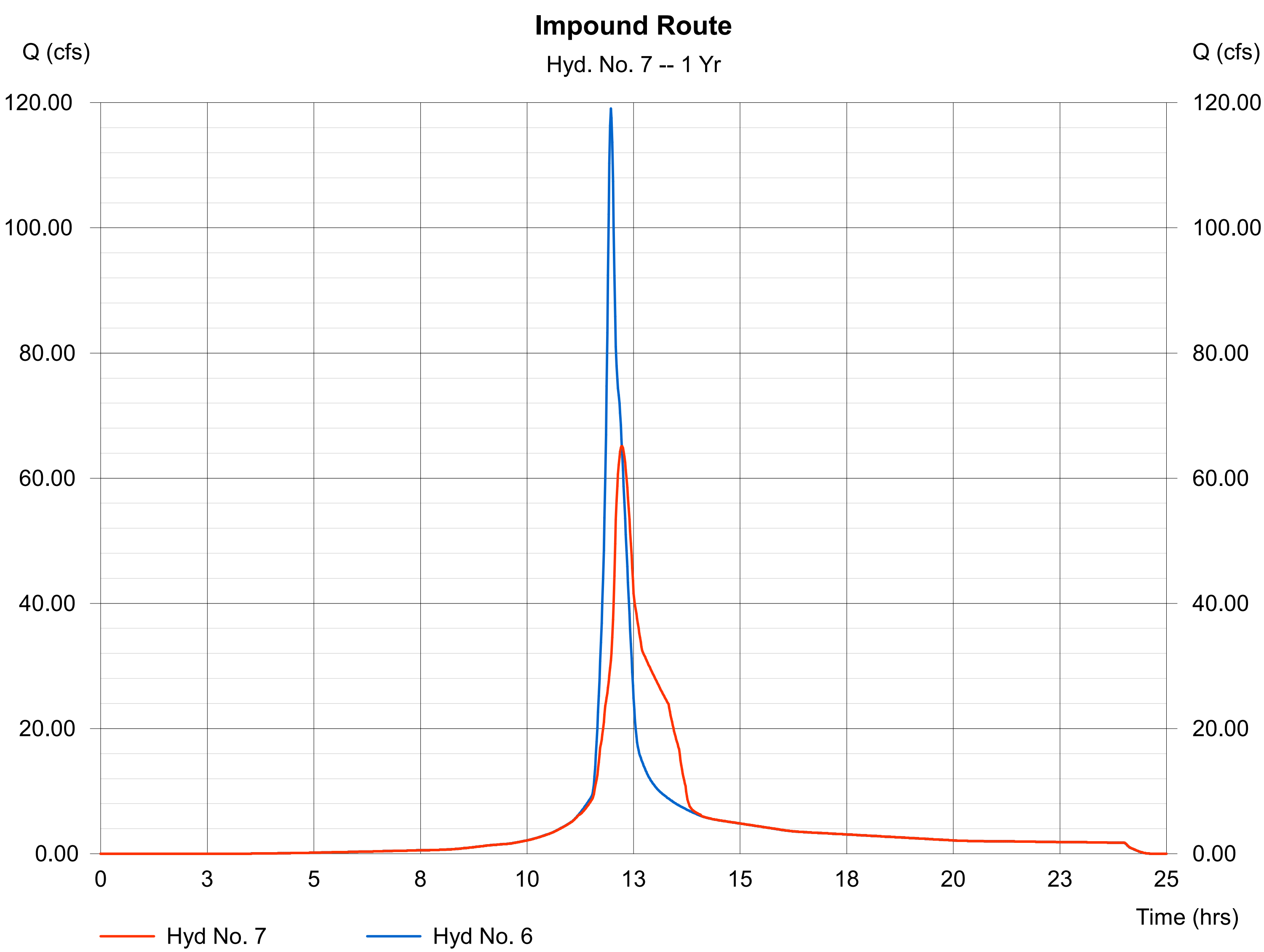
Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 7

Impound Route

| | | | |
|---|---|---|---|
| Hydrograph type | = Reservoir | Peak discharge | = 65.12 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Inflow hyd. No. | = 6 | Max. Elevation | = 983.35 ft |
| Reservoir name | = Impoundment | Max. Storage | = 77,723 cuft |

Storage Indication method used. | Hydrograph Volume = 398,375 cuft



# Pond Report

Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

## Pond No. 1 - Impoundment

### Pond Data

Pond storage is based on known contour areas. Average end area method used.

### Stage / Storage Table

| Stage (ft) | Elevation (ft) | Contour area (sqft) | Incr. Storage (cuft) | Total storage (cuft) |
|---|---|---|---|---|
| 0.00 | 978.00 | 150 | 0 | 0 |
| 1.00 | 979.00 | 200 | 175 | 175 |
| 2.00 | 980.00 | 1,656 | 928 | 1,103 |
| 3.00 | 981.00 | 4,757 | 3,207 | 4,310 |
| 4.00 | 982.00 | 16,416 | 10,587 | 14,896 |
| 5.00 | 983.00 | 58,854 | 37,635 | 52,531 |
| 5.20 | 983.20 | 73,670 | 13,252 | 65,783 |
| 5.40 | 983.40 | 88,487 | 16,216 | 81,999 |
| 5.60 | 983.60 | 103,303 | 19,179 | 101,178 |
| 5.80 | 983.80 | 118,120 | 22,142 | 123,320 |
| 6.00 | 984.00 | 132,936 | 25,106 | 148,426 |

### Culvert / Orifice Structures

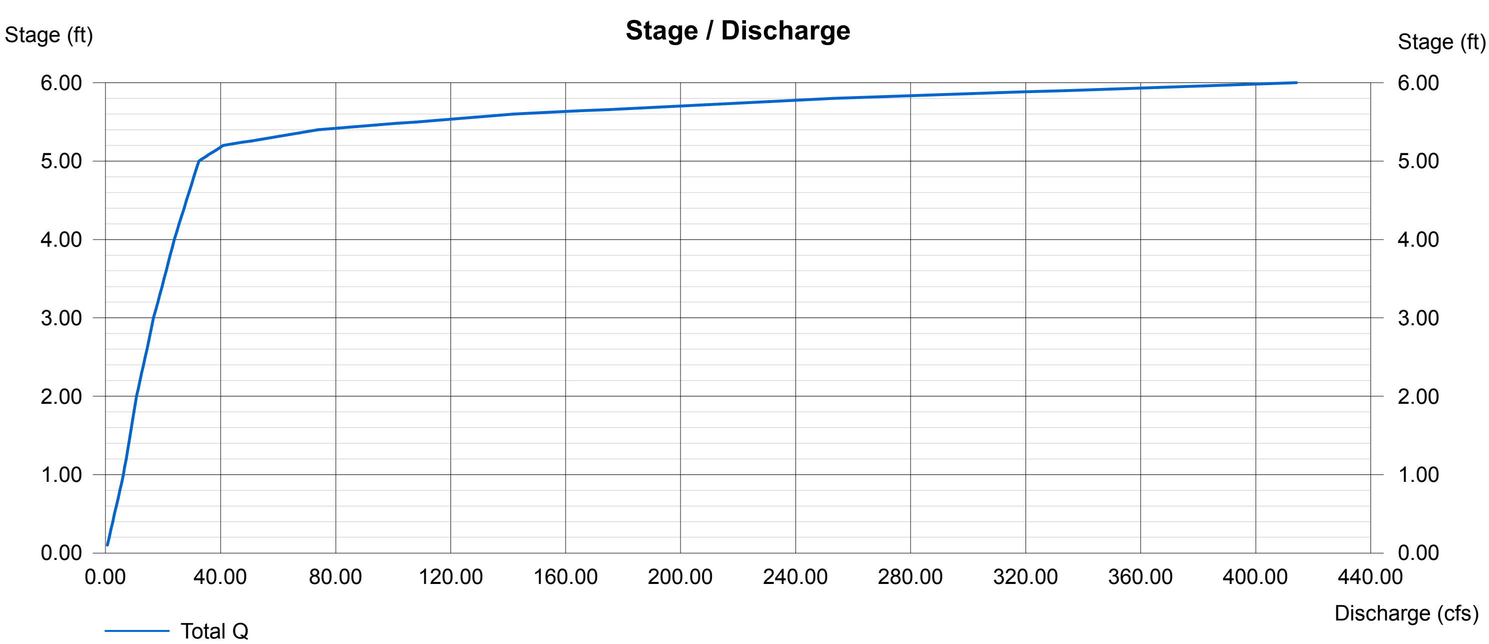
| | [A] | [B] | [C] | [D] |
|---|---|---|---|---|
| **Rise (in)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Span (in)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **No. Barrels** | = 0 | 0 | 0 | 0 |
| **Invert El. (ft)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Length (ft)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Slope (%)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **N-Value** | = .000 | .000 | .000 | .000 |
| **Orif. Coeff.** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Multi-Stage** | = n/a | No | No | No |

### Weir Structures

| | [A] | [B] | [C] | [D] |
|---|---|---|---|---|
| **Crest Len (ft)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Crest El. (ft)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Weir Coeff.** | = 3.33 | 3.33 | 3.33 | 3.33 |
| **Weir Type** | = --- | --- | --- | --- |
| **Multi-Stage** | = No | No | No | No |

**Exfiltration =** 0.000 in/hr (Contour) Tailwater Elev. = 0.00 ft

Note: Culvert/Orifice outflows have been analyzed under inlet and outlet control.



# Hydrograph Plot

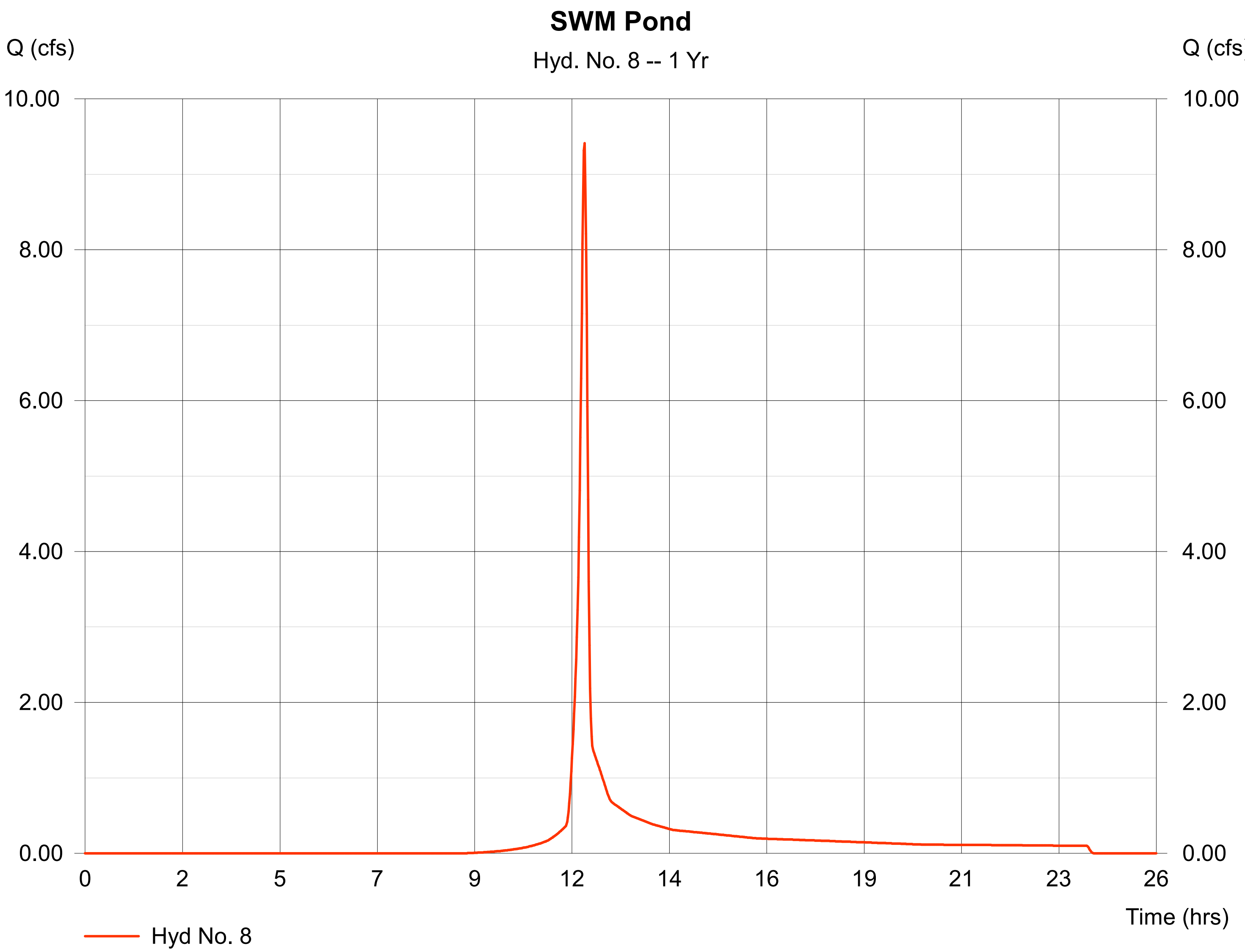
Hydraflow Hydrographs by Intelisolve — Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 8

SWM Pond

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 9.41 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Drainage area | = 1.530 ac | Curve number | = 65 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = USER | Time of conc. (Tc) | = 5.00 min |
| Total precip. | = 7.26 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

Hydrograph Volume = 18,929 cuft



# Hydrograph Plot

Hydraflow Hydrographs by Intelisolve

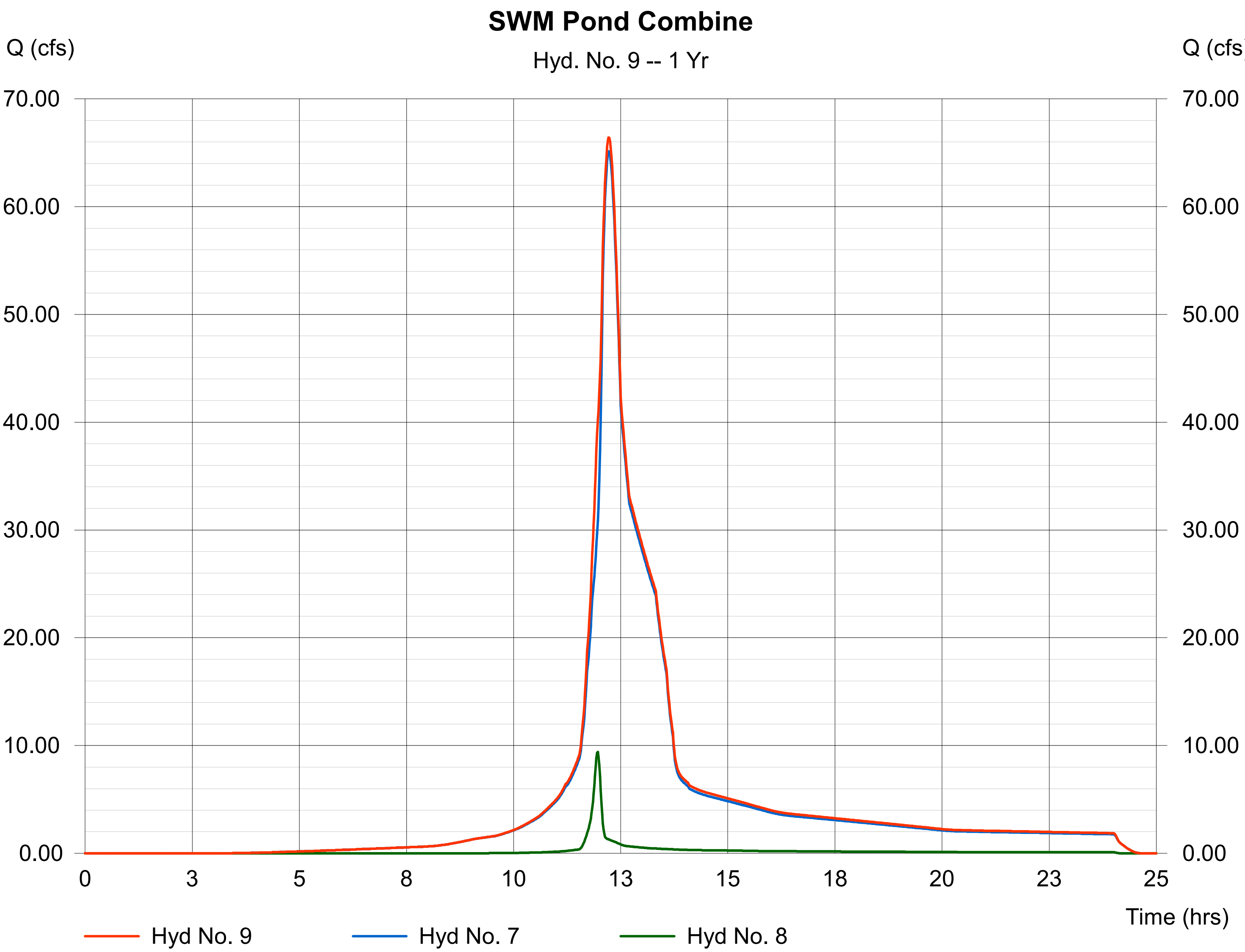
Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 9

SWM Pond Combine

| | | | |
|---|---|---|---|
| Hydrograph type | = Combine | Peak discharge | = 66.42 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Inflow hyds. | = 7, 8 | | |

Hydrograph Volume = 417,304 cuft



# Hydrograph Plot

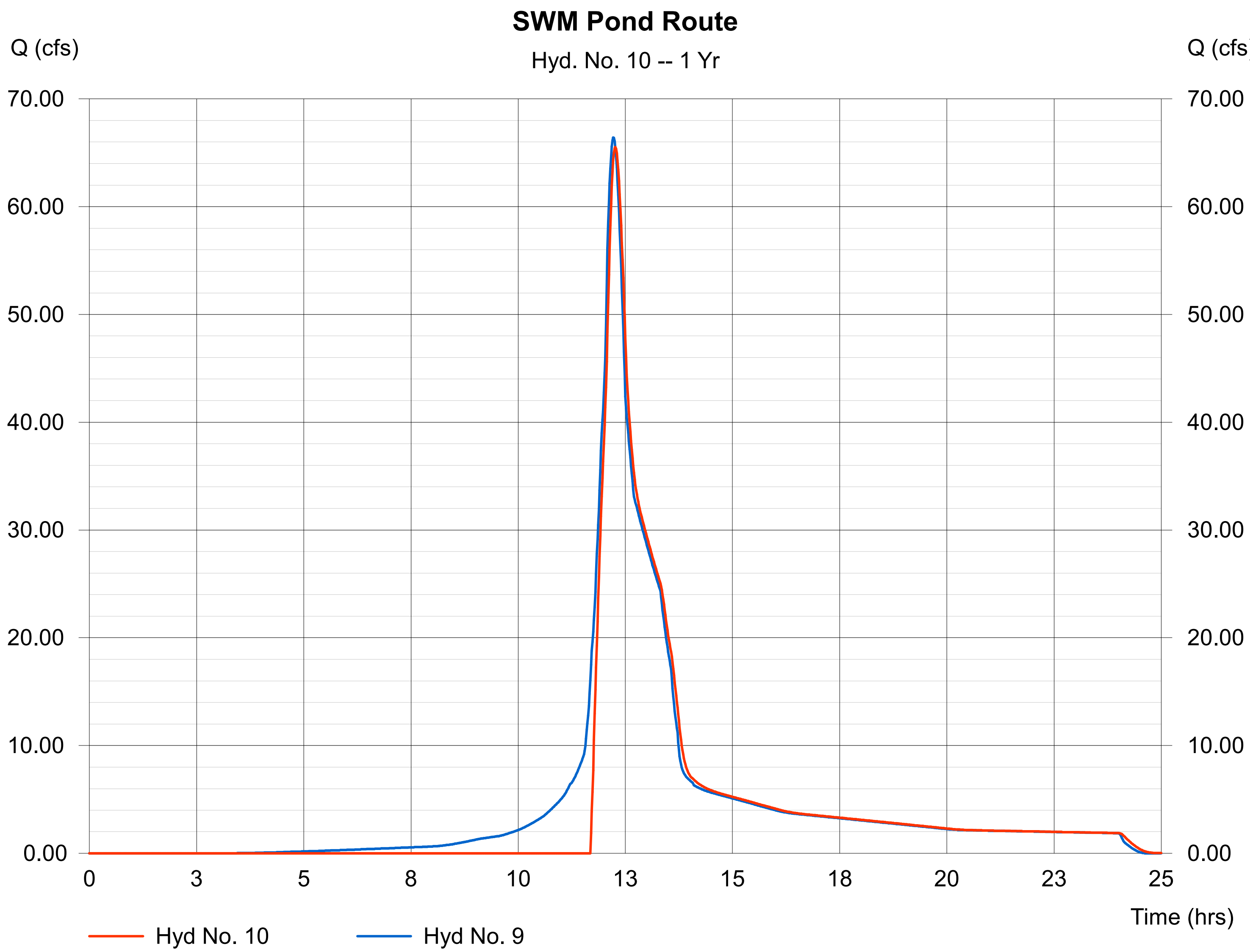
Hydraflow Hydrographs by Intelisolve — Tuesday, Apr 17 2018, 12:32 PM

## Hyd. No. 10

SWM Pond Route

| | | | |
|---|---|---|---|
| Hydrograph type | = Reservoir | Peak discharge | = 65.53 cfs |
| Storm frequency | = 1 yrs | Time interval | = 1 min |
| Inflow hyd. No. | = 9 | Max. Elevation | = 975.94 ft |
| Reservoir name | = SWM Pond | Max. Storage | = 60,036 cuft |

Storage Indication method used. — Hydrograph Volume = 371,824 cuft



# Pond Report

Hydraflow Hydrographs by Intelisolve — Tuesday, Apr 17 2018, 12:32 PM

### Pond No. 2 - SWM Pond

### Pond Data

Pond storage is based on known contour areas. Average end area method used.

### Stage / Storage Table

| Stage (ft) | Elevation (ft) | Contour area (sqft) | Incr. Storage (cuft) | Total storage (cuft) |
|---|---|---|---|---|
| 0.00 | 972.00 | 118 | 0 | 0 |
| 1.00 | 973.00 | 2,731 | 1,425 | 1,425 |
| 2.00 | 974.00 | 12,654 | 7,693 | 9,117 |
| 3.00 | 975.00 | 26,948 | 19,801 | 28,918 |
| 4.00 | 976.00 | 39,298 | 33,123 | 62,041 |

### Culvert / Orifice Structures

| | [A] | [B] | [C] | [D] |
|---|---|---|---|---|
| **Rise (in)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Span (in)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **No. Barrels** | = 0 | 0 | 0 | 0 |
| **Invert El. (ft)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Length (ft)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **Slope (%)** | = 0.00 | 0.00 | 0.00 | 0.00 |
| **N-Value** | = .013 | .013 | .013 | .000 |
| **Orif. Coeff.** | = 0.60 | 0.60 | 0.60 | 0.00 |
| **Multi-Stage** | = n/a | No | No | No |

### Weir Structures

| | [A] | [B] | [C] | [D] |
|---|---|---|---|---|
| **Crest Len (ft)** | = 0.00 | 80.00 | 0.00 | 0.00 |
| **Crest El. (ft)** | = 0.00 | 975.50 | 0.00 | 0.00 |
| **Weir Coeff.** | = 3.33 | 2.80 | 0.00 | 0.00 |
| **Weir Type** | = --- | Rect | --- | --- |
| **Multi-Stage** | = No | No | No | No |

**Exfiltration =** 0.000 in/hr (Contour) Tailwater Elev. = 0.00 ft

Note: Culvert/Orifice outflows have been analyzed under inlet and outlet control.