Section L
Hydrologic and Hydraulic Analysis

Status

Stormwater data included in this report references the revised PCSM Plan dated September 15, 2011 and prepared by Pennoni Associates, Inc. The revised PCSM Plan incorporates technical review comments issued by the Luzerne Conservation District in December 2010. Revisions were made to address those comments and to balance the site cut/fill to the greatest extent possible.

Hydrology and Hydraulics Analysis

PPL Bell Bend Nuclear Power Plant
Salem Township, Luzerne County, PA

1. Introduction and Purpose

This document is intended to meet the JPA requirement for a Hydrologic and Hydraulic Analysis of the activities involving obstructions or encroachments to jurisdictional waters associated with the proposed BBNPP. This report does not include any new work, but summarizes the analyses prepared in other reports related to this site. Specifically, the Floodplain Studies for Walker Run (LandStudies, 2011) and the Susquehanna River (LandStudies, 2011), as well as the Post Construction Stormwater Management Plan (Pennoni, 2011) are referenced. In addition, information requirements noted in Chapter 105 Subchapters C though G are discussed as they pertain to specific impacts. Finally, the need for an additional Risk Assessment is determined based on the potential for increased risk to life, property, or the environment as a result of the identified impacts.

2. Site History and Conditions

Two United States Geological Survey (USGS) gaging stations are located upstream and downstream of the BBNPP intake structure; Wilkes-Barre, PA (Station No. 01536500), and Danville, PA (Station No. 01540500. The Wilkes-Barre gaging station is located approximately 22 mi upstream from the proposed BBNPP intake structure. Streamflow records have been recorded at the Wilkes-Barre location since April 1899 (USGS, 2008b). The USGS gage at Danville, PA is located approximately 28 mi downstream from the BBNPP intake structure, and has been in continuous operation since April 1905 (USGS, 2008a).

Tropical Storm Agnes is the maximum flood on record on the NBSR. An average of 6-10 inches of rain fell over the Mid-Atlantic region from June 21-25, 1972 (NOAA, 2008). Rainfall was nearly continuous over this time period. These high rainfalls produced record flooding on the Susquehanna River, equaling or exceeding flood recurrence intervals of 100 years along portions of the Susquehanna River (NOAA, 2008). Tropical Storm Agnes generated peak stream flows of 345,000 cubic feet per second (cfs) and a flood level of 40.9 ft at Wilkes-Barre on June 24^{th} (USGS, 2008b). The Danville gaging station peaked at 363,000

cfs and a flood level of 32.16 ft on June 25th (USGS, 2008a). On June 25, 1972, a river crest of 517.36 ft mean sea level (MSL) was observed near the SSES intake structure (Ecology III, 1986). BBNPP plant grade will be at elevation 674 ft MSL, approximately 157 ft above the recorded peak flood elevation of the 1972 flood near the present location of the SSES intake structure.

The mean daily streamflow data recorded for a 108-year period (1899-2000) is 13,641 cfs at the Wilkes-Barre gaging station (USGS, 2008b). The mean daily stream flow data recorded at Danville during the 102-year period (1905-2006) is 15,483 cfs (USGS, 2008a).

There is no gaging station within the Walker Run watershed.

No significant flooding problems are currently known to exist on the site. No existing structures, fill, or other influences result in adverse hydraulic conditions.

3. Hydrology

Existing Federal Emergency Management Agency (FEMA) Flood Insurance Studies were referenced to determine the 100-year peak discharge rates for the NBSR and Walker Run. The peak discharge rate for the unnamed tributary to Walker Run was calculated using the SCS TR-55 methodology. All peak discharge rates for the NBSR and for Walker Run and its tributary are discussed in the Flood Study Reports for the NBSR and Walker Run, as prepared by LandStudies, Inc. (LandStudies, 2011). Peak flow rates, calculation methodologies, and sources are summarized in Table 1.

Peak flow rates for the railroad culvert on the unnamed tributary to the NBSR were developed using the USGS StreamStats website, as presented in Appendix L of the Post Construction Stormwater Management (PCSM) Narrative (Pennoni 2011). StreamStats is a web-based application that uses spacial and statistical data to develop hydrologic estimates for a specified location. Peak flow rates for the proposed culvert connecting the "Teardrop Wetland" to the unnamed Tributary 1 to Walker Run were developed using the SCS TR-55 methodology by Pennoni Associates.

Peak discharge rates at all stormwater outfalls were developed using the SCS TR-55 methodology by Pennoni Associates and are summarized on Pages 10 and 11 of the PCSM Narrative (Pennoni, 2011). Eighteen points of interest (POI) have been identified for the purposes of comparing pre-development to post development peak runoff rates and volumes. These POI locations are discussed on pages 7-18 of the PCSM Narrative and identified on the drainage area maps in Appendix F of the PCSM Narrative. The values listed in Table 1, below, reflect the existing and proposed conditions peak rates.

The Watershed to the North Branch Canal was modeled using Autodesk's Hydraflow Hydrographs software using the TR-20 methodology. This analysis included the development of runoff Hydrographs from two subareas, the routing of one subarea through Lake Took-A-While, and the combination of the resultant hydrographs. A more detailed description of the watershed characteristics and complete model input and results can be found in the Design Report for the Riverlands Mitigation Site in Section R of this JPA.

Table 1. Summary of Proposed Peak Discharge Rates

Watercourse	Method	Source	Existing 100-year peak Discharge (cfs)	Proposed 100-year peak Discharge (cfs)
NBSR	Adjusted Gauge Data	Luzerne County FIS	260,000	260,000
Walker Run	Regional Regression	Luzerne County FIS	1,860	1,860
Unnamed Tributary To Walker Run	TR-55	Walker Run Flood Study	300	300
Trib. To NBSR	StreamStats	PCSM Narrative	N/A	49.2
Teardrop Wetland Outfall	TR-55	Pennoni Associates	N/A	12.7
Stormwater Point of Interest (POI) 1	TR-55	PCSM Narrative	1,955.30	2,036.39
POI 2	TR-55	PCSM Narrative	473.21	645.18
POI 3A	TR-55	PCSM Narrative	202.69	417.17
POI 3B	TR-55	PCSM Narrative	8.48	0.00
POI 3C	TR-55	PCSM Narrative	9.42	4.84
POI 4	TR-55	PCSM Narrative	157.24	235.34
POI 5	TR-55	PCSM Narrative	115.21	352.43
POI 6	TR-55	PCSM Narrative	484.85	484.50
POI 7	TR-55	PCSM Narrative	15.86	13.38
POI 8	TR-55	PCSM Narrative	381.57	370.33
POI 9	TR-55	PCSM Narrative	305.85	348.71
POI 10	TR-55	PCSM Narrative	787.31	783.79
POI I-1	TR-55	PCSM Narrative	0.00	3.70
POI I-2	TR-55	PCSM Narrative	0.0.	10.50
POI I-3	TR-55	PCSM Narrative	8.70	17.50
POI I-4	TR-55	PCSM Narrative	0.70	0.70
POI I-5	TR-55	PCSM Narrative	28.40	28.10
POI I-6	TR-55	PCSM Narrative	12.40	13.20
North Branch Canal	TR-20	Riverlands Mitigation Site Design Report	473.19	473.19

4. Hydraulic Analysis

4.1 Hydraulic Studies

Detailed Flood Studies have been completed for the NBSR and Walker Run, including unnamed tributary #1 to Walker Run (LandStudies 2011). Reports and Flood Maps detailing these studies are included in Section N (Floodplain Management Analysis) of this Joint Permit Application. Both studies used HEC-RAS models and were completed on reaches for which there was an existing FEMA Flood Insurance Study (FIS), although unnamed tributary #1 to Walker Run was not originally included in the detailed FIS. The existing FIS models were supplemented with newer and more detailed topographic data for the existing conditions. Geometric data of proposed conditions included all proposed grading, structures, and land cover changes. Proposed bridges 2 through 7, as well as the proposed channel and floodplain restoration on Walker Run are evaluated in the Walker Run Flood Study. The fill associated with the proposed intake structure on the NBSR was considered in the Susquehanna River Flood Study. No increases in the 100-year water surface elevations are projected along the NBSR. Minor (<1 ft), localized (on-site) increases are anticipated in some locations on Walker Run and unnamed tributary #1 due to hydraulic changes associated with the removal of existing culverts the construction of new bridges, and hydraulic transitions into the mitigation area on Walker Run. Base flood elevations are reduced significantly along much of Walker Run as a result of the stream and wetland mitigation activities.

The proposed railroad culvert over the unnamed tributary to the NBSR and the proposed culvert outfall for the Teardrop Wetland were sized by Pennoni Associates using the Federal Highway Administration HY-8 culvert analysis software. The railroad culvert has been designed as a 48" reinforced concrete pipe culvert and the Teardrop Wetland outfall was designed as a 36" reinforced concrete pipe culvert. HY-8 output for both structures is attached for reference.

All stormwater outfall locations are shown on the PCSM Plans. Outfall pipe sizes, configurations and outfall protection are detailed on Sheet CS6103. As stated in the PSCM Narrative, "Culvert and swale flows were calculated using the rational method for the 25

year design storm in PennDOT Region 5. Swales were designed using North American Green Software 4.31. Culverts were designed using HY-8 version 7.2"

A stop log structure is proposed at the inlet to the proposed culvert on the North Branch Canal. This structure was modeled, along with the 48" pipe culvert, using the TR-20 basin routing routine in the Hydraflow Hydrographs software by Autodesk in order to account for the storage in the canal. HY-8 was also used to more accurately predict the overtopping conditions. A discussion of the structure design and complete model input and results can be found in the Design Report for the Riverlands Mitigation Site in Section R of this JPA.

4.2 Bridges and Culverts (Chapter 105, Subchapter C)

Six bridges are proposed as part of this project. One bridge (#2/#6) will serve as both a vehicular access bridge as well as a pipe bridge. Three culverts are also proposed to provide rail and pedestrian access and to accommodate proposed grading, as noted below. A summary of the proposed bridges and culverts is provided in Table 2.

Table 2. Summary of Bridges and Culverts

Structure ID	Watercourse	Use	Type of Structure
Bridge #1	Wetland 19	Vehicular Access	Concrete Span w/ Piers
Bridge #2, #6	Trib. to Walker Run	Vehicular Access, Pipe Bridge	Concrete Span w/ Piers
Bridge #3	Trib. to Walker Run	Vehicular Access	Concrete Span w/ Piers
Bridge #4	Walker Run	Vehicular Access	Concrete Span w/ Piers
Bridge #5	Trib. to Walker Run	Rail Access	Concrete Span w/ Piers
Bridge #7	Trib. to Walker Run	Pipe Bridge	Prefabricated Metal Truss w/ Piers
Culvert	Trib. to NBSR	Rail Access	125 lf of 48" Reinforced Concrete Pipe
Culvert	Teardrop Wetland/ Tributary #2	Replace Ex. Pipe	428 lf of 36" Reinforced Concrete Pipe
Culvert	North Branch Canal	Pedestrian Access	40 lf of 48" Smooth Lined Corrugated Polyethylene Pipe

Hydraulic calculations for bridges and culverts were completed as described in the hydraulics section above. All structures are designed to safely convey the 100-year peak discharge. No increase in the 100-year water surface elevation of Walker Run is anticipated

as a result of Bridge #4. Small, local increases in the 100-yr water surface elevation may occur on the unnamed tributary due to changes in flow regime, although the overall conveyance area will be maintained or increased (Bridge 3), and the bridges will not cause any significant restriction of flood flows. Any increase in flood elevation will be contained on the project site. A detailed FEMA Flood Insurance Study exists for Walker Run, but the unnamed tributary was not included in that detailed study.

The railroad culvert on the unnamed tributary to the NBSR may result in a localized backwater, but any increase in flood elevation will be limited to the project site.

Wetland 11, commonly referred to as the "Teardrop Wetland," currently drains to an existing 6" PVC pipe, likely connected to a tile drain system under the adjacent fields, and discharges to the wetlands associated with the unnamed tributary to Walker Run. Storm flows overtop the pipe and are conveyed to the wetland via a grassed waterway though the fields. A 428-foot long, 36" diameter reinforced concrete pipe is proposed to replace the underdrain and grass swale system. This significantly larger pipe will reduce the backwater condition at the pipe entrance.

The proposed culvert on the North Branch Canal will have no affect on the 100-year water surface elevation, as the entire area is inundated by the flood waters of the NBSR.

All structures have been designed in a manner that will not cause increased erosion to the streambed or banks. The bridges on Walker Run and the unnamed tributary to Walker Run span the entire 100-year floodplain. The piers represent a relatively minor encroachment in the floodplain and accelerated erosion is not anticipated as a result. Riprap outfall protection is proposed to stabilize the outfall of the proposed railroad culvert. Stability calculations are provided in Appendix L of the PCSM Narrative. The proposed culvert on the North Branch Canal will be partially submerged on both the upstream and downstream ends. Due to the depth and low velocity of flow in the canal, accelerated erosion is not anticipated.

Based on this analysis, all requirements of 25 PA Code Chapter 105, Subchapter C are met.

4.3 Stream Enclosures (Chapter 105, Subchapter D)

Two stream enclosures are proposed as part of this project. The 428-foot long, 36" diameter reinforced concrete pipe proposed to replace the underdrain and grass swale system at the outfall of the teardrop wetland is considered a stream enclosure. This significantly larger pipe is designed to convey the 100-year peak runoff and will reduce the backwater condition at the pipe entrance. The culvert is necessary because the grading required to accommodate the facility infrastructure will not allow the flow to be daylighted. Calculations for this culvert were completed by Pennoni Associates and are attached for reference. A plan view of this structure is depicted on plan sheets CS 3105 and CS 3106 and a profile of the proposed culvert is provided in Figure 6E of plan sheet CS 3203. Plan sheets are located in Section F of the JPA.

The railroad culvert on the unnamed tributary to the NBSR is also considered a stream enclosure, as this structure will be 125 feet in length. This length is necessary to accommodate the fill needed to maintain an acceptable grade for the proposed rail siding. This culvert may result in localized backwater, but any increase in flood elevation will be limited to the project site. Calculations for this culvert were prepared by Pennoni Associates and are attached for reference. A plan view of the railroad culvert is shown on plan sheet CS 3110. A cross section view is provided in Figures 7B and 7C of plan sheet CS 3204.

Based on this analysis, all requirements of 25 PA Code Chapter 105, Subchapter D are met.

4.4 Channel Changes (Chapter 105, Subchapter E)

Two channel changes are proposed as part of this project. The floodplain of Walker Run will be restored, and the channel will be relocated to provide wetland mitigation, stream stability, and improved aquatic habitat as part of the stream and wetland mitigation being proposed for this project. The Stream and Wetland Mitigation Design Report for Walker Run and the associated mitigation plans are included in Section R of this JPA and provide the location and extent of the proposed change, longitudinal profiles, cross sections, an Erosion and Sediment Pollution Control Plan including disposal provisions, and a complete geomorphic analysis and design calculations. The proposed conditions of this channel change are modeled in the Walker Run Flood Study, as described above and included in Section N of the JPA.

The existing manmade outfall channel from the weir structure located on the North Branch Canal will be abandoned to accommodate the proposed water intake structure for the Bell Bend Nuclear Power Plant. The original alignment of the canal will be restored and the weir removed, eliminating the need for the current outfall channel. This change is described in detail in the Wetland Mitigation Design Report for the Riverlands Site. The associated Mitigation Plans for this site include the location and extent of the proposed change, longitudinal profiles, cross sections, and an Erosion and Sediment Pollution Control Plan including disposal provisions. The referenced Design Report and Plans are included in Section R of this JPA. The entire area affected by this change is currently within the 100-year floodplain of the NBSR, as modeled in the Susquehanna River Flood Study included in Section N of the JPA.

Based on this analysis, all requirements of 25 PA Code Chapter 105, Subchapter E are met.

4.5 Fills (Chapter 105, Subchapter F)

Three instances of filling waters of the commonwealth are proposed as part of this project. Wetland 5 is a 0.12 acre isolated wetland located within the area of fill required to construct the power block portion of the project. Structural fill will be used to elevate this area to create a level pad for the facility. A plan view of this impact is depicted on plan sheet CS 3102 and a cross section view is shown on plan sheet CS 3203, Figure 5F. All plan sheets are found in Section F of this JPA. As this is an isolated wetland that is located outside of the 100-year floodplain and is not associated with a watercourse, there are no issues related to flooding or backwater effects resulting from this fill.

A similar fill is proposed in Wetlands 49A and 49B, which are 0.02 and 0.04 acre in size, respectively. This fill is necessary to accommodate an expansion of the existing Susquehanna Steam Electric Station 500KV switchyard needed to accommodate the project. Structural fill will be used to elevate this area to create a level pad for the switchyard expansion. A plan view of this impact is depicted on plan sheet CS 3132. Cross sectional views are provided in Figures 6H through 6K located on plan sheet CS 3204. These wetlands are located outside of the 100-year floodplain and are not associated with a

watercourse, so there are no issues related to flooding or backwater effects resulting from this fill.

The proposed cooling water intake structure is to be located on the bank of the NBSR. The access road and pad associated with this facility will require the filling of 1.45 ac of wetland including Wetlands 43 and 44 and the Canal outfall channel. This is the largest single wetland impact associated with this project. A plan view of the proposed impact is depicted on plan sheet CS 3116. Cross section views are shown in Figures 8F through 8H on plan sheet CS 3205. The Flood Study for the Susquehanna River, provided in Section N of the JPA concludes that no increases in the 100-year water surface elevation will result from this fill and no substantial increases in velocity will occur.

Based on this analysis, all requirements of 25 PA Code Chapter 105, Subchapter F are met.

4.6 Stream Crossings, Outfalls, and Headwalls (Chapter 105, Subchapter G)

The proposed cooling water intake and blow down lines will cross under the North Branch Canal immediately downstream of the existing access drive crossing and over the unnamed tributary to Walker Run (Bridge #6), as shown on plan sheets CS 3116, CS 3130, and CS 3106, respectively. A cross section of the canal crossing is shown in Figure 8J on plan sheet CS 3205. A complete permitting plan set is provided in Section F of this JPA.

All stormwater outfalls are described in the PCSM Narrative and shown on the PCSM Plans. Refer to these documents in Section M of this JPA for pipe sizes, configurations and outfall protection,

An 18" pipe is proposed to maintain the hydrology of the wetland area behind the proposed intake structure fill. The headwall of this pipe is set 0.5 ft. above grade and the outfall is located on the bank of the NBSR. The pipe is intended to drain excess runoff from the area that would otherwise be impounded by the proposed fill. A more detailed description of this pipe is provided in Wetland Mitigation Design Report for the Riverlands Site, and a plan, profile and details of the pipe are provided in the associated Mitigation Plan set in Section R of this JPA (plan view is located on sheet CS 3116 and cross sectional view in Figure 8H on plan sheet CS 3205).

Based on this analysis, all requirements of 25 PA Code Chapter 105, Subchapter F are met.

5. Evaluation of Need for Risk Assessment

Based on the data summarized above none of the proposed impacts will result in an increase of peak runoff rates or result in a significant increase of base flood elevations. No adverse hydrologic or hydraulic affects are anticipated on any upstream or downstream properties as a result of this project. Therefore, no Risk Assessment is required, per 25 PA Code Chapter 105.13.(d)(1)(vii).

6. References

Conceptual Design of Stormwater Management, Bell Bend Nuclear Power Plant. UniStar Nuclear Energy. Report No. SL-009446, Revision 5, July 28, 2010

Flood Study Report for the Susquehanna River. LandStudies, Inc. Rev 3, August 2011.

Flood Study Report for Walker Run. LandStudies, Inc. Rev 2, September 2011.

Middle Atlantic River Forecast Center, Hurricane Agnes. NOAA, 2008. Website: http://ahps.erh.noaa.gov/marfc/Flood/agnes.html, Date accessed: February 7, 2008.

Mitigation Design Report, Riverlands Site. LandStudies Inc. Rev 0, November 2010.

Peak Streamflow for Pennsylvania USGS 01540500 Susquehanna River at Danville, PA. USGS. 2008a. Website: http://nwis.waterdata.usgs.gov/pa/nwis/peak?site_no=01540500&agency_cd=USGS&format=html, Date accessed: January 25, 2008.

Peak Streamflow for Pennsylvania USGS 01536500 Susquehanna River at Wilkes-Barre,PA. USGS. 2008b. Website: http://nwis.waterdata.usgs.gov/pa/nwis/peak?site_no=01536500&agency_cd=USGS&format=html, Date accessed: January 25, 2008.

Post Construction Stormwater Management Narrative. Pennoni Associates, Inc. September 15, 2011.

Post Construction Stormwater Management Plan. Pennoni Associates, Inc. September 15, 2011

Pre-Operational Studies of the Susquehanna River in the Vicinity of the Susquehanna Steam Electric Station, 1971-1982. Ecology III, Inc. December 1986.

Stream and Wetland Mitigation Design Report, Walker Run Site. LandStudies Inc. Rev 0, November 2010.

Attachment 1:

Teardrop Wetland Outfall Culvert Calculations

Pennoni Associates, Inc.

Table 1 - Summary of Culvert Flows at Crossing: Teardrop Culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
680.63	6.64	6.64	0.00	1
680.81	8.99	8.99	0.00	1
680.98	11.35	11.35	0.00	1
681.07	12.71	12.71	0.00	1
681.28	16.06	16.06	0.00	1
681.41	18.41	18.41	0.00	1
681.55	20.76	20.76	0.00	1
681.72	23.12	23.12	0.00	1
681.90	25.47	25.47	0.00	1
682.08	27.83	27.83	0.00	1
682.30	30.18	30.18	0.00	1
698.00	62.13	62.13	0.00	Overtopping

Rating Curve Plot for Crossing: Teardrop Culvert

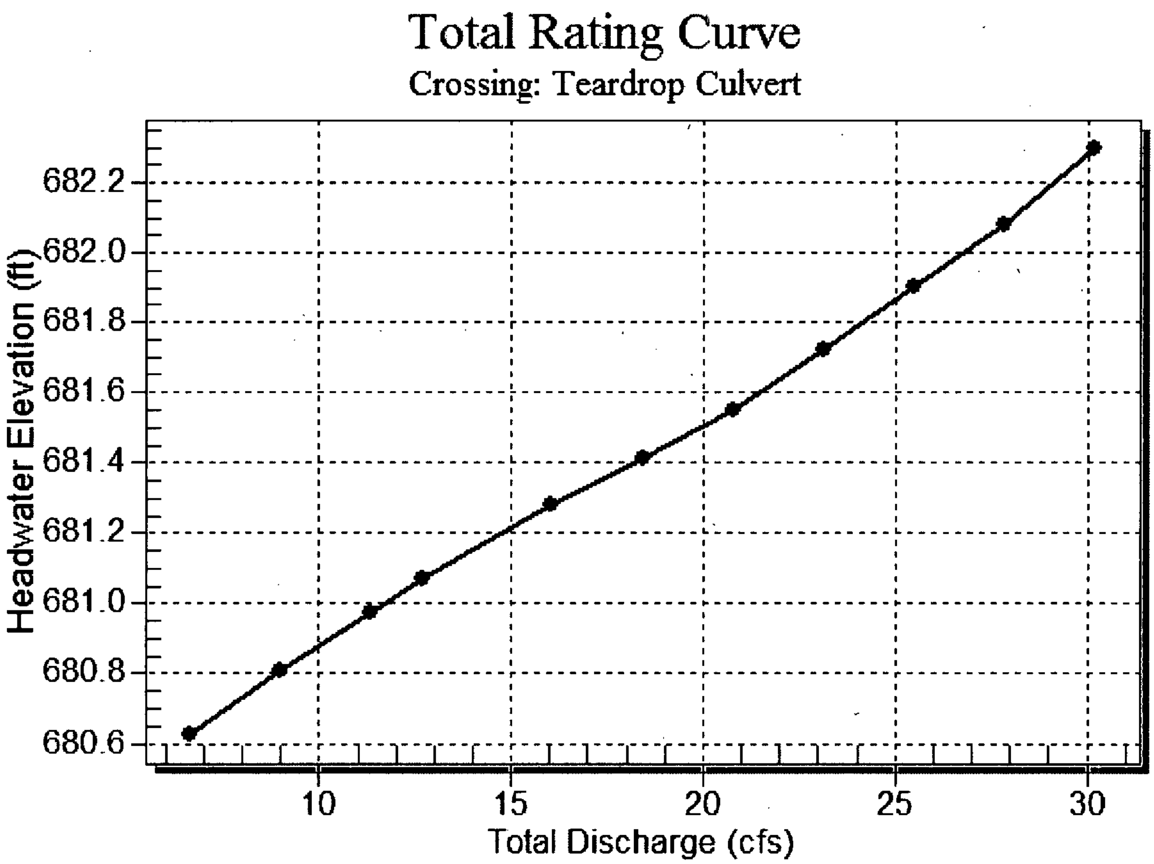

Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
6.64	6.64	680.63	0.817	0.0*	1-S2n	0.482	0.540	0.482	0.723	4.703	6.357
8.99	8.99	680.81	0.998	0.0*	1-S2n	0.585	0.660	0.585	0.810	5.228	6.858
11.35	11.35	680.98	1.165	0.0*	1-S2n	0.672	0.769	0.672	0.884	5.730	7.268
12.71	12.71	681.07	1.262	0.0*	1-S2n	0.722	0.828	0.722	0.922	5.977	7.477
16.06	16.06	681.28	1.471	0.0*	1-S2n	0.838	0.963	0.842	1.006	6.464	7.927
18.41	18.41	681.41	1.605	0.0*	1-S2n	0.915	1.050	0.915	1.059	6.847	8.203
20.76	20.76	681.55	1.739	0.0*	1-S2n	0.991	1.133	0.992	1.108	7.131	8.453
23.12	23.12	681.72	1.911	0.0*	1-S2n	1.064	1.214	1.064	1.154	7.431	8.683
25.47	25.47	681.90	2.092	0.0*	5-S2n	1.137	1.285	1.137	1.197	7.693	8.896
27.83	27.83	682.08	2.272	0.0*	5-S2n	1.211	1.357	1.212	1.237	7.916	9.095
30.18	30.18	682.30	2.486	0.0*	5-S2n	1.285	1.424	1.285	1.275	8.162	9.281

* theoretical depth is impractical. Depth reported is corrected.

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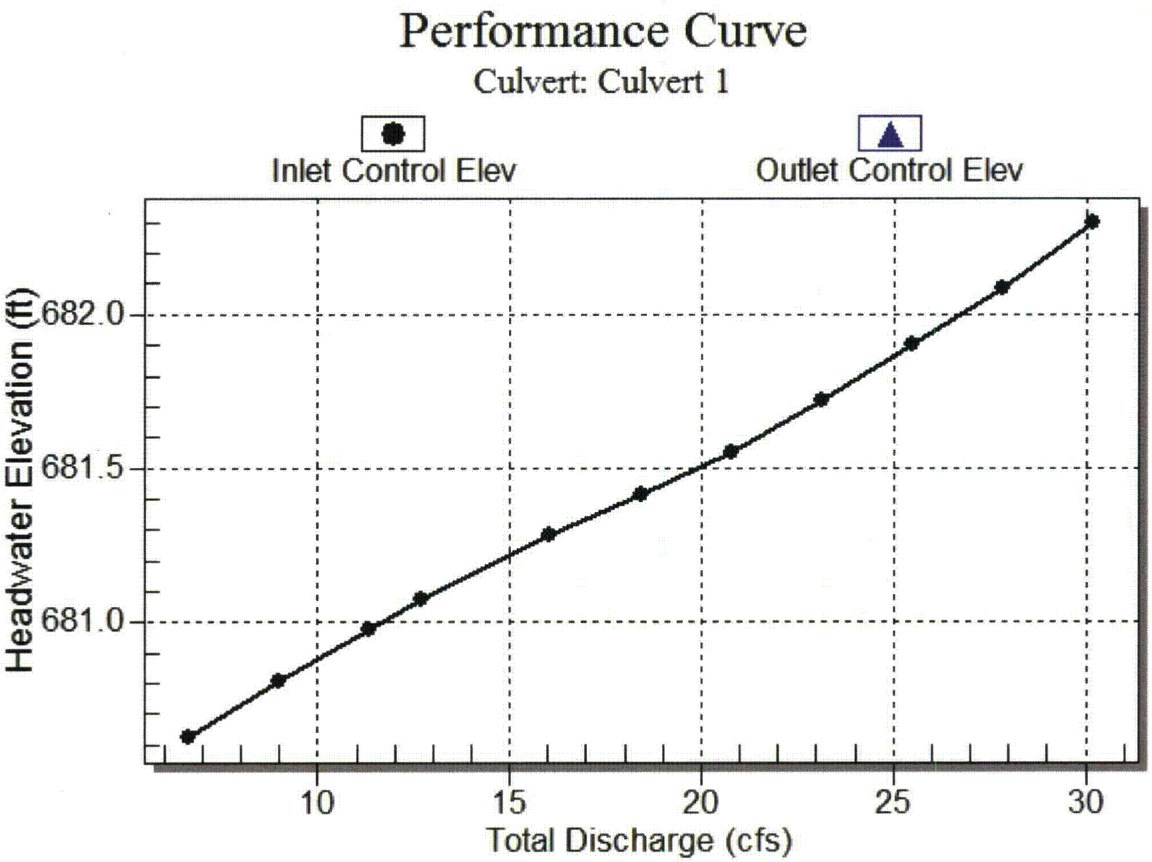
Inlet Elevation (invert): 679.81 ft, Outlet Elevation (invert): 666.00 ft

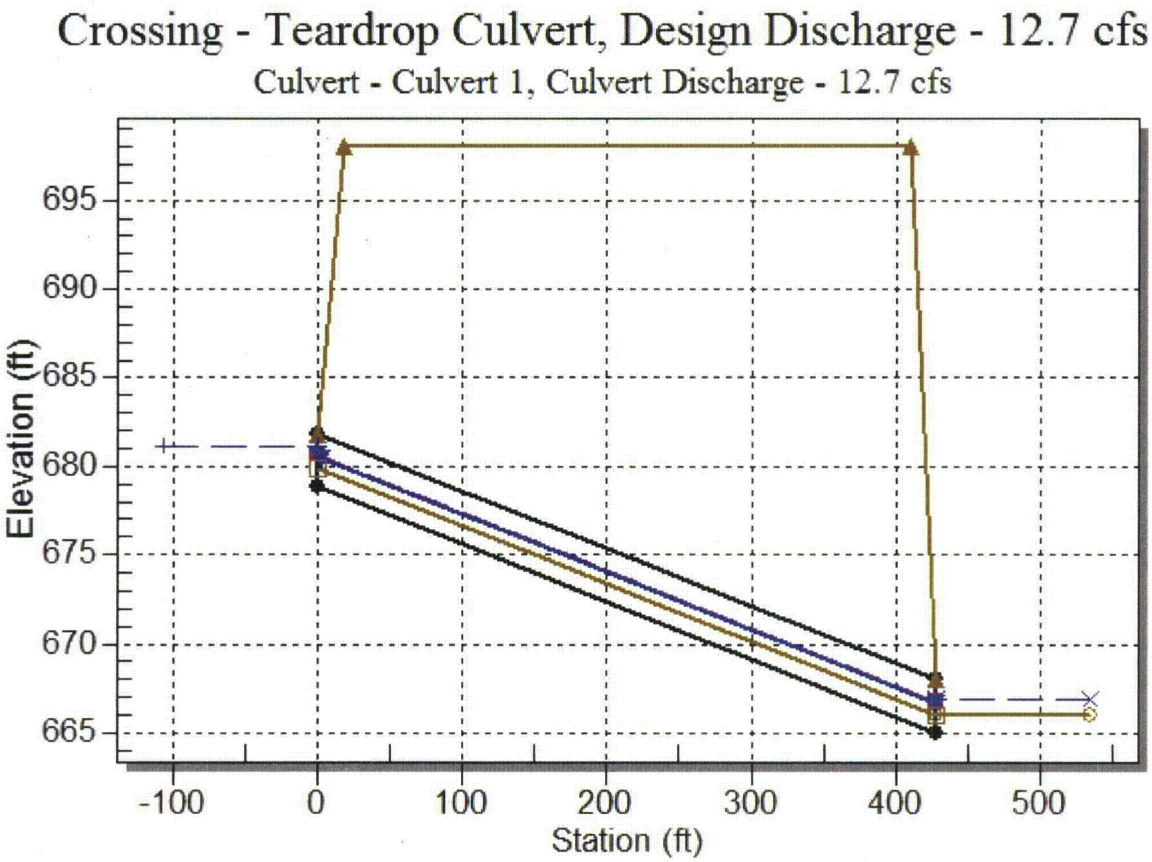
Culvert Length: 428.22 ft, Culvert Slope: 0.0323

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 678.81 ft

Outlet Station: 428.00 ft

Outlet Elevation: 665.00 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Concrete

Embedment: 12.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0350 (bottom)

Inlet Type: Conventional

Inlet Edge Condition: Beveled Edge

Table 3 - Downstream Channel Rating Curve (Crossing: Teardrop Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
6.64	666.72	0.72	6.36	1.49	1.86
8.99	666.81	0.81	6.86	1.67	1.90
11.35	666.88	0.88	7.27	1.82	1.93
12.71	666.92	0.92	7.48	1.90	1.94
16.06	667.01	1.01	7.93	2.07	1.97
18.41	667.06	1.06	8.20	2.18	1.99
20.76	667.11	1.11	8.45	2.28	2.00
23.12	667.15	1.15	8.68	2.38	2.01
25.47	667.20	1.20	8.90	2.46	2.03
27.83	667.24	1.24	9.09	2.55	2.04
30.18	667.28	1.28	9.28	2.63	2.05

Tailwater Channel Data - Teardrop Culvert

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0330

Channel Manning's n: 0.0200

Channel Invert Elevation: 666.00 ft

Roadway Data for Crossing: Teardrop Culvert

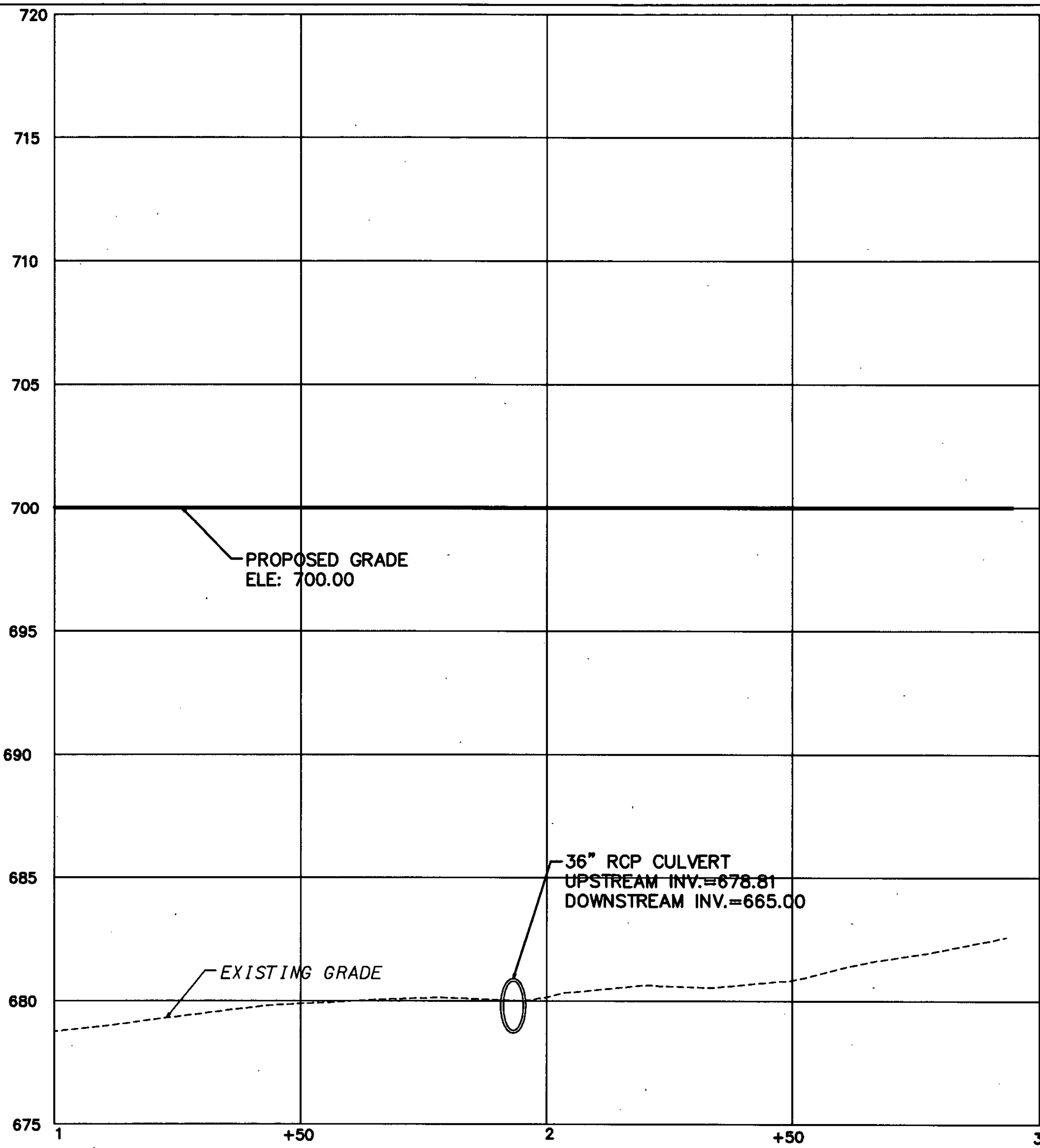
Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 698.00 ft

Roadway Surface: Paved

Roadway Top Width: 392.00 ft



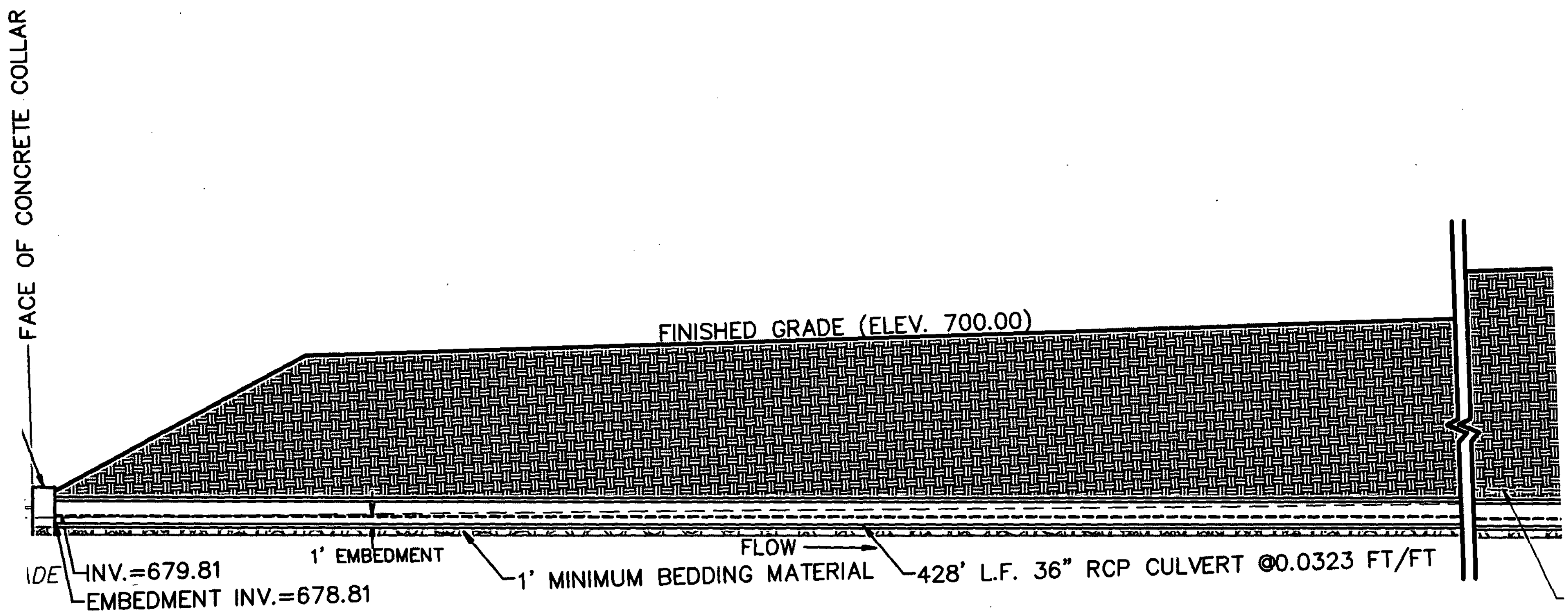
VERTICAL
SCALE: 1"=6'

HORIZONTAL
SCALE: 1"=30'

Pennoni
Pennoni Associates Inc.
100 N. Wilkes-Barre Blvd.
Wilkes-Barre, PA 18702

DRAWN BY: JMO	CHECKED BY: LGB	JOB No. PPLS0902
SCALE: AS SHOWN	SKETCH No.	
DATE: 03/29/2011		

1 OF 2



PROFILE SECTION

SCALE

Project Summary	
Title	PPL Bell Bend Nuclear Power Plant
Engineer	Lee G Borthwick
Company	Pennoni Associates, Inc
Date	11/29/2010

Notes

Table of Contents

Subsection: User Notifications

User Notifications?	No user notifications generated.

Subsection: Master Network Summary

Catchments Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (hours)	Peak Flow (ft³/s)
BY BASIN 11	BBNPP - Synthetic Curve, 100 yrs	100	0.861	12.017	12.71

Node Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (hours)	Peak Flow (ft³/s)
POI-11	BBNPP - Synthetic Curve, 100 yrs	100	0.861	12.017	12.71

Time-Depth Curve: TypeII 24hr (7.0 in)	
Label	TypeII 24hr (7.0 in)
Start Time	0.000 hours
Increment	0.100 hours
End Time	24.000 hours
Return Event	100 years

CUMULATIVE RAINFALL (in)
Output Time Increment = 0.100 hours
Time on left represents time for first value in each row.

Time (hours)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
0.000	0.0	0.0	0.0	0.0	0.0
0.500	0.0	0.0	0.1	0.1	0.1
1.000	0.1	0.1	0.1	0.1	0.1
1.500	0.1	0.1	0.1	0.1	0.1
2.000	0.2	0.2	0.2	0.2	0.2
2.500	0.2	0.2	0.2	0.2	0.2
3.000	0.2	0.2	0.3	0.3	0.3
3.500	0.3	0.3	0.3	0.3	0.3
4.000	0.3	0.3	0.4	0.4	0.4
4.500	0.4	0.4	0.4	0.4	0.4
5.000	0.4	0.4	0.5	0.5	0.5
5.500	0.5	0.5	0.5	0.5	0.5
6.000	0.6	0.6	0.6	0.6	0.6
6.500	0.6	0.6	0.6	0.7	0.7
7.000	0.7	0.7	0.7	0.7	0.7
7.500	0.8	0.8	0.8	0.8	0.8
8.000	0.8	0.9	0.9	0.9	0.9
8.500	0.9	0.9	1.0	1.0	1.0
9.000	1.0	1.0	1.1	1.1	1.1
9.500	1.1	1.2	1.2	1.2	1.2
10.000	1.3	1.3	1.3	1.4	1.4
10.500	1.4	1.5	1.5	1.5	1.6
11.000	1.6	1.7	1.7	1.8	1.9
11.500	2.0	2.1	2.5	3.0	4.0
12.000	4.6	4.7	4.9	5.0	5.0
12.500	5.1	5.2	5.2	5.3	5.3
13.000	5.4	5.4	5.5	5.5	5.5
13.500	5.6	5.6	5.6	5.7	5.7
14.000	5.7	5.7	5.8	5.8	5.8
14.500	5.8	5.9	5.9	5.9	5.9
15.000	5.9	6.0	6.0	6.0	6.0
15.500	6.0	6.1	6.1	6.1	6.1
16.000	6.1	6.1	6.2	6.2	6.2
16.500	6.2	6.2	6.2	6.2	6.3
17.000	6.3	6.3	6.3	6.3	6.3

CUMULATIVE RAINFALL (in)
Output Time Increment = 0.100 hours
Time on left represents time for first value in each row.

Time (hours)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
17.500	6.3	6.4	6.4	6.4	6.4
18.000	6.4	6.4	6.4	6.4	6.5
18.500	6.5	6.5	6.5	6.5	6.5
19.000	6.5	6.5	6.5	6.6	6.6
19.500	6.6	6.6	6.6	6.6	6.6
20.000	6.6	6.6	6.6	6.7	6.7
20.500	6.7	6.7	6.7	6.7	6.7
21.000	6.7	6.7	6.7	6.7	6.7
21.500	6.8	6.8	6.8	6.8	6.8
22.000	6.8	6.8	6.8	6.8	6.8
22.500	6.8	6.8	6.9	6.9	6.9
23.000	6.9	6.9	6.9	6.9	6.9
23.500	6.9	6.9	6.9	6.9	7.0
24.000	7.0	(N/A)	(N/A)	(N/A)	(N/A)

Runoff Curve Number Data

Soil/Surface Description	CN	Area (acres)	C (%)	UC (%)	Adjusted CN
IMPERVIOUS	98.000	0.680	0.0	0.0	98.000
CONST. LAYDOWN	91.000	0.710	0.0	0.0	91.000
Woods - fair - Soil A	36.000	5.510	0.0	0.0	36.000
MEADOW-A	30.000	4.550	0.0	0.0	30.000
COMPOSITE AREA & WEIGHTED CN --->	(N/A)	11.450	(N/A)	(N/A)	40.708

Unit Hydrograph Method (Computational Notes)
Definition of Terms

At	Total area (acres): At = Ai+Ap
Ai	Impervious area (acres)
Ap	Pervious area (acres)
CNi	Runoff curve number for impervious area
CNp	Runoff curve number for pervious area
fLoss	f loss constant infiltration (depth/time)
gKs	Saturated Hydraulic Conductivity (depth/time)
Md	Volumetric Moisture Deficit
Psi	Capillary Suction (length)
hK	Horton Infiltration Decay Rate (time^-1)
fo	Initial Infiltration Rate (depth/time)
fc	Ultimate(capacity)Infiltration Rate (depth/time)
Ia	Initial Abstraction (length)
dt	Computational increment (duration of unit excess rainfall) Default dt is smallest value of 0.1333Tc, rtm, and th (Smallest dt is then adjusted to match up with Tp)
UDdt	User specified override computational main time increment (only used if UDdt is => .1333Tc)
D(t)	Point on distribution curve (fraction of P) for time step t
K	2 / (1 + (Tr/Tp)): default K = 0.75: (for Tr/Tp = 1.67)
Ks	Hydrograph shape factor = Unit Conversions * K: = ((1hr/3600sec) * (1ft/12in) * ((5280ft)**2/sq.mi)) * K Default Ks = 645.333 * 0.75 = 484
Lag	Lag time from center of excess runoff (dt) to Tp: Lag = 0.6Tc
P	Total precipitation depth, inches
Pa(t)	Accumulated rainfall at time step t
Pi(t)	Incremental rainfall at time step t
qp	Peak discharge (cfs) for 1in. runoff, for 1hr, for 1 sq.mi. = (Ks * A * Q) / Tp (where Q = 1in. runoff, A=sq.mi.)
Qu(t)	Unit hydrograph ordinate (cfs) at time step t
Q(t)	Final hydrograph ordinate (cfs) at time step t
Rai(t)	Accumulated runoff (inches) at time step t for impervious area
Rap(t)	Accumulated runoff (inches) at time step t for pervious area
Rii(t)	Incremental runoff (inches) at time step t for impervious area
Rip(t)	Incremental runoff (inches) at time step t for pervious area
R(t)	Incremental weighted total runoff (inches)
Rtm	Time increment for rainfall table
Si	S for impervious area: Si = (1000/CNi) - 10
Sp	S for pervious area: Sp = (1000/CNp) - 10
t	Time step (row) number
Tc	Time of concentration
Tb	Time (hrs) of entire unit hydrograph: Tb = Tp + Tr
Tp	Time (hrs) to peak of a unit hydrograph: Tp = (dt/2) + Lag
Tr	Time (hrs) of receding limb of unit hydrograph: Tr = ratio of Tp

Unit Hydrograph Method
Computational Notes
Precipitation

Column (1)	Time for time step t
Column (2)	D(t) = Point on distribution curve for time step t
Column (3)	Pi(t) = Pa(t) - Pa(t-1): Col.(4) - Preceding Col.(4)
Column (4)	Pa(t) = D(t) x P: Col.(2) x P

Pervious Area Runoff (using SCS Runoff CN Method)

Column (5)	Rap(t) = Accumulated pervious runoff for time step t
	If (Pa(t) is <= 0.2Sp) then use: Rap(t) = 0.0
	If (Pa(t) is > 0.2Sp) then use:
	
	Rap(t) = (Col.(4)-0.2Sp)**2 / (Col.(4)+0.8Sp)

Column (6)	Rip(t) = Incremental pervious runoff for time step t Rip(t) = Rap(t) - Rap(t-1) Rip(t) = Col.(5) for current row - Col.(5) for preceding row.

Impervious Area Runoff

Column (7 & 8)...	Did not specify to use impervious areas.

Incremental Weighted Runoff

Column (9)	R(t) = (Ap/At) x Rip(t) + (Ai/At) x Rii(t) R(t) = (Ap/At) x Col.(6) + (Ai/At) x Col.(8)

SCS Unit Hydrograph Method

Column (10)	Q(t) is computed with the SCS unit hydrograph method using R(t) and Qu(t).

Storm Event	TypeII 24hr (7.0 in)
Return Event	100 years
Duration	35.000 hours
Depth	7.0 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	11.450 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	12.017 hours
Flow (Peak, Computed)	12.72 ft³/s
Output Increment	0.017 hours
Time to Flow (Peak Interpolated Output)	12.017 hours
Flow (Peak Interpolated Output)	12.71 ft³/s

Drainage Area	
SCS CN (Composite)	41.000
Area (User Defined)	11.450 acres
Maximum Retention (Pervious)	14.4 in
Maximum Retention (Pervious, 20 percent)	2.9 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.9 in
Runoff Volume (Pervious)	0.861 ac-ft

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.861 ac-ft

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	155.74 ft³/s

SCS Unit Hydrograph Parameters	
Unit peak time, Tp	0.056 hours
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	TypeII 24hr (7.0 in)
Return Event	100 years
Duration	35.000 hours
Depth	7.0 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	11.450 acres

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 0.017 hours
Time on left represents time for first value in each row.

Time (hours)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
11.767	0.00	0.00	0.03	0.19	0.72
11.850	1.70	3.16	4.91	6.81	8.61
11.933	9.92	10.72	11.25	11.79	12.42
12.017	12.71	11.78	9.83	7.65	5.91
12.100	4.87	4.22	3.80	3.50	3.29
12.183	3.16	3.09	3.04	2.98	2.89
12.267	2.81	2.76	2.74	2.71	2.66
12.350	2.57	2.49	2.43	2.40	2.37
12.433	2.31	2.22	2.13	2.06	2.02
12.517	1.99	1.95	1.89	1.83	1.78
12.600	1.76	1.74	1.72	1.70	1.68
12.683	1.67	1.66	1.65	1.64	1.62
12.767	1.60	1.59	1.58	1.57	1.56
12.850	1.54	1.52	1.50	1.49	1.49
12.933	1.47	1.45	1.43	1.41	1.40
13.017	1.40	1.38	1.37	1.35	1.34
13.100	1.33	1.33	1.32	1.30	1.29
13.183	1.28	1.28	1.28	1.27	1.26
13.267	1.25	1.24	1.23	1.23	1.22
13.350	1.21	1.20	1.19	1.18	1.18
13.433	1.17	1.16	1.14	1.13	1.13
13.517	1.13	1.12	1.11	1.09	1.09
13.600	1.08	1.08	1.07	1.06	1.05
13.683	1.05	1.04	1.04	1.03	1.02
13.767	1.02	1.01	1.01	1.00	1.00
13.850	0.99	0.98	0.97	0.97	0.96
13.933	0.95	0.94	0.94	0.93	0.92
14.017	0.92	0.92	0.91	0.90	0.90
14.100	0.90	0.89	0.89	0.89	0.88
14.183	0.88	0.88	0.88	0.88	0.88
14.267	0.87	0.87	0.87	0.87	0.87
14.350	0.87	0.86	0.86	0.86	0.86
14.433	0.86	0.85	0.85	0.85	0.85
14.517	0.85	0.84	0.84	0.84	0.83

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 0.017 hours
Time on left represents time for first value in each row.

Time (hours)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
14.600	0.83	0.83	0.83	0.83	0.82
14.683	0.82	0.82	0.82	0.82	0.82
14.767	0.81	0.81	0.81	0.81	0.80
14.850	0.80	0.80	0.80	0.80	0.79
14.933	0.79	0.79	0.78	0.78	0.78
15.017	0.78	0.78	0.77	0.77	0.77
15.100	0.77	0.77	0.76	0.76	0.76
15.183	0.75	0.75	0.75	0.75	0.75
15.267	0.74	0.74	0.74	0.74	0.73
15.350	0.73	0.73	0.72	0.72	0.72
15.433	0.72	0.72	0.71	0.71	0.71
15.517	0.71	0.70	0.70	0.70	0.69
15.600	0.69	0.69	0.69	0.68	0.68
15.683	0.68	0.68	0.68	0.67	0.67
15.767	0.66	0.66	0.66	0.66	0.66
15.850	0.65	0.65	0.65	0.65	0.64
15.933	0.64	0.64	0.63	0.63	0.63
16.017	0.63	0.62	0.62	0.62	0.62
16.100	0.62	0.62	0.62	0.61	0.61
16.183	0.61	0.61	0.61	0.61	0.61
16.267	0.61	0.61	0.61	0.61	0.61
16.350	0.60	0.60	0.60	0.60	0.60
16.433	0.60	0.60	0.60	0.60	0.60
16.517	0.60	0.60	0.60	0.59	0.59
16.600	0.59	0.59	0.59	0.59	0.59
16.683	0.59	0.59	0.59	0.59	0.59
16.767	0.58	0.58	0.58	0.58	0.58
16.850	0.58	0.58	0.58	0.58	0.58
16.933	0.58	0.58	0.57	0.57	0.57
17.017	0.57	0.57	0.57	0.57	0.57
17.100	0.57	0.57	0.57	0.56	0.56
17.183	0.56	0.56	0.56	0.56	0.56
17.267	0.56	0.56	0.56	0.56	0.56
17.350	0.55	0.55	0.55	0.55	0.55
17.433	0.55	0.55	0.55	0.55	0.55
17.517	0.55	0.54	0.54	0.54	0.54
17.600	0.54	0.54	0.54	0.54	0.54
17.683	0.54	0.54	0.54	0.53	0.53
17.767	0.53	0.53	0.53	0.53	0.53
17.850	0.53	0.53	0.52	0.52	0.52
17.933	0.52	0.52	0.52	0.52	0.52
18.017	0.52	0.52	0.51	0.51	0.51
18.100	0.51	0.51	0.51	0.51	0.51
18.183	0.51	0.51	0.50	0.50	0.50

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 0.017 hours
Time on left represents time for first value in each row.

Time (hours)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
18.267	0.50	0.50	0.50	0.50	0.50
18.350	0.50	0.50	0.49	0.49	0.49
18.433	0.49	0.49	0.49	0.49	0.49
18.517	0.49	0.49	0.49	0.48	0.48
18.600	0.48	0.48	0.48	0.48	0.48
18.683	0.48	0.48	0.48	0.47	0.47
18.767	0.47	0.47	0.47	0.47	0.47
18.850	0.47	0.47	0.46	0.46	0.46
18.933	0.46	0.46	0.46	0.46	0.46
19.017	0.46	0.46	0.45	0.45	0.45
19.100	0.45	0.45	0.45	0.45	0.45
19.183	0.44	0.44	0.44	0.44	0.44
19.267	0.44	0.44	0.44	0.44	0.44
19.350	0.43	0.43	0.43	0.43	0.43
19.433	0.43	0.43	0.43	0.43	0.43
19.517	0.42	0.42	0.42	0.42	0.42
19.600	0.42	0.42	0.42	0.41	0.41
19.683	0.41	0.41	0.41	0.41	0.41
19.767	0.41	0.41	0.40	0.40	0.40
19.850	0.40	0.40	0.40	0.40	0.40
19.933	0.40	0.40	0.39	0.39	0.39
20.017	0.39	0.39	0.39	0.39	0.39
20.100	0.39	0.39	0.39	0.39	0.39
20.183	0.39	0.39	0.39	0.39	0.39
20.267	0.39	0.39	0.39	0.39	0.39
20.350	0.38	0.38	0.38	0.38	0.38
20.433	0.38	0.38	0.38	0.38	0.38
20.517	0.38	0.38	0.38	0.38	0.38
20.600	0.38	0.38	0.38	0.38	0.38
20.683	0.38	0.38	0.38	0.38	0.38
20.767	0.38	0.38	0.38	0.38	0.38
20.850	0.38	0.38	0.38	0.38	0.38
20.933	0.38	0.38	0.38	0.38	0.38
21.017	0.38	0.38	0.38	0.38	0.38
21.100	0.38	0.38	0.38	0.38	0.38
21.183	0.38	0.38	0.38	0.38	0.38
21.267	0.38	0.38	0.38	0.38	0.38
21.350	0.38	0.38	0.37	0.37	0.37
21.433	0.37	0.37	0.37	0.37	0.37
21.517	0.37	0.37	0.37	0.37	0.37
21.600	0.37	0.37	0.37	0.37	0.37
21.683	0.37	0.37	0.37	0.37	0.37
21.767	0.37	0.37	0.37	0.37	0.37
21.850	0.37	0.37	0.37	0.37	0.37

HYDROGRAPH ORDINATES (ft^3/s)
Output Time Increment = 0.017 hours
Time on left represents time for first value in each row.

Time (hours)	Flow (ft^3/s)	Flow (ft^3/s)	Flow (ft^3/s)	Flow (ft^3/s)	Flow (ft^3/s)
21.933	0.37	0.37	0.37	0.37	0.37
22.017	0.37	0.37	0.37	0.37	0.37
22.100	0.37	0.37	0.37	0.37	0.37
22.183	0.37	0.37	0.37	0.37	0.37
22.267	0.37	0.37	0.37	0.37	0.37
22.350	0.37	0.37	0.36	0.36	0.36
22.433	0.36	0.36	0.36	0.36	0.36
22.517	0.36	0.36	0.36	0.36	0.36
22.600	0.36	0.36	0.36	0.36	0.36
22.683	0.36	0.36	0.36	0.36	0.36
22.767	0.36	0.36	0.36	0.36	0.36
22.850	0.36	0.36	0.36	0.36	0.36
22.933	0.36	0.36	0.36	0.36	0.36
23.017	0.36	0.36	0.36	0.36	0.36
23.100	0.36	0.36	0.36	0.36	0.36
23.183	0.36	0.36	0.36	0.36	0.36
23.267	0.36	0.36	0.36	0.36	0.36
23.350	0.36	0.36	0.35	0.35	0.35
23.433	0.35	0.35	0.35	0.35	0.35
23.517	0.35	0.35	0.35	0.35	0.35
23.600	0.35	0.35	0.35	0.35	0.35
23.683	0.35	0.35	0.35	0.35	0.35
23.767	0.35	0.35	0.35	0.35	0.35
23.850	0.35	0.35	0.35	0.35	0.35
23.933	0.35	0.35	0.35	0.35	0.35
24.017	0.33	0.29	0.22	0.14	0.09
24.100	0.05	0.03	0.02	0.01	0.01
24.183	0.00	0.00	0.00	0.00	(N/A)

Summary for Hydrograph Addition at 'POI-11'

Upstream Link	Upstream Node
<Catchment to Outflow Node>	BY BASIN 11

Node Inflows

Inflow Type	Element	Volume (ac-ft)	Time to Peak (hours)	Flow (Peak) (ft^3/s)
Flow (From)	BY BASIN 11	0.861	12.017	12.71
Flow (In)	POI-11	0.861	12.017	12.71

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Project Summary

Title	PPL Bell Bend Nuclear Power Plant
Engineer	Lee G Borthwick
Company	Pennoni Assiciates, Inc.
Date	11/29/2010

Notes

Table of Contents

Subsection: User Notifications

User Notifications?	No user notifications generated.

Subsection: Master Network Summary

Catchments Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (hours)	Peak Flow (ft^3/s)
AREA 11	BBNPP - Synthetic Curve, 100 yrs	100	5.461	12.083	71.66

Node Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ac-ft)	Time to Peak (hours)	Peak Flow (ft^3/s)
POI-11	BBNPP - Synthetic Curve, 100 yrs	100	5.461	12.083	71.66

Time-Depth Curve: TypeII 24hr (7.0 in)	
Label	TypeII 24hr (7.0 in)
Start Time	0.000 hours
Increment	0.100 hours
End Time	24.000 hours
Return Event	100 years

CUMULATIVE RAINFALL (in)
Output Time Increment = 0.100 hours
Time on left represents time for first value in each row.

Time (hours)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
0.000	0.0	0.0	0.0	0.0	0.0
0.500	0.0	0.0	0.1	0.1	0.1
1.000	0.1	0.1	0.1	0.1	0.1
1.500	0.1	0.1	0.1	0.1	0.1
2.000	0.2	0.2	0.2	0.2	0.2
2.500	0.2	0.2	0.2	0.2	0.2
3.000	0.2	0.2	0.3	0.3	0.3
3.500	0.3	0.3	0.3	0.3	0.3
4.000	0.3	0.3	0.4	0.4	0.4
4.500	0.4	0.4	0.4	0.4	0.4
5.000	0.4	0.4	0.5	0.5	0.5
5.500	0.5	0.5	0.5	0.5	0.5
6.000	0.6	0.6	0.6	0.6	0.6
6.500	0.6	0.6	0.6	0.7	0.7
7.000	0.7	0.7	0.7	0.7	0.7
7.500	0.8	0.8	0.8	0.8	0.8
8.000	0.8	0.9	0.9	0.9	0.9
8.500	0.9	0.9	1.0	1.0	1.0
9.000	1.0	1.0	1.1	1.1	1.1
9.500	1.1	1.2	1.2	1.2	1.2
10.000	1.3	1.3	1.3	1.4	1.4
10.500	1.4	1.5	1.5	1.5	1.6
11.000	1.6	1.7	1.7	1.8	1.9
11.500	2.0	2.1	2.5	3.0	4.0
12.000	4.6	4.7	4.9	5.0	5.0
12.500	5.1	5.2	5.2	5.3	5.3
13.000	5.4	5.4	5.5	5.5	5.5
13.500	5.6	5.6	5.6	5.7	5.7
14.000	5.7	5.7	5.8	5.8	5.8
14.500	5.8	5.9	5.9	5.9	5.9
15.000	5.9	6.0	6.0	6.0	6.0
15.500	6.0	6.1	6.1	6.1	6.1
16.000	6.1	6.1	6.2	6.2	6.2
16.500	6.2	6.2	6.2	6.2	6.3
17.000	6.3	6.3	6.3	6.3	6.3

Subsection: Time-Depth Curve
Label: BBNPP

Return Event: 100 years
Storm Event: TypeII 24hr (7.0 in)

CUMULATIVE RAINFALL (in)
Output Time Increment = 0.100 hours
Time on left represents time for first value in each row.

Time (hours)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
17.500	6.3	6.4	6.4	6.4	6.4
18.000	6.4	6.4	6.4	6.4	6.5
18.500	6.5	6.5	6.5	6.5	6.5
19.000	6.5	6.5	6.5	6.6	6.6
19.500	6.6	6.6	6.6	6.6	6.6
20.000	6.6	6.6	6.6	6.7	6.7
20.500	6.7	6.7	6.7	6.7	6.7
21.000	6.7	6.7	6.7	6.7	6.7
21.500	6.8	6.8	6.8	6.8	6.8
22.000	6.8	6.8	6.8	6.8	6.8
22.500	6.8	6.8	6.9	6.9	6.9
23.000	6.9	6.9	6.9	6.9	6.9
23.500	6.9	6.9	6.9	6.9	7.0
24.000	7.0	(N/A)	(N/A)	(N/A)	(N/A)

Time of Concentration Results

Segment #1: TR-55 Sheet Flow	
Hydraulic Length	100.00 ft
Manning's n	0.400
Slope	0.100 ft/ft
2 Year 24 Hour Depth	2.9 in
Average Velocity	0.14 ft/s
Segment Time of Concentration	0.198 hours

Segment #2: TR-55 Shallow Concentrated Flow	
Hydraulic Length	66.31 ft
Is Paved?	False
Slope	0.140 ft/ft
Average Velocity	6.04 ft/s
Segment Time of Concentration	0.003 hours

Segment #3: TR-55 Shallow Concentrated Flow	
Hydraulic Length	902.62 ft
Is Paved?	False
Slope	0.040 ft/ft
Average Velocity	3.23 ft/s
Segment Time of Concentration	0.078 hours

Time of Concentration (Composite)	
Time of Concentration (Composite)	0.279 hours

==== SCS Channel Flow

Tc =	R = Qa / Wp V = (1.49 * (R**(2/3)) * (Sf**-0.5)) / n (Lf / V) / 3600
Where:	R= Hydraulic radius Aq= Flow area, square feet Wp= Wetted perimeter, feet V= Velocity, ft/sec Sf= Slope, ft/ft n= Manning's n Tc= Time of concentration, hours Lf= Flow length, feet

==== SCS TR-55 Shallow Concentration Flow

Tc =	Unpaved surface: V = 16.1345 * (Sf**0.5) Paved Surface: V = 20.3282 * (Sf**0.5) (Lf / V) / 3600
Where:	V= Velocity, ft/sec Sf= Slope, ft/ft Tc= Time of concentration, hours Lf= Flow length, feet

Runoff Curve Number Data

Soil/Surface Description	CN	Area (acres)	C (%)	UC (%)	Adjusted CN
IMPERVIOUS	98.000	0.360	0.0	0.0	98.000
Woods - fair - Soil A	36.000	11.140	0.0	0.0	36.000
Meadow - cont. grass (non grazed) - ---- - Soil A	30.000	4.440	0.0	0.0	30.000
Woods - fair - Soil C	73.000	5.180	0.0	0.0	73.000
Meadow - cont. grass (non grazed) - ---- - Soil C	71.000	3.130	0.0	0.0	71.000
WOODS-C\D	76.000	1.180	0.0	0.0	76.000
MEADOW-C\D	74.000	1.480	0.0	0.0	74.000
Cultivated Field A	78.000	2.120	0.0	0.0	78.000
Cultivated Field C	88.000	1.500	0.0	0.0	88.000
Cultivated Field C/D	89.000	0.700	0.0	0.0	89.000
COMPOSITE AREA & WEIGHTED CN --->	(N/A)	31.230	(N/A)	(N/A)	55.355

Unit Hydrograph Method (Computational Notes)
Definition of Terms

At	Total area (acres): At = Ai+Ap
Ai	Impervious area (acres)
Ap	Pervious area (acres)
CNi	Runoff curve number for impervious area
CNp	Runoff curve number for pervious area
fLoss	f loss constant infiltration (depth/time)
gKs	Saturated Hydraulic Conductivity (depth/time)
Md	Volumetric Moisture Deficit
Psi	Capillary Suction (length)
hK	Horton Infiltration Decay Rate (time^-1)
fo	Initial Infiltration Rate (depth/time)
fc	Ultimate(capacity)Infiltration Rate (depth/time)
Ia	Initial Abstraction (length)
dt	Computational increment (duration of unit excess rainfall) Default dt is smallest value of 0.1333Tc, rtm, and th (Smallest dt is then adjusted to match up with Tp)
UDdt	User specified override computational main time increment (only used if UDdt is => .1333Tc)
D(t)	Point on distribution curve (fraction of P) for time step t
K	2 / (1 + (Tr/Tp)): default K = 0.75: (for Tr/Tp = 1.67)
Ks	Hydrograph shape factor = Unit Conversions * K: = ((1hr/3600sec) * (1ft/12in) * ((5280ft)**2/sq.mi)) * K Default Ks = 645.333 * 0.75 = 484
Lag	Lag time from center of excess runoff (dt) to Tp: Lag = 0.6Tc
P	Total precipitation depth, inches
Pa(t)	Accumulated rainfall at time step t
Pi(t)	Incremental rainfall at time step t
qp	Peak discharge (cfs) for 1in. runoff, for 1hr, for 1 sq.mi. = (Ks * A * Q) / Tp (where Q = 1in. runoff, A=sq.mi.)
Qu(t)	Unit hydrograph ordinate (cfs) at time step t
Q(t)	Final hydrograph ordinate (cfs) at time step t
Rai(t)	Accumulated runoff (inches) at time step t for impervious area
Rap(t)	Accumulated runoff (inches) at time step t for pervious area
Rii(t)	Incremental runoff (inches) at time step t for impervious area
Rip(t)	Incremental runoff (inches) at time step t for pervious area
R(t)	Incremental weighted total runoff (inches)
Rtm	Time increment for rainfall table
Si	S for impervious area: Si = (1000/CNi) - 10
Sp	S for pervious area: Sp = (1000/CNp) - 10
t	Time step (row) number
Tc	Time of concentration
Tb	Time (hrs) of entire unit hydrograph: Tb = Tp + Tr
Tp	Time (hrs) to peak of a unit hydrograph: Tp = (dt/2) + Lag
Tr	Time (hrs) of receding limb of unit hydrograph: Tr = ratio of Tp

Subsection: Unit Hydrograph Equations

Unit Hydrograph Method
Computational Notes
Precipitation

Column (1)	Time for time step t
Column (2)	D(t) = Point on distribution curve for time step t
Column (3)	Pi(t) = Pa(t) - Pa(t-1): Col.(4) - Preceding Col.(4)
Column (4)	Pa(t) = D(t) x P: Col.(2) x P

Pervious Area Runoff (using SCS Runoff CN Method)

Column (5)	Rap(t) = Accumulated pervious runoff for time step t
	If (Pa(t) is <= 0.2Sp) then use: Rap(t) = 0.0
	If (Pa(t) is > 0.2Sp) then use:
	
	Rap(t) = (Col.(4)-0.2Sp)**2 / (Col.(4)+0.8Sp)

Column (6)	Rip(t) = Incremental pervious runoff for time step t Rip(t) = Rap(t) - Rap(t-1) Rip(t) = Col.(5) for current row - Col.(5) for preceding row.

Impervious Area Runoff

Column (7 & 8)...	Did not specify to use impervious areas.

Incremental Weighted Runoff

Column (9)	R(t) = (Ap/At) x Rip(t) + (Ai/At) x Rii(t) R(t) = (Ap/At) x Col.(6) + (Ai/At) x Col.(8)

SCS Unit Hydrograph Method

Column (10)	Q(t) is computed with the SCS unit hydrograph method using R(t) and Qu(t).

Storm Event	TypeII 24hr (7.0 in)
Return Event	100 years
Duration	35.000 hours
Depth	7.0 in
Time of Concentration (Composite)	0.279 hours
Area (User Defined)	31.230 acres

Computational Time Increment	0.037 hours
Time to Peak (Computed)	12.087 hours
Flow (Peak, Computed)	71.77 ft³/s
Output Increment	0.017 hours
Time to Flow (Peak Interpolated Output)	12.083 hours
Flow (Peak Interpolated Output)	71.66 ft³/s

Drainage Area	
SCS CN (Composite)	55.000
Area (User Defined)	31.230 acres
Maximum Retention (Pervious)	8.2 in
Maximum Retention (Pervious, 20 percent)	1.6 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	2.1 in
Runoff Volume (Pervious)	5.461 ac-ft

Hydrograph Volume (Area under Hydrograph curve)	
Volume	5.461 ac-ft

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.279 hours
Computational Time Increment	0.037 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	126.86 ft³/s

SCS Unit Hydrograph Parameters	
Unit peak time, Tp	0.186 hours
Unit receding limb, Tr	0.744 hours
Total unit time, Tb	0.930 hours

Storm Event	TypeII 24hr (7.0 in)
Return Event	100 years
Duration	35.000 hours
Depth	7.0 in
Time of Concentration (Composite)	0.279 hours
Area (User Defined)	31.230 acres

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 0.017 hours
Time on left represents time for first value in each row.

Time (hours)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
11.033	0.00	0.00	0.00	0.00	0.01
11.117	0.01	0.02	0.03	0.05	0.06
11.200	0.08	0.10	0.13	0.16	0.19
11.283	0.22	0.26	0.30	0.35	0.39
11.367	0.44	0.49	0.54	0.60	0.66
11.450	0.72	0.79	0.85	0.93	1.01
11.533	1.10	1.22	1.34	1.53	1.71
11.617	1.98	2.28	2.67	3.14	3.68
11.700	4.40	5.16	6.21	7.27	8.68
11.783	10.14	12.00	14.09	16.55	19.52
11.867	22.71	26.85	31.00	36.04	41.14
11.950	46.39	51.71	56.61	61.07	65.10
12.033	67.88	70.59	71.13	71.66	70.25
12.117	68.34	65.52	61.98	58.31	54.35
12.200	50.42	46.67	42.91	39.68	36.53
12.283	33.89	31.54	29.43	27.68	26.01
12.367	24.65	23.29	22.17	21.07	20.12
12.450	19.23	18.41	17.66	16.94	16.30
12.533	15.66	15.10	14.54	14.04	13.56
12.617	13.10	12.68	12.28	11.92	11.57
12.700	11.27	10.97	10.71	10.46	10.23
12.783	10.03	9.84	9.67	9.50	9.36
12.867	9.22	9.09	8.97	8.85	8.74
12.950	8.64	8.54	8.43	8.33	8.23
13.033	8.14	8.04	7.95	7.86	7.77
13.117	7.68	7.60	7.52	7.44	7.37
13.200	7.29	7.23	7.16	7.09	7.03
13.283	6.97	6.91	6.85	6.80	6.74
13.367	6.69	6.63	6.58	6.53	6.48
13.450	6.42	6.37	6.32	6.27	6.22
13.533	6.17	6.12	6.07	6.02	5.97
13.617	5.93	5.88	5.83	5.78	5.74
13.700	5.70	5.65	5.61	5.57	5.53
13.783	5.49	5.45	5.41	5.37	5.33

Subsection: Unit Hydrograph (Hydrograph Table) Return Event: 100 years
Label: AREA 11 Storm Event: TypeII 24hr (7.0 in)

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 0.017 hours
Time on left represents time for first value in each row.

Time (hours)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
13.867	5.29	5.26	5.22	5.18	5.14
13.950	5.10	5.07	5.03	4.99	4.96
14.033	4.92	4.88	4.85	4.81	4.78
14.117	4.75	4.71	4.68	4.66	4.63
14.200	4.60	4.58	4.56	4.53	4.51
14.283	4.49	4.48	4.46	4.44	4.43
14.367	4.41	4.40	4.38	4.37	4.35
14.450	4.34	4.33	4.31	4.30	4.29
14.533	4.28	4.26	4.25	4.24	4.22
14.617	4.21	4.20	4.19	4.17	4.16
14.700	4.15	4.14	4.12	4.11	4.10
14.783	4.09	4.07	4.06	4.05	4.04
14.867	4.02	4.01	4.00	3.99	3.97
14.950	3.96	3.95	3.94	3.92	3.91
15.033	3.90	3.88	3.87	3.86	3.85
15.117	3.83	3.82	3.81	3.79	3.78
15.200	3.77	3.76	3.74	3.73	3.72
15.283	3.70	3.69	3.68	3.66	3.65
15.367	3.64	3.62	3.61	3.60	3.58
15.450	3.57	3.56	3.54	3.53	3.52
15.533	3.50	3.49	3.48	3.46	3.45
15.617	3.44	3.42	3.41	3.40	3.38
15.700	3.37	3.36	3.34	3.33	3.32
15.783	3.30	3.29	3.27	3.26	3.25
15.867	3.23	3.22	3.21	3.19	3.18
15.950	3.16	3.15	3.14	3.12	3.11
16.033	3.10	3.08	3.07	3.06	3.04
16.117	3.03	3.02	3.01	3.00	2.99
16.200	2.98	2.97	2.96	2.95	2.95
16.283	2.94	2.93	2.93	2.92	2.91
16.367	2.91	2.90	2.90	2.89	2.89
16.450	2.88	2.88	2.87	2.87	2.86
16.533	2.86	2.85	2.85	2.84	2.84
16.617	2.83	2.83	2.82	2.82	2.81
16.700	2.81	2.80	2.80	2.80	2.79
16.783	2.79	2.78	2.78	2.77	2.77
16.867	2.76	2.76	2.75	2.75	2.74
16.950	2.74	2.73	2.73	2.73	2.72
17.033	2.72	2.71	2.71	2.70	2.70
17.117	2.69	2.69	2.68	2.68	2.67
17.200	2.67	2.66	2.66	2.66	2.65
17.283	2.65	2.64	2.64	2.63	2.63
17.367	2.62	2.62	2.61	2.61	2.60
17.450	2.60	2.59	2.59	2.58	2.58

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 0.017 hours
Time on left represents time for first value in each row.

Time (hours)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
17.533	2.57	2.57	2.56	2.56	2.55
17.617	2.55	2.54	2.54	2.53	2.53
17.700	2.53	2.52	2.52	2.51	2.51
17.783	2.50	2.50	2.49	2.49	2.48
17.867	2.48	2.47	2.47	2.46	2.46
17.950	2.45	2.45	2.44	2.44	2.43
18.033	2.43	2.42	2.42	2.41	2.41
18.117	2.40	2.40	2.39	2.39	2.38
18.200	2.38	2.37	2.37	2.36	2.36
18.283	2.35	2.35	2.34	2.34	2.33
18.367	2.33	2.32	2.32	2.31	2.31
18.450	2.30	2.30	2.29	2.29	2.28
18.533	2.28	2.27	2.27	2.26	2.26
18.617	2.25	2.25	2.24	2.24	2.23
18.700	2.23	2.22	2.22	2.21	2.21
18.783	2.20	2.20	2.19	2.19	2.18
18.867	2.18	2.17	2.17	2.16	2.16
18.950	2.15	2.15	2.14	2.13	2.13
19.033	2.12	2.12	2.11	2.11	2.10
19.117	2.10	2.09	2.09	2.08	2.08
19.200	2.07	2.07	2.06	2.06	2.05
19.283	2.05	2.04	2.04	2.03	2.03
19.367	2.02	2.02	2.01	2.01	2.00
19.450	1.99	1.99	1.98	1.98	1.97
19.533	1.97	1.96	1.96	1.95	1.95
19.617	1.94	1.94	1.93	1.93	1.92
19.700	1.92	1.91	1.91	1.90	1.90
19.783	1.89	1.88	1.88	1.87	1.87
19.867	1.86	1.86	1.85	1.85	1.84
19.950	1.84	1.83	1.83	1.82	1.82
20.033	1.81	1.81	1.80	1.80	1.79
20.117	1.79	1.78	1.78	1.77	1.77
20.200	1.77	1.76	1.76	1.76	1.76
20.283	1.75	1.75	1.75	1.75	1.75
20.367	1.75	1.74	1.74	1.74	1.74
20.450	1.74	1.74	1.74	1.74	1.73
20.533	1.73	1.73	1.73	1.73	1.73
20.617	1.73	1.73	1.73	1.73	1.73
20.700	1.72	1.72	1.72	1.72	1.72
20.783	1.72	1.72	1.72	1.72	1.72
20.867	1.72	1.72	1.71	1.71	1.71
20.950	1.71	1.71	1.71	1.71	1.71
21.033	1.71	1.71	1.70	1.70	1.70
21.117	1.70	1.70	1.70	1.70	1.70

HYDROGRAPH ORDINATES (ft³/s)
Output Time Increment = 0.017 hours
Time on left represents time for first value in each row.

Time (hours)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)	Flow (ft³/s)
21.200	1.70	1.70	1.70	1.70	1.69
21.283	1.69	1.69	1.69	1.69	1.69
21.367	1.69	1.69	1.69	1.69	1.68
21.450	1.68	1.68	1.68	1.68	1.68
21.533	1.68	1.68	1.68	1.68	1.68
21.617	1.68	1.67	1.67	1.67	1.67
21.700	1.67	1.67	1.67	1.67	1.67
21.783	1.67	1.67	1.66	1.66	1.66
21.867	1.66	1.66	1.66	1.66	1.66
21.950	1.66	1.66	1.65	1.65	1.65
22.033	1.65	1.65	1.65	1.65	1.65
22.117	1.65	1.65	1.65	1.64	1.64
22.200	1.64	1.64	1.64	1.64	1.64
22.283	1.64	1.64	1.64	1.64	1.63
22.367	1.63	1.63	1.63	1.63	1.63
22.450	1.63	1.63	1.63	1.63	1.62
22.533	1.62	1.62	1.62	1.62	1.62
22.617	1.62	1.62	1.62	1.62	1.62
22.700	1.61	1.61	1.61	1.61	1.61
22.783	1.61	1.61	1.61	1.61	1.61
22.867	1.60	1.60	1.60	1.60	1.60
22.950	1.60	1.60	1.60	1.60	1.60
23.033	1.60	1.59	1.59	1.59	1.59
23.117	1.59	1.59	1.59	1.59	1.59
23.200	1.59	1.59	1.58	1.58	1.58
23.283	1.58	1.58	1.58	1.58	1.58
23.367	1.58	1.58	1.57	1.57	1.57
23.450	1.57	1.57	1.57	1.57	1.57
23.533	1.57	1.57	1.56	1.56	1.56
23.617	1.56	1.56	1.56	1.56	1.56
23.700	1.56	1.56	1.55	1.55	1.55
23.783	1.55	1.55	1.55	1.55	1.55
23.867	1.55	1.55	1.55	1.54	1.54
23.950	1.54	1.54	1.54	1.53	1.53
24.033	1.51	1.48	1.45	1.39	1.33
24.117	1.25	1.16	1.06	0.96	0.86
24.200	0.76	0.67	0.58	0.50	0.44
24.283	0.37	0.32	0.28	0.24	0.21
24.367	0.18	0.15	0.13	0.12	0.10
24.450	0.09	0.07	0.06	0.05	0.05
24.533	0.04	0.03	0.03	0.02	0.02
24.617	0.02	0.02	0.01	0.01	0.01
24.700	0.01	0.01	0.01	0.00	0.00
24.783	0.00	0.00	0.00	0.00	(N/A)

Summary for Hydrograph Addition at 'POI-11'

Upstream Link	Upstream Node
<Catchment to Outflow Node>	AREA 11

Node Inflows

Inflow Type	Element	Volume (ac-ft)	Time to Peak (hours)	Flow (Peak) (ft^3/s)
Flow (From)	AREA 11	5.461	12.083	71.66
Flow (In)	POI-11	5.461	12.083	71.66

Index

Trapezoidal Channel Analysis - Open Channel Flow (w/ Manning's Eq)

Client/Subject: **PPL, BELL BEND NUCLEAR POWER PLANT**
Description: **Teardrop/Unnamed Walker Run Tributary Connection**
Prepared by: **LGB**
Date: **25 Aug 11**

Print Date: 25 Aug 11 9:48 PM
Project #: PPLS0902

Checked by: CML

Objective:

Using Manning's equation, this spreadsheet will calculate the amount of flow through a trapezoidal or triangular (b=0) channel. By inputting the channel characteristics, the flow depth will be calculated. Other flow characteristics are also computed, including the critical slope and required freeboard based on E&S manual guidelines. The last line calculates the maximum allowable velocity as indicated by the PA E&S manual.

Method: See PA Erosion and Sedimentation Control Manual for reference.

Manning's Equation:

$$Q = \frac{1.486}{n} * A * \left(\frac{A}{P}\right)^{2/3} * \sqrt{S}$$

Given Input Data: Swale Calculation

Discharge, Q=	71.66	cfs
Left Side Slope =	3.0	H:1V
Right Side Slope =	3.0	H:1V
Base width of Channel, b=		feet
Bed slope, s=	0.0330	ft/ft
Available depth of channel:	2.00	feet
(OPTIONAL) Input Manning's 'n':	0.0200	
Lining Type:	**Bare**	

Calculate Flow Depth:

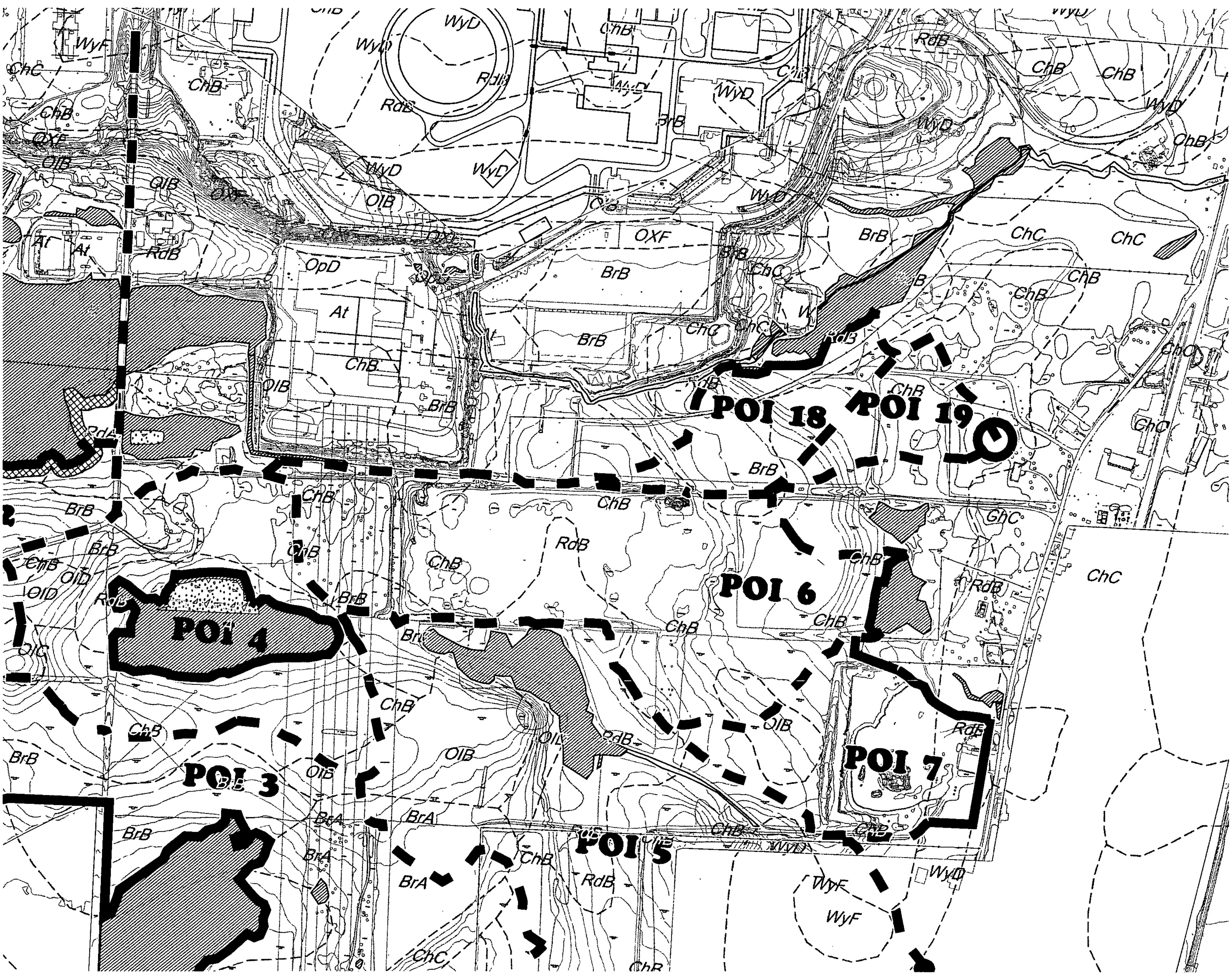
Flow depth, d=	**1.49**	**feet**

Calculated Results:

Design Acceptable?	V too high	
Freeboard, f=	0.51	feet
Calculated Velocity, V=	10.73	fps
Flow Top Width, T=	8.95	feet
Flow Area, A=	6.68	sq ft
Wetted Perimeter, P=	9.44	feet
Hydraulic Radius, R=	0.71	feet
Shear stress on channel bottom, τ =	3.07	lbs/sf
Critical Slope, S_c=	0.0069	ft/ft
Flow stable? (no if $.7S_c < s < 1.3S_c$)=	yes	
Required Freeboard=	0.5	feet
Allowable Velocity for Lining Material=	2.5	fps

Conclusions

R-3 riprap is needed for velocity.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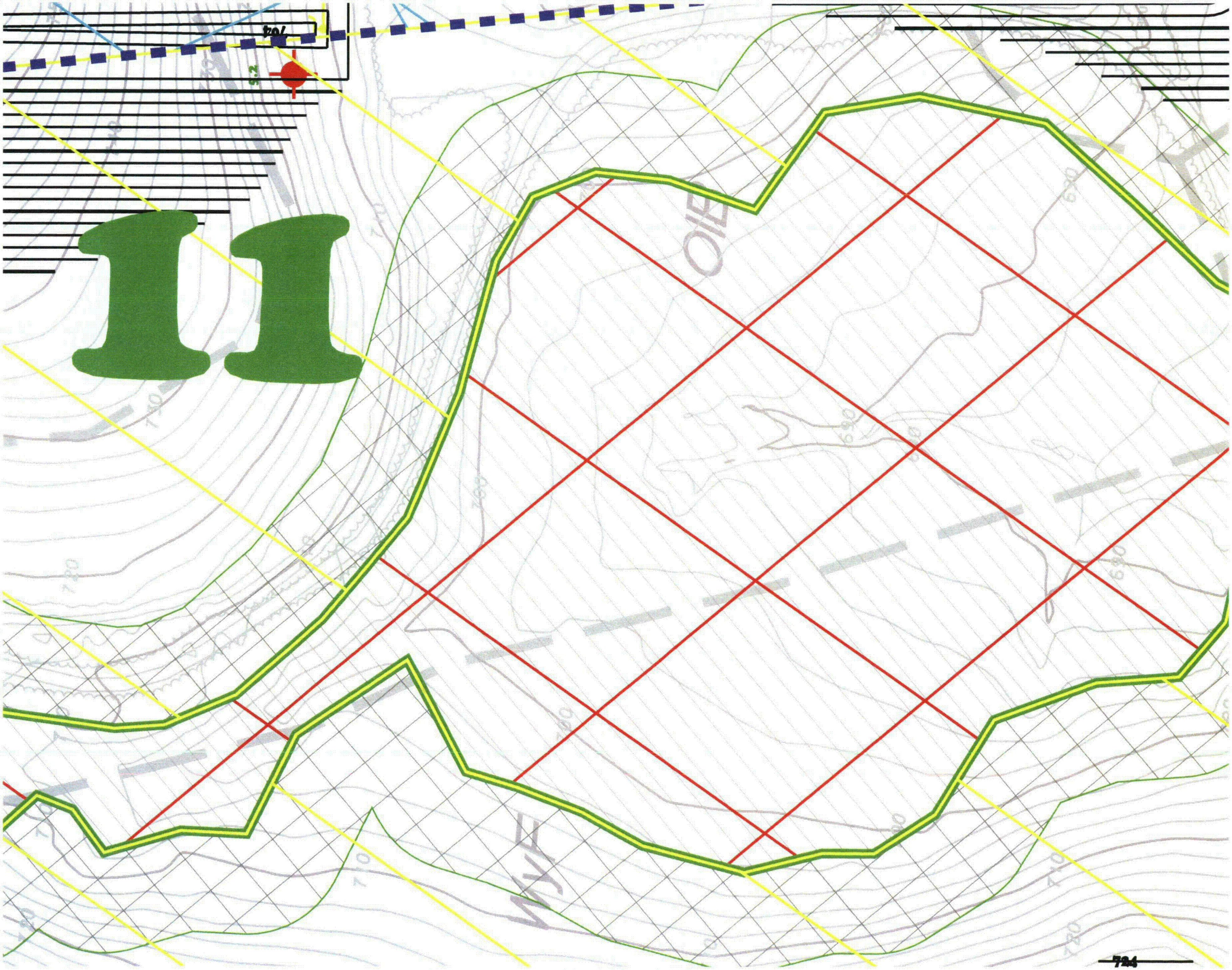
OlC


11
724

Attachment 2:

Railroad Culvert Calculations

Pennoni Associates, Inc.

Table 1 - Summary of Culvert Flows at Crossing: Rail Road Culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
632.75	40.30	40.30	0.00	1
632.89	43.66	43.66	0.00	1
633.00	47.02	47.02	0.00	1
633.07	49.20	49.20	0.00	1
633.21	53.74	53.74	0.00	1
633.32	57.10	57.10	0.00	1
633.43	60.46	60.46	0.00	1
633.54	63.82	63.82	0.00	1
633.67	67.18	67.18	0.00	1
633.82	70.54	70.54	0.00	1
633.96	73.90	73.90	0.00	1
670.00	390.48	390.48	0.00	Overtopping

Rating Curve Plot for Crossing: Rail Road Culvert

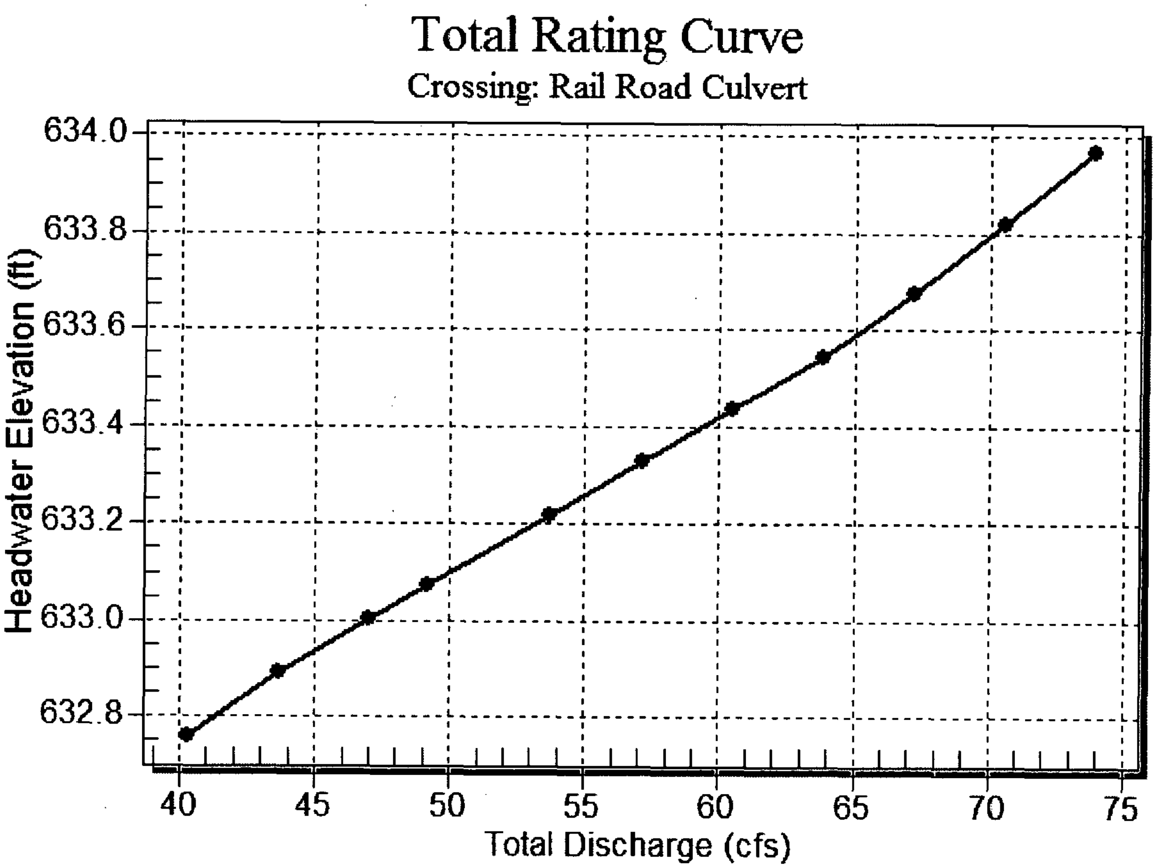


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40.30	40.30	632.75	2.254	0.0*	1-S2n	0.763	1.620	0.772	1.761	15.997	5.197
43.66	43.66	632.89	2.388	0.0*	1-S2n	0.799	1.702	0.844	1.815	15.633	5.302
47.02	47.02	633.00	2.496	0.0*	1-S2n	0.835	1.780	0.840	1.866	16.941	5.402
49.20	49.20	633.07	2.567	0.0*	1-S2n	0.859	1.825	0.865	1.898	17.124	5.463
53.74	53.74	633.21	2.713	0.0*	1-S2n	0.908	1.921	0.970	1.962	16.445	5.585
57.10	57.10	633.32	2.821	0.0*	1-S2n	0.944	1.991	1.011	2.007	16.671	5.670
60.46	60.46	633.43	2.930	0.0*	1-S2n	0.980	2.062	0.982	2.050	18.244	5.752
63.82	63.82	633.54	3.038	0.0*	1-S2n	1.016	2.128	1.093	2.093	17.093	5.830
67.18	67.18	633.67	3.169	0.0*	1-S2n	1.051	2.188	1.131	2.133	17.256	5.905
70.54	70.54	633.82	3.316	0.0*	1-S2n	1.082	2.249	1.170	2.173	17.437	5.978
73.90	73.90	633.96	3.462	0.0*	1-S2n	1.112	2.310	1.122	2.211	19.161	6.048

* theoretical depth is impractical. Depth reported is corrected.

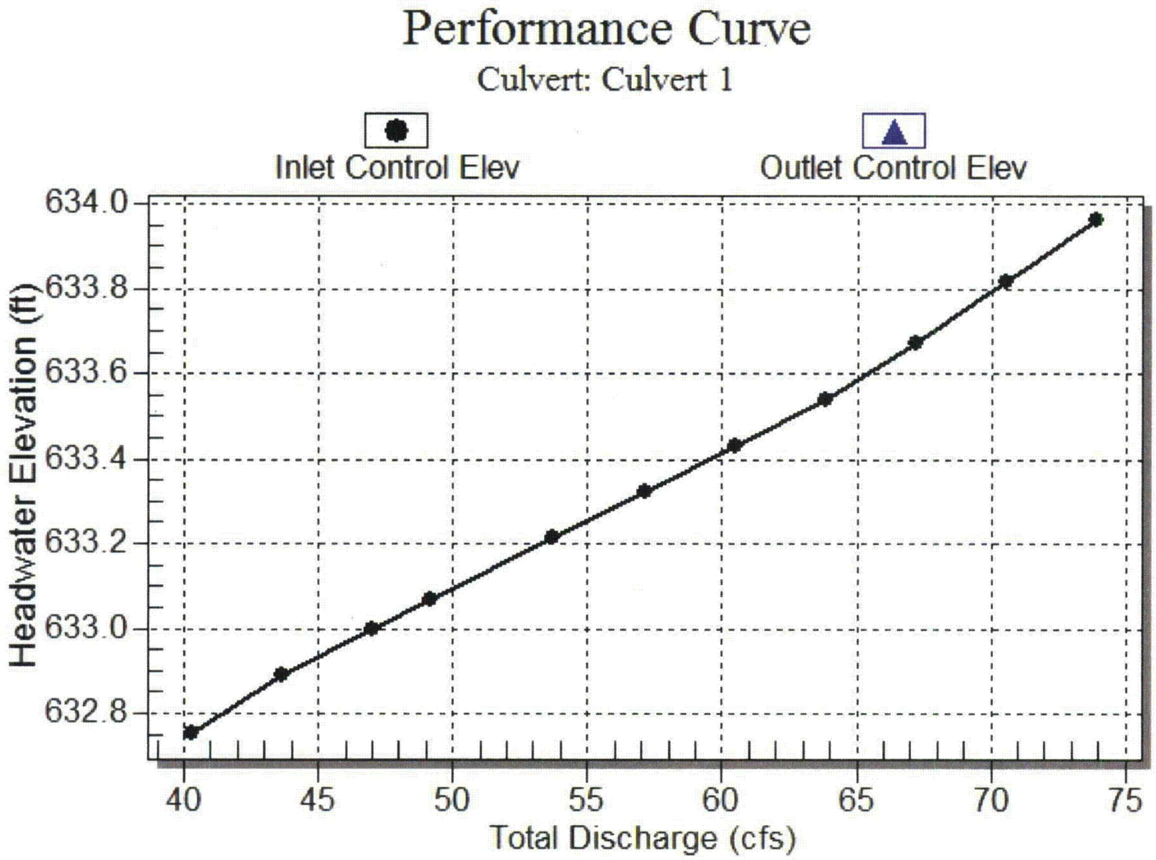
****

Inlet Elevation (invert): 630.50 ft, Outlet Elevation (invert): 625.10 ft

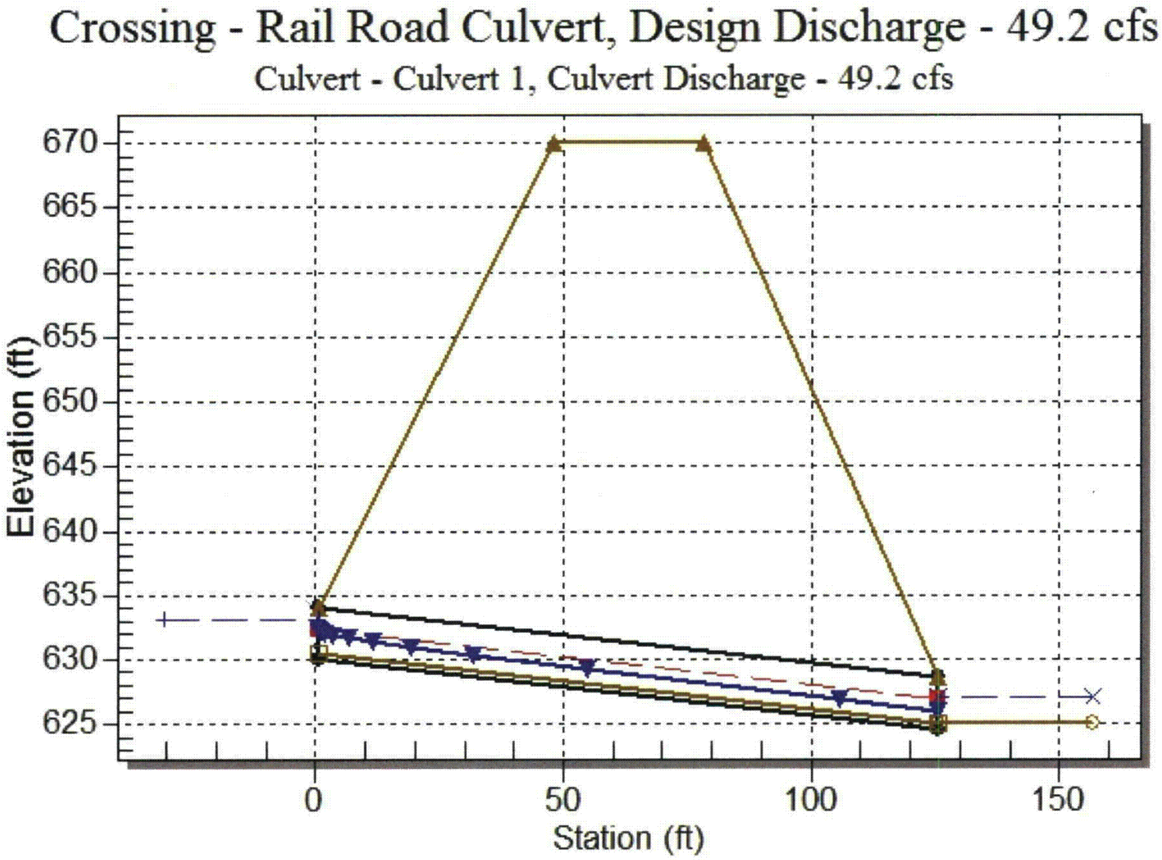
Culvert Length: 125.12 ft, Culvert Slope: 0.0432

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 630.00 ft

Outlet Station: 125.00 ft

Outlet Elevation: 624.60 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 4.00 ft

Barrel Material: Concrete

Embedment: 6.00 in

Barrel Manning's n: 0.0130 (top and sides)

Manning's n: 0.0130 (bottom)

Inlet Type: Conventional

Inlet Edge Condition: Beveled Edge

Table 3 - Downstream Channel Rating Curve (Crossing: Rail Road Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
40.30	626.86	1.76	5.20	4.40	0.98
43.66	626.91	1.81	5.30	4.53	0.98
47.02	626.97	1.87	5.40	4.66	0.99
49.20	627.00	1.90	5.46	4.74	0.99
53.74	627.06	1.96	5.58	4.90	0.99
57.10	627.11	2.01	5.67	5.01	1.00
60.46	627.15	2.05	5.75	5.12	1.00
63.82	627.19	2.09	5.83	5.22	1.00
67.18	627.23	2.13	5.91	5.32	1.01
70.54	627.27	2.17	5.98	5.42	1.01
73.90	627.31	2.21	6.05	5.52	1.01

Tailwater Channel Data - Rail Road Culvert

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 2.50 (_:1)

Channel Slope: 0.0400

Channel Manning's n: 0.0500

Channel Invert Elevation: 625.10 ft

Roadway Data for Crossing: Rail Road Culvert

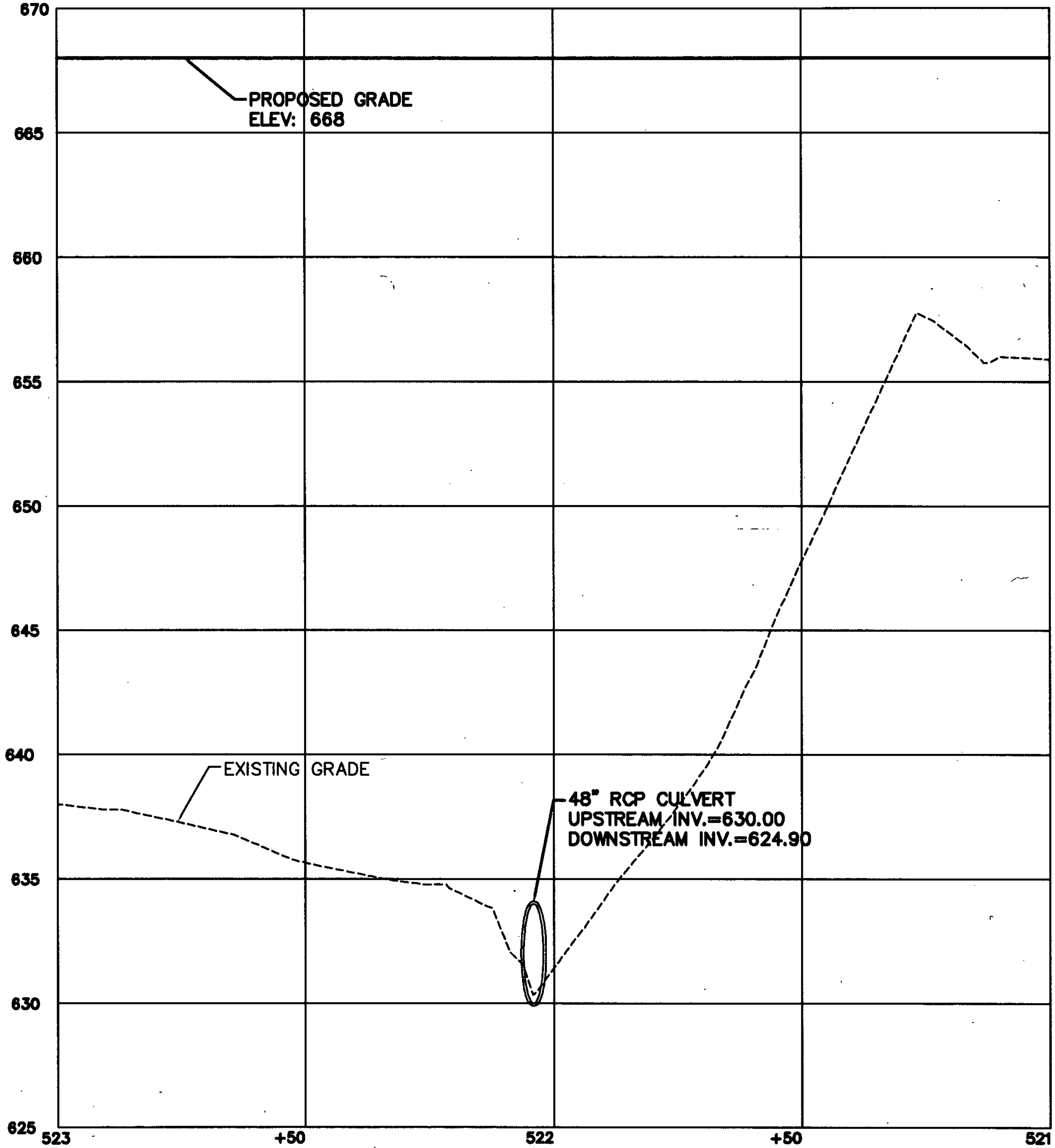
Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 670.00 ft

Roadway Surface: Gravel

Roadway Top Width: 30.00 ft



VERTICAL
SCALE: 1"=6'

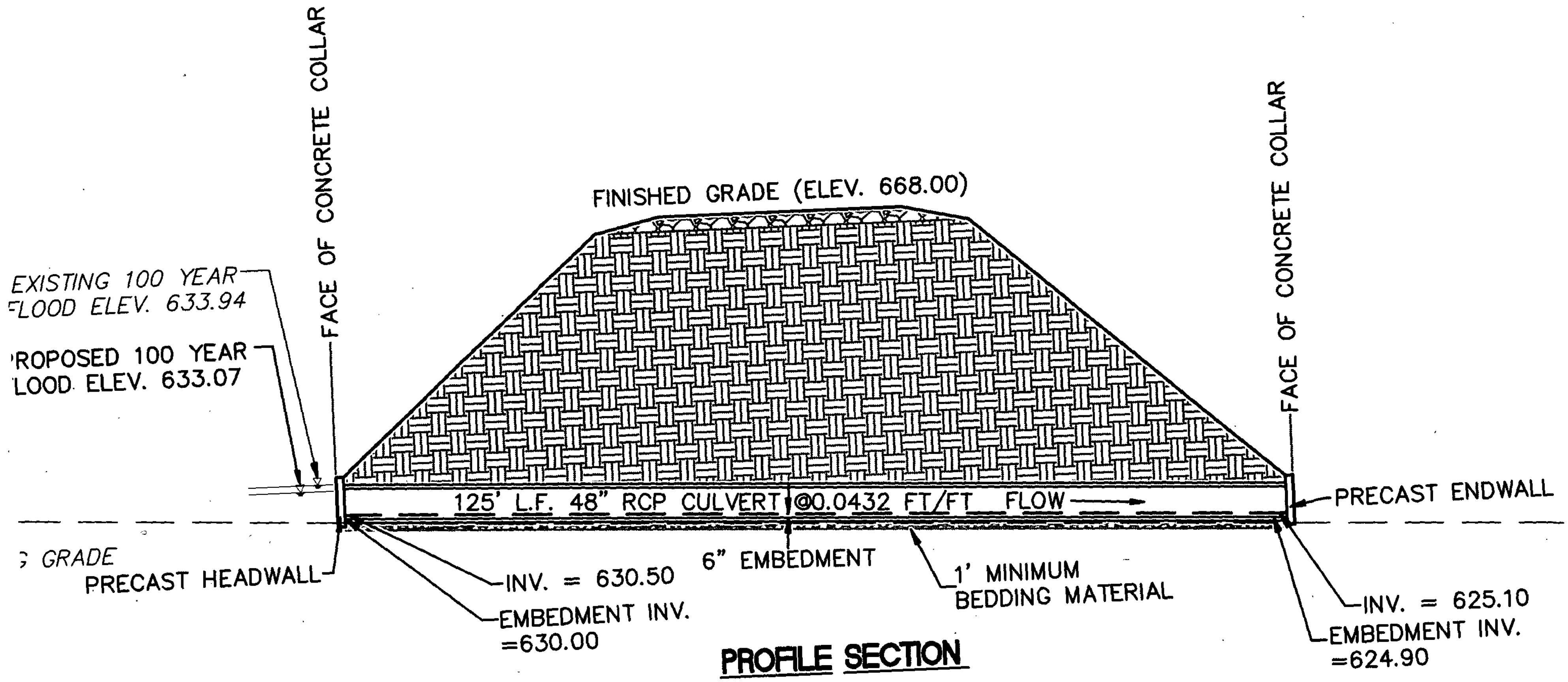
HORIZONTAL
SCALE: 1"=30'

Pennoni

Pennoni Associates Inc.
100 N. Wilkes-Barre Blvd.
Wilkes-Barre, PA 18702

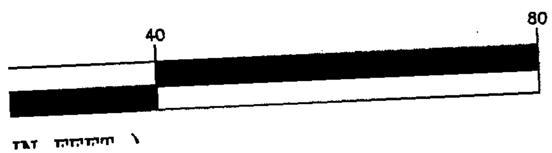
DRAWN BY: JMO
CHECKED BY: LGB
JOB No. PPLS0902
SCALE: AS SHOWN
DATE: 03/29/2011
SKETCH No.

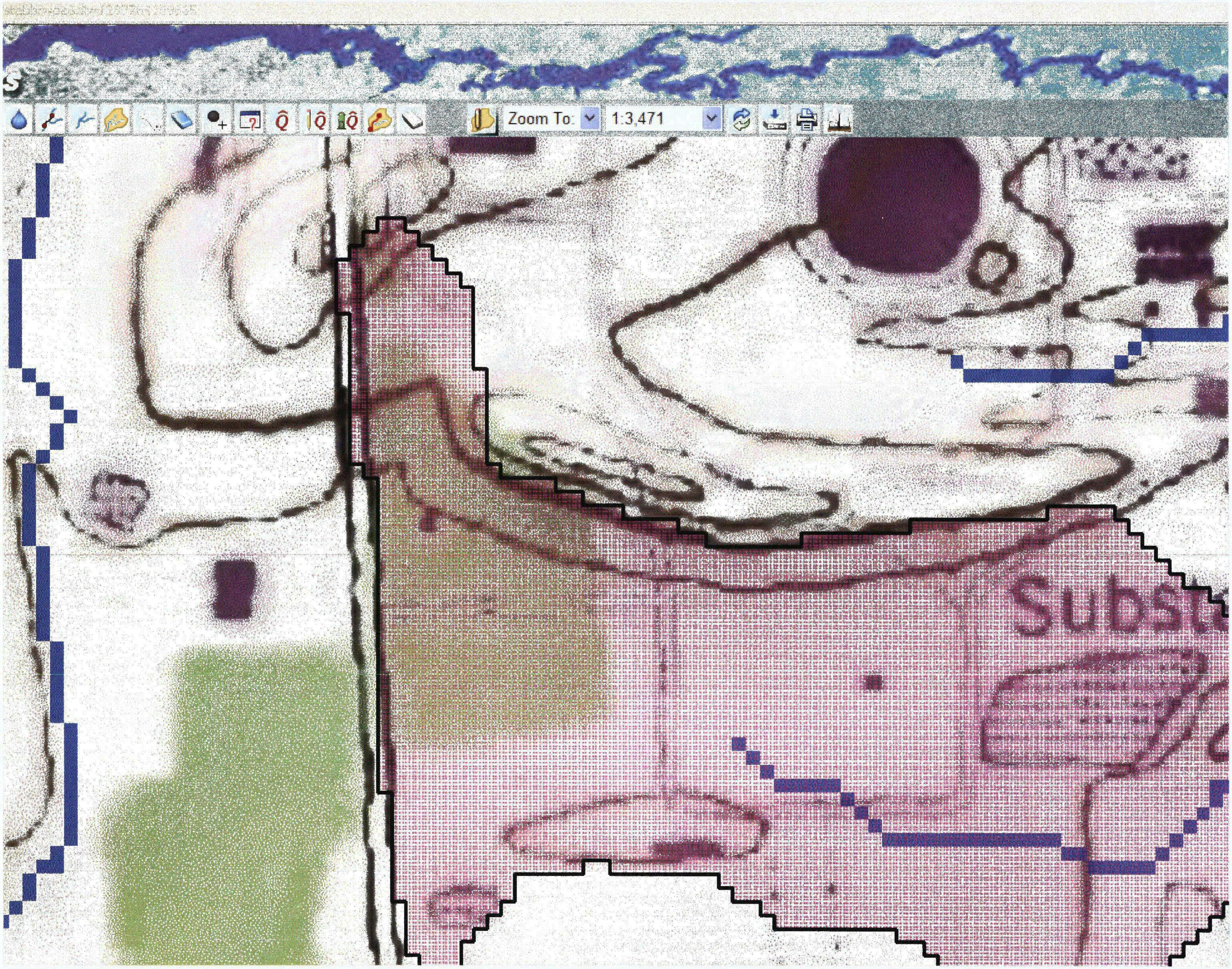
1 OF 2



PROFILE SECTION

HIC SCALE




Zoom To:
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USGS
Pennsylvania StreamStats

Streamstats Ungaged Site Report

Date: Fri Oct 22 2010 15:54:09 Mountain Daylight Time
Site Location: Pennsylvania
NAD27 Latitude: 41.0874 (41 05 15)
NAD27 Longitude: -76.1450 (-76 08 42)
NAD83 Latitude: 41.0875 (41 05 15)
NAD83 Longitude: -76.1447 (-76 08 41)
Drainage Area: 0.086 mi2

Low Flow Basin Characteristics

100% Low Flow Region 2 (0.086 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	0.086 (below min value 4.93)	4.93	1280
Mean Annual Precipitation (inches)	39.000	35	50.4
Stream Density (miles per square mile)	2.68	0.51	3.1
Depth to Rock (feet)	5.600	3.32	5.65
Percent Carbonate (percent)	0.0000	0	99

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Mean/Base-flow Basin Characteristics

100% Statewide Mean and Base Flow (0.086 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	0.086 (below min value 2.26)	2.26	1720
Mean Basin Elevation (feet)	676	130	2700
Mean Annual Precipitation (inches)	39.000	33.1	50.4
Percent Carbonate (percent)	0.0000	0	99
Percent Forest (percent)	14.1314	5.1	100
Percent Urban (percent)	2.9703	0	89

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Peak Flow Basin Characteristics

100% Peak Flow Region 1 (0.086 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	0.086 (below min value 1.72)	1.72	1280
Mean Basin Elevation (feet)	676	0	1960
Percent Carbonate (percent)	0.0000	0	83
Percent Urban (percent)	2.9703	0	20
Percent Storage (percent)	0.0000	0	21.2

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Low Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Standard Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
M7D2Y	0.00461				
M30D2Y	0.00646				
M7D10Y	0.002				
M30D10Y	0.00265				
M90D10Y	0.00435				

Mean/Base-flow Streamflow Statistics					
Statistic	Flow (ft^3/s)	Standard Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
QA	0.0865				
QAH	0.0104				
BF10YR	0.0238				
BF25YR	0.0201				
BF50YR	0.0181				

Peak Flow Streamflow Statistics					
Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK2	8.36		3		
PK5	16.2		6		
PK10	22.7		9		
PK50	40.3		13		
PK100	49.2		13		
PK500	73.9		14		

Trapezoidal Channel Analysis - Open Channel Flow (w/ Manning's Eq)

Client/Subject: **PPL, BELL BEND NUCLEAR POWER PLANT**
Description: **EXISTING SWALE UNDER RAIL 521+92.41**
Prepared by: **LGB**
Date: **25 Aug 11**

Print Date: 25 Aug 11 9:44 PM
Project #: PPLS0902

Checked by: CML

Objective:

Using Manning's equation, this spreadsheet will calculate the amount of flow through a trapezoidal or triangular (b=0) channel. By inputting the channel characteristics, the flow depth will be calculated. Other flow characteristics are also computed, including the critical slope and required freeboard based on E&S manual guidelines. The last line calculates the maximum allowable velocity as indicated by the PA E&S manual.

Method: See PA Erosion and Sedimentation Control Manual for reference.

Manning's Equation:

$$Q = \frac{1.486}{n} * A * \left(\frac{A}{P}\right)^{2/3} * \sqrt{S}$$

Given Input Data: RAIL CROSSING STA 521+92.41 — Swale Calculation

Discharge, Q=	49.20	cfs
Left Side Slope =	1.0	H:1V
Right Side Slope =	1.0	H:1V
Base width of Channel, b=		feet
Bed slope, s=	0.0150	ft/ft
Available depth of channel:	4.00	feet
(OPTIONAL) Input Manning's 'n':	0.0500	
Lining Type:	**Bare**	

Calculate Flow Depth:

Flow depth, d=	**3.44**	**feet**

Calculated Results:

Design Acceptable?	V too high	
Freeboard, f=	0.56	feet
Calculated Velocity, V=	4.15	fps
Flow Top Width, T=	6.88	feet
Flow Area, A=	11.84	sq ft
Wetted Perimeter, P=	9.73	feet
Hydraulic Radius, R=	1.22	feet
Shear stress on channel bottom, τ =	3.22	lbs/sf
Critical Slope, S_c=	0.0482	ft/ft
Flow stable? (no if $.7S_c < s < 1.3S_c$)=	yes	
Required Freeboard=	0.9	feet
Allowable Velocity for Lining Material=	2.5	fps

Conclusions

R-3 riprap is needed for velocity.