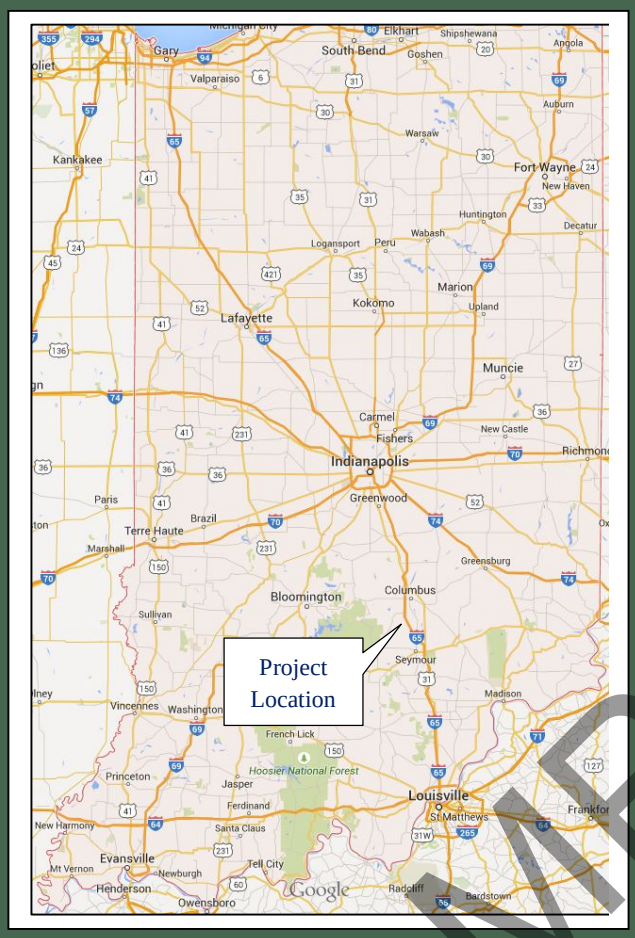
Hydraulic Analysis Report

Culvert I-65-62.11

November 30, 2016



Project Location Map

PREPARED FOR

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Hydraulic Analysis Report
Culvert I-65-62.11

Bartholomew County, Indiana
(Prepared by HNTB – 11/30/2016)

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Table of Contents

Introduction:

A hydraulic analysis was performed for the large culvert transporting flow from an unnamed tributary (UNT) to East Fork under I-65 in Bartholomew County, Indiana, with a corresponding structure number I-65-62.11. The existing culvert is a single, 36" diameter corrugated metal pipe approximately 272 feet long. The Bartholomew County Surveyor was contacted verify that this location was not a legal drain.

Hydrologic Data:

The drainage area for the culvert crossing is approximately 28 acres, so therefore this stream is not within of the jurisdiction of the Indiana Department of Natural Resources (IDNR) Division of Water (DOW). In order to determine the 100-year discharge, the Rational Method was used as outlined in the INDOT design manual to simulate a 100-year design storm rainfall-runoff event. Each of the watershed and rainfall parameters used in determining the 100-year flow rate are described in the following:

Drainage Area

The drainage area was delineated with 2 foot contours derived from 2011 LiDAR elevation data. Mapping is included on ***Figure 1*** in ***Appendix B*** which illustrates the drainage basin boundary from the aerial photography and contours, along with the time of concentration flow path. The calculated drainage area was estimated to be 28 acres.

Time of Concentration/Lag Time

The time of concentration was determined using methods and procedures as outlined in the INDOT Design Manual guidelines. After determining approximate flow paths and lengths from remote points in the watershed to the proposed stream crossing site, flow reaches were then divided by flow regime (i.e. sheet, shallow concentrated, channel, etc.), slope, and land use. Estimates of flow velocities were then determined and divided by the reach lengths to provide travel times for the various flow segments. The travel times for the flow segments were then combined and compared with travel times from other flow paths to determine the time of concentration for the watershed. The hydraulically most remote travel path is indicated on ***Figure 1*** in ***Appendix B.*** A spreadsheet summary of the travel time calculations, titled ***Table 1 - Time of Concentration Calculation***, has been included in ***Appendix B***.

The calculated time of concentration was estimated to be 0.46 hours (27.7 minutes)

Rational C-Values

Rational Method C-values were determined for the contributing watershed area based on Figure 202-2E in the INDOT guidelines. Utilizing aerial photography, obtained from the Indiana Spatial Data Portal (http://gis.iu.edu/) and dated 2014, as shown in ***Figure 1*** in ***Appendix B***, it was determined that there are two (2) primary land uses within the contributing watershed. These land uses were determined to be: row crops and impervious

(roadways).

In order to determine the soil type, soils information obtained from the NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) was obtained for the drainage area. The soils report for the watershed area obtained from the NRCS website has been included in ***Appendix A***, titled ***Soils Map and Map Unit Description***. The results from the report show that a majority of the soils are silt loam or clayey loam. Therefore, C-values corresponding to these characteristics were chosen for Rational Method calculations. Values used in calculations are: 0.5 for row crops and 0.95 for impervious.

Rainfall Volume and Distribution

The 100-year rainfall volume for the site was obtained from the National Oceanic and Atmospheric Administration (NOAA) Hydrometeorogical Design Studies Center Precipitation Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds/). A copy of the point precipitation frequency table has been included in ***Appendix A,*** titled ***Point Precipitation Frequency Estimates***.

A 100-year, 30-minute rainfall intensity of 4.55 inches per hour, obtained from the ***Point Precipitation Frequency Estimates***, was used in the Rational Method calculations.

Rational Method Results

Based on the results of the calculations, the 100-year peak discharge will be 64.5 cubic feet per second (cfs). 65 cfs was used in the hydraulic analysis. The results Rational Method calculations are included in ***Table 2 – Rational Method***, included in ***Appendix B***.

Hydraulic Analysis/Modeling Procedure:

Existing Conditions Analysis

The analysis was performed using HY-8 software, version 7.2, and analyzed for the peak 100-year discharge of 65 cubic feet per second (cfs). The peak 100-year discharge was calculated as described previously and seen in ***Appendix B***. A Hydraulic Field Visit was performed by INDOT Hydraulics and observed the culvert to be a single 36” diameter corrugated metal pipe approximately 172 feet long. Based on measurements made in ArcMap, and correspondence with INDOT Hydraulics, it was assumed that this length is more likely 272 feet, and was modeled as 272 feet. Existing roadway plans were not available. Site photographs are included in ***Appendix A***, titled ***Existing Site Photographs***. The field visit data referenced above can be found in ***Appendix A,*** titled ***Hydraulics Field Data***.

To estimate the tailwater depth, a cross section was estimated from the hydraulics field data on the downstream end of the culvert, and supplemented with 2011 LiDAR data. A normal slope of 0.018 was estimated using the channel slope from 2011 LiDAR elevation data**.** The culvert was modeled as a straight inlet type with a square edge with headwall. The inlet and

outlet flow line elevations were set at 614.89 and 612.94 feet NAVD, respectively, based on field survey data. The roadway crest elevation was set at 628.2 feet based on 2011 LiDAR elevation data.

The allowable outlet velocity used for sizing outlet erosion control measures is usually obtained from the 50-year flow rate, as defined in IDM Figure 203-2C. For these analyses, the outlet velocity used for sizing erosion control measures was taken as the outlet velocity from 90% of the Q_{100} flow rate. In this case, that is equal to 58.5 cfs.

The existing culvert is outlet controlled. The existing conditions headwater elevation was calculated to be 626.49 feet, and the roadway serviceability freeboard is 1.71 feet. The existing conditions outlet velocity at 58.5 cfs was calculated to be 7.53 ft/s. Based on photographs provided by INDOT, as seen in ***Appendix* A,** the existing culvert has a scour hole downstream of the culvert. Results from the hydraulic analysis can be found in ***Appendix C.***

Proposed Improvements Analyses

With the existing conditions model as a base condition, potential improvements were analyzed. Six potential improvements are summarized: an HDPE slip liner with a 21" additional pipe bored alongside the existing pipe at a slightly higher flowline (Alternative 1), a CIPP liner (Alternative 2), a five inch paved invert (Alternative 3), and 3 proposed replacement options: a corrugated replacement (Alternative 4) a semi-smooth replacement (Alternative 5) and a smooth replacement (Alternative 6).

The HDPE liner was modeled as a round pipe with an equivalent inside diameter of 26.6 inches, and equivalent outside diameter of 31 inches. The CIPP liner was modeled by reducing the pipe diameter by 2". The paved invert was modeled using the INDOT provided spreadsheet to size the geometry. The corrugated and semi-smooth replacement alternatives were each modeled as 42" diameter pipes, and the smooth replacement alternative was modeled as a 36" diameter pipe. Results from the hydraulic analysis can be found in ***Appendix C.***

Recommendation

Based on the results of the hydraulic analyses, all alternatives maintain or improve the backwater and headwater elevation from the existing conditions. Alternatives 1 and 3 modeled without the bored pipe would result in roadway overtopping, according to the model. Alternative 2 is recommended because it is the only alternative that would not require a bored pipe or replacement. Results for these scenarios are given below **Table 3.** An energy dissipater should be placed at the outlet. Results of the analyses are summarized in **Table 3**.

Table 3: Culvert Properties

Parameter	Existing	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Structure	36" Diameter Corrugated Metal Pipe	Existing Pipe w/ HDPE liner and 21" steel bored pipe	Existing Pipe w/ CIPP liner	Existing Pipe w/ 5" Paved Invert and 36" steel bored pipe	42" Diameter Corrugated Metal Pipe	42" Diameter Semi Smooth Metal Pipe	36" Diameter Smooth Pipe
End Treatment	Square Edge with Headwall	Square Edge with Headwall	Square Edge with Headwall	Square Edge with Headwall	Thin Edge Projecting	Thin Edge Projecting	Thin Edge Projecting
Drainage Area (acre)	28.0	28.0	28.0	28.0	28.0	28.0	28.0
Q100 (cfs)	65.0	65.0	65.0	65.0	65.0	65.0	65.0
Q100 tailwater elevation (ft)	615.60	615.60	615.60	615.60	615.60	615.60	615.60
Legal Drain?	No	No	No	No	No	No	No
Sump (in)	N/A	N/A	N/A	N/A	3.0	3.0	3.0
Available Flow Area	7.07 ft^2	6.28 ft^2	6.29 ft^2	12.89 ft^2	9.32 ft^2	9.32 ft^2	6.79 ft^2
Road Overflow Depth	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft
Backwater	5.94 ft	4.36 ft	3.41 ft	0.82 ft	1.85 ft	1.81 ft	2.62 ft
Q_{100} Headwater Elevation	626.49 ft	624.91 ft	623.96 ft	621.37 ft	622.40 ft	622.36 ft	623.17 ft
Outlet Velocity	7.53 ft/s	12.64 ft/s*	14.35 ft/s**	11.84 ft/s*	7.97 ft/s	9.27 ft/s	10.03 ft/s

*****Higher outlet velocity of the two pipes
**Requires an energy dissipater

Appendix A – General Project Information

1. Existing Site Photos
2. INDOT Hydraulic Field Data
3. Soils Map and Map Unit Description
4. Hydraulics QA Checklist

Site Photographs

Blind T between I65 and field road

DS Channel

Road Embankment

Inlet and field road

Inlet

Inside Pipe

Outlet

Scour Hole

Hydraulics Field Data Form Des #:_____

Site Location:

Route: I-65 RP: 62+11 Distance to intersection: 1.58 mi South of SR58

Stream Crossing: ~~East~~ UNT to East Fork White River County: Bartholomew

General Site Information:

Drainage Area: _____ Discharge: _____ Legal Drain (Y/N) _____

Flow direction: N-S__S-N __E-W___ W-E__ (if flow is SE for example, check N-S & W-E)

Field Notes:_____

Culvert Data:

Type: CMP Size: 36" Length: 172'

End Treatment: _____Scour: Outlet _____ Inlet _____

Photos? Yes*_____No_____Skew _____

*Photo Sequence: Outlet, Scour, Dnstrm Area, Highway & Ditches, Upstrm Area, Inlet

Attendees: AJS JFE _____ _____

Date: 10/25/16

Survey Data: Distance from structure to surveyed cross section 15 ft

Profile Grade 3.70 Outlet 18.96 Inlet ~~14.85~~ 14.01

20.64 - drop - water depth = 1 ft

~~12.76 = Top of pipe~~

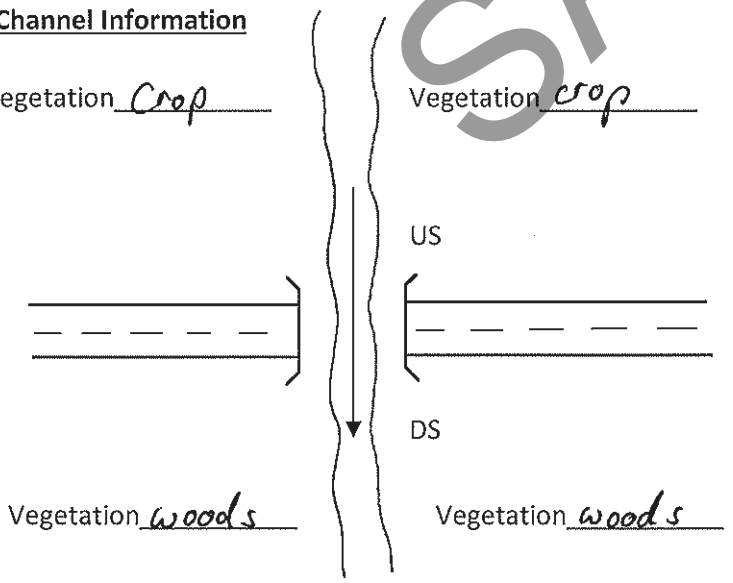
Channel Cross Section - Field Survey

Data Points	Tape Distance	Rod Reading	Constraints	Tape Distance	Rod Reading
1	3	17.69	I.E.: Crops,	*US Constraints*	
2	7.5	17.84	house,	crops	~~17.07~~
3	10.5	19.38	bridge,		10.90
4	13	19.99	culvert,		
5	15	19.75	parking lot,		
6	16.5	18.28	barn, shed,		
7	18	17.60	yard,		
8			business,		
9			etc.		
10				*DS Constraints*	
11			I.E.: Another		
12			culvert,		
13			pond WS,		
14			Scour Hole		
15			Size, etc.		
16					
17					
18					

Channel Information

Vegetation Crop

Vegetation crop

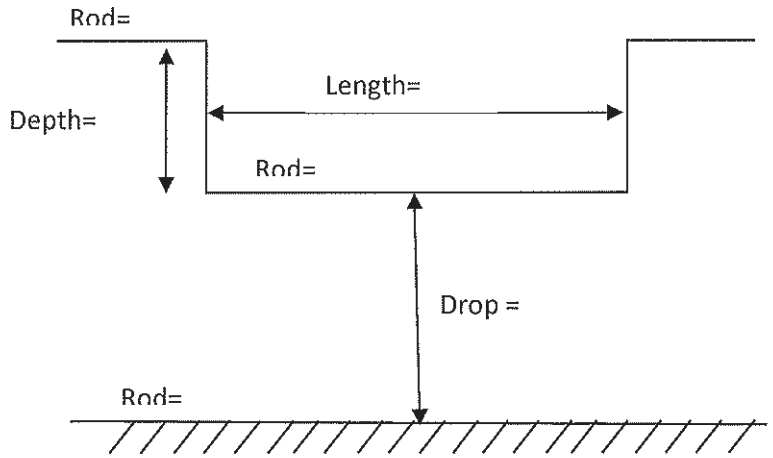


Vegetation woods

Vegetation woods

Weir Information

US or DS



Channel n = 0.05-0.06

Skew = _____

Culvert Length = _____


ClfA
AddA
NaaB2
BlgC2
Crossing Location
SAMPLE
Appendix A
Culvert I65-62.11
Soils Map
November 2016
HNTB
N
Feet
0
150
300
600

Engineering Properties

This table gives the engineering classifications and the range of engineering properties for the layers of each soil in the survey area.

Hydrologic soil group is a group of soils having similar runoff potential under similar storm and cover conditions. The criteria for determining Hydrologic soil group is found in the National Engineering Handbook, Chapter 7 issued May 2007(http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Listing HSGs by soil map unit component and not by soil series is a new concept for the engineers. Past engineering references contained lists of HSGs by soil series. Soil series are continually being defined and redefined, and the list of soil series names changes so frequently as to make the task of maintaining a single national list virtually impossible. Therefore, the criteria is now used to calculate the HSG using the component soil properties and no such national series lists will be maintained. All such references are obsolete and their use should be discontinued. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonal high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. Changes in soil properties caused by land management or climate changes also cause the hydrologic soil group to change. The influence of ground cover is treated independently. There are four hydrologic soil groups, A, B, C, and D, and three dual groups, A/D, B/D, and C/D. In the dual groups, the first letter is for drained areas and the second letter is for undrained areas.

The four hydrologic soil groups are described in the following paragraphs:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Depth to the upper and lower boundaries of each layer is indicated.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Classification of the soils is determined according to the Unified soil classification system (ASTM, 2005) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO, 2004).

The Unified system classifies soils according to properties that affect their use as construction material. Soils are classified according to particle-size distribution of the fraction less than 3 inches in diameter and according to plasticity index, liquid limit, and organic matter content. Sandy and gravelly soils are identified as GW, GP, GM, GC, SW, SP, SM, and SC; silty and clayey soils as ML, CL, OL, MH, CH, and OH; and highly organic soils as PT. Soils exhibiting engineering properties of two groups can have a dual classification, for example, CL-ML.

The AASHTO system classifies soils according to those properties that affect roadway construction and maintenance. In this system, the fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of particle-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines (silt and clay). At the other extreme, soils in group A-7 are fine grained. Highly organic soils are classified in group A-8 on the basis of visual inspection.

If laboratory data are available, the A-1, A-2, and A-7 groups are further classified as A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, or A-7-6. As an additional refinement, the suitability of a soil as subgrade material can be indicated by a group index number. Group index numbers range from 0 for the best subgrade material to 20 or higher for the poorest.

Percentage of rock fragments larger than 10 inches in diameter and 3 to 10 inches in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages are estimates determined mainly by converting volume percentage in the field to weight percentage. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 inches in diameter based on an ovendry weight. The sieves, numbers 4, 10, 40, and 200 (USA Standard Series), have openings of 4.76, 2.00, 0.420, and 0.074 millimeters, respectively. Estimates are based on laboratory tests of soils sampled in the survey area and in nearby areas and on estimates made in the field. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Liquid limit and *plasticity index* (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

References:

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Report—Engineering Properties

Absence of an entry indicates that the data were not estimated. The asterisk '*' denotes the representative texture; other possible textures follow the dash. The criteria for determining the hydrologic soil group for individual soil components is found in the National Engineering Handbook, Chapter 7 issued May 2007(http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Engineering Properties–Bartholomew County, Indiana														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
AddA—Avonburg silt loam, 0 to 2 percent slopes														
Avonburg	85	C/D	0-11	Silt loam	CL, CL-ML	A-6, A-4	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-85-90	23-27-33	6-8 -12
			11-21	Silt loam	CL, CL-ML	A-4	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-83-85	22-27-32	7-10-13
			21-40	Silty clay loam, silt loam	CL	A-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	85-88-90	33-37-38	16-19-19
			40-52	Silt loam, silty clay loam	CL	A-6	0- 0- 0	0- 0- 0	100-100-100	95-98-100	90-93-95	75-80-85	30-31-37	15-15-19
			52-83	Silt loam	CL	A-6	0- 0- 0	0- 0- 0	100-100-100	95-98-100	90-93-95	70-75-80	29-33-35	13-16-18
			83-90	Clay loam	CL	A-6, A-7-6	0- 1- 1	0- 1- 1	90-95-100	85-90-95	70-80-90	55-63-70	36-43-50	19-24-29

Engineering Properties–Bartholomew County, Indiana														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
BlgC2—Blocher-Cincinnati silt loams, 6 to 12 percent slopes, eroded														
Blocher	54	C	0-6	Silt loam	CL, CL-ML, ML	A-6, A-4	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-85-90	23-31-40	3-9 -15
			6-26	Silt loam, silty clay loam, loam	CL, CL-ML	A-4, A-7-6, A-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	80-90-100	65-78-90	24-36-48	5-16-27
			26-66	Clay loam, clay	CH, CL	A-6, A-7-6	0- 0- 0	0- 0- 0	90-94-100	85-90-95	75-85-95	60-68-75	30-42-53	11-22-33
			66-76	Clay loam, clay	CL	A-6, A-7-6	0- 0- 0	0- 0- 2	95-98-100	90-94-95	75-85-95	60-68-75	25-38-50	11-20-30
			76-80	Loam, clay loam	CL, CL-ML	A-4, A-6	0- 0- 0	0- 0- 2	95-98-100	90-93-95	75-83-90	55-63-70	19-32-40	4-12-20
Cincinnati	35	C	0-8	Silt loam	CL-ML, CL, ML	A-4, A-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-90-95	23-27-40	3-7 -15
			8-24	Silty clay loam, silt loam	CL, CL-ML	A-7-6, A-4, A-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-88-95	24-34-45	5-15-25
			24-74	Loam, silt loam	CL	A-4, A-6	0- 0- 0	0- 0- 0	98-100-100	95-97-100	85-90-95	55-70-85	24-32-44	8-16-25
			74-80	Clay loam, loam	CL	A-4, A-6, A-7-6	0- 0- 0	0- 1- 2	90-96-100	85-90-95	70-80-90	55-63-70	25-37-50	8-19-30

Engineering Properties–Bartholomew County, Indiana														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
ClfA—Cobbsfork silt loam, 0 to 1 percent slopes														
Cobbsfork	85	C/D	0-12	Silt loam	CL, CL-ML, ML	A-4	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	75-83-90	23-26-32	6-7 -9
			12-18	Silt loam	CL	A-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	75-83-90	21-29-32	6-12-13
			18-38	Silt loam, silty clay loam	CL	A-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-85-90	29-34-40	13-16-21
			38-50	Silt loam, silty clay loam	CL	A-6	0- 0- 0	0- 0- 0	100-100-100	95-97-100	90-95-100	80-85-90	29-30-37	13-14-19
			50-85	Silt loam	CL	A-6	0- 0- 0	0- 0- 0	100-100-100	95-97-100	90-95-100	75-83-90	29-31-35	13-15-18
			85-90	Clay loam	CL	A-6, A-7-6	0- 0- 0	0- 0- 0	90-95-100	85-90-95	70-80-90	55-63-70	36-42-48	19-23-27
NaaB2—Nabb silt loam, 2 to 6 percent slopes, eroded														
Nabb, eroded	78	C/D	0-7	Silt loam	ML, CL	A-4, A-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-85-95	22-28-39	6-8 -15
			7-13	Silt loam	CL	A-4, A-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-85-95	23-26-33	8-10-13
			13-33	Silt loam, silty clay loam	CL	A-6, A-7-6	0- 0- 0	0- 0- 0	100-100-100	100-100-100	90-95-100	80-88-90	31-38-42	13-19-21
			33-71	Silt loam, silty clay loam	CL	A-6	0- 0- 0	0- 0- 0	98-100-100	95-98-100	90-92-95	70-78-85	27-32-38	12-15-19
			71-79	Loam, clay loam	CL	A-7-6	0- 0- 2	0- 1- 2	90-95-100	85-90-95	70-84-90	55-66-70	34-41-49	16-22-27

Hydraulics QA Checklist

Route: I-65 Des No.
County: Bartholomew City or Town: Columbus
Description: I65 over UNT to East Fork
Designer: FSB Reviewer: RTP

MAPS
- ☐ USGS Quad. Scale Date
- ☒ ARC GIS Date 2011
- ☐ Flood-Insurance Firm and FHBM
- ☒ Soils Map
- ☒ Aerial Photos Scale 1:350 Date 2005

STUDIES BY EXTERNAL AGENCIES
- ☐ FEMA Flood-Insurance Studies
- ☐ NRCS Watershed Studies
- ☐ USGS Gages and Studies
- ☐ Interim Floodplain Studies

STUDIES BY INTERNAL SOURCES
- ☐ Office Records
- ☐ Flood Record (High Water, Newspaper)
  Gaging Da
- ☐ **BRIDGE INSPECTION REPORTS**

CALIBRATION OF HIGH-WATER DATA
- ☐ Discharge and Frequency of H.W. el.
- ☐ Influences Responsible for H.W. el. - Check Maps for Larger Streams Nearby that May Backwater the Site
- ☐ Analyze Hydraulic Performance of Existing Facility for 100-Year Flood
- ☐ Analyze Hydraulic Performance of Proposed Facility for 100-Year Flood
- ☐ Field Reconnaissance Revisions Report

DESIGN APPURTENANCES
- ☒ Dissipators, Riprap
- ☐ Scour Analysis/Evaluation

TECHNICAL RESOURCES
- ☒ *Indiana Design Manual*, Part II
- ☐ Other _____

DISCHARGE CALCULATIONS
- ☒ Drainage Area Delineation
- ☐ Drainage Areas of IN Streams
- ☐ DNR Discharge Letter
- ☒ Rational Formula
- ☐ HEC-HMS / TR-20
- ☐ NRCS
- ☐ Regional Analysis
- ☐ Coordinated Discharges of IN Streams
- ☐ Log-Pearson Type III Gage Rating

HIGH-WATER ELEVATIONS
- ☒ INDOT Survey
- ☐ Plans for Existing Structure
- ☐ DNR Historic Flood Profiles
- ☐ Maintenance Records
- ☐ External Sources
- ☐ Personal Reconnaissance

ENVIRONMENTAL REPORTS

☐ INDOT

TECHNICAL AIDS

☒ *Indiana Design Manual*, Part II
☐ INDOT and FHWA Directives
☐ FHWA Publications

COMPUTER PROGRAMS

☒ HY8
☐ HEC-RAS River Analysis System
☐ Log-Pearson Type III Analysis
☐ WSPRO Water-Surface Profile
☐ PFP-HYDRA
☐ HEC-HMS / TR 20
☐ HEC-RAS Scour Analysis

☐ Other_____

Designed by: Fred D. Ray **Date:** 11/30/16

Reviewed by: MM RG **Date:** 12/1/16

Appendix B – Hydrologic Data

1. Figure 1: Aerial Photography Drainage Area Map
2. Table 1 - Time of Concentration Calculation
3. Table 2- Rational Method

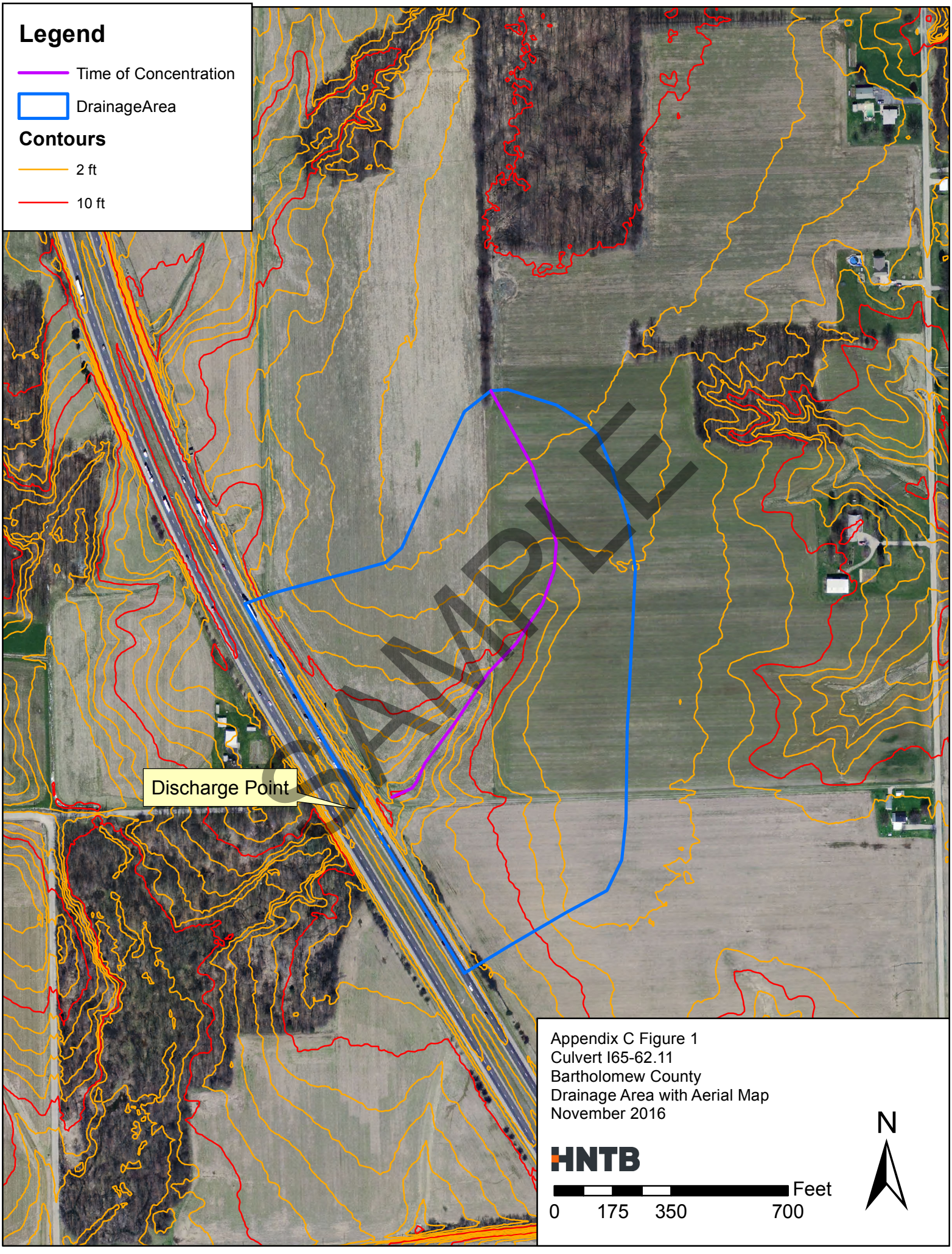

Legend
Time of Concentration
DrainageArea
Contours
2 ft
10 ft
Discharge Point
SAMPLE
Appendix C Figure 1
Culvert I65-62.11
Bartholomew County
Drainage Area with Aerial Map
November 2016
HNTB
Feet
0
175
350
700
N

Table 1 - Time of Concentration Calculation

Sheet Flow

$$T_t = \frac{0.007(nl)^{0.8}}{P^{0.5}S^{0.4}}$$

Hours	Min
0.32457	19.47

P=	3	2 year, 24 hour storm (in) from the Point Precipitation Frequency Estimate
S=	0.005	Sheet Flow slope (ft/ft) interpolated from contours
n=	0.17	Manning's n for Cultivated Soils from INDOT Design Manual, Figure 202-2B
l=	100	Sheet Flow Length (ft)

Shallow Concentrated Flow

$$T_{t1} = \frac{l}{3600V}$$

Hours	Min
0.102469	6.15

l=	664	Open Channel Flow Length (ft)
S =	0.013	Shallow Concentrated slope (ft/ft)
v=	1.8	Average Velocity (ft/s) from IDM Figure 202-2D

Total Length	1434
Sheet Flow	100
Shallow Concentrated Flow	664
Open Channel Flow	670

Open Channel Flow

$$T_{t1} = \frac{l}{3600V}$$

Hours	Min
0.035347	2.12

l=	670	Open Channel Flow Length (ft)
S =	0.016	Channel Slope (ft/ft)
V=	5.27	Average Velocity (ft/s) from Manning's Equation
P_w = 7.82 ft	A = 6 ft^2	*Dimensions produce a hydraulic radius equal to that of a 5 foot bottom width, 1 foot depth, 1:1 side slopes trapezoidal channel
	n = 0.03	

Total Time of Concentration

Total T_c	27.74	0.462386 hours

Approximate Watershed Lag Time

Total T_l	16.6459	0.277432 hours

Table 2: Rational Method

Drainage Area:

Total DA (A) = 28.03 acres

I = 4.55 in/hr (100 yr, 30 minute intensity)

C

	Total Area (acres)	C
Row Crops	27.66	0.5
Impervious (Road)	0.37	0.95
	Composite	0.51

Q =	**64.5**

Appendix C – Hydraulic Data

1. HY-8 Results

HY-8 Culvert Analysis Report- Existing

Headwater Elevation (ft)	Total Discharge (cfs)	Existing Discharge (cfs)	Roadway Discharge (cfs)	Iterations
617.89	0.00	0.00	0.00	1
618.97	6.50	6.50	0.00	1
619.46	13.00	13.00	0.00	1
619.89	19.50	19.50	0.00	1
620.28	26.00	26.00	0.00	1
620.67	32.50	32.50	0.00	1
621.29	39.00	39.00	0.00	1
621.62	45.50	45.50	0.00	1
621.99	52.00	52.00	0.00	1
624.36	58.50	58.50	0.00	1
626.49	65.00	65.00	0.00	1
628.20	69.68	69.68	0.00	Overtopping

Table 1 - Summary of Culvert Flows at Crossing: I65-62.11 - Existing

Table 2 - Culvert Summary Table: Existing

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)
0.00	0.00	617.89	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	6.50	618.97	1.082	0.0*	1-S2n	0.726	0.789	0.729	0.782	4.851	2.410
13.00	13.00	619.46	1.574	0.0*	1-S2n	1.050	1.140	1.050	1.070	5.874	2.975
19.50	19.50	619.89	2.001	0.0*	1-S2n	1.315	1.410	1.319	1.292	6.510	3.346
26.00	26.00	620.28	2.393	0.0*	1-S2n	1.557	1.640	1.559	1.478	7.008	3.628
32.50	32.50	620.67	2.779	0.0*	1-S2n	1.789	1.846	1.790	1.642	7.387	3.858
39.00	39.00	621.29	3.182	3.396	2-M2c	2.030	2.028	2.032	1.792	7.651	4.038
45.50	45.50	621.62	3.619	3.729	2-M2c	2.302	2.190	2.197	1.931	8.201	4.184
52.00	52.00	621.99	4.104	4.103	2-M2c	2.697	2.339	2.345	2.057	8.784	4.316
58.50	58.50	624.36	4.648	6.466	7-M2c	3.000	2.461	2.475	2.352	9.380	3.747
65.00	65.00	626.49	5.256	8.597	7-M2t	3.000	2.566	2.657	2.657	9.819	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 617.89 ft, Outlet Elevation (invert): 612.94 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - Existing

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 617.89 ft

Outlet Station: 272.00 ft

Outlet Elevation: 612.94 ft

Number of Barrels: 1

Culvert Data Summary - Existing

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: I65-62.11 - Existing)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	612.94	0.00	0.00	0.00	0.00
6.50	613.72	0.78	2.41	0.88	0.60
13.00	614.01	1.07	2.97	1.20	0.63
19.50	614.23	1.29	3.35	1.45	0.64
26.00	614.42	1.48	3.63	1.66	0.65
32.50	614.58	1.64	3.86	1.84	0.66
39.00	614.73	1.79	4.04	2.01	0.67
45.50	614.87	1.93	4.18	2.17	0.67
52.00	615.00	2.06	4.32	2.31	0.68
58.50	615.29	2.35	3.75	2.64	0.67
65.00	615.60	2.66	2.70	2.98	0.63

Tailwater Channel Data - I65-62.11 - Existing

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0180

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-37.00	620.00	0.0500
2	-27.00	618.00	0.0500
3	-12.00	616.00	0.0500
4	3.00	615.24	0.0500
5	7.50	615.09	0.0500
6	10.50	613.55	0.0500
7	13.00	612.94	0.0500
8	15.00	613.18	0.0500
9	16.50	614.65	0.0500
10	18.00	615.33	0.0500
11	68.00	616.00	0.0500
12	98.00	618.00	0.0500
13	118.00	620.00	0.0000

Roadway Data for Crossing: I65-62.11 - Existing

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 628.20 ft

Roadway Surface: Paved

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report – Alt 1 HDPE

Headwater Elevation (ft)	Total Discharge (cfs)	HDPE Discharge (cfs)	Bored Pipe Discharge (cfs)	Roadway Discharge (cfs)	Iterations
618.07	0.00	0.00	0.00	0.00	0
619.04	6.50	4.01	2.49	0.00	4
619.48	13.00	7.83	5.15	0.00	3
619.86	19.50	11.87	7.63	0.00	3
620.27	26.00	15.96	10.05	0.00	4
620.77	32.50	20.01	12.50	0.00	4
621.37	39.00	24.05	14.95	0.00	4
622.10	45.50	28.12	17.38	0.00	4
622.94	52.00	32.26	19.74	0.00	3
623.88	58.50	36.48	22.02	0.00	3
624.91	65.00	40.74	24.26	0.00	4
628.20	80.03	51.12	28.91	0.00	Overtopping

Table 1 - Summary of Culvert Flows at Crossing: I65-62.11 - HDPE

Table 2 - Culvert Summary Table: HDPE

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)
0.00	0.00	618.07	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	4.01	619.04	0.972	0.0*	1-S2n	0.452	0.679	0.454	0.782	7.069	2.410
13.00	7.83	619.48	1.408	0.0*	1-S2n	0.631	0.959	0.638	1.070	8.483	2.975
19.50	11.87	619.86	1.793	0.0*	1-S2n	0.785	1.194	0.793	1.292	9.535	3.346
26.00	15.96	620.27	2.202	0.0*	1-S2n	0.926	1.395	0.927	1.478	10.446	3.628
32.50	20.01	620.77	2.696	0.0*	5-S2n	1.052	1.569	1.059	1.642	10.973	3.858
39.00	24.05	621.37	3.302	0.0*	5-S2n	1.174	1.715	1.175	1.792	11.575	4.038
45.50	28.12	622.10	4.030	0.0*	5-S2n	1.294	1.836	1.295	1.931	12.004	4.184
52.00	32.26	622.94	4.872	0.0*	5-S2n	1.420	1.940	1.420	2.057	12.357	4.316
58.50	36.48	623.88	5.810	0.0*	5-S2n	1.549	2.046	1.550	2.352	12.638	3.747
65.00	40.74	624.91	6.838	4.733	4-FFf	1.702	2.154	1.702	2.657	12.816	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 618.07 ft, Outlet Elevation (invert): 613.12 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - HDPE

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 618.07 ft

Outlet Station: 272.00 ft

Outlet Elevation: 613.12 ft

Number of Barrels: 1

Culvert Data Summary - HDPE

Barrel Shape: Circular

Barrel Diameter: 2.22 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Mitered to Conform to Slope

Inlet Depression: NONE

Table 3 - Culvert Summary Table: Bored Pipe

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)
0.00	0.00	618.07	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	2.49	619.04	0.842	0.0*	1-S2n	0.382	0.566	0.385	0.782	6.444	2.410
13.00	5.15	619.48	1.278	0.0*	1-S2n	0.557	0.830	0.559	1.070	7.826	2.975
19.50	7.63	619.86	1.662	0.0*	1-S2n	0.690	1.021	0.690	1.292	8.647	3.346
26.00	10.05	620.27	2.072	0.0*	5-S2n	0.803	1.178	0.807	1.478	9.274	3.628
32.50	12.50	620.77	2.565	0.0*	5-S2n	0.914	1.312	0.914	1.642	9.833	3.858
39.00	14.95	621.37	3.172	0.0*	5-S2n	1.022	1.427	1.026	1.792	10.208	4.038
45.50	17.38	622.10	3.900	0.0*	5-S2n	1.132	1.514	1.133	1.931	10.561	4.184
52.00	19.74	622.94	4.741	0.0*	5-S2n	1.242	1.599	1.242	2.057	10.808	4.316
58.50	22.02	623.88	5.679	4.016	4-FFf	1.365	1.681	1.365	2.352	10.960	3.747
65.00	24.26	624.91	6.708	5.803	4-FFf	1.535	1.750	1.650	2.657	10.397	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 618.20 ft, Outlet Elevation (invert): 613.25 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - Bored Pipe

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 618.20 ft

Outlet Station: 272.00 ft

Outlet Elevation: 613.25 ft

Number of Barrels: 1

Culvert Data Summary - Bored Pipe

Barrel Shape: Circular

Barrel Diameter: 1.75 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Thin Edge Projecting

Inlet Depression: NONE

Table 4 - Downstream Channel Rating Curve (Crossing: I65-62.11 - HDPE)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	612.94	0.00	0.00	0.00	0.00
6.50	613.72	0.78	2.41	0.88	0.60
13.00	614.01	1.07	2.97	1.20	0.63
19.50	614.23	1.29	3.35	1.45	0.64
26.00	614.42	1.48	3.63	1.66	0.65
32.50	614.58	1.64	3.86	1.84	0.66
39.00	614.73	1.79	4.04	2.01	0.67
45.50	614.87	1.93	4.18	2.17	0.67
52.00	615.00	2.06	4.32	2.31	0.68
58.50	615.29	2.35	3.75	2.64	0.67
65.00	615.60	2.66	2.70	2.98	0.63

Tailwater Channel Data - I65-62.11 - HDPE

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0180

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-37.00	620.00	0.0500
2	-27.00	618.00	0.0500
3	-12.00	616.00	0.0500
4	3.00	615.24	0.0500
5	7.50	615.09	0.0500
6	10.50	613.55	0.0500
7	13.00	612.94	0.0500
8	15.00	613.18	0.0500
9	16.50	614.65	0.0500
10	18.00	615.33	0.0500
11	68.00	616.00	0.0500
12	98.00	618.00	0.0500
13	118.00	620.00	0.0000

Roadway Data for Crossing: I65-62.11 - HDPE

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 628.20 ft

Roadway Surface: Paved

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report – Alt 2 CIPP

Headwater Elevation (ft)	Total Discharge (cfs)	CIPP Discharge (cfs)	Roadway Discharge (cfs)	Iterations
617.97	0.00	0.00	0.00	1
619.07	6.50	6.50	0.00	1
619.59	13.00	13.00	0.00	1
620.03	19.50	19.50	0.00	1
620.46	26.00	26.00	0.00	1
620.89	32.50	32.50	0.00	1
621.36	39.00	39.00	0.00	1
621.89	45.50	45.50	0.00	1
622.50	52.00	52.00	0.00	1
623.18	58.50	58.50	0.00	1
623.96	65.00	65.00	0.00	1
628.20	91.97	91.97	0.00	Overtopping

Table 1 - Summary of Culvert Flows at Crossing: I65-62.11 - CIPP

Table 2 - Culvert Summary Table: CIPP

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)
0.00	0.00	617.97	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	6.50	619.07	1.104	0.0*	1-S2n	0.524	0.809	0.528	0.782	7.935	2.410
13.00	13.00	619.59	1.617	0.0*	1-S2n	0.744	1.163	0.753	1.070	9.604	2.975
19.50	19.50	620.03	2.064	0.0*	1-S2n	0.924	1.440	0.930	1.292	10.805	3.346
26.00	26.00	620.46	2.485	0.0*	1-S2n	1.080	1.674	1.083	1.478	11.720	3.628
32.50	32.50	620.89	2.918	0.0*	5-S2n	1.222	1.876	1.225	1.642	12.445	3.858
39.00	39.00	621.36	3.389	0.0*	5-S2n	1.357	2.058	1.358	1.792	13.072	4.038
45.50	45.50	621.89	3.920	0.0*	5-S2n	1.488	2.220	1.489	1.931	13.568	4.184
52.00	52.00	622.50	4.525	0.0*	5-S2n	1.616	2.347	1.620	2.057	13.970	4.316
58.50	58.50	623.18	5.213	0.0*	5-S2n	1.746	2.461	1.748	2.352	14.354	3.747
65.00	65.00	623.96	5.989	0.0*	5-S2n	1.879	2.575	1.884	2.657	14.635	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 617.97 ft, Outlet Elevation (invert): 613.02 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - CIPP

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 617.97 ft

Outlet Station: 272.00 ft

Outlet Elevation: 613.02 ft

Number of Barrels: 1

Culvert Data Summary - CIPP

Barrel Shape: Circular

Barrel Diameter: 2.83 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: I65-62.11 - CIPP)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	612.94	0.00	0.00	0.00	0.00
6.50	613.72	0.78	2.41	0.88	0.60
13.00	614.01	1.07	2.97	1.20	0.63
19.50	614.23	1.29	3.35	1.45	0.64
26.00	614.42	1.48	3.63	1.66	0.65
32.50	614.58	1.64	3.86	1.84	0.66
39.00	614.73	1.79	4.04	2.01	0.67
45.50	614.87	1.93	4.18	2.17	0.67
52.00	615.00	2.06	4.32	2.31	0.68
58.50	615.29	2.35	3.75	2.64	0.67
65.00	615.60	2.66	2.70	2.98	0.63

Tailwater Channel Data - I65-62.11 - CIPP

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0180

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-37.00	620.00	0.0500
2	-27.00	618.00	0.0500
3	-12.00	616.00	0.0500
4	3.00	615.24	0.0500
5	7.50	615.09	0.0500
6	10.50	613.55	0.0500
7	13.00	612.94	0.0500
8	15.00	613.18	0.0500
9	16.50	614.65	0.0500
10	18.00	615.33	0.0500
11	68.00	616.00	0.0500
12	98.00	618.00	0.0500
13	118.00	620.00	0.0000

Roadway Data for Crossing: I65-62.11 - CIPP

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 628.20 ft

Roadway Surface: Paved

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report – Alt 3 Pave Invert

Headwater Elevation (ft)	Total Discharge (cfs)	Paved Invert Discharge (cfs)	Bored Pipe Discharge (cfs)	Roadway Discharge (cfs)	Iterations
618.31	0.00	0.00	0.00	0.00	0
619.07	6.50	4.51	1.98	0.00	5
619.40	13.00	8.67	4.32	0.00	4
619.66	19.50	12.50	6.99	0.00	4
619.91	26.00	16.06	9.94	0.00	4
620.15	32.50	19.45	13.03	0.00	3
620.37	39.00	23.01	15.97	0.00	3
620.58	45.50	26.51	18.98	0.00	3
620.80	52.00	29.92	22.09	0.00	4
621.17	58.50	31.01	27.50	0.00	4
621.37	65.00	34.64	30.36	0.00	4
628.20	134.87	50.07	84.80	0.00	Overtopping

Table 1 - Summary of Culvert Flows at Crossing: I65-62.11 - Paved Invert

Table 2 - Culvert Summary Table: Paved Invert

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)
0.00	0.00	618.31	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	4.51	619.07	0.765	0.0*	1-S2n	0.548	0.584	0.553	0.782	4.124	2.410
13.00	8.67	619.40	1.093	0.0*	1-S2n	0.767	0.827	0.768	1.070	5.060	2.975
19.50	12.50	619.66	1.351	0.0*	1-S2n	0.934	1.012	0.941	1.292	5.623	3.346
26.00	16.06	619.91	1.603	0.0*	1-S2n	1.082	1.156	1.085	1.478	6.064	3.628
32.50	19.45	620.15	1.843	0.0*	1-S2n	1.215	1.289	1.218	1.642	6.388	3.858
39.00	23.01	620.37	2.061	0.0*	1-S2n	1.353	1.410	1.359	1.792	6.651	4.038
45.50	26.51	620.58	2.272	0.0*	1-S2n	1.488	1.529	1.488	1.931	6.915	4.184
52.00	29.92	620.80	2.486	0.0*	1-S2n	1.625	1.631	1.630	2.057	7.075	4.316
58.50	31.01	621.17	2.572	2.860	7-M1t	1.671	1.663	1.932	2.352	6.172	3.747
65.00	34.64	621.37	2.858	3.060	7-M1t	1.825	1.768	2.237	2.657	6.093	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 618.31 ft, Outlet Elevation (invert): 613.36 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - Paved Invert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 618.31 ft

Outlet Station: 272.00 ft

Outlet Elevation: 613.36 ft

Number of Barrels: 1

Culvert Data Summary - Paved Invert

Barrel Shape: User Defined

Barrel Span: 3.00 ft

Barrel Rise: 2.58 ft

Barrel Material: Corrugated Metal Riveted or Welded

Embedment: 0.00 in

Barrel Manning's n: 0.0240 (top and sides)

Manning's n: 0.0120 (bottom)

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: NONE

Table 3 - Culvert Summary Table: Bored Pipe

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)
0.00	0.00	618.31	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	1.98	619.07	0.625	0.0*	1-S2n	0.292	0.413	0.292	0.782	5.395	2.410
13.00	4.32	619.40	0.952	0.0*	1-S2n	0.405	0.642	0.432	1.070	6.661	2.975
19.50	6.99	619.66	1.212	0.0*	1-S2n	0.528	0.822	0.532	1.292	8.116	3.346
26.00	9.94	619.91	1.463	0.0*	1-S2n	0.639	0.989	0.648	1.478	8.971	3.628
32.50	13.03	620.15	1.704	0.0*	1-S2n	0.727	1.142	0.732	1.642	9.664	3.858
39.00	15.97	620.37	1.920	0.0*	1-S2n	0.811	1.270	0.819	1.792	10.145	4.038
45.50	18.98	620.58	2.132	0.0*	1-S2n	0.896	1.390	0.897	1.931	10.696	4.184
52.00	22.09	620.80	2.347	0.0*	1-S2n	0.965	1.511	0.970	2.057	11.143	4.316
58.50	27.50	621.17	2.719	0.0*	1-S2n	1.082	1.690	1.089	2.352	11.844	3.747
65.00	30.36	621.37	2.920	0.0*	1-S2n	1.144	1.784	1.153	2.657	12.114	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 618.45 ft, Outlet Elevation (invert): 613.50 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - Bored Pipe

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 618.45 ft

Outlet Station: 272.00 ft

Outlet Elevation: 613.50 ft

Number of Barrels: 1

Culvert Data Summary - Bored Pipe

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Thin Edge Projecting

Inlet Depression: NONE

Table 4 - Downstream Channel Rating Curve (Crossing: I65-62.11 - Paved Invert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	612.94	0.00	0.00	0.00	0.00
6.50	613.72	0.78	2.41	0.88	0.60
13.00	614.01	1.07	2.97	1.20	0.63
19.50	614.23	1.29	3.35	1.45	0.64
26.00	614.42	1.48	3.63	1.66	0.65
32.50	614.58	1.64	3.86	1.84	0.66
39.00	614.73	1.79	4.04	2.01	0.67
45.50	614.87	1.93	4.18	2.17	0.67
52.00	615.00	2.06	4.32	2.31	0.68
58.50	615.29	2.35	3.75	2.64	0.67
65.00	615.60	2.66	2.70	2.98	0.63

Tailwater Channel Data - I65-62.11 - Paved Invert

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0180

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-37.00	620.00	0.0500
2	-27.00	618.00	0.0500
3	-12.00	616.00	0.0500
4	3.00	615.24	0.0500
5	7.50	615.09	0.0500
6	10.50	613.55	0.0500
7	13.00	612.94	0.0500
8	15.00	613.18	0.0500
9	16.50	614.65	0.0500
10	18.00	615.33	0.0500
11	68.00	616.00	0.0500
12	98.00	618.00	0.0500
13	118.00	620.00	0.0000

Roadway Data for Crossing: I65-62.11 - Paved Invert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 628.20 ft

Roadway Surface: Paved

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report – Alt 4 Corrugated

Headwater Elevation (ft)	Total Discharge (cfs)	Corrugated Discharge (cfs)	Roadway Discharge (cfs)	Iterations
617.89	0.00	0.00	0.00	1
619.01	6.50	6.50	0.00	1
619.58	13.00	13.00	0.00	1
619.60	19.50	19.50	0.00	1
620.44	26.00	26.00	0.00	1
620.80	32.50	32.50	0.00	1
621.14	39.00	39.00	0.00	1
621.45	45.50	45.50	0.00	1
621.77	52.00	52.00	0.00	1
622.08	58.50	58.50	0.00	1
622.40	65.00	65.00	0.00	1
628.20	87.14	87.14	0.00	Overtopping

Table 1 - Summary of Culvert Flows at Crossing: I65-62.11 - Corrugated

Table 2 - Culvert Summary Table: Corrugated

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)
0.00	0.00	617.89	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	6.50	619.01	0.888	1.116	3-M1t	0.645	0.628	0.782	0.782	3.166	2.410
13.00	13.00	619.58	1.333	1.688	3-M1t	0.946	0.944	1.070	1.070	4.334	2.975
19.50	19.50	619.60	1.706	0.0*	1-S2n	1.189	1.190	1.189	1.292	5.716	3.346
26.00	26.00	620.44	2.123	2.554	3-M1t	1.411	1.406	1.478	1.478	5.896	3.628
32.50	32.50	620.80	2.540	2.914	3-M1t	1.620	1.603	1.642	1.642	6.527	3.858
39.00	39.00	621.14	2.925	3.253	3-M2t	1.820	1.773	1.792	1.792	7.089	4.038
45.50	45.50	621.45	3.304	3.563	2-M2c	2.023	1.940	1.940	1.931	7.576	4.184
52.00	52.00	621.77	3.687	3.878	2-M2c	2.230	2.084	2.092	2.057	7.983	4.316
58.50	58.50	622.08	4.079	4.188	3-M2t	2.465	2.226	2.352	2.352	7.973	3.747
65.00	65.00	622.40	4.470	4.511	3-M2t	2.767	2.352	2.657	2.657	7.922	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 617.89 ft, Outlet Elevation (invert): 612.94 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - Corrugated

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 617.64 ft

Outlet Station: 272.00 ft

Outlet Elevation: 612.69 ft

Number of Barrels: 1

Culvert Data Summary - Corrugated

Barrel Shape: Circular

Barrel Diameter: 3.50 ft

Barrel Material: Corrugated Steel

Embedment: 3.00 in

Barrel Manning's n: 0.0240 (top and sides)

Manning's n: 0.0350 (bottom)

Inlet Type: Conventional

Inlet Edge Condition: Thin Edge Projecting

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: I65-62.11 - Corrugated)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	612.94	0.00	0.00	0.00	0.00
6.50	613.72	0.78	2.41	0.88	0.60
13.00	614.01	1.07	2.97	1.20	0.63
19.50	614.23	1.29	3.35	1.45	0.64
26.00	614.42	1.48	3.63	1.66	0.65
32.50	614.58	1.64	3.86	1.84	0.66
39.00	614.73	1.79	4.04	2.01	0.67
45.50	614.87	1.93	4.18	2.17	0.67
52.00	615.00	2.06	4.32	2.31	0.68
58.50	615.29	2.35	3.75	2.64	0.67
65.00	615.60	2.66	2.70	2.98	0.63

Tailwater Channel Data - I65-62.11 - Corrugated

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0180

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-37.00	620.00	0.0500
2	-27.00	618.00	0.0500
3	-12.00	616.00	0.0500
4	3.00	615.24	0.0500
5	7.50	615.09	0.0500
6	10.50	613.55	0.0500
7	13.00	612.94	0.0500
8	15.00	613.18	0.0500
9	16.50	614.65	0.0500
10	18.00	615.33	0.0500
11	68.00	616.00	0.0500
12	98.00	618.00	0.0500
13	118.00	620.00	0.0000

Roadway Data for Crossing: I65-62.11 - Corrugated

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 628.20 ft

Roadway Surface: Paved

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report – Alt 5 SemiSmooth

Headwater Elevation (ft)	Total Discharge (cfs)	SemiSmooth Discharge (cfs)	Roadway Discharge (cfs)	Iterations
617.89	0.00	0.00	0.00	1
618.78	6.50	6.50	0.00	1
619.22	13.00	13.00	0.00	1
619.60	19.50	19.50	0.00	1
620.01	26.00	26.00	0.00	1
620.43	32.50	32.50	0.00	1
620.81	39.00	39.00	0.00	1
621.19	45.50	45.50	0.00	1
621.58	52.00	52.00	0.00	1
621.97	58.50	58.50	0.00	1
622.36	65.00	65.00	0.00	1
628.20	105.31	105.31	0.00	Overtopping

Table 1 - Summary of Culvert Flows at Crossing: I65-62.11 - Semismooth

Table 2 - Culvert Summary Table: SemiSmooth

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)
0.00	0.00	617.89	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	6.50	618.78	0.888	0.0*	1-S2n	0.587	0.628	0.588	0.782	4.441	2.410
13.00	13.00	619.22	1.333	0.0*	1-S2n	0.853	0.944	0.854	1.070	5.670	2.975
19.50	19.50	619.60	1.706	0.0*	1-S2n	1.069	1.190	1.069	1.292	6.498	3.346
26.00	26.00	620.01	2.123	0.0*	1-S2n	1.256	1.406	1.256	1.478	7.143	3.628
32.50	32.50	620.43	2.540	0.0*	1-S2n	1.422	1.603	1.422	1.642	7.710	3.858
39.00	39.00	620.81	2.925	0.0*	1-S2n	1.582	1.773	1.583	1.792	8.169	4.038
45.50	45.50	621.19	3.304	0.0*	5-S2n	1.734	1.940	1.734	1.931	8.589	4.184
52.00	52.00	621.58	3.687	0.0*	5-S2n	1.883	2.084	1.883	2.057	8.951	4.316
58.50	58.50	621.97	4.079	0.0*	5-S2n	2.033	2.226	2.033	2.352	9.271	3.747
65.00	65.00	622.36	4.470	0.0*	5-S2n	2.183	2.352	2.183	2.657	9.559	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 617.89 ft, Outlet Elevation (invert): 612.94 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - SemiSmooth

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 617.64 ft

Outlet Station: 272.00 ft

Outlet Elevation: 612.69 ft

Number of Barrels: 1

Culvert Data Summary - SemiSmooth

Barrel Shape: Circular

Barrel Diameter: 3.50 ft

Barrel Material: Corrugated Steel

Embedment: 3.00 in

Barrel Manning's n: 0.0150 (top and sides)

Manning's n: 0.0350 (bottom)

Inlet Type: Conventional

Inlet Edge Condition: Thin Edge Projecting

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: I65-62.11 - Semismooth)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	612.94	0.00	0.00	0.00	0.00
6.50	613.72	0.78	2.41	0.88	0.60
13.00	614.01	1.07	2.97	1.20	0.63
19.50	614.23	1.29	3.35	1.45	0.64
26.00	614.42	1.48	3.63	1.66	0.65
32.50	614.58	1.64	3.86	1.84	0.66
39.00	614.73	1.79	4.04	2.01	0.67
45.50	614.87	1.93	4.18	2.17	0.67
52.00	615.00	2.06	4.32	2.31	0.68
58.50	615.29	2.35	3.75	2.64	0.67
65.00	615.60	2.66	2.70	2.98	0.63

Tailwater Channel Data - I65-62.11 - Semismooth

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0180

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-37.00	620.00	0.0500
2	-27.00	618.00	0.0500
3	-12.00	616.00	0.0500
4	3.00	615.24	0.0500
5	7.50	615.09	0.0500
6	10.50	613.55	0.0500
7	13.00	612.94	0.0500
8	15.00	613.18	0.0500
9	16.50	614.65	0.0500
10	18.00	615.33	0.0500
11	68.00	616.00	0.0500
12	98.00	618.00	0.0500
13	118.00	620.00	0.0000

Roadway Data for Crossing: I65-62.11 - Semismooth

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 628.20 ft

Roadway Surface: Paved

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report – Alt 6 Smooth

Headwater Elevation (ft)	Total Discharge (cfs)	Smooth Discharge (cfs)	Roadway Discharge (cfs)	Iterations
617.89	0.00	0.00	0.00	1
618.79	6.50	6.50	0.00	1
619.25	13.00	13.00	0.00	1
619.68	19.50	19.50	0.00	1
620.07	26.00	26.00	0.00	1
620.44	32.50	32.50	0.00	1
620.90	39.00	39.00	0.00	1
621.39	45.50	45.50	0.00	1
621.91	52.00	52.00	0.00	1
622.50	58.50	58.50	0.00	1
623.17	65.00	65.00	0.00	1
628.20	84.12	84.12	0.00	Overtopping

Table 1 - Summary of Culvert Flows at Crossing: I65-62.11 - Smooth

Table 2 - Culvert Summary Table: Smooth

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)
0.00	0.00	617.89	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
6.50	6.50	618.79	0.900	0.0*	1-S2n	0.602	0.657	0.602	0.782	4.771	2.410
13.00	13.00	619.25	1.358	0.0*	1-S2n	0.876	0.994	0.876	1.070	6.102	2.975
19.50	19.50	619.68	1.788	0.0*	1-S2n	1.098	1.260	1.099	1.292	7.009	3.346
26.00	26.00	620.07	2.184	0.0*	1-S2n	1.286	1.487	1.286	1.478	7.776	3.628
32.50	32.50	620.44	2.551	0.0*	1-S2n	1.467	1.690	1.467	1.642	8.380	3.858
39.00	39.00	620.90	3.012	0.0*	5-S2n	1.640	1.870	1.641	1.792	8.884	4.038
45.50	45.50	621.39	3.496	0.0*	5-S2n	1.814	2.028	1.814	1.931	9.337	4.184
52.00	52.00	621.91	4.023	0.0*	5-S2n	1.993	2.176	1.993	2.057	9.712	4.316
58.50	58.50	622.50	4.606	0.0*	5-S2n	2.184	2.285	2.184	2.352	10.029	3.747
65.00	65.00	623.17	5.276	4.872	7-M1t	2.439	2.385	2.657	2.657	9.784	2.701

* theoretical depth is impractical. Depth reported is corrected.

****

Inlet Elevation (invert): 617.89 ft, Outlet Elevation (invert): 612.94 ft

Culvert Length: 272.05 ft, Culvert Slope: 0.0182

****

Site Data - Smooth

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 617.64 ft

Outlet Station: 272.00 ft

Outlet Elevation: 612.69 ft

Number of Barrels: 1

Culvert Data Summary - Smooth

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Corrugated Steel

Embedment: 3.00 in

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

Manning's n: 0.0350 (bottom)

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: I65-62.11 - Smooth)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	612.94	0.00	0.00	0.00	0.00
6.50	613.72	0.78	2.41	0.88	0.60
13.00	614.01	1.07	2.97	1.20	0.63
19.50	614.23	1.29	3.35	1.45	0.64
26.00	614.42	1.48	3.63	1.66	0.65
32.50	614.58	1.64	3.86	1.84	0.66
39.00	614.73	1.79	4.04	2.01	0.67
45.50	614.87	1.93	4.18	2.17	0.67
52.00	615.00	2.06	4.32	2.31	0.68
58.50	615.29	2.35	3.75	2.64	0.67
65.00	615.60	2.66	2.70	2.98	0.63

Tailwater Channel Data - I65-62.11 - Smooth

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0180

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-37.00	620.00	0.0500
2	-27.00	618.00	0.0500
3	-12.00	616.00	0.0500
4	3.00	615.24	0.0500
5	7.50	615.09	0.0500
6	10.50	613.55	0.0500
7	13.00	612.94	0.0500
8	15.00	613.18	0.0500
9	16.50	614.65	0.0500
10	18.00	615.33	0.0500
11	68.00	616.00	0.0500
12	98.00	618.00	0.0500
13	118.00	620.00	0.0000

Roadway Data for Crossing: I65-62.11 - Smooth

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 628.20 ft

Roadway Surface: Paved

Roadway Top Width: 150.00 ft