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Nature's Classroom Trail: Bridging Education and Recreation at the University of Southern Indiana

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James Wolfe – Facility Operations and Planning at USI

Dr. Allison Grabert – Director of Southwest Indiana STEM Resource Center

Dr. William Elliott – Interim Dean of the Pott College of Science, Engineering, and Education

Dr. Paul Kuban – Chair of Engineering Department at USI

Dr. Jason Hill – USI Professor

Dr. Adam Tennant – USI Professor

Dr. Kerry Hall – USI Professor

Matt Badger – CenterPoint Energy Survey Liaison

Hollie Buchanan – Vanderburgh County Floodplain Administrator

Curtis Winiger – Engineer at Metal Fabrications LLC

ABSTRACT

The purpose of this project was to create a new outdoor trail and bridge that can be used by the community and university students. Currently, there are existing trails near this location of campus and the proposed trail will connect the theater support building to the current trail network.

The project started with multiple meetings between the interim dean of the Pott College, Dr. William Elliott, the director of the Southwest Indiana STEM Resource Center, Dr. Allison Grabert, the chair of the engineering department at USI, Paul Kuban, and James Wolfe, the facility operations and planning at USI. The team then visited the proposed site multiple times to collect survey data using total stations and GNSS to establish control points. The survey will help create an alignment of the trail, data for culvert sizing and bridge design, and measurements of other important factors throughout the project. As mentioned above, a culvert analysis was completed for two separate areas that either had an existing ditch or needed a ditch to control flooding. A watershed analysis was also performed to determine the elevation of the proposed bridge deck over the existing creek that runs along the bluff. An estimate was completed for the entire project, and a plan set was created that consists of the alignment, bridge design, watershed analysis, clearing and grubbing, and cut and fill areas. Finally, the bridge and trail are to be constructed next year by a contractor.

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2025 BRIDGE USI AND TRAIL:

TRAIL DESIGN AND IMPLEMENTATION

1 INTRODUCTION

The University of Southern Indiana (USI) is home to a diverse network of nature trails that enhance the campus's natural beauty and provide outdoor learning opportunities. The idea for this project was presented by the Interim Dean of the Pott College of Science, Engineering, and Education, Dr. William Elliot. Upon learning about this initiative, our team decided to take on the challenge as our senior design project. This project focuses on developing a 1,000-foot footpath extension to connect the outdoor learning pavilion to USI's existing trail system. The extension will include the construction of a bridge over a stream, ensuring both safe and scenic passage. The new footpath will navigate a steep, wooded area, offering a picturesque route through the campus's natural landscape while enhancing connectivity to the broader trail network.

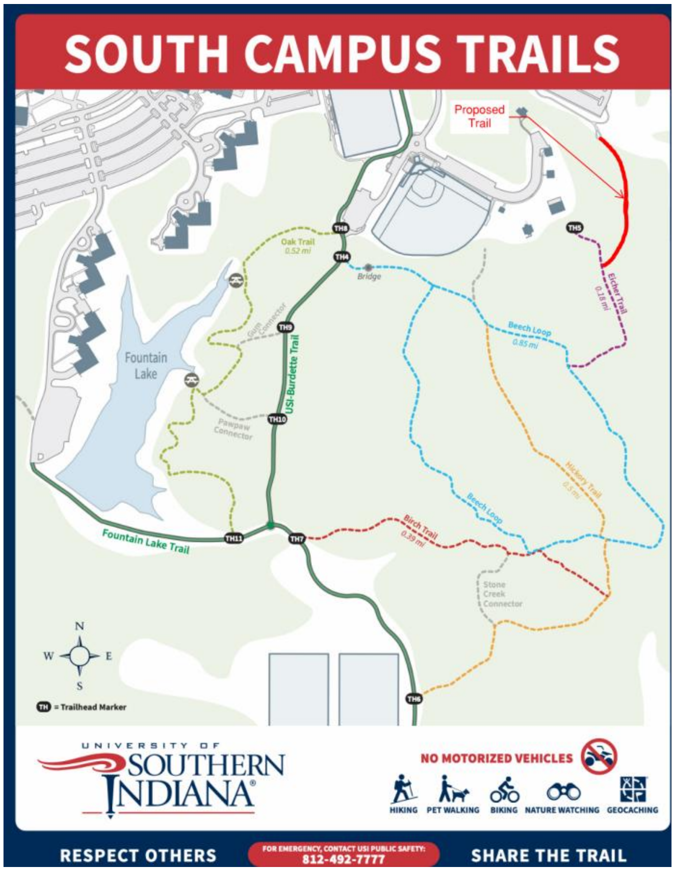

Figure 1: Trail System at the University of Southern Indiana

1.1 PROJECT SCOPE

The scope of this project encompasses a variety of tasks, including pre-design work, trail design, culvert analysis, watershed analysis, cost estimation, and the construction of the bridge plan set. To effectively address these areas, each team member took the lead on specific aspects of the project: Bailey Stambaugh led the trail design and watershed analysis, Ella Wolf took charge of the bridge design, and Tim Bohlen led the cost estimation efforts. While each area was led by a different team member, collaboration and teamwork ensured that all members gained familiarity with every aspect of the project.

The first step in the project was to establish meetings with key stakeholders. Throughout the spring semester, the team prioritized these discussions to gain a deeper understanding of the university's goals and the specific attributes desired for the trail. Key meetings were held with James Wolfe, Dr. William Elliott, Dr. Paul Kuban, and Dr. Allison Grabert, which were instrumental in shaping the final vision of the trail. These discussions also helped define the deliverables required for the project.

For the trail design, the team recognized the need for accurate landscape data. As a result, surveying was conducted early in the spring semester to map out the trail alignment and identify key features, such as potential bridge and culvert locations.

The bridge design focused on two areas where bridges were needed. Various resources were utilized to gather the necessary data for this analysis. RISA 3D was utilized to check hand calculations for the bridge design.

In the watershed analysis, two potential footbridge locations were identified. HEC-RAS modeling software was employed to assess the appropriate elevation for the bridge deck. Data for this analysis was sourced through online tools and consultations with experts.

For the bridge design, the team utilized RISA and RISA 3D modeling software to develop structural models. This allows for detailed analysis of the bridge's behavior under various loading conditions and ensures the design meets safety and performance requirements.

For the cost estimate, the team used Excel to compile a comprehensive estimate, factoring in labor, materials, and equipment costs. As the project is supported by a volunteer workforce, a bid schedule was developed based on field experience and material costs sourced from suppliers.

The final design and deliverables meet all of the university's requirements and align with university policies and procedures. As a result, the project is set to move forward with the finalized design in the fall semester.

2 SITE BACKGROUND

2.1 PRELIMINARY DISCUSSIONS/ MEETINGS

The initial meeting was held with Dr. Bill Elliott, Dr. Paul Kuban, and Allison Grabert. Dr. Elliott led a site tour outlining the proposed path and the location of the main bridge, which will be situated behind the oil rig on USI property. The planned trail will be a dirt path leading to the bridge and connecting to an existing trail. This existing trail extends to the Virgil C. Eicher Barn and will require additional improvements.

During the tour, it was noted that all trees removed during construction must be replaced elsewhere. Additionally, it was determined that a second bridge will be necessary. One potential solution for this crossing is the installation of a box culvert.

A subsequent meeting with Dr. Paul Kuban and Dr. Kerry Hall was held to address the team's questions. While Dr. Bill Elliott serves as the project's primary client, the main point of contact will be Mr. Jim Wolfe.

The bridge must be designed to support ATV traffic while integrating seamlessly into the natural environment.

2.2 GEOGRAPHIC LOCATION

The site is located on USI property, west of the oil rigs and east of the Virgil C. Eicher Barn. The bridge will be positioned at 37°57'32.3" N, 87°40'05.9" W. The trail will begin at the USI Theatre Support Center trail near the gazebo and will follow the creek until the west side of the creek widens, where the bridge will be constructed. From there, the trail will continue until it connects with the existing path leading to the Virgil C. Eicher Barn, as shown in the Figure 2: Overview of Site.

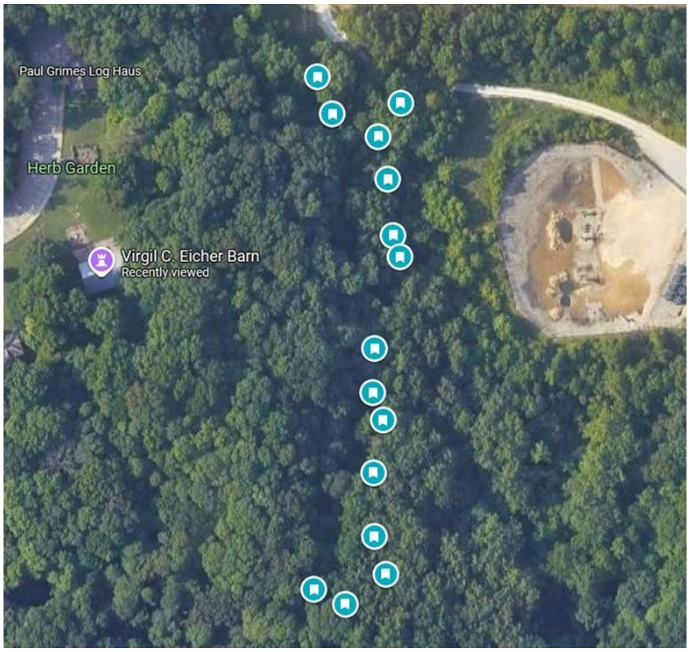

Figure 2: Overview of Site

2.3 *PROJECT SCHEDULE*

Construction is scheduled to begin in the spring semester of 2026, with a local contractor. The project officially commenced on February 25, 2025, with site surveying. While the surveying phase has progressed more slowly than anticipated, this delay has allowed additional time for research. The Spring 2025 semester was dedicated to conducting research and reaching out to relevant contacts, with numerous meetings and phone calls completed during this period.

Before construction can begin, eight key tasks must be completed: surveying, hydraulic analysis, bridge design, trail layout and design, construction drawings, cost estimation, and the final report. The design phase is expected to take 13 intensive weeks, as outlined in Table 2: Gantt Chart 1 and Table 1: Gantt Chart 2. To ensure timely completion, the latest possible start date is the week of July 7. However, recognizing the potential for delays, a total of 33 weeks has been allotted for project completion.

Table 2: Gantt Chart 1

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Surveying & Data Collection	█	█					
Hydraulic Analysis			█	█			
Bridge Conceptual Design			█	█			
Trail Layout & Design					█	█	
Bridge Structural Analysis					█	█	█
Finalizing Hydraulic & Drainage							
Construction Sequence & Drawings							
Cost Estimation							
Final Report & Presentation							

Table 1: Gantt Chart 2

Task	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Surveying & Data Collection						
Hydraulic Analysis	█	█				
Bridge Conceptual Design						
Trail Layout & Design						
Bridge Structural Analysis						
Finalizing Hydraulic & Drainage	█	█				
Construction Sequence & Drawings		█	█			
Cost Estimation			█	█		
Final Report & Presentation				█	█	█

2.4 ONLINE DATA SOURCES

The initial phase of any civil engineering project involves comprehensive site research to inform design decisions and mitigate potential issues. For this project, the team utilized several key resources to evaluate the site conditions. ArcGIS was used to assess flood zones. The National Wetlands Inventory (NWI) provided data on local watersheds, and USGS maps offered a preliminary overview of the site's topography, and LiDAR data were analyzed to obtain detailed elevation point clouds. Conducting this research at the outset is critical, as it identifies potential constraints, such as the need to relocate the site or obtain additional permits, thereby reducing the risk of delays or complications during later stages of the project.

2.4.1 ArcGis

ArcGIS is a powerful geographic information system (GIS) platform developed by Esri that allows users to analyze and visualize spatial data. In the context of this project, ArcGIS was utilized to access and interpret floodplain data relevant to the proposed site. By overlaying FEMA flood zone maps and other hydrological data layers, the team was able to identify areas with high flood risk, ensuring that site planning adhered to local, state, and federal regulations. ArcGIS also enabled the integration of multiple data sources, such as topography, land use, and soil types, to support a comprehensive environmental and geotechnical assessment. This level of spatial analysis is essential for making informed design decisions early in the project lifecycle.

It was discovered that the site was located in a flood zone A, as shown in Figure 3: ArcGIS Flood Zone. Because the details for designing a bridge in this floodplain were not readily available, we contacted water resources through the Department of Natural Resources (DNR) to learn more about the state's requirements for design. Because the details for designing a bridge in this floodplain were not readily available, we contacted water resources through the Department of Natural Resources (DNR) to learn more about the state's requirements for design. However, at that point, we were informed that the watershed area was too small to be under the Jurisdiction of the DNR, and so we were given the contact information for the floodplain administrator for Vanderburgh County, Hollie Buchanan, who informed us that the area had not been thoroughly studied and therefore had to use information from the Indiana Floodplain Information Portal. She used a Floodplain Analysis & Regulatory Assessment (FARA), and further hydraulic analysis is needed due to the drainage area being less than one square mile.

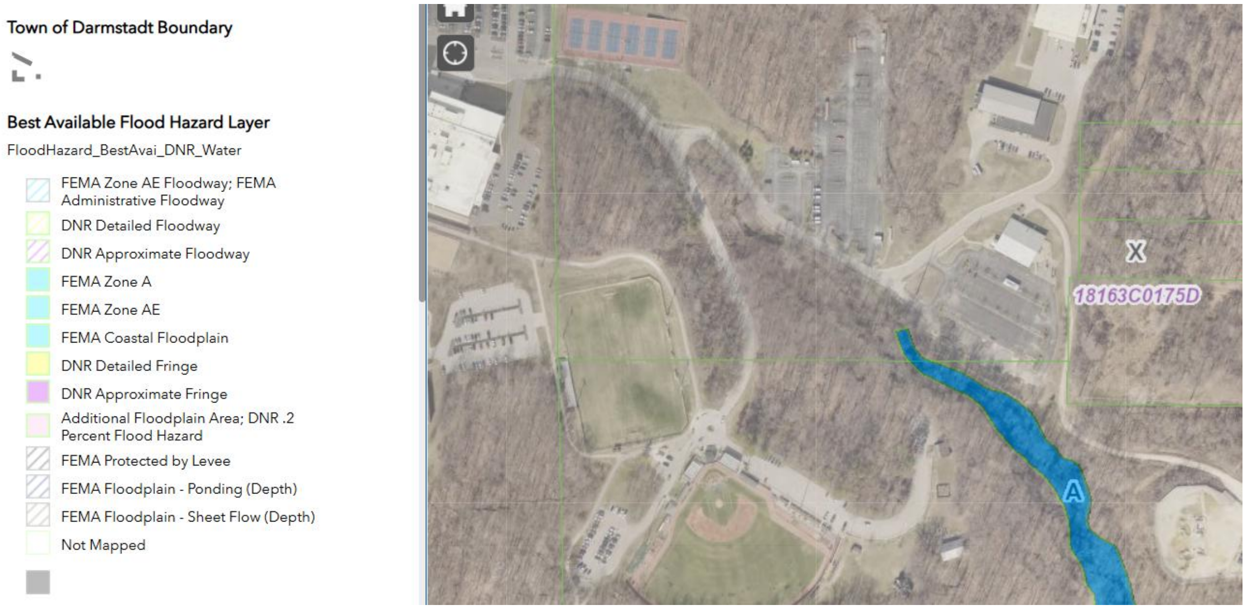

Figure 3: ArcGIS Flood Zone

2.4.2 NWI

The National Wetlands Inventory (NWI), managed by the U.S. Fish and Wildlife Service, provides detailed information on the location, type, and extent of wetlands and deepwater habitats across the United States. For this project, the NWI was consulted to identify any wetlands or sensitive ecological areas within or near the proposed site. Understanding the presence and classification of these areas is essential, as development within or adjacent to wetlands often requires special environmental permits and adherence to regulatory constraints. Incorporating NWI data early in the planning process supports environmentally responsible design and helps prevent regulatory violations or costly delays. The site is not located in a wetland according to NWI, as shown in Figure 4: NWI Map.

Figure 4: NWI Map

2.4.3 USGS

Topographic maps produced by the United States Geological Survey (USGS) offer a general overview of the physical features of a site, including contour lines that represent elevation changes, as well as natural and man-made landmarks. These maps were used in the preliminary stages of site analysis to assess terrain characteristics, drainage patterns, and potential access routes. While less detailed than LiDAR, USGS maps are valuable for providing a broad understanding of the site's physical layout and can help identify areas of concern, such as steep slopes or natural obstacles that may affect construction feasibility.

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2.4.4 LiDAR

Light Detection and Ranging (LiDAR) is a remote sensing technology that uses laser pulses to measure distances to the Earth's surface, generating high-resolution, three-dimensional data about terrain and surface features. For this project, LiDAR data was analyzed to create a detailed point cloud representing site elevations with high accuracy. This information was critical for developing a precise digital elevation model (DEM) used in grading analysis, drainage design, and earthwork planning. Compared to traditional surveying or topographic maps, LiDAR offers significantly greater detail and accuracy, enabling more efficient and informed design decisions.

LiDAR technology was employed to minimize the amount of on-site surveying required, significantly streamlining the data collection process. The raw LiDAR data, obtained through aerial scanning, included surface features such as vegetation and tree canopies—commonly referred to as "noise." LiDAR data is available for free on OpenTopographic with a point cloud. The selected area as shown in Figure 5: OpenTopography Area was used for the site. The data first needs to be processed before using it in AutoCAD. Autodesk ReCAP was utilized to process and clean the point cloud. ReCAP's filtering capabilities allowed the team to isolate ground points and remove non-essential elements, resulting in a more accurate representation of the site's true surface elevations. This refined data was essential for developing a reliable digital terrain model and supporting further design analysis.

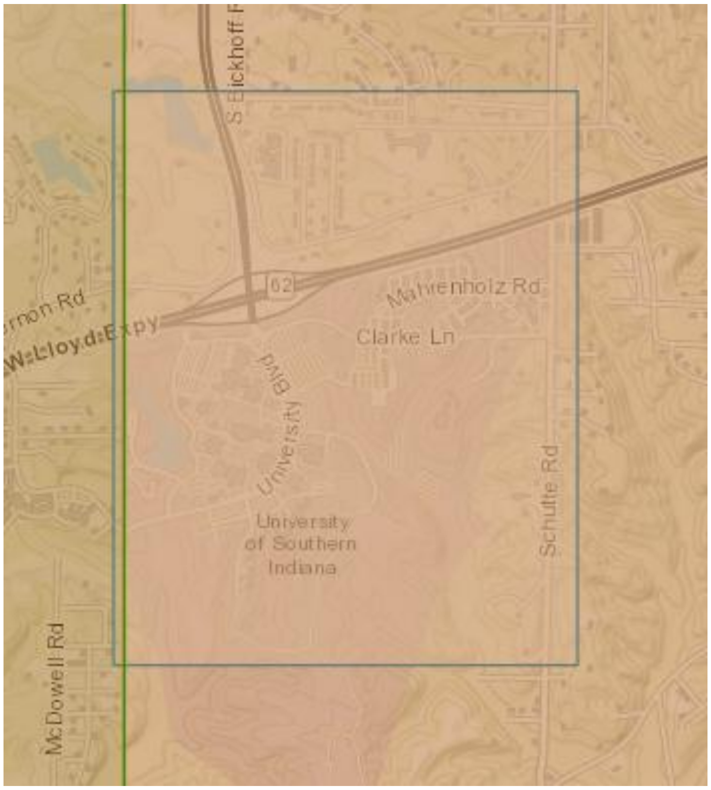


Figure 5: OpenTopography Area

3 BRIDGE USI AND NATURE TRAIL DESIGN

3.1 SURVEYING

The initial survey was attempted using the Global Navigation Satellite System (GNSS); however, due to dense tree cover, an insufficient number of satellites were in view, preventing successful data collection. As a result, surveying began on February 25 using a total station, with one total station and two prisms utilized. Approximately 8 hours were spent surveying the stream's cross-sections and banks. During this process, an estimated trail alignment was staked out. Cross-sections were recorded at locations where significant changes in the river profile were observed.

On March 2, a GNSS survey was conducted to establish two control points near the site. The collected data was then submitted to OPUS to obtain precise coordinates for these points. There were several challenges in obtaining the data using the total station and GNSS. Matt Badger from CenterPoint helped resolve the errors in the data from OPUS. Matt Badger from CenterPoint helped resolve the errors in the data from OPUS. Matt Badger has previously set up permanent control points on campus near the Business and Engineering Building called Dr. Jekyll and Mr. Hyde. The control point was shot in the Theater parking lot on April 8, and with Matt Badger's help, we got the data from OPUS on April 9.

On April 14, a total station and TSC7 control were used to shoot 3 more control points closer to the entrance of the site. The survey data was then imported into Civil 3D using CSV file type.

3.2 CIVIL 3D

Civil 3D was utilized to integrate the field survey data with LiDAR topographic information to produce a comprehensive digital terrain model of the project site. The combined dataset provided an accurate representation of existing ground conditions, enabling precise alignment of the channel geometry. From this model, cross-sections were systematically extracted and organized for import into HEC-RAS to support hydraulic analysis. These cross-sections were used to simulate flow characteristics, evaluate water surface elevations, and determine hydraulic parameters critical to establishing the design flood elevation and bridge deck height.

3.3 Drainage Analysis/ Hydrology and Hydraulics

A drainage analysis was completed for the project site to determine the design discharge and corresponding hydraulic and hydrological conditions for the proposed bridge. The analysis followed the NRCS TR-55 (Urban Hydrology for Small Watersheds) methodology, which estimates peak discharge based on rainfall, watershed characteristics, and flow path. Results from the hydrologic analysis were applied to a hydraulic model developed in HEC-RAS to establish the required bridge low chord elevation.

First, the hydrologic conditions of the site were assessed. Using site survey data, a field visit, and StreamStats, the contributing watershed area was delineated. To verify accuracy, the project team field-walked the watershed boundary and categorized flow segments into sheet flow, shallow concentrated flow, and channel flow. The watershed was determined to be 0.351 sq miles or 224.64 acres. Multiple potential flow paths were identified, and the longest hydraulic path was selected for the time of concentration (t_c) calculation, as recommended by TR-55. The total time of concentration was obtained by summing the travel times from each flow segment. Travel time is the time it takes water to travel from one location to another.

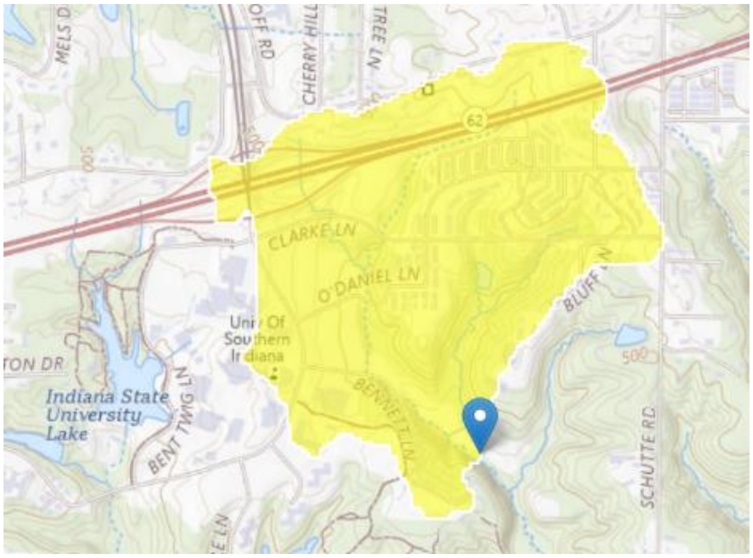


Figure 6: Approximate Watershed Boundary from StreamStats

The watershed path is shown in the figure below. The lengths were measured in the field, and the approximate path was laid out in Google Earth for viewing purposes. The length came out to 6,194.32 feet.

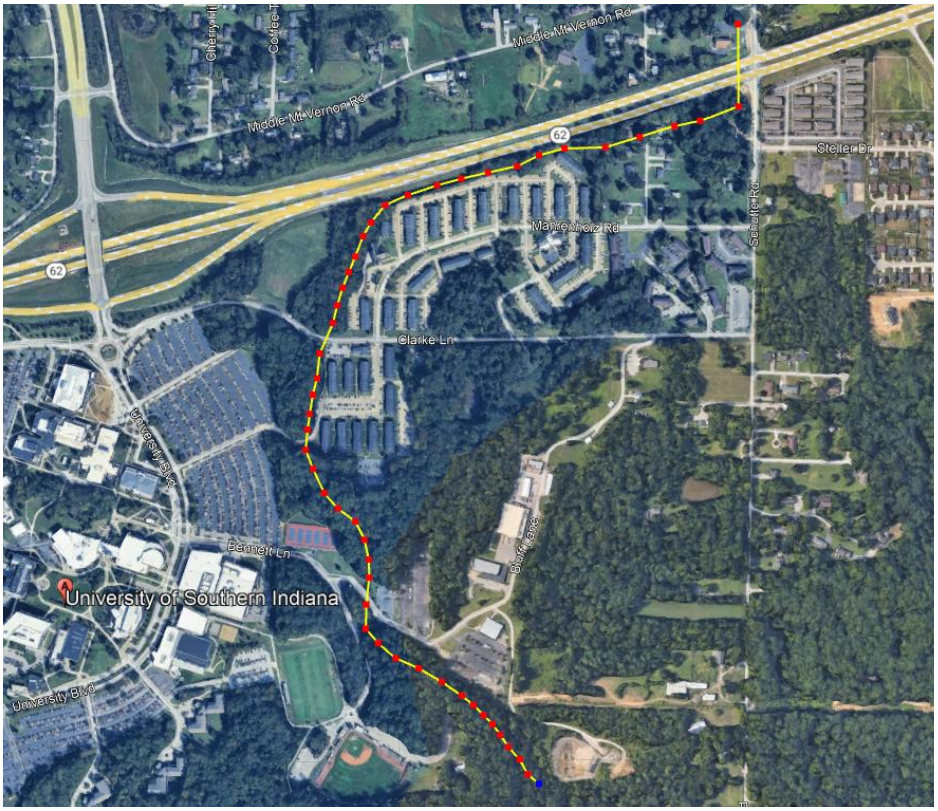


Figure 7: Path Analyzed for the Time of Concentration Calculations

A simplified rendition of Manning's kinematic solution was used to compute the travel time for sheet flow. This simplified form of the kinematic equation was developed by Welle and Woodward after studying the impact of various parameters on their estimates.

$$T_t = \frac{0.007\ (nl)^{0.8}}{(P_2)^{0.5} S^{0.4}}$$

Equation 1: Sheet Flow Time of Concentration

T_t = travel time, hour

n = Manning's roughness coefficient

l = sheet flow length, ft

P2 = 2-year 24-hour rainfall, in

S = slope of land surface, ft/ft

For the sheet flow time of concentration equation, a Manning's roughness coefficient of 0.15 was used after consulting Table 15-1 in Chapter fifteen – Time of Concentration – of the Hydrology National Engineering Handbook. The value for short-grass prairie was used for sheet flow.

Table 3: Table used for Manning's Roughness Coefficients

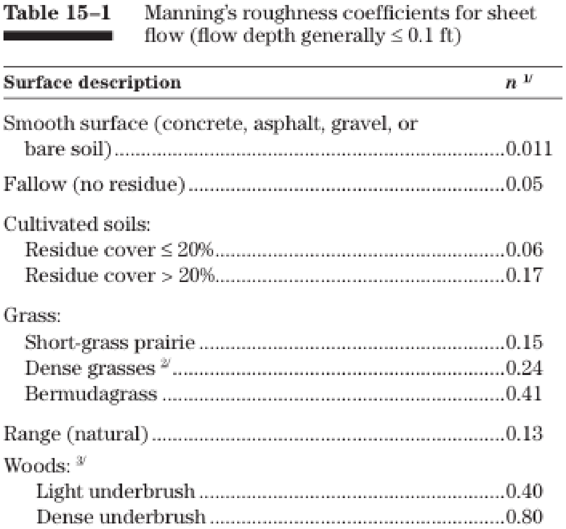
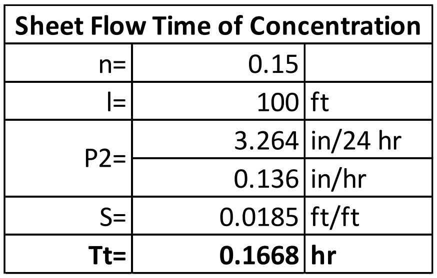


Table 15–1 Manning's roughness coefficients for sheet flow (flow depth generally ≤ 0.1 ft)

Surface description	n[1]
Smooth surface (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Grass:	
Short-grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

The length of the sheet flow (l) is assumed to be the first 100 feet of flow and was verified in the field. The slope of the sheet flow watershed is found using Streamstats values and verified in the field to be 0.0185 ft/ft. Below is a table with the calculations for the sheet flow. The time of concentration was found to be 0.1668 hours.

Table 4: Sheet Flow Time of Concentration Values



Sheet Flow Time of Concentration		
n=	0.15	
l=	100	ft
P2=	3.264	in/24 hr
	0.136	in/hr
S=	0.0185	ft/ft
Tt=	**0.1668**	**hr**

For calculating travel time in shallow concentrated and channel flow, first Manning's equation was applied as seen below to find the velocity. Shallow concentrated flow is assumed to begin once sheet flow ends. Beyond this point, open channel flow is considered to start where surveyed cross-section data is available, where channels are visible in aerial imagery, or where blue-line streams are shown on U.S. Geological Survey (USGS) quadrangle maps. The average flow velocity can be estimated using Manning’s equation or surface profile data, typically based on the bankfull flow conditions. The average flow velocity for this project is based on the average cross-section taken during the survey.

$$V = \frac{1.49 r^{\frac{2}{3}} S^{\frac{1}{2}}}{n}$$

Equation 2: Manning’s Velocity Equation

r = Hydraulic radius, area divided by wetted perimeter

Table 5: Manning's Velocity Values Used

Manning's Velocity Calculations		
r=	A/P	
A=	30	ft^2
P=	14.47	ft

For shallow concentrated flow the velocity was found from Figure 15-4 in Chapter fifteen – Time of Concentration – of the Hydrology National Engineering Handbook. The figure can be seen below.

Figure 15–4 Velocity versus slope for shallow concentrated flow

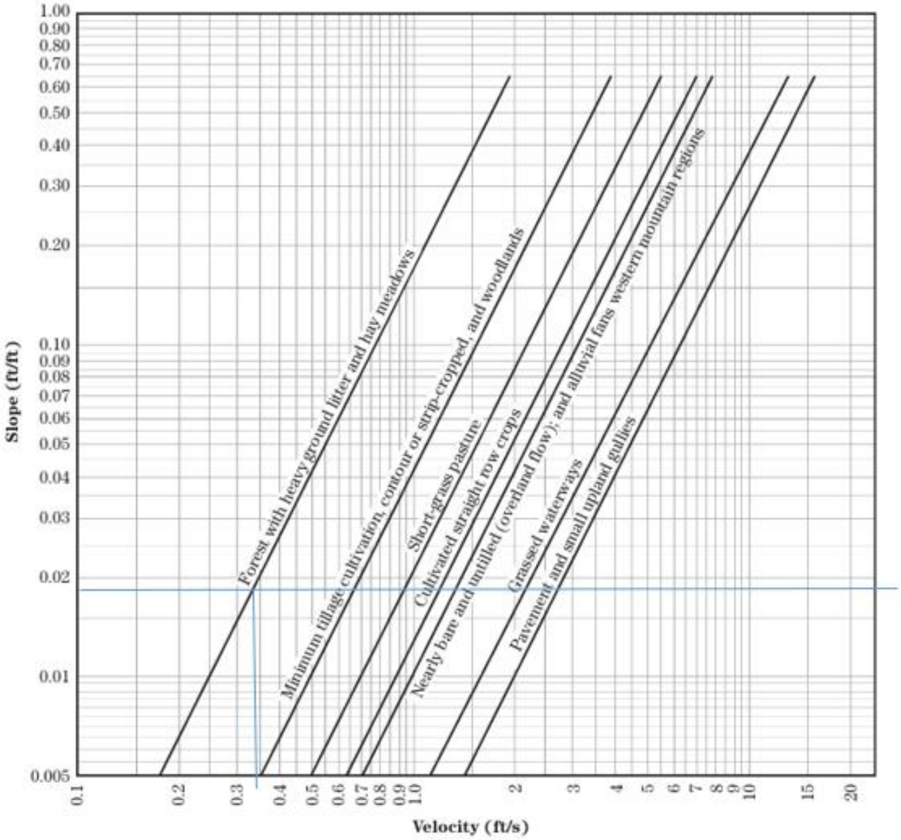


Figure 8: Figure used to find the velocity for shallow concentrated flow

To find the travel time for shallow concentrated flow and channel flow, the following equation was used:

$$T_t = \frac{l}{3600V}$$

Equation 3: Shallow Concentrated Flow and Channel Flow Time of Concentration

T_t = travel time, hour

V = average velocity of flow between two points, ft/s

l = distance between the two points under consideration, ft

3600 = conversion factor, seconds to hours

The following tables show the results for the time of concentration of the shallow concentrated and channel flow calculations. The shallow concentrated flow time of concentration was found to be 0.846 hours for 1065.7 feet. This distance was found by taking measurements in the field between where the channel starts and the sheet flow ends. The channel flow time of concentration was found to be 0.085 hours for 5028.67 feet.

Table 6: Shallow Concentrated Flow Time of Concentration Values

Shallow Concentrated Time of Concentration		
l=	1065.7	ft
V=	0.35	ft/s
Tt=	**0.846**	**hr**

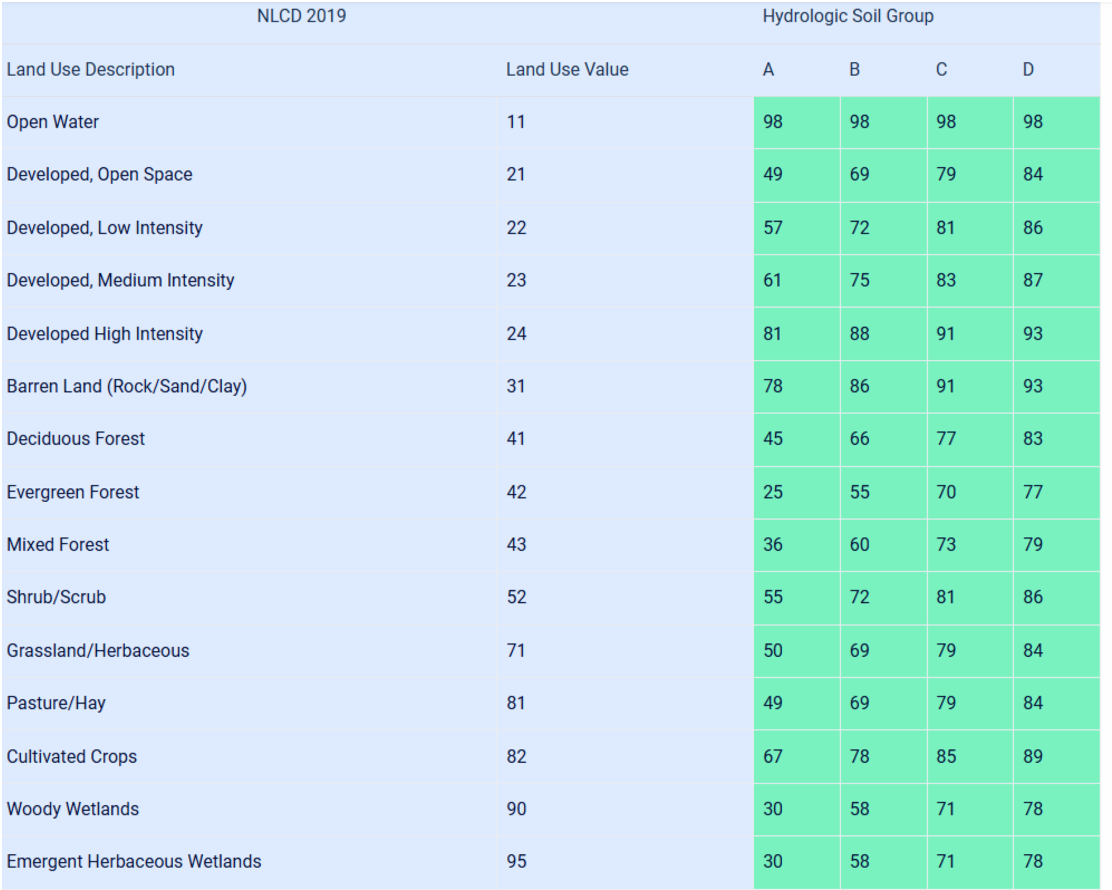
Table 7: Channel Flow Time of Concentration Values

Channel Flow Time of Concentration		
l=	5028.62	ft
V=	16.476	ft/s
Tt=	**0.085**	**hr**

The total time of concentration is found by summing the individual time of concentrations. The time of concentration was found to be 1.097 hours or 65.84 minutes.

The hydrologic soil groups (A, B, C, D) were obtained from the USDA Web Soil Survey, while land use/cover was obtained from the USGS National Land Cover Database (NLCD). Each land use-soil combination was assigned a curve number (CN). The first table below shows how each soil was classified. The second table shows this project's watershed classifications with percentages to determine the curve number. This was determined by overlaying the USDA Web Soil Survey and the USGS National Land Cover Database map and finding acre values.

Table 8: USGS National Land Cover Curve Number Classifications



NLCD 2019		Hydrologic Soil Group			
Land Use Description	Land Use Value	A	B	C	D
Open Water	11	98	98	98	98
Developed, Open Space	21	49	69	79	84
Developed, Low Intensity	22	57	72	81	86
Developed, Medium Intensity	23	61	75	83	87
Developed High Intensity	24	81	88	91	93
Barren Land (Rock/Sand/Clay)	31	78	86	91	93
Deciduous Forest	41	45	66	77	83
Evergreen Forest	42	25	55	70	77
Mixed Forest	43	36	60	73	79
Shrub/Scrub	52	55	72	81	86
Grassland/Herbaceous	71	50	69	79	84
Pasture/Hay	81	49	69	79	84
Cultivated Crops	82	67	78	85	89
Woody Wetlands	90	30	58	71	78
Emergent Herbaceous Wetlands	95	30	58	71	78

A weighted curve number for the watershed was computed using the following equation:

$$CN_W = \frac{\Sigma(CN_i A_i)}{\Sigma A_i}$$

Equation 4: Weighted Curve Number

CN_W = Weighted Curve Number

CN_i = Curve Number for each subarea

A_i = Area of each subarea

Table 9: Calculations for the Curve Number

Classification	Percentage	CN value	Acres	CN*A
(B) Developed Areas	42.8%	88	96.15	8460.84
(B) Forest Areas	26.4%	66	59.30	3914.13
(D) Developed Areas	8.6%	93	19.32	1796.67
(B) Pasture/Hay	6.8%	69	15.28	1054.01
(B/D) Developed Areas	5.7%	93	12.80	1190.82
(D) Forest Areas	5.0%	79	11.23	887.33
(D) Pasture/Hay	1.4%	84	3.14	264.18
(B/D) Forest Areas	3.3%	79	7.41	585.64
Σ	100.0%		Σ	18153.61
			CN	**80.812**

The weighted curve number was found to be 80.812.

Rainfall depths for the 100-year, 24-hour storm event were obtained from the NOAA Atlas 14 Precipitation Frequency Data Server. The rainfall intensity corresponding to the watershed time of concentration was used to generate the peak discharge.

In order to calculate the peak discharge, the TR-55 method for urban small watersheds was utilized. This method was developed by the National Resource Conservation Service (NRCS), which is within the U.S. Department of Agriculture (USDA). It came about originally to predict the daily runoff in small agricultural watersheds with different land uses. It is largely based on experimental work and is an empirical method that is widely used today. The notations that will be used to calculate the rainfall excess and then the peak discharge are as follows:

Q = Rainfall excess (runoff)

P = Precipitation

F = Retention

I_a = Initial abstraction (rainfall that is stored in the watershed before runoff begins – includes interception, infiltration, and depression storage)

S = Potential maximum retention

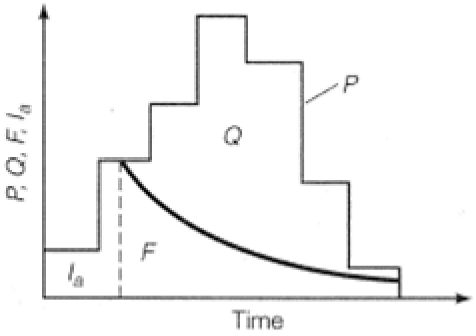


Figure 9: Depicts the Relationship between Notations in the TR-55 Method

The following relationship is the basis for the TR-55 method and includes the notations mentioned above:

$$\frac{F}{S} = \frac{Q}{P - I_a}$$

Equation 5: TR-55 Method Ratios

It is assumed that precipitation (P) is greater than the initial abstraction (I_a). Therefore, the equation for conservation of mass concludes the following equation:

$$F = P - Q - I_a$$

Equation 6: Assuming P > I_a

The equations can be combined, and I_a can be substituted for 0.2S – an experimental equivalence result – to give the following equation:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}\ assuming\ P > 0.2S$$

Equation 7: Runoff Equation for TR-55 Method

The potential maximum retention (S) is related to the weighted runoff curve number (CN) calculated earlier by the equation:

$$S = \frac{1000}{CN} - 10$$

Equation 8: Potential Maximum Retention Equation

Below is the table for the calculations leading to the calculation of the runoff depth (Q) using the above equations:

Table 10: Runoff Depth Calculations

Runoff Depth Calculations		
S=	2.37	in
P=	7.19	in
Q=	**4.96**	**in**

After calculating the runoff depth, the type of rainfall distribution was found to find the unit peak discharge. The figure below shows the NRCS rainfall distributions. It is evident from the figure that our project location is a type II rainfall distribution.

Figure 10: Rainfall Distribution Geographic Boundaries from NRCS

Peak discharge was then estimated using the TR-55 graphical method for type II rainfall distribution (dimensionless unit hydrograph), the unit peak discharge, and the computed time of concentration. The equation to find the peak discharge is as follows:

$$q_p = q_u A Q F_p$$

Equation 9: Peak Discharge Equation

q_p = Unit peak discharge, cubic feet per second per square mile inch

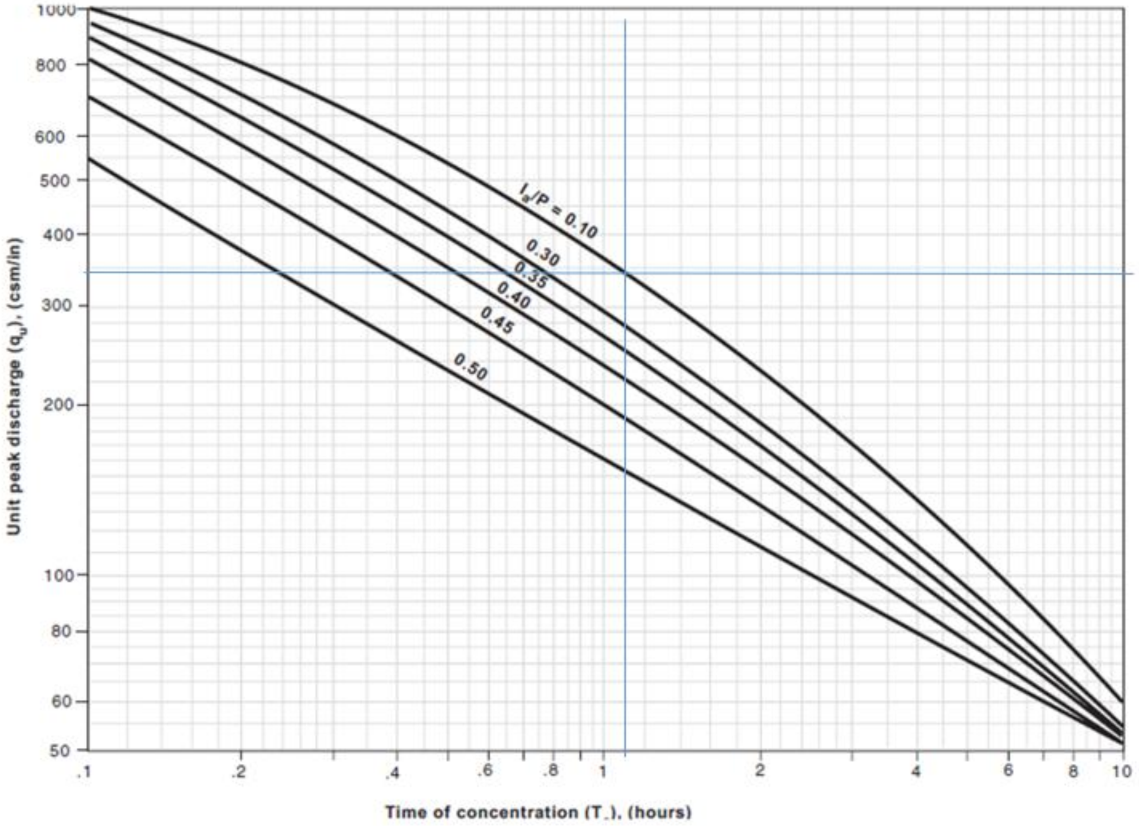
A = watershed area, square miles

Q = runoff depth, in

F_p = pond and swamp adjustment factor (assume 1)

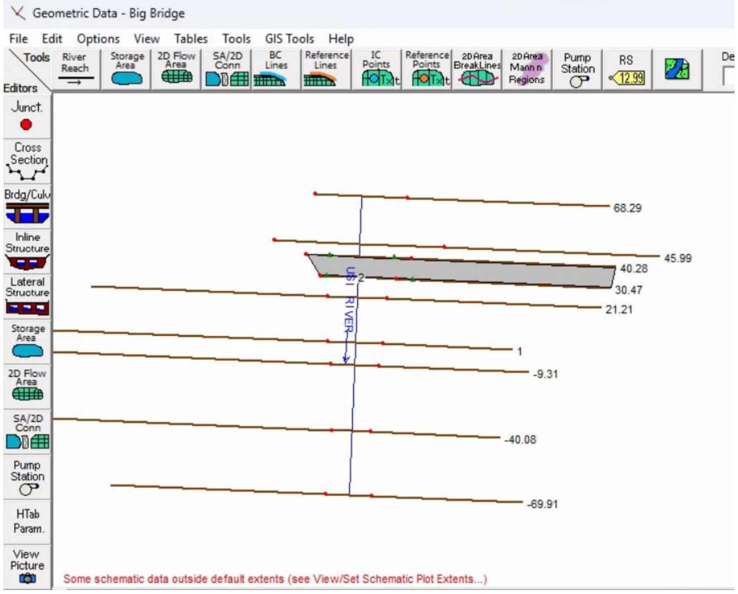
To find the unit peak discharge, the time of concentration and the following figure were used. This figure is also from the NRCS TR-55 manual. The unit peak discharge was found to be approximately 350 cubic feet per second per square mile inch.

Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution



After finding the unit peak discharge, the peak discharge was calculated. The peak discharge was found to be 609.455 cubic feet per second.

The calculated peak flow was applied to the HEC-RAS 6.1.0 model of the site. Survey data were used to generate channel cross-sections, and the bridge geometry (deck, abutments, and roadway profile) was modeled within HEC-RAS. One obstacle that was overcome with the HEC-RAS model was importing the survey data. Multiple attempts to use QGIS and other conversion software proved unsuccessful, so the data was imported into Civil3D, and elevations and distances were recorded by hand for cross sections. Below is an image from the HECRAS software that depicts the geometry and cross-section locations.



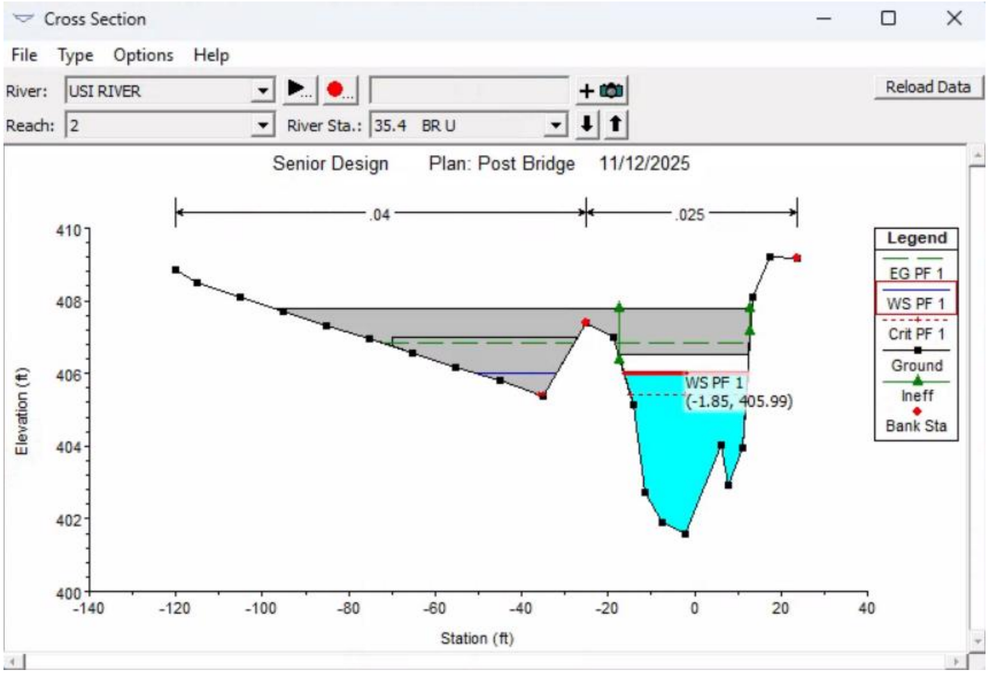
Some schematic data outside default extents (see View/Set Schematic Plot Extents...)

Figure 11: Geometry with Cross Sections

The model simulated steady-state hydraulic conditions for the 100-year event, producing a high water elevation at the bridge crossing. Based on permitting guidelines, the low chord elevation of the bridge was set 2.0 feet above the high water elevation, ensuring adequate freeboard and reducing the risk of overtopping. Freeboard is the difference between the water surface elevation and the low chord elevation.

After the model was run under steady-state assumptions, the high water elevation for a 100-year storm was found to be 405.99 feet. This can be seen in the HECRAS model cross-section view below. Therefore, the minimum low chord elevation of the bridge is 407.99 feet for the required 2 feet of freeboard.

The same process was completed for the smaller bridge in this project. A separate geometry HECRAS model was made using the cross sections from the survey data. The minimum low chord elevation for the smaller bridge is 408.03 feet for the required 2 feet of freeboard.



River: USI RIVER

Reach: 2

River Sta.: 35.4 BR U

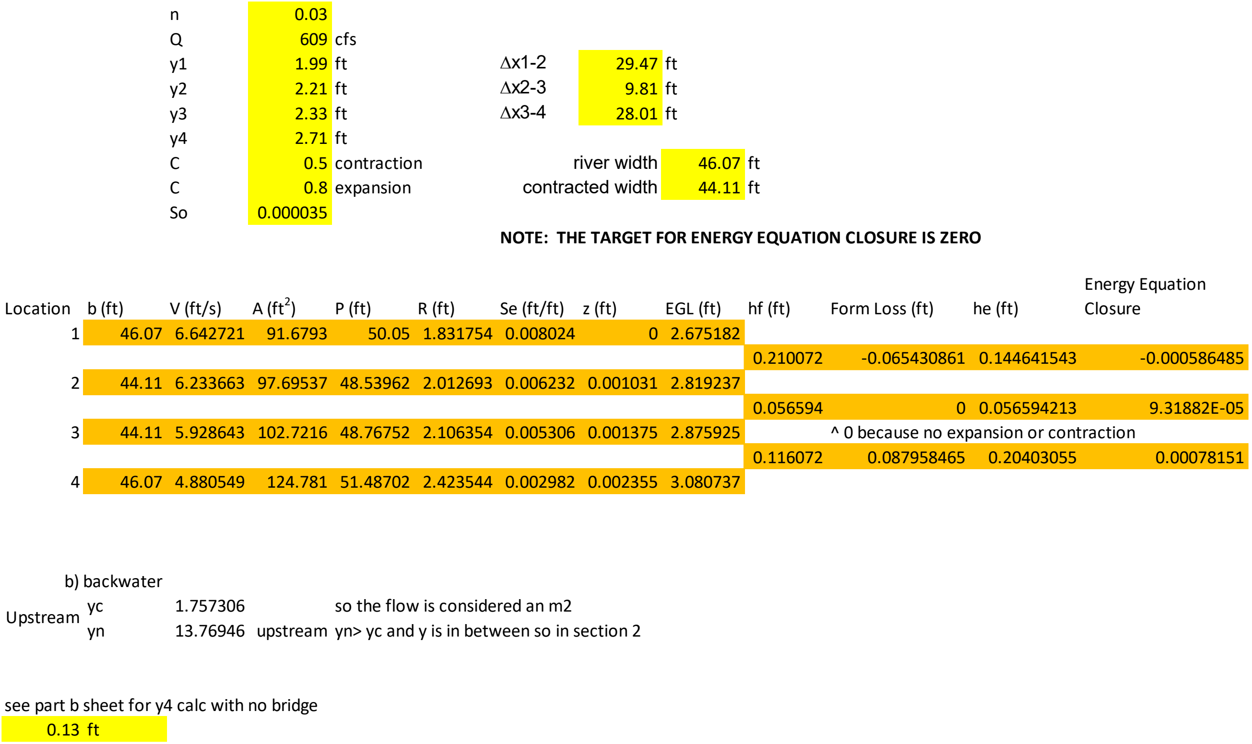
Senior Design Plan: Post Bridge 11/12/2025

Figure 12: Cross-section view from HECRAS depicting the high-water elevation

After finding the high-water elevation and minimum low chord length for the bridge, the design for the bridge could be finalized.

Another aspect that was analyzed during the hydraulic design was backwater. Backwater is the increase in the water level upstream of a bridge due to the bridge structure constricting the water flow. According to the Indiana Department of Transportation Design Manual, Chapter 203 – Hydraulics and Drainage Design – the maximum backwater should not exceed 0.14 feet.

In order to calculate the backwater, material from the Hydraulic Systems class was reviewed. A spreadsheet to calculate the backwater by utilizing the energy equation closure can be seen below. The EXCEL goal seek function was used to force the energy equation closure to zero by changing the depth of the water at each cross-section. This was done using both the preexisting conditions and proposed conditions, and subtracting the elevations to find the backwater. The bridge was found to have a backwater of 0.13 feet, which falls below the 0.14 feet restriction.



n	0.03	
Q	609	cfs
y1	1.99	ft
y2	2.21	ft
y3	2.33	ft
y4	2.71	ft
C	0.5	contraction
C	0.8	expansion
So	0.000035	

Δx1-2	29.47	ft
Δx2-3	9.81	ft
Δx3-4	28.01	ft

river width	46.07	ft
contracted width	44.11	ft

NOTE: THE TARGET FOR ENERGY EQUATION CLOSURE IS ZERO

Location	b (ft)	V (ft/s)	A (ft^2)	P (ft)	R (ft)	Se (ft/ft)	z (ft)	EGL (ft)	hf (ft)	Form Loss (ft)	he (ft)	Energy Equation Closure
1	46.07	6.642721	91.6793	50.05	1.831754	0.008024	0	2.675182				
									0.210072	-0.065430861	0.144641543	-0.000586485
2	44.11	6.233663	97.69537	48.53962	2.012693	0.006232	0.001031	2.819237				
									0.056594	0	0.056594213	9.31882E-05
3	44.11	5.928643	102.7216	48.76752	2.106354	0.005306	0.001375	2.875925		^ 0 because no expansion or contraction		
									0.116072	0.087958465	0.20403055	0.00078151
4	46.07	4.880549	124.781	51.48702	2.423544	0.002982	0.002355	3.080737				

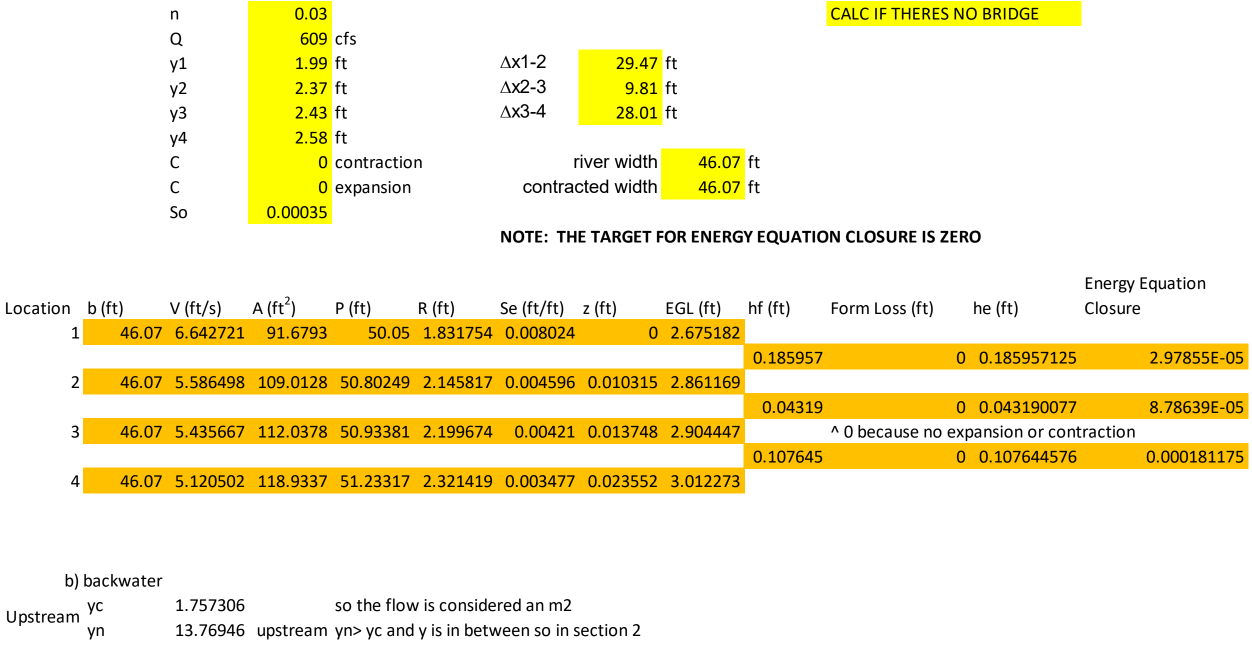
b) backwater

Upstream	yc	1.757306		so the flow is considered an m2
	yn	13.76946	upstream	yn> yc and y is in between so in section 2

see part b sheet for y4 calc with no bridge

0.13 ft

Figure 13: Calculations for Proposed Cross-Section Depths



CALC IF THERES NO BRIDGE

n	0.03	
Q	609	cfs
y1	1.99	ft
y2	2.37	ft
y3	2.43	ft
y4	2.58	ft
C	0	contraction
C	0	expansion
So	0.00035	

Δx1-2	29.47	ft
Δx2-3	9.81	ft
Δx3-4	28.01	ft

river width	46.07	ft
contracted width	46.07	ft

NOTE: THE TARGET FOR ENERGY EQUATION CLOSURE IS ZERO

Location	b (ft)	V (ft/s)	A (ft^2)	P (ft)	R (ft)	Se (ft/ft)	z (ft)	EGL (ft)	hf (ft)	Form Loss (ft)	he (ft)	Energy Equation Closure
1	46.07	6.642721	91.6793	50.05	1.831754	0.008024	0	2.675182				
									0.185957	0	0.185957125	2.97855E-05
2	46.07	5.586498	109.0128	50.80249	2.145817	0.004596	0.010315	2.861169				
									0.04319	0	0.043190077	8.78639E-05
3	46.07	5.435667	112.0378	50.93381	2.199674	0.00421	0.013748	2.904447		^ 0 because no expansion or contraction		
									0.107645	0	0.107644576	0.000181175
4	46.07	5.120502	118.9337	51.23317	2.321419	0.003477	0.023552	3.012273				

b) backwater

Upstream	yc	1.757306		so the flow is considered an m2
	yn	13.76946	upstream	yn> yc and y is in between so in section 2

Figure 14: Calculations for Existing Cross-Section Depths

Due to the high velocities – 5 feet per second to 6 feet per second – erosion control will be needed to ensure the foundation of the bridge does not excessively erode. Class 1A riprap will be used as the erosion control and will be placed as seen in the figure below. It is to be placed a length of 25 feet, as it is a greater distance than the depth multiplied by two.

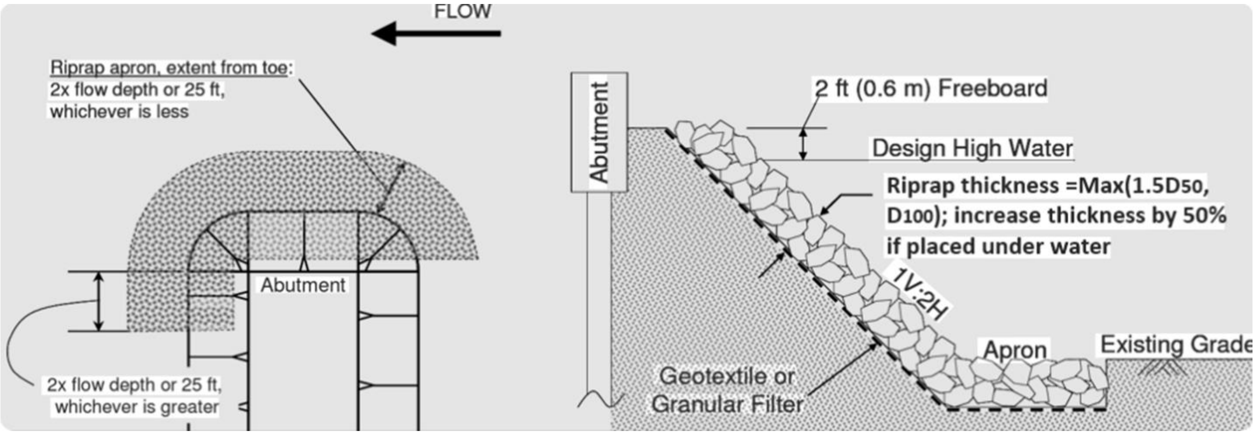


Figure 15: Depicts Rip Rap placement around the bridge abutment.

3.4 BRIDGE STYLE OPTIONS

On May 6th, a bridge design selection meeting was held with University of Southern Indiana (USI) faculty and the student design team to determine the most suitable bridge style for the proposed trail connection project. Faculty members in attendance included Dr. Paul Kuban, Dr. Kerry Hall, Bryan Morrison, James Wolfe, Dr. Allison Grabert, and Dr. Bill Elliott.

During the meeting, the design team presented five preliminary bridge concepts that explored a range of materials, aesthetics, and construction methods. The first concept featured a traditional timber bridge constructed with glulam beams and a wood deck. This option was valued for its simplicity, natural appearance, and alignment with the wooded setting of the trail site. The second concept modified the basic glulam design by incorporating a 2 ft by 8 ft midspan overhang to provide additional viewing space for pedestrians and enhance the overall visual appeal of the structure.

A third concept explored the use of concrete with rolled steel beams supporting a reinforced concrete deck. This design offered greater long-term durability and reduced maintenance needs but was determined to be more costly and visually less compatible with the natural environment of the site. The remaining two concepts considered prefabricated bridge systems, which could be manufactured off-site and installed as modular units or as sections that could be constructed at the site. These options provided advantages in construction speed and quality control but presented challenges related to cost, transportation logistics, and aesthetic integration with the surrounding landscape.

A preliminary cost estimate for each of these options is provided in Section 5.1 20% Development Estimate.

During the discussion, Dr. Kuban noted that free telephone poles were available for use as primary support members, providing a cost-effective and sustainable alternative to purchasing new glulam beams. Mr. Morrison clarified that the bridge would require a minimum clear width of seven feet to accommodate maintenance equipment such as the Kubota utility vehicle. It was also recommended that bollards and signage be installed at both approaches to restrict access for full-size vehicles while maintaining safe passage for pedestrians and maintenance crews.

Environmental considerations were an important component of the decision-making process. The team agreed to minimize tree removal during construction and to replace any trees that are removed with native or equivalent species. These replacement trees will be planted during the grand opening of the pavilion to support the university's sustainability goals and reinforce its commitment to environmental stewardship.

Two site locations were debated during the meeting, as shown in Figure 16: Site Locations. Site 1 is the original location during the first site visit. The span is 32 ft. The transition from the east to the bridge is smooth however, the west side has concerns for slope stability of the bluff. Site 2's span is 22 ft. This site is away from the bluff, however, does not have as smooth of transition on the east side. The west side would have a smooth transition and be away from the bluff.

Figure 16: Site Locations

Following a detailed evaluation of cost, constructability, aesthetics, and environmental impact, the design team and USI faculty reached a consensus to proceed with the simple timber bridge design utilizing the available repurposed telephone poles as the primary structural elements. This design was selected for its cost efficiency, straightforward construction process, and compatibility with the natural landscape of the USI trail system. The use of recycled materials also supports the university's sustainability goals and reduces overall project expenses. To maintain consistency across the project, the second, smaller bridge near the trail entrance will employ the same structural configuration and material selection, with adjustments made only to the span length to accommodate site-specific channel conditions. Together, these two bridges will enhance pedestrian connectivity and accessibility within the USI campus trail network while preserving the area's ecological and aesthetic integrity.

3.5 BRIDGE DESIGNS

The bridge design process was divided into distinct structural components that were analyzed both individually and as an integrated system to ensure overall stability and performance. The timber bridge design followed the National Design Specification (NDS) for Wood Construction (2015) criteria to verify material capacities and connection requirements. A top-down approach was employed, beginning with the design of the railing system, followed by the deck planks, primary glulam beams, and supporting foundation elements. Each component was evaluated for strength, serviceability, and constructability to meet applicable design standards.

Two bridge configurations were developed using the same design methodology, differing primarily in span length. The larger bridge has a total span of 39 feet, while the shorter bridge measures 10 feet. Structural analyses for both configurations confirmed that the shorter span exhibited reduced internal stresses and deflections, validating the scalability of the design approach.

3.5.1 RISA Bridge Loads

A single, integrated RISA-3D model was developed to represent both the deck and beam systems together. This approach allowed the loads to be applied to the deck. The railing is modeled as point loads of 100 lb on the decking ends, as shown in Figure 17 Railing Load: 39ft Span and Figure 18 Railing Load: 10ft Span. The 90 psf pedestrian live load as shown in Figure 19 Pedestrian Load: 39ft Span and Figure 20 Pedestrian Load: 10ft Span. A snow load of 23 lb/ft is applied to along the beams as shown in Figure 21 Snow Load: 39ft Span and Figure 22: Snow Load: 10ft Span. USI maintenance requires the bridge to be able to support a Kubota to cross the bridges. The 2,402 lb moving live load from the Kubota as shown in Figure 23: Kubota Load Case 1: 39ft Span and Figure 24: Kubota Load Case 2: 10ft Span. This modeling method provided a realistic simulation of load paths and structural interaction between the deck and beams, resulting in a comprehensive assessment of the bridge’s overall behavior under design loading conditions.

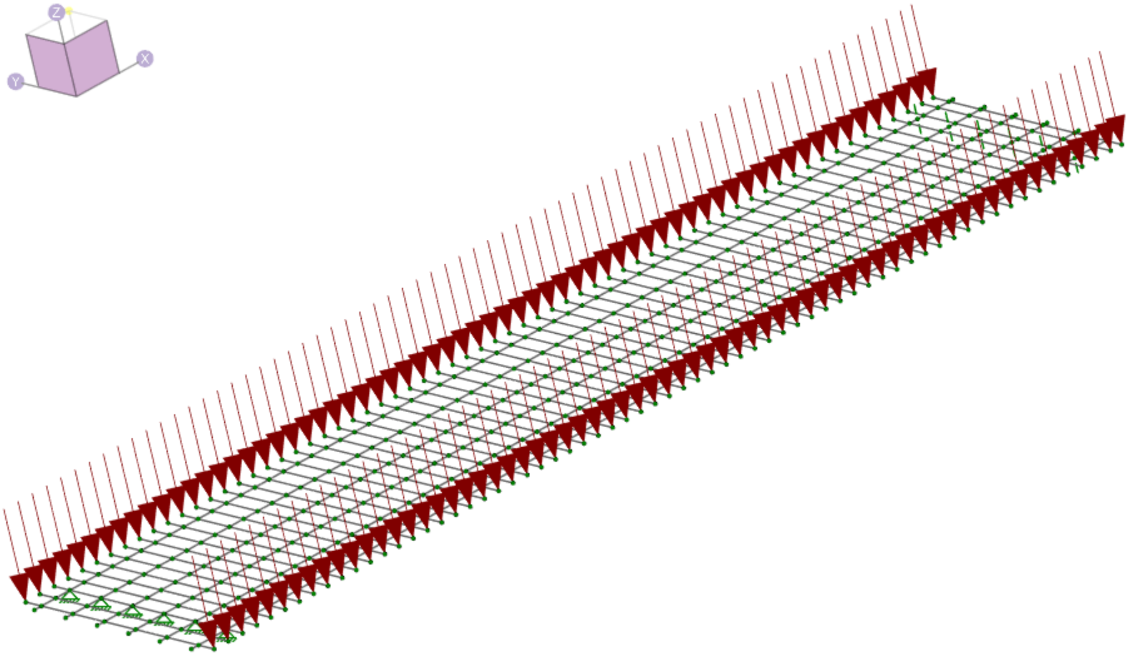


Figure 17 Railing Load: 39ft Span

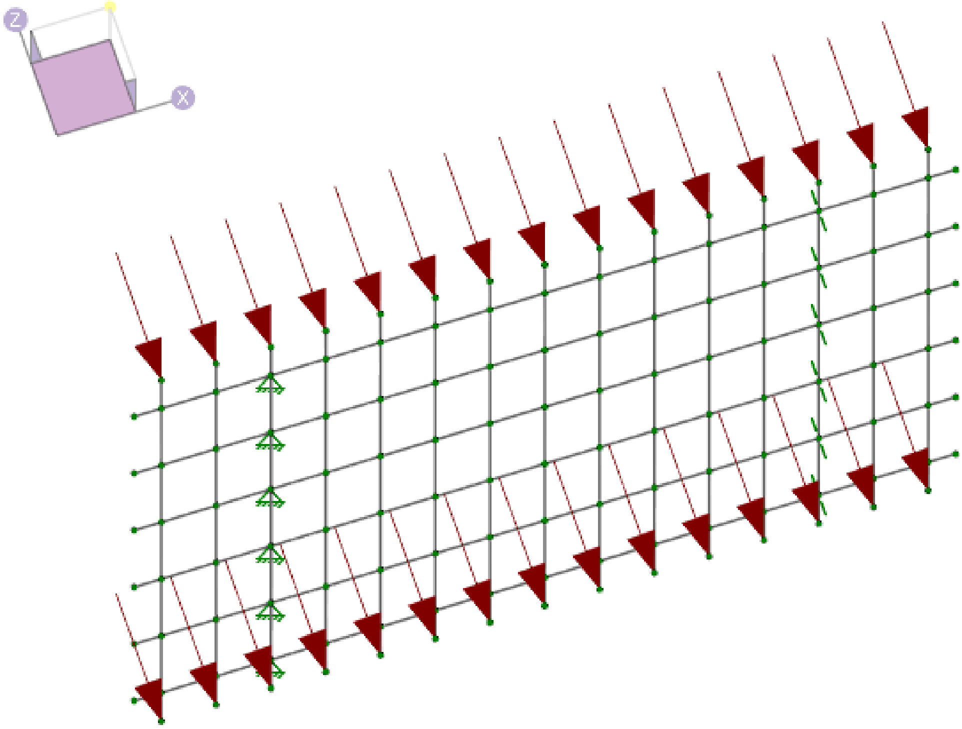


Figure 18 Railing Load: 10ft Span

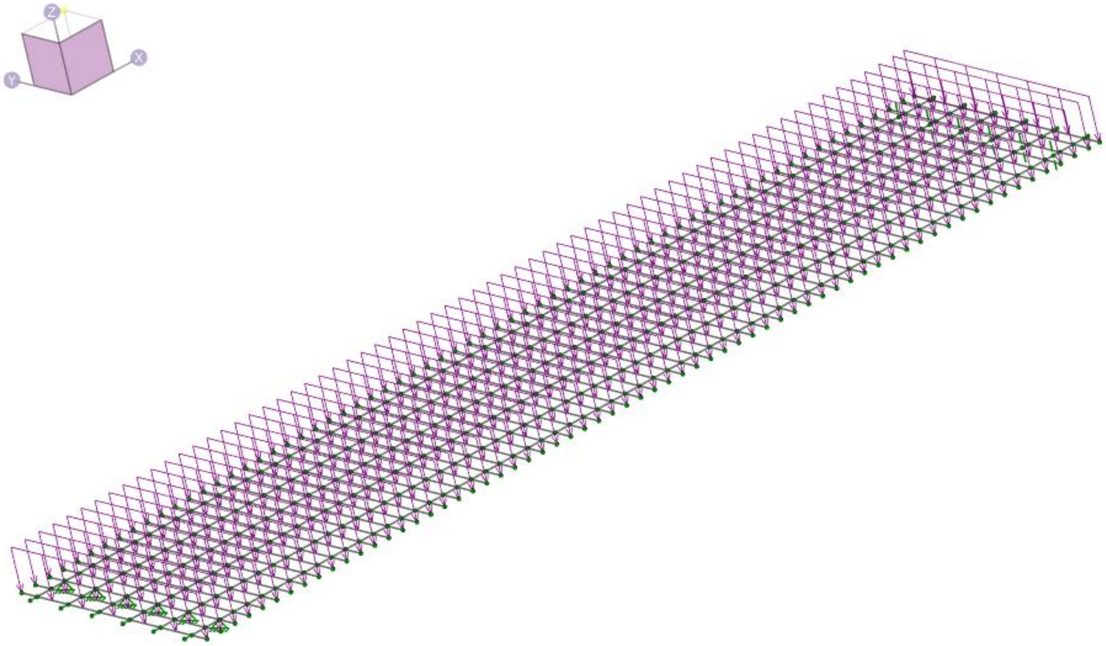


Figure 19 Pedestrian Load: 39ft Span

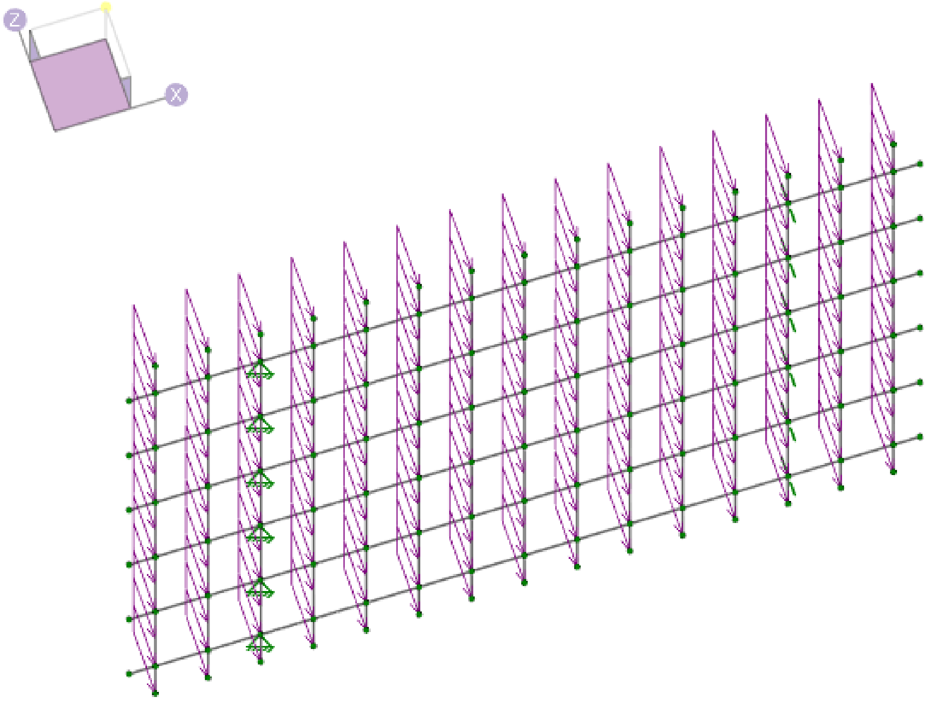


Figure 20 Pedestrian Load: 10ft Span

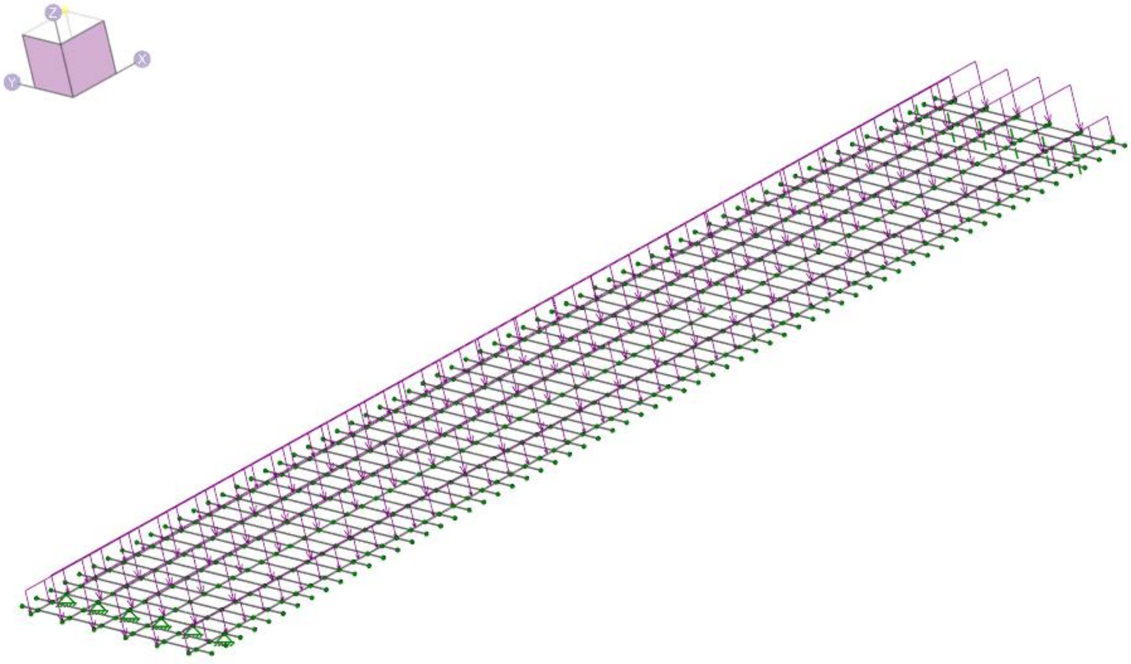


Figure 21 Snow Load: 39ft Span

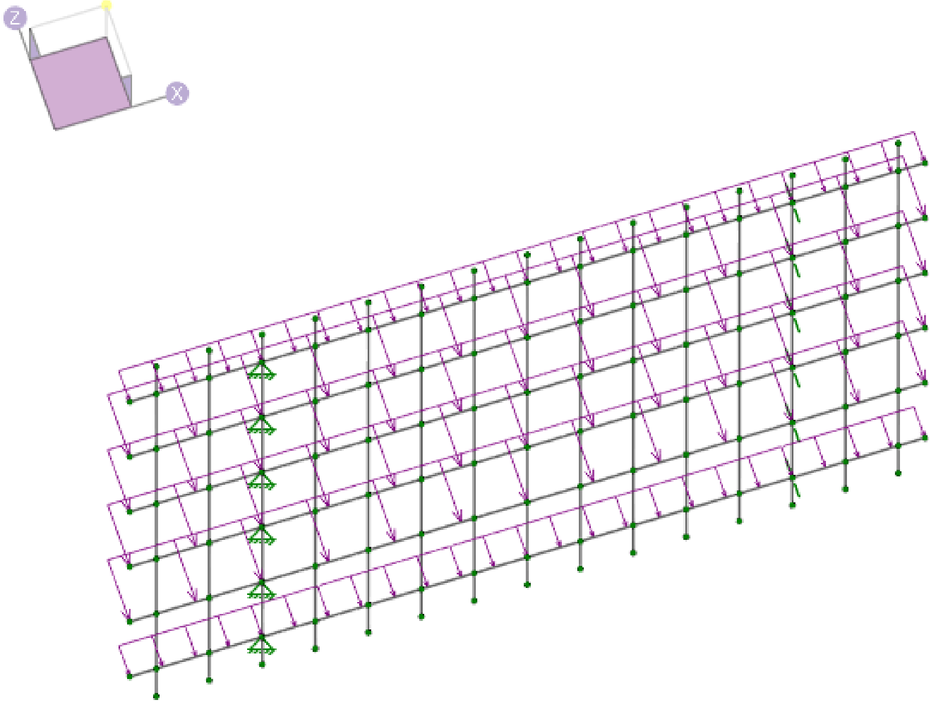


Figure 22: Snow Load: 10ft Span

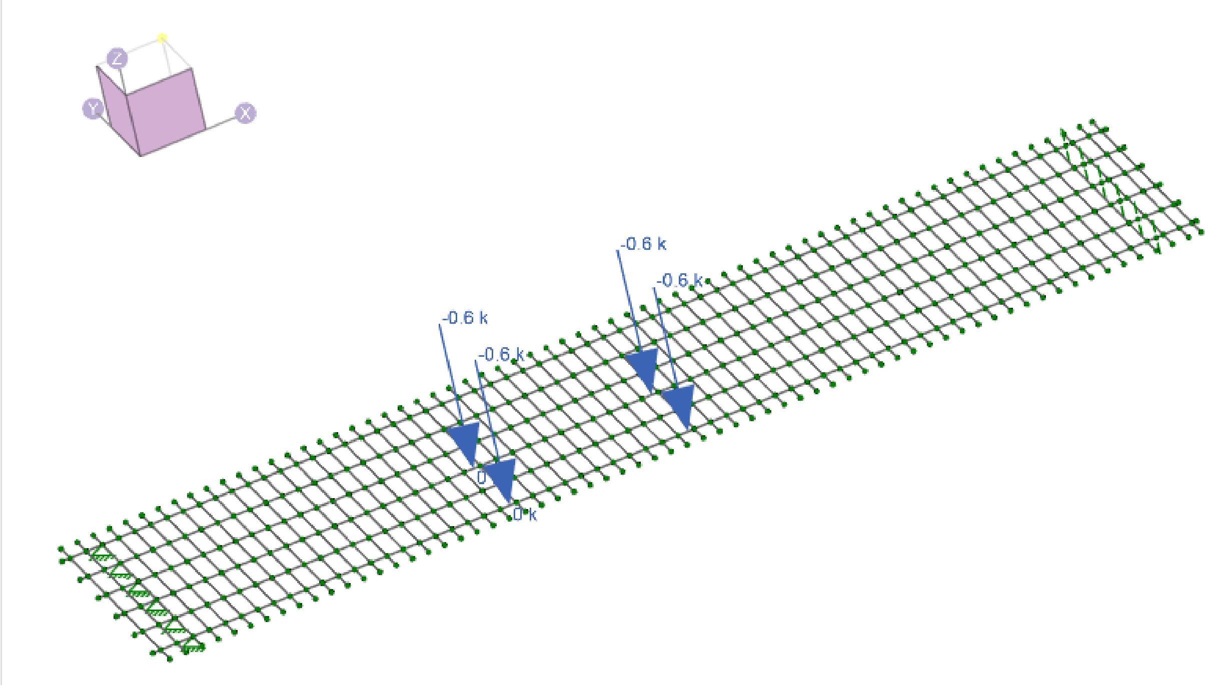


Figure 23: Kubota Load Case 1: 39ft Span

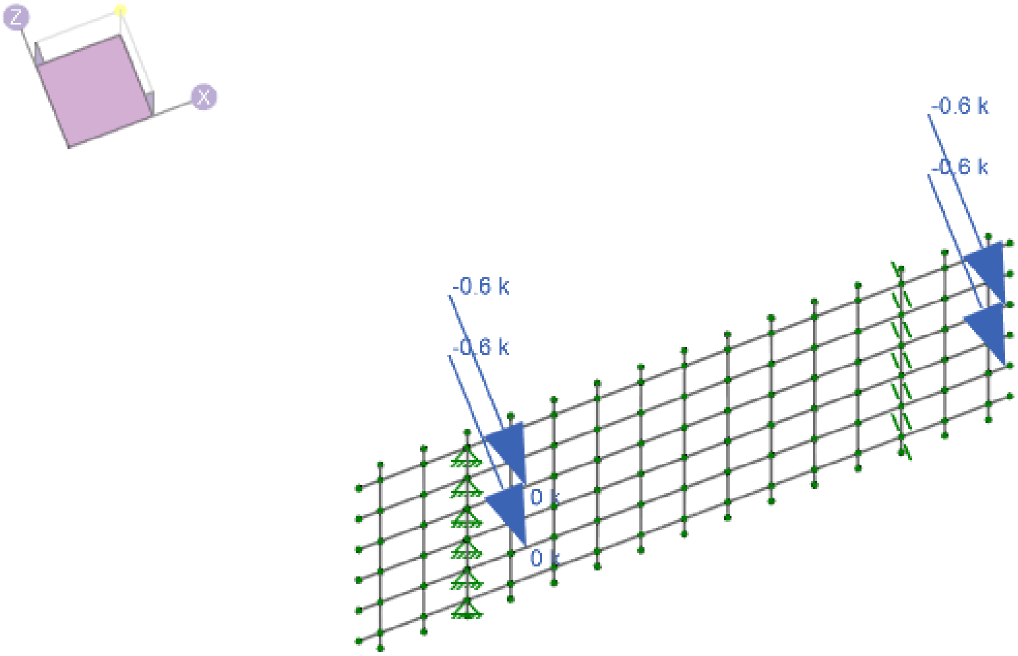
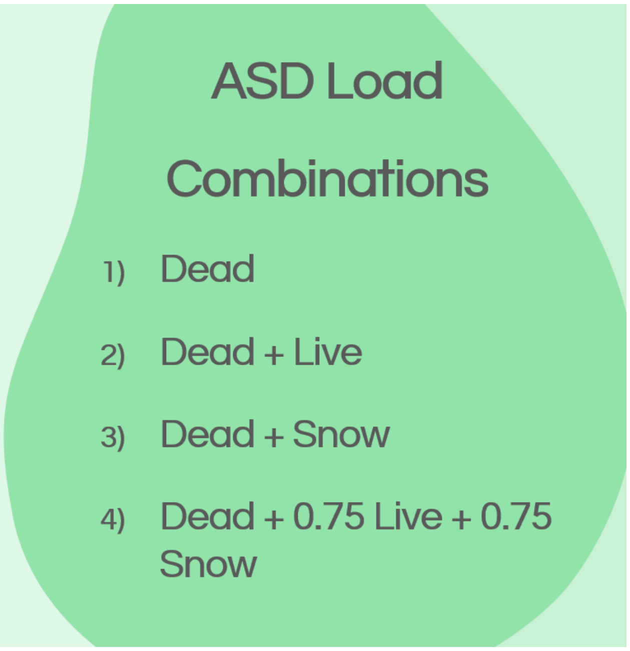


Figure 24: Kubota Load Case 2: 10ft Span

RISA 3D uses load combinations that are set as shown in Figure 25: ASD Load Combinations. The load combinations on RISA 3D allow the user to find the worst case simply. For the bridge design, the controlling case is dead plus pedestrian live load.



ASD Load Combinations

1) Dead
2) Dead + Live
3) Dead + Snow
4) Dead + 0.75 Live + 0.75 Snow

Figure 25: ASD Load Combinations

3.5.2 Railing

The design process for the bridge railing began by contacting local fabrication companies to evaluate prefabricated railing systems that could be adapted to meet the project's specific requirements. Metal Fabricators Incorporated was identified as a primary contact based on recommendations provided by one of our advisors. Through discussions with one of their engineers, we received guidance on key design considerations for handrail systems, including the requirement to withstand a 250-lb lateral load. This load represents the expected force generated by a person leaning against the railing and was considered essential given the anticipated pedestrian use of the bridge for gathering, photography, and general viewing.

Following this initial consultation, the project team met with the bridge owners to determine any aesthetic preferences, performance expectations, or specific design requirements they wished to see incorporated into the railing. No formal guidance was provided other than a request to maximize the use of recycled materials. To ensure compliance with campus safety standards, we also met with the University of Southern Indiana's Safety Administrator. The purpose of this meeting was to confirm that the university did not require lateral load capacities exceeding industry standards before finalizing the structural design.

With design criteria established, preliminary modeling was completed using RISA-3D. The initial concept prioritized the reuse of recycled telephone poles obtained from CenterPoint Energy. This first layout consisted of six vertical columns fabricated from the recycled poles to support the railing system. However, structural analysis indicated that the resulting railing assembly was excessively heavy and would require significant increases to the bridge superstructure to adequately support the load. Because maintaining an economical and constructible design was a primary project goal, the decision was made to replace the majority of the railing posts with lighter, more economical steel members.

In the revised design, steel posts were incorporated to substantially reduce overall weight while improving constructability. The end posts remained as recycled wood sections embedded in concrete to provide fixed support conditions and ensure overall system stability. The steel posts were designed with welded base plates to develop adequate fixity and minimize deflection under horizontal loading. The horizontal rail members consist of 2×3-inch rectangular steel tubing, while the intermediate balusters are designed using ½-inch steel tubing.

The final railing system will consist of five prefabricated sections for each side to facilitate transport, installation efficiency, and site constructability. The University of Southern Indiana emphasized durability and low maintenance as final performance requirements. In response, cost estimates are currently being obtained for powder coating and painting options, which will be submitted to the bridge owner for selection of the final finish.

In conclusion, the proposed handrail system is designed to provide long-term structural performance, user safety, and durability while balancing cost efficiency and the use of recycled materials. The completed railing is expected to perform effectively for several decades with minimal maintenance.

Figure 26: RISA 3D depicting of railing

There will be additional railing constructed for the small span bridge. However, it will only comprise of a single span railing of 10’ made to match the large span railing above. The smaller bridges handrails are detailed along with the large bridges railing. See CAD file for detail drawings.

3.5.3 Deck

The bridge deck design process began with preliminary hand calculations to establish a baseline understanding of structural behavior and load distribution. These manual calculations provided conservative estimates for bending, shear, and deflection under applied loads. Following this, a RISA-3D model was developed to verify and refine the hand-calculated results, ensuring that the deck design met all relevant strength and serviceability criteria. This two-step approach, combining analytical methods with computer-based validation, ensured accuracy, efficiency, and compliance with design standards.

Hand calculations

The bridge deck is designed using 2×8 Spruce-Pine-Fir (SPF) No. 2 or better lumber to provide a durable and structurally efficient walking surface. The design accounts for a pedestrian live load (LL) of 90 pounds per square foot (psf), consistent with AASHTO LRFD pedestrian bridge design criteria, as well as a moving live load of 2,402 pounds to represent an all-terrain vehicle (ATV) crossing for maintenance access. Due to the relatively low additional load contribution from the railing system, the railing load was excluded from the deck hand calculations. For simplicity in the manual analysis, the moving live load was modeled as an equivalent distributed load applied uniformly across the deck surface. The dead load of the deck planks was determined based on an assumed constant material density of 40 pounds per cubic foot (pcf). These load assumptions and simplifications provided a conservative basis for the structural evaluation and were later verified through detailed modeling in RISA-3D.

For the larger span bridge, the total load is the total dead load plus the total live load, using ASD. The total load used in the following calculations for the planks is 101.84 psf. The load per plank is 12.73 plf. The maximum moment per plank was 5.16 lb-ft using Equation 10: Moment Equation. The section modulus was 13.14 in^3 using Equation 11: Section Modulus Equation.

For the small span bridge, the total load is the total dead load plus the total live load, using ASD . The total load used in the following calculations for the planks is 101.84 psf. The load per plank is 15.21 plf. The maximum moment per plank was 6.16 lb-ft using Equation 10 Moment Equation. The section modulus was 13.14 in^3 using Equation 11 Section Modulus Equation.

$$M = \frac{wL^2}{8}$$

Equation 10: Moment Equation

$$s = \frac{b\,d^2}{6}$$

Equation 11: Section Modulus Equation

For the large bridge, The first check for the planks is for bending using Equation 12: Actual Bending to find actual bending stress, f'$_b$. For the larger span bridge, the capacity according to NDS is 875 psi for SPF #2. The actual bending stress was calculated to be 4.71 psi. Since the capacity of 875 psi is much greater than the actual stress of 4.71 psi, the planks pass for bending stress.

For the small bridge, The first check for the planks is for bending using Equation 12: Actual Bending Stress to find actual bending stress, f'b. For the larger span bridge, the capacity according to NDS is 875 psi for SPF #2. The actual bending stress was calculated to be 5.63 psi. Since the capacity of 875 psi is much greater than the actual stress of 5.63 psi, the planks pass for bending stress.

$$M_{allow} = f'_b S$$

Equation 12: Actual Bending Stress

For the large bridge, the next check is to check the shear stress on the plank using Equation 13: Actual Shear Stress. For the larger span bridge the capacity according to NDS is 135 psi for SPF #2. The actual shear stress was calculated to be 1.05 psi. Since the capacity of 135 psi is much greater than the actual stress of 1.05 psi, the planks pass for shear stress.

For the small bridge, the next check is to check the shear stress on the plank using Equation 13: Actual Shear Stress. For the larger span bridge the capacity according to NDS is 135 psi for SPF #2. The actual shear stress was calculated to be 1.26 psi. Since the capacity of 135 psi is much greater than the actual stress of 1.26 psi, the planks pass for shear stress.

$$f'_v = \frac{V}{A}$$

Equation 13: Actual Shear Stress

For the large bridge, the last check for the decking is the deflection using Equation 14: Actual Deflection and Equation 15: Allowable Deflection. For the larger span bridge, the actual deflection was found to be 0.0000526 in and an allowable deflection of 0.06 in. Since the allowable deflection, 0.06 in, is greater than the actual deflection of 0.00000526 in, the planks pass for deflection.

For the small bridge, the last check for the decking is the deflection using Equation 14: Actual Deflection and Equation 15: Allowable Deflection. For the larger span bridge, the actual deflection was found to be 0.0000629 in and an allowable deflection of 0.06 in. Since the allowable deflection, 0.06 in, is greater than the actual deflection of 0.00000629 in, the planks pass for deflection.

$$\Delta = \frac{5wL^4}{384EI}$$

Equation 14: Actual Deflection

$$\Delta = \frac{L}{360}$$

Equation 15: Allowable Deflection

The hand calculations for he decking pass the checks for bending stress, shear stress, and deflection. Since all three checks had a significant difference between the capacity and actual, a lower quality wood could be considered. Also, due to the larger difference, additional load factors were not applied to the checks as they would also pass.

RISA 3D Model

The bridge deck was modeled in RISA-3D to evaluate its structural performance and verify the results obtained from hand calculations. The model incorporated Southern Pine No. 1 material properties consistent with those used in the manual analysis, including a modulus of elasticity of 1,500,000 psi, an allowable bending stress of 1,350 psi, and an allowable shear stress of 165 psi. Load combinations followed the Allowable Stress Design (ASD) methodology to maintain consistency between analytical methods. The loads used in the model can be found in Section 3.5.2 of this report.

To further validate the design, the decking system was also modeled individually in RISA-3D to assess performance under the worst-case loading scenario. In this analysis, the loads were applied according to the most critical influence line positions, ensuring that maximum bending and shear effects were captured within the planks. The results confirmed that the deck members remained within the allowable limits for stress and deflection, even under the most unfavorable load placement. This verification demonstrated that the deck design provides adequate strength and stiffness to safely transfer loads to the supporting beams without overstressing individual members.

Overall, the RISA-3D analyses provided valuable confirmation of the hand calculations and validated the assumptions used in both the beam and deck analyses. The strong agreement between manual and modeled results supports confidence in the bridge’s structural integrity, serviceability, and constructability.

3.5.4 Beams

The beams are telephone poles from Center Point. The telephone poles have tapers and inconsistent diameters so a conservative diameter of 14 in was used as an average for both hand calculations and RISA 3D model.

Hand calculations

The beams were evaluated for bending stress, shear stress, and deflection to ensure they met the required performance and safety standards. The applied loads were determined using Allowable Stress Design (ASD) load combinations and converted into a uniformly distributed load acting along each beam. This load served as the basis for calculating the actual stresses within the members. To achieve an efficient design, adjustment factors were applied in accordance with the National Design Specification (NDS) for Wood Construction.

The timber beams were visually graded as Southern Pine No. 1, which possesses a modulus of elasticity of 1,500,000 psi, an allowable bending stress of 1,350 psi, and an allowable shear stress of 165 psi. Due to the relatively short span length and narrow beam spacing, the inclusion of diaphragms was determined to be unnecessary.

The first check focused on bending capacity. The allowable bending stress was determined using Equation 12: Actual Bending Stress, as outlined in Chapter 6 of the NDS (2015). Adjustment factors were applied as follows: a load duration factor (C_d) of 1.25 for temporary loading, a temperature factor (C_t) of 1.0 to account for outdoor exposure, a condition treatment factor (C_{ct}) of 1.0 for air-dried wood, a size factor (C_f) of 1.0 since the beam diameter was not significant, and a load sharing factor (C_{ls}) of 1.0, conservatively assumed.

For the large bridge, using Equation 16: Bearing Stress Capacity, the resulting capacity, for the larger span, was calculated as 1,687 psi, while the actual bending was 1,569 psi. Since the bending capacity significantly exceeds the actual bending stress, the beams satisfy the bending requirement with an acceptable margin of safety.

For the small bridge, using Equation 16: Bearing Stress Capacity, the resulting capacity, for the smaller span, was calculated as 1,687 psi, while the actual bending was 103 psi. Since the bending capacity significantly exceeds the actual bending stress, the beams satisfy the bending requirement with an acceptable margin of safety.

$$F'_b = F_b C_D C_t C_{ct} C_F C_{ls}$$

Equation 16: Bearing Stress Capacity

For the large bridge, the next check involved checking the shear stress within the timber beams. The same load combinations and adjustment factors applied in the bending analysis were used for consistency. The shear capacity for the larger span bridge was determined using Equation 17: Shear Stress Capacity, resulting in a value of 206.25 psi. The actual shear stress was calculated using Equation 13: Actual Shear Stress, resulting in a value of 35.2 psi. Since the calculated shear capacity significantly exceeds the actual applied shear stress, the beams safely meet the shear design requirements as specified by the NDS (2015). This confirms that shear is not a controlling factor in the design of the structural members.

For the small bridge, the next check involved checking the shear stress within the timber beams. The same load combinations and adjustment factors applied in the bending analysis were used for consistency. The shear capacity for the smaller span bridge was determined using Equation 17: Shear Stress Capacity, resulting in a value of 206.25 psi. The actual shear stress was calculated using Equation 13: Actual Shear Stress resulting in a value of 9.03 psi. Since the calculated shear capacity significantly exceeds the actual applied shear stress, the beams safely meet the shear design requirements as specified by the NDS (2015). This confirms that shear is not a controlling factor in the design of the structural members.

$$F'_v = F_v C_D C_t C_{ct}$$

Equation 17: Shear Stress Capacity

The final check for the timber beams involved evaluating deflection under service loads. Using Equation 15: Allowable Deflection, the maximum permissible deflection for the larger span bridge was calculated to be 0.60 inches. The actual deflection for both small and larger bridge was determined using Equation 14: Actual Deflection, was found to be 0.11 inches. Since the actual deflection is well below the allowable limit, the beams satisfy the deflection criteria outlined in the NDS (2015). This confirms that the members provide adequate stiffness to ensure structural performance and user comfort without excessive deformation.

The hand calculations performed for the timber beams demonstrate that the design satisfies all strength and serviceability requirements in accordance with the NDS (2015) provisions. The beams were verified for bending, shear, and deflection, each meeting or exceeding the necessary design criteria. The small bridge is safer than the larger bridge because the same design was applied to both. The only difference is the span of the bridges. The results indicate that the Southern Pine No. 1 timbers provide sufficient capacity to safely support the applied pedestrian and vehicular loads while maintaining acceptable limits for stress and deformation. These calculations confirm the adequacy of the proposed design and serve as the foundation for further validation using the RISA-3D structural model.

RISA 3D Model

The model incorporated Southern Pine No. 1 material properties consistent with those used in the manual analysis, including a modulus of elasticity of 1,500,000 psi, an allowable bending stress of 1,350 psi, and an allowable shear stress of 165 psi. Load combinations followed the Allowable Stress Design (ASD) methodology to maintain consistency between analytical methods.

A single, integrated RISA-3D model was developed to represent both the deck and beam systems together. This approach allowed the loads applied to the deck comprising the 90 psf pedestrian live load, the 2,402 lb moving live load from the ATV, and the additional 0.1 kip point load from the railing. This load is to be automatically transferred through the deck elements and into the supporting beams. This created a more realistic simulation of load paths and interactions between structural components, resulting in a comprehensive analysis of the bridge's behavior under service conditions.

RISA-3D was then used to evaluate the bending moment, shear force, and deflection responses of the beams and deck under these combined design loading conditions. The results were compared to the hand calculations to validate the assumptions and simplifications made during the manual analysis. The maximum bending stress, shear stress, and deflection values obtained from the model closely aligned with the calculated results, confirming that the design was both conservative and structurally sound.

In addition, the RISA-3D model provided a detailed visualization of load distribution and interaction between the deck and beams, confirming uniform behavior and identifying any localized stress concentrations. This verification process validated that the integrated bridge design satisfies all performance requirements, ensuring the structure's safety, serviceability, and long-term efficiency.

The corresponding RISA-3D output diagrams are shown in Figure 27: Board Envelope Shear and Moment Diagram and Figure 28: Beam Envelope Shear and Moment Diagram. The decking plots show localized variations in shear approximately ±0.06 kips and low bending moments with peak values near 0.012 k-ft. The beam illustrates significantly larger internal forces. The beam shear diagram shows a maximum of approximately 3.46 kips near the support, decreasing toward midspan, while the moment diagram displays a smooth parabolic curve with a maximum moment of approximately 29.3 k-ft at midspan. Both sets of diagrams align closely with the patterns predicted in the hand calculations, confirming that the modeled internal forces behave as expected for the structural system.

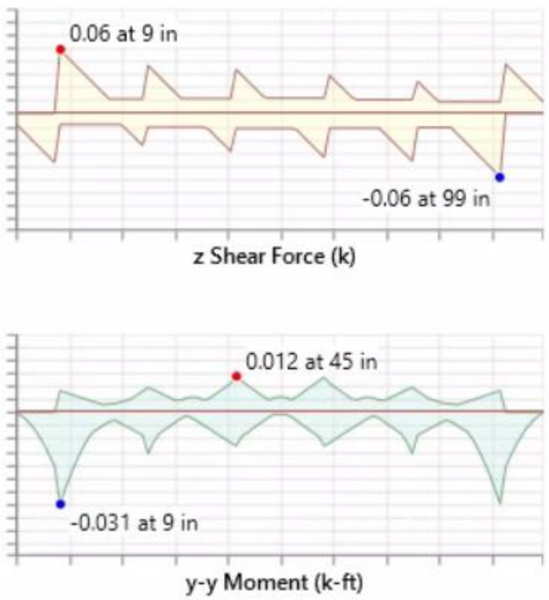


Figure 27: Board Envelope Shear and Moment Diagram

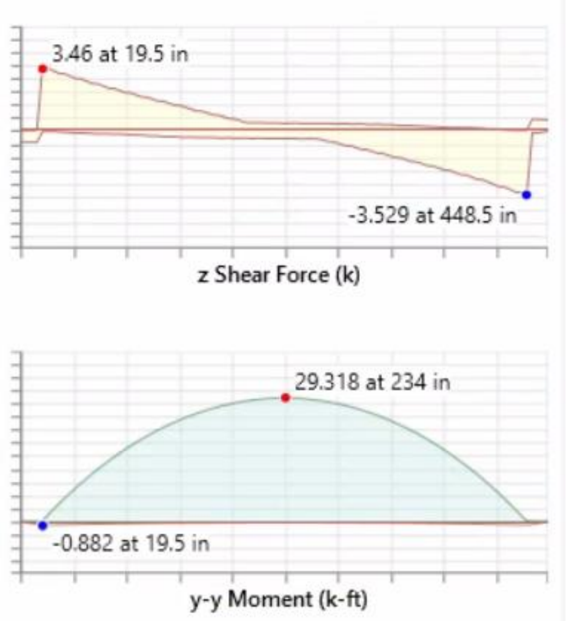


Figure 28: Beam Envelope Shear and Moment Diagram

3.5.5 Foundation

The foundation system for the bridge was developed to provide long-term stability, efficient load transfer, and compatibility with the varied subsurface conditions along the project corridor. The system is designed to maintain consistent structural performance while allowing for practical constructability in the field.

The bridge beams bear on sill plate placed directly on the geocell pad, as shown in Figure 29: Foundation Cross Section. These pads distribute loads evenly, accommodate minor rotations, and prevent damage. The out-to-out spacing of stringers is maintained according to the superstructure design requirements, ensuring structural uniformity and efficient load transfer.

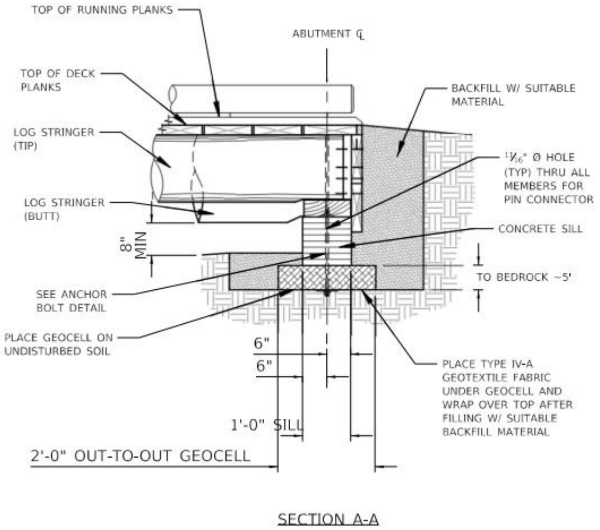


Figure 29: Foundation Cross Section

To achieve a level crossing across both abutments, the top of the foundation is set at an elevation of 407.99 feet.

The geocell panels are placed on undisturbed native soil with Type IV-A geotextile fabric installed beneath and wrapped over the top after filling. This configuration prevents soil migration, increases confinement, and maintains long-term structural integrity Figure 29: Foundation Cross Section. The geocell foundation footprint extends 6 inches beyond the sill on all sides, ensuring adequate load distribution and edge stability.

A cast-in-place sill is placed directly over the geocell mattress following compaction and shaping of the granular infill Figure 30: Foundation. Anchor bolts embedded into the sill secure the superstructure connection in the same manner used for the bedrock-supported abutments, ensuring consistent performance across both foundation types.

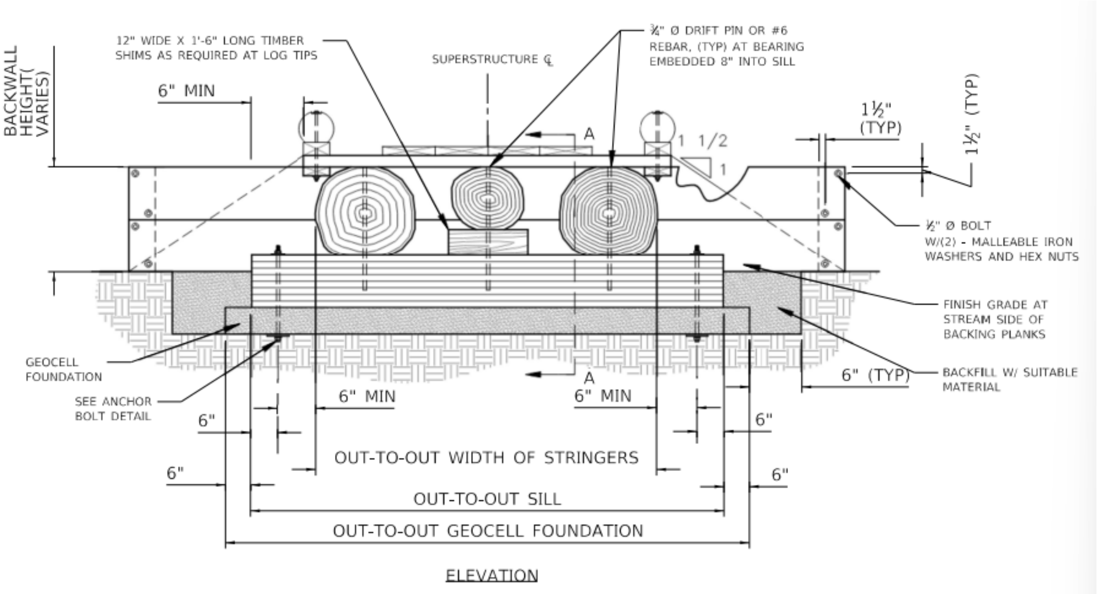


Figure 30: Foundation

Riprap armoring is installed around the abutment to protect the foundations from scour under high-flow conditions, as shown in Figure 31: Riprap Design. The design follows standard hydraulic countermeasure guidelines, with the riprap apron extending a distance equal to twice the flow depth or 25 feet, whichever is less, and wrapping around the abutment to shield both the upstream and downstream faces. The riprap blanket is placed on geotextile or granular filter material to prevent undermining and loss of support. The section uses a 1V:2H slope, with riprap thickness determined as Max(1.5D_{50}, D_{100}) and increased by 50% when placed underwater, ensuring stability under the design high water condition and providing 2 feet of freeboard above the predicted hydraulic grade line.

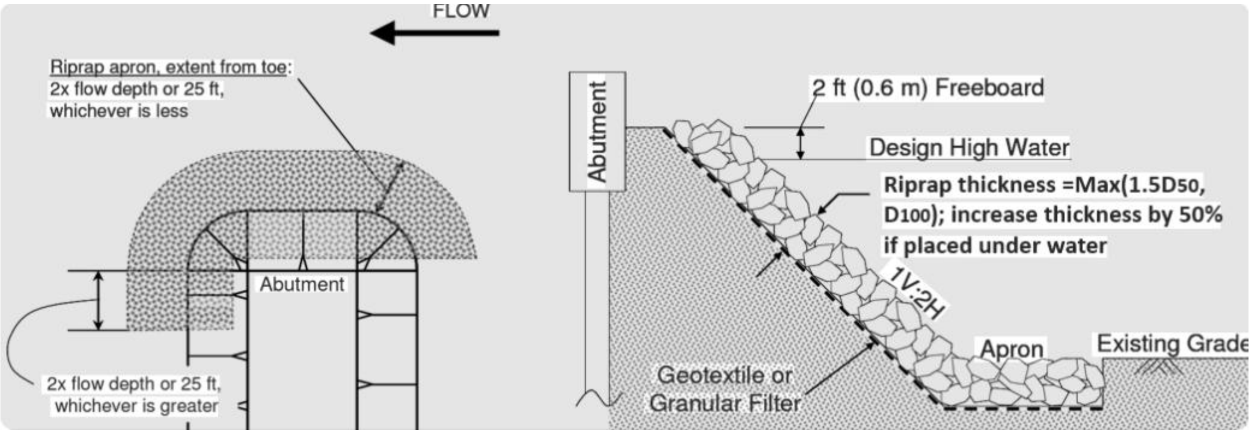


Figure 31: Riprap Design

The foundations were determined by field conditions, constructability, and the desire to minimize excavation depth and environmental disturbance. Together, these systems provide a reliable, durable, and adaptable foundation solution well-suited to the natural terrain and hydrologic conditions of the USI trail corridor.

4 DESIGN CONSIDERATIONS

4.1 SUSTAINABLE DESIGN

When designing a trail and bridge over a small stream, sustainability plays a key role in ensuring the structure has minimal environmental impact while remaining safe, durable, and cost-effective over time. A sustainable design approach considers how construction and materials affect the surrounding ecosystem, including water quality, vegetation, and wildlife habitats. Ideally, the trail and bridge should preserve natural water flow, minimize soil erosion, and use environmentally friendly materials. Locally sourced materials, durable construction, and low-maintenance designs are all part of reducing the project's long-term footprint. The bridge material could be wood, steel, or concrete, and can significantly influence the project's sustainability.

Wood is often considered the most natural and eco-friendly option, especially if sourced from sustainably managed forests. It has lower embodied energy compared to steel and concrete, and blends well with natural landscapes. A wood bridge design can also make future maintenance easier and less invasive.

Steel bridges offer high strength and durability while allowing for minimal use of material. Although steel has a higher environmental cost in terms of energy use and emissions during production, it is highly recyclable. Using weathering steel can eliminate the need for painting and reduce maintenance. The steel bridge design would be prefabricated off-site, so there is no wasted material.

Concrete bridges are extremely durable and require minimal maintenance, which can be a sustainable advantage over time. However, concrete has one of the highest embodied carbon footprints due to cement production. This impact can be reduced by using supplementary materials like fly ash or slag in the mix, as well as recycled aggregates. Precast concrete components can also be fabricated off-site, reducing on-site disruption to natural areas. Although concrete is less recyclable than steel, it can be crushed and reused in other applications, helping to offset its initial environmental impact.

Beyond the bridge itself, the trail design should also follow sustainable practices. Trails should avoid steep slopes and sensitive habitats, instead following natural contours to reduce the need for excavation and erosion control.

Incorporating sustainable design principles into the planning of both the bridge and trail ensures a long-lasting, environmentally responsible project. Whether using wood, steel, or concrete, each material offers different advantages and challenges in terms of sustainability. Thoughtful choices in materials, construction methods, and trail layout can significantly reduce the environmental impact while creating a safe and functional crossing for years to come.

4.2 PUBLIC HEALTH, SAFETY, AND WELFARE

Public health, safety, and welfare are central to the design of any infrastructure project, especially when the site presents known risks and when the bridge must accommodate emergency response needs. In this case, the bridge is being designed not only for pedestrian use but also to support the movement of a rescue vehicle. This requirement directly influences the structural design, load-bearing capacity, and overall stability of the bridge. It ensures that in the event of an emergency, first responders can quickly and safely access individuals on the other side of the stream without delay.

The presence of a cliff adjacent to the trail introduces an additional layer of risk that must be addressed through careful planning. The area is already known as a hazard for the public, and the design must aim to prevent accidental falls or injuries. This can be achieved by incorporating physical barriers, such as guardrails or fencing, along dangerous areas. Signage should also be placed at key points to warn visitors of the danger. Clear and consistent communication helps protect users who may be unfamiliar with the terrain, including children, elderly individuals, or those visiting for the first time.

From a structural standpoint, the bridge must be engineered to support heavier live loads than a typical pedestrian bridge. The bridge is required to have reinforced foundations, wider decking, and stronger materials like steel or high-strength concrete for emergency vehicles to cross.

Accessibility also plays a role in public welfare. The trail leading to and from the bridge should be stable and graded to accommodate. Ensuring that the path is wide enough, free of obstructions, and properly maintained promotes inclusivity and reduces the chance of injury for all users.

Designing the bridge with public health, safety, and welfare in mind means creating a structure that is both strong enough for emergency access and secure enough to prevent accidents near a dangerous cliffside.

4.3 SOCIAL/LOCAL IMPACT

The addition of the new bridge to the existing trail system on the University of Southern Indiana (USI) campus brings social and local benefits to students, staff, and the surrounding community. By providing a more direct and accessible route between the Theater Support Building and Eicher Barn, the project enhances connectivity across campus and encourages greater use of outdoor spaces for both functional and recreational purposes. This improved link supports campus operations by reducing travel time between facilities.

The bridge contributes to a more walkable and cohesive campus environment. Students and visitors will have an easier, safer way to explore the natural areas of the USI campus without needing to navigate difficult terrain. As Eicher Barn is sometimes used for community events, the bridge also has the potential to improve access for residents attending functions on campus. This increased access to trails can promote healthy lifestyles, offering a more convenient way to enjoy walking, jogging, or cycling while moving between academic or event-related activities. In addition, the improved connection between campus buildings encourages more outdoor interaction, helping to build a stronger sense of community and shared space.

The project also has a positive local impact by showcasing USI’s commitment to sustainable development and thoughtful campus planning. Creating infrastructure that integrates with nature and serves multiple purposes for education and recreation demonstrates how public institutions can invest in student well-being.

4.4 ENVIRONMENTAL

The environment is a key component of this trail and bridge project, especially since the construction takes place within a natural area on the University of Southern Indiana (USI) campus. Efforts have been made to minimize disruption to the surrounding landscape, protect wildlife habitats, and preserve the natural beauty of the area. As part of the planning process, care was taken to route the trail and position the bridge in a way that reduces the need for extensive land clearing or alterations to the existing stream bed.

In cases where tree removal is unavoidable for construction access or bridge placement, a sustainable replanting policy will be followed: for every tree that is removed, a new tree will be planted elsewhere on campus. This replacement helps offset the environmental impact of the project and supports long-term ecosystem health by ensuring that forest cover is maintained or even increased over time. Native tree species will be prioritized to promote biodiversity and strengthen the resilience of the local environment.

Bridge design itself also reflects environmentally responsible choices. Materials will be selected not only for their durability and strength, but also for their environmental performance. Additionally, construction practices will aim to reduce runoff, erosion, and sediment disruption, particularly in areas near the stream.

By integrating the new bridge into the existing trail system with minimal ecological disturbance and commitment to restoring what is displaced, this project supports the broader goal of preserving green space on campus. It encourages responsible interaction with nature, allowing students, staff, and visitors to enjoy the outdoors while protecting the environment for future generations.

4.5 ECONOMIC

The economic impact of the bridge and trail extension project on the University of Southern Indiana (USI) campus is notably positive, particularly due to the efficient use of resources and community involvement. The cost of the project is also going to be covered by a grant. This approach substantially reduces overall project costs, allowing funds to be allocated to quality materials, environmental protections, and long-term maintenance rather than labor expenses.

In addition to the reduced labor costs, the bridge will provide long-term economic benefits by improving access between key campus locations, such as the Theater Support Building and Eicher Barn.

The project also has the potential to indirectly support local economic activity by enhancing the attractiveness of the campus for events, outdoor activities, and community involvement. With better trail connectivity and safer access to scenic and functional parts of campus, the university may be better positioned to host more outdoor programs, workshops, and community events.

By using volunteers and designing with long-term use in mind, this project demonstrates a cost-effective, community-driven approach to campus development. It provides value not only through physical infrastructure but also through strengthened relationships between the university and the people it serves.

4.6 ETHICAL AND PROFESSIONAL

Ethical and professional responsibility is fundamental to the planning and execution of this bridge and trail project on the University of Southern Indiana (USI) campus. From the earliest design stages to final construction, the project has been approached with a strong commitment to safety, transparency, environmental stewardship, and respect for the public good. As this is a student-led initiative, it also serves as an educational opportunity to apply professional standards in real-world practice while upholding the core values of engineering.

A key ethical component of the project is ensuring that the bridge is structurally sound and fully capable of supporting a rescue vehicle, which is critical for public safety. Every design decision must be made with the highest degree of accuracy and care to protect users and ensure long-term reliability. Even though the construction will be completed by volunteers, proper supervision, training, and adherence to construction best practices are essential to meet professional standards and prevent injury during the build.

Transparency and community accountability are also important ethical responsibilities. The project has been communicated openly with campus stakeholders, and efforts have been made to consider the input and needs of those who will use the trail and bridge most often.

Ethical design also extends to the environment, like protecting the natural landscape and committing to replanting trees for every tree removed.

The project reflects well on the university and its students by showcasing responsible design, collaboration, and planning. Working within real constraints, addressing public safety concerns, and maintaining clear documentation and communication throughout the process are all hallmarks of a professional approach. Ultimately, the project upholds the ethical duty of designers to serve the health, safety, and welfare of the public while modeling integrity and accountability in every phase of development.

5 BID ESTIMATE

5.1 20% DEVELOPMENT ESTIMATE

On May 6, 2025, a design review meeting was held to determine the preferred bridge style for the project. At the request of the University of Southern Indiana (USI) faculty, three bridge concepts were developed to represent varying levels of complexity: a simple bridge, an advanced bridge, and a prefabricated bridge option. Preliminary cost estimates for each of the three designs were prepared for both proposed bridge sites to evaluate constructability and budget feasibility.

During the discussion, it was noted that a secondary, smaller bridge would also be required near the trail entrance to improve connectivity and site access. Two design alternatives were considered for this smaller crossing: a concrete box culvert and a timber bridge. While the timber bridge offered advantages in terms of material cost and visual consistency with the main structure, the concrete box culvert provided reduced construction time and lower long-term maintenance requirements. These factors were carefully evaluated to guide the final selection and development of the 20% design plans.

The simple design option is a wood bridge similar to DNR's bridge, as shown in Figure 32 DNR Glulam Bridge. The advanced design will include an overlook in a wood style. The overlook would be a modified version of DNR's bridge. For the prefabricated bridge, the company Bedford Reinforced Plastics gave a quote. The company gave a quote for both spans with options.

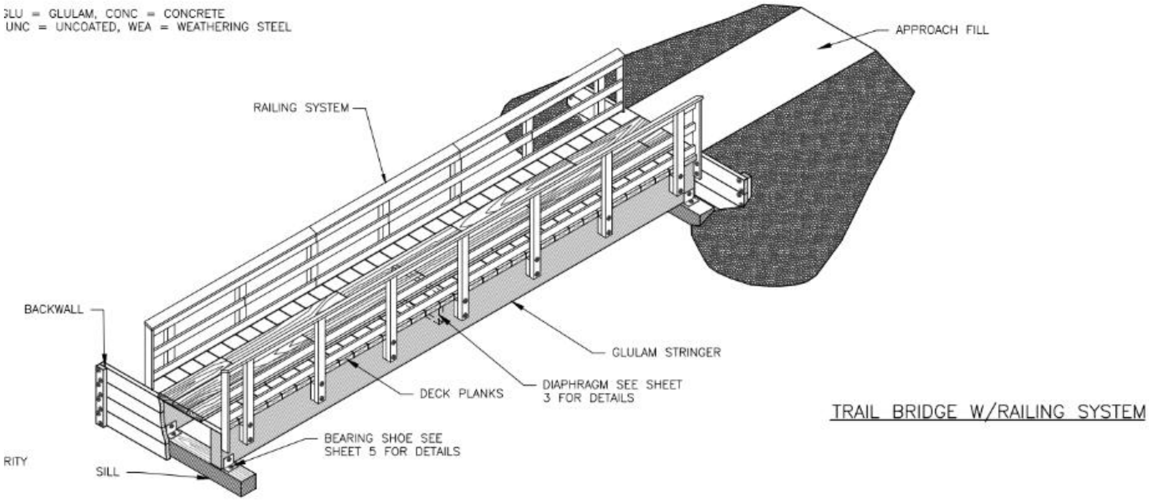
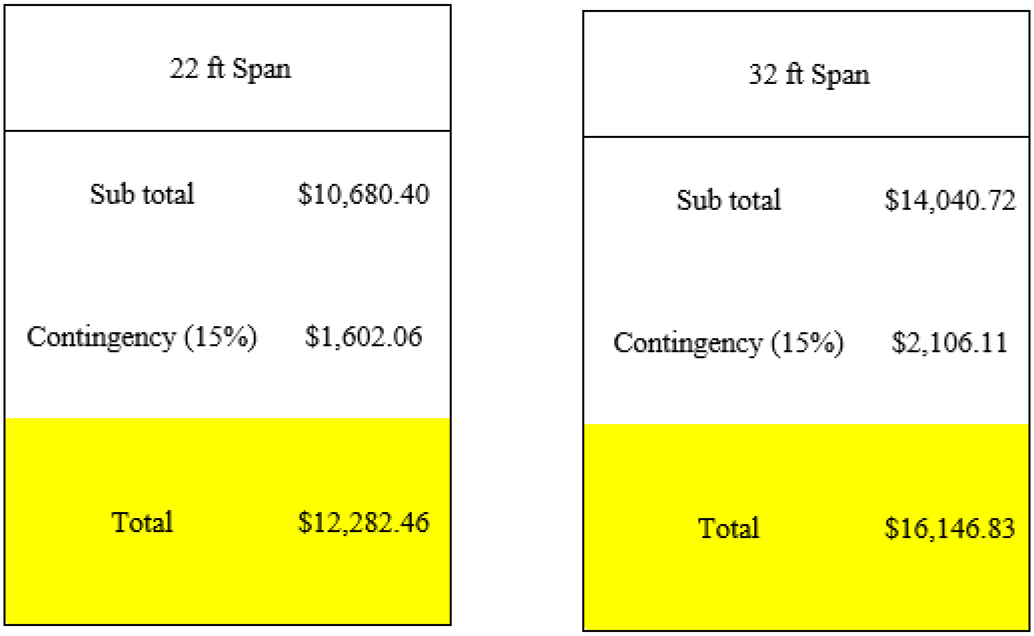


Figure 32 DNR Glulam Bridge

Based on the above information a very basic estimate was completed from research online from local companies. The estimates presented are shown in Table 11 and Table 12. The following estimates only include the differences between the design. They do not include the foundation, labor, or clearing and grubbing.

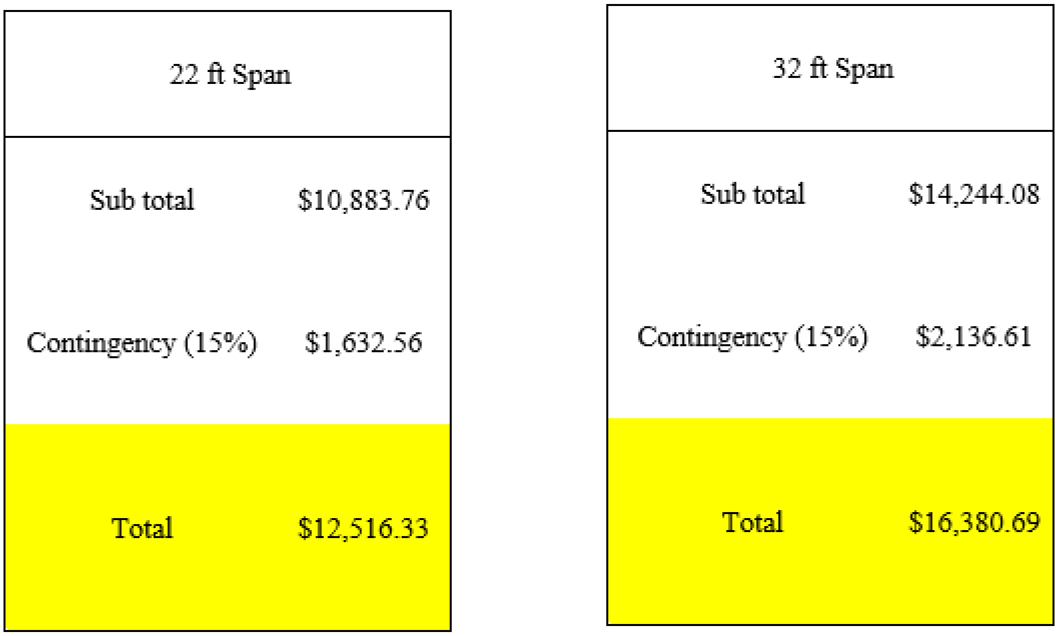
Table 11 No Overhang



22 ft Span	
Sub total	$10,680.40
Contingency (15%)	$1,602.06
Total	$12,282.46

32 ft Span	
Sub total	$14,040.72
Contingency (15%)	$2,106.11
Total	$16,146.83

Table 12 Overhang (8ft x 2ft On Center)

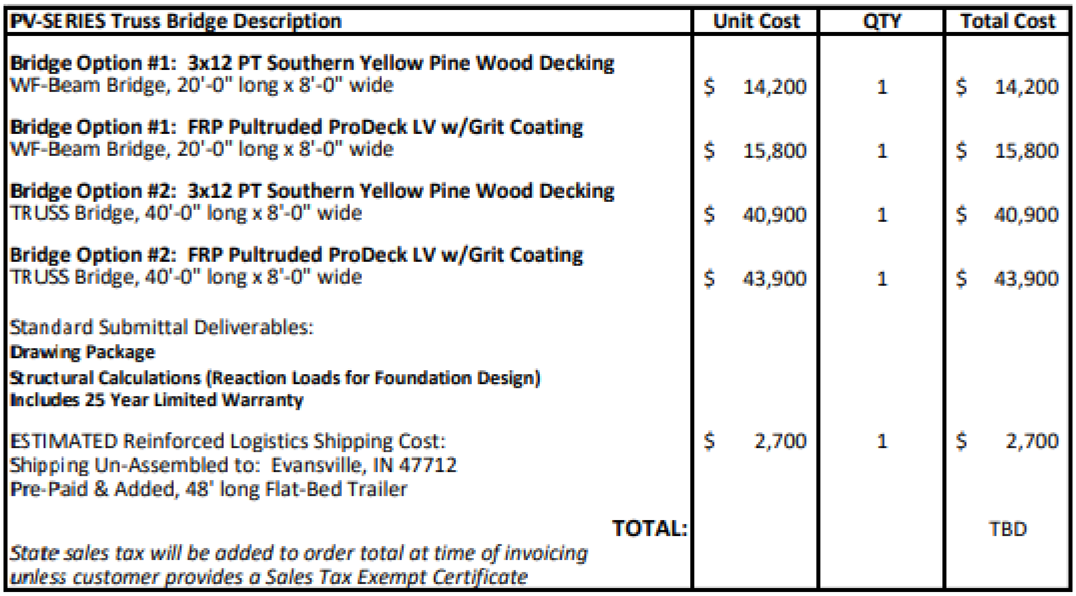


22 ft Span	
Sub total	$10,883.76
Contingency (15%)	$1,632.56
Total	$12,516.33

32 ft Span	
Sub total	$14,244.08
Contingency (15%)	$2,136.61
Total	$16,380.69

Of the prefabricated bridge suppliers contacted, Bedford Reinforced Plastics was the only company that provided a complete response and formal cost proposal. Their quote is summarized in Table 13. Bedford offered two design alternatives for each of the two bridge spans, with the primary difference being the deck material. The lower-cost option utilized yellow pine decking, which met basic structural requirements but did not satisfy the long-term durability expectations outlined by the university. The second option incorporated FRP decking with a factory-applied gritty surface coating. This configuration offered improved slip resistance, particularly under wet conditions, and was therefore considered a safer and more appropriate solution for reducing potential liability. Bedford also provided aesthetic renderings of the proposed bridge system, which are presented in Figure 33 Bedford Reinforce Plastics Bridge Design.

Table 13 Bedford Reinforece Plastics Quote



PV-SERIES Truss Bridge Description	**Unit Cost**	**QTY**	**Total Cost**
Bridge Option #1: 3x12 PT Southern Yellow Pine Wood Decking WF-Beam Bridge, 20'-0" long x 8'-0" wide	$ 14,200	1	$ 14,200
Bridge Option #1: FRP Pultruded ProDeck LV w/Grit Coating WF-Beam Bridge, 20'-0" long x 8'-0" wide	$ 15,800	1	$ 15,800
Bridge Option #2: 3x12 PT Southern Yellow Pine Wood Decking TRUSS Bridge, 40'-0" long x 8'-0" wide	$ 40,900	1	$ 40,900
Bridge Option #2: FRP Pultruded ProDeck LV w/Grit Coating TRUSS Bridge, 40'-0" long x 8'-0" wide	$ 43,900	1	$ 43,900
Standard Submittal Deliverables: **Drawing Package** **Structural Calculations (Reaction Loads for Foundation Design)** **Includes 25 Year Limited Warranty**			
ESTIMATED Reinforced Logistics Shipping Cost: Shipping Un-Assembled to: Evansville, IN 47712 Pre-Paid & Added, 48' long Flat-Bed Trailer	$ 2,700	1	$ 2,700
TOTAL: *State sales tax will be added to order total at time of invoicing unless customer provides a Sales Tax Exempt Certificate*			TBD

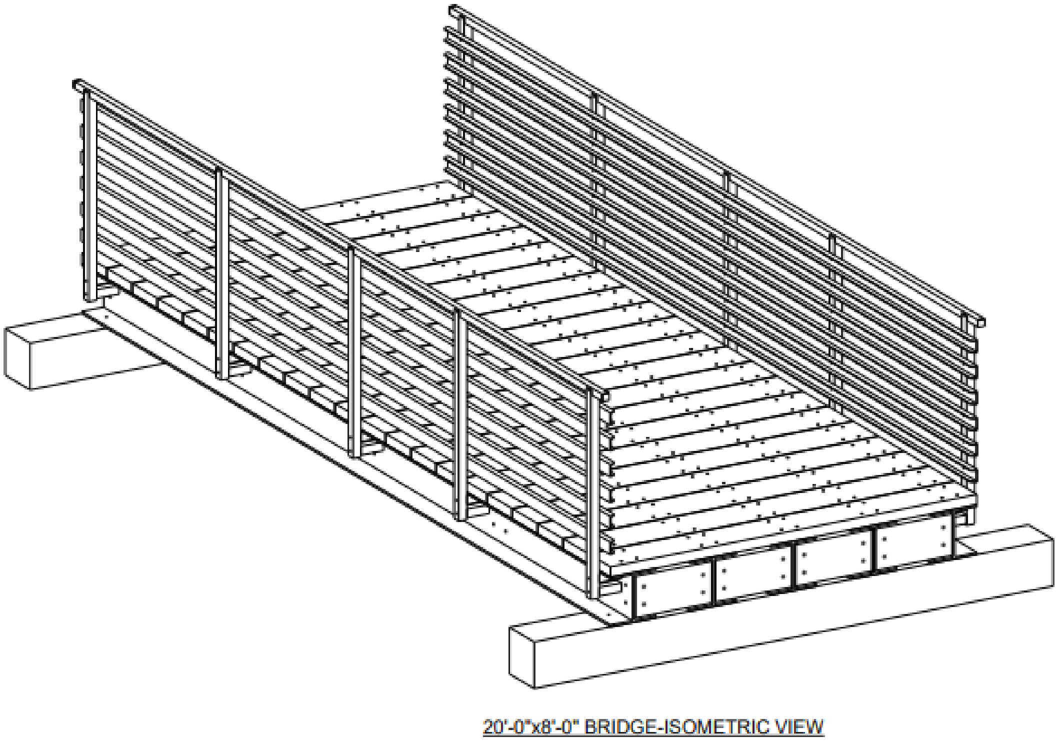


Figure 33 Bedford Reinforce Plastics Bridge Design

5.2 EXCEL

To create an estimate for the construction of the bridge, we wanted to come up with the most accurate and thorough estimate so that the university could reach out and find the funds to cover the entire cost of the bridge. With this in mind, we wanted to get the most update costs for labor, materials, and equipment by researching reliable sources for these products.

5.3 LABOR

For the estimation of labor costs, we researched the local union wages for the workers that we deemed appropriate for the job. We first started by adding a foreman because we would need someone to be in charge and organize the entire project and follow the plans. With the foreman as the leader and organizer, we considered him to be working any time that there was work being done on the project. After we considered all of the tasks necessary for the project, we determined that the duration of the project would be approximately 70 hours, and because the foreman was in charge, we accounted for paying him all 70 hours.

When considering the need to be around the extraction of the bridge, finally, we considered that the foreman would need help to perform all the necessary tasks. For this help, we decided to estimate using 2 laborers, which would significantly speed up the time it would take to complete each task. However, because there were tasks in the project that would not require laborers or just require 1 laborer, we estimated that for the 70-hour duration, the laborers would only need to be at the project for 66 hours, which saved the project a little money.

To operate all of the equipment and position all of the heavy items of construction, we estimated the use of 1 operator. Again, as we budgeted time for each task, we decided that the operator would only need to be on the project for 60 hours, and when pricing equipment, we budgeted the cost to reflect the amount of time that the operator would be on site operating equipment at the site.

Labor/equipment Cost

Role	# of people	$/Hour	Estimated # of hours needed	Cost
Foreman	1	$43.00	70	$3,010.00
Laborers	2	$30.00	66	$3,960.00
Operator	1	$38.00	50	$1,900.00
Telehandler	1	$79.85	12	$958.20
Mini excavator	1	$120	38	$4,560.00
			Total Labor/equipment cost=	$14,388.20

Figure 34: Table of Labor Estimate

5.4 *MATERIALS*

For the materials for the bridge, we used the called-out number of materials found on the plan sheets and design so that we could get an accurate quantity of materials that would need to be procured before construction began. For the cost of materials, we went online and investigated the different options for the materials and tried to come up with quality and affordable products to be used.

For the construction of the abutments, 40ft of Geocell, which was found to cost about $11.23 /ft and the total amount needed would cost $449.20. We then priced the Concrete for the abutment; we looked into the cost from IMI and also the costs incurred of forms and constructing the forms. For the cost of the concrete, we used $165/CY, which we needed about 12 CY, so this cost was $1980. Then we added the cost of rebar in which the plans called out 90 ft of #4 rebar and 354ft of #5 rebar. At a cost of $.3/ft and $.5/ft respectively, the total cost of rebar was $203. For the cost of the forms, we priced 8 sheets of plywood and 20 2x4s to construct the forms. We also predicted that we would need about 20 pounds of nails throughout the project to construct forms and hold the deck in place. These were considered average usage for this kind of project through normal construction processes. For the sheets of plywood, we found that the cost per sheet would be approximately $46.18. This was priced from Home Depot as well as the 2x4s, which cost $3.48. The cost of the screws was $4 per pound and would cost $80 for the 20 lbs. needed. With these materials accounted for, we started to look into the deck and the cost associated with that. To start the structure for the deck, comprised of the free telephone poles that were acquired from CenterPoint Energy. These poles were free, so we did not associate any cost with them for the estimate. We then quoted the anchor bolts, which would hold the beams to the abutments. For the Anchor bolts and lag bolts to be used, we assumed another 20lbs and at a cost of $6/lb came out to be $120. Finally, we accounted for the cost of the bridge deck itself, which would be constructed of 2x8s laid next to each other. We assumed using 60 boards for the deck of the large bridge and another 15 boards for the small bridge. We also added an extra 15 boards to make sure we had plenty for the project. Each 2x8 costs $14.68, which gives the total cost of the decking being $1321.20. With the primary costs of constructing the bridge, we added the quoted costs of the handrails, which cost $11,750. Bringing the total cost of materials to $18,724.74.

Material Costs

Item	Quantity	Unit cost	Total Cost
Concrete	12 CY	$165/CY	$ 1,980.00
Rip Rap	45 tons	$52.94/ton	$ 2,382.30
#4 rebar	90 ft	$0.3/ft	$ 27.00
#5 rebar	354 ft	$0.5/ft	$ 176.00
1/2" Plywood	8 sheets	$46.18/per	$ 369.44
2x4 lumber	20 pcs	$3.48/per	$ 69.60
2x4 lumber	90 pds	$14.68/per	$ 1,321.20
Deck Screws	20 lbs	$4/lb	$ 80.00
Lag Bolts	20 lbs	$6/lb	$ 120.00
Geocell	40ft	$11.23/ft	$ 449.20
Telephone pole beams	8	Free (CNP)	$ -
Large Bridge Handrail	1	BSS Quote	$ 8,500.00
Small Bridge Handrail	1	BSS Quote	$ 3,250.00
		Total material Costs=	$18,724.74

Figure 35: Table of Materials Estimate

5.5 *EQUIPMENT*

To estimate the cost incurred by the project by the equipment I used some Construction standards and personal judgment to estimate the time that would be required to have the equipment at the location of the bridge site. For this, I estimated the Equipment to be needed for a total of 50 hours, during which the equipment would be used. I found pricing for 2 pieces of equipment that I thought would play a large role in the construction of the bridge, and the hourly prices that I used in the estimate were found using an average cost of rentals in the local area. Once we had the cost per hour to rent the equipment, we determined the time that we would need the equipment on location. For this, we again researched and used judgments based on construction standards to determine that the Telehandler would need to be rented for 12 hours at a cost of $79.85 an hour and that a mini excavator would need to be rented for 38 hours at a cost of $120 an hour. With these times and costs added, we determined that the cost of equipment would $5,518.20.

5.6 QUOTES

For the estimate of this project, we reached out to three companies to receive quotes for the fabrication of the handrails. The three companies we contacted were Metal Fabrications Incorporated, NIX Industrial in Poseyville, Indiana, and Bradley Stevens Services in Cynthiana, Indiana. After sending out our plan set for the handrail, we received a response from Metal Fabrications stating that they were not interested in providing a quote. From the other two companies, Nick's Industrial and Bradley Stevens Services, we received pricing. NIX Industrial was the only company that provided an official quote with detailed steel fabrication costs, while Bradley Stevens Services gave us a ballpark estimate for the handrail fabrication. Both fabricators included powder coating in their pricing, which was a requirement by the university to ensure longevity and low maintenance for the bridge's coating. Of the two quotes, NIX Industrial came in at $15,722.46, and Bradley Stevens Services came in at $8,500. Based on these quotes, we recommended to the university that they select Bradley Stevens Services to fabricate the handrails. These were the only quotes we received for the construction of the USI trail bridge.

The official quote from NIX Industrial can be found in Appendix C

5.7 TOTAL ESTIMATE

Before submitting the plans and estimates to the university, we completed the overall cost estimate by adding all material, labor, and equipment costs associated with the construction of the trail bridge, as well as a 15% contingency to cover any additional expenses that were not accounted for in the initial estimate. We are confident that our estimate is accurate and that, with the proper grant funding, the bridge can be successfully constructed. With the materials and services included in our estimate, the bridge should stand for many years to come.

Based on our calculations, the total estimated cost for this bridge is $42,685.63.

6 PLAN SET

6.1 PLAN SET DELIVERY

The plan sheet set for the pedestrian bridges and trail design at the University of Southern Indiana represents the combination of detailed design work completed using MicroStation OpenRoads Designer. The plan set includes a comprehensive plan view layout, grading, drainage structures, and connections to adjacent pathways. The trail alignment was developed with careful consideration of topography, accessibility standards – for example – and environmental impacts to ensure a safe and sustainable route for pedestrians and cyclists. Design elements such as horizontal and vertical geometry, spot elevations, and limits of construction are clearly depicted to guide accurate implementation during construction.

In addition to the trail layout, the plan set includes a series of structural design sheets for the two pedestrian bridges along the route. These sheets detail the geometry, framing plans, abutment and foundation layouts, and material specifications required for construction. Each bridge was designed to accommodate pedestrian loads while maintaining aesthetic integration with the surrounding natural environment. The plan sheets provide dimensions, callouts, and section views to ensure clarity for contractors and field engineers. Together, the trail and bridge design plans form a coordinated and constructable package that effectively communicates the design intent and supports the delivery of an accessible, long-lasting infrastructure improvement on campus.

7 CONCLUSION AND EXPERIENCE

The ultimate goal of this project was not only to deliver a complete bridge design but also to gain meaningful experience in the civil engineering process from concept to final documentation. Throughout the semester, the team developed a comprehensive understanding of structural design principles, hydraulic considerations, foundation engineering, and construction planning. The structural analysis involved hand calculations, advanced modeling in RISA-3D, material selection, and iterative refinement based on real-world constraints. Similarly, the hydraulic component required careful evaluation of flow conditions, riprap protection, and risk mitigation to ensure long-term stability and resilience of the bridge in a natural watershed environment.

Collaboration with the University of Southern Indiana played a key role in shaping the project. Meetings with USI representatives provided insight into site-specific requirements, maintenance expectations, and community needs. These interactions strengthened the team's ability to design within client constraints, communicate technical decisions clearly, and adapt solutions to the conditions of the project site. The coordination process also emphasized the importance of professional responsibility and stakeholder engagement, which ties into the core skills for practicing civil engineers.

The team's success was supported by effective communication and an understanding of each member's strengths. With each individual contributing expertise in different areas of structural analysis, hydraulics, geotechnical considerations, modeling, drafting, or cost estimation. Throughout the project, the group also learned when to seek guidance from professors and practicing engineers. These interactions improved the technical accuracy of the design and provided valuable exposure to the expectations of professional engineering practice.

In developing the final design, the team became proficient in new engineering software platforms and modeling tools, investing many hours into learning their functions and applying them effectively. This experience reinforced the importance of continuous learning, especially as modern civil engineering increasingly depends on digital modeling and simulation. The skills developed will extend well beyond this project and serve as a foundation for the team's future careers.

Overall, the project achieved its goals by delivering a structurally sound, hydraulically resilient, and constructible bridge design while providing the team with hands-on experience that reflects real-world engineering practice. The process strengthened the team's problem-solving abilities, technical knowledge, and professional confidence, marking the project as a successful culmination of academic learning and collaborative engineering effort.

REFERENCES

1 ASCE Code of Ethics: https://www.asce.org/-/media/asce-images-and-files/career-and-growth/ethics/documents/asce-code-ethics-july-2017.pdf

2 American Concrete Institute: (2019). ACI CODE-318-19(22): Building Code Requirements for Structural Concrete and Commentary (Reapproved 2022). American Concrete Institute.

3 American Wood Council: (2015). 2024 National Design Specification (NDS®) for Wood Construction. American Wood Council.

4 American Society of Civil Engineers. (2022). Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-22). American Society of Civil Engineers.

5 Autodesk Civil 3D: Autodesk. (2024). Autodesk Civil 3D (Version 2024) [Computer software]. Autodesk. https://www.autodesk.com/

6 Autodesk ReCap: Autodesk. (2024). Autodesk ReCap (Version 2024) [Computer software]. Autodesk. https://www.autodesk.com/

7 Bentley OpenRoads Designer (MicroStation/OpenRoads): Bentley Systems, Inc. (2024). OpenRoads Designer (Version 2024) [Computer software]. Bentley Systems. https://www.bentley.com/

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9 Illinois Department of Transportation. (n.d.-a). *IROADS Public*. IROADS - Illinois Roadway Analysis Database System. https://webapps1.dot.illinois.gov/IROADS/

10 RISA-3D: RISA Technologies. (2024). RISA-3D (Version 23) [Computer software]. RISA Technologies. https://risa.com/

11 National Wetlands Inventory: U.S. Fish and Wildlife Service. (2024). National Wetlands Inventory (NWI) Dataset. U.S. Department of the Interior.

APPENDIX

Appendix A: Meeting Minutes

Appendix B: Quotes for Pre-Fabricated Bridges

Appendix C: Quotes for Railings

Appendix D: Hand Calculations for Bridge Design

Appendix E: Plan Set

Appendix F: 20% Design Options

Appendix G: Soil Report

Appendix H: USGS Topographic Map

Appendix A

3:00 to 3:30 p.m. CST February 6th, 2025

Scoping Meeting Minutes

Attending

Dr. Paul Kuban
Dr. Kerry Hall
Timothy Bohlen
Bailey Stambaugh
Ella Wolf

Announcements

- Reviewed Proposal for pedestrian bridge, trail, pavilion and interactive outdoor classroom.

Discussion

Questions:

Ella asked if the deadline of April is set in stone.

- Dr. Kuban replied yes, he would allow the senior design team to complete the project this semester and report on it next semester.

Ella asked if there is a location in mind for the bridge.

-Dr. Kuban said that would be part of the design process and senior design group would determine location of bridge and trail.

Ella asked who is the ‘owner/’main client in this project.

-Dr. Kuban said he believes Bill but will get back with a definitive answer.

Ella asked if since the project is in a Flood A zone would the senior design team fill out the permits.

-Dr. Kuban said yes that would be part of the senior project scope.

Dr. Kuban asked if the senior design group could keep in mind that solar panels might be installed to light the path later down the road.

-Senior Design Team said they will keep that in mind.

Dr. Kerry Hall asked if the structural analysis of the Westwood Lodge would still be in the scope of the project.

-Dr. Kuban said that is a good idea but will not be completed under the current grant proposal.

1:10 to 2:10 p.m. CST February 14th, 2025

Scoping Meeting Minutes

Attending

Dr. Paul Kuban
Dr. Bill Elliott
Allison Grabert
Timothy Bohlen
Bailey Stambaugh
Ella Wolf

Announcements

- Reviewed Proposal for pedestrian bridge, trail, pavilion and interactive outdoor classroom.

Discussion

Dr. Elliott lead a tour through the possibility path and showed the location of the bridges.

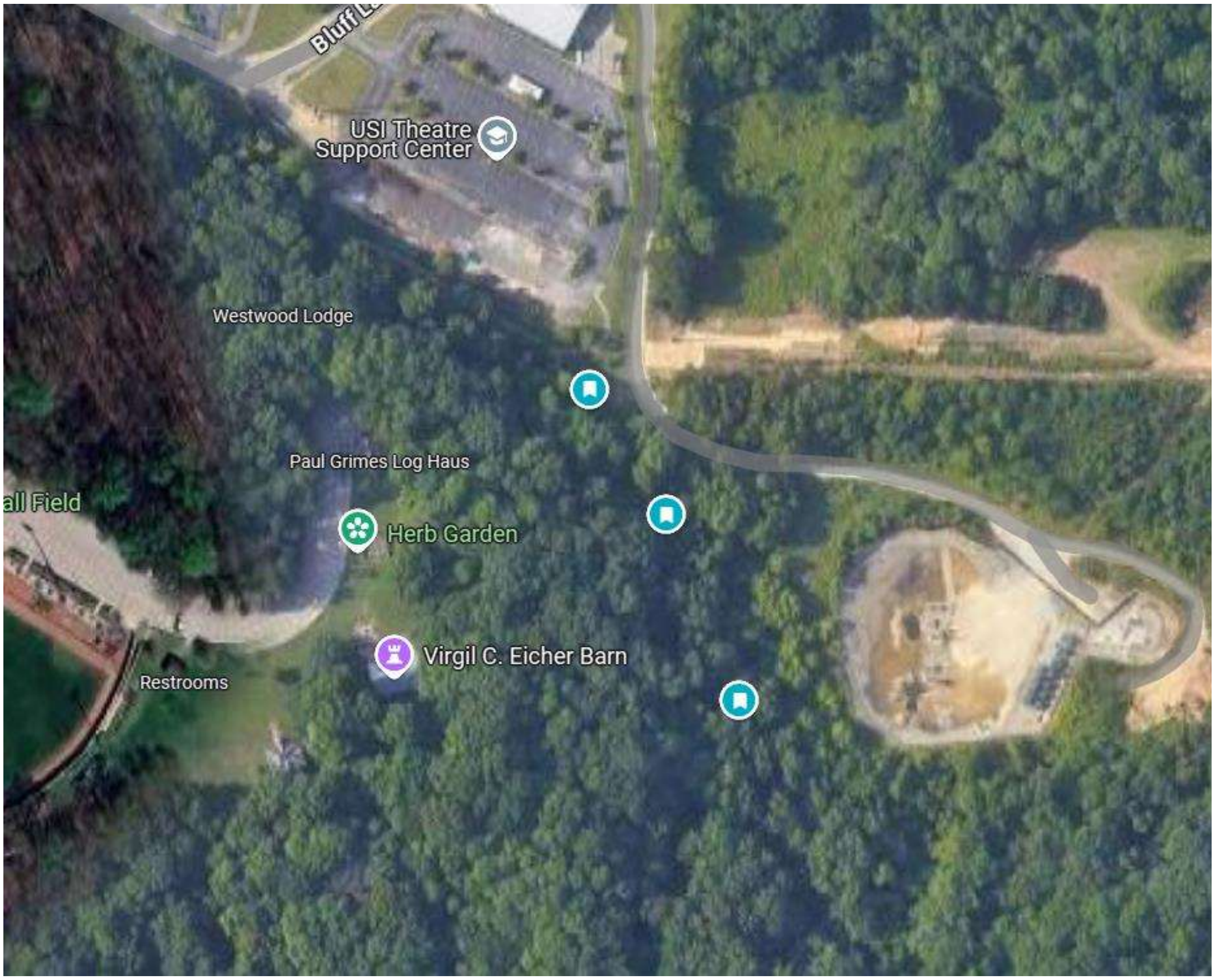
Dr. Elliott wants a dirt trail that leads to the bridge and connects to an existing trail. The existing trail may also require some work. The connected trail comes out by Eicher Barn but wants the trail to connect to Burdette Trail.

Dr. Elliott requires that for every tree that is taken out to be replaced.

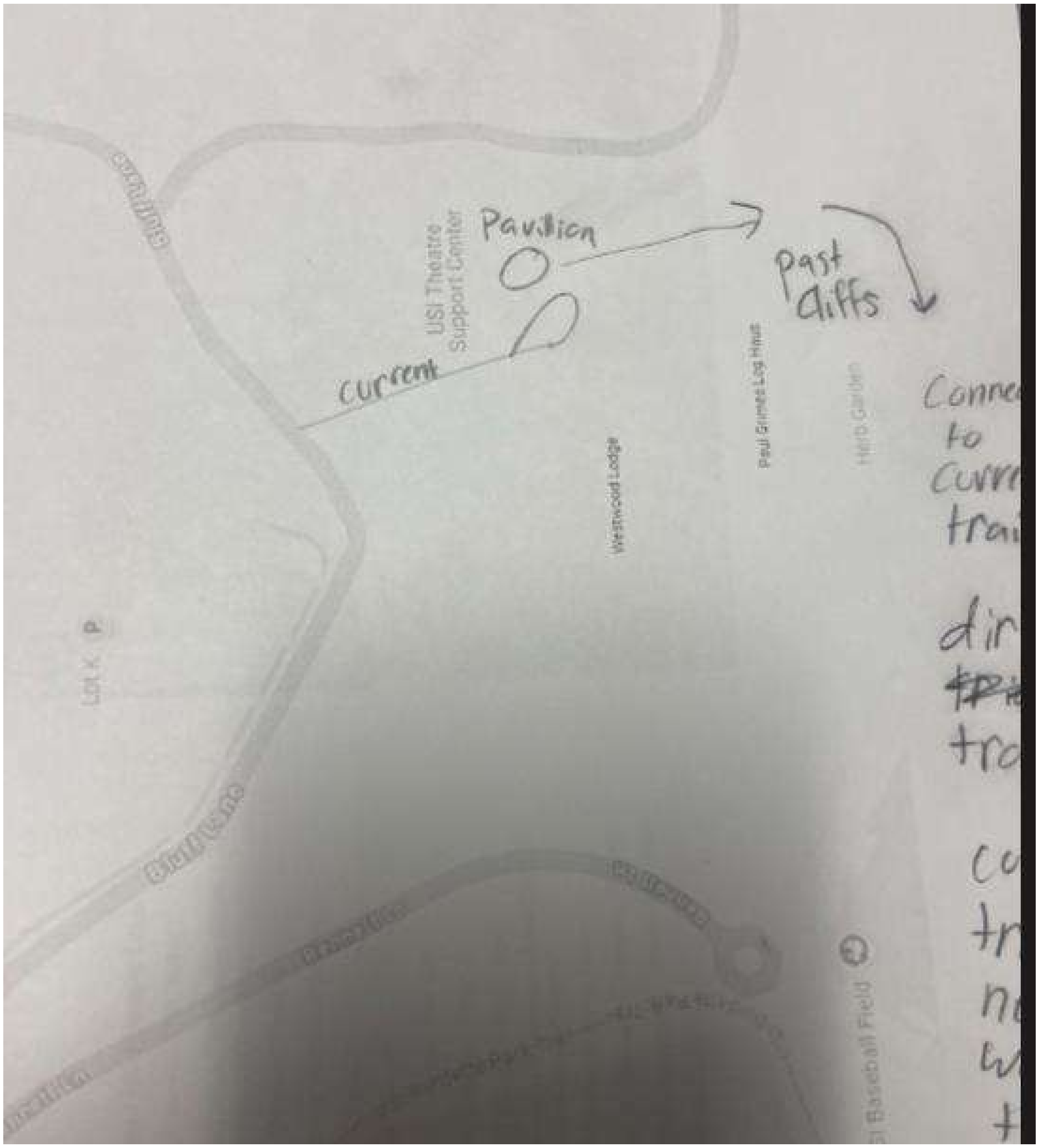
Dr. Elliott informed the team that the Amphitheater was a senior design project in the past.

Dr. Elliott said we must talk with Dr. Kuban about adding Westwood Lodge structural analysis to the project scope.

Below are notes taken by Ella.



From North marker to south marker, start of trail, bridge 1, bridge 2 (main crossing).


Pavilion
Past Cliffs
current
USI Theatre Support Center
Westwood Lodge
Paul Grimes Log Haus
Herb Garden
Lot K P
Baseball Field
Conne
to
curre
trai
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5:00 to 6:00 p.m. CST February 17th, 2025

Scoping Meeting Minutes

Attending

Mr. Jim Wolfe
Timothy Bohlen
Bailey Stambaugh
Ella Wolf

Announcements

- Reviewed Proposal for pedestrian bridge, trail and pavilion.

Discussion

Ella asked if there is any old survey data in the area.

Mr. Wolfe said he will find out.

Ella asked if Mr. Wolfe was okay with putting stakes in the ground.

Mr. Wolfe said yes.

Ella asked if there is old drawings on Westwood Lodge.

Mr. Wolfe said there are going to demolish the building.

Ella asked how involve does Mr. Wolfe want to be.

Mr. Wolfe said when we have plans.

3:00 to 3:30 p.m. CST February 6th, 2025

Scoping Meeting Minutes

Attending

Dr. Paul Kuban
Dr. Kerry Hall
Bryan Morrison
James Wolfe
Dr. Allison Grabert
Dr. Bill Elliott
Timothy Bohlen
Bailey Stambaugh
Ella Wolf

Announcements

- Reviewed Proposal for pedestrian bridge

Discussion

Dr. Kuban mention that there are free telephone poles that we might be able to have.

It was decided that if we could get the telephone poles that the same first bridge would be wood bridge.

There was a huge favor in going with site 1, 32 ft span.

Mr. Bryan said that the span of the bridge would only need to have 7 ft of clear space for the Kubota to cross.

It was also mention to add ballads and signage to prevent full size vehicles from crossing the bridges.

It was decide that the access road for equipment to the site would be from the oil rig road, south of the first bridge. The team will need to clear mark a path to be cleared. The road would need to be marked every 50ft?????? And be 5-10ft wide.

If need to we can call the oil rig company to get access to the site. The name is on the gate.

Dr. Elliott said to plan on the stream to be cleared of debris. Also that we can email him for any more questions.

During the construction there will need to be a hired contractor to supervise both builds. The grading of the site will also need to be done by a professional. We will also need to hire an operator for the heavy equipment.

There are still many questions about the volunteers from Toyota. We think that they ill be there for as long as it takes.

For every tree removed we will try to replace it with the same species or at least native to the area. The trees will be planted at the grand opening of the pavilion.

Appendix B

Quote No: 25BRP3262
Date: 4/8/25

TO: Timothy Bohlen
Company: University of Southern Indiana
Address: 8600 University Blvd.
Evansville, IN 47712
Phone: 812.449.3082
Email: tgbohlen@eagles.usi.edu

PROJECT: 20x8 and 40x8 Campus Pedestrian & Vehicle Bridge, University of Southern Indiana

Bridge Width	**Allowable Traffic**
8' wide:	Pedestrian & Vehicles, H5 10,000 lbs.

Environmental loads (snow & wind) are specified by local
Building Code ASCE-7 for the geographic bridge location

Pedestrian Live Load:	60	PSF
Ground Snow Load:	15	PSF
Wind Load:	106	MPH

PV-SERIES Truss Bridge Description	**Unit Cost**	**QTY**	**Total Cost**
Bridge Option #1: 3x12 PT Southern Yellow Pine Wood Decking WF-Beam Bridge, 20'-0" long x 8'-0" wide	$ 14,200	1	$ 14,200
Bridge Option #1: FRP Pultruded ProDeck LV w/Grit Coating WF-Beam Bridge, 20'-0" long x 8'-0" wide	$ 15,800	1	$ 15,800
Bridge Option #2: 3x12 PT Southern Yellow Pine Wood Decking TRUSS Bridge, 40'-0" long x 8'-0" wide	$ 40,900	1	$ 40,900
Bridge Option #2: FRP Pultruded ProDeck LV w/Grit Coating TRUSS Bridge, 40'-0" long x 8'-0" wide	$ 43,900	1	$ 43,900
Standard Submittal Deliverables: **Drawing Package** **Structural Calculations (Reaction Loads for Foundation Design)** **Includes 25 Year Limited Warranty**			
ESTIMATED Reinforced Logistics Shipping Cost: Shipping Un-Assembled to: Evansville, IN 47712 Pre-Paid & Added, 48' long Flat-Bed Trailer	$ 2,700	1	$ 2,700
TOTAL: *State sales tax will be added to order total at time of invoicing unless customer provides a Sales Tax Exempt Certificate*			TBD

The 40x8 TRUSS bridge includes the following:

- FRP PROForms Pultruded Shapes w/Polyester Resin
- Truss Design w/Diagonal Braces
- SLOPED-End Design
- 54" High Handrailings
- 3" C-Channel Safety Mid-Rails w/4" Spacing
- A307 Hot-Dipped Galvanized Steel Hardware Kit
- DECKING: SEE OPTIONS & PRICING ABOVE
- Standard Color: Olive Green
- Dead Load Camber Design

The 20x8 WF-BEAM bridge includes the following:

- FRP PROForms Pultruded Shapes w/Polyester Resin
- WF-Beam Design w/C10 x 1/2" Channel Diaphragm Braces
- 12" x 1/2" thick WF Main Beams (x5 per structure)
- 42" High Handrailings
- 3" C-Channel Safety Mid-Rails w/4" Spacing
- A307 Hot-Dipped Galvanized Steel Hardware Kit
- DECKING: SEE OPTIONS & PRICING ABOVE
- Standard Color: Olive Green
- Dead Load Camber (NONE - Flat Design)

The following items are excluded from this quote:

1. Anchor bolts for securing bridge to foundations
2. Removal of parts from delivery truck
3. Field assembly & installation
4. Foundation engineering & design services

Authorized Signature for Order **Date**

PLEASE PRINT NAME

Appendix C

NIX INDUSTRIAL®

Carl A Nix Welding Service dba Nix Industrial
6751 Frontage Rd, Poseyville, IN 47633
Phone: (812) 874-2422 | Fax: (812) 874-2424
www.nixindustrial.com

QUOTATION

NIX CONTACT TITLE & NAME		EMAIL ADDRESS	PHONE NUMBER	ESTIMATE NUMBER	QUOTATION DATE	TERMS
Estimator	Ryan Weinzapfel	rweinzapfel@nixindustrial.com	(812) 365-1022	137272	12/1/2025	NET 30
Sales Rep	Jonathan Muehlbauer	jmuehlbauer@nixindustrial.com	(812) 598-4120			

NAME: University of Southern Indiana

STREET ADDRESS:

CITY, STATE, ZIP:

ATTENTION: Timothy Bohlen

- The pricing shown is based upon the information available at the time of this quotation. Any additions, changes, or deletions may affect the price.
- ***Quotation pricing is valid for fifteen (15) days after date listed on this letter.***
- ***Pricing is based upon current material costs. Due to market conditions and the high volatility of the steel market at this time, Nix reserves the right to adjust our price to reflect current material market conditions up to the date of receipt of approved shop drawings.***
- Nix standard terms and conditions will apply to this project, unless stated otherwise.
- Any letter of intent and/or purchase order must reference the Nix estimate number listed above.

Project Description

Project Name: **Trail Bridge Handrail** **Total Project Cost:** **$15,722.46**

ITEM	QUANTITY	DESCRIPTION	UNIT PRICE	AMOUNT
1	1	Supply the following	$15,722.46	$15,722.46
2				$0.00
3				$0.00
4				$0.00
5				$0.00
6				$0.00

****NOTE: Pricing and estimated lead times are valid for fifteen (15) days from Quotation Date.**

Scope of Work & Clarifications:

Fabrication Description:

- Fabricate approx. 80 lineal feet of handrail of handrail per supplied drawings

Coatings Description:

- Zinc prime and powder coat

Assembly & Installation Description:

- Excluded

Excluded Items:

- Sales Tax.
- P.E. Stamp.
- Unloading, Erection and/or Installation.

Standard Terms and Conditions

General:
These customer Terms and Conditions (“Contract Terms”) are incorporated by reference in the Estimate, Work Order, Invoice, and/or Contract by **Carl A. Nix Welding Service Inc. dba Nix Industrial** with the purchaser, contractor, sub-contractor or end user, hereafter known as “Customer”.

Drawing & Document Ownership:
Drawings, sketches, material lists, or any document produced by Nix Industrial for the purpose of estimating, manufacturing or providing work/service are the property of Nix Industrial and should only be used between the Customer and Nix Industrial unless otherwise agreed upon in writing by Nix Industrial.

Customer Documents:
Any conflicting or additional terms in a purchase order, letter, or other documents, issued by Customer will only be incorporated in any agreement if specifically accepted and acknowledged in writing by Nix Industrial. Upon Customer's issue of purchase order or approval to proceed and the written acceptance of Purchase Order by Nix Industrial, the Purchase Order and other documents shall constitute the agreement of the parties (the "Contract"), unless otherwise agreed upon in writing by Nix Industrial.

Shipping, Delivery & Payment:
The price for goods/services shall be due and payable within the parties agreed upon terms and payment shall be triggered upon the issue of an invoice from Nix Industrial. General terms are NET 30 unless otherwise negotiated or described in the "Contract". Finance charge of 1.5% will be assessed 30 days after invoicing. On all past due accounts, finance charges of 18% annually, $2.00 minimum. **Down payment terms are required for but not limited to orders greater than $20,000. A 40% down payment of the total amount is required. If the purchase of material exceeds 40% of the total order, a down payment for the cost of materials is required.** Milestone billing terms are required for but not limited to field service work including coatings, welding and mechanical. A monthly payment for all incurred costs is required until the completion of the job. Shipping or Delivery are not included unless otherwise negotiated and documented on the Estimate, Purchase Order or Contract.

Coatings:
Coatings are not included unless otherwise negotiated and documented on the Estimate, Purchase Order or Contract.

Color Matching:
Attempts to color match may not provide an exact match of the actual paint colors. Paint colors are affected by many factors, including light, age, type of finish, type of substrate and adjacent colors. Some colors may require more than one coat for complete coverage. If final color appearance and color matches are critical, paint should be tested on the actual surface before full application. The customer is responsible for selecting the paint color code and notifying Nix Industrial of any desired color match.

Paint and Coating Finish:
The luster or shininess of paints and coatings are generally classified as flat, semi-gloss, or gloss. The same paint color code with the same description may have a quite different appearance based on the type of finish selected. The customer is responsible for selecting the type of finish and notifying Nix Industrial of any desired finish. Nix Industrial does not guarantee or warranty the actual gloss level of the finish product unless specified in writing.

Paint Cure:
Paint cure times can vary. After a product has been painted, the paint should be allowed to cure to the paint manufacturers specification before any heavy cleaning, scrubbing, waxing and exposure to impact or abrasion are applied to the paint surface.

Assembly & Installation:
Assembly and/or installation are not included unless otherwise negotiated and documented on the Estimate, Purchase Order or Contract.

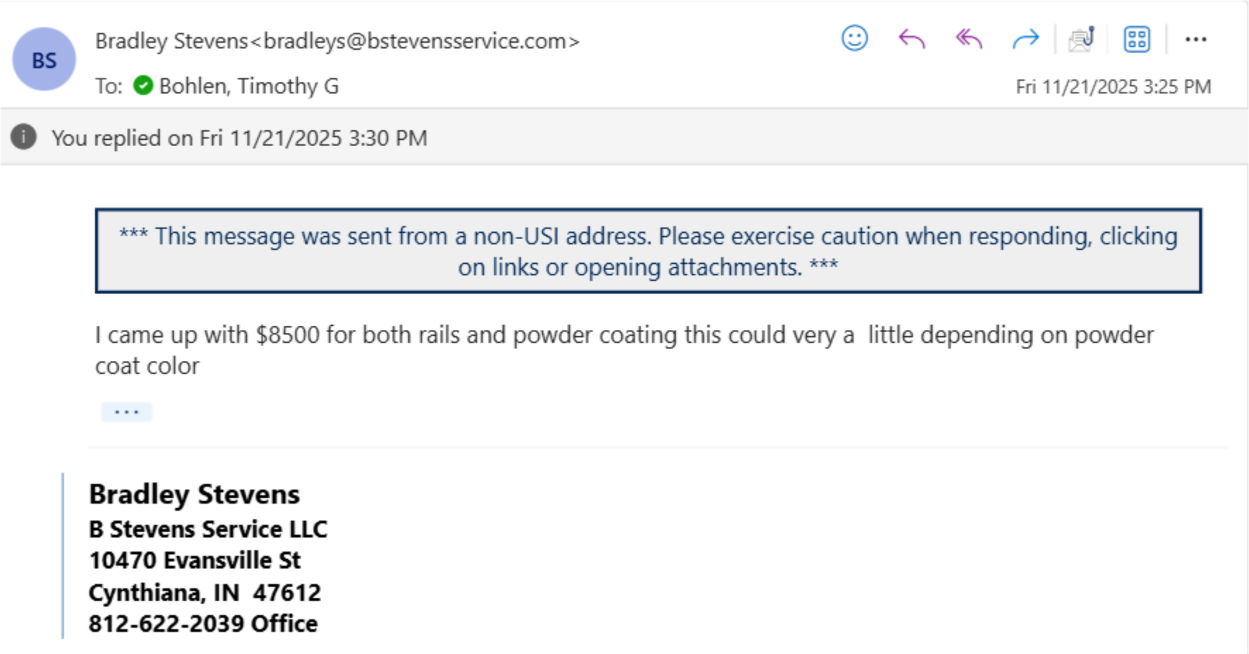
Force Majeure:
No party shall be liable or responsible to the other party, nor be deemed to have defaulted under or breached this agreement, for any failure or delay in fulfilling or performing its obligations under this agreement if such failure or delay is caused by or results from acts beyond the impacted party's reasonable control, including, but not limited to (a) acts of God; (b) natural disasters; (c) war, terrorist threats or acts, riot or other civil unrest; (d) strikes, lockouts or labor disputes; (e) epidemics or pandemics; (f) government order or law or action by any government authority; (g) shortage of power or transportation facilities; and (h) any other events beyond the reasonable control of the impacted party. The impacted party shall take all reasonable steps to mitigate the impact of the force majeure event, including exploring alternative means of fulfilling its obligations. The impacted party shall promptly notify the other party in writing of the occurrence of such event, its expected duration, and any anticipated changes in pricing or obligations resulting from the event. If the force majeure event significantly impacts the cost of performance, the parties shall negotiate in good faith to adjust the pricing obligations to reflect any increased costs incurred due to such event. Financial inability or changes in market conditions unrelated to a force majeure event shall not constitute a force majeure event.

Acceptance

Nix Industrial will accept approval of this proposal by either 1 of 2 ways: (1) Receipt of a customer purchase order in the amount that matches the quote letter "Total Project Cost" or (2) By signing and dating below and emailing all pages of this proposal, with a purchase order to follow, to the Nix Industrial contact listed above. Receipt of a purchase order and/or of the signed quote letter, shall signify that the Customer accepts this proposal and agrees to the terms and conditions and provisions as stated herewith. Please do not hesitate to contact Nix Industrial if you should have any questions or if further information is desired on the above proposal. Please include the Estimate Number in all correspondence and purchase orders. We thank you for allowing us the opportunity to provide you with our proposal and look forward to working towards a successful and profitable project together.

Signature

Date



Bradley Stevens<bradleys@bstevensservice.com>

To: Bohlen, Timothy G

Fri 11/21/2025 3:25 PM

You replied on Fri 11/21/2025 3:30 PM

I came up with $8500 for both rails and powder coating this could very a little depending on powder coat color

Bradley Stevens
B Stevens Service LLC
10470 Evansville St
Cynthiana, IN 47612
812-622-2039 Office

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	1
	INDIANA			

Appendix E

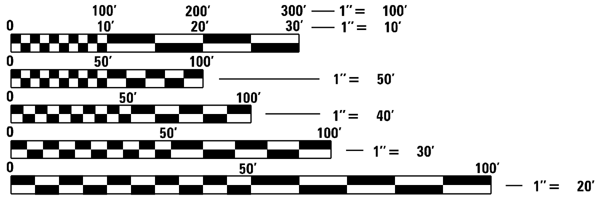
UNIVERSITY OF SOUTHERN INDIANA

POTT COLLEGE OF SCIENCE, ENGINEERING, AND EDUCATION

INDEX OF SHEETS

PROPOSED TRAIL PLANS

TRAIL IMPROVEMENTS
CITY OF EVANSVILLE
VANDERBURGH COUNTY
NOVEMBER 2025

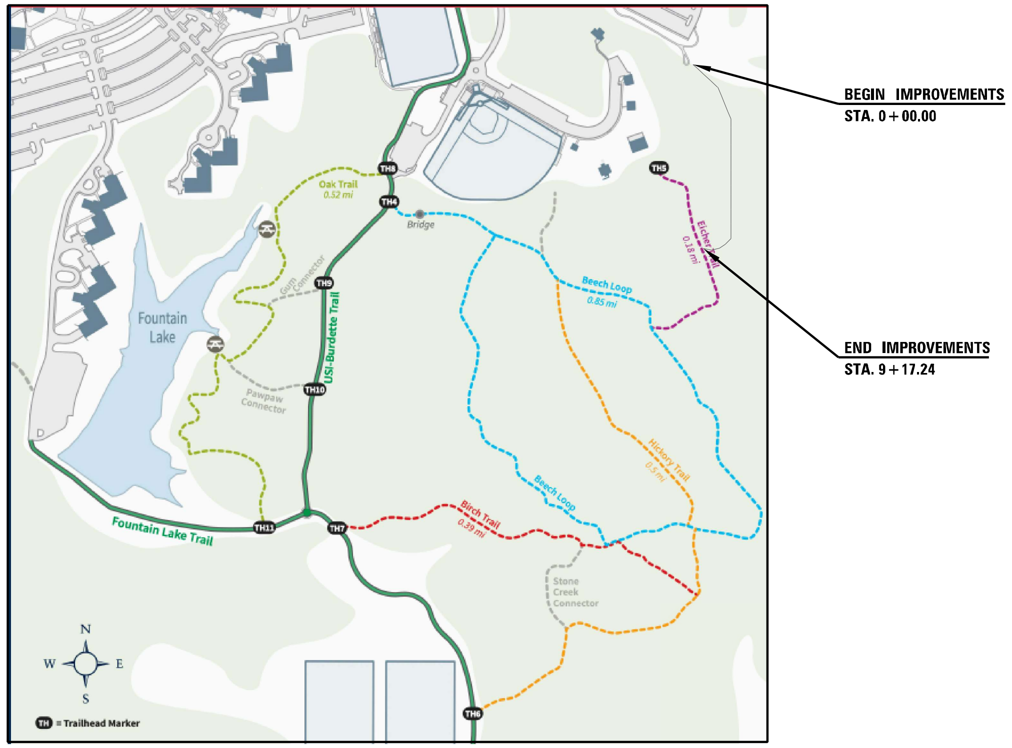


FULL SIZE PLANS HAVE BEEN PREPARED USING STANDARD ENGINEERING SCALES. REDUCED SIZED PLANS WILL NOT CONFORM TO STANDARD SCALES. IN MAKING MEASUREMENTS ON REDUCED PLANS, THE ABOVE SCALES MAY BE USED.

J.U.L.I.E.
JOINT UTILITY LOCATION INFORMATION FOR EXCAVATORS
1–800–892–0123
OR 811

PLANS PREPARED BY:

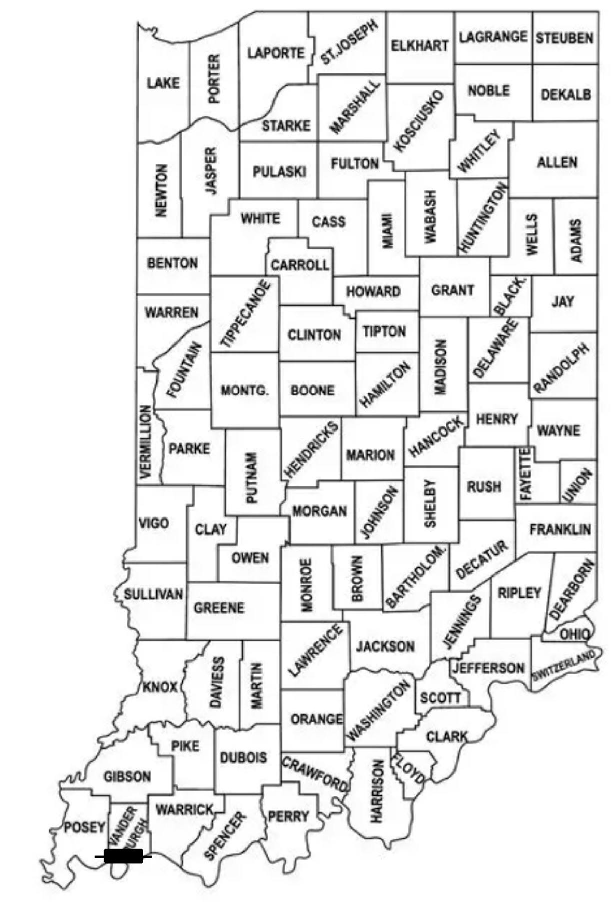
B.E.T. DESIGN



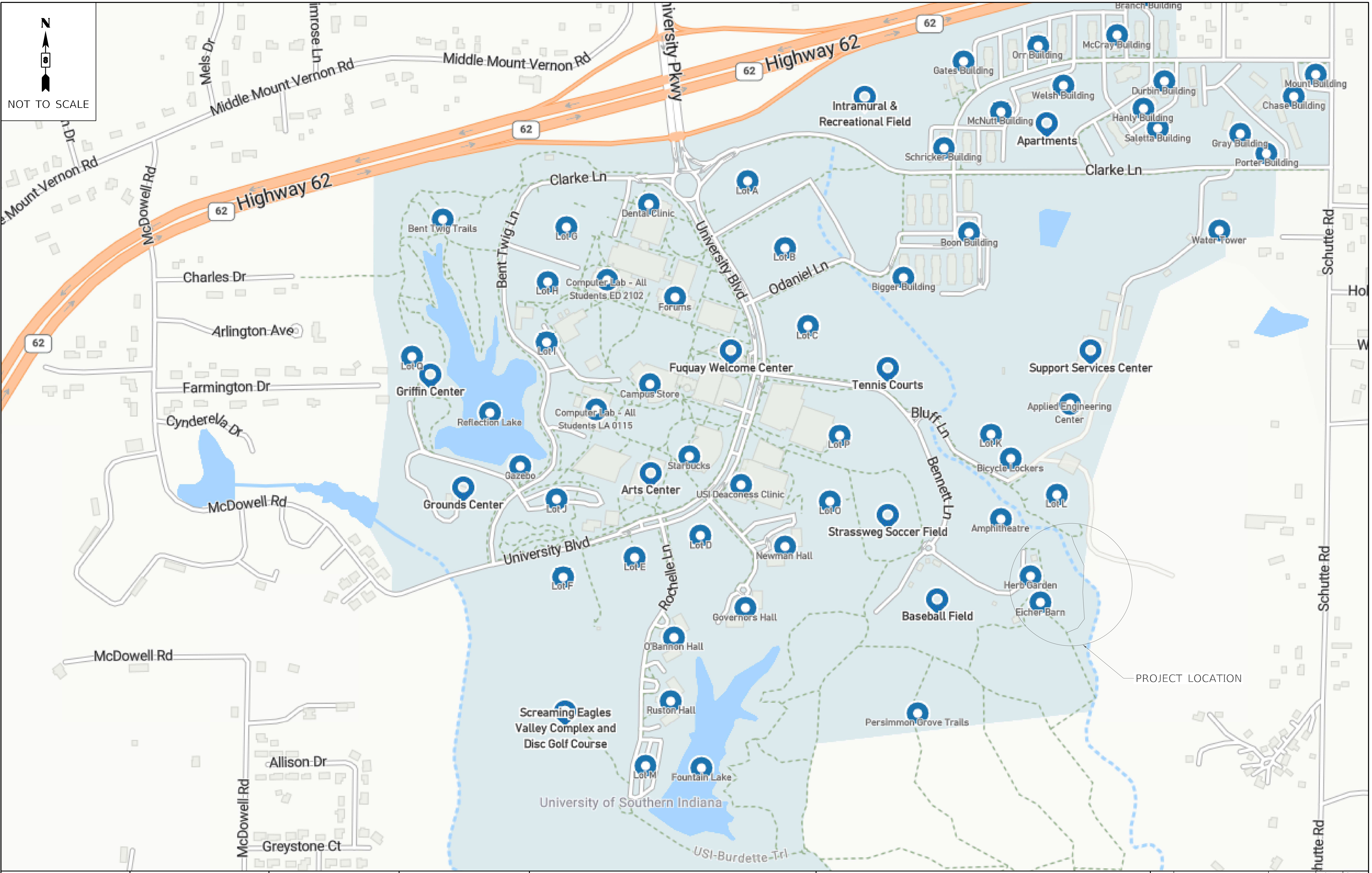
N.T.S.

GROSS LENGTH = 3082.05 FT = .584 MILE

NET LENGTH = 3082.05 FT = .584 MILE



LOCATION OF SECTION INDICATED THUS: –



MODEL: Default
FILE NAME: C:\Users\bstambaugh\Desktop\helpful\sen_design\sht-loc_map.dgn

UNIVERSITY OF SOUTHERN INDIANA

USER NAME = bstambaugh	DESIGNED - BCS	REVISED -
	DRAWN - BCS	REVISED -
PLOT SCALE = 40.0000 ' / in.	CHECKED - EMW	REVISED -
PLOT DATE = 11/24/2025	DATE - SEPT 2025	REVISED -

UNIVERSITY OF SOUTHERN INDIANA

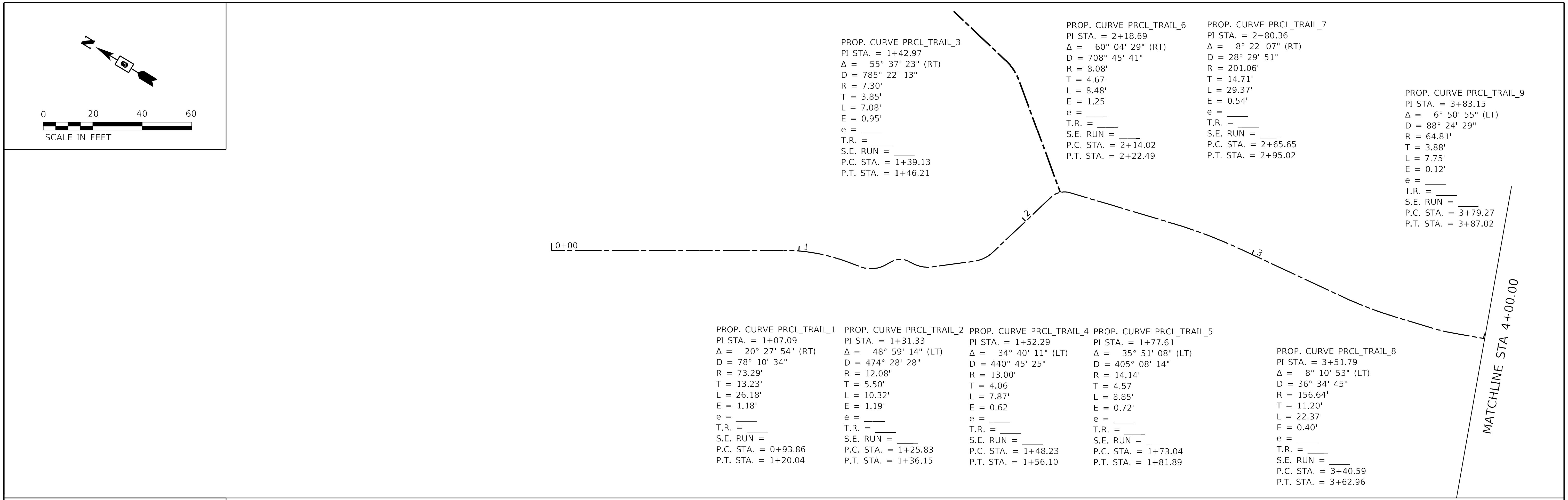
USI TRAIL – LOCATION MAP

SCALE: NTS SHEET 1 OF 1 SHEETS STA. TO STA.

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	

CONTRACT NO.

INDIANA FED. AID PROJECT



PROP. CURVE PRCL_TRAIL_3
PI STA. = 1+42.97
Δ = 55° 37' 23" (RT)
D = 785° 22' 13"
R = 7.30'
T = 3.85'
L = 7.08'
E = 0.95'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 1+39.13
P.T. STA. = 1+46.21

PROP. CURVE PRCL_TRAIL_6
PI STA. = 2+18.69
Δ = 60° 04' 29" (RT)
D = 708° 45' 41"
R = 8.08'
T = 4.67'
L = 8.48'
E = 1.25'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 2+14.02
P.T. STA. = 2+22.49

PROP. CURVE PRCL_TRAIL_7
PI STA. = 2+80.36
Δ = 8° 22' 07" (RT)
D = 28° 29' 51"
R = 201.06'
T = 14.71'
L = 29.37'
E = 0.54'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 2+65.65
P.T. STA. = 2+95.02

PROP. CURVE PRCL_TRAIL_9
PI STA. = 3+83.15
Δ = 6° 50' 55" (LT)
D = 88° 24' 29"
R = 64.81'
T = 3.88'
L = 7.75'
E = 0.12'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 3+79.27
P.T. STA. = 3+87.02

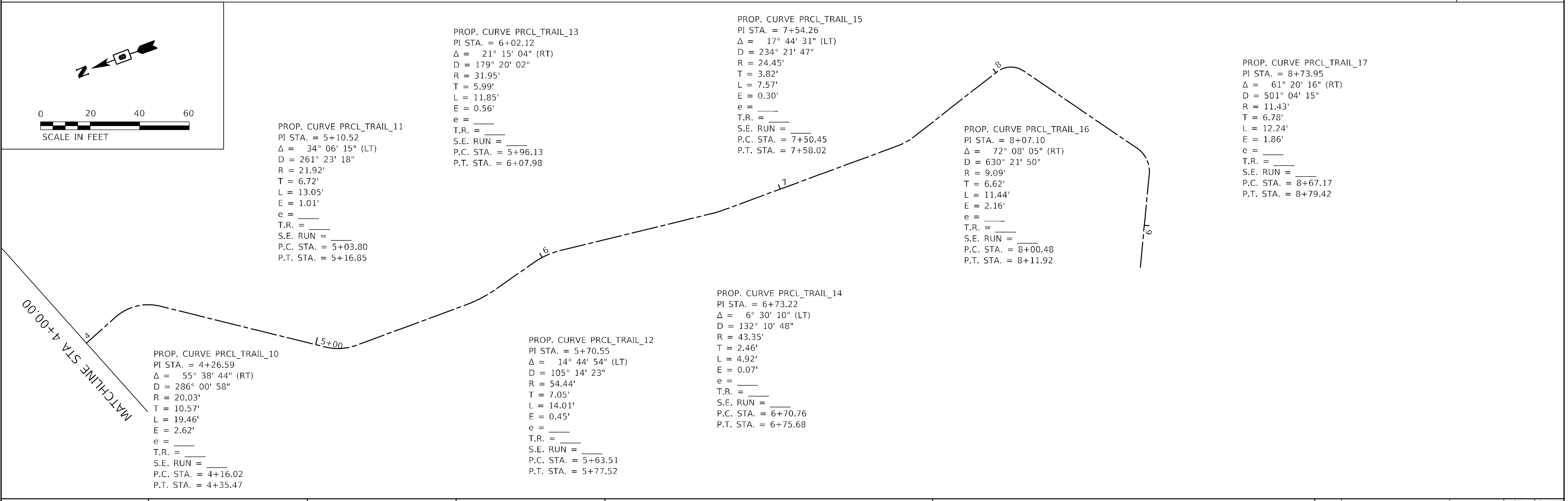
PROP. CURVE PRCL_TRAIL_1
PI STA. = 1+07.09
Δ = 20° 27' 54" (RT)
D = 78° 10' 34"
R = 73.29'
T = 13.23'
L = 26.18'
E = 1.18'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 0+93.86
P.T. STA. = 1+20.04

PROP. CURVE PRCL_TRAIL_2
PI STA. = 1+31.33
Δ = 48° 59' 14" (LT)
D = 474° 28' 28"
R = 12.08'
T = 5.50'
L = 10.32'
E = 1.19'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 1+25.83
P.T. STA. = 1+36.15

PROP. CURVE PRCL_TRAIL_4
PI STA. = 1+52.29
Δ = 34° 40' 11" (LT)
D = 440° 45' 25"
R = 13.00'
T = 4.06'
L = 7.87'
E = 0.62'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 1+48.23
P.T. STA. = 1+56.10

PROP. CURVE PRCL_TRAIL_5
PI STA. = 1+77.61
Δ = 35° 51' 08" (LT)
D = 405° 08' 14"
R = 14.14'
T = 4.57'
L = 8.85'
E = 0.72'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 1+73.04
P.T. STA. = 1+81.89

PROP. CURVE PRCL_TRAIL_8
PI STA. = 3+51.79
Δ = 8° 10' 53" (LT)
D = 36° 34' 45"
R = 156.64'
T = 11.20'
L = 22.37'
E = 0.40'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 3+40.59
P.T. STA. = 3+62.96



PROP. CURVE PRCL_TRAIL_13
PI STA. = 6+02.12
Δ = 21° 15' 04" (RT)
D = 179° 20' 02"
R = 31.95'
T = 5.99'
L = 11.85'
E = 0.56'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 5+96.13
P.T. STA. = 6+07.98

PROP. CURVE PRCL_TRAIL_15
PI STA. = 7+54.26
Δ = 17° 44' 31" (LT)
D = 234° 21' 47"
R = 24.45'
T = 3.82'
L = 7.57'
E = 0.30'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 7+50.45
P.T. STA. = 7+58.02

PROP. CURVE PRCL_TRAIL_17
PI STA. = 8+73.95
Δ = 61° 20' 16" (RT)
D = 501° 04' 15"
R = 11.43'
T = 6.78'
L = 12.24'
E = 1.86'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 8+67.17
P.T. STA. = 8+79.42

PROP. CURVE PRCL_TRAIL_11
PI STA. = 5+10.52
Δ = 34° 06' 15" (LT)
D = 261° 23' 18"
R = 21.92'
T = 6.72'
L = 13.05'
E = 1.01'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 5+03.80
P.T. STA. = 5+16.85

PROP. CURVE PRCL_TRAIL_16
PI STA. = 8+07.10
Δ = 72° 08' 05" (RT)
D = 630° 21' 50"
R = 9.09'
T = 6.62'
L = 11.44'
E = 2.16'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 8+00.48
P.T. STA. = 8+11.92

PROP. CURVE PRCL_TRAIL_14
PI STA. = 6+73.22
Δ = 6° 30' 10" (LT)
D = 132° 10' 48"
R = 43.35'
T = 2.46'
L = 4.92'
E = 0.07'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 6+70.76
P.T. STA. = 6+75.68

PROP. CURVE PRCL_TRAIL_12
PI STA. = 5+70.55
Δ = 14° 44' 54" (LT)
D = 105° 14' 23"
R = 54.44'
T = 7.05'
L = 14.01'
E = 0.45'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 5+63.51
P.T. STA. = 5+77.52

PROP. CURVE PRCL_TRAIL_10
PI STA. = 4+26.59
Δ = 55° 38' 44" (RT)
D = 286° 00' 58"
R = 20.03'
T = 10.57'
L = 19.46'
E = 2.62'
e = ____
T.R. = ____
S.E. RUN = ____
P.C. STA. = 4+16.02
P.T. STA. = 4+35.47

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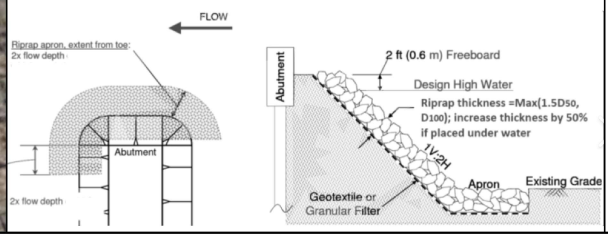
USI TRAIL – ALIGNMENT

SCALE: 1"=20' | SHEET 1 OF 1 SHEETS | STA. 0+00.00 TO STA. 9+25.83

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	
		CONTRACT NO.		
		INDIANA	FED. AID PROJECT	

RIP RAP DETAIL



NOTES:

1. ALIGNMENT IS SUBJECT TO CHANGE UNDER THE DISCRECTION OF THE OPERATOR TO AVOID CUTTING DOWN EXCESS TREES.
2. TO MINIMIZE ENVIRONMENTAL IMPACT, ANY TREE REMOVED MUST BE REPLANTED AT THE DESCRETION OF THE FIELD ENGINEER.
3. STAKES ARE MARKED IN FIELD WITH PINK PAINT/ TAPE.

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USI TRAIL – PLAN

SCALE: 1"=20' | SHEET 1 OF 1 SHEETS | STA. 0+00.00 TO STA. 9+25.83

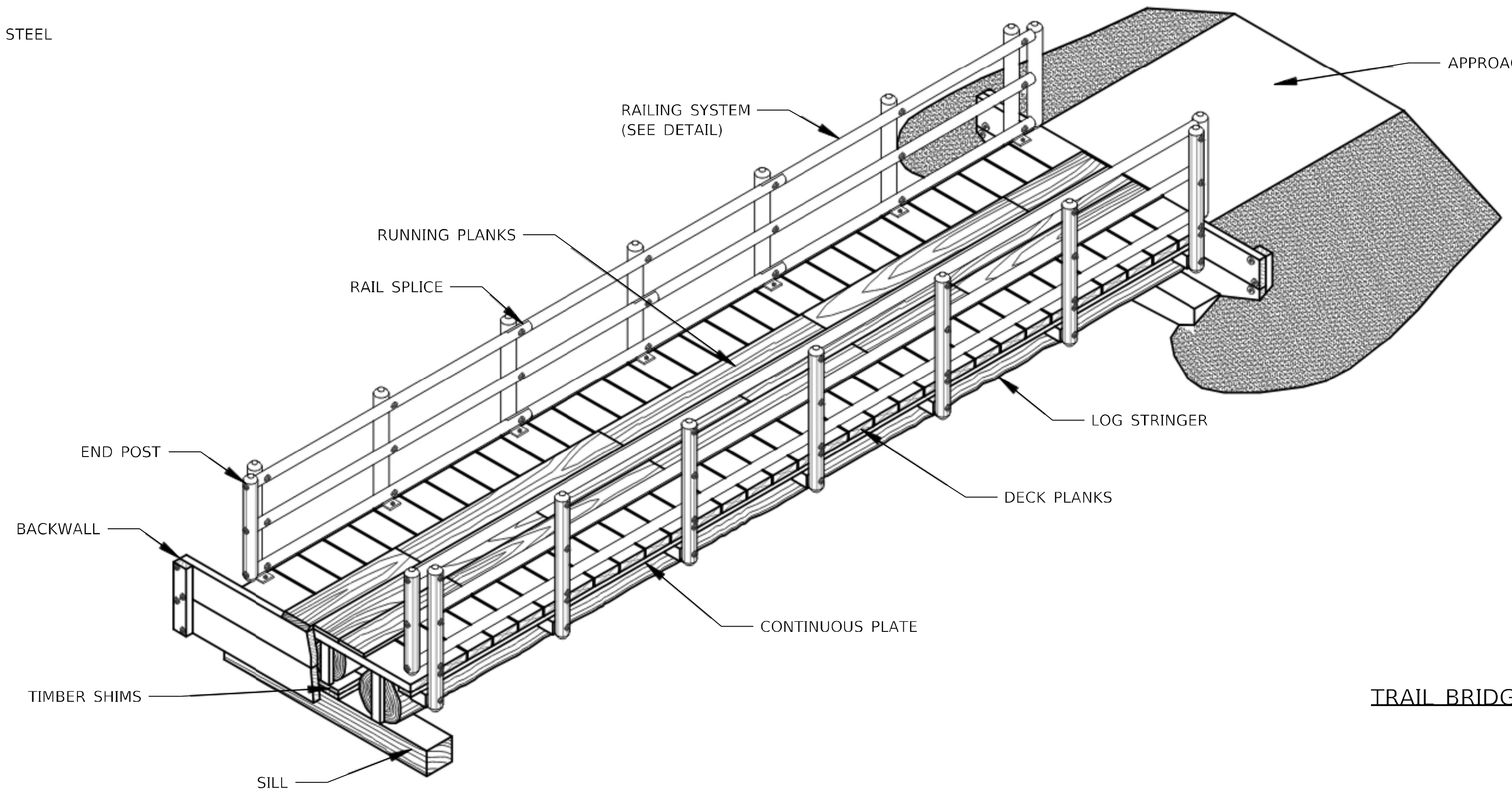
F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	
		CONTRACT NO.		
	INDIANA	FED. AID PROJECT		

								STRINGER				DECK			BACKWALL					
STRUCTURE NUMBER	TRAIL	BRIDGE LOCATION	BRIDGE LENGTH OUT-TO-OUT	STRINGER SPAN ℄-℄ BRNG	BRIDGE CLEAR WIDTH	PEDESTRIAN LOAD	GROUND SNOW LOAD	SPECIES	NUMBER	MATERIAL SIZE (DIAMETER)	TREATMENT	SPECIES	SIZE	TREATMENT	TYPE	SPECIES	SIZE	WIDTH	DEPTH	TREATMENT
1	USI TRAIL	~ 1+35	9'-2"	10'-0"	9'-0"	97 PSF	20 PSF	SP #1	6	14"	PRE TREATED	SPF #2	2" X 8"	YES	NA	NA	NA	NA	NA	NA
2	USI TRAIL	~ 4+60	9'-2"	39'-0"	9'-0"	97 PSF	20 PSF	SP #1	6	14"	PRE TREATED	SPF #2	2" X 8"	YES	NA	NA	NA	NA	NA	NA

NA = NOT APPLICABLE, BACKWALL TYPE: ST = STONE, W = WOOD

	RAILING SYSTEM					RUNNING PLANK				SILL			APPROACHES						HARDWARE	
STRUCTURE NUMBER	SPECIES	TYPE	HEIGHT	MATERIAL TYPE	TREATMENT	SPECIES	SIZE	WIDTH	TREATMENT	TYPE	SIZE	SPECIES	LENGTH		WIDTH	MATERIAL TYPE	MATERIAL DEPTH	GEO-SYNTHETIC TYPE	COATING	COMMENTS
													NEAR	FAR						
1	S	NA	SEE DETAIL	SEE DETAIL	SEE DETAIL	NA	NA	NA	NA	WOOD	6" X 12"	SPF #1	20'	20'	14'-0"	CONC	TO BEDROCK	NA	GALV	SEE CALCS
2	S	NA	SEE DETAIL	SEE DETAIL	SEE DETAIL	NA	NA	NA	NA	WOOD	6" X 12"	SPF #1	40'	25'	14'-0"	CONC	TO BEDROCK	NA	GALV	SEE CALCS

RAILING SYSTEM MATERIAL TYPE: R = ROUND LOG, D= DIMENSIONAL LUMBER, S = STEEL
ABUTMENT MATERIAL TYPE: SS = SOLID SAWN, GLU = GLULAM, CONC = CONCRETE
HARDWARE COATING TYPE: GALV = GALVANIZED, UNC = UNCOATED, WEA = WEATHERING STEEL



TRAIL BRIDGE W/ RAILING SYSTEM

APPROACH NOT SHOWN FOR CLARITY

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USI TRAIL – TRAIL BRIDGE

SCALE: NTS | SHEET 1 OF 4 SHEETS | STA. TO STA.

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	

CONTRACT NO.

INDIANA | FED. AID PROJECT

GENERAL NOTES:

SPECIFICATIONS: MATERIALS AND CONSTRUCTION OF THIS STRUCTURE SHALL BE IN ACCORDANCE WITH THE STANDARD SPECIFICATION FOR CONSTRUCTION OF ROADS AND BRIDGES ON FEDERAL HIGHWAY PROJECTS (FP-03) AND STANDARD SPECIFICATIONS FOR CONSTRUCTION OF TRAILS AND TRAIL BRIDGES ON FEDERAL PROJECTS

LOG MEMBERS: LOGS USED FOR STRINGERS SHALL BE RECYCLED TIMBER POLES AND REVIEWED BY THE FIELD ENGINEER PRIOR TO PLACEMENT. TAPERED ENDS SHALL BE PLACED IN AN ALTERNATING PATTERN AS APPROVED BY THE FIELD ENGINEER.

TIMBER & LUMBER: SOLID SAWN TIMBER MEMEBERS SHALL CONFORM TO THE REQUIREMENTS OF GRADING RULES AND AGENCY FOR THE SPECIES, TYPE, AND GRADE SPECIFIED BELOW.

DECKS PLANKS, SILLS, AND BACKING PLANKS
  - SPRUCE PINE FIR NO. 2 GRADING RULES AGENCY - SPIB
RUNNING PLANKS
  - SPRUCE PINE FIR NO. 2 GRADING RULES AGENCY - SPIB

TREATMENT: SEE PROJECT CRITERIA FOR MEMBERS IDENTIFIED TO BE TREATED AND FOR TREATMENT TYPE. PRESERVATIVE TREATMENT SHALL BE IN ACCORDANCE WITH THE CURRENT AMERICAN WOOD PROTECTION ASSOCIATION (AWPA) SPECIFICATIONS USING THE TREATMENT MATERIALS LISTED BELOW. TREATMENT WILL COMPLY WITH THE REQUIREMENTS OF THE CURRENT EDITION OF WESTERN WOOD PRESERVERS INSTITUTE (WWPI) "BEST MANAGEMENT PRACTICES FOR THE USE OF TREATED WOOD IN AQUATIC ENVIRONMENTS".

STRINGERS, DECKING, RUNNING PLANKS, IF TREATED
  - AWPA USE CATEGORY SYSTEM (U1) FOR USE CATEGORY 3B ABOVE GROUND-EXPOSED (UC3B)
  - PENTACHLOROPHENOL IN LIGHT OIL (TYPE C SOLVENT)
  - COPPER NAPHTHENATE (CuN) IN HEAVY OIL (TYPE A SOLVENT)
SILLS, BACKING PLANKS, CRUBS, & TIMBER WALLS, IF TREATED
  - AWPA USE CATEGORY SYSTEM (U1) FOR USE CATEGORY 4B GROUND CONTACT-HEAVY DUTY (UC4B)
  - PENTACHLOROPHENOL IN HEAVY OIL (TYPE A SOLVENT)
  - COPPER NAPHTHENATE (CuN) IN HEAVY OIL (TYPE A SOLVENT)

FIELD TREATMENT: COPPER NAPHTHENATE (2% SOLUTION) SHALL BE FURNISHED FOR FIELD TREATING OF WOOD. ALL ABRASIONS AND FIELD CUTS - APPROVED BY THE C.O.R. - SHALL BE CAREFULLY TRIMMED AND GIVEN THREE BRUSH COATS OF THE FIELD TREATMENT SOLUTION. WHERE APPROVED, FIELD DRILLING OF BOLT, SCREW OR NAIL HOLES IS REQUIRED. THE HOLES SHALL BE FILLED WITH PRESERVATIVE PRIOR TO INSERTING THE FASTENERS.

THE ENDS OF UNTREATED LOG STRINGERS (REFER TO THE PROJECT DESIGN CRITERIA), SHALL ALSO RECIEVE THREE BRUSHE COATS OF THE FIELD TREATMENT PRIOR TO INSTALLATION OF THE BACKING PLANKS.

HARDWARE AND STRUCTURAL STEEL: SEE PROJECT DESIGN CRITERIA FOR STELL HARDWARE FINISH. GALVANIZED OR UNFINISHED HARDWARE SHALL MEET THE REQUIREMENTS OF AASHTO M270, GRADE 36, WITH NUTS AND BOLTS CONFORMING TO ASTM A307, GRADE A. WEATHERING STEEL AND HARDWARE SHALL MEET THE REQUIREMENTS OF AASHTO M270, GRADE 50W, WITH BOLTS AND NUTS CONFORMING TO ASTM A325, TYPE 3. USE MALLEABLE IRON WASHERS AGAINST WOOD UNLESS OTHERWISE NOTED.

WHEN STRUCTURAL STEEL IS TO BE WELDED, THE WELDING PROCEDURE SHALL BE IN ACCORDANCE WITH AWS D1.1 AND SHALL BE SUITABLE FOR THE GRADE OF STEEL AND INTENDED USE OR SERVICE.

FABRICATION: SUBMIT SHOP DRAWINGS FOR ALL MANUFACTURED BRIDGE COMPONENTS (EXCEPT TIMBER RUNNING PLANKS). SHOW ALL DIMENSIONS AND FABRICATION DETAILS FOOR ALL CUT OR BORED TIMBER. FIELD DRILLING OF HOLES SHALL NOT BE ALLOWED UNLESS OTHERWISE NOTED ON THE PLANS.

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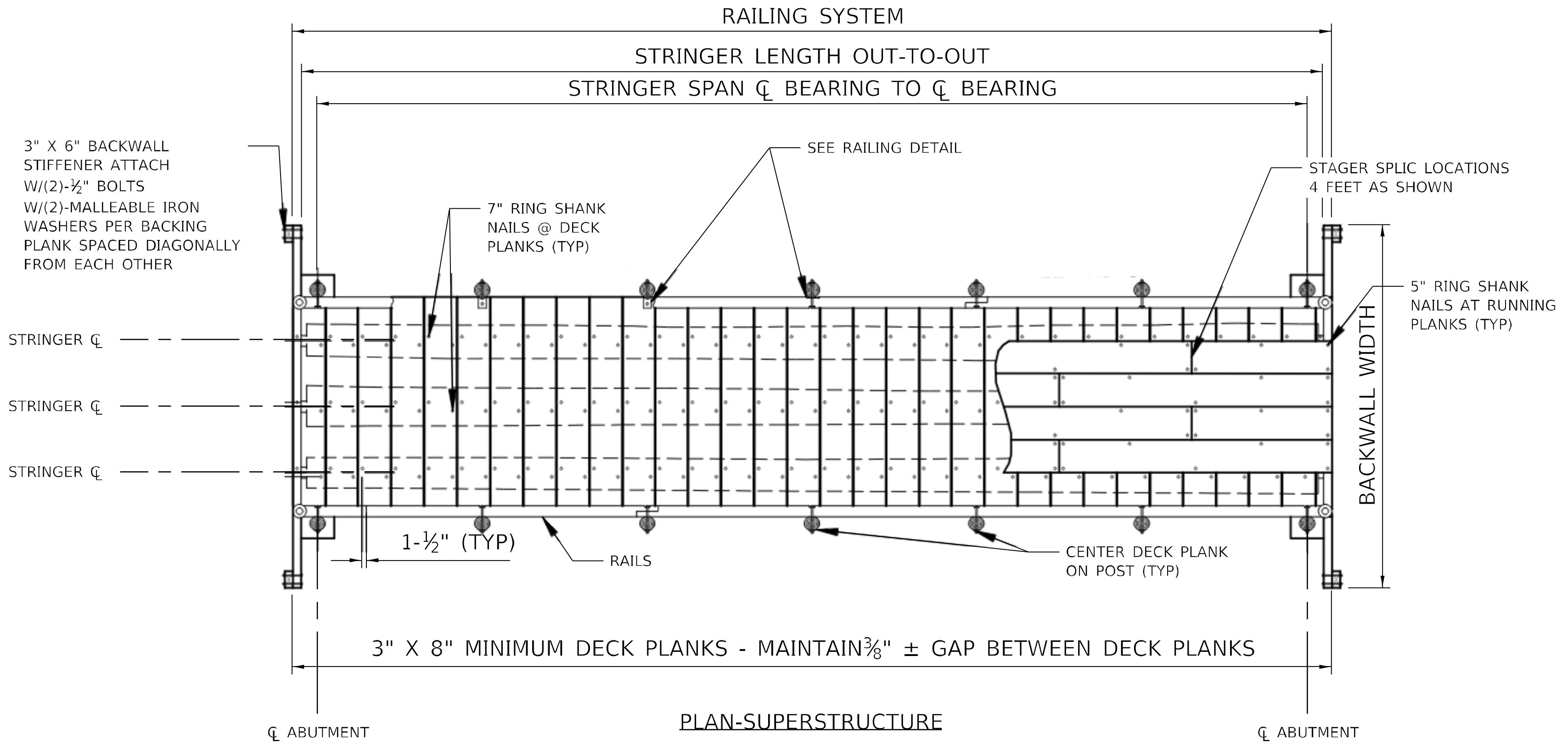
USI TRAIL – TRAIL BRIDGE

SCALE: NTS | SHEET 2 OF 4 SHEETS | STA. TO STA.

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	

CONTRACT NO.

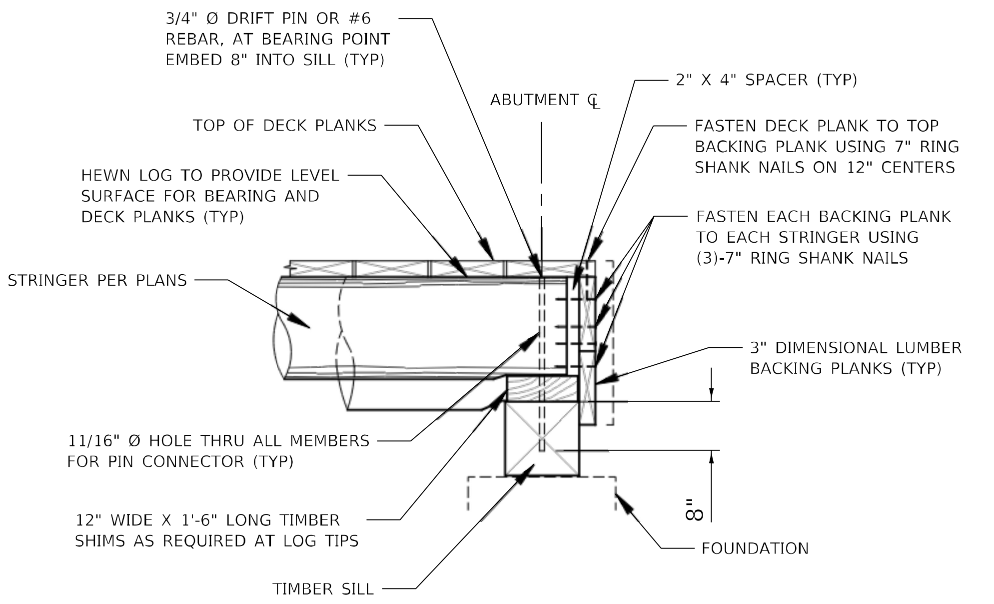
INDIANA FED. AID PROJECT



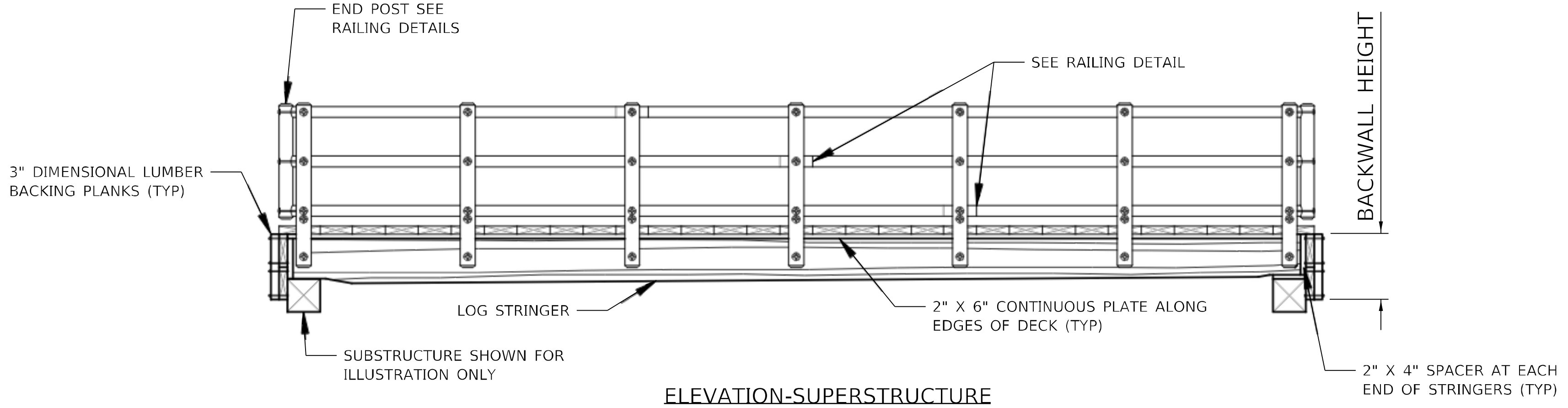
PLAN-SUPERSTRUCTURE

* NAIL PATTERN OFFSET 1½INCH EACH WAY FROM THE ℄ OF THE STRINGER

** NAIL 1½INCH FROM EDGES OF BOARD

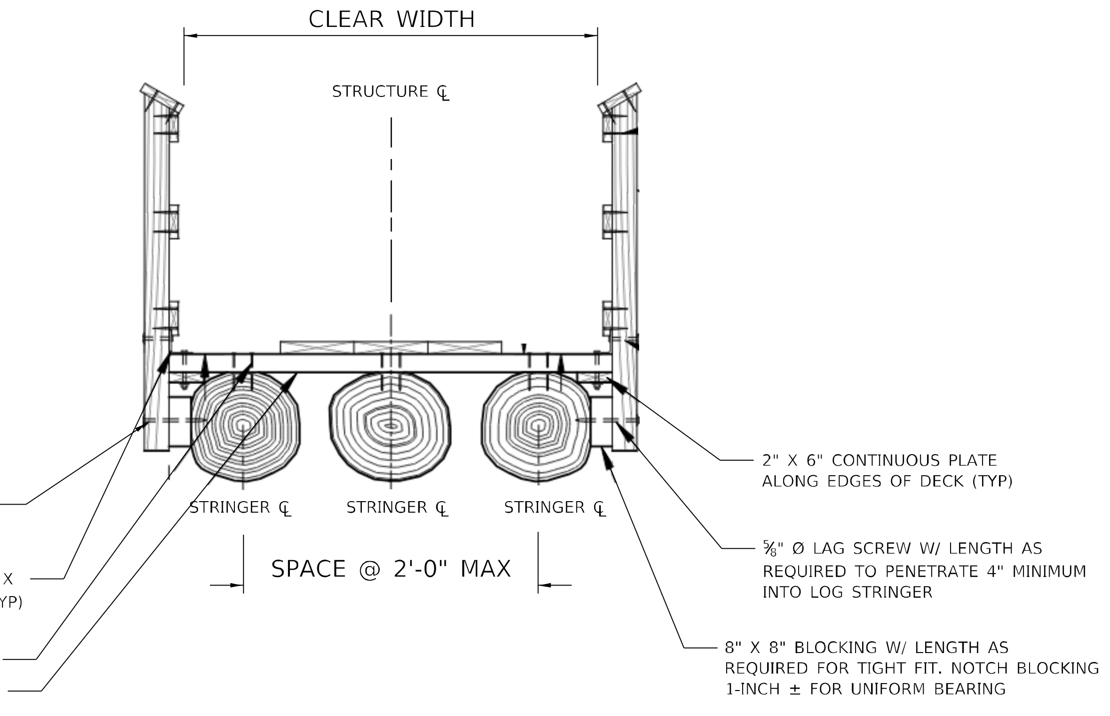


LOG STRINGER BRIDGE ABUTMENT CONNECTION DETAILS



ELEVATION-SUPERSTRUCTURE

GRADE SHOWN AT 0.0%, RUNNING PLANKS NOT SHOWN FOR CLARITY

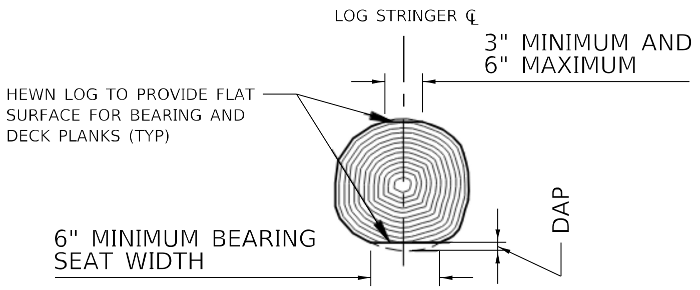


DECK SECTION W/ RAILING SYSTEM

* SEE RAILING SHEET FOR DETAILS

NOTES:

1. SPLICE RAILS AT POSTS. RAILS SHALL BE CONTINUOUS FOR A MINIMUM OF TWO POST SPACES. ALTERNATE RAIL SPLICES AT POSTS.
2. FASTEN RUNNING PLANKS TO DECK WITH 40d 5-INCH LONG RING SHANK NAILS AT 24-INCH SPACING. ALTERNATE SIDES WITH TWO AT EACH END. SEE PLAN-SUPERSTRUCTURE FOR LAYOUT TYPICAL.
3. FASTEN DECK PLANKS TO STRINGERS WITH TWO ROWS 5/16-INCH DIAMETER X 7-INCH RING SHANK NAILS PER PLANK AT EACH STRINGER. ALTERNATE SIDES.



LOG STRINGER DAPPING

MAXIMUM DEPTH OF DAP SHALL NOT EXCEED 10% OF LOG DIAMETER OR 2-INCH

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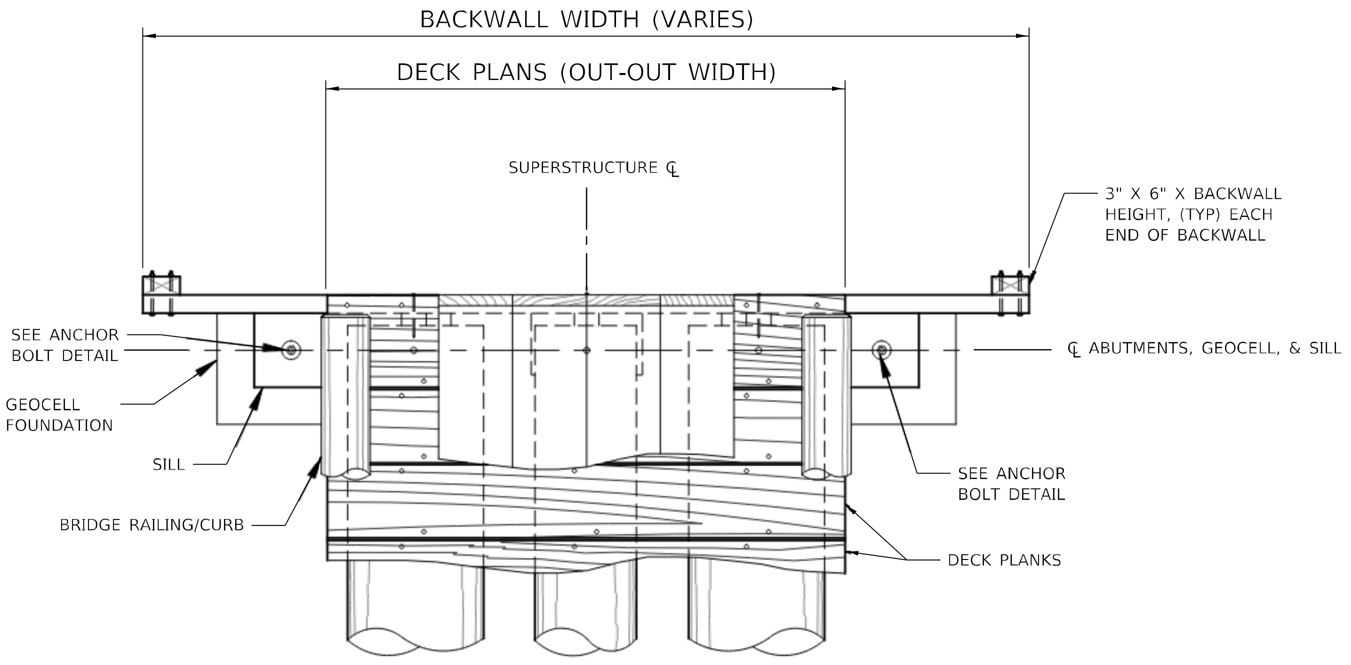
USI TRAIL – TRAIL BRIDGE

SCALE: NTS | SHEET 3 OF 4 SHEETS | STA. TO STA.

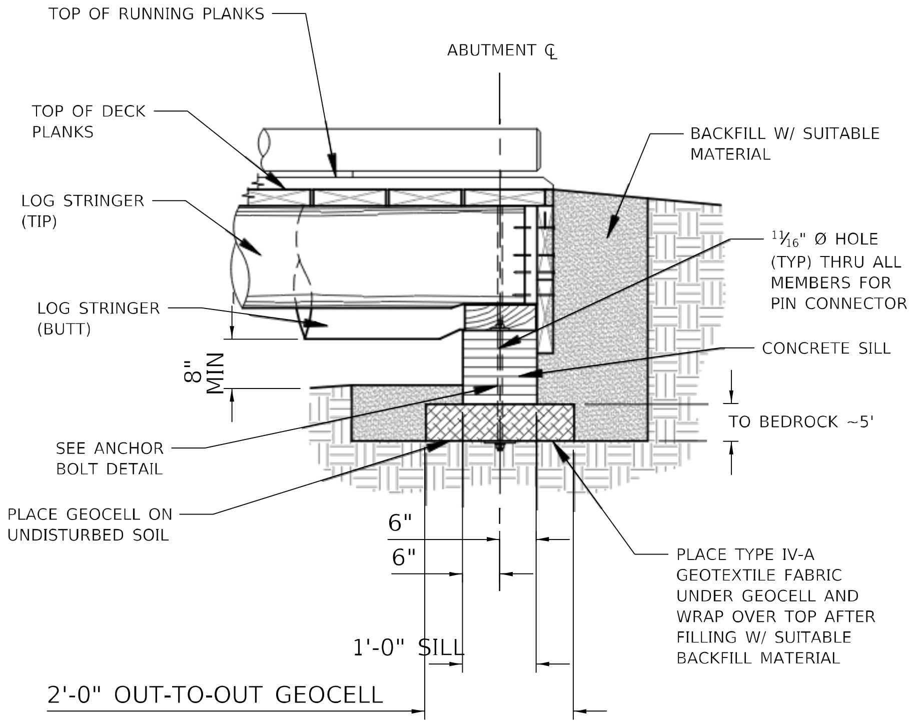
F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	

CONTRACT NO.

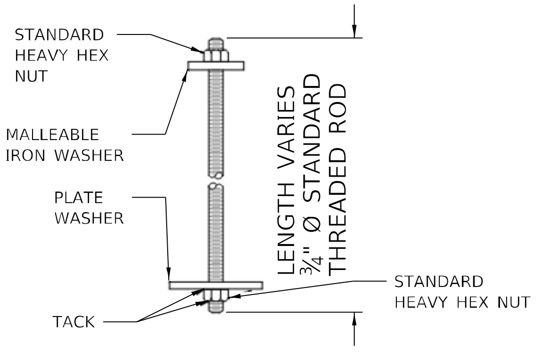
INDIANA | FED. AID PROJECT



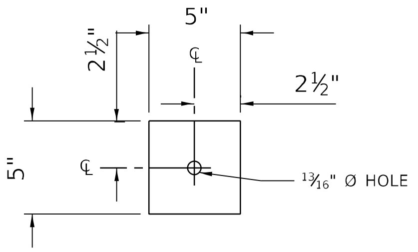
PLAN



SECTION A-A

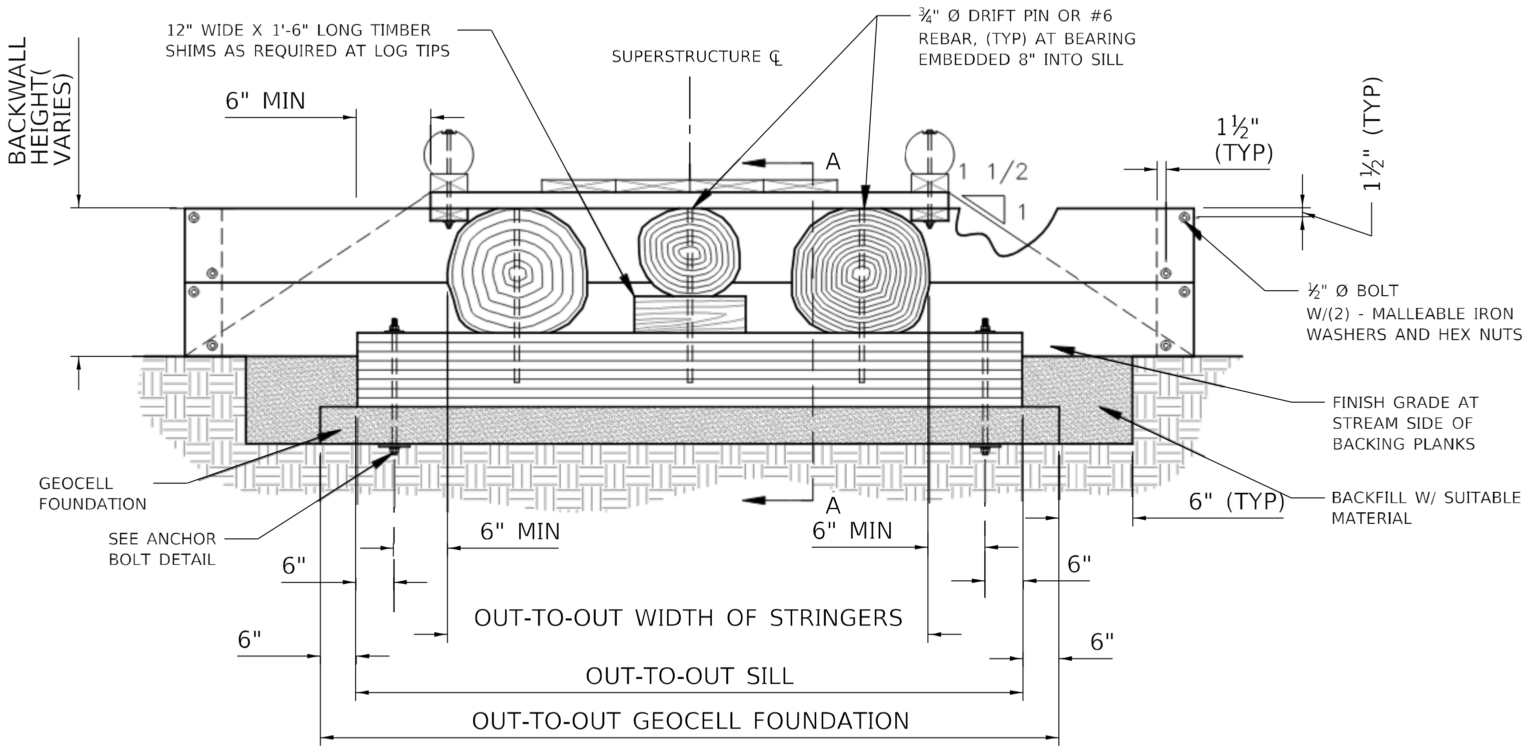


ELEVATION



⅜" A-36 STEEL PLATE WASHER DETAIL, ANCHOR BOLT DETAIL

FOUNDATION NOTES:



ELEVATION

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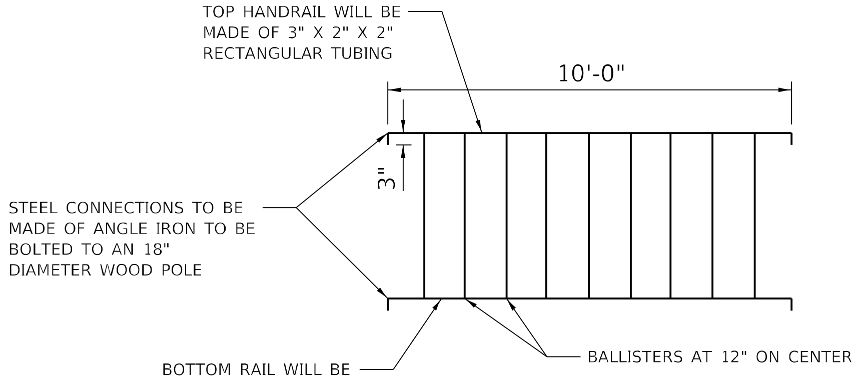
USI TRAIL – TRAIL BRIDGE

SCALE: NTS | SHEET 4 OF 4 SHEETS | STA. TO STA.

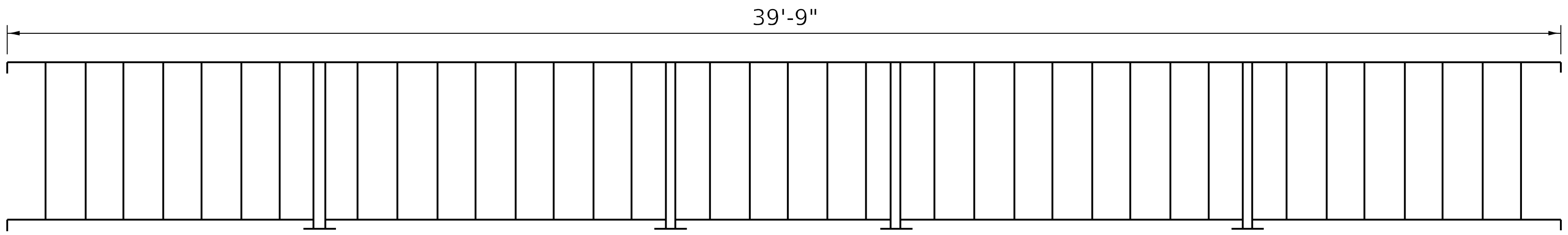
F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	

CONTRACT NO.

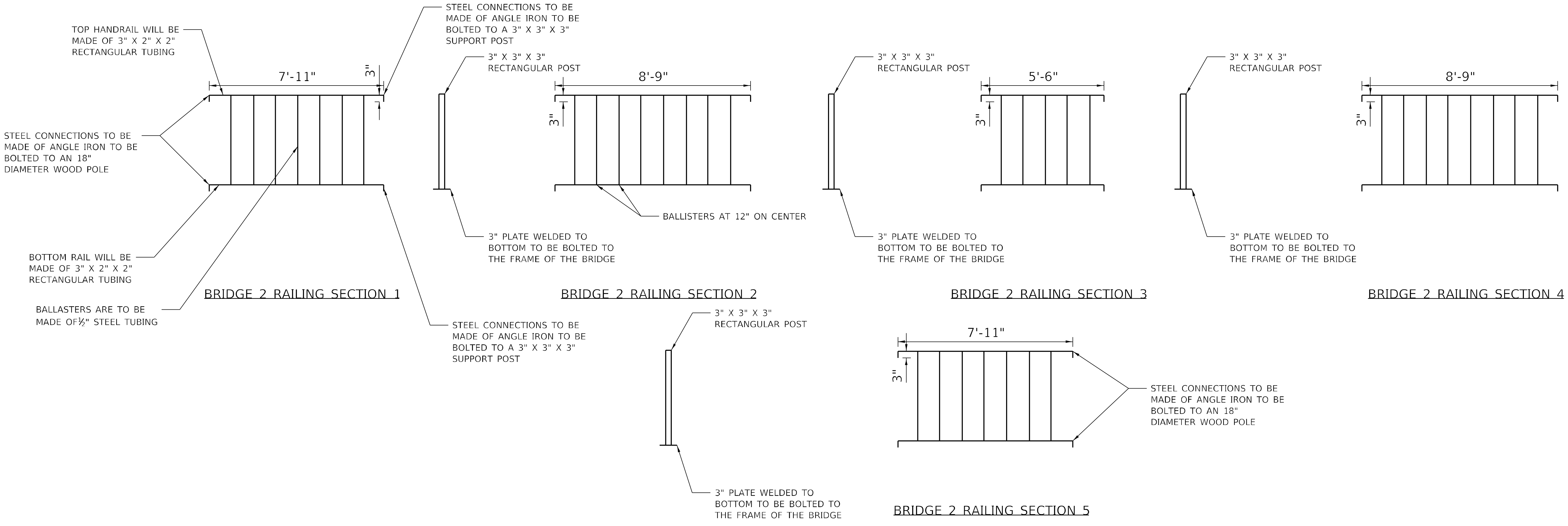
INDIANA | FED. AID PROJECT



BRIDGE 1 RAILING



BRIDGE 2 RAILING



BRIDGE 2 RAILING SECTION 1

BRIDGE 2 RAILING SECTION 2

BRIDGE 2 RAILING SECTION 3

BRIDGE 2 RAILING SECTION 4

BRIDGE 2 RAILING SECTION 5

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USI TRAIL – BRIDGE RAIL DETAIL

SCALE: NTS
SHEET 1 OF 1 SHEETS
STA. TO STA.

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
N/A	USI BRIDGE & TRAIL	VANDERBURGH	9	

CONTRACT NO.

INDIANA FED. AID PROJECT

Appendix D

Big Bridge Hand Calculations

Loads

Pedestrian		90	psf	
ATV		2402	lbs	
		6.843304843	psf	add to pedestrian load

Geomentry

O-O Coping	most extreme width	9	ft			
Span A Length	from center endbent to center endbent	39	ft			
				typical		
Plank span Length		8	in	actual	7.25	in
Plank width		2	in	actual	1.5	in
pole spacing		21.6	in	actual spacing is 18 in		

For planks

Assumptions

Span (for plank)		21.6	in			
		1.8	ft			
Plank span Length		8	in	actual	7.25	in
Plank width		2	in	actual	1.5	in
density (assumed)		40	pcf			
plank thickness		0.125	ft			
Self Weight for plank		5	psf			
Railing Dead Load (metal)		0	psf	assume no significant weight		
Total dead on plank		5	psf			
Total Load (DL+LL)		101.8433048	psf			
for planks (assume SPF #2)	E	1.20E+06	psi	from NDS		
	Fb	875	psi	from NDS		
	Fv	135	psi	from NDS		

Calcs

letter/name	**equation**	**value**	**units**	**notes**
w	w = total load / plank width	12.73041311	plf	
Mmax	$M = \frac{wL^2}{8}$	5.16	lb-ft	
		61.87	lf-in	
S	$S = \frac{bd^2}{6}$	13.14	in^3	
I	I = bh^3/12	47.63	in^4	
check bending plank				
fb	$M_{allowable} = F_b' \cdot S$	4.71	psi	
Fb		875	psi	from NDS above
		Okay		

Check Shear Stress

V	V=wL/2	11.457	lb	
A	A = b*L	10.875	in^2	
fv	fv = V/A	1.054	psi	
Fv		135	psi	from NDS above
		Okay		

Check Deflection

$$\Delta = \frac{5wL^4}{384EI}$$

δ		5.26E-05	in
δallow	L/360	0.06	in
		Okay	

Dead load Calcs

area of deck	width x length	351	ft^2
Beam Dead Load			
Diameter		14	
length		39	
density of wood		40	pcf
number of beams		6	beams
spacing		21.60	in
V	pi x r^2 x h	41.69	ft^3
wbeam	V x density	1,667.66	lb per beam
total beam weight	wbeam x number of beams	10,005.97	
wbeam,psf	total beam weight/deck area	28.51	psf

Telephone Poles

Inputs					
Total area of Bridge		351.00	ft^2		
Total Live Load	LL*O-O Coping * deck length	31,590.00	lb		
DL Decking		5.00	psf		
DL Poles		28.51	psf		
DL total	DL Decking + DL Poles	11,760.97	lb		
total load	DL + LL	43,350.97	lb		
w	pedestian + DL Deck + DL Poles(self weight)	123.51	psf		
	w*total area of bridge	43,350.97	lb		
rough estimate # beams	deck width/24	4.50	=	6	beams
rough spacing	deck width/4	21.60	" on center		
E	assume southern pine #1	1,500,000.00	psi	from NDS	
Fb		1,350.00	psi	from NDS	
Fv		165.00	psi	from NDS	
load per beam	total load / number of beams	7,225.16	lb per beam		
w	load per beam / span length	185.26	lb/ft		

Bending Check

Mmax	$M = \frac{wL^2}{8}$	35,222.67	lb-ft			
Vmax	$V = \frac{wL}{2}$	3,612.58	lb			
	Telephone pole capacity check					
pole diameter		14.00	in			
Smax	$S = \frac{\pi d^3}{32}$	269.39	in^3			
Cd		1.25	from NDS			
Cm		1.00	from NDS			
Cl		1.00	from NDS			
Ct		1.00	from NDS			
Fb'	$F_b' = F_b \times C_d \times C_m \times C_L \times C_t$	1,687.50	psi	fb	1568.987	psi
S	$S = \frac{M}{F_b}$	250.47	in^3			
S<Smax	Okay			Okay		

Shear check

A	$A = \frac{\pi}{4} d^2$	153.94	in^2	
Ashear	$A_s = \frac{2}{3} A$	102.63	in^2	
Tau	$\tau = \frac{V}{A_s}$	35.20	psi	over estimate
F'v		206.25		
Fv>T	Okay			

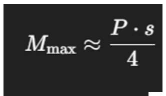
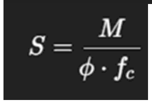
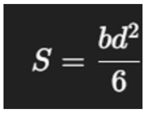
Deflection Check

allow	L/180	1.30	in
w	total load in psi	10.29	lb/in
L	span length	32.00	ft
E		1,200,000.00	psi
I	$I = \frac{\pi d^4}{64}$	1,885.74	
rho max	$\delta_{\max} = \frac{5wL^4}{384EI}$	0.11	in
	Okay		

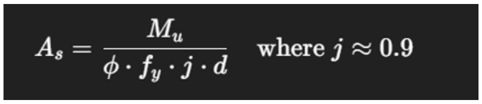
End Bents / Abutments

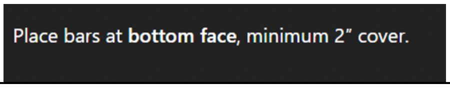
pile diameter (concrete)		12.00	in	assume using concrete piles
length of pile		5.00	ft	from field for both sites
Total Span		39.00	ft	
Deck Width		9.00	ft	
Total DL		11,760.97	lb	
LL	pedestrain x deck width x total span	31,590.00	lb	
Total Load	DL+LL	43,350.97	lb	
Total reaction at each end	total load / 2	21,675.49	lb	
# of Piles		4.00	piles per side	
Ppile	total load at ends / number of piles	5,418.87	lb per pile	
Pile Capacity				
end bearing				
base area	pi x d^2 /4	0.79	ft^2	
stiff soil	assume	2,000.00	psf	
Ab	basse area x stiff soil	1,570.80	lb	
Skin friction				
As	pi x d x h	15.71	ft^2	
skin friction	assume	300.00	psf	
Qb		4,712.39	lb	
Qpile	Ab+Qb	6,283.19	lb	Okay
Lateral Load Capacity	10% x total load	2,167.55	lb	
Per pile	lateral load / number of piles	541.89	lb per pile	Okay

Pile Cap Design

Width		14.00	ft
Depth		36.00	in
Length		3.00	ft
number of spaces between beams	total number of beams - 1	5.00	
number of beams		6.00	
span between piles		3.00	ft
diameter of beam		14.00	in
f'c		3,000.00	
Fy		60,000.00	psi
Load at each beam location	total load / number of beams	7,225.16	lb
Mmax	 $M_{\max} \approx \frac{P \cdot s}{4}$	5,418.87	lb-ft
S	 $S = \frac{M}{\phi \cdot f_c}$	263.83	in
h		18.00	in
S	 $S = \frac{bd^2}{6}$	756.00	Okay

Shear Check

V		7,225.16	
phi * Vc		17,253.26	
As	 $A_s = \frac{M_u}{\phi \cdot f_y \cdot j \cdot d}$ where $j \approx 0.9$	0.09	
assume 2 #5		0.62	



Place bars at **bottom face**, minimum 2" cover.

Pier Cap Rebar Design

Bridge width		9	ft
cap length		3.00	ft
cap width		3.00	ft
cap depth		36.00	in
supports		4.00	piles
beams		6.00	
load per beam		7,225.16	lb per beam
total load on cap		43,350.97	per pier
span between piles		3.00	ft
Mbend	$M = \frac{P \cdot L}{4}$	32,513.23	lb-ft
f'c (concrete)		4000	psi
fy (rebar)		60000	psi
effective depth	total depth -2	34.00	in
phi		0.90	
j		0.90	
As	$A_s = \frac{M}{\phi \cdot f_y \cdot jd}$	0.02	in
As,min	$A_{s,\min} = \max\left(\frac{3\sqrt{f'_c}}{f_y} \cdot b \cdot d, \frac{200}{f_y} \cdot b \cdot d\right)$	4.08	in
assume 6 #8 on bottom	6x 0.79	4.74	in
		Okay	

stirrups

Vu	total load from beams /2	21,675.49	lb	actual
Vc	$V_c = 2\sqrt{f'_c} \cdot b \cdot d$	154,825.11	lb	capcity
		Stirrups not required for shear strength		

Bearing pad

Load per beam	load at beam beam end	7,225.16	lb	
Beam End diameter		14		
Bearing surface		concrete cap		
Pad material		SPF #1		
Target max stress		175	psi	
Areq	$A_{\text{required}} = \frac{\text{Load}}{\text{Allowable Stress}}$	41.29	in^2	
Pad width		6.00	in	
Pad length		12.00	in	
σ	load / area	100.35	psi	Okay
t (min thickness of pad)	$t = \frac{l}{6}$ min pad thickness	1.00	in	

Screw

Note: **Can use the screws called out in plan, screws below, or better**

Assumptions

Plank span Length		8	in	actual	7.25	in
Plank width		2	in	actual	1.5	in
w		12.73041311	plf			
beam spacing		21.6	in			
Plank screw to beams						
lateral load per screw						
assume worse-case screw resists lateral shear						
V	$V = \frac{wL}{2}$	11.46	lb			
assume 2 screws per support						
Vscrew	V/2	5.73	lb/screw			
F lat,allow		140	lb/screw	per NDS and Simpson table for SDWS screw into softwood		
		Okay				
Withdrawal/uplift check						
assume wind uplift		30	psf			
w	w x l x t	6.75	plf			
U	w x s	12.15	lb uplift per plank			
assume 2 screws each need to resist						
Screw withdrawal		150	lb	Screw withdrawal for SDWS in softwood		
		Okay				
screw per plank	number of beams x 2	12	screws			
number of planks	deck width / plank width	72	planks			
total	screw per plank x number of planks	864				
10% buffer	110% x total	950.4	screws	¼" diameter × 4" long (SDWS25400)		
Bearing pad to beam						
per beam end		2	screws			
timber bearing pad	number of beams x screw per beam end	24.00	screws	¼" × 3.5–4" SDS or RSS screws		
timber pad to concrete cap						
anchor per beam		2	anchors			
total anchors	number of beams x anchor per beam x 2	24.00	anchors	¼–⅜" Tapcons, wedge anchors, or embedded bolts		

Small Bridge Hand Calculations

Loads

Pedestrian	90	psf	
ATV	2402	lbs	
	26.68888889	psf	add to pedestrian load

Geomentry

O-O Coping	most extreme width	9	ft			
Span A Length	from center endbent to center endbent	10	ft			
				typical		
Plank span Length		8	in	actual	7.25	in
Plank width		2	in	actual	1.5	in
pole spacing	21.6	in	actual spacing is 18 in			

For planks

Assumptions

Span (for plank)		21.6	in			
		1.8	ft			
Plank span Length		8	in	actual	7.25	in
Plank width		2	in	actual	1.5	in
density (assumed)		40	pcf			
plank thickness		0.125	ft			
Self Weight for plank		5	psf			
Railing Dead Load (metal)		0	psf	assume no significant weight		
Total dead on plank		5	psf			
Total Load (DL+LL)		121.6888889	psf			
for planks (assume SPF #2)	E	1.20E+06	psi	from NDS		
	Fb	875	psi	from NDS		
	Fv	135	psi	from NDS		

Calcs

letter/name	equation	value	units	notes
w	w = total load / plank width	15.21111111	plf	
Mmax	$M = \frac{wL^2}{8}$	6.16	lb-ft	
		73.93	lf-in	
S	$S = \frac{bd^2}{6}$	13.14	in^3	
I	I = bh^3/12	47.63	in^4	
check bending plank				
fb	$M_{allowable} = F_b' \cdot S$	5.63	psi	
Fb		875	psi	from NDS above
		Okay		

Check Shear Stress				
V	V=wL/2	13.690	lb	
A	A = b*L	10.875	in^2	
fv	fv = V/A	1.259	psi	
Fv		135	psi	from NDS above
		Okay		
Check Deflection				
	$\Delta = \frac{5wL^4}{384EI}$			
δ		6.29E-05	in	
δallow	L/360	0.06	in	
		Okay		

Dead load Calcs

area of deck	width x length	90	ft^2
Beam Dead Load			
Diameter		14	
length		10	
density of wood		40	pcf
number of beams		6	beams
spacing		21.60	in
V	pi x r^2 x h	10.69	ft^3
wbeam	V x density	427.61	lb per beam
total beam weight	wbeam x number of beams	2,565.63	
wbeam,psf	total beam weight/deck area	28.51	psf

Telephone Poles

Inputs					
Total area of Bridge		90.00	ft^2		
Total Live Load	LL*O-O Coping * deck length	8,100.00	lb		
DL Decking		5.00	psf		
DL Poles		28.51	psf		
DL total	DL Decking + DL Poles	3,015.63	lb		
total load	DL + LL	11,115.63	lb		
w	pedestian + DL Deck + DL Poles(self weight)	123.51	psf		
	w*total area of bridge	11,115.63	lb		
rough estimate # beams	deck width/24	4.50	=	6	beams
rough spacing	deck width/4	21.60	" on center		
E	assume southern pine #1	1,500,000.00	psi	from NDS	
Fb		1,350.00	psi	from NDS	
Fv		165.00	psi	from NDS	
load per beam	total load / number of beams	1,852.61	lb per beam		
w	load per beam / span length	185.26	lb/ft		

Bending Check

Mmax	$M = \frac{wL^2}{8}$	2,315.76	lb-ft			
Vmax	$V = \frac{wL}{2}$	926.30	lb			
	Telephone pole capacity check					
pole diameter		14.00	in			
Smax	$S = \frac{\pi d^3}{32}$	269.39	in^3			
Cd		1.25	from NDS			
Cm		1.00	from NDS	hall confirm (don't include)		
Cl		1.00	from NDS			
Ct		1.00	from NDS			
Fb'	$F_b' = F_b \times C_d \times C_m \times C_L \times C_t$	1,687.50	psi	fb	103.155	psi
S	$S = \frac{M}{F_b}$	16.47	in^3			
S<Smax	Okay			Okay		

Shear check

A	$A = \frac{\pi}{4}d^2$	153.94	in^2	
Ashear	$A_s = \frac{2}{3}A$	102.63	in^2	
Tau	$\tau = \frac{V}{A_s}$	9.03	psi	over estimate
F'v		206.25		
Fv>T	Okay			

Deflection Check

allow	L/180	0.33	in
w	total load in psi	10.29	lb/in
L	span length	32.00	ft
E		1,200,000.00	psi
I	$I = \frac{\pi d^4}{64}$	1,885.74	
rho max	$\delta_{\max} = \frac{5wL^4}{384EI}$	0.11	in
	Okay		

End Bents / Abutments

pile diameter (concrete)		12.00	in	assume using concrete piles
length of pile		5.00	ft	from field for both sites
Total Span		10.00	ft	
Deck Width		9.00	ft	
Total DL		3,015.63	lb	
LL	pedestrain x deck width x total span	8,100.00	lb	
Total Load	DL+LL	11,115.63	lb	
Total reaction at each end	total load / 2	5,557.82	lb	
# of Piles		4.00	piles per side	
Ppile	total load at ends / number of piles	1,389.45	lb per pile	
Pile Capacity				
end bearing				
base area	pi x d^2 /4	0.79	ft^2	
stiff soil	assume	2,000.00	psf	
Ab	basse area x stiff soil	1,570.80	lb	
Skin friction				
As	pi x d x h	15.71	ft^2	
skin friction	assume	300.00	psf	
Qb		4,712.39	lb	
Qpile	Ab+Qb	6,283.19	lb	Okay
Lateral Load Capacity	10% x total load	555.78	lb	
Per pile	lateral load / number of piles	138.95	lb per pile	Okay
Pile Cap Design				
Width		9.00	ft	
Depth		12.00	in	
Length		3.00	ft	
number of spaces between beams	total number of beams - 1	5.00		
number of beams		6.00		
span between piles		3.00	ft	
diameter of beam		14.00	in	
f'c		3,000.00		
Fy		60,000.00	psi	
Load at each beam location	total load / number of beams	1,852.61	lb	
Mmax	$M_{\max} \approx \frac{P \cdot s}{4}$	1,389.45	lb-ft	
S	$S = \frac{M}{\phi \cdot f_c}$	67.65	in	
h		18.00	in	
S	$S = \frac{bd^2}{6}$	756.00	Okay	

Shear Check

V		1,852.61
phi * Vc		17,253.26
As	$$A_s = \frac{M_u}{\phi \cdot f_y \cdot j \cdot d} \quad \text{where } j \approx 0.9$$	0.02
assume 2 #5		0.62

Place bars at **bottom face**, minimum 2″ cover.

Pier Cap Rebar Design

Bridge width		9	ft
cap length		3.00	ft
cap width		2	ft
cap depth		12.00	in
supports		4.00	piles
beams		6.00	
load per beam		1,852.61	lb per beam
total load on cap		11,115.63	per pier
span between piles		3.00	ft
Mbend	$M = \frac{P \cdot L}{4}$	8,336.73	lb-ft
f'c (concrete)		4000	psi
fy (rebar)		60000	psi
effective depth	total depth -2	10.00	in
phi		0.90	
j		0.90	
As	$A_s = \frac{M}{\phi \cdot f_y \cdot jd}$	0.02	in
As,min	$A_{s,\min} = \max\left(\frac{3\sqrt{f'_c}}{f_y} \cdot b \cdot d, \frac{200}{f_y} \cdot b \cdot d\right)$	0.80	in
assume 3 #5 on bottom	3 x 0.31	0.93	in
		Okay	

stirrups

Vu	total load from beams /2	5,557.82	lb	
Vc	$V_c = 2\sqrt{f'_c} \cdot b \cdot d$	30357.86554	lb	
		Stirrups not required for shear strength		
bw		24	in	
Av/s >	$\frac{A_v}{s} \geq \frac{50 \cdot b_w}{f_y}$	0.02	in	
try #4 2 leg				
A	2 x 0.2	0.4	in	
s	$\frac{A_v}{s} \geq \frac{50 \cdot b_w}{f_y}$	20	in	
	use #4, 2 leg at 20in spacing			

Bearing pad

Load per beam	load at beam beam end	1,852.61	lb	
Beam End diameter		14		
Bearing surface		concrete cap		
Pad material		wood		
Target max stress		400	psi	
Areq	$A_{\text{required}} = \frac{\text{Load}}{\text{Allowable Stress}}$	4.63	in^2	
Pad width		6.00	in^2	
Pad length		12.00	in^2	
σ	load / area	25.73	psi	Okay
t (min thickness of pad)	$t = \frac{l}{6}$ min pad thickness	1.00	in	

Screw

Assumptions						
Plank span Length		8	in	actual	7.25	in
Plank width		2	in	actual	1.5	in
w		15.21111111	plf			
beam spacing		21.6	in			
Plank screw to beams						
lateral load per screw						
assume worse-case screw resists lateral shear						
V	$V = \frac{wL}{2}$	13.69	lb			
assume 2 screws per support						
Vscrew	V/2	6.85	lb/screw			
F lat,allow		140	lb/screw	per NDS and Simpson table for SDWS screw into softwood		
		Okay				
Withdrawal/uplift check						
assume wind uplift		30	psf			
w	w x l x t	6.75	plf			
U	w x s	12.15	lb uplift per plank			
assume 2 screws each need to resist						
Screw withdrawal		150	lb	Screw withdrawal for SDWS in softwood		
		Okay				
screw per plank	number of beams x 2	12	screws			
number of planks	deck width / plank width	72	planks			
total	screw per plank x number of planks	864				
10% buffer	110% x total	950.4	screws	¼" diameter × 4" long (SDWS25400)		
Bearing pad to beam						
per beam end		2	screws			
timber bearing pad	number of beams x screw per beam end	24.00	screws	¼" × 3.5–4" SDS or RSS screws		
timber pad to concrete cap						
anchor per beam		2	anchors			
total anchors	number of beams x anchor per beam x 2	24.00	anchors	¼–⅜" Tapcons, wedge anchors, or embedded bolts		

Appendix H

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

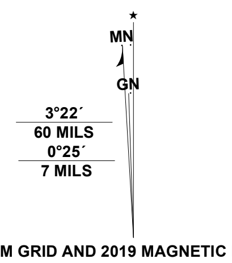
The National Map
US Topo

WEST FRANKLIN QUADRANGLE
INDIANA - KENTUCKY
7.5-MINUTE SERIES

Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid:Universal Transverse Mercator, Zone 16S

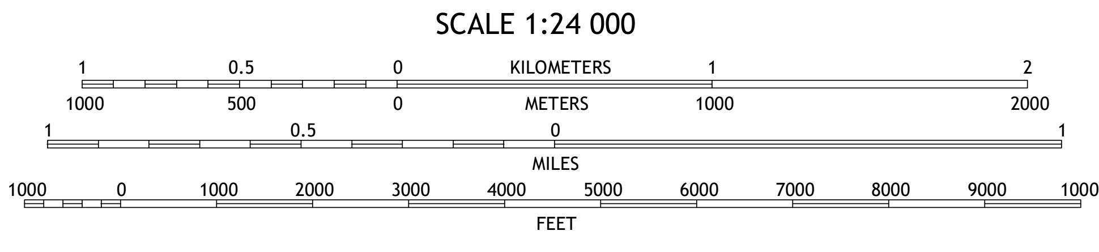
This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.

Imagery..NAIP, June 2020 - July 2020
Roads....................................... U.S. Census Bureau, 2015 - 2019
Names...GNIS, 1979 - 2022
Hydrography...............................National Hydrography Dataset, 2001 - 2022
Contours...National Elevation Dataset, 2016
Boundaries.............Multiple sources; see metadata file 2019 - 2021
Public Land Survey System..BLM, 2020
Wetlands................FWS National Wetlands Inventory 1980 - 1983



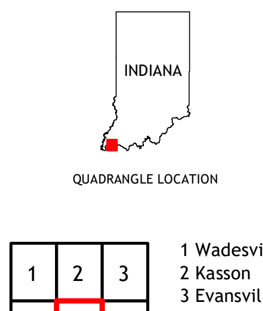
UTM GRID AND 2019 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

U.S. National Grid
100,000 - m Square ID
DH
DG
Grid Zone Designation
16S



CONTOUR INTERVAL 10 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

This map was produced to conform with the
National Geospatial Program US Topo Product Standard.



QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

1 Wadesville
2 Kasson
3 Evansville North
4 Caborn
5 Evansville South
6 Smith Mills
7 Wilson
8 Henderson

ADJOINING QUADRANGLES

ROAD CLASSIFICATION

Expressway	▬	Local Connector	▬
Secondary Hwy	▬	Local Road	▬
Ramp	▬	4WD	- - -

Interstate Route · US Route · State Route

WEST FRANKLIN, IN, KY

2022

NSN. 7643016366556
NGA REF NO. USGSX24K48190

Appendix G

United States
Department of
Agriculture

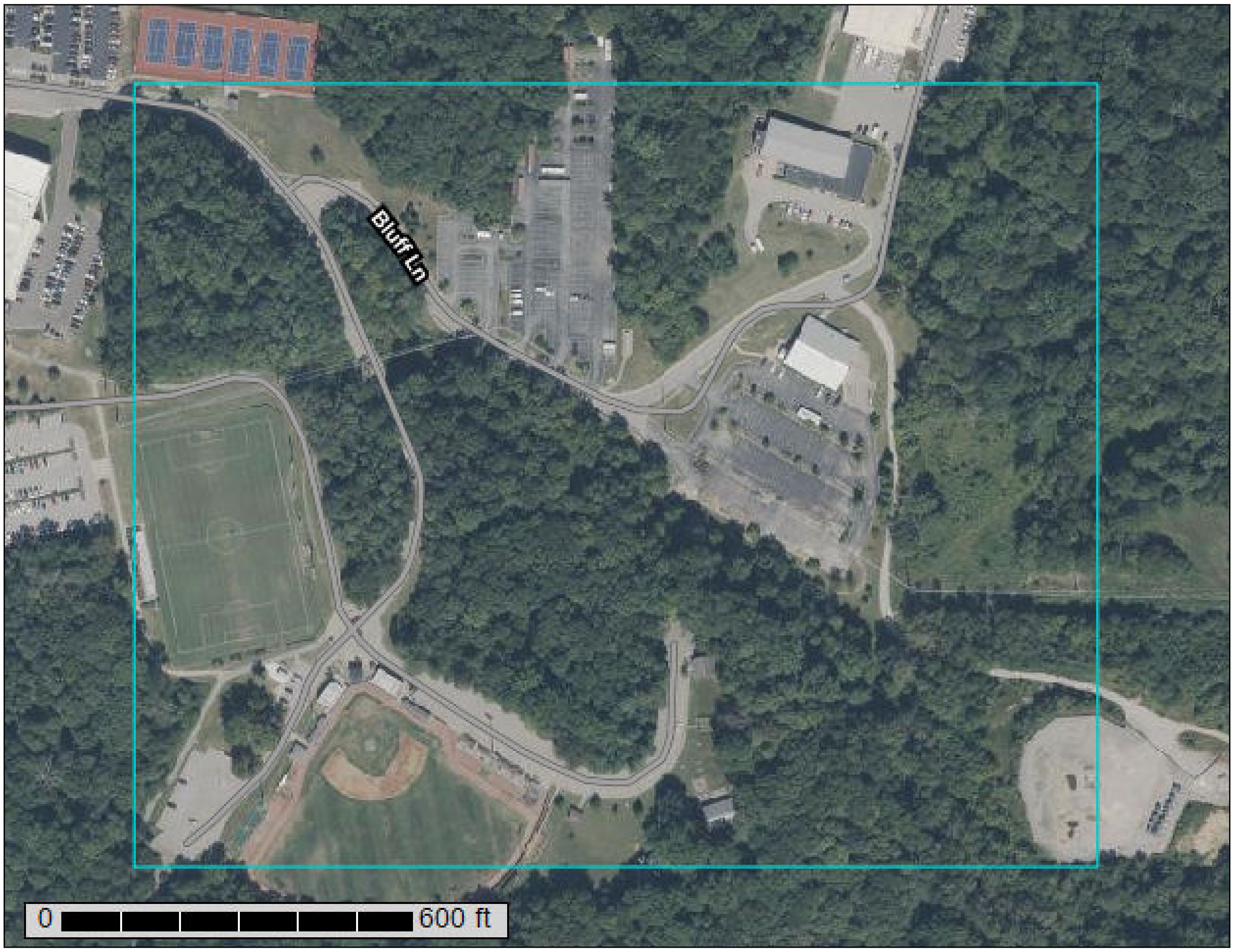
NRCS

Natural
Resources
Conservation
Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Vanderburgh County, Indiana



February 3, 2025

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require

Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map

Map Scale: 1:3,440 if printed on A landscape (11" x 8.5") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Vanderburgh County, Indiana
Survey Area Data: Version 24, Aug 23, 2024

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Apr 10, 2023—Oct 10, 2023

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AlB2	Alford silt loam, 2 to 5 percent slopes, eroded	7.6	15.0%
AlC3	Alford silt loam, 5 to 10 percent slopes, severely eroded	8.4	16.6%
MuA	Muren silt loam, 0 to 2 percent slopes	8.3	16.4%
St	Stendal silt loam	5.1	10.2%
Wa	Wakeland silt loam, 0 to 2 percent slopes, frequently flooded	8.4	16.6%
WeD3	Wellston silt loam, 10 to 18 percent slopes, severely eroded	4.0	7.9%
WeE2	Wellston silt loam, 18 to 25 percent slopes, eroded	8.7	17.2%
Totals for Area of Interest		**50.4**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Vanderburgh County, Indiana

AlB2—Alford silt loam, 2 to 5 percent slopes, eroded

Map Unit Setting

National map unit symbol: 2x067
Elevation: 330 to 850 feet
Mean annual precipitation: 41 to 48 inches
Mean annual air temperature: 52 to 59 degrees F
Frost-free period: 170 to 200 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Alford, eroded, and similar soils: 95 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alford, Eroded

Setting

Landform: Loess hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Loess over gritty loess

Typical profile

Ap - 0 to 6 inches: silt loam
Bt1 - 6 to 26 inches: silty clay loam
Bt2 - 26 to 73 inches: silt loam
2BC - 73 to 79 inches: silt loam

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 11.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: B
Ecological site: F114XB803IN - Wet Silty Eolian Forest
Hydric soil rating: No

Minor Components

Hosmer, eroded

Percent of map unit: 5 percent
Landform: Ridges
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Ecological site: F115XA004IL - Fragic Upland
Hydric soil rating: No

AlC3—Alford silt loam, 5 to 10 percent slopes, severely eroded

Map Unit Setting

National map unit symbol: 2x06c
Elevation: 330 to 850 feet
Mean annual precipitation: 41 to 48 inches
Mean annual air temperature: 52 to 59 degrees F
Frost-free period: 170 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Alford, severely eroded, and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alford, Severely Eroded

Setting

Landform: Loess hills
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Loess over gritty loess

Typical profile

Ap - 0 to 4 inches: silt loam
Bt1 - 4 to 44 inches: silty clay loam
Bt2 - 44 to 73 inches: silt loam
2BC - 73 to 79 inches: silt loam

Properties and qualities

Slope: 5 to 10 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)

Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 11.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: F114XB803IN - Wet Silty Eolian Forest
Hydric soil rating: No

Minor Components

Hosmer, severely eroded

Percent of map unit: 6 percent
Landform: Loess hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Ecological site: F115XA004IL - Fragic Upland
Hydric soil rating: No

Wakeland, frequently flooded

Percent of map unit: 2 percent
Landform: Flood plains
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: F114XB203IN - Wet Floodplain Forest
Hydric soil rating: No

Alvin

Percent of map unit: 2 percent
Landform: Hills
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Ecological site: F114XB801IN - Sandy Eolian Woodland
Hydric soil rating: No

MuA—Muren silt loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 5gc8
Elevation: 340 to 700 feet

Mean annual precipitation: 40 to 46 inches
Mean annual air temperature: 52 to 57 degrees F
Frost-free period: 170 to 210 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Muren and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Muren

Setting

Landform: Loess hills
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess

Typical profile

Ap - 0 to 9 inches: silt loam
Bt - 9 to 54 inches: silty clay loam
C - 54 to 80 inches: silt loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 12 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: High (about 11.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 1
Hydrologic Soil Group: B/D
Ecological site: F114XB803IN - Wet Silty Eolian Forest
Hydric soil rating: No

St—Stendal silt loam

Map Unit Setting

National map unit symbol: 5gcl
Elevation: 340 to 700 feet
Mean annual precipitation: 40 to 46 inches
Mean annual air temperature: 52 to 57 degrees F
Frost-free period: 170 to 210 days

Farmland classification: Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season

Map Unit Composition

Stendal and similar soils: 97 percent
Minor components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Stendal

Setting

Landform: Flood plains
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Acid silty alluvium

Typical profile

Ap - 0 to 11 inches: silt loam
B - 11 to 41 inches: silt loam
Cg - 41 to 60 inches: stratified silt loam to silty clay loam to loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Available water supply, 0 to 60 inches: Very high (about 12.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: B/D
Hydric soil rating: No

Minor Components

Bonnie

Percent of map unit: 3 percent
Landform: Backswamps, flood plains
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Concave
Across-slope shape: Linear
Hydric soil rating: Yes

Wa—Wakeland silt loam, 0 to 2 percent slopes, frequently flooded

Map Unit Setting

National map unit symbol: 2wyhj
Elevation: 340 to 490 feet
Mean annual precipitation: 38 to 49 inches
Mean annual air temperature: 50 to 59 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season

Map Unit Composition

Wakeland, frequently flooded, and similar soils: 95 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Wakeland, Frequently Flooded

Setting

Landform: Flood plains
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Silty alluvium

Typical profile

Ap - 0 to 8 inches: silt loam
Cg1 - 8 to 19 inches: silt loam
Cg2 - 19 to 63 inches: silt loam
Cg3 - 63 to 73 inches: silt loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Available water supply, 0 to 60 inches: Very high (about 13.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: B/D
Ecological site: F114XB203IN - Wet Floodplain Forest
Hydric soil rating: No

Minor Components

Birds, frequently flooded

Percent of map unit: 5 percent
Landform: Flood plains
Landform position (three-dimensional): Dip
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: F113XY919IL - Wet Silty Floodplain Forest
Hydric soil rating: Yes

WeD3—Wellston silt loam, 10 to 18 percent slopes, severely eroded

Map Unit Setting

National map unit symbol: 2wyjc
Elevation: 340 to 1,010 feet
Mean annual precipitation: 38 to 49 inches
Mean annual air temperature: 50 to 57 degrees F
Frost-free period: 190 to 225 days
Farmland classification: Not prime farmland

Map Unit Composition

Wellston, severely eroded, and similar soils: 95 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Wellston, Severely Eroded

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Concave
Across-slope shape: Linear
Parent material: Loess over residuum weathered from sandstone and siltstone and/or shale

Typical profile

Ap - 0 to 3 inches: silt loam
Bt - 3 to 33 inches: silty clay loam
2BC - 33 to 51 inches: gravelly loam
2Cr - 51 to 61 inches: bedrock

Properties and qualities

Slope: 10 to 18 percent
Depth to restrictive feature: 35 to 72 inches to paralithic bedrock
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.13 in/hr)

Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: Moderate (about 8.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: B
Ecological site: F114XB302IN - Residuum Upland Forest
Hydric soil rating: No

Minor Components

Zanesville, severely eroded

Percent of map unit: 5 percent
Landform: Ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Linear
Ecological site: F113XY910IL - Fragic Backslope Woodland
Hydric soil rating: No

WeE2—Wellston silt loam, 18 to 25 percent slopes, eroded

Map Unit Setting

National map unit symbol: 2wyj4
Elevation: 340 to 1,010 feet
Mean annual precipitation: 38 to 49 inches
Mean annual air temperature: 50 to 57 degrees F
Frost-free period: 190 to 225 days
Farmland classification: Not prime farmland

Map Unit Composition

Wellston, eroded, and similar soils: 95 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Wellston, Eroded

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess over residuum weathered from sandstone and siltstone and/or shale

Typical profile

A - 0 to 6 inches: silt loam
Bt - 6 to 35 inches: silt loam
2C - 35 to 51 inches: fine sandy loam
2R - 51 to 61 inches: bedrock

Properties and qualities

Slope: 18 to 25 percent
Depth to restrictive feature: 35 to 72 inches to lithic bedrock
Drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.13 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: Moderate (about 8.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: B
Ecological site: F114XB302IN - Residuum Upland Forest
Hydric soil rating: No

Minor Components

Zanesville, eroded

Percent of map unit: 5 percent
Landform: Ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Linear
Ecological site: F113XY910IL - Fragic Backslope Woodland
Hydric soil rating: No

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Appendix F

Wood Design (Simple) (32 ft Span)

		Item		Quantity	Units	Unit Cost	Total Cost
Substructure	Foundation		Concrete (8 CY total) (5ksi)	4.44	CY	$165	$733
		Rebar (Vertical: #5 @ 12" O.C, 90 lf)(Horizontal: #4 @ 12" O.C., 90 lf)(Footing: #5 @ 12" O.C. for two layers 264 lf)	#4 rebar	90	LF	$0.30	$27
			#5 rebar	354	LF	$0.50	$176
		Formwork	3/4" exterior Grade Plywood	1	Sheets	$34.71	$35
			2x4x8 ft Stud and Waler	48	EA	$3.24	$156
			#9 x 3" exterior wood screws	384	EA	$0.13	$49
			Anchor Bolts 3/4" diameter x 12"	16	EA	$19	$299
			Anchor Washer 3/4"	16	EA	$0.42	$7
			Anchor Nuts 3/4"	16	EA	$0.74	$12
			Bearing Pads (10" x 10" x 1/2")	8	Pads	$199.95	$1,600
Superstructure	Beams/ Girders	Glulam Beams	5 1/8" x 21" Glumlam (Douglas Fir) (pressure treated)	4	EA	$2,392	$9,567
		Cross Bracing 3 sets	2x6x8 Pressure Treated	6	Boards	$6.92	$42
			#10 x 3" Exterior Screws 4 per brace	48	EA	$0.18	$8
	Decking	Pressure treated decking	Decking (288 SF of 2x6 Pressure treated)	576	LF	$0.88	$507
			#10 X 3" Exterior Wood Screws	307.2	EA	$0.18	$54
	Railing	Wood	Top and Mid rail (2x6x8 pressure treated)	16	Boards	$6.92	$111
			Posts 4" x 6" x 4" (every 5ft)	18	Post	$13.52	$243
			Rail Cap	18	Post	$20.70	$373
			Kick Rail (2x4x8 pressure treated)	8	Boards	$5.41	$43
						Sub total	$ 14,040.72
						Contingency (15%)	$ 2,106.11
						Total	$ 16,146.83

Wood Design (Overhang) (2ft x 8ft) (32 ft Span)							
	Item			Amount	Units	Unit Cost	Total Cost
overhang		2x8x10' PT Framing Lumber		4	EA	$ 11.56	$ 46.24
		2x6x8' PT Decking Boards		5	EA	$ 7.05	$ 35.25
		4x4x8' PT Railing Posts		4	EA	$ 10.40	$ 41.60
		2x6x8' PT Railing Boards		3	EA	$ 7.05	$ 21.15
		2x4x8' PT Kick Rail		1	EA	$ 5.41	$ 5.41
		#10 x 3" exterior screws		184	EA	$0.18	$ 32.20
		3/8" x 4" lag bolts		16	EA	$ 1.27	$ 20.32
		3/8" x 4" lag washer		17	EA	$ 0.07	$ 1.19
Substructure	Foundation		Concrete (8 CY total) (5ksi)	4.44	CY	$165	$ 733.33
		Rebar (Vertical: #5 @ 12" O.C, 90	#4 rebar	90	LF	$0.30	$ 26.73
			#5 rebar	354	LF	$0.50	$ 176.47
		Formwork	3/4" exterior Grade Plywood	1	Sheets	$34.71	$ 34.71
			2x4x8 ft Stud and Waler	48	EA	$3.24	$ 155.52
			#9 x 3" exterior wood screws	384	EA	$0.13	$ 48.66
			Anchor Bolts 3/4" diameter x 12"	16	EA	$19	$ 299.47
			Anchor Washer 3/4"	16	EA	$0.42	$ 6.72
			Anchor Nuts 3/4"	16	EA	$0.74	$ 11.84
			Bearing Pads (10" x 10" x 1/2")	8	Pads	$199.95	$ 1,599.60
Superstructure	Beams/ Girders	Glulam Beams	5 1/8" x 21" Glumlam (Douglas Fir) (pressure treated)	4	EA	$2,392	$ 9,566.67
		Cross Bracing 3 sets	2x6x8 Pressure Treated	6	Boards	$6.92	$ 41.52
			#10 x 3" Exterior Screws 4 per brace	48	EA	$0.18	$ 8.40
	Decking	Pressure treated decking	Decking (288 SF of 2x6 Pressure treated)	576	LF	$0.88	$ 507.36
			#10 X 3" Exterior Wood Screws	307.2	EA	$0.18	$ 53.76
	Railing	Wood	Top and Mid rail (2x6x8 pressure treated)	16	Boards	$6.92	$ 110.72
			Posts 4" x 6" x 4" (every 5ft)	18	Post	$13.52	$ 243.36
			Rail Cap	18	Post	$20.70	$ 372.60
			Kick Rail (2x4x8 pressure treated)	8	Boards	$5.41	$ 43.28
						Sub total	$ 14,244.08
						Contingency (15%)	$ 2,136.61
						Total	$ 16,380.69

Concrete Design (Rolled Steel Beam with Concrete Deck) (from MNDOT table 4.6)

	Item	Source	Units	Amount	Total Cost
Foundation	Structural concrete footing (24" thick × 4' wide, each end)		CY	8	$ 1,200.00
	Reinforcing steel for footings		LB	1000	$ 900.00
	Foundation drain (4" perforated pipe) + gravel		LF	40	$ 600.00
	Backfill (granular) + compaction		CY	20	$ 700.00
Superstructure	Precast prestressed I-beams (typ. 3-beam spacing)	gov/dot/div/contracts	LF	96	$7,680
	Cast-in-place concrete deck, 8" thick (5Ksi)	concrete/evansville-i	CY	8	$1,320
	Deck reinforcement (rebar, 50 lb/CY)		LB	400	$360
	Formwork for deck		SQ FT	288	$432
	Structural tube railing (both sides)		LF	64	$3,200
				Sub total	$16,392
				Contingency (15%)	$ 2,458.80
				Total	$18,851