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Dunn Right Engineering
Rose-Hulman Institute of Technology, CM 1669
5500 Wabash Avenue
Terre Haute, Indiana 47803

March 28, 2008

Mr. Raymond Hess
City of Bloomington Planning Department
401 N. Morton Street
Bloomington, Indiana 47402

Dear Mr. Hess:

Dunn Right Engineering is pleased to provide you with the final report for the Dunn Street Modernization study. This report details our project approach, design work, and our recommendation.

Contained in the report is a design for the upgrade of the Indiana Avenue and 12th Street and Indiana and 13th Street intersections. Also included are the renovation of the underpass on Indiana Avenue under the railroad crossing and the design of a pedestrian bridge crossing the Indiana Rail Road at Dunn Street. In addition, a sidewalk improvement plan along with the addition of bike lanes is included. Finally, we included a detailed breakdown estimating the cost of materials and construction for the project.

Thank you for choosing Dunn Right Engineering for this project. We have enjoyed working on this project and appreciate all of the assistance and feedback you have provided. Please contact Brian McIlwaine at 317-402-2718 if you have any questions or concerns.

Sincerely Yours,

Austin Hastings
Project Engineer

Brian McIlwaine
Project Manager/ Client Liaison

Katie Benner
Project Editor

Ryan Pattenaude
Project Engineer

Enclosed: Final Report

Final Report

Dunn Street Modernization Study

Prepared For

The City of Bloomington Planning Department

March 28, 2008

DISCLAIMER

The contents of this engineering design report were prepared by civil engineering students at Rose-Hulman Institute of Technology for their senior capstone design class. **Dunn Right Engineering** is a fictitious company created by these students (**Katie Benner, Austin Hastings, Brian McIlwaine, and Ryan Pattenaude)** for the purpose of this class. These students are not registered professional engineers! All material presented herein should be reviewed and stamped by a professional engineer prior to construction. A liability waiver has been signed by the client, and copies are available from the client and from Rose-Hulman Institute of Technology.

Executive Summary

The City of Bloomington Planning Department is interested in a solution to alleviate longstanding traffic issues in and around the north-south corridor of Indiana Avenue. They would also like to improve the effectiveness of the public transit and alternative transportation methods in the area. This report proposes an upgrade of the existing conditions, which will result in an overall improvement of current traffic problems.

Dunn Right Engineering also investigated three other solutions to improve traffic flow along the Indiana Avenue corridor. These include a bridge at Dunn Street over the Indiana Rail Road, an underpass at Dunn Street under the Indiana Rail Road, and at at-grade crossing at Dunn Street over the Indiana Rail Road. The upgrade of existing conditions proved to be the best solution.

In the upgrade of existing conditions, multiple changes take place. The intersection of Indiana Avenue and 13th Street will upgrade to a stoplight. The intersection of Indiana Avenue and 12th Street will widen to increase the available turning radius onto 12th Street. The railroad overpass spanning Indiana Avenue is in need of renovation. We will replace this with a pre-fabricated overpass that will widen the overall passage for traffic. A pedestrian bridge will span the railroad tracks crossing Dunn Street.

In addition, the sidewalks along Indiana Avenue need improvement and will be connected along the entire corridor. A bike path is also proposed along Indiana Avenue. These both provide an upgrade from the existing sidewalk facilities, thus providing a safer means for both pedestrians and bicyclists to travel the Indiana Avenue corridor.

The upgrade of existing conditions will cost an estimated $800,000.

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1.0 Project Description

The City of Bloomington, Indiana is located in central Indiana. (See Figure 1.1.) Over the years, Bloomington has developed into a thriving community with 69,291 residents and approximately 40,000 students, making it the seventh largest city in Indiana. The transportation system has failed to accommodate demand with the industrial and residential expansion. Over the past few years, inspections and surveys have found several routes that need improvement in order to handle the volume of traffic that congests the streets of Bloomington safely.

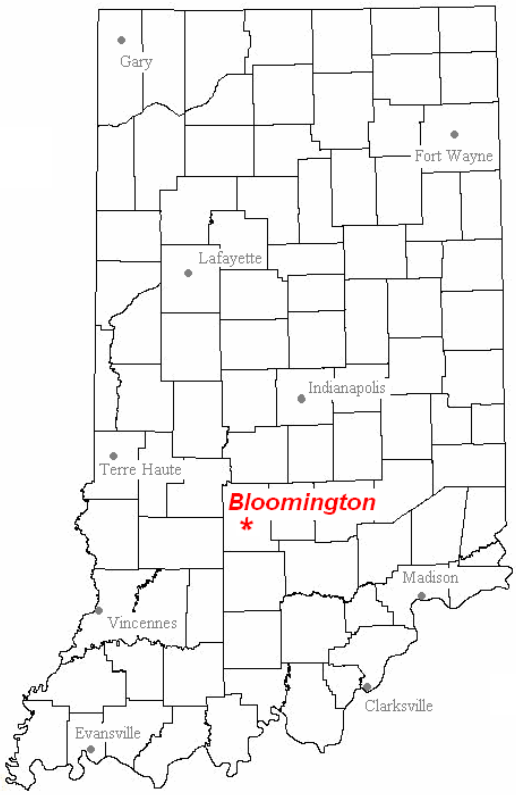

Figure 1.1: Location of Bloomington, Indiana (MapQuest, 2007)

One of these routes is Dunn Street. Dunn Street is a north-south street that runs alongside Indiana University's campus. (See Figure 1.2.) Currently the Indiana Rail Road bisects Dunn Street causing all traffic to turn onto 13th Street. (See Figure 1.3.) Just south of the railroad, Dunn Street continues to run south through Bloomington. Because the railroad prohibits through traffic on Dunn Street, more traffic flows into Indiana Avenue making it overcrowded and unsafe.

Our client is the City of Bloomington's Planning Department, located in the City Hall. The Planning Department deals with a variety of issues including environmental planning, long-range and neighborhood planning, provision of adequate transportation infrastructure, zoning code compliance, and development proposal and permit review. They have asked us to help relieve the congestion on Indiana Avenue by developing a design to improve traffic flow in the area of Dunn Street and the Indiana Rail Road.

Figure 1.2: Location of Site in Bloomington
(Adapted from Google Earth, 2007)

Figure 1.3: Dunn Street Site
(Adapted from Google Earth, 2007)

2.0 Design Requirements

2.1 Client Requirements

Our client, the City of Bloomington, requests that we supply them with several viable designs that will alleviate the congestion along the north-south corridor of Indiana Avenue in the city of Bloomington. Our client requires that we incorporate public transportation needs such as pedestrian traffic, bicycle and on-foot, as well as the public transit service.

2.2 Constraints

The Dunn Street Modernization study has two constraints. First, the client indicated that cost should not be an immediate concern, but he would like a rough cost estimate for each design option. Second, the residents living along Dunn Street have indicated that they are in opposition to congesting their quiet street.

The railroad company, Indiana Rail Road, has indicated that they will not allow an at-grade crossing for Dunn Street. For this reason, our client has informed us that at this time an at-grade crossing is not feasible.

2.3 Deliverables

We provided our client with a progress report with multiple design options for the Dunn Street Modernization Study. The progress report described all viable design options. Dunn Right Engineering rated these options based on client-selected criteria using a decision matrix, and from which we provided the City of Bloomington our recommendation. We sent one digital PDF copy of the progress report via email to the clients: Scott Robinson and Raymond Hess.

The final report contains everything from the progress report and the final design. There will be one digital PDF copy of the final report sent via email to our clients Scott Robinson and Raymond Hess.

The format for printing drawings is 8.5 x 11 pages. AutoCAD 2004 is the format for digital drawings.

3.0 Project Approach

Dunn Right Engineering completed the City of Bloomington's design requests for the Dunn Street Modernization Study based upon the following project approach:

Preliminary Feasibility Study

- Locate Utilities
- Site Visit
- Determine Soil Types

Codes and Regulations

- AASHTO Green Book (AASHTO, 2004)
- AASHTO Bike Book (AASHTO, 1999)
- INDOT Specifications (INDOT, 2007)
- Manual on Uniform Traffic Control Devices (FHWA, 2004)
- Americans with Disabilities Act (ADA, 1994)
- Bloomington Municipal Codes (City of Bloomington, 2007)

Photographic Survey

- Documentation of key locations on site

Topographic Data

- Map constructed from data collected by Dunn Right Engineering that shows elevations of site

Traffic Flow Analysis

- Determine how the changes will impact the traffic flow

Design Options

- Overpass
- Underpass
- Upgrade of Existing Conditions

- At-Grade Crossing
- Additional design options that should be considered

Assessment of Design Options

- Rate each option so that the best option is found

Overpass Replacement

- Provide a safer clearance for vehicles and pedestrians

Pavement Design

- Design adequate pavement to replace the pavement removed from the overpass and widened intersection

Indiana Avenue Non-Motorized Traffic Plan

- Best methods to protect the pedestrian and bike traffic

Signage, Signals, and Markings

- Provide signage, signals and pavement markings for safety of motorists and pedestrians

Pedestrian Bridge Design

- Provide a safe passage over the Indiana Rail Road crossing at Dunn Street

Foundation Design

- Retaining walls that will be needed
- Recommendations about the soil types

Erosion Control Plan

- Prevent excessive erosion during construction

Cost Estimate

- Found from historical data and RS Means manual (RS Means 2007)
- Estimate to client on total cost

4.1 Preliminary Feasibility Study

Dunn Right Engineering researched the site characteristics, topography, soil conditions, wetlands, floodplains, and zoning. In addition, our design team performed a physical site inspection to find any pre-existing conditions that were not apparent in prior research. We completed the preliminary feasibility study to gain an understanding of the condition of the site and to discover any difficulties that we may face. Through this study, we found a high density of local utilities, steep approaches, lack of right-of-way, and the Indiana Rail Road line that runs directly through the site. Closing the railroad is an important part of the final cost estimate. These issues complicate the design process along with political feasibility. Though Dunn Right Engineering finds this project feasible, there are many necessary steps to handle the complications. These steps include an additional soil study, utility relocation, and further interaction with residents and Indiana Rail Road officials. Detailed information regarding the preliminary findings is in Appendix A.

4.2 Codes and Regulations

Dunn Right Engineering reviewed the *American Association of State Highway and Transportation Officials: Guide for the Development of Bicycle Facilities* (AASHTO, 1999), the *American Association of State Highway and Transportation Officials: A Policy on Geometric Design of Highways and Streets* (AASHTO, 2004), the *American Association of State Highway and Transportation Officials: LRFD Bridge Design Specifications* (AASHTO, 2007), the *Americans with Disabilities Act*: *Standards for Accessible Design* (ADA, 1994), the City of Bloomington Municipal Codes (City of Bloomington, 2007) and the *Indiana Department of Transportation Standards and Specifications Manual* (INDOT, 2006) in order to assist in the design of the Dunn Street Modernization Study. Our team used the state and federal codes to ensure that Dunn Right Engineering's design is safe and meets the higher government's standards. Municipal codes are necessary to meet the more stringent local regulations when applicable. Appendix B includes a detailed summary of each of the codes listed in this section.

4.3 Photographic Survey

Dunn Right Engineering took photographs of key locations at the site to supply the reader with a general visual background of the project as well as to assist our design team in the design

process, as we could not visit the site frequently. The majority of the photographs highlight the existing problems that affect our final design option. These photographs allow the reader to visualize the site. The photographic survey is located in Appendix C.

4.4 Topographic Survey

Our design team surveyed the site with a Nikon total station to determine the exact slopes of Dunn Street to the north and the south of the railroad tracks. We performed this survey to determine where the overpass and underpass design options can tie into the existing roadway. This data is also necessary in determining the amount of cut or fill needed for the underpass and overpass options. Upon completion of the survey, our team discovered that the site needs little alteration, as the slopes are consistent between the two sections of road. Appendix D includes the profile view of our site as well as a map showing the location of the station points on an aerial view.

4.5 Traffic Flow Analysis

Dunn Right Engineering performed a traffic flow analysis for each of the design options in order to rank them in a decision matrix. Our design team worked with a city of Bloomington engineer using Synchro Studio 7 to complete the traffic flow analysis. We studied both the Vehicles per Day (VPD) along Indiana Avenue and Level of Service (LOS) of intersections along Indiana Avenue. Upon completion of this analysis, our team was able to determine the impact of each of the design options on the travel time through the site. We have used this data to assess which option is optimal (Appendix G). Detailed results of the analysis are in Appendix E.

4.6 Design Options

Our design team has created four different design options and recommended one as the best design option for our client. We investigated all four design options and developed a list of advantages and disadvantages of each choice. The first design option is an overpass. This design consists of using an overpass to connect Dunn Street over the railroad tracks. The next design option is an underpass, which connects Dunn Street under the railroad tracks. Another design option is an at-grade crossing. This uses an at-grade crossing with the proper signage to cross the railroad tracks. The final design option is an upgrade of existing conditions. This

option will not connect Dunn Street but will instead focus on upgrading the conditions around the site. It consists of four specific locations: the intersection of Indiana Avenue and 13th Street, the intersection of Indiana Avenue and 12th Street, the current underpass on Indiana Avenue at the Indiana Rail Road line, and a pedestrian bridge at Dunn Street. Appendix F includes a detailed description of each option.

4.7 Assessment of Design Options

Dunn Right Engineering created a decision matrix in which we rated each design option using three criteria weighted by the client based on importance. These criteria are cost, traffic flow, and political feasibility. Our design team evaluated each design option with respect to the weighted criteria in order to determine the best design option. Accordingly, Dunn Right Engineering recommends the upgrade of existing conditions. With client approval, we focused on creating a detailed design of this option. Appendix G includes the detailed assessment of each design option and an explanation of each criterion.

4.8 Overpass Replacement

The railroad overpass located on Indiana Avenue and 12th Street is in poor condition and the current design creates unsafe sight triangles for vehicles and pedestrians. In addition, clearance is too low to accommodate emergency vehicles safely. The Indiana Rail Road, which operates the railroad lines, is against any lengthy shutdown of their lines. Because of this, Dunn Right Engineering is proposing a complete replacement of the old overpass with a prefabricated steel deck, which will minimize the shutdown time experienced by Indiana Railroad.

The proposed construction involves three phases that take place on weekends, which will allow for minimum disturbance to the public as well as Indiana Rail Road. The first phase will consist of installing the new piers and cross support beams. The second phase requires the delivery and assembly of the prefabricated steel structure next to the site. The third and final phase consists of the removal of the existing structure and the placement of the new structure. Further details of the construction process as well as the design of the concrete members are in Appendix H.

4.9 Pavement Design

Our design team has designed the pavement for the updated intersection and underneath the updated railroad bridge on Indiana Avenue. We chose to use hot mix asphalt. The Dunn Right Engineering Design Team referred to the Asphalt Institute: Thickness Design Manual (AI 1981), as quoted by our client, to help with the structural design of the pavement. Further details on the design of the pavement are in Appendix I.

4.10 Indiana Avenue Non-Motorized Traffic Plan

The City of Bloomington Planning Department requested that Dunn Right Engineering try to incorporate all modes of transportation into the design. With this in mind, Dunn Right Engineering determined that a sidewalk and bike path shall be installed separated from the roadway. Throughout design, Dunn Right Engineering referred to the AASHTO Bike Guide, ADA, and the local Bloomington Municipality Codes.

A buffer of four feet separates the sidewalk from Indiana Avenue. The sidewalk shall run parallel to Indiana Avenue and be located on the west side of the roadway. The bike path shall be separated from the roadway with a 2-foot buffer, run parallel to Indiana Avenue, and be located on the east side of Indiana Avenue. Further details on the design of the non-motorized traffic plan are in Appendix J.

4.11 Signage, Signals, and Markings

After any road construction or reconstruction, it is important that the proper signage, signaling, and pavement markings be installed on the site. Dunn Right Engineering has determined the locations of new signage and pavement markings in the project area.

The installation of the bike path requires extra pavement markings and an upgrade in the surrounding signage. The upgrade of the intersection of Indiana Avenue and 13th Street requires the installation of a traffic signal. Further details on signage, signals, and pavement markings are in Appendix K.

4.12 Pedestrian Bridge

The current crossing conditions at the Indiana Rail Road through Dunn Street are not only illegal but also unsafe. A pedestrian bridge removes all forms of non-motorists from crossing the tracks. In addition, it provides a direct route for bicyclists, who could not traverse the tracks. The shared use path over the railroad tracks uses a bridge constructed of reinforced concrete and steel girders. Design detail is preliminary and done in order to calculate cost estimate. Further details on the pedestrian bridge design are in Appendix L.

4.13 Intersection Design

Dunn Right Engineering has designed a wider turning radius for the northwest corner of the intersection of Indiana Avenue and 12th Street. During design, Dunn Right Engineering referred to the AASHTO Green Guide (AASHTO, 2004) as a reference on widening and turning. The widening of this intersection allows for larger vehicles such as buses and emergency vehicles to maneuver safely through this intersection. Further details on the intersection design are in Appendix M.

4.14 Foundation Design

Dunn Right Engineering designed the foundation to support the pedestrian bridge. We have determined that a drilled shaft foundation should be used to handle the load from the bridge. Since were not able to obtain an accurate geotechnical survey, we assumed conservative values to complete our design. Design detail is preliminary and done in order to calculate cost estimate. Further details on the foundation design are in Appendix N.

4.15 Erosion Control Plan

An erosion control plan is necessary during construction in order to preserve the site grounds. This plan outlines the steps and precautions needed throughout the construction process. Sediment and silt control devices shall be installed to protect the sewers. Fences are necessary to prevent soil from leaving the site and polluting the surrounding streets. Further details on the erosion control plan are in Appendix O.

4.16 Cost Estimate

Dunn Right Engineering has created a detailed cost estimate based on RS Means (RS Means, 2007) unit prices and information acquired from prospective subcontractors. The cost estimate is broken down into each major task. Table 4.1 shows the cost breakdown of each task. The final cost estimate for the Dunn Street Modernization Study is $800,000. A complete cost breakdown for the entire project is in Appendix P.

Table 4.1 – General Cost Breakdown

Task	Cost
Pedestrian Bridge	$240,000
Overpass Replacement	$306,000
Sidewalks and Bike Lanes	$57,000
13th Street Intersection	$175,000
12th Street Intersection	$15,000
Total	**$800,000**

5.0 Future Work

As with any road project, there will be continued costs associated with maintaining roads so that they continue to be usable in the future. However, since most of the construction deals with non-motorists, and there are no additional roadways, the continuing costs of the project should not be significantly higher than the current road maintenance budget of the City of Bloomington, Indiana. The highest additional costs will come from maintenance of the pedestrian bridge.

Dunn Right Engineering did not conduct a soil investigation due to on site dangers. Therefore, we recommend that a full soil investigation be conducted before the design is finalized. This soil investigation may change some design elements and may change measures in the erosion control plan. All designs are preliminary, however, and will need detailed design.

Dunn Right Engineering also recommends considering North Fess Avenue and North Woodlawn Avenue for alleviating the traffic congestion through this corridor. Currently North Fess Avenue crosses the Indiana Rail Road with an underpass. This underpass has a low vertical clearance and the potential for improvement so that traffic can safely maneuver through this road. The Indiana Rail Road currently interrupts North Woodlawn Avenue, but unlike Dunn Street has few residential houses in the surrounding area.

In addition, Dunn Right Engineering recommends that the City of Bloomington re-evaluate the residential opinion of crossing the Indiana Rail Road at any of these locations. Throughout our interactions, the residents appear in favor of connecting another road across the tracks. This may change the decision matrix and other options may require re-evaluation.

6.0 References Cited

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Appendix A – Preliminary Feasibility Study

A.1 Introduction

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion on Indiana Avenue. Needed is an additional north south street to create a one-way pair with Indiana Avenue. The Dunn Street site is the suggested location of this additional route. This site is located between 12th Street and 13th Street on Dunn Street in Bloomington, Indiana. (See Figures A.1 through A.5.)

This feasibility study is a preliminary study undertaken to determine and document the viability of Dunn Street modernization. It involves research of site characteristics, topography, soil conditions, wetlands and floodplains, and zoning. In addition, Dunn Right Engineering performed a physical site inspection to find any pre-existing conditions that are not apparent from the research. This appendix contains the results of this study.

A.2 Site Characteristics and Topography

The Dunn Street site slopes from the north to the south dropping approximately 32 feet over 600 feet. In between the road and the railroad, on both the north and south side, there are narrow lines of dense trees and shrubs. (See Figure A.6.) On the south side of the tracks, there are several large trees located beside the narrow road. Three rail tracks intersect the site running east to west. (See Figure A.7.)

On the north side of the tracks, where Dunn Street bends into 13th Street, there are several utilities, which are described in Section A.7. On the south side of the tracks, there are two houses very close to Dunn Street. (See Figure A.8.)

A.3 Soils

The Natural Resource Conservation Service (NRCS) performed the Monroe County Soil Survey (Natural Resources Conservation Service, 1998). The Dunn Street site contains the types of soils listed in Table A.1.

Table A.1: Dunn Street Project Soil Types from Natural Resources Conservation Service

Symbol	Soil Name	Grade	Percent of Project
CtB	Crider-Urban land complex	2-6% Slope	36%
CtC	Crider-Urban land complex	6-12% Slope	64%

The two Crider-Urban soil types are located on the site. (See Figure A.9.) Crider-Urban land complex soils are usually low in strength and therefore the upper layer of the soil needs replacement with a more suitable base material or strength improvement. Although, further investigation into soil types and depth of bedrock would create more accurate data that would assist in designing foundations and determining cost, Dunn Right Engineering will not perform any tests. This is due to the danger of hitting one of the many underground utilities.

A.4 Wetlands and Floodplains

There are no wetlands or floodplains at the site.

A.5 Site Inspection

We performed a site inspection at the site and the surrounding areas.

A.5.1 12th Street and Dunn Street

This intersection is to the south of the site. (See Figure A.10.) There is only a small amount of traffic at this intersection. The lot to the northeast is empty. The lots to the north-west and south-west have residential houses. Our client believes that both houses are from the early 1900's. To the southwest, there is an apartment complex.

A.5.2 13th Street and Dunn

This intersection is to the north of the site and follows a ninety-degree turn as shown in Figure A.11. There is more traffic on this side of the site than the south side. To the north-west of the intersection is an apartment complex; while to the northeast is an electrical substation.

A.5.3 Dunn Street

Dunn Street is a north-south road that starts north of the Indiana University stadium. (See Figure A.12.) From the north, it continues south to 13th street. Dunn Street turns into 13th street at this point and continues to intersect Indiana Avenue. From the south, Dunn Street begins at East Atwater Avenue and terminates at 12th street. An Indiana Rail Road crossing just north of 12th street interrupts its north south flow.

A.5.4 13th Street and Indiana Avenue

This intersection is one of the most dangerous intersections in Bloomington, Indiana. (See Figure A.13.) Indiana Avenue is a north-south street that goes by the Indiana University campus and the athletic stadium. This intersection is difficult to see when driving because of the underpass at the Indiana Railroad.

A.6 Utilities

Storm water pipes run east along the north of the railroad and into the site. (See Figure A.14.) It crosses the site then turns back west and crosses the site again, following the sidewalk. There is also another branch of a storm water pipe that is south of the site and runs under the west sidewalk.

A waterline runs along the east side of Dunn Street and crosses directly under the railroad tracks. (See Figure A.15.) When it reaches 12th Street it branches and continues to follow Dunn Street south while following 12th Street in both the east and west directions. This is also a potential problem for all design options.

The sanitary sewer system follows Indiana Avenue and turns east on 13th Street. (See Figure A.16) In addition, another section runs east west along 12th Street.

Overhead high voltage power lines are located on the site. (See Figure A.17.) They start at the Duke metering station and head southwest over the site crossing the railroad tracks.

The Vectren natural gas line runs parallel to the railroad tracks on both sides, with metering stations located on both sides. (See Figure A.18.)

A.7 Zoning

The area surrounding the Dunn Street site has multiple zoning classifications: residential high density, industrial, planned unit development, and residential core. (See Figure A.19.) The railroad intersects Dunn Street between 12th Street and 13th Street. (See Figure A.20.) Indiana Rail Road owns this land, and currently any pedestrian crossing the tracks is a trespasser.

A.8 Conclusion

The information gathered in this feasibility study will assist the design of each option. The research portion of this study includes the site characteristics, topography, soil conditions, wetlands and floodplains, and zoning. The physical site inspection provides a way to investigate site conditions that are not apparent in research.

Dunn Right Engineering has determined that it is feasible to construct a crossing connecting both sides of Dunn Street. However, during the design and construction of this project the large amounts of utilities need to be taken in to account. Several of these will need to be relocated. In addition, since the soil is Crider-Urban land complex the upper level of this will require removal or increase in strength using appropriate materials. Another limitation to this site is the steep grade and lack of right-of-way. We assess these limitations in Appendix G.

A.9 References

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Google Earth (2007). *Google Earth.* Accessed 6 December 2007.

Natural Resources Conservation Service (1998), *Web Soil Survey 2.0.* <websoilsurvey.nrcs.usda.gov/appl> Retrieved 22 October 2007.

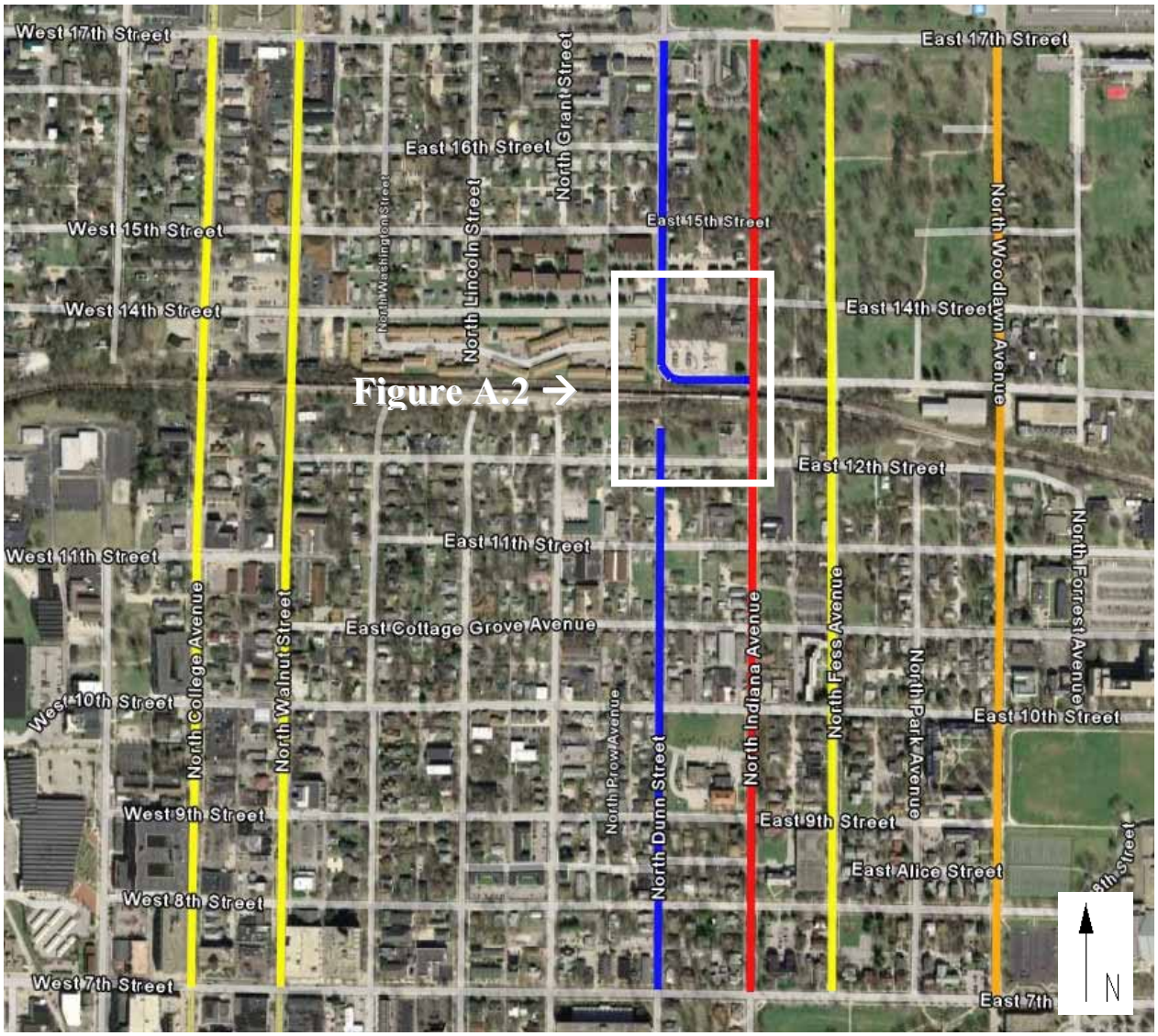

Figure A.1 – Image of current north south corridors (Indiana Avenue in red, others in yellow) and potential north south corridors (Dunn Street in blue and Woodland Avenue in orange) (Adapted from Google Earth, 2007)

Figure A.2: Location of railroad crossing at Dunn Street (in blue); Indiana Avenue in red (Adapted from Google Earth, 2007)

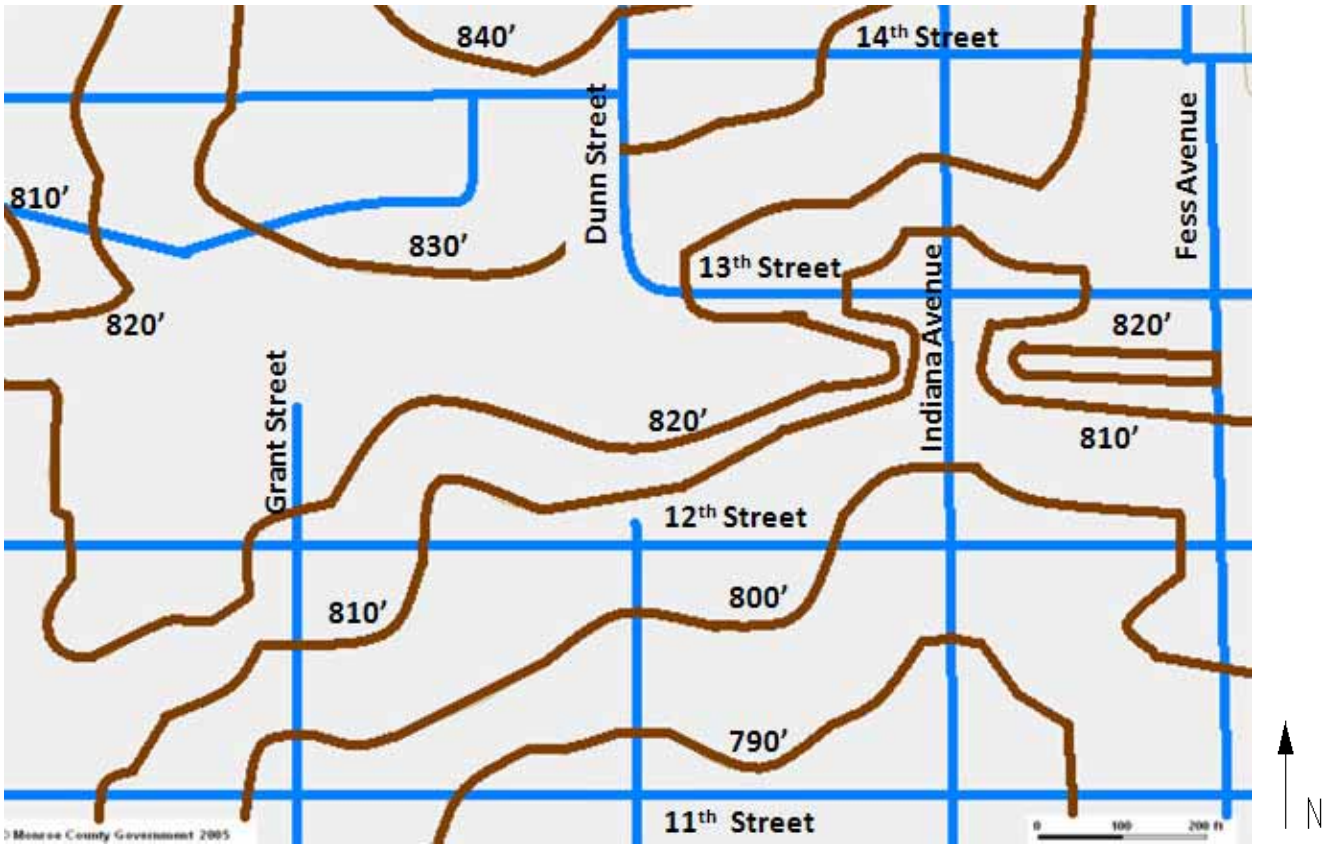

Figure A.3: Contour Map
(City of Bloomington, 2006)

Figure A.4: Parcel Map
(City of Bloomington, 2006)

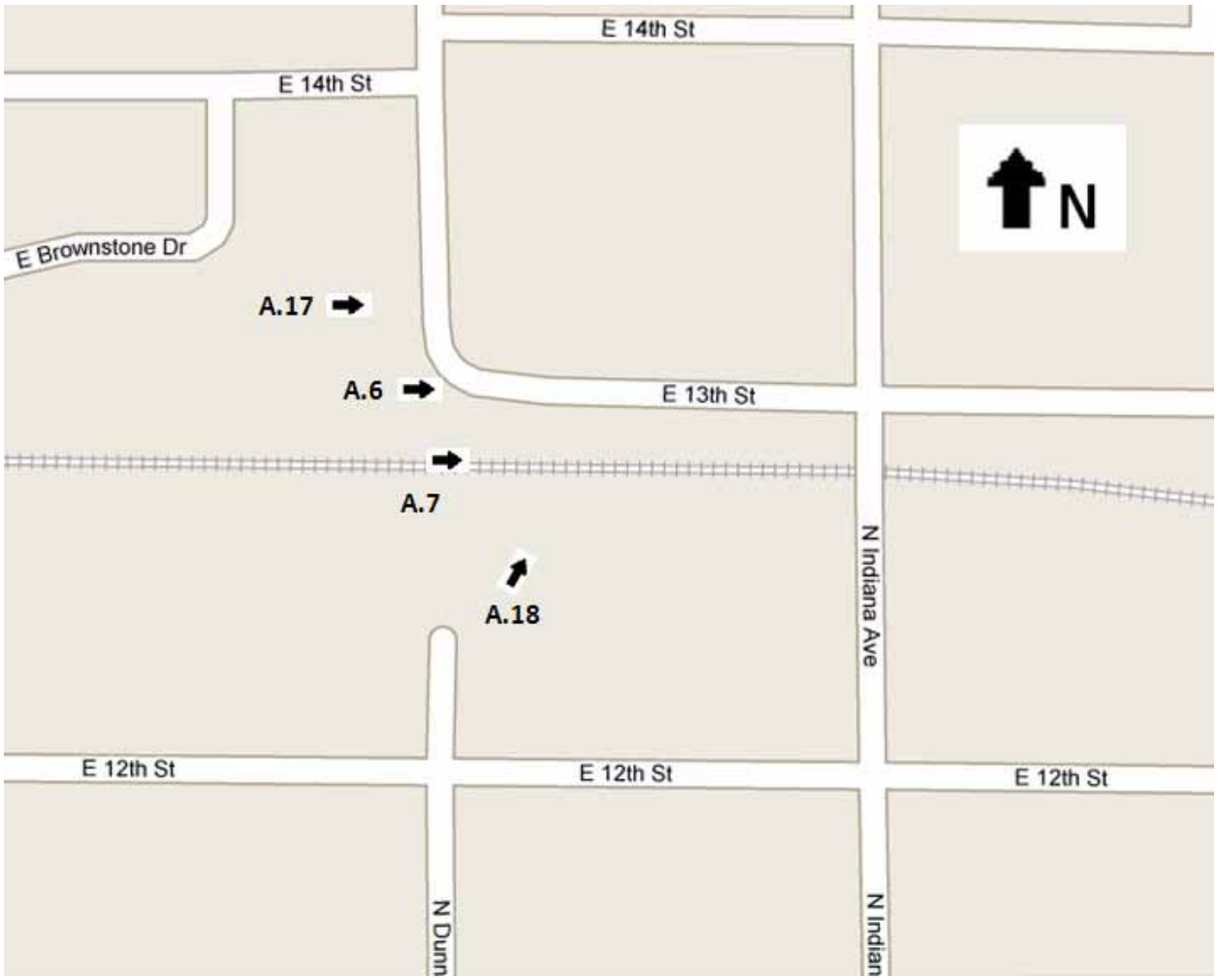

Figure A.5: Shows the location of all photographs included in the Preliminary Feasibility Study (Adapted from Google Earth, 2007)

Figure A.6: 13th street with row of trees on right. See Figure A.5 for location of photograph.

Figure A.7: Indiana Rail Road tracks cut through the middle of the site. See Figure A.5 for location of photograph.

Figure A.8: Two houses located south of Indiana Rail Road crossing at Dunn Street.
(Adapted from Google Earth, 2007)

Figure A.9: Soils
(Natural Resource Conservation Service, 1998)

Figure A.10: Intersection at 12th Street and Dunn Street.
(Adapted from Google Earth, 2007)

Figure A.11: Intersection of 13th street and Dunn Street.
(Adapted from Google Earth, 2007)

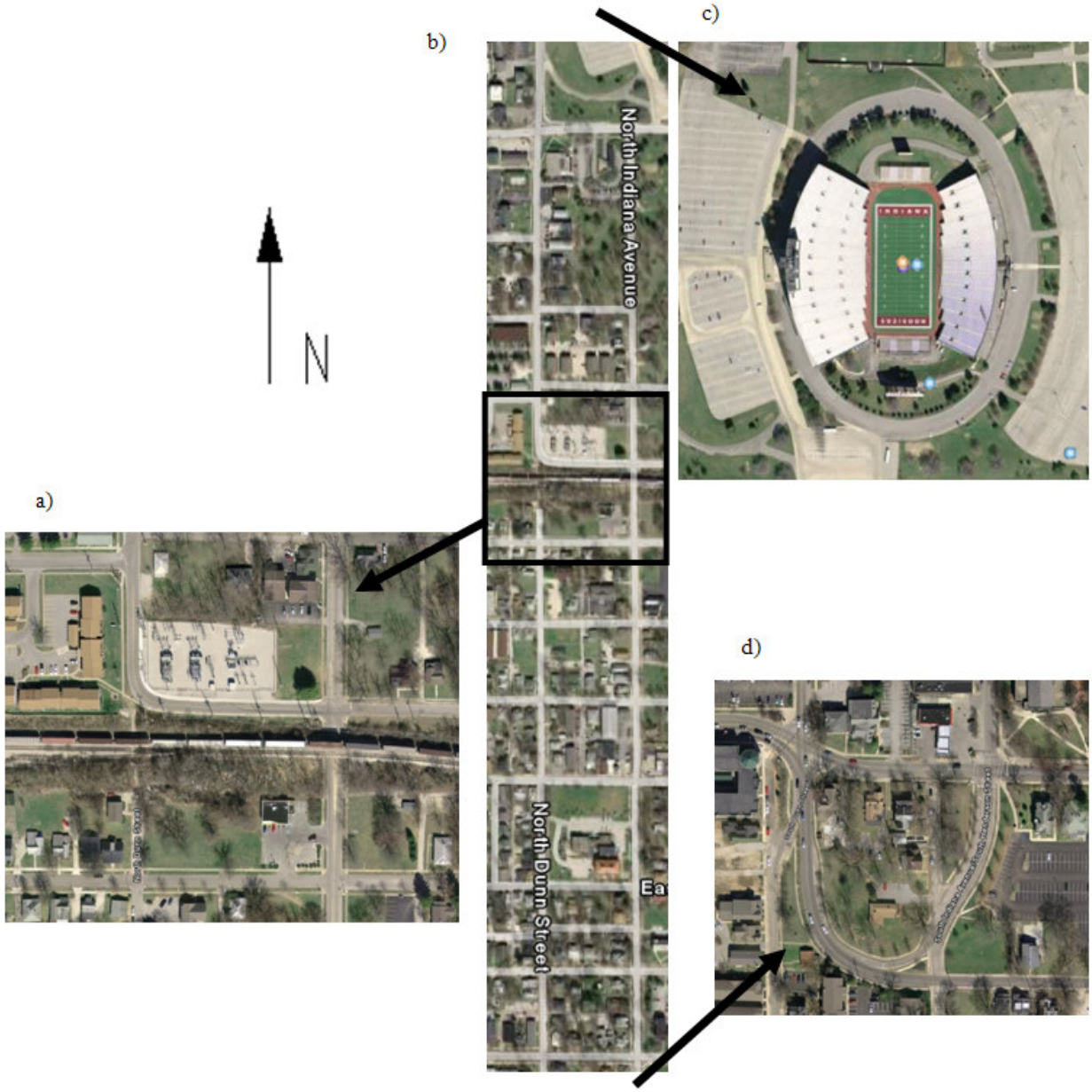

Figure A.12: From left, a) Dunn Street site location, b) span of Dunn Street, c) Indiana University Stadium, d) terminus of Dunn Street at Atwater Avenue.
(Adapted from Google Earth, 2007)

Figure A.13: Intersection of 13th Street and Indiana Avenue.
(Adapted from Google Earth, 2007)

Figure A.14: Stormwater Pipes
(City of Bloomington, 2006)

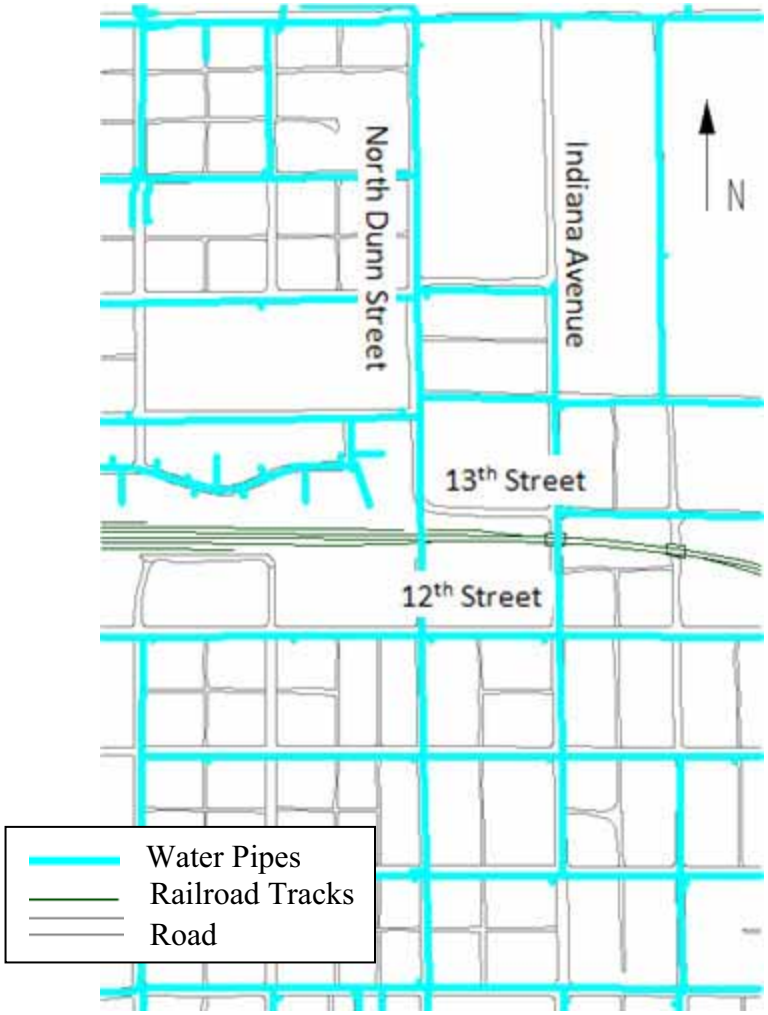

Figure A.15: Water Pipes
(City of Bloomington, 2006)

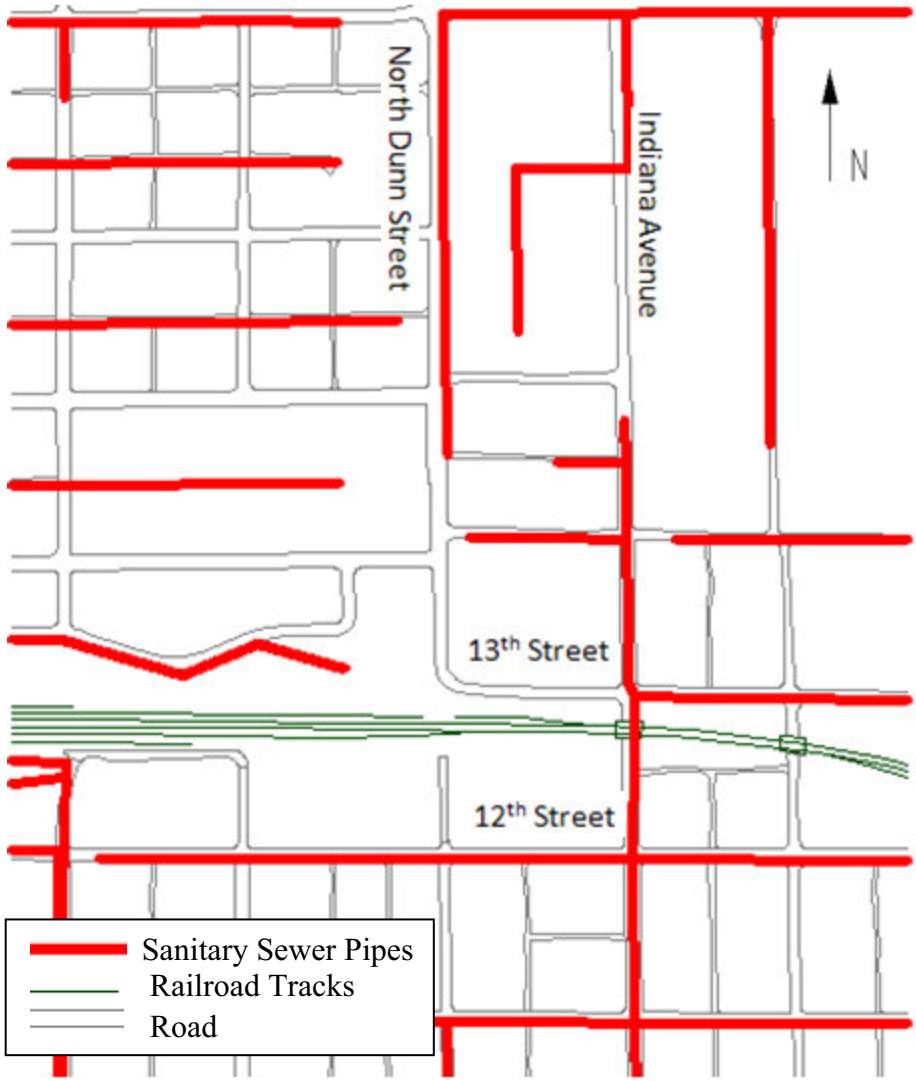

Figure A.16: Sanitary Sewer
(City of Bloomington, 2006)

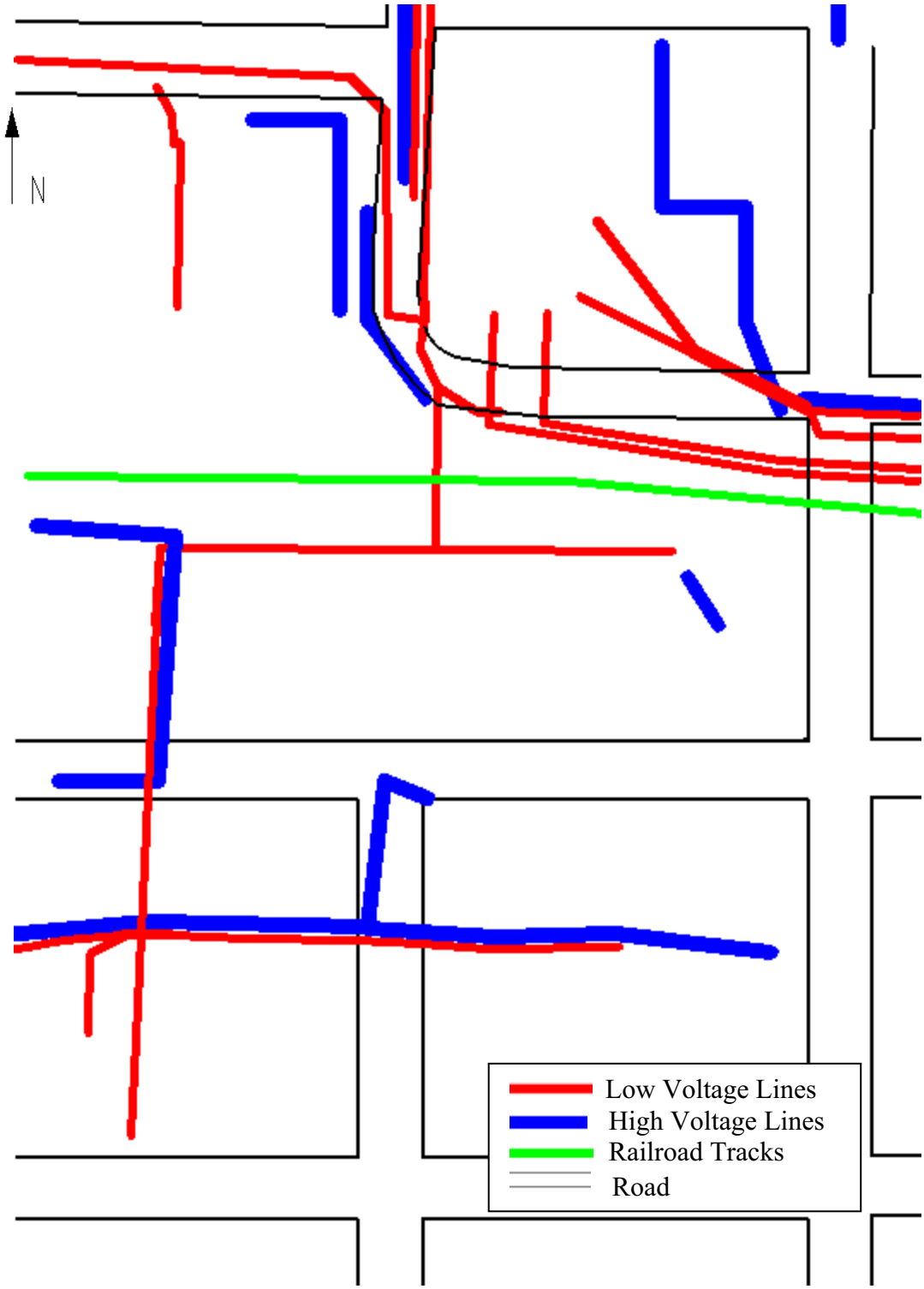

Figure A.17: Overhead Power Lines.
(Adapted from Duke Energy)

Figure A.18: Gas lines on the south side of the tracks. See Figure A.5 for location of photograph.

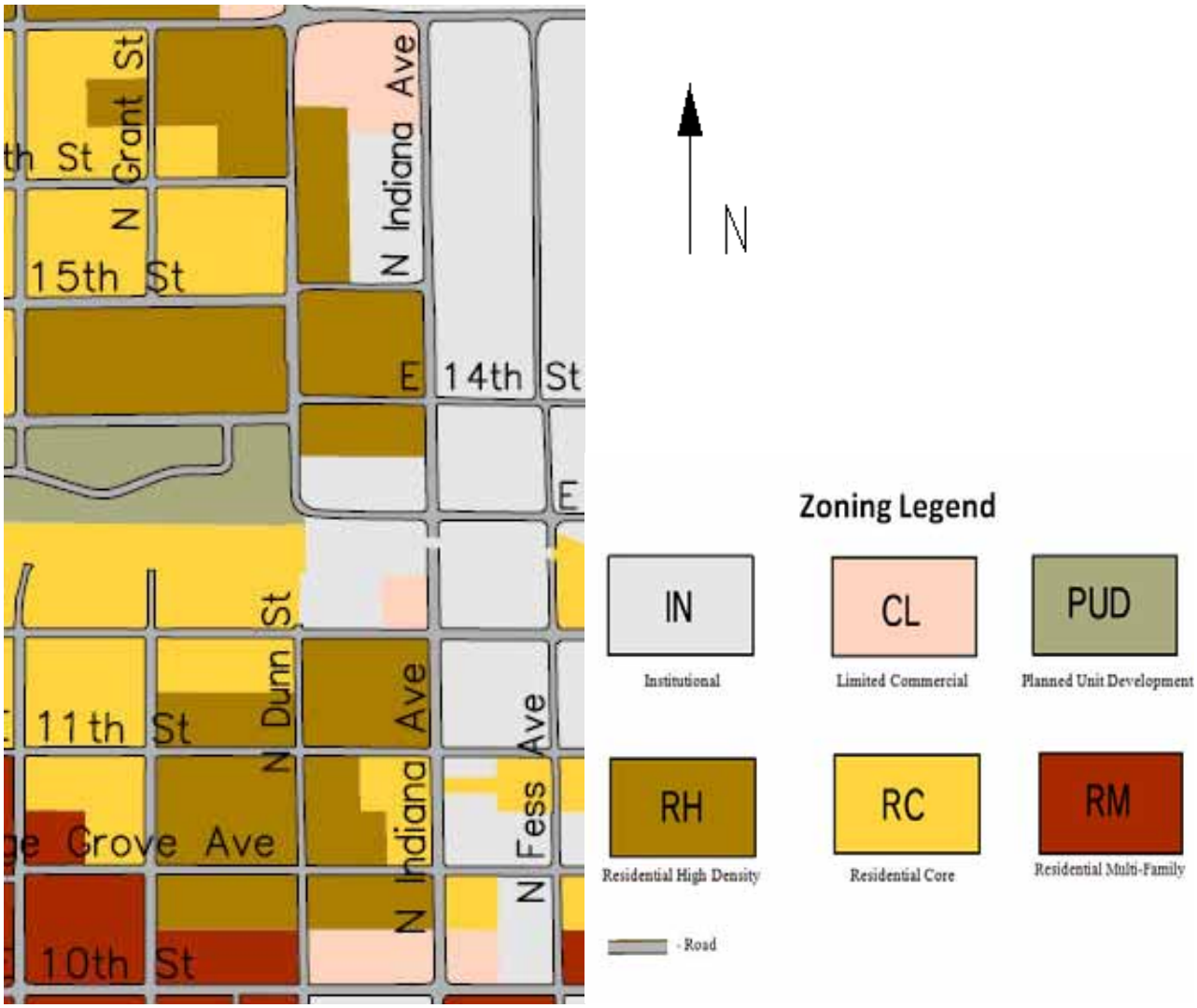

Figure A.19: Zoning Map
(City of Bloomington, 2007)

Figure A.20: Railroad Right-of-Way
(City of Bloomington, 2006)

Appendix B – Codes and Regulations

B.1 Codes and Regulations

The City of Bloomington Planning Department requires that our design team follow several federal and local regulations in the design of the Dunn Street Modernization Project. The proposed multiple-use side path option must be in accordance with the American Association of State Highway and Transportation Officials (AASHTO) Bike Book (AASHTO 1999). The AASHTO Bike Book provides standards for designing side paths. All design options are required to comply with the City of Bloomington Municipal Building Code (City of Bloomington 2007). Roadway design features are in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) (FHWA, 2003). This is required for safe signage, pavement markings, and signals. All design aspects that include earthwork, pavement and the construction of structures will follow the Indiana Department of Transportation Standard Specifications (INDOT 2008). The American with Disabilities Act (ADA) Standards for Accessible Design (USDOT 1994) is very important in the design of side paths and roadway slopes.

B.2 City of Bloomington Municipal Code

The City of Bloomington Police Department and the City Council enforce this code. The City Council votes for each new code. Mathew Bender & Company, Inc. a member of LexisNexis, a professional municipal code company, originally wrote the code. Anyone living inside the city limits is required to follow the code under penalty of the law. The purpose of this code is to regulate all local construction.

This code is relevant to our project because we are going to alter the surrounding area around the site. We will change the land, add sidewalks, adjust the location of utilities, and remove trees. The extent of each of our design options will determine how much of the code we will use.

The Municipal Code will affect our project when we formulate our Non-Motorized Traffic Plan, Stormwater System Design, and Roadway Design. This code will require us to design each system so that it will meet or exceed all Municipal Codes. This code will

regulate our design in the following areas: Stormwater Design, Excavation, Thoroughfare Development, Removal of Trees, Safety, Traffic Rules, Parking, and Speed Regulations.

B.3 Manual on Uniform Traffic Control Devices

The Federal Highway Administration (FHWA) developed the Manual on Uniform Traffic Control Devices (MUTCD) to promote safe, uniform, and efficient operation of the traffic system. The MUTCD regulates all traffic control devices such as signs, signals, markings, and any other mechanism that is used to warn or guide the public, that are associated with any public agency or other official having jurisdiction that have adopted the MUTCD. Local or federal laws back the regulations, put into effect by local law enforcement. These regulations are necessary so that the national transit system can function safely, uniformly, and efficiently.

The MUTCD assures that street signs, road markings, and all other traffic control devices are uniform throughout the nation. This helps to ensure that the public can safely know what each traffic control device represents throughout the nation, decreasing confusion and thus the likelihood of an accident. Use of these regulations for this project will require our design team to meet all standards for traffic control devices and to design the placement of all required devices. In using these regulations, data such as projected traffic conditions is required to design the intersections with either stop signs or lights. Other information such as traffic speed is important for us to consider while designing the traffic control devices. This is to account for stopping and sight distance and safely determine the required location of warning signs.

B.4 AASHTO Guide for the Development of Bicycle Facilities

The AASHTO Guide for the Development of Bicycle Facilities (AASHTO, 1999), commonly referred to as the Bike Book, was written by the American Association of State Highway and Transportation Officials to assist engineers, architects, and planners in the design of bicycle trails and paths. The purpose of this guide is to aid designers in

choosing the proper type of path to use, which varies from project to project, and in making the path as safe and functional as possible.

The Bike Book provides guidance and important design features such as stopping sight distance, vertical and horizontal curve alignments, and maximum grades. In addition, the guide provides information on signage and pavement markings. However, the Bike Book does not just provide technical assistance to the user. It also provides ideas for aesthetics and presents the logic and theory behind each design aid. Dunn Right Engineering will implement the regulations and guidelines outlined in the Bike Book to design a safe multiple-use path. The challenge will be fitting the path into the existing landscape of the City of Bloomington while providing adequate safety for all users.

B.5 ADA – American Disability Act-Standards for Accessible Design

The Federal Government, specifically the Department of Justice, enforces the American with Disabilities Act- Standards for Accessible Design (ADA) (USDOT, 1994). Across the country, almost all aspects of design and construction use this code. The purpose of this code is to ensure that all structures and projects are handicap accessible. It is necessary to comply fully with this code since the Federal Government requires it. Use of this code for this project will require us to follow a series of regulations that will govern everything from slope of our roadway and ramps to the maximum height of stairs.

The main section of code from the ADA that will affect our design is Section 4-Accessible Elements and Spaces. From this section, we will focus on Section 4.1-Minimum Requirements, which discusses new construction and accessible buildings. We will also review Section 4.3-Accessible Routes, Section 4.8-Ramps, and Section 4.9-Stairs. Utilizing these standards our design team will ensure accessibility for all pedestrians.

B.6 AASHTO Geometric Design of Highway and Streets

The American Association of State Highway and Transportation Officials (AASHTO) Geometric Design of Highway Streets (AASHTO, 2004), also known as the AASHTO Green Book, is set of guidelines on the geometric dimensions of the roadway. The AASHTO Green Book guides engineers and designers in meeting the needs of highway users while maintaining the integrity of the environment.

The AASHTO Green Book (AASHTO, 1994) provides guidelines and requirements on the design of highways and streets as well as information on road markings, street grading, levels of service, curbing, over and underpass design, and pedestrian safety. In this project, we will use these regulations to design the safest possible roadway that also meets our client's needs.

B.7 Indiana Department of Transportation Standards and Specifications

The Indiana Government enforces the Indiana Department of Transportation Standards and Specifications (INDOT, 2008). This code is used to govern all construction completed in the state of Indiana. We will follow this code in all aspects of the design of this project.

The main sections of this code that our design team will focus on is Section 200-Earthwork, Section 400-Bituminous Pavement, Section 700-Structures and Section 800-Traffic Control Devices and Lighting. State law requires Dunn Right Engineering to follow all design standards and specifications listed in this code.

B.8 Conclusion

These codes will be essential to the proper design of the Dunn Street Modernization. Throughout the study, we will refer to each of these codes and regulations in our design process.

B.9 References

AASHTO (1999). *American Association of State Highway and Transportation Officials: Guide for the Development of Bicycle Facilities*, 3rd Edition, 1999. Washington, D.C.: AASHTO. Published Guidelines.

AASHTO (2004). *American Association of State Highway and Transportation Officials: A Policy on Geometric Design of Highways and Streets,* 5th Edition, 2004. Washington, D.C.: AASHTO. Published Guidelines.

ADA (1994). *Americans with Disabilities Act: Standards for Accessible Design* <http://www.usdoj.gov/crt/ada/stdspdf.htm> Accessed 25 September 2007.

City of Bloomington, Indiana (2007). <bloomington.in.gov/egov/apps/document/center.pl> Accessed 25 September 2007.

FHWA (2004). *Federal Highway Administration: Manual on Uniform Traffic Control Devices.* 2003 Ed., Rev. 1. Washington, D.C.: FHWA.

INDOT (2008), *Indiana Department of Transportation: Standard Specifications.* <http://www.state.in.us/dot/div/contracts/standards/book/sep07/sep.htm> Accessed 25 September 2007

Appendix C – Photographic Survey

C.1 Project Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion on Indiana Avenue. The Dunn Street site would be the preferred location of an alternate route. This site is located between 12th Street and 13th Street on Dunn Street in Bloomington, Indiana (See Figure C.1.).

Dunn Right Engineering has conducted a photographic survey of Dunn Street to serve as a visual aid as the project progresses. Included in the photographic survey are aerial photos and close-up pictures of significant features around North Dunn Street. We have included an aerial map showing the location of each photograph (See Figures C.2 and C.2a). The figure number represents the location of each photograph and the direction we took the picture. All Figures are on the page with the same orientation as the arrow shows. Note: All aerial photographs and maps are from Google Earth, 2007.

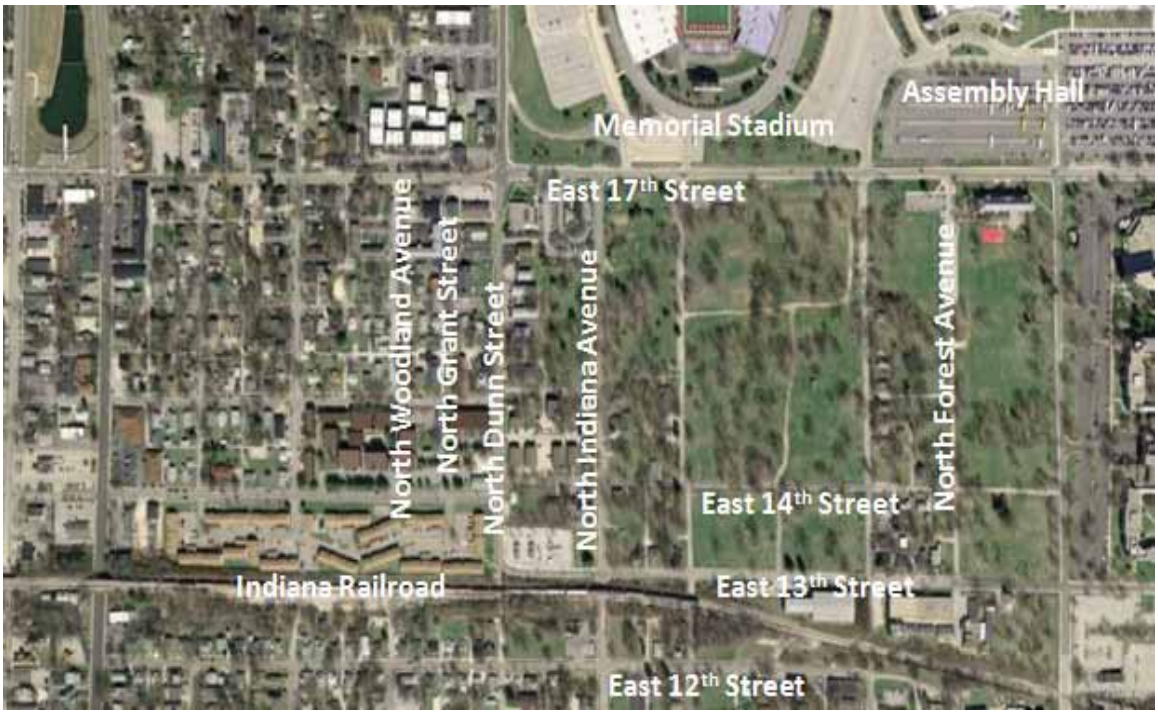

Figure C.1: Aerial photograph of the corridor.

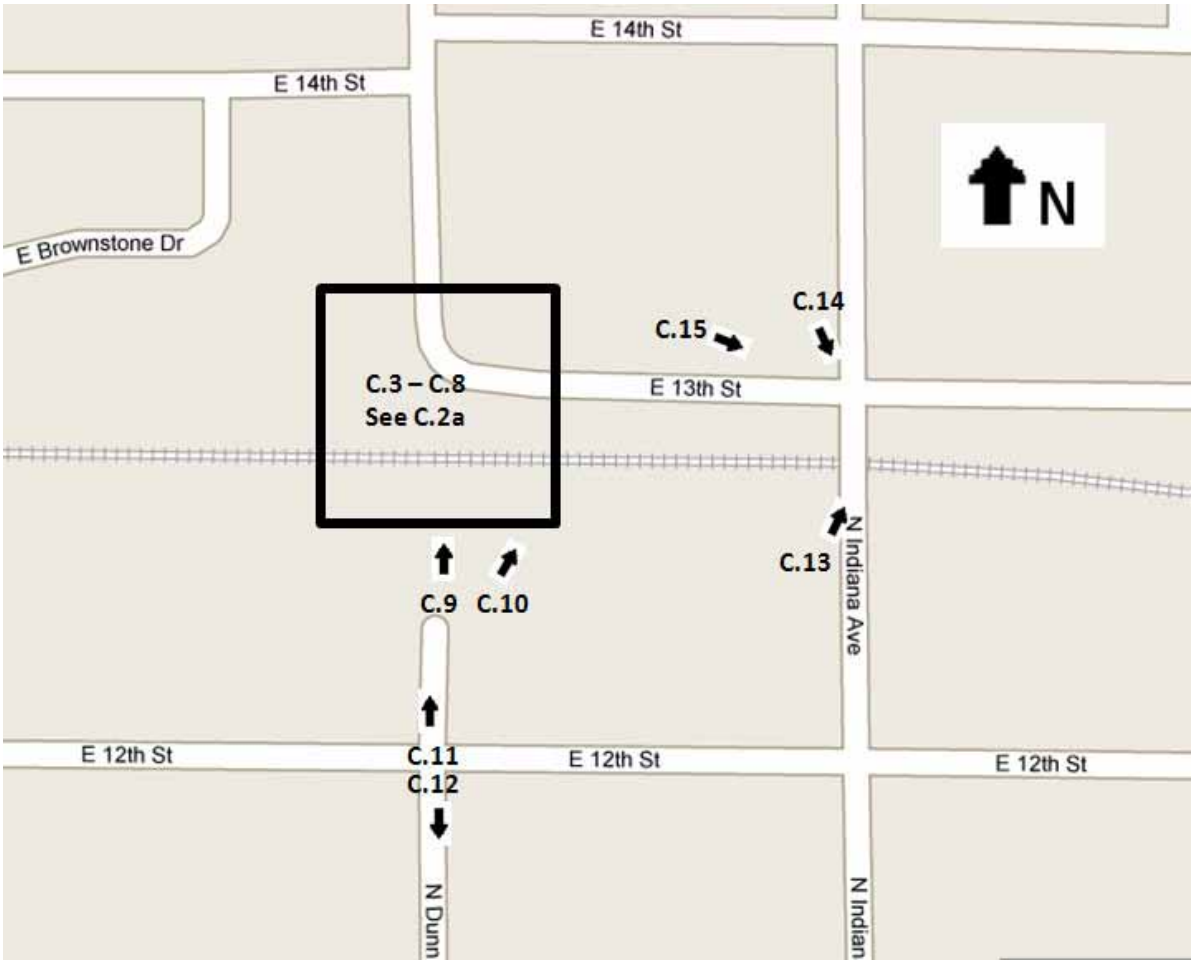

Figure C.2 (Top): Map showing location and direction of photographs.

Figure C.2a (Right): Close up of 13th and Dunn Street intersection.

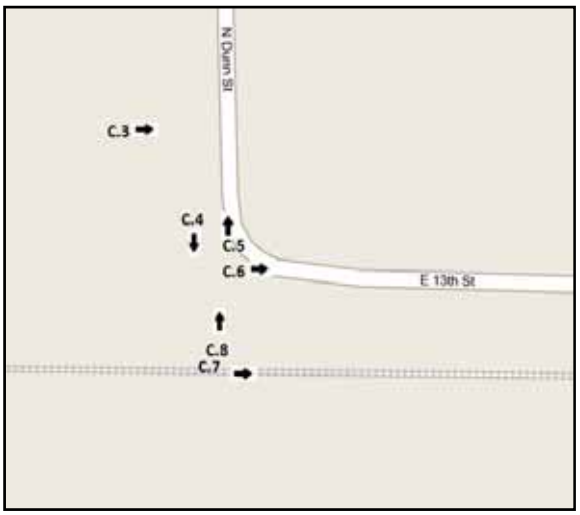

Figure C.3: Electrical substation to the east of the site.

Figure C.4: Current site: Note the walking path across the railroad tracks and the gas lines.

Figure C.5: Current site of 13th and Dunn Street intersection.

Figure C.6: Current state of 13th Street.

Figure C.7: Indiana Railroad tracks that cut through the middle of the site.

Figure C.8: Walking path over the railroad tracks.

Figure C.9: Walking path over the railroad tracks.

Figure C.10: Gas lines on the south side of the tracks.

Figure C.11: Current state of intersection 12th Street and North Dunn Street.

Figure C.12: Current state of North Dunn Street, South of Indiana Rail Road.

Figure C.13: Current state of underpass on Indiana Avenue.

Figure C.14: Current state of intersection of Indiana and 13th Street.

Figure C.15: Current state of intersection of Indiana and 13th Street.

Appendix D – Topographic Survey

D.1 Project Overview

The City of Bloomington Planning Department contacted Dunn Right Engineering to perform the Dunn Street Modernization Study. The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion on Indiana Avenue. The Dunn Street site is the current suggestion for the location of an alternate route.

D.2 Data Collection

Our design team surveyed the site in order to obtain the exact slope of the north and south sections of Dunn Street to aid us in our design process. On December 5, 2007, the crew of Austin Hastings and Ryan Pattenaude used the Nikon NPL332 to obtain a horizontal and vertical layout of the current conditions of the site. From the data obtained, we were able to produce a Roadway Profile (Figure D-1) of the site. Our data centered off a chosen datum on the middle of the railroad tracks (1000N, 1000E, 100Z) (Northing, Easting, and Elevation) to show the location and elevation of the road relative to the tracks. We chose this point because the railroad tracks are approximately level and run through the middle of the site. Therefore, our data reflects the difference between this central location and the location of each point. Figure D.1 shows the location of the points surveyed from an aerial view. Figure D.2 plots the station versus the elevation data. Our design team was able to determine that the slope of the North section of Dunn Street is -5.79% and the slope of the south section is -5.98%, meaning these sections slope downward from north to south at their respected values. The calculations of these values are in Table D.1.

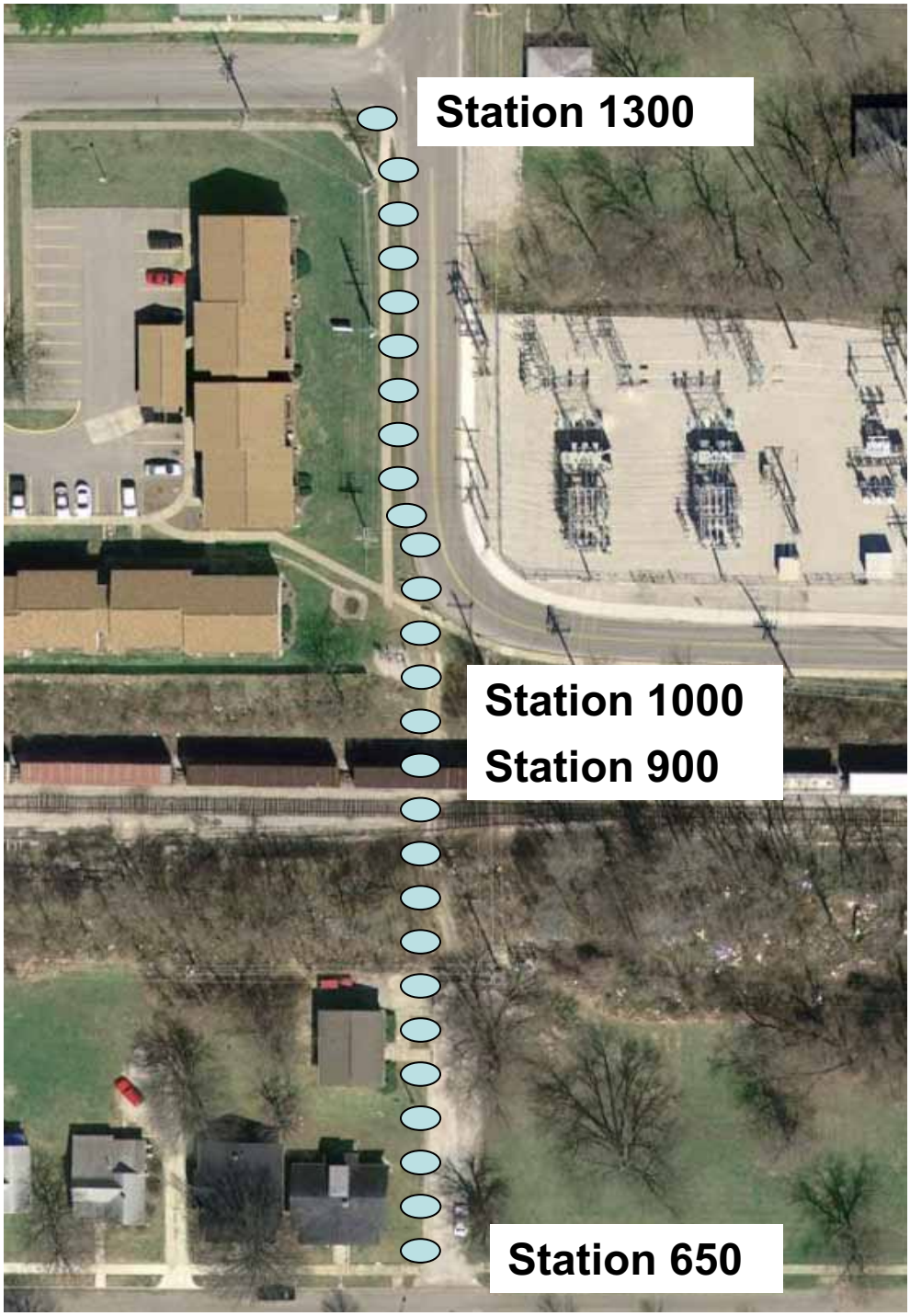

Figure D.1: Arial location of Roadway Profile stations

(Adapted from Google Earth, 2007)

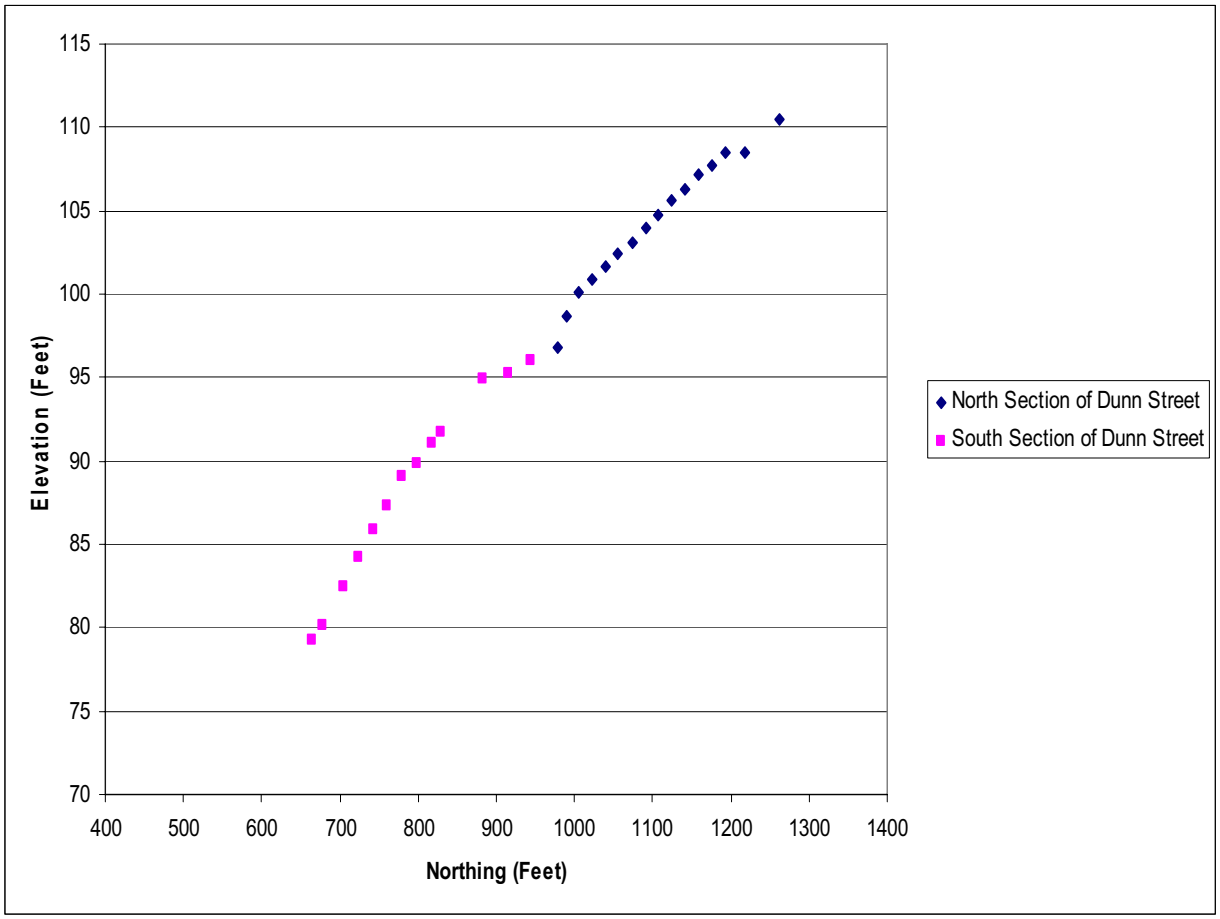

Figure D.2: Roadway Profile of Dunn Street with station versus elevation data

Table D.1: Calculations for north and south sections of Dunn Street

Dunn Street Northern Section

Station 2

$Northing_2 := 1262.13ft$

$Elevation_2 := 110.45ft$

Station 17

$Northing_{19} := 968.26ft$

$Elevation_{19} := 93.45ft$

$$NorthSlope := \frac{Elevation_2 - Elevation_{19}}{Northing_2 - Northing_{19}}$$

$$NorthSlope = 5.785 \%$$

Dunn Street Southern Section

Station 42

$Northing_{42} := 944.19ft$

$Easting_{42} := 96.07ft$

Station 54

$Northing_{54} := 663.68ft$

$Easting_{54} := 79.3ft$

$$SouthSlope := \frac{Easting_{42} - Easting_{54}}{Northing_{42} - Northing_{54}}$$

$$SouthSlope = 5.978 \%$$

Appendix E – Traffic Flow Analysis

E.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion on Indiana Avenue. The suggested alternate route is Dunn Street, which is located directly to the west of Indiana Avenue. This site is located between 12th Street and 13th Street on Dunn Street in Bloomington, Indiana.

The purpose of this appendix is to compare each design option in terms of traffic flow. We performed an intersection analysis and a travel time analysis to help determine which option would result in the quickest mode of transportation.

E.2 Intersection Analysis

Dunn Right Engineering established a system to compare the traffic effects of each design option. Figure E.1 shows the two intersections analyzed in this study by using Synchro, the traffic analysis software used by the City of Bloomington. We analyzed each intersection to evaluate how the traffic flow changes when Dunn Street is connected. Tables E.1 and E.2 present the results of each option. The "Do Nothing" option leaves the existing roadway the same and does not connect Dunn Street at the intersection of the Indiana Rail Road. The "Proposed Connection" option is to connect the north and south side of Dunn Street on both sides of the tracks.

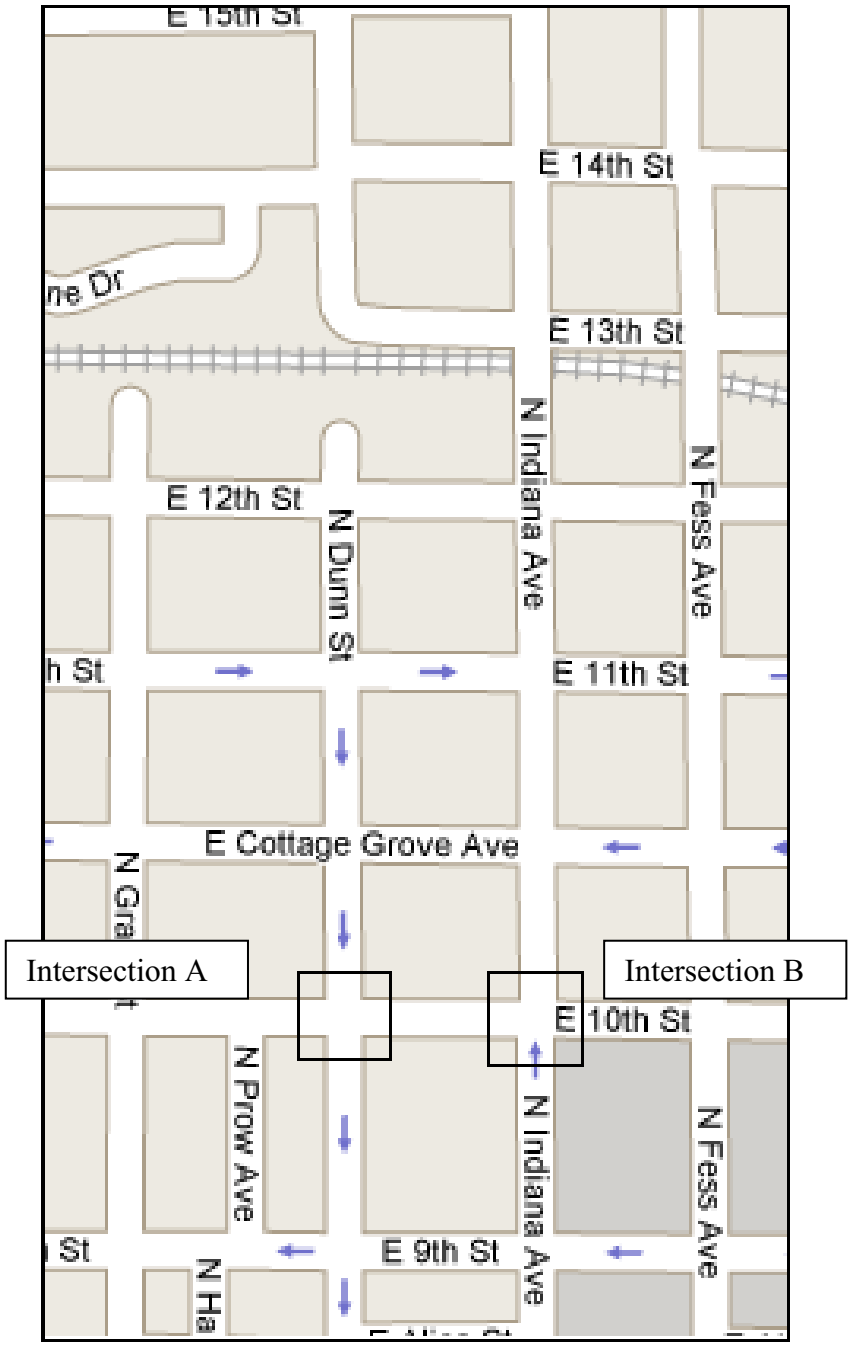

Figure E.1 - Location of Intersections
(Adapted from Google Maps, 2007)

Table E.1: Intersection A – Dunn Street & 10th Street

	Do Nothing Approach	Proposed Connection
Total Delays	less	more
LOS	A	C
Stops (vhh)	less	more
CO2 Emissions	less	more
Flow	less	more

Table E.2: Intersection B – Indiana Ave. & 10th Street

	Do Nothing Approach	Proposed Connection
Total Delays	more	less
LOS	C	B
Stops (vhh)	more	Less
Peak Flow	more	Less

Definitions:

- LOS = Level of Service - Determines the quality of service of signals by measuring traffic density. Ranked A – F with A being the safest intersection
- vph = vehicles per hour

These two intersections provide a good representation of total traffic flow. The intersection at Indiana Avenue and 10th Street already has a high volume of traffic without the proposed Dunn Street connection. The proposed connection increases the capacity and LOS of Intersection B. The increased capacity will assist traffic flow and lessen total travel time. The LOS improvement means that the intersections are more efficient, and therefore provide a better traffic flow, and lessen total travel time. The intersection at Dunn Street and 10th street currently has the best level of service possible. The proposed connection will downgrade this intersection to a 'C' rating which is still in a safe region. Once combined, however, the one-way pair of Dunn Street and Indiana Avenue is capable of handling a higher overall traffic flow. With the

increased capacity, public transportation will be able to utilize routes that are more direct and efficient.

E.3 Travel Time Analysis

Another approach to analyze the traffic flow for each design option is to determine the time it takes for a vehicle to travel across the site. This analysis will start at the intersection at 17th Street and Dunn Street and finish at 10th Street and Dunn Street. (See Figure E.2.) This provides a good representation of how each design option will function with respect to travel time.

Each option has an associated travel time calculated by accounting for stoppage time, the posted speed limit, and safety maneuvers like slowing down to cross railroad tracks. (See Section E.4.) The underpass and overpass options take the least amount of travel time while the upgrade of existing conditions option takes the most amount of travel time. The at-grade crossing travel time does not account for railroad interference. When a train is crossing, this option will take the most amount of travel time. The speed limit through each option is 30 mph. All options assume that traffic acts safely and lawfully. These times are assuming that no traffic or delays have occurred.

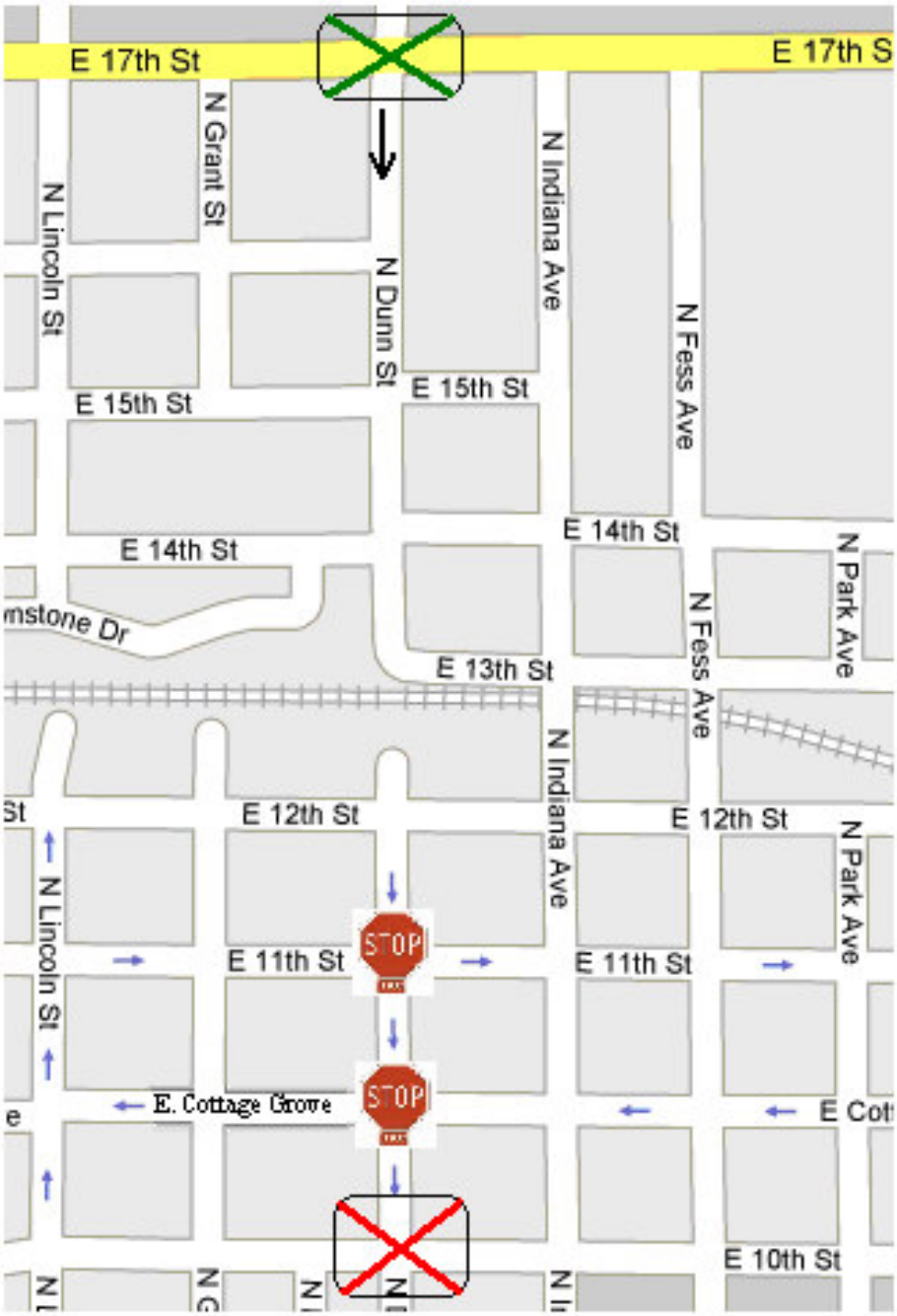

Figure E.2: Starting and Ending Points for Travel Time Analysis
(Adapted from Google Maps, 2007)

E.4 Calculations

Underpass/Overpass Option

Stop Signs at:

11th & Dunn Street
Cottage Grove Ave. & Dunn Street

Total Distance from North to South = 2672 ft

Time to Stop at each Stop Sign:

V_o(mi/hr) = 0
A (ft/s^2) = 14
V (mi/hr) = 30

$$t := -\frac{v - v_0}{a}$$

The acceleration rate of 14 ft/sec^2 was found in the AASHTO Green Book. This is a conservative value for acceleration.

Time = 3.14 seconds accelerate for each stop sign
The same time is used for deceleration.
Total time at Stop sign = **6.28 seconds**

Use a **2.5 second** delay at the stop sign. This accounts for the time to look in both directions for safety purposes.

Start and Stop total time is **8.8 seconds** for each stop sign

Total Time = (V/Total Distance) + Total Stopping Time
=(30 mph/2672 ft) + (6.28 + 2.5 + 8.8) sec

Total Time = 78 Seconds

At-Grade Crossing

The time of 78 seconds from the Underpass and Overpass will be used as the base amount. We only included a few changes for this design option.

Time at the Railroad Crossing

V_o(mi/hr) = 15
A (ft/s^2) = 14
V (mi/hr) = 30

$$t := -\frac{v - v_0}{a}$$

Time at crossing = **3.1 seconds**

This extra time is due to people slowing down when they cross the tracks.

The total time for this option = (V/Total Distance) + Total Stopping Time
= 78 + 3.1

Total Time = 81 Seconds

Upgrade of Existing Conditions

We used the same stop sign locations as the previous options.

The extra time for this option will be the three turns

13th & Indiana Avenue
Indiana Avenue & 12th Street
12th Street & Dunn Street

Total Travel Distance of 3432 feet

Total Time for distance = **78 Seconds**

Turn Time

V_o(mi/hr) = 5
A (ft/s^2) = 14
V (mi/hr) = 30

$$t := -\frac{v - v_o}{a}$$

The total time for each turn (accelerate and decelerate) = **5.2 Seconds**

Total Time for this option = (V/Total Distance) + Total Stopping Time
= 78 + [5.2(3 turns) + 8.8(2 stop signs)]

Total Time = 112 Seconds

E.5 Conclusion

The intersection and travel time analysis both evaluate each design option for the traffic flow criterion in Appendix G. The time saved by connecting Dunn Street is a very important factor in determining which option is the most effective. Both the underpass and overpass options have the greatest improvement in travel time resulting in improved traffic flow.

Appendix F – Design Options

F.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the north south corridor of Indiana Avenue in Bloomington, Indiana. (See Figures F.1 and F.2.) Currently Indiana Avenue is one of the major roads making up the corridor. It is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. Dunn Street is the preferred road that the city of Bloomington Planning Department would like to use to alleviate these problems. The following sections describe alternatives to alleviate the crowding and safety issues. The design option which best meets the client's requests was determined using a decision matrix, which is presented in Appendix G.

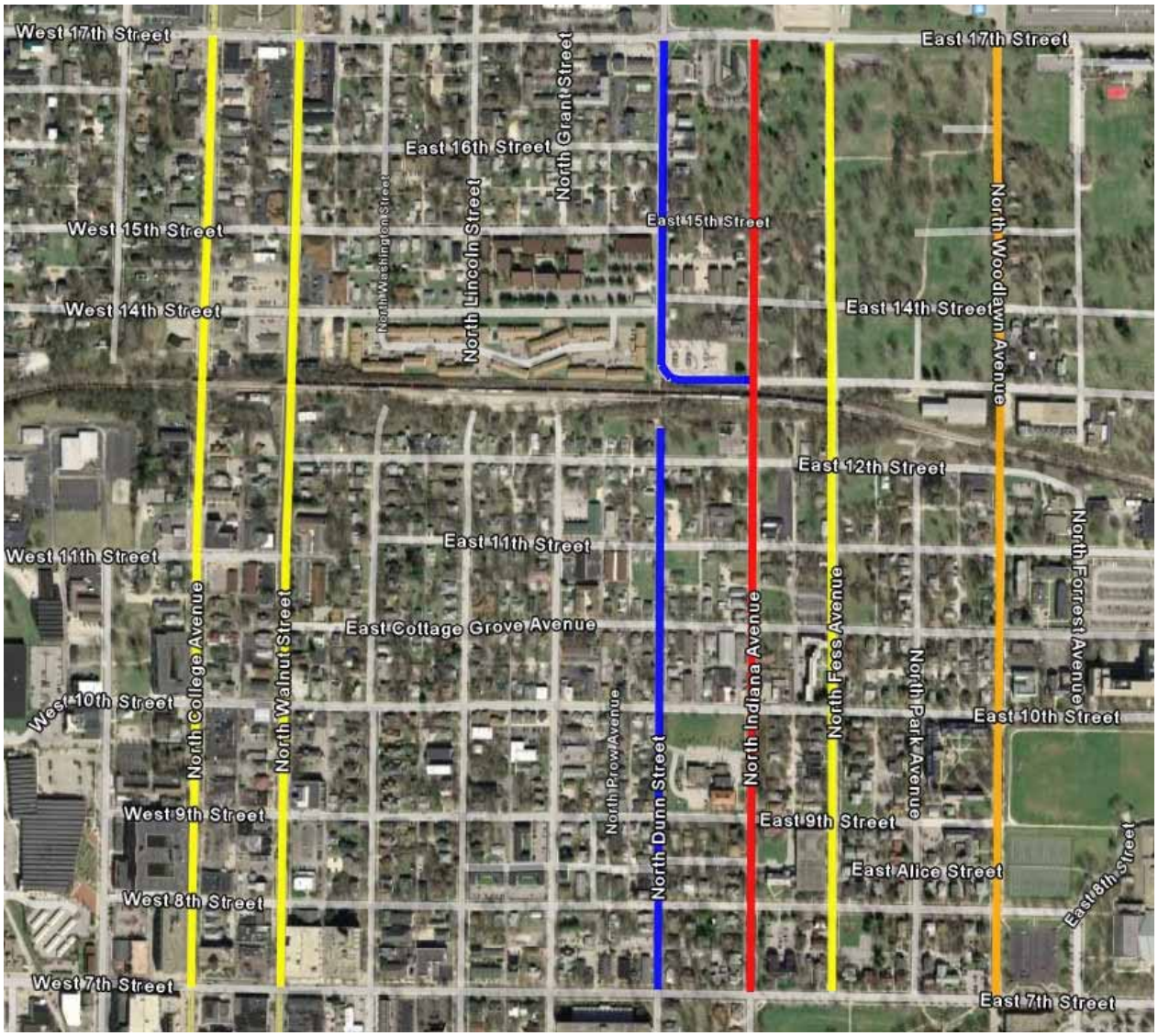

Figure F.1: Image of current north south corridors (Indiana Avenue in red, others in yellow) and potential north south corridors (Dunn Street in blue and Woodland Avenue in orange) (Adapted from Google Earth, 2007)

Figure F.2: Dunn Street site location
(Adapted from Google Earth, 2007)

F.2 Overpass

This option focuses on constructing a bridge over the railroad crossing at Dunn Street. (See Figure F.3.) Due to the limited right-of-way, realignment may be necessary. This crossing would create a north south one-way corridor with Indiana Avenue. It would be especially effective because it starts north of the Memorial Stadium, Indiana University's football stadium, and flows into East Atwater Avenue which is south of 7th Street. This option alleviates the major congestion at the intersection of Indiana and 13th street, which is one of the most dangerous intersections in Bloomington. An overpass also greatly increases the safety of the Indiana University students that currently trespass across the Indiana Rail Road tracks. An overpass option also has disadvantages. For instance, this design option would cause a higher volume to

flow into the historical neighborhood on the south side of the railroad tracks. The maximum reasonable grade for the approaches is 8% causing an approach length of at least 350 feet. This will alter the flow of other roads onto Dunn Street.

Figure F.3: Proposed location of the Dunn Street Overpass
(Adapted from Google Earth, 2007)

F.2.1 Cost

Dunn Right Engineering used historical information to estimate the cost for this design option using an overpass project in Rosenburg, Texas built in 2001 (Potential Infrastructure Improvements, 2006). This similar project consists of a busy two-lane road disconnected due to a railroad crossing. The city needed to create a crossing to relieve the traffic on the nearby main road. Because it too crosses a railroad, closure costs and other railroad costs are included in the

total project cost. The cost of this project is an estimated $5 million. We adjusted this amount to the equivalent cost in Bloomington, Indiana for 2007. Using the RS Means Manual, Dunn Right Engineering adjusted this figure accounting for the location and time period to calculate total of $7.95 million. In order to do this we used adjustment factors associated to the location and year and multiplied the original cost by them. We used the small town of Odessa, Texas as a representative city because the town of Rosenburg, Texas is not in the RS Means Manual and they are of the same size and region. The results of this cost adjustment are in Table F.1. Additional costs may emerge as the design progresses. Because of the extent of the approach lengths, additional streets will need roadwork in order to flow into Dunn Street. This will require additional soil work, utility interference, and road closures.

Table F.1 Overpass Cost Adjustment

Total Cost		$5,000,000	
<u>Historical Cost Indexes</u>			
Current Year	166.3		
Built 2000	125.1		
		Percentage	133.2%
<u>City Cost Indexes</u>			
Bloomington	90.7		
Ft. Wayne	75.8		
		Percentage	119.6%
Total Cost	**$7,953,000**		

F.2.2 Political Feasibility

Dunn Right Engineering has split the criterion of political feasibility into three groups: Indiana Rail Road, City of Bloomington residents, and Indiana University public transit and the Bloomington Fire Department. The Dunn Street Modernization affects each in different ways.

The Indiana Rail Road does not want any railroad interference, as closures cost money. Too many closures could also cause a loss of a rail line. The local residents do not want to lose their quiet atmosphere nor do they want they want a busy neighborhood road. The Indiana University public transit system is currently inefficient because it avoids most of Indiana Avenue due to congestion. A crossing would benefit them because it would open a new, more efficient route that may provide better service and cost less. The Bloomington Fire Department currently just barely clears the underpass on Indiana Avenue. Any improvement to this underpass or additional crossings will help their response time, which directly relates to public safety. These three groups are the most affected by the Dunn Street Modernization. Approval from each is important when assessing each design option.

F.2.2.1 Indiana Rail Road

The Indiana Rail Road is in favor of this design option. This option allows traffic to cross the railroad tracks without interfering with the railroad. During construction, the railroad would be able to continue with its normal scheduled routes with minimal disturbances.

F.2.2.2 City of Bloomington Residents

The residents are opposed to this design option. It will drastically change the historical neighborhood south of the Indiana Rail Road. The overpass approaches may obstruct and impede on the residents' land and the increase in traffic will disrupt the quiet neighborhood. Interpretations of the residents' responses are from information provided by the City of Bloomington Planning Department.

F.2.2.3 Indiana University and Bloomington Fire Department

Indiana University and the Bloomington Fire Department are in favor of this design option. It would allow for articulated buses and fire ladder trucks to cross the tracks safely. This option would also provide new bus routes and faster response times from the fire department.

F.2.3 Traffic Flow

Dunn Right Engineering determined that the construction of an overpass would have a total travel time of 78 seconds to drive through this corridor. Refer to Table E.3 for calculations. This time is more efficient than the current 112 seconds. We determined that all stop signals currently have a delay of 8.8 seconds, see Appendix E for calculations.

F.3 Underpass

This option consists of the construction of a tunnel underneath the railroad. (See Figure F.4.) In order to construct an underpass on Dunn Street, the railroad tracks would temporarily close and be removed. Constructing an underpass will improve traffic flow on the north south corridor as well as on the local east west streets. This option alleviates the major congestion at the intersection of Indiana and 13th street, which is one of the most dangerous intersections in Bloomington. An underpass also greatly increases the safety of the Indiana University students that currently trespass across the Indiana Rail Road tracks. An underpass option also has disadvantages. For instance, this design option would cause a higher volume to flow into the historical neighborhood on the south side of the railroad tracks. Pedestrians may not feel as safe walking through a tunnel at night. The maximum reasonable grade for the approaches is 8% causing an approach length of at least 350 feet. This will alter the flow of other roads onto Dunn Street.

Figure F.4: Proposed location of the Dunn Street Underpass
(Adapted from Google Earth, 2007)

F.3.1 Cost

Dunn Right Engineering used historical information to estimate the cost for this design option using an underpass project in Garrett, Indiana built in 2000. A major road had an at-grade crossing that caused major traffic delays. The underpass fixed the traffic delays. The original cost for this project was $7.5 million. We adjusted this amount to the equivalent cost in Bloomington, Indiana for 2008. Using the RS Means Manual (RS Means, 2007), Dunn Right Engineering adjusted this figure accounting for the location and time period to calculate total of $10.55 million. In order to do this we used adjustment factors associated to the location and year and multiplied the original cost by them. We used the nearest city, Fort Wayne, Indiana, for the city adjustment using the RS Means Manual. This information is in Table F.2. According to the

Monroe county engineer the depth of bedrock is generally shallow, somewhere in the range of 5-10 feet. Dunn Right Engineering recommends that the city complete a more in-depth study to find the exact depth of bedrock. The presence of bedrock too close to the surface will drastically increase the cost estimate. Because of the extent of the approach lengths, additional streets will need roadwork in order to flow into Dunn Street. This will require additional excavation, utility relocation, and road closures.

Table F.2: Underpass Cost Adjustment

Total Cost		$7,500,000	
Historical Cost Indexes			
Current Year	166.3		
Built 2000	120.9		
		Percentage	137.6%
City Cost Indexes			
Bloomington	90.7		
Ft. Wayne	88.7		
		Percentage	102.3%
Total Cost	**10,549,000**		

F.3.2 Political Feasibility

Dunn Right Engineering has split the criterion of political feasibility into three groups: Indiana Rail Road, City of Bloomington residents, and Indiana University public transit and the Bloomington Fire Department. The Dunn Street Modernization affects each in different ways.

F.3.2.1 Indiana Rail Road Opinion

The Indiana Rail Road is strongly opposed to this option. An underpass will cause constant conflict with the railroad during construction. Track removal is necessary while excavating for the new underpass. Track replacement occurs once the underpass is

constructed. This would cost the Indiana Rail Road a large sum of money while the tracks are out of service.

F.3.2.2 City of Bloomington Residents

The residents are opposed to this design option. It will drastically change the historical neighborhood south of the Indiana Rail Road. The underpass approaches will obstruct and impede on the residents' land, and the increase in traffic will disrupt the quiet neighborhood. Interpretations of the residents' responses are from information provided by the City of Bloomington Planning Department.

F.3.2.3 Indiana University and Bloomington Fire Department

Indiana University and the Bloomington Fire Department are in favor of this design option. It would allow for articulated buses and the fire ladder trucks to cross the tracks safely and in a more effective manner. This option would also provide new bus routes and faster response times from the fire department.

F.3.3 Traffic Flow

Dunn Right Engineering determined that the construction of an underpass would have a total travel time of 78.3 seconds to drive through this corridor. Refer to Table E.3 for calculations. This time is more efficient than the current 112 seconds. We determined that all stop signals would have a delay of 8.8 seconds, see Appendix E for calculations.

F.4 Up-Grade of Existing Conditions

This option focuses on updating the existing conditions of the surrounding area. It will not connect Dunn Street, but will focus on the addition of traffic signals at the intersection of Indiana and 13th Street. The frequency and duration for the traffic signals are based on traffic-activated devices on both intersecting streets to ensure the most efficient traffic flow. Currently Indiana Avenue crosses the Indiana Rail Road using an underpass that has a low vertical clearance and a concrete column in the middle of the road. The expansion of this underpass provides an extra two feet of vertical clearance and removal of the center column provides a clear line of sight and a wider roadway and pedestrian path. The intersection of Indiana and 12th Street also requires

reconstruction including a larger turning radius to allow for larger transit vehicles such as articulated buses to maneuver in this area safely. Currently this intersection has a very small radius, making the turn from 12th Street onto Indiana Avenue impossible for busses. Finally, a pedestrian bridge connects the flow of bicycle and pedestrian traffic safely over the railroad tracks on Dunn Street. (See Figure F.5.)

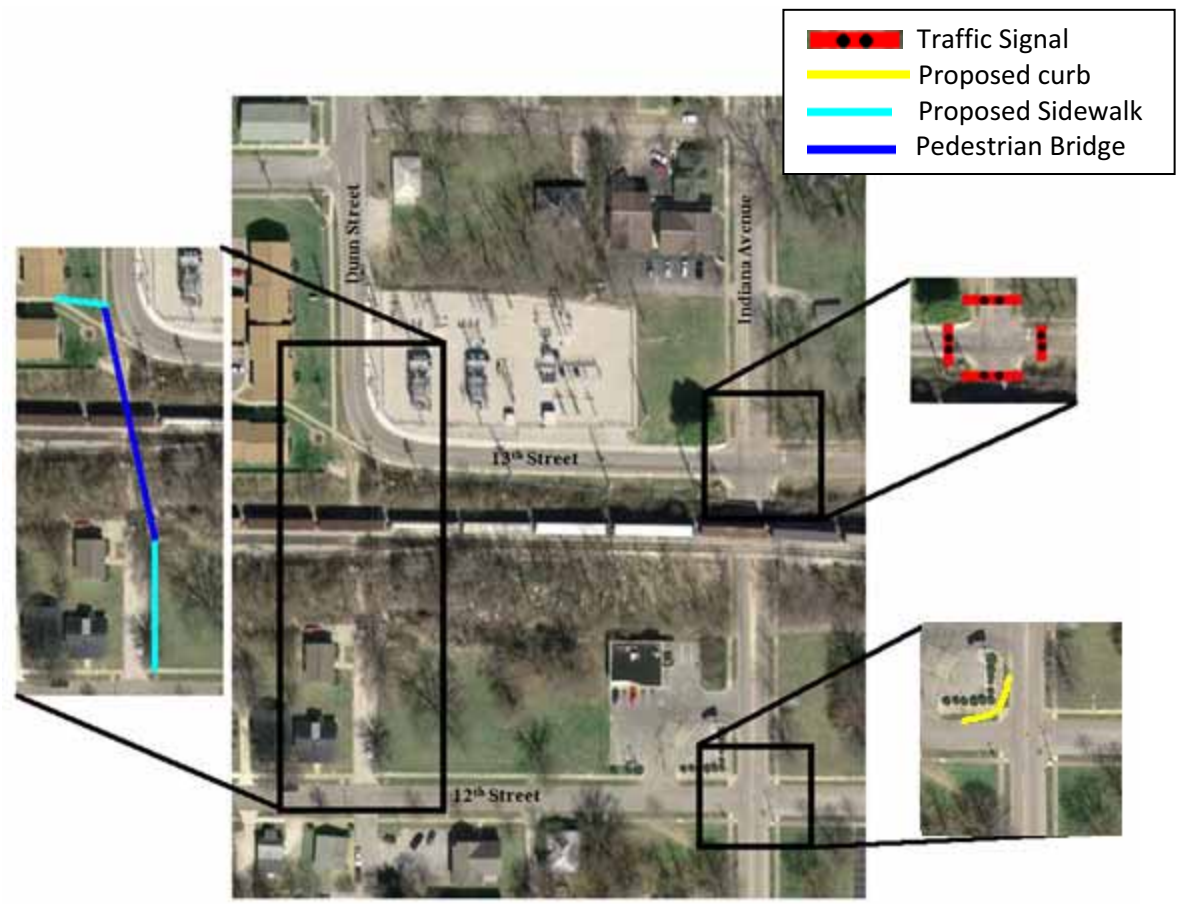

Figure F.5 – Proposed upgrade of existing conditions

F.4.1 Cost

The cost estimates for the upgrade use just the major construction elements. We used the RS Means Manual (RS Means, 2007) to estimate the cost of each element. We estimated the intersection signals at 13th and Indiana Avenue at $161,000 and the pedestrian bridge at $190,000. The estimated cost of upgrading the Indiana Avenue underpass is $80,000. These are only the basic items tabulated; any other upgrades will raise the cost only a fraction compared to the total cost of $430,500. This information is in Table E.3.

Table F.3 Upgrade of Existing Conditions Adjustment
<u>Intersection Traffic Signals</u> Total: $160,640 <u>Pedestrian Bridge</u> Cost per square feet: $126.58*(150'*10') = $189,870 **Total Cost: $430,500**

F.4.2 Political Feasibility

Dunn Right Engineering has split the criterion of political feasibility into three groups: Indiana Rail Road, City of Bloomington residents, and Indiana University public transit and the Bloomington Fire Department. The Dunn Street Modernization affects each in different ways.

F.4.2.1 Indiana Rail Road Opinion

The Indiana Rail Road is in favor of this design option. This design option causes the least railroad interference. The railroad would only have to close its tracks for approximately a short period once the major excavation finishes. In this period the removal of the existing bridge occurs, an additional excavation will provide more vertical clearance, and an installation of the prefabricated pre-stressed bridge occurs.

F.4.2.2 City of Bloomington Residents

The residents are in favor of this design option because it minimizes the impact on the neighborhood. Very little right-of-way is required by the city; no driveway realignment is necessary; and no residents will lose their houses. Interpretations of the residents'

responses are from information provided by the City of Bloomington Planning Department.

F.4.2.3 Indiana University and Bloomington Fire Department

Indiana University and the Bloomington Fire Department are in favor of this design option. It would allow for articulated buses and the fire ladder trucks to use the Indiana Avenue underpass safely and more quickly due to increased clearance.

F.4.3 Traffic Flow

Dunn Right Engineering determined that the total travel time of 112 seconds is necessary to drive through this corridor for the upgrade of existing conditions. Refer to Table E.3 for calculations. This design option allows additional traffic flow and it upgrades the safety of all types of traffic. We determined that all stop signals will have a delay of 8.8 seconds, see Appendix E for calculations.

F.5 At-Grade Crossing

This option includes extending Dunn Street to cross the Indiana Rail Road tracks and an upgrade of the current conditions of Dunn Street. (See Figure F.6) It allows for any type of vehicular traffic including articulated buses and fire ladder trucks to cross safely. This design option would also include the construction of bike paths along Dunn Street in order to ensure the safety of cyclists.

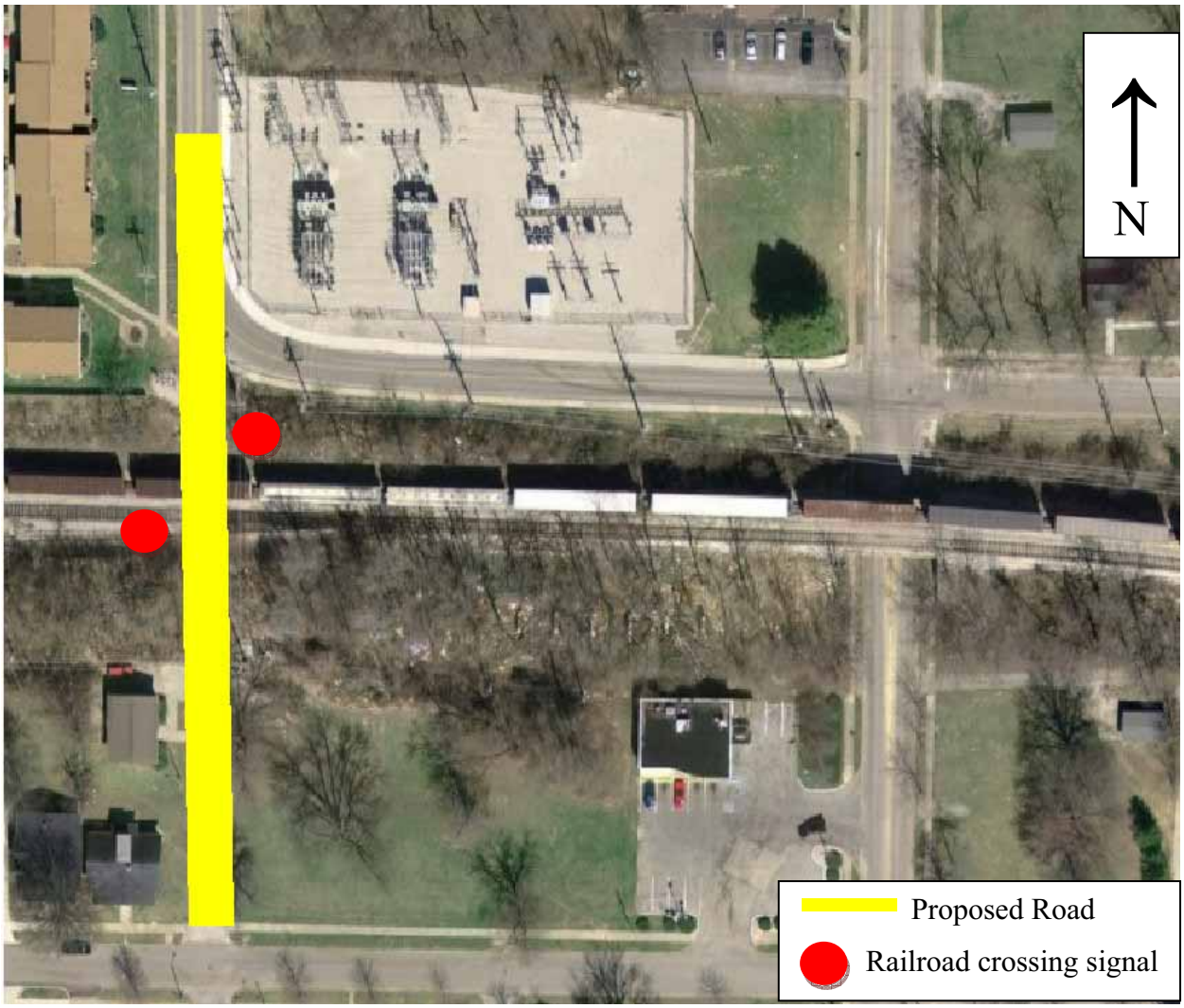

Figure F.6 Proposed location of at-grade crossing

(Adapted from Google Earth, 2007)

F.5.1 Cost

Dunn Right Engineering used historical information to estimate the cost for this design option from an at-grade crossing located in the City of Bakersfield, California. (City of Bakersfield, 2004) That project cost the city $250,000 to construct. We adjusted this amount to the equivalent cost in Bloomington, Indiana for 2008. Using the RS Means Manual (RS Means, 2007), Dunn Right Engineering adjusted this figure accounting for the location and time period to calculate total of $251,000. In order to do this we used adjustment factors associated to the location and year and multiplied the original cost by them. Table F.4 presents the calculations.

Table F.4 At-Grade Cost Adjustment			
Total Cost		$250,000	
Historical Cost Indexes			
Current Year	166.3		
Built 2004	143.7		
		Percentage	115.8%
City Cost Indexes			
Bloomington	90.7		
Bakersfield	104.5		
		Percentage	86.8%
Total Cost	**251,000**		

F.5.2 Political Feasibility

Dunn Right Engineering has split the criterion of political feasibility into three groups: Indiana Rail Road, City of Bloomington residents, and Indiana University public transit and the Bloomington Fire Department. The Dunn Street Modernization affects each in different ways.

F.5.2.1 Indiana Rail Road Opinion

The Indiana Rail Road is completely against this design option. Currently the Indiana Rail Road opposes this option because it is trying to reduce the number of at-grade crossings. They use this area not only as a through route but also as a holding station where trains will stop and wait for other trains to pass. This design option would have minimal effects on the railroad during construction, but it would cause several more vehicle and train interactions causing large delays and decreasing the safety of the public. The city fines the Indiana Rail Road for long delays.

F.5.2.2 City of Bloomington Residents

The residents are in favor of this design option because it minimizes the impact on the neighborhood yet they will gain a more efficient route to their houses. Very little right-of-way is required by the city, no driveway realignment is necessary, and no residents will lose their house. Interpretations of the residents' responses are from information provided by the City of Bloomington Planning Department.

F.5.2.3 Indiana University and Bloomington Fire Department

Indiana University and the Bloomington Fire Department are in favor of this design option. It would allow for articulated buses and the fire ladder trucks to cross the tracks safely and in a more effective manner. This option would also provide new bus routes and faster response times from the fire department.

F.5.3 Traffic Flow

Dunn Right Engineering determined that the construction of an at-grade crossing would have a total travel time of 81 seconds to drive through this corridor. Refer to Table E.3 for calculations. This time is more efficient than the current 112 seconds. We determined that all stop signals will have a delay of 8.8 seconds. See Appendix E for calculations.

F.6 Future Design Options

Dunn Right Engineering has determined that by performing modernization studies on Woodlawn Avenue and Fess Avenue in the future the north-south corridor may improve. These are both north-south roads that have the potential to open up as one-way pairs. Currently the Indiana Rail Road tracks bisect Woodlawn Avenue with no crossing. There is a possibility that purchasing right-of-way at this site is easier because of fewer residents living along these roads. Fess Avenue currently has a narrow underpass that has an extremely low vertical clearance. In the future, these sites could create another north-south one-way pair to alleviate the university traffic if updated. (See Figure F.7)

Figure F.7: Location of North Fess Avenue (Blue) and North Woodlawn Avenue (Red)

(Adapted from Google Earth, 2007)

F.7 References

City of Bakersfield (2004). *Before the public utilities commission of the State of California* http://docs.cpuc.ca.gov/published/Final_decision/39142-04.htm

Google. (2007). *Google Earths.* <earth.google.com> Accessed 7 December 2007.

Idaho Transportation Department (2003). *Idaho Transportation News Release* <http://itd.idaho.gov/press/2003PRESS/090303B.htm>

Potential Infrastructure Improvements (2006). *Houston Region Freight Rail Study* <http://www.houstonrailplan.com/projects/glidden.htm> Accessed 6 December 2007.

RS Means. (2007). *Building Construction Cost Data.* United States of America: Reed Construction Data.

Appendix G – Assessment of Design Options

G.1 Introduction

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion on Indiana Avenue. The Dunn Street site is the suggested location of an alternate route. This site is located between 12th Street and 13th Street on Dunn Street in Bloomington, Indiana.

This appendix explains the criteria used to evaluate each design option discussed in Appendix F and to present the ratings with a recommended best option. With the help of the City of Bloomington, Dunn Right Engineering chose three criteria with which to rate each design option. These are cost, political feasibility, and traffic flow. Each criterion has a possible rating of one through three with a rating of three being the best.

G.2 Cost

The cost criterion uses the overall construction cost of the design option. It does not include future costs for maintenance. These costs use amounts discussed in Appendix F. The City of Bloomington finds this criterion to be the most important, therefore giving it a weight of 50%.

Table G.1 presents the thresholds for the three possible ratings for cost. These are from the maximum cost preferred by the City of Bloomington Planning Department, which is $1.3 million. From there, the cost thresholds provide a moderate score for projects that exceed this cost. The lowest rating is for costs far beyond the city budget.

Table G.1: Rating Thresholds for Cost Criterion

Rating	Criterion
3	< $1.3 Million
2	$1.3 Million - $10 Million
1	> $10 Million

G.3 Political Feasibility

The political feasibility criterion uses the approval of three different entities in Bloomington, Indiana. These entities are Indiana University and the Bloomington Fire Department, the Indiana Rail Road, and the nearby residents. It is important for these three groups to approve of the

Dunn Street Project because they will be the most affected by its changes. The City of Bloomington finds this criterion equally important to traffic flow, assigning a weight of 25% as well.

Table G.2 presents the thresholds for the three possible ratings for political feasibility. They each use the amount of approval that exists for each design option. Because each group has equal importance, only the number of approvals is considered. If all three entities approve, that design option earns the highest possible score. The approval of each option is in Appendix F.

Table G.2: Descriptions of the Ratings for the Political Feasibility Criterion

Rating	Criterion
3	All three entities approve of the option
2	Two entities approve of the option
1	One or zero entities approve of the option

G.4 Traffic Flow

The traffic flow criterion uses the flow of three different types of traffic. The three types are automobiles, bus and emergency vehicle traffic, and pedestrian and bicycle traffic. These are the three main types of traffic that will flow through the Dunn Street site. Each option assumes that pedestrians follow the safest route lawfully and therefore a level of safety is included in each option. The City of Bloomington considers this equally important to political feasibility, assigning it a weight to it of 25%.

Table G.3 presents the thresholds for the three possible ratings for traffic flow. The scores use the time of travel for each option. Each option has an associated travel time, which is in Appendix E.

Table G.3: Descriptions of Ratings for the Traffic Flow Criterion	
Rating	Criterion
3	Travel time is < 80 seconds
2	Travel time is between 80 – 100 seconds
1	Travel time is >100 seconds

G.5 Design Option Recommendation

Dunn Right Engineering evaluated each option with respect to each criterion and arrived at the ratings in Table G.4. Based on the total weighted average rating, Dunn Right Engineering recommends the upgrade of existing conditions option. The at-grade crossing option also has the same score and is, therefore, a reasonable choice for the client. The Indiana Rail Road is adamant about decreasing current at-grade crossings, however, so the best recommendation is the upgrade. Dunn Right Engineering has proceeded with the design of the components that upgrade the existing conditions.

Table G.4: Dunn Street Modernization Study Decision Matrix

Criteria	Importance Factor	Overpass	Underpass	At-Grade Crossing	Upgrade of Existing Conditions
Cost	0.50	2	1	3	3
Political Feasibility	0.25	2	1	2	3
Traffic Flow	0.25	3	3	2	1
Total	**1.0**	**2.3**	**1.5**	**2.5**	**2.5**

Appendix H – Overpass Replacement

H.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the Indiana Avenue corridor in Bloomington, Indiana. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. The City of Bloomington Indiana Planning Department prefers to alleviate these problems using Dunn Street by creating a crossing at the Indiana Rail Road tracks. However, Dunn Right Engineering has determined that the best method of alleviating these problems is an upgrade of the existing infrastructure near Dunn Street.

H.2 Existing Situation and Proposed Solution

The railroad overpass on Indiana Avenue is the major reason that the intersection located just north of this overpass is one of the most dangerous intersections in Monroe County (MPO, 2007). Currently there are several major problems associated with this overpass. The current clearance of 12 feet 4 inches is too low to safely accommodate the articulated buses of the public bus system and fire trucks, both of which have a height of 12 feet 3 inches. This limits routes for the articulated buses and detours the fire department. In addition, the center pier creates an obstruction for the sight triangles (See Figure H.1.) and naturally slows traffic for those traveling on North Indiana Avenue.

Figure H.1: View of current condition of overpass on N. Indiana Ave.

In order to alleviate these problems, Dunn Right Engineering recommends a complete replacement of the current structure with one that will rectify the current problems by allowing sufficient clearance for public vehicles as well as remove all sight obstructions. Replacing the overpass presents several challenges because the railway operates approximately six trains daily and the railroad has expressed concern about delaying any trains across the overpass. The replacement of the overpass will require the closure of North Indiana Avenue during the major construction phases of this replacement. This will require the rerouting of vehicular and public bus traffic around the intersection of Indiana Avenue and East 13th Avenue. In order to minimize the impact on vehicular traffic, closure of this intersection will occur over several weekends.

Dunn Right Engineering proposes that the new overpass be a prefabricated steel structure with reinforced concrete piers and cross beams. We will utilize the existing retaining walls while adding three reinforced concrete piers with pier caps on either side of the overpass to create a structure that will support the steel deck. The steel structure allows the removal of the existing middle pier, thus increasing the sight triangles through the intersection. In addition, the replacement of the existing concrete deck with a shallower steel deck will allow for the proper

vertical clearance of 14 feet for articulated busses and fire trucks. The basis for the construction phasing and design in this appendix comes from the Federal Highway Administration's Prefabricated Bridge Elements and Systems webpage (FHWA, 2008). Actual implementation of this plan will require review and planning by a licensed professional engineer.

Construction phasing of this overpass replacement will be crucial to the success of this project, as it will influence the length of shutdown the railroad as well as inconvenience to public traffic in the area. In order to minimize closure as well as cost to the railroad and to maximize traffic flow efficiency, construction will occur over several 48 to 60 hour periods over weekends while rail and public traffic are at their lowest. Construction periods will not take place during home football games due to the site being in close proximity to the football stadium.

H.3 Traffic Rerouting Plan

Dunn Right Engineering plans to shut down four intersections as well as the streets between these intersections surrounding the site during the several weekend construction periods. White "X's" mark these intersections shown in Figures H.2 and H.3. The blockage of these intersections will allow for a safe work environment for the construction crew as well as eliminate any public disturbances, creating a more efficient work environment. In order to minimize the impact on the public, closures will not occur until after rush hour on Fridays and must be open by 6:00 am on Mondays to accommodate Indiana University traffic. This will allow for an approximate work time each weekend of 60 hours. Figures H.2 and H.3 display the proposed detour routes around the closed intersections.

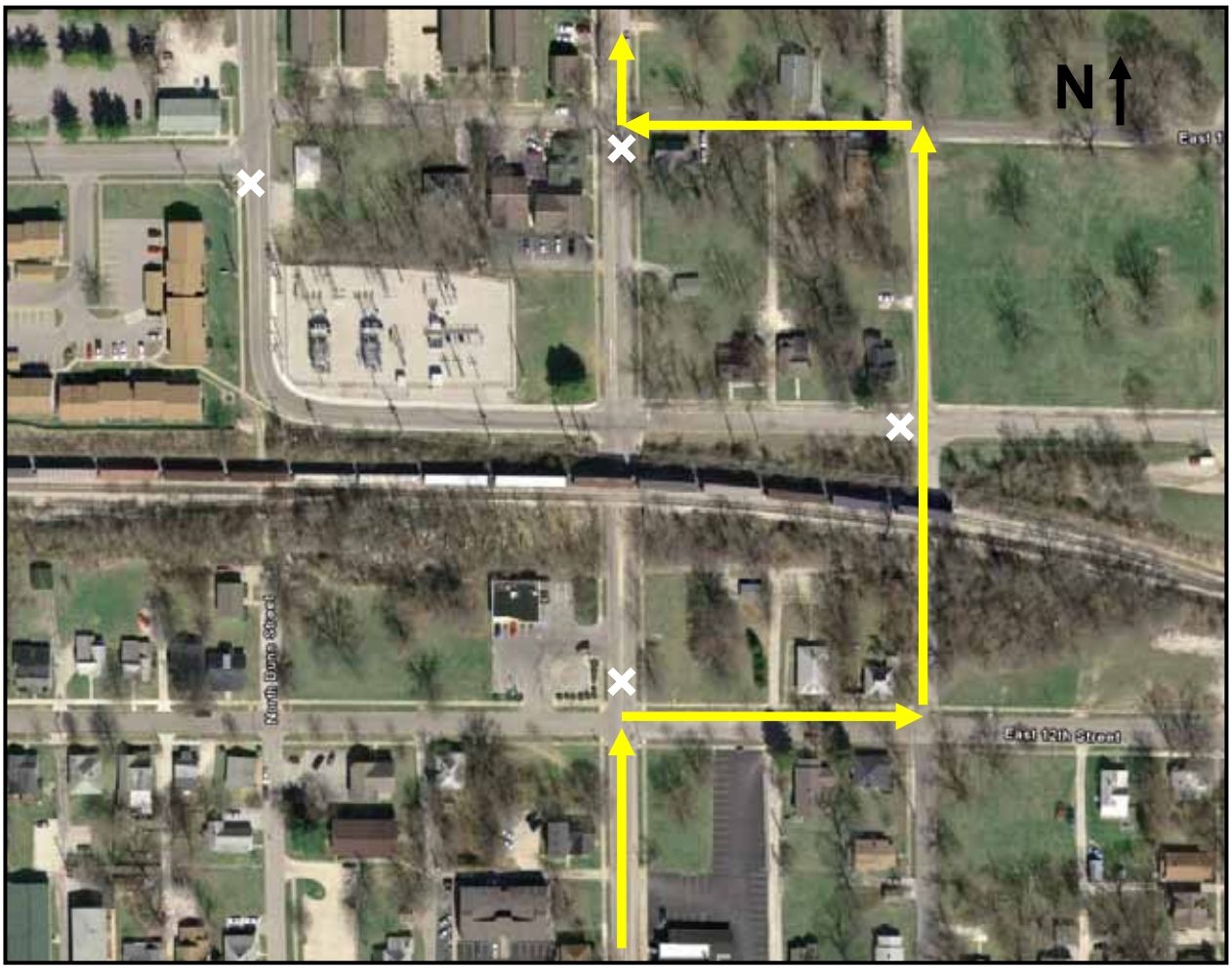

Figure H.2: Rerouting pattern for northbound traffic on North Indiana Avenue.
(Adapted from Google Earth, 2008)

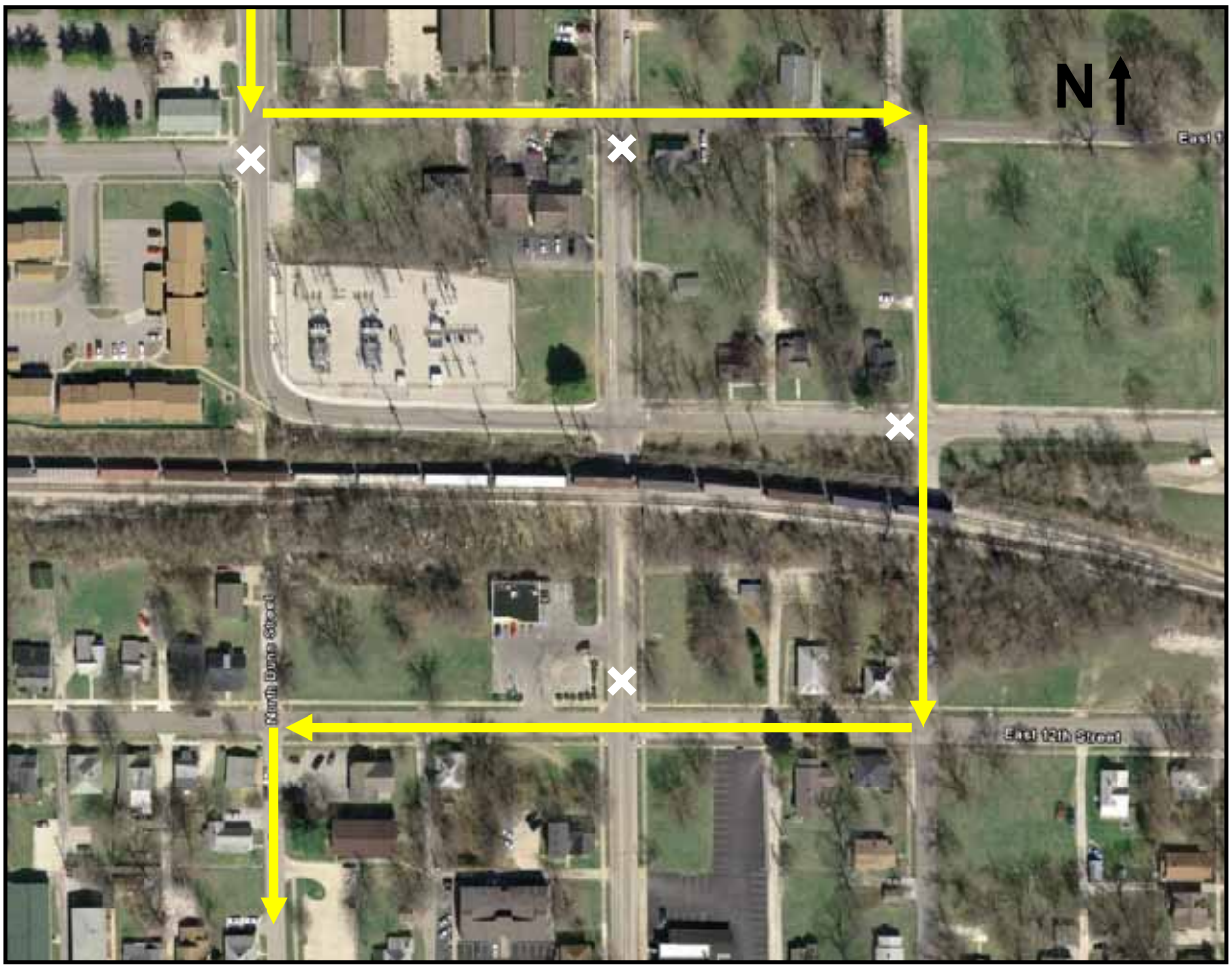

Figure H.3: Rerouting pattern for southbound traffic on Dunn Street .
(Adapted from Google Earth, 2008)

H.4 Phase One: Pier Construction

The first phase of the overpass construction is the construction of the piers. (Figure H.4) We designed the piers to accommodate the weight of the trains that use it daily as well as the weight of the prefabricated steel structure that will replace the current concrete structure. The construction crews will need to drill to bedrock so that the piers have sufficient strength to support the loads they will experience. This will require crews to drill to a depth of approximately 7 feet, as this is the approximated depth given to us by our client. Upon reaching bedrock, construction crews will place formwork and reinforcing steel in the shafts to give the piers sufficient strength. Concrete placement can occur once the reinforcing steel and formwork are in place. The concrete then needs time to cure. Please refer to Section H.7 for the design of these piers.

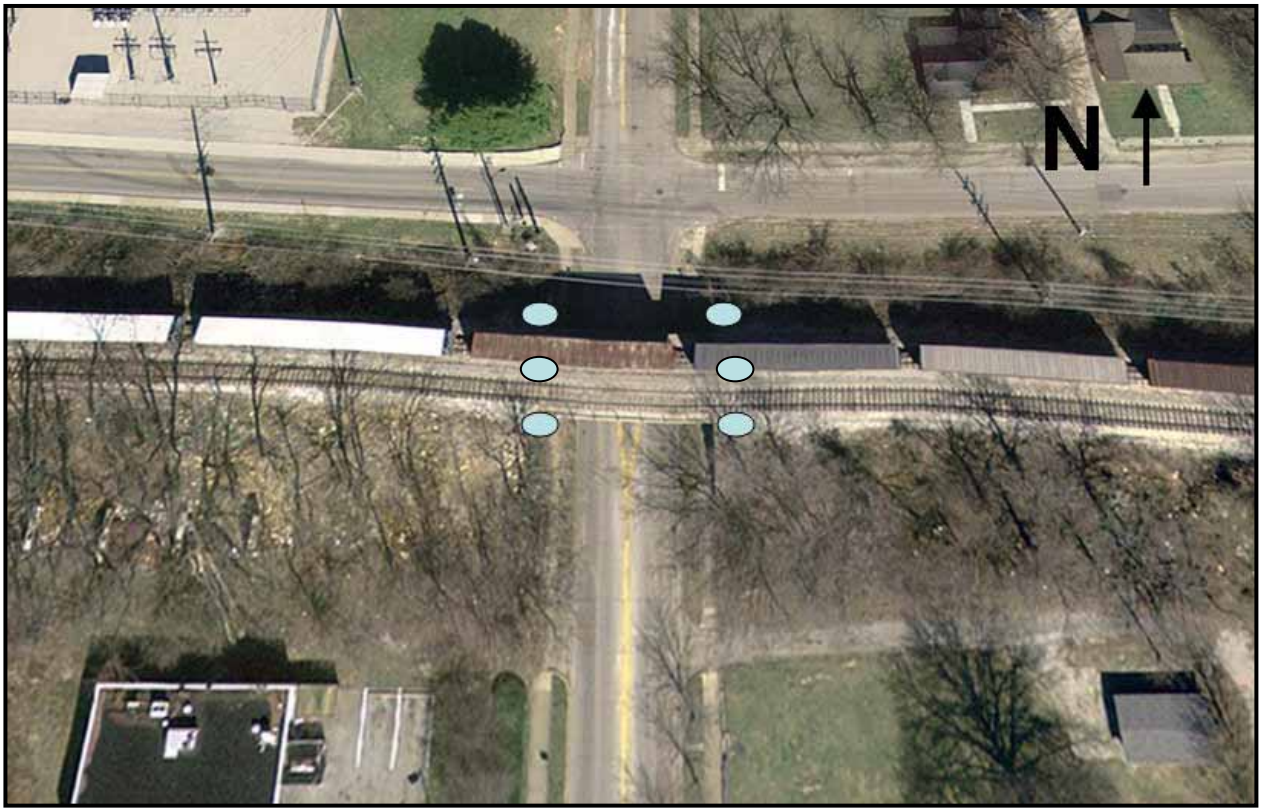

Figure H.4: Location of the piers constructed in Phase 1 of the overpass construction. (Adapted from Google Earth, 2008)

H.5 Phase Two: Prefabricated Structure Construction

Dunn Right Engineering proposes using the Railspan® bridge system by the Skip Gibbs Company. These prefabricated bridges are not pre-engineered as Railspan® designs each bridge to the required specifications. The material used is ASTM A588 grade 50 weathering steel. The prefabricated bridge will be delivered in four equal sections of 55-foot length by 10 foot width.

Due to the size of the prefabricated steel overpass replacing the concrete overpass; it must be constructed on site. Dunn Right Engineering proposes using the vacant area to the southeast of the site (Figure H.5) to assemble the prefabricated structure. The University of Indiana owns this particular parcel of land and will allow the area to be used for this purpose. Assembling the overpass on this lot during the week will allow the structure to be lifted into place by two cranes after the current structure is removed.

Figure H.5: Recommended location for assembling prefabricated structure (Adapted from Google Earth, 2008)

H.6 Phase Three: Overpass Removal and New Structure Placement

Removing the existing overpass and installing the new prefabricated structure requires the most careful planning as completion may require more than 48 hours causing an extended delay to the Indiana Rail Road and the local motorists. The existing structure needs to be completely removed before the new structure can be placed. The demolition crew will need to take into account the power line to the north of the overpass. A licensed engineer should ultimately decide upon this process. After complete removal of the overpass, the new overpass is positioned to the south of the site, and moved into place using two cranes. The assembly and placement of the prefabricated structure will take no longer than 6 hours (Skip Gibbs Company). The new structure then needs anchoring to the piers from Phase 1. (See Figure H.4.) Upon successful inspection of the new structure by a licensed engineer, the new overpass opens to railroad traffic. Repaving of the road beneath the overpass is necessary before Indiana Avenue can open to through traffic with sufficient vertical clearance and fewer sight obstructions. The repaving of the section where the center abutment once was will be repaved during the final weekend period and will be safe to drive on once the work period is completed. Also the site must be removed of all hanging debris before the street can be opened to motorists as well as pedestrians to ensure their safety.

H.7 Pier Design

Dunn Right Engineering designed new piers to carry the weight of the steel deck and dead loads because of the removal of the center pier. This doubled the loads seen by the exterior piers and required new piers be designed to support the increased loads. Dunn Right Engineering designed the six reinforced concrete piers to carry not only the weight of the prefabricated structure but also the loads of the trains as specified by the American Railway Engineering Association's *Specifications for Steel Railway Bridges* (AREA 1976). The load case used for this design is the Cooper E 80 load as specified in section 1.3.3 of the *Specifications for Steel Railway Bridges* (AREA 1976). From these specifications, our design team was able to calculate a total live load of 1176 kips. This load is assuming both railroad tracks are occupied simultaneously. We used the specifications given by Skip Gibbs Company to determine the load created by the structure.

Dunn Right Engineering was able to determine the total weight of the structure based on an average weight of a 500 pounds/ linear foot of a typical 8.5-foot section. From this data, our design team calculated the structure to weigh approximately 129.4 kips. In order to ensure a safe design we calculated the total load to be $1.2*L_D + 1.6*L_L$.

We designed the reinforced piers using the American Institute of Steel Construction (AISC) Steel Construction Manual (AISC 2005). Please refer to the following calculations for the complete design of the reinforced piers, and Appendix P for the typical cross section of each column. Note: All piers are assumed to experience the same load and therefore all have the same design.

P_u = 326 Kips M_u = 64 ft*Kips Unsupported Length=16 ft

Factored Loads: ϕP_u = 548 Kips M_u = 108 ft*Kips

$Pu := 548000lb \quad Mu := 108000lb \cdot ft \quad fc := 3000\frac{lb}{in^2} \quad fy := 60000\frac{lb}{in^2} \quad \rho t := .015$

Trial Area of Column

$Ag := \frac{Pu}{.4(fc + fy \cdot \rho t)} \quad Ag = 351.282\,in^2$ (19 in square) --> $h := 19in$

$e := \frac{Mu}{Pu} \quad e = 0.197\,ft \quad e = 2.365\,in$

$\frac{e}{h} = 0.124$ ---> use bars in 4 faces since e/h < 0.2

Check For Slenderness

$k := 1.0$ (Assumed) $lu := 192in \quad r := .3 \cdot h \quad M1 := 0 \quad M2 := 108$

$\frac{k \cdot lu}{r} = 33.684 \quad < \quad 34 - 12\left(\frac{M1}{M2}\right) = 34$ a ---> Neglect Slenderness

*Assume #8 reinforcement with #3 ties

$\gamma := \frac{19 - 2(1.5 + .375 + .5)}{19}$ $\gamma = 0.75$

$Ag := 19in \cdot 19in$ $Ag = 361\ in^2$ $\phi Pn := Pu$

$\frac{\phi Pn}{Ag} = 1.518 \times 10^3 \frac{lb}{in^2}$

$h := 19in$ $\phi Mn := Mu$

$\frac{\phi Mn}{Ag \cdot h} = 188.949 \frac{lb}{in^2}$

From Figure A-10 (Interaction diagram with γ=0.75)

$\rho t := 0.01$

Select Reinforcement

$Ast := \rho t \cdot Ag$ $Ast = 3.61\ in^2$ (8 #7 Bars)

8 #7 Bars ---> $Ast := 4.80in^2$

Check Maximum Load Capacity

$\phi := .65$ ---> For Columns $Max := 1$

$\phi Pn_{Max} := .8 \cdot \phi \cdot [.85 \cdot fc \cdot (Ag - Ast) + fy \cdot Ast]$

$\phi Pn_{Max} = 6.221 \times 10^5\ lb$ > $Pu = 5.48 \times 10^5\ lb$

Select Ties

Select the Smallest Spacing of:

16 Longitudinal Bar Diameters:= 16 x 7/8 = 14 in <--- Choose

48 Tie Diameters:= 48 x 3/8 = 18 in

Least Dimension of Column:= 16 in

***Note:** All loads and moments were calculated in MASTAN: a structural analysis program.

H.7 Pier Cap Design

Two reinforced pier caps act as cross supports for the steel railway deck above it. Each cap spans across the three reinforced columns on either end of the structure. Using the same load factor equation as for pier design and by determining the load of the structure as well as the live load of the Cooper E 80 loading scenario we calculated the total load (See Figure H.2).

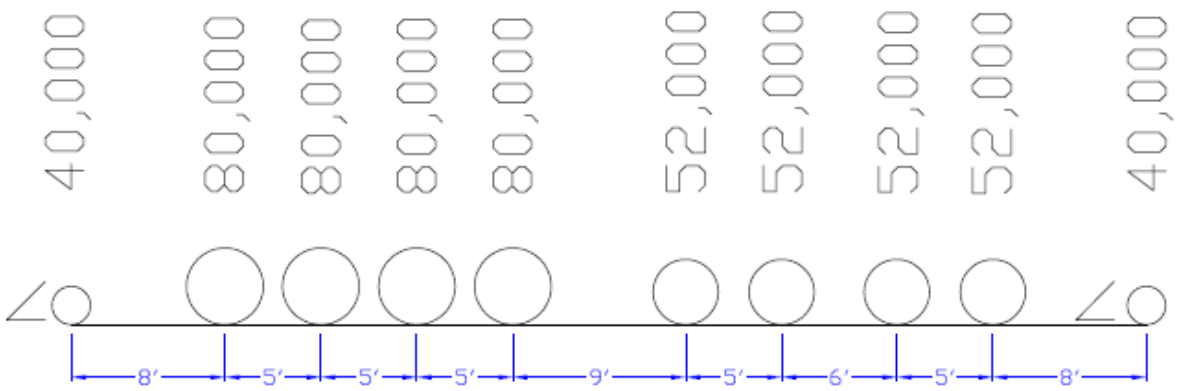

Figure H.2 – Standard Cooper E 80 Load

***Note:** This figure represents the standard loading case of a railroad train. Each circle represents a contact point of the train.

We designed the pier caps using the American Institute of Steel Construction (AISC) Steel Construction Manual (AISC 2005). Please refer to the following calculations for the complete design of the reinforced beams, and Appendix P for the typical cross section of each beam. Note: Both pier caps experience the same load, and therefore both have the same design.

Design of Maximum Negative Moment

M_{-Max}= 810 ft*Kips

Compute b and d

$Mu := 810000 \cdot lb \cdot ft$ $\quad \phi := .9$ $\quad kn := 546.9$ $\quad fy := 60000 \frac{lb}{in^2}$ $\quad fc := 4000 \frac{lb}{in^2}$

$\frac{Mu}{\phi \cdot kn} := \frac{bd^2}{12000}$ ---> b*d^2 :=19747.67 in^3

$b := 19in$ $\quad d := 32.5in$

Assume 2 Layers of Steel

$h := d + 3.5in$ $\quad h = 36\,in$

Compute the Area A_s

Compute jd = d-a/2 = 0.875d = .875*32.5 = 28.4375 $\quad jd := 28.4375in$

$As := \frac{Mu}{\phi \cdot fy \cdot jd}$ $\quad As = 6.33\,in^2$

Check As > As(Min)

$As(min) := \frac{3\sqrt{4000} \cdot 19 \cdot 36}{60000} > \frac{200 \cdot 19 \cdot 36}{60000}$

$As(min) := 2.16in^2 > 1.92in^2$

$As > As(min)$ <--- Good

Select Reinforcing Steel

8 #7 Bars = 7.0 in^2 $\quad As := 7.0in^2$

Bar Spacing

$BarSpacing := \frac{19in - 2 \cdot 1.5in - 2 \cdot .375in - 4 \cdot .875in}{3}$

$BarSpacing = 3.917\,in$ > 1.33in

Required Spacing By Code

1 in

1 bar Diameter = 0.875in

$1 \cdot 1.33in = 1.33\,in$ <---Largest

Compute ξs and Check Whether fs=fy

$a := \frac{As \cdot (fy)}{.85fc \cdot b}$ $\beta_1 := 0.85$ $\xi c := .003$

$a = 6.502\,in$ $c := \frac{a}{\beta_1}$ $c = 7.649\,in$

$\xi s := \xi c \cdot \frac{(d - c)}{c}$

$\xi s = 9.747 \times 10^{-3}$ > .005 ---> fs=fy

Compute ΦMn

$\phi Mn := \phi \cdot As \cdot fy \cdot \left(d - \frac{a}{2}\right)$

$\phi Mn = 9.214 \times 10^{5}\,ft \cdot lb$ > Mu

$\%Increase := \frac{\phi Mn - Mu}{Mu}$

$\%Increase = 13.747\,\%$ ---> Slightly conservative (Could consider reducing As)

Note: Calculations for positive moment of 405 ft*k are not included in this report. The process is the same as shown for the negative moment calculation. The typical cross section of the reinforced beams is located in the Appendix P and shows the location of the reinforcing steel. All loads and moments were calculated using MASTAN.

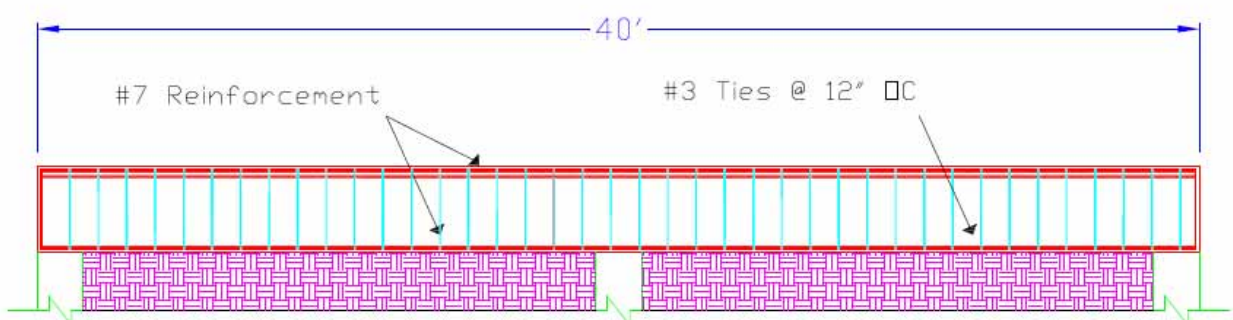

Figure H.3 – Pier Cap Elevation Cross-Section

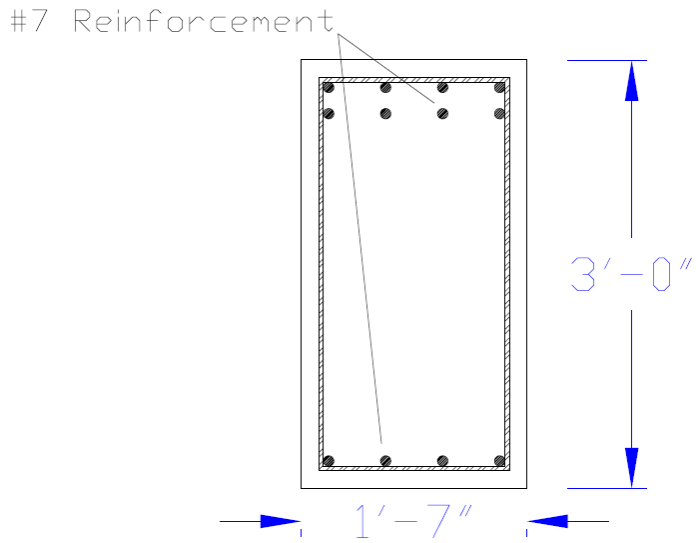

Figure H.4 – Pier Cap Cross-Section

H.8 References

AISC (2005). *American Institute of Steel Construction: Steel Construction Manual,* 13th Edition, 2005. United States of America: American Institute of Steel Construction, Inc..

AREA (1976). *American Railway Engineering Association*: *Specifications for Steel Railway Bridges,* 1976 United States of America: American Railway Engineering Association.

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Appendix I – Pavement Design

I.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the Indiana Avenue corridor in Bloomington, Indiana. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. The City of Bloomington, Indiana Planning Department prefers to alleviate these problems using Dunn Street by creating a crossing at the Indiana Rail Road tracks. However, Dunn Right Engineering has determined that the best method of alleviating these problems is an upgrade of the existing infrastructure near Dunn Street.

The replacement of pavement underneath the bridge on Indiana Avenue and addition of pavement at the intersection of 12th Street and Indiana Avenue requires new pavement design. Dunn Right has completed the pavement design. Dunn Right Engineering evaluated multiple designs in order to find the best fit.

I.2 Pavement Material

Dunn Right Engineering has chosen to use hot mix asphalt (HMA) pavement to replace the pavement underneath the bridge on Indiana Avenue and to provide additional pavement at the intersection of 12th Street and Indiana Avenue. HMA is a cheaper solution in both life cycle cost as well as initial cost compared with Portland Cement Concrete. The HMA still provides the structural support and adequate friction in case of adverse conditions.

I.3 Pavement Design Process

Dunn Right Engineering developed a design solution for the additional pavement required on Indiana Avenue. The plan requires complete removal of the existing pavement under the entire underpass. The existing pavement currently has 10 to 12 inches of Portland Cement Concrete with a 2-inch asphalt overlay.

We used the Federal Highway Administration (FHWA) vehicles classes to find the Equivalent Single Axel Load (ESALs) per Vehicle as shown in Table I.1.

Table I.1 – FHWA Vehicle's ESAL Classification

(Adapted from FHWA 2007)

Class	Type	Description	Typical ESALs per Vehicle[2]
1	Motorcycles	All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handle bars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State.	negligible
2	Passenger Cars	All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.	negligible
3	Other Two-Axle, Four-Tire Single Unit Vehicles	All two-axle, four tire, vehicles, other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, and carryalls. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification.	negligible
4	Buses	All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. All two-axle, four-tire single unit vehicles. Modified buses should be considered to be a truck and be appropriately classified.	0.57
5	Two-Axle, Six-Tire, Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having two axles and dual rear wheels.	0.26
6	Three-Axle Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.	0.42
7	Four or More Axle Single Unit Trucks	All trucks on a single frame with four or more axles.	0.42

Dunn Right Engineering designed the ESALs per Vehicle using both buses and trucks. Any smaller vehicle is negligible as shown in Table I.1. This provides a total ESAL/day of 0.99 after totaling all expected vehicle types. This section of road has an Average Daily Traffic of 12,654 vehicles per day. Assuming traffic is 8% trucks and buses yields approximately 507 trucks and buses per day. The calculation of ESALs is in Table I.2. We designed the pavement thickness using the *Asphalt Institute Thickness Design* (Asphalt Institute, 1981).

Table I.2 – Equivalent Single Axel Load Calculations

ESAL/Vehicle			
Buses	0.57		
Single Unit Trucks	0.42		
Sum	0.99		
EAL =	12,654		
2 Lane	0.5		Number of trucks estimated: 506
% Trucks and Buses	0.08		
ESAL =	501		
ESAL / Year		182,901	
Growth = 2% per 10 years		2,002,765	
Growth = 4% per 10 years		2,196,640	

I.4 Pavement Thickness Design

The pavement design uses the Asphalt Institute: Thickness Design Manual as a reference (Asphalt Institute, 1981). Figure I.2 shows the Sub-grade Resilient Modulus, M_r. This value is an estimation of the existing soil conditions in the surrounding area. The Estimated Single Axel Load (ESAL) value we found was 501; therefore, the design percentile value is approximately 65% which gave a value of 9800 psi.

Table I.1 – Required Sub-grade Mr Value as a Function of ESAL
(Asphalt Institute, 1981)

		Design Sub-grade, M_r	
ESAL	Design Percentile Value	MPa	Psi
10^4	60	69.0	10,000
10^5	75	64.1	9,300
10^6	87.5	56.9	8,250

Using the ESAL value of 12,600 and Sub-grade Resilient Modulus of 9800 psi, we considered two alternatives: full depth asphalt and asphalt with a six-inch aggregate base.

Using 2 million for the ESAL growth rate in Figures I.1 and I.2, the layered asphalt option results in cheaper construction costs yet still provides an equal amount of structural support as

the full depth asphalt. Therefore, we recommend using a 6" aggregate base with a 4" hot mix asphalt (HMA) top layer. This is shown below in Figure I.1.

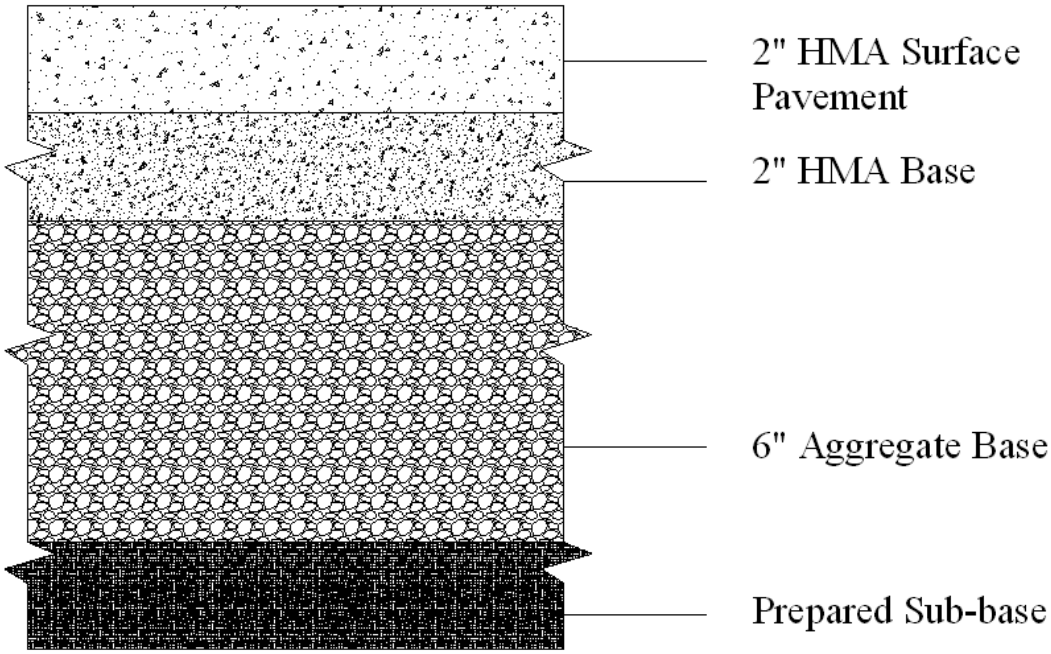

Figure I.1 – Pavement Design Recommendation

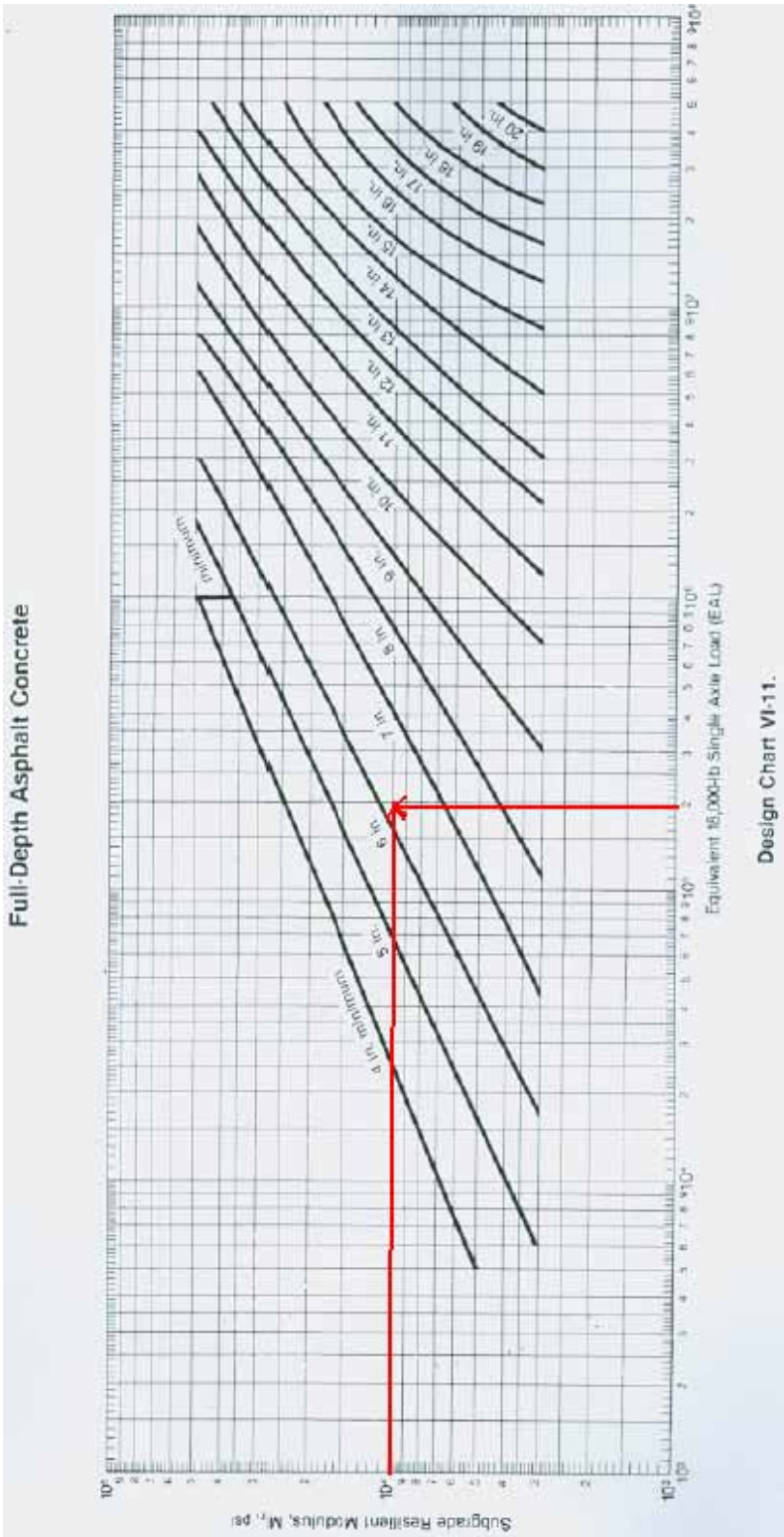

Figure I.1 – Design of Full Depth Asphalt Concrete Option

(Adapted from The Asphalt Institute, 1981)

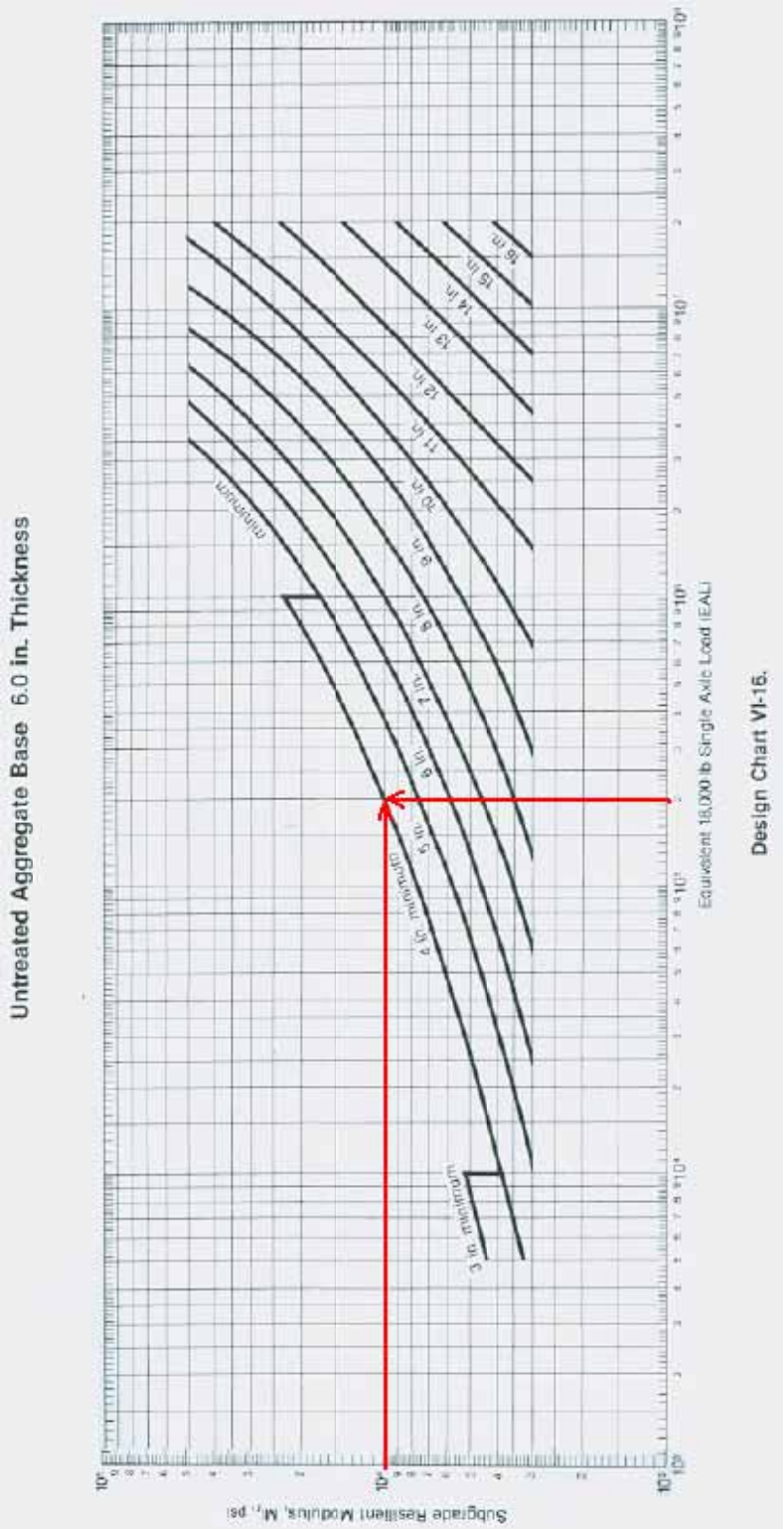

Figure I.2 – Design of 6” Aggregate Base Option

(Adapted from The Asphalt Institute, 1981)

I.6 Conclusion

Dunn Right Engineering performed a structural pavement analysis and recommends using a 6" aggregate base with a 4" HMA surface for the pavement under the bridge and in the new intersection. This design will perform well under the anticipated loads expected at the typical traffic volume and type of traffic.

I.7 References

AASHTO (2004). *American Association of State Highway and Transportation Officials: A Policy on Geometric Design of Highways and Streets,* 5th Edition, 2004. Washington, D.C.: AASHTO. Published Guidelines.

Asphalt Institute, The. *Thickness Design – Asphalt Pavements for Highways and Street.* College Park, Maryland: AI, 1981.

Pavement Interactive. *FHWA Traffic Monitoring Guide.* Retrieved February 15, 2008 from: http://pavementinteractive.org/index.php?title=Main_Page

Appendix J – Indiana Avenue Non-Motorized Traffic Design

J.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the Indiana Avenue corridor in Bloomington, Indiana. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. The City of Bloomington, Indiana Planning Department prefers to alleviate these problems using Dunn Street by creating a crossing at the Indiana Rail Road tracks. However, Dunn Right Engineering has determined that the best method of alleviating these problems is an upgrade of the existing infrastructure near Dunn Street.

This appendix presents the non-motorized traffic design for Indiana Avenue. The upgrade consists of the addition of a bike path and upgrade in the current sidewalk system. It safely removes the cyclists from the roadway without forcing them to travel on the same small path as pedestrians. This significantly improves the safety of all travelers through the corridor.

J.2 Sidewalk Design

There are no federal regulations for sidewalks. Therefore, the City of Bloomington Municipality Code governs (City of Bloomington 2007). The municipality codes state that sidewalks should have a 5-inch aggregate base, 1-1/2 inch concrete base, and a 1-1/2 inch concrete surface with a width of at least 5 feet. Based on the recommendation of Adrian Reed, a Bloomington City Engineer, Dunn Right Engineering has determined that a 6-inch aggregate stone base, 2-inch concrete base, and 2-inch concrete surface is preferred. He also recommended a width of 5 feet. (See Figure J.1.) The 5-foot sidewalk allows for a 4-foot buffer from vehicular traffic. The Americans with Disabilities Act (ADA) requires that all newly constructed or upgraded sidewalks have curb ramps at all intersections (ADA 1994). These curb ramps are required to have a maximum longitudinal slope of 1:12, a maximum cross slope of 2 percent, and at least a 30-inch level landing at both the top and bottom of the ramp. Figure J.2 displays an example of the ramp design.

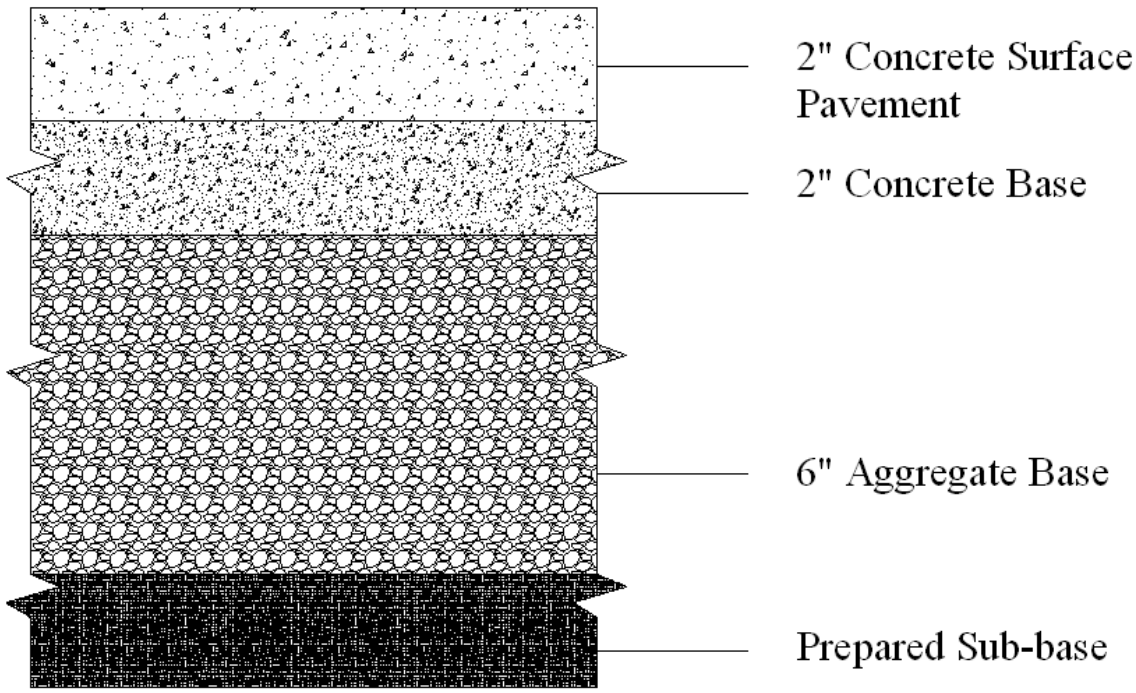

Figure J.1 – Recommended sidewalk cross section

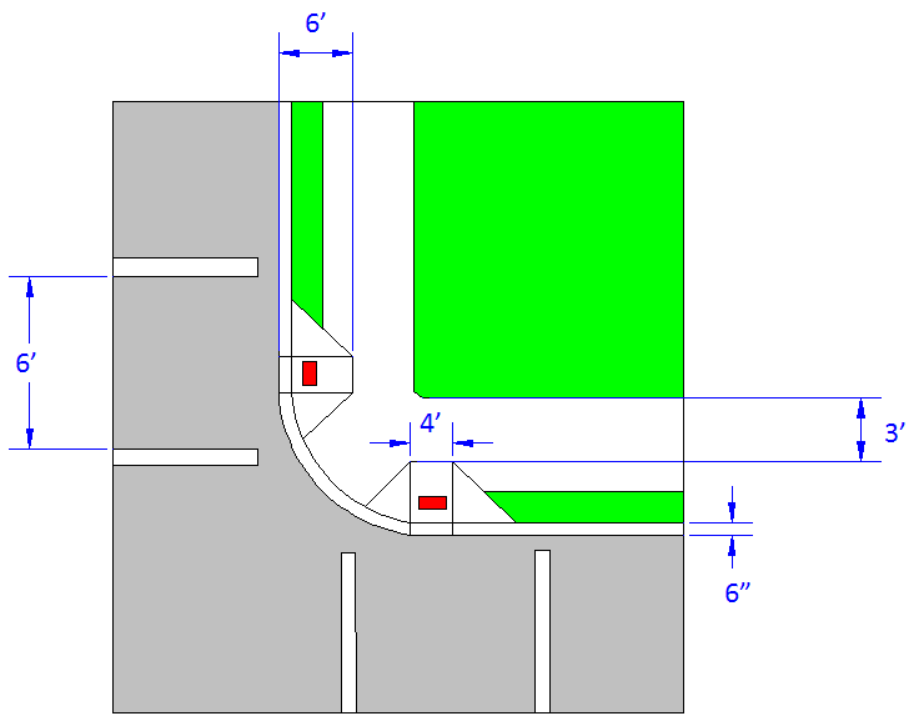

Figure J.2 – Corner curb ramp design for sidewalks

(ADA 1994)

Dunn Right Engineering determined that the best location for the new sidewalk is on the west side of Indiana Avenue, in the same location as the existing sidewalk. (See Figure J.3.) The sidewalk design is in four sections due to differing existing conditions. (See Figure J.4.) Section one travels from 10th Street to 13th Street; section two begins at 13th Street and continues north 230 feet; section three begins 230 feet north of 13th Street and travels to 15th Street; and the final section begins at 15th Street and ends at 17th Street. After a site investigation, Dunn Right Engineering determined that section one is in good condition, and there is no upgrade needed to meet Municipality or ADA codes. Section two, however, does not comply with ADA codes and, therefore, requires an upgrade. This upgrade will consist of the construction of three curb ramps. The first ramp is located at the intersection of Indiana Avenue and 13th street. The second and third ramps cross a driveway, which is approximately 150 feet north of 13th Street. (See Figure J.5.) Dunn Right Engineering determined that section three complies with both the Municipality and ADA codes. Section four currently has no existing sidewalk through its section. Therefore, the section requires a new sidewalk design to meet the required municipality and ADA codes. In order to comply with the ADA, two ramps are required: one at 15th Street and one at 17th Street. (See Figure J.6) Figure J.7 displays the driveway ramp design. The sidewalk across the driveway shall have a maximum cross slope of 2 percent.

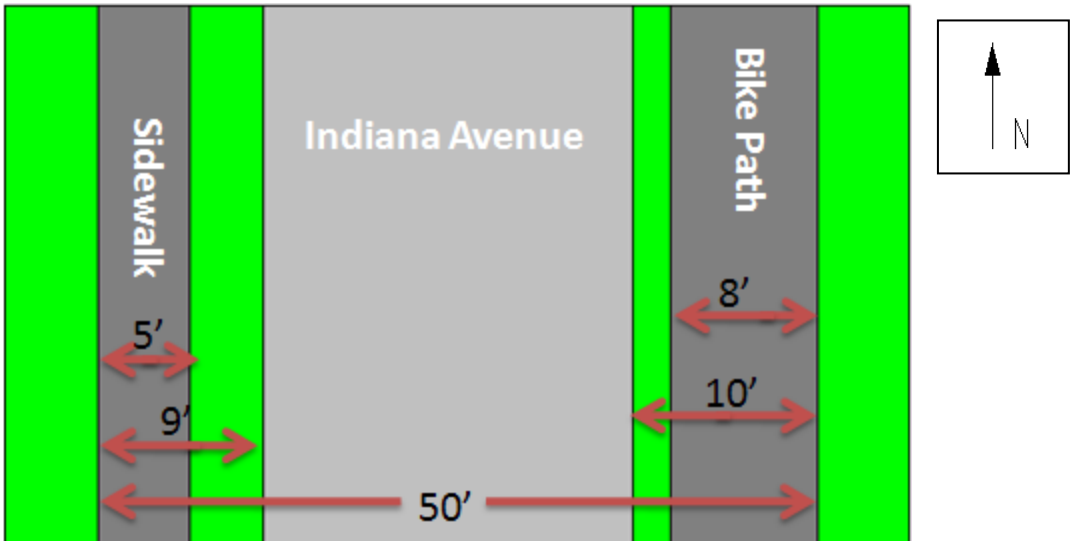

Figure J.3 – Schematic of sidewalk and bike path placement relative to Indiana Avenue

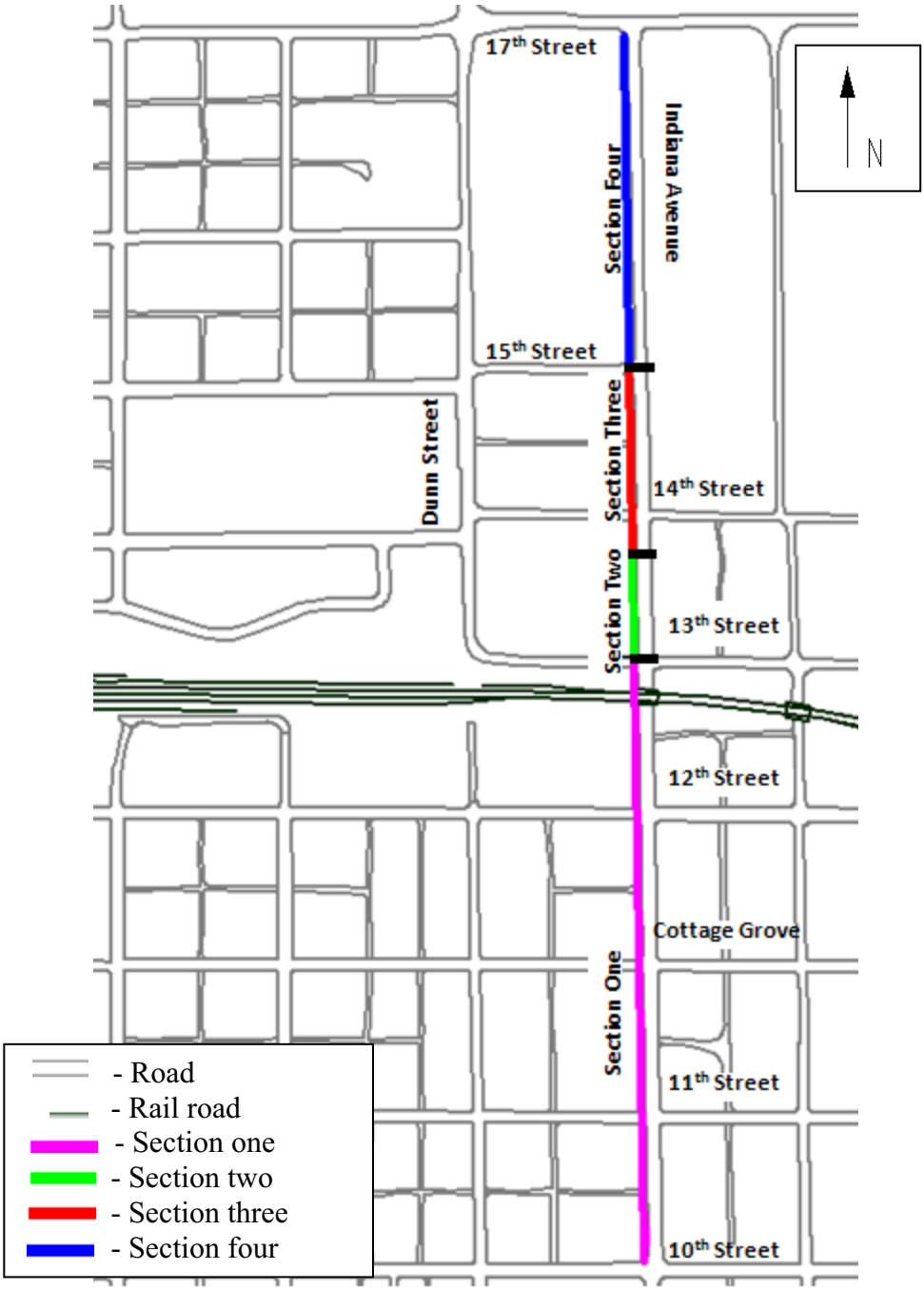

Figure J.4 – Location of sidewalk sections

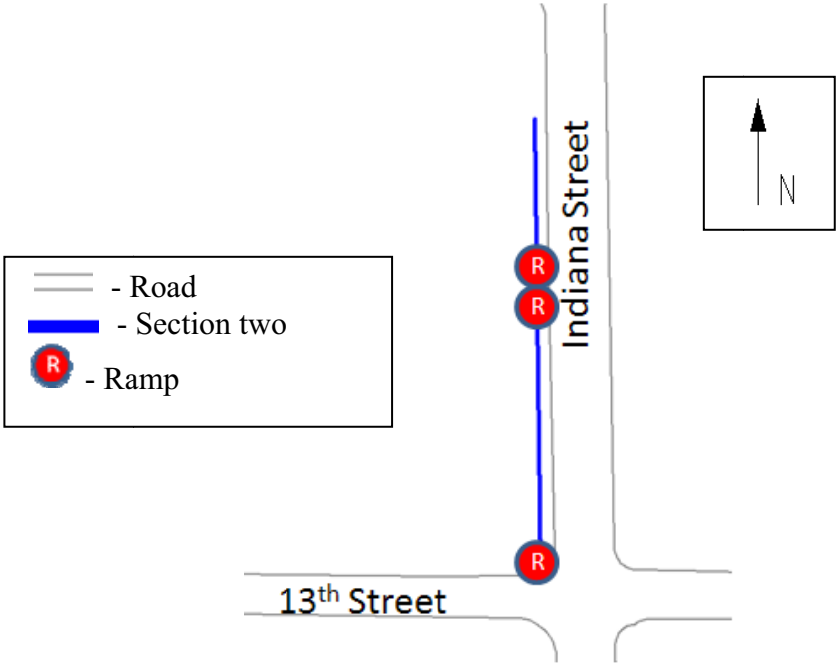

Figure J.5 – Location of ramps in section two

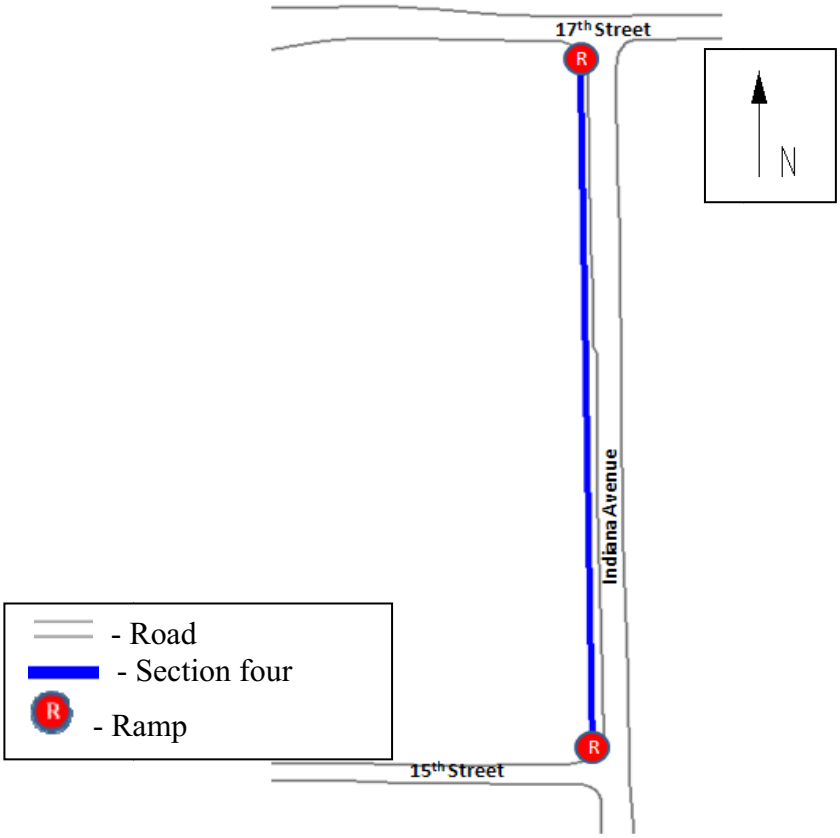

Figure J.6 – Location of ramps in section four

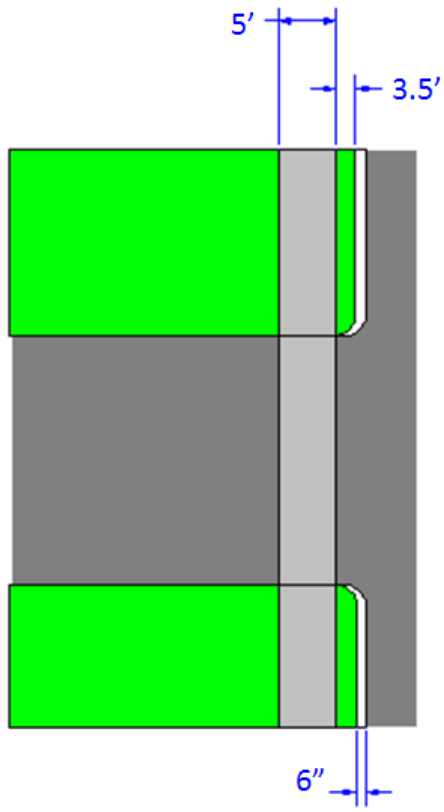

Figure J.7 – Driveway ramp detail along sidewalk of Indiana Avenue

J.3 Bike Path Design

There are no federal regulations for bike path designated sidewalks. Therefore, the City of Bloomington Municipality Codes govern. The City of Bloomington Right-of-Way Excavation Manual, quoted by our client, states that sidewalks designated as bike paths should have a 5-inch aggregate base, 1-1/2 inch asphalt base, and a 1-1/2 inch asphalt surface with a width of at least 8 feet. Based on the recommendation of Adrian Reed, a Bloomington City Engineer, Dunn Right Engineering has determined that a 6-inch aggregate stone base, 2-inch concrete base, and 2-inch concrete surface are preferred. (See Figure J.8.) He also recommended a width of 8 feet. The 8-foot bike path allows for a 2-foot buffer from vehicular traffic.

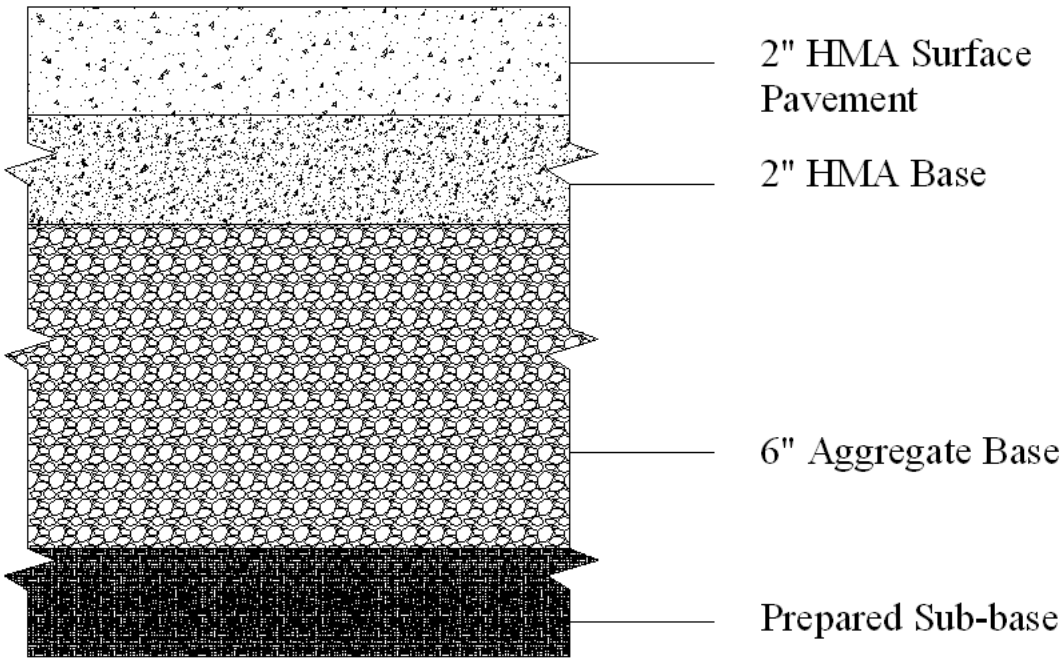

Figure J.8 – Recommended bike path cross section

Dunn Right Engineering determined that the best location for the sidewalk designated bike path is on the east side of Indiana Avenue, replacing the existing sidewalk. (See Figure J.3.) The Bike path design is in two sections due to differences in existing conditions. (See Figure J.9.) Section one travels from 10th Street to 15th Street. This section requires that an 8-foot asphalt path replace the existing sidewalk. The ADA requires 28 ramps in this section as shown on Figure J.9. Section two runs from 15th Street to 17th Street. Since there are no driveways or intersections, this section requires no ramps. Figure J.10 displays the driveway ramp design. The bike path crossing the driveway shall have a maximum cross slope of 2 percent.

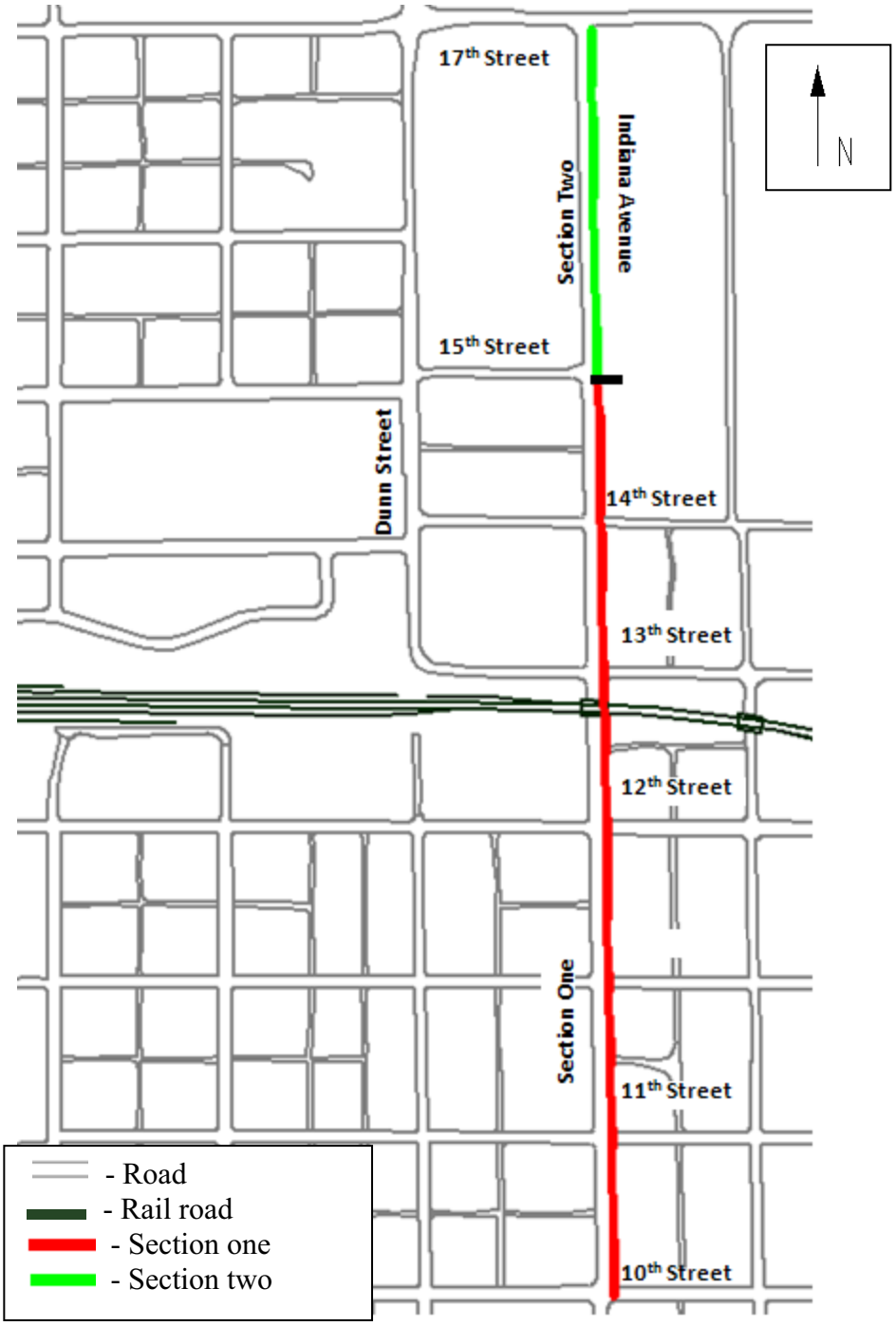

Figure J.9 – Location of proposed bike path

Figure J.10 – Location of curb ramps for proposed bike path

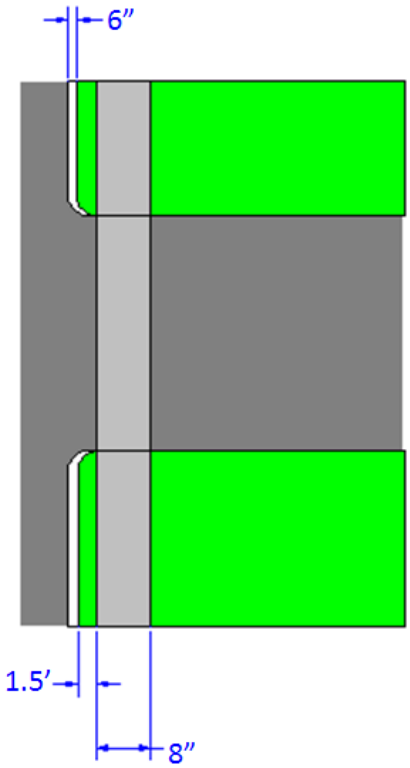

Figure J.11 – Driveway ramp detail along bike lane of Indiana Avenue

J.4 Conclusion

The addition of the bike path safely separates bicyclists from the roadway and pedestrian traffic, significantly decreasing the likelihood of serious conflicts. Safe walking paths may encourage parking farther away from the Indiana University Stadium and, therefore, reduce traffic along Indiana Avenue during events. All signage and markings relevant to these paths are described in Appendix K.

J.5 References

AASHTO (1999). *American Association of State Highway and Transportation Officials: Guide for the Development of Bicycle Facilities*, 3rd Edition, 1999. Washington, D.C.: AASHTO. Published Guidelines.

ADA (1994). *Americans with Disabilities Act: Standards for Accessible Design* <http://www.usdoj.gov/crt/ada/stdspdf.htm> Accessed 25 September 2007.

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Google Earth (2007). *Google Earth.* Accessed 6 December 2007.

Google Maps (2007). *Google Maps*. <maps.google.com> Accessed 10 September 2007.

Appendix K – Signage, Signals, and Markings

K.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the Indiana Avenue corridor in Bloomington, Indiana. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. The City of Bloomington, Indiana Planning Department prefers to alleviate these problems using Dunn Street by creating a crossing at the Indiana Rail Road tracks. However, Dunn Right Engineering has determined that the best method of alleviating these problems is an upgrade of the existing infrastructure near Dunn Street.

The Indiana Avenue upgrade of existing conditions requires an upgrade in traffic control devices such as signs, signals, and markings. All traffic control devices should coincide with the Indiana Department of Transportation (INDOT) design manuals (INDOT 2008). We used the Manual of Uniform Traffic Control Devices (MUTCD) for the design (FHWA 2003). The proper location of signage, signals, and markings is not only important in order to conform to legal standards, but is also essential in preserving the safety of all users of the roadway. INDOT standards state that all signs should be reflectorized (INDOT 2008). Dunn Right Engineering, therefore, recommends placing reflectorized signs throughout the project. After the repaving of Indiana Avenue, pavement markings need to be applied. Dunn Right Engineering recommends that the City of Bloomington use a thermoplastic paint that meets INDOT Section 76-3.01 for all pavement markings (INDOT 2008). This paint is commonly used and has proven to be highly visible in less than optimal conditions.

K.2 Motorized Traffic Signage and Signals

Currently along Indiana Avenue through the project area, no intersections are controlled by traffic signals. After reconstruction of the railroad overpass on Indiana Avenue, Dunn Right Engineering recommends signalizing the intersection of Indiana Avenue and 13th Street. (See Figure K.1.)

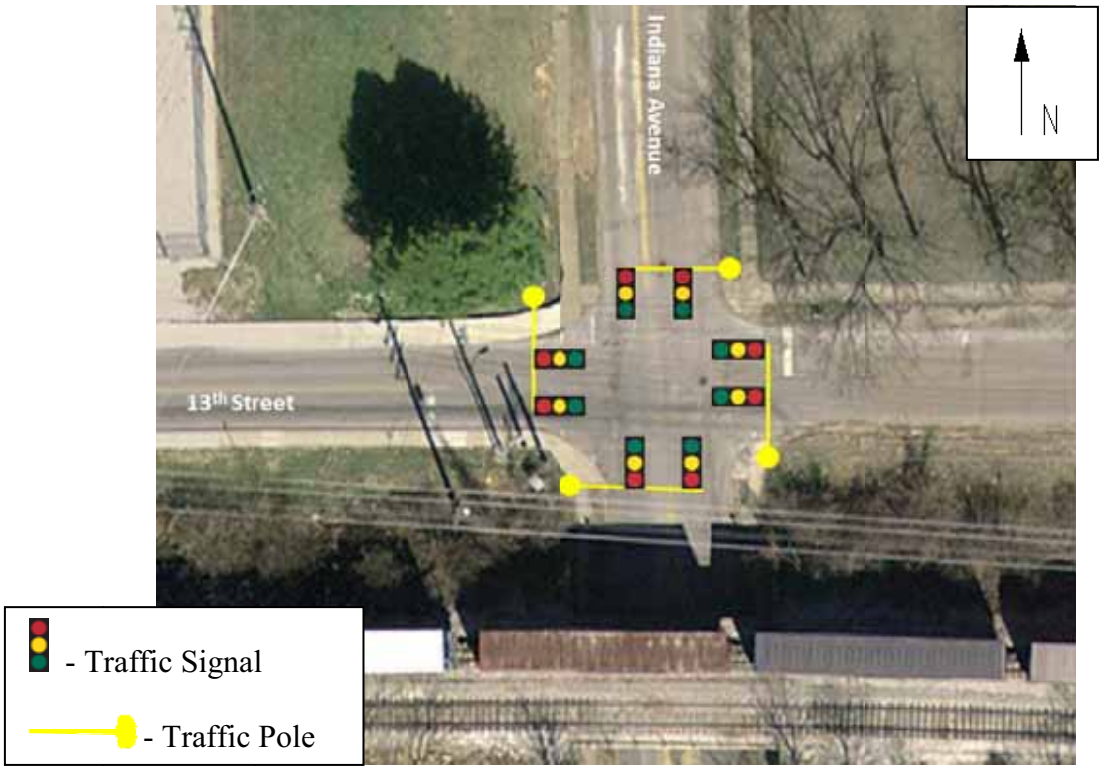

Figure K.1 – Location of Traffic Signal

(Adapted from Google Earth, 2007)

Since drivers from the south have an obstructed view of the traffic signal due to the overpass, we recommend installation of a W3-3 Traffic Control Symbol sign, a W3-4 "BE PREPARED TO STOP" sign, a "WHEN FLASHING" plaque, and a warning beacon that is interconnected to the traffic signal. According to MUTCD Section 2C.29, the warning beacon and warning signs shall be placed 450 feet before the traffic signal (FHWA, 2003). This is unsafe because they would then be located on the south side of 12th street. Therefore, Dunn Right Engineering determined that the advanced warning system of a W3-4 sign, "WHEN FLASHING" plaque, and the warning beacon should be located 200 feet before the traffic signal while the W3-3 Traffic Control Symbol should be located 250 feet before the signal. (See Figure K.2.) The City of Bloomington should determine the proper timing cycle for this intersection.

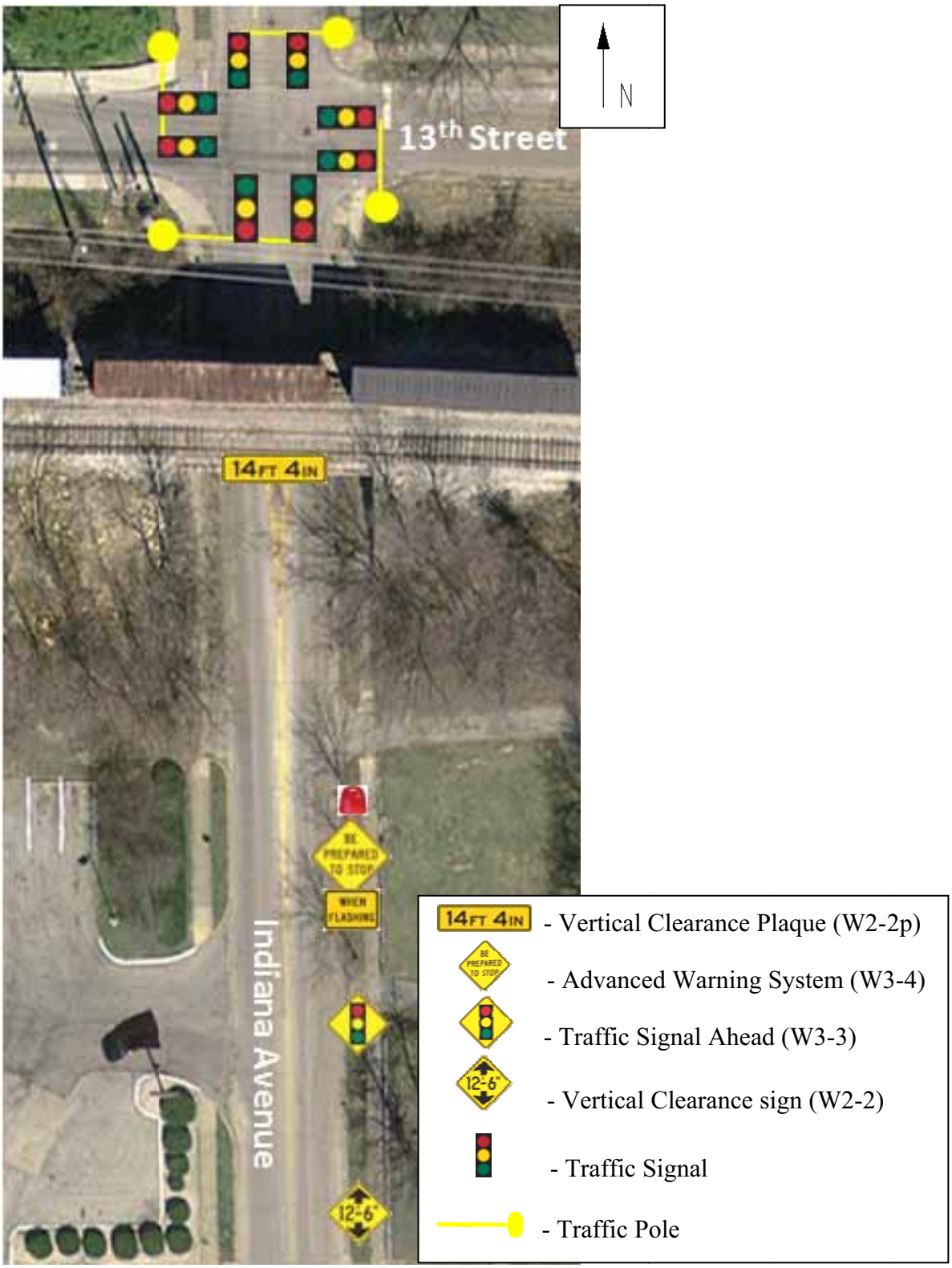

Figure K.2 – Location of Advanced Warning Signs

(Adapted from Google Earth, 2007)

Replacement of the Indiana Rail Road overpass will change the vertical clearance of the underpass. Therefore, all vertical clearance signs, W2-2 and W2-2p, need to be updated. (See Figure K.2.) In accordance with MUTCD Section 2C.40, a "Bicycle Crossing Ahead" sign (W1-11) needs placement on every east-west street (FHWA, 2003). (See Figure K.3.)

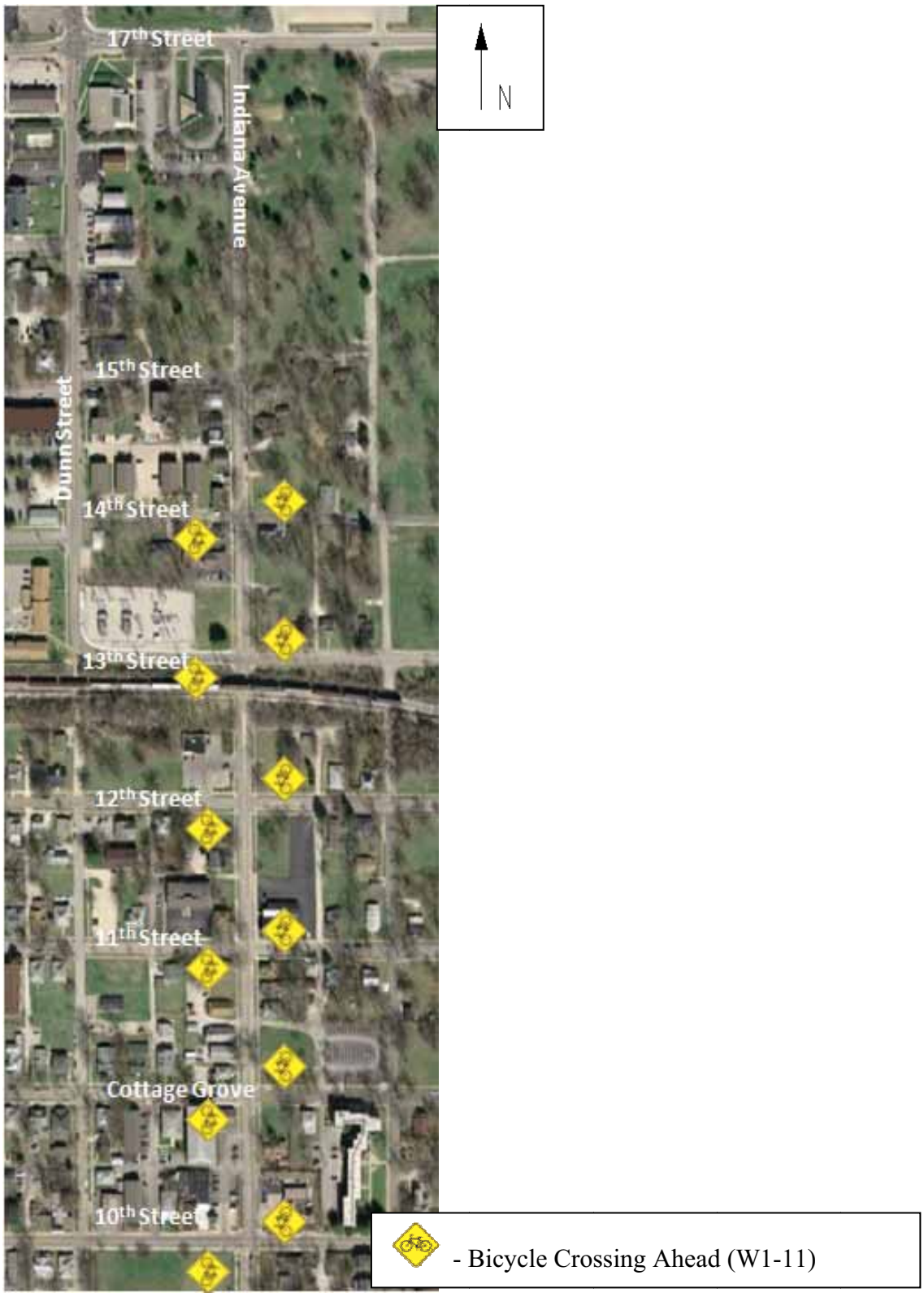

Figure K.3 – Location of W11-1 Signage

(Adapted from Google Earth, 2007)

K.3 Pavement Markings

Indiana Avenue needs a centerline and edge lines. The centerline must be a solid double yellow line in accordance with INDOT Section 76-2.01(01) (INDOT, 2005). This centerline should be 6 inches wide and should not continue across intersections with public roads, but it shall continue across residential driveways. The edge lines must be a solid, 4 inch wide, white line in accordance with INDOT Section 76-02.01(03) (INDOT, 2005).

Crosswalk lines shall be solid white, reflectorized lines no less than 6 inches wide. The crosswalk lines shall encompass all sidewalk and bike path curb ramps, be no less than 6 feet apart, and shall be in accordance with INDOT Section 76-2.03(02) (INDOT, 2005).

Stop lines should be solid white, reflectorized lines 2 feet in width. The stop lines shall extend across all approach lanes and end at the centerline of the street. Each stop line shall be placed 4 feet in advance of the nearest crosswalk. If no crosswalk is located at the intersection, the stop line shall be no farther than 30 feet and no less than 4 feet from the edge of the nearest travel lane. All stop lines shall be in accordance with INDOT Section76-2.03(01) (INDOT, 2005).

K.4 Bike Path Markings

The new bike path requires a 4 inch wide yellow centerline. This centerline shall not continue across intersections with public roads, but shall continue across residential driveways. Other markings that are required are stop lines and bike only symbols. (See Figure K.4.) These symbols shall be in accordance with the AASHTO Bike Book (FHWA, 1999).

Figure K.4 – Bike Path Symbol
(AASHTO, 1999)

K.5 Non-Motorized Signage and Signals

The new bike path requires a yield sign before each minor intersection and a stop sign before each major, non-signalized intersection. Therefore, all intersections except Indiana Avenue and 13th Street should have a yield sign in accordance with the AASHTO Bike Book (FHWA, 2003). See Figure K.5 for the location of all non-motorized traffic signage.

Figure K.5 – Location of Non-Motorized Traffic Signage on Bike Path

(Adapted from Google Earth, 2007)

K.6 References

AASHTO (1999). *American Association of State Highway and Transportation Officials: Guide for the Development of Bicycle Facilities*, 3rd Edition, 1999. Washington, D.C.: AASHTO. Published Guidelines.

FHWA (2003). *Federal Highway Administration: Manual on Uniform Traffic Control Devices.* 2003 Ed., Rev. 1. Washington, D.C.: FHWA.

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Appendix L – Pedestrian Bridge Design

L.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the Indiana Avenue corridor in Bloomington, Indiana. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. The City of Bloomington, Indiana Planning Department prefers to alleviate these problems using Dunn Street by creating a crossing at the Indiana Rail Road tracks. However, Dunn Right Engineering has determined that the best method of alleviating these problems is an upgrade of the existing infrastructure near Dunn Street.

In order to improve the safety and flow of pedestrian traffic over the Indiana Rail Road tracks crossing Dunn Street, a pedestrian bridge is necessary. Currently, pedestrians cross the railroad tracks illegally and there is no crossing for bicyclists. This appendix contains the preliminary design for the pedestrian bridge.

This is a general design with the purpose of sizing the primary members in order to obtain the cost estimate in Appendix P. Dunn Right Engineering performed preliminary design the slab, girders, and columns for the bridge but performed no detail work. Only gravity loads were considered, lateral wind loads and earthquake loads were not calculated.

L.2 Superstructure Selection

Due to the length of span and loading requirements, Dunn Right Engineering chose to use a rolled-beam bridge. Of this type of bridge there are two main designs – the simple span beam supported at its ends and the cantilever. This design uses the simple span beam, which is found, in practice, to provide the most economical form of bridge when the span is relatively small, namely up to about 150-feet. The beam bridge consists of a concrete slab supported by W section steel beams. This design is widely used because of its simple design and construction.

L.3 Design Criteria

We considered all pertinent loads and loading combinations from the *AASHTO: LRFD Bridge Design Specifications* (AASHTO 2007). The following subsections discuss each load and serviceability deflection limits.

L.3.1 Dead Load

Dead load for the bridge consists primarily of the deck and girder self weight. The handrail weights are also included, but are approximations. To calculate self weight, we used weight densities of 150 pcf for concrete and 490 pcf for steel. We also used 14 plf for handrails.

L.3.2 Live Load

According to the *AASHTO: LRFD Bridge Design Specifications* (AASHTO 2007), the required pedestrian load is 86 psf. This load is uniformly distributed across the entire bridge deck.

L.3.3 Wind Load

A wind load acting vertically on the deck also requires consideration when determining maximum loads. The *AASHTO: LRFD Bridge Design Specifications* (AASHTO 2007) states that the wind pressure creates an upward force of 20 psf on the deck. This reduces the load and is only applicable if it causes uplift. Because no uplift occurs, the wind load was not used in the final design.

L.3.4 Factored Loads

In order to adequately account for all forces, we used the load combinations from *AASHTO: LRFD Bridge Design Specifications* (AASHTO 2007). Dunn Right Engineering used the six combinations shown in Table L.1.

L.4 Handrails

A handrail is defined as either a circular cross section with an outside diameter of 1-1/4” to 2” or a non-circular section with a perimeter dimension of 4” to 6-1/4” and a cross section dimension

of 2-1/4" maximum. The height must be between 34" and 38" (ADA 1994). Building codes also require that no opening in a guard be of a size such that a 4" sphere may pass (IBC 2003). This design utilizes 2" diameter circular aluminum handrails with a total weight of 14 plf. The railing will be bolted to the slab.

L.5 Bridge Width

We designed the bridge to be a shared use path. The *AASHTO: Guide for the Development of Bicycle Facilities* (AASHTO 1999) defines a shared use path as the following:

> "A bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other non-motorized users."

The *AASHTO: Guide for the Development of Bicycle Facilities* (AASHTO 1999) specifies that bicyclists require at least 40 inches of essential operating space based solely on their profile. (See Figure L.2) An operating space of 5 feet is desirable for a facility designed for mixed-use traffic and variable speeds. The ADA specifies that the minimum width to allow two wheelchairs to pass safely is 60 inches (ADA 1994). (See Figure L.3.) Due to the height of the structure, sight distances are limited. That, and differences in the speed of users, require adequate operating space. The width of 12 feet exceeds requirements and provides plenty of room for multiple forms of pedestrian traffic in two directions.

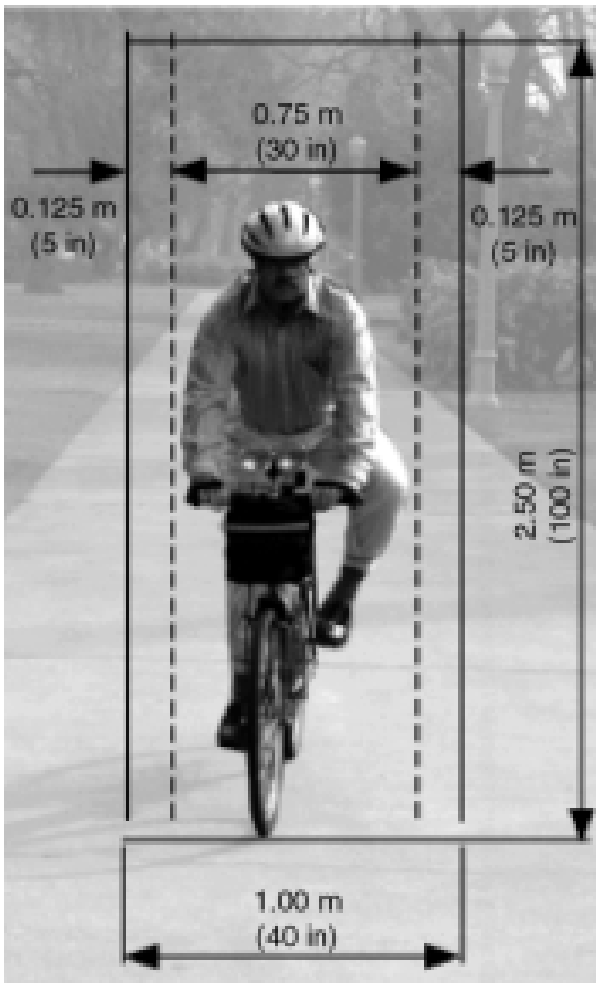

Figure L.2 – Minimum Bicyclist Operating Space

(AASHTO 1999)

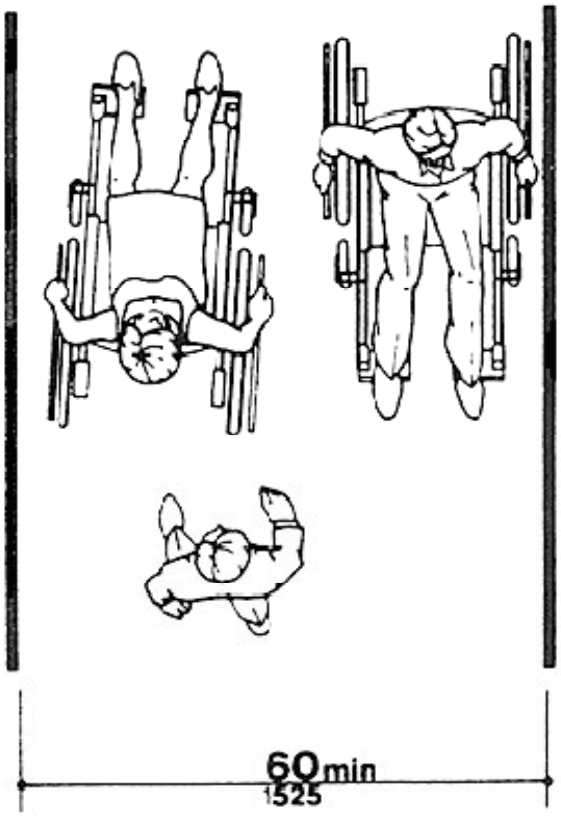

Figure L.3 – Minimum Wheelchair Operating Space
(ADA 1994)

L.6 Slab Design

The bridge decking will consist of a 7.5-inch thick cast-in-place concrete slab supported by two steel girders. (See Figure L.4) In designing the slab, the maximum moments were determined. We modeled the slab as simply supported by the two girders. The design calculations for the slab follow. Figure L.5 shows the cross-section details of the slab design.

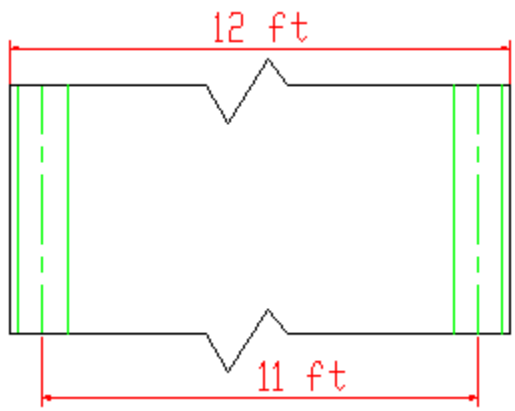

Figure L.4 – Plan View of Slab and Girders of Bridge Deck

1. Estimate the thickness of the slab

The initial selection of the floor thickness will be based on ACI Table 9.5(a), which gives the minimum thicknesses.

h min = L/20 = 144"/20 = 7.2"

Therefore, try a 7.5 inch slab. Assuming 1.5 inches of clear cover and #4 bars,

effective depth = h - (clear cover + bar area/2) = 7.5 - (1.5 + .5/2) = **5.75"**

2. Compute the trial unfactored loads

Given the thickness selected in step 1, it is now possible to compute a first estimate of the unfactored uniform loads.

DL = (7.5"/12") * 150 lb/ft^3 = **93.75 lb/ft^2**

LL = from AASHTO Bridge Book = **86 lb/ft^2**

W = from AASHTO Bridge Book = **20 lb/ft^2**

* snow load need not be considered (AASHTO 2007)

3. Select load and strength-reduction factors

Use the load factors and load combinations from ACI 318-02 Section 9.2.1 and the strength-reduction factors from ACI 318-02 Section 9.3.

	Load Combination		lb/ft^2
(1)	1.4*D	=	131.6
(2)	1.2*D + 1.6*L + 0.5*(Lr or S or R)	=	250.4
(3)	1.2*D + 1.6*(Lr or S or R) + (0.5*L or 0.8*W)	=	155.8 128.8
(4)	1.2*D + 1.6*W + 0.5*L + 0.5*(Lr or S or R)	=	187.8
(5)	1.2*D +/- 1.0*E + 0.5*L + 0.2*S	=	155.8
(6)	0.9*D +/- (1.6*W or 1.0*E)	=	116.6 52.6

D	=	94	lb/ft^2
L	=	86	lb/ft^2
W	=	20	lb/ft^2

Table L.1 – ACI Load Combinations

The maximum factored load on the slab is 250.4 psf. The factored load per foot on a one foot wide strip of slab is 1 ft x 250.4 psf = 250.4 lb/ft

4. Select strength-reduction factors

Assume the slab is tension-controlled and meets the definition of a "beam." ACI Section 10.3.4 defines a tension-controlled member as one that has an extreme tensile strain greater than or equal to 0.005 at ultimate. We have chosen to use the factors in ACI Section 9.3.1, which uses ϕ = 0.90 for flexure, provided the extreme tensile strain exceeds 0.005.

5. Check whether the slab thickness is adequate for the moment

Since $w_L < 3w_D$ and other requirements of ACI Section 8.3.3 are met, use the ACI moment coefficients to calculate the moments. *Note: fy = 60,000 psi and fc' = 4000 psi

$$\frac{bd^2}{12000} = \frac{Mu}{\phi ku}$$

$$w = \frac{p*fy}{fc'} = \frac{.01*60000}{4000} = \mathbf{0.15}$$

$$\phi kn = \phi*[fc'*w*(1-0.59*w)]$$
$$= 0.9*[4000*0.15*(1-0.59*0.15)]$$
$$= \mathbf{492.2}$$

$$Mu = \frac{w_u*l_n^2}{8} = \frac{250.4*12^2}{8} = \mathbf{4507.2}$$

$$bd^2 = \frac{Mu*12000}{\phi ku}$$

But we are designing a 1 foot wide strip with b = 12 inches

d = 2.70 in

A minimum d = 2.70 inches keeps $p \leq 0.01$. Since d exceeds the minimum, the slab will be OK for flexure.

<u>6. Check whether thickness is adequate for shear</u>

Use ACI Section 11.5.5.1 for slabs

$$\mathbf{Vu} = \frac{Cv*(wu*ln)}{2} = \frac{1.15*(250.1*12)}{2} = 1725.69 \text{ lb} = \mathbf{1.726\ k}$$

$$\mathbf{\phi Vc} = \phi*2*sqrt(fc')*bw*d = 0.75*2*sqrt(4000)*12*5.75 = 6545.91 \text{ lb} = \mathbf{6.546\ k}$$

ACI Section 9.3.2.3 gives $\phi = 0.75$ for shear and torsion

Since $\phi Vc > Vu$, the slab chosen is adequate for shear. Therefore use h = 7.5 inches, d = 5.75 inches, and $w_u = 250.4$ lb/ft^2.

7. Design of reinforcement (See Figure L.5)

Use ACI Section 7

The clear span, l_n, is 144 inches

Calculate the area of steel, for the first trial assume jd = 0.925*d. Also assume ϕ = 0.90:

$$\textbf{As} = \frac{Mu}{\phi * fy * jd} = \frac{3.601*12000}{0.9*60000*0.925*5.75} = \textbf{0.150 in}^2\textbf{/ft}$$

$$\textbf{a} = \frac{As*fy}{0.85*fc'*b} = \frac{0.150*60}{0.85*4*12} = \textbf{0.221 in}$$

$$\textbf{jd} = d - a/2 = 5.75 - 0.221/2 = \textbf{5.64}$$

Because the first estimate of As was based on a guess of jd, we will recomputed the required As.

$$\textbf{As} = \frac{Mn*12000}{0.9*60000*5.64} = \textbf{0.039*Mu}$$

This gives us As = 0.176 in^2/ft

Compute the minimum flexural reinforcement, using ACI section 10.5.4, which refers to ACI Section 7.12 for amount and spacing

$$\textbf{As min} = p*b*h = 0.0018*12*7.5 = \textbf{0.162 in}^2\textbf{/ft}$$

For maximum spacing, ACI Section 7.6.5 gives 3h = 22.5 inches, but not more than 18 inches. Therefore, maximum spacing = 18 inches.

8. Check reinforcement spacing for crack control

To control the width of cracks on the tension face of the slab, ACI Section 10.6.4 limits the maximum spacing of the flexural reinforcement closest to the tension face of the slab to:

$$S = \frac{15*40000}{fs} - 2.5*\text{clear cover} \leq \frac{12*40000}{fs}$$

$$= \frac{15*40000}{40000} - 2.5*1.5 \leq \frac{12*40000}{40000}$$

$$= 11.25 \leq \mathbf{8''}$$

This overrides the 18 inch maximum selected in the previous step of design.

9. Determine the shrinkage and temperature reinforcement

ACI Section 7.12 requires shrinkage and temperature reinforcement perpendicular to the span of the slab:

$$\mathbf{As} = 0.0018*b*h = 0.0018*12*7.5 = 0.162 \text{ in}^2/\text{ft}$$

Maximum spacing = 18 inches

Therefore, provide #4 bars at 12 inches on center as shrinkage and temperature reinforcement.

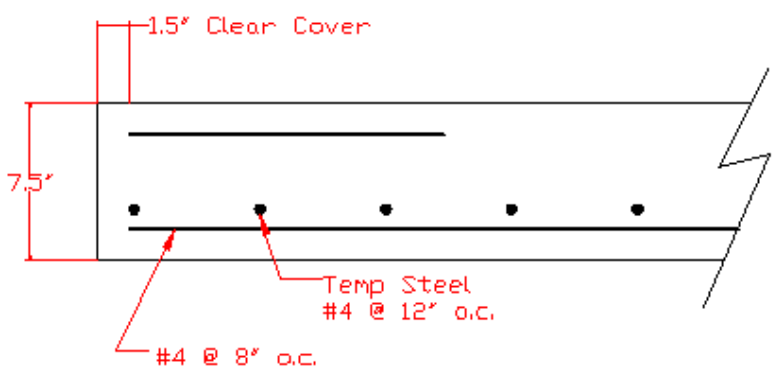

Figure L.5 – Slab Design

L.7 Girder Design

The pedestrian bridge uses two girders to span the 60-foot length across the Indiana Rail Road tracks. (See Figure L.6) Two W36x256 girders are adequate. The design calculations for the girders follow.

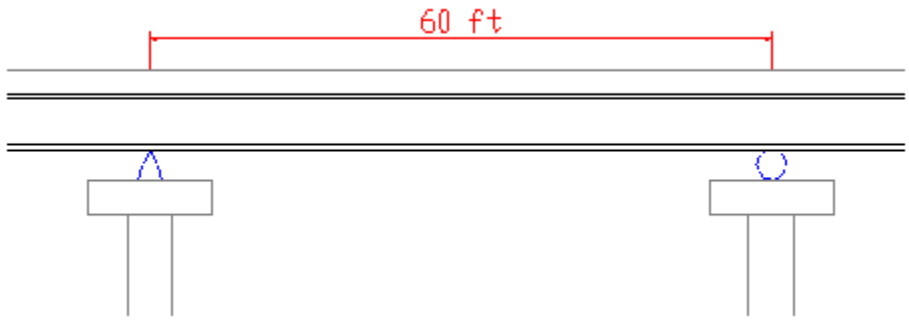

Figure L.6 – Elevation view of bridge girders

1. Calculate moment

Factored Load = 250.4 psf = $\frac{250.4 \text{ lb}}{\text{ft}^2}$ * 12' = 3.00 klf

Mu = $\frac{w_u * l_n^2}{8}$ = $\frac{3.00*60^2}{8}$ = **1350** **ft-k**

Vu = $\frac{w_u * l_n}{2}$ = $\frac{3.00*60}{2}$ = **90** **k**

ϕMn = $\frac{\phi Mn}{Cb}$ = $\frac{1620}{1.14}$ = **1421.05**

2. Check for web local buckling

Calculate web slenderness, λ (Table B4.1)

λ = h/t_w = $\frac{32.125}{0.96}$ = **33.46**

Calculate web slenderness, λp (Table B4.1, case 9)

λ_p = 3.76*√(E/Fy) = 3.76*√(29000/50) = **90.55**

$\lambda \le \lambda_p$, therefore the web has a compact failure and **ϕMn = ϕMp** (Eq F2-1)

3. Check for flange local buckling

Calculate flange slenderness, λ (Table B4.1)

$\lambda = b/t = \frac{6.1}{1.73} =$ **0.35**

Calculate flange slenderness, λp (Table B4.1, case 9)

λ_p = 0.38*√(E/Fy) = 0.38*√(29000/50) = **9.15**

$\lambda \le \lambda_p$, therefore the flange has a compact failure and **ϕMn = ϕMp** (Eq F2-1)

4. Check for lateral torsional buckling

Determine the unbraced length, L_b

L_b = **60 feet**

Calculate the limiting unbraced length, Lp (Eq F2-5)

L_p = 1.76*r_y*√(E/Fy) = 1.76*3.36*√(29000/50) = **142.42 in**

$L_b \le L_p$, therefore the flange has a compact failure and **ϕMn = ϕMp** (Eq F2-1)

Therefore, the **W37x256** section is adequate and exceeds design requirements. Deflections in the girders under the designed service load combinations shall not impair the serviceability of the structure.

L.8 Column Design

The pedestrian bridge is supported using four reinforced concrete columns. They are each 25 feet tall and 16 x 16 inches. The design calculations for the columns follow. Figure L.7 shows the cross-section details.

Pu = $\frac{250.4psf*60'*12'}{4000\ lb}$ = **45 k/col**

Mu = Pu*e = **45*.3** = **15 ft-k**

choose 16" square column

e = $\frac{Mu}{Pu}$ = $\frac{15}{45}$ = **3.91 in**

e/h = $\frac{3.91"}{16"}$ = **0.244**

b=16"

h = 16"

rebar = #8
ties = #3
clear cover = 1.5"

γh = 16-2(1.5+.375+.5) = $\frac{11.25"}{16"}$ = **0.703**

use interaction diagram to determine pt

$\frac{\phi Pn}{bh}$ = $\frac{Pu}{bh}$ = $\frac{45}{16*16}$ = **0.359**

$\frac{\phi Mn}{bh^2}$ = $\frac{Mu}{bh^2}$ = $\frac{15}{16*16^2}$ = **0.0073**

pg = **0.0193**

Select Steel

pt = $\frac{Ast}{Ag}$ = 0.0193*16*16 = **4.94" -> use 8 bars**

Select Tie Spacing

min =	16*db	=	16"	
	48*dt	=	18"	*** ACI 7.10.5.2.1-2
	h (column size)	=	16"	

use 16" tie spacing with 8 #8 bars

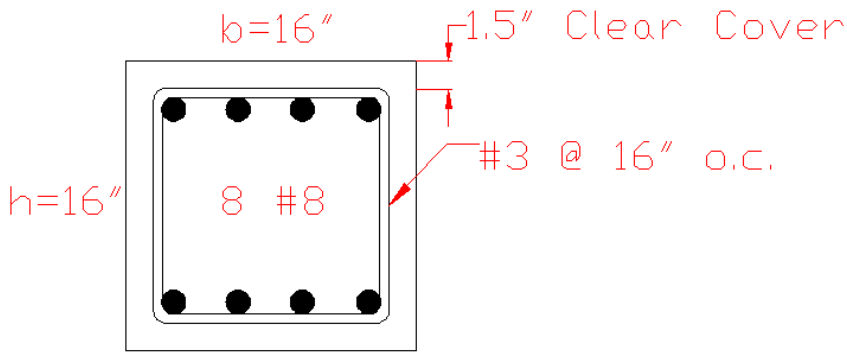

Figure L.5 – Column Cross-Section Details

L.9 Approaches

The pedestrian bridge requires approaches on the north and south ends of the bridge. On the north end, the approach will consist of built up soil. (See Figure L.6) On the south end, the approach will be in the style of a spiral due to length and slope restrictions. (See Figure L.7) The slabs, girders, and columns will consist of the same material used for the bridge. The sizes of the girders and columns, however, will be different due to smaller span requirements. A fence should be constructed along the railway in order to prevent at-grade pedestrian crossing and posts should be placed across the approaches in order to prevent vehicles from crossing.

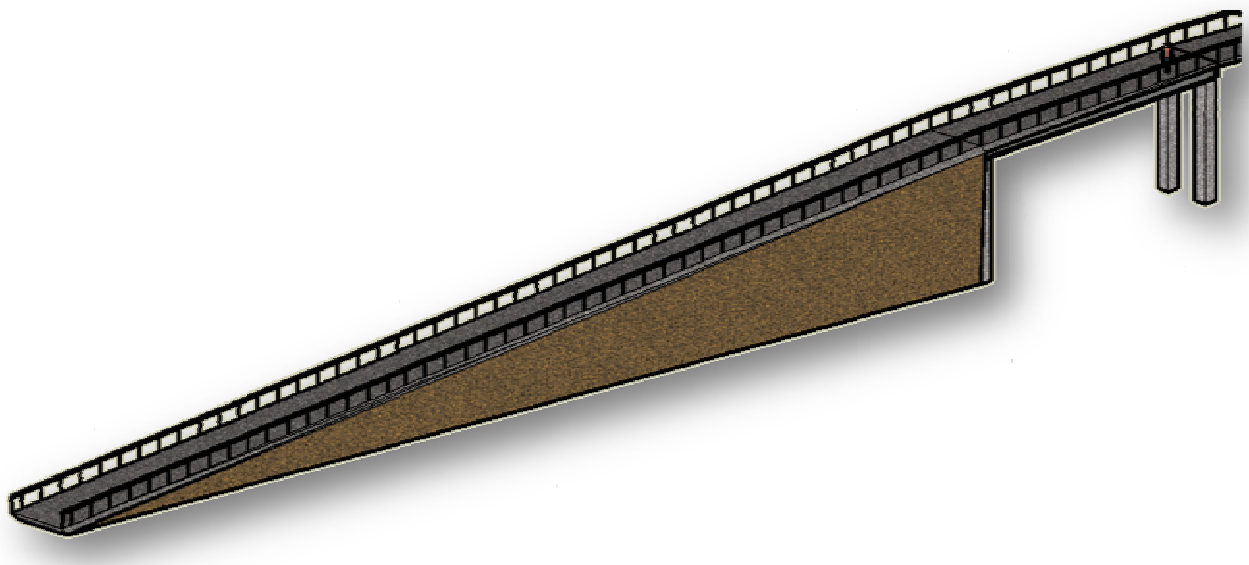

Figure L.6 – North approach for pedestrian bridge

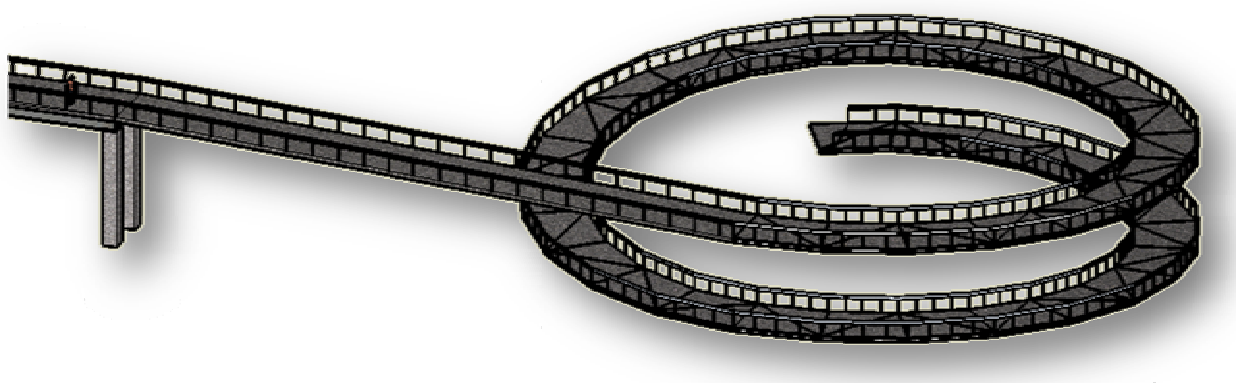

Figure L.7 – South approach for pedestrian bridge

L.10 Conclusion

A pedestrian bridge will span the Indiana Rail Road crossing at Dunn Street. It is made of both concrete and steel and will be fully accessible by pedestrians, bikers, and other non-motorists. The approaches will use land owned by Indiana University and some right-of-way along the sidewalks of North Dunn Street. The final design is presented in Figure L.8.

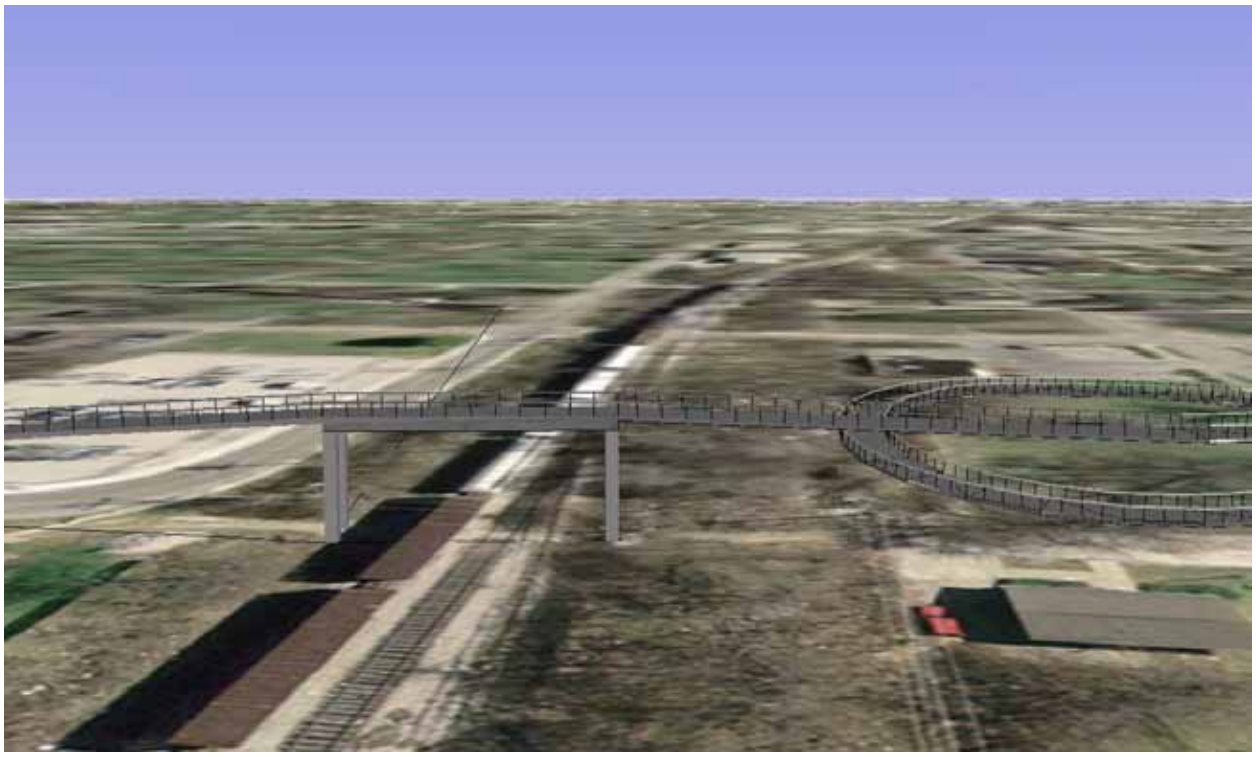

Figure L.8 – Rendering of Pedestrian Bridge

Appendix M – Intersection Design

M.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the Indiana Avenue corridor in Bloomington, Indiana. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. The City of Bloomington, Indiana Planning Department prefers to alleviate these problems using Dunn Street by creating a crossing at the Indiana Rail Road tracks. However, Dunn Right Engineering has determined that the best method of alleviating these problems is an upgrade of the existing infrastructure near Dunn Street. In order to extend the public transit system and provide a safe route for fire trucks, Dunn Right Engineering developed an intersection re-design for 12th Street and Indiana Avenue.

M.2 Current Situation

Indiana University Executive Director, Kent McDaniel requested widening of the intersection of Indiana and 12th Street. The public bus system comes from the north and turns right on to 12th Street. On the pedestrian ramp in the northwest corner of the intersection, there are tread marks from buses. Therefore, turning buses pose a potential hazard for pedestrians.

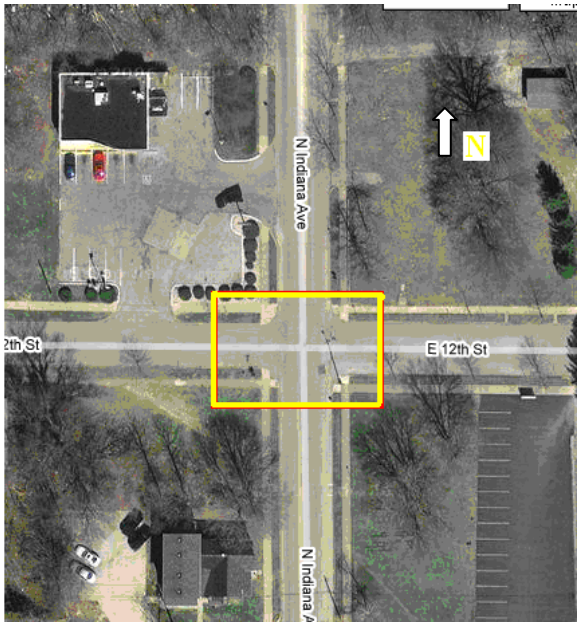

Figure M.1 – Location of Indiana and 12th Street

(Adapted from Google Earth 2008)

M.3 Design Solution

Dunn Right Engineering used the AASHTO Green Book to design a wider turning radius (AASHTO, 2004). We used the Single Unit trucks and City Transit Buses for our design. The recommended geometry from the Green Book is in Figure M.2. This figure shows the first of the two design solutions considered by Dunn Right Engineering.

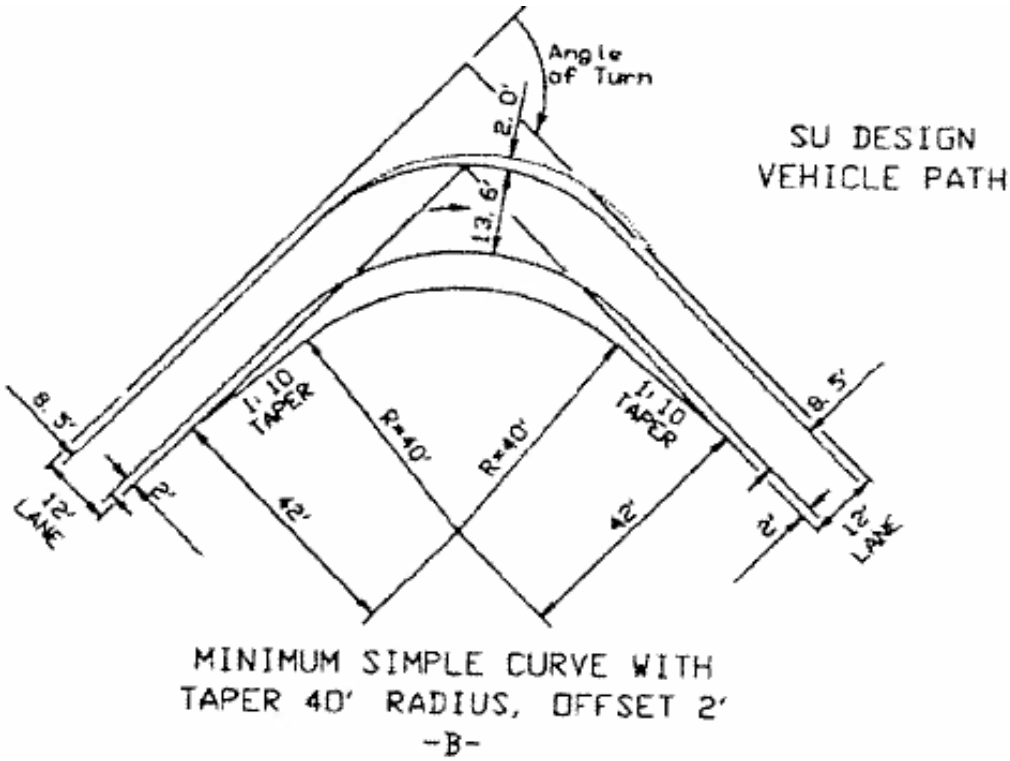

Figure M.2 – Single Unit Truck Minimum Travel Distance

(AASHTO, 2004)

The resulting redesigned turn is in Figure M.3 in red. A dashed line denotes the existing curb. This redesigned turn radius results in the removal of up to 17 feet of property to the northwest of the intersection.

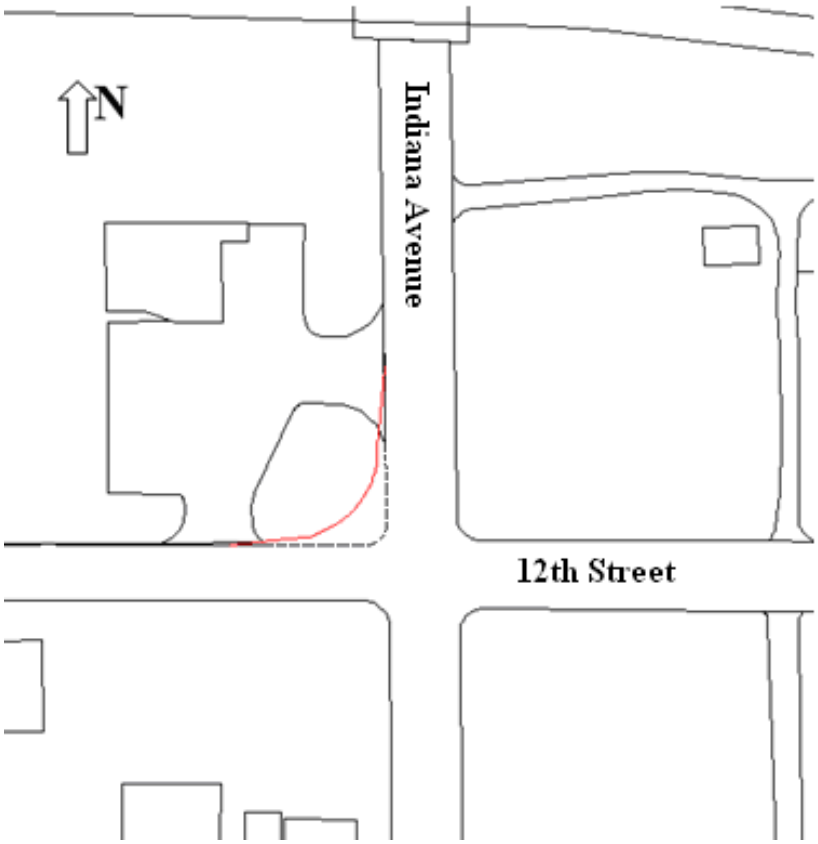

Figure M.3 – Widening Solution A of Indiana and 12th Street

The key purpose of upgrading this intersection is to enable articulated buses to travel through on the normal bus route. Dunn Right Engineering has decided that the space required to accommodate this exact design is not feasible. Therefore, we redesigned the turn using the turn radius for a normal bus. The AASHTO guideline for busses is in Figure M.4 and the resulting design is in Figure M.5. The redesigned turn radius removal results in up to 11 feet of property loss.

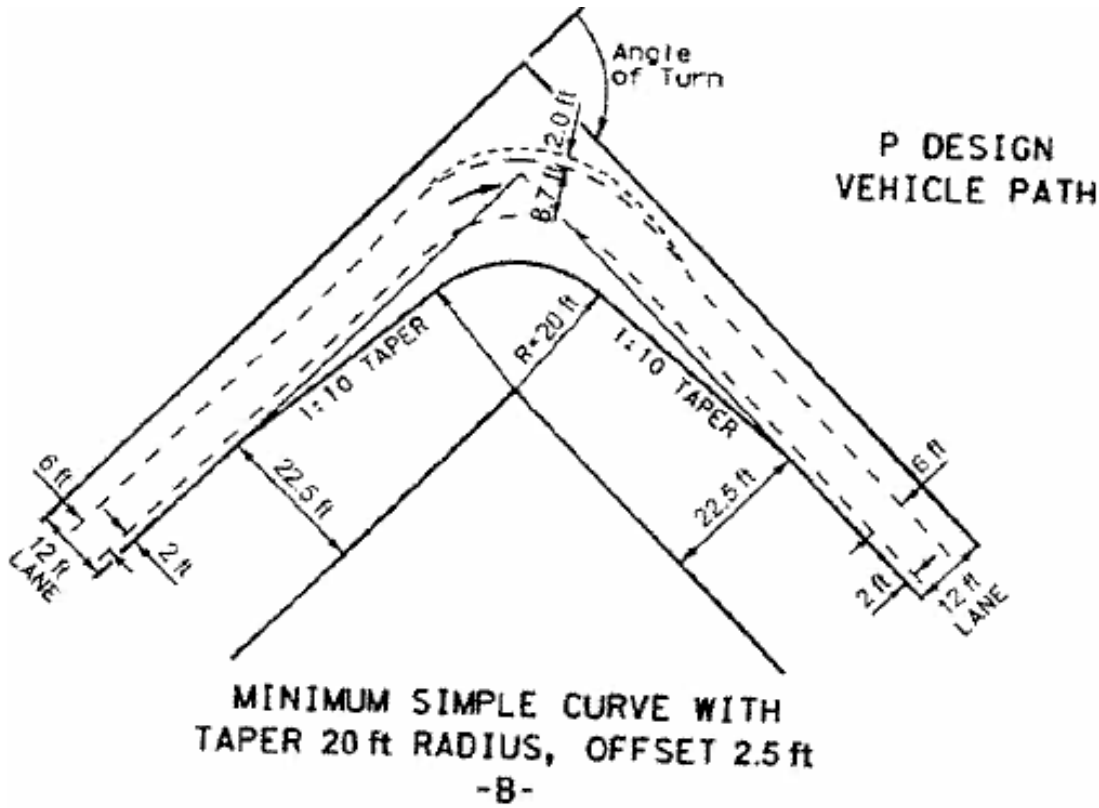

Figure M.4 – Passenger Minimum Travel Distance – (AASHTO, 2004)

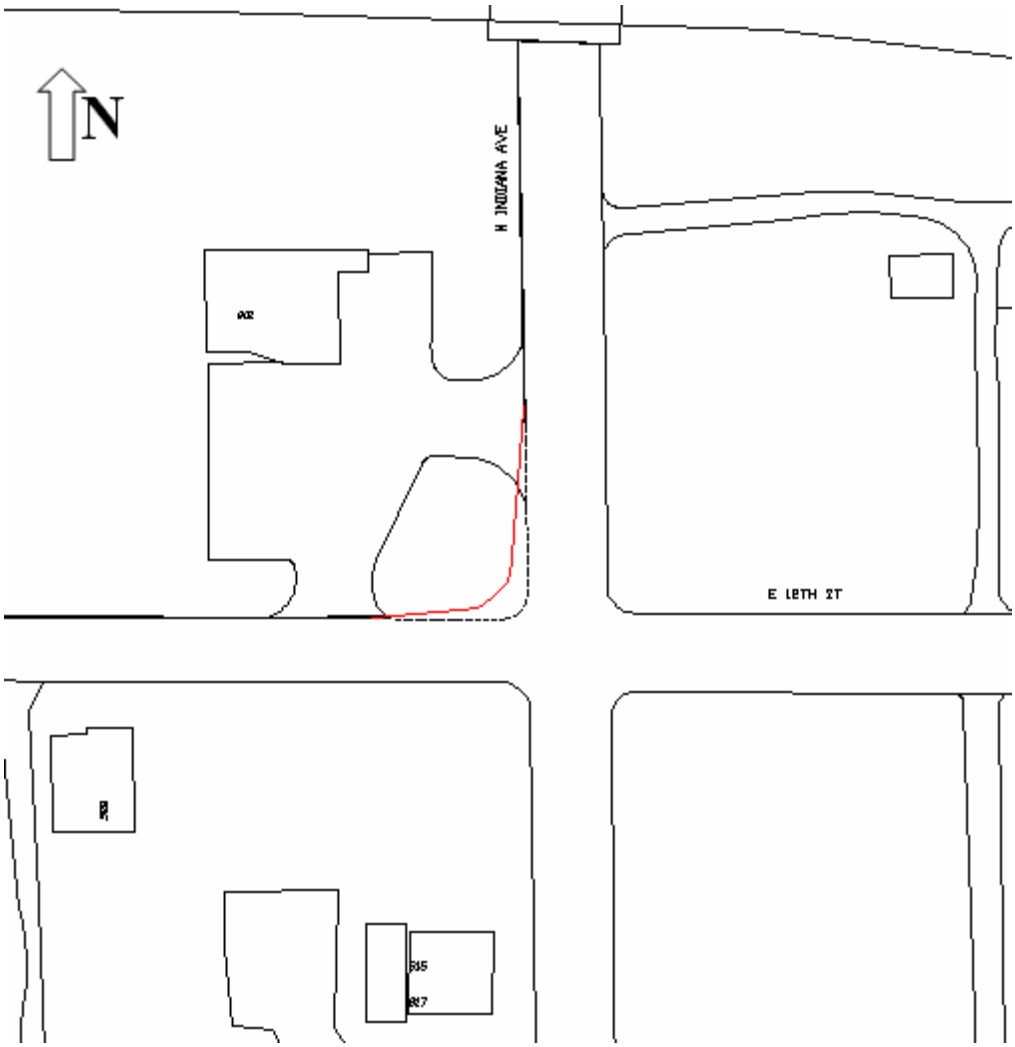

Figure M.5 – Widening Solution B Indiana and 12th Street

Using Solution B is more feasible for the City of Bloomington to construct because less right-of-way needs to be purchased. The key difference between the existing turning radius and the proposed design is the 1:10 foot taper. This taper allows an easy approach line for the buses that travel through this section. The upgrade is a simple way to protect the public, while increasing maneuverability through this intersection. Buses will travel through this intersection with more ease than with the existing condition. Solutions A and B are shown together in Figure M.6 to illustrate the differences.

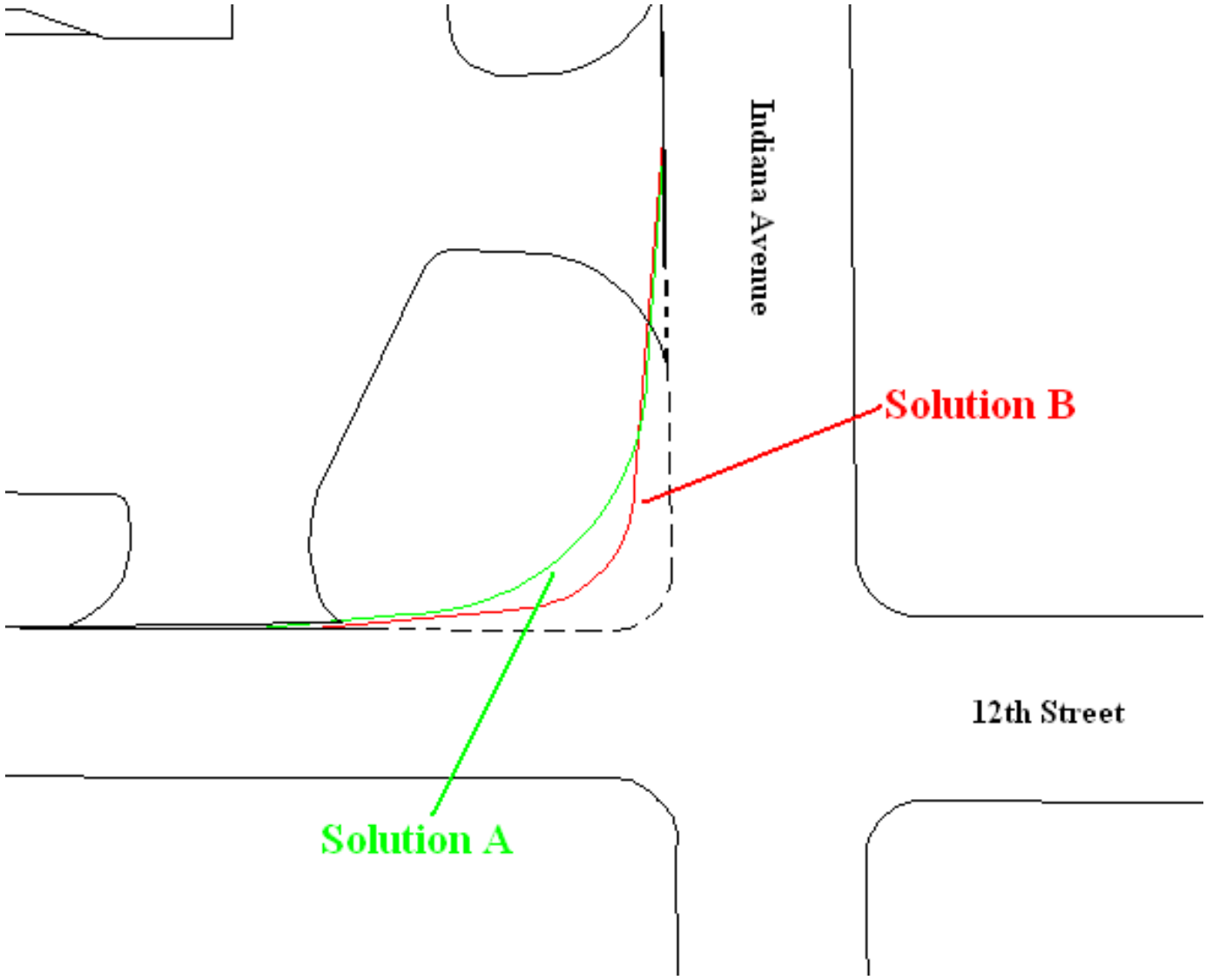

Figure M.6 – Solutions A and B

M.4 Conclusion

Dunn Right Engineering promotes widening the turn from Indiana Avenue to 12th Street by 11 feet. This upgrade will allow for improved pedestrian safety, a key goal for the city of Bloomington, Indiana.

M.5 References

AASHTO (2004). *American Association of State Highway and Transportation Officials: A Policy on Geometric Design of Highways and Streets,* 5th Edition, 2004. Washington, D.C.: AASHTO. Published Guidelines.

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Google Earth (2007). *Google Earth.* Accessed 6 December 2007.

Appendix N – Foundation Design

N.1 Overview

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the Indiana Avenue corridor in Bloomington, Indiana. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. Dunn Street is the preferred road that the City of Bloomington Planning Department would like to use to alleviate these problems by crossing the Indiana Rail Road tracks. However, Dunn Right Engineering has determined that the best method of alleviating these problems is an upgrade of the existing infrastructure near Dunn Street including a pedestrian bridge over the railroad at Dunn Street.

Dunn Right Engineering has performed the preliminary design for the foundations of the pedestrian bridge described in Appendix L. Due to the prohibition of a geotechnical investigation, Dunn Right Engineering has made general assumptions. A geotechnical investigation should be completed before a detailed design is performed.

This is a general design with the purpose of sizing the foundation in order to obtain the cost estimate in Appendix P. Dunn Right Engineering performed preliminary design the foundations for the bridge but performed no in depth work.

N.2 Soils Overview

Dunn Right Engineering was not able to perform a subsurface investigation due to the concerns about underground utilities. We have consulted the Monroe County Soil Survey (NRCS, 2007) to obtain a definition of the soil type. The soil is made of a Crider-Urban (CtC) land complex which consists of mostly silt loam. The top 10 inches are dark brown silt loam, and the following 80 inches or more is silty clay. Due to Bloomington's karst terrain, we have assumed a bedrock depth of 10 feet. This is a conservative estimate that was suggested by the Bloomington City Engineer, Adrian Reed. We used the Federal Highway Administration Soils and Foundation Reference Manual to design the foundation (FHWA, 2006).

The term "karst terrain" refers to Bloomington's limestone bedrock and the chemical properties. Karst terrain is normally created when rainwater comes into contact with soluble bedrock which in most cases is limestone or dolomite (Karst Topography, 2008).

N.3 Design Solution

Dunn Right Engineering has chosen to use drilled shafts for the pedestrian bridge. Drilled shafts are a type of deep foundation. Given that we are assuming conservative values and this is a preliminary design, we will only design one of these shafts to be used in all four locations. A drilled shaft is simply a hole dug in the ground to a certain depth and then filled in with a concrete or grout mixture from the bottom to the top. Since the exact depth of bedrock is not known, we recommend drilling until the bedrock is reached and then drill six inches further. Due to the fact that the foundation is short, we ignored the shaft or side resistance. A major problem with not knowing the exact strength of soil or limestone (bedrock) is the unconfined compressive strength. This value is critical in determining how wide the shaft must be.

To find the needed rock strength, Dunn Right Engineering would perform an Unconfined Compressive Strength of Intact Rock Core test (ASTM International 2007). This test essentially compresses the rock until it fails. This would give the strength and type of failure for the rock. Since we do not have this ability, we used a handbook value of strength. Limestone has an unconfined compressive strength, q_u, of approximately 7200-14,500 psi (Miners Life, 2008). To be conservative, we used 7,200 psi for the preliminary design. From Appendix L, the load from each of the columns is 30 kips. The design calculations are shown in Table N.1.

N.4 Drilled Shaft Design Calculations – (FHWA, 2006)

Table N.1 – Drilled Shaft Design Calculations

9.12.7.2 Tip Resistance in Rocks

If the rock below the base of the drilled shaft to a depth of 1.0 diameter is either intact or tightly jointed, i.e., there are no compressible materials or gouge-filled seams, and the depth of the socket is greater than 1.5 diameters, then the tip resistance of the rock may be evaluated as follows (FHWA, 1999):

$$Q_{tr} = A_t q_{tr} \qquad 9\text{-}48$$

$$q_{tr} = 2.5\, q_u \qquad 9\text{-}49$$

where: A_t = tip area of rock socket

q_{tr} = unit tip resistance, which is evaluated in terms of q_u, where q_u = unconfined compressive strength of intact rock (tsf)

$dia := 1.5ft$ $\quad qu := \frac{7200}{2000}\frac{ton}{ft^2}$ $\quad Area := \pi \cdot \left(\frac{dia}{2}\right)^2$ $\quad q := 2.5 \cdot qu$

Tip Capacity

$Qtip := Area \cdot q$

$Qtip = 31.809kips$

Shaft Capacity

$Qshaft := 0kips$

Rock Capacity Equation

$Qtot := Qshaft + Qtip$

$Qtot = 31.8\ kips$

N.5 Foundation Illustration

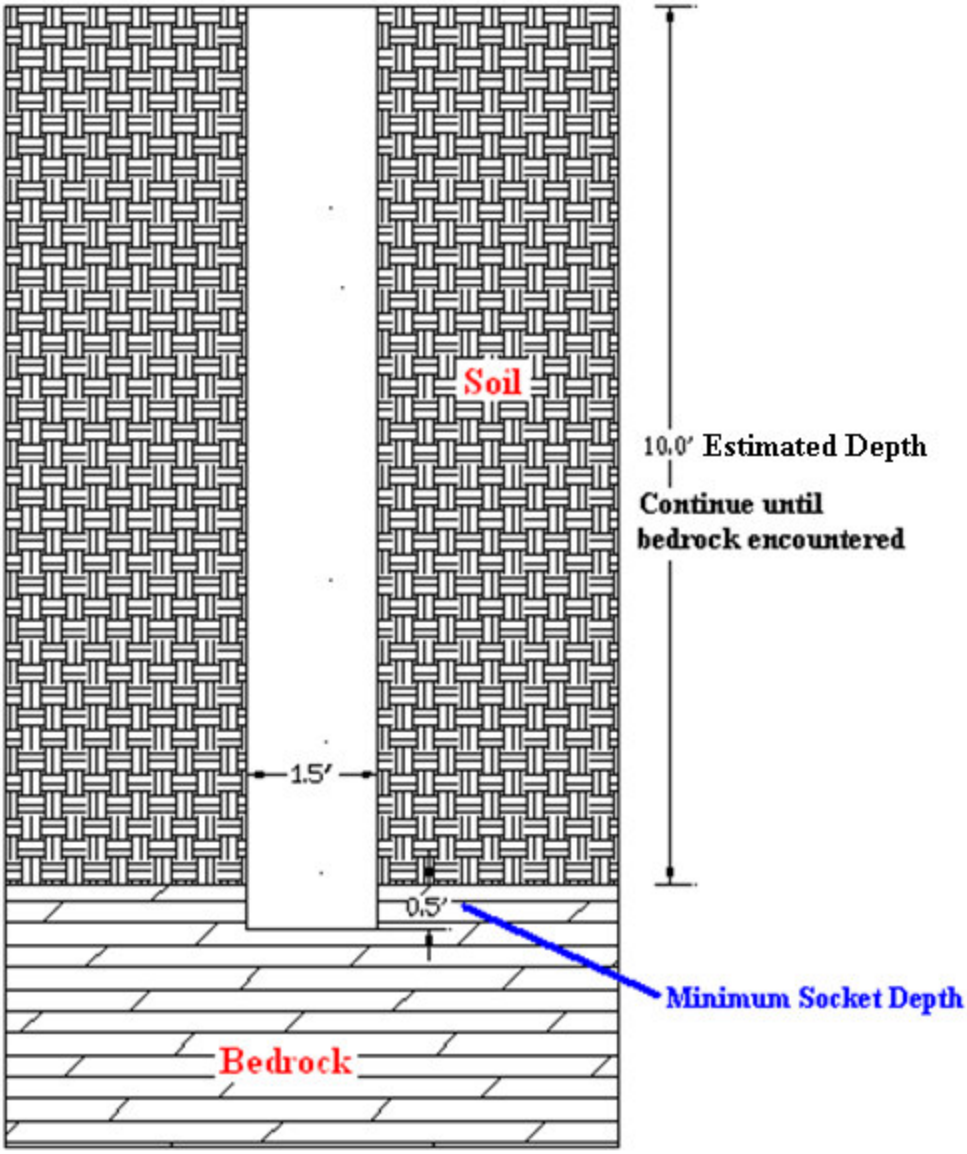


Figure N.1 – Schematic of Drilled Shaft Design

N.6 Conclusion

Dunn Right Engineering has used assumed values of rock compressive strength and depth to bedrock for the preliminary foundation design. We assumed these values of 7,200 psi and 10 feet respectively based on suggestions from our client and from handbook sources. There will be four shafts for the pedestrian bridge with an estimated drilling depth of 10 feet.

N.7 References

ASTM International, 2007. *ASTM D7012-07 Standard Test Method.* ASTM International, West Conshohocken, PA. www.astm.org

FHWA (2006). *Soils and Foundations: Reference Manual Vol. 1*. USDOT December 2006.

Karst Topography. *Wikipedia.* Accessed March 17, 2008. http://en.wikipedia.org/wiki/Karst

Mining Life. *Miners Toolbox: Unconfined Compressive Strength.* Accessed March 10, 2008. http://www.mininglife.com/Miner/rockmech/UCS_Field_Index.htm

NRCS, 2006. *Web Soil Survey 2.0*. http://websoilsurvey.nrcs.usda.gov/

Appendix O – Erosion Control Plan

O.1 Introduction

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the north south corridor. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. The erosion control plan outlines the procedures that are necessary to avoid excessive erosion during construction. (See Figure O.1)

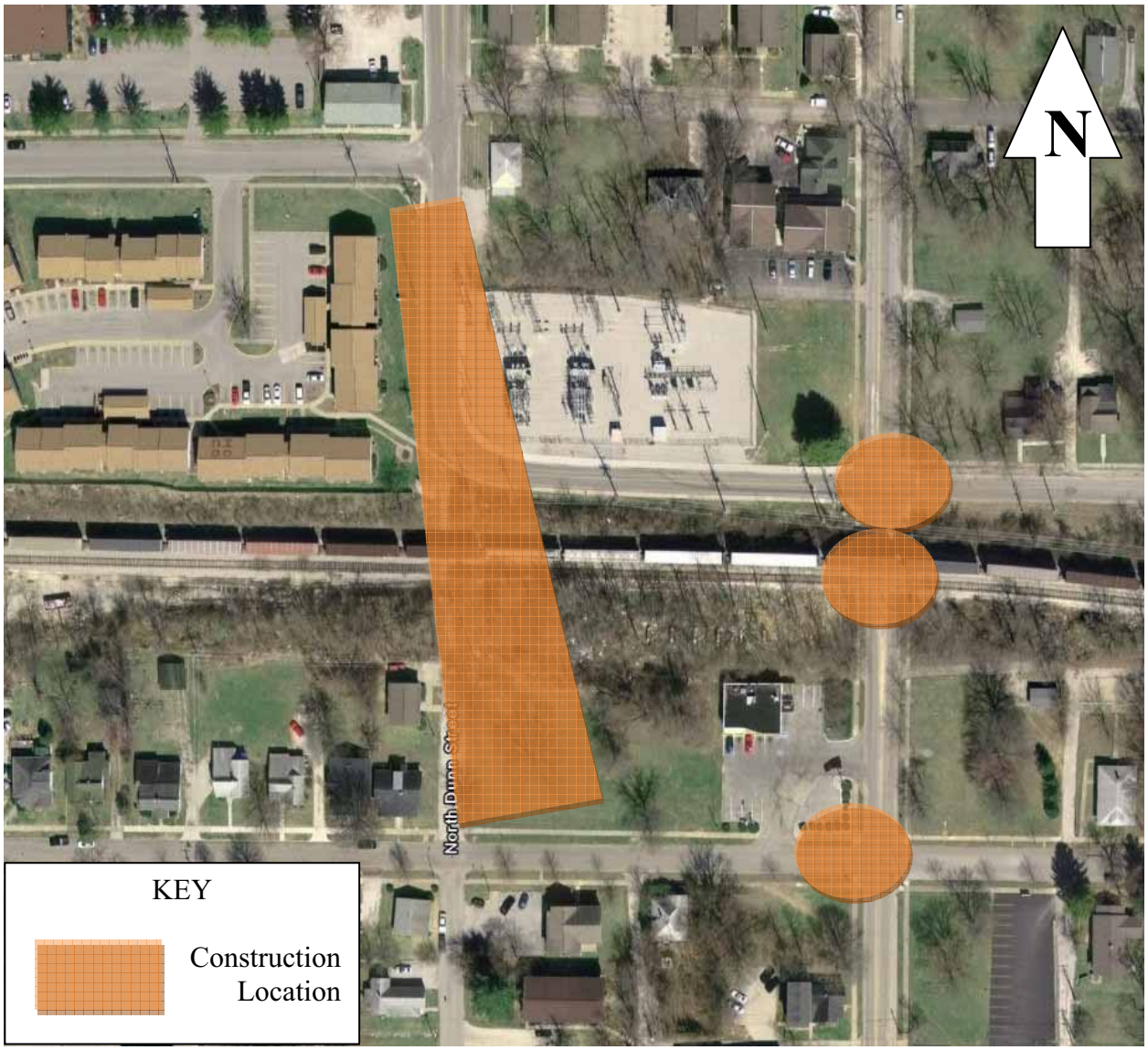


Figure O.1 – Project Site Construction Locations

(Adapted from Google Earth)

O.2 Narrative

The purpose of this project is to alleviate the traffic in the north-south corridor along Indiana Avenue in Bloomington, Indiana. In order to solve this problem, multiple steps need to be taken. The railroad overpass spanning Indiana Avenue needs widening. The intersection of Indiana Avenue and 13th street requires a stop light and the intersection of Indiana Avenue and 12th street needs a larger turning radius. In addition, a pedestrian bridge will span the railroad tracks crossing Dunn Street. Finally, the sidewalks along Indiana Avenue need repair and will span the entire corridor along with a new bike lane. Approximately 0.75 acres will be disturbed during this construction period.

The slope throughout the site is approximately 5 to 6% downward from north to south. Most of the site is paved, though there is a little vegetation surrounding the pedestrian bridge site. Some trees may need protection during construction though many will need removal. There is no evidence of significant erosion under present site conditions. Land use in the vicinity is mostly residential. The Indiana Rail Road runs through the site. The area surrounding the site is mostly developed. Most runoff should occur from the north.

The soil in the project area is mapped as Crider-Urban land complex in B and C slope classes. The Crider series consists of very deep, well-drained, moderately permeable soils on uplands. The surface is a brown silt loam, 6 inches thick. The subsurface consists of a reddish brown silt loam, 18 inches thick. The subsoil is dark red silt clay loam, 12 inches thick. Below that is dark red clay to bedrock.

Due to the permeability of the subsoil exposed during grading, there should be significant surface wetness associated with high runoff following significant rainfall events. No groundwater problem is expected. Vegetation will grow easily in this soil.

O.3 Planned Erosion and Sedimentation Control Practices

Tree Preservation and Protection – A minimum 2-foot high protective fence will be erected around any trees that will not be removed at the drip line to prevent damage during construction. Sediment fence materials may be used for this purpose.

Land Grading – Light grading is necessary for the pedestrian bridge. The flatter slope after grading will reduce the overall erosion potential of the site.

Temporary Sediment Trap – Small sediment traps will be placed in each onsite inlet. This is necessary to prevent sediment from entering the sewer.

Sediment Fence – A sediment fence will be constructed around the site and along drainage channels. This prevents sediment from entering the site or the drainage channels.

Dust Control – Dust control should not be a problem due to the small area of exposure, the undisturbed vegetation around the site, and the short time of exposure. If excessive dust occurs, it will be controlled by sprinkling.

O.4 Construction Schedule

1. Obtain plan approval and other applicable permits.

2. Flag the work area limits and mark trees that need protection.

3. Hold pre-construction conference at least one week prior to starting construction.

4. Install storm drain sediment traps.

5. Complete site clearing for entire site.

6. Rough grade site, stockpile topsoil, and install sediment fence as needed.

7. Complete final grading of site, topsoil critical areas, and permanently vegetate, landscape, and mulch.

8. All erosion and sediment control practices will be inspected weekly and after rainfall events. Needed repairs will be made immediately.

9. After the site is stabilized, remove all temporary measures and install permanent vegetation on the disturbed areas.

10. Estimated time before final stabilization – 1 month.

Appendix P – Cost Estimate

P.1 Introduction

The purpose of the Dunn Street Modernization Study is to design alternative vehicular and pedestrian traffic routes to alleviate the problems associated with the congestion of the Indiana Avenue corridor in Bloomington, Indiana. Currently Indiana Avenue, one of the major roads making up the corridor, is experiencing major traffic overcrowding, and is therefore unsafe for vehicle and non-motorized traffic. Dunn Street is the preferred road that the City of Bloomington Planning Department would like to use to alleviate these problems by crossing the Indiana Rail Road tracks. However, Dunn Right Engineering has determined that the best method of alleviating these problems is an upgrade of the existing infrastructure near Dunn Street.

Dunn Right Engineering has estimated the cost of construction for the proposed designs. These costs are based on the RS Means (RS Means, 2007), and data obtained from proposed subcontractors. The estimate includes construction, materials, overhead, and profit.

P.2 Cost Estimates

The estimates provided in Table P.1 list unit prices, RS Means unit price item numbers, RS Means unit cost, and material quantities for each phase of the project. Table P.1 is broken down into the major phases of the project. This will allow the client to choose one or all phases of the proposal. If the client decides to take this project through all proposed phases from Dunn Right Engineering, our design team estimates the final cost of the project to be $800,000.

Table P.1 – Cost Estimate Breakdown

Task	Unit	Unit Cost	# of Units	Cost	RS Means Unit Number/ Data Source
Sidewalk removal					
Concrete	SY	$6.24	1128	$7,039	24113.3341
Sidewalk replacement					
Aggregate	SY	$1.13	422	$477	
Concrete	SY	$1.54	422	$650	
Concrete	SY	$1.54	422	$650	
Bike Path Replacement					
Aggregate	SY	$1.13	2347	$2,652	

Table P.1 – Cost Estimate Breakdown (continued)

Pavement	SY	$7.30	2347	$17,133	320610.1
Pavement	SY	$7.30	2347	$17,133	320610.1
Painting					
4"	LF	$0.99	7470	$7,395	321723.1307
6"	LF	$1.38	1200	$1,656	321723.1307
12"	LF	$2.82	282	$795	321723.1308
Letters	SF	$5.09	105	$534	321723.1308
Signage					
Yield	1 sign	$22.50	8	$180	Decker Supply Company
Vertical Clearance	1 sign	$31.45	1	$31	Decker Supply Company
Vertical Clearance Plaque	1 sign	$60.80	1	$61	Decker Supply Company
Bike X-ing	1 sign	$31.45	12	$377	Decker Supply Company
Traffic control symbol	1 sign	$31.45	1	$31	Decker Supply Company
Be Prepared to Stop	1 sign	$31.45	1	$31	Decker Supply Company
When flashing plaque	1 sign	$60.80	1	$61	Decker Supply Company
Post	1 post	$27.10	25	$678	101453.2015
Warning Beacon	1	$234.00	1	$234	eProcurement
Traffic Signal with pole	1 signal	$173,500	1	$173,500	347113.101
Pavement					
HMA	SY	$11.80	211	$2,490	321216.1305
Coarse	SY	$23.40	211	$4,937	321126.1312
Finishing/ Sealing	SY	$42.21	211	$8,906	321313.2303
Hauling	CY	$13.23	58.6	$775	312323.1806
Grading	SY	$2.60	211	$549	312216.1011
Removal	SY	$67.00	180	$12,060	24113.1754
Foundation					
Concrete Pier	FT	$38.70	11	$426	316329.0085
Hauling	CY	$8.63	3	$26	312323.1802
Overpass Replacement					
Purchase Prefabricated Structure	Unit	$210,000	1	$210,000	Skipp Gibbs Company
Delivery & Installation	Unit	$60,000	1	$60,000	Skipp Gibbs Company
Removal Of Existing Structure	Unit		1	$0	L.L. Geans Company
Cast-In-Place Concrete (Columns)	CY	$856.00	7.8	$6,677	33053.4009
Cast-In-Place Concrete (Beams)	CY	$764.50	14.07	$10,757	33053.40035

Reinforcing Steel	Ton	$725.00	1.67	$1,211	32113.1003
Excavation	CY	$92.95	21.87	$2,033	312316.3025
Pedestrian Bridge					
Concrete Bridge Deck	SF	$73.97	720	$53,258	24113.1754
Cast-In-Place Concrete (Columns)	CY	$856.00	177.8	$152,197	33053.4009
Reinforcing Steel	Ton	$725.00	3.98	$1,211	32113.1003
Steel Girders	LF	$236.38	120	$28,366	5122375.7900
Railing	LF	$32.57	120	$3,908	55213.500010
Total:				**$791,085**	

Note: All costs include the cost of labor.

P.3 References

Decker Supply Company, Inc: Traffic Safety Equipment. http://www.deckersupply.com/. 2008.

Skipp Gibbs Company. www.skipgibbs.com/index.html 2008.

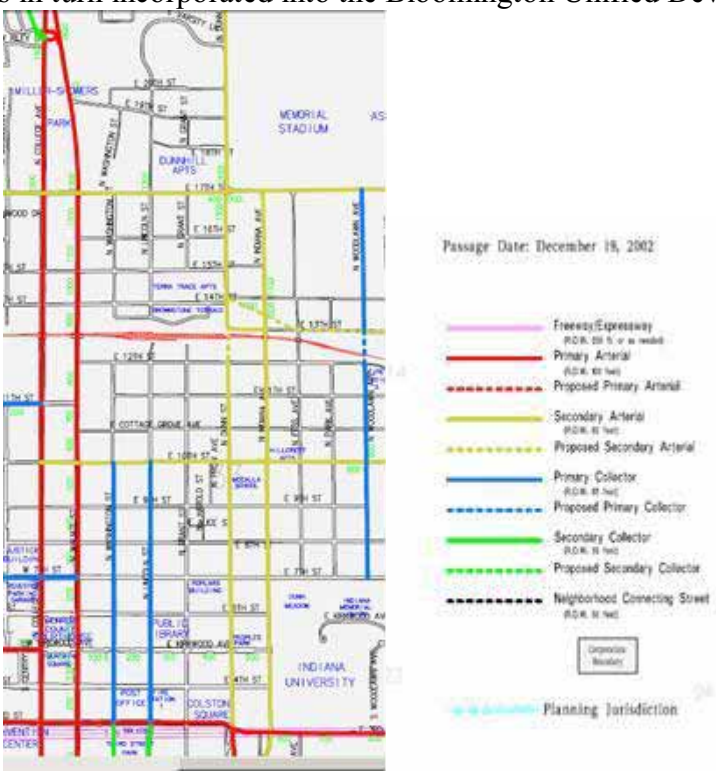
Waier, Phillip. RS Means Building Construction Cost Data: Reed Construction Data, Inc. United States of America.2007

OLD NORTHEAST ONE DOWNTOWN NEIGHBORHOOD ASSOCIATION
A Bloomington Blend

TO: City of Bloomington Planning Department
FROM: Old Northeast Downtown Neighborhood Association
RE: Progress Report for the Dunn Street Modernization Study
DATE: February 14, 2008

The purpose of this document is to provide the comments of the Old Northeast Downtown Neighborhood Association on the progress report for the "Dunn Street Modernization Study" by Dunnright Engineering (Rose-Hulman Institute of Technology).

Page 1, "Dunn Street is a north-south street that runs alongside Indiana University's Campus." This is an understatement or mischaracterization. In fact, Dunn Street is designated as a secondary arterial in the City's Master Thoroughfare Plan/Map[1] (shown below). We note that the Master Thoroughfare Plan is incorporated by reference into the 2002 Growth Policies Plan of the City of Bloomington[2] ; the 2002 Growth Policies Plan is in turn incorporated into the Bloomington Unified Development Ordinance[3]



[1] http://bloomington.in.gov/maps/imgs/pdfs/planning_thoroughfare.pdf.
[2] City of Bloomington. 2002 Growth Policies Plan (Adopted December 19, 2002). See Chapter 5, p. 79, in its entirety. Specifically, see the section regarding Secondary Arterials beginning on p. 88.
[3] City of Bloomington, Indiana. **Bloomington Unified Development Ordinance**, February 12, 2007. §20.01.420(d), viz., "Growth Policies Plan Incorporated Herein: The Growth Policies Plan, which includes the Master Thoroughfare Plan, the Alternative Transportation and Greenways System Plan, and all Subarea Plans, which include among others, the Downtown Vision and Infill Strategy Plan and The Plan for West Kirkwood, is hereby incorporated into and made a part of this Unified Development Ordinance."

Page 4, ¶2.2, "Second, residents living along Dunn Street have indicated that they are in opposition to congesting their quiet street." Who are these residents. The street in question is not currently "quiet" and would better serve the neighborhood if the north-south connectivity were improved. Also, "The railroad company, Indiana Rail Road, has indicated that they will not allow an at-grade crossing for Dunn Street." Can the Indiana Railroad legally deny the City of Bloomington the option of installing an adequate at-grade crossing?

Page A-3, ¶A.5.1 "The lots to the north-west and south-west have residential houses. Our client believes that both houses are from the early 1900's." This is an error in fact. Monroe County Property Tax records indicate that the house at 901 North Dunn Street, immediately adjacent to the railroad, was in fact constructed in 1992. The other house mentioned, located at 429 East Twelfth Street is listed by the same source as being constructed in 1925. Moreover, neither property is listed as being of any historical significance in the City of Bloomington's Interim Report on Indiana Historic Sites and Structures Inventory[4].

MONROE COUNTY, INDIANA
Property Assessment Detail Report
Parcel Number: 013-21090-00

GENERAL PARCEL INFORMATION

Parcel Number:	013-21090-00
Alt Parcel Number:	13-33.13 -0084.000
Property Address:	901 N. DUNN STREET IN
Neighborhood:	1310 1
Property Class:	510 1 Family Dwell - Platted Lot

Owner's Name / Address
ELKINS, BARRY

2010 W THAT RD
BLOOMINGTON 47403

Legal Description
COTTAGE GROVE PT LOTS 90 & 91

Taxing District

Township: BLOOMINGTON TOWNSHIP. Corporation: MONROE COUNTY COMMUNITY SCHOOL CORPORATI
District: BLOOMINGTON CITY-BLOOMINGTON T.

Site Description

Public Utilities Water: Y Sewer: Y Gas: Y Electricity: Y All: Y

LAND DESCRIPTION **Total Acreage: 0.0758**

Land Type	Dimensions	Acreage
F	50x66	0.0758

SUMMARY OF IMPROVEMENTS

Buildings	Grade	Year of Constr.	Effective Year	Condition	Size / Area
Single-Family Residence C1	C	1992	1992	Average	1680

MONROE COUNTY, INDIANA
Property Assessment Detail Report
Parcel Number: 013-01940-00

GENERAL PARCEL INFORMATION

Parcel Number:	013-01940-00
Alt Parcel Number:	13-33.13 -0085.000
Property Address:	429 E. 12TH STREET IN
Neighborhood:	1310 1
Property Class:	510 1 Family Dwell - Platted Lot

Owner's Name / Address
BRITTON, JAMES R. & SANDRA S.

2521 N KINSER PIKE
BLOOMINGTON IN 47404

Legal Description
COTTAGE GROVE PT L-90 &91

Taxing District

Township: BLOOMINGTON TOWNSHIP. Corporation: MONROE COUNTY COMMUNITY SCHOOL CORPORATI
District: BLOOMINGTON CITY-BLOOMINGTON T.

Site Description

Public Utilities Water: Y Sewer: Y Gas: Y Electricity: Y All: Y

[4] City of Bloomington, Housing and Neighborhood Development Department. **City of Bloomington Interim Report (Indiana Historical Sites and Structures Inventory), April 2004.** See pages 7-11, Cottage Grove Historic District (105-055-61001-105). See also, pages 134-143, City of Bloomington Scattered Sites (105-055-90001-192). Neither property is included at any level in the Interim Report.

LAND DESCRIPTION — Total Acreage: 0.0758

Land Type	Dimensions	Acreage
F	50x66	0.0758

SUMMARY OF IMPROVEMENTS

Buildings	Grade	Year of Constr.	Effective Year	Condition	Size / Area
Single-Family Residence C1	C-1	1925	1925	Average	

Page A-3, ¶A.5.1 "To the southwest, there is an apartment complex." This is an error in fact. To the southwest are single family residences which serve as student rental housing. To the southeast are apartment buildings (not apartment complexes) which also provide student housing.

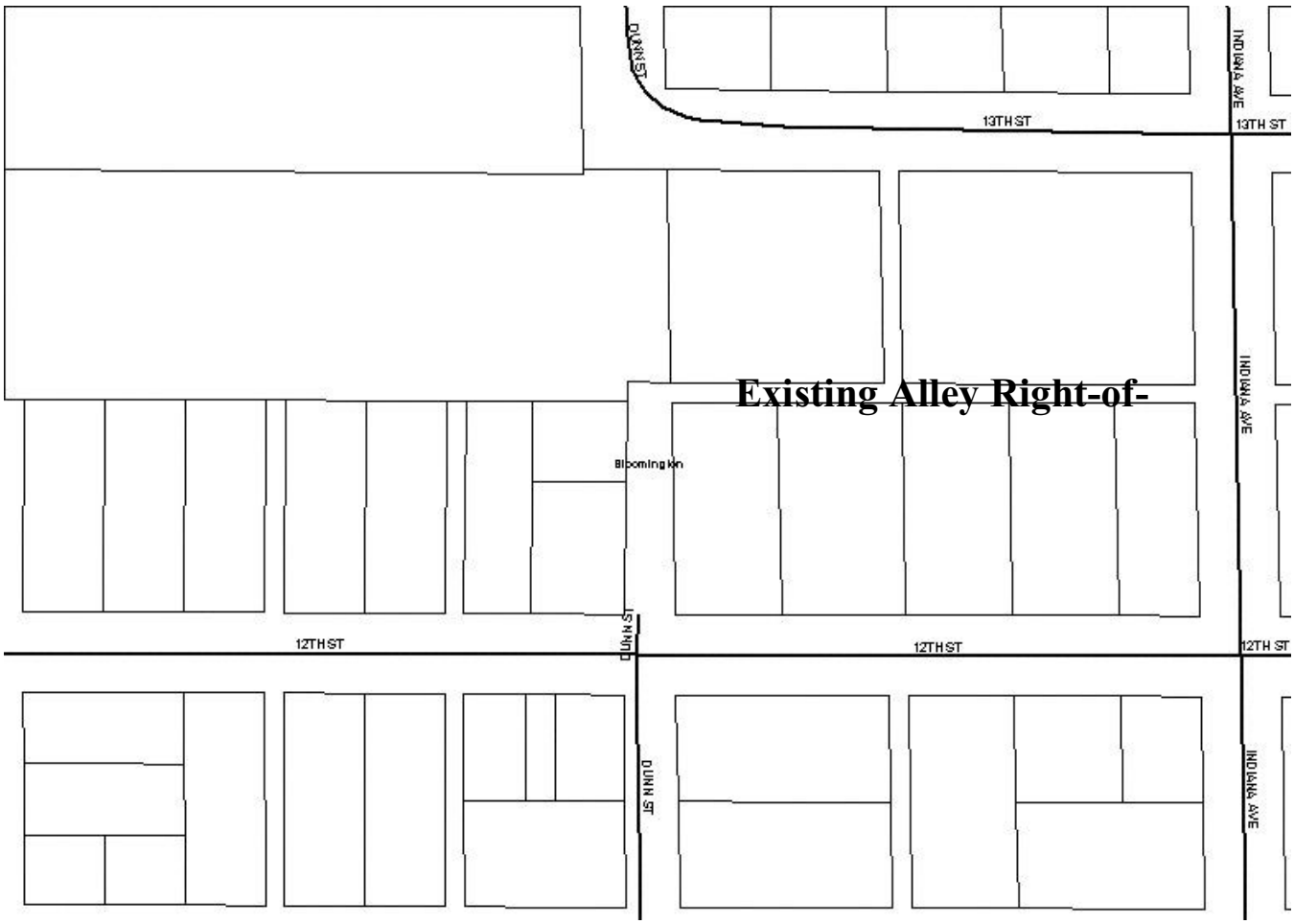
Page A-4, ¶A.5.3, "From the south, Dunn Street begins at East Atwater Avenue and terminates at 12th street." In this entire section, Dunn Street is one way southbound, and actually does not terminate at East Atwater Avenue, but continues south to 2nd Street. In terms of connectivity, this is important, since East Atwater Avenue provides connectivity to points east; connectivity to points south is provided via 2nd Street to South Henderson Street; and connectivity to points west and southwest is provided by 2nd Street.

Page A-4, ¶A.7. "There is also another branch of a storm water pipe that is south of the site and runs under the west sidewalk." No such branch is reflected in the referenced Figure A.14, page A-18.

Page A-4, ¶A.7. "Overhead high voltage power lines are located on the site. (See Figure A.17.) They start at the Duke metering station and head southwest over the site crossing the railroad tracks." Actually, the site involves primary and secondary service lines, as well as high-voltage transmission lines. We also note that there is no mention of the buried high-voltage lines which are readily apparent from a visual inspection of the substation.

Page A-6, Figure A.1. The caption lists "Woodland Avenue" as part of a potential north-south corridor. We believe the intended reference is "Woodlawn Avenue".

Page A-24, Figure A.20. The target streets of the study are mislabeled. The street labeled as "13th Street" is actually 12th Street in this figure; the street labeled as "12th Street" in this figure is actually 11th Street. We also note that there is no mention of the existing alley right-of-way along the south side of the railroad tracks east of Dunn Street.



Page E-4, "Once combined, however, the one-way pair of Dunn Street and Indiana Avenue is capable of handling a higher overall traffic flow. With the increased capacity, public transportation will be able to utilize routes that are more direct and efficient." We wish to emphasize this statement. A continuous Dunn Street from the Memorial Stadium (and points north) through the downtown area would greatly improve public transportation options. We note that the main IU Student parking area is located at IU's

Memorial Stadium parking lot on Dunn Street. Significant numbers of students utilize public transportation from this lot to the IU Campus. A continuous Dunn Street, crossing the railroad tracks between 12th and 13th Streets, and a traffic signal at 10th Street, would be able to access the IU Campus directly via 10th Street, 7th Street, and the Atwater Corridor. New bus routes would be possible along these major thoroughfares. Moreover, we note that the area bounded by 10th Street on the South, Walnut Street on the West, Indiana Avenue on the east, and the Indiana railroad on the north currently is not served by either the IU or city bus routes (i.e., there are no bus stops in this area).

p. E-7 and following. Incorrect Units Analysis. Velocity divided by distance does not yield time. (miles/hour)/(miles) results in units of inverse time. The correct formula would be time = distance/velocity, with a units analysis of [(miles)/(miles/hour) = hours] and appropriate conversion factors.

> Therefore, the term given as "(30 mph/2672 ft) becomes (2672 ft/30 mi/hr)*(1 mi/5280 ft)*(3600 s/hr) = (89.066)*(189.4)$(10)^{-6}$*(3600) = 60.727 seconds. The calculation is based on two stops, but the Total Time equation only accounts for a single stop.
>
> The Total Time
>
> Total Time = 60.727 seconds + (2 stops)*(8.8 seconds/stop)= 78.32 seconds
>
> This assumes that the total stopping time of 8.8 seconds = 6.28 seconds at the stop sign and a 2.5 second delay per stop sign. Viz., 6.28 seconds + 2.5 seconds = 8.78 seconds.

Page E-8 and following. The errors on page E-7 have been carried forward.

Total Time = 78.32 s + 3.1 s = 81.43 seconds

Page E-9, "Total Time = 112 Seconds." The error on page 3-7 has been carried forward. Also, assuming that stops would be required at the intersections at 13th and Indiana, 11th & Dunn, and Cottage Grove Avenue and Dunn Street, this is a miscalculation which omits the stopping time for one stop.

Total Time = (Distance/Velocity) + Total Stopping Time
= 60.727 s + [(5.2 s/turn)*(3 turns) + (8.8 s/stop)* (3 stops)]
= 102.727 seconds

We also note that this calculation does not account for the deceleration required to make the 90 degree turn from Dunn Street onto 13th Street. Assuming this additional curve would add 5.2 seconds for deceleration and acceleration, the Total Time would increase to 107.927 seconds.

Page F-4, ¶F.2 "An overpass also greatly increases the safety of the Indiana University students that currently trespass across the Indiana Rail Road tracks." We suggest that an overpass would increase the safety of **all pedestrian traffic** crossing the railroad tracks, not just Indiana University students.

Pages F-4 & F-5, ¶F.2, "For instance, this design option would cause a higher volume to flow into the historical neighborhood on the south side of the railroad tracks." As previously noted, the

neighborhood south of the Indiana Railroad along Dunn Street has not been designated as historic. See our comments on page A-3.

Page F-7, "The local residents do not want to lose their quiet atmosphere nor do they want they want a busy neighborhood road." We dispute this characterization of the neighborhood along Dunn Street south of the Indiana Railroad. This vicinity is, and has been for many decades, rental housing which primarily serves the community of Indiana University students. We assert that the residents and other stakeholders in this neighborhood desire better connectivity with the rest of the city and better public transportation service.

Page F-7, ¶F.2.2.2, "The residents are opposed to this design option. It will drastically change the historical neighborhood south of the Indiana Rail Road. The overpass approaches may obstruct and impede on the residents' land and the increase in traffic will disrupt the quiet neighborhood. Interpretations of the residents' responses are from information provided by the City of Bloomington Planning Department." The Old Northeast Downtown Neighborhood Association refutes this as a gross mischaracterization.

Page F-8, ¶F.2.3. As previously noted, none of the calculations given in Table E-3 are correct.

Page F-8, ¶F.3, "An underpass also greatly increases the safety of the Indiana University students that currently trespass across the Indiana Rail Road tracks." Once again, all pedestrian traffic would be more accurate. Also, "The maximum reasonable grade for the approaches is 8% causing an approach length of at least 350 feet. This will alter the flow of other roads onto Dunn Street." We note that the approach length of 350 feet is the same as the calculation for the overpass option. Given the topography in question, the length and location of the approaches would necessarily differ for the overpass and underpass options.

Page F-9, ¶F.3.1 We question the comparability of the cities and locales used for cost comparison bases.

Page F-10, ¶F.3.2, "The local residents do not want to lose their quiet atmosphere nor do they want they want a busy neighborhood road." This statement has absolutely no basis in fact.

Pages F-11 & F-12, "Dunn Right Engineering determined that the construction of an underpass would have a total travel time of 78.3 seconds to drive through this corridor. Refer to Table E.3 for calculations. This time is more efficient than the current 112 seconds are. We determined that all stop signals would have a delay of 8.8 seconds, see Appendix E for calculations." These calculations have been shown to be erroneous.

Page F-13, ¶F4.1, "The estimated cost of upgrading the Indiana Avenue underpass is $80,000." We note that the estimated cost of a similar underpass upgrade along the 10th Street Corridor was magnitudes of order higher ($5,240,000)[5]. The quoted estimate seems to be unrealistically low. Also, "This information is in Table E.3." should read "This information is in Table F.3.".

[5] Urban Engineering (Rose-Hulman Institute of Technology). **Final Report: 10th Street Extension and Modernization**. See Table 1, "Final Cost Estimate", p. 19.

Page F-15, ¶F4.2.2. "The residents are in favor of this design option because it minimizes the impact on the neighborhood. Very little right-of-way is required by the city; no driveway realignment is necessary; and no residents will lose their houses. Interpretations of the residents' responses are from information provided by the City of Bloomington Planning Department." The Old Northeast Downtown Neighborhood Association does not concur with the City of Bloomington Planning Department's characterization of their wants or needs. We also note that this paragraph adds factors which were not discussed in the other design options.

Page F-15, ¶F.4.3, "Dunn Right Engineering determined that the total travel time of 112 seconds is necessary to drive through this corridor for the upgrade of existing conditions. Refer to Table E.3 for calculations. This design option allows additional traffic flow and it upgrades the safety of all types of traffic. We determined that all stop signals will have a delay of 8.8 seconds, see Appendix E for calculations." The 112 second calculation should read 102.727 seconds. The 8.8 seconds actually addresses stop signs rather than traffic signals.

Page F-17, Table F.4. There is no mention of the cost of acquiring additional right-of-way.

Page F-18, ¶F.5.2.1. "The Indiana Rail Road is completely against this design option." We admit that this should be taken into account, but we question whether the preferences of the Indiana Railroad should in fact take precedence over the needs of the citizens of Bloomington.

Page F-18, ¶F.5.2.1 "They use this area not only as a through route but also as a holding station where trains will stop and wait for other trains to pass." The aerial views of the site in question reveal other workable solutions. Namely, could the entrance to the southernmost siding (the third track), currently located just east of Dunn Street, be relocated to a point slightly further west? Is the southernmost siding even serviceable? Likewise, could the entrance to the northern siding (the middle track), currently located near the intersection of 12th Street and Park Avenue also be relocated to a point west of Dunn Street? Such options would preserve the railroad use of the siding as a holding area, while greatly simplifying the at-grade crossing option.

Page F-19, ¶F.6, "Dunn Right Engineering has determined that by performing modernization studies on Woodlawn Avenue and Fess Avenue in the future the north-south corridor may improve. These are both north-south roads that have the potential to open up as one-way pairs. Currently the Indiana Rail Road tracks bisect Woodlawn Avenue with no crossing. There is a possibility that purchasing right-of-way at this site is easier because of fewer residents living along these roads. Fess Avenue currently has a narrow underpass that has an extremely low vertical clearance. In the future, these sites could create another north-south one-way pair to alleviate the university traffic if updated. (See Figure F.7)" With regard to the feasibility of making a new one-way pair of Fess and Woodlawn Avenues, we note that this would impact the University Courts Addition, which was recently listed on the National Historic Register. We also note that these two street have limited connectivity; both are bounded by 7th Street on the south and 12th Street on the north. We furthermore note that Fess Avenue south of 10th Street is a historic brick street, which would be adversely impacted by increased traffic flow. We submit that the option proposed in the paragraph is neither realistic or desirable.

Page G-4, Table G.4, "Dunn Street Modernization Study Decision Matrix". Assuming that the cost estimate for the upgrade of existing options is seriously understated, and that the stakeholders of the neighborhood do not oppose upgrading Dunn Street to provide better connectivity, public transportation and emergency vehicle access, the table would be changed as follows.

		Overpass		**Underpass**		**At-Grade Crossing**		**Upgrade of Existing**	
	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	0.5	2	1	1	0.5	3	1.5	**1**	**0.5**
Political Feasibility	0.25	**3**	**0.75**	**3**	**0.75**	2	0.5	**1**	**0.25**
Traffic Flow	0.25	3	0.75	3	0.75	2	0.5	1	0.25
Total	**1.0**		**2.5**		**2.0**		**2.5**		**1.0**