APPENDIX C

RAISED RAIL AND DEPRESSED FACILITY OPTIONS

Appendix C1

Raised Rail Option

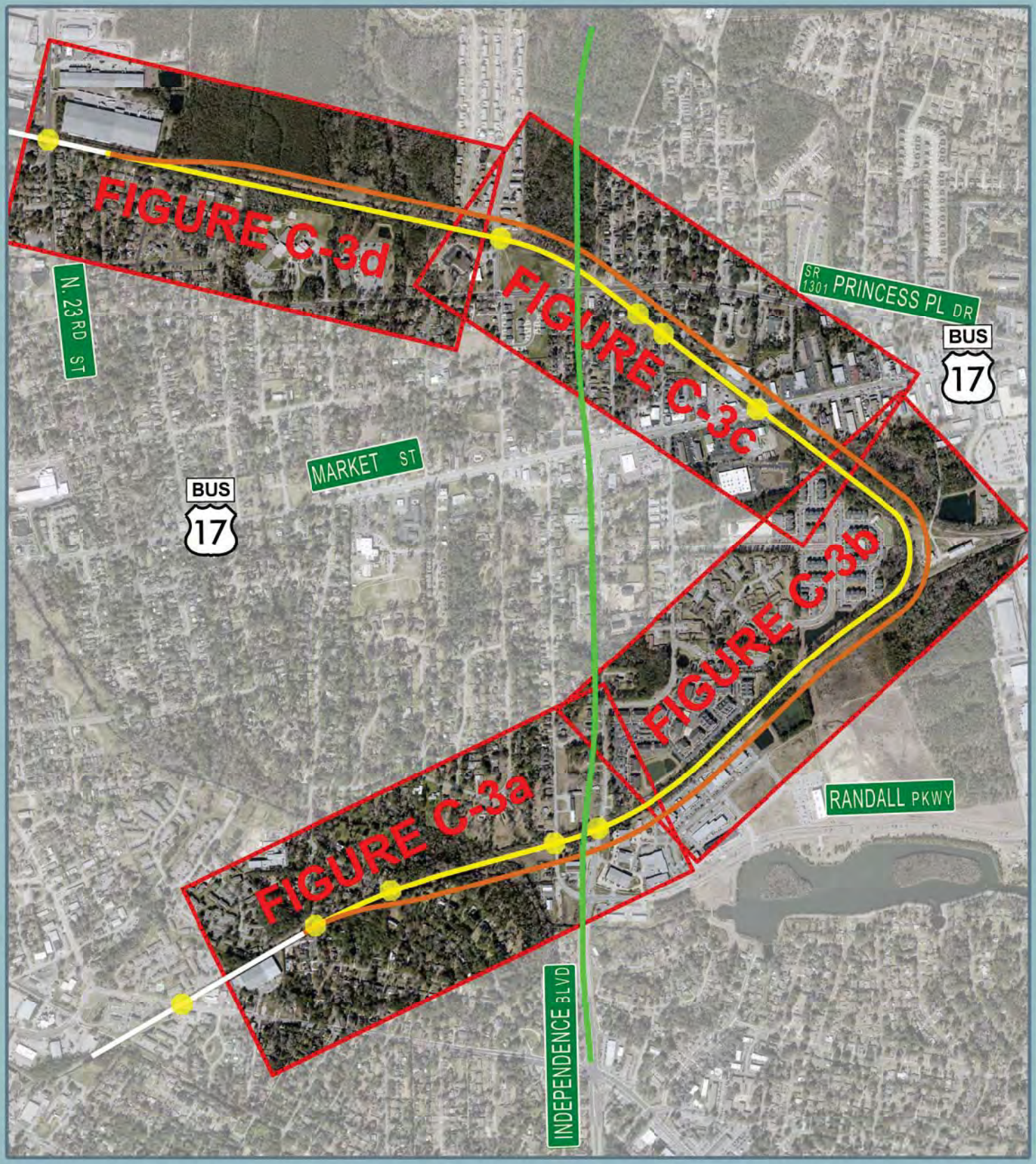
Table 1: U-4434 RAISED RAILROAD CONCEPTUAL ALTERNATIVE IMPACT COMPARISON

IMPACT DESCRIPTION	RAISED RAILROAD ALTERNATIVE			REPRESENTATIVE ELEVATED FACILITY (Bridge Over Exist. RR)*
	RAISED RR Portion	BOULEVARD Portion	TOTAL RAISED RR & BOULEVARD	
RELOCATIONS				
Residential				
Owner	27 **	75 **	102	69
Tenant	135 **	40 **	175	63
Subtotal			**277**	**132**
Business				
Owner	17 **	17 **	34	26
Tenant	**	**	**	17
Non-Profit	**	**	**	3
Subtotal			**34**	**46**
TOTAL RELOCATIONS			**311**	**178**
COST				
Right-of-Way (millions)	$100.08 **	$48.53 **	$148.61	$77.38
Utility Relocations (millions)	**	**	**	$0.66
Construction (millions)***	$52.90	$68.80	$121.70	$76.60
TOTAL COST			**$270.31**	**$154.64**
Railroad Closures				
Close existing RR crossings (Forest Hills Dr. and Princess Place Dr.)	2	none	2	none
Close or bridge existing RR crossings (Mercer Ave., Henry St., Clay St., N. 30th St.)	4	none	4	none

* Alternative 7 Tight Urban Diamond Interchange (TUDI) impacts and costs data shown for comparison purposes.

** Relocation and Right of Way costs estimated using GIS analysis of parcel data containing appraised building and land values. Should this alternative be carried forward for detailed study, a Right of Way Cost Estimates, Relocation Report , and Utility Cost Estimates would be completed.

***Note: Construction cost estimates based on functional design with cost per mile unit rates.



North Carolina
Department of Transportation

Date: January 2013

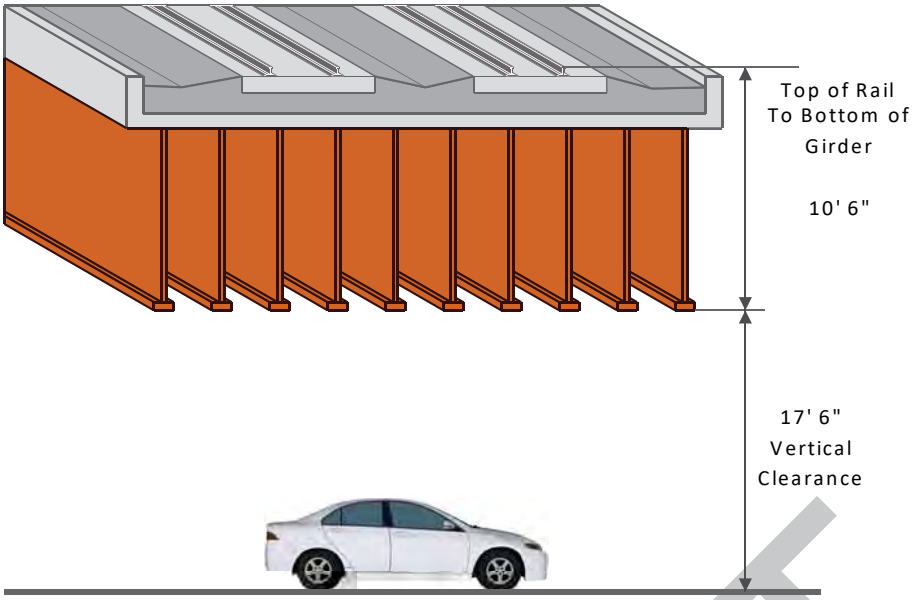
Legend

- Existing At-grade Railroad Crossing
- Existing Railroad Track
- Proposed Railroad Track
- Independence Blvd. Extension

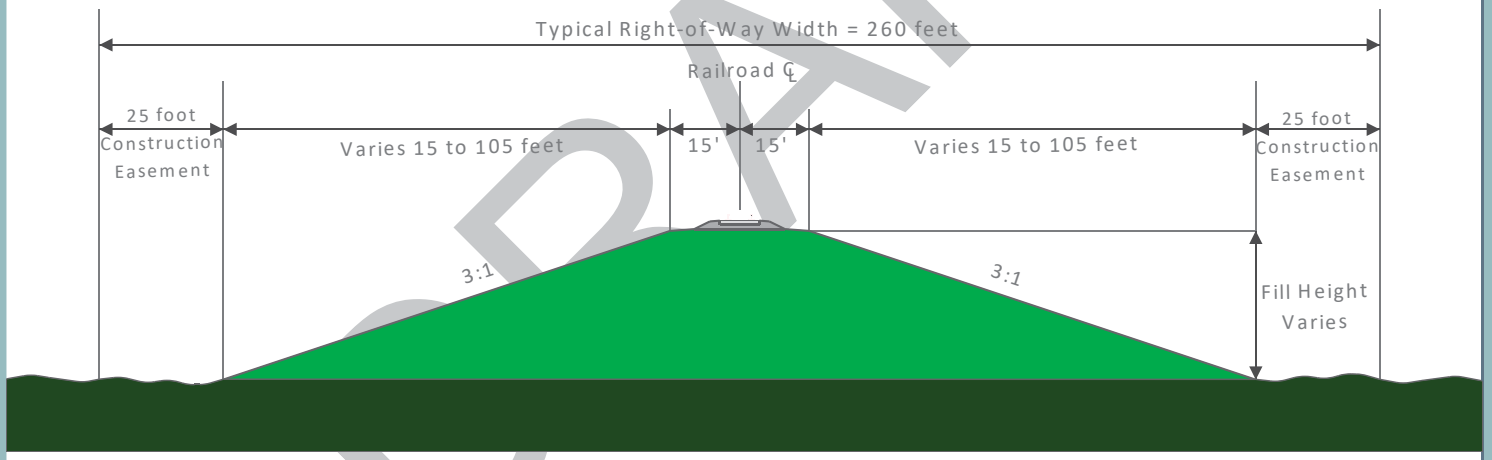
Independence Boulevard
Extension Project
New Hanover County, NC
STIP U-4434

Figure C-1

Elevated Railroad
Overview Figure



Railroad Bridge Typical Section



Elevated Railroad Typical Section

North Carolina
Department of Transportation

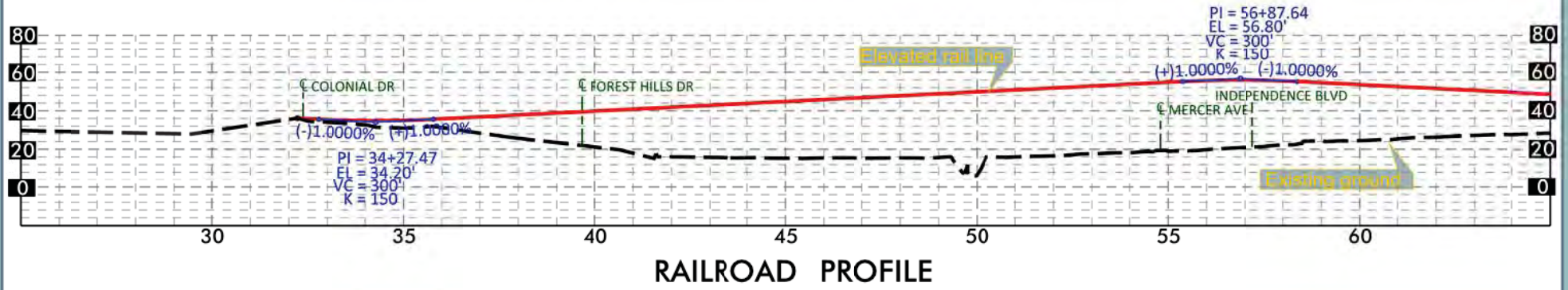
Date: January 2013

Legend

Independence Boulevard
Extension Project
New Hanover County, NC
STIP U-4434

Figure C-2

Elevated Railroad
Typical Sections



RAILROAD PROFILE

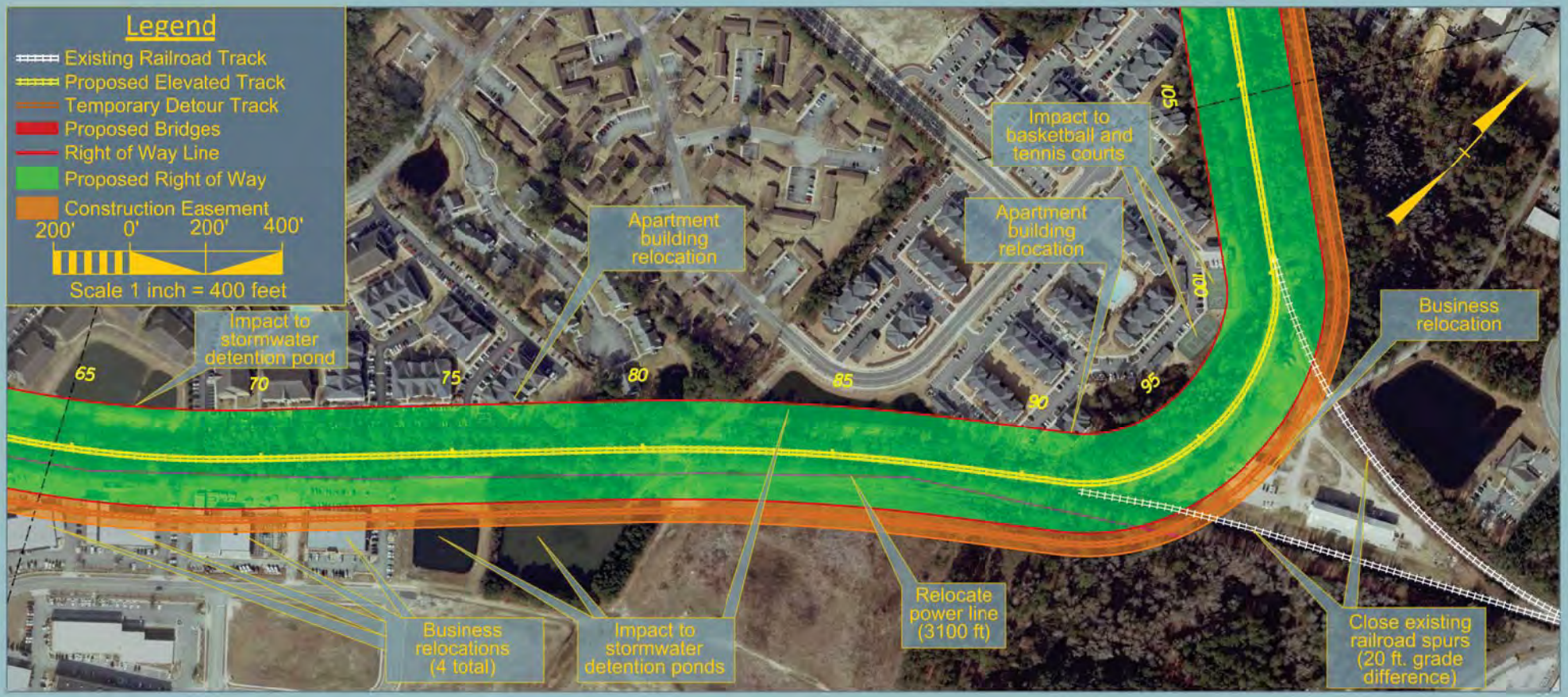
North Carolina
Department of Transportation

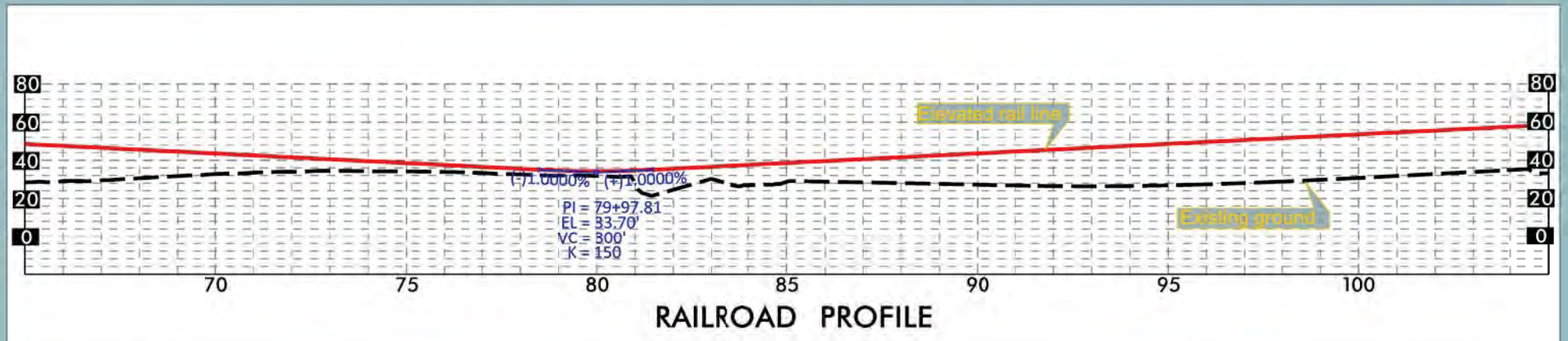
Date: January 2013

Independence Boulevard Extension Project
New Hanover County, NC
STIP U-4434

Figure C-3a

Conceptual Designs
Elevated Railroad





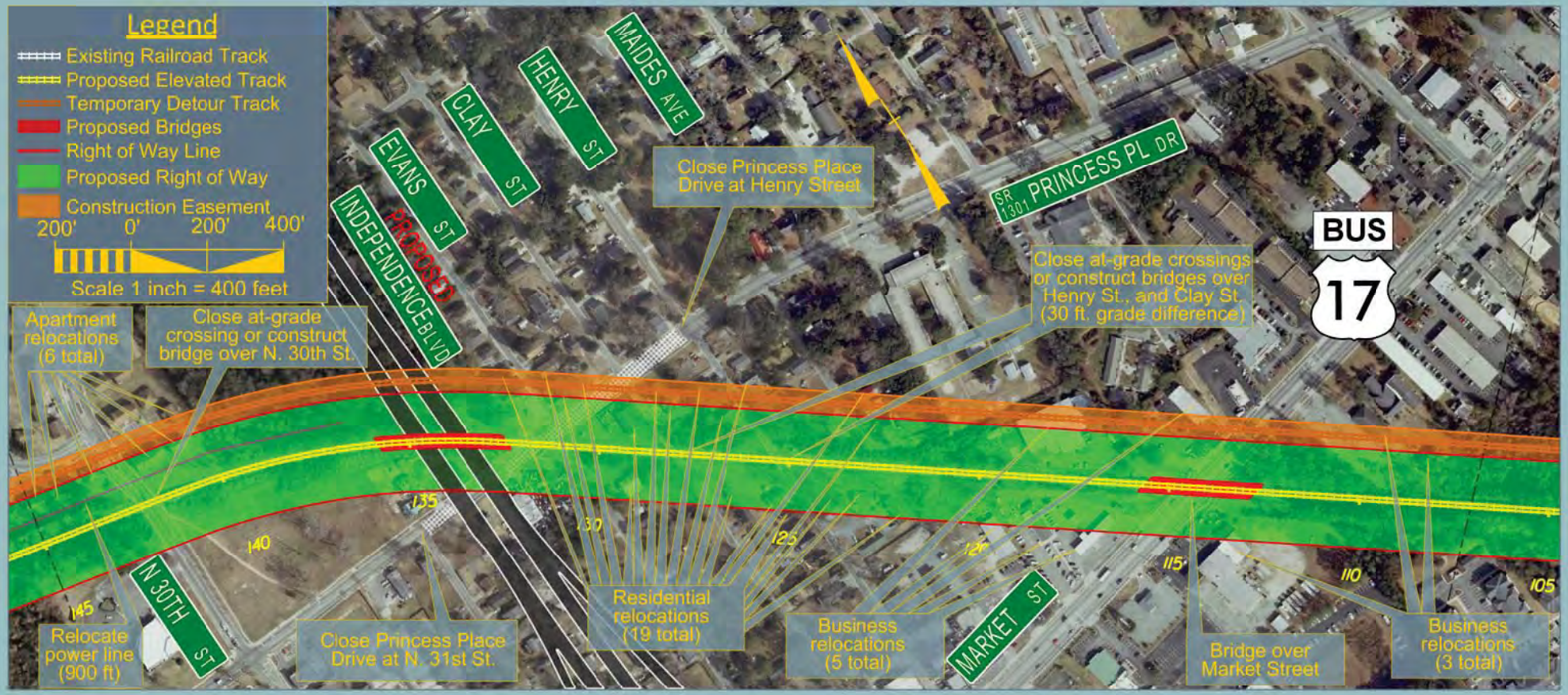
North Carolina Department of Transportation

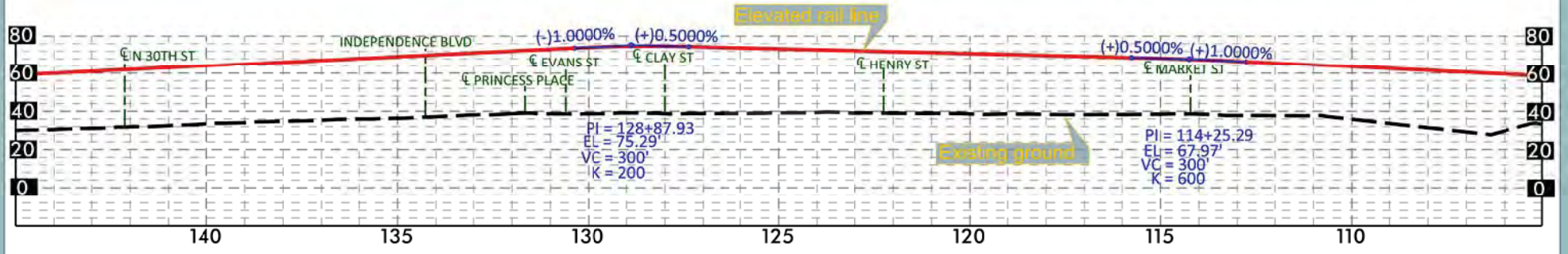
Date: January 2013

Independence Boulevard Extension Project
New Hanover County, NC
STIP U-4434

Figure C-3b

Conceptual Designs
Elevated Railroad





RAILROAD PROFILE

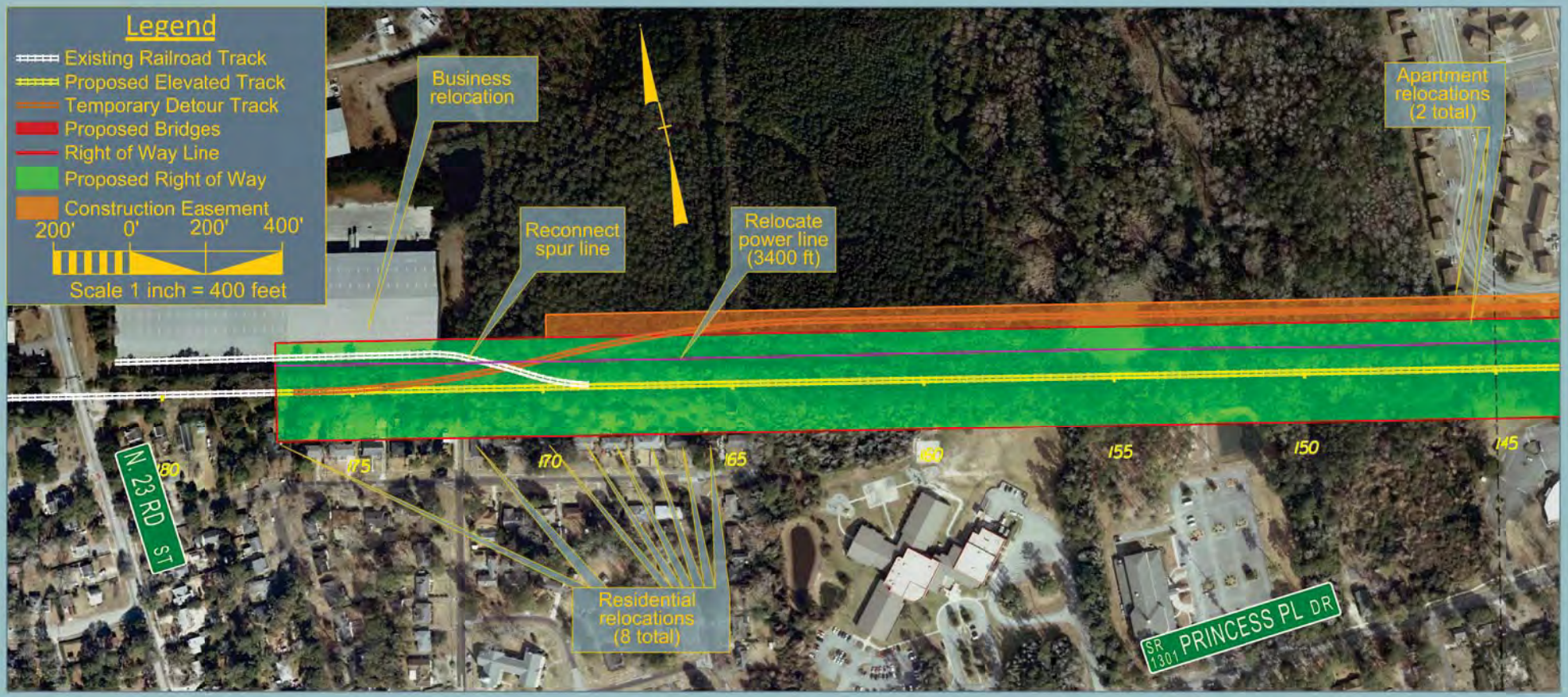
North Carolina
Department of Transportation

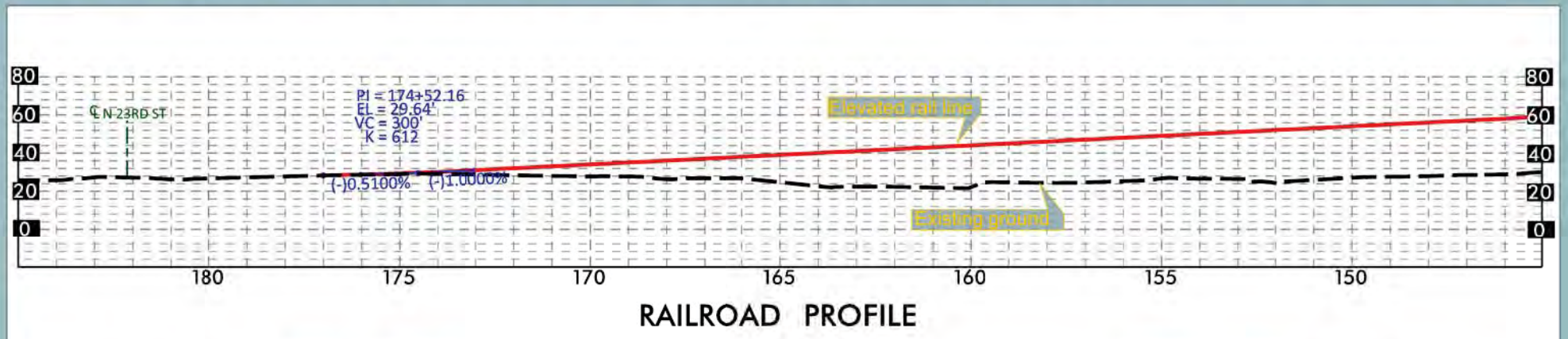
Date: January 2013

Independence Boulevard Extension Project
New Hanover County, NC
STIP U-4434

Figure C-3c

Conceptual Designs
Elevated Railroad





RAILROAD PROFILE

North Carolina
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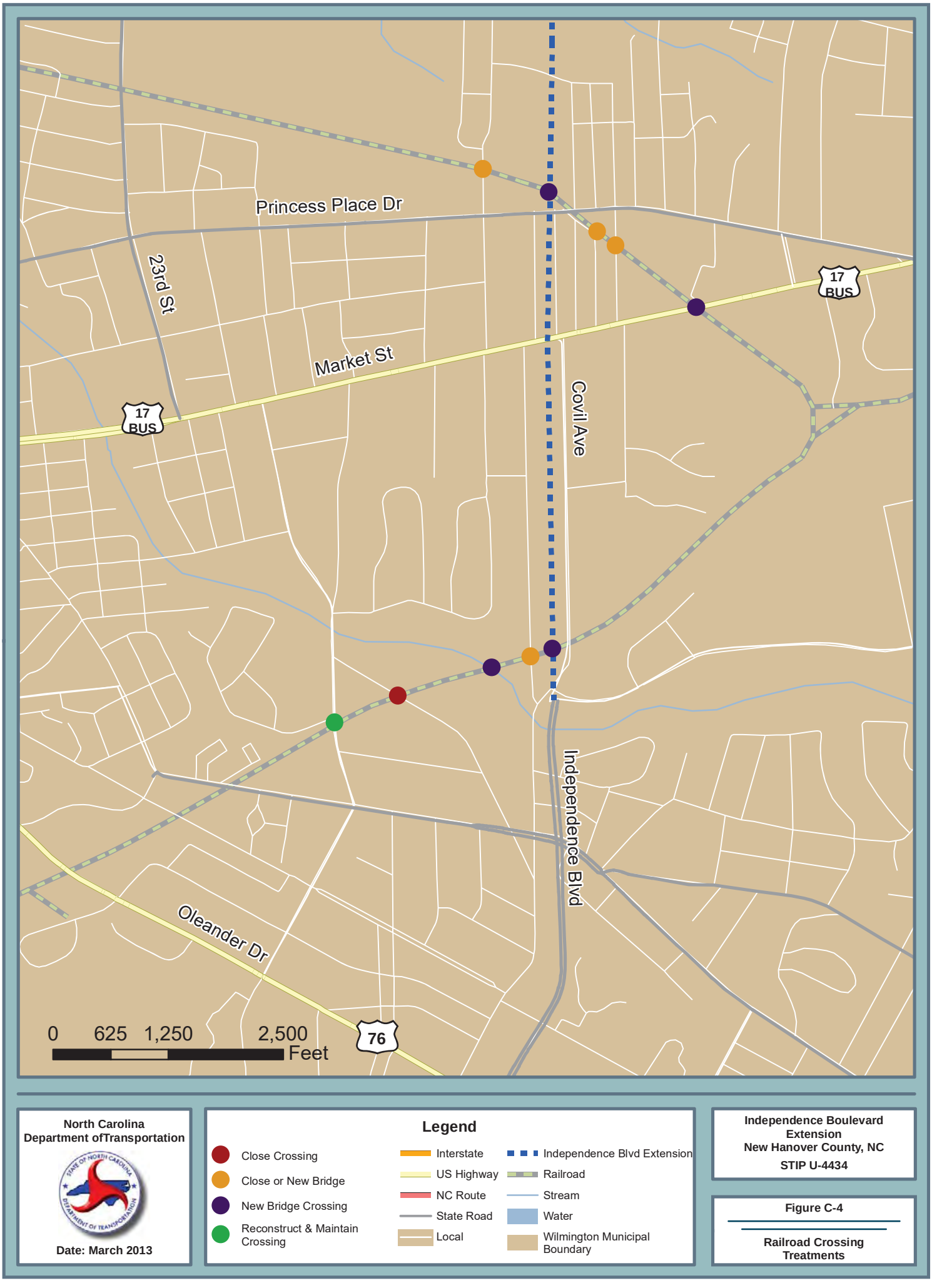
Date: January 2013

Independence Boulevard Extension Project
New Hanover County, NC
STIP U-4434

Figure C-3d

Conceptual Designs
Elevated Railroad



North Carolina Department of Transportation

Date: March 2013

Legend

- Close Crossing
- Close or New Bridge
- New Bridge Crossing
- Reconstruct & Maintain Crossing
- Interstate
- US Highway
- NC Route
- State Road
- Local
- Independence Blvd Extension
- Railroad
- Stream
- Water
- Wilmington Municipal Boundary

Independence Boulevard Extension
New Hanover County, NC
STIP U-4434

Figure C-4

Railroad Crossing Treatments

Appendix C2

Depressed Facility Option

Appendix D – Depressed Facility Functional Alternative (April 2014)

The following section describes the development of an alternative that would utilize a "depressed urban facility" cross section for the proposed Independence Boulevard Extension. Photographs showing several depressed urban facilities in the United States are included at the end of this section.

Purpose:

The purpose of this memorandum is to summarize the approach and methodology used to develop and evaluate the viability a depressed roadway facility alternative (DF) for the U-4434 project in New Hanover County. This memorandum summarizes the assumptions and evaluation utilized in developing the plans and estimates for the DF, including considerations for constructability and long term operation and maintenance.

Background:

Although not common in North Carolina, depressed facilities have been successfully utilized in other locations around the country. Typically, the vertical profile of a depressed facility is approximately 20 feet below the existing grade, allowing cross roads to be bridged over the facility at or near the existing grade of the cross roads, which minimizes impacts to the adjacent area and maintains roadway network and community continuity.

A typical cross section for a depressed urban facility would include a narrow center median with a median barrier and retaining walls or steep slopes on the outside. These treatments are typically used to minimize the right of way required. The structures over the facility are typically two-span and include a center pier which coincides with the median barrier.

General Advantages of a Depressed Urban Facility:

- Reduced right of way results in lower ROW impacts and costs
- Reduced visual impact
- Reduced noise impact

Generally, impacts to neighborhoods with a depressed facility are less than with a typical at-grade or elevated facility. More of the surrounding area is preserved due to the smaller footprint and the facility is not visible until you are very close to it. A raised or at-grade roadway, particularly one with noise walls, acts more like a barrier dividing the neighborhood through which it passes than does a depressed roadway.

General Disadvantages of a Depressed Urban Facility:

- Higher construction cost
- Pump stations are usually required to accommodate surface drainage
- Aesthetics for facility traffic are decreased due to adjacent walls and median barriers

- Extensive relocation/lowering of utilities such as gas mains, water mains, sanitary sewers, storm sewers, electric power, and telecommunication lines are typically required. Lift stations are typically required for sanitary sewers which cross the roadway.
- Fencing may be required on the retaining walls to prevent objects from being dropped or thrown onto vehicles below.
- When the facility is located below the water table, additional expense is required to counteract the buoyancy force of the water table on the pavement and to prevent groundwater from entering the storm sewer and being continually pumped.

The pump stations required for a depressed facility invariably come with an initial construction cost and on-going operation and maintenance costs for the life of the facility. There also is a continual operating risk associated with relying on pump stations to protect the facility from surface water. If a pump fails due to damage or power failure, the facility can become flooded. Flood damage to the facility and the electrical components of the pump stations would be costly. To mitigate this potential, most pump stations for depressed facilities include emergency alarm and notification provisions and redundant backup electrical systems to protect and maintain operations in extreme weather conditions.

Nationwide, typically pump stations are designed to accommodate a fifty year storm event. At least three pumps are used; in the event one pump fails, the station still has 67 percent capacity. Four or five pumps are not unusual.

Provisions for backup power include:

- Emergency power receptacle used with a portable generator that is brought to the site.
- On-site emergency generator with automatic transfer switch; diesel or gas powered generators are most common.
- Electrical power supplied by two separate primary power feeds.

Sensitive equipment is located above the 100 year flood level, preferably with one foot of freeboard. Modern stations are trending toward placing such equipment in a building completely separate from the station.

Independence Boulevard DF Project Background

The consideration of a depressed roadway facility was introduced to objectively consider if a facility such as this could be constructed and reduce impacts for the Independence Boulevard Extension project over those of more traditional raised facility type alternatives. The project team held numerous internal and external coordination meetings to openly discuss the viability of these types of facilities given the project location, size of the roadway facility, adjacency of neighborhoods and other community features. The project team relied heavily upon the knowledge of various NCDOT units and that of national experts with experience in the typical issues likely to be encountered on facilities such as these. These experts were relied on for their specific knowledge and experience relating to construction dewatering, groundwater control, specialty structural design, geotechnical engineering, stormwater and pumping systems, as well as the traditional roadway, rail and structure design disciplines.

Given the location of the proposed project and available subsurface information from the general vicinity, the design team identified several construction, operation and maintenance considerations that would need to be evaluated to determine a practical solution that could be implemented for a depressed roadway facility for this project. These included:

- Addressing construction groundwater issues
- Construction methodologies to counteract uplift forces from buoyancy
- Stormwater pumping and conveyance
- Methods to minimize post-construction groundwater intrusion

Roadway Design Criteria

American Association of State Highway and Transportation Officials (AASHTO), North Carolina Department of Transportation (NCDOT), and American Railway Engineering and Maintenance of Way Association (AREMA) guidelines and standards were used in to develop the design criteria for the depressed facility functional alternative. The design criteria assumed for this evaluation are as follows:

- Independence Boulevard: Four lane median divided facility with 10-foot inside shoulders and 12-foot outside shoulders
- Design Speed: 60 mph
- Minimum Vertical Clearance : 16.5 feet
- Maximum roadway grade: 5%
- Maximum Railroad grade: 1%
- Local roadways would match existing alignments and profiles (where possible).

Proposed Design

The proposed functional design, including a typical cross section, plan and profile are shown at the end of this appendix. The design was developed using a "tight" cross section with a median barrier and retaining walls on the outside where needed. During development of the functional design, primary attention was given to minimizing right-of-way impacts and minimizing the depth and extent to which Independence Boulevard will be below the ground water table.

In keeping with these goals, the structures over Independence Boulevard each have a center pier which coincides with the median barrier and full height abutment walls on the outside. This minimizes the span lengths and structural depth of the bridges, which allows for a higher facility profile and less intrusion into the groundwater table. The functional design developed includes the following features:

- The project horizontal location would match the currently proposed Alternative 7 Tight Urban Diamond configuration to allow for comparison.

- The two railroad crossing locations would be raised to lessen the intrusion into assumed project groundwater table.
- Railroad grade changes would require horizontal realignment at both locations to facility continuity of rail operations.
- The profiles for Market Street and Princess Place follow the existing profiles.
- Covil Avenue and Mercer Avenue were connected south of Darlington Avenue with a bridge over the DF to maintain local access, allow for raising the grade of the DF, and to avoid intrusion below the assumed groundwater table.
- Market Street would now be bridged over the DF as well as Princess Place and two (2) railroad crossings.
- The depressed portion of Independence Boulevard ends south of Hurst Street. North of this point, including Independence Boulevard over Hurst Street and the Interchange with MLK, are the same as Alternative 7.
- There are three low points in the Independence Boulevard profile. Pump Stations are assumed to be required at all three of these low points.

Geotechnical Design

Based on the likelihood of significant groundwater issues and the effects associated with them, the team considered two potential construction approaches that were carefully developed and evaluated to facilitate the project. Cost estimates were developed for each system since the exact subsurface conditions inside the project corridor are unknown at this time.

1. Subgrade Jet Grouting combined with construction wellpoint dewatering systems and permanent sheet pile installation
2. Cutoff Walls socketed into an impermeable clay layer combined with construction wellpoint dewatering systems and permanent sheet pile installation

These two solutions were deemed the most practical options to evaluate in implementing a depressed roadway facility for this project.

According to the roadway profile, the alignment will be depressed from approximately Stations 19+00 through 77+00, where approximately 4 to greater than 32 feet of cut sections are anticipated. The 100 year flood elevations are +15 feet for Burnt Mill Creek near Station 14+00, and +8 feet for an unnamed creek to Smith Creek near Station 98+00. Due the deep excavation depths and high groundwater levels, temporary shoring will have to be utilized to facilitate the depressed facility construction.

Subsurface investigation has not been performed at the time of the cost estimate. However, subsurface information from adjacent projects indicate an impervious stratum (PeeDee Formation Clay) may exist near an elevation of -20 feet. The temporary shoring system can be embedded in this stratum to cut off the groundwater. If this impervious stratum does not exist, jet grouting has to be utilized to cut off the groundwater. Cost estimates were prepared based upon these two scenarios.

Assumptions for the temporary/permanent shoring system are as follows:

- Temporary shoring will be needed if groundwater is higher than proposed subgrade or if excavation depth is greater than 10'.
- Temporary shoring system consists of soil cement deep mixing wall with steel soldier beams and tiebacks.
- Seasonal high groundwater level is at elevation +15 feet for Stations 19+00 through 40+00, and elevation +12 feet for Stations 40+00 through 77+00.
- Jet grout will be utilized for the no impervious stratum scenario. A factor of safety of 1.6 is used for buoyancy resistance.
- For the impervious stratum scenario, the cutoff walls will be embedded 5’ into the PeeDee Formation clay.
- A 12-inch permanent concrete facing will be placed along the shoring.

Example photos of various stages of construction, proposed typical sections, and a sample pump station detail can be found in the following pages.

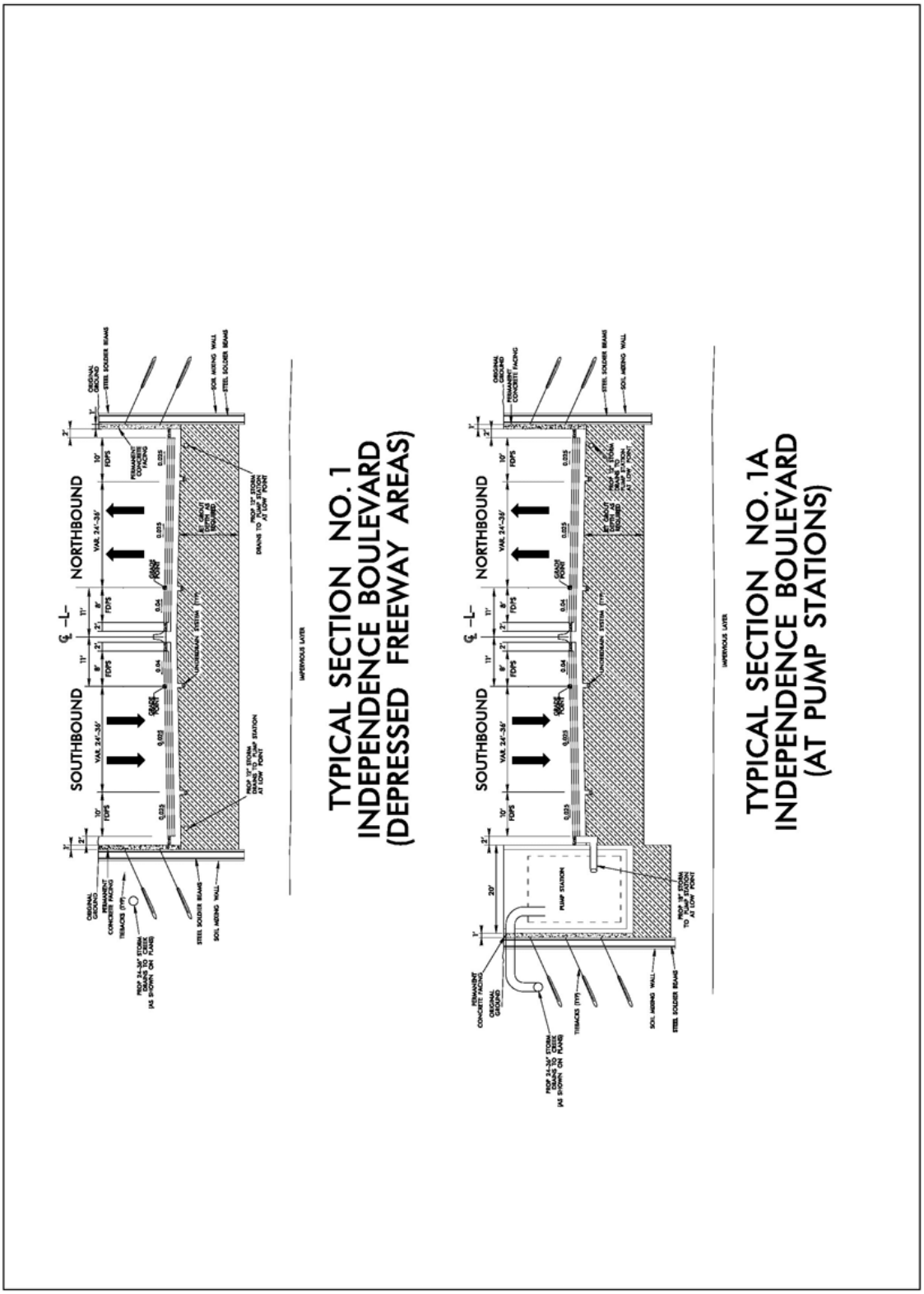
TYPICAL DEEP EXCAVATION DEWATERING

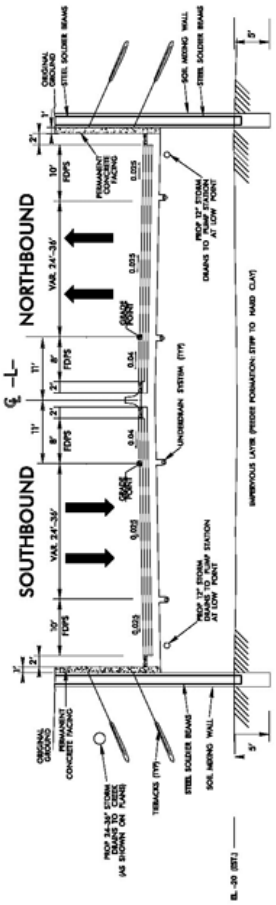
TYPICAL EXCAVATION DEWATERING

TYPICAL DEEP EXCAVATION WITH TIE-BACK

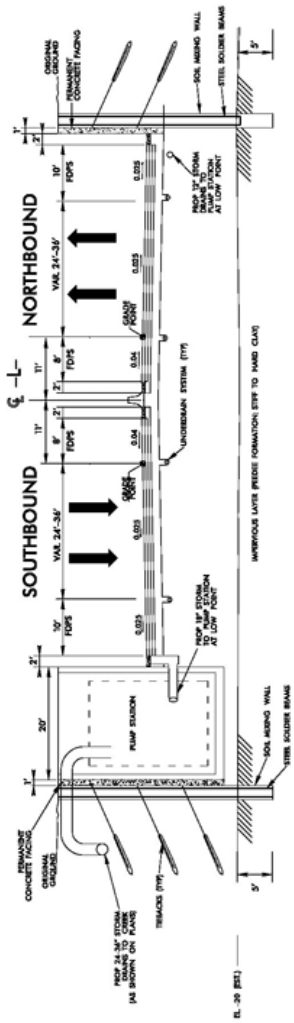
TYPICAL TIE-BACK INSTALLATION

TYPICAL SECTIONS



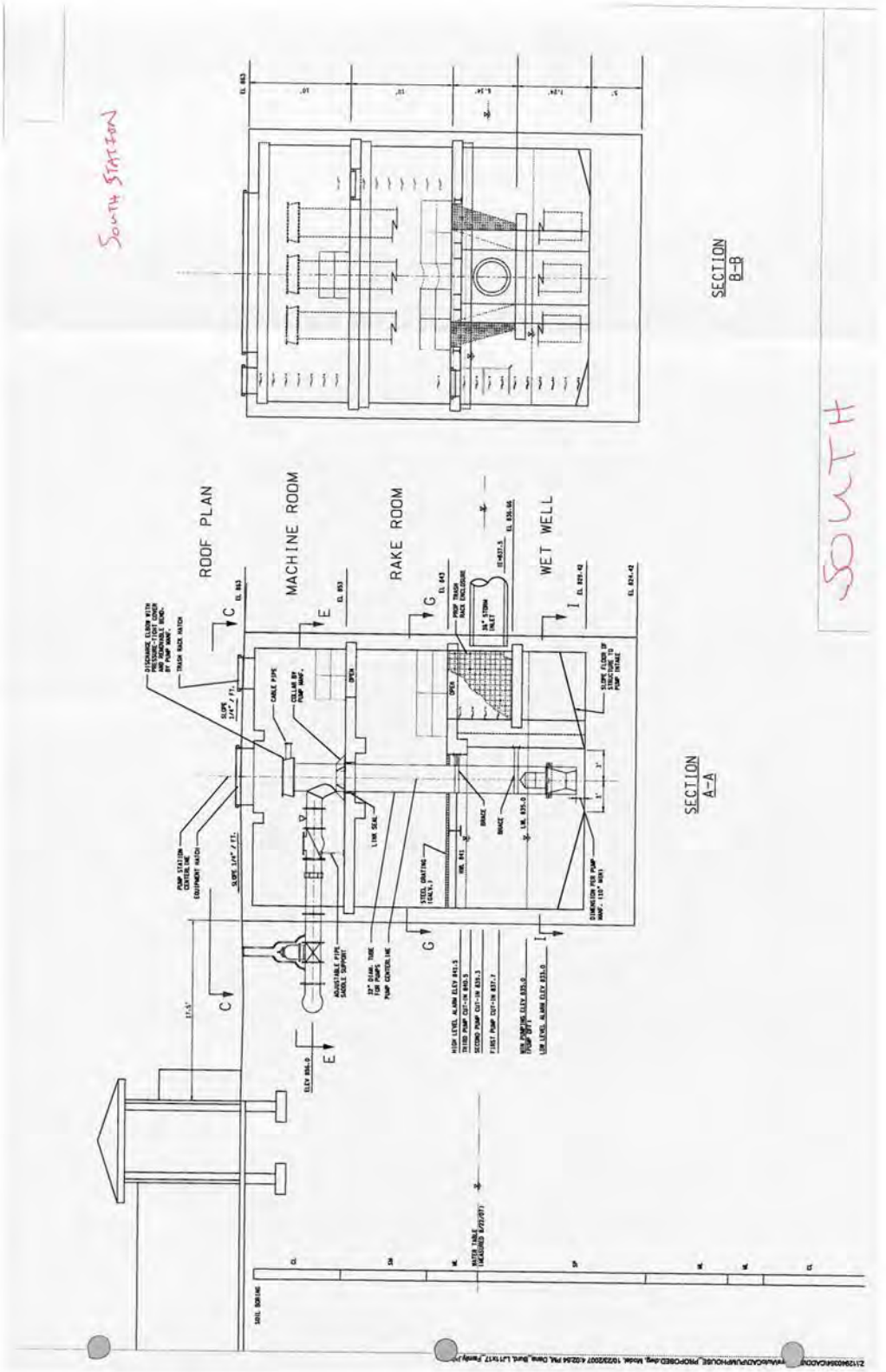


TYPICAL SECTION NO. 1
INDEPENDENCE BOULEVARD
(DEPRESSED FREEWAY AREAS)



TYPICAL SECTION NO. 1A
INDEPENDENCE BOULEVARD
(AT PUMP STATIONS)

SAMPLE PUMP STATION DETAIL



Drainage Design

The proposed storm sewer placement dictates the flow going to the three pumps stations. The pump station sizing assumes $2.5 Million each for the pump stations in the construction cost estimate.

Assumptions for the pump stations are as follows:

- HEC 24 recommends using a 50 year return period for the design of the stations. This is because depressed highways have no other overflow routes during large storms. Discharge pipes also need to be designed for the 50 Year Storm, so the entire enclosed storm sewer system needs to be designed for the 50 Year Storm.

- Probable operation and maintenance costs for each pump station is $500.00 per cubic feet per second per year. Using the pipe sizes and slopes shown to estimate flows, this works out to between $15,000 and $20,000 per station per year. This covers routine maintenance, energy, and agency labor to monitor the pump stations. $20,000 per pump station per year = $60,000 per year.

Replacement costs are usually separate from operation and maintenance costs because replacement will take place all at one time. Pumps and electronics have a design life of about 25 years. Their cost is about 1/3 the initial capital cost ($ 0.83 million per station). Using an interest rate of 2 percent, this would require an annual investment in today's dollars of $43,000 per station. For three pump stations the annual cost for pump and other major part replacement comes to $130,000 per year.

Impact Evaluation for the Depressed Urban Facility Functional Design

The principal advantages of the depressed urban facility concept, when compared with the other concepts, are that the footprint, right of way requirements, and neighborhood division impacts are reduced.

Right of way requirements for this concept include:

- Residential
  - Owner : 57
  - Tenant : 39
- Business
  - Owner : 24
  - Tenant: 16
  - Non-Profit: 3

Noise impacts will be less than with other alternatives. Additional noise analysis will need to be prepared should this alternative be selected for detailed study.

Disadvantages of the Independence Boulevard depressed urban facility concept include higher costs and constructability issues related to construction below the water table.

Construction Estimate

Construction costs are estimated to be $139 million for this alternative with the cut off wall, and $172 million with jet grouting. A detailed breakdown of the construction cost estimates follows at the end of this appendix. The right-of-way cost for the DF alternative is estimated at $75.425 million.

The plans (attached at the end of this appendix) were developed based on assumptions of the depth of groundwater, available surface drainage options, and other known constraints. Based on the approach methodology and the plan for the roadway facility, the profile was fine-tuned and cross sections were developed as well as preliminary quantities for the construction of the facility. For ease of presenting the complexities and estimation assumptions for a project of this magnitude, the estimate was separated into 3 primary sections:

- Part A – Roadway Construction Costs – Roadway construction costs were treated very similar to traditional NCDOT Preliminary Roadway Estimate procedures. Appropriate quantities for typical roadway design elements were quantified and estimated at a Preliminary Design level for the entire project to be equally compared with traditional raised facility alternatives. These costs included typical miscellaneous and mobilization costs normal for this level of design. Additionally they included the stormwater pump stations, wet wells, housing structures and pressure conveyance system costs specific to this type of facility along with the traditional roadway gravity flow drainage costs for draining the pavement areas.

- Part B – Railroad Construction Costs – Rail construction costs were estimated based on length of relocation required to accomplish the raising of the grade for the tracks, traditional bridging costs, as well as normal miscellaneous and mobilization costs consistent with the level of design.

- Part C – Groundwater/Constructability Methods – The costs included the construction methodologies to address the temporary and long-term groundwater issues, shoring, sheet piling, tiebacks, and retaining walls. The methods to address the groundwater, subgrade jet grouting and groundwater cutoff walls were quantified and estimated separately based on limited knowledge of subsurface conditions.

Summary

A depressed facility alternative was developed in order to determine if the impacts associated with this alternative would be less than the impacts of bridging Independence Boulevard over the CSX Railroad. The horizontal location would match the currently proposed Alternative 7 Tight Urban Diamond configuration and include a “tight” cross section with a median barrier and retaining walls on the outside where needed to minimize right-of-way impacts and to minimize the depth and extent to which Independence Boulevard will be below the ground water table. Structures over Independence Boulevard would include a center pier which coincides with the median barrier and full height abutment

walls on the outside, minimizing span lengths and structural depths of the bridges, to allow for a higher facility profile and less intrusion into the groundwater table. This alternative would include an at-grade intersection with Randall Parkway/Mercer Avenue, include a grade separation under the CSX railroad (which will need to be slightly raised), include a new grade separation south of Darlington Avenue over the extension of Independence Boulevard, include an interchange at Market Street, include a grade separation under Princess Place Drive and the under the northern crossing of the CSX railroad. North of this point, the designs will match all other alternatives which include a grade separation over Hurst Street and include an interchange with Martin Luther King Junior Parkway.

Although every effort was made to minimize intrusion into the ground water table with the Independence Boulevard roadway, groundwater in this area is expected to be high and approximately 4300 feet of the Independence Boulevard roadway will likely be below the ground water elevation.

The existing ground water table will likely match the elevations of the two creeks where Independence Boulevard crosses them. Away from the creeks, the groundwater table will rise as the ground rises. Where data is available nearby, the groundwater was measured at between five and ten feet below existing ground during the dry season. Groundwater elevations seasonally rise and the groundwater may be even less than five feet below existing ground at some locations for portions of the year. With cuts up to 30 feet deep to the top of pavement, the roadway could be as much as 25 feet into the water table.

Construction of a depressed facility where groundwater is high has been done in other areas. For a section of I-64/I-55 in East Saint Louis, Illinois, a dewatering system was used which includes an extensive system of high capacity (700 gpm) pumped alluvial wells. Operation and maintenance costs are very high for this section of roadway. Lowering the groundwater table, as was done for this location, also can result in damage to nearby properties from settlement if compressible soils are present and extensive studies of the effects on the area associated with lowering the groundwater table would be needed. This option for construction below the ground water table should be avoided, if possible. For the cut and cover tunnel portion of the Atlantic City-Brigantine Connector constructed in 2001 in Atlantic City, New Jersey, a thick concrete slab was used to counteract the buoyancy force. This is a more common approach to constructing below the groundwater table and the approach used to estimate costs for this alternative. Although pumping groundwater permanently is not needed with this approach, substantial pumping during construction is still required.

Based on the likelihood of significant groundwater issues and the effects associated with them, two potential construction approaches that were developed and evaluated to facilitate the project. Option 1 included Subgrade Jet Grouting combined with construction wellpoint dewatering systems and permanent sheet pile installation. Option 2 included Cutoff Walls socketed into an impermeable clay layer combined with construction wellpoint dewatering systems and permanent sheet pile installation. According to the roadway profile, the alignment will be depressed from approximately Stations 19+00 through 77+00, where approximately 4 to greater than 32 feet of cut sections are anticipated. The 100 year flood elevations are +15 feet for Burnt Mill Creek near Station 14+00, and +8 feet for an unnamed creek to Smith Creek near Station 98+00. Due the deep excavation depths and high groundwater levels,

temporary shoring will have to be utilized to facilitate the depressed facility construction. Subsurface investigation has not been performed; however, subsurface information from adjacent projects indicate an impervious stratum (PeeDee Formation Clay) may exist near an elevation of -20 feet. The temporary shoring system can be embedded in this stratum to cut off the groundwater. If this impervious stratum does not exist, jet grouting has to be utilized to cut off the groundwater. Cost estimates were developed for each system since the exact subsurface conditions inside the project corridor are unknown at this time.

Given there are three locations with depressions three pump stations will be required to accommodate surface drainage. Pump stations are designed to accommodate a fifty year storm event, with at least three pumps per station in the event one pump fails, the station still has 67 percent capacity. Provisions for pump station backup power include emergency power receptacle used with a portable generators that are brought to the site, on-site emergency generators with automatic transfer switch (diesel or gas powered generators typically), and electrical power supplied by two separate primary power feeds. The proposed storm sewer placement dictates the flow going to the three pumps stations. The pump station sizing assumes $2.5 Million each for the pump stations for construction cost estimates. Given depressed facilities have no other overflow routes during large storms, 50 year return period was assumed. Discharge pipes also need to be designed for the 50 Year Storm, so the entire enclosed storm sewer system needs to be designed for the 50 Year Storm.

Impacts associated with the extension of Independence Boulevard as a Depressed Facility include:

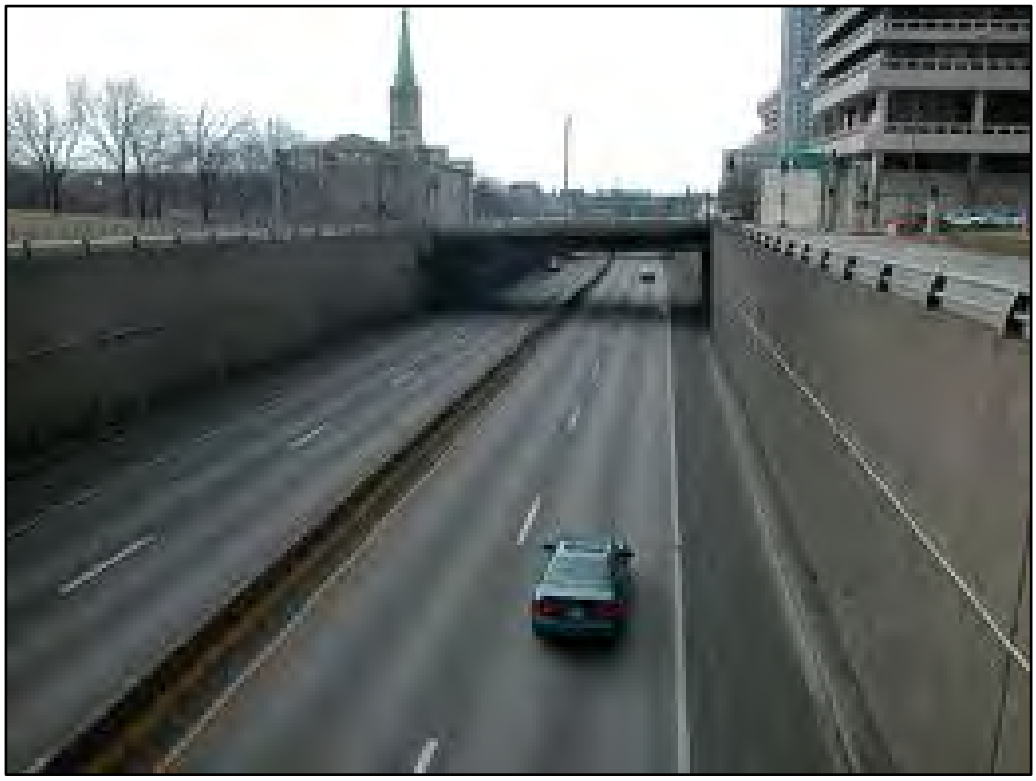
- Raising the profile of the southern CSX crossing of the project
- Rerouting Darlington Avenue and Covil Avenue access to Randall Parkway via a grade separation over Independence Boulevard to Mercer Avenue
- 96 residential relocations (57 owner and 39 tenant)
- 43 Business relocation (24 owner, 16 tenants, and 3 Non-Profit)

Construction cost estimates for the Depressed Facility Alternative with the cut off wall is approximately $139,000,000 and approximately $172,000,000 with jet grouting, with an additional $75,425,000 required for purchase of right of way and an additional $452,000 in utility relocation. Depending upon construction method utilized, total cost for the Depressed Facility Alternative ranges from $214,877,000 to $248,877,000. In comparison, construction cost estimates for a representative elevated facility, Alternative 7 TUDI is approximately $76,600,000 with an additional $75,325,000 required for purchase of right of way and an additional $633,000 in utility relocation, resulting with a total cost of $151,558,000. Should this alternative be carried forward for detailed study, detailed Right of Way Cost Estimates, a Utility Estimate and a Relocation Report would be completed. The Depressed Facility Alternative reduces impacts when compared to Alternative 7 TUDI (which includes 132 residential relocations and 46 business relocations).

In conclusion, construction and maintenance of a depressed facility includes design, constructability, geotechnical, drainage and maintenance complexities. Due to these complexities and the increase in

total cost ranging from 42% to 64% more than Alternative 7 TUDI, it is recommended that the Depressed Facility Alternative should not be considered as a Detailed Study Alternative for the proposed project.

DEPRESSED FACILITY EXAMPLES



I-70 in Saint Louis, Missouri

Vine Street in Philadelphia, Pennsylvania

Depressed facility approach to tunnel below water table, Atlantic City, New Jersey

Davison Facility, Detroit Michigan

I-96, Livonia, Michigan showing facility, slip ramp, and one-way frontage road

I-75 near Mack Avenue, Detroit, Michigan

I-696, Royal Oak, Michigan showing a park constructed on top of a bridge over the facility

M-10 Freeway in Detroit, Michigan. 206 foot wide ROW for the freeway, ramps, and frontage roads used in this area

U-Turn Roadway between frontage roads and over I-696 in Oakland County, Michigan.

Stormwater Pump Station along I-75 in Detroit, Michigan