I-81 INDEPENDENT FEASIBILITY STUDY

November 2017

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

APPENDIX A - FEASIBLE BUILD ALTERNATIVES + PROFILES

APPENDIX B - FEASIBLE BUILD ALTERNATIVES FLY-THROUGH DESCRIPTIONS

APPENDIX C - COMMUNITY GRID PLANS

APPENDIX D - GEOTECHNICAL CONDITIONS

APPENDIX E - TUNNEL DESIGN + CONSTRUCTION

APPENDIX F - TUNNEL SYSTEMS

APPENDIX G - EXISTING VIADUCT + EXISTING VIADUCT CONDITIONS

APPENDIX H - HIGHWAY DESIGN CRITERIA TABLES

APPENDIX I - UTILITIES

APPENDIX J - PROPERTY IMPACTS

APPENDIX K - COST ESTIMATE

APPENDIX L - PUBLIC COMMENTS ANALYSIS REPORT

APPENDIX M - ELIMINATED ALTERNATIVES

APPENDIX N - CASE STUDIES

1 EXECUTIVE SUMMARY

1.1 PROJECT OVERVIEW

WSP has conducted this I-81 Independent Feasibility Study (Independent Feasibility Study) of the I-81 viaduct within the designated Study Area in Syracuse, New York, because the current infrastructure is approaching the end of its service life. This I-81 Independent Feasibility Study is to ensure that a tunnel and depressed highway were sufficiently analyzed to asses their feasibility and cost. In addition, this study examines alternatives that would adequately provide for vehicular traffic to replace the existing I-81 viaduct through the center of Syracuse. This study works “independently” from previous efforts that analyzed I-81 in Syracuse—such as the I-81 Corridor Study, I-81 Viaduct Project, and the I-81 Draft Environmental Impact Statement, which is underway.

As documented within previous I-81 Viaduct Project efforts, the I-81 viaduct and I-81/I-690 interchange have been the subject of community and agency concerns because of ongoing congestion and safety issues, as well as aging infrastructure. The I-81 Corridor Study identified a section of I-81 and I-690 in and near downtown Syracuse as a priority area for improvements due to a concentration of structural and geometric deficiencies, as well as frequent congestion and high vehicle crash and collision rates. Although the I-81 corridor is maintained in a state-of-good repair to ensure that its structural integrity remains safe for the traveling public, continued deterioration could lead to increased maintenance costs, weight and speed restrictions on bridges, and potentially, eventual closure of bridges.

This Independent Feasibility Study report summarizes the technical feasibility and cost of the depressed highway and tunnel alternatives. The report also documents the engineering and analyses performed, the construction cost estimates, construction duration, and the operations and the maintenance costs of the potential alternatives.

1.2 STUDY AREA

The Study Area for this Independent Feasibility Study encompasses the general downtown Syracuse neighborhood, and portions of the Park Avenue, Franklin Square, Prospect Hill, Hawley-Green, Southside, and University Hill neighborhoods. I-81 and I-690 are the two critical highways that bisect the Study Area and provide key connections to the downtown and metropolitan area for residents, employment, and students. Along I-81, the Study Area extends from Bear Street W. in the north, to just south of Martin Luther King E. in the south. Along I-690, the Study Area extends from N. Geddes Street in the west, to Walnut Street in the east (Figure 1).

1.3 INDEPENDENT FEASIBILITY STUDY PURPOSE

This Independent Feasibility Study is to ensure that tunnel and depressed highway alternatives were sufficiently analyzed to assess their feasibility, cost, and their ability to meet project goals of the overall I-81 Viaduct Project.

This report is a technical engineering report and not an environmental study. This I-81 Independent Feasibility Study was not prepared in accordance with the Department’s Project Development Manual, NEPA, SEQRA and the Viaduct Project’s August 2013 Notice of Intent to Prepare a DEIS. The I-81 Independent Feasibility Study did not study the social, economic, and environmental considerations required by NEPA and SEQRA.

If it is determined that a tunnel alternative is to be considered for further study in the I-81 Corridor DEIS, it will be subject to review under NEPA, SEQRA, etc. to determine if it is feasible and practical. In addition, connections between Interstates and any modifications to the Interstate access would need to be considered and approved by FHWA.

To provide cohesive comparisons between the alternatives put forth in this Independent Feasibility Study—and those

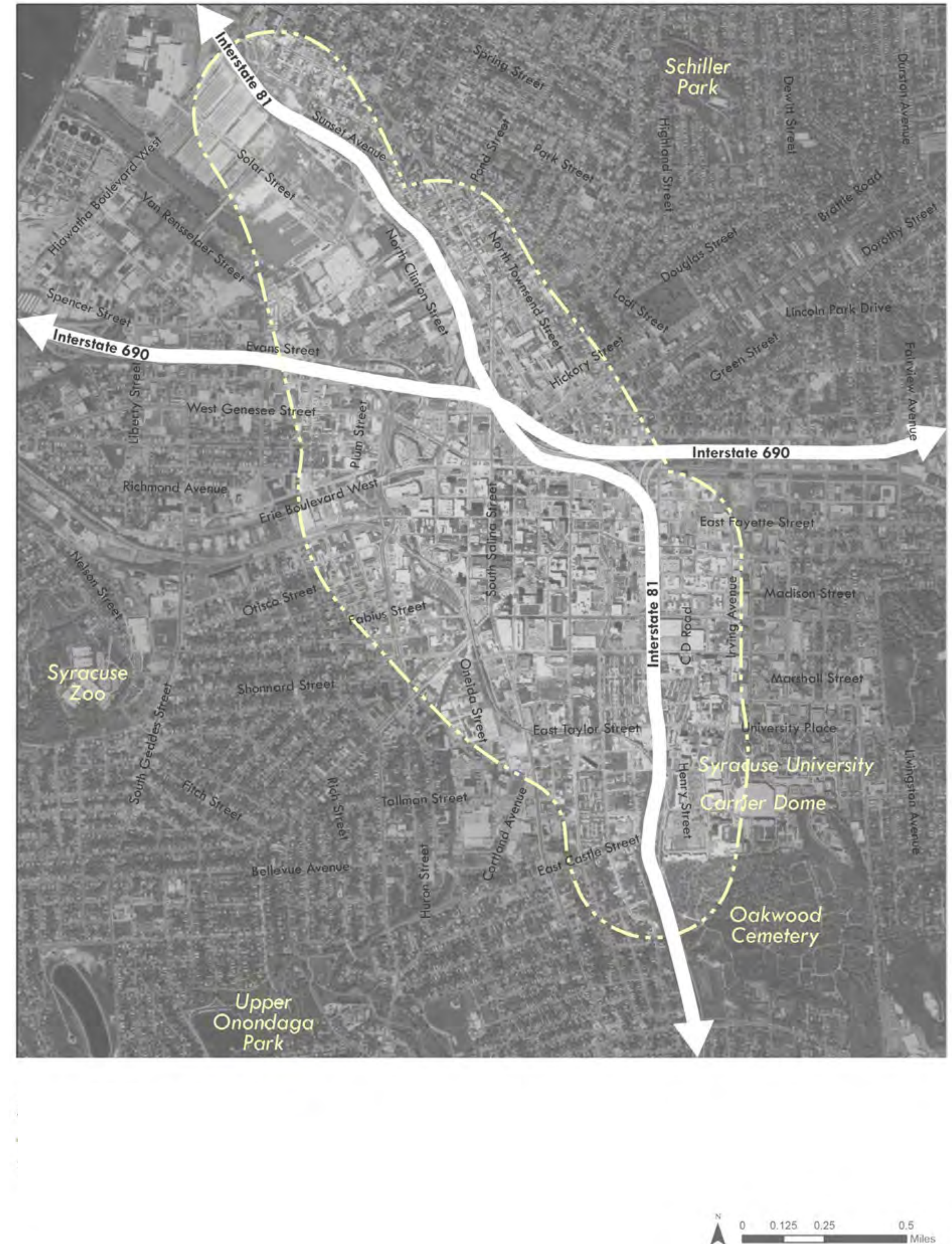


FIGURE 1: I-81 Independent Feasibility Study – Study Area

that have been previously developed—this study used the same two goals established for the overall I-81 project:

1. Improve safety and create an efficient regional and local transportation system within and through greater Syracuse.

2. Provide transportation solutions that enhance the livability, visual quality, sustainability, and economic vitality of greater Syracuse.

Section 2.2 provides the full list of goals and objectives that were used to develop and analyze the alternatives advanced throughout this study.

1.4 TUNNEL SOLUTIONS FOR HIGHWAYS

Placing urban highways in tunnels has several advantages and disadvantages compared with viaduct or at-grade solutions, but there are many considerations to determine the best design and construction approaches. What size of tunnel can be accommodated? What are the optimal construction methods? How can the existing highways be connected to the tunnel facility? What safety features are required in the tunnel?

Ground conditions in Syracuse are characterized by urban fill over varying glacial deposits (sands, gravels, boulders, silts, clays), over shale bedrock with potentially high in-situ horizontal stresses, and groundwater with a high saline content. Current tunneling techniques for both cut-and-cover or mined options, using a custom-designed and manufactured tunnel boring machine (TBM), can deal with the ground and water conditions. Techniques to build tunnels in coastal areas adjacent to seawater can be adapted and applied to the saline groundwater conditions here. The challenges of tunneling in an urban area include selecting an alignment that would avoid deep piles below buildings and other structures, performing ground improvement (such as grouting or ground freezing), and underpinning nearby structures as tunneling proceeds.

Constructing a tunnel facility is a significant undertaking, but by working with the community, construction and traffic impacts may be mitigated. There are suitable open areas adjacent to existing I-81 facilities where future roadway connections can be made, and that can be used during tunnel construction operations for material staging and spoil (muck) handling and hauling operations. An example of mitigating an impact would be to require spoil dump trucks to operate during daytime hours in order to reduce nighttime noise.

Tunnels for highways would be designed to comply with National Fire Protection Association (NFPA) 502: Standard for Road Tunnels, Bridges, and Other Limited Access Highways. In addition to meeting the geometric requirements for roadways, the tunnel facility would provide a safe environment for roadway operations and would support emergency responses. Hazardous cargo and fuel trucks would be prohibited from using the tunnel. The tunnels would have a ventilation system to ensure the air is safe during traffic made up of internal combustion engine vehicles and to provide the ability to control smoke and heat in an emergency fire condition. The ventilation system would work in conjunction with fire detection and protection systems. In case of emergency, emergency egress routes for people to walk out of the incident tunnel would be provided. The roadway would be well lighted and signed for both day-to-day operations as well as under emergency conditions, to include traffic control systems, dynamic (variable) message signs, and closed-circuit televisions. The tunnel would have drainage systems to control stormwater as well as water within the tunnel to include that from maintenance washing and fire suppression. All water collected in the tunnels will be sent to the appropriate facility for treatment before discharge.

Please see the body of the report and appendices for more information and details on the topics mentioned above.

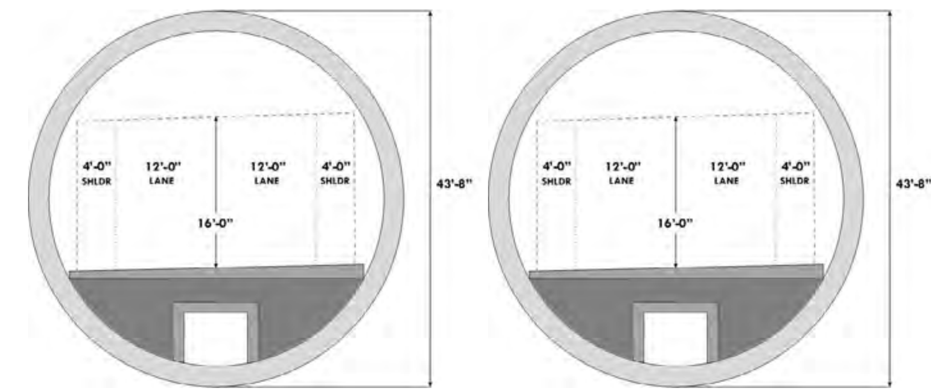


FIGURE 2: Twin Bored Tunnels

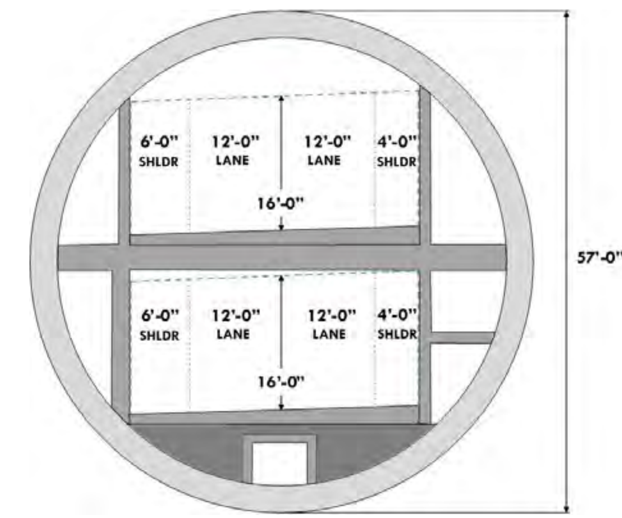


FIGURE 3: Single Bi-Level Bored Tunnel

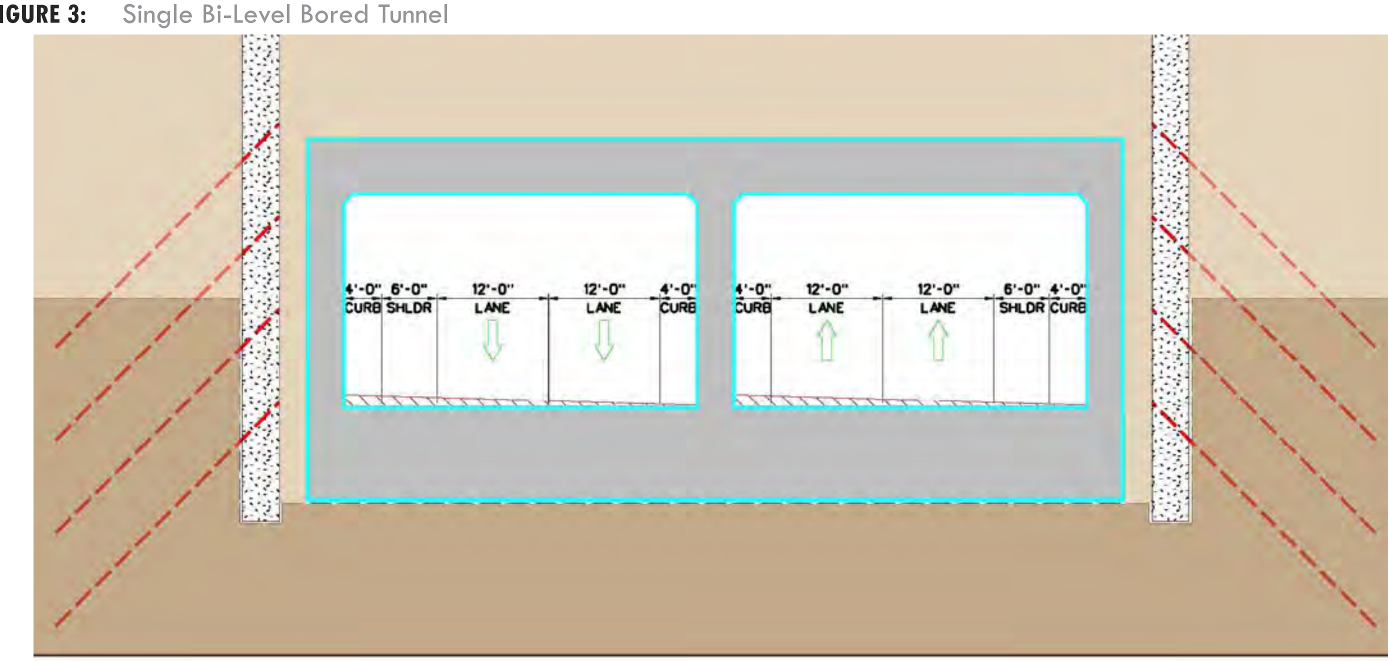


FIGURE 4: Cut and Cover Tunnel

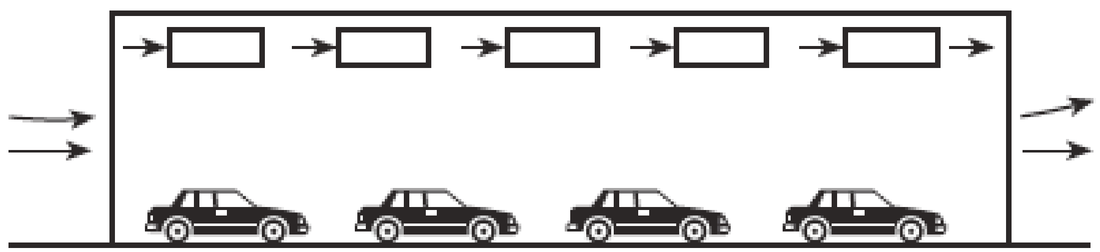


FIGURE 5: Jet Fan System

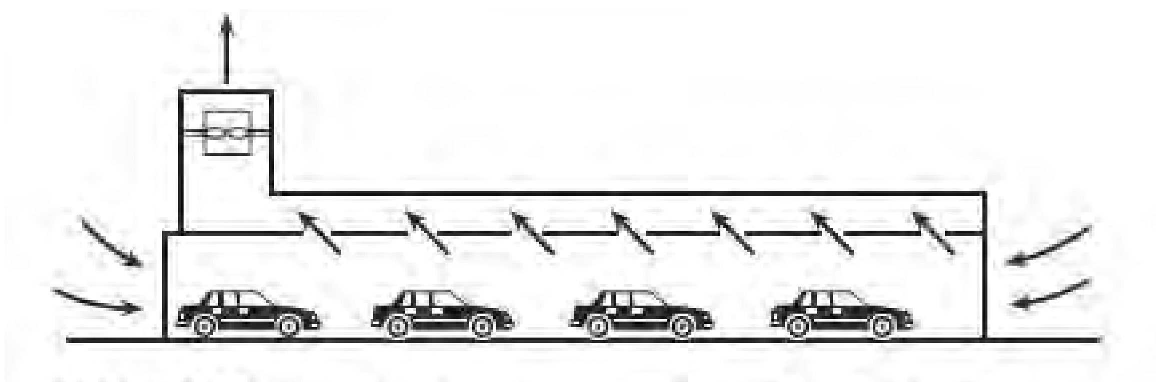


FIGURE 6: Semi -Traverse Point Exhaust System

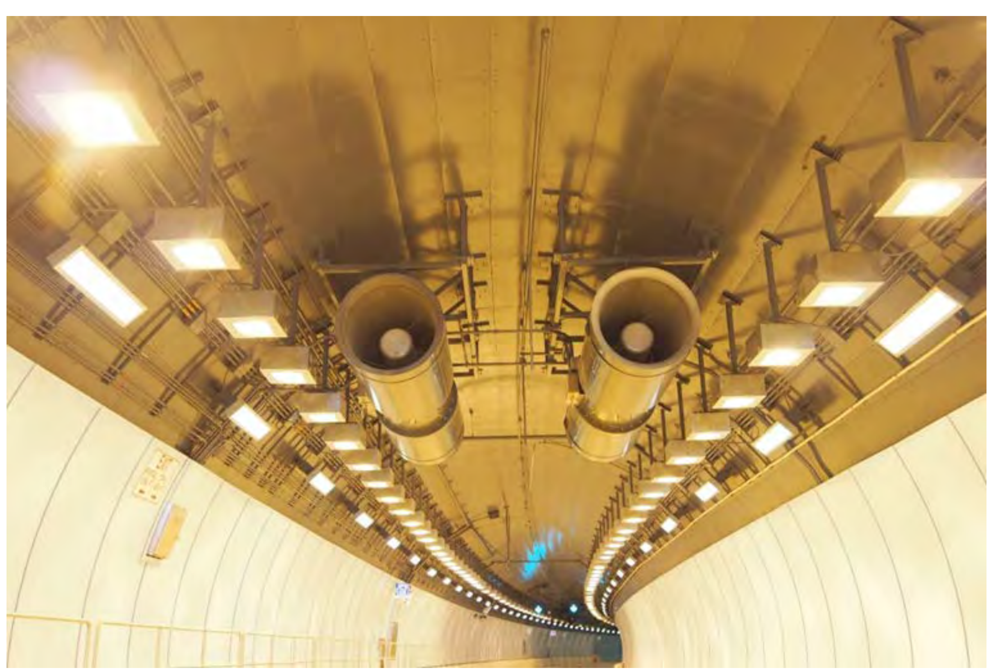


FIGURE 7: Single Bi-Level Tunnel with Jet Fan Instillation

FIGURE 8: Dynamic (Varible) Message Signs (DMS)

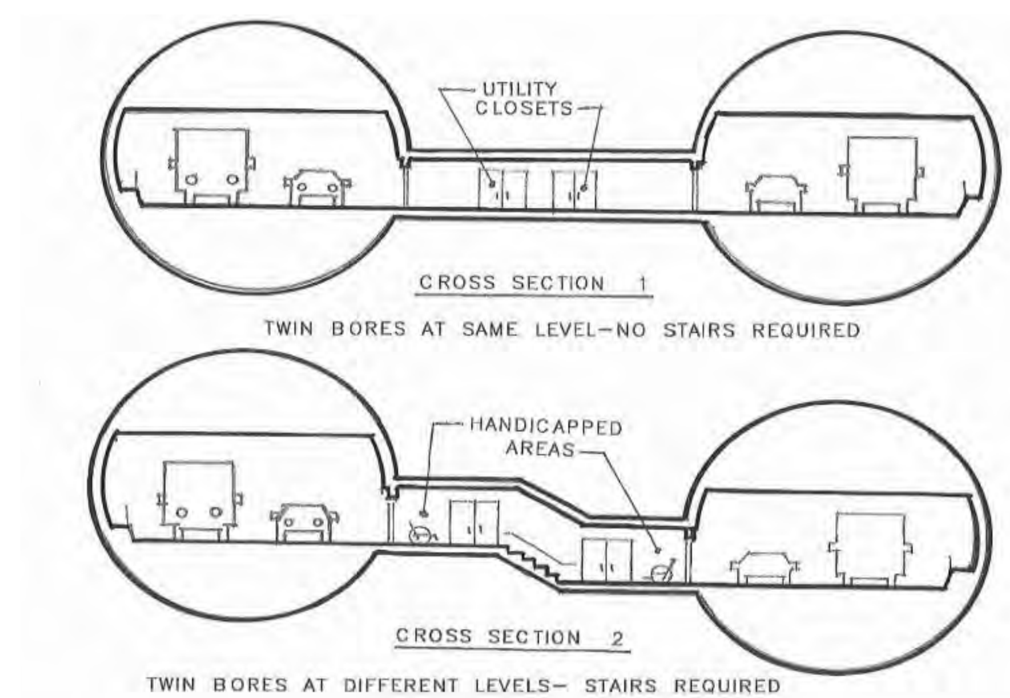


FIGURE 9: Twin Bored Tunnel with Configureations with Cross Passages

1.5 COMMUNITY GRID SOLUTIONS

All of the alternatives examined as part of this study would replace and remove the existing I-81 viaduct in downtown Syracuse. This would require reconstruction of the Almond Street corridor and its intersecting streets. To be feasible, the depressed highway or tunnel alternatives would need to operate in conjunction with an improved surface street condition, which would have to accommodate most traffic to and from downtown. Therefore, it became apparent that each of the alternatives inherently need to incorporate some version of the Community Grid Alternatives established in the I-81 Viaduct Project Scoping Report and currently being analyzed as part of the Draft Environmental Impact Statement. Each tunnel option would likely have a different approach to implementing a community grid system. These alternatives could improve downtown vehicular traffic, and pedestrian and bicycle connectivity, while providing state land disposition opportunities and economic development potential. Applying these same principles, each tunnel alternative explored as part of this study would be in essence a hybrid approach. In other words, each tunnel alternative would be coupled with a supportive community grid improvement alternative to maximize downtown and regional connectivity.

Each alternative that meets the major goals of this study would affect not only traffic conditions on the highways but also on local streets. To maintain a similar amount of access to the downtown area, some existing ramps would be replaced with local access routes that would use existing corridors such as Almond Street and Erie Boulevard. These and some of the smaller roadways that provide important east-west and north-south connections through the downtown area would need to be improved to accommodate a higher level of traffic demand while balancing the needs of pedestrians and bicyclists. Therefore, the level of enhancement of the local streets would largely depend on the percentage of traffic that uses the I-81 viaduct that will divert to the surface street network (rather than into the tunnel, or onto alternative routes). Geometric features such as the number of lanes, lengths of turn bays, and new connections were considered for each alternative. Other intersection features such as signal timing and progression were also relied upon in terms of their ability to convert the existing street network into a viable community grid that would help distribute traffic as efficiently as possible.

FIGURE 10: Exisiting Almond Street & E. Genesee Street Perspective

FIGURE 11: Almond Street & E. Genesee Street Perspective

FIGURE 12: Exisiting Almond Street and Jackson Street

FIGURE 13: Almond Street and Jackson Street Perspective

1.6 WHAT ALTERNATIVES ARE BEING CONSIDERED?

This Independent Feasibility Study addresses the needs and challenges in downtown Syracuse and the overall region. A long list of tunnel and depressed highway alternatives, in combination with a community grid element, were identified for consideration for their ability to improve local and regional mobility and connectivity, and to strive to promote economic growth.

We conducted a public outreach effort to help guide alternative development ideas and assist the study team with evaluation criteria and measures.

Thel-81 Independent Feasibility Study began with the intent of evaluating two depressed highway alternatives and two tunnel alternatives, each with and without Community Grid improvements. (Figure 14)

Two depressed highway alternatives were examined, both along the exiting I-81 corridor. Depressed highways are structurally similar to cut-and-cover tunnels, but have no roof and could be built at a shallower depth. The long-term impact on the urban landscape would typically be worse than cut-and cover tunnels since the highway trench would reduce connectivity between neighborhoods, especially if the highway were too shallow to allow the existing street pattern to be maintained.

Seven tunnel alternatives, with various sub-options were considered. Highways in tunnels are "out of sight and out of mind," compared with elevated, at-grade, or depressed alternatives. Removing some of the existing highway viaducts from the urban landscape and placing highways in tunnels create conditions that promote urban renewal. However, for traffic to descend into a tunnel from a viaduct or other highway, a transition structure is required with sections that are either elevated, at-grade, or depressed. Minimizing any negative impact of these transition sections on downtown Syracuse while achieving the objectives for traffic flow were key considerations during this study.

The two applicable tunneling methods would be bored and cut-and-cover. Bored (or mined) tunnels would be constructed using TBMs. These machines can be operated to result in negligible settlement at the ground surface, which can allow tunnels to be constructed under existing buildings, streets and other infrastructure with minimal disturbance.

Cut-and-cover tunneling would involve excavating a trench that is wider than the highway. This would require most existing features within the footprint to be removed, which limits its potential in urban areas. Upon completion, the land over the tunnel could be redeveloped. Cut-and-cover tunnel alignments were studied among the existing interstate corridors and on certain nearby city streets. Limited additional sections of cut-and-cover tunnel were studied where such tunnels would be required for transitions into bored tunnels.

As each alternative examined included demolition of I-81 viaduct, it became clear that just relocating I-81 into a tunnel or depressed highway alignment would not work without reconstruction of local city streets. Therefore, it was determined that each alternative examined would include community grid improvements. The community grid includes enhancements to existing streets along the I-81 corridor, and elsewhere. The studied alternatives would have fewer connections between the interstates and the city streets than presently exist. The enhanced street grid would allow for local flow of traffic and connectivity.

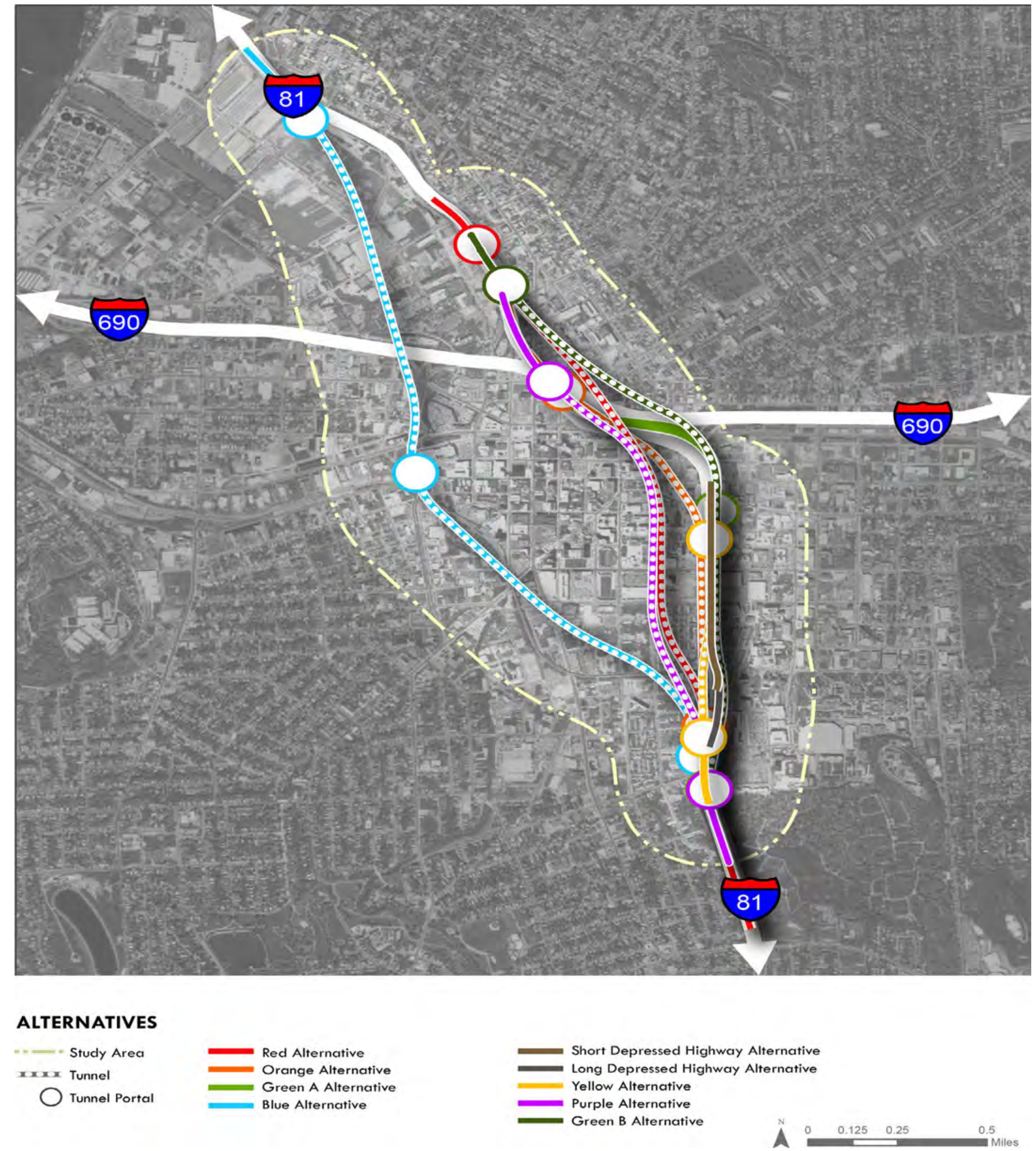


FIGURE 14: Proposed Alternatives

FIGURE 16: TBM Tunneling in Saline Conditions, Miami, FL

FIGURE 15: Soilder Pile and Lagging, 2nd and Hope Station, Metro Regional Connector, Los Angeles, Ca

FIGURE 17: Double - Deck Tunnel, Seattle, WA

1.7 KEY FINDINGS & CONCLUSIONS

The original study scope anticipated developing two tunnel alternatives and two depressed highway alternatives—all with and without community grid improvements. The existing I-81 and I-690 interstate systems in downtown Syracuse are largely on viaduct structures. The key challenge to take an elevated highway (I-81) and place it underground but try to re-establish connections with I-690 that would remain elevated. The team briefly considered placing both interstates underground, but trying to establish an underground interchange was quickly determined to not be a feasible alternative due to constructibility issues, property required, as well as high cost.

- After initial development of two depressed highway alternatives and seven potential tunnel alternatives, an initial screening was conducted. The study team came to consensus on the following points: The depressed highway alternatives did not meet the goals of the study. The options would further divide neighborhoods and close off more local streets. Significant construction challenges for utility relocations and to keep I-81 viaduct open during construction (or electing to close I-81 for several years to allow construction) are additional disadvantages for these alternatives. Depressed highway alternatives are not recommended and were eliminated from further study.
- Community grid improvements are integral to each tunnel alternative that was examined. It is clear that no alternative should be recommended without community grid improvements.
- The seven tunnel alignments were reviewed and Green B, Yellow and Purple alternatives were dismissed from further consideration and study.

Therefore, the Independent Feasibility Study shifted to examine in greater detail four tunnel alternatives, each with community grid improvements. These tunnel alternatives would have different northern portals and roadway connections that would provide distinct choices and unique features as to the advantages and disadvantages. These four tunnel alternatives carried forward are as follows:

- The Red Alternative would minimize construction complexity and risk by mining under I-690 without a direct interstate-to-interstate connection.
- The Orange Alternative would maintain connectivity between I-81 and I-690, including reconstruction and improvement of the I-690 viaduct.
- The Green Alternative would maintain connectivity between I-81 and I-690, while maximizing the use of the existing I-690 infrastructure. It would also minimize easements required outside of the public right-of-way.
- The Blue Alternative would maintain connectivity between I-81 and I-690, while facilitating future reconstruction of the I-690 viaduct. It would also minimize weaving maneuvers between I-81 and I-690 and minimize disruption to interstate traffic during construction.

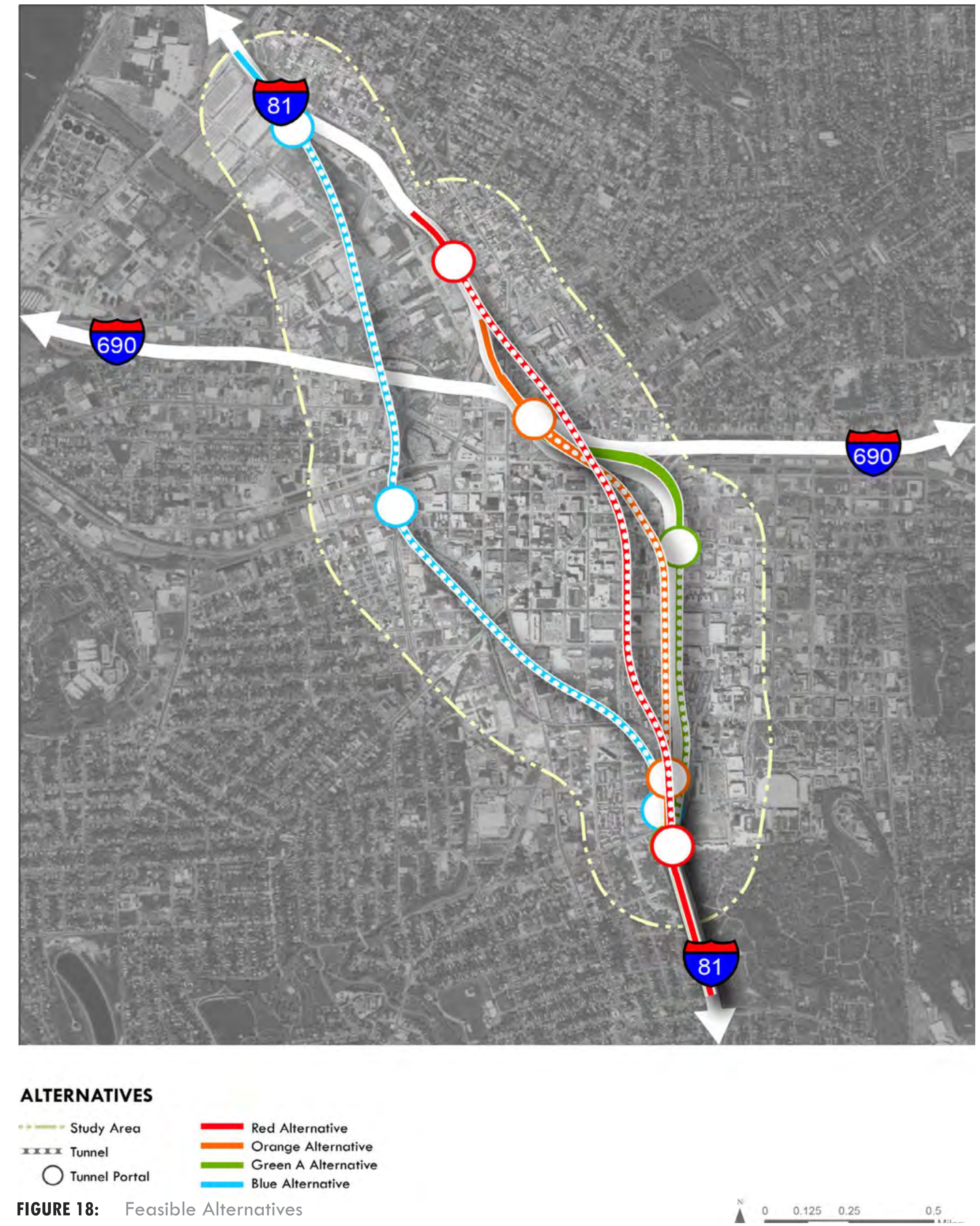


FIGURE 18: Feasible Alternatives

Short Depressed Highway Alternative

ALIGNED ALONG THE EXISTING I-81 VIADUCT

* If I-81 is closed and demolished before construction, cost is lower and duration is shorter. If I-81 remains open during construction, cost is higher and duration is longer.

LENGTH 0.65 Miles

SCHEDULE: 7-10 Years *

COST: $3-3.5 B*

PROPERTY No full takings | No building takings

ADVANTAGES:
- Maintains existing connections to I-690
- Short alignment / lower cost
- Martin Luther King Boulevard could remain open

DISADVANTAGES:
- Permanent division of City with limited (or no) connections to community grid
- Extended closure of I-81 during construction
- Major disruption to city streets during construction
- Multiple city streets closed permanently
- Snow removal difficult

Long Depressed Highway Alternative

ALIGNED ALONG THE EXISTING I-81 VIADUCT

* If I-81 is closed and demolished before construction, cost is lower and duration is shorter. If I-81 remains open during construction, cost is higher and duration is longer.

LENGTH 0.9 Miles

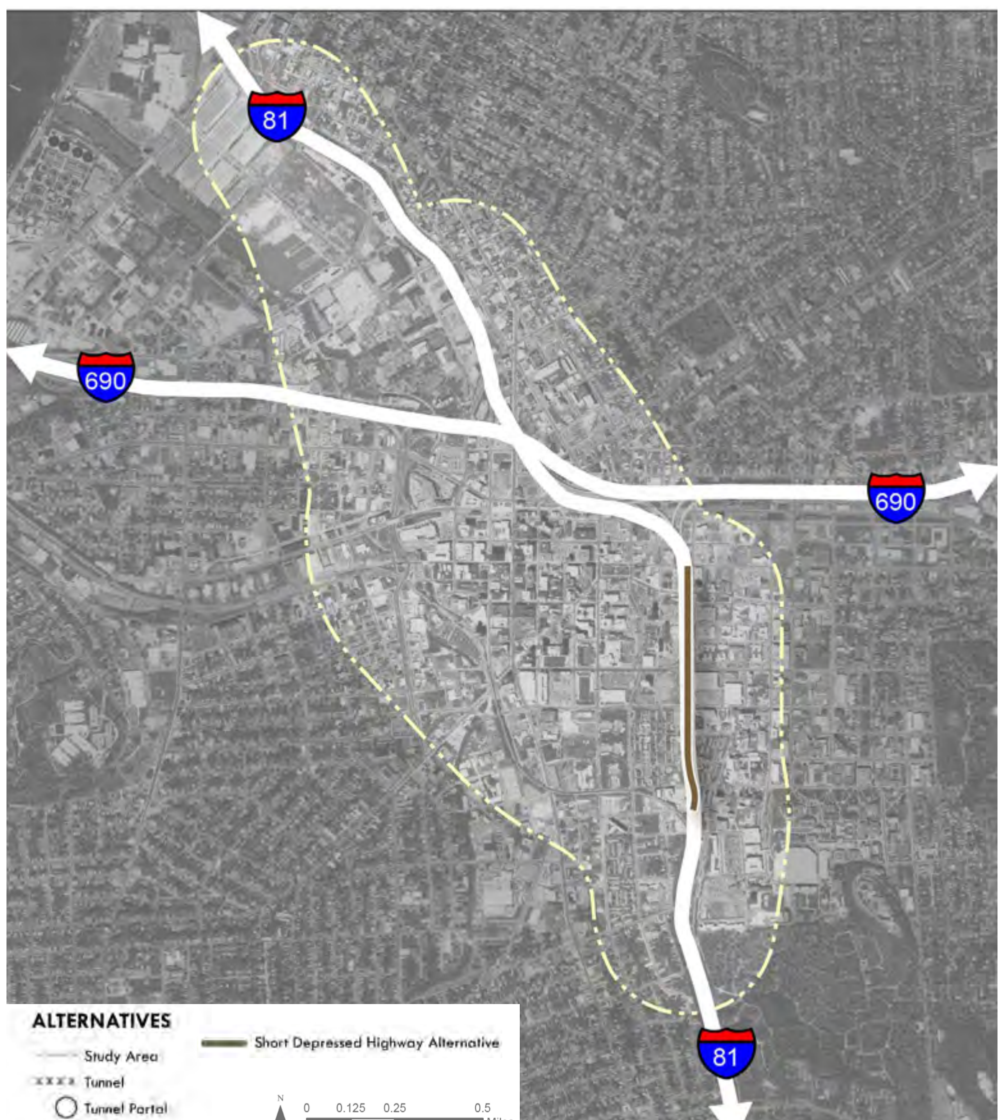
SCHEDULE: 7-10 Years *

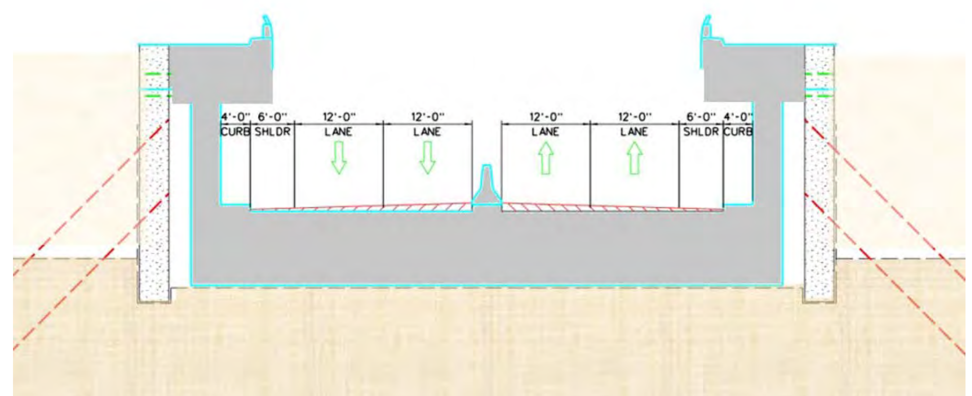
COST: $3.5 - 4 B

PROPERTY No full takings | No building takings

ADVANTAGES:
- Maintains existing connections to I-690
- Martin Luther King Boulevard could remain open
- Relatively short

DISADVANTAGES:
- Permanent division of City with limited (or no) connections to community grid
- Extended closure of I-81 during construction
- Major disruption to city streets during construction
- Harrison Street closed permanently
- Buried valley crossing the alignment result in deep walls and high cost





Red Alternative

GENERALLY ALIGNED WEST OF THE EXISTING I-81 VIADUCT, ALONG SOUTH TOWNSEND STREET.

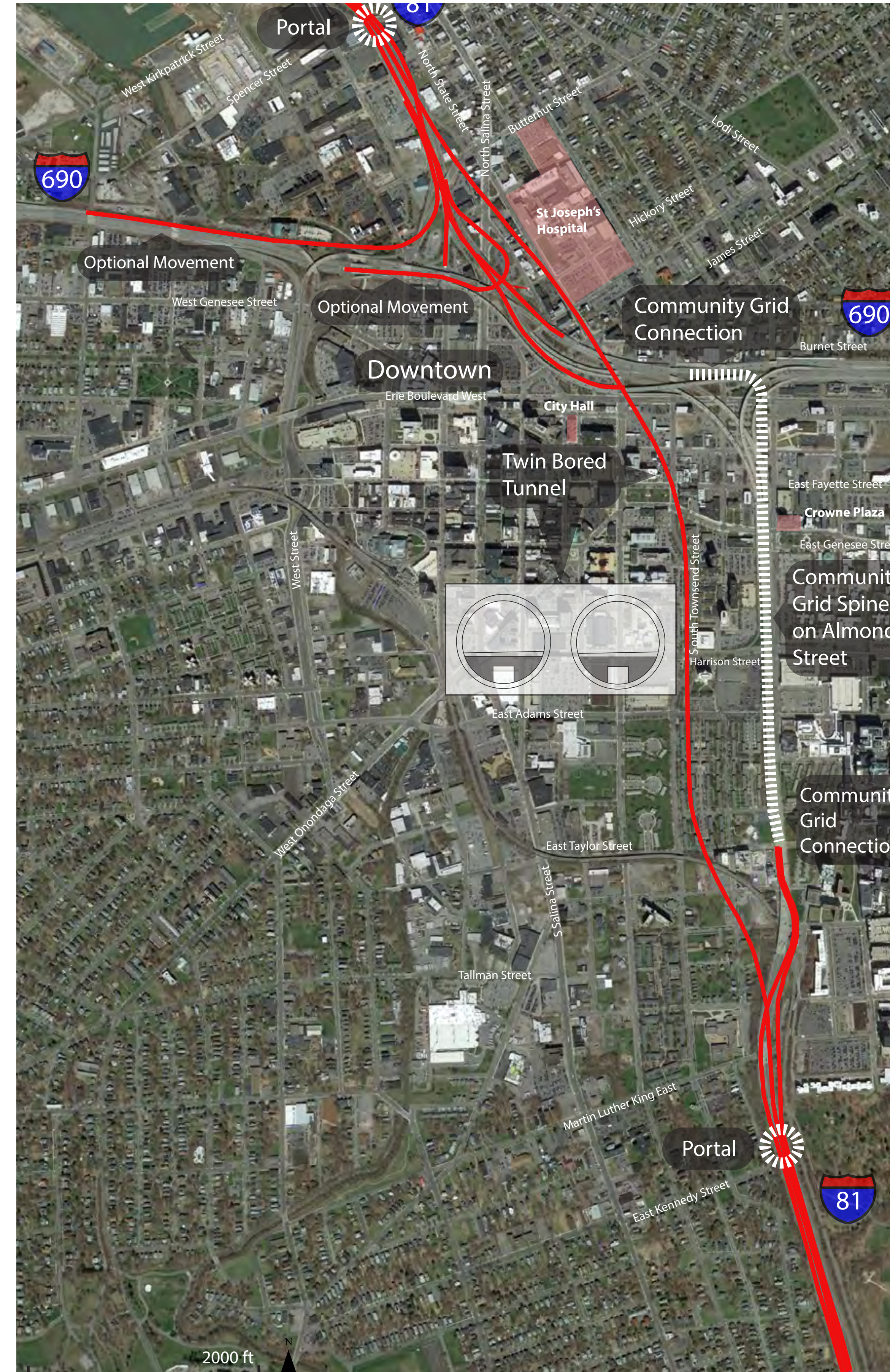
LENGTH	2.2 Miles
SCHEDULE:	9 Years
COST:	$3.3 B | Tunnel Work - 70% Surface Work - 30% Annual O&M Cost: $14 M
PROPERTY	Total full takings: 30 | Total full takings with buildings: 17 2 historic building takings - 315/329 North Salina Street (Optional)

ADVANTAGES:
- Favorable geometry for a tunnel mining portal south of the railroad
- Avoids risk of tunneling under I-81
- Construction costs are relatively low compared to orange and green alternatives

DISADVANTAGES:
- No direct connection between I-81 and I-690
- Traffic interstate connection viable by I-481and I-90
- Passes under private land

Red North Portal - Looking South Along I-81 Towards Downtown Syracuse

Red Alternative Composite Map



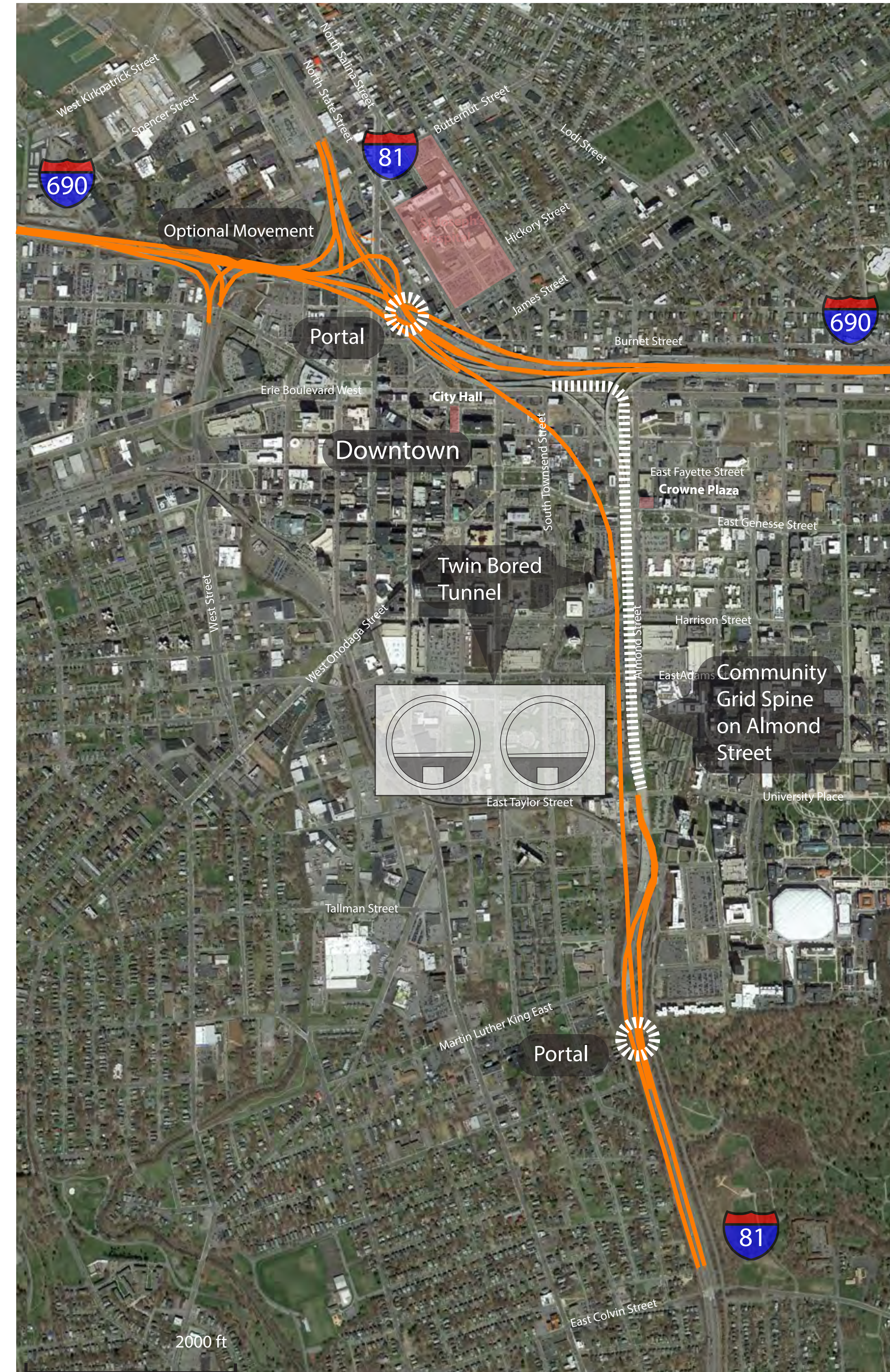
Orange Alternative

ALIGNED IMMEDIATELY WEST OF THE I-81 VIADUCT.

LENGTH	1.6 Miles
SCHEDULE:	9 Years
COST:	$3.6 B | Tunnel Work - 50% Surface Work - 50% Annual O&M Cost: $10 M
PROPERTY	Total full takings: 22 | Total full takings with buildings: 12 1 historic building takings- 315 North Salina Street (Optional)
ADVANTAGES:	• Enables connections to I-690 • Relatively short tunnel • Reconstruction of I-690 fixes non-conforming features
DISADVANTAGES:	• Replacement of the railroad bridge at Burt Street. Impact to railroad operations. • Passes under multi-story parking structure for Madison Towers • Passes under private land

Orange Portal - Looking South East Near Downtown Syracuse

Orange Alternative Composite Map



Green Alternative

ALIGNED IMMEDIATELY EAST OF THE I-81 VIADUCT.

LENGTH	1.2 Miles
SCHEDULE:	9 Years
COST:	$3.0 B | Tunnel Work - 60% Surface Work - 40% Annual O&M Cost: $8 M
PROPERTY	Total full takings: 6 | Total full takings with buildings: 2 | No historic building takings

ADVANTAGES:
- Enables connections to I-690, while limiting modifications to the existing I-690 roadways and structures
- Relatively short tunnel
- Requires less reconstruction of I-690 than the Orange Alternative

DISADVANTAGES
- Does not address I-690 deficiencies and limits future options for improving I-690
- Confined geometry throughout
- Requires permanent closure of Water Street, Washington Street and E Fayette Street
- I-690 WB to I-81 SB connection will be permanently removed

Green Portal - Looking West Towards Downtown Syracuse

Green Alternative Composite Map

Blue Alternative

ALIGNED SOUTHWEST OF DOWNTOWN SYRACUSE, AND CONNECTS INTO WEST STREET CLOSE TO THE INTERCHANGE WITH I-690.

LENGTH 2.6 Miles

SCHEDULE: 10 Years

COST: $4.5 B | Tunnel Work - 75%   Surface Work - 25%
Annual O&M Cost: $17 M

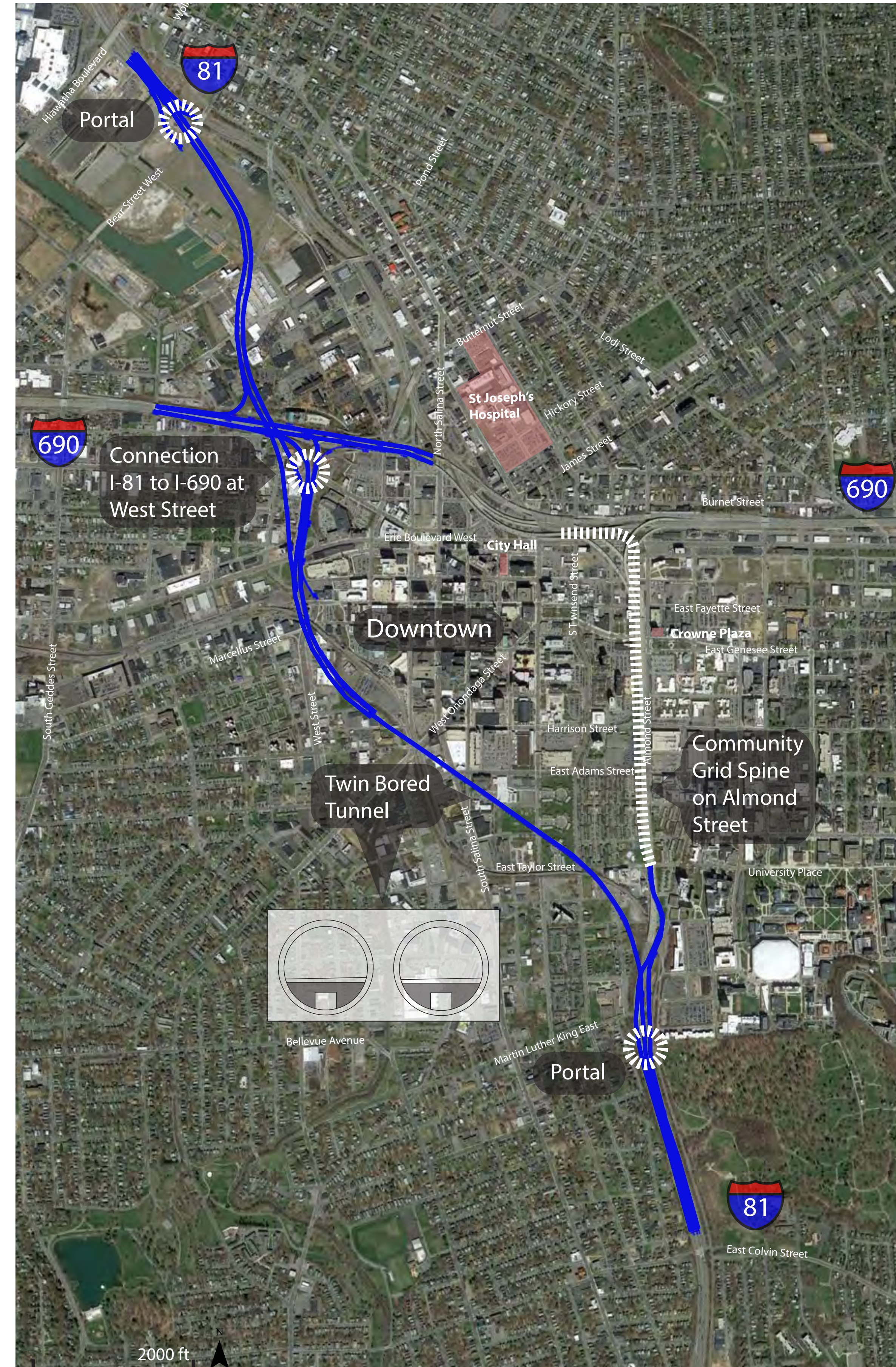
PROPERTY Total full takings: 42 | Total full takings with buildings: 22 | No historic building takings

ADVANTAGES:
- Avoids risk of tunneling under I-81 (encountering piles, settlement)
- Has limited impact on I-690 elevated section.
- Uses existing West Street interchange (with modifications) for connecting to I-690

DISADVANTAGES:
- Longest tunnel
- Property acquisitions required at West Street
- Utility relocations required at West Street

Blue Portal - Looking North Near Inner Harbor and Destiny Mall

Blue Alternative Composite Map



As mentioned above, the community grid is a vital part of all options, with a central Almond Street corridor that would provide connections for local traffic to efficiently reach local destinations and to access the interstate highways. Each alternative appears to be technically feasible, but the estimated costs and benefits would be different. Future studies could combine certain attributes from two or more alternatives.

Please refer to Chapter 5 for details on the connections and functions that would be achieved by each alternative. The design and construction of any of these tunnel alternatives in downtown Syracuse would be a major undertaking. The capital costs would be significant and are summarized in Table 1. (See Section 5.7 and Appendix K for more.)

Costs include:

- Tunneling and Heavy Civil
- Ventilation and Fire Life Safety Systems
- Bridge & Ramp
- Civil Highway
- Right of Way and Property Easement
- Soft Costs
- Escalation and risk reserve

Alternative	Cost
Red	$3.3 B
Orange	$3.6 B
Green	$3.0 B
Blue	$4.5 B

TABLE 1: Alternative Cost Estimates

The project schedule was developed starting at the end of the environmental process with receipt of the Record of Decision (ROD). The time to compete the required geotechnical exploration program, obtain needed permits, procure needed property for right-of-way and perpetual subterranean easements, complete final design, construct the new facilities and demolish the existing viaduct would take about nine years (plus or minus). The project could be delivered by conventional design-bid-build or by an alternative delivery method such as design-build. (See Section 5.8 for more.)

As presented in more detail in Chapter 6, Table 2 summarizes how each of the four final alternatives compares in relation to the I-81 Viaduct Project goals.

It is technically feasible to design and construct a tunnel alternative that meets the study goals and improve the transportation system in Syracuse metropolitan area.

A tunnel alternative is not the low cost option.

Community grid improvements must be incorporated into all alternatives that remove the I-81 viaduct

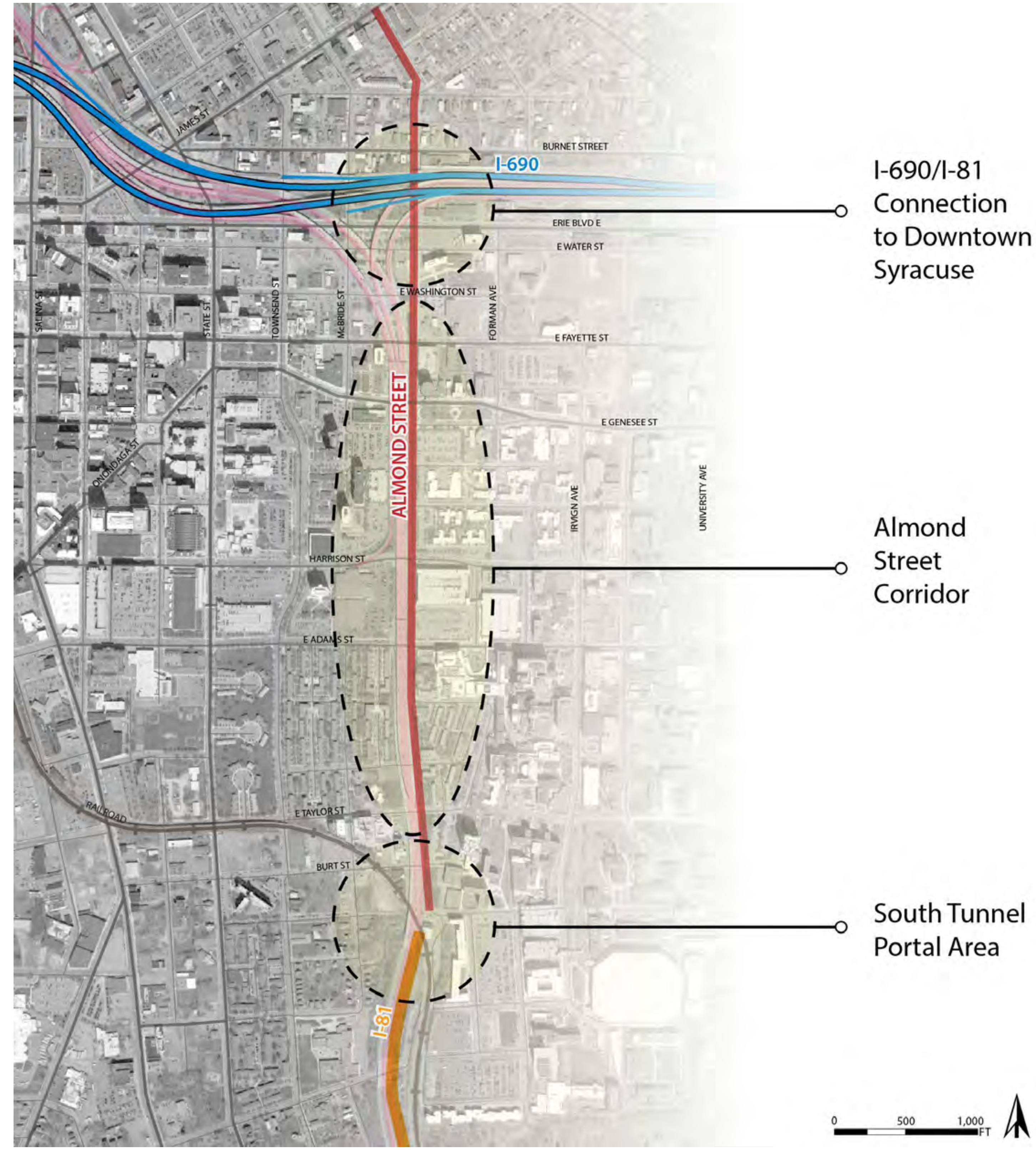


FIGURE 19: Community Grid Focus Areas

If a tunnel alternative is determined to be considered further for study in the I-81 Corridor DEIS, the Orange Alternative, as presented in the I-81 Independent Feasibility Study, is recommended as the tunnel option to be included. The tunnel portion is relatively short compared to other alternatives and the north portal would be near the existing I-81 and I-690 interchanges. This alternative would also reconstruct and reconfigure significant portions of I-690 to make better connection to I-81 coming out of its tunnel, which would drive the cost higher than other alternatives, but would provide more benefits (as shown in the Table 22, the Alternative Comparison Matrix in Chapter 6 on page 93).

Please note that comparing the tunnel alternatives in this Independent Feasibility Study to the rebuild the viaduct alternative, the community grid alternative, or the no-build alternative was beyond the scope of this study.

GOALS	OBJECTIVES	RED	ORANGE	GREEN	BLUE
Improve safety and create an efficient regional and local transportation system within and through greater Syracuse	Improve interstate geometry	◑	●	◑	◑
	Maintain or enhance interstate-to-interstate connections	○	◕	◕	●
	Minimize Cost	◑	◔	◑	○
Provide transportation solutions that enhance the livability, visual quality, sustainability, and economic vitality of greater Syracuse	Enhance livability of the surrounding area	◑	●	◑	◕
	Minimize adverse environmental impacts	◕	◔	◑	◔

TABLE 2: Overall Alternative Evaluation Matrix

2 PROJECT PLANNING CONTEXT

2.1 PROJECT OVERVIEW & HISTORY

The Interstate-81 (I-81) corridor is vital to the regional transportation network and provides the downtown and greater Syracuse area with a critical north-south transportation route for commuters, travelers, and commercial vehicles. I-81—specifically the 1.4-mile elevated viaduct near downtown Syracuse—is deteriorating and nearing the end of its useful life due to age, wear, and harsh winter weather conditions. Ramps to I-690 connect I-81 to the critical east-west highway. Both I-81 and I-690 provide transportation access through Syracuse's dense urban center and influence the urban fabric and economic makeup of the region's largest economic center. The purpose of this project is to perform an "independent" feasibility study, separate from the I-81 Viaduct Project and other past and ongoing study efforts (Table 3), to understand the infrastructure needs and assess different tunnel construction solutions along this corridor. A preferred alternative should provide the I-81 corridor with the infrastructure needed to support long-range planning efforts and effectively consider the community's vision of downtown Syracuse and the greater metropolitan area.

Past Proposals & Studies	Possible Alignments	Details

I-81 Corridor Study	Four potential build strategies were proposed:
	• Reconstruction of the viaduct
	• Viaduct removal with at-grade/boulevard
	• Viaduct removal with tunnel
	• Viaduct removal with depressed highway
		• The study considered the infrastructure needs in the larger context of the community it serves and the environment in which it operates.
		• The study assessed and documented the highway's existing conditions and deficiencies, identified multimodal transportation and community needs and priorities, analyzed potential strategies for the future of the corridor, evaluated such strategies, and recommended strategies for further study.
		• This study investigated the long-term viability along the corridor and has provided the framework for future studies and alignments.
		• The report identified that additional studies would need to be conducted to determine which strategies would meet the goals to:
		  ◦ Enhance the overall transportation network and improve regional mobility.
		  ◦ Improve public safety and quality of life.
		  ◦ Maintain or improve economic opportunities.
		  ◦ Support community quality of life.
		  ◦ Preserve or enhance environmental health.

I-81 Viaduct Project	Project alternatives considered (# of alternatives): • Viaduct Alternative (5) • Community Grid Alternative (2) • Tunnel Alternative (7) • Depressed Highway Alternative (2) • Other Alternative (2	• Within the Scoping Report, NYSDOT recommended three viaduct alternatives, two community grid alternatives, and the No Build Alternative to be further evaluated in the Draft Environmental Impact Statement (DEIS). • All tunnel and depressed highway options were dismissed. • The I-81 Viaduct Project identified structural deficiencies and nonstandard highway features while making an effort to improve the I-81 corridor and support long-range transportation and planning efforts. • This report was intended to assist agencies and the public to better understand the purpose and need for the project, project objectives, potential alternatives and environmental.
I-81 Draft Environmental Impact Statement	Review of alignments advanced in the I-81 Viaduct Project	• At this time, the DEIS is underway, reviewing three viaduct alternatives, two community grid alternatives, and three tunnel alternatives.
American Institute of Architects Urban Design Study of the I-81 Project Area	Review of alignments presented in the I-81 Viaduct Project	• The goal of the American Institute of Architect's Chapter I-81 Task Force, has been to support the NYSDOT design team by bringing an urban design and planning element to the project. • The Task Force analyzed alignment options put forward in the I-81 Viaduct project and recommends/supports the Community Grid option.
Develop Cost-Effective Transportation Options	Reroute I-81 through a two-mile tunnel under University Hill, bypassing the viaduct and constructing a boulevard in its place	• Provides for permanent removal of the viaduct while maintaining I-81 through the city. • Preserves exiting traffic patterns on I-81 during the constructions period of the tunnel. • Provides traffic relief and prevents gridlock. • Minimal property taking required.

TABLE 3: I-81 Historical Background

2.2 STUDY GOALS

The goals of this I-81 Independent Feasibility Study (Independent Feasibility Study) were derived from the previous and ongoing efforts of the I-81 Viaduct Project (as described in Section 1.3). The goals of this study and previous studies were intended to align in order to help develop an equal basis for comparing alternatives. Although the goals of these study efforts align, the objectives for this feasibility study were formed at the its outset in an effort to perform an independent analysis. The goals and objectives of this Independent Feasibility Study serve to identify, assess, and select alternatives. The following are the two major goals and five key categories of this Independent Feasibility Study used in the evaluation process:

- Improve safety and create an efficient regional and local transportation system within and through greater Syracuse
  - Improve interstate geometry
  - Maintain or enhance interstate-to-interstate connections
  - Minimize cost
- Provide transportation solutions that enhance the livability, visual quality, sustainability, and economic vitality of greater Syracuse
  - Enhance livability of the surrounding area
  - Minimize adverse environmental impacts

As shown in Table 4, the selected goals and objectives address a range of issues including roadway design, interstate connectivity, land/infrastructure management, environmental and pedestrian impacts, and cost effectiveness. The goals provide a broad measure of characteristics that would be required to meet the project's purpose. The objectives in turn define a series of specific metrics to allow for an objective comparison among alternatives. The goals and objective were used throughout the alternative development phase to inform the development of criteria and performance measures, and to lend coherence to the decision-making and selection process.

Goal	Objective	Criteria
Improve safety and create an efficient regional and local transportation system within and through greater Syracuse	Improve interstate geometry	○ Decommission aging viaduct structure(s). ○ Maintain I-81 interstate status, with interstate highway standards. ○ Correct non-conforming highway geometry on I-81 and I-690. ○ Improve safety. ○ Improve mobility.
	Maintain I-81 interstate status, with interstate highway standards.	○ Maintain I-81 through movement on interstate highway. ○ Maintain or enhance connections between I-81 (south of Syracuse) and I-690 (west of Syracuse). ○ Maintain or enhance other connections between I-81 and local streets.
	Minimize Cost	○ Minimize capital cost. ○ Minimize operations, maintenance and repair costs. ○ Replace infrastructure that has limited remaining service life and high maintenance costs. ○ Utilize existing transportation infrastructure that has decades of remaining service life.
Provide transportation solutions that enhance the livability, visual quality, sustainability, and economic vitality of greater Syracuse	Enhance the livability of the surrounding area	○ Minimize use of elevated or depressed highways. ○ Minimize disruption to the local street grid, including street closures and altering the vertical or horizontal geometry of local streets. ○ Enhance north-south and east-west connectivity on local streets. ○ Maintain and improve access to transit services. ○ Maximize opportunities for land development. ○ Enhance pedestrian and bicycle accessibility, experience and safety. ○ Preserve historic buildings and structures. ○ Enhance the visual character and streetscape of affected local streets.
	Minimize adverse environmental impacts	○ Minimize noise, vibration and dust during construction. ○ Minimize traffic impacts to interstate highways during construction. ○ Minimize traffic impacts to local streets during construction. ○ Minimize residential displacements. ○ Minimize community facility displacements. ○ Minimize commercial displacements. ○ Minimize impacts to Onondaga Creek. ○ Minimize air quality, noise and vibration impacts. ○ Minimize visual impacts.

TABLE 4: Project Goals & Objectives

Note: Connections between Interstates and any modifications to the Interstate access would need to be considered and approved by FHWA

2.3 TRAFFIC CONDITIONS & DEFICIENCIES

Much of the traffic congestion experienced on the existing highway network is attributed to the I-690 interchange with I-81and with the ramps that provide access to the downtown area. In particular, the weaving sections and off-ramps on I-81 near Harrison Street operate very poorly during the peak hours. This is partially a result of the signalized intersections immediately adjacent to the ramps and their limited capacity to process the large demand of traffic generated by the major institutions in the area. The section of I-81 northwest of the I-690 interchange is also problematic given the numerous access points and lack of capacity on the mainline. The high volume of traffic demand in this area results in poor levels of service and is made worse by the large numbers of vehicles making weaving maneuvers.

The high volume of exiting or entering highway traffic creates congestion at these local points of contact. The local street network in downtown Syracuse does not provide ideal circulation for vehicles. As a result, traffic congestion and delays on the local streets occur primarily around the access points to and from I-81 such as East Adams Street and Harrison Street as well as along the major corridors such as Almond Street and Erie Boulevard. to optimize distribution among the surface street network, any tunnel alternatives need to also incorporate the maintenance and enhancement of connections between the interstates and the city streets. A solution that displaces part of the existing traffic volume carried by the existing elevated highway directly onto the surface street network will tend to exacerbate existing issues unless mitigated.

2.4 LAND USE PLANNING IN SYRACUSE

While developing alternatives for I-81, it is important to understand the current land use planning context. This context provides some clarity as to local transportation and land use policy goals and objectives and will ensure that each alternative is not in conflict with future economic development goals of the City of Syracuse. These plans—which include the City of Syracuse Comprehensive Plan 2040—highlight the need for the downtown to preserve and strengthen its urban identity and to reinforce downtown and University Hill as the core of regional employment and business and economic development.

Each alternative investigated as part of this Independent Feasibility Study—particularly the community grid elements—is consistent with achieving these goals. Some community grid improvements would reconnect downtown to the Medical Centers and Syracuse University area, which is a particularly important goal of the City of Syracuse.

2.5 PUBLIC ENGAGEMENT

The importance of a proactive public involvement process is a common theme across all infrastructure projects. A robust but targeted public outreach process facilitates the collection of meaningful, substantive input to inform the development and evaluation of infrastructural alternatives and roadway changes that best address the project's purpose and need, and goals and objectives. Extensive public outreach and stakeholder involvement has been part of the multi-year I-81 Viaduct Project. Nevertheless, public outreach for this Independent Feasibility Study was undertaken to solicit input from the public about the specific scope of this study regarding the feasibility of tunnel and depressed-highway alternatives. The public outreach has assisted in the consultant teams' evaluation criteria and measures to evaluate alternatives. Ideas and concerns that the public raised were shared with all project team members so that they could be appropriately integrated into the planning, engineering and design elements of the project.

The public outreach approach was a multi-level approach to ensure that the City of Syracuse and the surrounding areas were aware of the ongoing project. The effort began March 9, 2017, and concluded April 7, 2017. The following communication tools were used to support the public outreach effort.

- Newspaper
  - A letter requesting information was posted in The Citizen and The Post-Standard newspapers. Public input was received by email (to I-81input@pbworld.com) or sent by regular mail to WSP.
  - A website was created (www.I-81independentstudy.com/) that provides the same information as the letter but also includes a Study Area map that defines the project limits.
- Online Media
  - Informational pop-up ads and banners appeared on www.auburnpub.com and www.syracuse.com webpages (at random). These pop-up ads were clickable and would then forward the reader to the I-81 Independent Study website to read the letter and look at the Study Area map.
- Email ("E-Blast")
  - The I-81 Viaduct Project's team shared a database of email addresses of interested parties in the project area. An email of the letter requesting information was sent out to those parties for input.

During the open public comment period, the project team categorized and analyzed over 350 responses. Most of the responses received were from residents, employees, and public officials in the greater Syracuse metropolitan area. For those in favor of an infrastructural solution, the following key takeaways were discovered during the analysis of all responses received:

- 33 percent (116) of respondents prefer to keep I-81 and either fix, redesign, or enhance it.
- 19 percent (67) of respondents prefer a community grid or some kind of a local boulevard.
- 11 percent (39) of respondents prefer a tunnel.
- 11 percent (40) of respondents prefer a hybrid solution.

Although many of the comments acknowledge that a change is needed to repair current infrastructure, several non-favorable responses included concerns over cost, traffic, and environmental conditions. Most notably, of the 350+ responses received:

- (35 percent) 122 do not want a tunnel.
- (11 percent) 38 total respondents do not want a community grid.
- (8 percent) 27 total respondents do not want to repair/redesign I-81.
- (6 percent) 26 total respondents do not want a depressed highway.
- (12 percent) 43 respondents, while offering no real solution, were very adamant about what they did NOT want to happen. Of those who solely expressed objections, 38 (88 percent) do not want a tunnel.

For more information regarding the analysis and breakdown of all comments received see Appendix L.

3 DESIGN & ENGINEERING CONSIDERATIONS

3.1 HIGHWAY DESIGN

Prior to developing alignment alternatives, design criteria were developed for urban principal arterials-interstate and ramps that were used to guide the development of the various tunnel alternatives, including sections of I-690 and I-81 and ramps as recommended in any given alternative. Design criteria were also developed for local urban roads, collector, and arterial roads that were used to guide the development of various modifications to local streets. All alternatives would reconstruct local roads and connections, and modify interstate ramp connections to meet project goals and objectives.

Design criteria for civil elements were developed using the following reference documents:

- NYSDOT Highway Design Manual Chapter 2, Design Criteria (February 27, 2017)
- AASHTO Technical Manual for the Design and Construction of Road Tunnels (November 2010)

The criteria for the alternatives were developed using the same reference documents. The AASHTO Technical Manual draws reference to the AASHTO Green Book and to local regulatory requirements but also points out that standards should be developed for each project on a case-by-case basis to ensure that the most efficient tunnel section is used. Separate from the reference documents, the design criteria were adopted in a manner that considered the most efficient tunnel section that could be provided for both single bore and twin bore tunnels. In the case of the alternatives reviewed, the design criteria for urban principal arterials-interstate were able to be accommodated by the proposed tunnel alignment and sections.

The tunnel alternatives were conceptually designed to satisfy the urban principal arterial-interstate standards as shown in the NYSDOT Design Manual. Key components of the standards used for tunnel mainline (interstate) include the following:

- Design Speed = 50 mph. All tunnel alternatives were evaluated with a design speed of 50 mph standard. Design speeds in the approaches beyond the tunnel section and at grade tunnel downgrades would be consistent with existing conditions. Preliminary investigations determined that this minimum design speed would not result in design conflicts that would have suggested use of lower design speeds. Should subsequent design effort reveal a desire to increase curvature to avoid specific properties or structures to better optimize the project, a lower design speed could be evaluated. The design speed criteria did not affect the selection of the tunnel section. The design standard of 50 mph dictates the following critical design criteria:
  - Maximum Grade 6% – The design team reviewed alternatives and attempted to use a 4% grade. This was generally achievable at the southern tunnel portal. However, using a 4% grade for the northern portals, near downtown Syracuse, resulted in unacceptable impacts to the existing city street grid, so this approach was not pursued. A 6% grade is permitted in rolling terrain within urban areas. It is also permissible in accordance with AASHTO. Grades greater than 4% (while being at or less than 6%) were solely employed in areas where flatter grades would result in undesirable impacts to urban development.
  - Minimum Stopping Sight Distance 425 feet – Sight distance horizontal geometry elements were developed cognizant of stopping sight distances, consistent with AASHTO guidance, which indicates that sight distance can be a governing criteria. The location of tunnel walls was reviewed to ensure that minimum distances could be met within the tunnel. Adjustment of shoulder widths and curve radii have generally been implemented in this study to accommodate design requirements for sight distances based on each tunnel tube's diameter. For example, in the single-bore bidirectional tunnel, the larger shoulder would be located on the inside of radial curves to maximize sight distances without further flattening the curve or further increasing tunnel diameter.
  - Minimum Radius Curve – Tunnel alignments were developed to exceed this minimum radius curvature. In most cases, the tunnel alignment would not follow right-of-way limits and thus reduction in the curve radius and speed would not have a tangible benefit other than minimizing property easement acquisition. We also note that the alternatives that seek to following the current right-of-way would have additional constructibility concerns (such as existing I-81 viaduct piles) that could obfuscate the benefits of minimizing easement acquisitions by way of minimizing the radius curve by reducing the design speed. A curve radius of less than approximately 1,500 feet would require special tunnel boring machine (TBM) considerations. The curve radius used within the proposed tunnel alternatives is far greater than the minimum radius of 833 feet. Minimum radius is less important in cut-and-cover areas of construction since the section would be able to be widened to accommodate additional shoulder width separate from geometric restrictions imposed by TBM. Minimum radius used to design bored tunnels were as follows:
    - Twin Bore (43 feet 8 inches diameter) – min radius = 2,269 feet
    - Single Bore (57 feet 0 inches diameter) – min radius = 1,500 feet
  - The radii used for design purposes exceed the minimum requirement from Chapter 2 and exceeds the minimum requirement within the AASHTO document but is consistent with the governing nature of sight distance on other design elements.
  - Shoulder Widths – The tunnel alternatives would not provide the full shoulder width as indicated in the Highway Design Manual. A single-bore bi-level tunnel would accommodate a 6-foot shoulder width but would vary its location such that it would be placed on the interior of each curve. In the case of traffic moving northbound on a left trending curve, the wider shoulder would be located on the left side of traffic, not the right side as prescribed in the Highway Design Manual. In the case of both the single bore and twin bore tunnel options, the geometry of the bore would not permit the design of a 10-foot shoulder. The proposed twin bore tunnel concepts would provide two 4-foot shoulders on both the right and left sides, which is consistent with the recommendations for tunnels contained in the AASHTO Manual. The AASHTO document indicates that many factors should be considered when developing criteria for shoulder widths but notes that a minimum of 4-foot shoulders are acceptable widths. Further, the document notes that it is common to reduce the shoulder width of interstate sections from that shown in the approaching section due to geometry constraints within the tunnel. The proposed single bore tunnel concepts propose one 6-foot shoulder and one 4-foot shoulder. To compensate for shoulder width reductions, the horizontal curvature was subsequently increased to permit the stopping sight distance to be compliant. The unique relationship between tunnel diameter, shoulder widths, horizontal curvature, and design speed is described below and illustrated in Table 5 and Table 7. Outside of the tunnel construction, the approach roadways transition to the Chapter 2 shoulder width sections.

- Roadway Section Lane Widths of 12 feet – Typical tunnel alignments would include two lanes (both north and southbound) along with shoulder widths as indicated above. We note per previous discussion that shoulder width locations would vary to optimize the alignment based on tunnel geometry (wall locations). The roadway lane widths would be consistent with requirements in both Chapter 2 and the AASHTO Manual.

- Vertical Clearance of 16 feet – All tunnel alternatives would permit truck traffic. The vertical clearance would be consistent with the requirements in both Chapter 2 and the AASHTO Manual. Further, the vertical clearance was developed cognizant of tunnel system needs and most efficient tunnel diameter to accommodate the number of lanes. A lower vertical clearance requirement within both single and twin bore tunnel sections would not have any impact on the selection of the tunnel diameter circular section since the size would be driven by the width of the lanes/shoulders/egress, not the height requirement.

Design criteria used for the tunnel alternatives is as shown to the left. See Appendix G for more detail:

Additionally, the alternatives described within this report have been screened against various I-690 options. I-690—specifically within the I-81 ramp zone—has a significant number of non-standard features, ranging from horizontal curvature, line of sight, shoulder width, and others. The tunnel alternatives would be independent of work along I-690 except where otherwise noted. The Red and Blue Alternatives would be implemented with the existing I-690 viaduct or with a reconstructed I-690 that addresses design criteria deficiencies. The Green Alternative would require the existing I-690, while the Orange Alternative would require a reconstructed I-690.

In contrast to the interface with I-690, the Almond Street corridor would be significantly affected by all tunnel alternatives in that portions of the existing I-81 viaduct would be removed and require reconstruction of the street corridor. Further, the tunnel alternatives would all rely consistently on a new Almond Street interchange with I-690 to both facilitate local connectivity to the University Area from points north and west in addition to providing connections to I-690 eastbound from the south and to I-81 southbound from points east via I-690 westbound. All alternatives would include a similar concept to reconstruct the Almond Street corridor and a new I-690/Almond Street interchange. The new interchange would include a combination of flyover ramps, which would seek to replicate the function of the existing Harrison Street ramps. These heavily traveled ramps would be constructed within the median of the reconstructed Almond Boulevard, terminating near Fayette Street. The Green Alternative differs slightly from the other options, which would include maintaining a direct interstate connection from northbound I-81 to eastbound I-690.

Ramp connections would be developed for various alternatives; however, each alignment would offer varying degrees of potential connectivity to I-690 and the local street grid (Table 6). The Green Alternative—with the shortest tunnel—would afford maximum connectivity to I-690 since the alignments would permit viaduct reconstruction, and ramp connections, consistent with the

	Element	Standard
1	Design Speed	50 mph HDM Section 2.7.1.1.A
2	Lane Width	12 feet HDM Section 2.7.1.1.B
3	Shoulder Width	Varies. Right shoulder 10 feet (bridges), 4 feet (min) (tunnels) Left Shoulder 4 feet (min). HDM Section 2.7.1.1.C Exhibit 2-2
4	Horizontal Curve Radius	758 feet Min (at emax=6%) HDM Section 2.7.1.1.D
5	Superelevation	6% Max. HDM Section 2.7.1.1.E
6	Stopping Sight Distance (Horizontal and Vertical)	425 feet Min. HDM Section 2.7.1.1.F
7	Maximum Grade	6% HDM Section 2.7.1.1.G, Exhibit 2.2
8	Cross Slope	1.5% Min. to 2% Max. HDM Section 2.7.1.1.H
9	Vertical Clearance (above traveled way)	16 feet Min.HDM Section 2.7.1.1.I
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3
11	Pedestrian Accommodations	Complies with HDM Chapter 18

TABLE 5: Critical Design Elements for Interstate Tunnel Sections

Design criteria tables as applicable to specific alternatives is provided in Appendix H. The tables detail non-standard features where applicable in addition to confirming that the standards were applied for critical design elements. The existing condition column are blank since the facilities being provided are essentially new.

Alternative	I-81 NB to I-690 WB	I-81 NB to I-690 EB	I-81 SB to I-690 WB	I-81 SB to I-690 EB	I-690 EB to I-81 NB	I-690 EB to I-81 SB	I-690 WB to I-81 NB	I-690 WB to I-81 SB
Red	X	X	Optional	✓	Optional	X	✓	X
Orange	✓	X	Optional	✓	X	✓	✓	X
Green	✓	Optional	Optional	✓	Optional	✓	✓	X
Blue	✓	X	Optional	✓	X	✓	✓	X

TABLE 6: Connections to Each Alternative

**- Connection feasible by use of city street grid (Almond Street Corridor)*
***- Connection could be accommodated by constructing new viaduct ramps (separate from tunnel) (these are optional, but are included in the cost estimate)*

DEIS viaduct replacement alternative. The Red Alternative, which would have the longest tunnel, would effectively avoid ramp connections. The Orange and Blue Alternatives would have connectivity.

In addition to the interstate-to-interstate connections, the tunnel alternatives would include various ramps to facilitate local connections. Ramps would be provided at the north portal areas of various alternatives to facilitate access to and from I-81 before entering the tunnel from the southbound direction and subsequent to exiting the tunnel in the northbound direction.

Local road realignment and reconstruction would be necessary. For example, realignment of the Butternut Street bridge is provided within Red and Orange alternatives in order to facilitate other local/interstate ramps. Additionally, the Genant/Bear intersection is realigned under the Blue Alternative. Similarly significant work along the Almond corridor is required to implement the Community Grid. Burt Street is cutoff to provide local access to the Almond Street Corridor from I-81 under all alternatives. Washington and Water Streets are both cutoff to accommodate the Fayette Street Flyover Ramps under all alternatives. The design criteria for arterial roads would be applied for work required in concert with tunnel construction. All tunnel alternatives would rely on a reconstructed Almond Street to provide connectivity to the city street grid and in some cases to certain directions on I-690.

	Element	Standard
1	Design Speed	30 mph/40 mph HDM Section 2.7.5.2.A
2	Lane Width	- HDM Section 2.7.5.2.B Exhibit 2-9
3	Shoulder Width	3 feet 0 inches/6 feet 0 inches HDM Section 2.7.5.2.C
4	Horizontal Curve Radius	231 feet Min (30 mph) 485 feet Min. (40 mph) HDM Section 2.7.5.2.D
5	Superelevation	6% Max. HDM Section 2.7.5.2.E
6	Stopping Sight Distance (Horizontal and Vertical)	200 feet Min. (30 mph) 305 feet Min. (40 mph) HDM Section 2.7.5.2.F
7	Maximum Grade	7% Max. (30 mph) 6% Max. (40 mph) HDM Section 2.7.5.2.G,
8	Cross Slope	-
9	Vertical Clearance (above traveled way)	16 feet Min. HDM Section 2.7.5.2.I-
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3
11	Pedestrian Accommodations	Complies with HDM Chapter 18

TABLE 7: Critical Design Elements for Ramps

Design criteria tables as applicable to specific alternatives are provided in Appendix H. The tables will detail non-standard features where applicable in addition to confirming that the standards were applied for critical design elements. The existing condition column is blank since the facilities being provided are essentially new.

	Element	Standard
1	Design Speed	35 mph HDM Section 2.7.2.4.A
2	Lane Width	11 feet Min. HDM Section 2.7.2.4.B Exhibit 2-4a
3	Shoulder Width	0 feet 0 inches/6 feet 0 inches HDM Section 2.7.2.4.C
4	Horizontal Curve Radius	371 feet Min HDM Section 2.7.2.4.D
5	Superelevation	4% Max. HDM Section 2.7.2.4.E
6	Stopping Sight Distance (Horizontal and Vertical)	250 feet Min. (35 mph) HDM Section 2.7.2.4.F
7	Maximum Grade	8% Max. HDM Section 2.7.2.4.G
8	Cross Slope	1.5% Min. – 2.0% Max.
9	Vertical Clearance (above traveled way)	14 feet 6 inches Min. HDM Section 2.7.2.4.I
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3
11	Pedestrian Accommodations	Complies with HDM Chapter 18

TABLE 8: Critical Design Elements for Arterial Roads

3.2 GEOTECHNICAL CONDITIONS

3.2.1 SUBSURFACE CONDITIONS

Available information indicates that either a depressed roadway alternative or tunnel alternative would be constructed entirely or partially within the following materials:

- Fill
- Glacial outwash and delta deposits
- Glacial lake deposits
- Shale

The fill would be a product of the development of the city and generally would be derived from the glacial outwash and delta deposits and the glacial lake deposits. In addition to natural soils, older fill could contain various types of obstructions. These obstructions would preclude the use of steel sheetpile for support of excavation (SOE) walls.

The glacial outwash and delta deposits would consist of stratified sands and gravels deposited by flowing glacial melt water or from glacial or post-glacial streams. These deposits would contain cobbles (up to 12 inches across) and small boulders (up to 36 inches across). The cobbles and boulders can include hard and abrasive metamorphic rocks from the Adirondacks or the Canadian Shield. Boulders would preclude installation of sheetpile. All the materials, including hard and abrasive cobbles and small boulders, can be excavated by equipment normally used in slurry wall and secant pile wall construction.

The glacial lake deposits would consist of stratified layers of clay and silt deposited under quiet water conditions. They could contain fine to medium gravel.

Both outwash deposits and glacial lake deposits could contain medium to large ice-rafted boulders (between 36 inches and 60 inches across). Although these materials can be penetrated by equipment normally used in slurry wall and secant pile wall construction, removal of such materials would delay excavation and increase cost.

The underlying shale is known to contain noxious and explosive gases and to be subject to high horizontal stresses. The presence of gas would require classification of tunnel excavation as potentially gassy, which would require explosion-proof TBMs and ancillary equipment, and increased ventilation to dilute and purge gas.

Groundwater is described as saline, but the degree of salinity is unknown. Saline conditions would affect selection of slurry materials for slurry wall trench excavation and of conditioning agents used in pressurized face TBM excavation. Salinity would also affect concrete mix design for slurry walls, secant pile walls, and permanent structures and corrosion protection of reinforcement used in those structures.

See Appendix D for a more extensive description of subsurface conditions.

3.3 TUNNEL DESIGN & CONSTRUCTION

3.3.1 DEPRESSED ROADWAY, OPEN TUNNEL APPROACH, AND CUT-AND-COVER CONSTRUCTION

Portions of depressed roadway, tunnel approaches, and cut-and-cover tunnels constructed above the groundwater table could be supported by reinforced earth walls or conventional cantilever reinforced concrete retaining walls. Cantilever walls would be constructed within excavations supported by soldier pile and lagging SOE walls.

Roadway structures below the groundwater table would be supported by either slurry wall or secant pile wall SOE walls. The permanent construction of approach structures would either be continuous U-wall type, or would incorporate a roof to improve ventilation, reduce water accumulations and to better resist buoyancy. Cut-and-cover structures would be similar, except with backfill on the roof. The structure would be designed to resist hydrostatic uplift pressures by using self-weight of the structure and the (buoyant) weight of any backfill. Use of tiedowns is precluded by the saline groundwater condition, because the success of corrosion protection measures for tiedowns cannot be confirmed (Figure 20)

Both U-wall structures and cut-and-cover structures constructed within shale would require construction designed to resist lateral movement of shale resulting from stress relief.

See Appendix E for a more extensive discussion of SOE wall types, permanent construction types and buoyancy resistance.

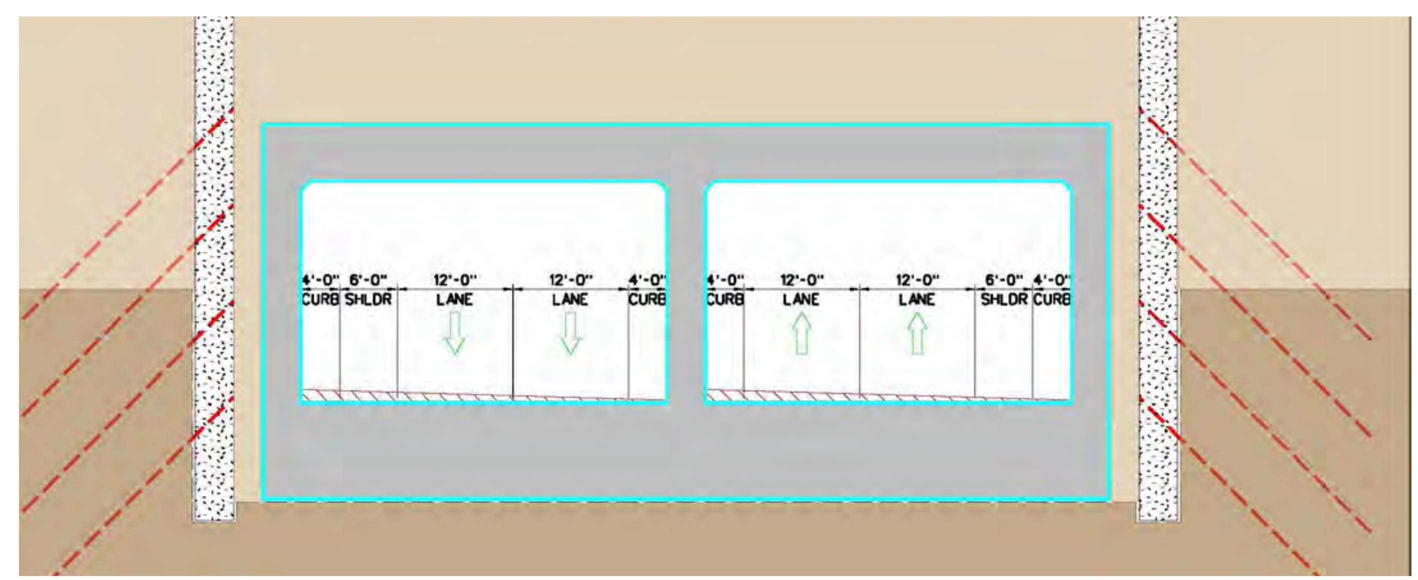


FIGURE 20: Cut-and-Cover Tunnel (with support of excavation system, prior to backfilling)

3.3.2 TUNNEL BORING MACHINE—MINED TUNNEL CONSTRUCTION

Mined tunnels would be constructed by earth pressure balance TBMs. To accommodate two lanes of traffic plus shoulders in each direction either a single bi-level tunnel can be constructed, or two parallel tunnels. The single tunnel would be approximately 57 feet in diameter. A far more common use on tunnels throughout the country, are approximately 44 feet in diameter for two parallel tubes (Figure 21).

Mined tunnels would be designed to resist vertical and horizontal earth pressures and hydrostatic pressures. As discussed for U-wall and cut-and-cover structures constructed within shale, tunnel lining segments would be designed to resist lateral movements of shale resulting from stress relief. Compressible annular grout could be used to reduce the resulting loads on the tunnel. The tunnels would be lined with precast, gasketed liners. Internal structures would be a combination of cast-in-place concrete and precast concrete panels. See Appendix E for a more extensive discussion of mined tunnel design and construction.

3.3.3 CROSS PASSAGE CONSTRUCTION

Cross passages would be required on twin bored tunnel alternatives (see Section 3.5.4). This would conform to the requirements of NFPA 502, and are anticipated to be spaced at 600 feet centers. Some cross passages would be constructed in shale, others would be constructed in soil

Cross passages in rock would be excavated using one of three possible excavation methods:

- Mechanical excavation
- Excavation by expansive chemical agents placed in drill holes
- Controlled blasting

Excavation crowns would be supported by a combination of rock reinforcement and welded wire fabric to prevent fallout and possible buckling of the rock in the roof as a result of high horizontal stresses. A cast-in-place concrete lining would be constructed within the stabilized excavation.

Cross passages in soil are expected to be constructed in glacial outwash sands and gravels or glacial lake clays. These soils would require stabilization by either jet grouting or ground freezing to permit excavation. The excavation would be supported by the stabilized ground. A cast-in-place concrete lining would be constructed within the stabilized excavation.

3.3.4 SPOIL (AKA "MUCK")

Tunneling operations require the removal of large quantities of material starting at the open cuts, through the cut-and-cover operations, the TBM mining operations as well as the cross passages. The considered tunneling options would each generate large total volumes of spoil greater than half a million cubic yards, but the volume would be spread out over the many months of tunneling operations. Efficiently handling, temporarily storing, removing and transporting from the site and disposing of the spoil (also referred to as "muck") will be key to successful tunneling operations. The project site—with easy access to highways and with several landfills, quarries and sand and gravel operations within 30 miles—suggest that there would be multiple options available for disposal sites.

See Appendix E for more discussion regarding muck disposal.

3.3.5 STRUCTURAL DURABILITY

Saline groundwater conditions and the use of highway deicing salts would require low permeability concrete mixes using low water/cement ratios and pozzolanic additives such as fly ash or blast furnace slag. Corrosion inhibitors such as calcium nitrite could be added to the mix. Concrete cover over exterior and interior reinforcement would need to be at least 3 inches, and potentially more. Epoxy-coated rebar or galvanized rebar should be considered for additional corrosion protection. A cathodic protection system could be cost effective, either to install from the outset, or for electrical continuity of rebar to be provided for potential later retrofitting should corrosion rates become problematic. Waterproofing membranes and design to limit cracking are other important measures. Such precautions are typical in marine environments. See Appendix E for a more detailed discussion on durability and corrosion control.

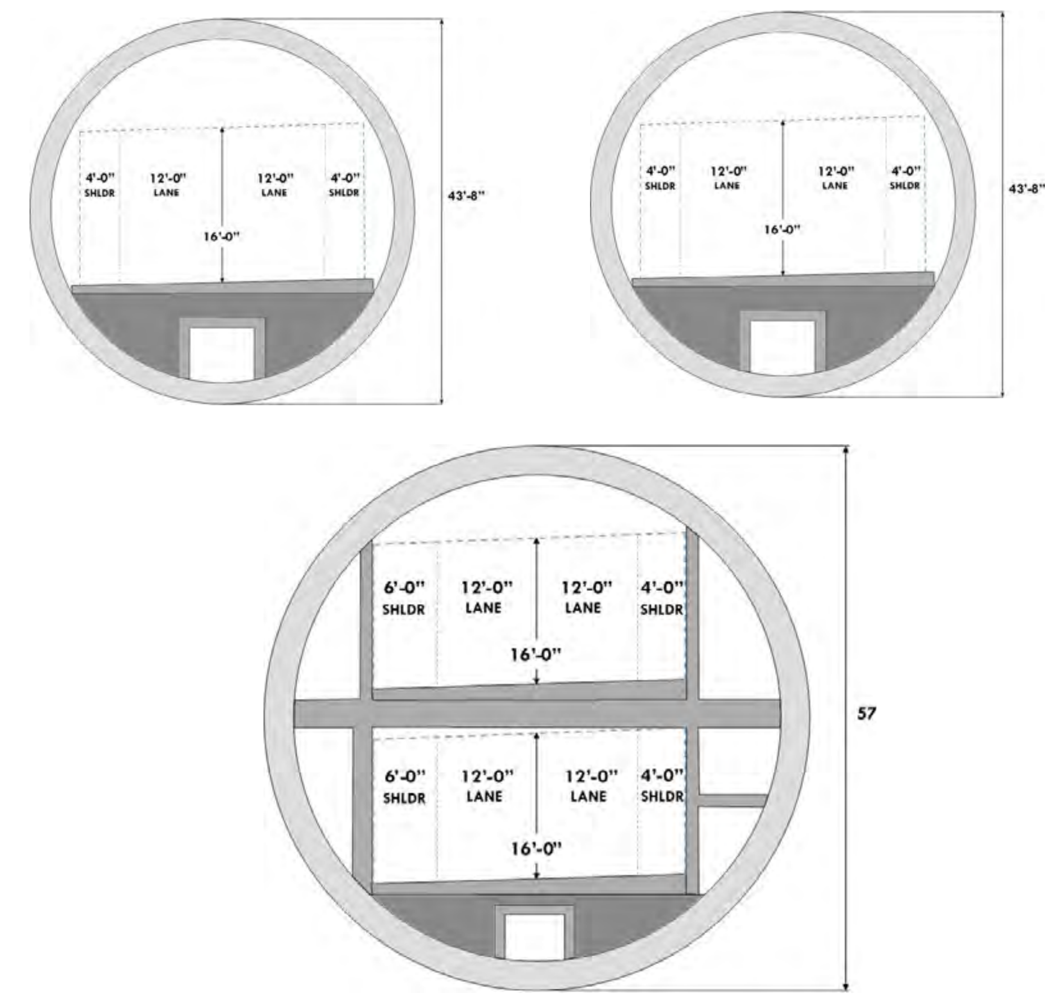


FIGURE 21: Twin Bored Tunnel (top), Single Bi-Level Bored Tunnel (bottom)

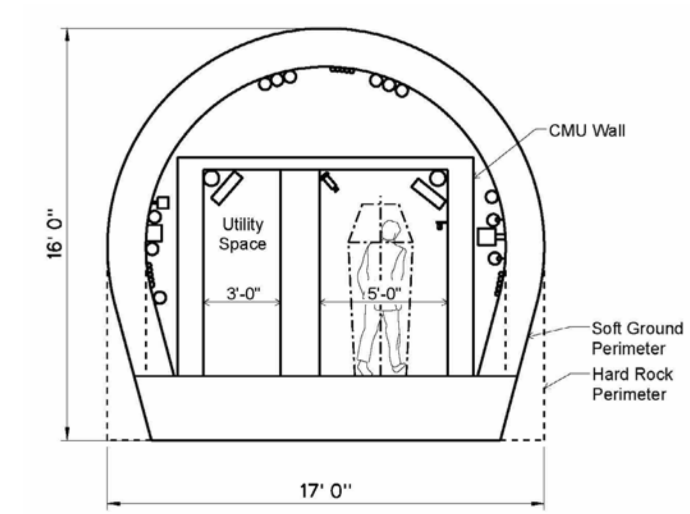


FIGURE 22: Typical Cross Passage Construction

3.4 VIADUCT DESIGN & CONSTRUCTION

3.4.1 RECONSTRUCTION AND MODIFICATION OF EXISTING I-690 VIADUCT

The existing I-690 viaduct has been documented to have a significant number of non-standard and non-conforming geometric features. Elements such as sight distance, shoulder width, lane width, grades, and ramp spacing are typical features that are either non-standard or non-conforming and have been contributing to safety and level of service issues within the stretch of I-690 from West Street to Almond Street. This section of the interstate—where I-690 was constructed in an "s-slalom" manner where it merges with I-81—is on the viaduct for the entire stretch along with various on- and off-ramps. All alternatives presented in this report have considered both the existing geometry of the viaduct along with the reconstruction of the viaduct required to accommodate the new tunnel alternative.

As described in Chapter 5, all the alternatives selected for further evaluation have some degree of connectivity design elements as it relates to the I-690 viaduct. The baseline assumption for all tunnel alternatives considers the work to reconstruct the I-690 viaduct to address non-standard and non-conforming design elements as an additional option that is not related to the tunnel alternative except where specifically noted otherwise.

Reconstruction of the I-690 viaduct in combination with tunnel construction would offer benefits. The reconstructed viaduct would be designed in a manner to addresses non-standard and non-conforming features, thus improving both the safety and level of service of the highway and its various ramp connections. Additionally, reconstruction would benefit the constructibility of the tunnel alternative in some cases. Each alternative would have unique impacts on the I-690 viaduct. Many of the alignment alternatives would require I-81 ramps to connect into I-690. In some alternatives, this could require significant reconstruction of I-690, whereas in other local modifications it could be sufficient.

- The Red Alternative would pass underneath the existing viaduct at a depth that would minimize impacts to local sections/spans of the existing viaduct. Local modification or protection could be required for the mainline and adjacent ramps. Reconstruction of the I-690 viaduct to address non-standard and non-conforming issues would depend on the tunnel alternative.
- The Orange Alternative would create a significant conflict with the existing I-690 viaduct since it would locate the portal in a location that would permit I-690 thru traffic to be captured by the tunnel. Significant staging and modifications to existing structure would be required to accommodate this alternative. Reconstruction of the I-690 viaduct would be required to allow construction of this alternative, and would also address other existing deficiencies. Additionally, reconstruction of the I-690 mainline near West Street would provide additional ramp connections between I-690 and I-81.
- The Green Alternative would have little impact on the mainline I-690 viaduct since the tunnel would rises above ground near Washington Street. Significant staging and reconstruction of I-81/I-690 ramps would be required for this alternative. Reframing of existing support structures could be required. Figure 23 shows an example of reframing of the I-84 viaduct in Hartford, Connecticut. On that project, existing crossheads were partially encapsulated inside a new extended crosshead. New columns were located outside the footprint of a new busway being constructed below. Reconstruction of the I-690 viaduct mainline to address non-standard and non-conforming issues would depend on the tunnel alternative.
- The Blue Alternative would replace the West Street interchange, passing through I-690 west of the viaduct; there would be no impact to the existing viaduct.
- As a side benefit, the tunnel alternatives would improve the visual impact of I-690 viaduct on neighboring areas through reconstruction. The elimination of the I-81 viaduct through tunnel construction would eliminate the need for portions of the I-690 viaduct to flyover portions of I-81 to facilitate connections.
- While it would be feasible to partially demolish these unnecessary connections, reconstruction of I-690 could be accomplished in a manner that reduces the overall height of the viaduct in some areas by nearly 15 feet. Aside from Green Alternative, all tunnel alternatives would permit reconstruction of I-690 in a reduced height manner. However, only the Orange Alternative would require this reconstruction.

3.5 TUNNEL SYSTEMS

The specific requirements for the systems and elements necessary to meet the fire protection and life safety goals for any of the tunnel alternatives being considered should be based on the minimum requirements established in National Fire Protection Association (NFPA) 502 Standard for Road Tunnels, Bridges, and Other Limited Access Highways.

The document is a standard and not a legal code requirement unless explicitly called out in the relevant fire code. Most jurisdictions, authorities, and agencies, at a minimum, adopt NFPA 502 as a guideline. NFPA 502 has been followed to develop the requirements for the I-81 tunnel option.

Each of the alternative tunnel options being considered for I-81 would require a variety of operational systems and features within the tunnel to support safe traffic operations and to provide the necessary level of fire protection and life safety. The various tunnel systems and features that would be required include the following:

- Tunnel ventilation
- Fixed firefighting system
- Emergency egress
- Tunnel drainage
- Tunnel fire protection
- Electrical system
- Traffic control system
- Tunnel finishes
- Tunnel lighting
- Operations and maintenance

Each of these systems is described in detail in Appendix F, and is summarized in the following sections.

3.5.1 TUNNEL VENTILATION

Ventilation is required for normal operations (management of vehicle emissions) and emergency operations (management of smoke). A key requirement in NFPA 502 is the provision of tenable conditions for egress and facilitation of conditions for firefighting. Achieving these goals relies on ventilation, means of egress and fire control. Ventilation is particularly integral with fire-life safety because it is essential to smoke management.

The likely applicable ventilation options for the various tunnel alternatives being considered herein for I-81 includes a longitudinal system using in-tunnel jet fans (Figure 23), a semi-transverse point exhaust using

FIGURE 23: Modification of I-84 Support Bents for Busway, Hartford, CT

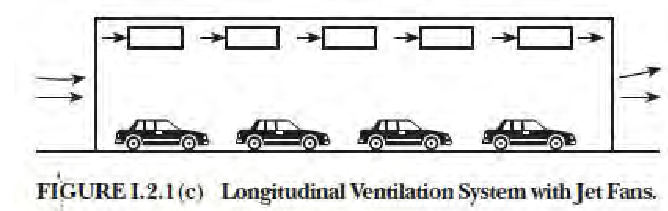


FIGURE 24: Jet Fan System (from NFPA 502)

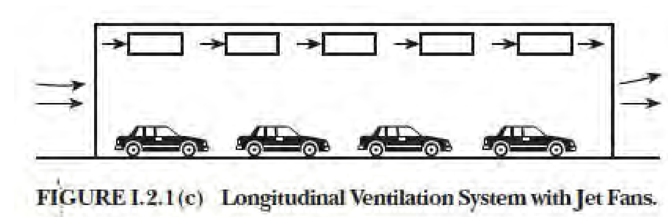


FIGURE 25: Semi-traverse Point Exhaust System (from NFPA 502)

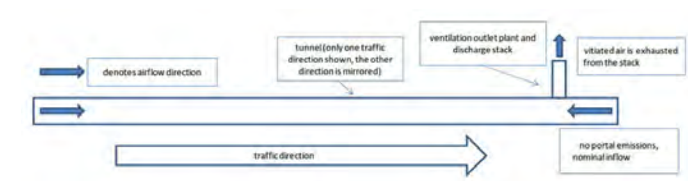


FIGURE 26: Point Exhaust Ventilation

a duct and operable dampers (Figure 24), or possibly a combination of a longitudinal system with point exhaust prior to the exit portal (Figure 25).

A longitudinal ventilation system using jet fans is considered the most appropriate option for the basis of the four study alternatives because:

- It is the most efficient system for tunnels designed for unidirectional traffic.
- It has the least impact on size of the tunnel compared with options that use exhaust ducts.

Portal emissions and achieving air quality compliance in surrounding areas would be critical with a longitudinal system. For the longer tunnel alternatives, use of a longitudinal ventilation system could cause emission levels from the tunnel portals to exceed allowable levels. An ambient air quality analysis of the emissions from the tunnel portals would be necessary with respect to any sensitive receptors in the surrounding areas near the exit portals. This ambient air quality analysis would need to incorporate the expected tunnel traffic on an hourly basis, the subsequent vehicle emissions, the expected airflow in the tunnel, and the impact of external meteorological conditions.

Emissions from the tunnel portals and achieving air quality compliance would be a critical design matter. If an acceptable level of air quality cannot be achieved then ventilation buildings at each portal could be required to exhaust and disperse vitiated air away from sensitive receptors. In the case of the longer tunnel alternatives, use of a longitudinal ventilation system could cause emission levels from the tunnel portals to exceed allowable levels. In this instance, a ventilation scheme where vitiated air is exhausted just before the exit portal and ejected via a tall vertical stack may be required.

Given the length of the tunnel options being considered, and examples of current practice in similar tunnels, a point exhaust system would likely be needed for the Red, Blue and Green Alternatives, and possibly the Orange Alternative. (At present, it has been assumed that this alternative would not require portal point exhaust.) The necessary ventilation and environmental analysis would be conducted to determine whether a portal point exhaust system would be required, or to determine a suitable air quality management approach. If an exhaust system is required, it would need ventilation buildings to house equipment at both tunnel portals as well as a large vertical stack to discharge vitiated air. Note that jet fans would still be required with or without this point exhaust.

There would be less available vertical clearance for a single bore tunnel with a stacked road deck, especially on the lower deck. The resultant space for the ventilation equipment would tend to be at the sides of the tunnel. Space proofing and ventilation analysis would be required to determine if jet fans can fit into the space. If sufficient space were not available, the space could better serve as a ventilation duct for a point extraction system option since space limitations could still exclude use of jet fans. This would need to be studied at a more detailed design phase. At present, it has been assumed that a ducted exhaust system and supporting building infrastructure would be provided.

3.5.2 FIRE PROTECTION SYSTEMS

Standpipe systems provide a water supply to remote locations within a facility for use by firefighters. Standpipes are considered a manual system that allows firefighters the ability to connect hoses to the system at locations where needed to fight the fire. A dry standpipe system would be appropriate for a road tunnel in Syracuse because of seasonal freezing conditions.

A fixed firefighting system (FFFS) is recommended for the I-81 tunnel alternatives described herein. The most commonly used type of fixed firefighting system for road tunnel application is an open-nozzle deluge type. This type of system would be the least complex and would consist mainly of a water supply main connecting to a series of deluge valves that each would serve to activate the system over only limited section of the tunnel. Upon activation, the deluge valves would allow water to flow through the normally "dry" distribution piping over the roadways and then discharge onto the fire site through the open nozzles. When designed and used properly, an FFFS can greatly reduce the life safety risk and property risk posed by a tunnel fire.

Based on the lengths of the four tunnel alternatives, it is recommend to include both a standpipe system and a fixed firefighting system in any selected alternative.

3.5.3 TUNNEL LIGHTING

The tunnel lighting system provides the required illumination so that a motorist can safely navigate and maintain speed while in a tunnel. This objective must be met during daytime, nighttime, and during an emergency. Daylight conditions require high levels of illumination at the entry portal avoiding the "black-hole" effect. Nighttime levels are significantly lower and consistent throughout the tunnel. During an emergency, light levels are maintained at the nighttime level to allow for egress.

It is recommended to use light emitting diode (LED) fixtures throughout the tunnel and egress facilities.

3.5.4 EMERGENCY EGRESS

NFPA 502 establishes emergency egress requirements from road tunnels, which requires emergency exits spaced at a maximum distance of 1,000 feet. For US road tunnels, the spacing requirements are typically closer together, in the order of 600 feet. The minimum egress path width is 44 inches (3.7 feet). Fire rated doors are required to separate the egress pathway from the tunnel. Sliding egress doors are typically used for cross passageways to allow for bidirectional egress travel. Suitable emergency signage, lighting, and pressurization are also required.

Access to the emergency exits would be provided at roadway level. Many road tunnels also provide a walkway for maintenance and responder access. This walkway is typically elevated 2 feet to 3 feet above the roadway with a handrail and a width in the order of 3 feet to 4 feet. It is proposed to provide such a walkway in the I-81 tunnels.

Options for the arrangement of emergency exits in road tunnels varies, based primarily on the tunnel configuration. For the tunnel alternatives considered herein, the following are the most likely options for emergency egress:

- In a single bore stacked tunnel, each roadway level can provide an egress pathway to safety in the other (non-incident) traffic level. To accommodate for this, stairway egress connections between the two traffic levels would be necessary. The stairways can be configured within the ancillary space at the side of the bore. In these cases, areas for wheelchairs or non-ambulatory persons would be required.
- In a twin bore version, twin parallel bores are placed adjacent to each other, with mined cross passages provided between them at intervals. If the twin bores cannot be constructed at the same level, short lengths of stairs would be required. In these cases, areas for wheelchairs or non-ambulatory persons would be required.

FIGURE 27: Single Bi-level Tunnel with Jet Fan Installation

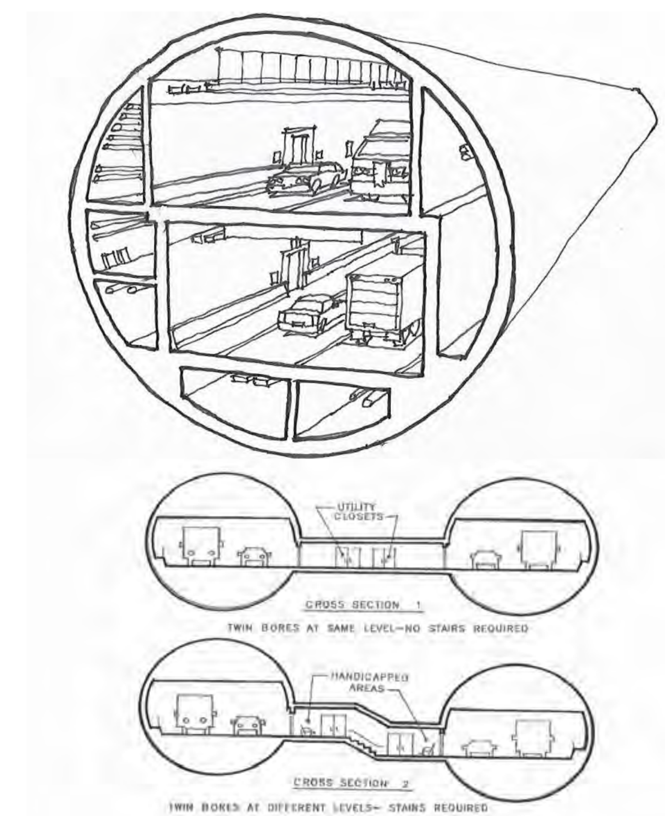


FIGURE 28: Bored Tunnel without Egress Corridor (Top) and Twin Bored Configurations with Cross Passages (Bottom)

3.5.5 TUNNEL FINISHES AND FIXED SIGNAGE

Tunnel finishes, which are further described in Appendix F, typically coordinate with various roadway and tunnel elements, including lighting, architectural appearance, cleaning, and fireproofing.

Fixed signage other than highway signage directs motorists, maintenance workers and first responders to emergency exits, cabinets, standpipe valves and similar elements.

3.5.6 ELECTRICAL SYSTEMS

Each of the tunnel alternatives identified herein for the I-81 corridor through Syracuse would require a variety of electrical systems to support safe traffic operation. The required installation methods and performance criteria of these various electrical systems for road tunnel application have been generally defined in within applicable codes and standards including NFPA 502 and the National Electrical Code. The required tunnel electrical systems include the following:

- Power distribution
- Fire alarm and detection
- Emergency communications
- Security
- Supervisory control and monitoring (SCADA)

3.5.7 TRAFFIC CONTROL

Roadway tunnels are required by NFPA 502 to be provided with a means to control traffic within the tunnel, as well as traffic on the approach roadways leading into the tunnel. These systems are necessary to control traffic within the tunnel or to prevent vehicles from entering the tunnel in the event of a traffic incident or emergency and also for tunnel maintenance. Traffic control systems would be required for each of the I-81 tunnel alternatives. The types of traffic control systems and devices likely to be required include the following:

- Automatic Incident Identification, based on an intelligent, programmable closed circuit television (CCTV) video stream
- CCTV for general surveillance is typically monitored from a dedicated tunnel operations control center.
- Dynamic (Variable) message signs are typically provided in the tunnel and tunnel approaches at regular intervals above the travel lanes to display instructions and emergency messages to motorists.
- Lane use/control signals are typically located along the tunnel walls or ceiling, and over the roadway at the tunnel portal approaches, at regular intervals to indicate the status of each travel lane as either opened or closed.
- Over-height vehicle detection/protection

3.5.8 DRAINAGE

Tunnel drainage systems normally consist of two independent systems: a stormwater control system and a tunnel drainage system.

Stormwater control systems are required at the tunnel portals to intercept stormwater flows that accumulate on the open approaches and transition roadways leading into and out of the tunnel. A separate tunnel drainage system, designed to be independent of inflow from sources outside the tunnel, is required to collect and discharge water and effluents generated within the tunnel. These effluent flows result from tunnel washing, use of fire suppression systems, vehicle carryover, and some groundwater seepage. The tunnel drainage system must also be designed and equipped to accommodate a potential fuel spill.

The profile of the selected tunnel alignment would dictate the location of the tunnel drainage pumping station since the drainage collection would need to occur at the lowest point in the roadway profile.

The stormwater collected at the tunnel portals is considered to be clean and therefore does not require special treatment prior to discharge. However, the tunnel drainage effluent could require some form of pre-treatment prior to discharge depending on local permitting requirements.

3.5.9 OPERATION AND MAINTENANCE

A dedicated and well planned tunnel operations and maintenance program is necessary to ensure a safe, well maintained, and reliable tunnel facility that maximizes public safety and roadway availability. Each of the various tunnel alternatives discussed in this report has an inherent requirement for a tunnel Operations and Maintenance Plan that fully considers the future operations and maintenance needs of the facility and adequately identifies all ancillary facilities, operating systems, infrastructure, staffing, maintenance equipment, and related items necessary to operate and maintain the facility.

Ancillary facilities that would be required to support operation of the tunnel alternatives considered herein would include provision of an operation and control center for tunnel operations staff who would be responsible for the operation and monitoring of the mechanical, electrical, and traffic control systems on a 24/7/365 basis.

Maintenance related facilities could include maintenance shops, garage facilities, and other storage spaces to house equipment and spare parts that are needed to maintain the tunnel. Appropriate maintenance requires a mix of personnel, including electricians, mechanics/millwrights, and general maintenance staff to maintain the facilities and various systems, support traffic control measures and respond to traffic incidents.

A significant level of planning and coordination is required to operate and maintain a major road tunnel facility. An Operations and Maintenance Plan consists of the various incident and emergency management plans, maintenance management plans, and operational procedures determined to be necessary for safe and efficient operation and maintenance of the tunnel facility.

During the planning and feasibility stage of a major urban road tunnel project such as the I-81 corridor it is important to consider the Operations and Maintenance Plan so the project design accounts for all of the facilities, infrastructure and other items needed to support the operation of the facility. The development of a Concept of Operations Report serves as the first step to developing the basis of the Operations and Maintenance Plan. The Concept of Operations Report provides a basic understanding of how the facility must function in relation to the overall road network and identifies the individual agencies, entities and other stakeholders dependent on the overall successful operation of the facility. The Concept of Operations Report summarizes the key decisions and operating policies established during the planning and design phases of a road tunnel project, and also serves as a basis to develop the actual operating procedures to be implemented within the Operations Plan portion of the Operations and Maintenance program.

3.6 CONSTRUCTION STAGING AREAS

Various construction staging areas would be required for materials, equipment, and personnel. The location of these would depend on various factors, including the availability of open space (or usable space), proximity to the work, ease of access for trucks, and distance from residential neighborhoods. Temporary easements would be required for staging areas located on private property.

The main construction staging areas are generally expected to be as follows:

- Southern tunnel portal
- Northern tunnel portal
- I-81 viaduct demolition and Almond Corridor reconstruction
- I-690 reconstruction (primarily for the Orange Alternative)
- West Street (Blue Alternative only)

One of the portal staging areas would be used to launch the TBM, handle bored tunnel spoils, and store precast tunnel segments. In general, this is expected to be the southern portal, but could be at the northern portal for the Blue Alternative due to greater availability of space.

Most staging areas would require parking areas for the main contractor and subcontractors, construction manager, and NYSDOT. Office trailers, change house, warehouses, electrical substation, mechanical/electrical shops, and equipment storage yard are likely to be required. The TBM launch site would require segment storage, crane, muck storage piles/silos, truck waiting/turnaround area plant. Portal staging areas would, most likely, require space for tying and storing rebar cages. Staging areas would likely be close to residences or businesses. They would require fences, silt control fences, wheel wash facilities, noise barriers, security, and lighting. Location maps of potential staging areas for each option are shown in Appendix E.

3.7 UTILITIES

Utility investigation and identification would be important to the design phases of this project. Maintaining active utility services without community disruption would be a crucial component. Cut-and-cover structures would have particular impact on utilities, requiring re-routing and alternative utility connections. Maintaining the major utilities around the university steam plant would be a significant requirement.

Preliminary utility investigations have identified some of the major utilities at the portals, and along Almond Street. These are described in Appendix I, and are summarized for each alignment in the following sections.

3.8 PROPERTY IMPACTS

3.8.1 OVERVIEW

Reconstructing an interstate highway through an urban area results in property impacts. A goal of this study is to minimize those impacts. This has been achieved by various methods, including selecting tunnel alignments and profiles that avoid structures, and using TBMs where possible. Cut-and-cover structures and tunnel approach structures would be located to minimize impact to existing buildings. Potential property impacts arising from the four alternatives have been identified, as described below, and summarized in Appendix J.

3.8.2 CUT-AND-COVER/OPEN-CUT TUNNELS

Where possible, tunneling would use TBM technology to minimize surface disruption. However, where the tunnel becomes shallower than approximately half the tunnel diameter, TBM tunneling is no longer feasible, so cut-and-cover construction would be required, which would require surface structures within the path of the cut-and-cover tunnel to be removed. While it is technically feasible to move some buildings, this is an extreme measure that is rarely enacted.

3.8.3 BORED TUNNELS

Large diameter TBMs, such as those proposed for the I-81 project, generally provide excellent control of surface settlement. All projects reviewed (Appendix N, and others) generally maintained surface settlement to less than half an inch. Settlement would likely be sufficiently small to be unmeasurable along much of the alignment. There could be occasional areas where larger settlement occurs, which could be significantly larger. Larger settlement could arise from encountering unexpected ground conditions or manmade obstruction, TBM breakdown, or operator error. Larger settlements are typically more common near the start of a tunnel drive during the "learning curve" from operating the TBM. Where alignments pass through a mixed face of rock and soil, higher settlements could occur. Tunneling though shale should present a low risk of settlement provided that shale is present above the crown.

Existing structures above or adjacent to the tunnel drives would need to be individually evaluated to determine the sensitivity to settlement. Most buildings can tolerate some settlement. However, historical structures, tall brick or stone structures, and structures with sensitive equipment (such as hospitals) could have a low displacement tolerance.

The proposed alignment alternatives would avoid tall buildings and sensitive structures, where possible.

Sensitive structures can be protected in a number of ways, including structural modifications, structural underpinning, ground treatment (such as jet grouting), cutoff walls (such as secant pile walls installed between the path of the TBM and the structure), and compensation grouting (where grout is injected below a structure through an array of pipes to intercept displacement before it reaches the structural footings). These measures are generally expensive, and the cost of such protective works must be weighed against the risk and impact of settlement.

3.8.4 METHODOLOGY FOR ASSESSMENT OF PROPERTY IMPACTS

The methodology to assess property impacts for each alternative consisted of the following:

- Determine the limits of property impacts associated with each alternative.
- Identify the affected parcels.
- Collect affected parcels data.
- Create impact assessment
- Value Assessment of Impacted properties

Appendix J presents additional detail on the methodology. A table summarizing the land use of all affected properties, under each of the four alternatives is provided in Chapter 5. Each table provides estimated needs for easements, partial fee acquisitions, and full fee acquisitions and estimates the costs for total fee takings per alternative.

- Temporary Easements
  - Temporary easements for the above classes of structures should extend 30 feet beyond the exterior of the SOE wall to accommodate temporary tieback installation.
  - Additional temporary easements would be required during construction for offices, storage, and laydown areas.
- Permanent Easements would be required for mined tunnels, cut-and-cover tunnels, open approach excavations and depressed roadways. These are primarily expected in areas where the bored tunnel would be located at significant depth.
- Partial Fee Acquisitions would be required for cut-and-cover impacts that would significantly affect the future use of the property.
- Full Fee Acquisitions would be required where the amount of taking would essentially render the remaining property without value, at least during construction. This would occur in areas of cut-and-cover construction or above-grade construction, and would include areas where tunnel construction requires demolition of an occupied structure.

3.8.5 CONSTRAINTS IMPOSED BY THE COMPLETED TUNNEL ON FUTURE DEVELOPMENT

The tunnel project would allow the existing viaduct structures to be demolished, removing a divisive barrier from the heart of Syracuse. Urban renewal around the Almond Street corridor is anticipated, with the potential for numerous new structures to be constructed. However, the Red, Orange and Green Alternatives would require tunnels to be constructed under these developable lots. The Blue Alternative would also pass under developable lots to the north, south and west of downtown. The tunnel would impose some constraints on future development, due to restrictions on foundation depth and due to the weight of the buildings acting on the tunnel structure.

As described in Appendix J, preliminary analyses have been performed to assess the impact of overbuild on bored tunnels. Spread footings and piled foundations were assessed, using simplified analytical methods. The analyses examined stress increases on the tunnel due to new construction above. It was assumed that the tunnel would be designed to accommodate a 30 percent increase in stress due to future overbuild.

It is estimated that two-story buildings would have essentially no impact on the tunnel. For soft ground, it is estimated that if the crown of the tunnel were 30 feet below grade, a five-story building could be constructed on spread footings. At 40 feet cover, the permissible building height would increase to ten-stories, and at 60 feet cover, 20-story builds would be permissible.

Where the tunnel is entirely within rock, piled foundations are assumed to transfer loads to the pile tips. Ten-story buildings could be constructed where the crown of the tunnel is at least 36 feet below the surface and 16 feet below the pile tips founded on rock. Twenty-story buildings could be constructed where the crown of the tunnel is at least 66 feet below the surface and 46 feet below pile tips founded on rock. If the tunnel is deeper, the influence of a building on the tunnel would be reduced.

If buildings are required above or adjacent to the tunnel, and the load on the tunnel would be too great, longer piles could be sleeved to below the invert of the tunnel. Transfer beams or trusses could be required within the building to offset load paths from the superstructure to the foundations.

Cut-and-cover structures could be designed to accommodate overbuild structures of 10 or 20 stories, or more. This can generally be accomplished with minimum premium because if soil is removed from the roof (to create basements), the weight reduction would offset the increase in weight due to superstructure loads. Clearly, the impact of load on individual footings, buoyancy during construction, and other conditions would need to be evaluated.

Indications of potential significance of these overbuild constraints for each of the four tunnel alternatives are provided later in this report.

4 COMMUNITY GRID CONSIDERATIONS

4.1 BACKGOUND AND PURPOSE

The Almond Street corridor and its intersecting streets would need to be reconstructed under any of the tunnel alternatives investigated in this study. This corridor is very important to the City of Syracuse and the region since it serves local and interstate traffic and provides connections to anchor institutions, commercial uses and other major employers in downtown Syracuse. It is also a highly visible component of the I-81 Project in downtown Syracuse (as opposed to the subgrade tunnel), and therefore requires more attention with respect to aesthetics and interaction with adjacent land uses.

The I-81 Viaduct Project Scoping Report looked at two alternatives that examined converting the Almond Street corridor into a major urban arterial. The Community Grid Alternatives are CG-1 (Boulevard) and CG-2 (Almond Street and Other Local Street(s)). CG-1 was dismissed for further study due to concerns about concentration of traffic flow along one corridor. CG-2 was recommended for further consideration in the DEIS as an alternative that optimizes the use of existing streets and disperses traffic through the network.

The community grid discussed in this Independent Feasibility Study was derived from the community grid concept defined in the DEIS. It is a separate set of interventions recommended for surface streets in downtown Syracuse to improve connectivity and mobility under each tunnel alternative. The community grid is of particular importance when discussing the replacement of a segment of I-81 with a tunnel, because a tunnel would limit the number of feasible connections that could be made between the highway and surface streets. The community grid would play the role of redirecting traffic and providing access at new locations.

The addition of a tunnel and the removal of existing viaducts in downtown Syracuse would change the traffic dynamics between interstate highways and local destinations. The general makeup of the vehicular demand would include local to local, local to regional, and regional to local trips. Various alternatives could have an impact on the percentage of each of these categories, but generally all three would need to be accommodated. A set of community grid recommendations for each tunnel alignment is an essential component of the discussion of an alternative.

Replacing the I-81 viaduct with a tunnel would allow the surface street network to operate more efficiently in some areas. This is especially true where local streets that were previously severed by the elevated highway infrastructure could be reconnected. New pedestrian and bicycle crossing could be incorporated and access would be improved. A more efficient urban street system would then take shape, allowing greater distribution of vehicular traffic, new route opportunities for pedestrians and bicyclists, and an upgrade of existing corridors such as Almond Street and Erie Boulevard. These roadway upgrades include eliminating non-standard intersections, increasing capacity, and eliminating existing bottlenecks like the ramp interchange at Harrison Street.

Removing the I-81 viaduct would free a large amount of land within the existing right-of-way for potential redevelopment and street improvements, including pedestrian and bicycle infrastructure, transit facilities, landscape, and street furniture. As a physical and visual barrier, the viaduct has likely constrained the development potential for properties adjacent to the structure. The land use pattern could evolve over the long term by removing the viaduct and introducing more connectivity.

4.2 GUIDING PRINCIPLES

The following principles were developed to guide the development of community grid design concepts. They are a series of goals and objectives that state priorities related to urban design and traffic considerations along the Almond Street corridor, which were derived from the I-81 Viaduct Scoping Report, studies by the American Institute of Architect's New York chapter, and best practices in urban design and traffic engineering.

- Enhance mobility and accessibility of Almond Street and its intersecting streets:
  - Improve connectivity for motorized and non-motorized traffic.
  - Enhance system capacity in absorbing and dispersing traffic.
  - Minimize turn prohibitions and provide adequate turn lanes.
  - Increase the number of through lanes where necessary.
  - Incorporate coordinated signals for optimal corridor progression (continuous flow of traffic at target speed).
- Provide equal accessibility to pedestrian, bicycles and cars:
  - Design signal timings to provide sufficient pedestrian crossing time.
  - Manage speed for increased safety.
  - Provide parking opportunities.
  - Incorporate bicycle lanes where feasible.
  - Minimize pedestrian crossing distance.
- Maximize economic development potential:
  - Maximize development potential.
  - Restore the urban grid to the extent possible.
  - Maximize land disposition opportunities.
  - Minimize property impacts.
  - Provide attractive streetscapes.

In addition to connectivity improvements, the reconstruction of the Almond Street corridor could substantially influence future economic development and urban design improvements in downtown Syracuse. Therefore, it was important to identify community grid treatments that restore urban block patterns and support urban land assembly and redevelopment. Equally important was maximizing the opportunity to free up land currently occupied by transportation infrastructure for disposal by the state.

The removal of existing interstate ramps would require vehicles destined for the central business district to divert their trip at least partially away from the highway system and instead use the surface street network to get to and from their destinations. Therefore, the community grid must be designed so that it could process this additional traffic demand. Typical treatments include turn lanes at major intersections and additional lanes to process throughput. Signal timing is also a critical component of the community grid. Allowing for the major street approaches to benefit from corridor progression while balancing the needs of side streets and pedestrian crossing times was a major goal in developing community grid options.

4.3 COMMUNITY GRID OPTIONS

4.3.1 APPROACH

Several design options were developed based on different priorities, such as optimizing mobility, increasing pedestrian accessibility, and maximizing redevelopment opportunity. These design options were then assessed with each tunnel alternative for their applicability and success in achieving urban design and traffic objectives.

4.3.2 KEY DESIGN AREAS

The most significant impact to the surface street network would occur along the existing viaduct between the south portal and I-690. In all the tunnel alternatives, significant change would be made to the connections between the southern I-81 and downtown (existing entrance and exit at Adams Street), the southern I-81 and I-690, and downtown and the northern I-81 (existing entrance and exit at Harrison Street). Removing the existing I-81 viaduct would also physically affect Almond Street by day-lighting the corridor and opening up a large amount of space within the existing right-of-way. This would lead to reimaging and reconstructing the Almond Street corridor. Therefore, the community grid options would focus on the area south of I-690 and north of the south portal

For purposes of this study, the community grid is divided into three focus areas (from south to north):

- 1. South Tunnel portal
- 2. Almond Street corridor
- 3. I-690/I-81 Connection to downtown Syracuse

The north portal area is not discussed here as a focus area for community grid consideration, since in most cases the north portal affects surface streets outside of the downtown. In each tunnel alternative, existing ramp connections between the northern I-81 and surface street would be accommodated with minor modifications. There would be little impact to the local street network or traffic pattern around the north portal area. The relocation or reconfiguration of connections near the north portal are discussed in Chapter 5 with each tunnel alternative.

The following sections discuss potential community grid design options for each of the key areas and their general application to different tunnel alternatives. Chapter 5 then ties the specific community grid design recommendations and implications to each tunnel alternative for a more comprehensive comparison between each alternative.

FOCUS AREA A: SOUTH TUNNEL PORTAL

The community grid design in the south tunnel portal area would include I-81 on- and off-ramps and modifying or closing existing surface streets caused by vertical street clearance requirements of these ramps. Another design focus would be configuring the first at-grade intersection after the ramps have touched down and merged into Almond Street (Figure 29).

The explored option related to the South Tunnel Portal confluence with the Almond Street corridor is described in detail below. This design could be combined with any tunnel alternative and I-690/I-81 interchange scenario.

As a tunnel begins its descent underground, ramps would be built to connect I-81 to the surface street grid by curving in close near the U-wall and touching down at Almond Street. The first signalized intersection would be located at Taylor Street. Optionally, turns from Almond Street could be prohibited south of East Adams Street to provide maximum capacity to the I-81 through movements. In this scenario, there would also be an opportunity to reconnect Monroe Street and expand the local surface street grid.

Martin Luther King Boulevard and Burt Street would be maintained under the new connection ramps. Van Buren Street would be realigned along the descending ramp to continue providing local access.

The connection between the south portal and Almond Street would be a transition zone between a highway and an urban street environment. The design of this segment should incorporate traffic calming and signage to help alert drivers to adjust their speed.

The first at-grade intersection could be designed as a gateway to downtown Syracuse with landscape features. Multiple exit lanes from the southern I-81 would enter this intersection from the south. Depending on the tunnel alternative, the number of lanes exiting from I-81 would range from one to three lanes. Turn lane(s) would be needed to help disperse traffic to the east-west cross-street. The intersection would be treated with features to facilitate traffic calming and safe pedestrian and bicycle crossing.

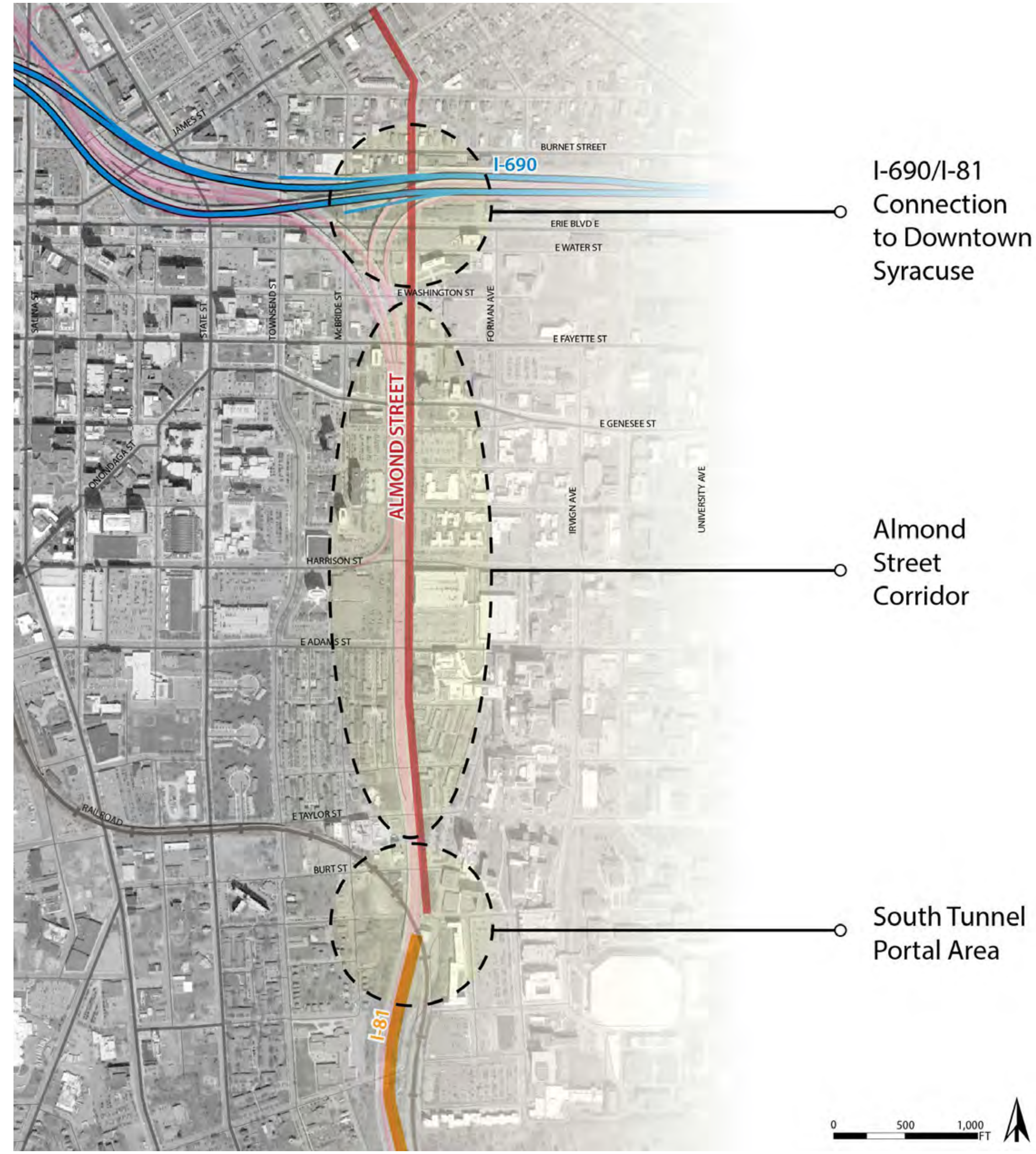


FIGURE 29: Community Grid Focus Areas

The specific configuration of this gateway intersection is discussed in Chapter 5 with each tunnel alternative.

FOCUS AREA B: ALMOND STREET CORRIDOR

The existing Almond Street corridor marks the eastern boundary of downtown Syracuse. It is one of the few undisrupted north-south thoroughfares in the eastern portion of the city. Under the scenario that I-81 would be relocated in a tunnel, the future Almond Street would become a more important corridor from both transportation and economic development perspectives.

A key component of the Almond Street corridor is the intended traffic distribution to local streets. In each tunnel alternative, Almond Street would play the role of a collector and distributor as well as a local street that serves surrounding properties.

Each of the explored options related to the Almond Street corridor in downtown Syracuse are described in detail below. All options can be combined with any tunnel alternative and I-690/I-81 interchange scenario.

- An Almond Street Boulevard that incorporates a frontage roadway would help separate vehicles making short distant trips from those making longer distance trips. Left turns would be prohibited from the frontage road, but all turns would be allowed from the mainline. Signalizing each intersection could be a challenge given the closely spaced intersections that would be formed along each side street as a result of the frontage road. The frontage road intersections themselves could be signalized or stop controlled. To provide additional capacity, it could be possible to grade separate one or more of the major intersections like Erie Boulevard to allow the bulk of the north-south traffic to flow unimpeded past primary east-west roadways; however, this would negatively affect adjoining cross-streets and properties. Each median between the frontage street and the mainline would be designed with a multiuse path and a tree-lined landscape strip. The pedestrian refuge on these medians at the intersection would reduce crossing distance (figure 30).
- A more traditional and streamlined option incorporates Almond Street as a consolidated roadway with turn lanes at each intersection and varying number of lanes in each direction, depending on the anticipated traffic volume. Compared to the boulevard option, this option would have a narrower typical cross-section and leave more width to the sidewalk and curbside public space. Grade-separated intersections could also be used in this scenario to gain additional throughput along the Almond Street corridor; however, this could be unfavorable from an urban design perspective (figure 31).
- A Hybrid Option that combines the two configurations mentioned above could be applied depending on the anticipated traffic volume of the tunnel alternative being studied. The boulevard cross-section could be applied to the southern portion of Almond Street near the connection ramps from the south tunnel portal, and the consolidated roadway cross-section could be applied to the northern portion of Almond Street where local access takes priority over traffic making long distance trips.

The application of the design options above are further discussed under each tunnel alternative in Chapter 5.

Figure 32 and Figure 33 show existing conditions and a rendered perspective of Almond Street at E. Genesee Street, respectively.

Figure 34 and Figure 35 show existing conditions and rendered perspective of Almond Street at Water Street, respectively.

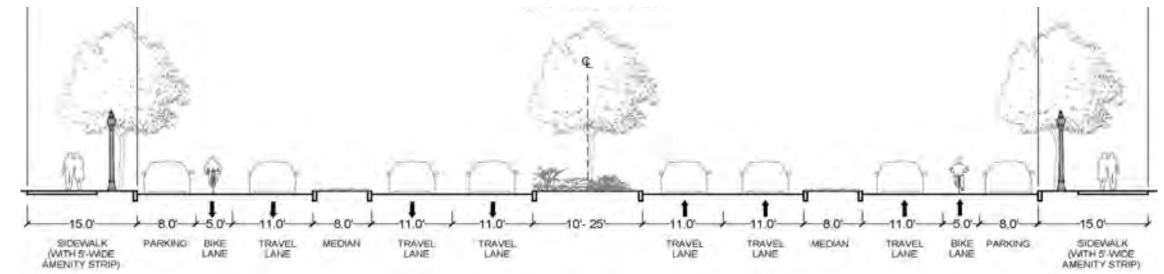


FIGURE 30: Illustrative Cross-Section of Almond Street Boulevard Scheme

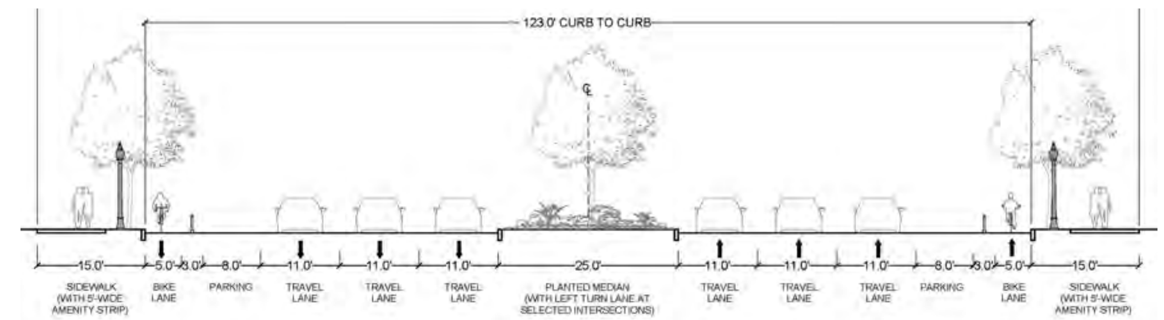


FIGURE 31: Illustrative Cross-Section of Almond Street Roadway Scheme

FIGURE 32: Almond Street & E. Genesee Street (Existing)

FIGURE 34: Almond Street & Water Street (Existing)

FIGURE 33: Almond Street & E. Genesee Street (Rendered Perspective)

FIGURE 35: Almond Street & Water Street (Rendered Perspective)

I-690 is an important connection between I-90 and the western suburbs of Syracuse. It also provides an alternative access route to and from southern I-81. Removing the I-81 viaduct would also remove the existing ramps that connect I-81 with I-690. Some of the I-690 connection ramps are more heavily used than others, and opportunities do exist to reroute a fraction of the traffic to other highways. The heaviest movements occur on the ramps connecting I-690 eastbound (EB) to I-81 southbound (SB) and I-81 northbound (NB) to I-690 westbound (WB). This is because access to downtown Syracuse from the northwest region is provided by these ramps coupled with the Harrison Street interchange. Options were explored to create new connections between I-690 and a new community grid in order to maintain access to downtown and the major trip generators located there.

Each of the explored options related to the I-690/I-81 connection to downtown Syracuse, coupled with the community grid design are described in detail below. The following design options except for the No Build Alternative accommodate all four connections between existing southern I-81 and I-690 through existing and proposed Almond Street and I-690 connections. All options can be combined with any tunnel alternative.

- A Single Point Urban Interchange (SPUI) would allow for a full interchange between I-690 and Almond Street using a single signalized intersection. Right turns would be made at unsignalized slip ramps separated from the main intersection. Pedestrian signals could be installed at the slip ramps consistent with previous NYSDOT application at I-87 Exit 6. This configuration would relocate both the existing I-690 WB off-ramp to Townsend Street and the McBride Street on-ramp to I-690 EB ramp to Almond Street, creating a full I-690 interchange. Pedestrian and bicycle crossing across the slip ramps would be challenging. With the SPUI interchange providing all four connections between Almond Street and I-690, the four existing ramps between southern I-81 and I-690 would be removed (Figure 36). This would free up parcels between Erie Boulevard and Fayette Street for higher intensity development. Although there are clear benefits to providing an SPUI, there are considerable urban design and connectivity drawbacks, including challenges to pedestrian and bicycle connections and the need for urban land to accommodate on and off-ramps.
- A Full Diamond Interchange on Almond Street would provide a similar level of access to downtown Syracuse than an SPUI would (Figure 37). However, it would require additional signalized intersections that would be closely spaced to each other and the adjacent intersections along Almond Street. This configuration would relocate both the existing I-690 WB off-ramp to Townsend Street and the McBride Street on-ramp to I-690 EB ramp to Almond Street, creating a full I-690 interchange. Compared to the SPUI option, the signalization of the intersection would provide safer crossing condition for pedestrian and cyclists. Ramps of the diamond interchange could also be constructed closer to the mainline than the SPUI interchange option. This geometry would have less property impact immediately adjacent to the interchange. Similar to the SPUI option, all four existing ramps between the southern I-81 and I-690 would be removed and give way to future development. The design of both interchange options mentioned above would lead to a reconstruction of a segment of I-690, providing opportunity for tightening the mainline and generating more developable parcels along I-690.
- A Split Diamond Interchange would retain the existing I-690 WB off-ramp to Townsend Street and the McBride Street on-ramp to I-690 EB ramp while creating two new ramps on Almond Street that provide access from I-690 EB and to I-690 WB (Figure 38). This type of interchange would help distribute traffic throughout the surface street grid more so than a full interchange on Almond Street and could help prevent an excessive amount of vehicular volume from turning Almond Street into a very large multi-lane arterial. The split diamond would limit the number of highway access points on Almond Street, which would increase pedestrian comfort and safety. The four existing ramps between the southern I-81 and I-690 would also be removed under this scenario.
- Another option would incorporate Fayette Flyover Ramps that connect I-690 to Almond Street, with a touchdown point of approximately Fayette Street. This option would create two new ramps in approximately the same location as the current ramps that connect I-690 EB to I-81 SB and I-81 NB to I-690 WB. The ramps would provide grade separation at Erie Boulevard, with significant benefits for traffic flow compared with the other options. However, the flyover ramps would continue to affect properties that are currently affected by existing ramps between southern I-81 and western I-690. The ramp structure would continue to be a physical and visual barrier. Fayette Street and the Fayette-Almond Street intersection would need to be reconfigured to accommodate traffic to and from the flyover ramps. However, pedestrian and bicycle traffic on Almond Street are less likely to be directly affected (Figure 39, Figure 40) .
- It is assumed that the existing I-690 WB to I-81 SB and I-81 NB to I-690 EB ramps would be removed. Traffic that currently uses the I-81 ramps to reach downtown would divert to through other exits, such as at Townsend Street and McBride Street.

The Fayette Flyover Ramps have been selected as the option for including in the cost estimate of each tunnel alternative.

See Appendix A and Appendix C for further information on the Fayette Flyover Ramps.

No additional interstate connectivity is also considered as an option. The existing I-690 WB off-ramp to Townsend Street and the McBride Street on-ramp to I-690 EB ramp would be retained, but no new ramps would be built. Instead, drivers looking to access I-690 or the Almond Street corridor would rely heavily on the few east-west corridors in the downtown area such as Erie Boulevard or the East Adams Street/Harrison Street one-way couple. This option would remove existing overhead ramp structures without introducing any new connection in this area. From an urban design perspective, this option would minimize physical constraints created by any highway structure and create more opportunity for filling the gap of urban fabric between downtown and eastern Syracuse.

FIGURE 36: Single Point Urban Interchange (SPUI)

FIGURE 37: Full Diamond Interchange

FIGURE 38: Split Diamond/Modified Diamond Interchange

FIGURE 39: Southern Connection to Community Grid (Rendering)

FIGURE 40: Elevated Ramp off I-690 (Rendering)

5 ALTERNATIVES

5.1 ALTERNATIVES CONSIDERED

Seven tunnel alternatives with various sub-options were considered. Highways in tunnels are “out of sight and out of mind,” compared with elevated, at-grade, or depressed alternatives. Removing some of the existing highway viaducts from the urban landscape and placing highways in tunnel would create conditions that promote urban renewal. However, for traffic to descend into a tunnel from a viaduct or other highway, a transition structure is required with sections that are either elevated, at-grade, or depressed. Minimizing any negative impact of these transition sections on downtown Syracuse while achieving the objectives for traffic flow were key considerations during the Independent Feasibility Study.

The two applicable tunneling methods would be cut-and-cover and bored tunneling. Bored tunnels would be constructed using TBMs. These machines can be operated to result in negligible settlement at the ground surface, which can allow tunnels to be constructed under existing buildings, streets and other infrastructure with minimal disturbance.

The bored tunnel alternatives were considered as either a single bi-level tunnel, or twin bored parallel tunnels. The general merits of each method are discussed in Section 3.3. Specific differences relative to each alternative are discussed in the following sections and in Appendix E.

Cut-and-cover tunneling involves excavating a trench that is wider than the highway. This requires most existing features within the footprint to be removed, which limits its potential in urban areas. Upon completion, the land over the tunnel roof can be be redeveloped. Cut-and-cover tunnel alternatives were studied along the existing interstate corridors and on certain nearby city streets. Limited additional sections of cut-and-cover tunnel were studied where such tunnels would be required for transitions into bored tunnels. In the following descriptions, the shallowest parts of the tunnel approaches are described as open-cut (which is equivalent to a depressed highway). These open-cut sections could be covered, with roofs extending above ground level, depending on the requirements for ventilation, snow removal and other considerations.

Two depressed highway alternatives were examined, both along the existing I-81 corridor. Depressed highways are structurally similar to cut-and-cover tunnels, but have no roof and could be at a shallower depth. The long-term impact on the urban landscape is typically worse than cut-and-cover tunnels since the highway trench reduces connectivity between neighborhoods, especially if the highway is too shallow to allow the existing street pattern to be maintained.

Each alternative includes a community grid. The community grid includes enhancements to streets along the existing I-81 corridor and elsewhere. All the alternatives have fewer connections between the interstates and the city streets than presently exist. The enhanced street grid would allow for local flow of traffic and connectivity.

The southern end of all tunnel alternatives would be at a similar location, close to where I-81 crosses over Martin Luther King East (Figure 40 and Figure 41). This location would be south of the existing I-81 viaduct, and would have sufficient adjacent space within which to construct transition structures to ramp traffic into a tunnel. At this point, traffic would either flow into a tunnel, or diverge on the community grid by following the current alignment of I-81, passing over Martin Luther King East and the railroad before ramping down to street level.

FIGURE 41: Composite Highway Alignments

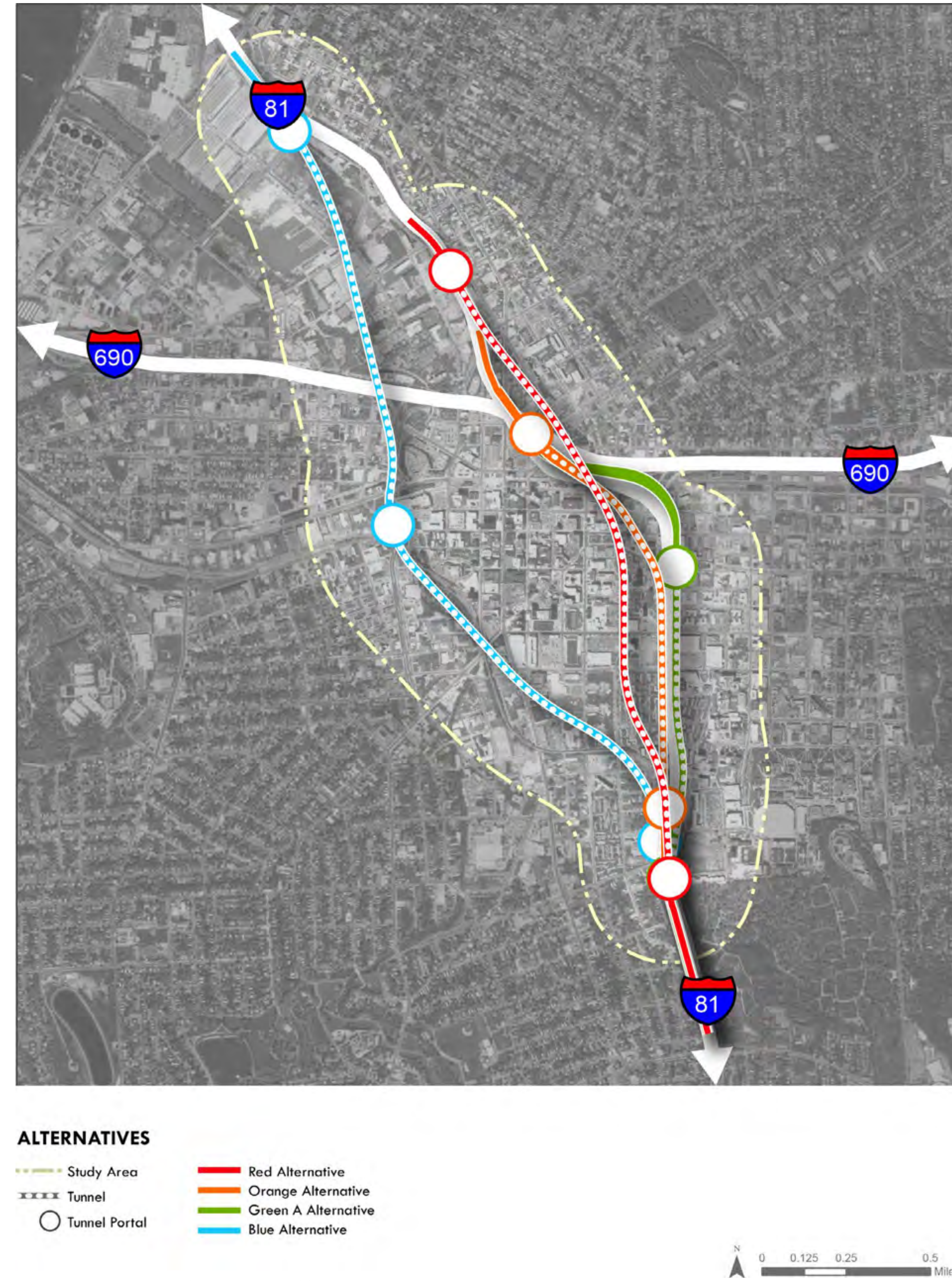


FIGURE 42: Feasible Build Alternatives Map

The northern end of each alternative would vary considerably, with different alignment alternatives having clear advantages and disadvantages, as discussed below. A major consideration was whether to have interstate connectivity between I-81 and I-690, or for an I-81 tunnel to bypass I-690 completely, with a tunnel portal farther north.

After developing the two depressed highway alternatives and seven tunnel alternatives, an initial screening was conducted. All depressed highways were eliminated from further study, and the Yellow, Green B, and Purple tunnel alternatives were dismissed (see section 5.2). Therefore the Red, Orange, Green, and Blue Alternatives, which all provide distinct and unique features, were chosen for further study.

Table 9 shows the length of each alternative.

5.2 ALTERNATIVES ELIMINATED FROM FURTHER STUDY

- The following alternatives were examined but eliminated from further study. Table 10 provides a summary. Appendix M provides additional information, listed by advantages and disadvantages, and fly-through descriptions of the alignments.

5.2.1 YELLOW ALTERNATIVE

The Yellow Alternative was a cut-and-cover tunnel that would be located on the same alignment as the existing I-81 viaduct, along Almond Street. An alignment within the Almond Street corridor is the only potentially viable alignment for a cut-and-cover tunnel, without major property takings. However, even this corridor construction would have to contend with street traffic, I-81 traffic, the I-81 viaduct, utilities and adjacent businesses and residences. The cost and disruption associated with cut-and-cover work along Almond Street/I-81 were the primary reasons for eliminating this options from further study.

5.2.2 GREEN B ALTERNATIVE

The Green B Alternative was generally aligned immediately east of the I-81 viaduct. From the southern limit, adjacent to Martin Luther King East, it was identical in plan alignment to the Green Alternative until East Fayette Street. It deviated from the Green Alternative by continuing northward to a similar north portal as the Red Alternative.

A single double-deck tube was considered preferable to twin tunnels due to the physical constraints along Almond Street.

The tunnel would have been functionally identical to the Red Alternative, but would have had higher construction risk, passing under more properties and close to others. The Red Alternative is a similar “base” cost but with a lower risk of delay and cost increases. For this reason, Green B Alternative was eliminated from further study.

5.2.3 PURPLE ALTERNATIVE

The Purple Tunnel Alternative demolished both the I-81 and I-690 viaducts, and replaced them with tunnels. This would have freed surface space for development and would have improved livability.

The I-81 tunnel would have been somewhat similar to the Red Alternative, and would have been constructed by TBM until Genesee Street. For the I-690 tunnel, cut-and-cover construction would have been required to accommodate the number of traffic lanes. A complicated series of cut-and-cover interchanges would have been required to achieve interconnections between I-81 and I-690.

This option was eliminated from further study, primarily due to the cost. The I-690 section alone could have cost 2 to 3 times the cost of the I-81 options carried forward. Overall project costs could have been 3 to 4 times more than focusing on I-81 alone. Furthermore, the disruption to

Alternative	Bored Tunnel Length (one way)	Open/Covered Cut Length (south)	Open/Covered Cut Length (Mid)	Open/Covered Cut Length (north)	Total Length (one way)
Red	1.6	0.3	—	0.4	2.3
Orange	1.0	0.4	—	0.3	1.7
Green	0.8	0.3	—	0.2	1.3
Blue	1.2+0.4	0.3	0.3	0.3	2.7

TABLE 9: Feasible Build Alternatives - Lengths (miles)

Alternative	Bored Tunnel Length (one way)	Open/Covered Cut Length (south)	Open/Covered Cut Length (Mid)	Open/Covered Cut Length (north)	Total Length (one way)
Yellow	—	—	0.5	—	0.5
Green B	1.7	0.2	—	0.2	2.1
Purple	1.0	0.1	—	0.6	1.6
Short	—	—	0.4	—	0.4
Long	—	—	0.6	—	0.6

TABLE 10: Eliminated Alternatives – Lengths (miles)

traffic and people during construction would have been more widespread and would have lasted much longer.

5.2.4 SHORT DEPRESSED HIGHWAY ALTERNATIVE

The Short Depressed Highway Alternative would have aligned along the same alignment as the existing I-81 viaduct. I-81 northbound would have had a bridge over the railroad, descending into a depressed highway. It would have risen to meet the I-690 ramps.

The purpose of examining this alternative was to determine the shortest practical depressed highway. However, this alternative was too short. It would have started and ended at a viaduct, and except for one cross-street (Adams), all other cross-streets would have been permanently blocked due to the highway either ramping down or ramping up.

- This option was eliminated from further study, primarily due to the required permanent closure of multiple city streets.

5.2.5 LONG DEPRESSED HIGHWAY ALTERNATIVE

The Long Depressed Highway was an open-cut depressed highway that would have followed the existing I-81 alignment. Compared with the Short Depressed Highway Alternative, this alternative would have remained at the full depth long enough for most transverse city streets to remain open. Community grid at street level would have been maintained by splitting Almond Street northbound and southbound, and cantilevering each direction over I-81 (see Appendix E).

- This option was eliminated from further study for two principal reasons: the requirement for an extended closure of I-81 during construction, and because the resulting depressed highway, ramps and viaducts would have perpetuated the division between the university area and the downtown area.

5.3 FEASIBLE BUILD ALTERNATIVE RED

5.3.1 GENERAL OVERVIEW

The Red Tunnel Alternative would be generally aligned west of the existing I-81 viaduct, along South Townsend Street (see Figure 43).

It would start south of the Martin Luther King East overpass and trend to the northwest. An open-cut would transition to a cut-and-cover tunnel immediately south of Martin Luther King East. Twin bored tunnels would pass to the west of the Syracuse University Steam Station & Chilled Water Plant. The tunnels would generally follow South Townsend Street, passing below private residences and private parking lots in some areas. The tunnel would then strike northwest to align with State Street, passing below various private properties near Washington Street and Water Street. The tunnel would pass under I-690 with no interconnections, at sufficient depth to avoid the existing piles (see profiles in Appendix E). Based on record drawings, the I-690 piles would extend 53 feet below grade and the crown of the tunnel would be approximately 80 feet deep. The tunnel would then follow North State Street before deviating to the west to rejoin I-81 at a new intersection north of Butternut Street.

Twin tube tunnels are recommended rather than a single bi-level tunnel. Twin bored tunnels provide greater flexibility at the portals, and shorter cut-and-cover approaches (since the smaller diameter tunnels require less cover). However, the out-to-out width of twin tunnels would be approximately 110 feet, which would be wider than Townsend Street. More private property easements would therefore be required. It would also require mining under additional buildings compared with a single larger tunnel, which would increase risk.

- Advantages of Red Alternative
  - Bypasses Syracuse University Steam Station & Chilled Water Plant
  - Favorable geometry for a tunnel mining portal south of the railroad
  - Avoids risk of tunneling under I-81 (potentially encountering piles, or requiring traffic shutdowns)
  - Has negligible impact on I-690
  - Construction costs are relatively low compared to the other alternatives
  - Simpler construction staging compared to Orange

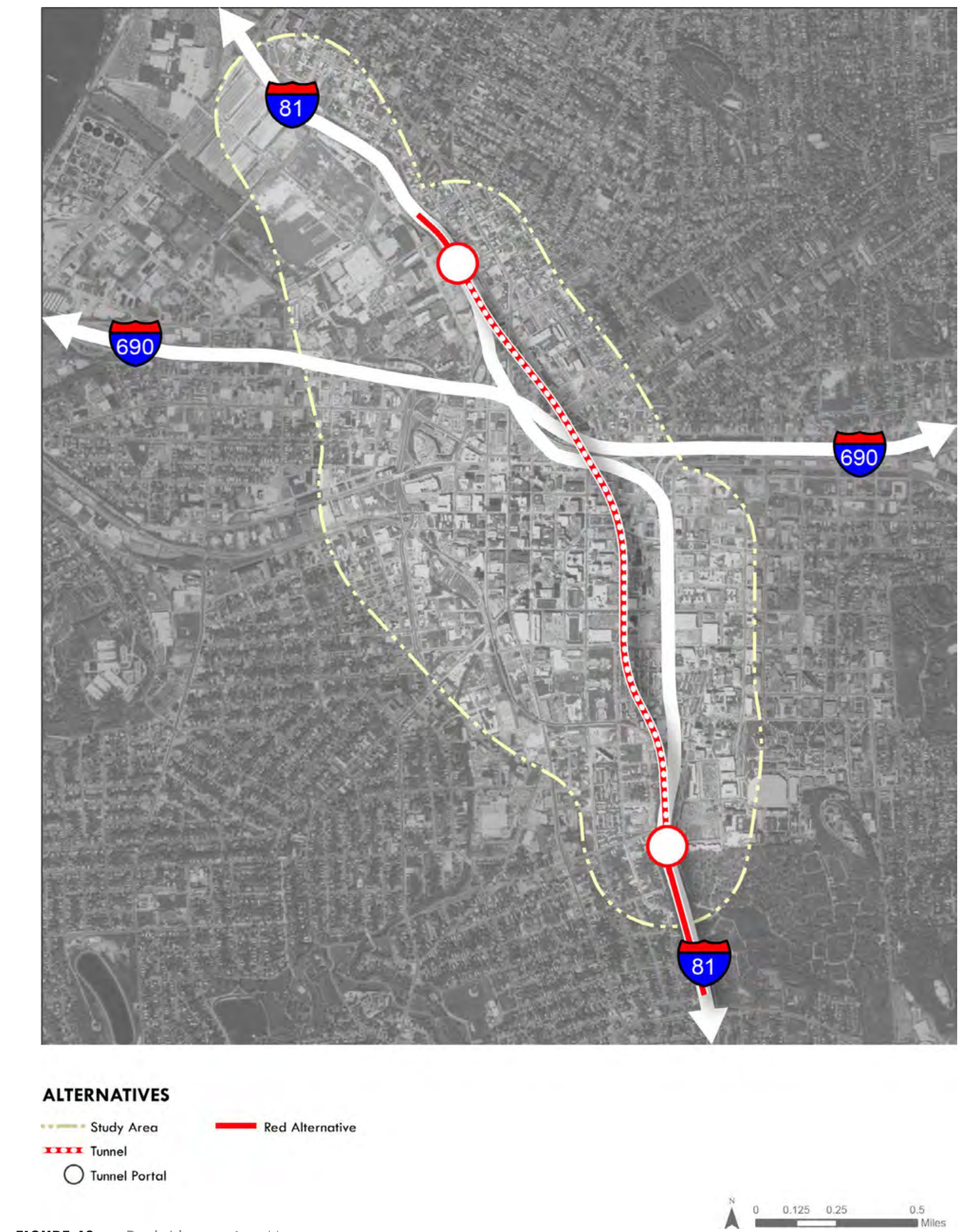


FIGURE 43: Red Alternative Map

and Blue alternatives
    - Improvements to I-690 are independent of this alternative.

- Disadvantages of Red Alternative
    - Does not provide a direct interconnection with I-690
    - Passes under private land
    - Passes under buildings, such as on Fayette St, N State St and N Salina Street
    - Construction of northern tunnel approaches would be disruptive to I-81 traffic and would result in a temporary reduction to two lanes for each direction approximately between Butternut St and Spencer Street.

5.3.2 HIGHWAY DESIGN

TUNNEL TRAFFIC

Traffic demand in the tunnel would be the lowest of all alternatives. Given the elimination of all connections between I-81 and I-690, the bulk of the drivers using the existing interchange would exit from the highway system prior to entering the tunnel and use the local surface street grid to access the downtown area. Anticipated traffic volumes would range from 500 vehicles per hour (vph) during the AM peak hour in the northbound direction to approximately 1,350 vph during the PM peak hour in the southbound direction. (For details on traffic volumes see Appendix C-3 of the DEIS.)

5.3.3 COMMUNITY GRID

FOCUS AREA A: SOUTH TUNNEL PORTAL

The south tunnel portal would be connected to Almond Street via on- and off-ramp structures from the I-81 mainline, and first tie in at-grade at Taylor Street. This connection would require the closure of Burt Street due to vertical clearance requirements. Martin Luther King East/Renwick Avenue would be maintained. The existing segment of Almond Street south of Taylor Street would be converted to a one-way northbound frontage road, providing connections between Van Buren Street, Burt Street, and Taylor Street on the east side of Almond Street. A two-way bicycle track would be located adjacent to the general purpose travel lane and would provide direct bicycle connections from Almond Street to Van Buren Street and the Syracuse University campus.

FOCUS AREA B: ALMOND STREET CORRIDOR

The Almond Street corridor—generally defined as Almond Street between the south tunnel portal and I-690—would have a right-of-way of up to approximately 150 feet. It would range between two and three general purpose travel lanes in each direction, with designated curbside bicycle lanes and 15-foot sidewalks on the east and west sides of the street. Where possible, parallel on-street parking would be provided for convenience and to slow traffic. To mitigate Almond Street's wide cross-section and provide a visual buffer from potentially high traffic volumes, side and center medians would be constructed, which would provide area for substantial tree planting and canopy, add aesthetic interest, physically separate travel lanes, and provide green space. A side median with adjacent northbound frontage road would be constructed adjacent to Syracuse Housing Authority's Pioneer Homes between Taylor Street and Adams Street. A wide center median would be constructed north of Adams to I-690. In combination, these improvements would make Almond Street a heavily landscaped urban boulevard, and a walkable, multimodal "Complete Street." All intersecting streets along the Almond Street corridor would remain unchanged in terms of travel lane assignment and cross-sectional configuration.

Under this alternative there would be residual state-owned rights-of-way currently occupied by I-81 viaduct and ramps not required for the reconstruction of Almond Street. This freed up land—most notably on block frontages westerly adjacent to Almond Street—could be redeveloped by others if the state decided to dispose of the property.

FOCUS AREA C: I-690/I-81 CONNECTION TO DOWNTOWN SYRACUSE

Focus Area C generally refers to the area north of Fayette Street where new on- and off-ramps would be constructed under the Red Alternative to provide grade-separated access to I-690 from the Almond Street corridor. Providing a direct local-to-interstate connection is critical to maintaining acceptable levels of service in downtown Syracuse. To provide this connection from the north end of Almond Street, on- and off-ramps would begin and end in a wide center median at Almond Street's intersection with Fayette Street, and ascend north and west toward

FIGURE 44: Red Alternative South Portal

FIGURE 45: Red Alternative North Portal

	2050 – Red Alternative			
	Weekday AM Peak Hour		Weekday PM Peak Hour	
	Northbound	Southbound	Northbound	Southbound
Volume (vph)	499	922	905	1,356
Estimated Level of Service	A	A	A	B

Assumptions:
1. *Closure of I-81 NB to I-690 EB Ramp*
2. *Closure of I-690 WB to I-81 SB Ramp*
3. *Closure of I-81 NB to I-690 WB Ramp*
4. *Closure of I-690 EB to I-81 SB Ramp*
5. *Two-Lane Tunnel*

TABLE 11: Weekday Peak Hour Tunnel Traffic (vph): 2050 Build – Red Alternative

over Washington Street, Water Street, and Erie Street, ultimately tying in to eastbound and westbound I-690. This would necessitate the closure of Washington Street and Water Street due to vertical clearance requirements. Almond Street would continue as two lanes in each direction with wide sidewalks and bicycle lanes north of the I-690 ramps to Burnet Avenue where Almond Street narrows to a four-lane cross-section with no center median.

The closure and demolition of existing ramps form I-81 to I-690 and the introduction of new ramp connections from Almond Street to I-690 envisioned as part of the Red Alternative would provide a substantial amount of residual state-owned land for potential disposal north of Fayette Street between McBride Street and Almond Street.

Figure 46 and Figure 47 show existing conditions and a rendered perspective of Almond Street at Jackson Street, respectively.

5.3.4 GEOTECHNICAL CONDITIONS

Based on limited available geotechnical information, ground conditions for the Red Alternative appear to be favorable for closed mode TBM construction. The portals of the bored tunnels have been located so that most of the tunneling would be in the bedrock (shale). (Appendix D provides anticipated geotechnical profiles.) However, limited geotechnical information from the area of the university steam plant (near the south portal) indicates that rock could dip to the west, resulting in some mixed face tunneling. Settlement above the tunnel should be low, but mixed face conditions are less favorable than a full face of rock.

5.3.5 TUNNEL DESIGN & CONSTRUCTION

The Red Alternative tunnel would consist of a twin bore carrying I-81 traffic through downtown Syracuse. Beginning south of Syracuse University, the tunnel would start in a cut-and-cover section for approximately 700 feet. This portion of the mainline construction would be constructed under MLK Boulevard, thus allowing it to remain open, while the Almond Connector ramps would be constructed above the existing street crossing. The twin bore would continue for approximately 10,000 feet. Within this section, the tunnel would descend to roughly 80 feet below grade at a slope of 4%. The bulk of the tunnel bore would be 80 feet below grade before ascending at 6% grade within I-81 right-of-way north of I-690. The tunnel section would continue in a cut-and-cover section for another 700 feet, tying to the existing I-81 alignment north of Spencer Street. The design speed for this option would be 50 mph. The minimum horizontal curvature for this option would be 2,269 feet, greater than that required by design criteria, although the necessary minimum to provide the sight distance requirement for vehicles traveling 50 mph in the tunnel. The shoulder widths within the tunnel section would be a non-standard design feature. Due to the diameter of the bore, shoulders of 4 feet would be provided on the left and right sides adjacent to the 12-foot lanes. Each bore would contain two 12-foot lanes and two 4-foot shoulders to convey traffic southbound and northbound along I-81. Shoulders would transition to 10 feet once outside of the bored tunnel structure

The Red Alternative includes the following interstate connections:

- I-81 SB to I-690 EB – new ramp on viaduct
- I-690 WB to I-81 NB – new ramp on viaduct

There would be an option to provide two additional interstate connections, independent from the tunnel construction: from I-690EB to I-81NB, from I-81SB to I-690WB. Although elimination of select local access would be required to accommodate these movement.

The Red Alternative would include reconstructing Almond Street into a boulevard, constructing a new interchange at Almond Street/I-690, and various traffic operational improvements throughout the street grid. The street grid would be required to complete several other movements:

- I-81 NB to I-690 WB – must use new Almond Street/I-690 interchange (Fayette Street Flyover)
- I-81 NB to I-690 EB – must use new Almond Street/I-690 interchange
- I-690 WB to I-81 SB – must use new Almond Street/I-690 interchange
- I-690 EB to I-81 SB – must use new Almond Street/I-690 interchange (Fayette Street Flyover)

Separate from the actual tunnel construction, this alternative would construct two viaduct ramps extending from the western leg of I-690 to Fayette Street. Working in combination with the Almond/I-690 interchange, these viaduct ramps would replace the existing Harrison Street ramps, which were heavily used, and permit the Erie Boulevard/Almond Street intersection to be at-grade. Local connectivity would be maintained with the Red Alternative in that access to the local street grid would be provided at the I-690/West Street interchange, new I-690/Almond Street interchange, and new local ramps located near the north portal at Hickory (to I-81 NB), Clinton (from I-81 SB), and Taylor (to I-81SB and from I-81 NB). Local streets would be marginally affected with permanent closures expected at Martin Luther King East and Burt Street near the south portal. Additionally, Water and Washington Street would be closed to through traffic across Almond Street as a result of the Fayette Street flyover ramps.

The Red Alternative would pass beneath I-690 in a manner that would minimize disruption to the existing structure. Further, any work on the geometric deficiencies for I-690 could be performed independent of the Red Alternative.

PROTECTION OF STRUCTURES

The Red Alternative's Tunnel would be at least 40 feet below the existing structures' pile foundations; however, it would be important to evaluate the soil to see if there would be impacts to settlement due to the tunneling operations. Most of the existing structures would be avoided under this alternative, and the tunnels would generally be in shale rock. Therefore, there would be no anticipated need for additional protection of structures. The existing Butternut Street bridge and Spencer Street bridge would be expected to need replacement under this alternative to accommodate the widened roadway over this section of I-81. This may need to be completed before starting the other construction operations. The new structures could be designed such that the new roadways and tunnel would not affect the new structures.

5.3.6 VIADUCT DESIGN & CONSTRUCTION

The Red Alternative would avoid impacts to the existing I-690 due to the new I-81 tunnel bypassing the interchange completely at a sufficient depth to avoid existing pile foundations. New and replacement bridges would be of standard construction—such as reinforced concrete deck on steel or concrete girders and concrete piers—unless circumstances require a different approach. Under this alternative, a new connection would be created with a new elevated ramp from I-690 EB to I-81 NB, which could be

FIGURE 46: Almond Street & Jackson Street (Existing)

FIGURE 47: Almond Street & Jackson Street (Rendered Perspective)

built with little to no impact to the existing I-690. Another new partially elevated ramp would directly connect I-81 SB to I-690 WB, while the existing connections of I-81 SB to local streets and the West Street arterial would be maintained. The existing Butternut Street bridge would be removed and replaced with a new structure north of the existing to accommodate the new connections. The existing Spencer Street bridge would also be replaced to accommodate the widened I-81 roadway at this location. The widening would be necessary to accommodate the proposed I-81 emerging tunnel roadways, the new I-690 connecting ramps and the existing connecting ramps to I-690 EB and from I-690 WB, as they merge into existing I-81 at-grade. The existing I-81 bridge over N. Salina Street could also be replaced to accommodate a new alignment for the existing I-690 connecting ramp roadways to remain. The existing viaducts and interchange could be maintained during construction with limited impacts outside of the staged construction area required near the north portal north of Butternut Street, as noted in Section 5.3.8. The existing I-81 viaducts could be removed once the new I-81 tunnel is in service. Drawings for a potential construction sequence of the northern end of the project are included in Appendix E (showing tunnel elements only, with approximated roadway alignments).

At the southern end of the project, the proposed I-81 roadway and tunnel could be built independently and would avoid affecting the existing I-81 entirely. Drawings for a potential construction sequence of the southern end of the project are included in Appendix E. The same would be true for the new ramp over the existing railroad, which would lead to the newly constructed community grid for downtown Syracuse.

The Red Alternative would not require reconstruction of I-690, meaning the non-standard features of the viaduct would not be improved upon. However, by eliminating the existing I-81 viaduct and replacing the existing connections between I-690 and I-81, the final proposed geometry would allow future improvements of I-690. This would include lowering the existing flyovers and the ability to realign the westbound and eastbound roadways so that they would be adjacent to each other, reducing I-690's footprint on the city and allowing for further land development.

As most of the existing bridges and viaducts would be supported by piles, it can be assumed that the new bridges, viaducts, and ramps would also be supported by piles. In some locations, new foundations could be seated on the top of the tunnel roof or lining, such as the flyover ramp near Spencer Street, to avoid overly long spans.

5.3.7 TUNNEL SYSTEMS

Tunnel systems would be similar for the Red, Orange and Blue Alternatives' tunnel options and would generally vary only by the quantity of equipment required. For instance, with jet fans spaced at 500 linear feet and installed in pairs would require 96 fans. A ventilation building may be required at each portal with point exhaust to remove vitiated air and discharge it at high velocity above the ground level. Given the length of this option, it would be unlikely that an environmental assessment of air quality would eliminate the need for a ventilation building and allow ventilation with jet fans alone. However, environmental air quality assessment would still be necessary to confirm operational requirements.

Egress passages between the bores, spaced at about 600 linear feet, would number approximately 18 to 19. Other systems such as electrical, drainage and fire protection, finishes, controls and ITS, would scale in quantity based on the tunnel length.

5.3.8 CONSTRUCTION STAGING

Many of the proposed structures under this alternative could be built with limited impact to the existing structures and roadways with simple construction staging. This includes the new ramps from I-690 to I-81 over North Salina Street and from I-81 to I-690 over North Franklin Street. Demolition of the existing I-81 at the interchange could be performed once the tunnel is complete and open to traffic, with limited impacts to the existing I-690. Some structures carry traffic for both I-690 and to be demolished I-81 ramps. These structures would require modifications, which could be performed with the staged construction, but the impacts to traffic during these operations would be very limited, since they would no longer carry the combined traffic of I-81 and I-690.

The existing Spencer Street bridge carries two lanes of traffic, one in each direction, and is accessible to pedestrians via sidewalks on each side of the roadway. Replacing the existing structure would keep the existing structure geometry and the existing features, where appropriate. Despite the single-lane usage of the structure, it would be wide enough to accommodate two lanes per direction, which would allow staged construction to be used to limit impacts to the traveling public. The new Butternut Street bridge could be built without affecting the existing structure and would opened to the public before demolishing the existing structure.

5.3.9 UTILITIES

Utility impacts for this alternative would be present at the south and north portals. Additional impacts would be expected within the Almond Boulevard reconstruction zone, although these utilities would be readily located within the work zone. Major relocations would be expected for utilities affected by the north and south portals since relocation would typically be needed outside the portal zone.

Utility investigation and identification would be important to the design consideration phases of this project, and would help in determining what alignments would be further studied and what alignment options could be eliminated. Along the I-690 and I-81 viaducts as they approach the city's inner limits, ground space below would either function as a highway interchange such as at the north end of I-81, or would be consumed by vegetation with side streets connecting neighborhoods to the Syracuse University campus at the south end of I-81. These less populated areas would allow for portal points to be further considered as areas of entries and egress into the alternative alignments discussed.

The community grid area along I-81 between the northern constraint of Erie Boulevard and the southern constraint of Martin Luther King East shares a variety of residential housing, student housing facilities, small business, large business, medical facilities, educational facilities and large industrial facilities. Maintaining active utility services without community disruption would be a crucial component at the time of the design consideration phase of this connective corridor between the eastern portion of the inner city to the Syracuse University campus area and medical facilities. This should ensure that the revitalization of this area will have a positive impact on the community as well and improving traffic flow and pedestrian access.

Site specific utility impacts for this alternative are shown in Appendix I.

5.3.10 PROPERTY IMPACTS

A property impact analysis was prepared for the various alternatives. The efforts required under this property analysis task included the following:

- Determining the limits of property impacts associated with each alternative.
- Identifying the affected parcels.
- Collecting affected parcels data.
- Assessing impact.
- Assessing value of affected properties.

Assumptions and the methodology use utilized to determine the impacts are summarized in Section 3 while backup documentation and maps relative to each alternative is shown in Appendix J.

	Property Impact Classification by Land Use							
	Commercial	Residential	Industrial	Vacant	Parks	Public Services	Comm. Services	Unknown
Partial Fee Taking	3	0	1	7	0	2	1	2
Full Fee Taking	12	6	0	11	0	0	1	0
Permanent Easement	53	4	0	18	1	5	4	0

TABLE 12: Property Takings: Red Alternative

Thirty (30) Full Fee Takings are projected for this option. The Full Fee Takings include seventeen (17) properties containing building that will require demolition. The remaining thirteen (13) properties are either vacant or have uses that do not require buildings (i.e. parking lot). The above described takings were used to develop estimates for property acquisition costs.

5.3.11 DEVELOPMENT CONSTRAINTS

The future construction of buildings directly above the Red Alternative tunnel would be minimally constrained by the allowable depth of footings/piles and the allowable weight of buildings (Appendix J). The south end of the tunnel would be in a residential area where future development of buildings greater than five stories tall would be unlikely. Buildings of this size could likely be constructed above both the tunnel with no adverse impact.

The Red Alternative would pass relatively close to downtown, under developable land along Townsend Street and State Street. The depth to the crown of the tunnel would be typically around 80 feet, and the tunnel would be expected to be in rock, which should result in little or no constraint on future high rise development (geotechnical profiles, Appendix D). The cut-and-cover tunnel near the north portal would be situated directly below the reconstructed I-81 highway.

5.4 FEASIBLE BUILD ALTERNATIVE ORANGE

5.4.1 GENERAL OVERVIEW

The Orange Alternative would be aligned immediately west of the I-81 viaduct (Figure 48). It would start south of Martin Luther King East and continue due north in a cut-and-cover tunnel, passing under both Martin Luther King East. A TBM launch wall would be constructed just south of the South McBride Street and Van Buren Street Intersection . The TBM tunnels would be mined under vacant space at the Syracuse University steam station and chilled water plant. To avoid the risk of encountering piles (from previously demolished buildings), a cut-and-cover tunnel method could be used, which could disrupt operations and could require multiple utilities to be rerouted or supported.

The bored tunnels would continue under Taylor Street, pass under the Pioneer Homes housing project, and then continue parallel to I-81. It would pass under both the parking lot of the Upstate University Medical Center and the parking structure for Madison Towers. An alternative alignment would be under the I-81 viaduct, which would avoid private properties, but the risk of encountering a pile (from the I-81 viaduct) could increase.

At East Genesee Street, the tunnel would head to the northwest, passing under private land and various low-rise buildings. The bored tunnel would end at Erie Boulevard, transitioning to a cut-and-cover tunnel. The at-grade parking lots in this area could potentially be acquired to make an efficient reception/launch site for the bored tunnels.

North of Erie Boulevard, cut-and-cover construction would be used, with the I-690 viaducts being underpinned and support structures reconstructed as required. To achieve connections from I-81 NB to I-81 NB and to I-690 WB, extensive reconstruction of I-690 would be required. This would include reconstructing much of the existing viaduct, which would enable existing geometric deficiencies to be remedied.

- Advantages of Orange Alternative
  - Enables connections to I-690
  - Relatively short tunnel
  - Improvements to I-690's currently non-conforming features would be inclusive for this alternative
  - Open view under new I-690 viaduct compared to existing wide viaduct.
- Disadvantages of Orange Alternative
  - Passes under unused space at Syracuse University steam station and chilled water plant, with risk of encountering abandoned piles and need to protect sensitive utilities.
  - Passes under private land
  - Passes under multi-story parking structure for Madison Towers
  - Tunnel could limit future development requiring piles, such as on Townsend Street between Washington Street and Water Street
  - Construction of northern tunnel approaches would

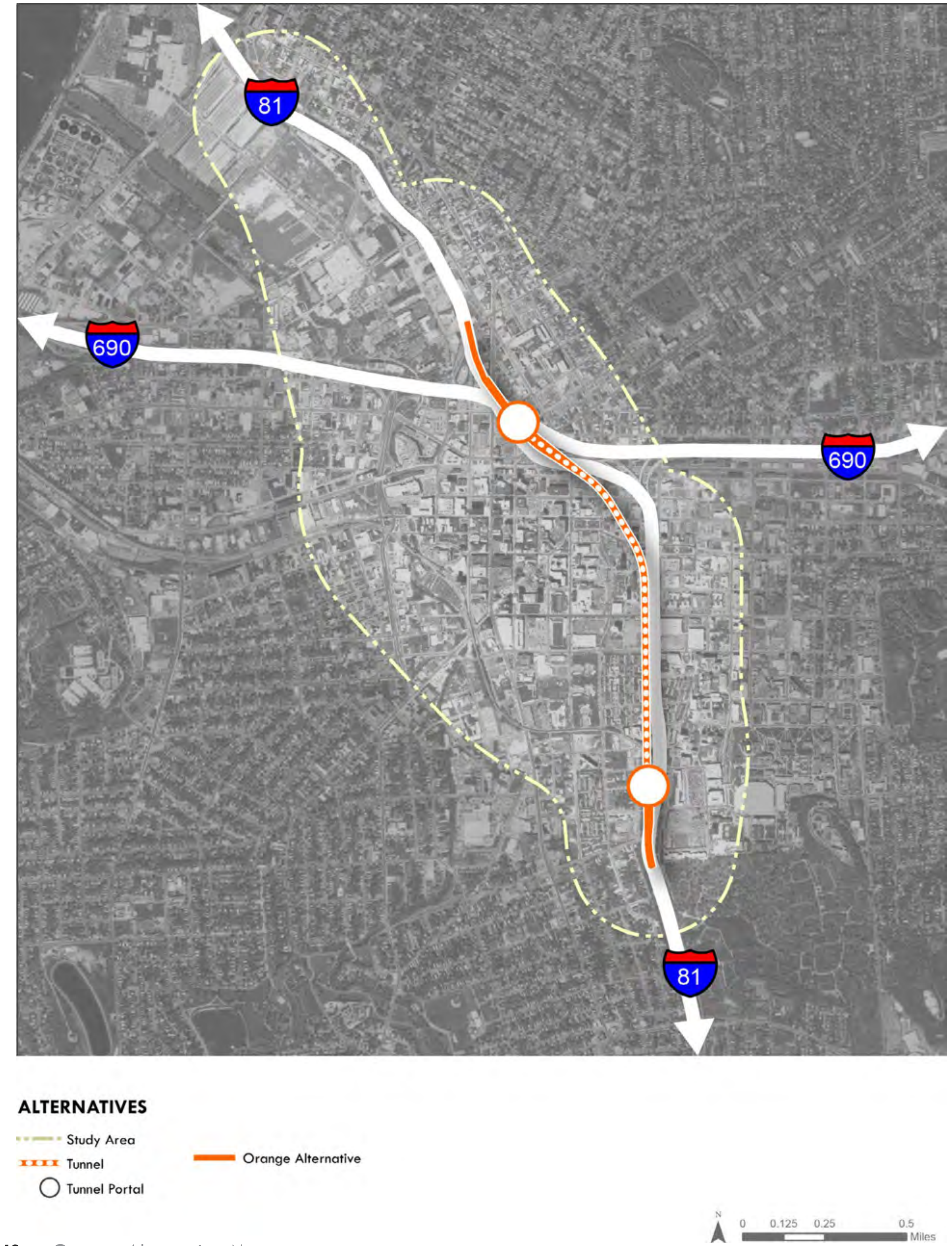


FIGURE 48: Orange Alternative Map

- be disruptive to I-690 traffic, requiring temporary connections and structures to divert traffic around the tunnel portal area.
- Complex staging would be needed to build proposed structures around the existing viaducts, resulting in difficult construction.
- Requires temporary supports or reframing of piers for a large section of existing I-690 due to the cut-and-cover area underneath the I-690 and its connections.
- Would require modifications to the existing West Street and I-690 interchange to accommodate new I-690 WB alignment.

For the Orange Alternative, twin tube tunnels are recommended rather than a single bi-level tunnel. Twin bored tunnels would provide greater flexibility at the portals, and shorter cut-and-cover approaches (since the smaller diameter tunnels require less cover). However, the out-to-out width of twin tunnels would be approximately 110 feet, which would increase the risk of encountering piles under the steam plant (see below and Appendix E). Also, more private property easements would be required.

5.4.2 HIGHWAY DESIGN

TUNNEL TRAFFIC

Traffic demand in the tunnel would be higher than in the Red Alternative. The elimination of the I-81 NB ramp to I-690 EB and the I-690 WB ramp to I-81 SB would still place a large number of vehicles on the local surface street grid since many drivers use these connections to go to and from the Harrison Street ramps use these connections. Anticipated traffic volumes would range from 1,200 vph during the AM peak hour in the northbound direction to approximately 2,050 vph during the PM peak hour in the southbound direction. (For details on traffic volumes see Appendix C-3 of the DEIS.)

5.4.3 COMMUNITY GRID

FOCUS AREA A: SOUTH TUNNEL PORTAL

The south tunnel portal would be connected to Almond Street via on- and off-ramp structures from the I-81 mainline, and first tie in at-grade at Taylor Street. This connection would require the closure of Burt Street due to vertical clearance requirements. Martin Luther King East/Renwick Avenue would remain open. The existing segment of Almond Street south of Taylor Street would be converted to a one-way northbound frontage road, providing connections between Van Buren Street, Burt Street, and Taylor Street on the east side of Almond Street. A two-way bicycle track would be located adjacent to the general purpose travel lane and would provide direct bicycle connections from Almond Street to Van Buren Street and the Syracuse University campus.

FOCUS AREA B: ALMOND STREET CORRIDOR

The Almond Street corridor—generally defined as Almond Street between the south tunnel portal and the I-690—would have a right-of-way of up to approximately 150 feet. It would range between two and three general purpose travel lanes in each direction, with designated curbside bicycle lanes and 15-foot sidewalks on the east and west sides of the street. Where possible, parallel on-street parking would be provided for convenience and to slow traffic. To mitigate Almond Street's wide cross-section and provide a visual buffer from potentially high traffic volumes, side and center medians would be constructed, which would provide area for substantial tree planting and canopy, add aesthetic interest, physically separate travel lanes, and provide green space. A side median with adjacent northbound frontage road would be constructed adjacent to Syracuse Housing Authority's Pioneer Homes between Taylor Street and Adams Street. A wide center median would be constructed north of Adams Street to I-690. In combination, these improvements would make Almond Street a heavily landscaped urban boulevard and a walkable, multimodal "Complete Street." All intersecting streets along the Almond Street corridor would remain unchanged in terms of travel lane assignment and cross-section configuration.

Under this alternative, there would be residual state-owned rights-of-way currently occupied by the I-81 viaduct and ramps not required to reconstruct Almond Street. This freed up land–most notably on block frontages westerly adjacent to Almond Street–could be redeveloped by others if the state decided to dispose of the property.

FOCUS AREA C: I-690/I-81 CONNECTION TO DOWNTOWN SYRACUSE

Focus Area C generally refers to the area north of Fayette Street where new on- and off-ramps would be constructed under the Orange Alternative to provide grade-separated access to I-690 from the Almond Street corridor. Providing a direct local-to-interstate connection would be critical

FIGURE 49: Orange Alternative North Portal

	2050 – Orange Alternative			
	Weekday AM Peak Hour		Weekday PM Peak Hour	
	Northbound	Southbound	Northbound	Southbound
Volume (vph)	1,194	1,721	1,497	2,049
Estimated Level of Service	A	B	B	C

Assumptions:
1. *Closure of I-81 NB to I-690 EB Ramp*
2. *Closure of I-690 WB to I-81 SB Ramp*
3. *Two-Lane Tunnel*

TABLE 13: Weekday Peak Hour Tunnel Traffic (vph): 2050 Build – Orange Alternative

FIGURE 50: Almond Street and Cedar Street (Rendered Perspective)

to maintaining acceptable levels of service in downtown Syracuse. To provide this connection from the north end of Almond Street, on- and off-ramps would begin and end in a wide center median at Almond Street's intersection with Fayette Street, and ascend north and west toward over Washington Street, Water Street, and Erie Street, ultimately tying in to I-690 EB and WB. This would necessitate the closure of Washington Street and Water Street due to vertical clearance requirements. Almond Street would continue as two lanes in each direction with wide sidewalks and bicycle lanes north of the I-690 ramps to Burnet Avenue where Almond Street would narrow to a four-lane cross-section with no center median.

The closure and demolition of existing ramps from I-81-to-I-690 and the introduction of new ramp connections from Almond Street to I-690 ramp connections envisioned as part of the Orange Alternative would provide a substantial amount of residual state-owned land for potential disposal north of Fayette Street between McBride Street and Almond Street.

5.4.4 GEOTECHNICAL CONDITIONS

Based on limited available geotechnical information, ground conditions for the Orange Alternative appear to be favorable for closed mode TBM construction. The portals of the bored tunnels would be located so that most of the tunneling would be in the bedrock (shale). (Appendix D contains the anticipated geotechnical profiles.) However, limited geotechnical information from the area of the university steam plant (near the south portal) indicates that rock could be lower than under the existing I-81 viaduct, resulting in some mixed-face tunneling. Settlement above the tunnel should be low, but mixed face conditions would be less favorable than a full face of rock.

5.4.5 TUNNEL DESIGN & CONSTRUCTION

The Orange Tunnel would consist of a twin bore carrying I-81 and I-690 traffic through downtown Syracuse. Beginning south of Syracuse University, the tunnels would begin in a cut-and-cover section for approximately 1100 feet, beginning south of Martin Luther King East / Renwick. This portion of the construction would run under the Martin Luther King Boulevard crossing while the Almond Street Ramps would be elevated above the existing roadway crossing. The twin bore would continue approximately 5,400 feet. Within this section, the tunnel would descend to roughly 80 feet below grade at a slope of 4%. The bulk of the tunnel bore would be 80 feet below grade prior to ascending at 6% grade within the I-81 right-of-way north of Erie Boulevard. The tunnel section would continue in a cut-and-cover section for another 700 feet, tying to the existing I-81 alignment north of James Street. The design speed for this option would be 50 mph. The minimum horizontal curvature for this option would be 2,269 feet, which would be greater than that required by design criteria, although the minimum necessary to provide the sight distance required for vehicles traveling 50 mph in the tunnel. The shoulder widths within the tunnel section would be a non-standard design feature. Due to the diameter of the bore, shoulders of 4 feet would be provided on left and right sides adjacent to the 12 feet lanes. Each bore would contain two 12-foot lanes and two 4-foot shoulders to convey traffic both southbound and northbound along I-81. Shoulders would transition to 10 feet once outside of the bored tunnel structure. The Orange Alternative would include the following interstate connections:

- I-81 SB to I-690 EB – new ramp on viaduct
- I-81 NB to I-690 WB – new ramp on viaduct
- I-690 EB to I-81 SB – new ramp on viaduct
- I-690 WB to I-81 NB – new ramp on viaduct

- There would be an option to provide two additional interstate connections, independent from the tunnel construction: from I-690EB to I-81NB, from I-81SB to I-690WB. Although elimination of select local access would be required to accommodate these movement.

The Orange Alternative would reconstruct Almond Street into a boulevard—similar to all other alternatives—construct a new interchange at Almond Street/I-690, and various traffic operational improvements throughout the street grid. The street grid would be required to complete several other movements including the following:

- I-81 NB to I-690 EB – must use new Almond Street/I-690 interchange
- I-690 WB to I-81 SB – must use new Almond Street/I-690 interchange

Separate from the actual tunnel construction, this alternative would construct two viaduct ramps extending from the western leg of I-690 to Fayette Street. Working in combination with the Almond Street/I-690 interchange, these viaduct ramps would replace the existing Harrison Street ramps, which were heavily used, and permit the Erie Boulevard/Almond Street intersection to be at-grade. Local connectivity would be maintained with the Orange Alternative in that access to the local street grid would be provided at the I-690/West Street interchange, new I-690/Almond Street interchange, and new local ramps located near the north portal at Hickory (to I-81 NB), Clinton (from I-81 SB), and Taylor (to I-81SB and from I-81 NB). Local streets would be marginally affected with permanent closures expected at Burt Street near the south portal. Willow Street would be cut off near the northern portal while cross-streets would be maintained since the alignment would be on a structure passing above the street grid at that point. This would be consistent with the existing alignment. Additionally, Water Street and Washington Street would be closed to through traffic across Almond Street as a result of the Fayette Street flyover ramps.

The Orange Alternative would be extremely disruptive to the existing I-690 corridor substructures. The baseline alternative could be implemented with either the existing alignment or a reconstructed alignment, which would address the existing geometric deficiencies. Addressing the existing deficiencies in combination with the Orange Alternative would improve the overall constructability of the northern portal area.

PROTECTION OF STRUCTURES

Under this alternative, the cut-and-cover operations would greatly affect the existing I-690 structures. To adequately protect the existing structures and maintain traffic during construction, reframing and/or underpinning existing roadway supports and using temporary piers would need to be incorporated. The limited space between the existing and proposed structures would result in complex detailing, and it would be expected to be difficult to construct while protecting the existing structures. Besides the difficulties surrounding the area where the cut-and-cover operations would be, many of the proposed structures would overlap in some cases, which would require either staging to use portions of the existing structure or temporary connections and flyovers to divert I-81 traffic around the tunnel construction zone to avoid overly complex staging. Temporary shoring as well as excavation support would be required for existing structures/embankment at the tunnel cut-and-cover, and open-cut areas.

5.4.6 VIADUCT DESIGN & CONSTRUCTION

New and replacement bridges would be a standard construction of reinforced concrete deck on steel or concrete stringers and reinforced concrete piers, unless circumstances require a different approach. I-690 WB and EB would be realigned and improved with new structures through the existing interchange area since the existing interchanges could remain open to traffic during construction. The new structures could need to be built as flyovers to avoid conflicting with active roadways and affecting the traveling public. The proposed structures would have many constraints in its design due to the close proximity of the existing and proposed structures. This alternative would include improvements to the existing non-standard features of I-690 WB and EB due to the new viaduct being built to permanently replace the existing.

A new ramp with a flyover would replace the existing connection from I-81 NB to I-690 WB. Another new ramp would connect I-81 SB to I-690 EB. The existing ramps connecting the West Street arterial and I-690 would be rebuilt under to accommodate the new alignment of I-690 WB. The existing Butternut Street bridge would be removed and replaced with a new structure north of the existing to accommodate the new connections.

Under the Orange Alternative, one complex area that would need special emphasis would be the proposed I-690 EB over the existing I-81, which would be above the cut-and-cover area for approximately 300 feet. Protection of structures and construction staging would be critical for this area of the Orange Alternative.

5.4.7 TUNNEL SYSTEMS

Tunnel systems would be similar for then Red, Orange and Blue Alternatives' tunnel options and would generally vary only by the quantity of equipment required. For instance, with jet fans spaced at 500 linear feet and installed in pairs, this alternative would require 64 fans. A ventilation building may be required at each portal with point exhaust to remove vitiated air and discharge it at high velocity above the ground level. This would be the shortest of all the bored tunnel options, and there would be a possibility that an environmental assessment of air quality would eliminate the need for a ventilation building and allow ventilation with jet fans alone. However, environmental air quality assessment would still be necessary to confirm operational requirements.

Egress passages between the bores, spaced at about 600 linear feet, would number approximately 13 to 14. Other systems such as electrical, drainage and fire protection, finishes, controls and ITS, would scale in quantity based on the tunnel length.

5.4.8 CONSTRUCTION STAGING

The Orange Alternative would have the most complicated staging of the feasible build alternatives largely due to the cut-and-cover operations taking place within the most congested area of the I-81 and I-690 interchange. Limited space within this area means proposed structures would need to be built around the existing structures and would require staging in some cases to tie the proposed into existing and vice versa. In many of these cases, the staging would result in traffic diversions using temporary structures, until the proposed tunnel is open to traffic. Maintaining the existing interchange while building the proposed structures could be accomplished but would be a challenge and could prolong construction operations. Staging and construction would be simplified if a portion of I-81 through traffic can be temporarily diverted to I-481 and I-90 during construction.

One possible staging approach to get the tunnel operational and connected to I-81 at the northern terminus would be as follows:

- Build a flyover ramp from I-81 NB to the ramp from I-690 WB to I-81 NB. Provide temporary widening as necessary to accommodate projected traffic volumes.
- Build a connection ramp from I-81 SB (just south of the I-690 WB flyover bridge) to I-690 EB. Provide widening of the elevated viaduct as necessary to accommodate projected traffic volumes and provide length for the weaving for I-81 SB traffic entering on the left to exit on the right for the ramp back onto I-81. A flyover connection could also be considered to avoid the weaving.
- Divert all I-81 through traffic to temporary connections NB and SB.
- Build the tunnel cut-and-cover and open-cut portions, providing temporary shoring to the I-690 EB viaduct,

	Property Impact Classification by Land Use							
	Commercial	Residential	Industrial	Vacant	Parks	Public Services	Comm. Services	Unknown
Partial Fee Taking	8	0	0	2	0	2	1	0
Full Fee Taking	7	6	0	8	0	0	1	0
Permanent Easement	23	0	1	2	1	5	2	0

TABLE 14: Property Takings: Orange Alternative

and make the tunnel connections to existing I-81 roadways.

- Open I-81 traffic through the new tunnel, allowing for removal of the I-81 structures, allowing for the other improvements, specifically realigning I-690 through the intersection.

The existing ramps connecting I-690 and the West Street arterial would be replaced to accommodate the new alignment of I-690 EB and WB. Since this would be a major connection, it would need to be replaced via staged construction, which could temporarily reduce each of the ramp roadways to a single lane. In some instances, the existing piers could be used for the new structures. The new alignment of I-690 WB would also be expected to replace the I-690 over Onondaga Creek, which would also require a staged construction while limiting impact to traffic. The I-690 WB over Onondaga Creek, which leads to the connection for West Street, as well as a new connection ramp from I-81 SB to I-689 WB would require special attention since the ramp structure replacement would be coordinated and developed with the I-690 WB bridge replacement.

Under this alternative, the existing connections for I-81 NB to I-690 EB and for I-690 WB to I-81 SB would be permanently removed and replaced with a community grid connection to Almond Street. The proposed I-690 EB on the eastern side of the project site would be tied into the existing I-690 EB via staged construction. During this time, there would be at least a one lane reduction, and initial expectations are for the construction to be completed in at least three stages.

5.4.9 UTILITIES

Utility impacts for this alternative would be present at the south and north portals. Additional impacts would be expected within the Almond Boulevard reconstruction zone although these utilities would be readily located within the work zone. Major relocations would be expected for utilities affected by north and south portals since relocation would typically be needed outside the portal zone.

Utility investigation and identification would be important to the design consideration phases of this project, and would help determine what alignments would be further studied and what alignment options could be eliminated.

The Syracuse University steam station and chilled water plant would be located close to the southern portal. Numerous steam pipes, chilled water lines and high voltage cables would be tunneled beneath on Burt Street, East Taylor Street, and within the plant.

Along the I-690 and I-81 viaducts as they approach the city's inner limits, ground space below either would function as a highway interchange (such as at the north end of I-81) or would be consumed by vegetation with side streets connecting neighborhoods to the Syracuse University campus at the south end of I-81. These less populated areas would allow for portal points to be further considered as areas of entries and egress into the alternative alignments discussed.

The community grid area along I-81 between the northern constraint of Erie Boulevard and the southern constraint of Martin Luther King East shares a variety of residential housing, student housing facilities, small business, large business, medical facilities, educational facilities, and large industrial facilities. Maintaining active utility services without community disruption would be a crucial component at the time of the design consideration phase of this connective corridor between the eastern portion of the inner city to the Syracuse University campus area and medical facilities. This should ensure that the revitalization of this area would have a positive impact on the community as well and improving traffic flow and pedestrian access.

Site-specific utility impacts for this alternative are shown in Appendix I.

5.4.10 PROPERTY IMPACTS

A property impact analysis was prepared for the various alternatives. The efforts required under this property analysis task included the following:

- Determining the limits of property impacts associated with each alternative.
- Identifying the affected parcels.
- Collecting affected parcels data.
- Assessing impacts.
- Assessing value of affected properties.

Assumptions and the methodology used to determine the impacts are summarized in Section 3 while backup documentation and maps relative to each alternative are shown in Appendix J.

Twenty two (22) Full Fee Takings are projected for this option. The Full Fee Takings include twelve (12) properties containing building that will require demolition. The remaining ten (10) properties are either vacant or have uses that do not require buildings (i.e. parking lot). The described takings were used to develop estimates for property acquisition costs.

5.4.11 DEVELOPMENT CONSTRAINTS

The future construction of buildings directly above the Orange Alternative tunnel would be minimally constrained by the allowable depth of footings/piles and the allowable weight of buildings (Appendix J). The south end of the tunnel, south of the railroad, would be in a residential area where future development of buildings greater than five stories tall would be unlikely. Buildings of this size could likely be constructed above the tunnel with no adverse impact.

Immediately north of the railroad, the alignment would pass through the university's steam plant. If future industrial development is anticipated on this site, it could be preferable to construct the tunnel as a cut-and-cover tunnel that could be designed for future overbuild loads (rather than the currently shown bored tunnel, which would be suitable for low-rise overbuild).

The Orange Alternative would pass east of downtown under developable land near McBride Street and Townsend Street. The depth to the crown of the tunnel would be typically around 80 feet, and the tunnel would be expected to be in rock, which should result in little or no constraint on future high rise development (geotechnical profiles, Appendix D). The cut-and-cover tunnel on both sides of Erie Boulevard, near the north portal, could be designed for future overbuild at a moderate cost premium

5.5 FEASIBLE BUILD ALTERNATIVE GREEN

5.5.1 GENERAL OVERVIEW

The Green Alternative would be aligned immediately east of the I-81 viaduct (see Figure 51).

The Green Tunnel Alternative would start in the south, south of to Martin Luther King East, and would bend to the east to clear the existing I-81 alignment immediately south of the railroad. The southern end of the bored tunnel would be close to this location. To achieve this geometry, reverse curves would be required on both the through tunnel and ramp leading to the community grid (see Appendix-A).

A single bi-level tunnel would be recommended due to the restricted width of available space between the piles of the I-81 viaduct (to the west) and the Crowne Plaza Hotel and hospital buildings (to the east).

From the south portal, the bored tunnel would pass under the Pioneer Homes housing project and immediately adjacent to the Upstate Medical University Hospital, and beneath the I-81 northbound off-ramp to Adams Street (see drawing in Appendix "Green Alignment – Bored Tunnel at Monroe St"). The crown of the tunnel would be expected to be below the tip of existing piles of I-81 Ramp I (northbound to Adams) and Ramp III (northbound from Harrison). Some piles would be steel and others battered cast-in-place piles. The risk of encountering piles would need to be reviewed in detailed design, a deeper tunnel alignment could be adopted to reduce the risk.

The northern portal would be located within the footprint of Almond Street, resulting in traffic disruption and utility relocations. The bored tunnel would be very shallow in this location (see profile in Appendix E) requiring special measures to restrain the TBM from becoming buoyant.

The bored tunnel would end at East Fayette Street. The at-grade parking lots in this area would be acquired to make an efficient reception/launch site for the bored tunnel (Appendix E), in addition to being necessary for future viaduct ramp construction. Areas adjacent to future ramps remaining from the acquisition could be leased/sold back to interested developers for parking or other suitable uses.

A cut-and-cover tunnel would turn westward to connect into the ramps of the existing I-81 viaduct. Connections from I-81 NB to both I-690 WB and I-81 NB would be maintained along with the reverse flows. A ramp for I-81 NB to I-690 EB would be constructed while no reverse ramp would be included. Some underpinning and reconstruction of I-690 would be required.

Advantages of Green Alternative:

- Enables connections to I-690, while limiting modifications to the existing I-690 roadways and structures
- Relatively short tunnel
- Requires less reconstruction of I-690 than the Orange Alternative
- Generally passes under public land
- Avoids Syracuse University Steam Station & Chilled Water Plant

- Disadvantages of Green Alternative
  - Confined geometry throughout
  - Requires permanent closure of Water Street, Washington Street and East Fayette Street
  - Passes close to foundations of hospital and Crowne Plaza Hotel
  - I-690 WB to I-81 SB connection would be permanently removed
  - Special buoyancy control measures would be required for the bored tunnel
  - Risk of encountering piles from I-81 viaduct and ramps
  - Steeper tunnel (6%), at the southern portal, compared with other options (4%)

FIGURE 51: Green Alternative Map

FIGURE 52: Green Alternative North Portal

5.5.2 HIGHWAY DESIGN

TUNNEL TRAFFIC

Traffic volumes in the tunnel would be the highest of all alternatives. All connections between I-81 and I-690 would remain but the Harrison Street ramps would still be eliminated, requiring some drivers to use the local surface street grid to access the downtown area. Anticipated traffic volumes would range from 2,030 vph during the AM peak hour in the northbound direction to approximately 2,050 vph during the PM peak hour in the southbound direction. (For details on traffic volumes see Appendix C-3 of the DEIS.)

5.5.3 COMMUNITY GRID

FOCUS AREA A: SOUTH TUNNEL PORTAL

The south tunnel portal would be connected to Almond Street via on- and off-ramp structures from the I-81 mainline and first tie in at-grade at Taylor Street. This connection would require the closure of Burt Street due to vertical clearance requirements. Martin Luther King East/Renwick Avenue would remain open. The existing segment of Almond Street south of Taylor Street would be converted to a one-way northbound frontage road, providing connections between Van Buren Street, Burt Street, and Taylor Street on the east side of Almond Street. A two-way bicycle track would be located adjacent to the general purpose travel lane and would provide direct bicycle connections from Almond Street to Van Buren Street and the Syracuse University campus.

This ramp connection would be constructed directly above the cut-and-cover tunnel portal, requiring the tunnel to be completed before construction of the ramp.

FOCUS AREA B: ALMOND STREET CORRIDOR

The Almond Street corridor—generally defined as Almond Street between the south tunnel portal and I-690—would have a right-of-way of up to approximately 150 feet. It would range between two and three general purpose travel lanes in each direction, with designated curbside bicycle lanes and 15-foot sidewalks on the east and west sides of the street. Where possible, parallel on-street parking would be provided for convenience and to slow traffic. To mitigate Almond Street's wide cross-section and provide a visual buffer from potentially high traffic volumes, side and center medians would be constructed, which would provide area for substantial tree planting and canopy, add aesthetic interest, physically separate travel lanes, and provide green space. A side median with adjacent northbound frontage road would be constructed adjacent to Syracuse Housing Authority's Pioneer Homes between Taylor Street and Adams Street. A wide center median would be constructed north of Adams Street to I-690. In combination, these improvements would make Almond Street a heavily landscaped urban boulevard, and a walkable, multimodal "Complete Street."

Most intersecting streets along the Almond Street corridor would remain unchanged in terms of travel-lane assignment and cross-section configuration. However, this alternative would divert Almond Street to McBride Street at Genesee Street to provide continued north-south connectivity while avoiding the north tunnel portal located north of the intersection with Genesee Street. To accommodate the north tunnel portal, Fayette Street, Washington Street, and Water Street would be closed.

Under this alternative, there would be residual state-owned rights-of-way currently occupied by I-81 viaduct and ramps not required for the reconstruction of Almond Street. This freed up land, most notably on block frontages westerly adjacent to Almond Street, could be redeveloped by others if the state decided to dispose of the property.

FOCUS AREA C: I-690/I-81 CONNECTION TO DOWNTOWN SYRACUSE

Focus Area C generally refers to the area north of Fayette Street where new on- and off-ramps would be constructed under the Green Alternative to provide grade-separated access to I-690 from the Almond Street corridor. Under the Green Alternative, the I-81 north tunnel portal would also be in this location and aligned in the center of the existing Almond Street right-of-way north of Fayette Street. This would require closing Fayette Street, Washington Street, and Water Street and realigning Almond Street west to McBride Street to maintain north-south connectivity. The Almond Street/McBride Street realignment would continue as two lanes in each direction with wide sidewalks and bicycle lanes north of the I-690 ramps to Erie Boulevard, where Almond Street/McBride Street narrows to a four-lane cross-section with no center median.

Providing a direct local-to-interstate connection would be critical to maintaining acceptable levels of service in downtown Syracuse. To provide this connection from the north end of Almond Street, on- and off-ramps would begin and end in a wide center median at the intersection of Almond Street with Fayette Street, and ascend north and west toward over Washington Street, Water Street, and Erie Street, ultimately tying in to I-690 EB and WB.

The closure and demolition of existing ramps from I-81 to I-690 and the introduction of new ramp connections from Almond Street to I-690 as part of the Green Alternative would provide a substantial amount of residual state-owned land for potential disposal north of Washington Street between McBride Street and Almond Street.

5.5.4 GEOTECHNICAL CONDITIONS

Based on limited available geotechnical information, ground conditions for the Orange Alternative appear to be favorable for closed mode TBM construction. The southern portal of the bored tunnel would be located so that most of the tunnel face would be in the bedrock (shale). Appendix D provides anticipated geotechnical profiles. However, the northern portal would be in a zone of mixed face, with the upper part of the TBM in soil. Ground treatment, such as jet grouting, could be required. In addition, the TBM could need to mine between rows of secant piles with a concrete cap slab, in order to resist buoyancy and to control settlement adjacent to the Crowne Plaza Hotel (see Appendix E). With these measures in place, settlement above the tunnel should be low.

5.5.5 TUNNEL DESIGN & CONSTRUCTION

The Green Tunnel would consist of a single bore carrying I-81 traffic through downtown Syracuse. This alignment would be limited to the area south of I-690 to the south portal area, south of Martin Luther King East. Beginning south of Syracuse University, the tunnels would begin in a cut-and-cover section for approximately 1300 feet. This portion of the construction would cross under Martin Luther King East while the ramps to Almond Street would be constructed on viaduct above the existing roadway crossing. The single bore would continue for approximately 4,300 feet. Within this section, the tunnel would descend to a depth of roughly 65 feet below grade at a slope of 6%. The bulk of the tunnel bore would be 65 feet below grade before ascending at 6% grade within the I-81 right-of-way at Fayette Boulevard, cutting it off from east-west circulation. The bored section runs almost exclusively in the Almond Street right-of-way corridor. The tunnel section continues in a cut-and-cover section for another 500 feet tying to the existing I-81 alignment north of Washington Street. The design speed for this option would be 50 mph. The minimum horizontal curvature for this option would be 1,500 feet, greater than that required by design criteria, although the minimum necessary to provide the sight distance requirement for vehicles traveling 50 mph. The design includes non-standard design features for shoulder widths within tunnel sections only before transitioning to full width shoulders outside of the tunnels. Due to the diameter of the bore, shoulders of 6 feet would be provided on both left and right sides adjacent to the 12-foot lanes. The bore contains two 12-foot lanes and two 6-foot shoulders to convey traffic both southbound and northbound along I-81.

The Green Alternative includes the following interstate connections:

- I-81 SB to I-690 EB – existing ramp on viaduct
- I-81 NB to I-690 WB – new ramp on viaduct
- I-81 NB to I-690 EB – new ramp on viaduct
- I-690 EB to I-81 SB – new ramp on viaduct
- I-690 WB to I-81 NB – existing ramp on viaduct

There would be an option to provide a connection from I-690 EB to I-81 NB, which would not interfere or affect the tunnel construction for the Green Alternative. This work would be completely independent of the green tunnel work since it would not interfere or affect the tunnel construction.

The Green Alternative would include reconstructing Almond Street into a boulevard, similar to all other alternatives, along with demolishing the existing viaduct from nearly Washington Street to Burt Street. Constructing a smaller limited interchange at Almond Street/I-690 and various traffic operational improvements throughout the street grid would be required to replace the local street access lost by eliminating the Harrison Street ramps. However, the existing viaduct could be maintained in combination with the new tunnel to permit a reconstructed set of Harrison Street ramps. Separate from the actual tunnel construction, this alternative would construct two viaduct ramps, extending from the western leg of I-690 to Fayette Street. Working in combination with the Almond Street/I-690 interchange, these viaduct ramps would replace the existing Harrison Street ramps, which are heavily used, and permit the Erie Street/Almond Street intersection to be at-grade.

Access to the local street grid would be maintained and provided at the I-690/West Street interchange, modified I-690/Almond Street interchange, and includes the Fayette Street flyover ramps. Maintenance of the local ramps located near the north portal at Hickory (to I-81 NB), Clinton (from I-81 SB), and Taylor (to I-81 SB and from I-81 NB). Local streets would be significantly affected with permanent closures expected at Burt Street near the south portal. Martin Luther King East and Renwick will remain open. Water Street and Washington Street would be cut off near the northern portal due to limited vertical clearance from the tunnel mainline and local ramp viaduct structures as would be a portion of Almond Street, which would be relocated to avoid the ascending tunnel/viaduct at Fayette. Fayette Street would be cut off due to the ascending single bore tunnel.

The Green Alternative would be completely independent from the work to correct the existing I-690 geometric deficiencies. The baseline alternative could be implemented with either the existing alignment or a reconstructed alignment, which would address the existing geometric deficiencies.

PROTECTION OF STRUCTURES

Under the Green Alternative, the construction of the proposed ramps between I-81 and I-690 would interfere with an existing pier at the existing I-690 EB structure over Townsend Street. To protect this structure, reframing of the existing piers and temporary supports would be necessary. In this case, the existing structure could be replaced where necessary, before construction operations. During construction, the contractor would need to take care that operations and equipment would not be in danger of damaging existing structures. Although the existing and proposed structures would be within close proximity as laid out by the Green Tunnel Alternative alignments, this type of construction would not be uncommon and could be accomplished in a manner that safely protects the existing structures.

At the southern end of the project, the proposed I-81 roadway approach to the Alternative tunnel could be built independently and would avoid affecting the existing I-81 traffic. The same would be true for the new ramp over the existing railroad, which would lead to the newly constructed community grid for downtown Syracuse.

Along the existing I-81 viaduct portion, which goes through downtown Syracuse, the Green Alternative tunnel would go directly underneath and adjacent to the existing structure. Within this area, it would be important to evaluate the tunnel's impacts on the surrounding soil and existing foundations, and thus the need for temporary shoring or reframing the viaduct to maintain traffic during construction.

5.5.6 VIADUCT DESIGN & CONSTRUCTION

The Green Alternative layout would run the tunnel parallel to the existing viaduct, and would come above ground just before the existing interchange. This design would establish limited connections between I-81, I-690, and the community grid and would maintain most of the existing I-690 structures and roadways. New and replacement bridges would be of standard construction, such as reinforced concrete deck on steel or concrete girders and concrete piers, unless circumstances require a different approach. The existing I-81 NB ramp would be replaced with an adjacent ramp. Since traffic volumes on the ramp from I-690 WB to I-81 SB would be relatively light, it was determined to eliminate this connection and the structure to be demolished at the start of construction to create more space. The new I-81 NB and SB elevated roadways from the tunnel through the interchange can mostly be built separately, one elevated roadway at a time, and tie into the existing I-81near Willow Street. Localized staged construction would be needed where the existing and new overlap. Most of the existing I-690 structures could be maintained with slight modifications to accommodate the new alignments. The existing I-690 EB flyover would need reframing to accommodate the new alignments. At the southern end of the viaduct, where tunneling begins, a new structure would be built over the railroad. This new structure would not affect the existing structure and would be tied into the community grid when open to traffic.

Since most of the existing bridges and viaducts would be supported by piles, it can be assumed that the new bridges, viaducts, and ramps would also be supported by piles.

5.5.7 TUNNEL SYSTEMS

The Green Alternative with its single bi-level tunnel would be unique with respect to other alternatives for the tunnel systems design, particularly ventilation and egress. An exhaust duct is recommended for this alternative, with operable dampers spaced every 300 feet (approximately 88 dampers needed). A ventilation building may be needed at each end of the tunnel to house equipment for ventilation, including exhaust fans. Jet fans would primarily be needed for air balance control, rather than primary ventilation. With jet fans spaced at 1,000 linear feet and installed in pairs, the fan estimate for this alternative would require 32 fewer fans than other alternatives. Ventilation could be operated in normal conditions for this alternative to minimize discharge of vitiated air at the portals. An environmental assessment of air quality for this alternative would still be necessary to confirm operational requirements.

Egress would be provided between the levels by connecting fire-rated stairways spaced at about 600 linear feet, approximately 10 to 11. Holding areas for non-ambulatory people would be required. Other systems such as electrical, drainage and fire protection, finishes, controls and ITS, would scale in quantity based on the tunnel length.

5.5.8 CONSTRUCTION STAGING

The Green Alternative would have less complex staging than the Orange Alternative and could be done with limited impacts to traffic. The new I-81 NB to I-690 EB ramp would be built adjacent to the existing alignment to start, and then would be tied into the existing alignment as it enters I-690 EB. This could be done with staged construction. Since the existing ramp would be one lane with shoulders on each side, the staged construction in this area would have negligible impact on traffic. At this time, the tunnel could be open to traffic for using I-81 NB as a connection to I-690 EB, while the existing viaduct could remain open for the remaining connections. The existing I-81 NB to I-690 EB could be removed to eliminate its obstruction to the proposed I-81 ramps. With both the existing I-81 NB to I-690 EB and I-690 WB to I-81 SB removed, the proposed I-81 NB ramp could be built with no obstructions adjacent to and north of the existing ramp and tied into the existing roadways where feasible, using typical localized staging. Upon completing the new I-81 NB ramp, the existing ramp could be demolished. With the existing I-81 NB demolished, the new I-81 SB ramp could be built and tied into the existing structure. Finally, the new I-690 EB to I-81 SB ramp could also be tied into the existing ramp structure with limited staged construction. With all proposed structures in place, the remaining existing structures could be removed.

After removing the existing structure, the southern connection from I-81 to Almond Boulevard would be constructed, on top of the tunnel.

5.5.9 UTILITIES

Utility impacts for this alternative would be present at the south and north portals. Additional impacts would be expected within the Almond Boulevard reconstruction zone, although these utilities would be readily located within the work zone. Major relocations would be expected for utilities affected by north and south portals since relocation would typically be needed outside the portal zone.

Utility investigation and identification would be important to the design consideration phases of this project, and would help in determining what alignments would be further studied and what alignment options could be eliminated. Along the I-690 and I-81 viaducts as they approach the city's inner limits, ground space below would either function as a highway interchange (such as at the north end of I-81) or would be consumed by vegetation with side streets connecting neighborhoods to the Syracuse University Campus at the south end of I-81. These less populated areas would allow for portal points to be further considered as areas of entries and egress into the alternative alignments discussed.

The community grid area along I-81 between the northern constraint of Erie Boulevard and the southern constraint of Martin Luther King East shares a variety of residential housing, student housing facilities, small business, large business, medical facilities, educational facilities and large industrial facilities. Maintaining active utility services without community disruption would be a crucial component at the time of the design consideration phase of this connective corridor between the eastern portion of the inner city to the Syracuse University campus area and medical facilities. This should ensure that the revitalization of this area would have a positive impact on the community as well and improving traffic flow and pedestrian access.

Appendix I shows site-specific utility impacts for this alternative.

5.5.10 PROPERTY IMPACTS

A property impact analysis was prepared for the various alternatives. The efforts required under this property analysis task included the following:

- Determining the limits of property impacts associated with each alternative
- Identifying the affected parcels
- Collecting affected parcels data
- Assessing impact
- Assessing value of affected properties

The assumptions and methodology used to determine the impacts are summarized in Section 3 while backup documentation and maps relative to each alternative is shown in Appendix J.

Six (6) Full Fee Takings are projected for this option. The Full Fee Takings include two (2) properties containing building that will require demolition. The remaining four (4) properties are either vacant or have uses that do not require buildings (i.e. parking lot). The described takings were used to develop estimates for property acquisition costs.

5.5.11 DEVELOPMENT CONSTRAINTS

The future construction of buildings directly above the Green Alternative tunnel would be minimally constrained by the allowable depth of footings and the allowable weight of buildings (Appendix J). The south end of the tunnel, near the railroad, would be in a residential area where future development of buildings greater than five stories tall would be unlikely. Buildings of this size could likely be constructed above the tunnel with no adverse impact.

The rest of the alignment would run directly below Almond Street, so future development directly above the bored tunnel or north portal cut-and-cover would be unlikely.

	2050 Green Alternative			
	Weekday AM Peak Hour		Weekday PM Peak Hour	
	Northbound	Southbound	Northbound	Southbound
Volume (vph)	2,031	1,721	2,131	2,049
Estimated Level of Service	C	B	C	C

TABLE 15: Weekday Peak Hour Tunnel Traffic (vph): 2050 Build – Green Alternative

Assumptions:

1. Closure of I-690 WB to I-81 SB Ramp

2. Two-Lane Tunnel

5.6 FEASIBILE BUILD ALTERNATIVE BLUE

5.6.1 GENERAL OVERVIEW

As analyzed for this feasibility study, the Blue Tunnel Alternative would be aligned southwest of downtown Syracuse, and would connect into West Street close to the interchange with I-690. It would include two separate sections of tunnel: Martin Luther King East to West Street, and West Street to near Destiny Mall (Figure 53).

The Blue Alternative would start south of Martin Luther King East and would trend to the northwest. A cut and cover tunnel would transition to a bored tunnel near South McBride Street. A TBM launch shaft would be located south of the Van Buren and South McBride Street Intersection. The bored tunnels would pass under the railroad, and stay west of the Syracuse University steam station & chilled water plant.

The tunnels would pass under the southwest corner of the Pioneer Homes housing project, Roesler Park, and low-rise buildings on South Warren Street. The tunnel would continue under the railroad and Onondaga Creek, and would pass to the south of the parking lot for the Museum for Science and Technology, which overlies water storage tunnels that comprise the Clinton CSO Facility. The tunnels would re-cross both the creek and the railroad as they approaches West Street.

The bored tunnel would transition to cut-and-cover at West Fayette Street. The existing interchanges at Erie Boulevard and I-690 would require significant reconstruction. A connection with I-690 would be constructed. Significant open-cut excavation would be required during construction, but the finished condition above the cut-and-cover structures at West Street would be substantially the same as today. Northbound off-ramps and southbound on-ramps would provide connections to I-690 and city streets.

The bored tunnel would re-commence south of I-690, continue north under low-rise buildings, and pass east of the Inner Harbor. The tunnel would daylight and rise onto a viaduct to span over Bear Street and I-81 SB. A new intersection with I-81 would be constructed close to Destiny Mall along with a realigned Genant Drive / Bear Street intersection.

Both tunnel sections would comprise twin tube tunnels, with cut-and-cover sections at the north and south portals, and at West Street.

The open space in this area would be a favorable TBM launch location.

- Advantages of Blue Alternative:
  - Bypasses Syracuse University steam station & chilled water plant
  - Favorable geometry for tunnel portal site south of the railroad, or south of Destiny Mall
  - Avoids risk of tunneling under I-81 (encountering piles, settlement)
  - Has limited impact on I-690 elevated section.
  - Uses existing West Street interchange (with modifications) for connecting to I-690
  - Interchanges with I-81 would be located in areas with available land
  - Traffic on the existing I-81 and I-690 at the interchange would not be affected during construction.

- Disadvantages of Blue Alternative
  - Longest tunnel
  - Passes under private land
  - Property acquisitions required at West Street
  - Utility relocations required at West Street
  - Tunnel could limit future development requiring piles.
  - West Street interchange could experience heavy traffic.
  - Unknown depth of rock for much of the alignment could result in cost increases
  - A variation to the Blue Alternative would be to construct only the southern section, as far as West Street, and to maintain a through movements on I-81 via West Street, and new flyover ramps to I-81 NB. This option would include multiple curved ramps and elevated structures, but could be less expensive than the full Blue Alternative. It is not considered further here, but could be studied as future design development.

5.6.2 HIGHWAY DESIGN

TUNNEL TRAFFIC

Traffic volume in the tunnel would be somewhere between the levels seen in the Orange and Green Alternatives. Although the current I-81/I-690 ramps would be eliminated, the same movements would be replicated at the West Street interchange. Drivers currently using the Harrison Street ramps to access the downtown area would need to avoid the tunnel. Drivers traveling between areas along I-81 to the south and along I-690 to the east would split their reroutes between the local street grid and the West Street interchange to get to their destination. Anticipated traffic volumes would range from 1,600 vph during the AM peak hour in the northbound direction to approximately 2,350 vph during the PM peak hour in the southbound direction.

5.6.3 COMMUNITY GRID

FOCUS AREA A: SOUTH TUNNEL PORTAL

The south tunnel portal would be connected to Almond Street via on- and off-ramp structures from the I-81 mainline, and first tie in at-grade at Taylor Street. This connection would require the closure of Burt Street due to vertical clearance requirements. Martin Luther King East/Renwick Avenue would remain open. The existing segment of Almond Street south of Taylor Street would be converted to a one-way northbound frontage road, providing connections between Van Buren Street, Burt Street, and Taylor Street on the east side of Almond Street. A two-way bicycle track would be located adjacent to the general purpose travel lane and would provide direct bicycle connections from Almond Street to Van Buren Street and the Syracuse University campus.

FOCUS AREA B: ALMOND STREET CORRIDOR

The Almond Street corridor, generally defined as Almond Street between the south tunnel portal and I-690, would have a right-of-way of up to approximately 150 feet. It would range between two and three general purpose travel lanes in each direction, with designated curbside bicycle lanes and 15-foot sidewalks on the east and west sides of the street. Where possible, parallel on-street parking would be provided for convenience and to slow traffic. To mitigate Almond Street's wide cross-section and provide a visual buffer from potentially high traffic volumes, side and center medians would be constructed, which would provide area for substantial tree planting and canopy, add aesthetic interest, physically separate travel lanes, and provide green space. A side median with adjacent northbound frontage road would be constructed adjacent to Syracuse Housing Authority's Pioneer Homes between Taylor Street and Adams Street. A wide center median would be constructed north of Adams to I-690. In combination, these improvements would make Almond Street a heavily landscaped urban boulevard, and a walkable, multimodal "Complete Street." All intersecting streets along the Almond Street corridor would remain unchanged in terms of travel lane assignment and cross-sectional configuration.

	Property Impact Classification by Land Use							
	Commercial	Residential	Industrial	Vacant	Parks	Public Services	Comm. Services	Unknown
Partial Fee Taking	6	0	0	0	0	1	1	1
Full Fee Taking	4	0	0	2	0	0	0	0
Permanent Easement	3	0	0	1	0	3	5	0

TABLE 16: Property Takings: Green Alternative

Under this alternative, there would be residual state-owned rights-of-way currently occupied by I-81 viaduct and ramps not required to reconstruct Almond Street. This freed up land, most notably on block frontages westerly adjacent to Almond Street, could be redeveloped by others if the state decided to dispose of the property.

FOCUS AREA C: I-690/I-81 CONNECTION TO DOWNTOWN SYRACUSE

Focus Area C generally refers to the area north of Fayette Street where new on and off-ramps would be constructed under the Blue Alternative to provide grade separated access to I-690 from the Almond Street corridor. Providing a direct local-to-interstate connection would be critical to maintaining acceptable levels of service in downtown Syracuse. To provide this connection from the north end of Almond Street, on- and off-ramps would begin and end in a wide center median at the intersection of Almond Street with Fayette Street, and ascend north and west toward over Washington Street, Water Street, and Erie Street, ultimately tying in to I-690 EB and WB. This would necessitate the closure of Washington Street and Water Street due to vertical clearance requirements. Almond Street would continue as two lanes in each direction with wide sidewalks and bicycle lanes north of the I-690 ramps to Burnet Avenue where Almond Street narrows to a four-lane cross-section with no center median.

The closure and demolition of existing ramps from I-81 to I-690 and the introduction of new ramp connections from Almond Street to I-690 would provide a substantial amount of residual state-owned land for potential disposal north of Fayette Street between McBride Street and Almond Street.

5.6.4 GEOTECHNICAL CONDITIONS

Geotechnical information along the Blue Alternative alignment is limited. At West Street/I-690, available boring logs encountered no rock to depths of 100 feet. It is assumed that the whole alignment would be either in soft ground (soil) or potentially in mixed face. In either case a pressurized face EPM tunneling machine is proposed, which would be suitable for these conditions (see Appendix E).

The depth of rock at the West Street cut-and-cover structures is unknown but has been assumed as 100 feet. A similar depth has been assumed for the north portal. For cost estimating purposes support of excavation walls have been extended to this depth. If future geotechnical boring programs determine that rock would be significantly deeper, the cost of the support walls would increase, and it could be necessary to install a jet grout invert plug.

5.6.5 TUNNEL DESIGN & CONSTRUCTION

The Blue Alternative would run westerly of all others, essentially replacing the West Street interchange with a new limited movement highway interchange. Local connections at West Street would then be implemented farther east of West Street. The Blue Alternative evaluated both twin bore and single bore options. The twin bore option is preferred since it would provide better highway connections at West Street.

The Blue Alternative tunnel would consist of a twin bore carrying I-81 and I-690 traffic through downtown Syracuse. This alignment would be the longest in-tunnel length and would include two bored sections with an intermediate cut-and-cover section in the middle that facilitates connections to I-690. Beginning south of Syracuse University, the roadway would be realigned leading to the beginning of tunnel construction via cut-and-cover. The single bore would continue for approximately 4,100 feet. Within this section, the tunnel would descend to roughly 80 feet below grade at a slope of 4%. The bulk of the tunnel bore would be 80 feet below grade prior to ascending at 6% grade to a cut-and-cover section at West Street. Moving north roughly 1,300 feet, the tunnel would be constructed using cut-and-cover methods, which would permit the various I-690 ramps to merge into I-81. North of this cut-and-cover section, a second bored alignment would be designed leading farther north again descending at 6% grade beneath Onondaga Creek and I-690 to 80 feet below grade. The second bored section would finish at 5,500 feet just south of the Solar Street/Court Street intersection. The tunnel section would continue in a cut-and-cover section for another 500 feet, before rising on viaduct to flyover existing Bear Street and I-81 Southbound. Significant realignment of Genant Street including a new intersection at Bear Street is required. The design speed for this option would be 50 mph. The minimum horizontal curvature for this option would be 1,500 feet, greater than that required by design criteria, although the minimum necessary to provide the sight distance requirement for vehicles traveling 50 mph. Non-standard shoulder widths would be provided within the tunnel section, which would transition to compliant widths outside the actual tunnel construction. Due to the diameter of the bore, shoulders of 4 feet would be provided on both left and right sides adjacent to the 12-foot lanes. Each bore would contain two 12-foot lanes and two 4-foot shoulders to convey traffic both southbound and northbound along I-81.

The Blue Alternative includes the following interstate connections:

- I-81 SB to I-690 EB – existing ramp on viaduct. I-81 would be maintained through several connections to I-690 that would be not facilitated by the new tunnel.
- I-81 NB to I-690 WB – new ramp from tunnel cut-and-cover area
- I-81 NB to I-690 EB – new ramp from tunnel cut-and-cover area
- I-690 EB to I-81 SB – new ramp from tunnel cut-and-cover area
- I-690 WB to I-81 NB – existing ramp on viaduct

- The option exists to provide a connection from I-81SB to I-690 WB. This work would be completely independent of the Blue Alternative work since it would not interfere or affect the tunnel construction.

The option exists to provide a connection from I-690 EB to I-81 NB. This work would be completely independent of the Blue Alternative work since it would not interfere or affect the tunnel construction. However, inclusion of this ramp would be on structure and require modification to the city street grid to facilitate.

The Blue Alternative includes reconstructing Almond Street into a boulevard, similar to all other alternatives, along with demolishing the existing viaduct from nearly Washington Street to Burt Street. The construction of a smaller limited interchange at Almond Street/I-690 and various traffic operational improvements throughout the street grid would be required to replace the local street access lost by eliminating the Harrison Street ramps. However, the existing viaduct could be maintained in the Blue Alternative to permit a reconstructed set of Harrison Street ramps to be included within the Green Alternative. The street grid would be required to complete several other movements:

- I-690 WB to I-81 SB – must use new Almond Street/I-690 interchange

Separate from the actual tunnel construction, this alternative would include constructing two viaduct ramps that would extend from the western leg of I-690 to Fayette Street.

FIGURE 53: Erie Boulevard West Overpass (over North West Street) (Looking South)

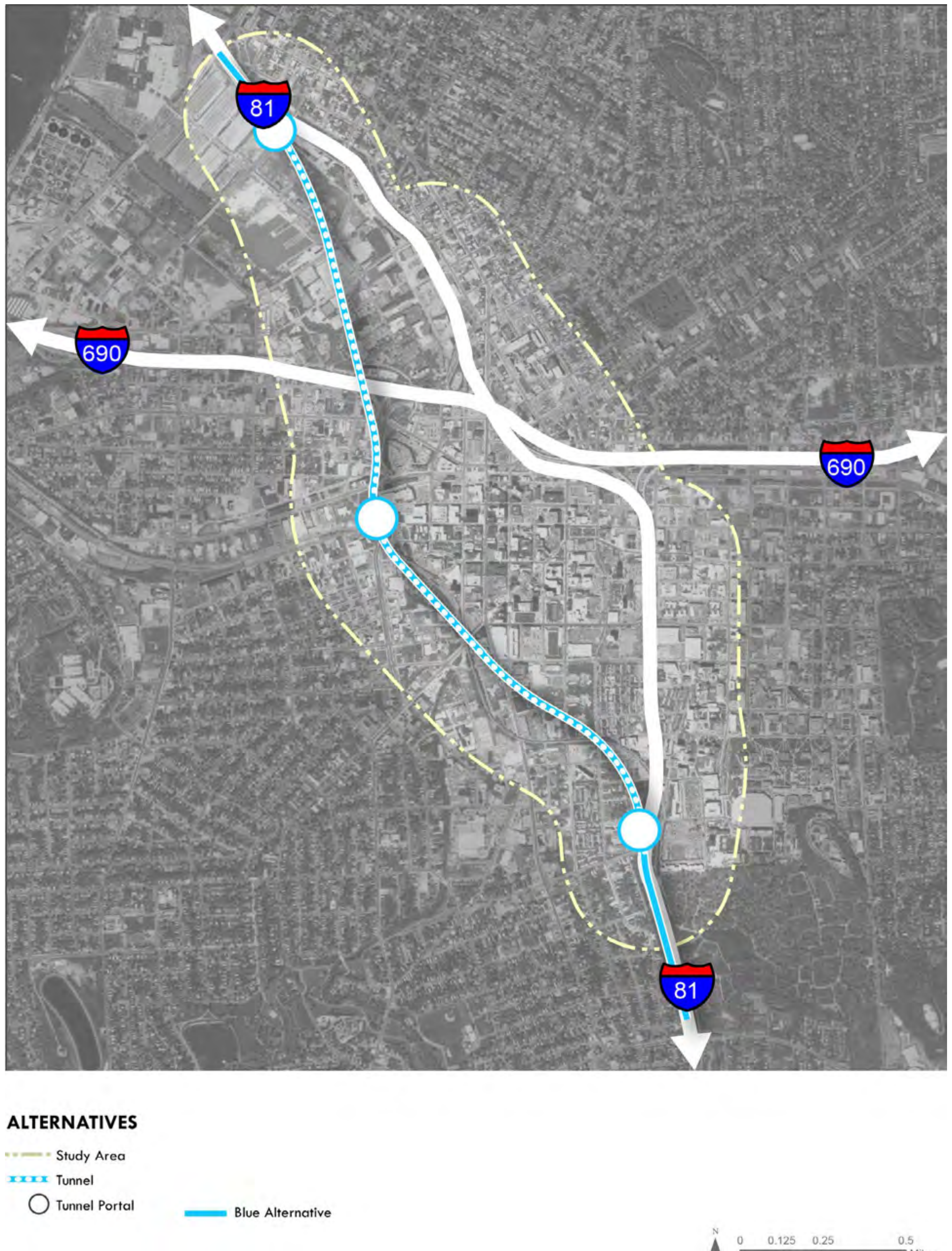


FIGURE 54: Blue Alternative Map

FIGURE 55: Blue Alternative North Portal

FIGURE 56: Blue Alternative – West Street

Working in combination with the Almond Street/I-690 interchange, these viaduct ramps would replace the existing Harrison Street ramps, which were heavily used, and permit the Erie Street/Almond Street intersection to be at-grade.

Local connectivity would be significantly altered in the Blue Alternative. While this option would provide a new interchange at I-690/Almond Street, the interchange at West Street would be effectively removed. Genesee Street would be maintained along with constructing a new north-south West Street above the cut-and-cover tunnels to Erie Boulevard. Access to the local street grid would be maintained and provided at the I-690/West Street interchange, modified I-690/Almond Street interchange, and includes the Fayette Street flyover ramps. Maintenance of the local ramps located near the north portal at Hickory Street (to I-81 NB), Clinton Street (from I-81 SB), and Taylor Street (to I-81 SB and from I-81 NB). Additionally, an off-ramp from I-690 EB would be designed to Salina Street while an on-ramp to I-690 WB begins at Clinton Street. Local streets would be marginally affected with permanent closures expected at Burt Street near the south portal in addition to Water Street and Washington Street to accommodate the Fayette Street ramps.

The Blue Alternative would be completely independent from the work to correct the existing I-690 geometric deficiencies. However, the new tunnel would eliminate various ramp connections in the I-690/I-81 merge area that would ultimately reduce the overall structure height should that section be reconstructed. The baseline option could be implemented with either the existing alignment or a reconstructed alignment, which would address the existing geometric deficiencies.

PROTECTION OF STRUCTURES

Under the Blue Alternative, the existing I-690 and I-81 interchange would be avoided and the existing structures in this area would not be affected during construction. The existing Erie Boulevard over West Street Bridge would overlap with the cut-and-cover area of the project and would be affected greatly by construction operations and would need replacement. Traffic would need to be diverted while cut-and-cover operations are in progress. The West Street and I-690 connections would need replacement ramps built, with reframing possible where proposed alignments would overlap with the existing, such as where the proposed West Street to I-690 WB ramp would overlap with the existing I-690 WB to West Street SB ramp. The replacement of I-690 WB and EB could be performed after the completion of the tunnel's construction and the removal of existing I-81 connections. The new I-690 would be built using a combination of newly constructed and existing roadways, but could be accomplished via staging while limiting impacts to traffic.

5.6.6 VIADUCT DESIGN & CONSTRUCTION

The Blue Alternative would align the I-81 tunnel to the west toward West Street, and would come to ground level to allow for connections to the West St and I-690 interchange, before continuing underground. At the northern end, the tunnels would reach existing grade just past the intersection of Solar Street and Court Street. A new bridge would be needed to bring traffic above Bear Street, a major roadway carrying traffic going to and from Destiny USA Mall, I-690, and existing I-81. New and replacement bridges would be of standard construction, such as reinforced concrete deck on steel or concrete girders and concrete piers, unless circumstances require a different approach. A portion of the existing I-81 would remain under this alternative, to the north of the existing interchange. At the southern end of the project, the proposed I-81 roadway and tunnel could be built independently and would avoid affecting the existing I-81 entirely. The same would be true for the new ramp over the existing railroad, which would lead to the newly constructed community grid for downtown Syracuse.

The replacement of I-690 WB and EB could be performed after completing the tunnel's construction and removing existing I-81 connections. The new I-690 would be built using a combination of newly constructed and existing roadways, but could be accomplished via staging while limiting impacts to traffic. Under this alternative, the West Street and I-690 interchange ramps would be replaced to accommodate the new alignments of I-690.

As most of the existing bridges and viaducts would be supported on piles, it can be assumed that the new bridges, viaducts and ramps would also be supported on piles.

5.6.7 TUNNEL SYSTEMS

Tunnel systems would be similar for the Red, Orange and Blue Alternatives and would generally vary only by the quantity of equipment required. For instance, with jet fans spaced at 500 linear feet and installed in pairs, this alternative would require 104 fans. A ventilation building may be required at each portal with point exhaust to remove vitiated air and discharge it at high velocity above the ground level. Given the length of this alternative, it is unlikely that an environmental assessment of air quality for this alternative would eliminate the need for a ventilation building and allow ventilation with jet fans alone. Environmental air quality assessment would still be necessary to confirm operational requirements.

Egress passages between the bores, spaced at about 600 linear feet, would number approximately 21 to 22. Other systems such as electrical, drainage and fire protection, finishes, controls and ITS, would scale in quantity based on the tunnel length.

	2050 Blue Alternative			
	Weekday AM Peak Hour		Weekday PM Peak Hour	
	Northbound	Southbound	Northbound	Southbound
Volume (vph)	1,613	1,977	1,814	2,330
Estimated Level of Service	B	B	B	C

TABLE 17: Weekday Peak Hour Tunnel Traffic (vph): 2050 Build – Blue Alternative

Assumptions:

1. *Closure of I-81 NB to I-690 EB Ramp*
2. *Closure of I-690 WB to I-81 SB Ramp*
3. *Closure of I-81 NB to I-690 WB Ramp*
4. *Closure of I-690 EB to I-81 SB Ramp*
4. *Two-Lane Tunnel*

5.6.8 CONSTRUCTION STAGING

For the Blue Alternative, staged construction would be needed primarily for the newly constructed I-690 roadways and structures. The new alignments would take advantage of the existing roadways and bridges to allow for staged construction with limited impacts to traffic. The West Street NB to I-690 WB ramp and the West Street NB to I-690 EB would need to be replaced to accommodate the new alignments of I-690, which could be accomplished with localized staging. Some aspects of these structures could also be built independently without affecting traffic in any way, such as the proposed West Street NB to I-690 EB, which would have a portion of the structure over currently unused land.

The north end of the project limits would also have limited staging areas. A new exit roadway from I-81 SB to Bear Street could be constructed and opened to traffic prior to the construction of the I-81 over Bear Street bridges. Since these structures would also cross a portion of the existing I-81, traffic would be maintained via staging using a portion of the existing roadways and using widened roadways as necessary.

5.6.9 UTILITIES

Utility impacts for this alternative would be present at the south portal, West Street, and north portal. Additional impacts would be expected within the Almond Boulevard reconstruction zone although these utilities would be readily located within the work zone. Major relocations would be expected for utilities affected by north and south portals since relocation would typically be needed outside the portal zone.

Utility investigation and identification would be important to the design consideration phases of this project, and would help in determining what alignments would be further studied and what alignment options could be eliminated. Along the I-690 and I-81 viaducts as they approach the city's inner limits, ground space below would either function as a highway interchange (such as at the north end of I-81) or would be consumed by vegetation with side streets connecting neighborhoods to the Syracuse University campus at the south end of I-81. These less populated areas would allow for portal points to be further considered as areas of entries and egress into the alternative alignments discussed.

Significant utility relocations would be anticipated at West Street, as noted in Appendix I.

The community grid area along I-81 between the northern constraint of Erie Boulevard and the southern constraint of Martin Luther King East shares a variety of residential housing, student housing facilities, small business, large business, medical facilities, educational facilities and large industrial facilities. Maintaining active utility services without community disruption would be a crucial component at the time of the design consideration phase of this connective corridor between the eastern portion of the inner city to the Syracuse University Campus area and medical facilities. This should ensure that the revitalization of this area would have a positive impact on the community as well and improving traffic flow and pedestrian access.

Appendix I shows site-specific utility impacts for this alternative.

5.6.10 PROPERTY IMPACTS

A property impact analysis was prepared for the various alternatives. The efforts required under this property analysis task included the following:

- Determining the limits of property impacts associated with each alternative
- Identifying the affected parcels
- Collecting affected parcels data
- Assessing impacts
- Assessing value of affected properties

Assumptions and methodology utilized to determine the impacts are summarized in Section 3, while backup documentation and maps relative to each alternative is shown in Appendix J.

Forty two (42) Full Fee Takings are projected for this option. The Full Fee Takings include twenty two (22) properties containing building that will require demolition. The remaining twenty (20) properties are either vacant or have uses that do not require buildings (i.e. parking lot).

The described takings were used to develop estimates for property acquisition costs.

5.6.11 DEVELOPMENT CONSTRAINTS

The future construction of buildings directly above the Blue Alternative tunnel would be somewhat constrained in some areas by the allowable depth of footings/piles and the allowable weight of buildings (Appendix J). The south end of the tunnel, south of the railroad, would be in a residential area where future development of buildings greater than five stories tall is unlikely. Buildings of this size could likely be constructed above both the tunnel with no adverse impact.

The crown of the bored tunnel would be generally around 50 feet deep, but slightly shallower close to the portals. It would be anticipated that this tunnel would be primarily in soil, with some areas of mixed face comprising soil and rock (geotechnical profiles, Appendix D).

The Blue Alternative would pass south and west of downtown. It would pass under developable land near Clinton Street and Salina Street. The height of new development would likely be limited to approximately 10 stories on shallow footings. Further analysis would be required to determine whether settlement of buildings of this approximate height would be acceptable if piles were used.

Around the West Street interchange the tunnel would be constructed using cut-and-cover construction, which could be designed to support future high rise overbuild at a moderate cost premium.

The Blue Alternative would pass to the southeast of the Inner Harbor, as a cut-and-cover tunnel, under areas suitable for future development. According to the COR Development Company's master plan for the waterfront area, most of the development would be residential or office of five stories or less. This could be built on top of a previously constructed tunnel. Any development that occurs ahead of tunnel construction could be affected by the tunnel construction. Realignment of the tunnel could be possible to minimize any adverse impact on development.

	Property Impact Classification by Land Use							
	Commercial	Residential	Industrial	Vacant	Parks	Public Services	Comm. Services	Unknown
Partial Fee Taking	9	0	0	9	0	0	1	1
Full Fee Taking	16	9	0	16	0	0	1	0
Permanent Easement	22	1	3	29	2	7	5	3

TABLE 18: Property Takings: Blue Alternative

5.7 CAPITAL COST ESTIMATION

This study looked at building tunnel alternatives set in an urban environment to replace the aging I-81 viaduct section in downtown Syracuse. Successfully delivering one of these alternatives would present many challenges to overcome in the design and construction of the facilities and engage many trades and equipment and construction materials. In developing the cost estimate for each alternative, the work was broken into different areas:

- Tunneling and Heavy Civil work –This includes the major work excavations for the cut and the cut-and-cover transitions to the mining portal, major reinforced concrete work for the cut-and-cover tunnels, the TBM drive(s), handling and disposal of muck, along with the placement of precast concrete segmental liners for the tunnel, providing the temporary power, draining pumps and ventilation needed to work underground.
- Ventilation and Fire-Life Safety Systems –This work includes the permanent ventilation fans and equipment, fire protections, final tunnel drainage, lighting and finishes and special systems in the tunnel.
- Bridges & Ramps (new, temporary and demolishing portions of existing viaduct) – The cost estimate was prepared by calculating the quantities for each alternative on a square-foot basis for the different types of bridge, ramps, temporary structures, underpinning/temporary support of existing structures as well as the portions of the existing viaduct to be demolished.
- Civil Highway and Miscellaneous – This cost estimate includes all the pavement, roadway construction, surface drainage, concrete barriers, guide rails, lighting, signs, landscaping, and utilities for each alternative.
- Right-of-Way and Property Easement – This cost estimate was prepared by reviewing the number of parcels by type that would be affected by the tunnel and roadway alignments.
- Soft Costs (project management/construction management and support, design services, geotechnical exploration program, procurement services, legal, public outreach, etc.) – This estimate accounts for costs associated with successfully delivering a large multi-year project in an urban area.
- Escalation and Risk Reserve – This cost estimate accounts for escalation and a risk reserve associated with successfully delivering a large multi-year project in an urban area.

Table 19 provides the total estimated project costs for each alternative. Please see Appendix K for more details.

5.8 CONSTRUCTION SCHEDULE

Each of the tunnel alternatives considered in this study would be a multi-year project. The project could be packaged to be delivered as a conventional design-bid-build or as a design-build or other alternative delivery process. Regardless of the delivery method, there would be a minimum of two and half to three years of design development and geotechnical exploration needed before any construction could begin. In addition, all needed property rights-of-way and perpetual underground easements must be identified and acquired—a considerable effort by itself. The geotechnical investigation would be needed to inform the tunnel design as well as provide the input to guide the design and manufacture of the project-specific TBM. Once design is complete, construction could commence, which could take five to seven years, depending on the alternative and what time of year construction would start.

The design, manufacture, and delivery of a TBM typically takes a year. It should be noted that for a single bore large diameter TBM another three to six months could be required. During this TBM procurement time, the contractor could mobilize, begin temporary construction to support MOT operations, and excavate the cut-and-cover transition tunnel area and prepare the portal where TBM mining would begin. The TBM operations would start out slowly to let the operator learn how the TBM operates and how the ground responds—this would be the learning curve period. Efficiency increases as mining progresses. It would be assumed that only one TBM would be used for the twin tunnel alternatives, so once the machine mines the first tunnel (taking between eight to eleven months, depending on the length of the tunnel), it would break through and undergo an approximately three-month period of maintenance and configuration to bore the second tunnel. The second tunnel would have a similar duration as the first, but would typically go a little faster.

After the tunnels are complete, the work would shift to installing the roadway surfaces, the permanent ventilation system, and other fire-life safety systems and equipment. This effort would take over a year and significantly longer for the large single bore tunnel with stacked roadways. It should be noted that once everything is installed in the tunnel, the systems must be tested and commissioned before any traffic is allowed.

As the tunnel fit-out nears completion, the contractor could shift his work efforts to building new ramps and connecting roadways, tying into the existing network. After the tunnel is ready and the connections made, traffic could shift into the new tunnels. The contractor could then begin demolishing and removing the old viaduct structure. Duration would be governed by the amount of viaduct being demolished. Once demolition is well under way, the final work of reconstructing Almond Street could begin to finish up the project.

In summary, the project schedule to deliver a tunnel option would require about 9 years.

A comparative schedule was prepared for each alternative (Table 20).

These schedules would be only preliminary and based on the identified scope of work and subject to adjustments based on results of geotechnical explorations, design development, and risk analysis. Typical project schedules for each alternative are presented on Figure 56 through Figure 59.

Alternative	Red	Orange	Green	Blue
Project Cost	$ 3.3 B	$ 3.6 B	$ 3.0 B	$ 4.5 B

TABLE 19: Alternatives Project Capital Cost Estimation

Alternative	Red	Orange	Green	Blue
Total Project Schedule	8.5 years	9 years	9.2 years	9.5 years

TABLE 20: Total Project Schedule by Alternative

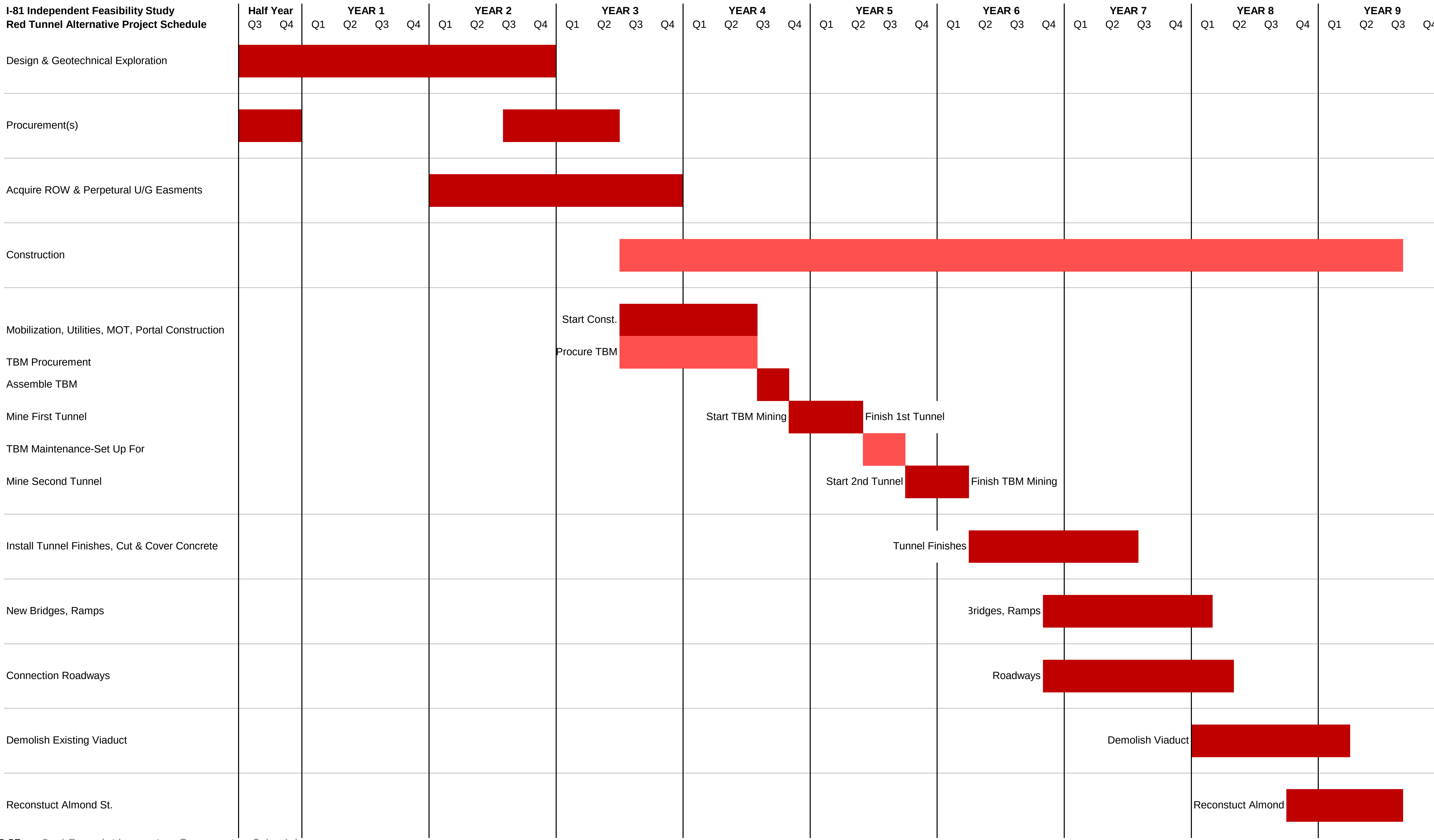


FIGURE 57: Red Tunnel Alternative Construction Schedule

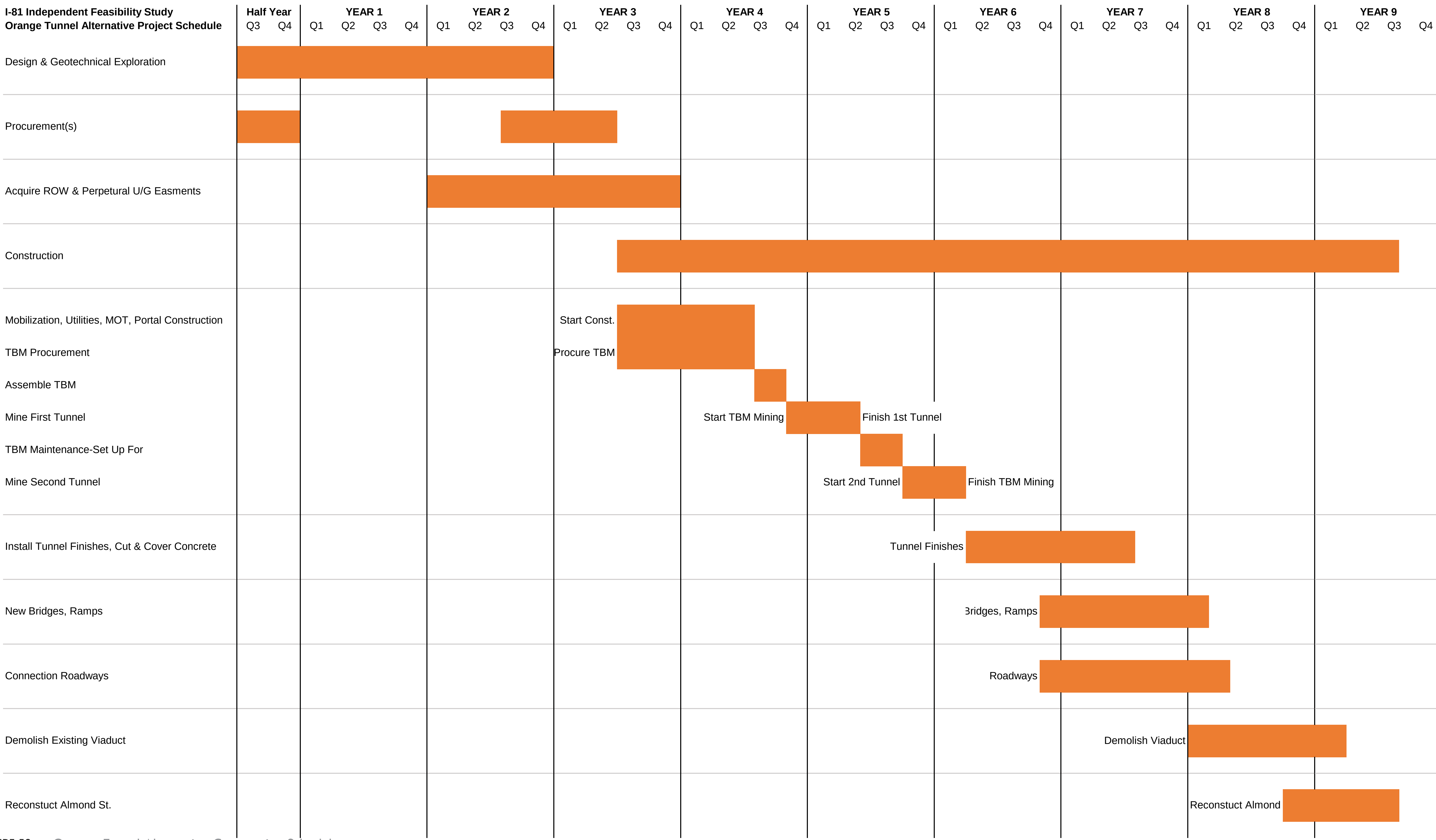


FIGURE 58: Orange Tunnel Alternative Construction Schedule

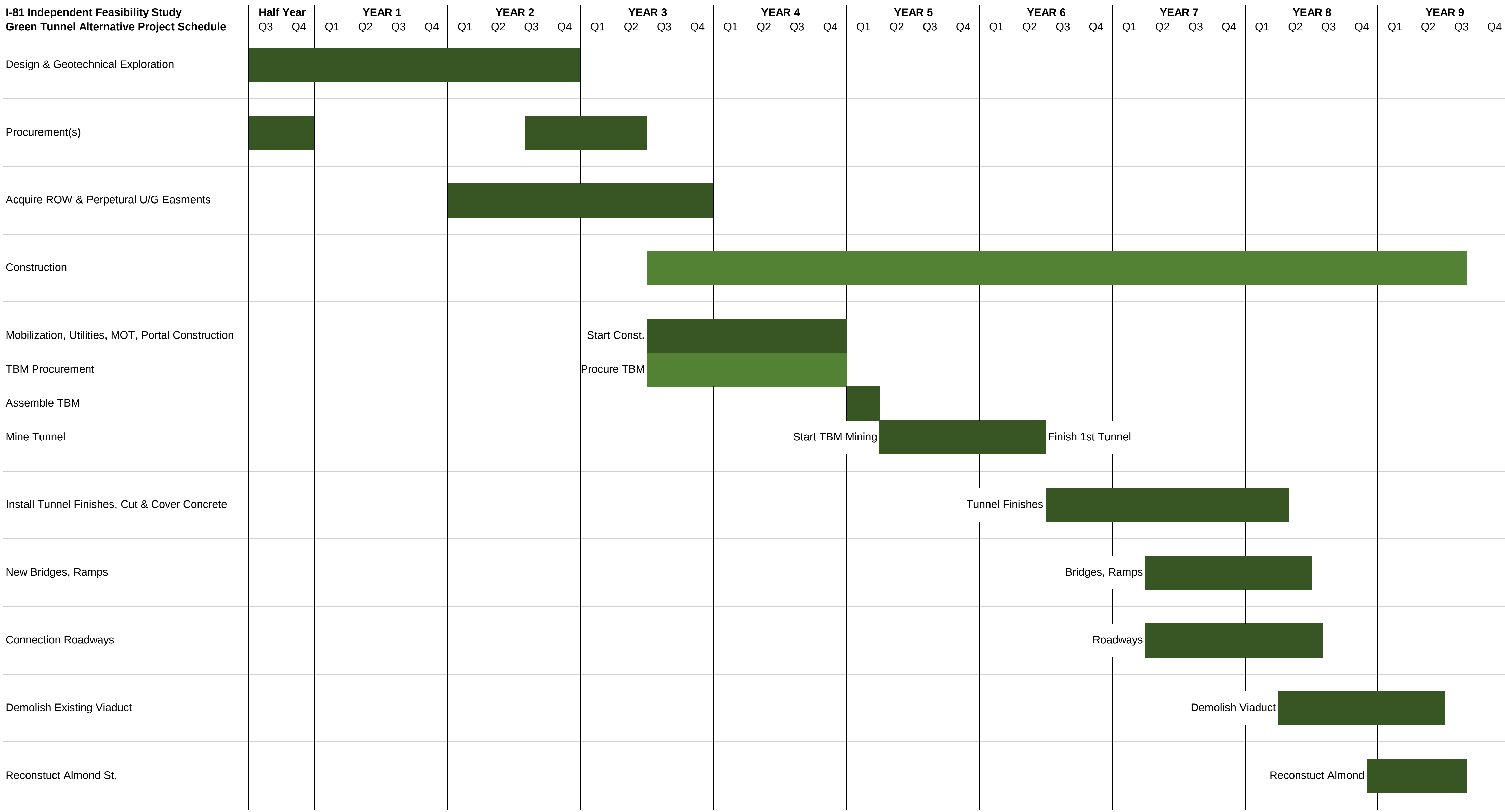


FIGURE 59: Green Tunnel Alternative Construction Schedule

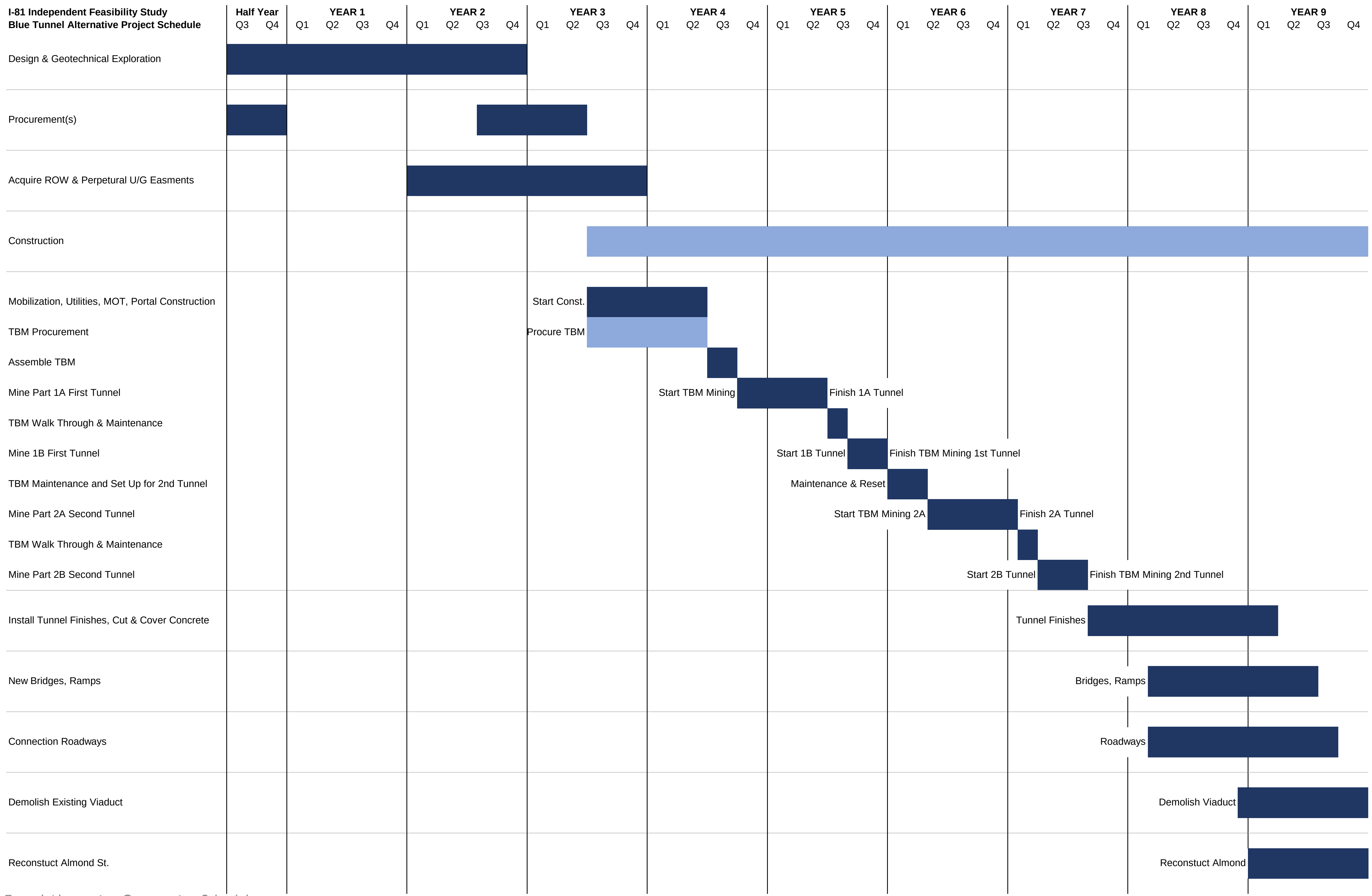


FIGURE 60: Blue Tunnel Alternative Construction Schedule

5.9 OPERATION & MAINTENANCE (O&M) COST ESTIMATION

5.9.1 TUNNEL SYSTEMS – OPERATIONS AND MAINTENANCE COST + REPLACEMENT COST

Life-cycle costs for tunnel systems are broken into three major categories:

- Initial Construction cost
- Operations and Maintenance cost
- Replacement cost

Costs have been estimated based on previous project experience. Operations and maintenance cost and replacement cost were estimated on a net present value basis over a 50 year life-cycle. Replacement cost relates to items that could require replacement during the assumed life-cycle. System replacement periods vary from 15 years (lighting) to 50 years (finishes).

The construction cost of tunnel systems is included in the estimated total construction cost.

Table 21 presents the present value of operations and maintenance cost plus the replacement cost for tunnel systems, over 50 years.

TABLE 21: Alternatives Project Operations and Maintenance Cost Estimation

Alternative	Red	Orange	Green	Blue
Project Cost	\$ 519 M	\$ 359 M	\$ 295 M	\$ 606 M

6 KEY FINDINGS & CONCLUSIONS

The original study scope anticipated developing two tunnel alternatives and two depressed highway alternatives—all with and without community grid improvements. The existing interstate system in downtown Syracuse of I-81 and I-690 are largely on viaduct structures. The key challenge was taking the elevated I-81 highway and putting it underground, but trying to re-establish connections with I-690 that would remain elevated. The team briefly considered putting both interstates underground, but trying to establish an underground interchange was quickly determined to not be a feasible alternative due to constructability issues, property required, as well as high cost. Eight alignment alternatives were initially developed of which four were selected to be examined in greater detail. As the Independent Feasibility Study progressed, the study team came to consensus on the following points:

- The depressed highway alternatives did not meet the goals of the study at all, and in fact were seen to be detrimental to the city. These alternatives would further divide neighborhoods and close off more local streets. Therefore, depressed highway alternatives are not recommended.
- Community grid improvements would be integral to each alternative that was studied further. It is not recommended to consider a tunnel alternative without community grid improvements.

Therefore, the Independent Feasibility Study shifted to examine in greater detail four tunnel alternatives, each with community grid improvements. These tunnel alternatives would have different northern portals and roadway connections that would provide distinct choices and unique features as to the advantages and disadvantages.

Table 22 illustrates how the four alternatives meet the study goals and objectives. Table 23 provides an overall comparative rating for each of the studied alternatives.

It would be technically feasible to design and construct a tunnel alternative that meets the study goals and improve the transportation system in Syracuse Metropolitan Area.

The study teams recommends that the Orange Alternative be considered for further study as a viable tunnel alternative. The tunnel portion would be relatively short compared to other alternatives and the north portal would be near the existing I-81 and I-690 interchanges. This alternative also reconstructs and re-configures significant portions of I-690 to make better connection to I-81 coming out of its tunnel, which drives the cost higher than other alternatives, but provides more benefits as shown in the Alternative Comparison Matrix

It would be noted that comparing the tunnel alternative to the rebuild of the viaduct alternative, the community grid alternative, or the No Build Alternative would be beyond the scope of this study.

TABLE 22: Alternative Comparison Matrix

GOALS	OBJECTIVES	CRITERIA	RED	ORANGE	GREEN	BLUE
Improve safety and create an efficient regional and local transportation system within and through greater Syracuse	Improve interstate geometry	Decommission aging viaduct structure(s)	◕	●	◕	●
		Maintain I-81 interstate status, with interstate highway standards	◕	◕	◕	◕
		Correct non-conforming highway geometry on I-81 and I-690	◑	●	◑	◑
		Improve safety	●	◕	◕	●
		Improve mobility	◑	◕	◑	◑
	Maintain or enhance interstate-to-interstate connections	Maintain I-81 through moves on interstate highway	●	●	●	●
		Maintain or enhance connections between I-81 (south of Syracuse) and I-690 (west of Syracuse)	○	●	●	●
		Maintain or enhance other connections between I-81 and local streets	○	○	○	◑
	Minimize Cost	Minimize capital cost	◑	◔	◑	○
		Minimize operations, maintenance and repair costs	◑	◑	◕	◔
		Replace infrastructure that has limited remaining service life and high maintenance	◑	◕	◑	◑
		Utilize existing transportation infrastructure that has decades of remaining service life	◑	◔	◑	◑

GOALS	OBJECTIVES	CRITERIA	RED	ORANGE	GREEN	BLUE
Provide transportation solutions that enhance the livability, visual quality, sustainability, and economic vitality of greater Syracuse	Enhance livability of the surrounding area	Minimize use of elevated or depressed highways	◑	◕	◔	◑
		Minimize disruption to the local street grid, including street closures and altering the vertical or horizontal geometry of local streets	●	●	◔	◑
		Enhance north-south and east-west connectivity on local streets	◑	◑	◔	◑
		Maintain and improve access to transit services	◔	◑	◑	◑
		Maximize opportunities for land development	◕	◕	◑	◑
		Enhance pedestrian and bicycle accessibility, experience and safety	◕	◑	◑	◕
		Preserve historic buildings and structures	◑	◕	◕	◔
		Enhance the visual character and streetscape of impacted local streets	◕	◕	◔	◕
	Minimize adverse environmental impacts	Minimize noise, vibration and dust during construction	◕	◑	◔	○
		Minimize traffic impacts to interstate highways during construction	◑	◔	◔	◑
		Minimize traffic impacts to local streets during construction	◕	◑	◔	◔
		Minimize residential displacements	◕	◔	●	◑
		Minimize community facility displacements	◑	◑	◕	◔
		Minimize commercial displacements	◔	◔	◕	○
		Minimize impacts to Onondaga Creek	●	●	●	◕

TABLE 23: Overall Alternative Evaluation Matrix

GOALS	OBJECTIVES	RED	ORANGE	GREEN	BLUE
Improve safety and create an efficient regional and local transportation system within and through greater Syracuse	Improve interstate geometry	◑	●	◑	◑
	Maintain or enhance interstate-to-interstate connections	○	◕	◕	●
	Minimize Cost	◑	◔	◑	○
Provide transportation solutions that enhance the livability, visual quality, sustainability, and economic vitality of greater Syracuse	Enhance livability of the surrounding area	◑	●	◑	◕
	Minimize adverse environmental impacts	◕	◔	◑	◔

APPENDIX A: FEASIBLE BUILD ALTERNATIVES PLANS + PROFILES

TABLE OF CONTENTS

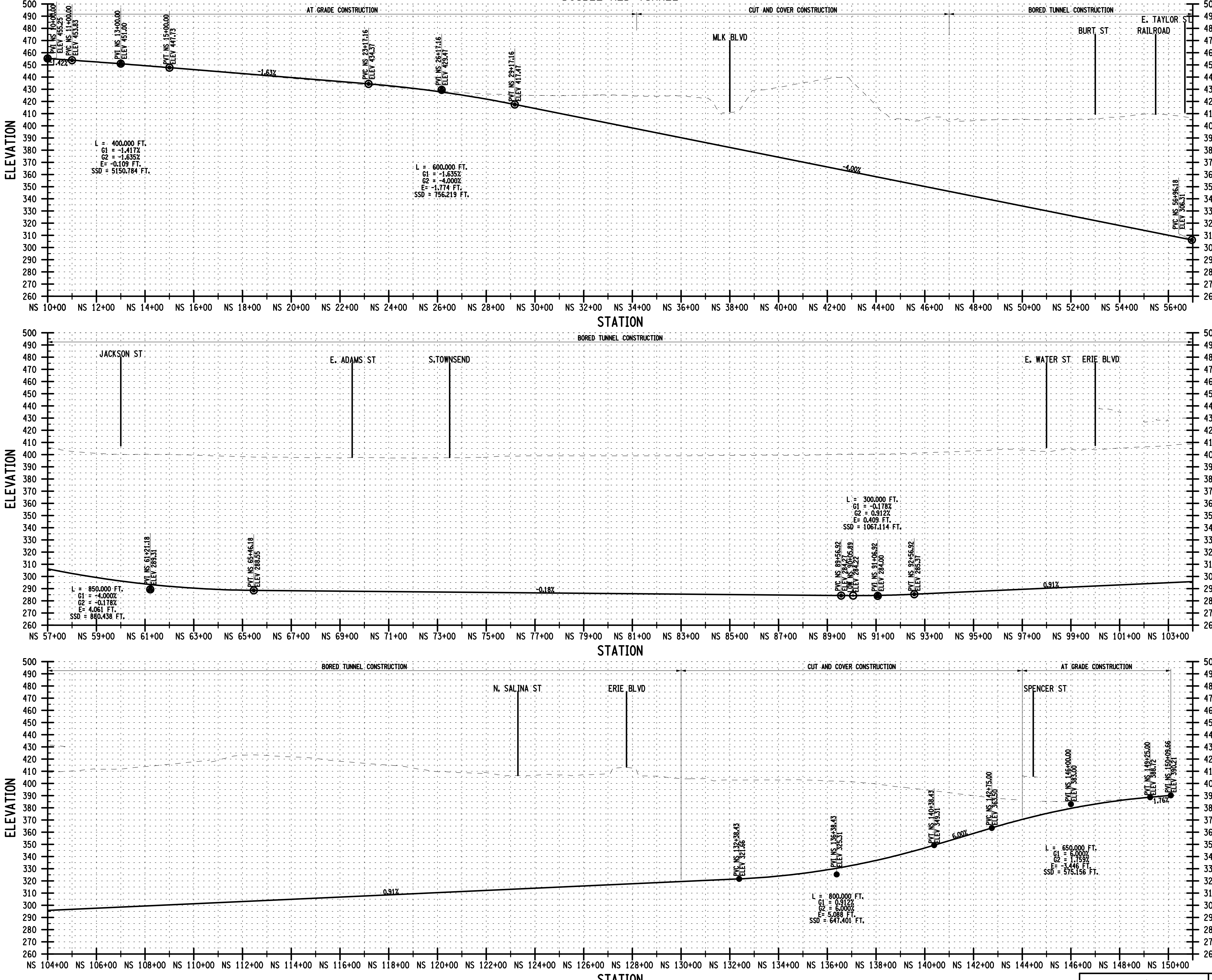
WSP USA Inc.

I-81 INDEPENDENT FEASIBILITY STUDY

ALTERNATIVE

BORED DOUBLE RED TUNNEL PLAN VIEW

DOUBLE RED TUNNEL



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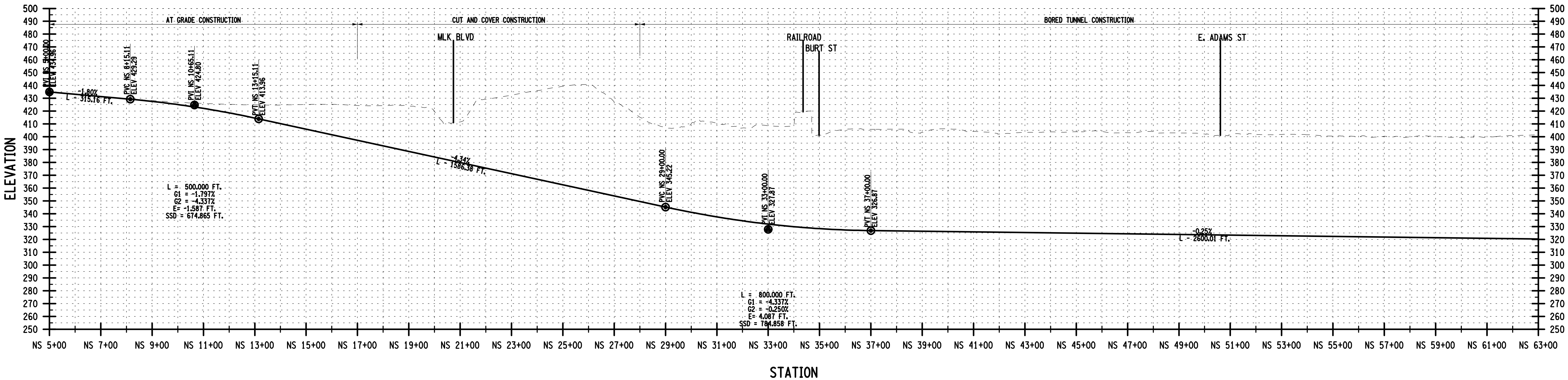
WSP USA Inc.

I-81 INDEPENDENT FEASIBILITY STUDY

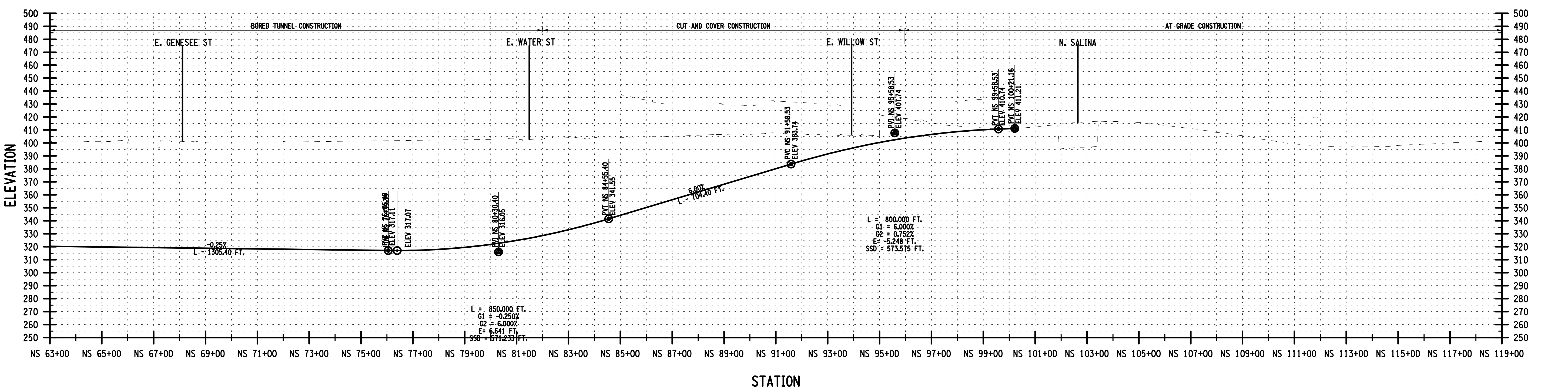
ALTERNATIVE

BORED ORANGE TUNNEL PLAN VIEW

DOUBLE ORANGE TUNNEL



DOUBLE ORANGE TUNNEL



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	DOUBLE ORANGE - PROFILE	1 OF 1

LEGEND

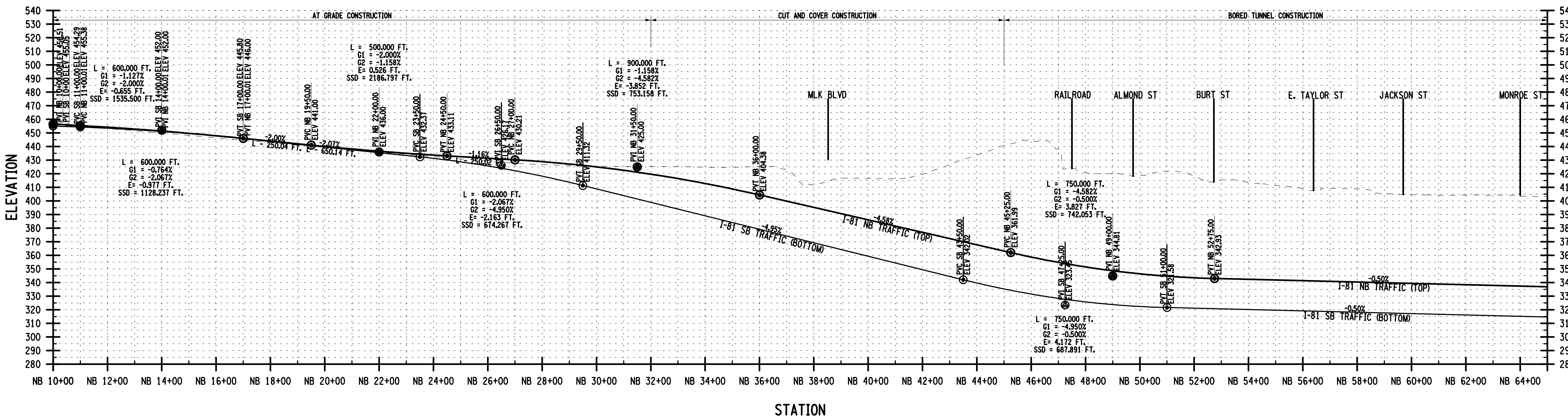
- AT GRADE CONSTRUCTION
- CUT/COVER CONSTRUCTION
- BORED TUNNEL
- VIADUCT/BRIDGE CONSTRUCTION
- VIADUCTS/STREETS TO BE REMOVED

SCALE IN FEET

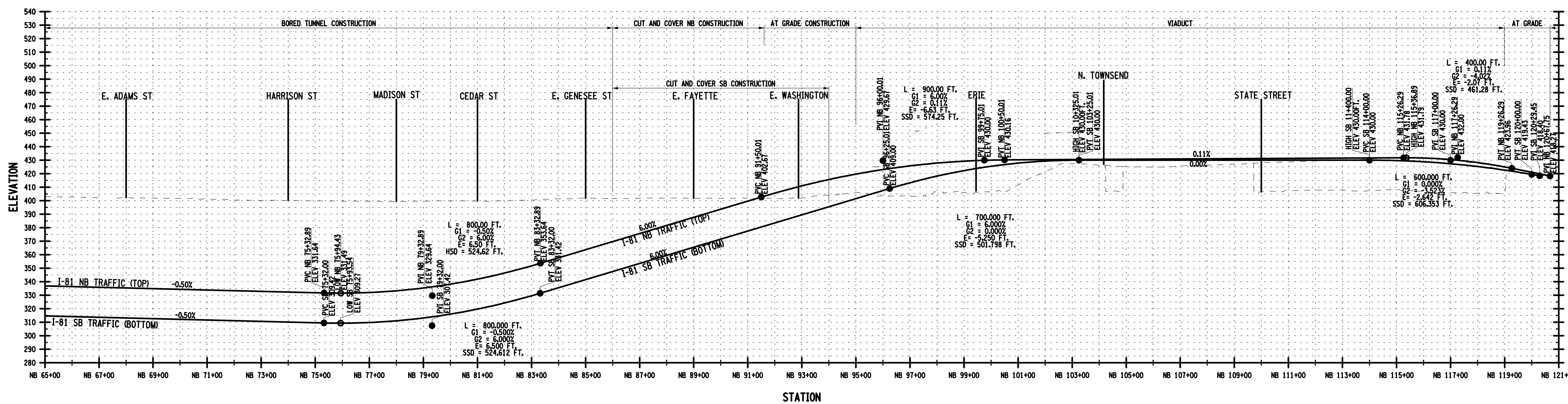
200' 100' 0 200' 400'

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY
	ALTERNATIVE BORED SINGLE GREEN TUNNEL PLAN VIEW

GREEN TUNNEL - NB



GREEN TUNNEL - NB



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		ALTERNATIVE	SHEET NO.
		SINGLE GREEN - PROFILE	1 OF 1

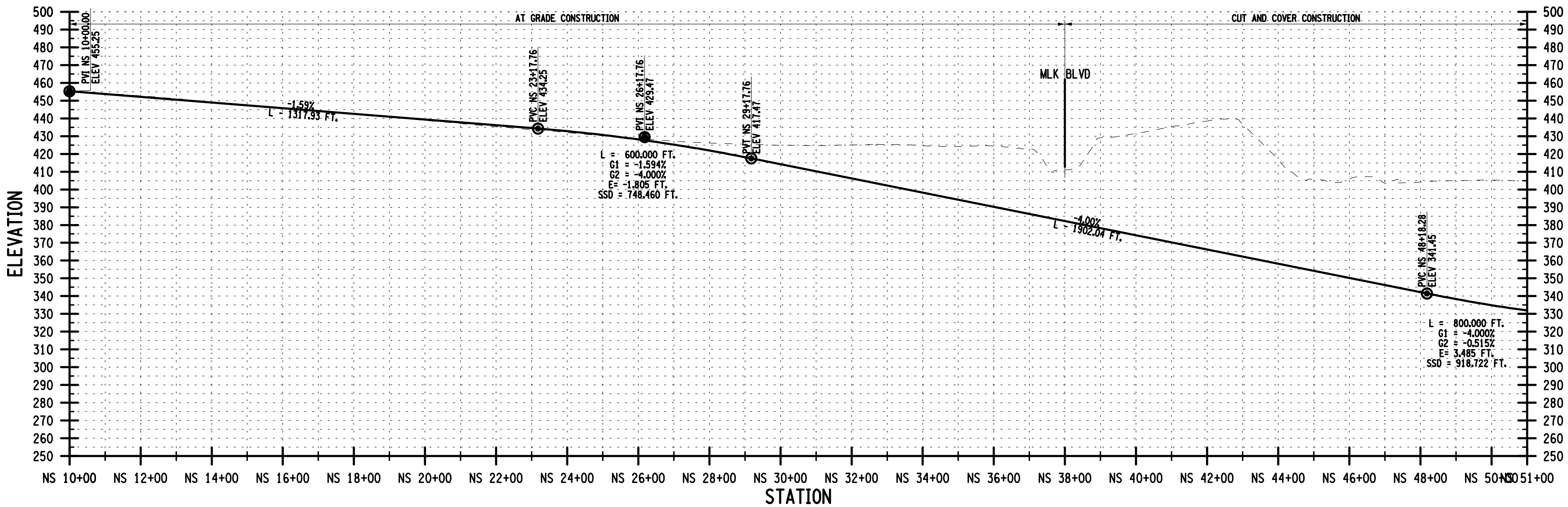
WSP USA Inc.

I-81 INDEPENDENT FEASIBILITY STUDY

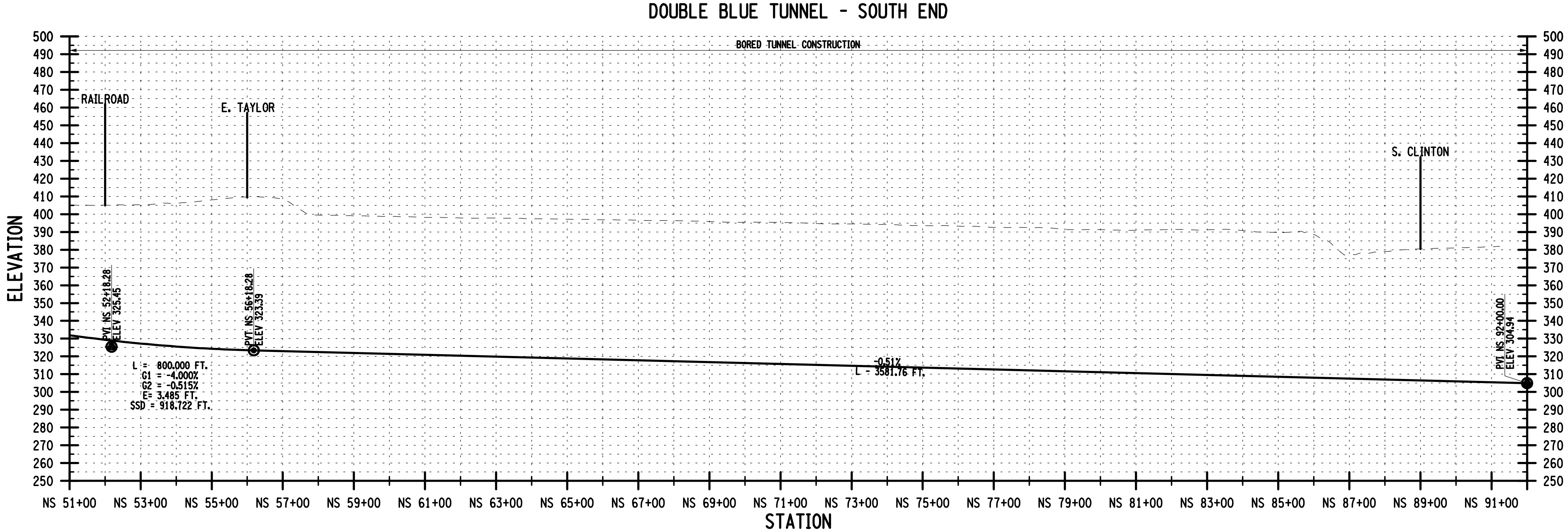
ALTERNATIVE

BORED DOUBLE BLUE TUNNEL PLAN VIEW

DOUBLE BLUE TUNNEL - SOUTH END



DOUBLE BLUE TUNNEL - SOUTH END



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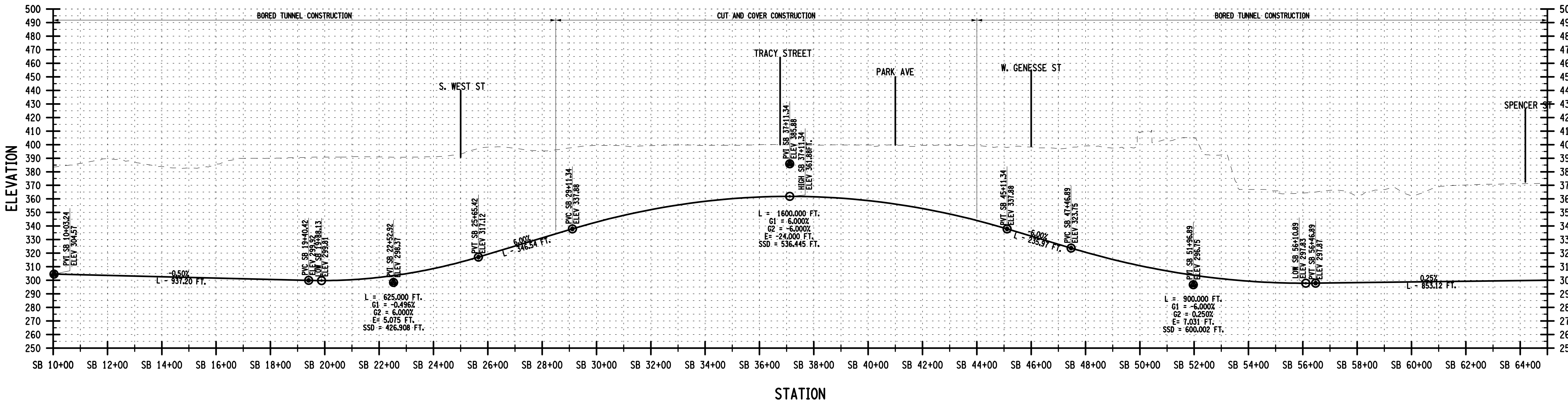
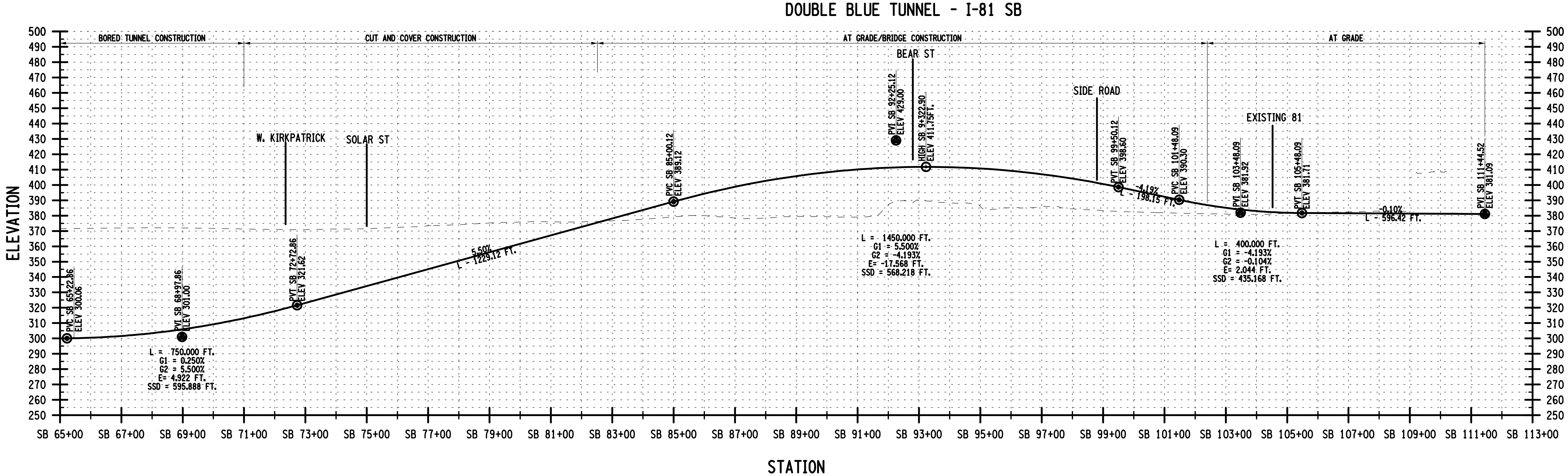
DOUBLE BLUE TUNNEL - I-81 SB



DOUBLE BLUE TUNNEL - I-81 SB



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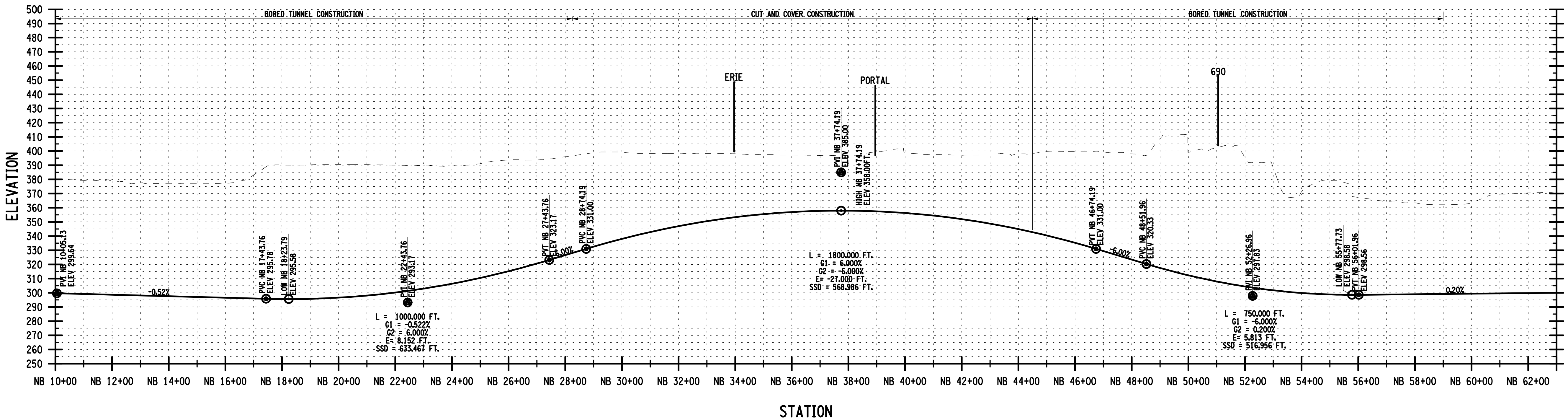
	DOUBLE BLUE 81 SB - PROFILE	2 OF 3

DOUBLE BLUE TUNNEL - I-81 NB



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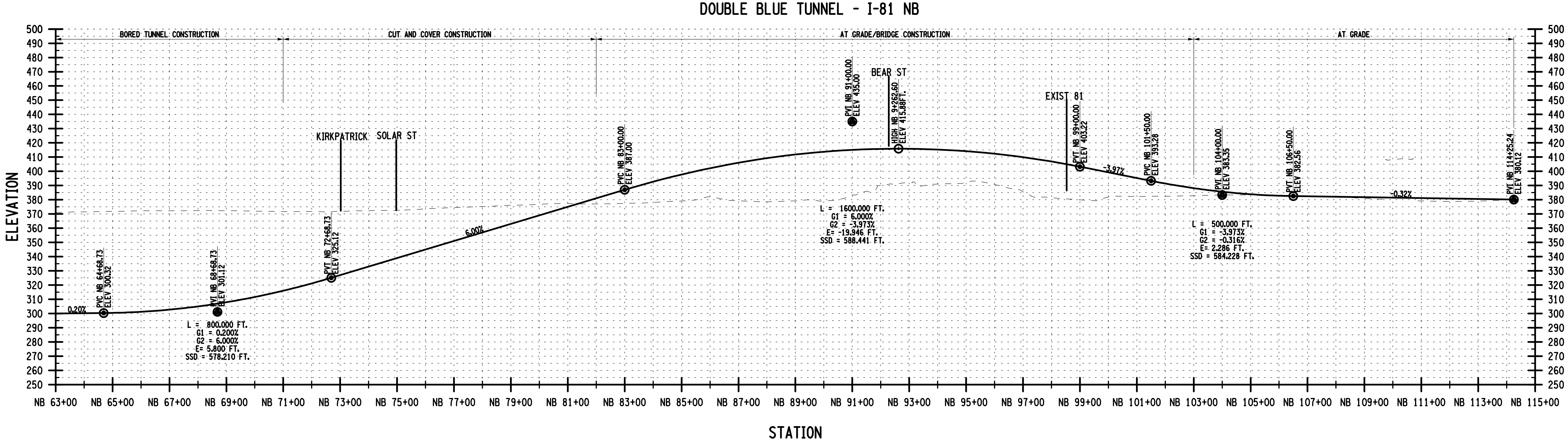

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	DOUBLE BLUE 81 NB - PROFILE	3 OF 3

APPENDIX B: FEASIBLE BUILD ALTERNATIVES FLY-THROUGH DESCRIPTIONS

TABLE OF CONTENTS

FIGURES

1 FEASIBLE BUILD ALTERNATIVES

Below, Figure 1 and Figure 2 show a composite highway alignment map of each of the feasible build alternatives. These maps illustrate the start and end locations of each alternative and connections made to I-81, I-690, and the local street network.

FIGURE 1: Composite Highway Alignments (1 of 2)

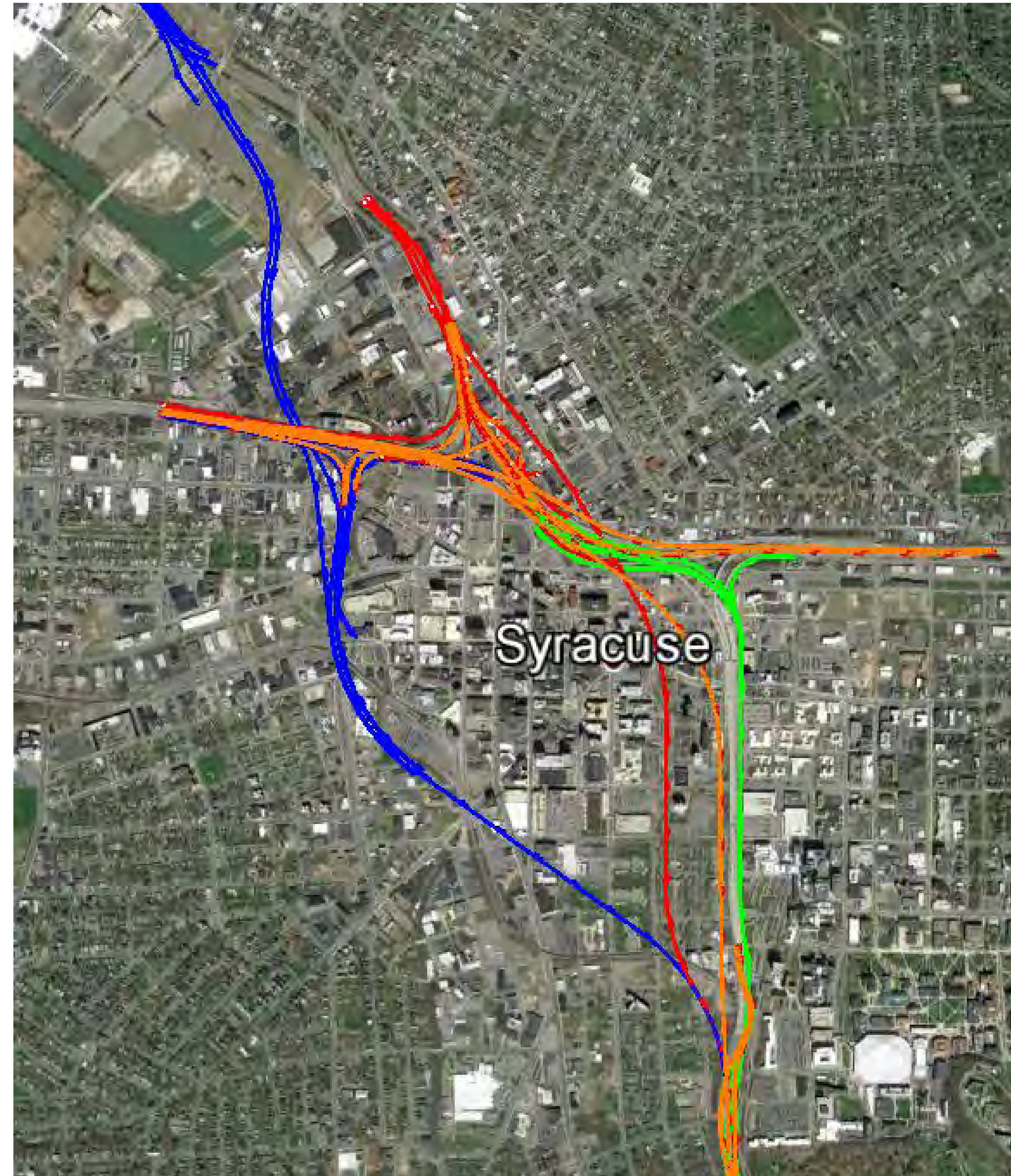
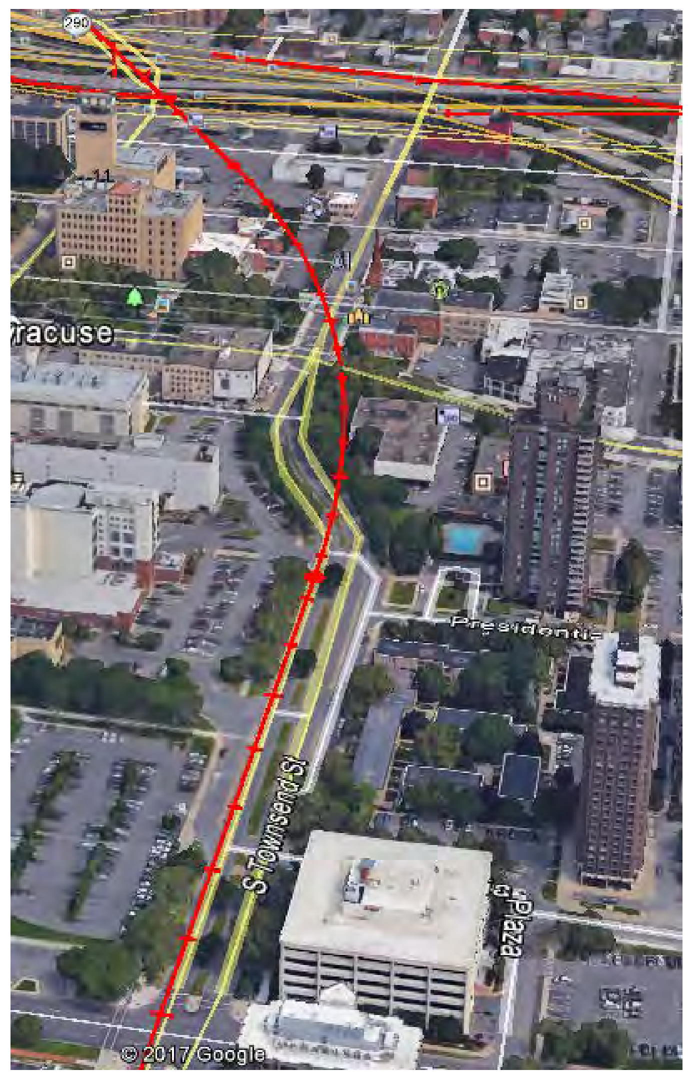


FIGURE 2: Composite Highway Alignments (2 of 2)

2 RED TUNNEL ALTERNATIVE

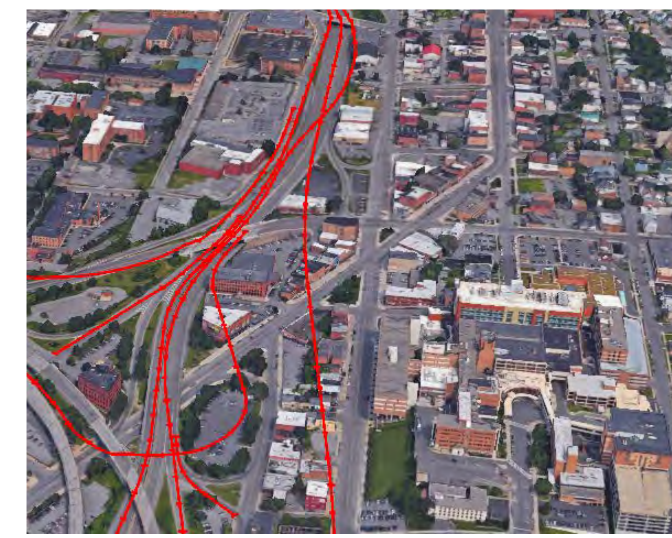
The Red Tunnel Alternative starts in the south, south of Martin Luther King East and trends to the northwest. Starting as a cut and cover tunnel it would transition to twin bored tunnel near South McBride Street. The tunnels would pass under the railroad, and stay west of the Syracuse University Steam Station & Chilled Water Plant.

The tunnels pass under the west side of the Pioneer Homes housing project before aligning below South Townsend Street. The street itself meanders east and west, so the tunnels would pass below private parking lots in some areas.



The tunnels would then strike northwest to align with State Street, passing below various private properties in the vicinity of Washington Street and Water Street. The tunnels would pass under I-690 with no interconnections, at sufficient depth to avoid the existing piles.

The tunnels would then follow North State Street before deviating to the west to rejoin the existing I-81 alignment north of Butternut St.

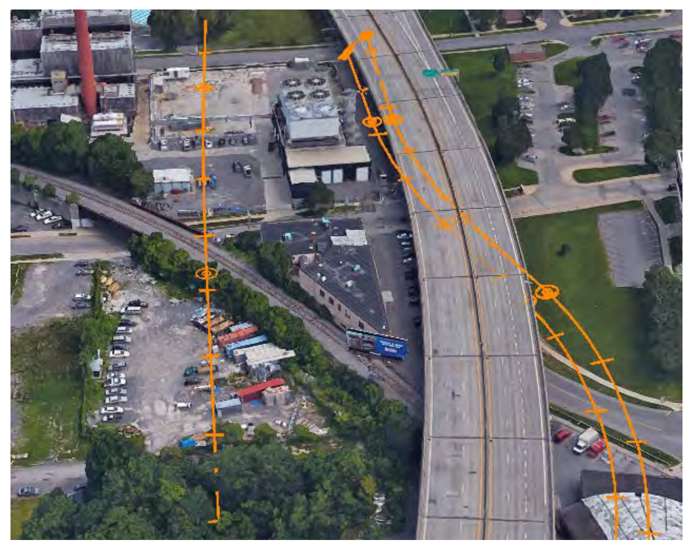


An intersection between the existing I-81 and the I-81 tunnel would be constructed near Spencer Street.

3 ORANGE TUNNEL ALTERNATIVE

The Orange Tunnel Alternative starts as a cut and cover tunnel in the south, south of Martin Luther King East, and continues due north. The cut and cover structure would transition to twin bored tunnels south of the railroad near Burt Street.

The bored tunnels would pass under the railroad and continue under the Syracuse University Steam Station & Chilled Water Plant. It is anticipated that the tunnels will be deep enough to avoid the pies from a previously demolished structure. However, a cut and cover tunnel would avoid this risk (Appendix E) but could be disruptive to operations, and may require multiple utilities to be rerouted or supported.



The bored tunnels would continue under Taylor Street, and would pass under the Pioneer Homes housing project. They would then continue parallel to I-81. They would pass under the parking lot of the Upstate University Medical Center, and under the parking structure for Madison Towers. An alternative alignment would be under the I-81 viaduct, which would avoid private properties, but the risk of encountering a pile (from the I-81 viaduct) could increase.

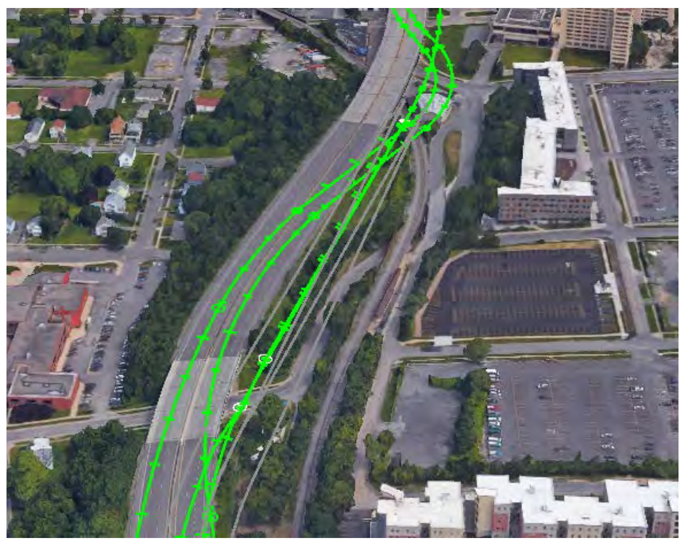
At E Genesee Street the tunnel would head to the northwest, passing under private land and various low-rise buildings.

The bored tunnel would end at Erie Boulevard, transitioning to a cut and cover tunnel. The at-grade parking lots in this area could potentially be acquired to make an efficient reception/launch site for the bored tunnels.

North of Erie Blvd cut and cover construction would be used, with the I-690 viaducts being underpinned and the I-690 viaduct reconstructed on top of the tunnel box. To achieve connections from I-81 northbound to I-81 northbound and to I 690 westbound extensive reconstruction of I-690 would be required. This would include reconstruction of much of the existing viaduct, enabling existing geometric deficiencies to be remedied.

4 GREEN TUNNEL ALTERNATIVE

The Green Tunnel Alternative starts in the south, south of Martin Luther King East, and bends to the east to clear the existing I-81 alignment immediately south of the railroad. The southern end of the bored tunnel would be close to this location. To achieve this geometry, reverse curves are required on both the through-tunnel and ramp leading to the community grid (see Appendix A).



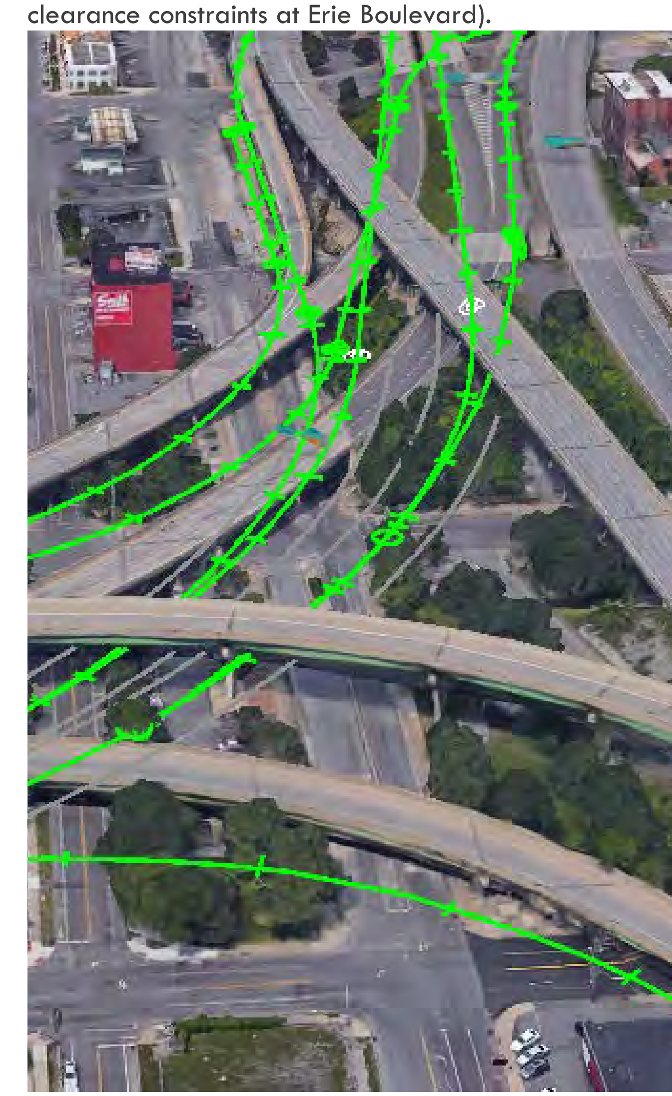
A single bi-level tunnel is recommended due to the restricted width of available space between the piles of the I-81 viaduct (to the west) and the hotel and hospital buildings (to the east). The bored tunnel would pass under the Pioneer Homes housing project and immediately adjacent to the Update Medical University Hospital, beneath the I-81 northbound off-ramp to Adams Street.

The alignment would continue northbound under Almond Street., passing close to the high-rise Crowne Plaza Hotel. The profile and alignment would be detailed to miss piled foundations.

At E Fayette Street the bored tunnel would end. The at-grade parking lots in this area could potentially be acquired to make an efficient reception/launch site for the bored tunnel (Appendix E).

A cut and cover tunnel would turn westwards, to connect into the ramps of the existing I 81 viaduct.

Connections from I-81 northbound to both I-690 westbound and I-81 northbound would be maintained (along with the reverse flows). An I 81 northbound to I-690 eastbound ramp is also proposed (but no reverse move due to vertical clearance constraints at Erie Boulevard).

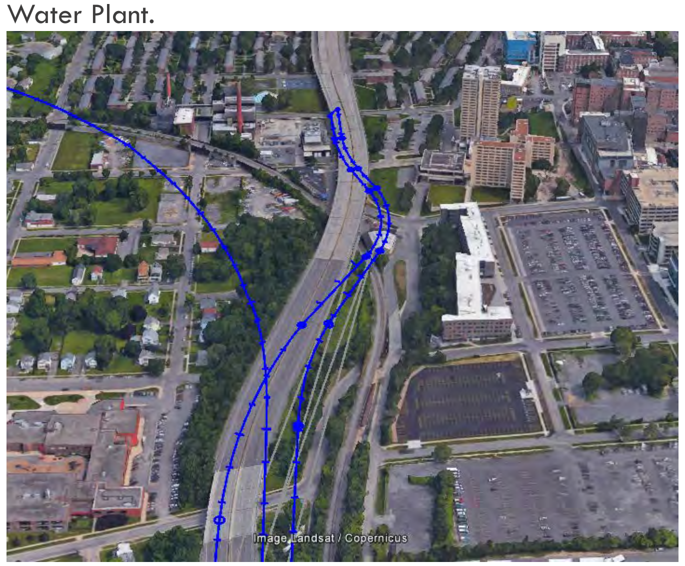


5 BLUE TUNNEL ALTERNATIVE

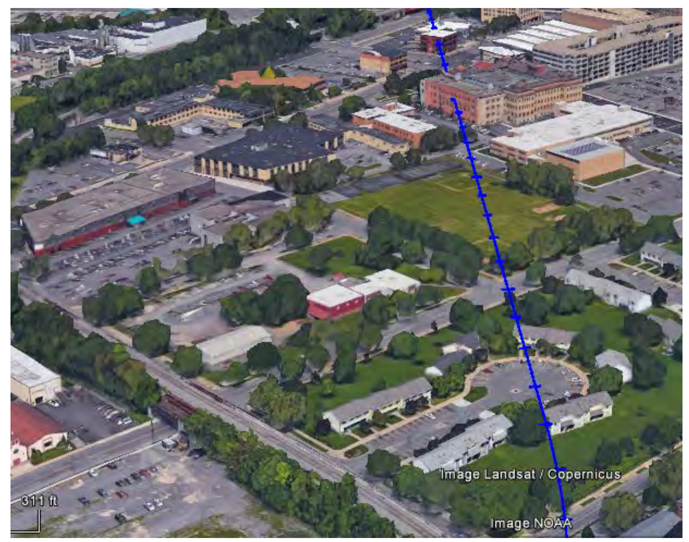
The Blue Tunnel would comprise twin tube tunnels, with cut and cover sections at the north and south portals, and also at a central section near West Street.

The Blue Tunnel Alternative starts in the south, south of Martin Luther King East and trends to the northwest. A cut and cover tunnel would transition to twin bored tunnels near South McBride Street, where a TBM launch shaft could be located.

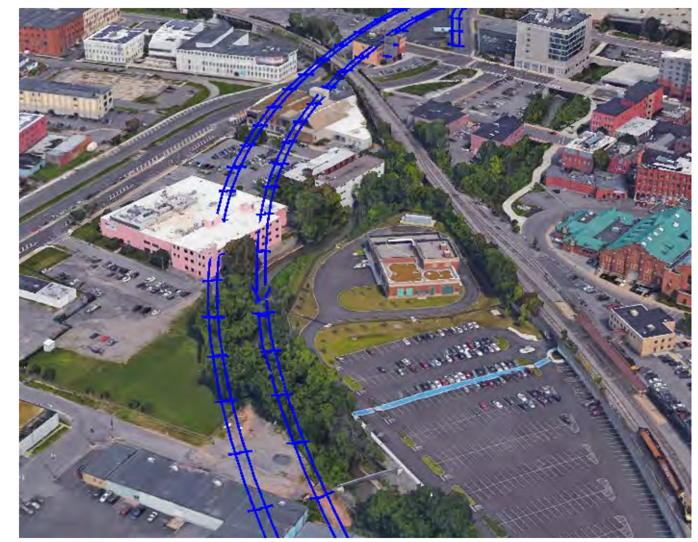
The bored tunnels would pass under the railroad, and stay west of the Syracuse University Steam Station & Chilled Water Plant.



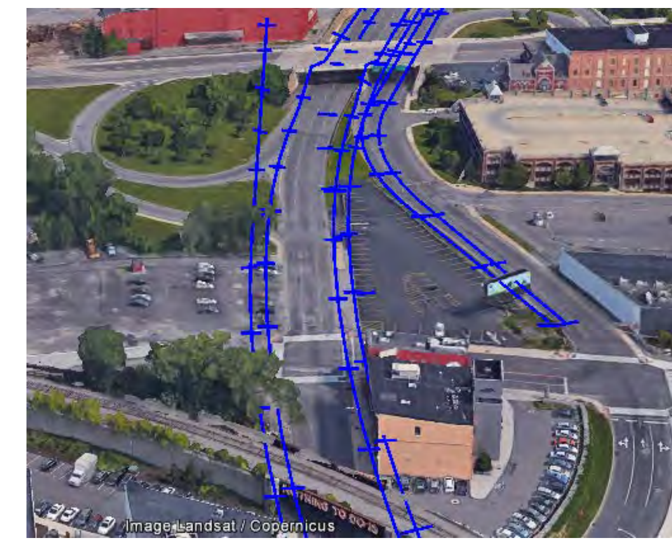
The tunnels pass under the southwest corner of the Pioneer Homes housing project, Roesler Park, and some low-rise building on South Warren Street. The tunnels continue under the railroad, Onondaga Creek, and just south of the parking lot for the Museum for Science and Technology.



The tunnels re-cross the railroad as they approach West Street.



The bored tunnel would transition to cut and cover at West Fayette Street. The existing interchanges at Erie Boulevard and I-690 would require significant reconstruction.



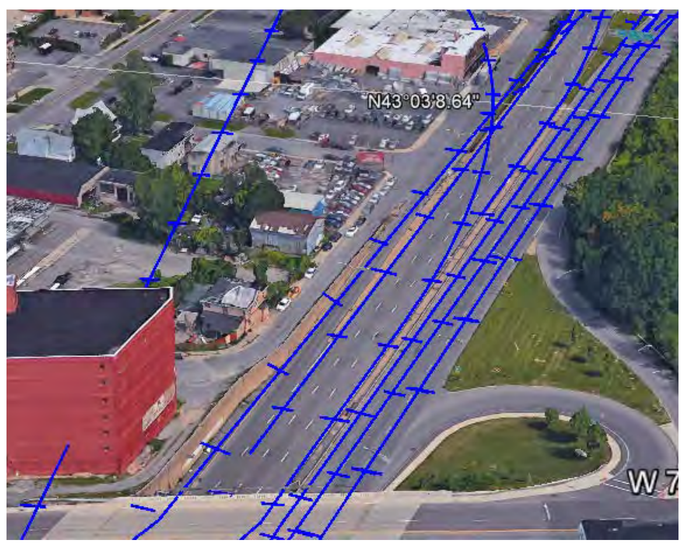
A connection with I-690 would be constructed, accommodating I-81 northbound to eastbound and westbound I-690, and also the reverse moves. The cut and cover tunnel in this area would require the demolition of several low-rise structures.

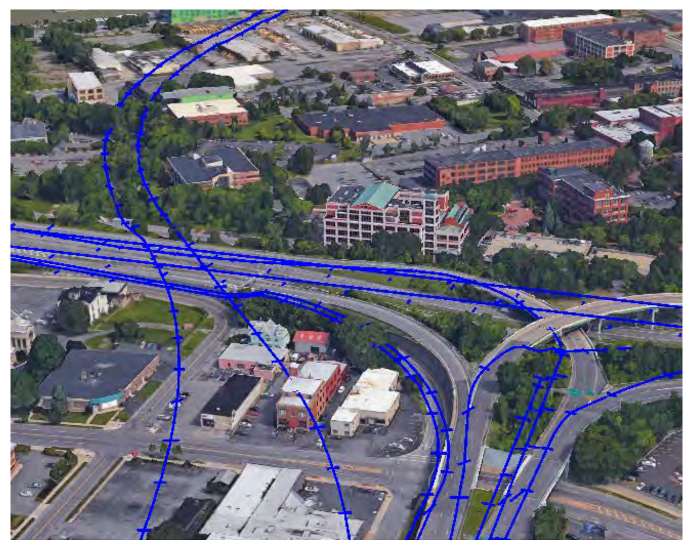
The bored tunnels would re-commence south of I-690, continue north under low-rise buildings, and pass to the southeast of the Inner Harbor.

The conceptual alignment is adjacent to the southeast corner of the currently proposed inner harbor redevelopment.

The tunnels would daylight and rise onto a viaduct and other ramp structures to create a new intersection with the existing I-81 close to Destiny Mall.

The open space in this area would be a favorable TBM launch location.





APPENDIX C: COMMUNITY GRID PLANS

TABLE OF CONTENTS

COMMUNITY GRID – RED TUNNEL ALTERNATIVE

I-81 INDEPENDENT FEASIBILITY STUDY (DRAFT)

COMMUNITY GRID – ORANGE TUNNEL ALTERNATIVE

I-81 INDEPENDENT FEASIBILITY STUDY (DRAFT)

COMMUNITY GRID – GREEN TUNNEL ALTERNATIVE

I-81 INDEPENDENT FEASIBILITY STUDY (DRAFT)

COMMUNITY GRID – BLUE TUNNEL ALTERNATIVE

I-81 INDEPENDENT FEASIBILITY STUDY (DRAFT)

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APPENDIX D: GEOTECHNICAL CONDITIONS

TABLE OF CONTENTS

FIGURES

TABLES

1 SOIL AND SUBSURFACE CONDITIONS

1.1 AREA GEOLOGY

The Syracuse region is located in the Northern Lowlands and Tug Hill Plateau Physiographic Province, specifically within that section of the Province known as the Ontario Lowland. It is underlain by three different geologic formations. The sequence of sedimentary rock underlying the region can be divided into three units separated by unconformities (the erosional surface on the older rock unit, which represents missing time and which is buried by the younger rock unit). The first unit is of late Proterozoic through early Ordovician time, the second unit is of Middle through late Ordovician time, and the third unit is of Silurian time. The oldest unit rests on an unconformity on the Proterozoic basement rock. The rocks in the first unit crop out in the Mohawk Valley, the Champlain Valley, and the St. Lawrence Valley. They were deposited during Late Cambrian through Early Ordovician time. An unconformity bounds the top of this unit.

Approximately 500 million years ago, a mountain range formed along what is the East Coast of North America. As the mountain range gradually rose, a large shallow depression to the west became inundated to form an inland sea. Precipitation and runoff over millions of years slowly eroded the mountain range and deposited thousands of feet of sediments into the inland sea. These sediments were later consolidated into thick layers of shale that underlie the region. The upper rock unit has been designated the Salina Shale Formation. The Salina Shale consists of layers of shale interbedded with salt.

Pleistocene glaciation deposited most of the natural soils in the project area. These deposits consist of glacial outwash deposits, delta deposits and stream terrace deposits. Recent (post-glacial) soils of similar characteristics are also present. Development of Syracuse from the 18th century to the present included cutting and filling operations that generated the fill deposits that immediately underlie much of the study area.

1.2 GENERALIZED SUBSURFACE CONDITIONS

A small scale geologic profile provided by NYSDOT, and shown in Figure 1 indicates that the project site is underlain by the following units:

- Fill, either controlled fill associated with highway construction and other recent construction or uncontrolled fill associated with the development of Syracuse in the 18th, 19th and early 20th century. Fill may consist of sand, silt, clay, gravel, brick and stone masonry fragments, rock and construction debris. Its composition can be highly variable over relatively short distances.
- Sand, non-plastic silt and gravel of unknown origin. It may be recent alluvium, or Pleistocene glacial till and glacial outwash. Fines content (percentage of material passing #200 sieve) is unknown. It must be assumed water-bearing below the groundwater table and be moderately to highly permeable. The groundwater may be saline, with variable salt concentrations, ranging from brackish (least saline) to briny (most saline). This unit may also contain hydrogen sulfide gas and methane gas that has moved upward from the underlying shale formation.
- Plastic silt and clay of unknown origin, perhaps including glacial lake deposits or deposits from a more extensive Onondaga Lake. As for the previous unit, it may be a mixture of Recent and Pleistocene deposits.
- Weathered rock. Material developed from the physical or chemical weathering of the underlying bedrock. It may range from disintegrated rock fragments to clay.
- Rock, assumed to be shale, is thinly to moderately bedded with a significant clay content. Interlayers of siltstone and sandstone may be encountered within the shale. Siltstone and sandstone generally are stronger, harder and more abrasive than shale. The shale may contain hydrogen sulfide and methane gas, which are significant safety hazards in closed excavations and tunnels. Hydrogen sulfide, which is heavier than air can accumulate at the bottom of excavations when air circulation is limited. The rock contains halite (common salt) at depth, which was mined by various methods from the 18th century through the 20th century. Generally, the salt beds are at such depth below the existing ground surface in the study area that they should not affect construction operations.

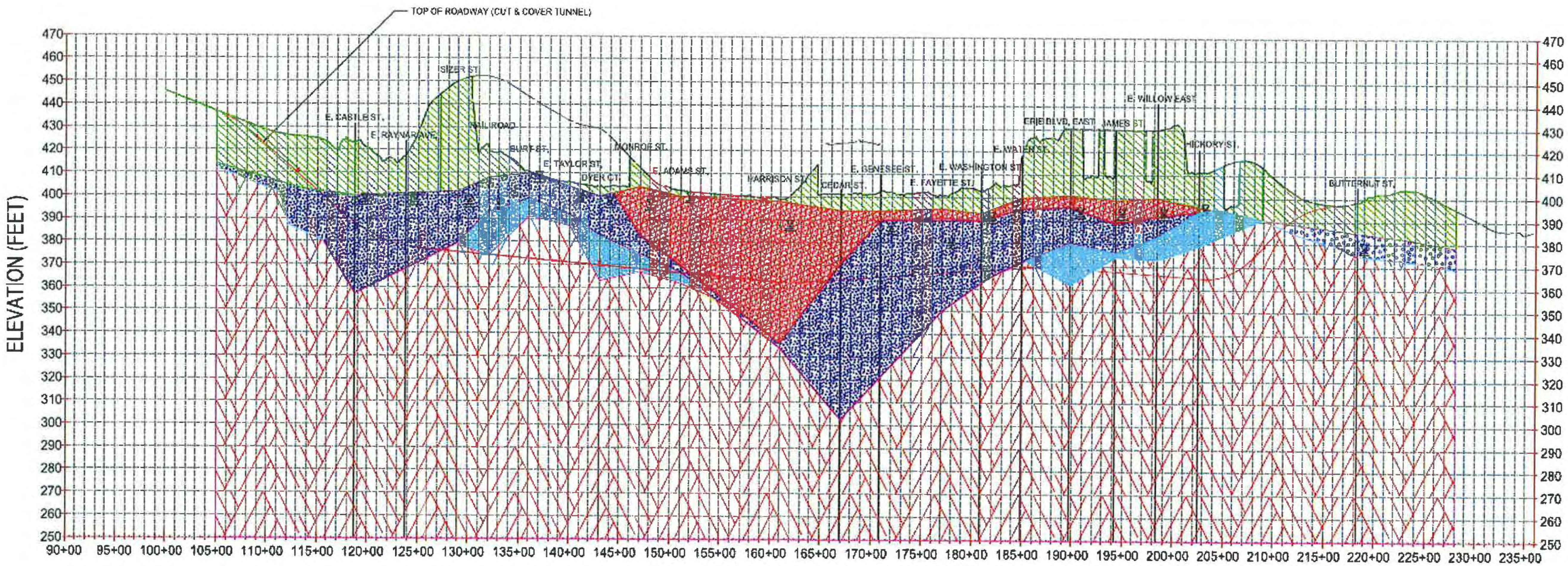


FIGURE 1: Geotechnical Profile

1.3 NYSDOT BORING LOGS

NYSDOT provided a number of boring logs which confirm the generalized subsurface conditions described in Section 1.2. Most of these borings are 50 years or greater in age and generally do not describe the soils in terms consistent with current practice. Also, determination of apparent top of rock sometimes is difficult, because of ambiguities in the notes on the logs. Location of the rock line is of greater importance for depressed roadway construction and cut-and-cover tunnel construction than for mined (bored) tunnel construction, because support of the excavation walls generally below extend down to the top of rock.

1.4 ONONDAGA COUNTY SOIL SURVEY/ ONONDAGA COUNTY CUSTOM SOIL RESOURCE REPORT

The Onondaga County Soil Survey and the Onondaga County Custom Soil Resource Report, prepared by the U.S. Department of Agriculture (USDA) confirm the generalized subsurface conditions described above These documents identify the agricultural soil units (soil series) through which the I-81 alignment in the study area passes or the soils which abut the alignment. The distribution of the various soil series along the alignment are shown in Figure 2 and Figure 3. The documents describe the geologic origins of the various units, the landforms on which they developed, and selected engineering properties for each unit down to a depth of 60 inches (5 ft. – 1.5m) below ground surface. The soils below 60 inches essentially have the same properties as the lower soil horizon contained within the soil series description.

Urban land derives from reworking of natural soils resulting from the development of Syracuse from the 18th century to the present. Soil deposits originating from development prior to the second quarter of the 20th century routinely contain brick and stone masonry fragments, timber, abandoned foundations and miscellaneous construction debris. This additional material represents obstructions to the placement of some types of Support of Excavation (SOE) wall, such as steel sheet pile. Sites developed more recently generally do not contain as much extraneous material.

Urban land deposits may be tens of feet deep in locations where fill was placed in swales, ravines, and stream valleys. Urban land may contain contaminated groundwater and materials classified as hazardous by the NYSDEC. Groundwater contamination may extend into more permeable natural soils located beneath the urban land.

Excavations for depressed roadway structures and cut-and-cover tunnels will penetrate through urban land deposits into generally undisturbed natural soil deposits and, possibly, rock. Mined tunnels generally will be constructed within natural soil deposits and rock.

A more detailed discussion of the information contained in the Onondaga County Soil Survey and the Onondaga County Custom Soil Resource Report is contained in Section 3.2.1 of this report.

Soil Series Name	Map Symbol
Alton gravelly fine sandy loam, rolling	A | C
Arkport very fine sandy loam, 2 to 6 percent slopes	ArB
Arkport very fine sandy loam, rolling	ArC
Cazenovia silt loam, 2 to 8 percent slopes	CfB
Howard gravelly fine sandy loam, rolling	HwC
Palmyra gravelly loam, 0 to 3 percent slopes	PgA
Palmyra gravelly loam, 3 to 8 percent slopes	PgB
Urban land	Ub

TABLE 1: Soil Units

FIGURE 2: Soil Map 1 of 2

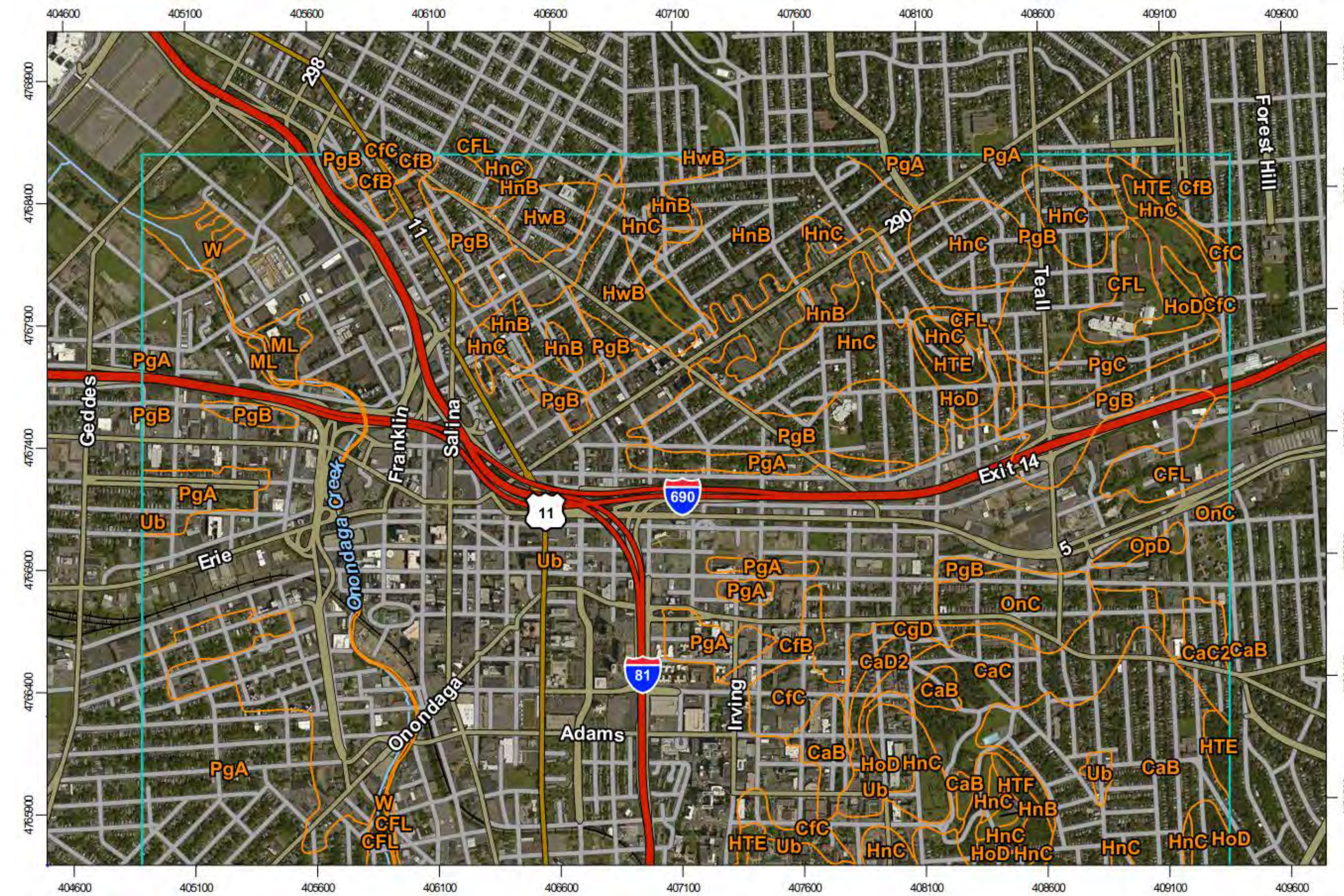


FIGURE 3: Soil Map 2 of 2

1.5 GAS

Gas monitoring will be required for open excavations and tunnel excavations. Hydrogen sulfide and methane may be dissolved in the groundwater and may come out of solution as a result of excavation. Hydrogen sulfide, which is heavier than air, may accumulate in the bottom of surface and underground excavations.

Any mined tunnels constructed as part of the project must be classified as "potentially gassy" in accordance with OSHA requirements. Such conditions require continuous monitoring for gas at the tunnel face and explosion-proof Tunnel Boring Machines (TBMs) and ancillary equipment. Because gas may be discharged anywhere along the tunnel at any time, monitoring will be required at all locations where miners are working. Gas monitoring equipment also should be installed on locomotives used for hauling personnel and material through the tunnel. Ventilation airflow requirements are also increased to provide effective diffusion/dispersal of the gas.

1.6 IN-SITU STRESS EFFECTS

Horizontal stresses in the rocks in upstate New York are known to be in excess of geostatic stress, because of their geological history. This result in convergence of the sidewalls and heaving of the invert in open excavations as a result of stress relief, requiring secondary excavation after movement has assumed asymptotic conditions and prior to the construction of permanent structures. In open excavations, compressible materials often are placed between the structure's exterior wall and the rock surface to mitigate the effects of long-term continuing movement.

Similarly, in tunnels supported by precast concrete segmental linings installed concurrently with excavation, additional forces are applied to the tunnel lining, which restricts sidewall convergence and invert heaving. Linings must be designed for additional loadings related to restrained movement.

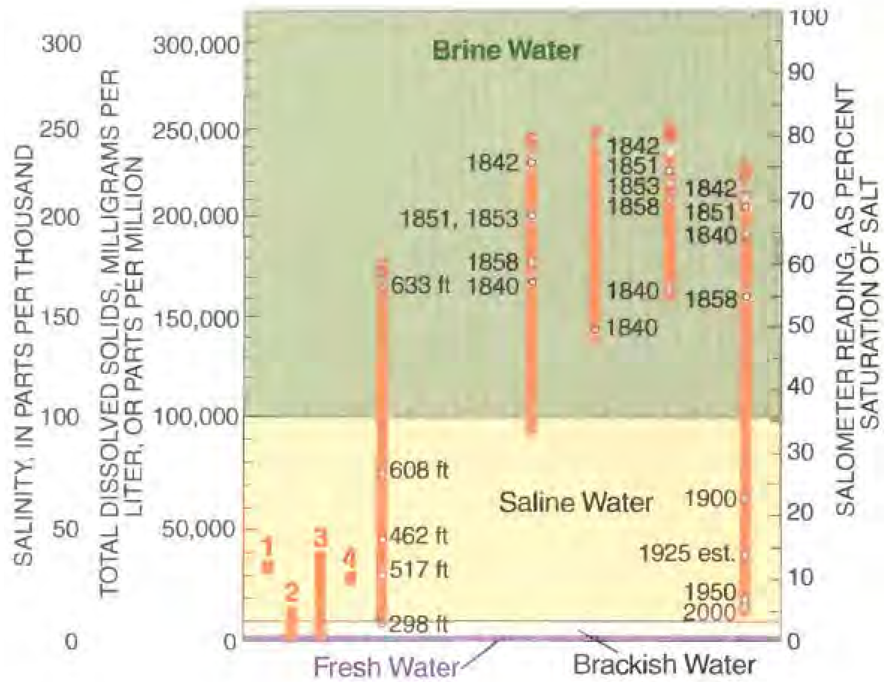
1.7 GROUNDWATER AND SALINITY

Both the depressed roadway alternatives and the underground roadway alternatives generally will be constructed below the groundwater table. The groundwater is presumed to be saline.

Brines obtained from springs in and around the southern end of Onondaga Lake, and from wells that tapped halite (common salt) beds near Tully, N.Y., 15 miles south of Syracuse, were used commercially from the late 1700's through the early 1900's for salt production.

The brine originates from halite beds of the Salina Shale. The dissolution of halite by ground water creates a brine that moves through an unconsolidated basal aquifer northward to the springs near Syracuse. Figure 4 illustrates range of total dissolved solids concentration, salinity, and salometer readings from several sites and depths in the Onondaga Creek Valley, in relation to ranges that define freshwater, brackish water, saline water, and brine. For reference, seawater typically has approximately 35 parts per thousand.

The halite beds that supply the brine springs at the south of Syracuse at depths greater than 1,000 ft. were eroded during the Glacial Age. The glacial soils above the bedrock in the Onondaga Creek valley provide a hydraulic connection between the halite deposits and the springs to the immediate south of Onondaga Lake, as shown in Figure 5



1 Average seawater value

2 Tully Valley mudboil discharge (1992-2000). Data from USGS.

3 Springs within 1993 Tully Valley mudslide (1993-2000). Data from Curran (1999), and USGS.

4 Discharge water from "cooling plant" wells in downtown Syracuse, N.Y., July 1991. Data from New York State Department of Environmental Conservation.

5 Water samples from mudboil-area drillhole - 1994. 298-foot sample from unconsolidated sand and gravel; deeper samples from bedrock. Data from Kappel and others, (1996).

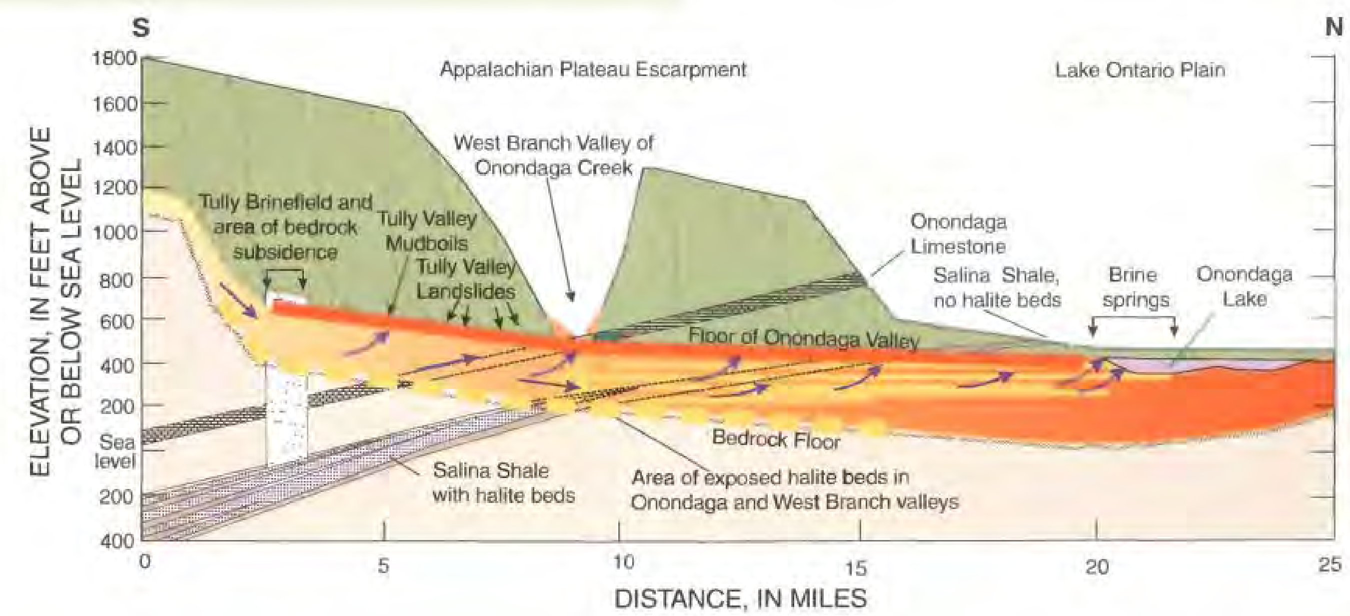
6 Salina Group wells in Onondaga Salt Reservation. Depth ranges from 132 to 312 feet. Data from Higgins (1951), and Geddes (1859).

7 Geddes Group wells in Onondaga Salt Reservation. Average well depth 338 feet. Data from Higgins (1951), and Geddes (1859).

8 Syracuse Group wells in Onondaga Salt Reservation. Well depths 237 to 360 feet. Data from Higgins (1951), and Geddes (1859).

9 Liverpool Group wells in Onondaga Salt Reservation, depth of wells unknown. Data from Higgins (1951), and Geddes (1859). Data for year 2000 collected at Gale Spring near Liverpool by USGS, July 2000.

FIGURE 4: Range of total dissolved solids concentration, salinity, and salometer readings from several sites, datum's, and depths in the Onondaga Creek Valley



EXPLANATION

COARSE AQUIFER DEPOSITS - (Gravel, sand, some silt) - basal aquifer along bedrock floor where dashed, valley-fill deposits elsewhere.

FINE CONFINING-UNIT DEPOSITS - (silt, clay, and marl) - generally clay along valley floor, becoming more prevalent on Lake Ontario Plain and around north end of Onondaga Lake.

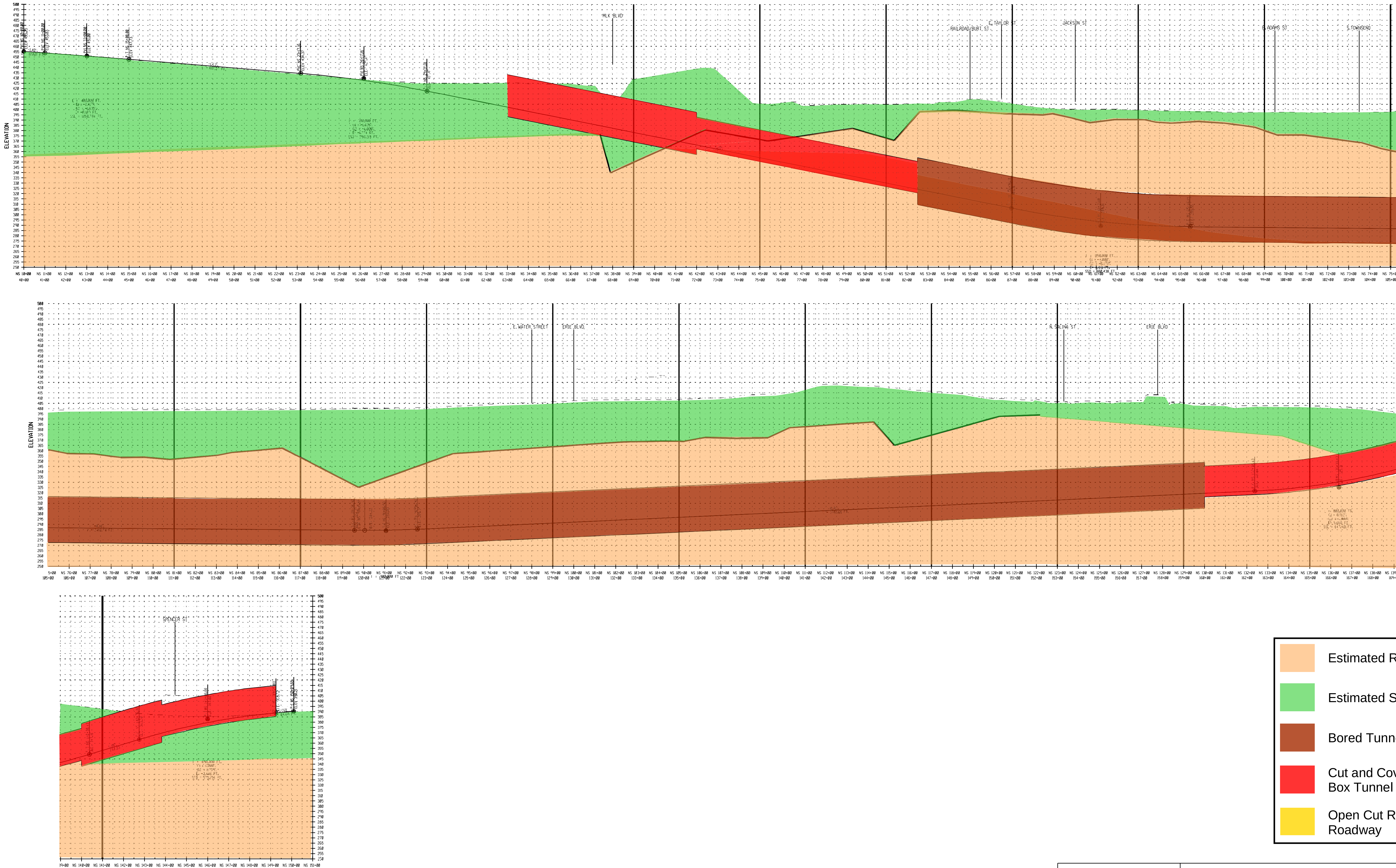
ONONDAGA UPLANDS - significant elevation differences within the Appalachian Plateau, minimal elevation differences on the Lake Ontario Plain.

DIRECTION OF GROUND-WATER FLOW - Onondaga Valley aquifer system.

PROJECTION OF BEDROCK UNITS, removed by glaciation in the Onondaga Valley.

Figure 4. Idealized geologic section along Onondaga Creek Valley, Onondaga County, N.Y., showing locations of halite beds, Tully Valley brinefield, mudboils, and landslides, and Onondaga Lake brine springs.

FIGURE 5: Idealized geologic section along Onondaga Creek Valley, Onondaga county, NY, showing locations of halite beds, Tully Valley brine field, mud boils, and landslide, and Onondaga Lake brine springs (Ref: USGS)



- Estimated Rock
- Estimated Soil
- Bored Tunnel
- Cut and Cover Box Tunnel
- Open Cut Recessed Roadway

WSP USA Inc.

I-81 INDEPENDENT FEASIBILITY STUDY

ALTERNATIVE
BORED RED TUNNEL - TWIN

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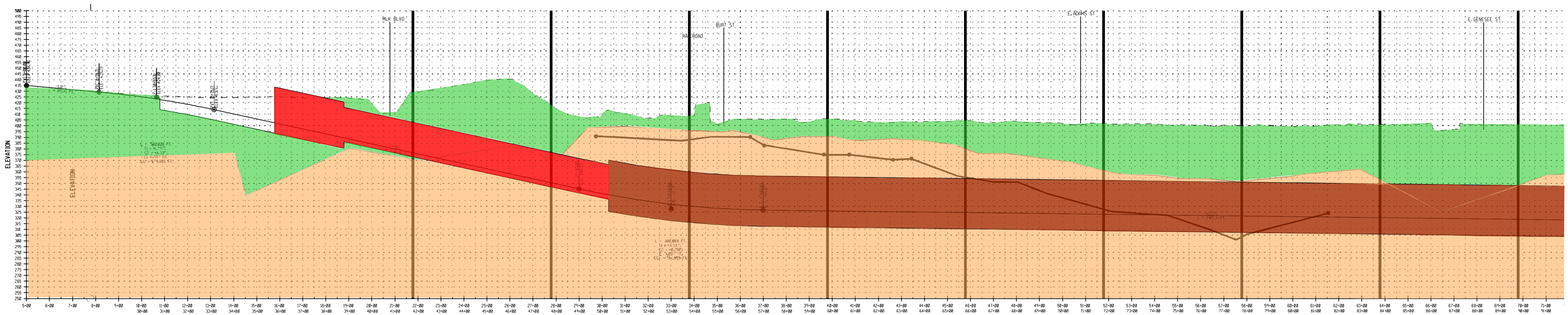

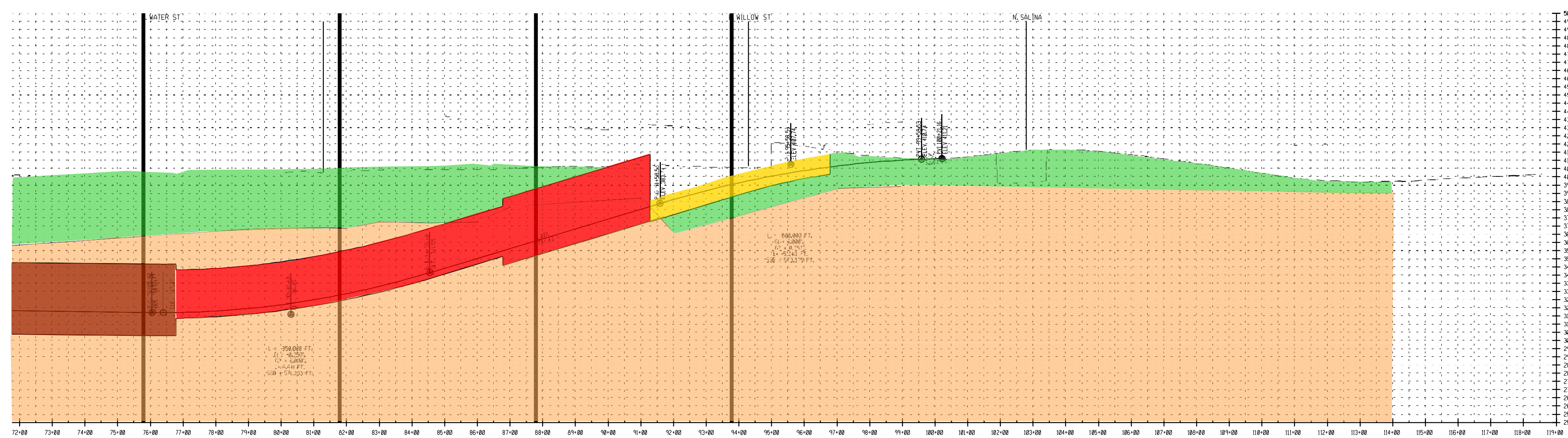

Estimated Rock

Estimated Soil

Bored Tunnel

Cut and Cover Box Tunnel

Open Cut Recessed Roadway

WSP USA Inc.

I-81 INDEPENDENT FEASIBILITY STUDY

ALTERNATIVE
BORED ORANGE TUNNEL - DOUBLE

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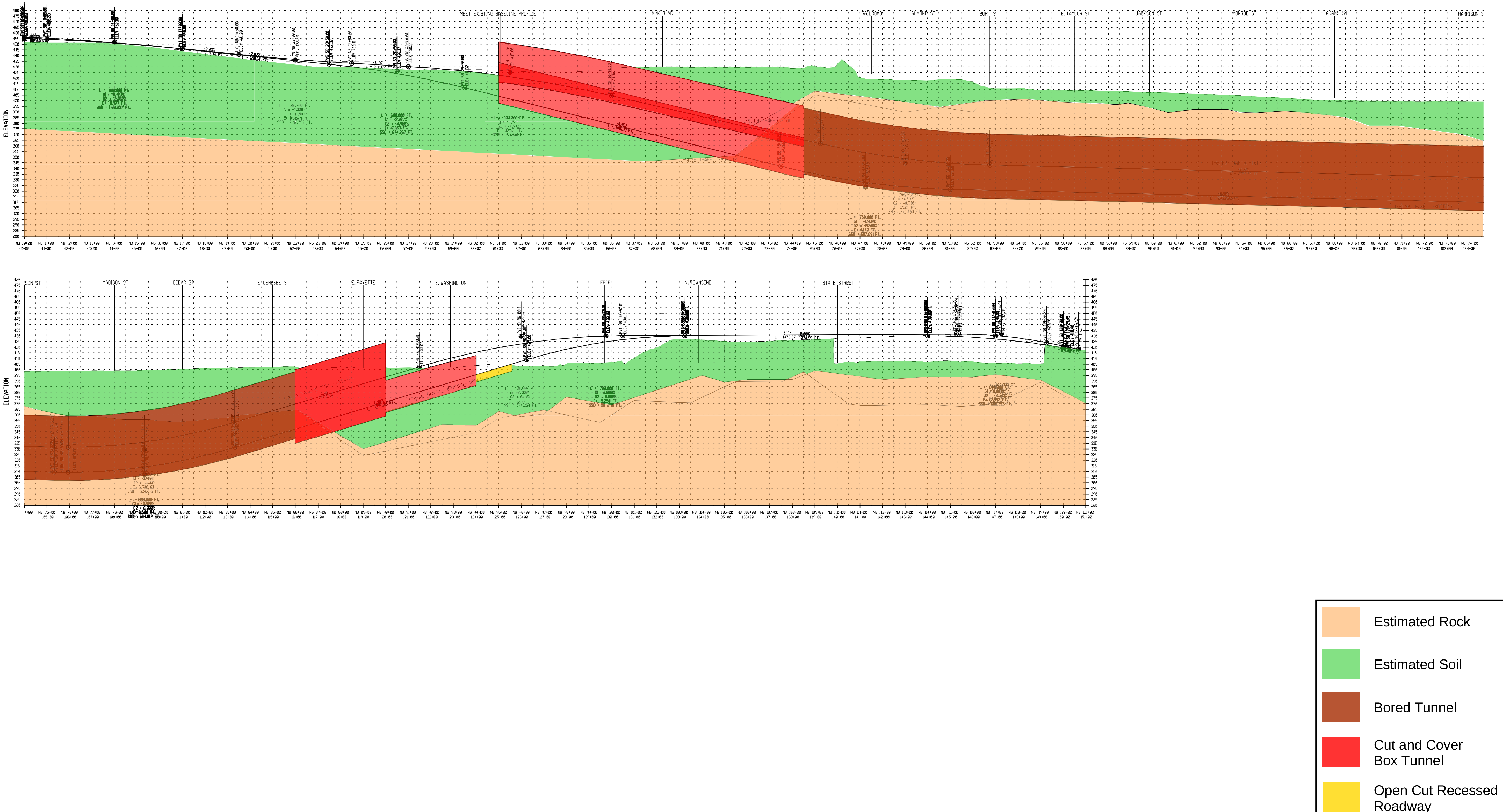


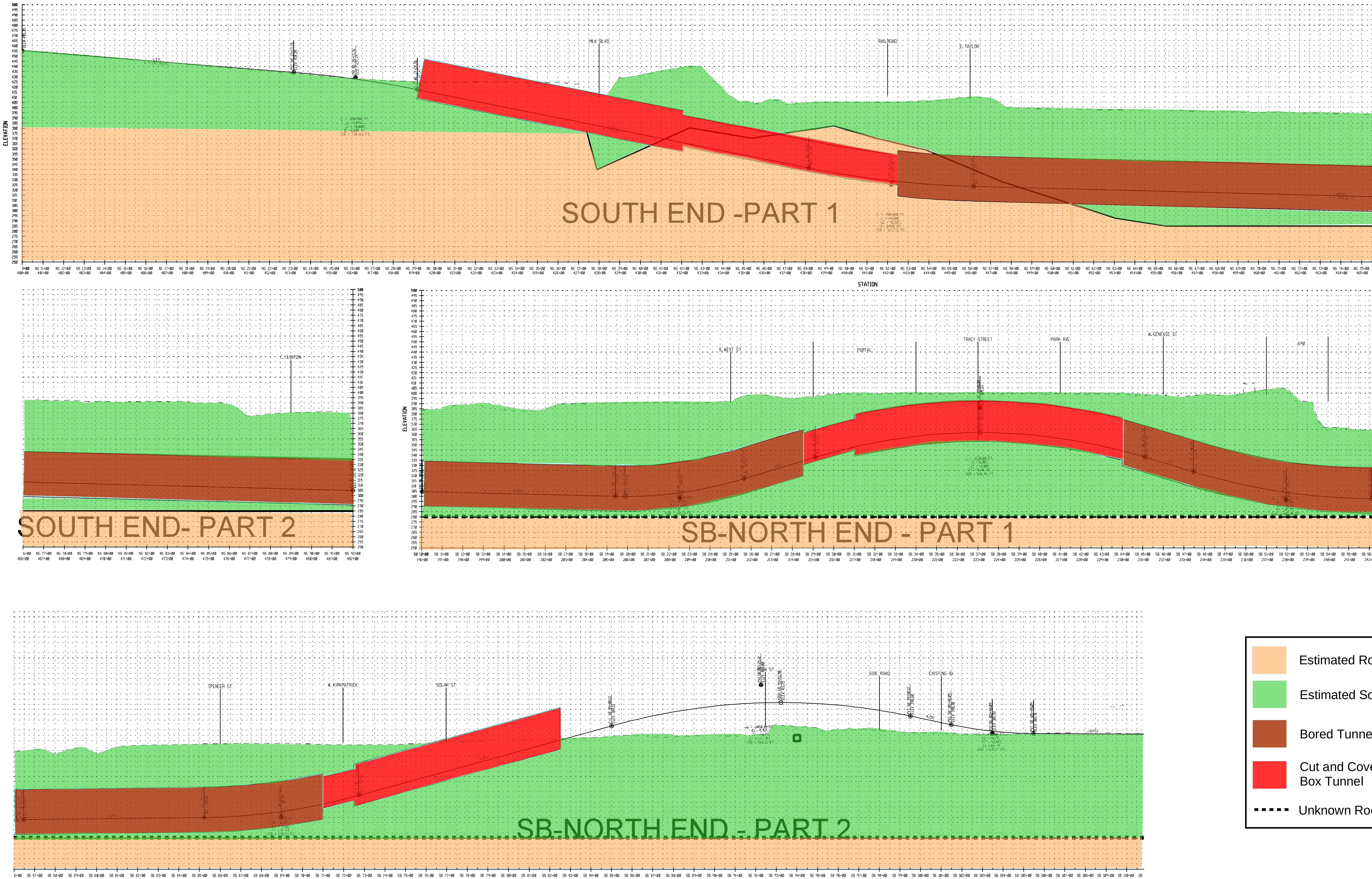
WSP USA Inc.

I-81 INDEPENDENT FEASIBILITY STUDY

ALTERNATIVE

BORED GREEN TUNNEL - STACKED

SHEET NO.



Estimated Rock

Estimated Soil

Bored Tunnel

Cut and Cover Box Tunnel

Unknown Rockline

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WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
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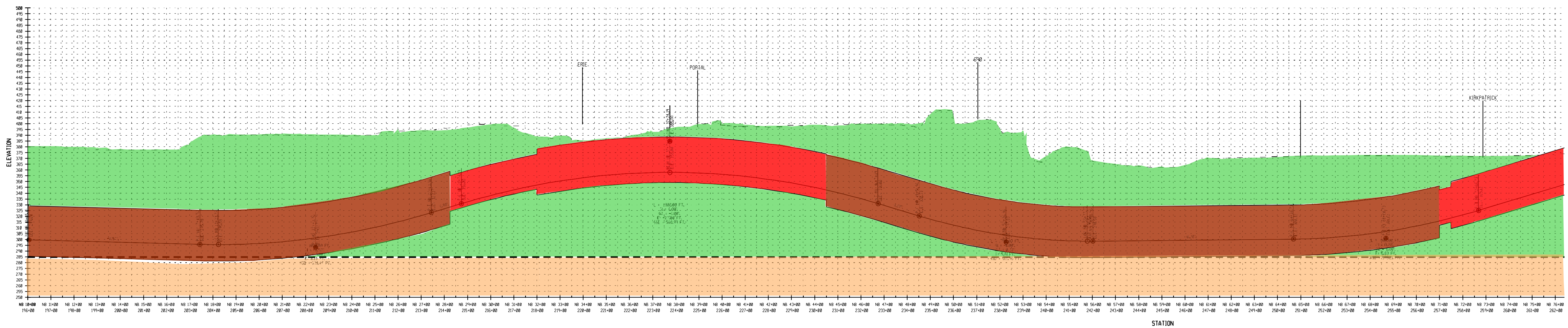

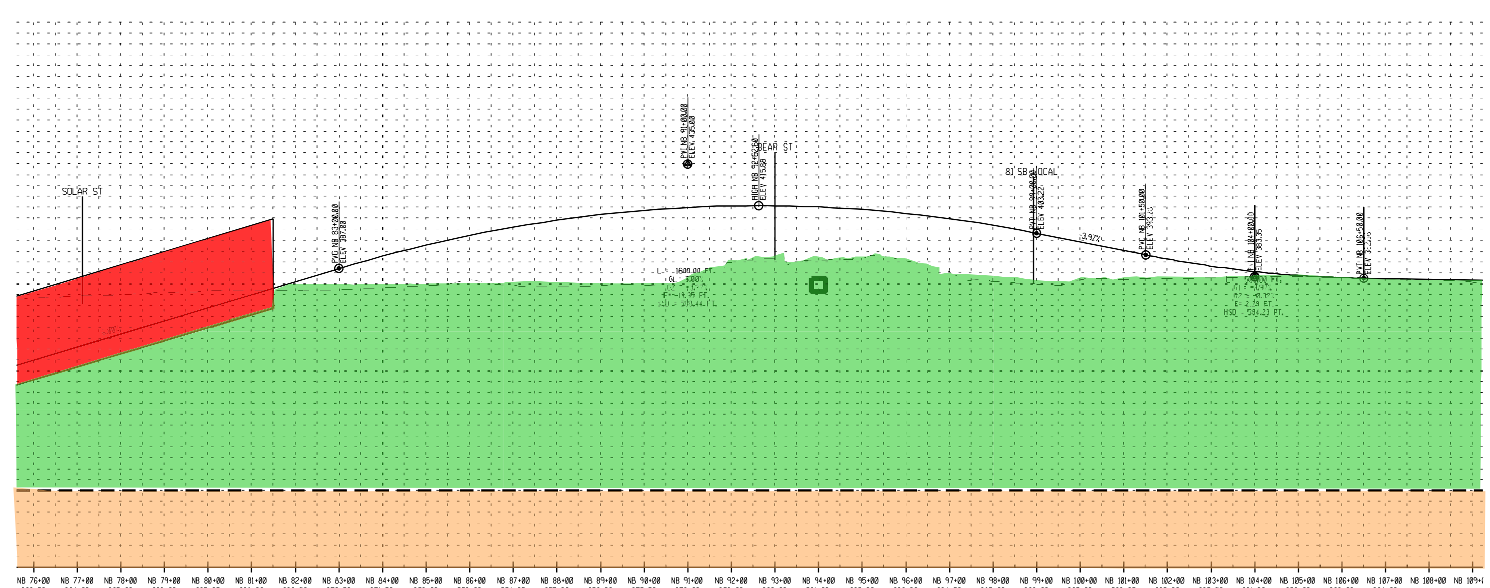

- Estimated Rock
- Estimated Soil
- Bored Tunnel
- Cut and Cover Box Tunnel
- Unknown Rockline

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WSP USA Inc.

I-81 INDEPENDENT FEASIBILITY STUDY

ALTERNATIVE
BORED BLUE TUNNEL 2
- NB-NORTH END

SHEET NO.

APPENDIX E: TUNNEL DESIGN + CONSTRUCTION

TABLE OF CONTENTS

FIGURES

1 TUNNEL DESIGN + CONSTRUCTION METHODS

Final structures will consist of the following construction types:

- Retaining wall construction
- U-wall construction
- Cut-and-cover tunnel construction
- Mined (TBM-bored) tunnel construction

Retaining wall construction may consist of various types, such as cantilever retaining walls or retained earth retaining walls. Retaining wall construction and U-wall construction will be used for depressed roadway alternatives and for approaches to tunnel alternatives.

1.1 SPECIAL CONSIDERATIONS

The following special considerations will affect structural design and construction:

- Saline groundwater
- High snowfall accumulations and deicing salts
- Shale bedrock
- Potential high in-situ stress in rock.

1.1.1 SALINE GROUNDWATER

Saline groundwater apparently will be encountered during construction of both depressed roadway and underground roadway sections. The degree of salinity is unknown. Salinity can be qualitatively described as brackish (relatively low salinity) to briny (relatively high salinity). See the discussion re salinity above. Saline groundwater, irrespective of degree of salinity, will require treatment before discharge into municipal sewers, in accordance with NYSDEC requirements. The required level of treatment and the corresponding cost of treatment will be a function of the degree of salinity.

Therefore, dewatering should be minimized. Strict limits should be placed on allowable groundwater drawdown. This will require relatively impermeable Support of Excavation (SOE) walls with limited dewatering within the excavation for depressed roadway, tunnel approaches, and cut-and cover tunnel construction. Such wall types would include slurry walls and secant pile walls. Saline groundwater conditions will affect the slurry used to stabilize trenches during the excavation stage of slurry wall construction, will influence concrete mix design, and will require use of anti-corrosion measures for all concrete structures, temporary and permanent.

1.1.2 HIGH SNOWFALL ACCUMULATIONS AND DEICING SALTS

According to AccuWeather, Syracuse is the snowiest major city in the US, with an annual average snowfall of approximately 124 inches. It has commensurately high use of road salt, which is applied in both crystalline and brine forms. Anti-corrosion measures would be required in the concrete structures to protect against deicing salts.

Depressed highways would be need to be cleared of snow accumulations. In addition, deicing would be required. This would likely be through the use of deicing salts. However, heating the road deck may be possible.

Tunnels are protected from snow, so snow is not a concern in covered sections. Ramps leading into tunnels are typically left open to the sky. However, a combination of gradient, ice, and snow accumulation could make covered approaches cost effective. Covered approaches can also improve the dispersal efficiency of air exhausted from ventilation systems.

Deicing salts are carried into tunnels by vehicles, and should be considered in the structural design.

1.1.3 SHALE BEDROCK

It is common practice to terminate both slurry wall construction and secant pile wall construction at or immediately below top of rock when soil is underlain by medium to high strength rock. For these conditions, it is important to know the top of rock location for evaluating the cost of slurry wall or secant pile wall construction. The top of rock elevation determined on the basis of the borings provided by NYSDOT has an unknown degree of certainty. Fortunately, the shale bedrock that will be encountered on this project is a weak rock, with an estimated unconfined compressive strength of between 2,000 psi to 5,000 psi. This means that it will be possible to economically install either a slurry wall or secant pile wall to the full depth of excavation. Theoretically, the wall then can be incorporated in the final construction. However, as discussed below, potential high in-situ stresses in the rock may preclude this potentially cost-effective measure.

1.1.4 POTENTIAL HIGH IN-SITU STRESS IN ROCK

The sedimentary rocks in the Ontario Lowland are known to contain high levels of horizontal stress, related to their geologic history. The low strength, low modulus shales, such as those in the project area, often exhibit time-dependent deformation upon excavation. This results in lateral movement of excavation sidewalls into the excavation and buckling and heaving of the excavation invert. The lateral movement can persist for decades, but will reach an asymptote in a few months, based on measurements during tunnel construction in Rochester in 1980s. Such lateral movement has affected the alignment of turbines in electric power plants in Ontario, Canada.

In-situ stress measurements to determine the orientation and magnitude of high horizontal stress are routinely performed during the detailed design stage of a project. The magnitude of high horizontal stress may vary between measurement locations.

Standard practice in dealing with this phenomenon in foundation excavations includes the following procedures:

- Remove rock in excavation sidewalls that has extended into the concrete wall section.
- Install compressible material against the trimmed rock face before constructing the wall.
- Remove buckled and heaved rock in invert and replace with lean concrete.

The pressures that the rock can apply to walls that restrain movement can be quite high and may result in wall failure. Thus, it may be inappropriate to extend slurry walls or secant pile walls through the rock to the bottom of the excavation.

For tunnel construction, the restraint against lateral movement of the tunnel sidewalls and buckling/heave of the invert will increase the load placed on precast concrete segmental lining sections.

1.2 SUPPORT OF EXCAVATION SYSTEMS

To excavate a depressed highway trench, or cut and cover tunnel, the adjacent soil and structures must be retained using a support of excavation (SOE) system. Methods that may be applicable include:

- Soldier pile and lagging
- Slurry walls (also known as diaphragm walls)
- Secant piles
- Jet grout infill panels
- Bracing and tie-backs

Sheet piles may also be applicable to shallow excavations, but as noted above, the fill materials contain obstructions that could interfere with installation.

1.2.1 SOLDIER PILE AND LAGGING

Soldier pile and lagging walls would require augering cased holes to the required depth, and installing steel H-piles at (typically) 5ft to 8ft centers. During excavation, wooden lagging would be placed between the flanges of the piles to retain the soil behind. The lagging boards are not watertight, so the technique would only be applicable in shallow areas above the groundwater table. The technique is particularly useful where utilities cross the excavation. The soldier piles can be placed on either side of the utilities, which are then supported across the excavation.

1.2.2 SLURRY WALLS

Slurry walls are constructed by excavating trench a few feet wide, while the trench is maintained full with a slurry. The slurry, containing either bentonite clay or polymer, stabilizes the soil while a trench panel is excavated. Excavation is performed using either a clamshell or a hydromill (a vacuum lift with a rotating cutting tool, also known as a hydrofraise). A hydromill would likely be used on this project because it can excavate soil, weathered rock and weak unweathered rock (shale).

Alternate panels are excavated, followed by placement of reinforcement and then concreting. When concrete has attained sufficient strength, intervening panels will be excavated. The flexural strength of slurry walls is provided by either pre-tied reinforcing cages or multiple steel H-piles. The latter method is known as a Soldier Pile Tremie Concrete (SPTC) wall. This variant eliminates the requirement for a reinforcement cage.

Concrete is placed in the panel using the tremie method, which displaces the slurry. When all panels are complete, the wall is essentially watertight. Toe depths of 150-ft or more can be achieved.

1.2.3 SECANT PILE WALLS

Secant pile walls are constructed by auguring overlapping piles that are typically 3-ft to 5-ft in diameter. Temporary steel casing is typically used to support the ground during augering. Alternating pile – primary piles – are excavated first and filled with unreinforced concrete as the casing is withdrawn. The infill piles – secondary piles – are then constructed and include steel reinforcement cages or soldier-piles. A high degree of water tightness can be achieved, but leakage is generally higher than with slurry walls. Toe depths of 90-ft or more can be achieved

1.2.4 JET GROUT INFILL PANELS

Where obstructions such as utilities would cause a gap in an SOE walls, the ground can be strengthened and made watertight with grout. Jet grout is a common technique, in which a mixture of cement and water in injected into the ground through a nozzle. The nozzle is drilled to the required depth, and slowly withdrawn while rotating to create a column of 'soilcrete'.

1.2.5 BRACING AND TIE-BACKS

As excavation proceeds, all the SOE systems noted above require a system of wales and either bracing or tiebacks to be installed to resist the lateral force of the soil and groundwater. No dewatering will occur outside the excavation. The slurry wall or secant pile wall will serve as a water barrier and will be designed for water pressure as well as lateral earth pressure.

Struts are placed between wales on each side of the excavation, typically at 10-ft to 20-ft centers. Wales run horizontally across multiple piles at typical vertical spacing of 10-ft to 20-ft and cause the walls to act monolithically rather than as individual piles. The space between struts must be sufficient for construction equipment to pass. The location of struts can interfere with the permanent structure, so temporary works and permanent works must be designed to achieve good constructability.

Tie-back anchors are installed in holes drilled through the support walls, and are grouted into soil or rock sufficiently far from the wall that stresses have no significant impact on the wall. Tie-backs are pre-tensioned and locked off at an anchor plate, which typically bears against a double channel wales. Tie-backs extend outside the line of the excavation, therefore the nature of adjacent structures and land ownership must be considered.

FIGURE 2: Slurry Wall – East Side Access, New York

FIGURE 1: Soldier Pile and Lagging, 2nd & Hope Station, Metro Regional Connector, Los Angeles

FIGURE 3: Secant Piles, Struts and tiebacks – South Ferry Station, New York

1.3 SUPPORT OF EXCAVATION CONSIDERATIONS FOR CUT AND COVER OR DEPRESSED HIGHWAY

Shallow excavations above the groundwater table for a depressed highway or tunnel open approaches can be supported by soldier pile and timber lagging SOE walls. Excavations extending below the groundwater table into saline water conditions should use either slurry wall or secant pile wall construction. Soldier Pile Tremie Concrete (SPTC) walls (a type of slurry wall) may be optimal. Compared with secant piles they can extend deeper, and reduce water leakage during construction.

A panel width of 10 feet could be applicable, with a panel thickness of 36 inches, and W36 soldier piles. These are common SPTC wall dimensions. Secant piles could be approximately 1000mm (approximately 39 inches) in diameter.

Using soldier piles rather than rebar cages would be beneficial as there is generally insufficient laydown area for large reinforcement cages. Figure 4 shows a rebar cage being tied, prior to installation.

It would be possible to construct a depressed roadway or cut-and-cover tunnel beneath the viaduct, but this would require low headroom excavation equipment. Low-headroom slurry wall rigs can typically achieve greater depths than secant pile rigs (Figure 5 and Figure 6). Limited headroom results in the rebar cage or soldier piles being lowered in sections and spliced together. Generally it is more cost effective to splice soldier piles, but both methods are slow and labor intensive. Limited headroom areas frequently have pile caps and other obstructions to be worked around. This can result in walls being constructed piecemeal, which tends to favor secant piling. Given that the cost of both methods is similar, the selection should generally be left to the contractor's SOE designer, who can perform a detailed evaluation of conditions at each location.

The top of rock elevation varies throughout the various alternatives (see rock-line shown on alternative profiles in Appendix A). In areas where the top of rock is part-way up the tunnel or depressed highway walls, the SOE walls could either terminate a couple of feet into rock (Figure 7) or could be extended to beyond the bottom of the invert slab (Figure 8). The shale bedrock is relatively weak, which should permit full-depth wall installation using conventional equipment.

If the walls terminate at top of rock, the rock face created during bulk excavation would likely be reinforced with rock dowels and shotcrete. Typically, a small rock ledge is left at the toe of the SOE walls (Figure 7), but as shown in (Figure 3 – South Ferry) this is not always the case.

It may be necessary to place compressible material against the rock face to account for continuing time-dependent movement of the rock as a result of excavation-induced stress relief. Time-dependent movement may require termination of slurry walls or secant pile walls above top of rock, precluding their incorporation in the final structure.

The SOE walls will generally run parallel to the centerlines of the tunnel or depressed highway. However, local deviations around existing viaduct pile caps may be required.

A combination of tie-backs and bracing is likely to be cost effective (see Figure 7 and Figure 8). Tie backs would need to consider the piled foundations of adjacent structures, including the existing I-81 and I-690 viaducts.

FIGURE 4: Rebar Cage for slurry wall, First Street Tunnel, Washington DC

FIGURE 5: Slurry Wall Construction, 13 ft. 10 in overhead clearance

FIGURE 6: Secant Pile Wall Construction (23-ft vertical clearance), East Side Access, New York clearance

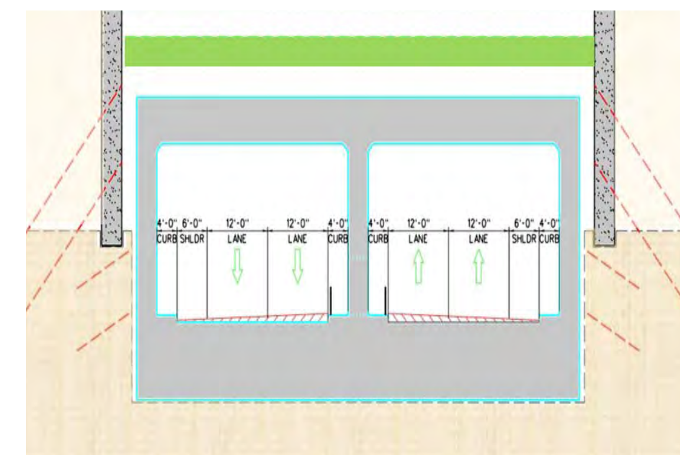


FIGURE 7: SOE Walls Key into Rock, above Rock Dowels

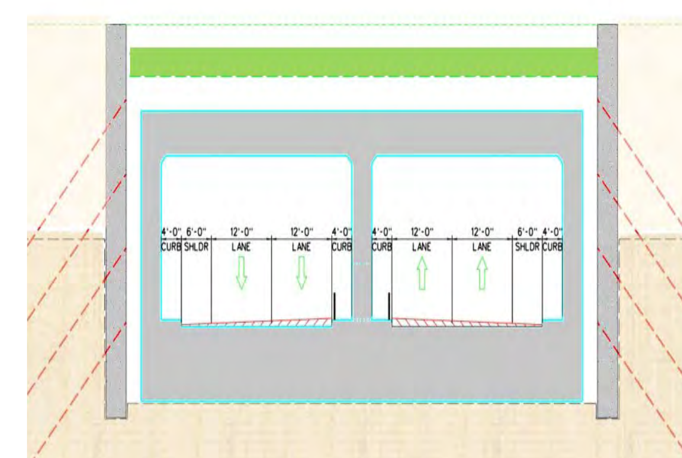


FIGURE 8: SOE Walls Extend Full Depth

1.4 POTENTIAL CONSTRUCTION METHODS

Depressed roadway alternatives and cut-and-cover tunnel alternatives constructed along the existing I81 viaduct alignment will generally have a broader footprint than the viaduct, so that SOE walls will be located outside the viaduct footprint (Figure 9 – Stage 1). Existing on/off ramps and piles – especially raking piles – will require special considerations both for piling equipment and to ensure that the existing structure is not compromised while it is still in service. Traffic Management on Almond Street and other city streets would be necessary to minimize disruption, but the number of available travel lanes would be reduced during construction, and some closures would likely be necessary.

Once continuous SOE walls are in place, excavation under the viaduct could commence. However, excavation below the pile caps would remove confinement of the piles, which would decrease lateral and vertical capacity, and would ultimately result in piles buckling. While it may be possible to install bracing, a more cost effective method may be to install underpinning of the viaduct crossheads, as shown in Figure 9 Stages 2 and 3, and also in Figure 10 and Figure 11. The underpinning would be designed to transfer loads into the SOE system, or into new temporary foundations. The underpinning would be expensive, and given the low headroom under the existing viaduct (Figure 12) would preclude decking over the cut to maintain traffic on Almond Street. However, it would potentially allow traffic on I-81 to be maintained during much of the tunnel or depressed highway construction.

Compared with the cost of underpinning, it may be more cost effective and less disruptive to city traffic to close I-81 at the beginning of construction, demolish it, and install decking throughout its length to provide a temporary 'community grid spine road' until the project is complete.

The I-690 viaduct is generally higher above grade, and does not have roads running continuously beneath. This makes underpinning of the I-690 viaduct more feasible while minimizing traffic impacts on city streets.

If surface traffic is to be maintained on streets that cross the cut-and-cover construction or depressed highway construction, a decking system would be required (Figure 13). A system of girders would span the excavation, from support wall to support wall. Intermediate 'king posts' could be placed to reduce spans, where necessary. Common decking girder configurations used in cut-and-cover construction include twin W36 sections or 60 inch welded plate girders. The former configuration often is used when utilities must be maintained within the limits of the excavation. Decking panels would span between girders. The decking panels would have a non-skid surface. Typical decking panels include 10 foot long X 5 foot wide X 1 foot thick precast concrete panels or 10 foot long X 5 foot wide by ½ inch thick steel plates with longitudinal W4 or W6 steel ribs at 1'-6" transverse spacing.

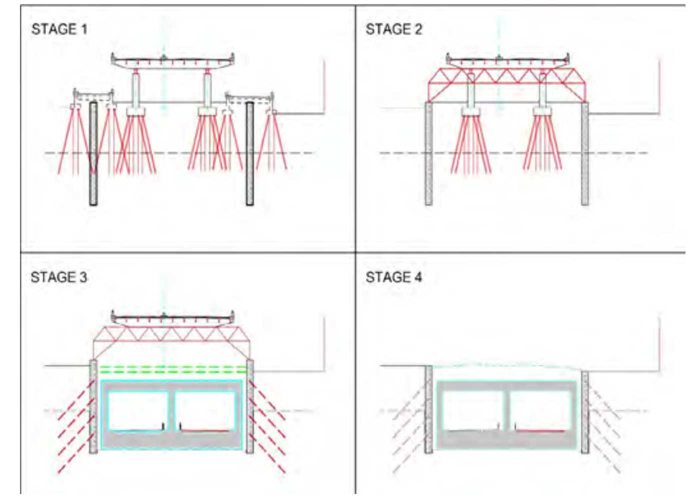


FIGURE 9: Potential Construction Sequence for Cut and Cover Tunnel

FIGURE 12: Low Headroom under Existing I-81 Viaduct

FIGURE 10: Support Trusses (100'L x 12'D), Midland Links, Birmingham UK

FIGURE 13: Pre-cast Street decking (top), Steel Street Decking (bottom) – 50th and 55th Streets Manhattan, NY

FIGURE 11: Plate Girder Support Beams (100'L x 7'D), Midland Links, Birmingham, UK

Instead of constructing a cut and cover highway directly under I-81, it is proposed to construct a stacked cut and cover tunnel along the northbound lanes of Almond Street, immediately east of the I-81 viaduct (Figure 14). The western SOE wall (left) is shown in a location where jet-grout infill panels would be used between other SOE methods (secant piles or slurry wall) where existing I-81 raking piles might conflict with an SOE wall. A stacked cut and cover arrangement would be used at the northern end of the Green Alternative, at the transition from a single-bore (stacked roadway) tunnel to cut and cover, north of Fayette Street.

The transition from a stacked tunnel to a side-by-side configuration at each end of the Green Alternative tunnel is shown on two drawings at the end of this appendix ("Green Alignment – North Sections", and "Green Alignment – South Sections").

It is probable that earth excavation within the cut will be performed by front end loaders directly loading trucks inside the cut. Trucks will likely exit the cut en route to the disposal site using a ramp excavated as part of the depressed roadway/tunnel approach section. This would eliminate the need for cranes at street level to service the excavation. Decking panels along the curb line could be removed and the openings protected by barriers to provide ventilation of the cut. Alternatively, mechanical ventilation similar to mined tunnel ventilation can be installed beneath the decking.

Weathered rock and unweathered rock (shale) excavation probably can be done by ripping, because of the low strength and thin to moderate sub-horizontal bedding of the rock. Front end loaders will load the rock into trucks for transport to the disposal site. Work can proceed from both ends toward the middle for an all depressed roadway or an all cut-and-cover tunnel option.

Dewatering inside the excavation will be performed by eductors when excavating in cohesion-less soil (sand, non-plastic silt, gravel) and by sumping and pumping in cohesive soils (plastic silt, clay).

1.5 TUNNELING UNDER THE RAILROAD

All four preferred alignment alternatives pass under the New York, Susquehanna and Western Railway. This is a single railroad track that carries freight services, but no passengers. It is located close to the southern tunnel portal. Availability of track outages for tunnel and community grid viaduct construction would need to be determined. Alternative rail-freight routes may be possible, such as via currently out-of-service tracks through Utica. Tracks would be instrumented to monitor movements during tunneling, to ensure that any settlement stays within FRA safety thresholds.

On the Red Alternative, the alignment passes under the railroad close to Oakwood Avenue. An EPB tunnel boring machine is proposed, and the tunnel is expected to be in rock. Minimal settlement is anticipated, resulting in no impact to railroad operations.

On the Orange Alternative, the alignment passes under the railroad at Burt St, west of the existing I-81 viaduct (Figure 15). At this location, the railroad is elevated above grade. Bored tunnels are proposed, but the depth of piles supporting the existing railroad bridge over Burt Street would need to be determined to ensure no conflict

On the Blue Alternative, the alignment passes under the railroad in three locations: near Townsend Street, near Onondaga Street, and near West Street. In each location the railroad is elevated, either on retained earth or on a bridge. An EPB tunnel boring machine is proposed, and the tunnel is expected to be in soil, or a mixed face of soil and rock. Pressurized face tunneling should result in minimal settlement, resulting in no impact to railroad operations. Foundations of the railroad structures would need to be investigated to ensure no conflict.

On the Green Alternative, the alignment passes under the railroad near Van Buren St, east of the existing I-81 viaduct (Figure 16). At this location the railroad is at grade. Bored tunneling is proposed, which should result in minimal settlement

It may be possible to deliver materials (such as TBM segments) and to remove muck by rail. However, trucking is likely to be more cost effective and to provide better schedule flexibility.

Passenger services were provided on the line from 1994 to 2007. Ridership was low, so passenger services are unlikely to be reintroduced.

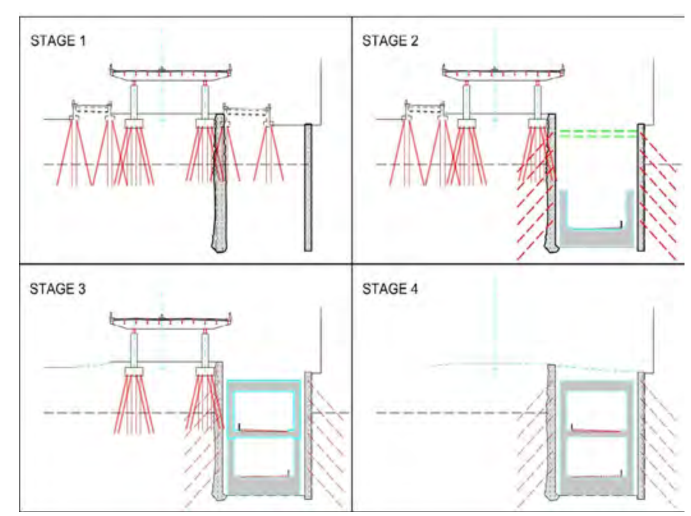


FIGURE 14: Stacked cut and cover

FIGURE 15: Railroad above bored tunnels Orange

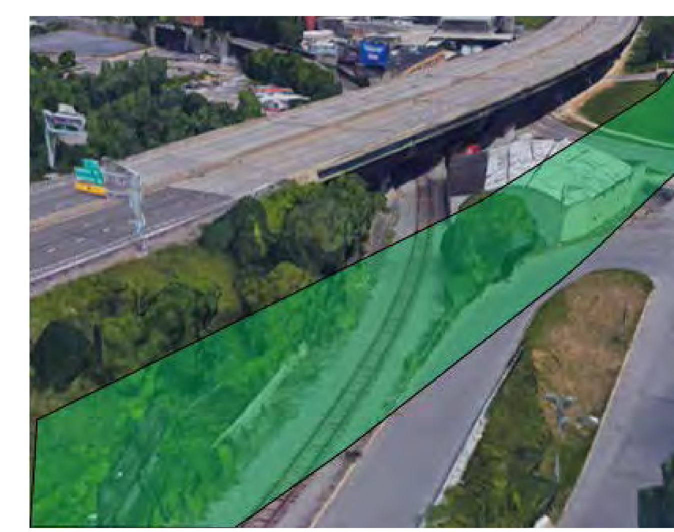


FIGURE 16: Railroad above boreed tunnels Green

1.6 TUNNELING UNDER THE SYRACUSE UNIVERSITY STEAM PLANT

The tunnels of the Orange Alternative pass under the Syracuse University Steam Plant. The steam plant property is immediately north of the southern limit of the TBM section of tunnel. As shown on Figure 17, the tunnels pass below part of the property that is not currently developed but close to buildings on both sides. To the west is the Riley Steam Station that was constructed around 1950. The building includes a tall chimney, approximately 150-ft high. To the east is the Chilled Water Plant and the Steam Station Garage. The footprint under which the tunnels will pass was formerly occupied by a Cogeneration Plant, constructed around the year 1991. This was demolished between 2009 and 2011. Steam pipes, water pipes, electrical cables and other utilities cross the site at grade and elevated. Lightweight garage and storage structures also exist above the tunnel alignment.

The Chilled Water Plant had piled foundations, approximately half of which were timber, and the other half 12” steel pipes. The piles were located directly on the alignment of the tunnel. The delivered pile length was “35-ft to 45-ft”, but the installed length was permitted to be less provided specified criteria were met. Installed lengths are not known.

A rail spur trestle for coal deliveries historically crossed the tunnel alignment, but this had shallow footing.

The crown of the bored tunnels, based on the currently proposed profile, is approximately 45-ft below grade where they pass under the redundant piles. It is recommended to extend the 4.3% down grade as far as the railroad, which will increase the depth of the tunnel to approximately 60-ft under the steam plant. Available geotechnical information (from steam plant record drawings) indicates that top of rock (shale) is approximately 10-ft below grade close to Almond Street, but as deep as 45-ft closer to McBride Street. It is therefore possible that multiple piles, and potentially up to approximately 100 wooden piles and 90 steel piles could extend to 45-ft depth but it is considered unlikely that any would extend to 60-ft depth or into the path of the TBMs. The TBMs would likely not be able to mine through either steel or wooden piles. As seen on the Alaskan Way project (Appendix I), if a TBM encounters a steel pile it can have significant negative consequences for cost and schedule.

To minimize the risk of encountering a pile, additional investigations would be required, such as obtaining as-built records and excavating exploratory pits.s

FIGURE 17: Syracuse University Steam Plant – Cogen Facility (black roof) – Prior to Demolition

2 PERMANENT STRUCTURES: BORED TUNNEL, DEPRESSED ROADWAY AND CUT-AND-COVER TUNNEL

2.1 DEPRESSED ROADWAY & CUT AND COVER TUNNEL

Final construction of depressed roadway sections would probably consist of combinations of retained earth walls, conventional reinforced concrete retaining walls, permanently anchored retaining walls and U-walls (monolithic walls and invert slab) – Figure 18 and Figure 19. Cut-and-cover tunnel sections will consist of an invert slab, sidewalls, and roof slabs. Cut-and-cover sections would likely include an interior structural wall separating two, unidirectional roadways. This will improve safety during operation and will have the beneficial effect of reducing roof and invert slab thickness.

Buoyancy of the final structure will be a significant concern, and will likely result in a thicker invert that would be necessary to resist structural stresses.

Heavyweight concrete that uses iron ore or other dense aggregate could be considered (per ACI 211.1). Concrete densities of up to 230 pounds per cubic foot (pcf) could be achieved, which would generally reduce the invert thickness by approximately 50%. However, this material has not previously been used for a transportation project on the scale of the I-81 Tunnel. The unit cost of the material is high, partly due to high transportation costs, but these could be moderated by bulk shipment via the Great Lakes to a port such as Oswego. Long-term performance would need to be evaluated, in particular the potential for alkali-silica reaction (ASR) and whether the magnetite/iron in the mix is susceptible to corrosion. Based on these concerns, heavy weight concrete is not currently recommended.

The weight of the SOE walls could be engaged to resist buoyancy, but the shear transfer would need to be designed to not compromise the waterproofing system. Also, the use of bentonite during construction of the SOE walls could reduce friction. Deflection of the SOE during excavation could reduce lateral loads (and therefore the frictional force), and the original in-situ loads may not recover prior to buoyant uplift forces occurring. It is possible to design physical interlock between SOE and a permanent structure, but this complicates waterproofing, corrosion control, rebar cages, and constructability. For these reasons the weight of the SOE has been neglected.

Permanent tie-downs could be used to resist buoyancy and thereby reduce the volume of concrete in the tunnel approach structures. Various projects have used this approach including two cut and cover stations on the North Shore Connector in Pittsburgh, PA; and stations in Berlin, Germany; Malmo, Sweden;, and Thessaloniki, Greece. Corrosions resistance can be designed. However, due to the corrosive groundwater in Syracuse permanent tie-downs are not recommended. Other concerns include the necessary penetrations through the invert waterproofing system, and the difficulty/inability to monitor/inspect the tension elements. If detailed design reveals a temporary condition where buoyancy is a concern (such as when the invert slab is placed, but prior to construction of the walls and roof) temporary tension elements (passive, or post-tensioned) could be considered.

Waterproofing will be applied to the interior face of the SOE wall or to the rock face prior to placement of reinforcement and forms and concrete placement. A smoothing layer of shotcrete (sprayed concrete) may be applied to the rock surface prior to placement of waterproofing. Waterproofing concrete additives may also be considered, but these are generally not effective for large volume applications.

The width of the tunnel is primarily determined by the number of lanes, the width of the lanes, the width of any shoulder, walkways (if used), any additional space for equipment mounted on the walls, and line-of-sight requirements (discussed below). The height of the tunnel is primarily determined by vehicular clearance required, and any additional height for signage, lights, ventilation and other equipment. These geometric requirements are discussed elsewhere in this report.

2.1.1 TUNNEL WIDTH TO MAINTAIN LINE OF SIGHT AT CURVES

The required internal widths of recessed roadways or tunnels can be affected by line-of-sight requirements for traffic driving around a curved segment of an alignment. A tunnel wall or bench that is on the inside of a horizontal curve can limit the length of the line of sight. The wall must be set back from the travel lanes sufficiently to maintain minimum AASHTO line of sight requirements for the project design speed. An extra-wide shoulder on the inside of the curve may be needed.

Of the alternatives studied, the Green alignment has the tightest horizontal curve of R=926' (located at the north portal near Fayette St which partially lies within the limits of a cut and cover structure) and will require a shoulder width of 18'-11" in order to maintain the clear line of sight as traffic exits the north portal. This is in contrast to the internal width of the cut and cover and bored tunnel immediately south, with both structures being on a tangent alignment. In that location the shoulder widths required are reduced to follow the minimum (4 ft) suggested by the AASHTO Manual. All bored tunnels have been sized according to various tangent and horizontal curves.

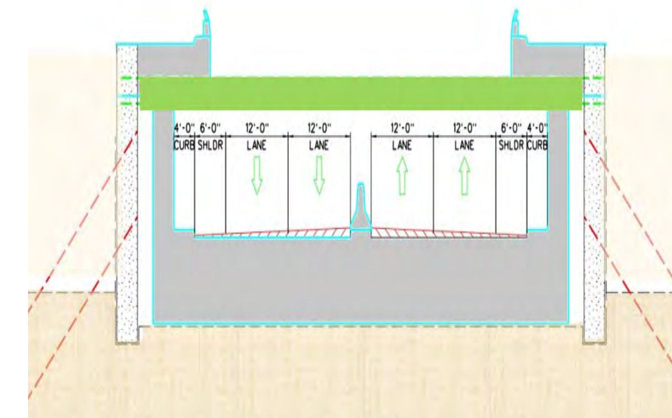


FIGURE 18: Depressed Highway with Cantilevered City Streets, Queens, NY

FIGURE 19: Depressed Highway with Cantilevered Almond Street

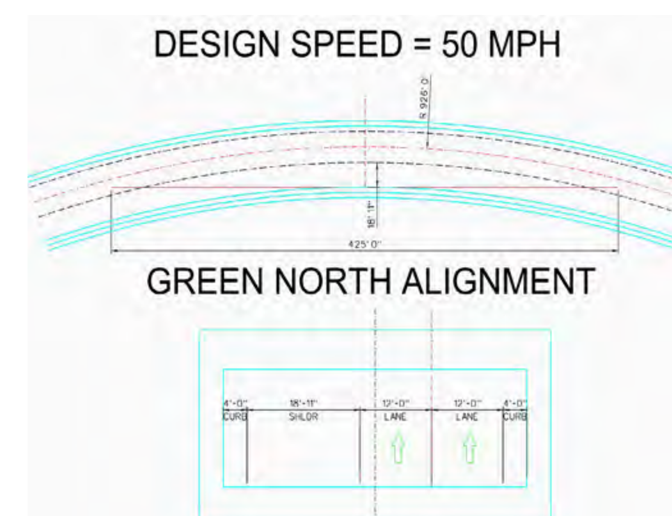


FIGURE 20: Line of Sight Requirements: 50 mph, 926' radius curve.

2.2 MINED (TBM-BORED) TUNNEL CONSTRUCTION

2.2.1 TUNNEL CONFIGURATION

Bored Tunnels could be either a pair of parallel uni-directional tunnels with cross-passages (Figure 21) or a single tunnel with a stacked highway (Figure 22: Single Bi-Level Tunnel).

Case histories of previous large diameter tunnel projects are provided in Appendix N, including the Eurasia Tunnel in Istanbul, Turkey (Figure 23)

The minimum pillar width between two adjacent mined tunnels should be approximately half a tunnel diameter. This prevents overstressing of the soil in the pillar, which can lead to large plastic deformations. The pillar width can be reduced for favorable ground conditions or if ground treatment can be used effectively.

2.2.2 TUNNEL BORING MACHINE (TBM) SELECTION

A pressurized face tunnel boring machine (TBM) capable of excavating through soil and rock will be required for the mined tunnel portions of this project. There are two general types of pressurized face TBM: the slurry shield and the earth pressure balance (EPB) TBM (Figure 24).

Slurry TBMs are generally used in cohesion-less soils (sand, non-plastic silt, gravel), while EPB TBMs generally are used in cohesive soils (plastic silts and clays). EPB machines often can be used in cohesion-less soils with the addition of conditioning agents. The effectiveness of conditioning agents may be affected by saline ground water. Slurry TBMs require more space at the ground surface to house a separation plant that removes bentonite slurry from the excavated material prior to disposal. This can be an important consideration in a confined urban site.

As described in Appendix D, ground conditions expected to be encountered by the TBM are variable. The soil is expected to comprise a mixture of sand, gravel, silt and clay. The rock is expected to be shale with a significant clay content, which may be interlayered with siltstone and sandstone. The shale is expected to be weak, with high horizontal stresses and the potential for producing hydrogen sulfide gas and methane. Groundwater will generally be close to the ground surface.

Earth pressure balance TBMs are considered more suitable for the geology. The anticipated high fines content of the soils should allow them to readily mix with water and conditioning agents within the TBM plenum to create a plastic material than can effectively maintain face pressures, and which can be removed through the TBM screw conveyor. In contrast, a slurry TBM would not be well suited to the high fines content, since the slurry separation plant would need to be large to remove the fines from the slurry circuit. The plant would require significant space at the surface, and fines removal could slow the advance rate of the TBM.

The shale is expected to be weak and to readily break down under the action of disc cutters mounted on the cutterhead. Disc cutters are also necessary in case boulders are encountered in the soil. Grille bars mounted on the cutterhead openings would prevent over-sized rock fragments from entering the plenum, which could subsequently clog the screw conveyor. Although it may, theoretically, be possible to mine the tunnel in open-mode, the limited rock cover above the crown of the tunnel could result in a high risk of groundwater inflows or weathered/fractured rock collapse. At least one diameter of rock cover is recommended in shale for working in open mode. It is assumed that that the EPB will be designed and operated only for closed mode. If, during final design supplemental geotechnical information and revised tunnel profiles result in more rock cover, some sections of the tunnel could be considered in open mode. In that case, a dual-mode TBM would be required that could be rapidly converted between modes. Probing ahead of the TBM cutterhead (up to 200-ft ahead) will be required to confirm whether the machine should operate in open mode or closed mode.

Wear protection will be required for the cutterhead and within the screw. Two of the tunnel alignments (Red and Orange) are anticipated to be entirely within shale, which would enable the TBMs to be optimized for mining rock. For the Blue and Green alternatives, the screw and other systems will need to be configured for mining through soil, mixed face and full face of rock.

Recently planned or constructed projects in shale that have used EPB TBMs include the Akron Ohio Canal Interceptor Tunnel, OH; and the West Trunk Sewer tunnel, Ontario.

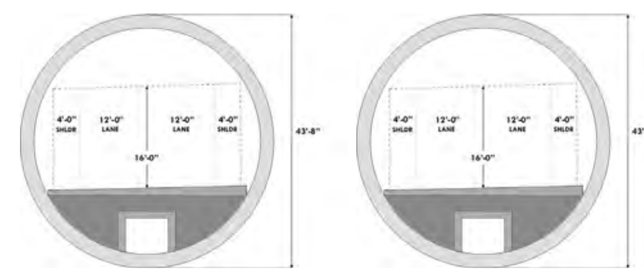


FIGURE 21: Twin Bored Tunnels

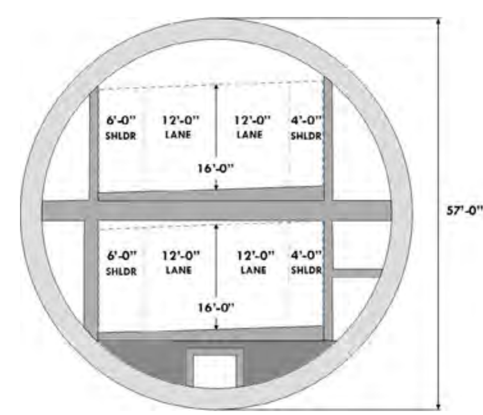


FIGURE 22: Single Bi-Level Tunnel

FIGURE 23: Eurasia Tunnel, Istanbul – before installation of internal structures

FIGURE 24: Slurry TBM (top) for Eurasia Tunnel, Turkey. EPM TBM (bottom) for First Street Tunnel, DC

The Akron Ohio TBM is 30-ft in diameter, and is convertible between open and closed modes.

2.2.3 TEMPORARY VENTILATION

The shale may contain hydrogen sulfide and methane gas, which are significant safety hazards in closed excavations and tunnels. Hydrogen sulfide, which is heavier than air can accumulate at the bottom of excavations when air circulation is limited. The tunnel is expected to be classified per OSHA as "potentially gassy". In a slurry machine, the closed slurry circuit would allow the gases to be released above ground at the separation plant. However in an EPB machine the gas would be released in the tunnel. Ventilation systems will be required to dilute the gases to safe levels. Gas monitoring will be required at multiple locations on the TBM and within the tunnel. If concentrations exceed allowable limits the TBM would be shut down until the gas concentrations are diluted. Life-safety systems will need to be non-sparking (intrinsically safe).

Hundreds of miles of tunnels have been constructed in gaseous environments throughout the US without incident when OSHA requirements are observed. Representative locations include Rochester, Pittsburgh, Cleveland, Milwaukee, and Detroit. While there are recorded cases of explosions during underground construction in gassy ground, these typically occurred several decades ago, before modern safety protocols were routinely enforced. Today, the risk to workers is very low, and there is essentially no public safety risk.

2.2.4 SEGMENTAL TUNNEL LINING

The mined tunnel will be lined with a precast concrete segmental lining, installed concurrently with advance of the TBM. For this study, a thickness of 2-ft has been assumed (for both tunnel diameters), based on precedent projects of similar size (Figure 25).

If tanker trucks containing flammable liquids are permitted within the tunnel, additional protective concrete cover may be required over the interior reinforcement. Fires involving tanker trucks in the Mont Blanc and Tauern tunnels in Europe destroyed the tunnel linings. The World Road Association (PIARC) developed fire protection requirements for highway tunnels after these incidents. It would be preferable to ban such vehicles from the tunnel.

Conventional reinforcement is expected to be used in the tunnel segments. Steel fibers are typically used for smaller diameters tunnels (for subways and water management) but are not well suited to the larger stresses induced when handling larger segments. Segments would be designed to resist short-term load conditions including demoulding, stacking, handling, transportation, erection, TBM jacking force and backfill grout pressures. They would also be designed to resists long-term load conditions including load from soil, rock, high overburden, low overburden, high groundwater, low groundwater, fire, seismic events, traffic, internal structures, and supported equipment

Special segments with increased reinforcement may be required near the portals, and at cross passage openings.

Segments will be interconnected with bolts on the radial joints (between the segments in a ring) and either dowels or bolts on the circle joints (between rings).

As discussed below, two gaskets per segment - inner and outer – are recommended to resist groundwater and gas.

Time dependent displacement in the shale is expected, which could result in high horizontal forces acting on the tunnel lining. To help counter this, a compressible backfill material may be required around the precast segments. The degree of compressibility and the thickness of the grout layer would need to be determined based on factors such as anticipated rock strain due to stress-relief, grout materials and the desired amount of cutterhead overcut. Compressible grout was recently used in shale on the West Trunk Sewer tunnel project in the city of Mississauga, Ontario. The mix included Styrofoam beads to achieve the desired higher stiffness at low strains and lower stiffness at high strains. The backfill grout will help to resist ingress of water and gases, although the gaskets will be the primary method.

2.2.5 BUOYANCY CONTROL

In downtown Syracuse the groundwater table is close to the surface, and the bored tunnels must be designed to resist buoyancy. Where the tunnels are in rock, buoyancy is not a concern. The Red and Orange alternatives are expected to be entirely in rock. However, the Green and Blue alternatives will have significant length in soil. In order to resist buoyancy, the minimum soil cover above the crown of the TBM should be approximately half the tunnel diameter. The tunnel profiles and the start/end of the bored tunnels (in both soil and rock) have been selected to achieve a ground cover of at least half the TBM diameter (except at the north portal of the Green Alternative, as described below).

This amount of soil cover could be reduced if ground treatment were used. The effectiveness of ground treatment may be affected by groundwater salinity. On the Alaskan Way project the ground above the TBM was jet grouted to help resist buoyancy. In addition, that project used a 5-ft thick concrete stab tied into secant piles to hold down the TBM and the surrounding ground. This approach is proposed for the north portal of the Green Alternative, as shown on the drawing "Green Alignment – Bored Tunnel at Genesee Street " at the end of this Appendix. The secant piles would also act as settlement cut-off walls to protect the adjacent hotel. Other projects, including the Port of Miami, have placed fill above existing grade to resist buoyancy.

In the bi-level single bore alternative, the internal structure is limited, adding little to the overall weight of the tunnel. However, in the twin bored tunnel alternatives, most of the volume below the roadway is backfilled with lower strength concrete. This significantly improves the factor of safety in the long term condition. The temporary construction case becomes the critical condition for buoyancy. On the Groene Hart (Netherlands) project, backfill was placed within 20-ft of the back of the TBM shield to add weight in the temporary condition (Figure 26). The short length of tunnel ahead of the backfilling operation was held down by spanning between the TBM ahead, and the backfilled tunnel behind.

2.2.6 INTERNAL STRUCTURES

In a twin bored tunnel arrangement, major internal elements are the backfill concrete (discussed above) and the bench/walkway (discussed in Appendix F).

A single bi-level tunnel requires more internal structures. Firstly the upper deck requires a reinforced concrete road deck that is generally attached at each end to the segmental tunnel lining. It is generally laterally free at one end to prevent point loads on the tunnel lining. The lower roadway can either be supported on a concrete deck, or on fill concrete. As shown in Figure 27, vertical reinforced concrete partition walls can provide separation for ventilation ducts, utility chases, emergency egress corridors and emergency egress stairways between decks.

As discussed in Appendix F, fireproofing is an important consideration. Concrete must be protected by a combination of fire-resistant panels, spray-on fireproofing, segment mix design, fire-suppression systems, and other means.

FIGURE 25: Precast Segments for Eurasia Tunnel, Turkey

FIGURE 26: Installing backfill and utility corridor in Groene Hart Tunnel, Netherlands

FIGURE 27: Paris A86 Tunnel – Installing Lower Deck

2.3 CROSS PASSAGES

2.3.1 CROSS PASSAGE GEOMETRY

Emergency egress/access will be required, in conformance to NFPA 502 recommendations. For twin bored tunnels cross passages will be required, for a single bi-bevel bored pressurized stairways between roadway decks will be needed.

Any tunnel alternative consisting of two, parallel uni-directional tunnels will require cross passages between tunnels to conform to the requirements of NFPA 502. Figure 28 shows a typical cross passage arrangement.

Figure 29 shows a typical cross-passage section. Each cross passage should have a minimum interior width of 17 feet to accommodate a 5 foot wide evacuation walkway, a 3 foot wide utility space, two 3 foot wide conduit spaces and three 12-in wide CMU partition walls, as shown in the figure. The cross passage will have fire-rated doors at each end, to conform to NFPA 502 requirements. The selected dimension can accommodate cable or conduit racked along both sides of the cross passage, protected by a fire-rated partition wall.

For planning purposes, it is assumed that the cross passages will have a lining thickness of 18 inches, doubly reinforced. A thicker flat invert is proposed, to resist higher bending stresses and to accommodate conduits. The lining will resist loads from groundwater, rock and soil.

This results in a nominal minimum excavation width of 20 feet. The cross-passage floor will be at roadway elevation, as shown in the figure. The cross passage will have an arched roof.

The interface between the cross passage and main tunnel will require a cast-in-place concrete closure pour. The fire-rated door will be located in this closure section.

2.3.2 CROSS PASSAGE CONSTRUCTION IN ROCK (BETWEEN BORED TUNNELS)

The natural tendency of an excavated opening in thinly-bedded shale is to form a natural corbelled arch roof, as the shale progressively ravels. In Syracuse, this tendency would be enhanced by the anticipated high horizontal stress condition. The immediate installation of the precast concrete segmental lining at the rear of the Tunnel Boring Machine will prevent the development of this corbelled arch. However, removal of segments from a minimum of four consecutive rings within each tunnel will be required at each cross-passage location (20 linear feet of tunnel). The removal of the segments may result in immediate fallout of rock from above tunnel springline. The segment removal procedure must consider this possibility.

Once the segments have been removed, untensioned rock reinforcement elements, such as Swellex bolts, should be installed in the exposed rock in combination with welded wire fabric (WWF). The rock reinforcement will tie the thinly-bedded rock together, to prevent stress-induced buckling and additional fallout and the welded wire fabric will minimize raveling of the rock surface between rock reinforcement elements. The rock reinforcement should be installed on a 5 foot X 5 foot pattern and the WWF opening should be no greater than 4 inches. Rock reinforcement element length should be 20 feet, approximately half the tunnel diameter. Rock reinforcement and WWF should be installed over a 120o arc in the tunnel roof.

Removal of segments and cross-passage excavation should be delayed until all mining-related utilities supported on the segments are removed, except for the water discharge line. The discharge line should be temporarily removed prior to segment removal and reinstalled prior to cross-passage excavation.

As an alternative to complete segment removal, a supporting frame can be installed within the tunnel, spanning across the minimum 20 foot wide opening for the cross-passage excavation. The frame will be designed to support the tunnel segments above mainline tunnel springline, which can be left in place. Detailing for the connection between the cross passage and the segments remaining in place will be more complicated than making the connection if complete rings are removed.

Some water inflow should be expected at each cross-passage excavation location, but the inflow should be low. Water can be handled by an air-operated pump located in a sump in the mainline tunnel invert, with the pump discharge hose connected to the mainline tunnel water discharge line.

The cross-passage tunnel should be mined from one mainline tunnel to the other, without interruption. To reduce vibration impacts on the adjacent tunnel segments from cross-passage excavation, the cross-passage excavation perimeter should be line drilled. Excavation can be performed by an impact hammer mounted on a Bobcat-type vehicle that can fit within the excavation or by using expansive chemical agents placed in drilled holes in combination with hand-held impact hammers. Controlled blasting methods, such as smoothwall blasting, conceivably can be used, but round length should be limited to 4 to 6 feet to reduce vibration damage to adjacent segments. Any water entering the cross-passage excavation can be drained to the previously mentioned sump and pumped out of the tunnel through the water discharge line.

The cross-passage excavation should be supported by rock reinforcement and WWF, as for the mainline tunnel excavation in the area of segment removal, for the reason described above. Rock reinforcement spacing should be reduced to 4 feet X 4 feet, and element length should be reduced to 6 feet.

A smoothing layer of shotcrete should be applied over the initial support, to accommodate a waterproofing membrane. This continuous PVC membrane would be glued to the tunnel segments at each end to form a watertight system.

The cross-passage final lining should be designed for rock load and for the theoretical water pressure at the cross-passage location. The assumed wall thickness of 18 inches is anticipated to be appropriate for these loads.

2.3.3 CROSS PASSAGE CONSTRUCTION IN SOFT GROUND (BETWEEN BORED TUNNELS)

Some alternatives may require cross passage construction in soft ground (soil). The soil formations along the alternative alignments are glacial outwash sands and gravels and glacial lake clays and silts, which are described in Appendix D. Although the final cross passage geometry will be the same as for cross passages excavated in rock, the construction methodology required to achieve the end result will be different.

Excavation will require ground treatment to stabilize the soil units to prevent ground loss and possible surface subsidence associated with ground loss. Because of the variable soil conditions, inability to obtain surface access at some possible cross passage locations, and geometric constraints imposed by operating within the mainline tunnels, ground freezing may be the optimal methods for ground stabilization.

The ground freezing method requires low temperature brine to be circulated within freeze pipes, which results in freezing of the soil pore water. This results in a self-supporting mass of frozen ground that provides strength and groundwater cut-off. A series of horizontal freeze pipes will be drilled around the perimeter of the final cross-passage section from within the mainline tunnels. Brine will

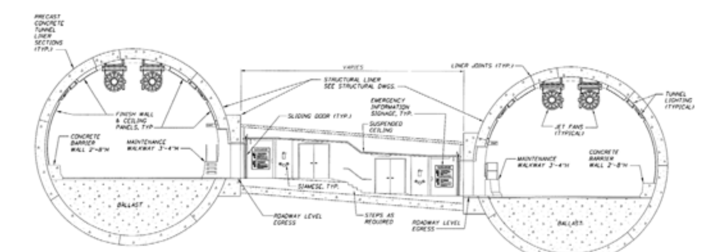


FIGURE 28: Typical Cross Passage – Longitudinal Section

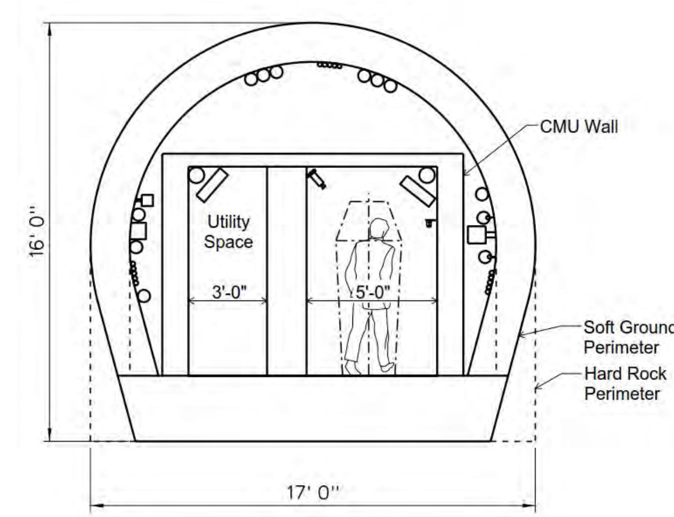


FIGURE 29: Typical Cross Passage Construction

be circulated to the individual cross passage locations from a freeze plant located on the ground surface.

After effective freezing is completed, as determined by thermocouples installed in the ground and probing, excavation will be performed. It is likely that frozen ground will extend into the excavation cross-section. This frozen ground will be removed using mechanical excavation, as described for the cross passages in rock.

After excavation is completed, insulation will be applied to the frozen ground surface, followed by installation of waterproofing membrane, as described for the cross passages in rock. Placement of concrete will follow placement of the waterproofing membrane (Figure 30). Additional concrete will be placed over the exterior reinforcement of the lining to account for possible frost effects, even with the placement of insulation. Bar size and spacing in the cross passage lining can be varied to suit site-specific combination of groundwater and earth pressure.

An alternative to ground freezing is jet grouting. In the jet grouting method, the equipment drills to the required elevation, and the drill stems are withdrawn while injecting pressurized grout in a spiral manner. This results in overlapping columns of soil-mixed-with-cement that create a stable, watertight, zone. Grouting would be performed from the surface prior to the TBMs passing. It requires surface access, appropriate ground conditions (generally sands and gravels rather than silts and clays) and is limited to approximately 100-ft depth. In final design, the optimal ground treatment methods for each cross-passage would be evaluated. For this study, it is assumed that soft ground cross passages will use ground freezing.

2.3.4 EMERGENCY EXIT DOORS (BETWEEN CUT AND COVER TUNNELS)

Most cut and cover tunnels will be a single structure, where the northbound and southbound lanes will be separated by a dividing wall. Emergency exit doors will be provided in the dividing wall to facilitate access from the 'incident' tunnel to the 'non-incident' tunnel, and vice versa for emergency responders.

2.3.5 EGRESS STAIR SHAFTS

Access/egress shafts could be used instead of cross-passages, but are generally not recommended on grounds of cost, surface property impacts and being less usable by mobility impaired persons. Egress stairs may be suitable for within the cut and cover tunnels, especially on the Blue Alternative near West Street where the northbound cut and cover tunnel and southbound cut and cover tunnel are physically separate structures.

If used, stairs should have minimum interior dimensions of 12 feet x 20 feet to accommodate a scissor stair. A fire-rated door will be installed at the egress shaft access point at each roadway level. A hatch should be installed at street grade, flush with the sidewalk. The hatch should be clearly marked, with a sign forbidding placement of material on the hatch cover. The hatch doors should be designed to facilitate opening from the inside. Access to the shaft from the outside should require a key to prevent unauthorized access. First responder organizations should be provided with keys to the hatch doors. Hatch locations should be monitored by CCTV.

2.4 SPOIL (AKA "MUCK")

Excavation of the cut and cover portion of the tunnels, the TBM mined tunnels and the cross passages will generate significant spoil (waste) material, often referred to as muck for tunneling operations. The tunneling options in this study would each generate large total volumes of spoil from 500,000 to 1,000,000 cubic yards or more, but the volume is spread out over the many months of tunneling operations. Efficiently handling, temporarily storing, removing and transporting from the site and disposing of the spoil (also referred to as "muck") is key to successful tunneling operations. Tunneling operations will probably occur during both day and night shifts so muck generation should be anticipated on all working shifts. As the material is excavated from the tunnel, the volume of material will expand or swell on the order of 1.3 to 1.5 times the in place volume (difference between bank cubic yards and loose cubic yards). This will require the project to store muck on-site during periods when hauling may not be permitted (e.g. during night time hours.) At this early stage of the project, it is too early to identify a selected disposal site(s). However, this project site, with easy access to highways and with several landfills, quarries and sand and gravel operations within 30 miles suggest that there will be multiple options available for disposal sites.). Often times on similar projects, disposal of the excavated material is left up to bidding contractors and market forces. The contractor with a good plan to deal with this issue—(e.g. "sell" the material as fill to another project) --will have a lower bid and the project benefits from that competition.

The TBM tunnel will be constructed through soil, mixed-face (soil overlying rock) and rock. The muck from the soil and mixed-face sections may be wet with a paste-like consistency. These materials may require temporary storage within an enclosed structure to prevent material from flowing over the work site. The materials will be loaded into sealed dump trucks for hauling to the final disposal site. It is not practical to dry these spoils onsite, as it would require very large areas and long drying times. In contrast, the muck from the rock sections will be similar to crushed stone, can be easily handled by conveyors and loaders, and can be stockpiled until ready for disposal. The latter do not need drying.

As a project develops, environmental analysis and Phase 1s will be done to identify any potential material in the project limits of disturbance that may be contaminated or hazardous. If any are identified, mitigation measures can be taken ahead of time, or measures incorporated into the construction contact documents to address the issue.

FIGURE 30: Waterproofing Membrane in Cross Passage (Port of Miami Tunnel)

2.5 STRUCTUAL DURABILITY

2.5.1 ELEVATED RICK OF CORROSION

Chloride ions, when in solution with a supply of oxygen, can permeate through concrete cover and cause rusting of steel. This, in turn, can result in section loss and cracking. Reinforced concrete structures in Syracuse are at an elevated risk of such corrosion.

Groundwater is presumed to be saline, based on proximity to historical salt production from groundwater, and limited contemporary data (see Appendix D). Data from USGS (July 2000) shows that the salinity is around 5%. The external face of the tunnel will potentially be exposed to this condition.

The annual average snowfall of Syracuse is approximately 124 inches, or 10 feet per year. This requires large quantities of road salt to be applied. Any open approaches to the tunnel would require road salt, particularly due to gradients of up to 6% required to transition to/from the tunnel. These salts are likely to be tracked into the bored tunnels by vehicles.

Based on these two factors, reinforced concrete structures will need to be designed with specific measures to control corrosion. Such measures will also protect against other potential causes of corrosion such as carbonation and sulfate attack.

It is anticipated that the design life for the tunnel will be 100 years, prior to requiring significant repairs. Detailed analyses can be performed to determine appropriate protection measures, which can include reference to standard texts such the Guide to Durable Concrete (ACI-201.2), Guide to Design and Construction Practices to Mitigate Corrosion of Reinforcement in Concrete Structure (ACI-222.3R) as well as predictive software such as Life 365. Potential corrosion control measures are described below. The level of protection required is expected to be similar to those in coastal/seawater environments. The concentration of salt in seawater is typically around 35 parts per thousand, which is similar to some of the pumped groundwater samples from Syracuse.

2.5.2 PROTECTIVE MEMBRANES AND GASKETS

Cut and cover structures and open cut structures should be protected from groundwater infiltration by including a waterproofing membrane between the support-of-excavation system and the permanent structure. This significantly reduces the inflow of water, and the associated supply of salt solution. Some residual leakage may occur (even after corrective measures such as grouting), and evaporation of such leaks could result in a localized build-up of salt on the walls or roof. This would result in conditions that could accelerate corrosion. Additional measures are therefore required.

It is not possible to include such membranes around segmentally lined bored tunnels. At cross-passages the effectiveness (and cost effectiveness) of such membranes is questionable. In both cases, alternative measures are required.

Each bored tunnel segments will be surrounded by EPDM (synthetic rubber) gaskets. Cast-in gaskets are recommended for improved watertightness. Double gaskets (one near the inside face, one near the outside face) and interconnecting “ladder rung” gaskets are recommended. The second gasket provides added assurance against infiltration of saline water, methane and hydrogen sulfide. Higher strength dowels (or bolts) may be required between rings to maintain compression in the gaskets during ring installation.

2.5.3 STEEL FIBERS VS REINFORCING BARS (REBAR)

Steel fiber concrete has better corrosion resistance than concrete with reinforcing bars. ACI 544.1R indicates that the depth of corrosion is typically limited to 0.10”. It may be possible to design the segmental tunnel liners using only steel fibers. This could be confirmed during detailed design. However, it is anticipated that due to the size of the precast segments and the stresses induced during demoulding and handling, rebar cages will be required.

2.5.4 CONCRETE MIX DESIGN:

The quality of concrete surrounding reinforcing bars is of primary importance in protecting the bars from corrosion. The concrete mix should be designed to have a very low permeability. A low water-cement ration should be used, in addition to using pozzolanic additives such as blast furnace slag, fly ash or (less commonly) silica fume. Slag and fly ash do not significantly add to the cost of concrete. Corrosion inhibitors such as calcium nitrite can be added to the mix, and this is recommended. Alternatively, waterproofing additives such as manufactured by Kryton and Xypex can be used. These may be applicable in cross-passages in lieu of, or in addition to, a waterproofing membrane.

2.5.5 CONCRETE COVER

Sufficient concrete cover should be provided to achieve the desired design life. The minimum concrete cover required by AASHTO for protection of reinforcement is 4.0 inches for concrete with direct exposure to salt water, and 3.0 inches for concrete exposed to soil. For the Syracuse tunnels either 3.0 or 4.0 inches of cover is likely to be applicable, depending on other corrosion control measures and the degree of exposure. The Midtown Tunnel, VA, used 3 inches minimum cover in a seawater environment.

2.5.6 STRUCTURAL DESIGN

Structures should be designed to control crack widths by minimizing strain in tensile rebar. Typically this is achieved by designing as environmental concrete structures in accordance with ACI 350 which states that “Below-grade structures… which may be exposed to external groundwater pressures, generally are designed as environmental concrete structures”. If other corrosion control measures are used less conservatives designs may be permissible.

2.5.7 STEEL REBAR CORROSION CONTROL MEASURES

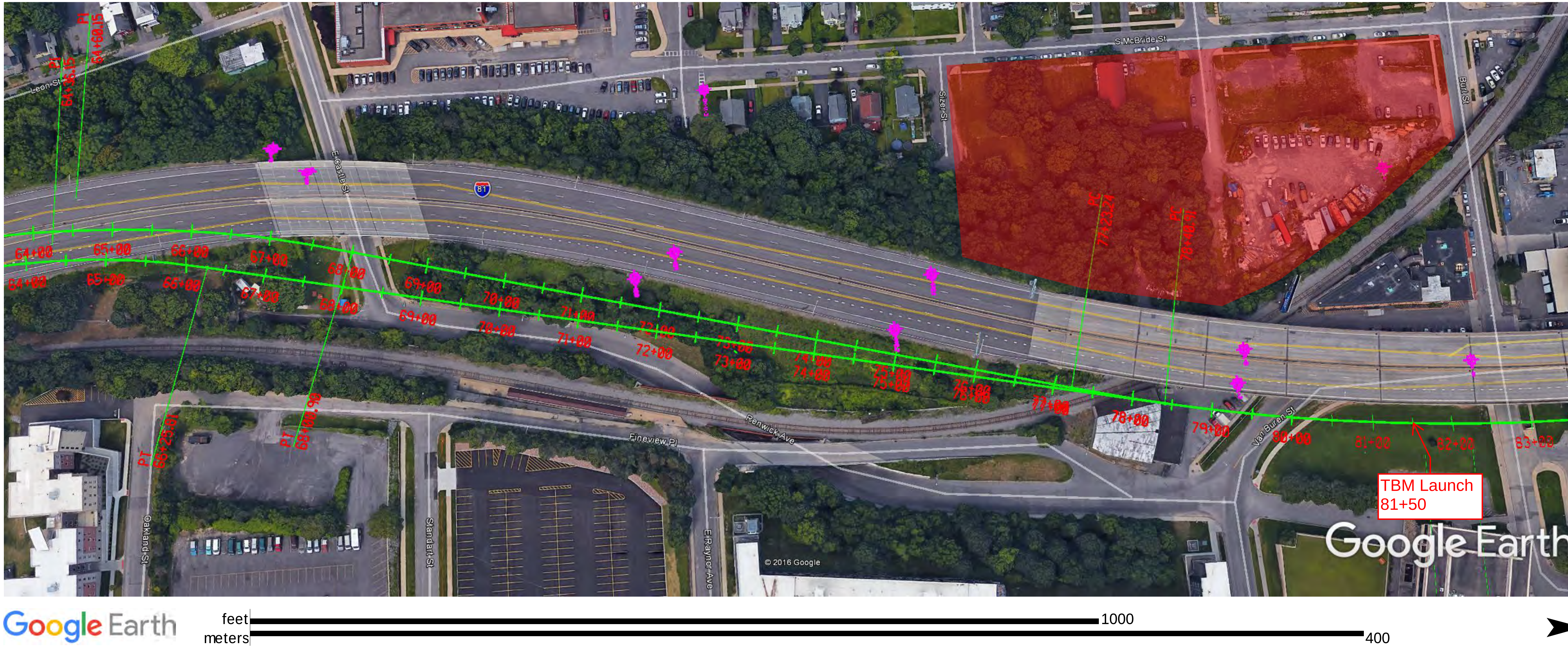
Epoxy coated rebar is frequently used to increase corrosion resistance. The epoxy coating is applied in a factory to the steel prior to shipping, so field bending is not possible. During handling and construction, coating defects can occur. These are frequently not observed and/or not repaired. Defects will lead to uneven corrosion through time, and contribute to the acceleration of corrosion. Although meriting further consideration, epoxy coated rebar is not currently recommended for the tunnels.

Stainless Steel typically has excellent durability, but its performance in saline environments is dependent on the specific stainless composition used. The grade supplied may not always meet the specification. The combination of high cost and questionable performance mean that stainless steel rebar is not recommended.

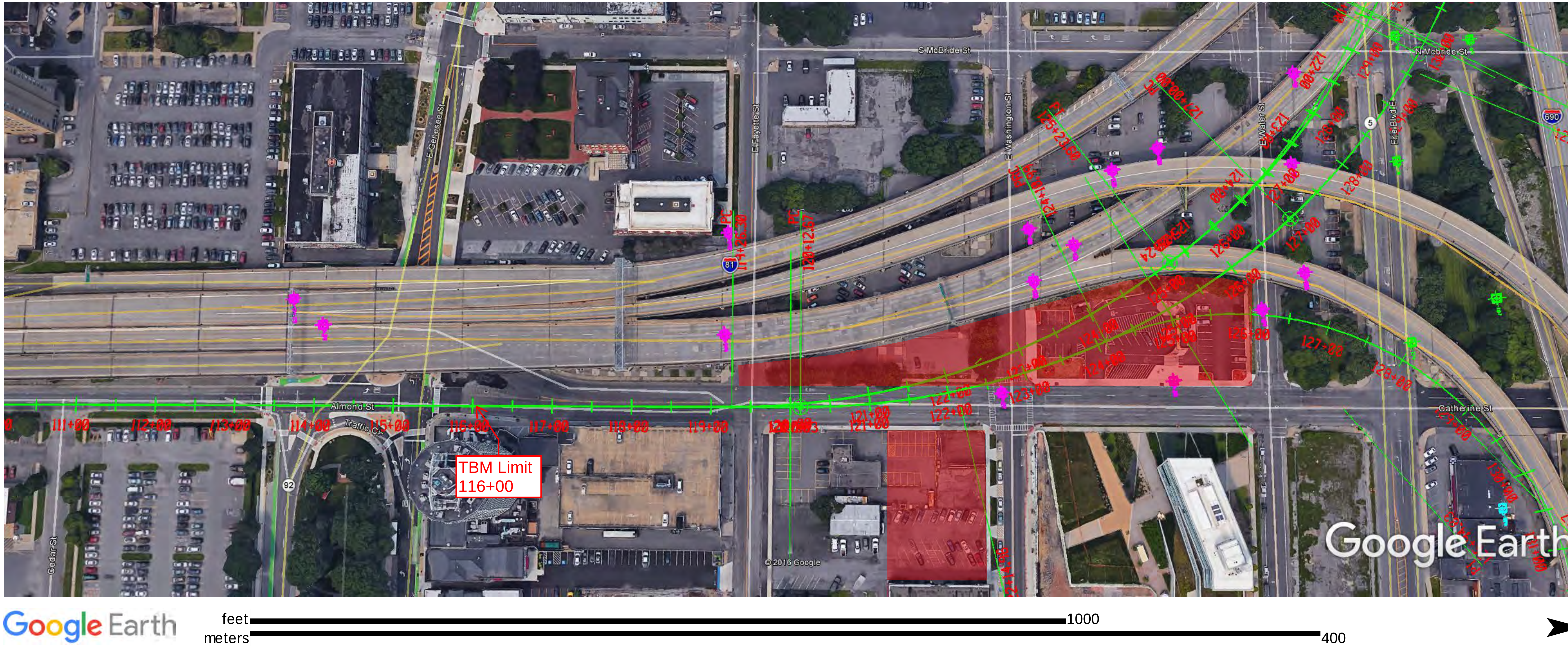
Galvanized reinforcing steel is hot-dipped prior to delivery. It can be bent on site, but the zinc coating can be susceptible to flaking during bending. However, the zinc provides a sacrificial action that protects the steel even where damage or minor discontinuity occurs in the coating. The purity of the zinc and thickness of the coating influence performance. Galvanized rebar may be suitable for Syracuse.

Anodic protection is a technique to control the corrosion of rebar by attaching zinc ‘pucks’, which corrode instead of the steel. The technique is commonly used during repairs of bridge decks exposed to deicing salts. The protection is unlikely to last for 100-years, and is not considered suitable for protecting the tunnels.

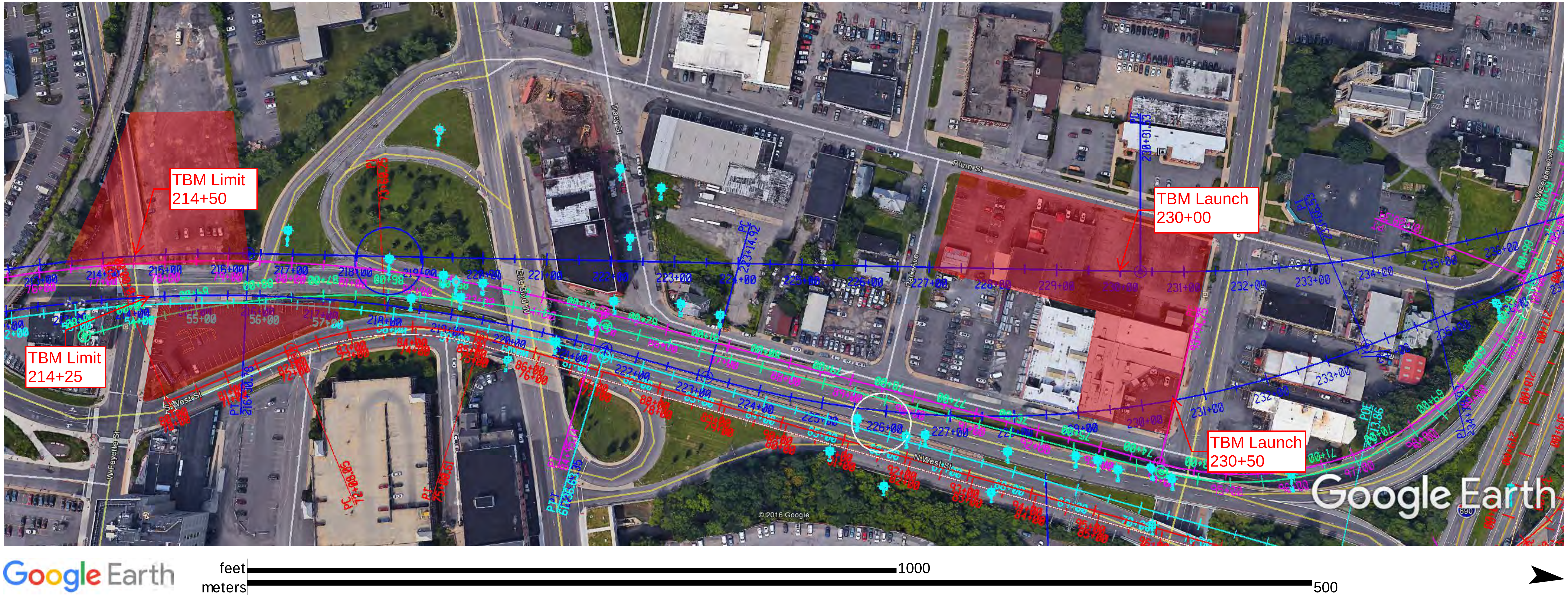
Impressed Current Cathodic Protection Systems (ICCP) use direct current (typically) to prevent the corrosion process from occurring. Some systems automatically adjust the current output to optimally protect the target structure. Typically, a protection system for a tunnel would be designed with multiple zones with separate cathodic protection transformer-rectifier circuits for each. Rebar within each zone would be welded for electrical continuity. In some tunnel structures, electrical continuity is provided during construction which enables installation of an imposed current at a later date should corrosion/potential difference measurement indicate this is required. During final design, consideration should be given to either make provisions for a future system, or to install a fully operation system. The Midtown Tunnel, VA, used the preparatory approach in a seawater environment.



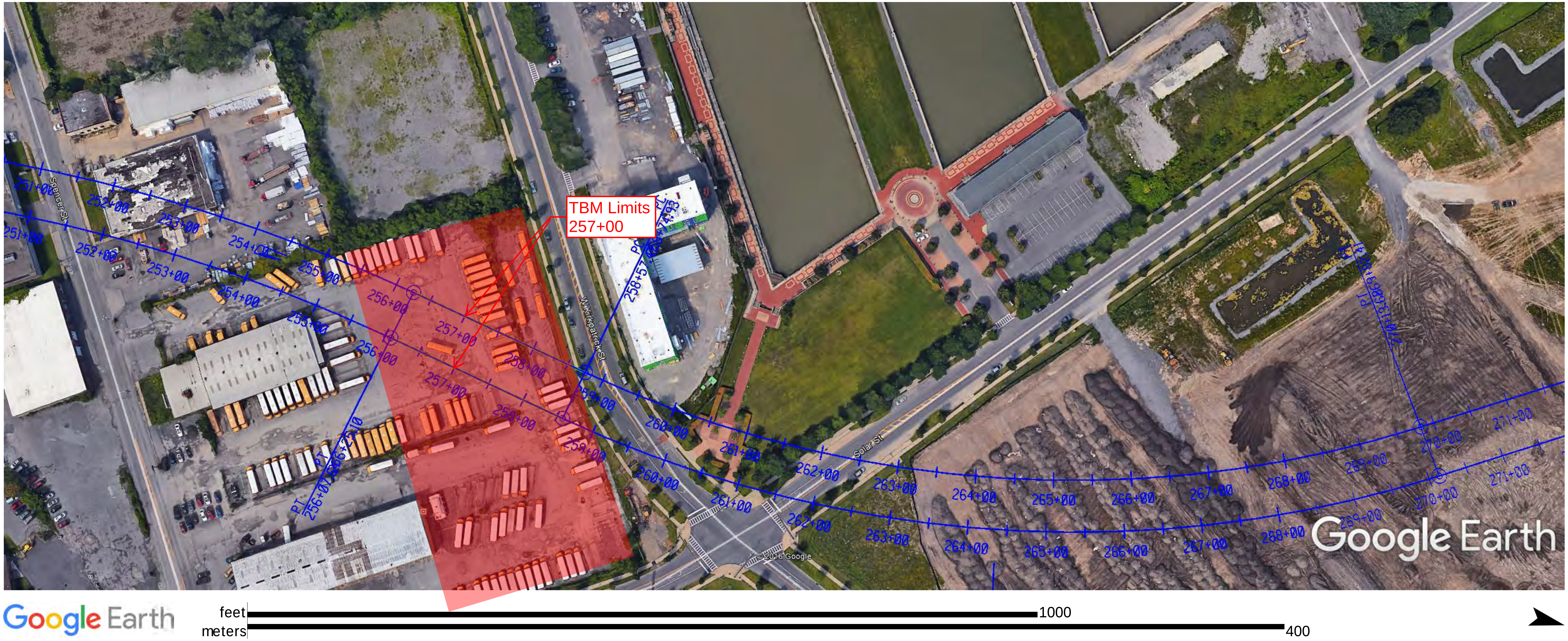
Potential Construction Staging Area - ALL Alternatives - South Portal



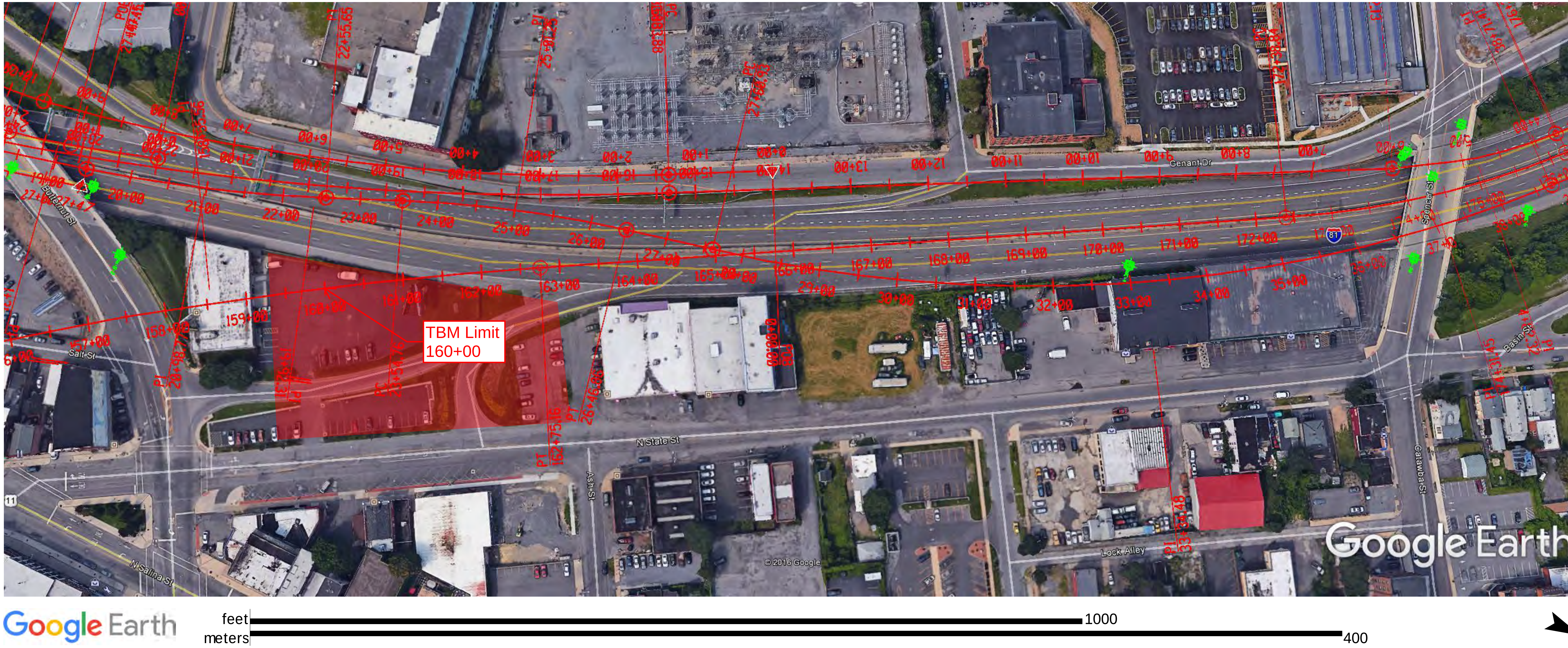
Potential Construction Staging Areas - Green Alternative - North Portal



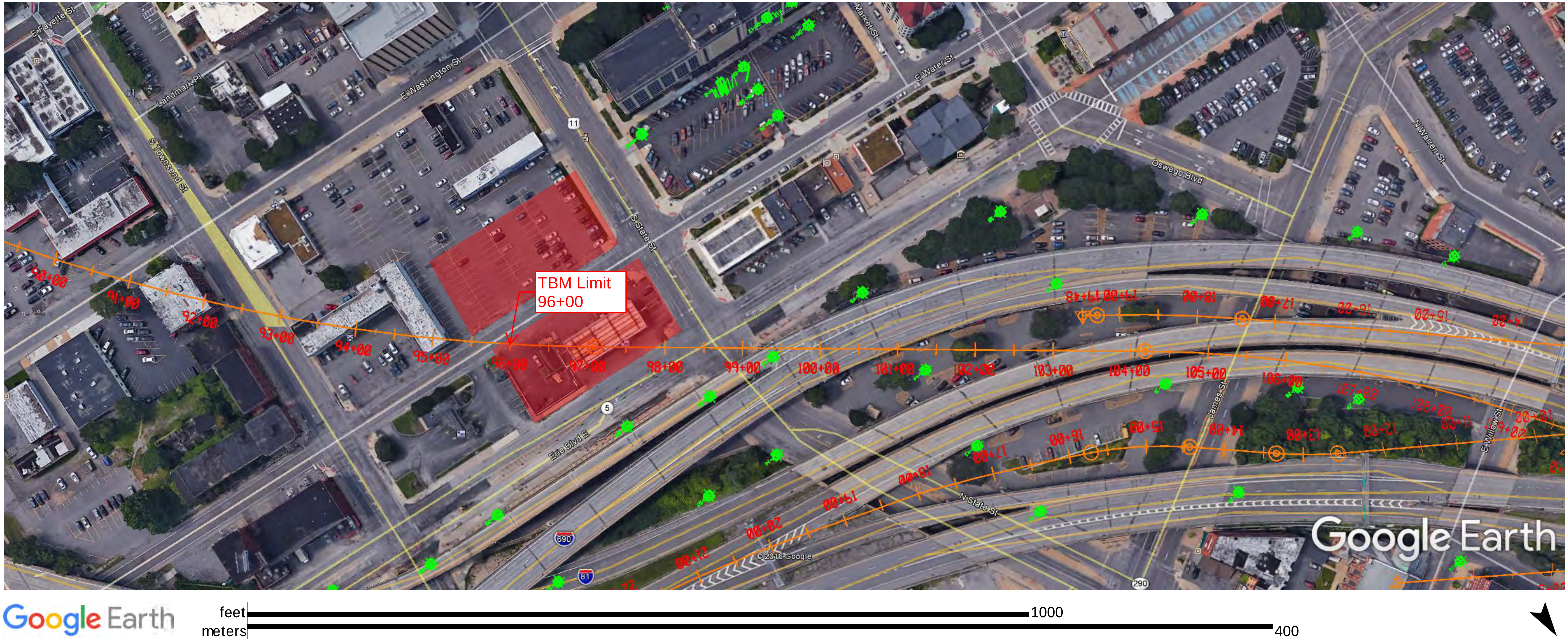
Potential Construction Staging Areas - Blue Alternative - West Street



Potential Construction Staging Area - Blue Alternative - North Portal



Potential Construction Staging Area - Red Alternative - North Portal



Potential Construction Staging Areas - Orange Alternative - North Portal

Note: Red Alignment shown here is indicative
and is for staging purposes only.

WSP | WSP USA Inc.

I-81 INDEPENDENT FEASIBILITY STUDY	
ALTERNATIVE SOUTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

Existing I-81 Viaduct

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE SOUTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

Proposed Red Alignment - Stage 1
*Current I-81 Viaduct to remain intact.
*Close off MLK and Renwick to traffic during construction.
*Soil to be flattened on the west embankment of viaduct to street elevation, set up Construction Staging Area.
*Retaining walls and soil embankment on the east of viaduct to be elevated to set up I-81 extension.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE SOUTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

Proposed Red Alignment - Stage 2
*Construct 4 lane bi-directional traffic for temporary I-81 extension.
*Modify existing I-81 viaduct, removal of existing jersey barriers and replacement of new mediums and barriers.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE SOUTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

Proposed Red Alignment - Stage 3
*Route SB and NB traffic over I-81 extension.
*Partial demolition of existing I-81 Viaduct in preparation of cut and cover excavation.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE SOUTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

Proposed Red Alignment - Stage 4
*Begin Cut and cover tunnel and
depressed roadway excavation
and construction.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE SOUTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

Proposed Red Alignment - Stage 5
*Re-deck SB viaduct over cut and cover tunnel/depressed roadway, install mediums/jersey barriers, and re-establish SB traffic.
*Launch TBM to north.

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I-81 INDEPENDENT FEASIBILITY STUDY

ALTERNATIVE
SOUTH PORTAL - RED ALIGNMENT
CONSTRUCTION STAGING PLAN

SHEET NO.

Proposed Red Alignment - Stage 6
*Construct ramp to depressed roadway

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE SOUTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

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Proposed Red Alignment - Stage 7
*Open access to SB and NB traffic to tunnel.
*Reopen MLK/Renwick

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE SOUTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

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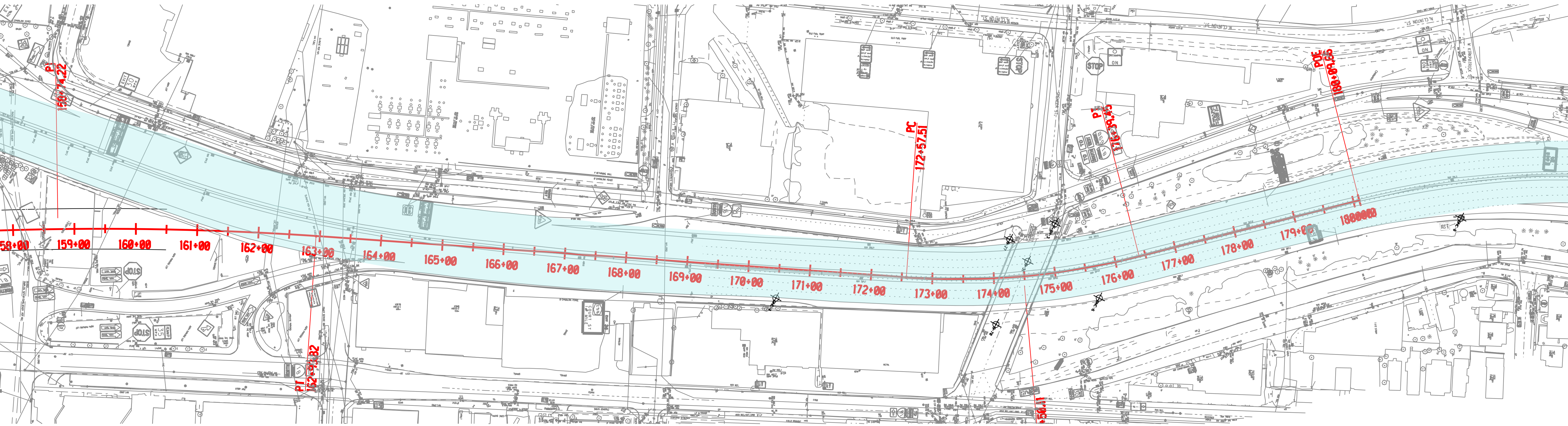
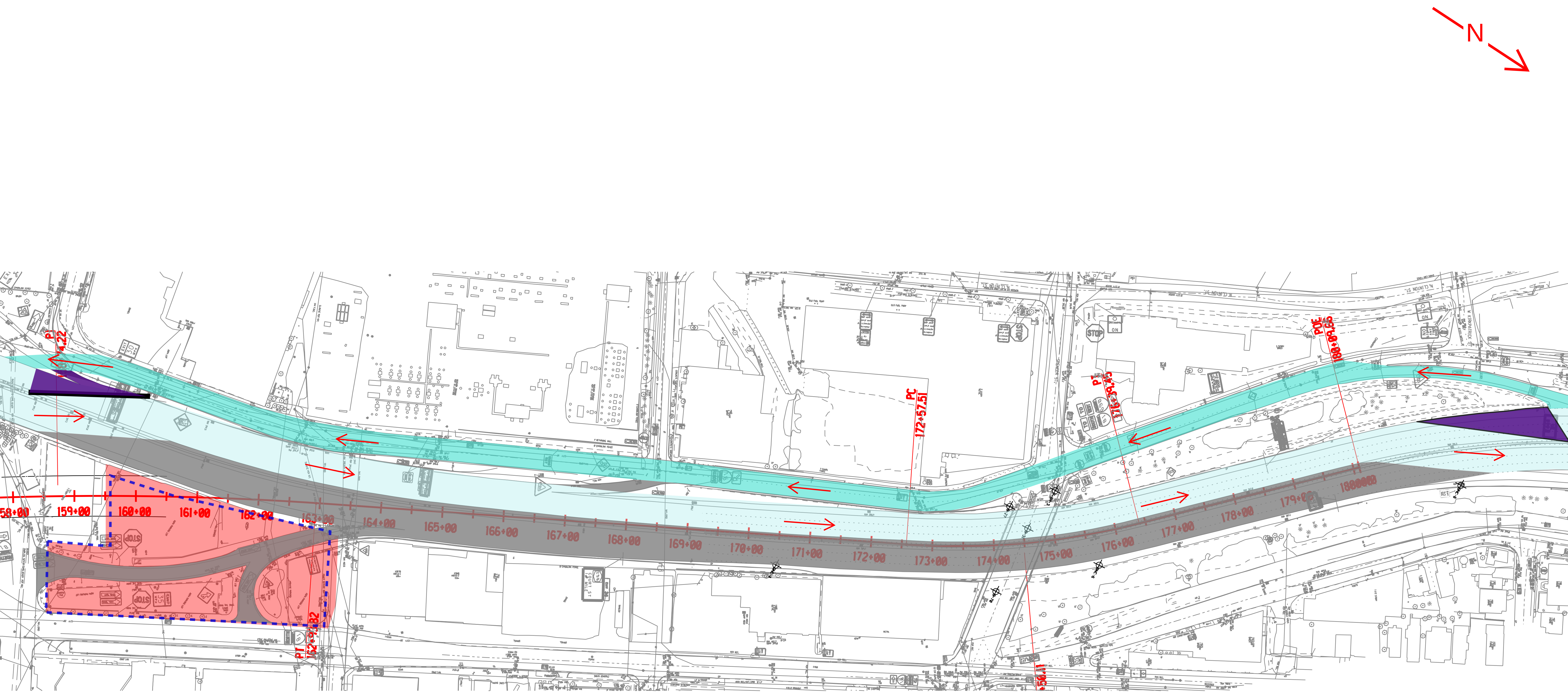


Existing I-81

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

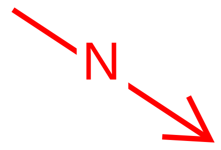


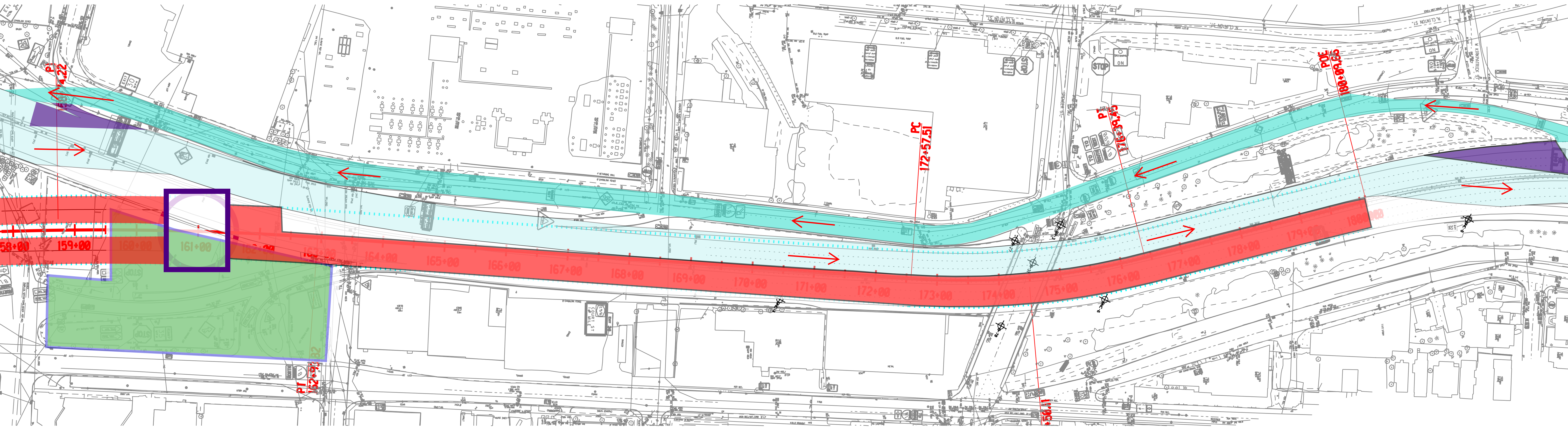
Proposed Red Alignment - Stage 1
*Route SB traffic onto community grid-Genant Drive. Route NB traffic onto former SB lanes. Close off NB lanes and on ramp.
*Set up Construction Staging Area.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

Proposed Red Alignment - Stage 2
*Install SOE of shaft and NB Cut and Cover Part-tunnel.
*Begin excavation and construction of TBM reception shaft (Assumed 1 shaft, Shape rectangular).

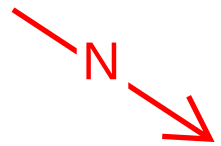
WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

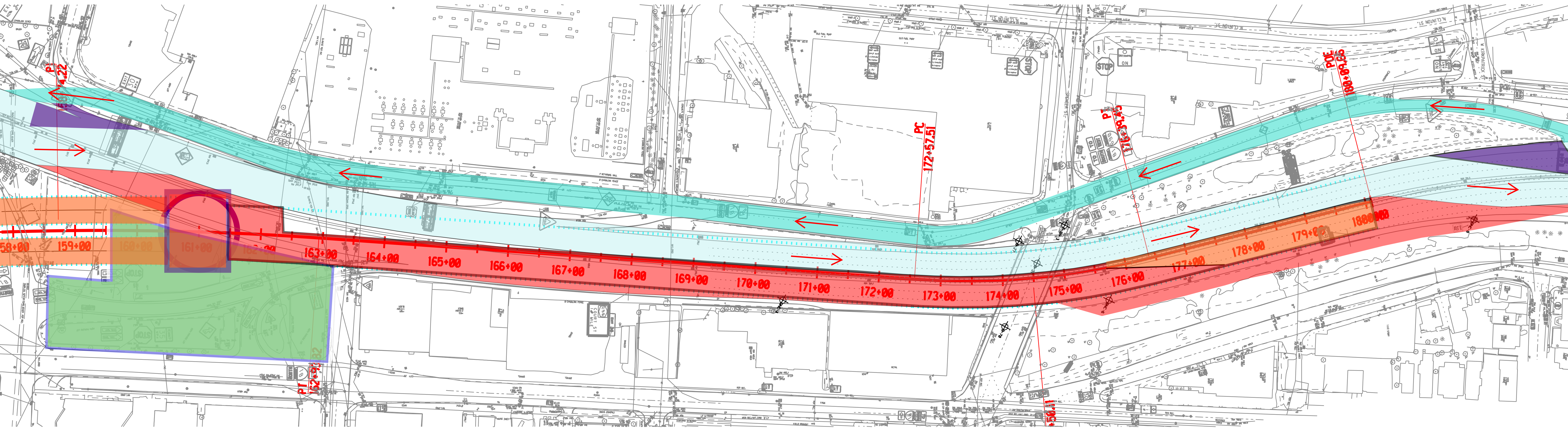




Proposed Red Alignment - Stage 3
*Prepare shaft and receive TBMs from south.
*Begin excavation and construction of NB Cut and Cover part-tunnel.

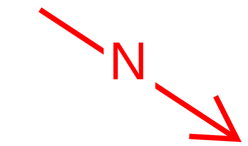
WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY		
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.	

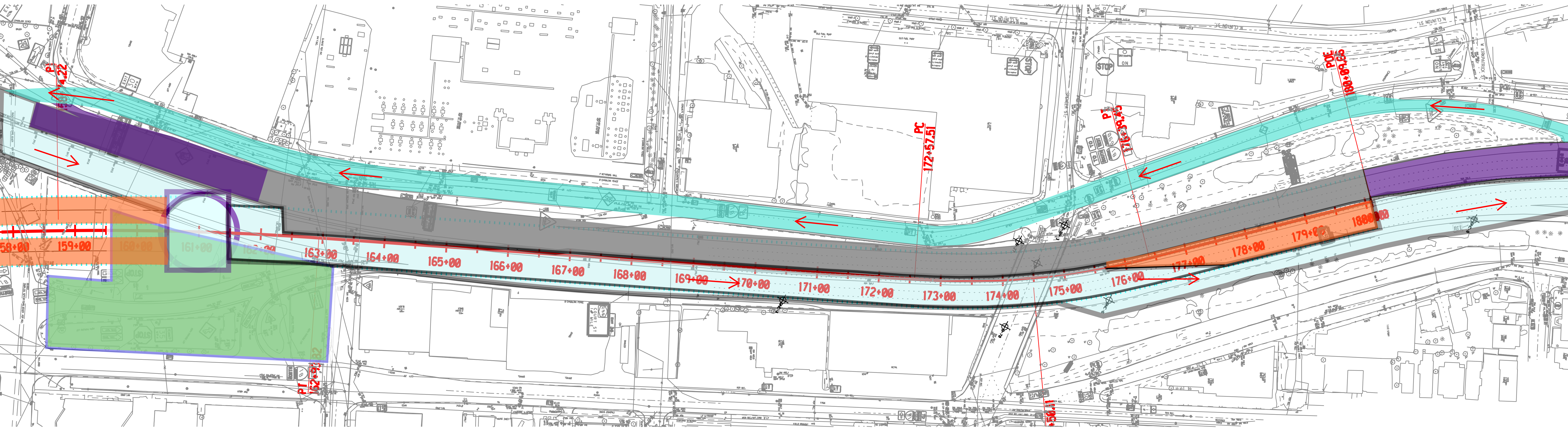




Proposed Red Alignment - Stage 4
*Deck over shaft.
*Back fill on top of NB cut and cover part-tunnel, widen I-81 NB roadway after Spencer Street Bridge and re-pave road-way.

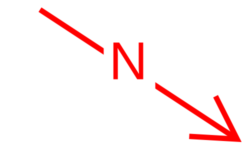
WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

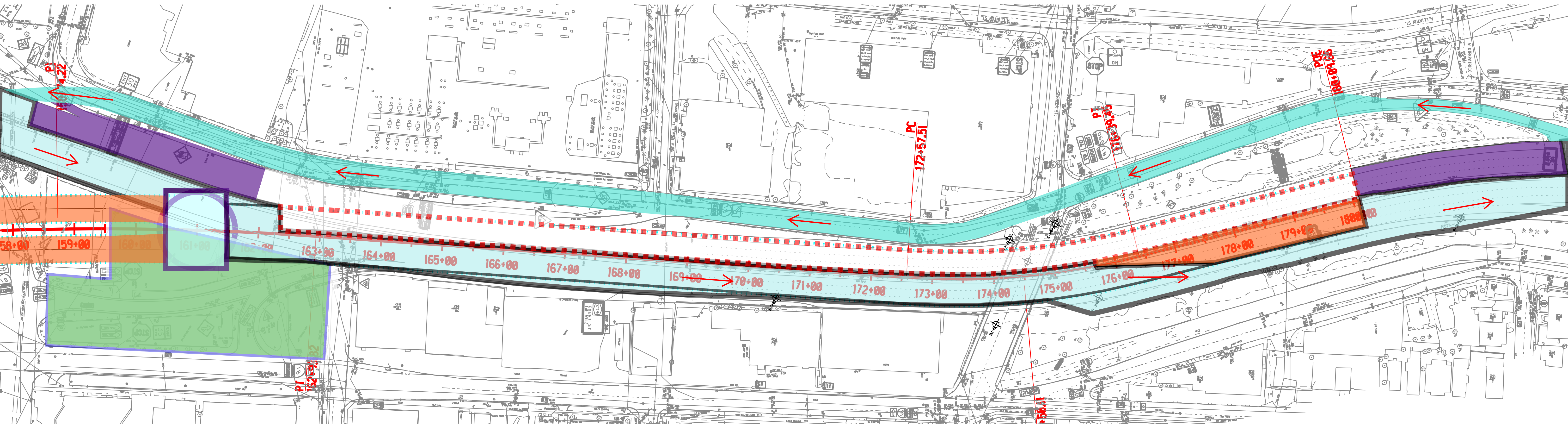




Proposed Red Alignment - Stage 5
*Reroute NB traffic on the newly paved NB I-81 roadway grade.
*Demolish limited length of former SB I-81 roadway grade.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.



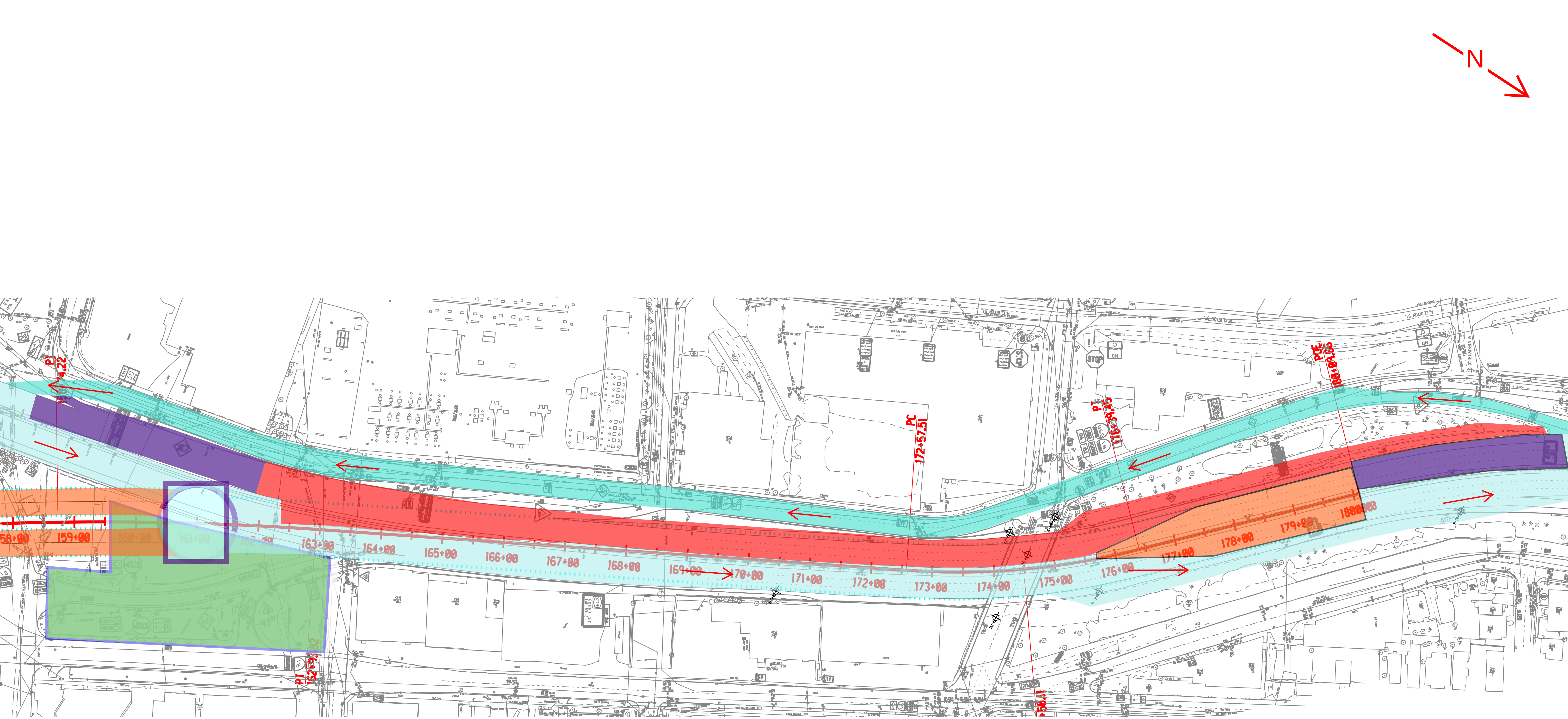


Proposed Red Alignment - Stage 6
*Install SOE of SB Cut and Cover Part-tunnel.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.

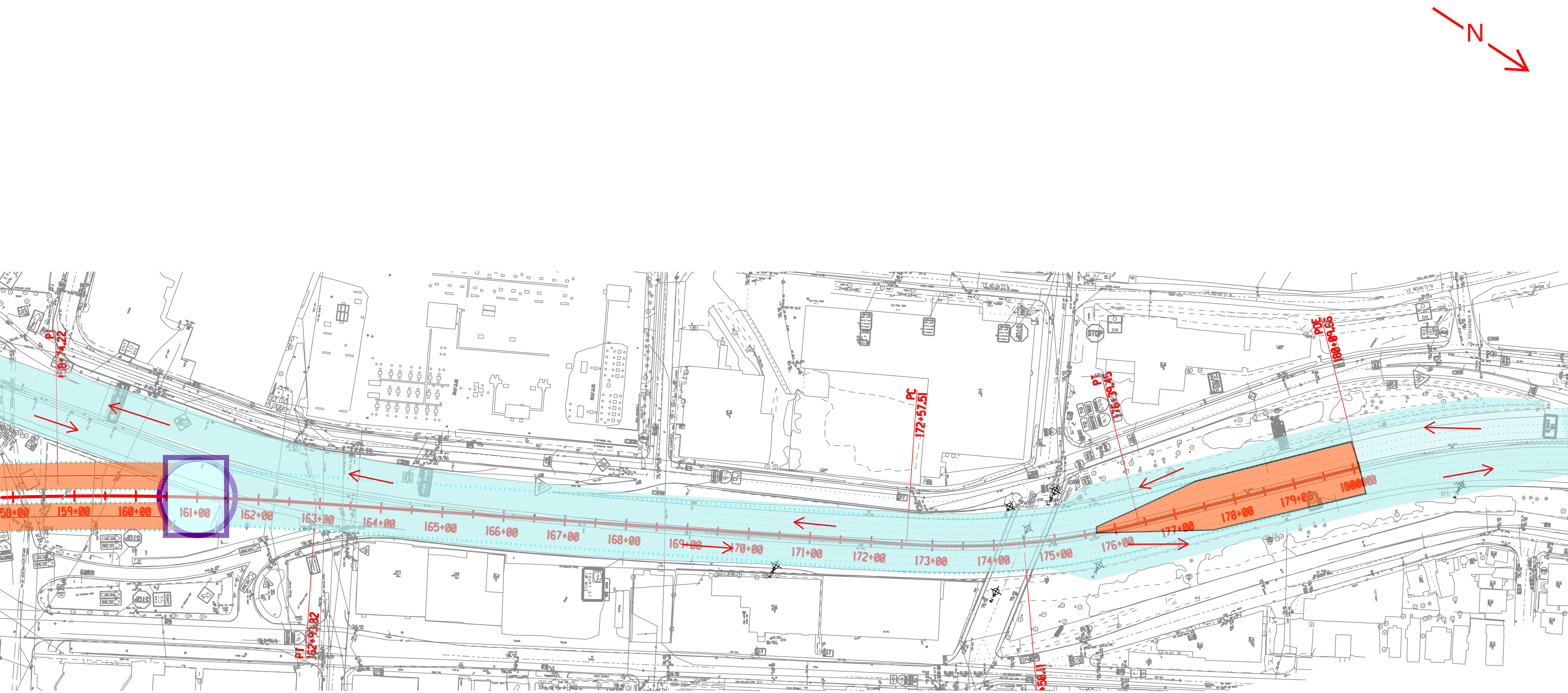
Proposed Red Alignment - Stage 7
*Begin excavation and construction of SB Cut and Cover part-tunnel, connecting to existing NB Cut and Cover.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.



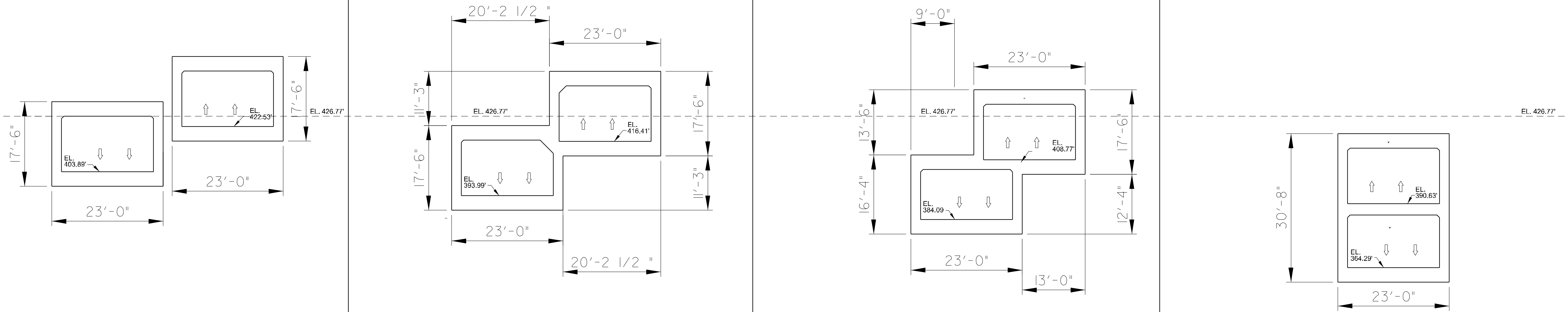
Proposed Red Alignment - Stage 8
*Back fill on top of SB cut and cover part-tunnel, widen I-81 SB roadway after Spencer Street Bridge and re-pave roadway.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.



Proposed Red Alignment - Stage 9
*Reroute SB traffic on the newly paved SB I-81 roadway grade.
*Re-establish all on and off ramps.

WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE NORTH PORTAL - RED ALIGNMENT CONSTRUCTION STAGING PLAN	SHEET NO.



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SECTION B-B
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SECTION C-C
STA 35+00

SECTION D-D
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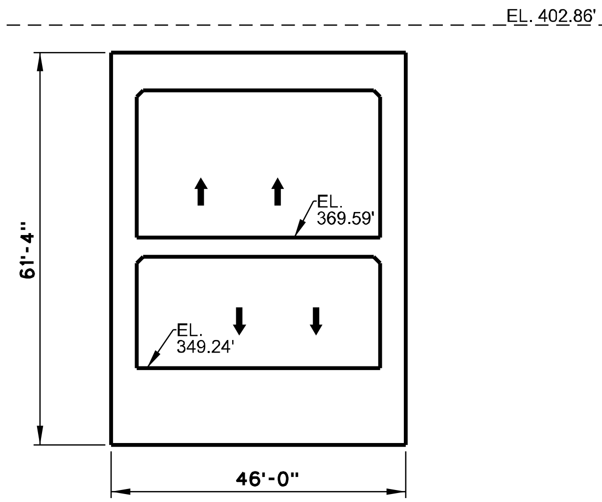

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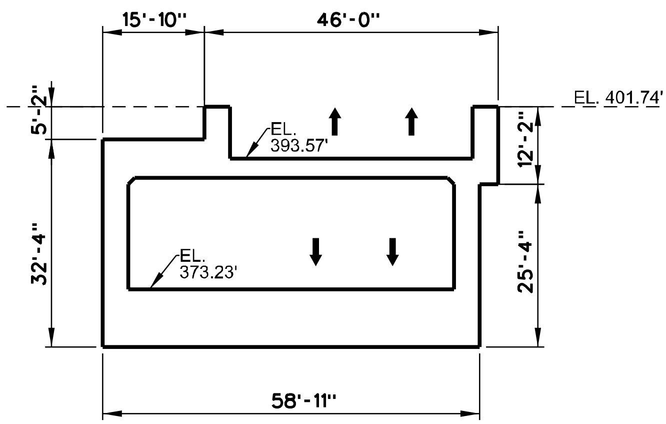

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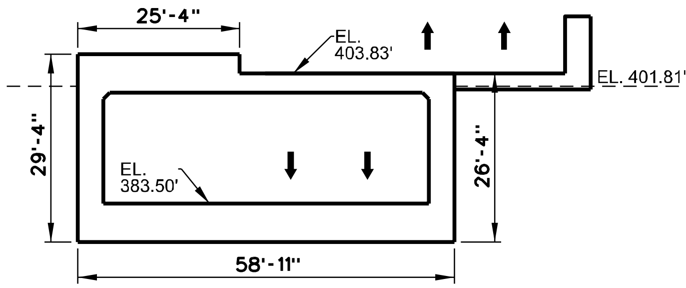

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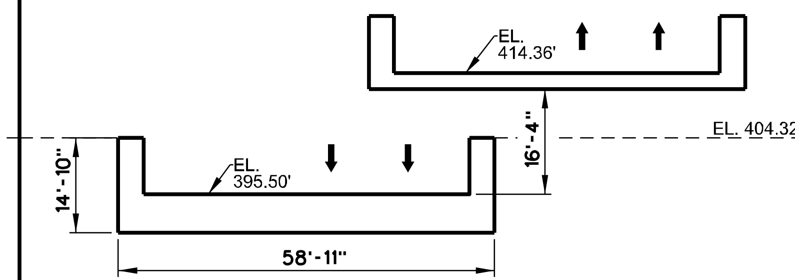

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I-81 INDEPENDENT FEASIBILITY STUDY	
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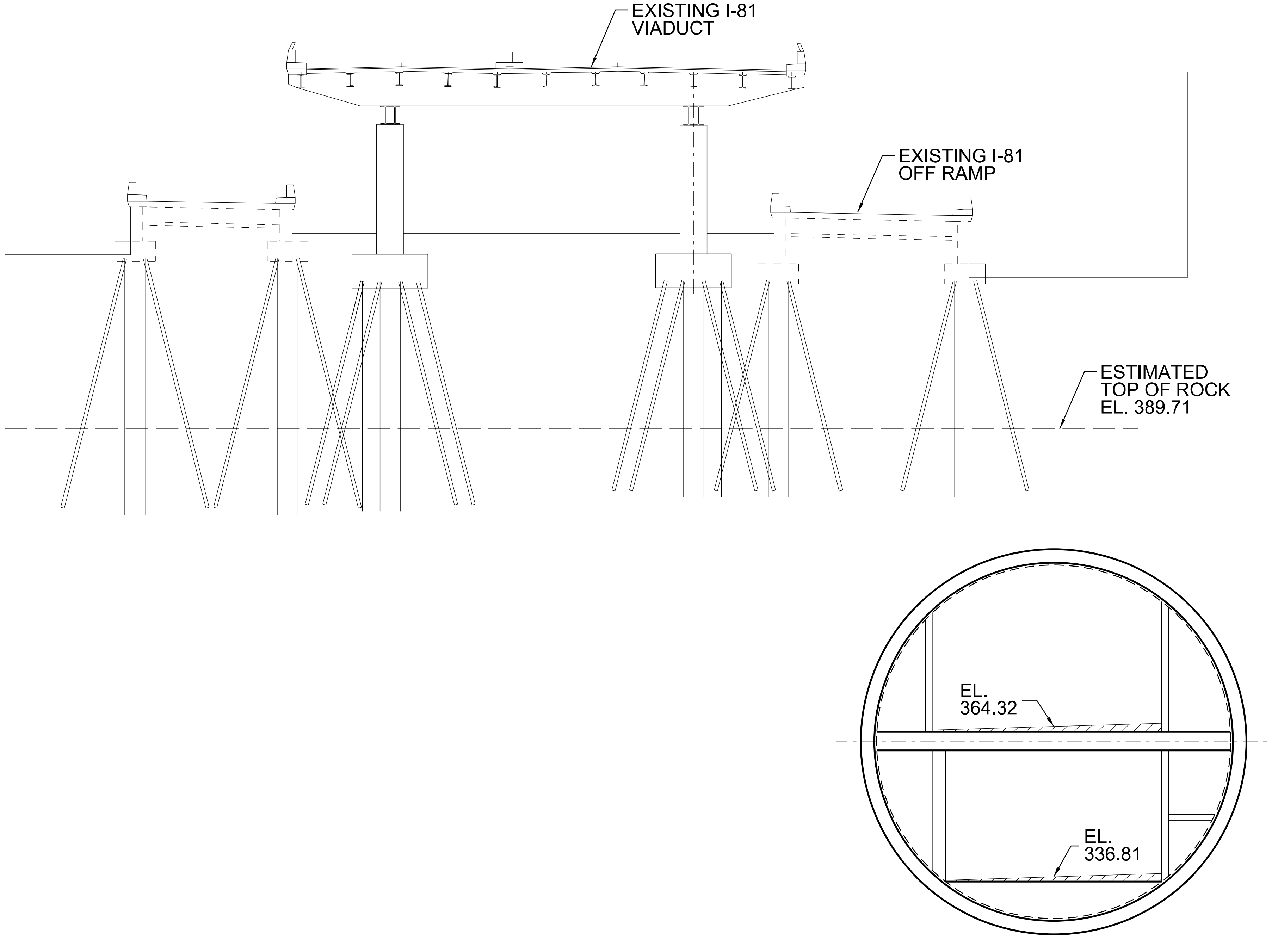

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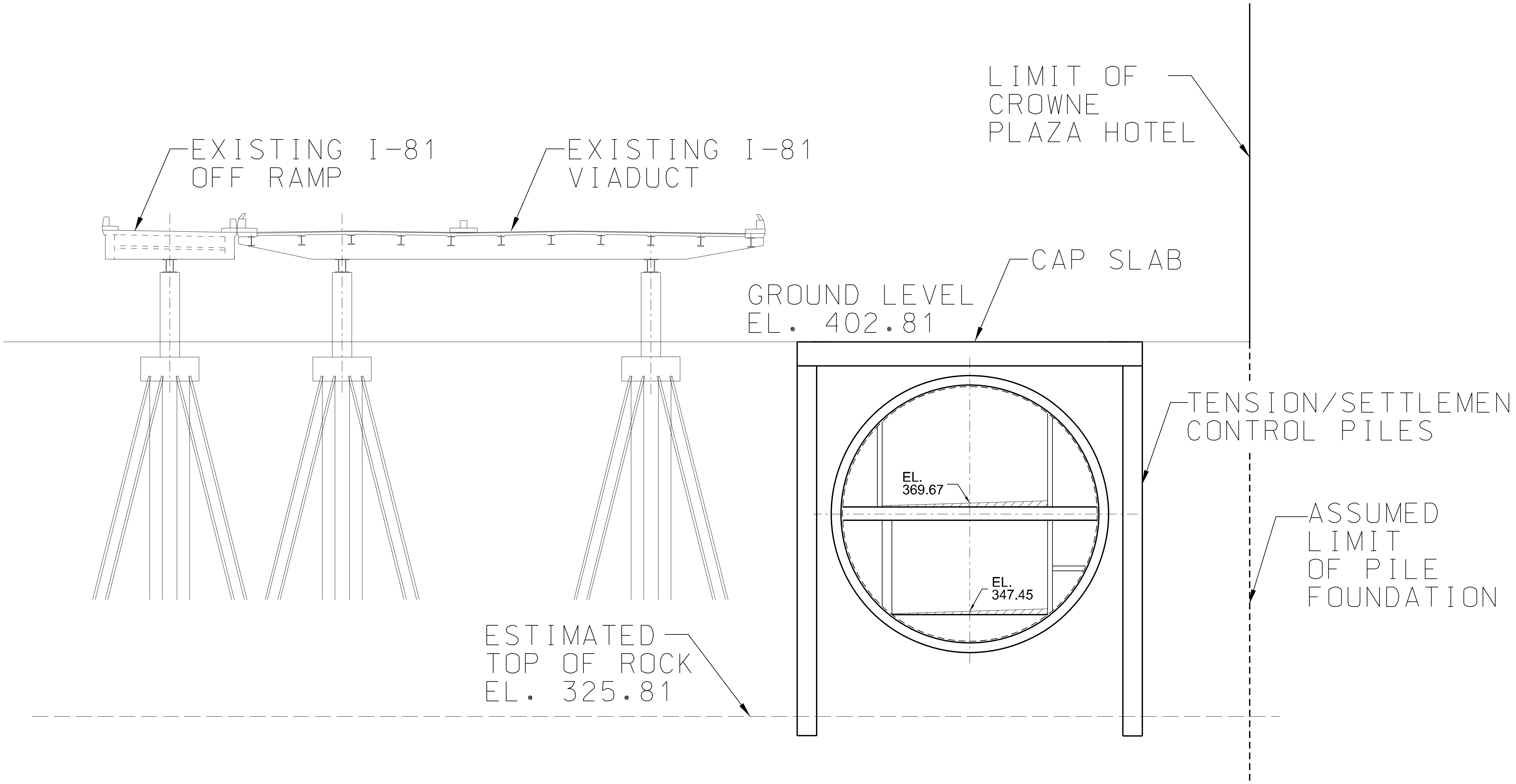

BORED TUNNEL - GREEN ALTERNATIVE
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	ALTERNATIVE GREEN ALIGNMENT - BORED TUNNEL AT GENESEE ST	SHEET NO.

APPENDIX F: TUNNEL SYSTEMS

TABLE OF CONTENTS

FIGURES

TABLES

1 TUNNEL SYSTEMS

1.1 INTRODUCTION

Each of the alternative tunnel options being considered for I-81 will require a variety of operational systems and features within the tunnel in order to support safe traffic operations and to provide the necessary level of fire protection and life safety. The various tunnel systems and features that will be required include:

- Traffic control and monitoring
- Roadway lighting
- Electrical power
- Communications
- Equipment control and monitoring (SCADA)
- Security
- Fire detection and alarm
- Fire protection and suppression
- Ventilation
- Drainage
- Emergency egress
- Tunnel finishes

1.2 FIRE PROTECTION AND LIFE SAFETY PROVISIONS

The specific requirements for the systems and elements necessary to meet the fire protection and life safety goals for any of the tunnel alternatives being considered for I-81 would be based on the minimum requirements established in National Fire Protection Association (NFPA) 502 Standard for Road Tunnels, Bridges, and Other Limited Access Highways. The fire protection and life safety provisions required by NFPA 502 are based on the tunnel's length and a site-specific assessment.

The I-81 tunnel alternative study area is an urban corridor that can be assumed to have a generally high volume of traffic inclusive of cars, buses and heavy goods vehicles. Emergency response agencies are assumed to be available within generally close proximity. Based on this, and the fact that the four tunnel alternatives being considered range between 1 mile to 2 miles in length, the fire protection and life safety requirements will be the same for each tunnel alternative and will include provision of the following:

- An engineering analysis to establish overall fire protection and life-safety concept
- Means for emergency egress and access
- Tunnel ventilation
- Tunnel fire suppression system
- Tunnel drainage systems
- Traffic control and monitoring
- Tunnel emergency lighting
- Fire alarm and detection
- Electrical power distribution
- Emergency communications
- Structural fire protection
- Exit and other special signage
- Intrusion detection/access control
- Emissions monitoring
  - Emergency and incident management plans

The above provisions have certain prescribed aspects many of which are performance-based. For example, a key requirement in NFPA 502 is the ability to establish tenable conditions in the case of a fire event in order to provide a safe path for the evacuation of motorists and to also facilitate response by fire fighters and other emergency personnel. Achieving these goals relies on the interaction of the tunnel ventilation system, available means of emergency egress and fire control. The assessment of whether or not tenable conditions are achievable can be subjective and depends on several factors, including but not limited to, the design fire, egress locations, ventilation approach, and provision of firefighting systems. NFPA 502 requires an engineering analysis that holistically considers the interaction of all available provisions and their ability to achieve the overall fire protection and life safety goal.

Given the potential for subjective interpretations and approaches when developing a performance-based approach to fire-life safety design, a consensus approach between stakeholders is needed in order to develop a credible set of design criteria, design basis and subsequent design. The Authority Having Jurisdiction (AHJ) is a critical stakeholder in this consensus approach to development of a fire-life safety strategy and design.

1.3 NFPA 502 COMPLIANCE AND AUTHORITY HAVING JURISDICTION

NFPA 502 defines the Authority Having Jurisdiction as "an organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure".

In most municipalities the AHJ is a designee of the fire services (either local or state) such as the fire marshal or district chief; however, in certain jurisdictions the designated AHJ may be the tunnel owner or operating authority as they have the overall responsibility for the facility. For a large infrastructure project like the development of a road tunnel for the I-81 corridor through Syracuse, a variety of other agencies and stakeholders will have formal and informal input during the planning process. For instance, the following organizations would be expected to have a significant role in defining and planning the traffic operations, life safety goals, incident management and emergency preparedness and response:

- First responders (local fire and police)
- State police
- Emergency medical services
- Hazardous material/spill units
- New York State Department of Transportation
- Federal Highway Administration
- City of Syracuse
- Local and state permitting and regulatory agencies
- Design consultants

NFPA 502 defers to the Authority Having Jurisdiction (AHJ) for the enforcement of its provisions. Therefore, the approach toward the implementation of NFPA 502 begins with the identification of the AHJ. It is then recommended that a "Fire and Life Safety Committee" (FLSC) be established to engage in a partnered approach with the key project participants, agencies and stakeholders in establishing the life safety design goals to be implemented as part of the tunnel design and construction phases, and ensuring they are in unison with the tunnel's operational concept for emergency and incident management response. The protocol of the FLSC will be to act as the technical and policy overseer for the safety issues affecting the tunnel and to make all key decisions and determinations by consensus. During preliminary planning stages the owner should facilitate a FLSC process and document the decisions as part of a NFPA 502 Compliance Report. The report will document all decisions made relative to the implementation of NFPA 502, including any traffic restrictions such as banning of bulk fuel carriers and other hazardous cargo vehicles, and identify any specific exceptions. This report would then serve as the "AHJ approved" life safety design criteria for the tunnel. The graphic below outlines the recommended FLSC process.

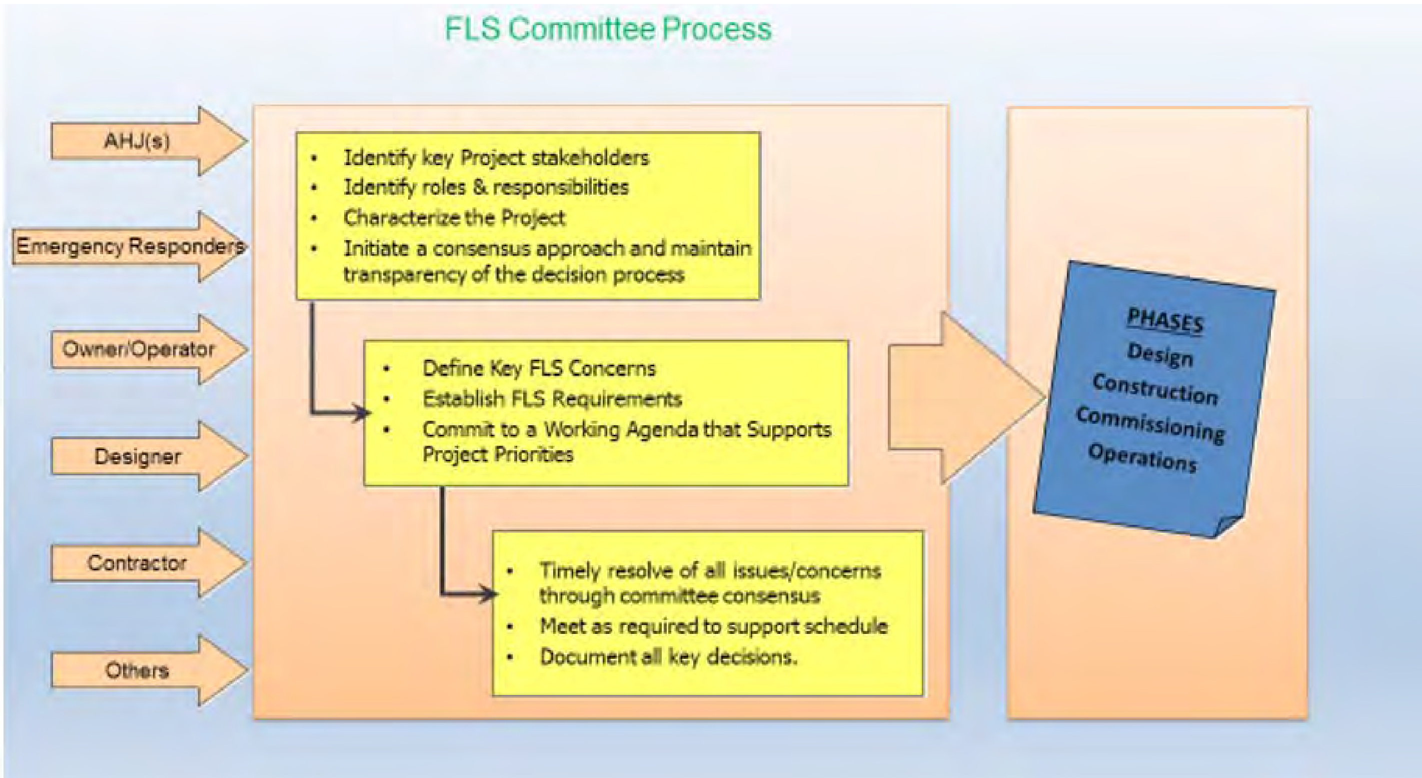


FIGURE 1: Fire and Life Safety Committee (FLSC) Process

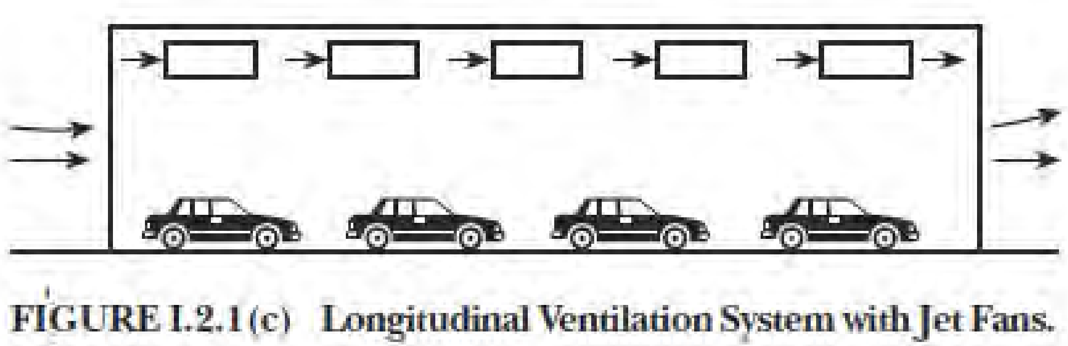


FIGURE 2: Jet Fan System (from NFPA 502)

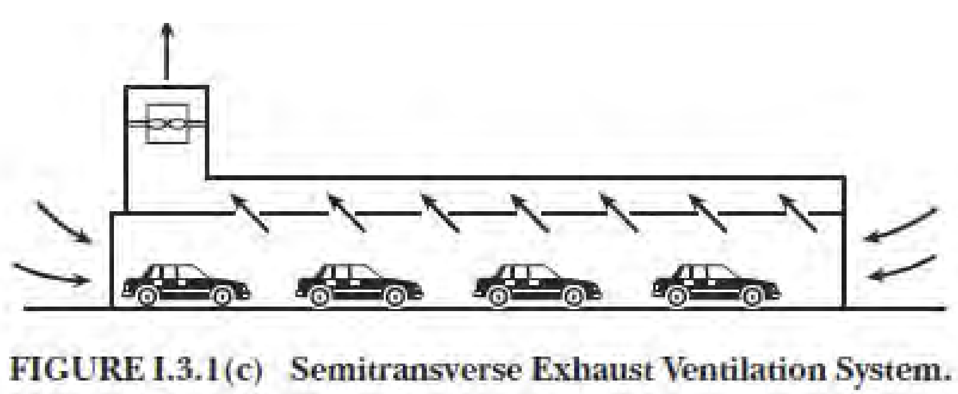


FIGURE 3: Semi-Traverse Point Exhaust System (from NFPA 502)

1.4 TUNNEL VENTILATION

Ventilation is a critical key to providing safe conditions within road tunnels. During normal traffic operations, ventilation is required to maintain the in-tunnel air quality by preventing the dangerous accumulation of vehicle-emitted pollutants (i.e., carbon monoxide, CO, and oxides of nitrogen, NOx) and to maintain visibility in the tunnel by preventing the accumulation of haze-producing pollutants. In the event of a fire emergency the tunnel ventilation system performs a major role in providing life safety support by controlling the flow of smoke and heat in a manner that protects motorists and facilitates evacuation and fire fighter access.

For normal tunnel operations, the tunnel length, traffic volume, and the direction of traffic movement (unidirectional versus bidirectional) are some of the key factors in determining whether the ventilation requirements can be achieved by passive means (the piston action airflow generated by the moving vehicles) or whether mechanical ventilation is required. The tunnel length is also a key factor in determining the need for mechanical ventilation during emergency operations, since it affects the overall pollution being emitted from the tunnel, and for a fire it affects the egress time from the tunnel, the number of motorists that could be exposed to the hazards of a fire, the degree of difficulty for fire department or emergency services intervention (longer is more difficult to access) and the overall probability of a fire (longer tunnels will have a greater fire probability).

Based on modern US road tunnels comparable to the I-81 tunnel alternatives being considered herein, a mechanical ventilation system will be required. The installed ventilation system capacity will ultimately be determined by the requirement for emergency smoke control during a tunnel fire incident (emergency operations). The ventilation requirements during normal tunnel operation (non-fire conditions) will be significantly less and determined by the prevailing traffic conditions.

The most likely applicable ventilation options for the various tunnel alternatives being considered herein for I-81 include a longitudinal system utilizing in-tunnel jet fans (Figure 2), a semi-transverse point exhaust using a duct and operable dampers (Figure 3) or, in the case of the longer tunnel alternatives, a combination of both system types.

1.5 STANDARDS OF REFERENCE

The design of road tunnel ventilation systems will be required to conform to the latest issues of the following standards and references:

- National Fire Protection Association – Standard for Road Tunnels, Bridges, & Other Limited Access Highways (NFPA 502).
- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) – Enclosed Vehicular Facilities.
- Recommended AASHTO Guidelines for Emergency Ventilation of Smoke in Road Tunnels.
- FHWA/EPA Guidance on CO Levels in Tunnels.

1.6 CRITICAL DETERMINATIONS

There are critical determinations to be made by the FLSC that will have a fundamental influence and affect to the overall approach to fire protection, life safety considerations, emergency response planning and tunnel system design in general which must be made in the early phase of any road tunnel project. These critical determinations are as follows:

1.6.1 DESIGN FIRE

The tunnel design fire is the fire size (heat release rate) that shall be considered in the design and planning for the fire protection and life safety provisions required. Therefore, selection of the design fire becomes one of the most critical determinations to the design of the tunnel systems. For example, NFPA 502 states the following: "The design of the emergency ventilation system shall be based on a fire scenario having defined heat release rates, smoke release rates, and carbon monoxide release rates, all varying as a function of time. The selection of the fire scenario shall consider the operational risks that are associated with the types of vehicles expected to use the tunnel. The fire scenario shall consider fire at a location where the most stringent ventilation system performance requirement is anticipated by an engineering analysis."

1.6.2 TRAFFIC TYPE AND HAZARDOUS CARGO

Defining the normal traffic mix and allowable vehicle types is a critical determination necessary to selecting the appropriate design fire. Per NFPA 502, "The selection of the design fire size (heat release rate) shall consider the types of vehicles that are expected to use the tunnel."

Given that I-81 is a major highway, it is reasonable to assume that a traffic fleet mix of cars, buses and heavy goods trucks would use the tunnel. However, should a tunnel alternative be implemented, it is necessary that the FLSC consider that fuel tankers and other regulated hazardous cargo vehicles be re-routed and not allowed to use the tunnel. I-481 provides a viable alternative interstate route. The practice of banning these types of vehicles from road tunnels is common practice in all US cities.

Table 1 has been excerpted from NFPA 502 and provides guidance on the magnitude of possible vehicular fires with respect to the types of vehicles that could use the tunnel. In assessing this data it is reasonable to assume that a multiple vehicle fire involving large heavy goods vehicles such as semi-trailer trucks could potentially reach a magnitude of up to 200 MW, according to NFPA 502. The representative fire heat release rate (FHRR) is 150 MW. Inclusion of a fixed firefighting system can be used as a basis to adopt a lower FHRR in the order of 70 – 100 MW.

1.7 NORMAL VENTILATION

During normal operating conditions the tunnel is expected to self-ventilate with free-flowing traffic. The piston action ventilation caused by traffic movement will be sufficient to maintain safe CO and opacity levels in the tunnels during free-flowing traffic conditions. Ventilation may need to be operated to provide dilution air during heavy traffic periods, when traffic speeds fall below 10 to 15 mph, and during adverse outdoor wind conditions. The tunnels will be continuously monitored for trends in the CO levels and rising CO levels will indicate the need for more dilution air, therefore additional pairs of fans would be activated until the CO levels are at acceptable levels.

The ventilation system must be sufficient to dilute the vehicle-emitted pollutants to safe levels. The limiting pollutant concentrations during normal tunnel operations have been established jointly by the FHWA and EPA. The guidelines are given in terms of allowable average CO concentration versus exposure time. In the US, CO is the primary pollutant of concern due to the large percentage of gasoline powered vehicles. Using ventilation to maintaining acceptable CO levels in a tunnel will also sufficiently maintain acceptable levels for all other vehicle emission constituents.

Fan operation during normal tunnel operations will be determined primarily on the basis of the carbon monoxide (CO) level in the tunnel. The tunnels should be continuously monitored for CO at a suitable number of locations. In addition, if a relatively large percentage of diesel powered trucks and buses are anticipated it is recommended to monitor the opacity of the tunnel air (haze) to ensure a safe level of visibility. The monitored data can be transmitted to control room where the data will be displayed for use by the system operators and automatic control system.

1.8 PORTAL EMISSIONS

During normal operations the vehicle piston effect is generally sufficient to provide dilution of vehicle emissions within the tunnel and analysis will be required at the design phase to confirm and quantify pollution levels during peak and non-peak traffic conditions. Compliance with environmental regulations with regard to pollution levels external to the tunnel will need to be demonstrated and approved.

An ambient air quality analysis of the emissions from the tunnel portals will be necessary with respect to any sensitive receptors in the surrounding areas near to the exit portals. This ambient air quality analysis will need to incorporate the expected tunnel traffic on an hourly basis, the subsequent vehicle emissions, the expected airflow in the tunnel, and the impact of external meteorological conditions.

Emissions from the tunnel portals and achieving air quality compliance will be critical. If this cannot be achieved then ventilation buildings at each portal may be required to eject and disperse vitiated air away from sensitive receptors. In the case of the longer tunnel alternative, use of a longitudinal ventilation system may cause emission levels from the tunnel portals to be in excess of allowable levels. In this instance a ventilation scheme whereby vitiated air is exhausted just prior to the exit portal and ejected via a tall vertical stack (Figure 4) would be required.

Vehicles	Experimental HRR		Representative HRR		Experimental HRR with fixed water-based firefighting systems	
	Peak HRR (MW)	Time to Peak HRR (min)	Peak HRR (MW)	Time to Peak HRR (min)	Peak HRR (MW)	Time to Peak HRR (min)
Passenger car	5–10	0–54[a]	5	10	—	—
Multiple passenger car	10–20	10–55[b]	15	20	10–15[g]	35[g]
Bus	25–34[c]	7–14	30	15	20[g,h]	—
Heavy goods truck	20–200[d]	7–48[e]	150	15	15–90[g]	10–30[g]
Flammable/ combustible liquid tanker	200–300	–	300	–	10–200[f]	

TABLE 1: Design Fire Data Based on Vehicle Type (NFPA 502)

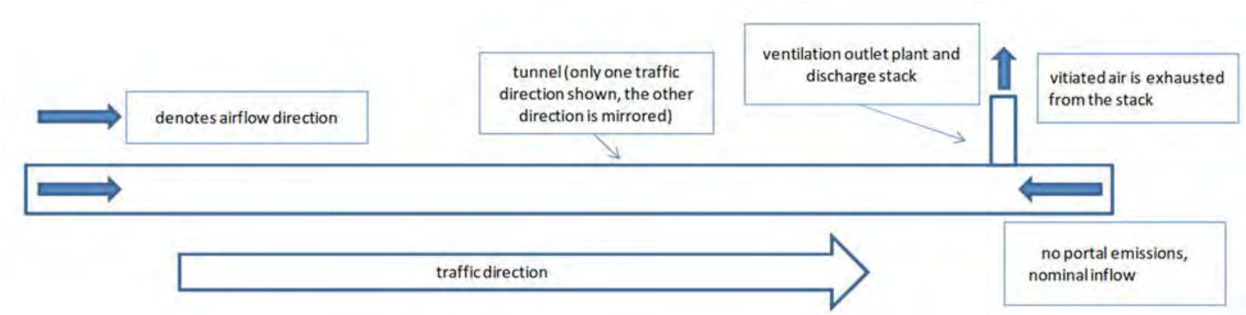


FIGURE 4: Portal Emission Prevention

1.9 PORTAL AIR RECIRCULATION

Recirculation of vitiated air at tunnel portals needs to be factored into a design if a system without point exhaust near the portal is used. Recirculation of vitiated air is typically managed by offsetting portals (by around 300 feet) or by providing a dividing wall structure.

1.10 CONTINUOUS EMISSION MONITORING

Emission monitors will be required in all tunnel alternatives to continuously monitor the levels of various pollutants and overall visibility. These systems will be utilized during normal traffic operations to regulate the ventilation system as needed for dilution of accumulated emissions or to signal an alarm when emission levels are exceeding their preset safe levels.

1.11 EMERGENCY VENTILATION AND SMOKE MANAGEMENT

In the case of a vehicle fire in the tunnel, longitudinal ventilation systems control the flow of smoke by producing a sufficient air velocity along the roadway to force the smoke movement downstream away from the fire site and the section of a tunnel most likely occupied by trapped motorists. The minimum air velocity required for smoke control is referred to as the critical velocity, that velocity which prevents reverse flow or back layering of smoke. The magnitude of the critical velocity is a function of the design fire heat release rate (fire size), the tunnel dimensions and the tunnel grade. The air flow induced in the tunnel must be sufficient to overcome the various resistances to flow (including vehicles in the tunnel, tunnel grade, adverse winds, etc.), while also exceeding the critical velocity.

Emergency ventilation and smoke management via a point exhaust system is achieved via a longitudinal duct (either over the roadway or in the side wall) with individually operable dampers. A schematic is provided in Figure 5. With a point exhaust system smoke is extracted from the roadway into a dedicated duct and dispersed via a remote fan shaft or fan building. The system is designed to contain smoke at/near the site of the fire and provide tenable conditions within the tunnel both upstream and downstream of the incident. Point exhaust systems have been implemented in tunnels in Europe and Australia and currently is being implemented in the Alaska Way Tunnel in Seattle. Point exhaust systems require a dedicated duct along the length of the tunnel and a large number of individually controlled dampers. In addition, an ancillary facility is required as a centralized location to house the exhaust fans serving the duct.

1.12 EGRESS PASSAGE OR STAIRWAY PRESSURIZATION

During a significant tunnel fire event where evacuation may be necessary, pressurization of the egress paths (cross-passages or stairways) is needed to prevent smoke ingress and contamination of egress route. In many cases, cross-passageways and stairways can be pressurized by operation of the ventilation system in the connecting (non-incident) bore. Where this is not achievable a dedicated fan system may be necessary to provide sufficient pressurization of these spaces.

1.13 TUNNEL VENTILATION SYSTEM OPERATION

For major urban road tunnels, such as that being considered for I-81, operation of ventilation systems during normal traffic conditions is typically arranged to be automatic based on pre-set level indications received from the emission monitoring system. In addition, alert/alarm indications regarding environmental conditions are also sent to a central operations control center so that any system adjustments can be manually made by a tunnel operator.

Jet fan based longitudinal ventilation systems do not require significant operator interaction or decision making that can lead to a delayed or incorrect response during a fire emergency. A point exhaust system requires the dampers near to the fire to be operated and, in the case of a vehicle fire, the appropriate response mode is dependent on the exact location of the fire within the tunnel. The ventilation system operation control software can be preprogrammed to operate the system in the appropriate mode based upon the operator's identification of the fire location.

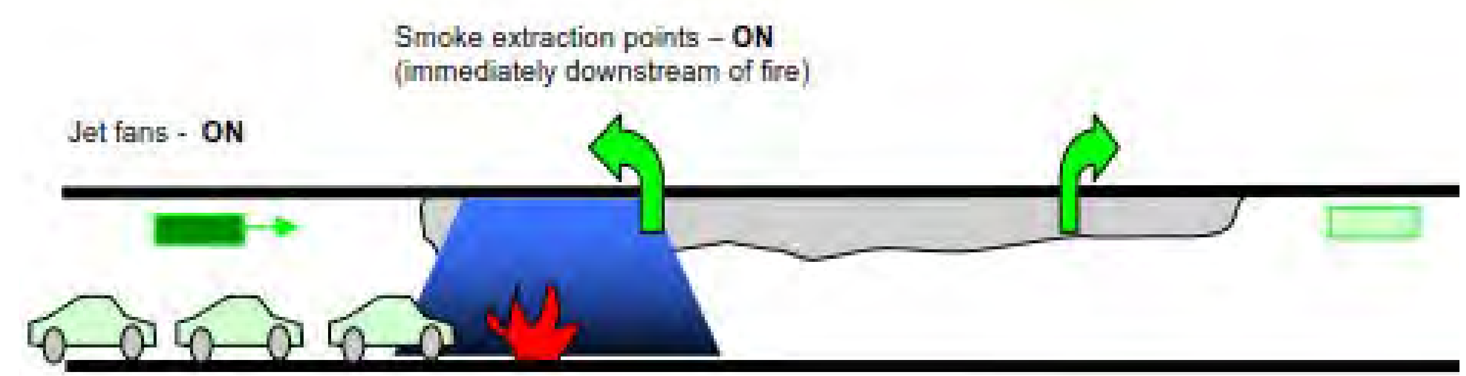


FIGURE 5: Smoke Extraction via Point Exhaust

1.14 RECOMMENDED VENTILATION OPTIONS FOR I-81 TUNNEL ALTERNATIVES

There are four tunnel alternatives identified herein for the potential replacement of the I-81 corridor through Syracuse, NY. The tunnel alternatives identified consist of differing length and alignment alternatives using two distinctly different variations of bored tunnel construction.

Each of the tunnel alternatives have been developed for two 12' travel lanes with minimum 4' shoulders on each side of the travel lanes, both northbound and southbound. Vertical vehicular clearance throughout is set at 16.0'.

The predominant bored tunnel variation for the different alternatives is a "single bore - stacked" tunnel with an upper and lower deck level that allow for the accommodation of northbound and southbound traffic separately. The Green A alternative assumes a single bore stacked tunnel option, and is approximately 5,800 feet in length.

The other bored tunnel variation being considered is referred to as the "twin bored tunnel" alternative which essentially consists of two separate and parallel bored tunnels that provide the necessary separation of northbound and southbound traffic. Alternatives considering the twin bore option range between 8,600 feet and 2.8 miles in length.

A longitudinal tunnel ventilation system using jet fans is recommended as the ventilation system design basis for each tunnel alternative with the inclusion of a point extraction system for the longer tunnel alternatives.

A jet fan based longitudinal ventilation system utilizes the jet fans to impart a high velocity air jet into the tunnel which induces a longitudinal flow along the length of the tunnel. The longitudinal flow in the tunnel pulls air into the entrance portal, and then the air travels the full length of the tunnel and is discharged out the other portal (options T1 and S1) or exhausted via a single extraction point (options T2, T3, S2 and S3).

Jet fans are typically mounted at the tunnel ceiling in pairs at longitudinal spacing of 300'. Reversible jet fans permit longitudinal flow in either direction.

A typical jet fan-sound attenuator unit has a 40" internal diameter, is about 17 feet long and weighs approximately 2,700 pounds.

Jet fan units are usually rated for high temperature operation as they are mounted in the tunnel and will be exposed to elevated temperatures in the event of a vehicle fire. In accordance with NFPA 502, the fans, their motors, and all related components that are exposed to the air stream must be able to remain operational for a minimum of 1 hour in an air stream temperature of 482 deg F (250 deg C). The system design will need to include an additional pair of fans in the tunnel bore to allow for the potential loss of a pair of fans by heat damage during a fire.

External wind conditions can have a significant effect on the operation of the longitudinal ventilation system. If the wind is acting opposite to the direction of ventilation, then the tunnel airflow will be reduced. The jet fan selections need to include the effect of adverse wind acting on the exiting portal.

Jet fans require a minimum clearance envelope in the order of 6'. For the twin bore tunnel options being considered for I-81 the diameter of the each tunnel bore is generally established based on the number of travel lanes, travel lane width, shoulder requirements, and vehicle height clearance. These parameters generally result in a tunnel diameter that is able to accommodate jet fans mounted in the crown of the tunnel above the vehicle clearance envelope. Refer to Figure 6 for a single bore tunnel with a stacked road deck there is less available vertical clearance, especially on the lower deck. The resultant space for the ventilation equipment tends to be at the sides of the tunnel which may better serve as a ventilation duct for a point extraction system option since space limitations may still exclude use of jet fans. Refer to Figure 7.

A longitudinal ventilation system using jet fans is considered the most appropriate option for the basis of the four study alternatives because:

- It is the most efficient system for tunnels designed for unidirectional traffic.
- It has the least impact on size of the tunnel structure.
- It does not require ancillary space of facilities to house the fans
- It is the most cost effective system.

FIGURE 6: Twin Bored Tunnel with Jet Fan Installation

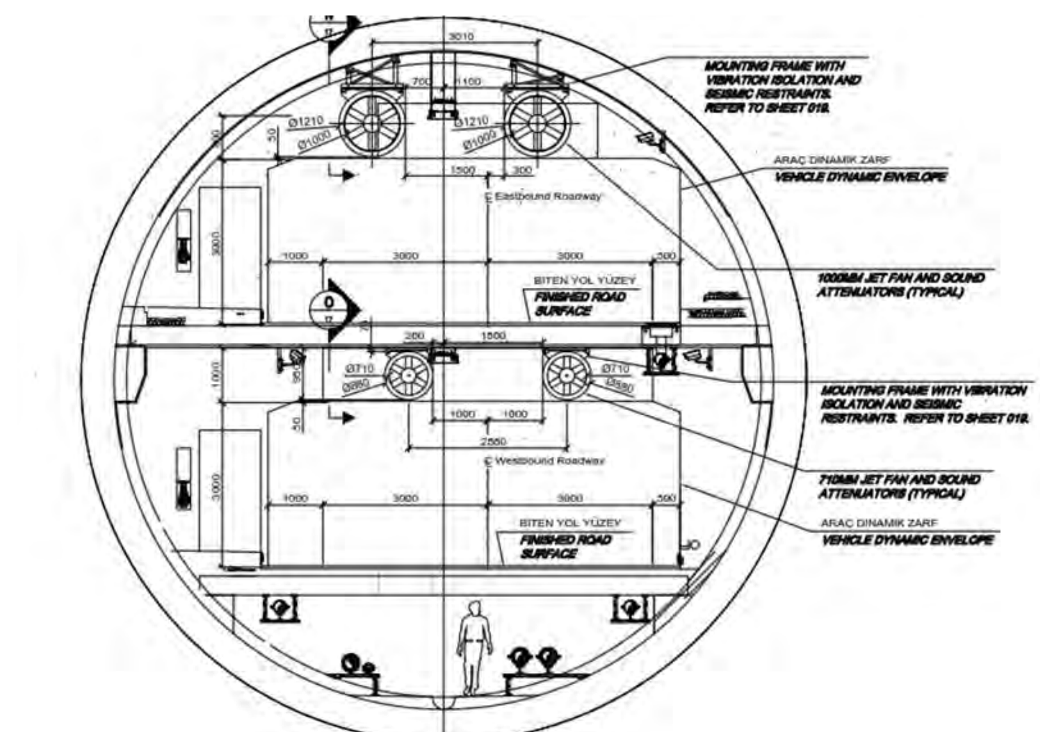


FIGURE 7: Single Bore Stacked Tunnel with Jet Fan Installation

1.15 SUMMARY

A summary of the various tunnel alternatives and recommended ventilation scheme is summarized in the table below. Detail of the recommended ventilation scheme for each tunnel alternative is provided in Table 3 for the twin bore tunnel options and in Table 4Table 4 for the single bore stacked tunnel option.

Ventilation options summary			
Tunnel alternative	Tunnel length (ft.)	Applicable ventilation schemes	Most likely scheme to be feasible at given length
Red (twin bored)	11,700	T1, T2, T3	T2
Green A (single bore stacked)	5,800	S1, S2, S3	S3
Blue (twin bored)	14,600	T1, T2, T3	T2
Orange (twin bored)	8,600	S1, S2, S3	T2

TABLE 2: Summary of Ventilation Options (refer Table 3 and Table 4 for ventilation scheme details)

Vent scheme	Tunnel and applicable alignments	Jet fans	Vent shafts or buildings	Portal exhaust	Exhaust duct	Egress vent	Comments
T1	Twin bore Red Blue Orange	Y 20 +/- per bore	N	N	N	Cross passage passive using jet fans	Jet fans only May not be feasible for longer tunnels with heavy traffic due to air quality impact at portals (see T2). Least costly option.
T2	Twin bore Red Blue Orange	Y 20 +/- per bore	Y Both ends	Y	N	Cross passage passive using jet fans	Jet fans plus exhaust shaft exit portal Ventilation shafts/buildings needed at each portal to mitigate portal emission impacts.
T3	Twin bore Red Blue Orange	Y 20 +/- per bore	Y Both ends	N	Y Overhead with dampers every 200'	Cross passage passive using jet fans	Jet fans plus point exhaust system using over-roadway plenum with op-erable dampers Most complex and costly option. Requires fan buildings/shafts at portals similar to T2.

TABLE 3: Summary of Ventilation Schemes for Twin Bore Tunnel Alternatives (Red, Blue and Orange alternatives)

Vent scheme	Tunnel and applicable alignments	Jet fans	Vent shafts or buildings	Portal exhaust	Exhaust duct	Egress vent	Comments
S1	Single bore, twin deck Green A	Y 20 +/- per bore	N	N	N	Stairway, passive using jet fans	Jet fans only Assume jet fans can be installed on both upper a lower roadway levels along the length of the tunnel (requires a large tunnel diameter)Same list of points as per twin bore option T1
S2	Single bore, twin deck Green A	Y 6 +/- per bore	Y Both ends	N	Y	Stairway, dedicated fans	Jet fans plus point exhaust system using side wall plenum with operable dampers Assume jet fans installed only at the transition sections into and out of tunnel. Exhaust ventilation duct runs along the side wall of the tunnel with operable dampers every 200' Most complex and costly option. Requires fan buildings/shafts at portals.
S3	Single bore, twin deck Green A	Y 6 +/- per bore	Y Both ends	Y	N	Stairway, dedicated fans	Jet fans plus exhaust building/ shaft at exit portal Assume jet fans can be installed on both upper a lower roadway levels along the length of the tunnel. Portal area exhaust is required to mitigate air quality conditions. Requires fan buildings/shafts at portals.

TABLE 4: Summary of Ventilation Schemes for Single Bore Stacked Tunnel Alternatives (Green A alternative)

2 TUNNEL FIRE PROTECTION & SUPPRESSION SYSTEMS

2.1 OVERVIEW

NFPA 502 – Standard for Road Tunnel, Bridges, and Other Limited Access Highways establishes the provision of a fire protection standpipe system in road tunnels greater than 300 feet long as a mandatory requirement. Installation of a fixed firefighting system (deluge sprinkler type system) is defined by NFPA 502 to be a "conditionally" mandatory requirement for any tunnel greater than 1,000 feet - meaning that for any road tunnel longer than 1,000 feet an engineering analysis must be performed to determine the need and benefit of a fixed firefighting system for that particular road tunnel facility. Based on the lengths of the four tunnel alternatives considered within this report, it is assumed that both a standpipe system and a fixed firefighting system will be required for any of the selected alternatives.

Standpipe systems are utilized to provide a water supply to remote locations within a facility for use by firefighters. Standpipes are considered a manual system that allows firefighters the ability to connect hoses to the system at locations where needed to fight the fire.

Installation of fixed firefighting systems (FFFS) has become common in newly commissioned urban road tunnels within the US due to the increasing concern for potentially large multi-vehicle or heavy goods vehicle cargo fires which, in addition to their threat to life safety, also pose the threat to cause significant damage to the tunnel facility itself. FFFS are considered to be effective in these types of vehicle fires because of their ability to prevent the spread of the fire from one vehicle to another. Limiting a fire incident to the initial fuel source (single vehicle) will limit the potential size of the fire; thus mitigating the threat to both motorist life safety and damage to the structure. Table 5 provides a list of recent US road tunnels that have installed, or are planning, a FFFS. The table provides the operational data for the tunnels as well as the water application rate (density) of the FFFS.

In addition to requirements for a standpipe and fixed firefighting system, NFPA 502 also requires deployment of portable multi-purpose type fire extinguishers along the length of the tunnel. These extinguishers are to be conspicuously located and easily accessible for use by motorists in the case of a minor fire emergency.

Tunnel	Alaska Way Tunnel	Midtown Tunnel	Port of Miami Tunnel	Doyle Drive Tun-nels	Eisenhower Tunnel
Location	Seattle, WA	Norfolk, VA	Miami, FL	San Francisco, CA	Dillon, CO
Year opened	UC	2016	2014	2015	1979
Length	9800 ft.	4054 ft.	4200 ft.	750 ft., 790 ft., 920 ft., 1030 ft.	8940 ft.
Bores	1, two level	1	2	4 tunnels (2 in each direc-tion)	2
New/Rehab	New	New	New	New	Rehab 2016
Traffic	Unidirectional, 2 lanes in each direction	Unidirectional, 2 lanes	Unidirectional, 2 lanes per bore	Unidirectional, 3 to 4 lanes per bore	Unidirectional, 2 lanes per bore
AADT		40,000	7000		34,000
Posted Speed	50 mph	45 mph	35 mph	65 mph	50 mph
Ventilation	Jet fans, point exhaust	Jet fan, longitudinal	Jet fan, longitudinal	Jet fan, longitudinal	Transverse
Water application	0.30 gpm/ft2	0.15 gpm/ft2	0.20 gpm/ft2	0.20 gpm/ft2	0.16 gpm/ft2
Urban or rural	Urban	Urban	Urban	Urban	Rural, mountain pass tunnel
Egress	Egress passage up/down, 650 ft. spacing	Egress corridor w/ doors spaced at 500 ft.	Cross passages, 650 ft. spacing		Cross passages

TABLE 5: Recent US Tunnels with FFFS

2.2 APPLICABLE STANDARDS

The following standards serve as the basis for establishing tunnel fire protection and suppression system requirements:

- NFPA 502 – Standard for Road Tunnel, Bridges, and Other Limited Access Highways
- NFPA 14 – Standpipe Systems
- NFPA 13 – Sprinkler Systems
- NFPA 10 – Fire Extinguishers

NFPA Standards are not considered code unless adopted legislatively by the local Authority Having Jurisdiction (AHJ). For the purposes of this feasibility report the assumed requirements for fire protection and suppression systems will adhere to NFPA requirements.

2.3 FIRE PROTECTION SYSTEM DESIGN CONSIDERATIONS

2.3.1 STANDPIPE SYSTEM

Standpipe systems within road tunnels are allowed by NFPA 502 to be either "wet" or "dry" meaning that the systems may be continuously kept full and pressurized or remain empty until needed. Dry standpipe systems are most commonly used in climates such as Syracuse where they will be subjected to freezing conditions. Where dry standpipe systems are used, NFPA requires that they are hydraulically designed to be fully charged by a reliable water source in less than ten minutes. Alternatively, wet standpipe systems could be used for the tunnel alternatives described, however, their design would be more complex requiring means such as pipe embedment, circulation pumps, heat tracing, insulation, etc. to ensure that water temperatures do not fall below 38 deg F.

Per NFPA 502 any tunnel standpipe system is required to be a Class 1 type system as defined by NFPA and hydraulically designed to maintain a flow of 750 gpm at a residual pressure of 100 psi to the most physically remote hose valve on the system. Special consideration must be given to the location and placement of hose valves within the tunnel. It is important to locate the valves so that they are conspicuous and convenient yet still adequately protected from damage.

2.3.2 FIXED FIREFIGHTING SYSTEM

Water deluge, mist and foam are the types of FFFS that have been use in road tunnels internationally. The most commonly used FFFS for road tunnels is an open-nozzle deluge type. This type of system is the least complex and consists mainly of a water supply main connecting to a series of deluge valves. The deluge valves open upon activation allowing water flow to the normally "dry" distribution piping over the roadways and then discharge onto the fire site through the open nozzles. This type of FFFS system arranged in short "deluge zones" along the length of the tunnel so as to minimize the total water demand of the system. The FFFS "deluge zones" each generally cover a length of about 100' of the tunnel roadway and are individually controlled so that the discharge from the FFFS can be concentrated on the site of the fire. It is typical that the FFFS is designed with a hydraulic demand that assumes activation of two or three "deluge zones" simultaneously.

The FFFS must be designed taking into account that most vehicle fires initiate in either the passenger, motor or cargo compartments and will be shielded from direct overhead water spray. Therefore, the selected water application rate needs to be sufficient to prevent the spread of fire, but not necessarily extinguish it.

Activation of the FFFS can be automatic based on system response to the fire detection system or manual by an on-site tunnel operator performing 24/7 supervision.

2.3.3 FIRE PROTECTION SYSTEM WATER SUPPLY

NFPA 502 requires provision of a water supply capable of sustaining the combined standpipe and FFFS demand for one hour. Storage tanks, municipal waterworks or private water services are all acceptable types of water supplies provided that they have an adequate flow rate and residual pressure and are of an acceptable integrity and reliability. For the purposes of this feasibility study it may be assumed that adequate water supply is available from the municipal water services within the City of Syracuse, however, confirmation of this would be necessary with hydrant flow and pressure testing during a preliminary design phase.

FIGURE 8: Typical Standpipe Hose Valve Cabinet

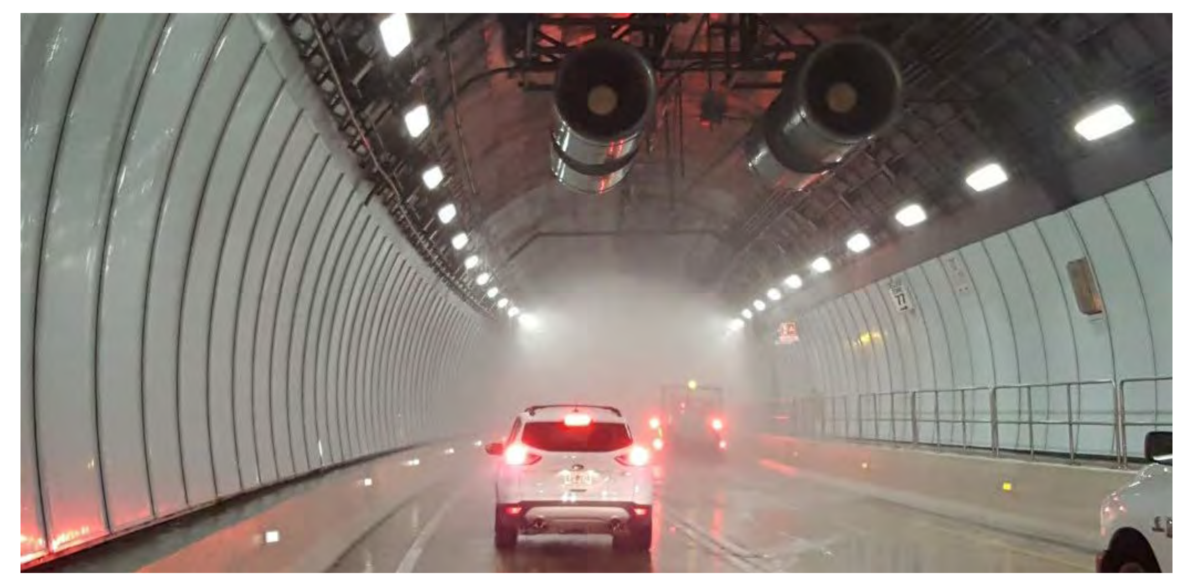


FIGURE 9: Activated FFFS

3 TUNNEL LIGHTING

3.1 OVERVIEW

The tunnel lighting system purpose is to provide the required illumination so that a motorist can safely navigate and maintain speed while in the tunnel. This objective must be met during daytime, nighttime, and during an emergency. Daylight conditions require high levels of illumination at the entry portal avoiding the "black-hole" effect. Nighttime levels are significantly lower and consistent throughout the tunnel. During an emergency, light levels are to be uninterrupted at the nighttime level to allow for egress.

3.2 STANDARDS AND REFERENCES

In addition to the Highway Lighting section of the NYSDOT Highway Design Manual (HDM), the design of road tunnel lighting systems will be required to conform to the latest issues of the following standards and references:

- Illumination Engineering Society (IES) – Recommended Practice Tunnel Lighting (ANSI/IES-RP22-2011)
- National Fire Protection Association (NFPA) – Standard for Road Tunnels, Bridges, & Other Limited Access Highways (NFPA 502)

The design of the depressed highway lighting systems will be required to conform to the latest issues of the following standards and references:

- American Association of State Highway and Transportation Officials, (AASHTO), Roadway Lighting Design Guide,
- U.S. Department of Transportation - Federal Highway Administration (FHWA), Roadway Lighting Handbook.

3.3 DESIGN CONSDERATIONS

Lighting requirements for entry into a tunnel are variable based on geographical orientation, traffic volume, traffic speed, portal wall design, and materials reflectance. The I-81 tunnel alternatives are conservatively based on a design speed of 60 mph, and are of varying lengths, with a predominantly North-South orientation.

The daytime light levels are based on the adaptation of the motorist's visual system. This is accomplished by gradually reducing the light in the tunnel, allowing for adaptation to a minimum of 8 cd/m2 within the tunnel. This reduction is accomplished by dividing the tunnel into threshold and transition zones originating at the entry portal and continuing for approximately 10 seconds at the posted speed limit. The remainder of the tunnel is then maintained at 8 cd/m2.

The I-81 alternatives will have similar length threshold and transition zones, with variation in the interior zones. The table below shows the variation for one direction. Each alternative will have a similar light reduction from portal to interior in each travel direction.

3.4 TUNNEL LIGHTING CONTROL SYSTEMS

The tunnel lighting control system is responsible for maintaining the required lighting levels for safe transit of the tunnel in all ambient light conditions. The necessary attributes of the system include:

- Integrated dimming, and monitoring of luminaries on an individual basis.
- Sensing of ambient luminance on the exterior of each portal
- Monitoring of illuminance levels within the tunnel
- Control algorithm to modify lumen output of the luminaries according to exterior brightness, Time of day, programmed schedule, and lumen maintenance over the life of the system.
- Integrate with SCADA and lighting asset management platforms.

3.5 TUNNEL LIGHTING FIXTURE CIRCUITING

Luminaries are connected to alternate phases of the circuit to ensure that if one phase is lost, only 33 percent of the total lighting fixtures served by the three phase circuit are affected; also that loads are balanced. To prevent the tunnel from being cast suddenly into complete darkness by simultaneous loss of power from all utility power sources, selected fixtures on the nighttime level circuit must be connected to a UPS (uninterruptible power supply) system.

The emergency lighting system must be designed to maintain the required level of illumination throughout the means of egress, and need to be in accordance with NFPA 502. The emergency lighting system utilizes a selected number of normal lighting fixtures and separately circuited to a UPS system.

3.6 TUNNEL LIGHTING FIXTURES

Light Emitting Diodes (LED) sources with dimming drivers are to be used. The luminaries used must provide the necessary luminance/control while physically staying outside the dynamic traffic envelope. All luminaires within the tunnel must be watertight and corrosion resistant to protect their interiors from periodic high-pressure (100 psi) wash downs of the tunnel environment (walls and ceiling). All luminaires used within the tunnel areas must be UL listed for wet locations and for direct spray applications. Manufacturers chosen to supply tunnel roadway luminaires must have a successful history for use within vehicular roadway tunnels. Where appropriate, dissimilar metals must be separated by appropriate insulators to minimize corrosion potential.

Daytime Supplemental Lighting Comparison				
Tunnel alternative	Tunnel Length	Threshold Length	Transition length	Interior length
Red (twin bored)	11,700	538 ft.	1,582 ft.	9,540 ft.
Green A (single bore stacked)	5,800	538 ft.	1,582 ft.	3,640 ft.
Blue (twin bored)	14,600	538 ft.	1,582 ft.	12,440 ft.
Orange (twin bored)	8,600	538 ft.	1,582 ft.	4,940 ft.

TABLE 6: Daytime Supplemental Lighting Consideration

3.7 TUNNEL EGRESS STAIRWELLS AND ANCILLARY SPACES

For tunnel emergency egress passageways and ancillary spaces, fixtures should be surface or pendent mounted and suitable for wet locations. Typically, such fixtures are provided with 1/8-inch thick acrylic lenses and utilize a 4000K LED source.

Egress passages must be designed for an average illuminance of 10 foot-candles (fc). Circuiting for cross passages and egress stairwells must be designed in accordance with requirements of the National Electrical Code. Although energized continuously, the luminaires need to be controlled in order to reduce energy consumption when spaces are unoccupied.

Exits within the tunnel need to be clearly identified by dedicated emergency exit lighting that lights the door and adjacent surfaces to a higher level than the interior of the tunnel, so as to provide the necessary level of demarcation. This exit lighting is in addition to the exit markings, strobe lights, and directional signs described in NFPA-502.

3.8 TUNNEL FIXED MESSAGE SIGN LIGHTING

Any ceiling mounted, non-internally illuminated signs that are required to be located in a road tunnel will need to be externally illuminated using either the luminance or illuminance methods in accordance with the following criteria:

Luminance*	-	80 cd/m2 minimum
Illuminance	-	40 fc (400 lux) minimum

* - 65 percent maintained reflectance

The maximum to minimum uniformity ratio on the sign face must not exceed 4 to 1. The maximum illumination gradient produced on the sign face should be 2 to 1.

Fixtures must be located so that they do not interfere with sign visibility for drivers of any type of vehicle.

3.9 APPROACH LIGHTING

The illumination level for a tunnel approach roadway is based on the nighttime roadway level inside the tunnel. In accordance with ANSI/IES RP-22 the illumination level for the approach roadways must be equal to 1/3 that of the nighttime tunnel illumination levels, with an average to minimum uniformity not to exceed 3 to 1.

4 TUNNEL FINISHES

4.1 OVERVIEW

Each of the road tunnel alternatives being considered herein for the I-81 Corridor will require consideration on the type and level of architectural finish elements that will be required and incorporated. These architectural finish elements can be categorized as follows:

- Highway Architecture, including approach roadway elements, retaining walls, U-wall sections, depressed roadway sections, and portals
- Interior tunnel elements including walls, ceilings, elevated walkways and railings, equipment cabinets, signage, egress doors, and structural fireproofing
- Egress elements including corridors, cross passages, wheelchair areas, and egress stairs

4.2 CODES, STANDARDS & REFERENCES

Guidance on the requirements and application of the architectural finish elements will be primarily provided and governed through the following documents:

- National Fire Protection Association (NFPA) 502, Standard for Road Tunnels, Bridges, and Other Limited Access Highways
- National Fire Protection Association (NFPA) 101, Life Safety Code
- New York State Building Code, latest edition
- U. S. Occupational Safety and Health Administration (OSHA)
- American Association of State Highway and Transportation Officials (AASHTO) – A Policy on Design Standards-Interstate System (2016)

4.3 HIGHWAY ARCHITECTURE ELEMENTS

4.3.1 TUNNEL APPROACH AND TRANSITION ROADWAYS

Highway Architecture requirements for the tunnel approach roadway elements, U-wall, retaining wall, and depressed roadway section design include the following:

- Design integration of the retaining walls, U-walls, and U-wall battering with the overall project design criteria
- Coordination of lighting, lighting pilasters, and embedded utility cabinets with the overall section design
- Design and integration of U-wall rustication with the overall design
- Other ornamental graphics or elements; these can be project specific, reflective of the area's history, or desired by the client or communities involved

4.3.2 ENTRANCE AND EXIT PORTALS

The portal design theme should be consistent with that of the overall architectural design and should emphasize common characteristics in order to:

- Maintain uniformity of perception in the driving experience and visually ease the transition from U-wall section to tunnel;
- Maximize the tunnel recognition by the driver
- Coordinate with other disciplines (Mechanical, Electrical, Plumbing) to embed or otherwise conceal conduit, fireproofing, standpipes, etc., from the view of motorists
- Complement aesthetic of the U-wall sections and other tunnel ancillary structures

4.4 INTERIOR TUNNEL ELEMENTS

4.4.1 TUNNEL WALLS

Tunnel walls may be finished or unfinished. Finishes are directly influenced by the requirements of NFPA 502, Standard for Road Tunnels, Bridges, and Other Limited Access Highways. Section 7.3 of this standard requires protection of structural elements sufficient to withstand RWS (Rikswaterstaat) time-temperature curve conditions for 120 minutes. Protection options (discussed in detail below below) include spray or board fireproofing, integral plastic fibers, and sacrificial layers of concrete. Spray and board fireproofing may be exposed, painted, or covered with architectural panels to provide a more finished architectural appearance. Finished surface materials of these panels includes painted steel, aluminum, precast concrete, or ceramic tile. Wall systems need to accommodate elements from other disciplines such as equipment cabinets, penetrations of conduits, and signage. Wall finishes visible to the motorist should be washable and impervious to water intrusion, salt, and permanent staining from airborne particulates.

4.4.2 TUNNEL CEILING

Similar to the tunnel walls, NFPA 502 requires ceiling structures to be fireproofed. This is usually accomplished with spray fireproofing, board fireproofing, concrete with embedded plastic fibers and/or sacrificial layers of concrete cover. Ceilings usually do not receive elaborate finished architectural treatment like walls, and sometimes consist of exposed fireproofing painted uniformly black to disappear visually into the tunnel background. Ceramicoat paint has been used effectively for this purpose.

4.4.3 TUNNEL WALKWAYS

Walkways in tunnels can be at roadway level or elevated. While elevated walkways are preferred by first responders and tunnel maintenance personnel, the elevation makes egress by motorists more difficult, especially in the case of mobility impaired persons. At the

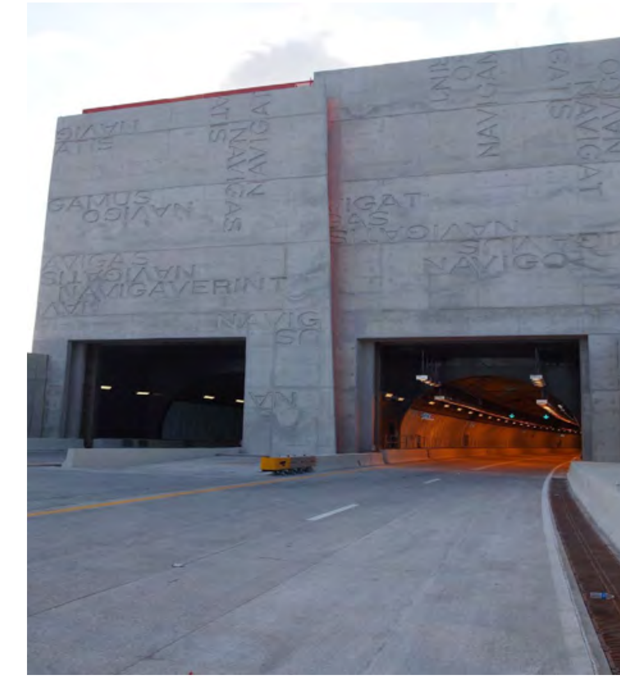


FIGURE 10: Construction Photo of Twin Bored Tunnel Portals and Approach Roadway Section

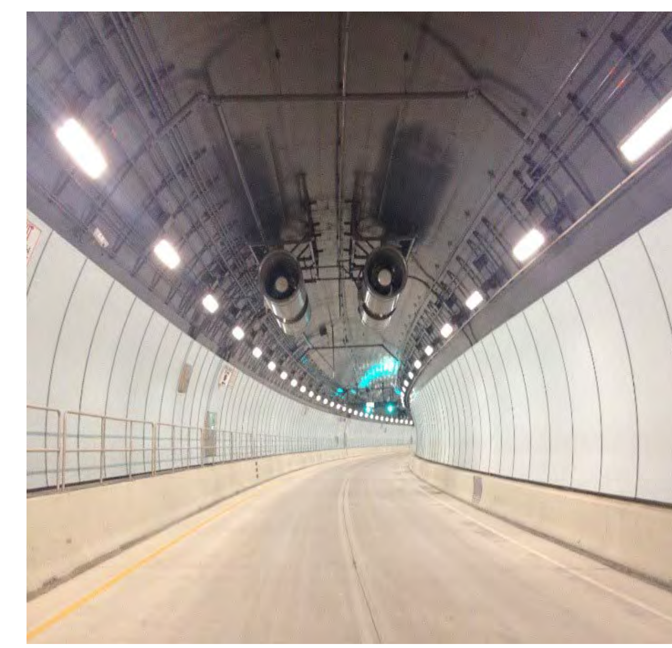


FIGURE 11: View of Bored Tunnel Showing Finish Features

Including traffic barriers, elevated walkway and railing, architectural wall panels, dark-painted ceiling fireproofing panels and utilities, and tunnel lighting fixtures

Central Artery project in Boston, MA, elevated walkways were desired by the Boston Fire Department since fighting fires from an elevated position was considered easier than from roadway level. In that particular case, the mobility impaired were required to wait for emergency personnel to assist them in accessing the elevated walkway. Elevated walkways serving the public require continuous 42" high railings, usually fabricated from stainless or galvanized steel. Wherever access to the elevated surface is desired, railings are interrupted and provided with grips on either side of the opening. Barrier faces receive toe holes at these locations. In tunnels where no railings are present, standalone toe-hole locations should be provided with vertical grips to facilitate access to the walkway.

4.4.4 TUNNEL EQUIPMENT CABINETS

Equipment cabinets for electrical, communications, fire protection, or other equipment should be fabricated from stainless steel. Locations, spacing, mounting heights, and penetrations of conduits and standpipes should be coordinated with the disciplines involved. Quick identification and easy access to these cabinets is extremely important in emergencies. Wall panel systems and fireproofing should be designed to seamlessly accommodate the cabinets. Cabinets that are surface mounted or project from the wall surface cannot reduce required walkway widths or intrude into the vehicular dynamic envelope. Cabinets can be open or closed boxes, and inclined cabinets with doors should be provided with hold open devices to prevent the doors from inadvertently slamming shut. Cabinets should be identified with appropriate signage, either with applied signage or signs immediately adjacent to the cabinet.

4.4.5 TUNNEL SIGNAGE

Signs for approach roadway sections, U-wall sections and tunnels should be as simple, visible, and legible as possible. They can be provided for either motorists or for tunnel personnel and first responders. Signage should be consistent over the length of the tunnel and open U-wall sections, and should complement the highway signage and other finished architectural elements in the tunnel. Signage may be fabricated from porcelain enamel steel, silkscreened aluminum, applied vinyl, or other approved materials. Where possible, anchoring should be concealed.

4.4.6 EMERGENCY EGRESS DOORS

Emergency egress requirements for road tunnels are described and defined in NFPA 502 with reference to NFPA 101. Emergency egresses require fire rated doors to provide fire separation between the safety of the egress and the tunnel roadway. The emergency egress doors should be well marked, and are required by NFPA 502 to be provided with illuminated exit signs. In addition, motorist call boxes, strobes, and fire protection cabinets containing fire standpipes and extinguishers can be provided at door locations. Doors can be of the swing or sliding variety. While sliding doors are specifically allowed by NFPA 502, they are not popular with fire authorities since in emergencies people can pile up against them without their being able to open. Swing doors, however, require more wall or corridor depth to open into and can, in the case of single cross passages, open against the flow of emergency egress from one direction. Sliding doors, when installed, should be placed on the inside of the wall rather than in the vehicular conduit since tunnel particulates, salt, etc., can accumulate on the overhead door tracks and impede operation over time. In general, sliding doors should be avoided if possible, and swing doors opening in the direction of egress travel should be employed if tunnel and egress geometry allow. Egress doors are typically rated at 1.5 hours for use in required 2.0 hour tunnel walls

FIGURE 12: Stainless Equipment Cabinet for Fire Hose Valve and Extinguisher

FIGURE 13: Example of Various Types of Signs Utilized in Road Tunnels to Identify Safety Related Features

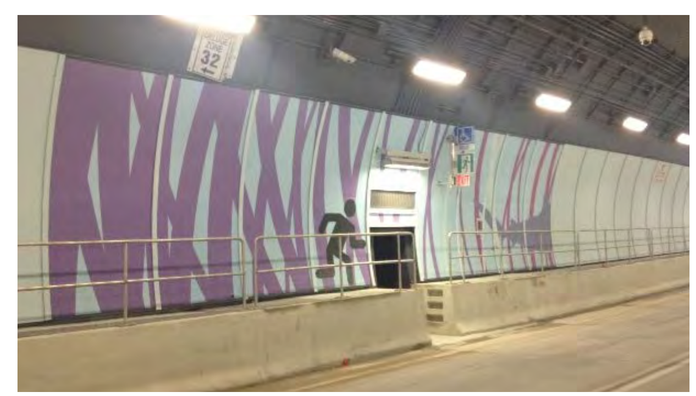


FIGURE 14: Tunnel Emergency Egress

Elevated walkway, railing, angled break in traffic barrier with toe holes, painted aluminum wall panels, egress graphics and signage, egress door opening, painted ceiling fireproofing and utilities, and tunnel lighting fixtures)

FIGURE 15: Photo showing egress opening, traffic barrier with angled interruption, painted board fireproofing, signage, and equipment cabinets

Sliding egress door is mounted behind tunnel wall, note accent light fixture at tunnel emergency egress opening)

FIGURE 16: Photo Showing Raised Safety Walk in Concrete Traffic Barrier

Toe holes, stainless steel railing, fire alarm pull station (FAPS, center), and stainless steel equipment cabinets, note removable steel grating on walking surface for equipment access (Port of Miami Tunnel)

FIGURE 17: Stainless Steel Sliding Egress Door

Applied vinyl signage, internally illuminated exit sign, and stainless steel screen at cross passage between two bored tunnel elements (Port of Miami Tunnel)
Toe holes, stainless steel railing, fire alarm pull station (FAPS, center), and stainless steel equipment cabinets, note removable steel grating on walking surface for equipment access (Port of Miami Tunnel)

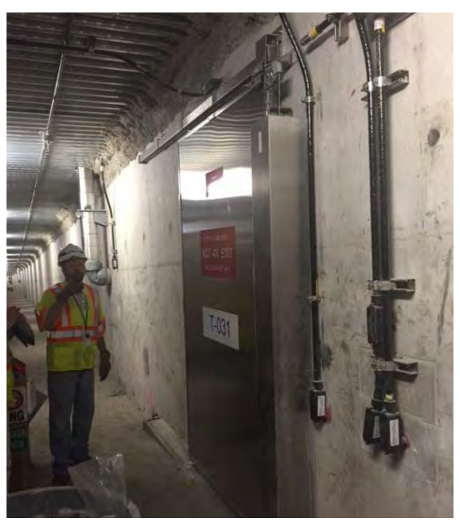


FIGURE 18: Construction Photo Showing Stainless Steel Sliding Egress Door inside Egress Corridor

Open track, vinyl adhesive signage, and stainless steel counterweight box (Midtown Tunnel, Virginia))

4.4.7 STRUCTURAL FIREPROOFING

Protection of tunnel structural elements is required by NFPA 502. Fireproofing should be coordinated with other engineering disciplines, and the Tunnel Finishes designer should assist as necessary in the processes of development of a hazard analysis, selection of fire protection systems, consultation with the AHJ on fire life safety issues, and integration of various fire protection systems, including fire suppression systems, into a comprehensive tunnel operation and emergency response plan. Options for fireproofing can include sacrificial layers of spray or board applied directly to the surface of the structure of the vehicular portions of the tunnel, or plastic fibers integral to the actual concrete structure, or layers of additional sacrificial concrete. The protection is seldom seen as a finished material in its own right, and should be complemented with an overall aesthetic architectural program including finished wall panels and painting of fireproofing, as appropriate.

The following presents advantages and disadvantages of the two most commonly used options for structural fireproofing in tunnels that should be considered, spray versus board versus concrete additives:

Spray fireproofing advantages:

- Effective, widely used fireproofing system
- Known technology
- Easy Installation, minimum detailing required
- Fast application
- Multiple suppliers; easier than board to obtain competitive bids
- Initial installation is more finished and uniform appearing than board

Spray fireproofing disadvantages:

- Extremely susceptible to de-bonding from water infiltration
- Requires a steel mesh anchored to substrate to enhance bonding
- Thicker dimensions required for fire ratings than board
- Poor performance at construction and expansion joints
- Masks structural defects; cracks do not generally telegraph through coating which makes defects more difficult to locate and fix
- Requires replacement when liner is inspected
- Rough surface discolors quickly
- Difficult to wash
- When areas are replaced, difficult to visually match surrounding areas

Board fireproofing advantages:

- Effective replacement for prior asbestos fireproofing – low thermal conductivity
- Relatively easy Installation
- More easily removed and replaced for tunnel liner inspection than spray
- Unaffected by water infiltration
- Leaks easier to detect and locate than spray
- Low maintenance cost
- Hard smooth finish; washable
- Can be installed to match construction and expansion joints
- Can be installed as part of the formwork of the concrete liner (lost formwork)
- Does not always require replacement after fire event
- Does not require specialized equipment to install

Board fireproofing disadvantages:

- More difficult application than spray
- More detailing required than spray
- Difficult to apply to tight radius tunnel geometries, although the use of two layers of thinner material with staggered joints can be used to fit to tighter curves
- Very few manufacturers; and only Promat, a Belgian product, has extensive history of use in the USA
- Unfinished appearance, with many fasteners and seams visible, but can be painted-Ceramicoat has been used successfully

Fire resistant concrete advantages:

- No additional fireproofing is required; less labor and shorter completion time
- Layer of concrete with fibers is good for the entire service life of the tunnel
- Unrestricted access for tunnel inspection
- Unaffected by water seepage
- Can reduce spalling at unprotected areas

Fire resistant concrete additives disadvantages:

- Can add up to 10" of thickness to the ceiling and walls being protected
- Fibers make concrete very stiff and difficult to work, and potentially porous

4.5 TUNNEL EMERGENCY EGRESS

Emergency egress requirements from road tunnels are established in NFPA 502 which also invokes applicable references NFPA 101, Life Safety Code. Depending on the configuration of the tunnel facility, emergency egress elements may include fire-rated doors, escape corridors, cross passage ways, and/or egress stairways. NFPA 502 requires emergency exits spaced at a maximum distance of 1000' (300m). Where egresses are used to provide escape from the incident to a non-incident tunnel such as a cross passageway the spacing requirements are reduced with typical distances between exits in the order of 600' (183m). The minimum egress path width is 3.7' (1.12m). Fire rated doors are required to separate the egress pathway from the tunnel. Sliding egress doors are typically used for cross passageways to allow for bi-directional egress travel. Suitable emergency signage, lighting, and pressurization are also required.

Options for the arrangement of emergency exits in road tunnels varies based, primarily, on the tunnel configuration. For the tunnel alternatives considered herein, the following are the most likely options for emergency egress:

4.5.1 SINGLE BORE STACKED TUNNEL OPTION

In a single bore stacked tunnel, each roadway level can provide an egress pathway to safety in the other (non-incident) traffic level. To accommodate for this, stairway egress connections between the two traffic levels are necessary. The stairways are can be configured within the ancillary space at the side of the bore. The space must be provided with fire rated doors to separate it from the roadway at each traffic level and configured to allow space where non-ambulatory persons can wait for rescue personnel. The stairways are required to be fire rated and pressurized. An egress corridor can also be provided; however, in a twin deck tunnel there may not be sufficient lateral space for this solution, and connecting stairs may be the only option.

4.5.2 DOUBLE BORED TUNNEL OPTION

In a double bore version, twin parallel bores are placed adjacent to each other, with mined cross passages provided between them at intervals. As in the stacked single bore option, each vehicle conduit can provide an egress pathway for an incident in the other conduit. No parallel egress corridors are required. If the twin bores cannot be constructed at the same level, short lengths of stairs are required. In these cases, areas for wheelchairs or non-ambulatory persons are required.

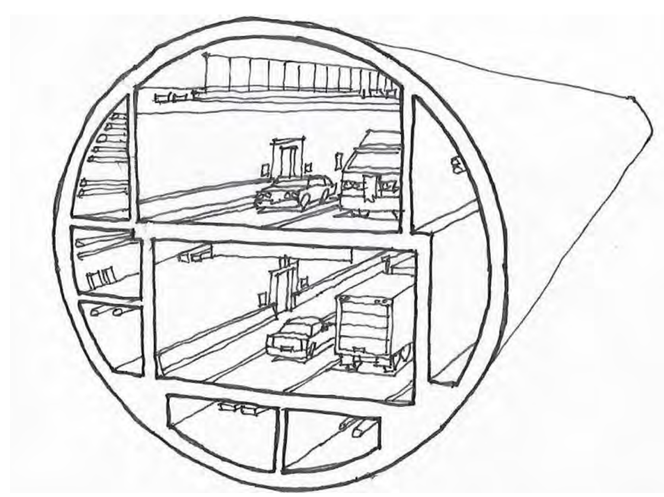


FIGURE 19: Stacked Single Bore Tunnel with Interconnecting Egress Stairs (Seattle Tunnel, WA)

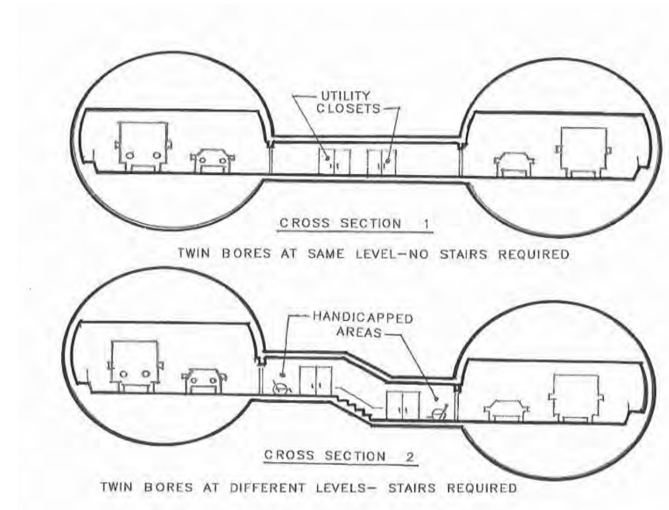


FIGURE 20: Twin Bored Tunnel Configurations with Cross Passages (bores can be at the same level or different levels (WSP USA renderings))

FIGURE 21: Cross Passage between Two Bored Tunnels Showing sliding door (open at far end), illuminated exit sign, equipment cabinets, pressurization fans, and emergency lighting fixtures (Port of Miami Tunnel)

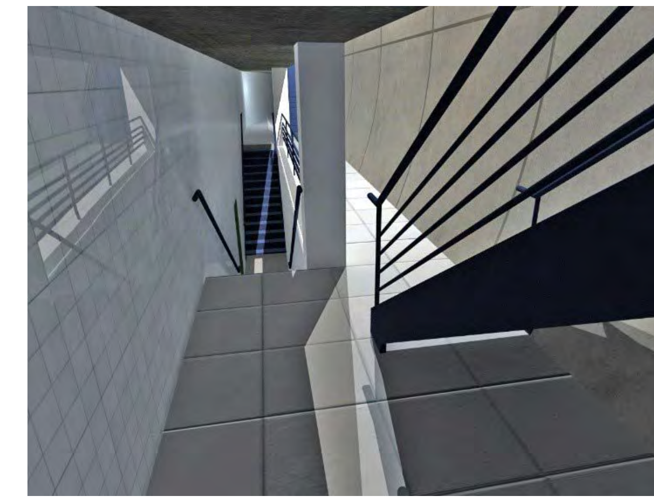


FIGURE 22: Cross Passage between Two Bored Tunnels (showing sliding door (open at far end), illuminated exit sign, equipment cabinets, pressurization fans, and emergency lighting fixtures (Port of Miami Tunnel))

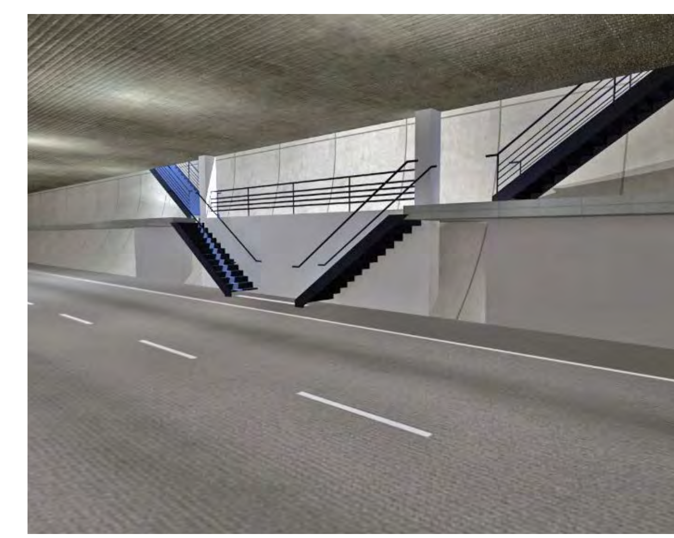


FIGURE 23: Rendering of Single Bore Stacked Tunnel Option

Tunnel roadway wall removed to show egress stair configuration beyond (WSP USA rendering)

5 ELECTRICAL SYSTEMS

5.1 OVERVIEW

Each of the tunnel alternatives identified herein for the I-81 Corridor through Syracuse will require a variety of electrical systems to support safe traffic operation. The required installation methods and performance criteria of these various electrical systems for road tunnel application have been generally defined in within applicable codes and standards including NFPA 502 and the National Electrical Code. The required tunnel electrical systems include:

- Power Distribution
- Fire Alarm and Detection
- Emergency Communications
- Security
- Supervisory Control and Monitoring (SCADA)

5.2 POWER DISTRIBUTION SYSTEM

Roadway tunnels typically are provided with redundant, reliable and robust electrical power supplies and power distributions systems. These same power requirements will be apply to each of the I-81 tunnel alternatives being considered herein. Specific aspects of the electrical power distribution system requirements are as follows.

5.2.1 REDUNDANT SUPPLIES

Power for the tunnel systems is usually supplied from two independent incoming medium voltage supplies, designated 'A' and 'B', each capable of supporting the entire electrical load, but normally supporting approximately 50% of the total electrical load. These 'A' and 'B' supplies typically are taken from each portal end local electrical utility distribution network respectively, to minimize the risk of common point failure.

5.2.2 LOAD SPLITTING

The total electrical load, including the lighting and ventilation systems, is then split approximately 50/50 between the 'A' and 'B' supplies so that if one supply fails, only 50% of the system capacity will be initially (momentarily) disrupted.

5.2.3 CABLE SEGREGATION

Cabling, transformers and switchgear associated with 'A' and 'B' supplies are usually physically segregated to the maximum practicable extent.

5.2.4 ALTERNATIVE SUPPLIES

If either supply should fail, or equipment needs to be temporarily taken out of service for inspection, maintenance or repair, provisions are also made for the whole of the tunnel electrical load to be transferred to the alternative supply until normal operation can be restored.

5.2.5 SWITCHGEAR CABLING

Switchgear controlling interconnecting cables between the 'A' and 'B' substations is interlocked to prevent through feeding between the portal local electrical utility distribution supply networks.

5.2.6 SECONDARY DISTRIBUTION SYSTEM

The secondary distribution systems in the United States typically operate at 480Y/277 Volts, in a main-tie-main configuration utilizing double–ended switchgear, electrically interlocked to prevent paralleling.

5.2.7 STANDBY POWER SYSTEMS

Standby power systems are also a standard implementation for roadway tunnels and consist of standby generators, switchboards, transfer switches, fuel supply and storage, accessories, and wiring as required to provide standby power to the following loads, usually as a minimum:

- Selected tunnel, utility room, egress corridor and egress stair lighting*;
- Tunnel drainage system;
- Storm water pump stations;
- Fire protection pumps;
- Minimum tunnel ventilation (25% of installed capacity);
- DMS and LUS equipment*;
- Communications such as radio, telephone, supervisory control and data acquisition (SCADA), and fire detection and alarm systems*;
- CCTV and incident detection;
- Selected building lighting*;
- Selected receptacles in fire cabinets, switchgear rooms, generator rooms, mechanical rooms, control rooms, rest rooms, stairways, maintenance shops, and offices.

* - Systems usually are also provided with battery-supported UPS for which standby power will provide long term back-up.

Standby power system design is based upon ANSI/IEEE Standard 446 and the elements defined herein. UPS units are connected to draw power from a standby source if normal power fails. Standby generators typically are located in or at the buildings at each end of the tunnel. Standby power switchboards may be located in the same room as the generators, and such room is provided with adequate ventilation and relatively dust free air. Transfer switches are located where it is most advantageous based upon access for operation, economic reasons, and other governing factors.

5.2.8 STANDBY GENERATOR UNITS

Standby generators are typically diesel engine-driven. Generator output is at 480/277 Volts, 60 Hertz, three phase, four wire, compatible with secondary distribution system. In general, one standby generator at each building should be sufficient to supply the load. If two or more standby generators per building is required, consideration is usually given to the advantages and disadvantages of parallel operation.

Another fuel source option is natural gas from the local utility system, and may be considered as the emergency fuel source in lieu of diesel, if acceptable to the AHJ. Regardless of fuel type, if storage tanks are used, sufficient tank storage or continuous commercial fuel supply (such as natural gas) is typically provided at each location to support a determined period of continuous operation, including a certain time period under emergency loading. Storage tanks must conform to all regulations that pertain and are in force in the local jurisdiction and the entire system must conform to NFPA 30 and NFPA 37.

The loss of normal power at the automatic transfer switch causes the associated standby generator(s) to start up automatically and assume the load if the normal power interruption continues. Loads may also be arranged for sequential starting if required, based on capacities available

5.2.9 STANDBY SWITCHBOARDS

480/277 Volt standby switchboards are indoor type, metal-enclosed, and are self-supporting structures. Switchboards usually utilize compartmentalized design with individually mounted devices in the distribution sections.

5.2.10 UNINTERRUPTIBLE POWER SUPPLIES (UPS)

UPS units provide uninterruptible electrical power to designated loads. The following are typical loads that are connected to UPS systems:

- DMS, LUS, CCTV and automatic incident detection equipment;
- Communications, supervisory control and data acquisition system, and fire detection and alarm systems;
- Selected tunnel, utility room, egress corridor and egress stair lighting;
- Selected building lighting;

The UPS units are designed to operate "on line" such that when normal power fails, the batteries will provide power for a designated period through the inverter output. If a UPS malfunctions, a static switch automatically connects the load directly to the normal supply while simultaneously opening the inverter-output circuit breaker. A maintenance by-pass is typically provided to manually transfer the load to the normal supply for routine service or maintenance of the UPS.

5.2.11 ELECTRICAL CIRCUIT CONDUCTORS (CABLE)

All sub-main and final sub-circuit conductors within the tunnel road space are protected from fire, either by the use of fire rated cables adhering to NFPA 502 as appropriate, or by being enclosed within fire protected ducts. All cables buried in the ground or passing through the structure are typically enclosed in ducts, with 25% spare ducts left empty for unspecified future use. Where it is not possible to obtain suitable fire rated versions of exposed cables required for instrumentation, data transmission or communications equipment in the tunnel, resilience to fire is provided by alternate means, such as duplication by alternate routing. Final connections to equipment that will be not be expected to continue operating under direct impingement of fire may be made in cables with fire rating similar to that of the equipment served. In such instances suitable precautions are taken to ensure the continued functioning of equipment not directly involved in the fire.

5.3 FIRE ALARM AND DETECTION SYSTEMS

Roadway tunnels and supporting facilities are required to be provided with fire alarm and detection systems in compliance with NFPA 502 and 72. Road tunnels are typically provided with manual pull stations for motorist use that located along the roadway at intervals complying with NFPA 502. The tunnel may also require a heat detection system capable of monitoring the traffic lanes. When utilized, roadway area the heat detection systems are typically a subsystem to the main fire alarm control panel.

Tunnel support buildings and other ancillary areas such as pump rooms or equipment rooms must also be provided with a means of automatic fire detection such as heat and smoke detectors. Annunciation of a fire condition in the ancillary space is typically through horn/strobes.

The main Fire Alarm Control Panel (FACP) used for a road tunnel facilities is typically an addressable type so that the location of each device within the facility can be readily identified. In road tunnels where a fixed fire suppression systems are used, the systems activation controls are often interfaced with the tunnel fire detection systems via the FACP.

5.4 EMERGENCY COMMUNICATION SYSTEMS

Roadway tunnels are typically provided with an emergency telephone system, with telephones located throughout the tunnel, for motorist use in case of vehicle breakdown or other emergency situation. The emergency telephones directly connected to the Operations Control Center and are designed so that an intelligible conversation can take place with background noise from traffic in the tunnel and the tunnel ventilation system.

The telephone system typically is served by two separately located telephone controllers. Each controller serves alternate telephones so that every other phone will be operational if one controller becomes disabled.

The Operations Control Center personnel usually is able to hold calls from, or call back to, any individual telephone on the system.

Radio rebroadcasting systems usually are also provided to maintain radio coverage in the tunnel of all channels required by the First Responders.

Commercial AM/FM radio rebroadcast systems may be installed in the tunnel, with Operations Control Center personnel override capability, to interrupt broadcasts with messages from the operators in case of emergency situations. This system can also be integrated with Highway Advisory Radio (HAR) messages to be broadcast within the tunnel.

Tunnels may also incorporate mobile telephone coverage within the space for uninterrupted motorist cell phone usage. This is typically accomplished by providing suitable space and UPS power supplies to enable third party cell phone service providers to install their equipment and antennas to give full coverage of all mobile telephone networks available in the tunnel.

5.5 SECURITY SYSTEMS

Roadway tunnels, their supporting buildings and facilities are typically provided with integrated security systems that are comprised of access control, intrusion detection and CCTV subsystems for monitoring of the facilities and preventing unauthorized access to the site, buildings and critical infrastructure spaces.

The perimeter of all areas around the tunnel portals, the Tunnel Support Buildings and the Operations Control Center are monitored to detect and alarm any unauthorized intrusion. An alarm is raised at the Operations Control Center through the SCADA Operations Control Center Interface with details of the location and time when an intruder is detected.

Security lighting and a CCTV surveillance system is provided to give full coverage of these areas and to enable the movements of intruders to be viewed and tracked.

An access control system is provided to cover designated entry points to restricted areas and buildings. The system is usually designed to permit only authorized vehicles and personnel to enter, and automatically log all movements in and out of the secure areas.

Every designated entry point is typically provided with a telephone link to the Operations Control Center, accessible from both sides of the door or gate, to enable users to request assistance.

The Operations Control Center personnel is provided with the means to override the control of individual entry points in abnormal circumstances, to allow free access by First Responders, maintenance and construction personnel.

A means of locally unlocking and locking access gates and doors is also provided for use in the event of system failure.

A Surveillance Closed Circuit Television (CCTV) system is typically provided to allow surveillance coverage of the facility and all controlled access areas, as described above.

5.6 SUPERVISORY CONTROL, MONITORING AND DATA ACQUISITION (SCADA) SYSTEM

A comprehensive supervisory control and data acquisition (SCADA) system will be necessary for any of the tunnel alternatives being evaluated herein to permit monitoring and controlling of key systems and equipment throughout the facility, including any remotely located equipment or facilities, from the dedicated tunnel control center. The architecture of the SCADA system employs a fail-safe topology. Each programmable logic controller (PLC) is designed with a redundant "hot-standby" configuration, capable of seamless transfer of data upon failure of the main processor. Additionally the programmable logic controller is usually equipped with redundant power supplies.

The SCADA system employs a universal remote input/output network protocol, allowing different network devices the ability to communicate with the programmable logic controller. Remote input/output (RIO) cabinets are distributed throughout the facility in order to minimize hardwire cable runs between field devices and the SCADA system. Each remote input/output cabinet is typically designed to accommodate the required number of points for the digital input (DI), digital output (DO), analog input (AI), and other data modules as needed.

Major mechanical and electrical equipment incorporate provisions for communication, control, and indication, via normally-open and normally-closed contacts, transducers, and auxiliary relays, or serial or IP Ethernet based communication, to provide control/indication to the SCADA system. System consists of communications networks, servers and operator interfaces. The communications network usually consists of dual fault tolerant, redundant fiber optic ring topology with management switches at each node.

Servers provided operate on a hot standby basis. Operator interfaces are typically provided at a dedicated remote operator control center and local to the tunnel, with different levels of system access protected by password for “guest”, “operator”, “supervisor” and “engineer”. The system also handles and manages data logging and transfer for alarms, alerts and record keeping for historical purposes.

5.7 TRAFFIC CONTROL

Roadway tunnels are required by NFPA 502 to be provided with a means for control of traffic within the tunnel, as well as traffic on the approach roadways leading into the tunnel These systems are necessary to control traffic within the tunnel and/or to prevent vehicles from entering the tunnel in the event of an traffic incident or emergency and also for purposes of tunnel maintenance. Traffic control systems will be required for each of the I-81 tunnel alternatives being considered herein. The types of traffic control systems and devices likely to be required for any of these tunnel alternatives are described below.

5.7.1 INCIDENT IDENTIFICATION

An intelligent, programmable, CCTV video stream based Automatic Incident Detection (AID) system within the tunnel and its immediate approaches is usually provided. The automatic incident detection system provides the following facilities:

- Traffic speed and flow data;
- Detection and alarm for a single stationary vehicle in the tunnel;
- Detection and alarm for congested traffic flow in the tunnel;
- Detection and alarm for congested traffic flow downstream of the tunnel; and
- Detection and alarm for a vehicle traveling in the wrong direction within or approaching the tunnel.

5.7.2 CLOSED CIRCUIT TELEVISION (CCTV)

A CCTV system for tunnel and approach roadways is provided for general surveillance purposes to enable the tunnel operator to view any part of the tunnel interior, emergency escape routes and approach roadways. Generally cameras will have pan, tilt and zoom (PTZ) capability.

Cameras are positioned so that if one camera fails, full coverage of the tunnel interior may be obtained by the use of the adjacent cameras on either side. SCADA system interfaces allow the nearest camera to an alarm event to be displayed automatically at the local tunnel operator control center through the use of presets. The alarm event is captured through an automatic real time recording feature for at least two cameras capturing alarm events simultaneously. The tunnel operator typically is able to manually start and stop the recording feature.

Each camera image usually also has an informational banner with identification, location, date and time in universal time coordinated format.

At a dedicated tunnel operations control center, there are typically multiple monitors and recording facilities to assure adequate redundancy in the system. One or more screens cycle all the cameras at least once every 60 seconds, while at least one of the other displays a single picture selected by the tunnel operator as a “spot” monitor. Systems are scalable and expandable to allow future addition of cameras or monitors.

5.7.3 DYNAMIC (VARIABLE) MESSAGE SIGNS (DMS)

Full matrix signs typically are provided in the tunnel and tunnel approaches at regular intervals above the travel lanes to display instructions and emergency messages to motorists. The signs are typically based on arrays of white LEDs on a black background, visible in bright sunlight and dimmable to suit the full range of ambient lighting conditions. Sign messages are remotely programmable by the tunnel operators.

5.8 TYPICAL DYNAMIC MESSAGE SYSTEM

5.8.1 LANE USE/CONTROL SIGNALS (LUS/LCS)

Signals are typically located along the tunnel walls or ceiling, and over the roadway at the tunnel portal approaches, at regular intervals to indicate the status of each travel lane as either opened or closed, through the use red and green symbols on black background suitable for the full range of ambient lighting conditions where located. Each signal head is independently controlled to indicate the status of each lane and is fully interlocked to prevent any possible conflicting indications, with fault conditions at a signal head to show a blank face. Signal heads are typically double aspect light emitting diode (LED) displays suitable for use with bidirectional traffic, as required. Traffic stop signals are provided to close the tunnel and prevent vehicles from entering in the event of an emergency.

5.8.2 OVER-HEIGHT VEHICLE DETECTION/PROTECTION (OVD)

The OVD system detection height is based on AASHTO required vertical clearance within the tunnel. The OVD system locates receiver/transmitter pairs along the roadway, outside of the tunnel entrance portals on approach roadways, such that the paths between each transmitter-receiver pair are parallel such that the beams between the pairs define a plane parallel to the detection height.

The OVD system operates in conjunction with DMS, LUS/LCS and CCTV components. In the event of an interruption of the beams crossing the roadway in the appropriate sequence, the detector controller activates downstream messages, and an audible alarm and strobe light warns the driver of the over height vehicle condition, and provides instructions to stop at a predetermined safe area and not enter the tunnel. An alarm is also generated to the tunnel operator.

FIGURE 24: Tunnel Incident Viewed on Closed Circuit Television System

FIGURE 25: Dynamic (Variable) Message Signs (DMS)

FIGURE 26: Typical Lane Use Signals

6 TUNNEL DRAINAGE SYSTEMS

6.1 OVERVIEW

Tunnel drainage systems normally consist of two independent systems; a storm water control system and a tunnel drainage system.

Storm water control systems are required at the tunnel portals to intercept storm water flows that accumulate on the open approaches and transition roadways leading into and out of the tunnel. These portal drainage systems are necessary to collect and discharge storm water before it has a chance of entering the tunnel. The approaches may be partially of fully covered to minimize accumulation, and also for other purposes.

A separate tunnel drainage system, designed to be independent of inflow from sources outside the tunnel, is required to collect and discharge water and effluents generated within the tunnel. These effluent flows result from tunnel washing, use of fire suppression systems, vehicle carryover, and normal groundwater seepage. The tunnel drainage system must also be designed and equipped to accommodate a potential fuel spill. The profile of the selected tunnel alignment will dictate the location the tunnel drainage pumping station(s) as the drainage collection needs to occur at the lowest point(s) in roadway profile.

6.2 APPLICABLE STANDARDS

The following standards and guidelines serve as the basis for the design of the tunnel and portal drainage systems:

- National Fire Protection Association (NFPA) 502 – Standard for Road Tunnel, Bridges, and Other Limited Access Highways
- Federal Highway Administration, Highway Engineering Circular (HEC) 12 – Drainage of Highway Pavement

6.3 DRAINAGE SYSTEM DISCHARGE CONSIDERATIONS

The storm water collected at the tunnel portals is considered to be clean and therefore does not require special treatment prior to discharge. However, the tunnel drainage effluent can be considered to consist of water contaminated with tunnel washing detergents, particulates, potentially saline infiltration water, and minor oily waste that are required to be connected to a municipal sanitary or industrial wastewater sewer system and may require some form of pre-treatment prior to discharge depending on local permitting requirements.

6.4 DRAINAGE SYSTEM CAPACITY BASIS

The portal area storm water drainage systems should be designed to collect and discharge storm water based upon the duration and intensity of an established storm event for the geographical location, typically 50-year storm event. This system will be at a higher elevation that the low point tunnel drainage system, and can potentially drain by gravity into the city sewer system.

The low point tunnel drainage system(s) should be designed to collect and discharge effluent based on a capacity equal to the expected tunnel seepage plus the flow of wash-down water or fire protection systems; whichever is the largest. The following provides guidance on establishing tunnel drainage system capacity:

- The quantity of water resulting from tunnel washing can vary in the range of 150 to 500 gpm depending on the maintenance equipment used.
- Water inflow from a fire-fighting event is determined from the fire protection system design flow.
- Generally in the case of a fuel spill, the drainage system pumps must be shut down so as to contain the spill within the pump station in order that it may be collected and legally disposed of as hazardous material. Therefore, the pump station well(s) must be designed with adequate storage.
- Normal anticipated amounts from structural seepage (< 1 gallon/minute/1,000 feet of tunnel) and rain water carried in by vehicles are likely to have no impact on design capacities.

6.5 DRAINAGE SYSTEM PIPING

The drainage collection systems used both inside the tunnel and along the open portal area transition and approach roadways will typically consist of cast iron grated drop inlets designed for 20 ton truck loading (HS-20), positioned outside of the travel lanes and spaced at intervals that will allow for cleaning between inlets. The drop inlets will connect to a drainage main embedded below the roadway surface that will use the roadway profile to convey effluent by gravity to either the city storm water system (where possible for portals) or to the associated pump station by gravity. Where possible, maintaining a minimum super elevated cross-slope of 1 percent will eliminate the need to provide inlets on both sides of the roadway.

6.6 DRAINAGE SYSTEM PUMPS AND PUMP STATIONS

Where required, portal area pump stations are likely to be of a significantly larger capacity than that of the tunnel low point pump station(s) and commonly require vertical turbine type pumps whereas tunnel low point pump stations are commonly designed with centrifugal type pumps which require much less overall space.

Bored tunnels such as those considered for the I-81 tunnel alternatives allow sufficient space below the roadway, within the tunnel lining, for locating the tunnel low point pump station(s). The profile of the tunnels has been developed to ensure only one low point, and associated pump station, between portals.

For both the portal and tunnel drainage systems pumps should be sized so that adequate capacity is available should any one pump be out of service due to planned or unplanned maintenance/repair. Pump stations should be designed to for automatic operation with the local pump control panel linked to communicate operational data/ equipment status remotely to a tunnel operator. Since the potential exists for collection of petroleum based fuels and oils within the tunnel drainage system, the tunnel drainage pump station(s), including all components and equipment, must be designed to comply with the requirements of the National Electrical Code (NFPA 70) for a Class I, Division II type hazard location. A hydrocarbon monitoring system is required within the tunnel drainage pump stations to detect unsafe vapor levels.

7 TUNNEL OPERATIONS AND MAINTENANCE

7.1 OVERVIEW

A dedicated and well planned tunnel operations and maintenance program is necessary to ensure a safe, well maintained, and reliable tunnel facility which maximizes public safety and roadway availability. Each of the various tunnel alternatives discussed in this report has an inherent requirement for a tunnel Operations and Maintenance Plan that fully considers the future operations and maintenance needs of the facility and adequately identifies all ancillary facilities, operating systems, infrastructure, staffing, maintenance equipment, and related items necessary to operate and maintain the facility.

Ancillary facilities that will be required to support operation of the tunnel alternatives considered herein will include provision of a dedicated operation and control center for tunnel operations staff who will be responsible for the operation and monitoring of the mechanical, electrical, and traffic control systems in response to various conditions and incidents.

For major road tunnel facilities similar to those considered herein, tunnel operators will be required to staff the operations control center on a 24/7/365 basis. The tunnel operations function may also include incident response capabilities such as patrol personnel who are available to provide assistance to disabled motor vehicles and provide towing services in order to quickly respond to disabled vehicles in order to mitigate impact to traffic and the potential of a more significant incident.

Maintenance related facilities may include maintenance shops, garage facilities, and other storage spaces to house equipment and spare parts that are needed to maintain the tunnel. The majority of the required maintenance may be performed during normal business hours however some level of maintenance staff need to be available 24/7 to respond to unplanned issues. Most in-tunnel maintenance activities need to occur during planned tunnel/lane closures during off-peak traffic hours. Appropriate maintenance requires a mix of personnel including electricians, mechanics/millwrights, and general maintenance staff to maintain the facilities and various systems, support traffic control measures and respond to traffic incidents.

A significant level of planning and coordination is required to operate and maintain a major road tunnel facility in a manner that will properly ensure the safety and protection of the motorists while minimizing traffic disruptions. An Operations and Maintenance Plan consisting of a compilation of the various incident and emergency management plans, maintenance management plans, operational procedures, and established protocols determined to be necessary to the safe and efficient operation and maintenance of the tunnel facility.

7.2 OPERATIONS & MAINTENANCE PLAN

The Operations and Maintenance Plan is a critical document used for the immediate and future planning of operational budget, staffing needs, and equipment requirements that support the operation of the tunnel facility as related to functionality and maintainability. The O&M Plan sets the course of direction for a variety of activities and identifies schedules. A well-developed Operations and Maintenance Plan will:

- Identify all of the key sub plans, procedures, and other documents that define how the facility and personnel are expected to operate.
- Identify the organizational staff plan requirements including staff positions, qualifications, locations, and work hours
- Identify the organizational policies, and procedures for hiring and training of staff
- Identify the types of facilities and fleet vehicles needed.
- Identify the tools, equipment, consumables, spare equipment and spare parts needed.
- Identify any subcontracts necessary for services that are to be performed by subcontractors.
- Identify incident response staff and patrol vehicles
- Identify all of the functions, procedures and manuals necessary to operate and maintain the project.

The Operations and Maintenance Plan should consist of several sub-plans and related documents that will serve to describe the various policies and specific procedures for proper operations and maintenance of the tunnel facility. The hierarchy of a representative Operations and Maintenance Plan is as follows:

Project Management Plans

- Safety Plan
- Security Plan
- Environmental Management Plan
- Emergency Response Plan
- Organization and Staffing Plan
- Budget Plan

Operations and Maintenance Plan

- Operations Manual
  - Operating Procedures
  - Incident Response Plan & Procedures
- Maintenance Manual
  - Asset Management Plan
  - Computerized Maintenance Management System (CMMS)
  - Maintenance Plans
  - Maintenance Procedures

During the planning and feasibility stage of a major urban road tunnel project such as the I-81 corridor it is important to consider the Operations and Maintenance Plan so the facility design accounts for all of the facilities, infrastructure and other items needed to support the proper functionality an operation of the facility. The development of a Concept of Operations Report is the first step to developing the basis of the Operations and Maintenance Plan as a Concept of Operations is necessary to outline a basic understanding of how the facility must function in relation to the overall road and traffic network and identifies the individual agencies, entities and other stakeholders dependent on the overall successful operation of the facility and defines the roles and responsibilities of each.

7.3 CONCEPT OF OPERATIONS

7.3.1 PURPOSE

The Concept of Operations is an umbrella document that provides a high-level definition of overall "traffic corridor", in this case I-81 through Syracuse, the expected traffic operational performance, strategies, and the responsibilities of individual agencies and entities. A Concept of Operations Report should include the following sections:

- Description of Project and Facilities
- Stakeholders
- Corridor Operations Activities
- Tunnel Systems and Operations Activities
- Incident Response and Emergency Response

The following paragraphs briefly explain the purpose of each of these sections in order to demonstrate the content and the importance to this document.

7.3.2 DESCRIPTION OF PROJECT AND FACILITIES

This section of the Concept of Operations Report will provide an overview description of the tunnel facility including all ancillary facilities such as control rooms, support buildings, maintenance shops, and the various mechanical, electrical and traffic control systems necessary to provide safe operation of the tunnel and related facilities. It should also define how the tunnel will operate integrally with the overall traffic corridor.

7.3.3 STAKEHOLDERS

This section of the report serves to identify the key stakeholders, their roles/responsibilities and jurisdictional boundaries. The project stakeholders typically include: the owner/operator, city and state transportation agencies, law enforcement agencies (state and local police), fire service agencies (local fire department, state fire marshal), local emergency medical services and other first responders. Each of these stakeholder is anticipated to have some level of participation in the safe operation and/or incident response activities along the entire traffic corridor and within the tunnel and therefore their input and participation is required during the development of the Concept of Operations Report. This section of the report should also outline each stakeholder's jurisdictional boundaries for traffic operations, security, enforcement and emergency response within the corridor.

7.3.4 TRAFFIC CORRIDOR OPERATIONS ACTIVITIES

Due to the integrated nature of the tunnel and upstream and downstream roadways serving the entire traffic corridor, it is necessary to establish the performance goals and strategies of the overall traffic corridor operations in order to define the performance requirements of the tunnel operations. The assumed primary operational objectives of any traffic corridor is to keep traffic flowing in a safe and efficient manner and to effectively manage different potential incidents and modes of operation. This section of the Concept of Operations report is intended to identify the circumstances where various agencies need to closely coordinate their operational aspects to support these objectives and where necessary develop agreements between the operating agencies and entities to clearly define roles and responsibilities.

7.3.5 INTEGRATION OF TUNNEL SYSTEMS AND OPERATIONS

Several mechanical, electrical and traffic control systems are necessary to support the safe operation of the tunnel and supporting facilities, therefore the Concept of Operations Report needs to include section that identifies the purpose of each operating system and functional description as to how each of these systems and subsystems is expected to operate. This section will describe the structure and logic of how these systems are to be integrated and identify the subsystems that must be monitored and controlled, either automatically or manually. This section of the report is critical to the basic operation of the tunnel and the future development of the systems operating procedures and incident response procedures. Figure 27 below provides a graphical overview of the concept for integrating the monitoring and control of the functioning systems within the tunnel through a centralized control and operation facility. Figure 28 shows an example control room.

7.3.6 INCIDENT RESPONSE AND EMERGENCY RESPONSE PLANNING

This section of the Concept of Operations Report establishes the foundation for the coordinated response to the variety of traffic incidents and events by the tunnel operator and/or other appropriate response agencies. An incident within a road tunnel, whether a minor vehicle breakdown, vehicular collision, or medical emergency, has a high potential to create traffic backups and slowdowns primarily due the lack of dedicated breakdown lane. As a result the potential for additional vehicular mishaps increases due to these rapid traffic slowdowns and congestion.

Depending upon the type of incident, the tunnel operators may be required to notify local fire/life safety agencies, deploy project incident response crews, and deploy traffic management plans to direct motorists away from the incident.

Tunnel operators and the first responders play a critical role in the determination of the proper level of incident response and initial incident management operations. The priorities for first responders are first to take such actions as to mitigate any further injury or loss of life, and second, to restore the facility to normal operations as quickly as possible. Each agency responding to an incident at the tunnel has specific priorities and responsibilities. On complex incidents, some of these roles may overlap and the priorities of some of some agencies may affect the ability of other agencies to perform their duties. This section of the report is critical to the proper operation of the tunnel and the future development of the incident response procedures.

In summary the Concept of Operations report is a critical document that serves the planning and design phases of a road tunnel project since its content summarizes the key decisions and operating policies. The report also will also serve as a basis for the development of the actual operating procedures to be implemented within the Operations Plan portion of the Operations and Maintenance Plan.

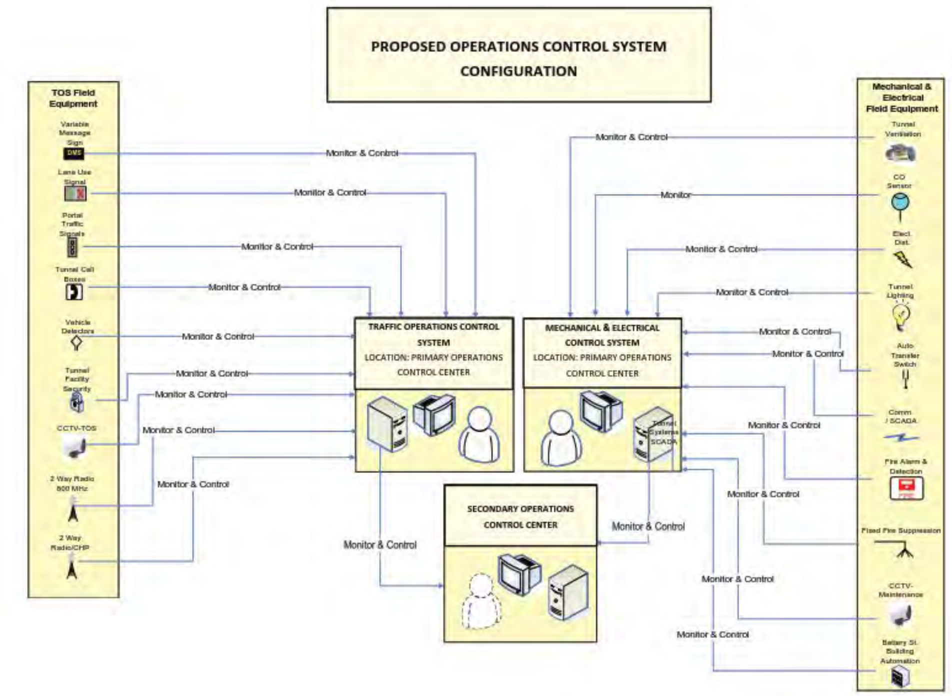


FIGURE 27: Tunnel Centralized Control and Operations Concept

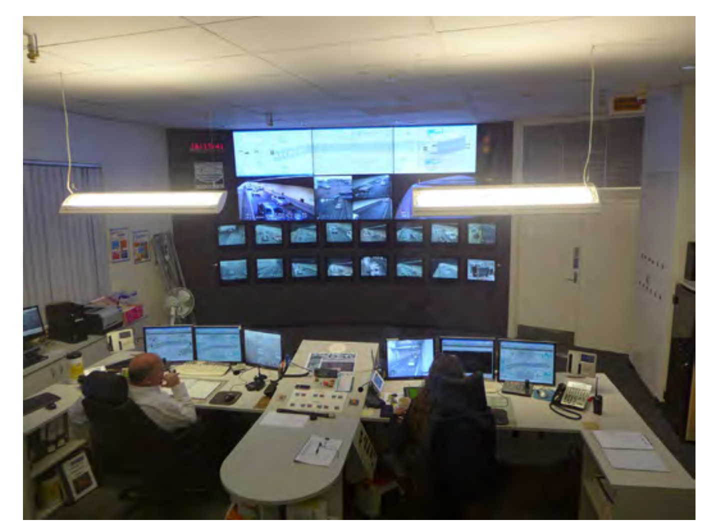


FIGURE 28: Example Control Room

APPENDIX G: EXISTING VIADUCT + VIADUCT FOUNDATIONS

TABLE OF CONTENTS

FIGURES

TABLES

1 EXISTING VIADUCT FOUNDATIONS

1.1 INTERCHANGE AREA OF I-81 AND I-690

The interchange area of I-81 and I-690 is encompassed by 23 bridge structures and 8 retaining walls, as depicted below in Figure 1. Of these, 8 structures are single span bridges while the remainder are multi-span bridges. Most of the piers for these structures are either reinforced concrete hammerhead piers or multi-column reinforced concrete piers with cap beams and supported by a single footing. A few of the piers, typically where I-81 and I-690 cross, are two-column bent systems The vast majority of the structures are composed of deep foundations with cast-in-place concrete piles, with several structures containing only a few piers which are comprised of spread footings on rock, spread footings on soil, or deep foundations with steel battered piles. For a more complete listing of the various pier types and foundation types for each structure, see Table 1.

The superstructures are typically made up of a steel multi-girder system supporting a reinforced concrete deck, with some of the structures supported by steel floor beams at several piers, typically where I-81 and I-690 cross. The roadways in the interchange area vary from 1 to 3 lanes.

FIGURE 1: I-81 & I-690 Interchange Area Structures Key

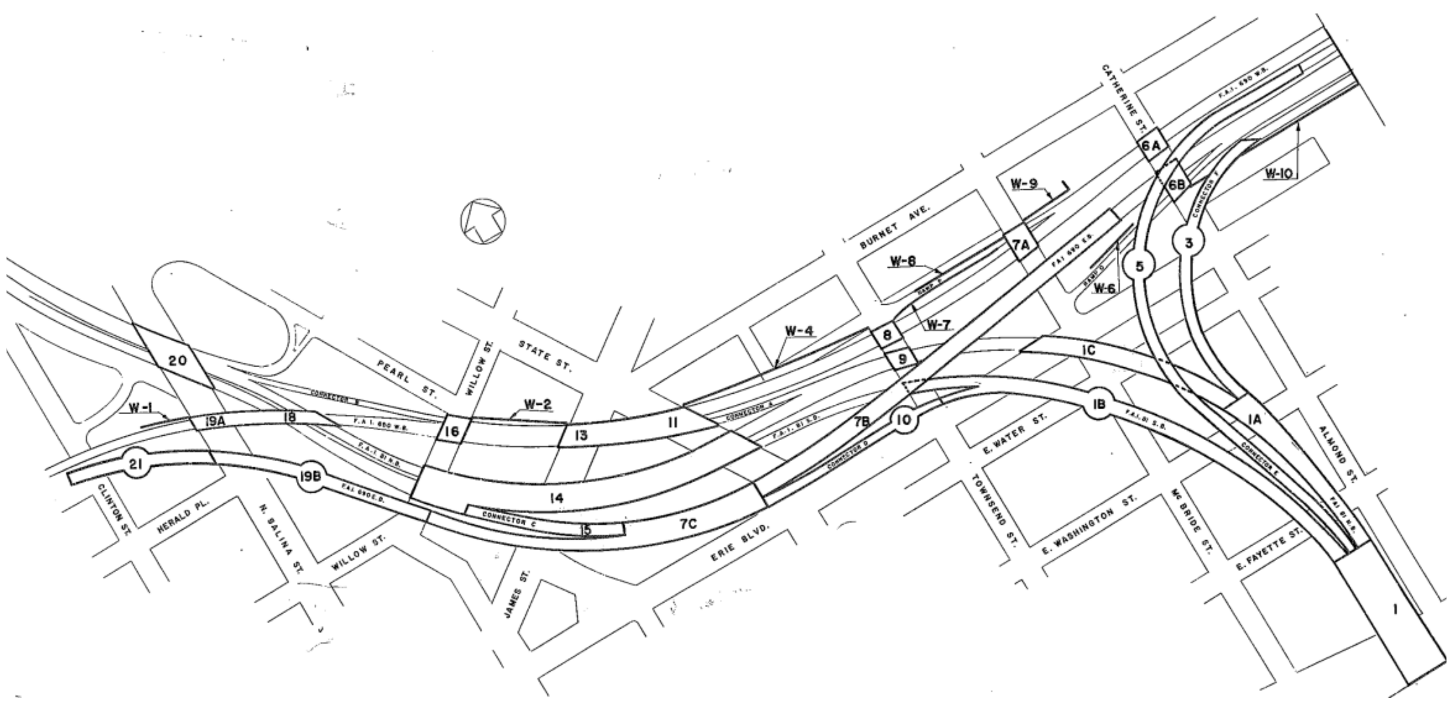


TABLE 1: Interchange Area Substructure Types

Structure	# of Abut.	# of Piers	# of Piers: Multi-col., single footing	# of Piers: Multi-col. bent	# of Piers: Hammerhead	# of Foundation Types: CIP Conc. Piles	# of Foundation Types: Steel Piles	# of Foundation Types: Spread Footing	Pile Lengths
1	-	3	2	1	-	3	-	-	54' - 57'
1A	-	6	6	-	-	6	-	-	19' - 45'
1B	1	15	14	1	-	15	1	-	11' - 45'
1C	1	7	7	-	-	5	-	3	13' - 30'
3	2	8	8	-	-	6	1	3	15' - 30'
5	1	16	-	3	13	12	2	3	13' - 42'
6A	2	-	-	-	-	-	-	2	-
6B	2	-	-	-	-	-	-	2	-
7A	2	-	-	-	-	-	-	2	-
7B	1	11	9	2	-	11	-	1	18' - 53'
7C	-	10	10	-	-	10	-	-	21' - 29'
8	2	-	-	-	-	2	-	-	25'
9	2	-	-	-	-	2	-	-	24' - 28'
10	-	6	-	-	6	6	-	-	15' - 30'
11 & 13*	4	6	5*	-	1	8	-	2	17' - 29'
14	2	9	9	-	-	11	-	-	22' - 29'
15	-	2	-	-	2	2	-	-	26' - 28'
16	2	-	-	-	-	2	-	-	20'
18	2	1	1	-	-	2	-	1	24'- 26'
19A	2	-	-	-	-	-	-	2	-
19B	-	5	1	-	4	5	-	-	14' - 19'
20	2	1	-	1	-	-	-	3	-
21	1	4	4	-	-	5	-	-	12' - 17'

Notes: * Two of the piers for Structure 11 & 13 are made up of reinforced concrete walls

1.2 I-81 SIZER ST TO GENESEE ST (SOUTH OF INTERCHANGE AREA)

With the exception of the Ramps, this section of the viaduct is comprised entirely of a Two-Column Bent Pier system with reinforced concrete columns. The foundations of the South Abutment and the following 11 piers, which approximately end at Jackson St., are comprised of square footings on rock. For the remainder of this section of the viaduct, approximately to Genesee Street, the foundations are made up of battered steel 10-pile to 17-pile foundations.

Ramps I and II, the I-81 Northbound Exit Ramp and I-81 Southbound Entrance Ramp, are located between Jackson Street and East Adams Street. Ramps III and IV, the I-81 Northbound Entrance Ramp and I-81 Southbound Exit Ramp, are located between Harrison Street and East Genesee Street. The Ramps are comprised of a Two-Column Bent Pier system with walls and abutment before becoming a 2-span or 3-span Single-Column Bent Pier system which then converges with the viaduct. The foundations of Ramps I and II are made up of a steel battered pile system, while the foundations of Ramps III and IV consist of a cast-in-place concrete battered pile system. For listing of the various pier types and foundation types for the structure, see Table 2 and Table 3.

The superstructure for this section of the viaduct is comprised of a steel stringer and floor beam system supporting a reinforced concrete deck with spans ranging from 85' to 120', and a bridge width ranging from approximately 65', where the roadway becomes 2 lanes in each direction, to approximately 108' where the structure converges with the ramps.

TABLE 2: Sizer Street to Genesee Street Foundations

Viaduct				
	Pier Column	Bottom of Footing Elevation	Foundation Type	Piles-Order Length
Sizer Street to Burt Street	South Abutment	438.00 - 440.00	14'-0" square on rock	No piles
	1a-e	406.00	14'-0" square on rock	No piles
	1a-w	406.00	14'-0" square on rock	No piles
	2a-e	406.00	14'-0" square on rock	No piles
	2a-w	406.00	14'-0" square on rock	No piles
	3a-e	406.00	14'-0" square on rock	No piles
	3a-w	406.00	14'-0" square on rock	No piles
	4a-e	406.00	14'-0" square on rock	No piles
	4a-w	406.00	14'-0" square on rock	No piles
	5a-e	397.00	14'-0" square on rock	No piles
Burt Street to Genesee Street	5a-w	397.00	14'-0" square on rock	No piles
	2w	393.76	14'-0" square on rock	No piles
	2e	394.35	14'-0" square on rock	No piles
	3w	393.97	14'-0" square on rock	No piles
	3e	396.81	14'-0" square on rock	No piles
	4w	393.94	14'-0" square on rock	No piles
	4e	393.86	14'-0" square on rock	No piles
	5w	369.45	14'-0" square on rock	No piles
Viaduct				
	Pier Column	Bottom of Footing Elevation	Foundation Type	Piles-Order Length
	5e	390.44	14'-0" square on rock	No piles
	6w	387.45	14'-0" square on rock	No piles
	6e	389.32	14'-0" square on rock	No piles
	7w	384.80	14'-6" square on rock	No piles
	7e	387.89	14'-6" square on rock	No piles
	8w	396.12	14 Steel Piles	26'
	8e	396.00	14 Steel Piles	34'
	9w	396.53	14 Steel Piles	32'
	9e	396.41	14 Steel Piles	38'
	10w	396.19	14 Steel Piles	36'
	10e	396.07	14 Steel Piles	28'
	11w	395.77	14 Steel Piles	30'
	11e	395.60	14 Steel Piles	28'
	12w	395.39	14 Steel Piles	34'
	12e	395.50	14 Steel Piles	32'
	13w	395.07	14 Steel Piles	36'
	13e	395.21	14 Steel Piles	30'
	14w	394.72	13 Steel Piles	38'
	14e	394.67	12 Steel Piles	44'
	15w	395.31	10 Steel Piles	46'
	15e	394.30	14 Steel Piles	42'
	16w	394.32	12 Steel Piles	48'
	16e	394.32	12 Steel Piles	46'
	17w	394.09	10 Steel Piles	52'
	17e	393.34	13 Steel Piles	50'
	18w	393.74	10 Steel Piles	54'
	18e	393.24	13 Steel Piles	56'
	19w	393.39	10 Steel Piles	68'
	19e	392.88	13 Steel Piles	64'
	20w	393.25	10 Steel Piles	74'
	20e	392.54	13 Steel Piles	68'
	21w	393.19	10 Steel Piles	76'

Viaduct				
	Pier Column	Bottom of Footing Elevation	Foundation Type	Piles-Order Length
	21e	392.44	13 Steel Piles	78'
	22w	392.59	10 Steel Piles	82'
	22e	391.84	13 Steel Piles	78'
	23w	392.51	10 Steel Piles	80'
	23e	391.54	13 Steel Piles	84'
	24w	391.77	10 Steel Piles	78'
	24e	391.35	13 Steel Piles	80'
	25w	392.07	14 Steel Piles	80'
	25e	391.83	11 Steel Piles	74'
	26w	393.07	14 C.I.P. Conc. Piles	30'
	26e	392.71	11 C.I.P. Conc. Piles	30'
	27w	393.60	14 C.I.P. Conc. Piles	30'
	27e	393.26	12 C.I.P. Conc. Piles	30'
	28w	394.16	17 C.I.P. Conc. Piles	30'
	28e	393.92	17 C.I.P. Conc. Piles	30'
	29w	393.97	16 C.I.P. Conc. Piles	45'
	29e	394.24	17 C.I.P. Conc. Piles	45'

TABLE 3: Sizer Street to Genesee Street - Ramp Foundations

Pier Column	Bottom of Footing Elevation	Foundation Type	Piles-Order Length
8R1	395.51	12 Steel Piles	25'
8R2	395.75	12 Steel Piles	35'
9R1	395.91	12 Steel Piles	32'
9R2	396.16	12 Steel Piles	40'
27R4	393.31	15 C.I.P. Conc. Piles	30'
28R3	394.32	15 C.I.P. Conc. Piles	30'
29R3	394.40	15 C.I.P. Conc. Piles	45'
29R3	394.40	15 C.I.P. Conc. Piles	45'

1.3 I-690 TO WEST STREET ARTERIAL – WEST OF INTERCHANGE AREA

The major structures of I-690 to the west of the interchange area include the two West Street Arterial Interchange structures, the four I-690 over Onondaga Creek structures, the two I-690 over Franklin Street structures, and the I-690 Westbound over Clinton Street structure.

The West Street Arterial structures are comprised of the I-690 Exit Ramp to West Street (Ramp DD) and the I-690 Westbound Entrance Ramp from West Street (Ramp BB). These structures are a 4-span and 5-span, steel multi-girder system supporting a reinforced concrete deck. The piers of these two structures are reinforced concrete multi-column pier with cap beam, with each pier supported by a single footing with battered cast-in-place concrete piles. The South Abutment of both structures is a spread footing, while the North Abutment of both structures contains battered cast-in-place concrete piles.

The I-690 over Onondaga Creek structures are all comprised of similar superstructure and substructure systems. The footings of piers and abutments are made up of deep foundations with cast-in-place concrete piles. The 3-span structures contain a steel multi-girder system that supports a reinforced concrete deck. These bridges also span across a pedestrian walkway that runs adjacent to the creek on the east side.

The remaining 3 structures, 2 over Franklin Street and 1 over Clinton Street, are single span bridges also with a steel multi-girder system supporting a reinforced concrete deck. Each structure carries three lanes of traffic in one direction. The abutments of the I-690 over Clinton Street Bridge have deep foundations with cast-in-place concrete piles. The abutments of the I-690 over Franklin Street Bridges have deep foundations with vertical and battered steel bearing piles.WW

APPENDIX H: HIGHWAY DESIGN CRITERIA TABLES

TABLE OF CONTENTS

TABLES

1 DESIGN CRITERIA TABLES

Critical Design Elements for Tunnels (Orange, Red, Blue)				
PIN:			NHS (Y/N):	Y
Route No. & Name:		I-81 NB and SB (BoredTunnel and Cut/Cover Tunnel)	Functional Classification:	Urban Principal Arterial - Interstate
Project Type:		Reconstruction	Design Classification:	Interstate (HDM Exhibit 2-1)
% Trucks:		Varies	Terrain:	Rolling
ADT:		Varies	Truck Access/Qualifying Hwy.	Qualifying Highway
Element		Standard	Existing Condition	Proposed Condition
1	Design Speed	50 mph1 HDM Section 2.7.1.1.A	N/A	50 mph
2	Lane Width	12 ft HDM Section 2.7.1.1.B	N/A	12 ft
3	Shoulder Width	Right shoulder 10 ft, Left Shoulder 4 ft HDM Section 2.7.1.1.C Exhibit 2-2 Right and Left Shoulder 4 ft. AASHTO Construction of Road Tunnels	N/A	4 ft
4	Horizontal Curve Radius	833 ft Min (at emax=6%) HDM Section 2.7.1.1.D 2269 ft.min. AASHTO Construction of Road Tunnels	N/A	2286 ft.
5	Superelevation	6% Max. HDM Section 2.7.1.1.E	N/A	TBD
6	Stopping Sight Distance (Horizontal and Vertical)	425 ft Min. HDM Section 2.7.1.1.F	N/A	425 ft
7	Maximum Grade	6% HDM Section 2.7.1.1.G, Exhibit 2.2	N/A	6%
8	Cross Slope	1.5% Min. to 2% Max. HDM Section 2.7.1.1.H	N/A	2%
9	Vertical Clearance (above traveled way)	16 ft Min. HDM Section 2.7.1.1.I	N/A	16 ft
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3	N/A	AASHTO HL-93
11	Pedestrian Accommodations	Complies with HDM Chapter 18	N/A	Yes

TABLE 1: Critical Design Elements for Tunnels (Orange, Red, Blue)

Critical Design Elements for Tunnels (Green)			
PIN:		NHS (Y/N):	Y
Route No. & Name:	I-81 NB and SB (BoredTunnel and Cut/Cover Tunnel)	Functional Classification:	Urban Principal Arterial - Interstate
Project Type:	Reconstruction	Design Classification:	Interstate (HDM Exhibit 2-1)
% Trucks:	Varies	Terrain:	Rolling
ADT:	Varies	Truck Access/Qualifying Hwy.	Qualifying Highway

Element		Standard	Existing Condition	Proposed Condition
1	Design Speed	50 mph1 HDM Section 2.7.1.1.A	N/A	50 mph
2	Lane Width	12 ft HDM Section 2.7.1.1.B	N/A	12 ft
3	Shoulder Width	Right shoulder 10 ft, Left Shoulder 4 ft HDM Section 2.7.1.1.C Exhibit 2-2 Right and Left Shoulder 4 ft. AASHTO Construction of Road Tunnels	N/A	6 ft
4	Horizontal Curve Radius	833 ft Min (at emax=6%) HDM Section 2.7.1.1.D 1500 ft.min. AASHTO Construction of Road Tunnels	N/A	XXXX ft.
5	Superelevation	6% Max. HDM Section 2.7.1.1.E	N/A	TBD
6	Stopping Sight Distance (Horizontal and Vertical)	425 ft Min. HDM Section 2.7.1.1.F	N/A	425 ft
7	Maximum Grade	6% HDM Section 2.7.1.1.G, Exhibit 2.2	N/A	6%
8	Cross Slope	1.5% Min. to 2% Max. HDM Section 2.7.1.1.H	N/A	2%
9	Vertical Clearance (above traveled way)	16 ft Min. HDM Section 2.7.1.1.I	N/A	16 ft
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3	N/A	AASHTO HL-93
11	Pedestrian Accommodations	Complies with HDM Chapter 18	N/A	Yes

TABLE 2: Critical Design Elements for Tunnels (Green)

Critical Design Elements for Interstate (outside tunnel Orange, Red, Blue, Green)				
PIN:			NHS (Y/N):	Y
Route No. & Name:		I-81 NB/SB and I 690 EB/WB	Functional Classification:	Urban Principal Arterial - Interstate
Project Type:		Reconstruction	Design Classification:	Interstate (HDM Exhibit 2-1)
% Trucks:		Varies	Terrain:	Rolling
ADT:		Varies	Truck Access/Qualifying Hwy.	Qualifying Highway
Element		Standard	Existing Condition	Proposed Condition
1	Design Speed	50 mph1 HDM Section 2.7.1.1.A	60 mph	50 mph
2	Lane Width	12 ft HDM Section 2.7.1.1.B	12 ft.	12 ft
3	Shoulder Width	Right shoulder 10 ft, Left Shoulder 4 ft HDM Section 2.7.1.1.C Exhibit 2-2	2-4 ft	10 ft RT 4ft LT
4	Horizontal Curve Radius	833 ft Min (at emax=6%) HDM Section 2.7.1.1.D	1054 ft	1480 ft.
5	Superelevation	6% Max. HDM Section 2.7.1.1.E	7.5%	6%
6	Stopping Sight Distance (Horizontal and Vertical)	425 ft Min. HDM Section 2.7.1.1.F	259 ft	425 ft
7	Maximum Grade	6% HDM Section 2.7.1.1.G, Exhibit 2.2	4%	6%
8	Cross Slope	1.5% Min. to 2% Max. HDM Section 2.7.1.1.H	1.5%-2.0%	2%
9	Vertical Clearance (above traveled way)	16 ft Min. HDM Section 2.7.1.1.I	14 ft	16 ft
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3	H20	AASHTO HL-93
11	Pedestrian Accommodations	Complies with HDM Chapter 18	N/A	Yes

TABLE 3: Elements for Interstate (outside tunnel Orange, Red, Blue, Green)

Critical Design Elements for Urban Principal Arterials (Orange, Red, Blue, Green)				
PIN:			NHS (Y/N):	Y
Route No. & Name:		Almond Street	Functional Classification:	Urban Principal Arterial
Project Type:		Reconstruction	Design Classification:	Urban Arterial
% Trucks:		Varies	Terrain:	Rolling
ADT:		Varies	Truck Access/Qualifying Hwy.	Qualifying Highway
Element		Standard	Existing Condition	Proposed Condition
1	Design Speed	35 mph HDM Section 2.7.1.1.A	35 mph	35 mph
2	Lane Width	11'(Min.) HDM Section 2.7.1.1.B Exhibit 2-4a	11 ft.	11 ft
3	Shoulder Width	0'-0" / 6'-0" HDM Section 2.7.2.4.C	1 ft curb offset	6.000'
4	Horizontal Curve Radius	371 ft. Min HDM Section 2.7.2.4.D	250 ft	470 ft
5	Superelevation	4% Max. HDM Section 2.7.2.4.E	4%	4%
6	Stopping Sight Distance (Hori-zontal and Vertical)	250 ft. Min. (35 mph) HDM Section 2.7.2.4.F	250 ft.	250 ft.
7	Maximum Grade	8% Max. HDM Section 2.7.2.4.G,	8%	7.2%
8	Cross Slope	1.5% Min. to 2.0% Max.	2%	2.0%
9	Vertical Clearance (above traveled way)	14'-6". Min. HDM Section 2.7.2.4.I	Varies 14 ft – 16 ft	16 ft
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3	HS-20	AASHTO HL-93
11	Pedestrian Accommodations	Complies with HDM Chapter 18	N/A	Yes

TABLE 4: Critical Design Elements for Urban Principal Arterials (Orange, Red, Green, Blue)

PIN:			NHS (Y/N):	Y
Route No. & Name:		Various Interstate Direct Connector Ramps(mainline design speed = 50 mph)	Functional Classification:	Urban Principal Arterial - Interstate
Project Type:		Reconstruction	Design Classification:	Ramps (Direct Connection)
% Trucks:		Varies	Terrain:	Rolling
ADT:		Varies	Truck Access/Qualifying Hwy.	Qualifying Highway
Element		Standard	Existing Condition	Proposed Condition
1	Design Speed	40 mph HDM Section 2.7.5.2.A	Varies	40 mph
2	Lane Width	15 ft HDM Section 2.7.5.2.B Exhibit 2-9	Varies	15 ft
3	Shoulder Width	3'-0" / 6'-0" HDM Section 2.7.5.2.C	Varies	3'-0" / 6'-0"
4	Horizontal Curve Radius	485' min. (40 mph) HDM Section 2.7.5.2.D	Varies	500 ft
5	Superelevation	6% Max. HDM Section 2.7.5.2.E	Varies	6%
6	Stopping Sight Distance (Hori-zontal and Vertical)	305 ft Min. (40 mph) HDM Section 2.7.5.2.F	Varies	305 ft
7	Maximum Grade	6% Max. (40 mph) HDM Section 2.7.5.2.G,	Varies	6%
8	Cross Slope	1.5% - 2%	Varies	1.5%-2%
9	Vertical Clearance (above traveled way)	16 ft Min.HDM Section 2.7.5.2.I	Varies	16 ft
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3	N?A	AASHTO HL-93
11	Pedestrian Accommodations	Complies with HDM Chapter 18	N/A	Yes

TABLE 5: Critical Design Elements for Interstate Direct Connector Ramps (Orange, Red, Green, Blue)

Critical Design Elements for Semi Direct and Diagonal Ramps (Orange, Red, Green, Blue)				
PIN:			NHS (Y/N):	Y
Route No. & Name:		Various Interstate Diagonal Ramps (mainline design speed = 50 mph)	Functional Classification:	Urban Principal Arterial - Interstate
Project Type:		Reconstruction	Design Classification:	Ramps (SD and Diag.)
% Trucks:		Varies	Terrain:	Rolling
ADT:		Varies	Truck Access/Qualifying Hwy.	Qualifying Highway
Element		Standard	Existing Condition	Proposed Condition[2]
1	Design Speed	30 mph HDM Section 2.7.5.2.A	Varies	30 mph
2	Lane Width	HDM Section 2.7.5.2.B Exhibit 2-9	Varies	15 ft.
3	Shoulder Width	3'-0" / 6'-0" HDM Section 2.7.5.2.C-	Varies	3'-0" / 6'-0"
4	Horizontal Curve Radius	231 ft Min (30 mph) HDM Section 2.7.5.2.D	Varies	238 ft
5	Superelevation	6% Max. HDM Section 2.7.5.2.E	Varies	6%
6	Stopping Sight Distance (Horizontal and Vertical)	200 ft Min. (30 mph) 305 ft Min. (40 mph) HDM Section 2.7.5.2.F	Varies	200 ft.
7	Maximum Grade	7% Max. (30 mph) HDM Section 2.7.5.2.G,	Varies	7%
8	Cross Slope	1.5% - 2%-	Varies	1.5% - 2%
9	Vertical Clearance (above traveled way)	16 ft Min.HDM Section 2.7.5.2.I	Varies	16 ft
10	Design Loading Structural Capacity	Specifications AASHTO HL-93 Live Load and NYSDOT Design Permit Vehicle BM Section 2.6, HDM 19.5.3	N/A	AASHTO HL-93
11	Pedestrian Accommodations	Complies with HDM Chapter 18	N/A	Yes

TABLE 6: Critical Design Elements for Semi Direct and Diagonal Ramps (Orange, Red, Green, Blue)

APPENDIX I: UTILITIES

TABLE OF CONTENTS

FIGURES

TABLES

1 UTILITIES

1.1 OVERVIEW

A preliminary screening has been performed to identify major utilities that could be impacted by the tunnel project (including viaducts and community grid), especially those that would be intersected by open cut construction at the tunnel portals, including:

- Southern Portal
- Central Community Grid
- BFAS Steam Distribution and Chilled Water Systems
- Northern Portals
- West Street

Research has included onsite observations, reviewing original construction plans, and current survey base mapping. Further investigation will be required during the planning and design phases.

1.2 SOUTHERN PORTAL

Shows the southern end of the tunnel project. The proposed layout is somewhat similar in all four tunnel alternatives. Heading north, I-81 descends into tunnel, requiring the temporary closure of Martin Luther King Boulevard.. Four utilities pass along this road, at the location of the proposed tunnel approach (Figure 1):

- (Yellow) 12 Inch Utility Gas Line Underground National Grid Gas Piping
- (Red) Utility Electric Line National Grid High Voltage Electric Power Lines and Duct Banks
- (Aqua Blue) 30 Inch Onondaga County Water Authority Piping Utility Waterline
- (Green) 24 Inch Utility, Sewer, Sanity Under Ground Piping

Depending on the depth of the exiting utilities it may be possible to work around them without disturbance. However, it is likely that relocation of some or all utilities will be required.

The Blue Alternative and Red Alternative bored tunnels will pass below National Grid's South McBride Street electrical substation (Figure 2). Settlement should be minimal, but a risk assessment should be conducted during detailed design, deformation monitoring performed, and contigency measures planned.

Additional details of utilities identified at the southern portal are provided in the tables below.

1.3 ALMOND STREET CORRIDOR - COMMUNITY GRID AND GREEN ALTERNATIVE

The Community Grid area, along the Almond street Corridor, is surrounded by low income housing / rental properties and Syracuse University resident housing. Utilities have been identified along Almond Street as follows:

- Catch Basin - City and County Owned
- Water Valves
- Electric Duct Banks - City Owned / University Owned
- Manholes, Electric
- National Grid Overhead Wires / University Owned Overhead Wires
- National Grid Electrical Pullbox / University Owned Pullbox
- National Grid Underground Electrical Primary Supply High Voltage
- Syracuse University Underground Electrical Primary Supply
- Fire Department Connections / Fire Hydrants
- National Grid Street Lighting Above Grade / Below Grade
- Syracuse University Street Lighting Above Grade / Below Grade
- Windstream Fiber Optic Duct Bank
- Manholes City Owned / County Owned
- Overhead Wires and Cables (Telecommunication and TV Cable)
- Sanitary Sewer City Owned / County Owned
- Combined Sewer University Owned
- Sewer Cleanout
- Sewer Manholes
- Storm Sewer City / County Owned
- Storm Sewer University Owned
- Traffic Control Devices
- Underdrain
- Electric Transformer Stations

Figure 3 below shows utilities identified at a typical intersection (East Adams Street and Almond Street).

For most of the length of Almond Street (Burt St to Genesee St) utilities such as these are above the bored tunnel, and are unlikely to require special protection measures. Demolition of the existing I-81 viaduct and reconstruction of Almond Street will need to be carefully planned so not to impact the utilities.

South of Burt Street, utilities associated with the University Steam Plant will require special consideration (described below)

North of Genesee Street, the Green Alternative transitions from bored tunnel to cut and cover. All utilities currently buried along Almond Street between Genesee and Washington Street will need to be relocated. Utilities running eat-west along Fayette St and Washington St will need to be permanently relocated to avoid the I-81 tunnel as it rises from the ground.

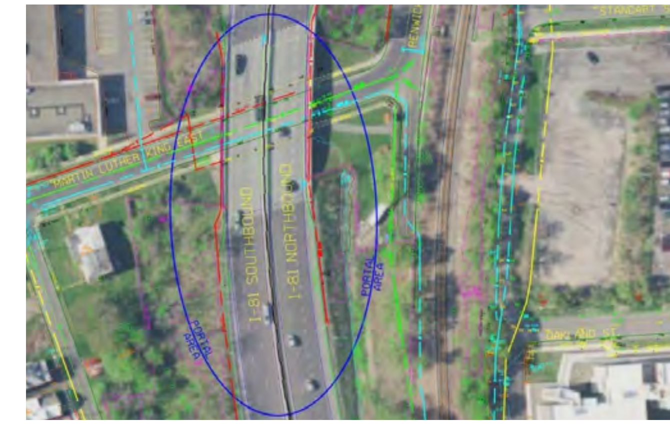


FIGURE 1: Utilities at Martin Luther King Boulevard – near the southern tunnel portal

FIGURE 2: South McBride Street Electrical Substation

FIGURE 3: Utilities at East Adams Street at Almond Street Intersection

1.4 BFAS STEAM DISTRIBUTION AND CHILLED WATER SYSTEMS

The BFAS Steam Distribution and Chilled Water Systems Facility operation has a major role in the operation and functionality of Syracuse University's daily operations. The facility is in operation 365 days a year, 24 hours a day, supplying services to Syracuse University academic buildings, research buildings and residence halls. The facility also supplies 40% of its services to neighboring hospital facilities and SUNY College of Environmental Science & Forestry.

BFAS Facility is located between East Taylor Street to the north, Almond Street to the east, Burt Street to the south and Oakwood Avenue to the west. The main connectivity corridor for the facility utilities to Syracuse University, medical facilities and SUNY ESF cross east-west under Almond Street. Facility utilities are at noted depths between 5 feet to 8 feet below pavement surface along the Almond Street corridor. At the time of the community grid conceptual design phases, the utilities within the BFAS Facility and surrounding premises should be reviewed at a more major scale due to the facilities 24 hour operation schedule.

The BFAS facility is powered by natural gas with two 12" supply lines branching off the National Grid primary main on Burt Street, along with its 12" supply lines from the eastern shoulder of Almond Street reaching a gas-cut station on the corner of East Taylor and Almond Street. See Figure 4 below.

The BFAS Facility supplies four steam condensate lines A, B, C & D, three of which are located leaving the facility East Taylor Street heading in the eastern direction toward University Hill. Lines A and B cross Almond Street and continue toward the University, where line D branches into the southern direction parallel to Almond Street in the southbound direction parallel to the eastern BFAS property line. Line D crosses Burt Street continuing in the southern direction parallel to Almond Street crossing at the Renwick Avenue and Van Buren Street intersection beginning its accent up the University Hill. Condensate line C picks up over in the University property. The BFAS facility has 161 active steam vaults throughout its areas of services. Figure 5 shows a replacement of a steam vault.

The BFAS Facility supplies chilled water service to 28 Syracuse University campus facilities providing services such as air conditioning. The facility has two 24 inch lines, one supply and one return that cross the Almond Street corridor in the east and west direction. Once the supply and return reach campus facilities, there is a complex below-grade system that feeds the University buildings. Figure 6 shows the BFAS utility locations.

The BFAS facility is located immediately above the Orange Alternative bored tunnel alignment. The 115kV primary electrical feed for the plant runs along Burt, street above the bored tunnels. The feeder would need to be monitored to ensure any settlement is within permissible limits.

As noted in Appendix F, limited plant equipment is located directly above the bored tunnel alignment, but several buried and elevated ducts need to be protect. Settlement from the TBM should be minimal, but various construction activities may be required on the property, such as pulling abandoned piles from the path of the TBM, and jet grouting. Utilities would need to be protected from grout intrusion. The sensitivity of ducts and equipment to settlement would need to be determined, and displacements carefully monitored during construction.

Several steam lines run along E Taylor St, and would be passed beneath by both the Orange Alternative TBMs and the Green Alternative TBM. Settlement should be minimal but would need to be monitored.

The demolition of the existing I-81 viaduct and reconstruction as ramps to feed into the community grid will need to be carefully planned and executed to avoid impacts to steam plant utilities, and others.

FIGURE 4: BFAS 1st Cut Gas House-12" Natural Gas Pipe Line at 600-800psi

FIGURE 5: Steam Vault Replacement at Southeast Corner of South McBride Street and East Taylor Street

FIGURE 6: BFAS Utility Locations

1.5 RED ALTERNATIVE – NORTH PORTAL

The North Portal of the Red Alternative is located within the existing I-81 interstate right of way, north of Butternut Street The TBM will pass beneath major sewer and electrical utilities on Butternut. No disruption to these services are anticipated. No major utilities are anticipated within I-81, as the cut and cover tunnel transitions to grade. Additional details are provided in the tables below.

1.6 ORANGE ALTERNATIVE – NORTH PORTAL AND VIADUCT RECONSTRUCTION

The north portal of the Orange Alternative is adjacent to Erie Boulevard. Reconstruction of the I-690 viaduct will span several city blocks. It is anticipated that numerous utility conflicts will be identified during detailed detail. Additional details of utilities identified in this study are provided in the tables below.

1.7 WEST STREET – BLUE ALTERNATIVE

The Blue Alternative requires extensive cut and cover construction along West Street between West Fayette and West Genesee. Primary gas supply lines and 115V feeder cables have been identified. Additional major utilities running east west are anticipated, which will need to be supported across the open cut structures. Additional details of utilities identified in this study are provided in the tables below.

1.8 UTILITY IMPACTS BY ALTERNATIVE

1.8.1 RED ALIGNMENT

Utility impact investigation of the southern red alignment indicates that general utilities include fiber optic cable and communications, utility sewer, utility waterlines, drainage culvert piping, power and natural gas servicing residential housing. It is identified at E. Raynor Avenue. A 48" reinforced concrete sewer pipe runs in the eastern & western direction across the alignment connecting the University to residential housing on S. McBride Street The sewer relocation can parallel Renwick Avenue in the southern direction crossing Martin Luther King Street in the western direction re-connecting the two zones tying back into S. McBride Street Sizer Street has an existing sewer and 24" waterline traveling from Renwick Avenue with main connections at Van Buren Street. Depicting the current cut and cover zone, utilities may be incorporated into the new design to utilize existing paths of service if the portal design is adequate. Utilities present at this portal consisting of fiber optic communications are minimal and parallel I-81 in the north and southbound directions on the east and west sides. Power service crosses at Martin Luther King Street, and can remain in place during construction phases if planned during design phases or be relocated to the south. Natural gas services are present, but service lines will not affect the cut and cover zones, gas lines run in the north & south directions on the east and west sides parallel to I-81. At Martin Luther King Street, Existing I-81 highway illumination lights poles with below grade electric servicing conduit will be removed at time of reconstruction. Utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) Wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes depending on the proposed structures at the design stage.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Southern Portal, MLK. Street, Burt Street, Renwick Avenue					
Cable & Communications	Fiber Optic & Cable Lines	300 lf	X	400 lf	X
Utility Sewer Sanitary	Onondaga County	X	1,198 lf	X	3,200 lf
Water	OCWA Utility Waterline	X	1,253 lf	X	3,100 lf
Drainage Culvert Pipe	Onondaga County	X	300 lf	X	600 lf
Power & Electric	National Grid	1,391 lf	974 lf	2,300 lf	Eliminated during highway reconstruction
Natural Gas	National Grid	X	200 lf	X	400 lf

TABLE 1: Red Alternative Southern Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

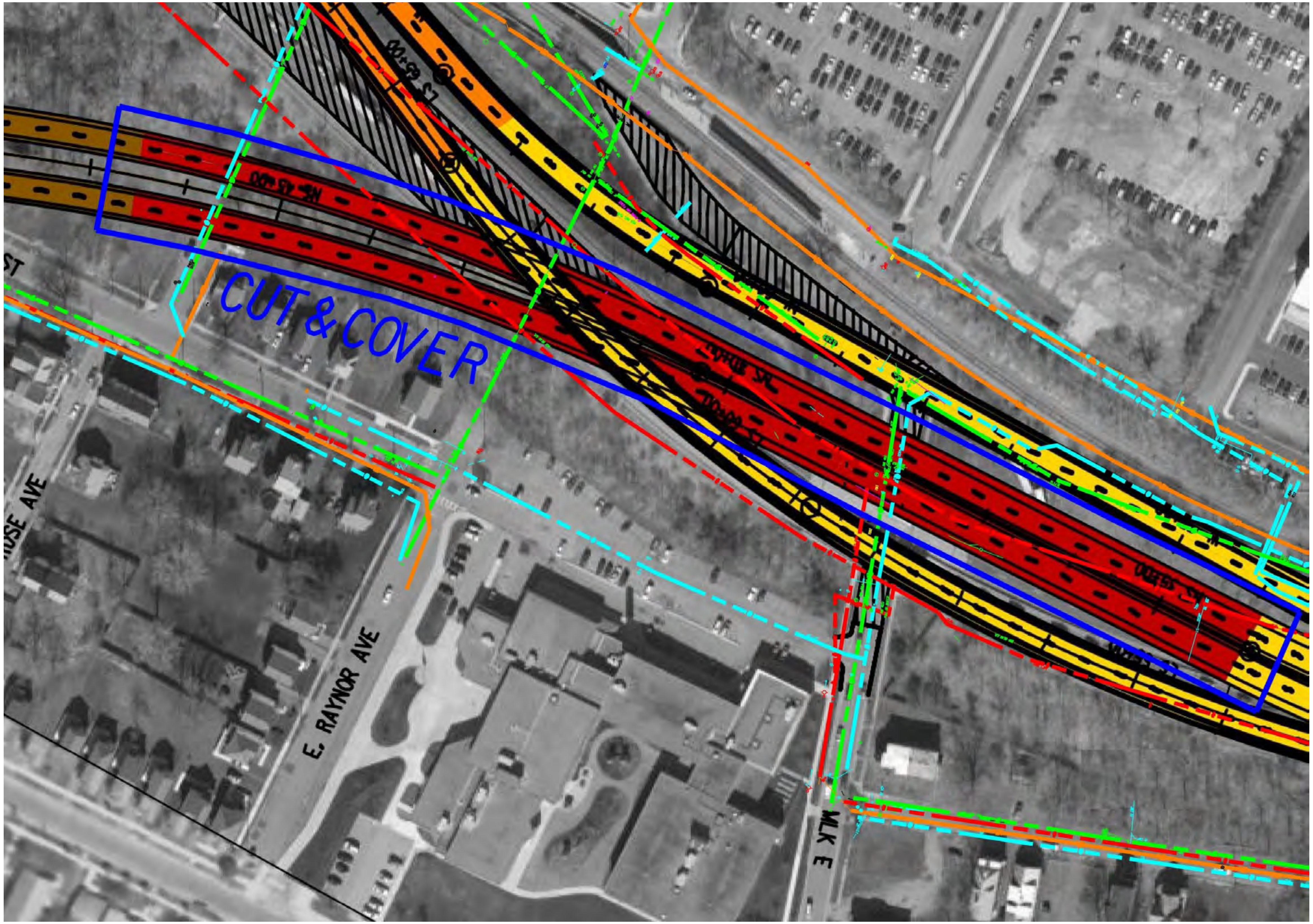


FIGURE 7: Red Alternative Southern Portal Utility Analysis Map

Utility impact investigation of the north red alignment indicates that general utilities include fiber optic cable and communications, utility sewer, utility waterlines, power and natural gas servicing a combination of small business, large commercial space. It is identified at adjacent cross streets running between North State Street on the eastern extents of the alignment & North Clinton Street on the western extents of the alignment will have utility conflicts. These streets affected are West Division Street, Ash Street, Catawba/Spencer Street. Utilities at these conflicted cross streets where the proposed mid-cut & cover zone is located can either be re-directed along Catawba/Spencer Street or the southern end of the portal cut and cover zone. Identified on West Division Street & North Clinton Street is an electrical transformer station that has high voltage supply lines above and below grade parallel to the I81 southbound lane to the west. Some of these lines may cross at Division or Ash Street. At Ash Street natural gas and fiber optic lines are present in the eastern and western directions; these utilities if affected can be relocated to the south at the portal limits. Water and sewer are present but seem to parallel I81 in the northbound and southbound directions which will have little impact other than highway drainage structures, or falling within portal cut and cover excavation limits depending on the total width for cut and cover. Existing electrical conduit is present running in the median of I81 which services highway illumination lighting that could be removed during construction phases. Further investigation will show at the time of design the implications, and re-routes may vary depending on their importance. At time of schematic design utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes or if untouched earth remain at the farthest separation points between routes to reconnect utilities that are disturbed and maintain their original set locations.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Northern Portal E.Division, N.Clinton, Catawba Street					
Cable & Communications	Fiber Optic & Cable Lines	400 lf	368 lf	780 lf	1,600 lf
Utility Sewer Sanitary	Onondaga County	X	400 lf	X	600 lf
Water	OCWA Utility Waterline	X	300 lf	X	500 lf
Drainage Culvert Pipe	Onondaga County	X	200 lf	X	400 lf
Power & Electric	National Grid	600 lf	2,308 lf	1,000 lf	5,500 lf
Natural Gas	National Grid	X	300 lf	X	900 lf

TABLE 2: Red Alternative Northern Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

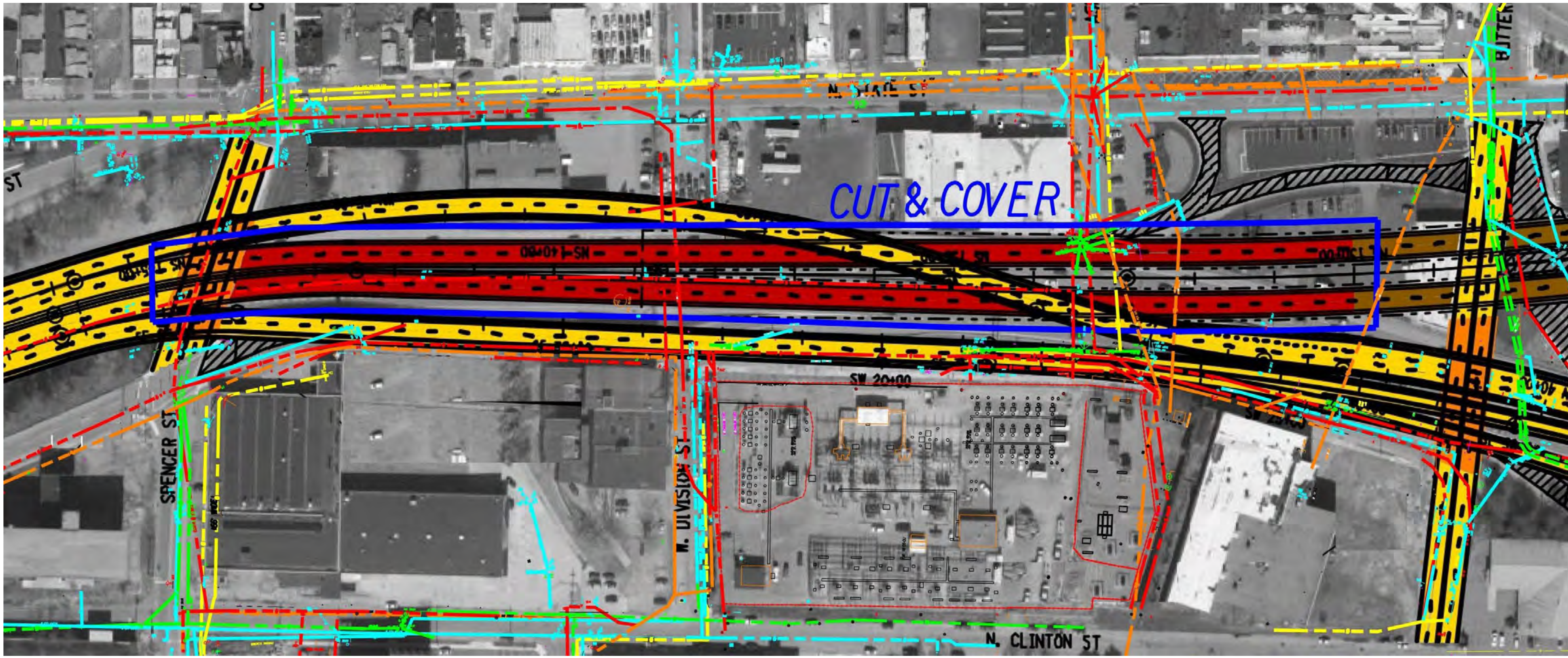


FIGURE 8: Red Alternative Northern Portal Utility Analysis Map

1.8.2 ORANGE ALIGNMENT

Utility impact investigation of the southern orange alignment indicates that general utilities include fiber optic cable and communications, utility sewer, utility waterlines, drainage culvert piping, power and natural gas servicing residential housing. It is identified at E. Raynor Avenue. A 48" reinforced concrete sewer pipe runs in the eastern & western direction across the alignment connecting the University to residential housing on S. McBride Street. The sewer relocation can parallel Renwick Avenue in the southern direction crossing Martin Luther King Street in the western direction re-connecting the two zones tying back into S. McBride Street. Sizer Street has an existing sewer and 24" waterline traveling from Renwick Avenue. with main connections at Van Buren Street. Depicting the current cut and cover zone, utilities may be incorporated into the new design to utilize existing paths of service if the portal design is adequate. Utilities present at this portal consisting of fiber optic communications are minimal and parallel I-81 in the north and southbound directions on the east and west sides. Power service crosses at Martin Luther King Street, and can remain in place during construction phases if planned during design phases or be relocated to the south. Natural gas services are present, but service lines will not affect the cut and cover zones, gas lines run in the north & south directions on the east and west sides parallel to I-81. At Martin Luther King Street, Existing I-81 highway illumination lights poles with below grade electric servicing conduit will be removed at time of reconstruction. Utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) Wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes depending on the proposed structures at the design stage.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Southern Portal, MLK. Street, Burt Street, Renwick Avenue					
Cable & Communications	Fiber Optic & Cable Lines	300 lf	X	400 lf	X
Utility Sewer Sanitary	Onondaga County	X	1,198 lf	X	3,200 lf
Water	OCWA Utility Waterline	X	1,253 lf	X	3,100 lf
Drainage Culvert Pipe	Onondaga County	X	300 lf	X	600 lf
Power & Electric	National Grid	1,391 lf	974 lf	2,300 lf	Eliminated during highway reconstruction
Natural Gas	National Grid	X	200 lf	X	400 lf

TABLE 3: Orange Alternative Southern Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

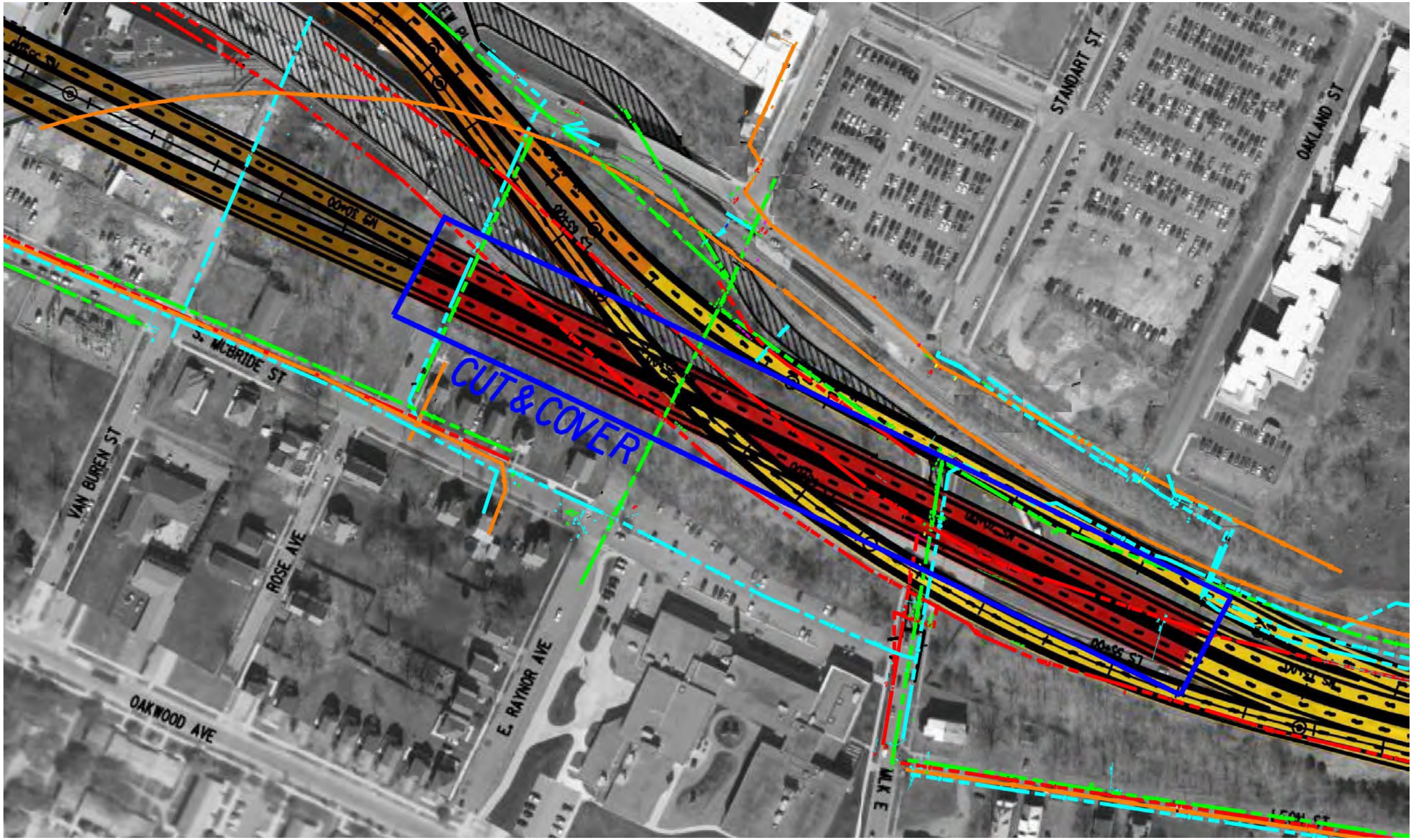


FIGURE 9: Orange Alternative Southern Portal Utility Analysis Map

Utility impact investigation of the northern orange alignment indicates that general utilities include fiber optic cable and communications, utility sewer, utility waterlines, drainage culvert piping, power and natural gas servicing small business, large business & residential housing. It is identified at E. Raynor Avevenue. A 72" 450 lf reinforced concrete sewer pipe runs in the western and southern direction across the alignment connecting East Willow Street & James Street. The sewer relocation can be re-routed on North State Street connecting the two zones avoiding the portal alignment limits. Major utilities are present along the James Street Corridor that runs through the cut and cover zone. These utilities can be re-routed to the north of the portal cut and cover extents if necessary. Depicting the current cut and cover zone, utilities may be incorporated into the new design to utilize existing paths of service if the portal cut and cover design presents an adequate alternative. Utilities present at the southern cut and cover zone consist of fiber optic communications, power & electric, natural gas and city water. These services can be re-routed to the southernmost location of the cut and cover zone if no other alternatives are feasible. At the southernmost point of the cut and cover zone a gas station falls within the zone limits and will need to be removed. Utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) Wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes depending on the proposed structures at the design stage.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Northern Portal E. Washington, E.Genesee Street					
Cable & Communications	Fiber Optic & Cable Lines	200 lf	789 lf	300 lf	3,880 lf
Utility Sewer Sanitary	Onondaga County	X	1,100 lf	X	4,004 lf
Water	OCWA Utility Waterline	X	400 lf	X	2,154 lf
Drainage Culvert Pipe	Onondaga County	X	1,536 lf	X	2,135 lf
Power & Electric	National Grid	250 lf	890 lf	300 lf	4,186 lf
Natural Gas	National Grid	X	1,266 lf	X	3,956 lf

TABLE 4: Orange Alternative Northern Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

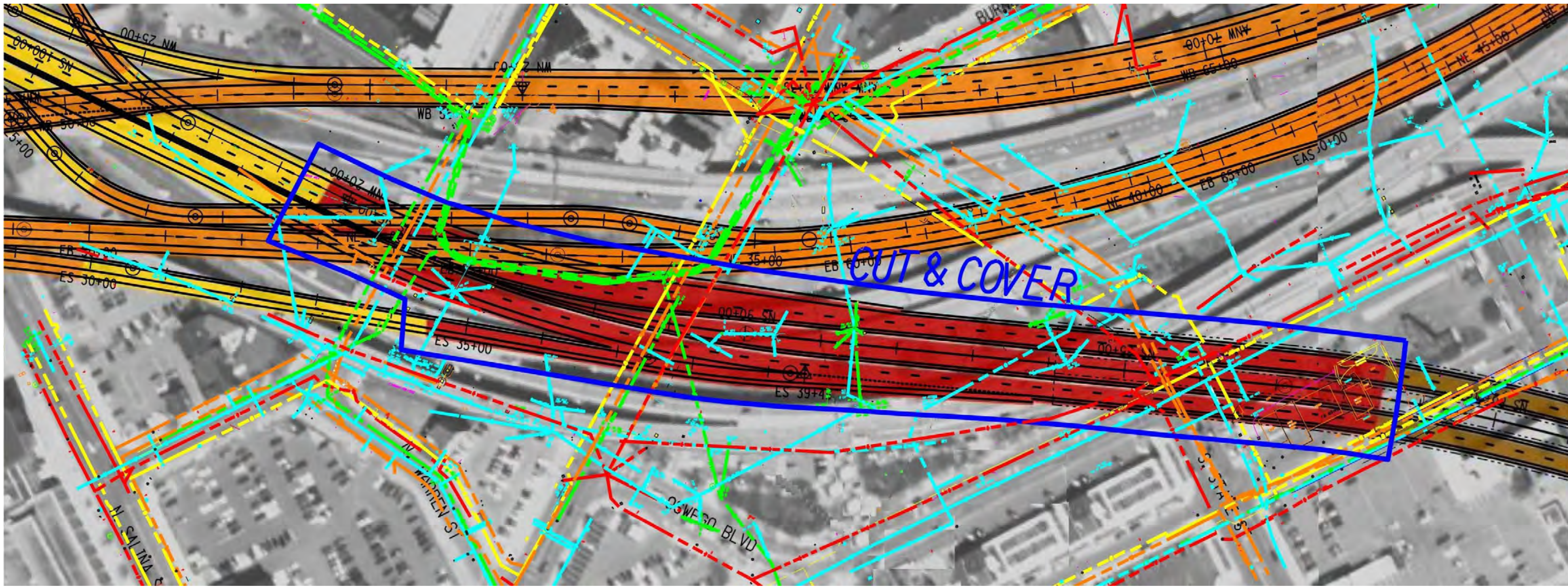


FIGURE 10: Orange Alternative Northern Portal Utility Analysis Map

1.8.3 GREEN ALIGNMENT

Utility impact investigation of the southern green alignment indicates that general utilities include fiber optic cable and communications, utility sewer, utility waterlines, drainage culvert piping, power and natural gas servicing residential housing. It is identified at E. Raynor Avenue. A 48" reinforced concrete sewer pipe runs in the eastern & western direction across the alignment connecting the University to residential housing on S. McBride Street. The sewer relocation can parallel Renwick Avenue in the southern direction crossing Martin Luther King Street in the western direction re-connecting the two zones tying back into S. McBride Street. Sizer Street. has an existing sewer and 24" waterline traveling from Renwick Ave. with main connections at Van Buren Street. Depicting the current cut and cover zone, utilities may be incorporated into the new design to utilize existing paths of service if the portal design is adequate. Utilities present at this portal consisting of fiber optic communications are minimal and parallel I-81 in the north and southbound directions on the east and west sides. Power service crosses at Martin Luther King Street, and can remain in place during construction phases if planned during design phases or be relocated to the south. Natural gas services are present, but service lines will not affect the cut and cover zones, gas lines run in the north & south directions on the east and west sides parallel to I-81. At Martin Luther King Street, Existing I-81 highway illumination lights poles with below grade electric servicing conduit will be removed at time of reconstruction. Utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) Wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes depending on the proposed structures at the design stage.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Southern Portal, MLK. Street, Burt Street, Renwick Avenue					
Cable & Communications	Fiber Optic & Cable Lines	300 lf	X	400 lf	X
Utility Sewer Sanitary	Onondaga County	X	1,198 lf	X	3,200 lf
Water	OCWA Utility Waterline	X	1,253 lf	X	3,100 lf
Drainage Culvert Pipe	Onondaga County	X	300 lf	X	600 lf
Power & Electric	National Grid	1,391 lf	974 lf	2,300 lf	Eliminated during highway reconstruction
Natural Gas	National Grid	X	200 lf	X	400 lf

TABLE 5: Green Alternative Southern Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

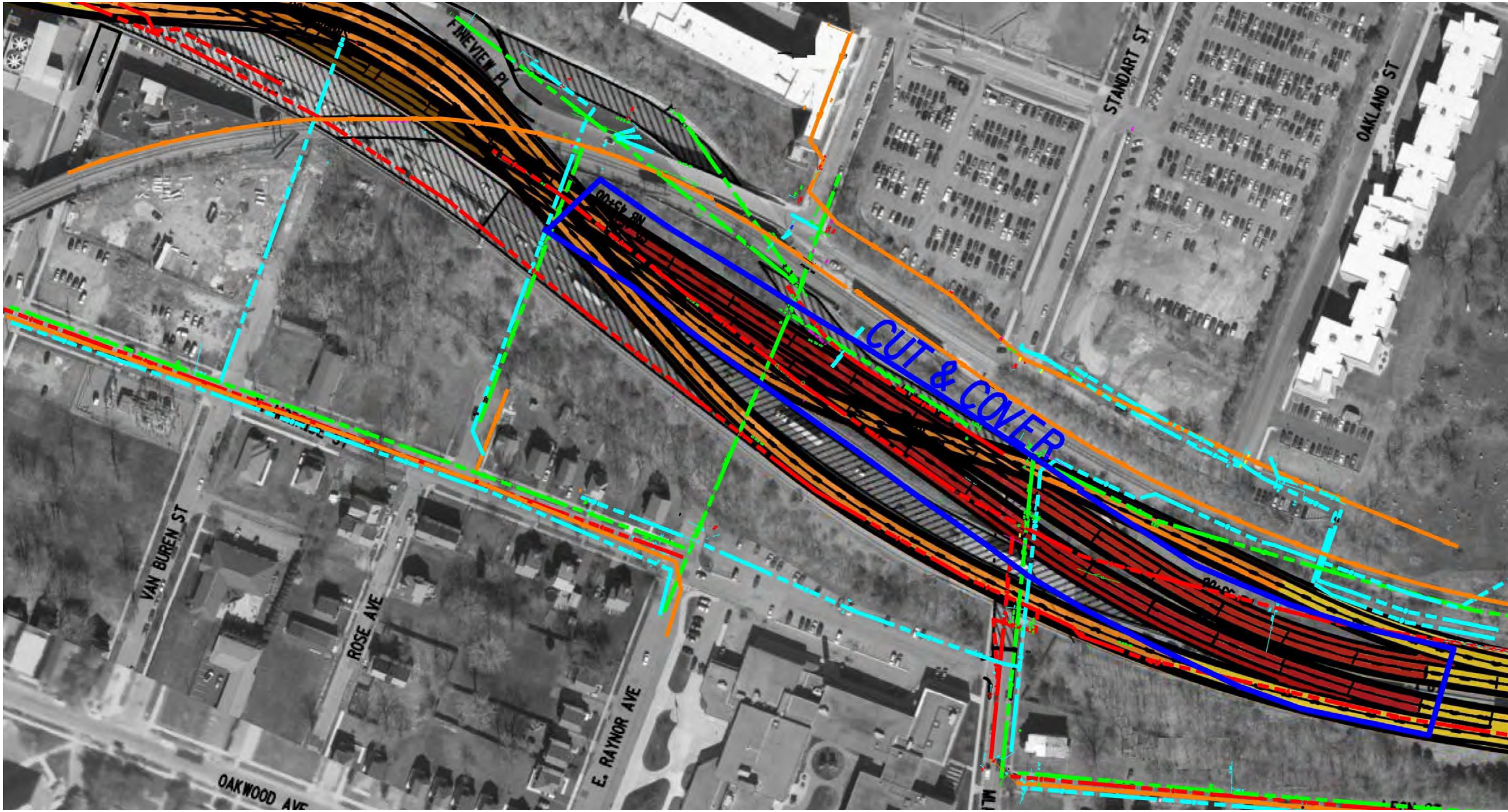


FIGURE 11: Green Alternative Southern Portal Utility Analysis Map

Utility impact investigation of the northern green alignment indicates that general utilities include fiber optic cable and communications, utility sewer, utility waterlines, drainage culvert piping, power and natural gas. It is identified at adjacent cross streets running between South McBride Street on the western extents of the alignment & Almond Street on the eastern extents these utilities are present. Utilities service small commercial businesses & large commercial businesses along East Fayette Street, East Washington Street & East Genesee Street. Depicting the current cut and cover zone, utilities may be incorporated into the new design to utilize existing paths of service if the portal design presents adequate span support during construction phases. It should be noted that utilities running in the north and southern directions along the centerline of the alignment include 12 " water line, 15" sewer line & fiber optic line. These utilities can be relocated to the eastern side of the new portal opening. A smaller portal cut and cover transition allows for various alternatives at the time of planning and design phases. Utilities in conflict can have two alternative routes to be relocated, one being the northern portal opening on East Water Street, the other being in the East Genesee corridor depending on final portal locations. Utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) Wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes depending on the proposed structures at the design stage.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Northern Portal E. Washington, E.Genesee Street					
Cable & Communications	Fiber Optic & Cable Lines	200 lf	968 lf	450 lf	2,072 lf
Utility Sewer Sanitary	Onondaga County	X	635 lf	X	1,435 lf
Water	OCWA Utility Waterline	X	1,773 lf	X	2,785 lf
Drainage Culvert Pipe	Onondaga County	X	380 lf	X	1,760 lf
Power & Electric	National Grid	150 lf	1,050 lf	350 lf	2,272 lf
Natural Gas	National Grid	X	300 lf	X	600 lf

TABLE 6: Green Alternative Northern Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

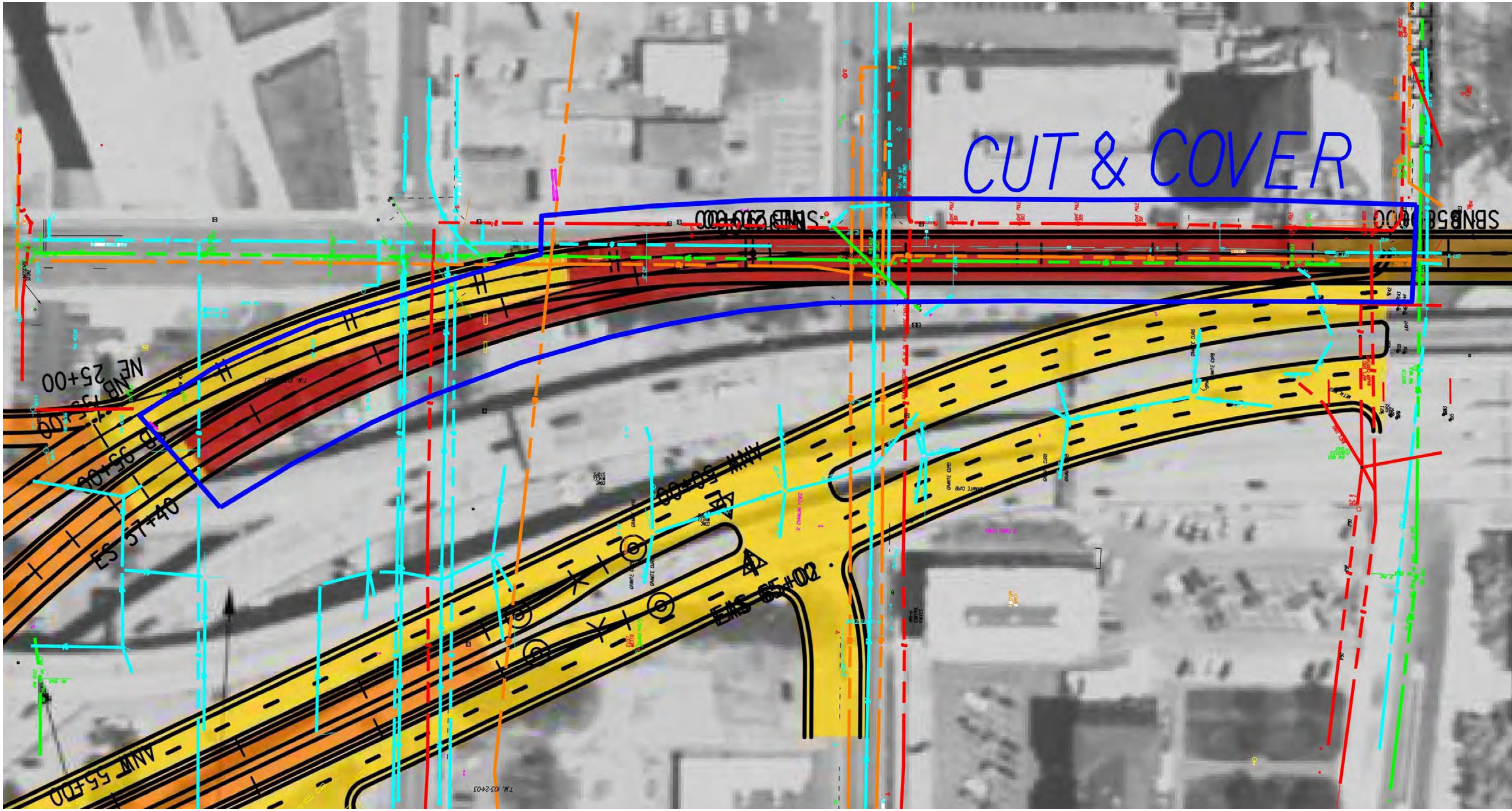


FIGURE 12: Gree Alternative Northern Portal Utility Analysis Map

1.8.4 BLUE ALIGNMENT

Utility impact investigation of the southern blue alignment indicates that general utilities include fiber optic cable and communications, utility sewer, utility waterlines, drainage culvert piping, power and electric, natural gas servicing residential housing. It is identified at E. Raynor Avenue. A 48" reinforced concrete sewer pipe runs in the eastern & western direction across the alignment connecting the University to residential housing on S. McBride Street. The sewer relocation can parallel Renwick Avenue in the southern direction crossing Martin Luther King Street in the western direction re-connecting the two zones tying back into S. McBride Street. Sizer Street has an existing sewer and 24" wat¬erline traveling from Renwick Avenue with main connections at Van Buren Street. Depicting the current cut and cover zone, utilities may be incorporated into the new design to utilize existing paths of service if the portal design is adequate. Utilities present at this portal consisting of fiber optic communications are minimal and parallel I-81 in the north and southbound directions on the east and west sides. Power service crosses at Martin Luther King Street, and can remain in place during construction phases if planned during design phases or be relocated to the south. Natural gas services are present, but service lines will not affect the cut and cover zones, gas lines run in the north & south directions on the east and west sides parallel to I-81. At Martin Luther King Street, Existing I-81 highway illumination lights poles with below grade electric servicing conduit will be removed at time of reconstruction. Utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) Wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes depending on the proposed structures at the design stage.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Southern Portal, MLK. Street, Burt Street, Renwick Avenue					
Cable & Communications	Fiber Optic & Cable Lines	300 lf	X	400 lf	X
Utility Sewer Sanitary	Onondaga County	X	1,198 lf	X	3,200 lf
Water	OCWA Utility Waterline	X	1,253 lf	X	3,100 lf
Drainage Culvert Pipe	Onondaga County	X	300 lf	X	600 lf
Power & Electric	National Grid	1,391 lf	974 lf	2,300 lf	Eliminated during highway recon-struction
Natural Gas	National Grid	X	200 lf	X	400 lf

TABLE 7: Blue Alternative Southern Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

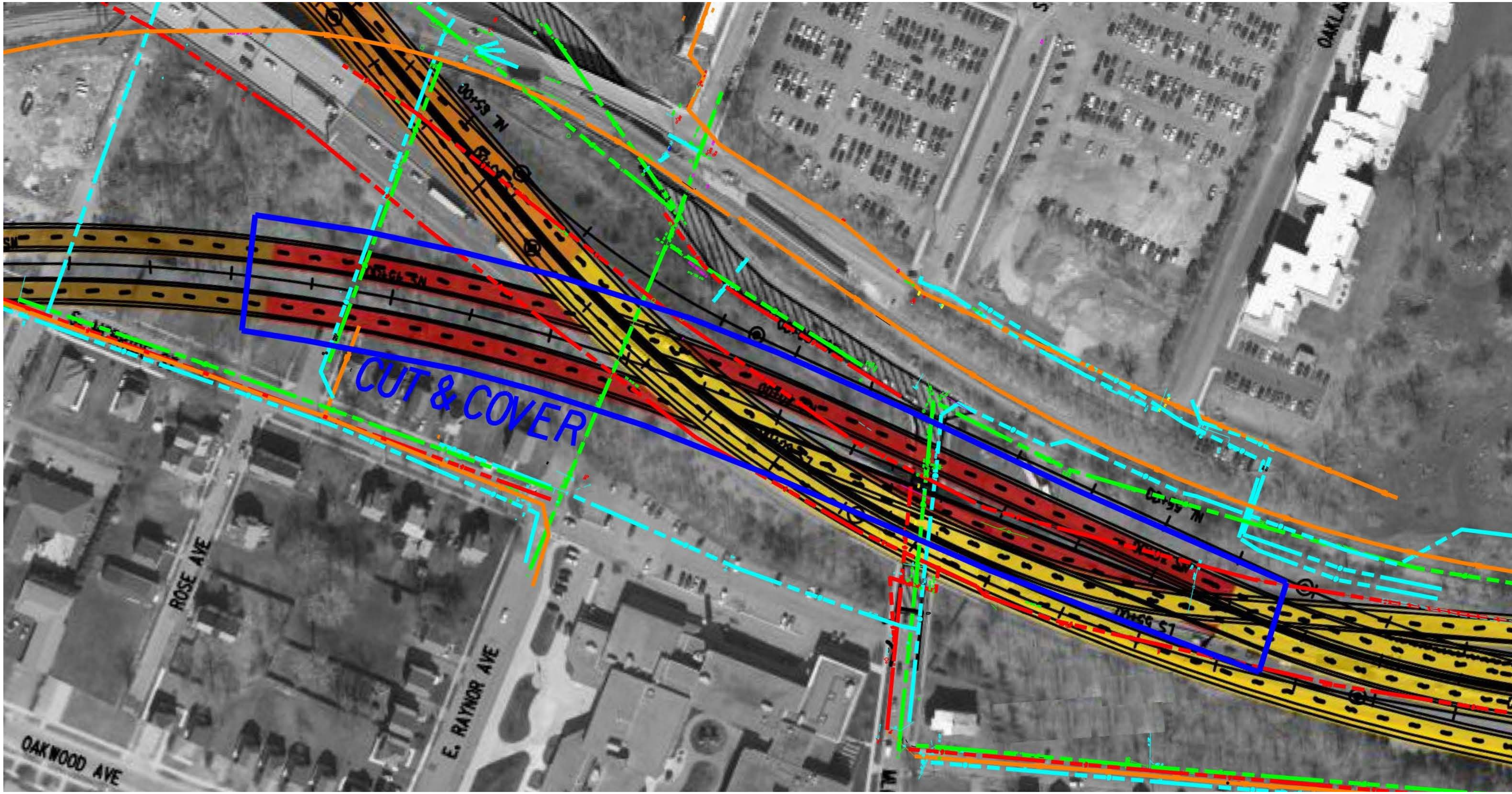


FIGURE 13: Blue Alternative Southern Portal Utility Analysis Map

Utility impact investigation of the mid cut & cover blue alignment indicates that general utilities include fiber optic cable and communications, utility sewer, utility waterlines, power and natural gas servicing a combination of small business, large commercial space, rental residential housing. It is identified at adjacent cross streets running between North West Street on the eastern extents of the alignment & Plum Street on the western extents of the alignment will have utility conflicts. These streets include West Genesee Street, Park Avenue, Tracy Street, Erie Boulevard & West Fayette Street. Utilities at these conflicted cross streets where the proposed mid-cut & cover zone is located can either be re-directed along Northwest Street, or Plum Street. The estimated length between the proposed northbound route and southbound route can vary from an estimated width of 45 ft to a maximum width of 220 ft. At time of schematic design utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes or if untouched earth remain at the farthest separation points between routes to reconnect utilities that are disturbed and maintain their original set locations. This route re-establishing existing connections would take place between Park Avenue & West Genesee Street. If utility relocation alternatives are to re-route at the northern and southern portal points, Belden Avenue at the northern cut and cover terminus can be utilized & West Fayette Street at the most southern cut and cover terminus can be utilized for relocation routes.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Mid Cut & Cover, W.Fayette Street, W.Genesee Street, Plum Street.					
Cable & Communications	Fiber Optic & Cable Lines	150 lf	1400 lf	300 lf	5,546 lf
Utility Sewer Sanitary	Onondaga County	X	2,890 lf	X	3,307 lf
Water	OCWA Utility Waterline	X	2,583 lf	X	6,173 lf
Drainage Culvert Pipe	Onondaga County	X	2,600 lf	X	3,200 lf
Power & Electric	National Grid	300 lf	4.050 lf	500 lf	8,500 lf
Natural Gas	National Grid	X	2,039 lf	X	7,900 lf

TABLE 8: Blue Alternative Mid Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

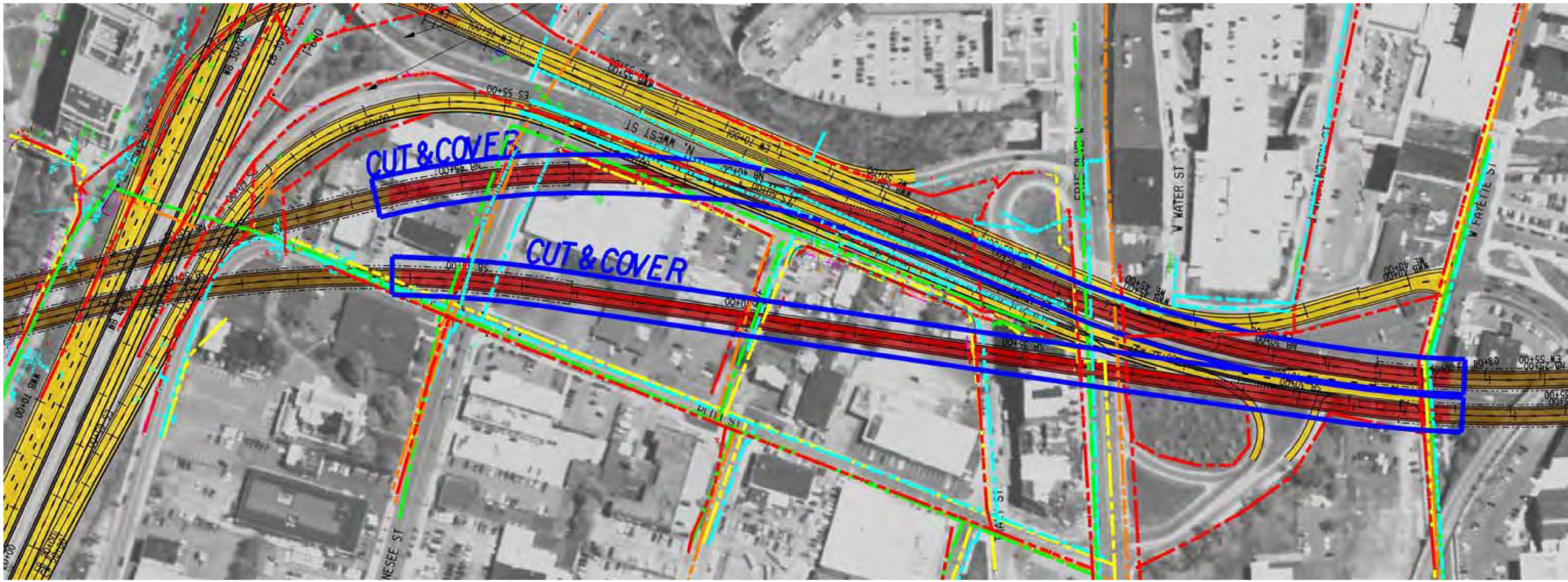


FIGURE 14: Blue Alternative Mid Portal Utility Analysis Map

Utility impact investigation of the northern blue alignment indicates that general utilities includes utility sewer, utility waterlines, power and natural gas servicing a nearby commercial business, these utilities are below surface grade and service surrounding streets, these utilities are part of the utility grid infrastructure system. It is identified at West Court Street & Solar Street that the utilities are present and can be relocated within reason at the cut and cover perimeters southern end. Utility conflict alternatives may also utilize the possibility of being suspended from the eastern support of excavation (SOE) wall to the western support of excavation (SOE) wall with mid-span support at the median for northbound and southbound lanes depending on the proposed structures at the design stage. Due to the limited utilities present the designer will need to decide if its cost effective to plan excavation while maintaining these utilities with little disturbance.

Location & Utilities	Identification	Length of Impact Above Grade	Length of Impact Below Grade	Length of Relocation Above Grade	Length of Relovaqtion Below Grade
Northern Portal, W. Court Street, Solar Street					
Cable & Communications	Fiber Optic & Cable Lines	X	X	X	X
Utility Sewer Sanitary	Onondaga County	X	551 lf	X	1,775 lf
Water	OCWA Utility Waterline	X	506 lf	X	1,851 lf
Power & Electric	National Grid	X	897 lf	X	2,370 lf
Natural Gas	National Grid	X	270 lf	X	1,055 lf

TABLE 9: Blue Alternative Northern Portal Utility Analysis

NOTE: Length of impact represents utilities that will be affected by alignment portal locations.

NOTE: Length of relocation represents utilities that will need re-routing & alternate utility connections at alignment portal locations.

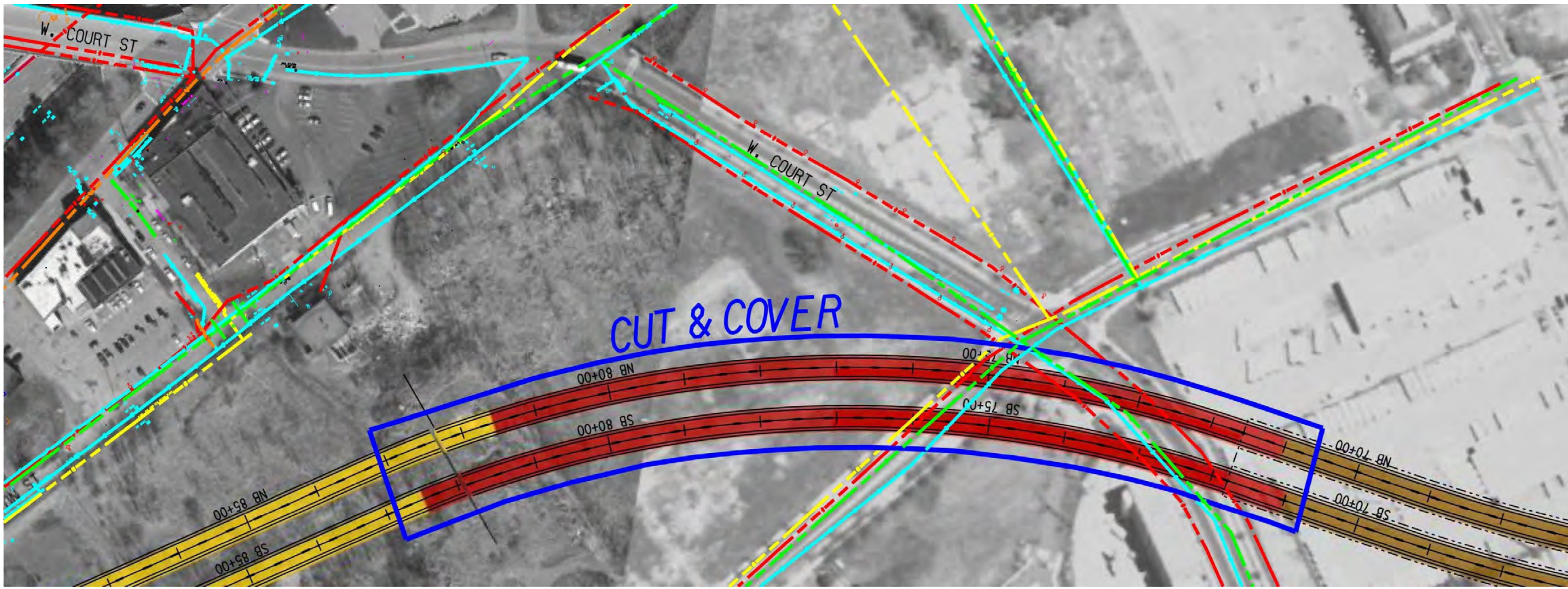


FIGURE 15: Blue Alternative Northern Portal Utility Analysis Map

1.9 UTILITY IMPACT SUMMARY

Utility investigation and identification will be important to the design phases of this project. Maintaining active utility services without community disruption will be a crucial component. Cut and cover structures will have particular impact on utilities, requiring re-routing and alternative utility connections. Maintaining the major utilities around the University Steam Plant will be a significant requirement.

APPENDIX J: PROPERTY IMPACTS

TABLE OF CONTENTS

TABLES

1 PROPERTY IMPACTS

1.1 METHODOLOGY FOR ASSESSMENT OF PROPERTY IMPACTS

The following methodology has been used for identifying impacted properties:

- Prepare conceptual horizontal alignment and profile for each alternative in In-Roads format.
- Prepare conceptual typical tunnel cross sections for Cut and Cover type, Bore- double tube, and bore single (two level) tube.
- The following assumptions were made to determine the extent and type of tunneling in each alternative (cut and cover versus bore):
  - Tunnel section at 35+ feet below existing grade would be bored
  - Tunnel sections that are less than 35 feet below existing grade will be cut and cover
  - Horizontal limits of property impact in the vicinity of the cut and cover tunnels section is determined based on 45-degree influence line extending from bottom of excavation to existing grade.
  - Horizontal limits of property impact in the vicinity of the double tube bored tunnel section is assumed to be 10 feet from the outside edge of each tube (refer to attached typical sections)
  - Horizontal limits of property impact in the vicinity of the single tube (two level) bored tunnel section is assumed to be 10 feet from the outside edges of tube (refer to attached typical sections)
  - Horizontal limits of property impact in the vicinity of the approach section between portal and at-grade varies based on the 45-degree influence line extending from bottom of excavation to existing grade.
  - Horizontal limits of property impact in the vicinity of the approach section at-grade is assumed to be 5 feet from the right edge of pavement in each direction.
- Parcel data for the private properties within the impact limits (as determined based on the above assumptions) were collected from Onondaga County and SOCPA on April 13th, 2017, and presented in the attached spread sheet, noting the following:
  - Any missing data/information within this spread sheet is a result of null values/ no information listed in the Onondaga County Tax Data.
  - The analysis performed utilizing Esri ArcGIS - Model Builder
  - All data projected to NAD83 State Plane New York Central FIPS 3102 (US FT.)
  - Parcel Sizes listed are products of Onondaga County Tax Data (Acres, Front Feet & Depth) and ArcGIS Software (Original Parcel Area & Impacted Area); these values could contain discrepancies and a field survey of the parcel would be needed to obtain accurate sizes of each parcel
  - "Percent Impacted Area" = The percentage of the parcel impacted within the specific options property impact limits
  - Equation used to calculate "Percent Impacted Area" = [("Shape_Area" (ArcGIS calculated impacted area of parcel (sq ft.))) / ("Orig_Area" (ArcGIS calculated geometry of total parcel area (sq ft.)))] * 100
  - Percent Impacted Area values equal to zero indicate an impacted percentage less than 1
  - Property Class Code Definitions retrieved from " https://www.tax.ny.gov/research/property/assess/manuals/prclas.htm"
  - Partial Impact indicates that 50% or less of the parcel area is impacted by the anticipated construction, full Impact indicates that greater than 50% of the parcel area is impacted by the anticipated construction. However, fore value assessments it is assumed that any impact, partial or full will result in full acquisition irrespective of percentage of lot size.
  - Permanent Easement is assumed required on all properties that are located directly above the structure limits of bored section of tunnel.
  - Properties owned by Public Agency are highlighted in the list of impacted properties

A table summarizing the land use of all impacted properties, under each of the four alternatives is provided in Section 5. Each table provides estimated needs for easements, partial acquisitions, and full acquisitions and estimates the costs for total takings per alternative.

- Permanent Easements
  - Permanent Easements will be required for mined tunnels, cut-and-cover tunnels, open approach excavations and depressed roadways.
- Partial Acquisitions
  - Partial Acquisitions will be required for cut and cover impacts that significantly affect the future use of the property
- Full Acquisitions
  - Full Acquisitions will be required where the amount of taking essentially renders the remaining property without value, at least during construction. This occurs in areas of cut and cover construction or above grade construction. This includes areas where tunnel construction requires demolition of an occupied structure.

1.2 MINED TUNNELS

1.2.1 BI-LEVEL TUNNEL

The bi-level tunnel will have an excavated diameter of approximately 60 feet. A permanent sub-surface easement approximately 75 feet wide will be required for tunnel constructed within public right-of-way.

For tunnel reaches outside the public right-of-way, a wider surface easement and a covenant will be required with respect to deep and shallow foundations. The surface easement should be extended to 85 feet wide. The covenant should stipulate what future buildings and building foundations are permissible above the tunnel (see below). Unless the tunnel is fully in rock, the covenant should state that no deep foundations can be installed within the surface easement, that load transfer of deep foundations cannot occur less than 10 feet below the tunnel invert, and that the load-bearing element (drilled pile or caisson) should be included within a steel casing to assure that no inadvertent load transfer occurs above the covenanted depth below the tunnel invert.

This is similar to restrictions the Port Authority of New York and New Jersey (PANYNJ) imposed on a high-rise structure straddling the PATH tunnels immediately west of the Exchange Place Station in Jersey City, New Jersey.

Surface structures supported on shallow foundations may be constructed over the tunnel, provided that numerical modeling indicates that the tunnel lining will not be overstressed.

1.2.2 SINGLE LEVEL TUNNEL

The single level tunnel alternative will consist of two parallel, uni-directional tunnels with an excavated diameter of approximately 43 feet and a 25 foot wide pillar between tunnels. A permanent easement of 120 feet will be required for tunnel constructed within public right-of-way.

For tunnel reaches outside the public right-of-way, a wider surface easement and a covenant will be required with respect to deep and shallow foundations. The surface easement should be extended to 130 feet.

The covenant should state the following:

- No deep foundations can be installed within the surface easement, except that deep foundation elements can be installed along the pillar centerline and no closer than 15 feet to a cross passage
- Load transfer of deep foundations cannot occur less than 10 feet below the tunnel invert
- Load-bearing elements (drilled pile or caisson) should be included within a steel casing to assure that no inadvertent load transfer occurs above the covenanted

depth below the tunnel invert.

Surface structures supported on shallow foundations may be constructed adjacent to over the tunnel, provided that numerical modeling indicates that the tunnel lining will not be overstressed.

1.3 CUT-AND-COVER TUNNELS, OPEN APPROACH EXCAVATIONS AND DEPRESSED ROADWAYS

- Permanent Easements
  - Permanent easements for cut-and-cover tunnels, open approach tunnels and depressed roadways should extend 10 feet beyond the footprint defined by the exterior of the Support of Excavation (SOE) wall.
  - For structures located outside of public right of way, buildings can be constructed over the cut-and-cover tunnels provided that the foundation load is no greater than a uniform surcharge of 600 psf. Zones with capacity for taller (heavier) structures could be incorporated into the tunnel design for a cost premium.

- Temporary Easements
  - Temporary easements for the above classes of structures should extend 30 feet beyond the exterior of the SOE wall to accommodate temporary tieback installation.
  - Additional temporary easements will be required during construction for offices, storage, and lay-down areas.

1.4 ANALYSIS OF INFLUENCE OF FUTURE CONSTRUCTION ON TUNNEL LOADING

A study was performed to evaluate the potential for future development over the I-81 bored tunnels. Simplified Boussinesq analyses were performed to assess the order of magnitude of the additional vertical stresses at the level of the tunnel crown if a building is constructed and founded over it. In reality, this is a complex foundation-soil-tunnel interaction problem that would have to be modeled and analyzed in 2D or 3D to obtain an accurate prediction of the effect of future shallow footings or piles on the tunnel loading and deformation. The simplistic approach used incorporates a lot of assumptions and was divided into two main alternatives. In the first scenario, the crown of the tunnel is located in soft soil and a building constructed over it would either sit on shallow foundation (Figure 1) or end-bearing piles going around and past the tunnel and into the soft rock. In the second scenario, the tunnel is located entirely within the weak shale and there is some rock above the crown to potentially accommodate end-bearing piles or shafts (Figure 2).

The main assumptions and simplifications made in order to get an approximate solution were the following. The analysis does not take the tunnel itself into account and stress distribution with depth is assumed to not be affected by its presence. Therefore reported stress increase is really in-soil stress and stress actually acting on the lining might be different if foundation-soil-tunnel interaction was incorporated in the analysis. Only a single building with between 2 and 20 stories was considered for all cases, no basements were assumed for all building options and the tunnel section was assumed to be centered under the building. The total load per story was taken as 350 psf (200 psf dead load and 150 psf live load for commercial spaces). Depth to top of rock was assumed to be either 20 ft. or 50 ft. in the area of analysis. For the shallow foundation analysis, loads are assumed to be applied at the ground surface. For the piles analysis, piles are assumed to transfer all the load at the tip, being either 20 ft. or 50 ft. below ground surface. Regarding the shallow foundation alternative, the effect of number of stories, building footprint, and continuous mat foundation vs. 10 ft. x 10 ft. square footings on a 20 ft. x 20 ft. grid was studied. The last option was only analyzed for one building footprint alternative for each number of stories examined. For the deep foundation, 2 ft. diameter piles were assumed to be placed on a 6 ft. x 6 ft. grid (three pile diameters). The effect of pile length, diameter and spacing was studied for some cases in addition to number of stories and building footprint. Note that no foundations were designed, i.e. no checks were performed for soil or rock capacity, etc. This study did not take soil properties into account and is a simple elastic stress bulb analysis.

The results are summarized in Tables 1 and 2 in terms of additional imposed vertical stress in the soil. The added stress is expressed as a percentage of the total vertical geostatic stress assuming unit weight of 110 pcf regardless of depth and soil or rock material. Values of main variables and of the approximate depth at which the additional stress is 30% of the geostatic stress are reported in the tables. A 30% increase was judged reasonable to be used as the maximum allowable stress increase in the tunnel lining. These tables can serve as a rough guide for the number of stories that can be built over a tunnel depending on its location, depth and acceptable stress increase on the lining either for a bored tunnel in soil (Table 1, Figure 1) or in rock (Table 2, Figure 2). If the values of stress increase in the table are not acceptable or the tunnel is very shallow, the alternative of slip coated piles that transfer loads below the tunnel invert may be considered. All loading cases considered (2 – 20 stories) are included in both tables for comparison, even though a 2-story building would not require piles bearing on rock. These tables should only be used to get an estimate, as more accurate assumptions and analyses could result in significant changes.

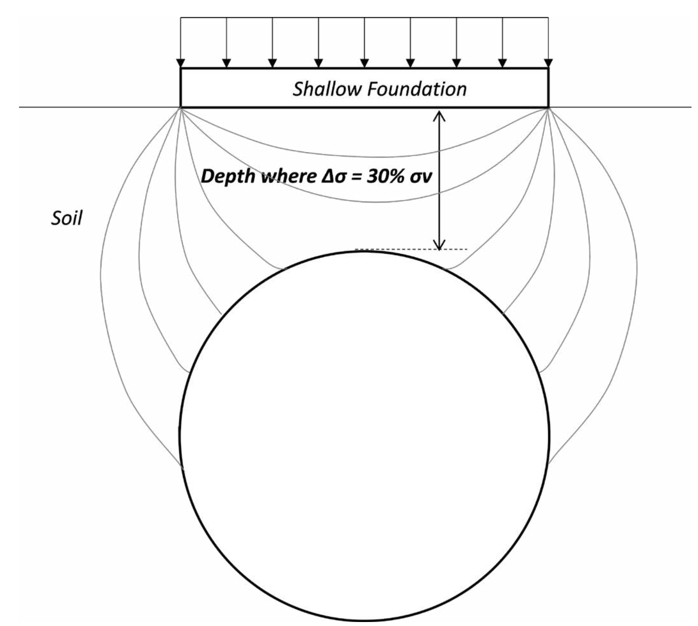


FIGURE 1: Shallow foundation – Representative Sketch (not to scale).

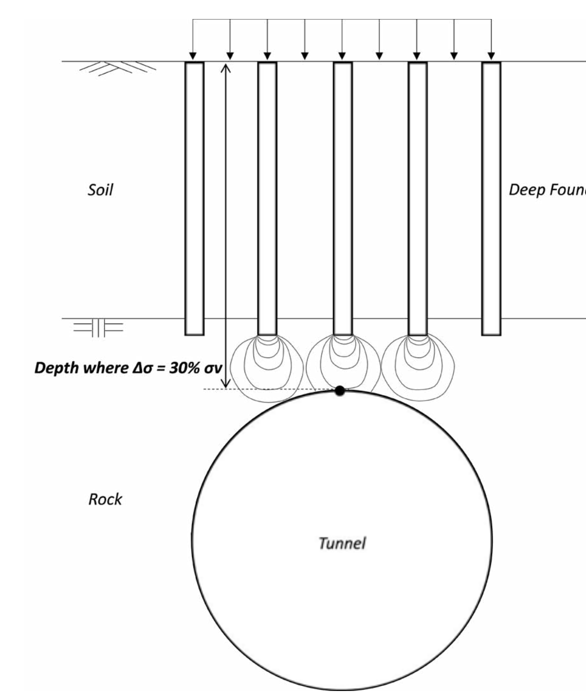


FIGURE 1: Deep foundation – Representative Sketch (not to scale)

Number of stories	Distributed load on foundation (psf)	Building Footprint		Depth from surface with 30% stress increase (ft)*: Continuous Mat Foundation	Depth from surface with 30% stress increase (ft)*: 10 ft x10 ft Footings on 20 ft x 20 ft Grid
2	700	50 ft	50 ft	19	16
		50 ft	Infinite strip	20	-
		100 ft	Infinitestrip	22	-
5	1750	50 ft	50 ft	32	30
		50 ft	Infinite strip	45	-
		100 ft	Infinite strip	73	-
10	3500	50 ft	50 ft	45	41
		50 ft	Infinite strip	55	-
		100 ft	Infinite strip	73	-
20	7000	50 ft	50 ft	60	-
		100 ft	100 ft	86	60

Additional stress in soil due to building load expressed in % of total vertical geostatic stress at that depth (assuming y=110pcf)

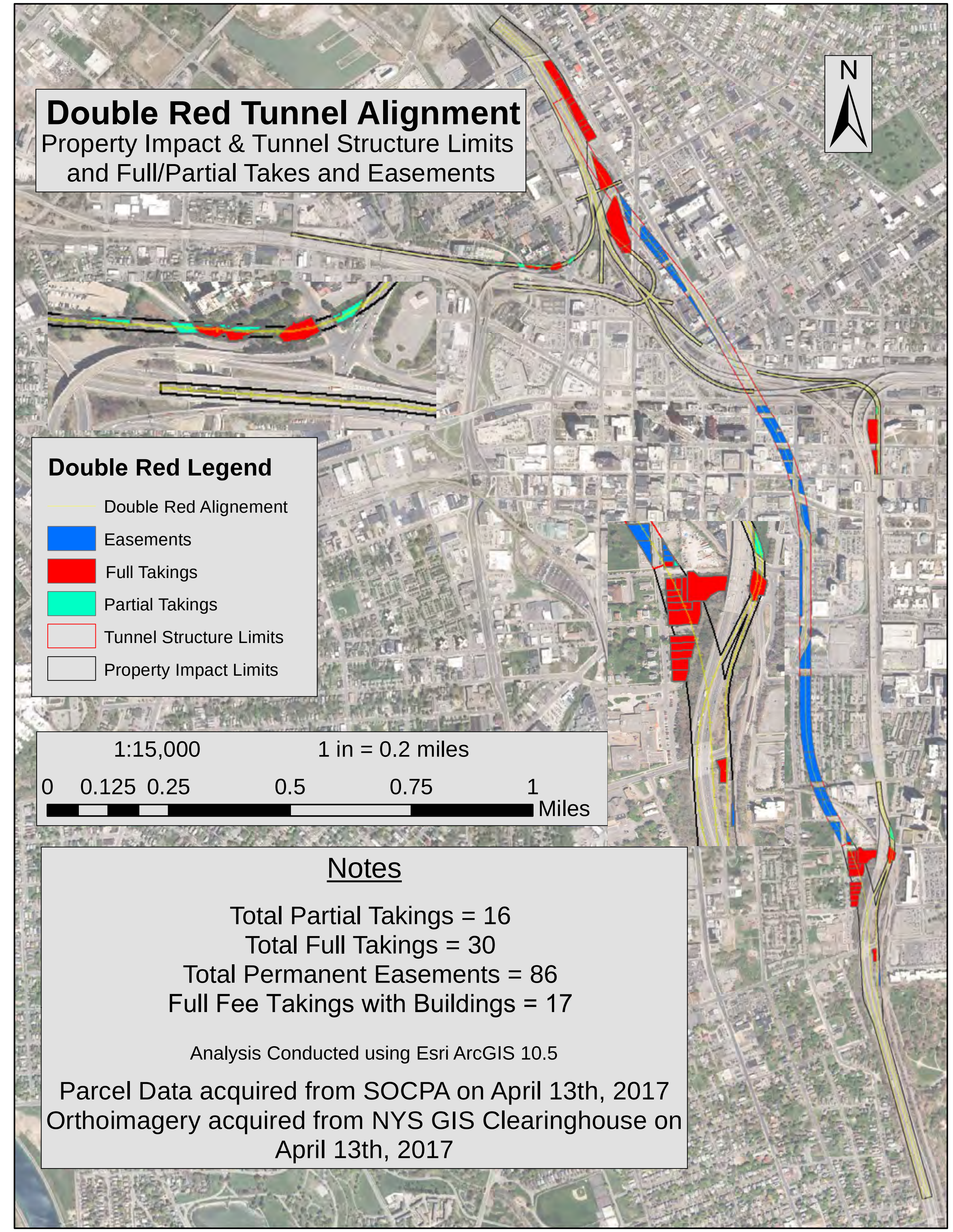
TABLE 1: Shallow foundation – Depth below surface with 30% stress increase due to building loads

Number of stories	Distributed load on foundation (psf)	Total load per pile (kips)	Building Footprint		Pile Length (ft)	Pile Spacing (ft)	Depth with 30% stress increase (ft)*: Depth from pile tip	Depth with 30% stress increase (ft)*: Depth from surface
2	6400	20	50 ft	50 ft	50	6	2	52
5	16000	50	50 ft	50 ft	50	6	3	53
10	32000	101	50 ft	50 ft	50	6	9	59
	77000	242	50 ft	50 ft	50	10	12	62
	32000	101	50 ft	50 ft	20	6	16	36
20	51000	160	100 ft	100 ft	50	5	15	65
	71000	223	100 ft	100 ft	50	6	18	68
	184000	578	100 ft	100 ft	50	10	26	76
	184000	578	100 ft	100 ft	20	10	46	66

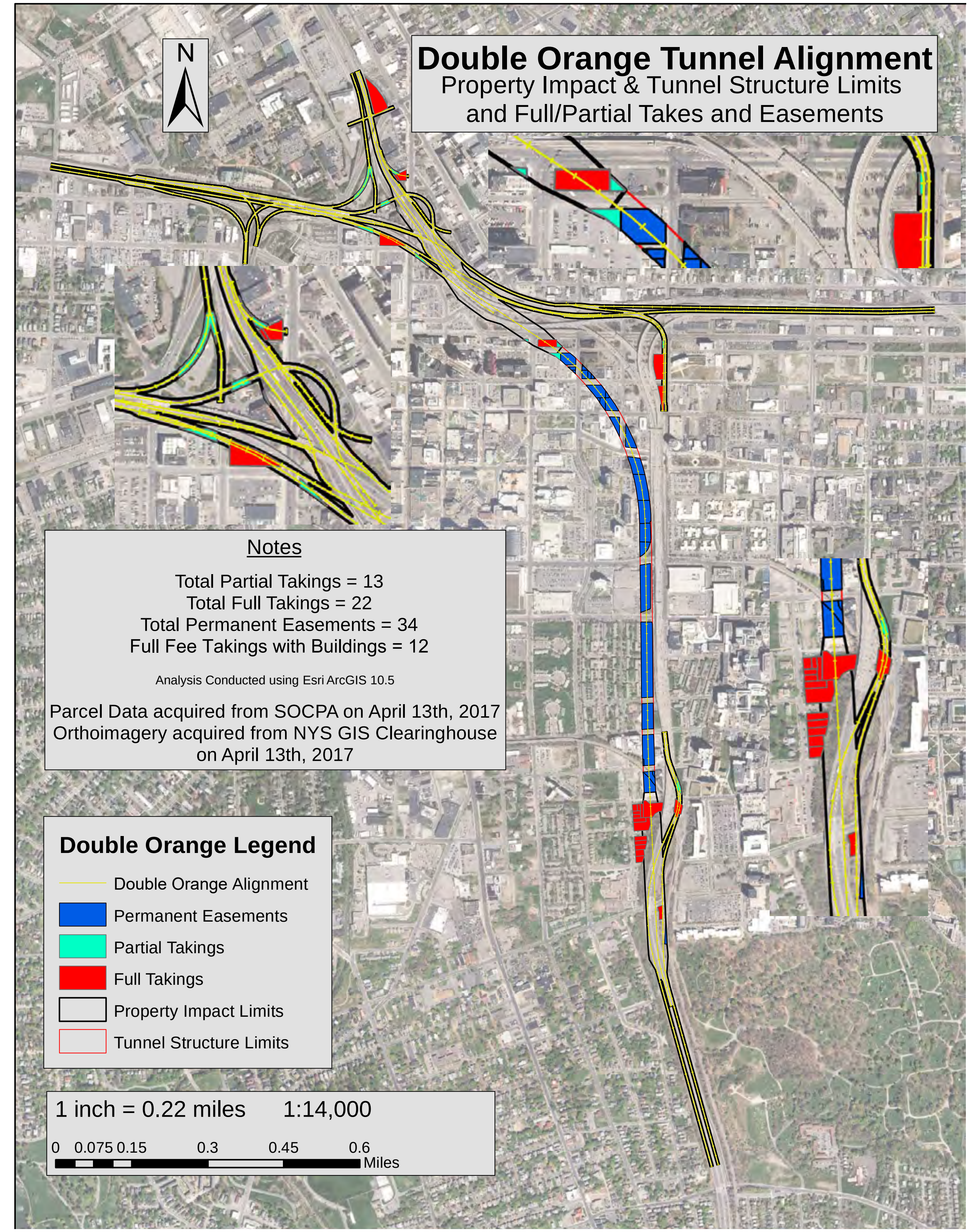
Pile Diameter is 2 ft.

TABLE 2: Deep foundation – Depth below pile tip with 30% stress increase due to building loads

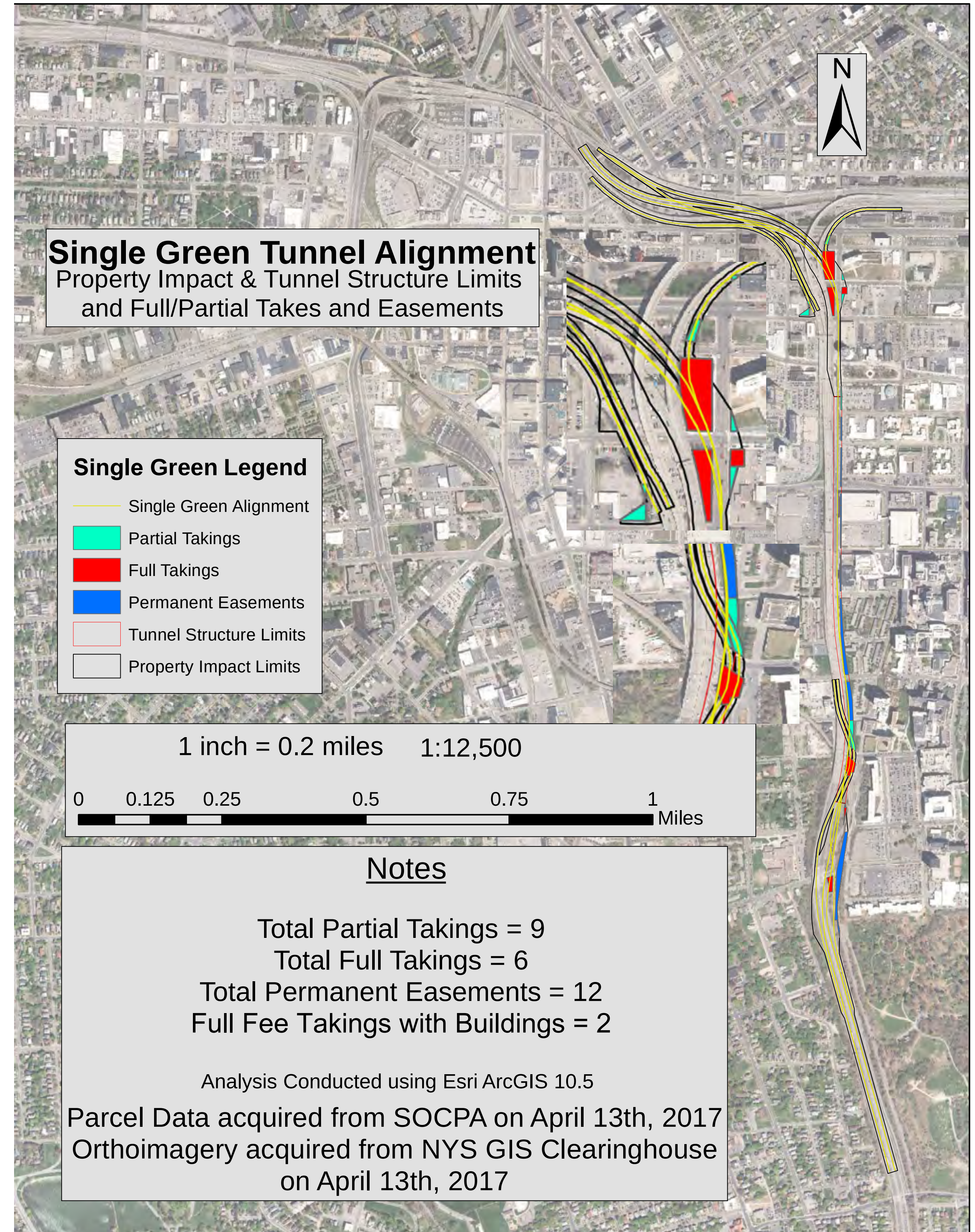
2 PROPERTY IMPACTS: RED ALTERNATIVE



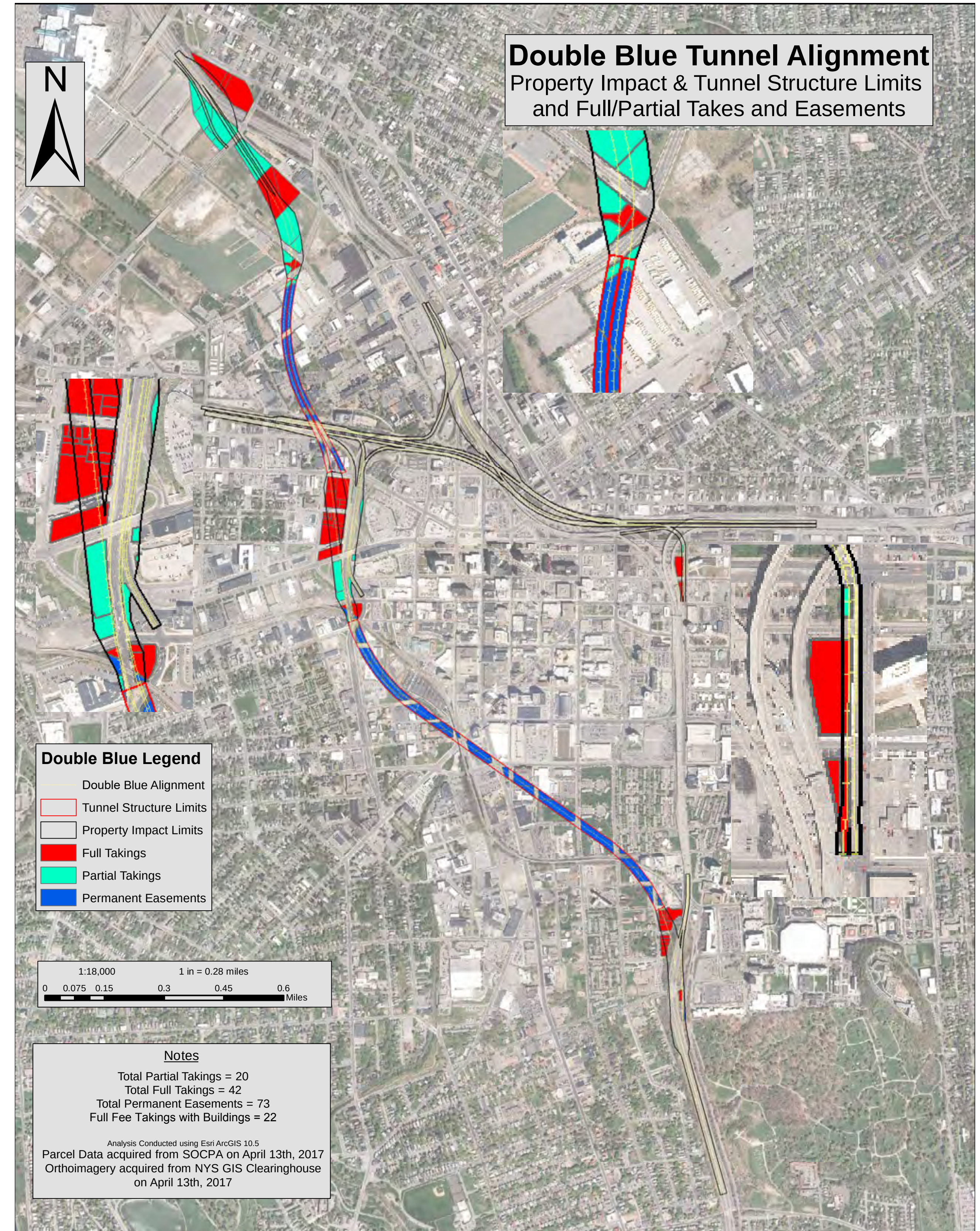
3 PROPERTY IMPACTS: ORANGE ALTERNATIVE



4 PROPERTY IMPACTS: GREEN ALTERNATIVE



5 PROPERTY IMPACTS: BLUE ALTERNATIVE



APPENDIX K: COST ESTIMATE

TABLE OF CONTENTS

TABLES

1 PROJECT COST ESTIMATION

1.1 OVERVIEW

This study looked at building tunnel alternatives set in an urban environment to replace the aging I-81 Viaduct section in downtown Syracuse. Successfully delivering one of these alternatives will present many challenges to overcome in the design and construction of the facilities and engage many trades and equipment and construction materials. In developing the cost estimate for the project, the work was broken down into the different areas to be addressed by experienced staff to determine the project cost for each alternative. The study team looked at the project in the following areas:

- Tunneling and Heavy Civil work—this includes the major excavations for the cut and the cut and cover transitions to the mining portal, the major reinforced concrete work for the cut and cover tunnels, the Tunnel Boring Machine (TBM) drive(s) and handling and disposal of muck, along with the placement of pre-cast concrete segmental liners for the tunnel as well as providing the temporary power, draining pumps and ventilation needed to work underground. This work was prepared by an experienced underground estimator with prior contractor bidding experience. The project work was detailed out and was "built" – by estimating crew size, man-hours, equipment usage and expected production rates, etc. The prevailing wages for Onondaga County were used as well as equipment quotes from TBM manufactures and precast concrete liner manufactures. The production rates of the work were applied to the quantities taken off for each alternative's conceptual design. The cost includes an appropriate contingency at this point of the project development.
- Ventilation and Fire Life Safety Systems work—this includes the permanent ventilation fans and equipment, fire protections, final tunnel drainage, lighting and finishes and special systems in the tunnel. Tunnels have requirement for 24 hour per day ventilation, lighting, and sump pump operation. This estimated cost was prepared for each alternative by experienced professionals with experience in new tunnels as well as renewal of systems in existing highway tunnels. The estimated costs were compared with recent similar projects to check for completeness and reasonableness. The cost also includes an appropriate contingency at this point of the project.
- Bridges & Ramps --new, temporary and demolishing portions of existing viaduct. This cost estimate was prepared by calculating the quantities for each alternative on a square foot basis for the different types of bridge, ramps, temporary structures, underpinning/temporary support of existing structures as well as the portions of the existing viaduct to be demolished. The cost includes an appropriate contingency at this point of the project.
- Civil Highway and misc. This scope includes all the pavement, roadway construction, surface drainage, concrete barriers, guide rails, lighting, signs, landscaping, and utilities for each alternative. The cost was developed based on unit prices of the typical bid items based on quantity take-offs for each alternative. A few items such as maintenance of traffic (MOT) or zone traffic control, and landscaping were estimated at a reasonable percentage of construction costs in accordance with other similar projects. The estimate includes an appropriate contingency at this point of the project.
- Right of Way (ROW) and Property Easement costs. This estimate was prepared by reviewing the number of parcels by type that are affected by the tunnel and roadway alignments. Fair market value was estimated and applied to each alternative.
- Soft Costs (Project Management/Construction Management and Support, Design Services, Geotechnical Exploration program, Procurement Services, Legal, Public Outreach, etc.) Delivering a large multi-year project in an urban area will take a considerable effort to successfully deliver. At this stage of a project, it is appropriate to estimate the "soft" cost of professional services costs at thirty-five percent of the construction cost.
- Escalation and risk reserve. Any tunnel alternative considered in this study would be a multi-year project to deliver. With the environmental analysis that would need to be done, along with required geotechnical investigation and design development needed, the earliest that construction could begin is estimated at three years. The construction duration would be between five and seven years. That puts the mid-point of construction in 2022, so dollars must be added to the current year costs to account for escalation. In addition, all underground construction has inherent risks that are usually greater than surface or elevated works. These tunnel alternatives have not been subject of a risk analysis yet. Faced with the many unknowns yet to be discovered through implementation of a geotechnical exploration program and design development, as well as potential issues that might arise during construction, it is strongly advisable and appropriate to carry a project reserve for risk at this point. We have recommended 20% as an appropriate value at this time.

Below are the tabulated estimated project costs for each alternative:

Item	Red	Orange	Green A	Blue	Remarks
Tunneling & Heavy Civil					
Site Prepration for tunneling	$177,987,009	$170,048,635	$151,004,363	$381,676,544	
TBM tunnel construction	$692,261,521	$461,507,988	$470,694,837	$779,889,341	
South Cut & Cover Concrete Works	$73,779,286	$46,261,773	$183,935,519	$216,976,272	
North Cut & Cover Concrete Works	$101,763,298	$100,481,294	$44,875,676	$102,386,235	
Mechanical & Electrical for tunnel construction	$22,158,919	$12,189,160	$5,531,250	$22,200,153	
Subtotal - Tunneling	**$1,067,950,033**	**$790,488,851**	**$856,041,644**	**$1,503,128,546**	
Ventilation & Fire Life Safety Systems					
Ventilation	$27,933,120	$24,212,520	$31,185,000	$28,848,960	
Tunnel fire protection	$24,901,781	$16,940,750	$15,798,024	$29,124,628	
Tunnel drainage	$8,069,695	$6,038,820	$5,405,400	$9,146,952	
Lighting	$10,916,259	$9,325,407	$9,002,624	$11,760,111	
Finishes	$75,764,158	$52,964,458	$45,549,108	$87,852,295	
Electrical	$20,369,323	$14,498,606	$11,055,825	$23,225,531	
Special Systems (ITS, etc.)	$8,611,744	$6,900,912	$5,603,410	$11,389,401	
Subtotal -Tunnel Ventilation & FLS systems	**$176,566,081**	**$130,881,473**	**$123,599,391**	**$201,347,877**	
Subtotal -Tunnel and Tunnel Systems	**$1,244,516,114**	**$921,370,324**	**$979,641,035**	**$1,704,476,423**	
Bridges & Ramps, Civil, roads, - demolition, temporary and new for					
I-81 Mainline work	$187,448,539	$302,983,175	$325,435,575	$343,225,846	includes demo, temporary works, new works
I-81 to I-690 connections	$257,742,178	$148,888,398	$125,991,367	$175,502,883	includes demo, new connections
I-690 Mainline	$678,960	$318,612,365	$17,188,867	$77,635,893	Includes demo and new structure and/or road
Local roads	$56,399,914	$197,849,582	$131,731,371	$38,636,330	incudes demo & new ramps and streets (Almond)
Subtotal - Bridges & Ramps, Civil, roads,	**$502,269,590**	**$968,333,520**	**$600,347,180**	**$635,000,951**	
ROW & Property Easements	**$35,500,000**	**$43,950,000**	**$24,700,000**	**$61,400,000**	

TABLE 1: Alternatives Project Cost Estimation

Item	Red	Orange	Green A	Blue	Remarks
Soft Costs (PM/CM, Design, procurement, outreach, etc.)	**$623,799,997**	**$676,778,845**	**$561,640,875**	**$840,307,081**	
Total project cost (2017 Dollars)	$2,406,085,701	$2,610,432,689	$2,166,329,090	$3,241,184,454	
Escalation & risk reserve					
	$457,156,283	$495,982,211	$411,602,527	$615,825,046	
	$481,217,140	$522,086,538	$433,265,818	$648,236,891	
Total Project Capital Budget	**$3,344,459,124**	**$3,628,501,438**	**$3,011,197,435**	**$4,505,246,392**	
Annual O & M Cost (Estimated in 2017 $)	**$14,000,000**	**$10,000,000**	**$8,000,000**	**$17,000,000**	

2 SYSTEM COST ESTIMATE

2.1 INTRODUCTION

The systems component of the cost estimate was broken down into the following categories:

- Ventilation
- Tunnel fire protection
- Tunnel drainage
- Lighting
- Finishes
- Electrical
- Special systems (ITS, etc.)
- Operations and maintenance

The overall cost of each item is provided in the table below. A detailed calculation sheet was developed listing all assumptions made. Discussion follows below outlining the approach taken for each item. The estimate is based primarily on previous project experience and an engineer's estimate, and the estimate is not based on any more detailed information at this time. As a concept and more detailed design is developed this estimate should be refined and eventually an estimator prepared cost estimate should be developed.

2.2 VENTILATION

The ventilation estimate assumed the following schemes:

- Red – longitudinal ventilation with jet fans (500 ft spacing), portal exhaust provided at each end.
- Orange – longitudinal ventilation with jet fans (500 ft spacing), portal exhaust provided at each end.
- Green – minimal number of jet fans for control of air balance (1000 ft spacing), exhaust duct provided.
- Blue – longitudinal ventilation with jet fans (500 ft spacing), portal exhaust provided at each end.

An allowance was also made for air quality sensors. A ventilation building allowance, at each portal region, was included for all options.

2.3 TUNNEL FIRE PROTECTION AND DRAINAGE

Estimates for these systems are based on related data from previous tunnel projects using both linear and area take-offs as primary cost basis. Allowances were assumed for portal and tunnel pumping equipment and supporting pump station infrastructure.

2.4 LIGHTING

Lighting was estimated based the length of tunnel and provision of a daylight portal at each end. Allowance was made for controls, fixtures, luminance meters, power and software.

2.5 FINISHES

Tunnel finishes includes items such as signage, elements such as hand railings, fire protection (structural), equipment cabinets, portal features and surface buildings. The estimate was progressed on a "per 100 linear foot" basis.

2.6 ELECTRICAL

The electrical estimate assumes two ventilation buildings, one at each end of the tunnel, where electrical equipment is housed. Allowances are made for items such as switchgear, uninterrupted power supply, motor control centers, cables and conduit. The quantities are based on the length of each tunnel option and are extrapolated from costs on previous projects.

2.7 SPECIAL SYSTEMS

Items include features such as fiber optic network, telephones, ITS, radio rebroadcast, fire alarm and detection, security system, CCTV, SCADA system, overheight detection and cabling.

2.8 OPERATIONS AND MAINTENANCE

Costs were based on per linear foot of tunnel length from four US tunnels in the year 2005. A discounting was applied to this cost to provide an estimate in 2017 equivalent dollars, and a margin was added due to the early status of the design. Costs were then applied to each option scaled by the option's length. The cost of this item is an annual cost, not an initial lump sum.

Item	Red	Green A	Blue	Orange	Remarks
Length (daylight to daylight portal):	11098	6100	12980	7550	
Ventilation	$26,352,000	$28,350,000	$27,216,000	$22,842,000	Refer to detailed notes for assumptions affecting number of jet fan, portal building inclusion, exhaust duct not included.
Tunnel fire protection	$23,492,246	$14,361,840	$27,476,064	$15,981,840	Includes: Dry standpipe system, deluge type fixed firefighting system, piping, supports, valves, pumps, hydrants, extinguishers and service connections. See notes for more information regarding assumptions.
Tunnel drainage	$7,612,920	$4,914,000	$8,629,200	$5,697,000	Includes: Portal pump stations and pumps, tunnel low point pump station(s) and pumps, roadway piping, roadway grated inlets and service connections. See notes for more information regarding assumptions.
Lighting	$10,298,358	$8,184,204	$11,094,444	$8,797,554	Includes: LED tunnel lighting fixtures, mechanical support, installation and adaptive lighting control system.
Finishes	$71,475,620	$41,408,280	$82,879,524	$49,966,470	Includes egress signs, includes fire proofing, does NOT include internal structures, jersey barriers or raised walkways.
Electrical	$19,216,343	$10,050,750	$21,910,878	$13,677,930	Refer to detailed notes for assumptions and elements used for estimating purposes. Cost for buildings in "Ventilation" assume space within for electrical rooms also.
Special Systems (ITS, etc.)	$8,124,287	$5,094,009	$10,744,718	$6,510,294	Refer to detailed notes for assumptions and elements used for estimating purposes. Cost for buildings in "Ventilation" assume space within for communications/special systems rooms also.
Total (not including O&M annual cost)	$166,571,774	$112,363,083	$189,950,828	$123,473,088	
Operations and maintenance (annual estimate)	$14,335,065	$7,879,248	$16,766,006	$9,752,184	Derived from a cost per foot basis from other tunnels/projects. Includes: staff, utilities, routine maintenance, major support equipment. Does not include: major equipment replacement/renewal, repaving, cyclical equipment replacements.

TABLE 2: Alternatives Operations & Maintenance Costs

APPENDIX L: PUBLIC COMMENTS ANALYSIS REPORT

TABLE OF CONTENTS

FIGURES

1 PUBLIC COMMENTS RESULTS

1.1 GENERAL OVERVIEW

Out of a total of 353 respondents, 89% (313) offered some sort of opinion on this project. 76% (270) of total respondents offered specific suggestions for the project.

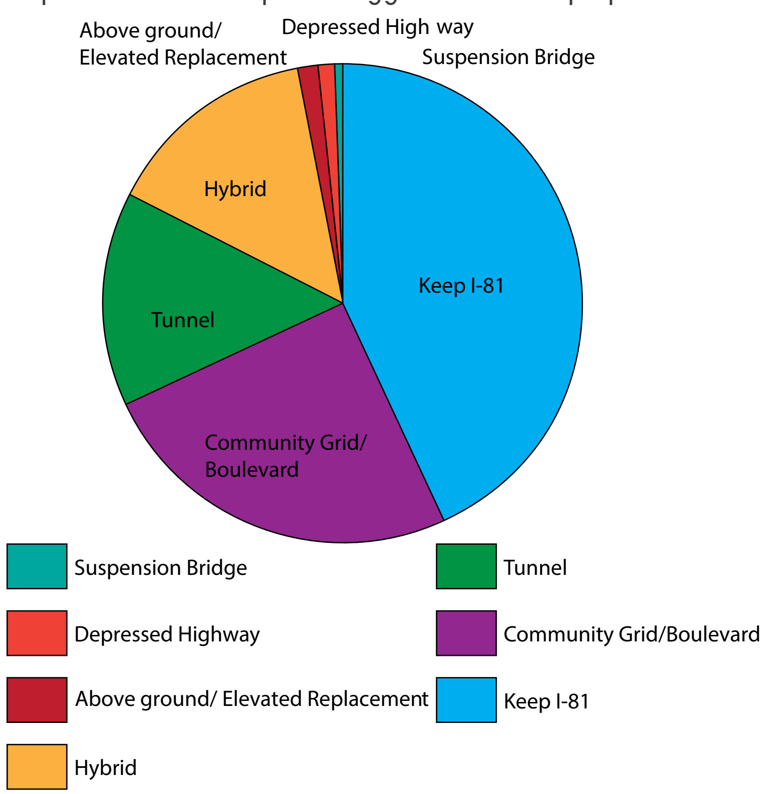


FIGURE 1: Breakdown of Public Comments

- 33% (116) of respondents prefer to keep Interstate 81 and either fix, redesign, or enhance it.
- 19% (67) of respondents prefer a community grid or some kind of a local boulevard.
- 11% (39) of respondents prefer a tunnel.
- 11% (40) of respondents prefer a hybrid solution.
- 1% (4) of respondents prefer some sort of aboveground or elevated replacement for Interstate 81.
- 1% (3) of respondents prefer a depressed highway.
- 0.25% (1) of respondents a suspension bridge.
- Of the 11% of respondents who want a hybrid solution:
    - 8 respondents want a community grid, a tunnel, and I-481
    - 7 respondents want to keep 1-81 and add a tunnel and/or depressed highway
    - 4 respondents want a tunnel and/or depressed highway
    - 4 respondents want a raised highway and a community grid
    - 3 respondents want a community grid, a tunnel, and/or depressed highway
    - 2 respondents want to eliminate I-81 in downtown, reroute all through traffic to the new I-81 (I-481 North), and leave what is left to a state-designated route or a boulevard
    - 2 respondents want a community grid, underground roundabouts, elimination of I-81, and a reroute of I-81 traffic to I-481
    - 2 respondents want to improve the design of I-81, but if a tunnel is necessary, do it via a depressed highway
    - 2 respondents want a tunnel or to lower I-81, with elevated side streets
    - 1 respondent wants to move I-81 out of downtown, add a I-481 North Beech Street tunnel, and a community grid
    - 1 respondent wants to eliminate I-81 from downtown and add a tunnel
    - 1 respondent wants stacked lanes
    - 1 respondent wants to build the western half of the I-481 bypass
    - 1 respondent wants to keep I-81, and add a community grid and tunnel and/or depressed highway
    - 1 respondent wants an underground highway, with a greenhouse and aviary

1.2 RESULTS ANALYSIS

Overall, the public favors keeping Interstate 81 and either repairing it or redesigning certain aspects of it. Suggestions include making I-81 taller and wider, connecting it to Route 690, and creating breakdown lanes. The second-most popular option is the community grid or boulevard.

Many of the respondents in favor of the tunnel cited aesthetics (the removal of the I-81 barrier that bisects the city was mentioned repeatedly) and the positive effects on commerce as major reasons for wanting the tunnel.

Some of those in favor of a depressed highway referenced depressed highways that they have driven on in other parts of the country, such as Chicago, Cleveland, and southern New Jersey. Those in favor of the depressed highway also stated that they believed a depressed highway would possess all the benefits of a tunnel without the high costs to build and maintain.

1.3 NON-FAVORABLE RESPONSES

- Of the 353 total respondents, 122 (35%) do not want a tunnel.
- 38 total respondents (11%) do not want a community grid.
- 27 total respondents (8%) do not want to repair/redesign Interstate 81.
- 26 total respondents (6%) do not want a depressed highway.
- 12% (43) of respondents, while offering no real solution, were very adamant about what they did NOT want to happen. Of those who solely expressed objections, 38 (88%) do not want a tunnel.

Overall, non-favorable responses were most centered on the possible construction of a tunnel. The most common reasons cited were the soil conditions and the cost. It was repeatedly stated by respondents that the proposed relocation of I-81 runs through swampy ground, and that the water is of a high saline content. Many respondents objected to the potentially high costs associated with digging a tunnel and relocation of utility lines. In addition, respondents objected to the cost of maintaining and operating the tunnel, including running drainage pumps that would need to be regularly repaired or replaced due to the salinity of the water.

The second least desirable option is the community grid. The most common reasons cited were the potential traffic congestion and pollution.

Many of the objections relating to the depressed highway focused on the potential for frequent flooding. Some respondents also referred to the City of Rochester's now-obsolete depressed highway as an example of why a depressed highway should not be constructed in Syracuse.

1.4 PUBLIC OFFICIALS

Of the nine public officials whose comments were documented, four (44%) were in favor of the community grid option. The reasons included that the grid would restore connectivity within the City and that it would lend to financial and cultural revitalization. Two (22%) officials were in favor of keeping Interstate 81. They believed that getting rid of the Interstate would adversely affect suburban municipalities and would hamper the ability of first responders to travel quickly, when needed. One (11%) official suggested a hybrid option consisting of a community grid with an Interstate 81 thoroughfare in the form of a depressed highway or a tunnel. Another official (11%) gave no opinion as to which option he preferred; however, he issued a word of caution regarding the construction and maintenance costs associated with both the tunnel and depressed highway options. The final official (11%) mailed in his response in the form of multiple CDs. The CDs were unable to be accessed at the time of this report.

1.5 OVERALL TRENDS

Regardless of what solution respondents were in favor of, a large number displayed concern for the social and economic impact that the final decision will have on the City's businesses and its residents. Many, even those who want to keep I-81, acknowledged the socio-economic impact that the construction of I-81 has had on the City. They seem to believe that I-81 has effectively cut off historically African-American neighborhoods from the rest of the City, leading to a decline in the vibrancy of those communities.

Many respondents in favor of keeping I-81 stated concerns that tearing it down would have a negative economic impact on the businesses located along its corridor, as well as the potential for traffic gridlock its elimination would cause.

Another topic of concern with many respondents is that some of the proposed options, including the tunnel, could require the demolition of several of the City's historic buildings.

In addition, several respondents suggest that whatever plan is adopted should include some sort of pedestrian-friendly greenspace. Some respondents also suggested that the ultimate project should focus on making Syracuse more public transportation friendly and less dependent on passenger vehicles, which they believe would alleviate City traffic and allow for more walkability, leading to possible cultural and economic growth.

1.6 CONCLUSION

Overall, the public is very much divided on what should be done. However, the largest number of respondents are in favor of keeping Interstate 81 and either repairing or redesigning portions of it. The second and third most popular options are fairly controversial topics. The second most popular option (the community grid) is supported by 19% of respondents, but 11% are against it. The third most popular option (the tunnel) is supported by 11% of respondents, yet 35% are against it. Other ideas, including a depressed highway, an aboveground/elevated replacement for I-81, and a suspension bridge did not gain much traction.

APPENDIX M: ELIMINATED ALTERNATIVES

TABLE OF CONTENTS

FIGURES

1 YELLOW TUNNEL ALTERNATIVE

1.1 GENERAL OVERVIEW

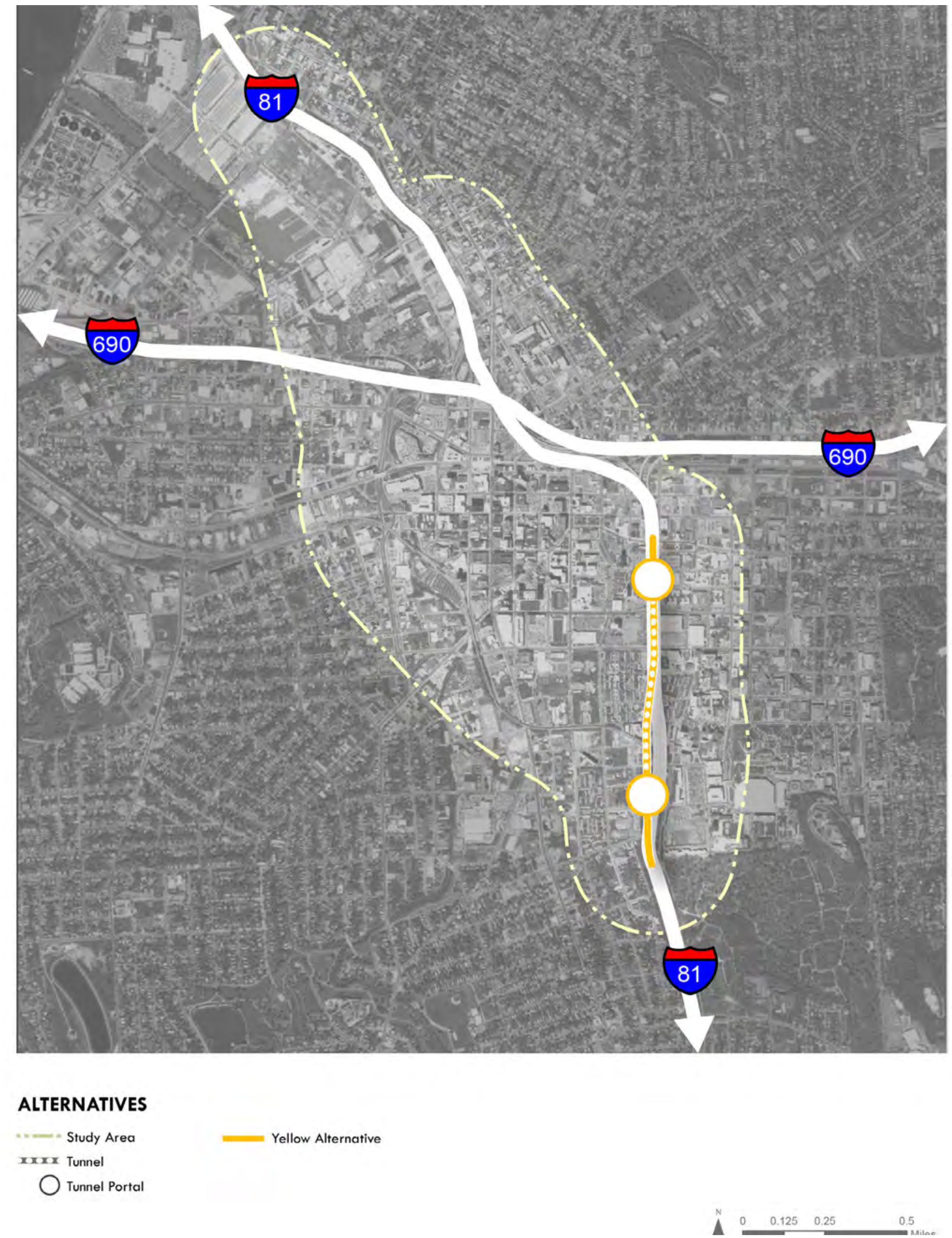
The Yellow Alternative is a cut and cover tunnel located on the same alignment as the existing I-81 viaduct, along Almond Street. An alignment within the Almond Street corridor is the only potentially viable alignment for a cut and cover tunnel, without major property takings. However, even on this corridor construction would significantly impact street traffic, I-81 traffic, the I-81 viaduct, utilities and adjacent businesses and residences. Some construction could occur with the existing I-81 viaduct remaining open, but an extended closure of I81 (likely more than a year) would be required to demolish the viaduct, complete the connections at each end, and for other works.

To minimize impact to I-81 during construction it may be possible, at the south end, to construct the cut and cover tunnel to the east of the viaduct (similar to Green), or west (similar to Orange – and as shown on the Yellow plan, below). However, it would likely be preferable to construct the north end and south end ramps concurrently duration a long-term closure of I-81. The alignment would be the same as the existing I-81 viaduct, per the fly-though description is provided below.

Where the highway transitions from below grade to above grade, near Harrison Street, it would be difficult to accommodate pedestrian crossings (bridges or underpasses). At the north end the I-690 connecting ramps would be the same as existing.

- Advantages of Yellow Alternative
  - Maintains existing connections to I-690
  - Relatively short tunnel
- Disadvantages of Yellow Alternative
  - Long-term closure of I-81during construction
  - Disruption to city streets during construction
  - Harrison Street closed permanently (see profile below)
  - Buried valley crossing the alignment result in deep retaining walls and high construction cost
  - Piling through existing footings could be problematic
  - Significant utility relocations
  - The cost and disruption associated with cut and cover work along Almond Street/I-81 were the primary reasons for eliminating this option from further study.

FIGURE 1: Yellow Tunnel Alternative



1.2 ALTERNATIVE FLY-THROUGH DESCRIPTION

The Yellow Tunnel Alternative is a cut and cover tunnel that follows the existing I-81 alignment.

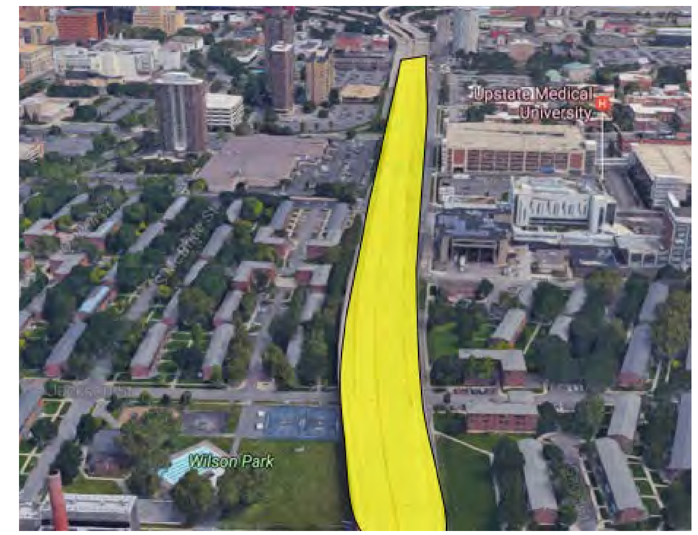
It starts in the south adjacent to Martin Luther King East, and continues generally north in a cut and cover tunnel, passing under the railroad. Construction of this section would require the temporary closure of I-81, and demolition of the existing structure.

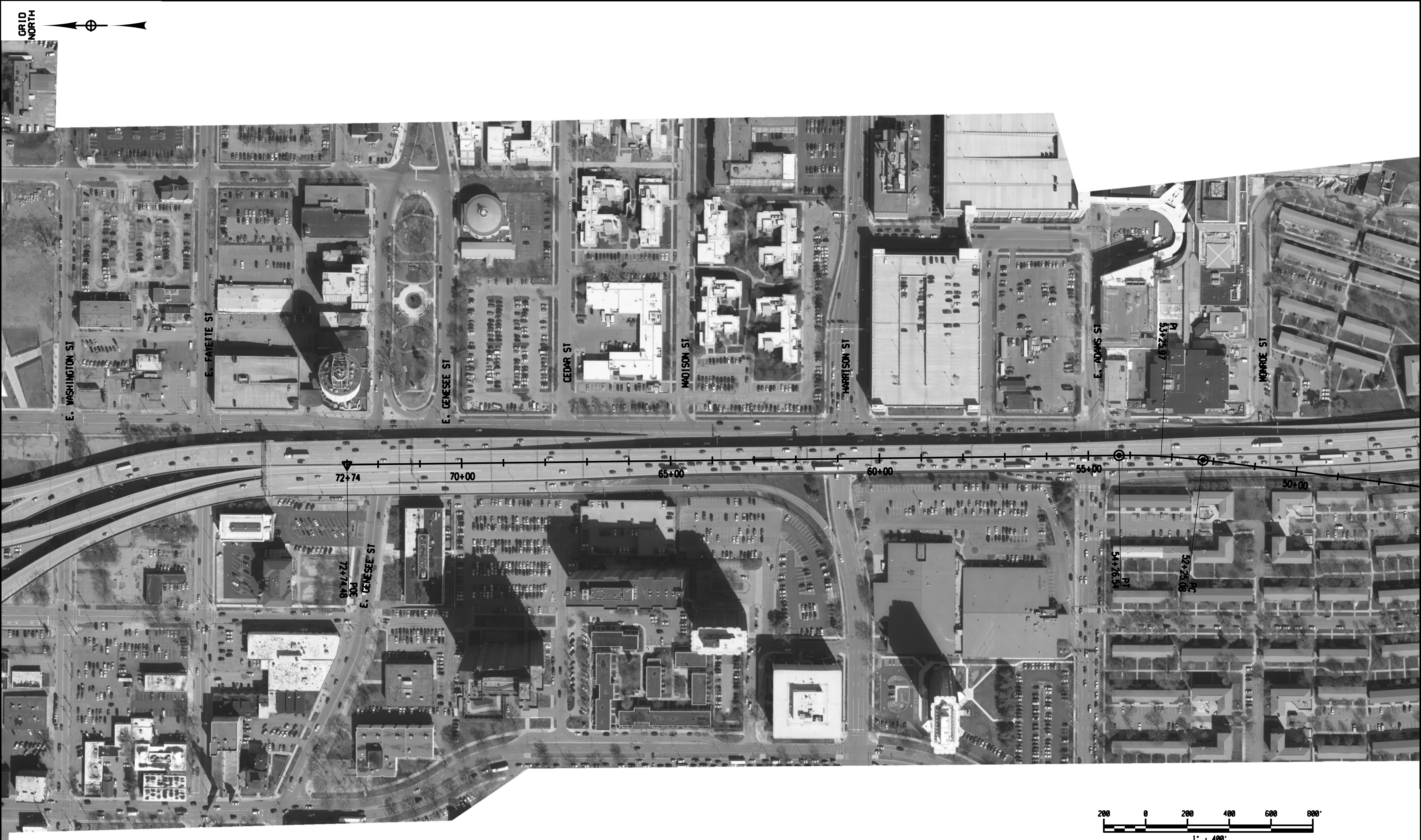
Significant utility r elocations would b e r equired along Almond Street, especially near the Steam Plant.

North of the railroad the cut and cover would follow the line of the existing viaduct. Some elements of the tunnel could be constructed the existing viaduct in operation, but significant disruption to traffic on city streets.

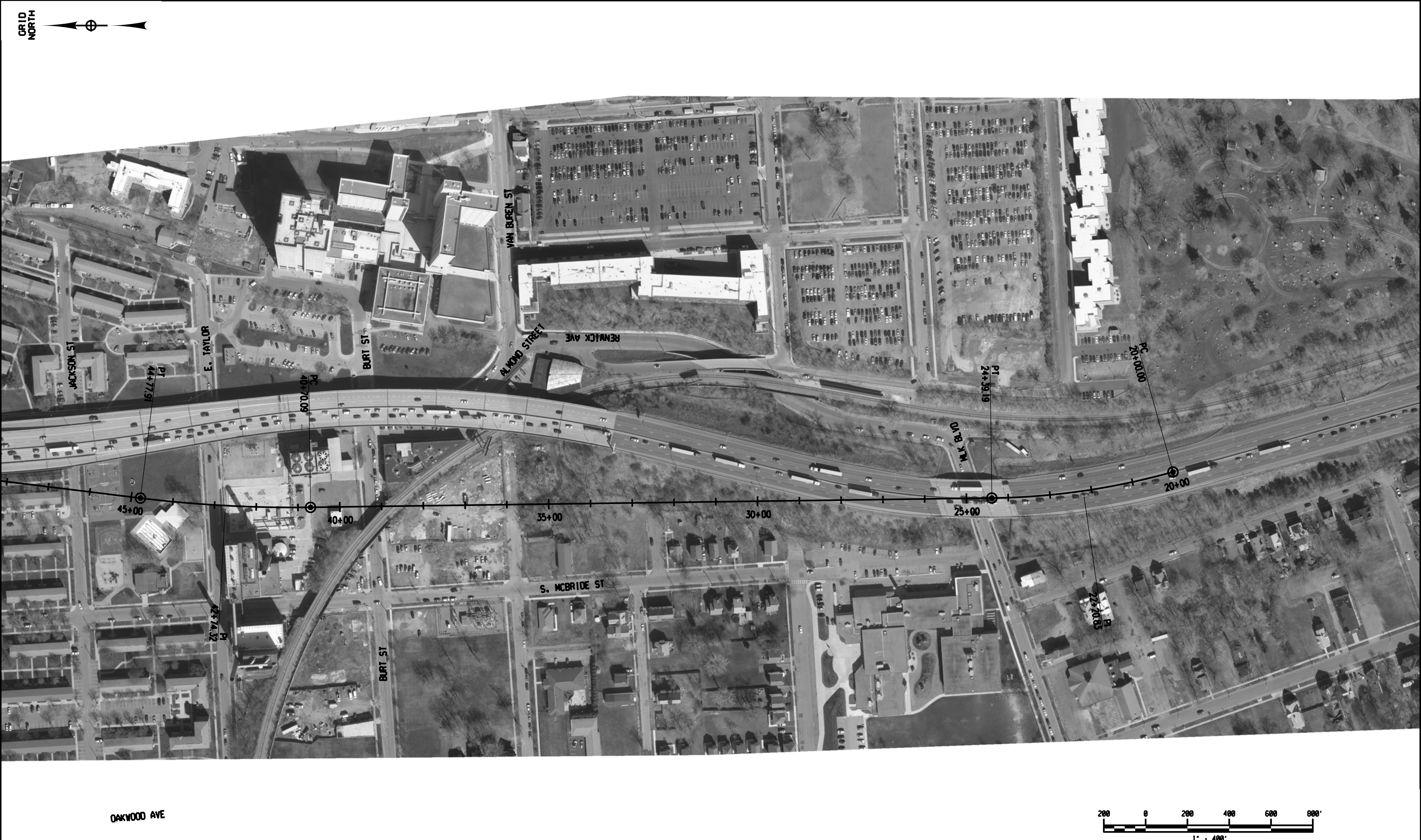
Construction of other elements would require significant underpinning of the existing structure, if it were to remain in operation. Completion of the cut and cover structure, and tie-in at each end, would require temporary closure of I-81.

The tunnel would rise up at the north end, coming above grade near Harrison Street, and meeting the existing viaduct connections to I-690 near Genesee Street, Harrison Street would be permanently blocked.

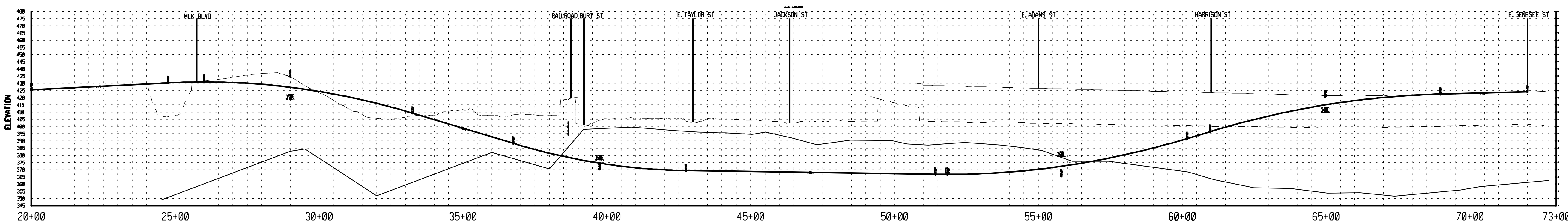


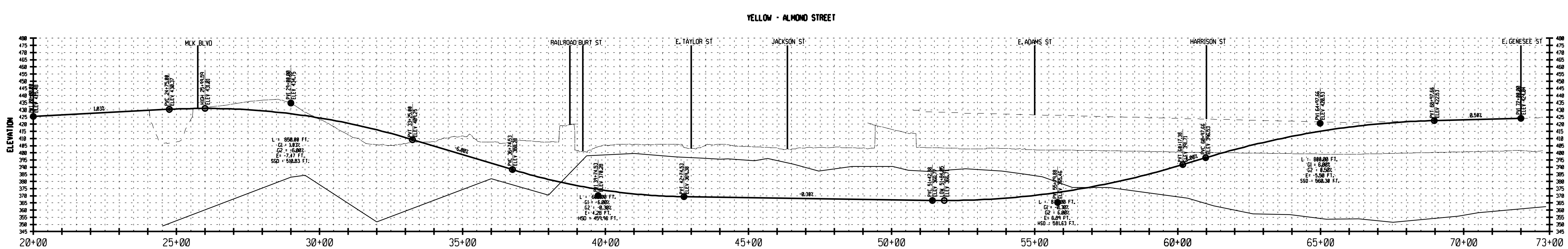


BORED YELLOW TUNNEL PLAN VIEW
SHEET 1 OF 2



BORED YELLOW TUNNEL PLAN VIEW
SHEET 2 OF 2





YELLOW ALMOND STREET

I-81 INDEPENDENT FEASIBILITY STUDY

DATE: 4/17/2017
WSP | PARSONS BRINCKERHOFF

2 GREEN B TUNNEL ALTERNATIVE

2.1 GENERAL OVERVIEW

The Green 'B' Tunnel Alternative is generally aligned immediately east of the I-81 viaduct. From the southern limit, adjacent to Martin Luther King East, it is identical in plan alignment to the Green Alternative until East Fayette Street. It then deviates from the Green Alternative by continuing northwards to a similar north portal as the Red Alternative. A fly-though description is provided below.

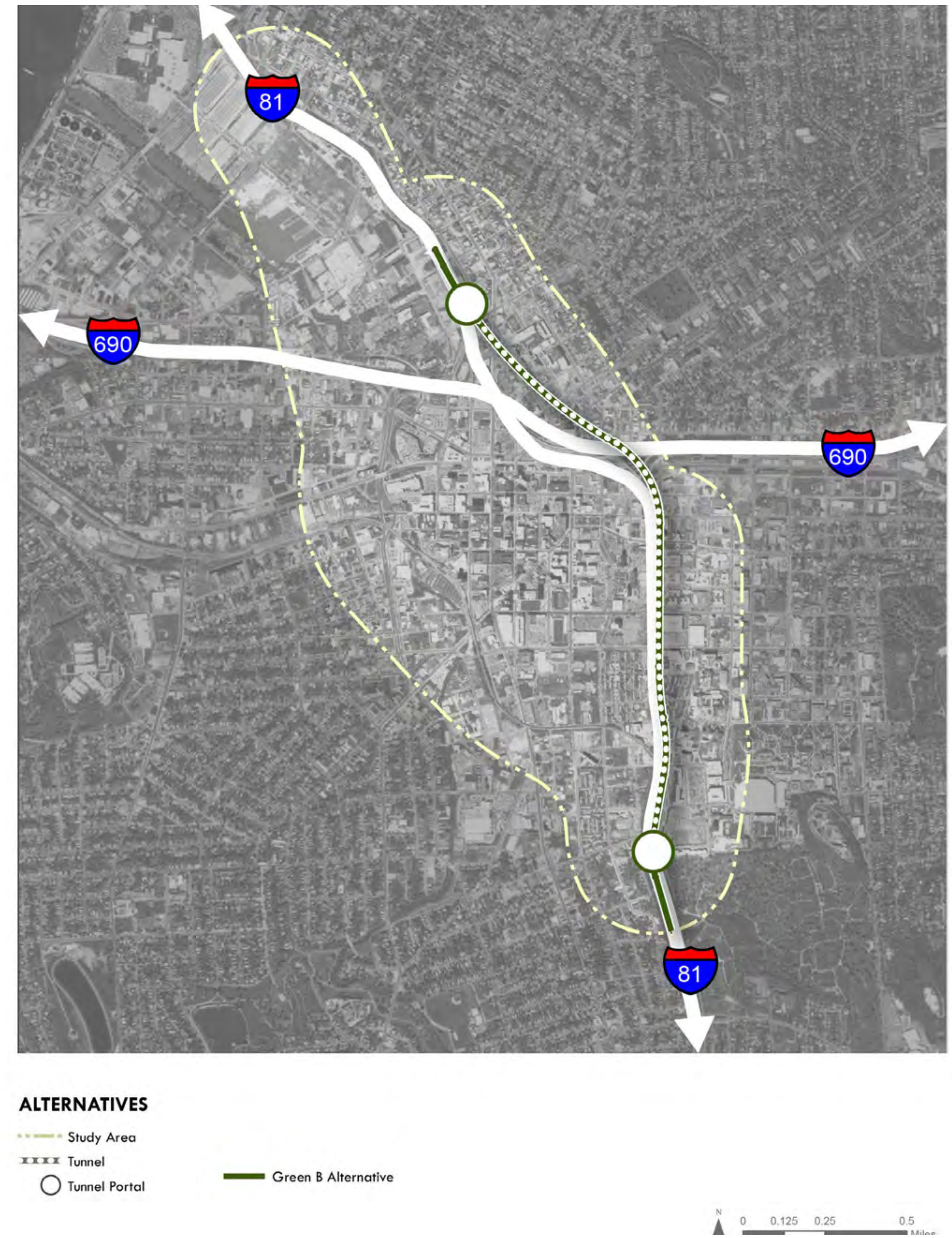
A single double-deck tube is considered preferable to twin tunnels due to the physical constraints along Almond Street (viaduct to the west; hospital and hotel to the east). The out-to-out width of twin tunnels is approximately 110-ft, which would be difficult to accommodate.

It may be possible to deepen the profile of the tunnel, such that it could be aligned below the existing viaduct. However, this would likely require the viaduct to be taken out of service during tunnel mining, as was done for the Alaskan Way Viaduct when the TBM passed below. It would also increase the risk of encountering and existing pile.

- Advantages of Green 'B' Alternative
  - Has negligible impact on I-690
  - No permanent street closures
  - Generally passes under public land
- Disadvantages of Green 'B Alternative
  - No connection to I-690
  - Relatively long tunnel
  - Passes under multiple low-rise buildings around Burnet Avenue.
  - Passes close to hospitals and Crowne Plaza
  - Construction of northern tunnel approaches would be disruptive to I-81 traffic
  - Limited space for TBM launch at either portal

The tunnel would be functionally be identical to the Red Alternative, but would have higher construction risk, passing under more properties and close to others. The Red Alternative would be a similar 'base' cost, but with a lower risk of delay and cost increases. For this reason, Green 'B' was eliminated from further study.

FIGURE 2: Green B Tunnel Alternative



2.2 ALTERNATIVE FLY-THROUGH DESCRIPTION

The Green ‘B’ Tunnel Alternative is generally aligned immediately east of the I-81 viaduct. From the southern limit, adjacent to Martin Luther King East, it is identical in plan alignment to the Green Alternative until East Fayette Street.

It bends to the east to clear the existing I-81 alignment immediately south of the railroad. The southern end of the bored tunnel would be at this location. To achieve this geometry requires reverse curves on the through-tunnel.

The bored tunnel would pass under the Pioneer Homes housing project and immediately adjacent to the Update Medical University Hospital, beneath the I-81 northbound off-ramp to Adams Street.

The alternative would continue northbound in bored tunnel under Almond Street., passing close to the high-rise Crowne Plaza Hotel.

Whereas the Green Alternative tunnel ends at this location and connects into I-690, the Green ‘B’ tunnel continues along Almond Street.

Green ’B’ continues as a bored tunnel to pass, at depth, below I-690 and below private properties and buildings in the vicinity of Burnet Street.

The bored tunnel then follows a similar alignment to the northern end of the Red alternative, connecting into I-81 at a similar point.

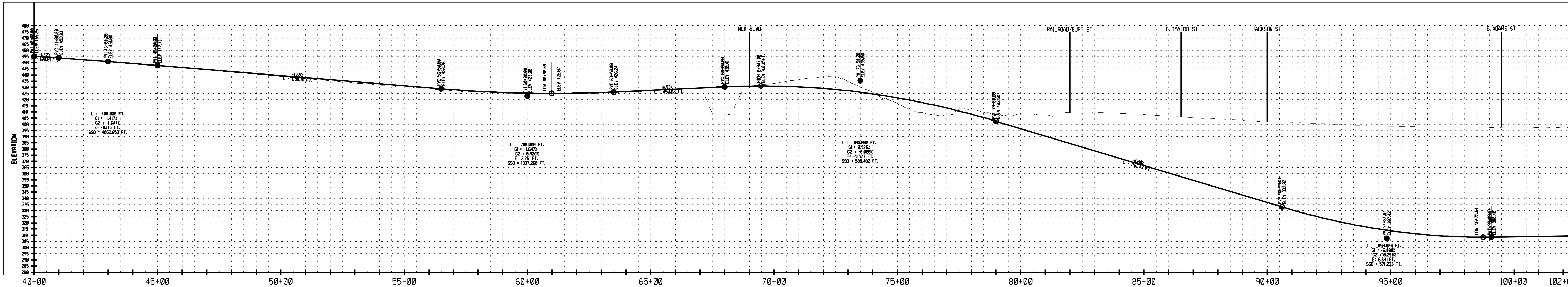
BORED GREEN B TUNNEL PLAN VIEW
SHEET 1 OF 5

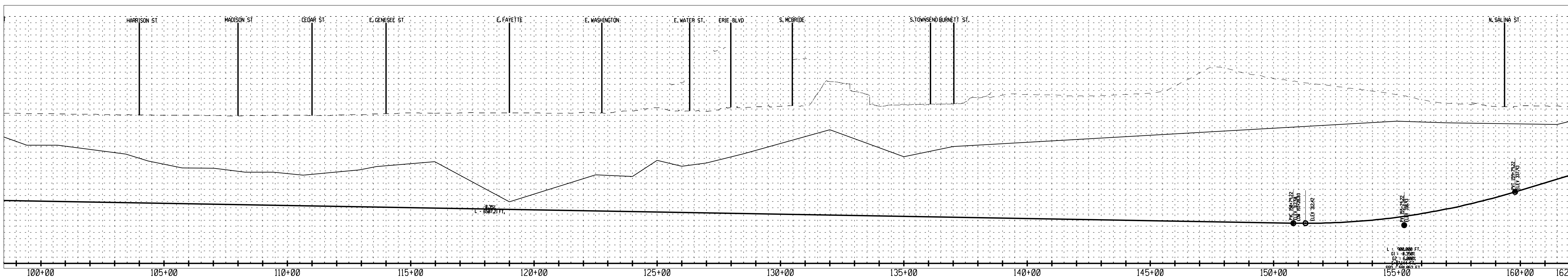
BORED GREEN B TUNNEL PLAN VIEW
SHEET 2 OF 5

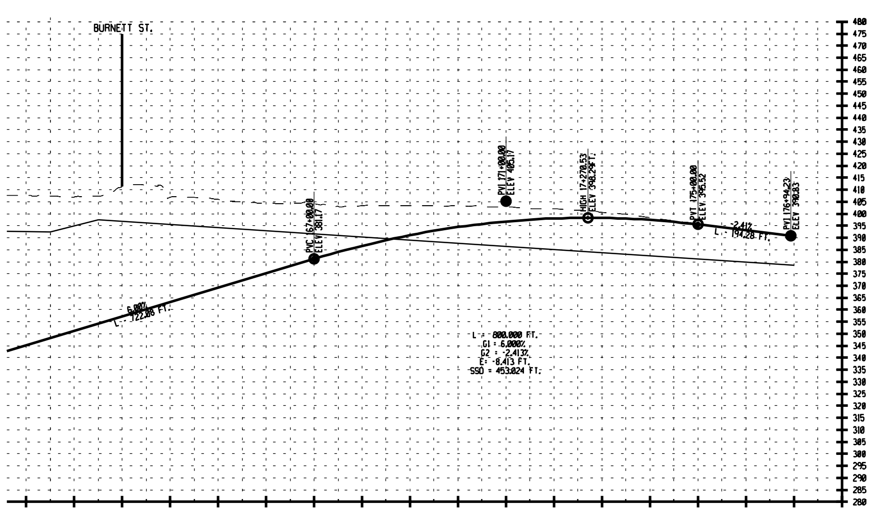
BORED GREEN B TUNNEL PLAN VIEW
SHEET 3 OF 5

BORED GREEN B TUNNEL PLAN VIEW
SHEET 4 OF 5

BORED GREEN B TUNNEL PLAN VIEW
SHEET 5 OF 5







I-81 INDEPENDENT FEASIBILITY STUDY

DATE: 4/17/2017
WSP | PARSONS BRINCKERHOFF

BORED GREEN B TUNNEL

3 PURPLE TUNNEL ALTERNATIVE

3.1 GENERAL OVERVIEW

The Purple Tunnel Alternative demolishes both the I-81 and I-690 viaducts, and replaces them with tunnels. Some existing interstate-to-interstate connections could potentially be maintained (the viability of this was not fully vetted; NB I-81 to EB I-690 would likely not be maintained, not the reverse move).

The I-690 tunnel would replace the existing viaduct throughout downtown Syracuse. In combination with removing the I-81 viaduct, this option would place most sections of interstate underground, freeing up surface space for development and improving livability. Numerous ramps would descend into the tunnel, which would still have some remaining impact on the surface, along with potential emergency exits and ventilation buildings.

The I-81 tunnel starts in the south adjacent to Martin Luther King East. A TBM would mine northwest and north, following alignment of the Red Alternative to Genesee Street., where the bored tunnel ends. Cut and cover construction would start there, with cut and cover ramp-tunnels connecting into the I690 tunnel. The I-81 tunnel would continue under the I-690 tunnel, to daylight near Butternut Street.

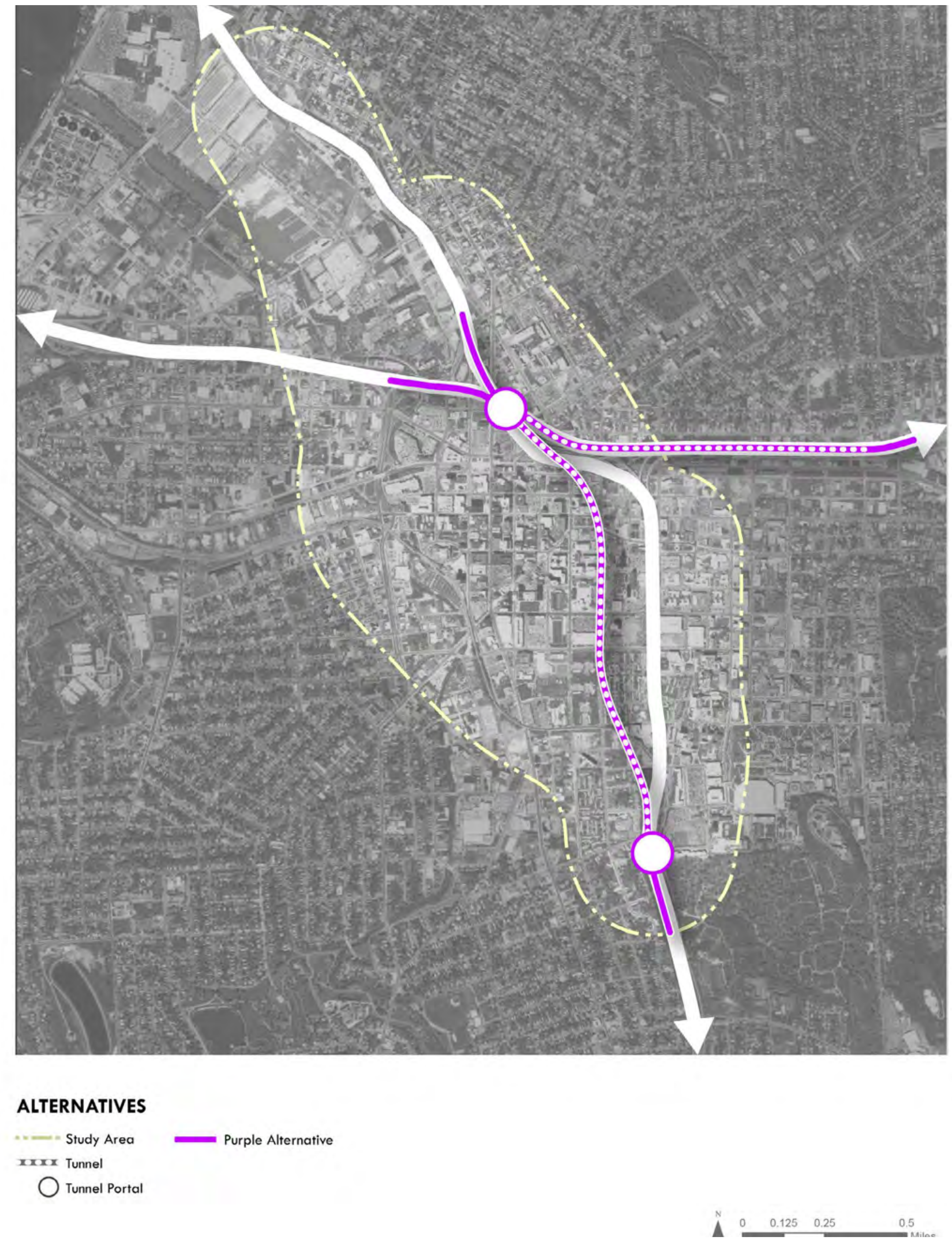
The I-690 tunnel starts in the east near Beech Street. and heads west, generally beneath Erie Boulevard. A cut and cover tunnel would be required for the I-690 tunnel. It would not be possible to fit three lanes plus on/off ramp lanes into bored tunnels. A fly-though description is provided below.

A complicated series of cut and cover interchanges would be required to maintain existing connections between I-81 and I-690. Eliminating some or all connections could result in significant cost savings.

- Advantages of Purple Alternative
  - Eliminates all interstate viaducts from downtown Syracuse
- Disadvantages of Purple Alternative
  - Major reconstruction of both I-81 and I-690
  - High cost
  - Significant disruption during construction to traffic and adjoining properties
  - Significant property acquisition and sub-surface easements required
  - Significant utility relocations.

This option was eliminated from further study, primarily due to the cost. The I-690 section alone could cost 2- to 3-times the cost of the I-81 options carried forward. Overall project costs could be 3- to 4-times more than focusing on I-81 alone. Furthermore, the disruption to traffic and people during construction would be more widespread and last much longer.

FIGURE 3: Purple Tunnel Alternative



3.2 ALTERNATIVE FLY-THROUGH DESCRIPTION

The I-690 tunnel starts in the east near Beech Street and heads west. It diverges from the existing I-690 alignment, ramping down into a cut and cover tunnel that runs under Erie Boulevard. The tunnel would require too many lanes for a bored tunnel. A stacked cut and cover tunnel would minimize its footprint, and minimize property takings.

The tunnel would stay under Erie Boulevard, south of the existing I-690 alignment, as far as the existing I-81 viaduct.

At I-81, the I-690 tunnel would turn north, into the existing interchange areas near State Street.

Underground ramps to I-81 (shown in white) could potentially be constructed using cut and cover, but at considerable cost, and causing significant disruption.

A complicated series of cut and cover interchanges would be required to maintain existing connections between I-81 and I-690. Eliminating some connections could result in significant cost savings.

The I-81 tunnel would pass under the I-690 tunnel, to daylight near Butternut Street.

The I-81 bored tunnel starts in the south (not shown) adjacent to Martin Luther King East and trends to the northwest, following the Red Alternative to Genesee Street, where the bored tunnel ends.

I-81 cut and cover construction would start here, with cut and cover tunnels potentially turning east and west to connect into the I 690 tunnel.

The I-690 cut and cover tunnel would rise up to meet the existing highway alignment close to West Street. New interchange ramps and other reconstruction would be required at West Street. Flow of the Onondaga Creek would be maintained.

4 SHORT DEPRESSED HIGHWAY ALTERNATIVE

4.1 GENERAL OVERVIEW

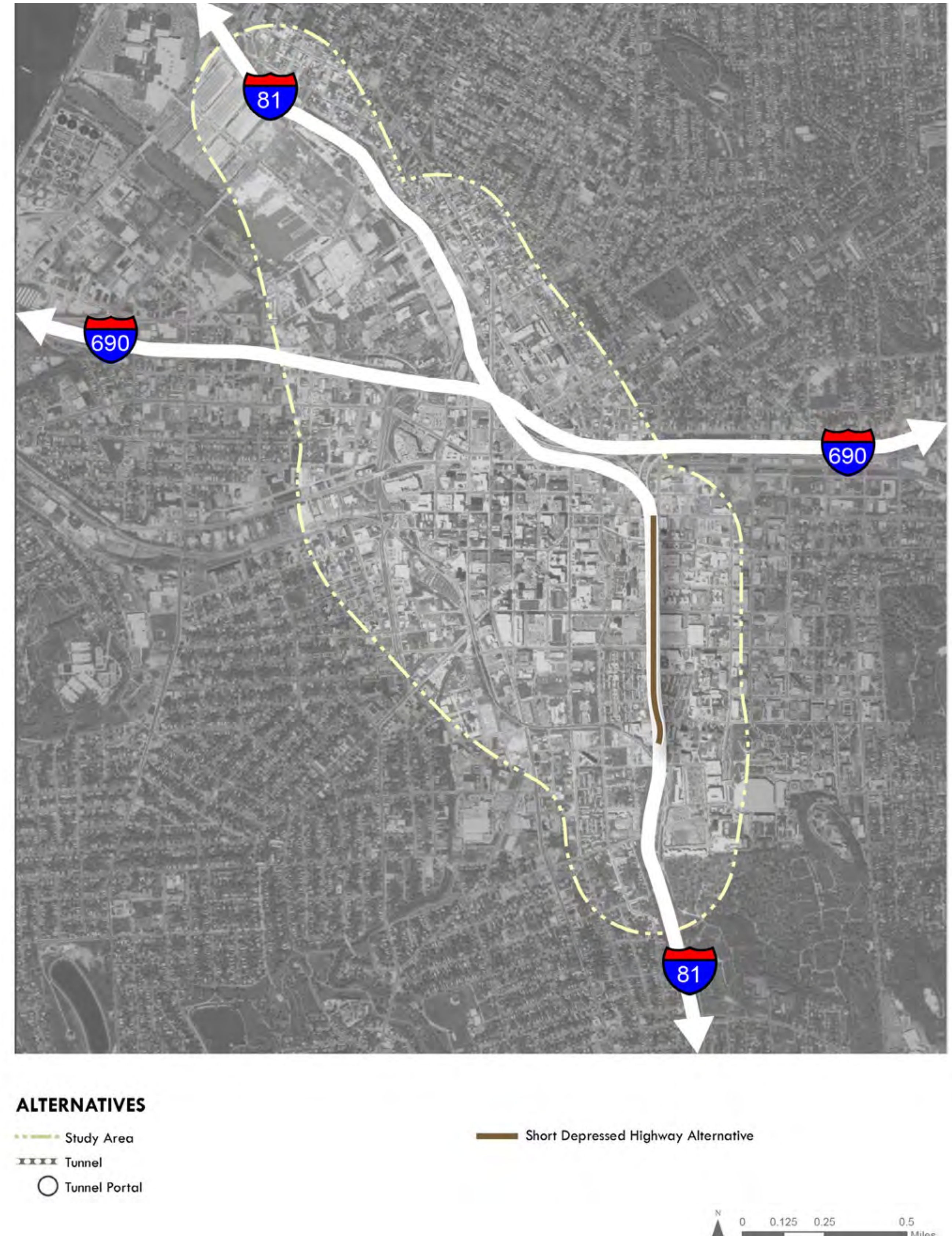
The Short Depressed Highway Alternative would be aligned along the same alignment as the existing I-81 viaduct. I-81 northbound would bridge over the railroad and then descend into a depressed highway. It would then rise up to meet the I-690 ramps. A fly-though description is provided below.

The purpose of examining this Alternative was to determine the shortest practical depressed highway. However this Alternative is too short. It starts and ends at a viaduct, and except for one cross-street (Adams) all other cross streets are permanently blocked due to the highway either ramping down or ramping up. See the profile, below.

The deep section of depressed highway is too short to allow adjacent streets (Almond Street) to be cantilevered, which limits the space for a community grid spine road. Also, there is insufficient space at each end to make connections between I-81 and the community grid.

- Advantages of Long Depressed Highway Alternative
  - Short
  - Lower cost
  - MLK Boulevard could remain open
- Disadvantages of Long Depressed Highway Alternative
  - Extended closure of I-81 during construction
  - Major disruption to city streets during construction
  - Multiple city streets closed permanently
  - Limited (or no) connections to community grid
  - Buried valley crossing the alignment result in deep walls and disproportionately high cost
  - Significant utility relocations, especially near Steam Plant
  - Piling through existing footings could be problem-atic
  - Snow removal difficult
  - Perpetuates the division of the university area from downtown
  - This option was eliminated from further study, primarily due to the required permanent closure of multiple city streets.

FIGURE 4: Short Depressed Highway Alternative



4.2 ALTERNATIVE FLY-THROUGH DESCRIPTION

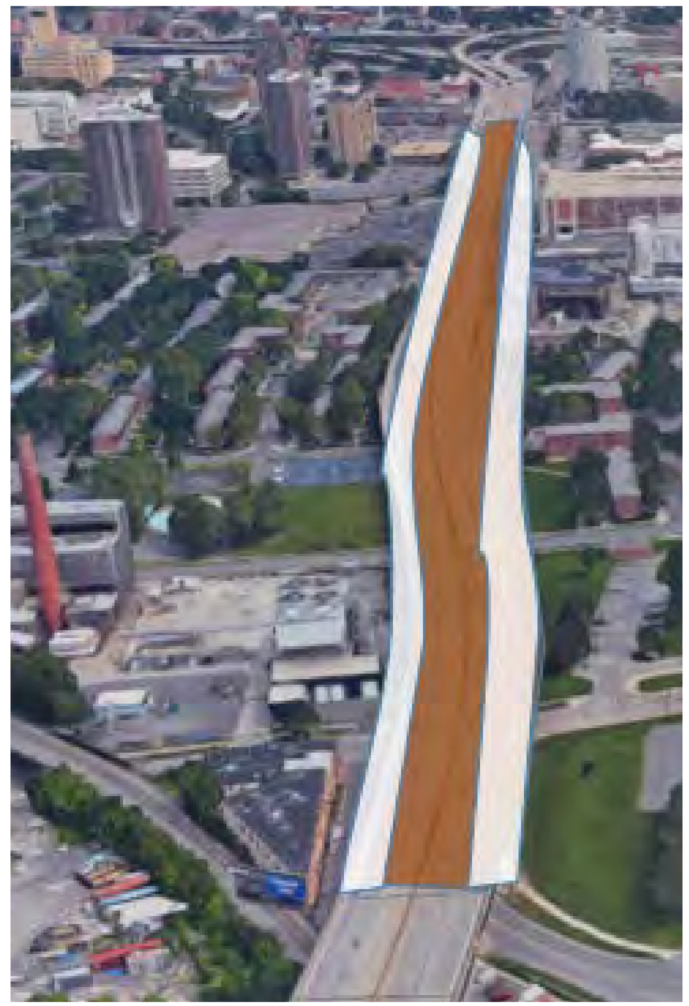
The Short Depressed Highway is an open-cut depressed highway that follows the existing I-81 alignment.

It has a similar plan alignment as the Yellow Tunnel Alternative, except that it starts north of the railroad.

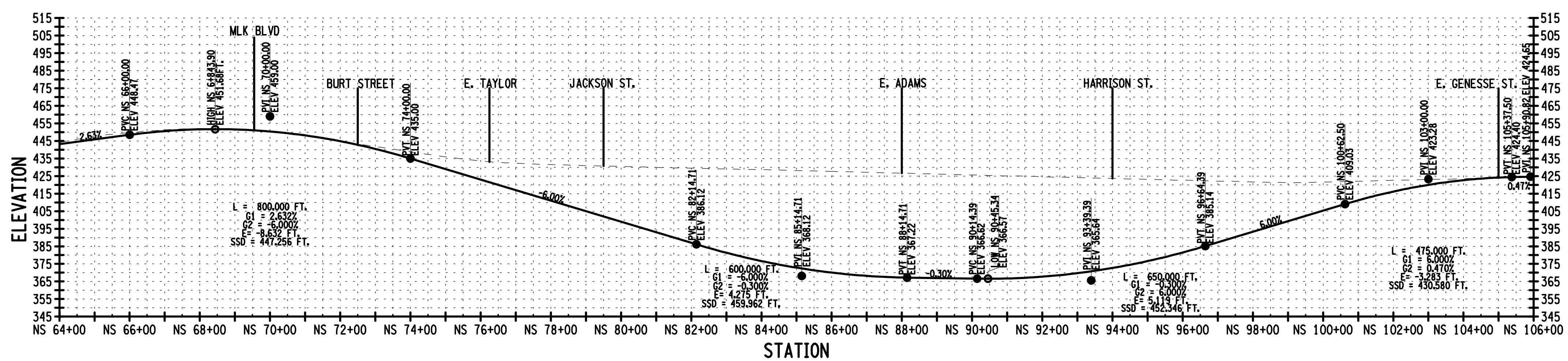
The existing bridge over the railroad would be reconstructed, and the roadway would then slope down to the north, to descend below city street level.

Almond Street would be divided, with northbound traffic located to the east of the depressed highway, and southbound traffic to the west. Due to the shorty length, and ramping down and up, I-81 would not been deep enough to permit Almond Street to be cantilevered over the interstate. Almond Street would ran along either side.

The roadway would rise up near Genesee St to meet the existing ramps connecting into I-690.



SHORT DEPRESSED HIGHWAY



WSP USA Inc.	I-81 INDEPENDENT FEASIBILITY STUDY	
	ALTERNATIVE	SHEET NO.
	SHORT DEPRESSED HIGHWAY - PROFILE	1 OF 1

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DATE/TIME = DGN$SYTIME0123456
USER = DGN$USERNAME

5 LONG DEPRESSED HIGHWAY ALTERNATIVE

5.1 GENERAL OVERVIEW

The Long Depressed Highway is an open-cut depressed highway that follows the existing I-81 alignment. It has the same plan alignment as the Yellow Tunnel Alternative described above. In profile the south end is similar to the Yellow alternative, and the north end is similar to the Long Depressed Highway alternative.

Compared with the Short Depressed Highway Alternative, this alternative can remain at the full depth long enough for most transverse city streets to remain open. However, Harrison Street would be closed permanently. Burt Street would also be closed for the community grid connection to I-81 – similar to other Alternatives. Community grid at street level would be maintained by splitting Almond Street northbound and southbound, and cantilevering each direction over I-81 (see Appendix E). A fly-though description is provided below.

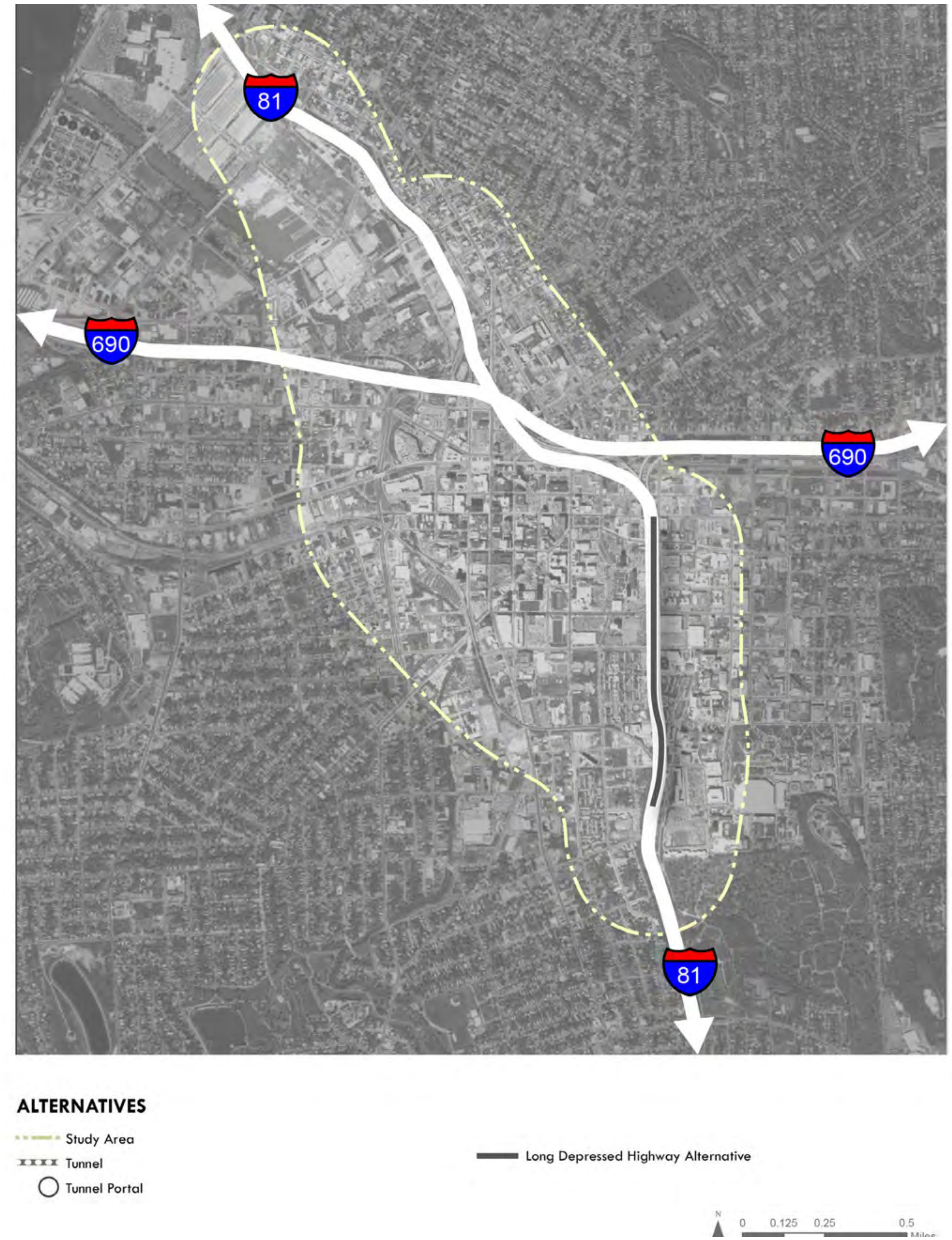
Some construction could occur with the existing I-81 viaduct remaining open, but an extended closure of I81 (likely more than a year) would be required to demolish the viaduct, complete the connections at each end, and for other works.

Pedestrian traffic would only be able to cross the depressed highway at cross streets, or other pedestrian bridges. Where the highway transitions from below grade to above grade, near Harrison Street, it would be difficult to accommodate pedestrian crossings (bridges or underpasses). At the north end the I-690 connecting ramps would be the same as existing. These elements would form a barrier that would perpetuate the division between the university side of I-81 and downtown.

- Advantages of Long Depressed Highway Alternative
  - Maintains existing connections to I-690
  - MLK Boulevard could remain open
  - Relatively short
- Disadvantages of Long Depressed Highway Alternative
  - Extended closure of I-81 during construction
  - Major disruption to city streets during construction
  - Harrison Street closed permanently
  - Buried valley crossing the alignment result in deep walls and high cost
  - Significant utility relocations, especially near Steam Plant
  - Piling through existing footings could be problem-atic
  - Snow removal difficult
  - Perpetuates the division of the university area from downtown

This option was eliminated from further study for two principal reasons: the requirement for an extended closure of I-81 during construction, and because the resulting depressed highway, ramps and viaducts would perpetuate the division between the university area and the downtown area.

FIGURE 5: Long Depressed Highway Alternative



5.2 ALTERNATIVE FLY-THROUGH DESCRIPTION

The Long Depressed Highway is an open-cut depressed highway that follows the existing I-81 alignment.

At the south end the depressed highway would pass under the railroad in a cut and cover tunnel. The community grid would pass over the railroad, and ramp down to grade.

Community grid at street level would be maintained by splitting Almond Street northbound and southbound, and cantilevering each direction over I 81 (see Appendix E).

The highway would rise up at the north end, coming above grade near Harrison Street and meeting the existing viaduct connections to I-690 near Genesee Street.

APPENDIX N: CASE STUDIES

TABLE OF CONTENTS

1 PORT OF MIAMI TUNNEL, FL

KEY ASPECTS OF THIS PROJECT ARE:

- Location: Miami, Florida
- Client: Florida Dept. of Transportation, Miami-Dade County, City of Miami
- Delivery: Public-Private Partnership
- Years built: (2010-2014)
- Tunnel Type: Automotive, Twin tubes
- Length: 4,200 feet per tunnel
- Interior diameter: 39 ft.
- TBM diameter: 42'-4" ft.
- TBM Type: Modified EPB
- Max surface settlement: 0.3"
- Ground type: Sand, silty sand, silt, limestone
- 2 lanes per tunnel
- Vertical vehicular clearance: 15 ft.
- Fixed firefighting (deluge) system. Hazardous vehicles are prohibited.

The Port of Miami Tunnel Project was conceived to relieve congestion in downtown Miami due to port related traffic. The project consists of twin bored tunnels constructed between Watson Island and Dodge Island.

The project was a public private partnership (PPP) between the Florida Department of Transportation and MAT Concessionaire, LLC. The concessionaire designed, built, and financed construction, and is also responsible for operation and maintenance. The tunnel will return to state ownership in 2044.

Construction began in May 2010, and the hybrid EPB Tunnel Boring Machine was launched on November 2011 from Watson Island heading eastbound and breaking through on July 2012. The TBM was repositioned and launched again on October 2012 heading westbound and was completed in May 2013. The project was open to traffic starting August 2014.

Several structures were identified as having a risk of damage from settlement, including a seawall, pedestrian bridge, storage shed, and swimming pool within the influence zone. Additionally, the TBM was required to pass close beside drilled piles supporting a two-span bridge abutment. Extremely porous and soft limestone discovered demanded that EPB TBM be adapted to safely mine without confinement overpressure. In addition, a specially developed mortar was injected into the porous coral to stabilize it during tunneling. Soil above shallow portal zones was treated using soil mixing.

The Florida Department of Transportation and MAT Concessionaire LLC reached a settlement in a dispute of how much the state must pay for unanticipated work on the project. The limestone found was extremely porous and many gaps in the rock needed to be filled with grout. The Resolution Board ruled modifications to the TBM were not compensable but the grouting costs were compensable. MAT and FDOT negotiated a settlement to an additional $58.5 million from project's contingency fund. The contingency fund was set up in advance with defined criteria for the concessionaire's access to funds. The dispute and settlement did not delay the work and the project remained on track to open in May 2014.

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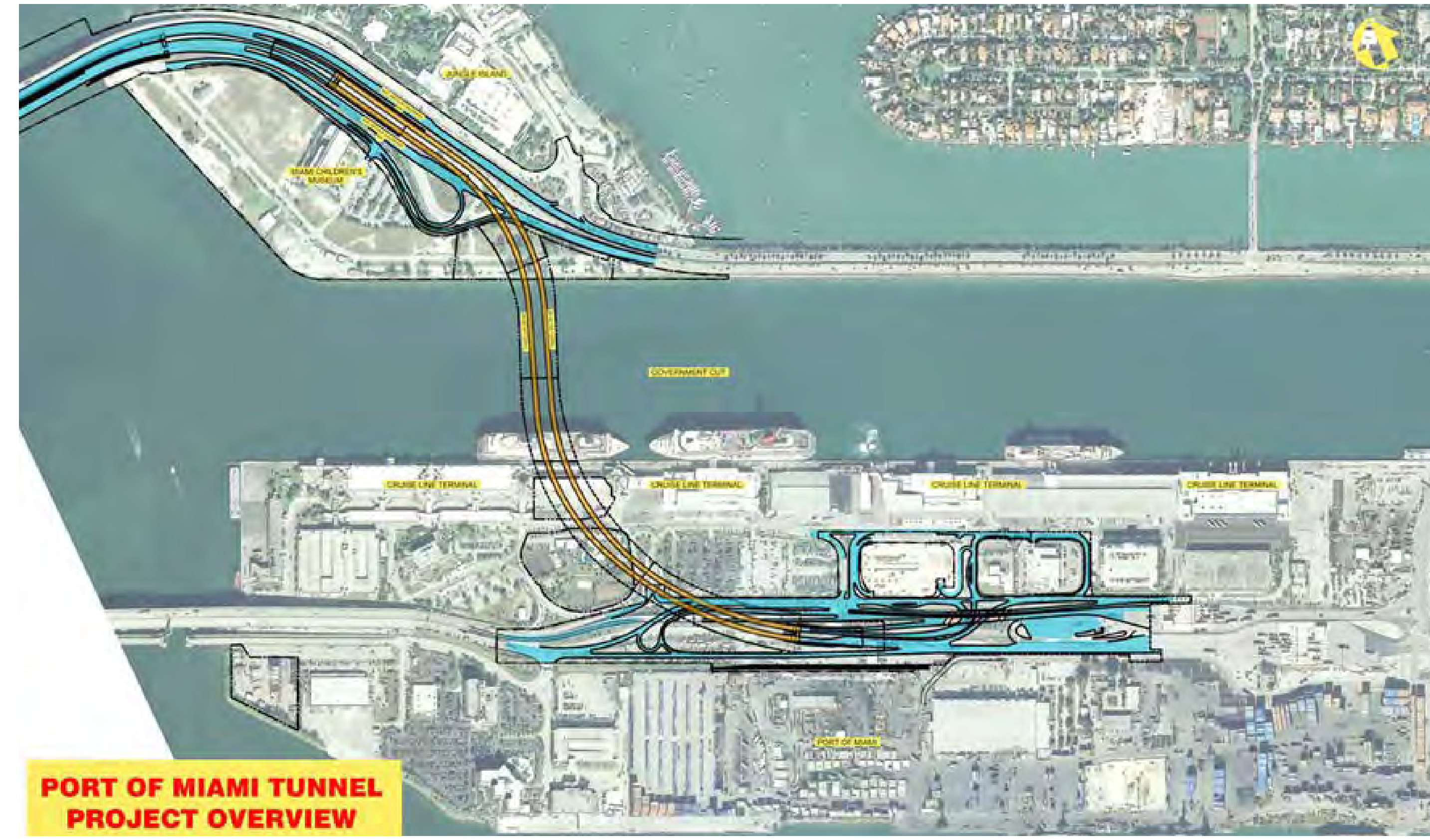
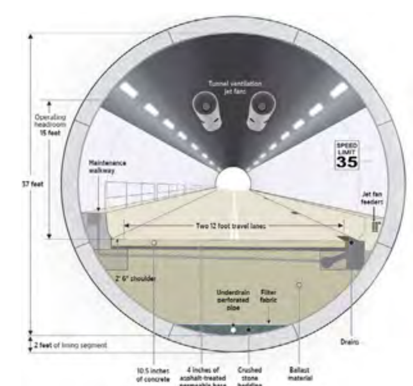
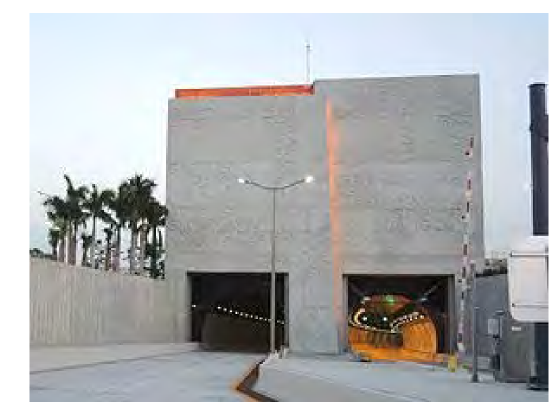






2 WATERVIEW TUNNEL, AUCKLAND, NEW ZEALAND

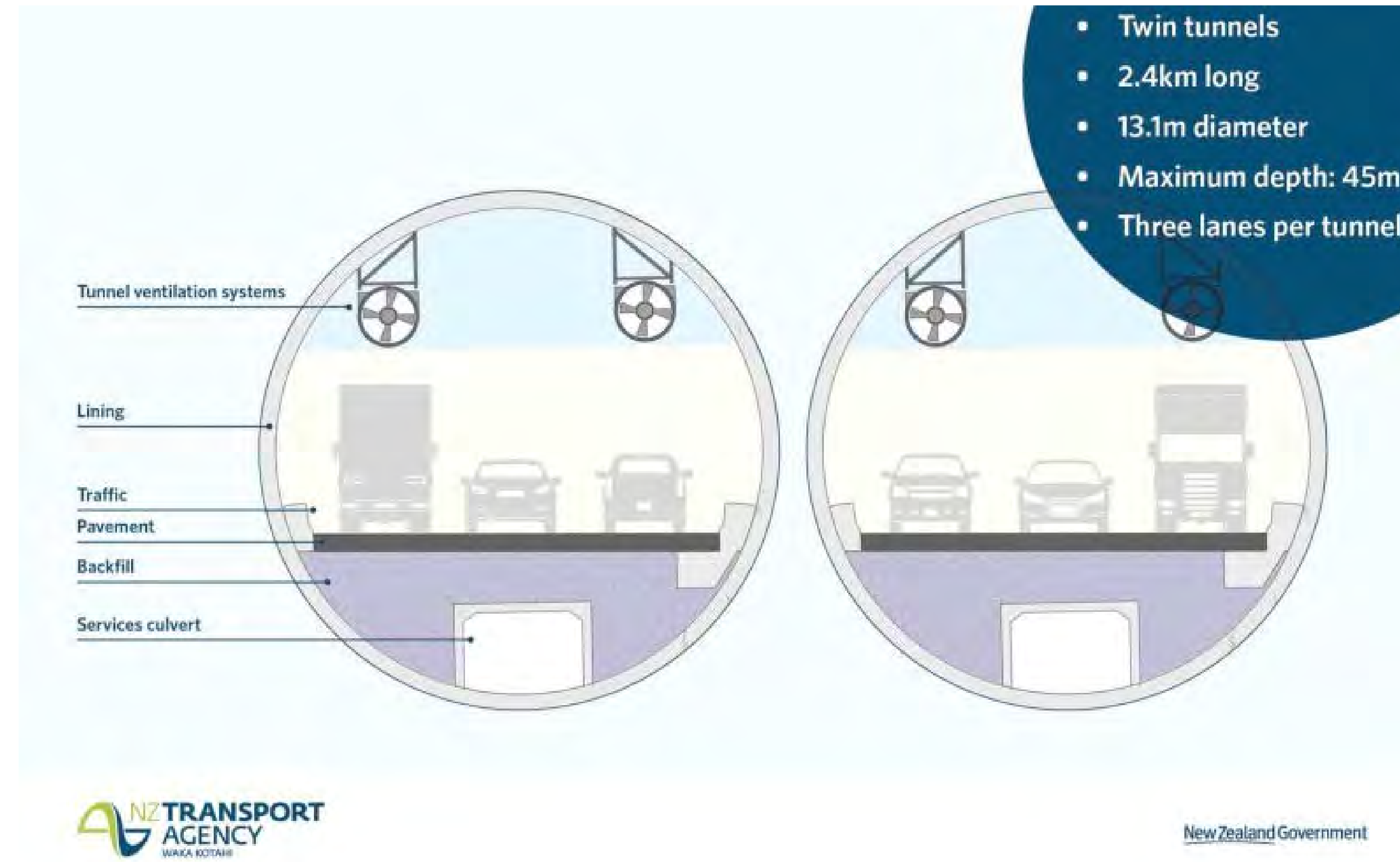
KEY ASPECTS OF THIS PROJECT ARE:

- Location: Auckland, New Zealand
- Client: Transit New Zealand
- Years built: (2011-2017)
- Tunnel Type: Automotive, Twin tubes
- Length: 5,200 ft per tunnel
- Interior diameter: 39 ft.
- TBM diameter: 47’-2”
- TBM Type: EPB
- Settlement: Negligible
- Ground type: alluvial soils and sandstones
- Lanes: 3 lanes per tunnel
- Vertical vehicular clearance: 16 ft.
- Fixed firefighting (deluge) system

Bored tunnels were announced as the preferred option for the Waterview tunnel in 2008. The New Zealand Transport Agency released report findings which showed that tunnel emissions would have negligible effect on the local air quality. These findings were disputed by representatives of the Waterview Primary School.

Tunnel segments were reinforced by a combination of steel fibers and reinforcing bars.

Tunnel opening is expected in July 2017, after a delay of 3 months. The primary reason delay was cited as being systems installation and testing.



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3 A1 SPARVO HIGHWAY TUNNEL, ITALY

KEY ASPECTS OF THIS PROJECT ARE:

- Location: Between Bologna and Florence, Italy
- Client: Autostrade per L'Italia S.p.A.
- Years built: (2011-2013)
- Length: 1.55 miles each tunnel (3.1miles total)
- Tunnel Type: Automotive, Twin tubes
- Interior diameter: 44.6 ft.
- TBM diameter: 51.2 ft.
- TBM Type: EPB
- Ground type: clay, argillite, and sandstone
- Volume Loss: (Unknown – mountainous)
- Lanes: 2 lanes plus full shoulder, each way

The Galleria Sparvo tunnel consists of two parallel tubes, each with a two-lane road and a third emergency lane. The contractor opted for an EPB Shield with a diameter of 51.2 ft. which represented a new world record for excavation diameter during the project's duration. Extremely complex geological conditions comprised heterogeneous material with spalling behaviour and hard rock inclusions. Both open and closed-face tunneling methods were used. Operating the TBM was a challenge for the crew as it had to be in closed EPB mode to help control methane gas release even though it was methane explosion protected. After the first drive broke through in July 2012, it took a U-turn to drive the second tube in the opposite direction in just fifteen days. In order to make the U-turn, an air propelled transporter was used to lift the massive TBM (in pieces) by a few millimeters. This allowed trucks to pull and guide the TBM into its new position.

Despite the gassy ground, the segments only used a single EPDM gasket.

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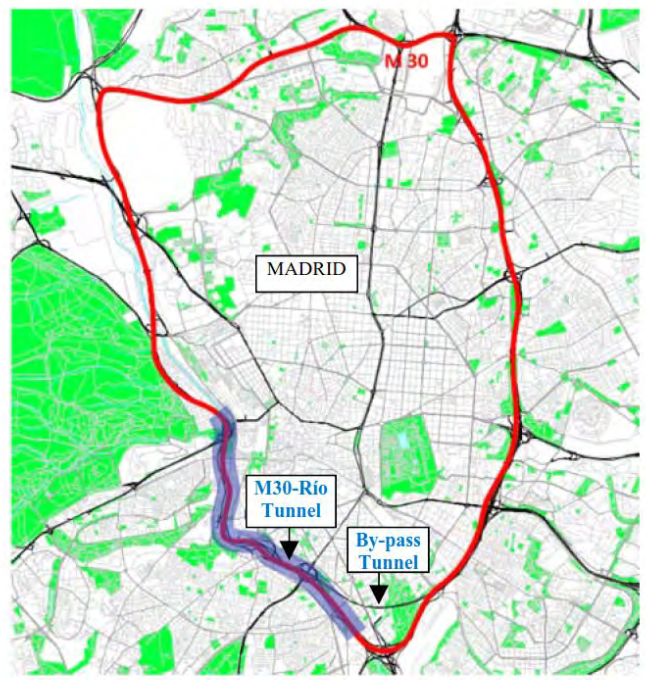
4 M30 SOUTHERN BYPASS TUNNEL, MADRID, SPAIN

KEY ASPECTS OF THIS PROJECT ARE:

- Location: Madrid, Spain
- Client: Local Madrid Road Authorities &
- Telvent Consultancy
- Years built: (2005-2008)
- Length: 11,800 ft, each tube
- Lanes: 2 lanes each way
- Tunnel Type: Automotive, Twin tubes
- Interior diameter: 44'-1"
- TBM diameter: 49'-1"
- TBM Type: EPB (two machines)
- Volume Loss: 0.1 to 0.4 %
- Ground type: alluvial deposits, fissured hard clay, gypsum, sand

The two TBMs used performed very well - one from Herrenknecht and one from Mitsubishi. Both performed well ahead of schedule. However, the Mitsubishi machine which was nearly six months late in being delivered on site. The Herrenknecht TBM completed its drive in eight months – a month ahead of schedule. The Mitsubishi, once started, completed its similar length drive through exactly the same ground, about a month quicker than the Herrenknecht machine. o

Portal Zones (very shallow cover) had compensation grouting and mortar pile improvement.



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5 ALASKAN WAY TUNNEL, SEATTLE, WA

KEY ASPECTS OF THIS PROJECT ARE:

- Location: Seattle, Washington
- Client: Washington State Department of Transportation
- Delivery: Public-Private Partnership
- Years built: (2013-2019)
- Length: 2 miles
- Tunnel Type: Single Stacked Tube
- Interior diameter: 52 ft.
- TBM diameter: 57'-3"
- TBM Type: EPB
- Volume Loss: 0.2%
- Ground type: glacial ands, silts, clay, High groundwater table
- Lanes: 2 lanes upper, 2 lanes lower
- Vertical vehicular clearance: 15 ft.

In 2009 government officials decided to replace the Alaskan Way Viaduct with a deep-bore tunnel. The Alaskan Way Tunnel project is being delivered as a public-private-partnership (PPP) between the contracting team of Dragados USA and Tutor Perini, known as Seattle Tunnel Partners, and client Washington State Department of Transportation.

Boring began in July 2013 with the largest diameter tunnel boring machine (TBM) to date. Although originally scheduled for completion in December 2015, the project was halted in December 2013 when it was discovered that the TBM had damaged several of its cutting blades after encountering a steel monitoring-well casing installed during planning for the project. A 120-ft deep recovery pit was dug from the surface over the next two years in order to access and lift the machine for repair and partial replacement. In December 2015, the TBM resumed tunneling but met with another delay due to a sinkhole near the launch pit above the TBM. Tunneling resumed on February 2016 and broke through the exit pit on April 2017. The project is expected to be complete in early 2019. An estimated $223 million in cost overruns were reported as a result of the two year stoppage.

It is anticipated that installing internal structures and systems will take up to two years. This is longer than would be typical for a twin bore tunnels. Installing internal structures

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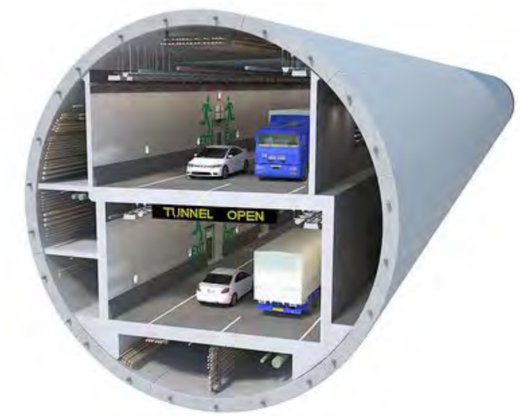

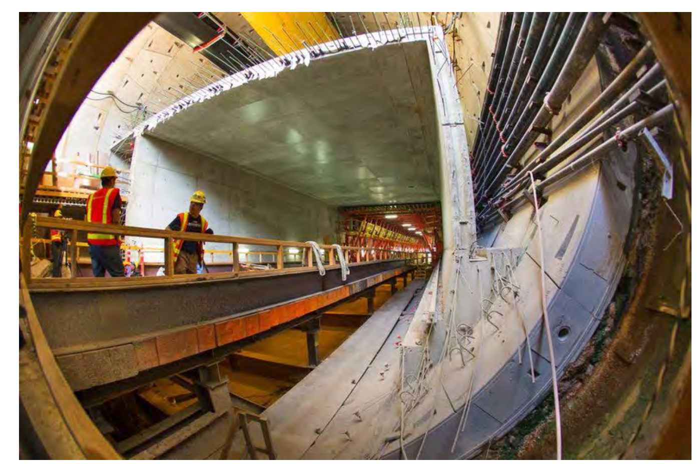

6 EURASIA TUNNEL, ISTANBUL, TURKEY

KEY ASPECTS OF THIS PROJECT ARE:

- Location: Istanbul, Turkey
- Client: Turkish Ministry of Transport, Maritime Affairs and Communications
- Delivery: Public Private Partnership (Design-Build-Operate-Transfer)
- Years built: (2011-2016)
- Length: 16,400-ft
- Tunnel Type: Single Stacked Tube
- Interior diameter: 39'-4"
- TBM diameter: 45 ft.
- TBM Type: Slurry
- Vertical vehicular clearance: 9'-10" (cars and van only)
- Volume Loss: unknown – underwater crossing
- Ground type: Alluvial sediment (sandy), sedimentary bedrock

The Eurasia Tunnel opened in December 2016 providing a double deck tunnel under the Bosphorus, thereby connecting the European and Asian parts of Istanbul. With the new tunnel travel was cut to five minutes.

The contractor and Concessionaire was Yapi Merkezi Construction in joint venture with SK Engineering and Construction. The Concessionaire will build and operate the facility for a concession period of 26 years, after which tunnel ownership will pass to the government.

The alignment is located in a seismically active region. The tunnel has been designed to withstand earthquakes up to 7.5 on Richter scale by using two flexible seismic joints. Double EPDM gaskets were used to resist 300-ft head of groundwater water.

Tunneling progressed well, with TBM breakthrough on August 22nd 2015. Tunnel operation started in December 2016.

Longitudinal ventilation was provided by jet fans in the ceiling of each roadway, working in conjunction with two ventilation buildings. The upper roadway deck was cast in situ and the lower deck was formed from precast concrete panels. The decks rested on corbels dowelled into the tunnel lining. The space beneath the lower deck accommodated electrical and mechanical systems, and utilities.

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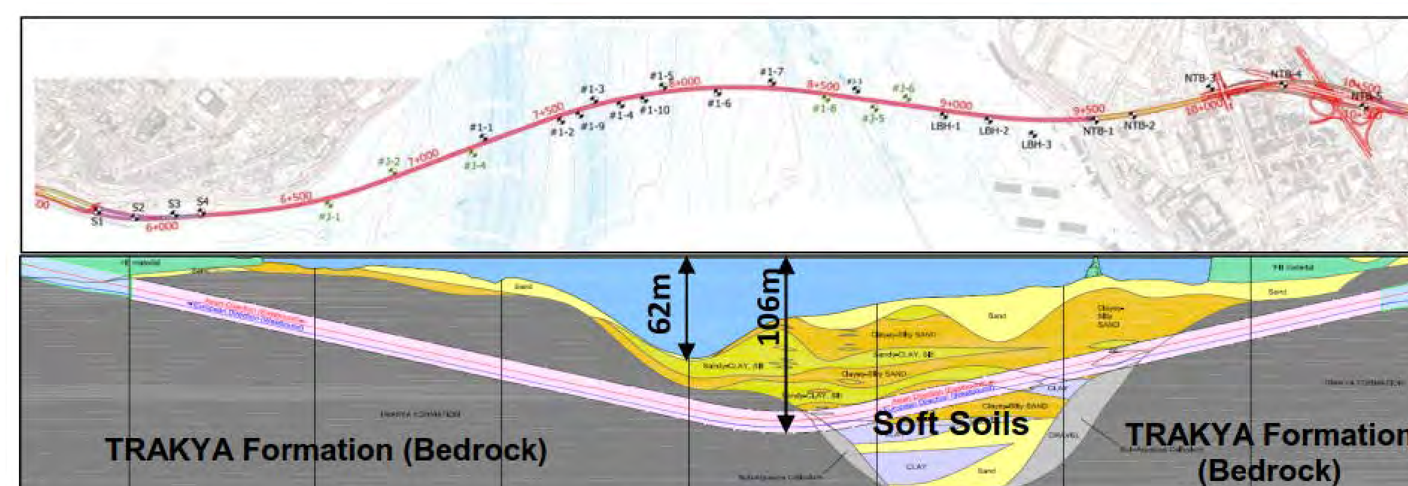

7 A86 TUNNEL, PARIS, FRANCE

Key aspects of this project are:

- Location: Paris, France
- Client: French State
- Delivery: Public-Private Partnership
- Years built: (1994-2011)
- Length:
- East Tunnel VL1: 15,300 ft; open to traffic in July 2009
- West Tunnel VL2: 17,400 ft; open to traffic in January 2011
- Tunnel type: Single Stacked Tube
- East Tunnel VL1: Single tube with two decks. Two lanes + full shoulder each deck, for cars only.
- West Tunnel VL2: Single tube with one deck. Two lanes (one lane each way). All vehicles.
- Interior diameter: 34 ft
- TBM diameter: 38 ft
- TBM Type: Slurry and EPB (convertible)
- Vertical vehicular clearance: East Tunnel VL1: 8'-5"
- West Tunnel VL2: 14'-9"
- Ground type: Fontainebleau Sands, Chalk, Plastic Clay, Rough Limestone, Marl

The A86 Tunnel is the final link of the 80 km ring road around Paris, France and is the world's longest urban motorway tunnel. It cuts the journey from Malmaison to Versailles to only ten minutes rather than 45 minutes. It includes two tunnels, the East Tunnel with two decks for small vehicles, and the West Tunnel for all vehicles. The double-deck tunnel has two lanes plus a full shoulder on each level. It was due to open in October 2007, but was delayed until July 2009. The West Tunnel has just two lanes total. It was due to open in December 2009 but was delayed until January 2011.

Transverse ventilation was provided, with two double-deck tube (VL1) having a separate pair of fresh air and extraction ducts for the upper and lower tunnels, as shown above. Some longitudinal ventilation is also provided. The tunnel operations center generally has the following personnel: during the day (6h-22h): 2 supervisors and 6 road patrollers; during the night (22h-6h): 2 supervisors and 4 road patrollers.

The project is a public-private partnership between the French government and a concessionaire led by Vinci. Vinci will own and operate the tunnel until 2086, when it will return to the state.

The bi-level tunnel has an intermediate interchange, for connections to local roads.

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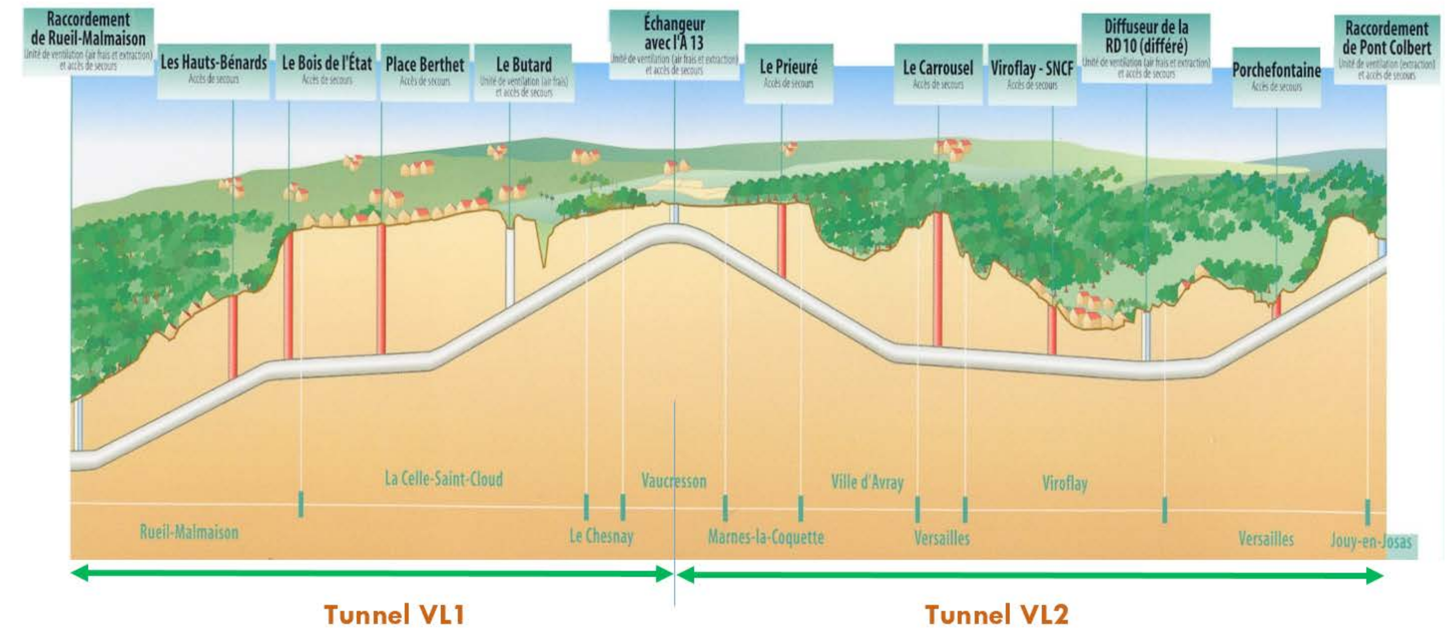
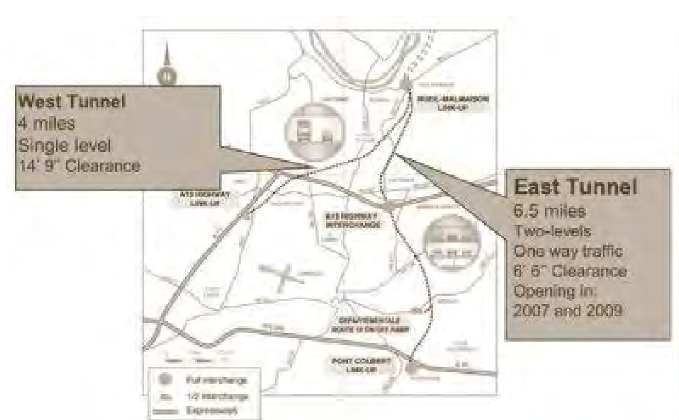



Extraction
Fresh air
Extraction
Fresh air


Tunnel VL1
Tunnel VL2
PARIS
A86
A14
A13
A1
A3
A4
A6
N118
N286
A126
A103
B.P.
Aéroport PARIS - ORLY


Extraction
Fresh air


West Tunnel
4 miles
Single level
14' 9" Clearance
East Tunnel
6.5 miles
Two-levels
One way traffic
6' 6" Clearance
Opening In:
2007 and 2009
Full interchange
1/2 interchange
Expressway