Appendix B-2
Tunnel Feasibility Study

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Concepts for Replacing the I-81 Viaduct in Syracuse with a Tunnel

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1.0 Introduction

The New York State Department of Transportation (NYSDOT) and Federal Highway Administration (FHWA) have conducted a study to assess the feasibility of constructing a tunnel through the center of Syracuse, NY that would replace the existing Interstate 81 (I-81) viaduct. For the feasibility study, three concepts (named T-5, T-6, and T-7) were developed and subsequently assessed based on cost and constructability. This report summarizes the results of the engineering and analysis of the feasibility study.

2.0 Objectives of the Feasibility Study

The objectives of the study were to develop concepts for replacing the existing I-81 viaduct through the center of Syracuse, NY with a tunnel and to examine the feasibility of those concepts related to cost and constructability. Both shallow and deep tunnel alignments through the center of Syracuse were evaluated. The shallow alignment concept (T-5) would meet interstate standards and follow the route of Almond Street, below the existing I-81 viaduct. The two deep tunnel concepts (T-6 and T-7) would be located west of existing I-81. Concept T-6 would meet interstate standards, while Concept T-7 would be designed as a high speed, non-interstate facility. These tunneling concepts are discussed in detail in Sections 4 and 5. Figure 1 presents plan views of the three concept alignments.

To develop the tunnel concepts described in this report, available geotechnical data and historic boring logs were examined to determine the subsurface soils and rock strata along the I-81 corridor. Concept T-5, the shallow tunnel concept, would involve a cut and cover tunnel to be constructed in the soils overlying the bedrock. Concepts T-6 and T-7, the two deep tunnel concepts, would consist of bored tunnels in the bedrock, with the shallow segments of the deep tunnels constructed using the cut and cover and Sequential Excavation Method (SEM) techniques. SEM involves sequentially excavating the tunnel face and monitoring the response of the ground to formation of an opening at different stages and optimizing the support system during construction (FHWA, 2009). Plans and vertical roadway profiles for these alignments were developed considering the subsurface ground conditions, surrounding structures, existing utilities, and other applicable constraints on the geometry. The risks associated with the tunnel construction methods and measures to reduce those risks were identified and are discussed in this report. The potential impacts on the adjacent structures and existing utilities during construction and the costs associated with those impacts are addressed. Conceptual cost estimates and construction durations for the tunnel concepts are also presented in this report.

The analysis for the tunnel concepts included assessment of the following:

- The need for and location of ancillary facilities, which could include ventilation buildings, ventilation shafts, maintenance structures, control rooms, access shafts, and cross passages;
- The need for and location of a groundwater control system necessitated by the high groundwater table in the Downtown area;
- The treatment and disposal of saline groundwater;

- The need for excavation support systems and underpinning of the nearby structures (e.g., underpinning of buildings and the existing viaduct) to reduce ground deformation, provide water tightness, and protect buildings adjacent to the tunnel from ground movements;
- The need for protection and relocation of existing utilities; and
- The need for temporary decking over areas of excavation to restore pedestrian, bicycle, and vehicular traffic.

For the purposes of conducting the engineering analysis and developing the cost estimates for this feasibility study, it was assumed that the concepts would meet all or most of the nonstandard and most nonconforming highway features within the section of I-81 between Dr. Martin Luther King, Jr. East (MLK, Jr. East) and Spencer Street. It was also assumed that the concepts would meet 60 MPH design standards, with a posted speed limit of 55 MPH. The tunnel concepts would include a new, fully directional interchange between I-81 and Interstate 690 (I-690). They would provide new ramps between eastbound I-690 and northbound I-81 and between southbound I-81 and westbound I-690. The tunnel concepts would also include surface street improvements, pedestrian and bicycle improvements, and context-sensitive design treatments.

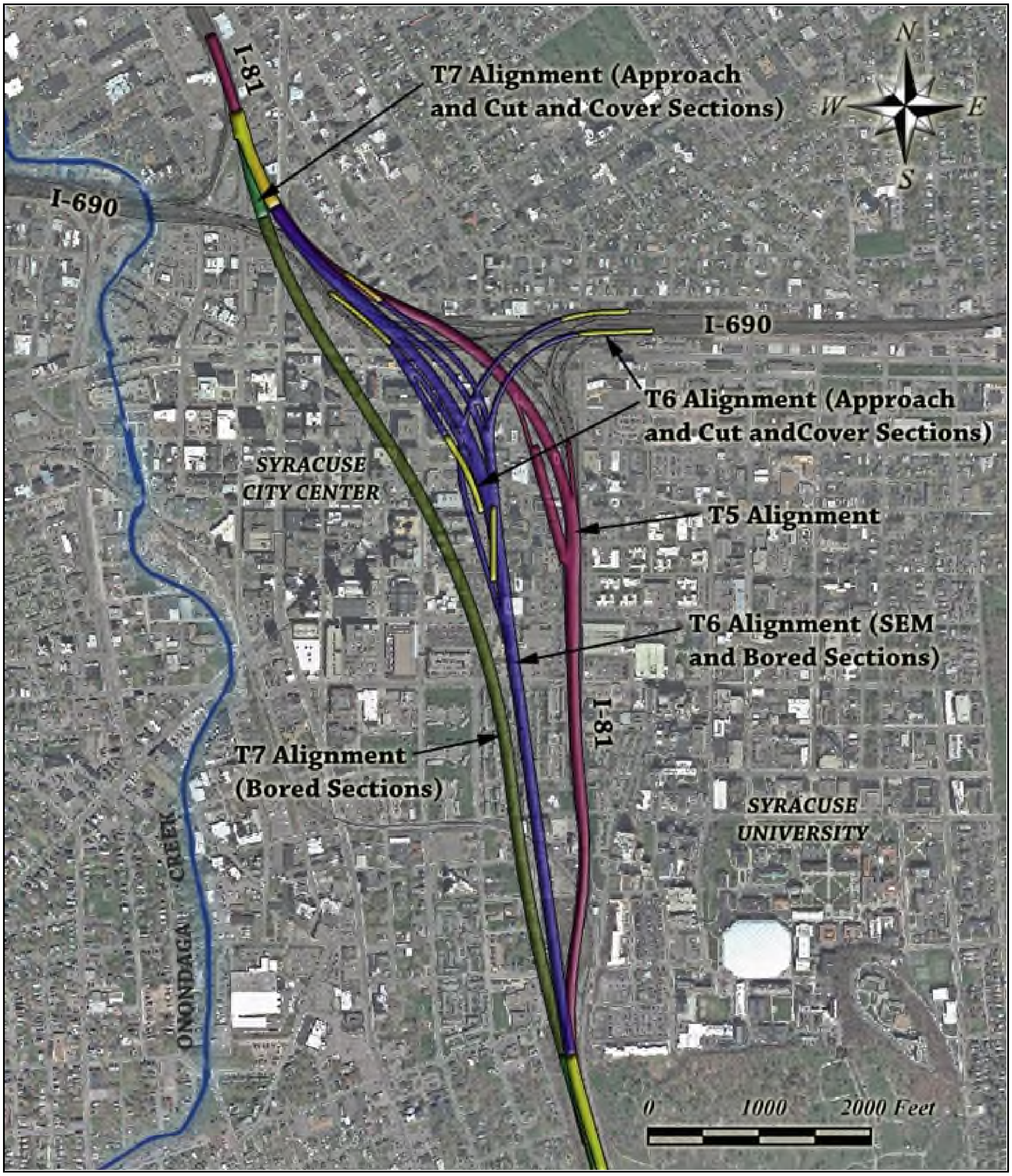


Figure 1: Location Map Showing Tunnel Concepts

3.0 Site Geology and Groundwater Characteristics

Figure 1 shows the approximate horizontal alignments for the three tunnel concepts evaluated in this report. This section documents the land surface elevations, bedrock elevations subsurface stratigraphy, groundwater flow, and groundwater quality that may impact or be impacted by the construction of the tunnel concepts.

3.1 Land Surface Elevations

Figure 2 shows the relative topography of the land surface with elevation contour intervals of 10 feet and a color gradation from light blue (elevation 362 feet NGVD - National Geodetic Vertical Datum 1929) through light red (elevation 580 feet NGVD 1929). These data were derived from Digital Elevation Data (DEM) (CUGIR, 2015) and the aerial photo base of Figure 1 is shown faintly visible for reference.

As the figure indicates, most of Syracuse City Center is fairly low-lying and flat with drainage to Onondaga Creek to the west. High lands at Syracuse University and to the northeast surface drain towards the City Center. Just below Interstate I-690, running in the east-west direction, is a valley in which the Erie Canal (now Erie Boulevard) was located. This valley represents a substantial source of drainage, both in terms of surface runoff and groundwater flow as addressed in Section 3.4.

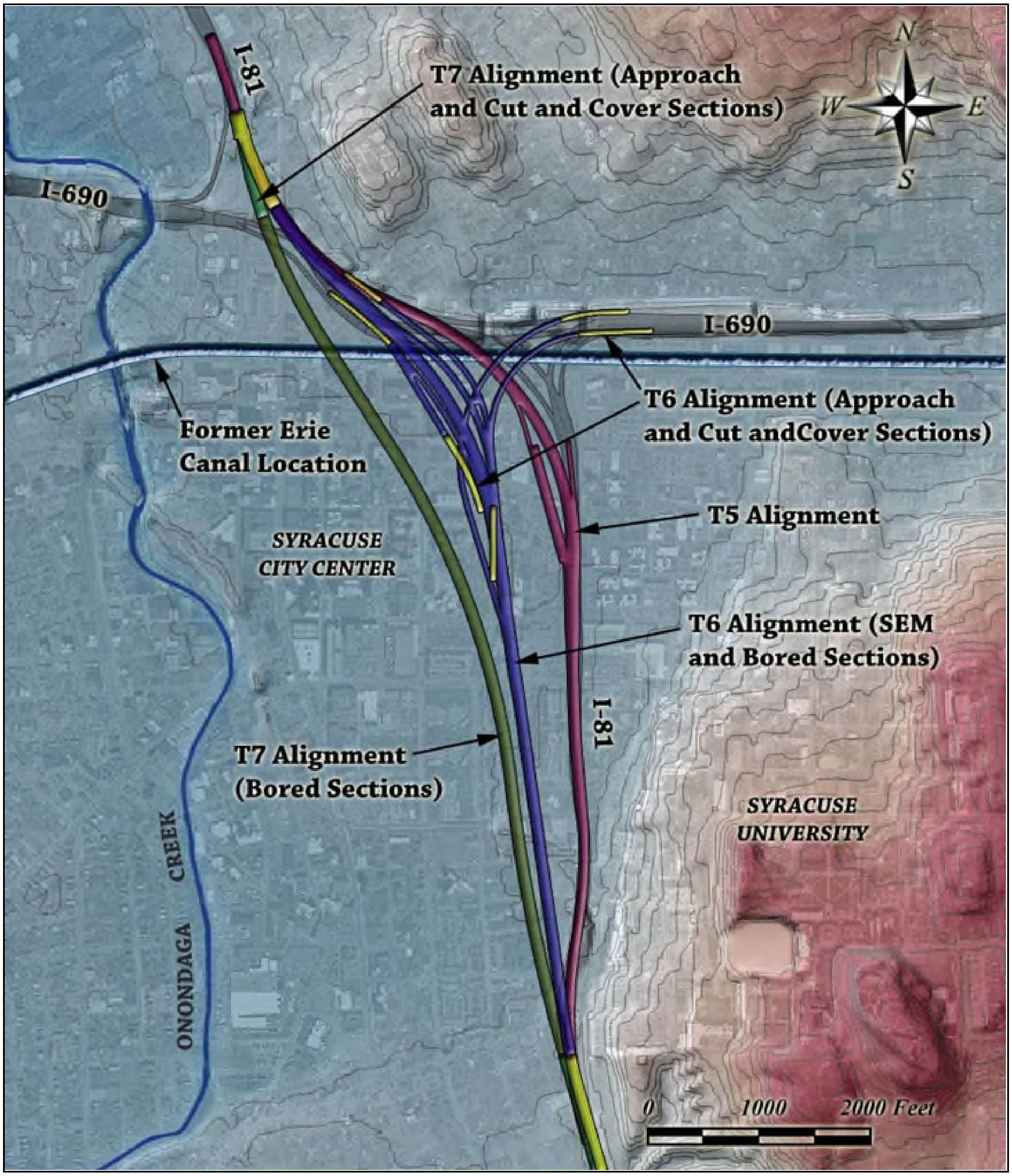


Figure 2: Generalized Map of Land Surface

3.2 Subsurface Information Sources and Previous Studies

Mapping of the surface and subsurface geology has been in process in the Syracuse area since the 1800s (Hopkins, 1914). Principal background sources used in this feasibility study include the current bedrock geology maps, which are reproduced in Figure 3, and studies by the United States Geological Survey (USGS) on halite brine underlying Syracuse and surrounding areas (USGS, 2000; Kappel, 2005; Yager, 2007). These features are shown in

Figure 3 with interstate highway, the tunnel concepts, and Onondaga Creek alignments superimposed for reference.

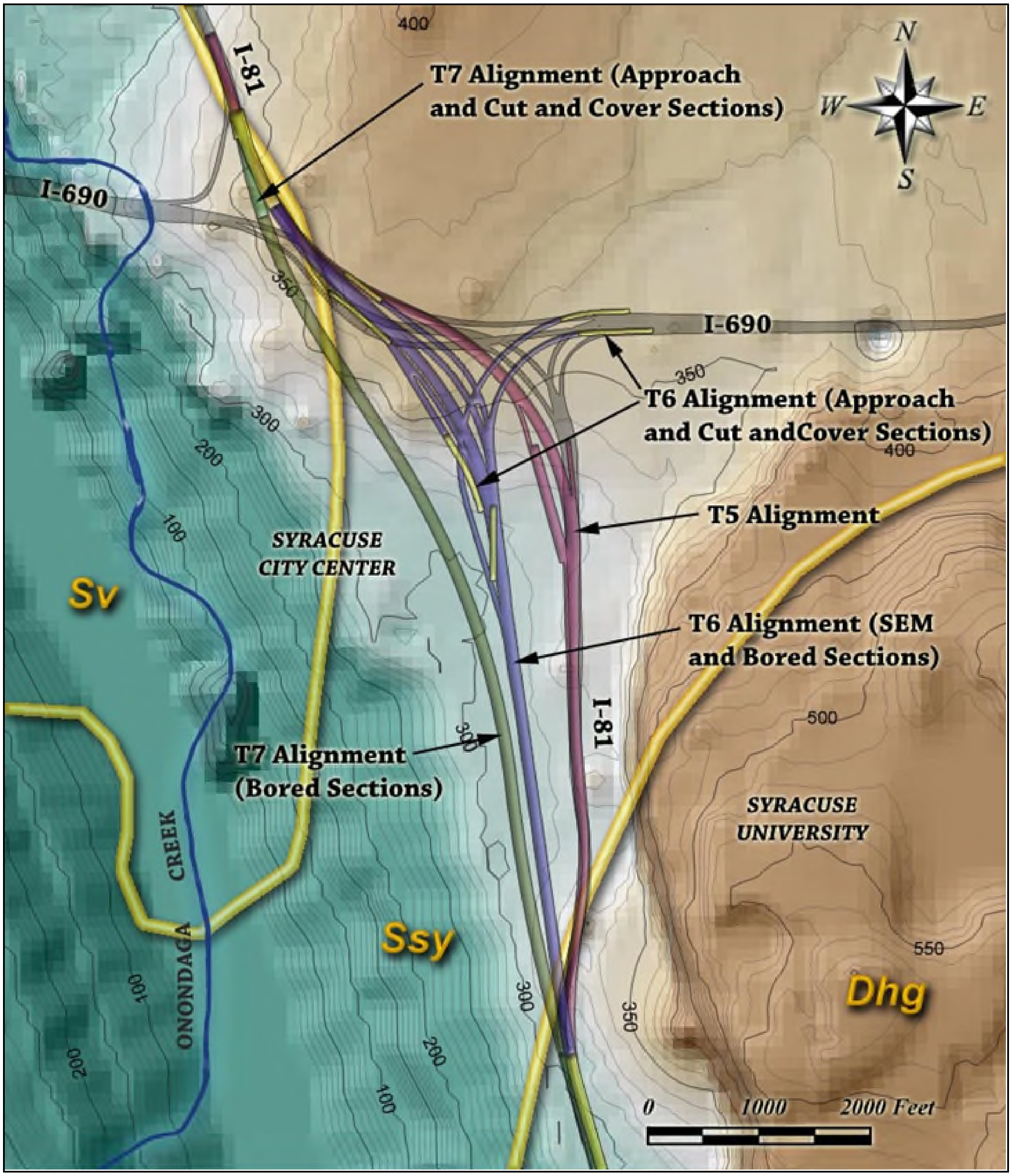


Figure 3: Bedrock Topography and Types

The bedrock elevations in Figure 3 are color shaded from a low elevation of about 0 feet NAVD88 (**North American Vertical Datum of 1988**) at the bottom of a trough (known as the Onondaga Trough) underlying Onondaga Creek to a high elevation of about 590 feet NAVD88 on the southern portion of the Syracuse University campus. Contour elevations are shown in bold on a 50-foot interval and in lighter lines on a 10-foot interval. This color shaded map and contours were generated from a bedrock DEM developed for the USGS study of the halite brine in the Onondaga Trough (Yager, 2015).

Also shown on Figure 3 are the limits of mapped bedrock types (shown as a thick yellow line) according to the Geologic Map of New York (Rickard, 1970) and provided as a shape file (New York State Museum, 2016). The bedrock underlying the area is all from the Paleozoic Era and includes the Coeymans and Manlius Limestones, Rondout Dolostone (Dhg – see Figure 3) of the Helderberg Group of the Lower Devonian Period; the Vernon Formation (Sv) of the Akron Dolostone, Cobleskill Limestone, and Salina Group in the Upper Silurian Period; and the Syracuse Formation (SSy), also of Akron Dolostone, Cobleskill Limestone, and Salina Group in the Upper Silurian Period. The lithology of the Vernon Formation includes shale and limestone and the lithology of the Syracuse Formation includes dolostone, shale, gypsum, and salt. The majority of the proposed tunnel alternatives alignments and all of the proposed bored tunnel alternatives alignments are situated within the region of the Syracuse Formation.

The bedrock map of Figure 3 shows that a bedrock valley (named "East Syracuse Channel" in "Hydrogeology of the Valley-Fill Aquifer in the Onondaga Trough, Onondaga County, New York," Kappel, 2005) extends east-northeast from the Onondaga Trough and underlies the central portion of the tunnel concepts. Bedrock elevations in this valley range from about 300 feet to approximately 320 feet NAVD88 at the valley floor and they extend well beyond I-690 to the northeast. Because of its configuration, the valley presents a likely pathway for substantial groundwater flow from east to west across the tunnel concept alignments. Figure 2 indicates that the surface valley generally corresponds to the configuration of the bedrock valley and flows to Onondaga Creek, which overlies the trough. Along the tunnel concept alignments, to the north and south of the valley, the bedrock and surface grades also generally slope downward from east to west.

3.3 Bedrock Surface and Stratigraphy

Bedrock surface topography is an essential component of this evaluation, both in terms of groundwater flow and in defining the limits and depths of bored tunnel portions. Because of this, the work by the USGS, as presented in Section 3.2 and shown in Figure 3, was supplemented by collecting and interpreting extensive boring and well log data sets within the vicinity of the concept alignments. In addition to NYSDOT data, data were obtained from the USGS (Kappel, 2016; USGS, 2016; Phillips, 2016), Syracuse University (Westcott, 2016), Onondaga County Department of Water Environment Protection (Suryadevara, 2016), and the City of Syracuse (Kivlehan, 2016; Robison, 2016). Of these data, many logs were not deep enough to encounter bedrock or to provide substantial relevant information. However, the locations of those logs that provided useful bedrock and/or unconsolidated stratigraphic information are shown in Figure 4.

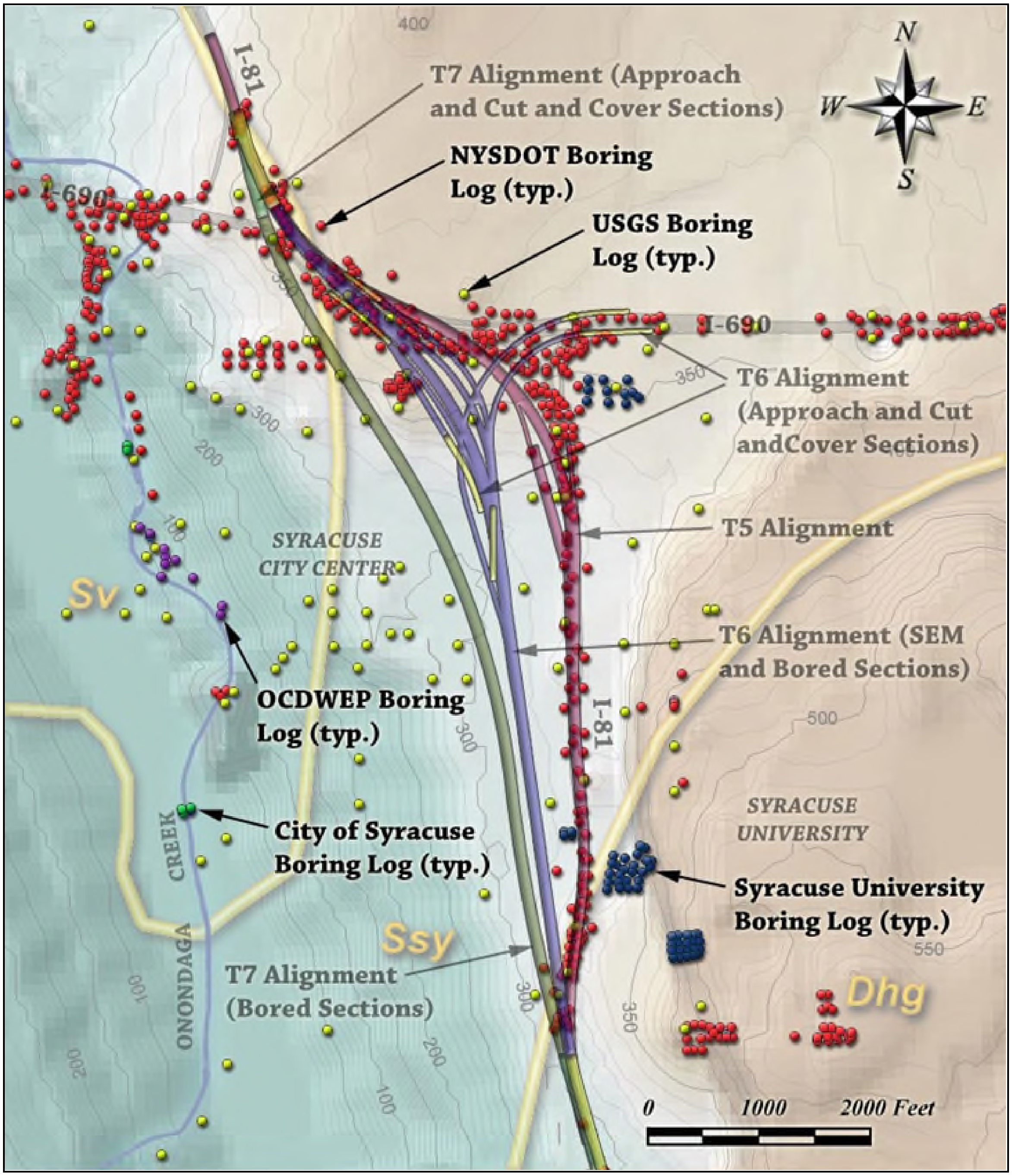


Figure 4: Locations of Boring Logs Reviewed in This Study

These data were evaluated and engineering judgments were made regarding the different nomenclature and how it relates to weathered rock, competent bedrock, and various unconsolidated material categories. On the basis of these data and interpretations, the USGS DEM presented in Figure 3 was modified as shown in Figure 5. This modified bedrock surface shows that the USGS DEM is largely consistent with the data of this feasibility study. Some changes include that the 300 foot NAVD88 contour advances farther toward the northeast and extends to approximately the present alignment of I-81. The bedrock valley beyond that point is much the same as presented by the USGS DEM. Bedrock to the west of

Syracuse University is higher than the USGS surface, particularly along the Concept T-5 alignment. Bedrock is also higher than the USGS surface at the northern terminus of all three tunnel concept alignments.

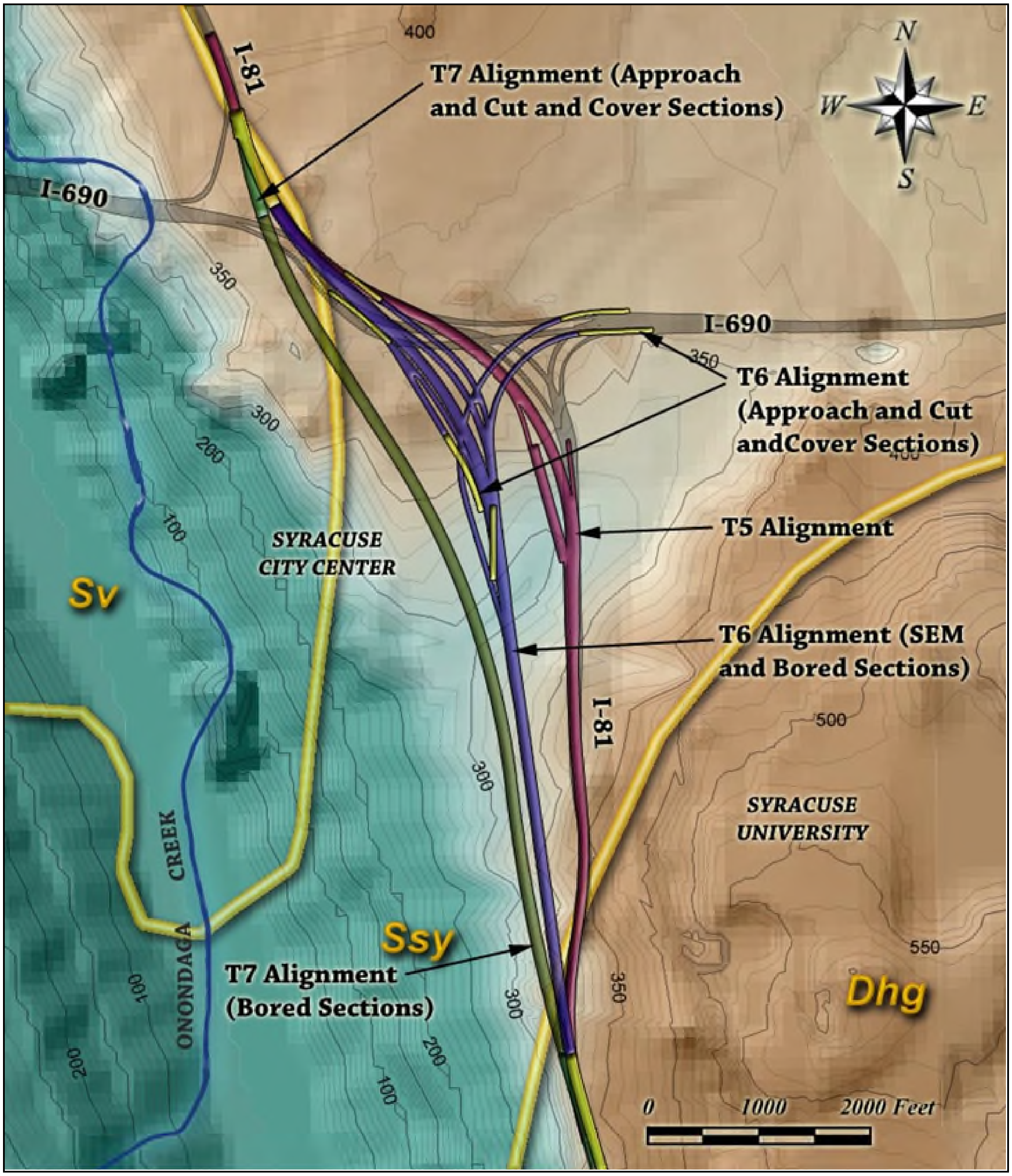


Figure 5: Revised Bedrock Surface

Figures 6, 7, and 8 show the profile alignments of all three tunnel concepts with respect to the land surface elevations of Figure 2 and the revised bedrock surface of Figure 5. The figures also show the vertical extents of those wells and borings shown in Figure 4, which are horizontally located within 200 feet of each alignment.

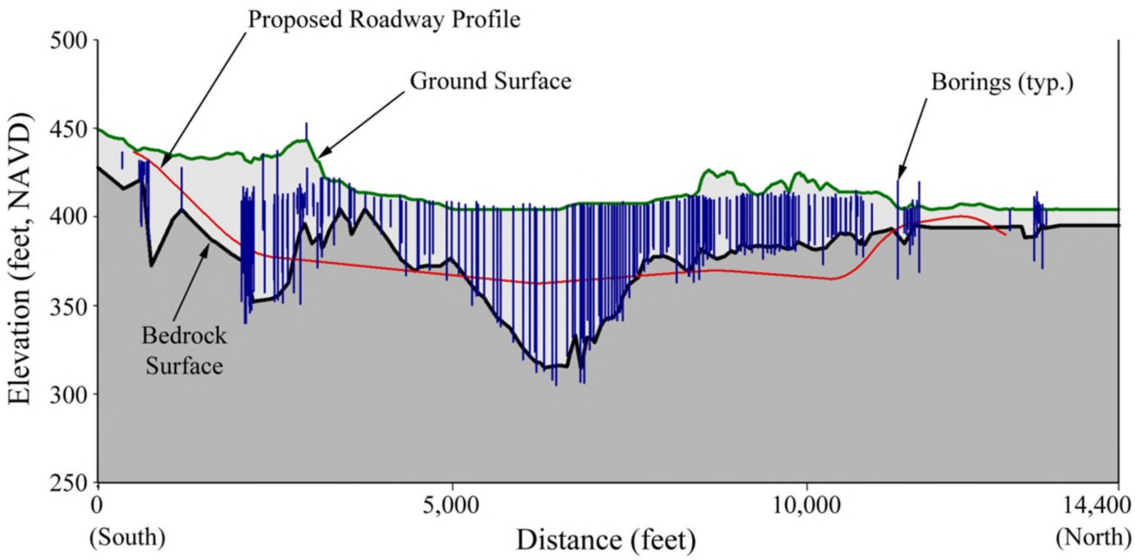


Figure 6: T-5 Profile Showing Borings within 200 Feet

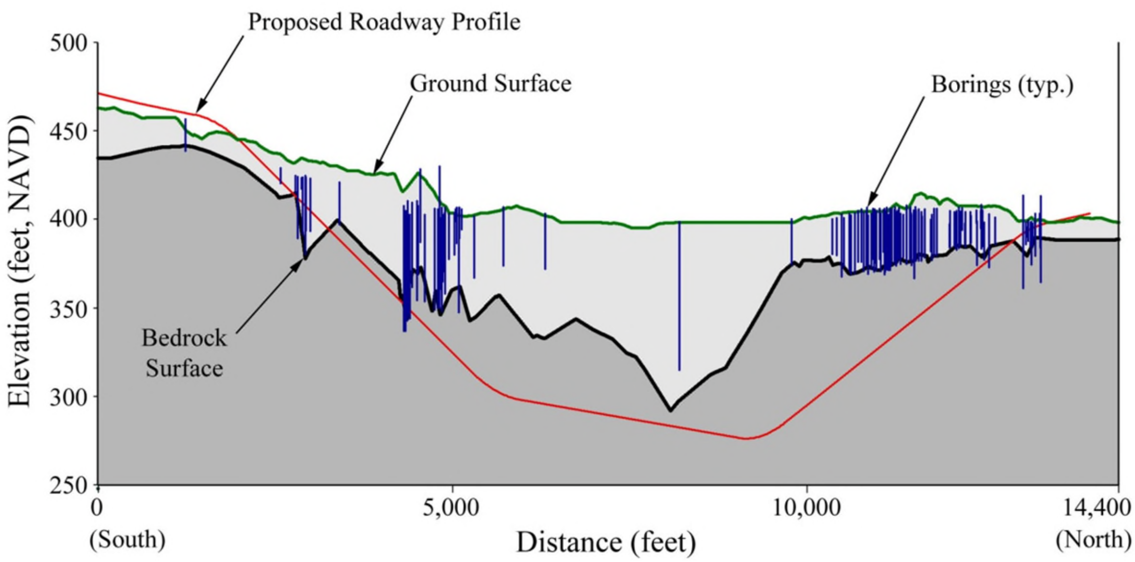


Figure 7: T-6 Profile Showing Borings within 200 Feet

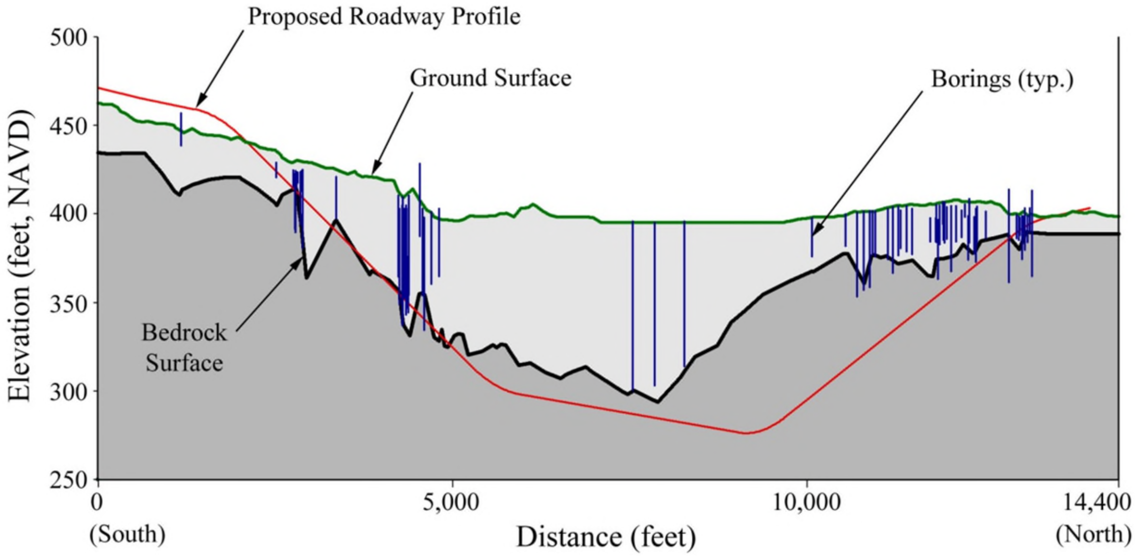


Figure 8: T-7 Profile Showing Borings within 200 Feet

The boring data were further interpreted and separated into generalized stratigraphic units of sands and gravels, clays, silts, and fill. A substantial sand and gravel unit was identified generally lying near the bottom of the East Syracuse Channel and extending to the west beneath Onondaga Creek. Substantial continuous low-permeability layers of silts and clays were generally found above and below this unit and a mixture of silts, sands, clays, and fill materials was identified at shallow elevations.

For illustration purposes, the following four figures (Figures 9 to 12) give an oblique view from the same vantage point (southwest) and show the land surface with aerial photo overlaid for reference, the top of the sand and gravel layer, the bottom of that layer, and bedrock. Each figure is contoured with an interval of 10 feet and shaded with identical limits from brown at elevation 265 feet to white at elevation 590 feet. The vertical exaggeration is 10:1 and the contours on Figure 12 do not extend below elevation 265 feet even though the actual bedrock surface is shown in brown to its lowest elevation of approximately 0 feet, as explained previously.

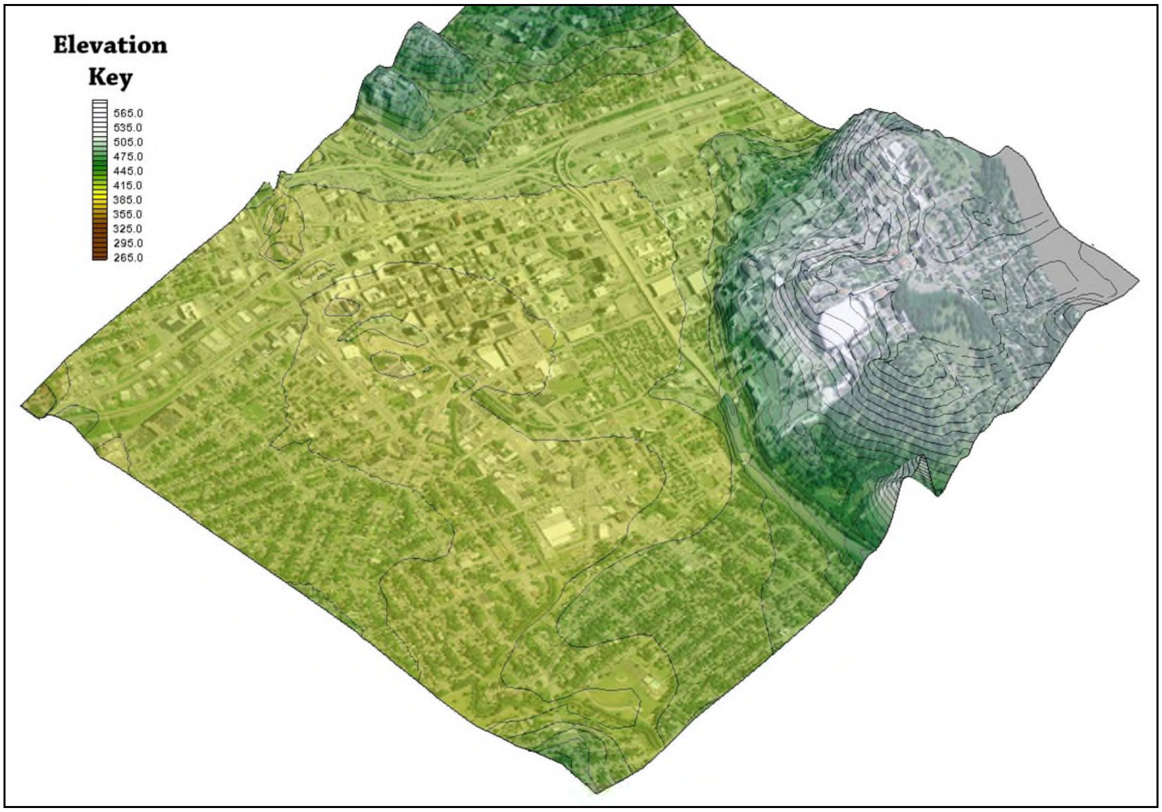


Figure 9: Oblique View of Land Surface (viewed from southwest)

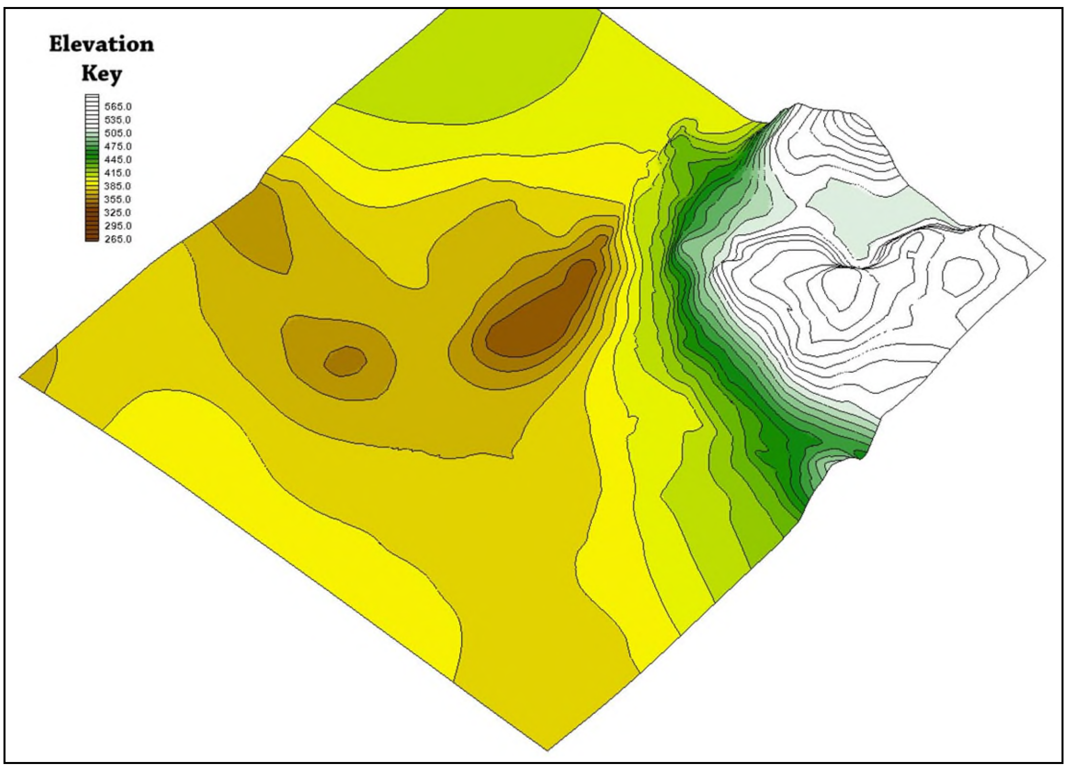


Figure 10: Oblique View of Top of Sand and Gravel Layer (viewed from southwest)

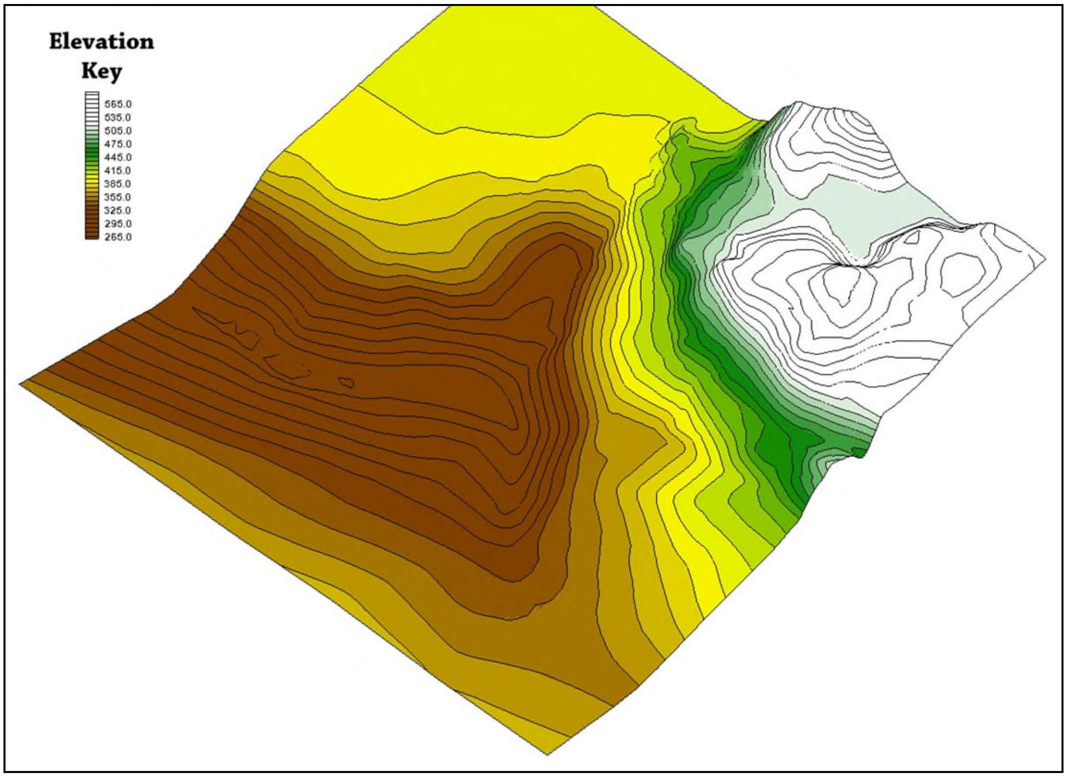


Figure 11: Oblique View of Bottom of Sand and Gravel Layer (viewed from southwest)

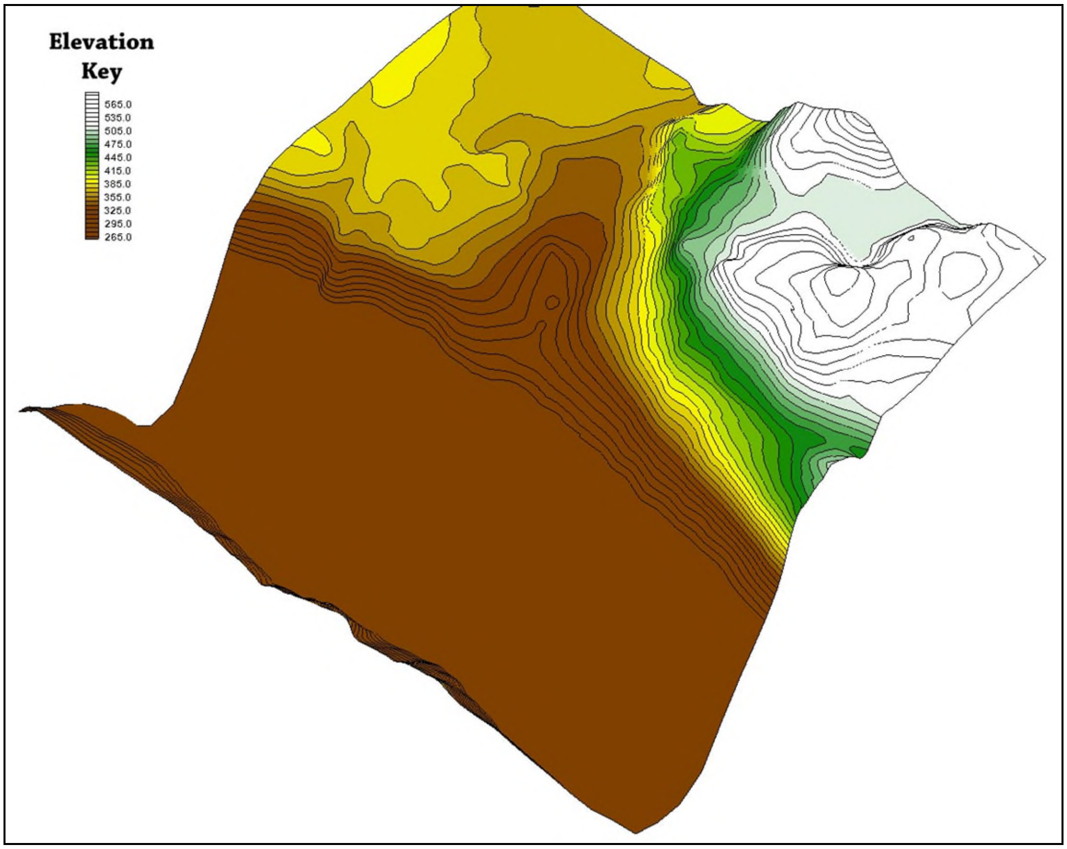


Figure 12: Oblique View of Bedrock Surface (viewed from southwest)

3.4 Groundwater Flow System Conceptual Model and Hydrologic Budget

The groundwater flow system in the vicinity of the tunnel concepts emanates from boundaries to the north and east and discharges to Onondaga Creek to the west and Onondaga Lake to the northwest. Groundwater boundaries are assumed to generally reflect watershed boundaries, especially in thin overburden areas in which most of the boundaries lie. The watershed boundaries are shown in Figure 13.

Also shown on Figure 13 are the groundwater elevation data available from the United States Geological Survey (USGS, 2015). The groundwater information on Figure 13 was measured on various dates from July 21, 1958 through February 17, 2006 with the greatest number measured in the 1961 to 1964 timeframe. Thus, the data likely reflect varying conditions, including climate cycles (wet year versus drought year) as well as possible pumping conditions in some areas. In addition, the data reflect water levels associated with the screened interval of the wells in which they were measured. Thus, the data do not represent average groundwater conditions for a particular hydrogeologic unit. However, for the purpose of the preliminary evaluation of this study, these data give a general and sufficient representation of the groundwater surface.

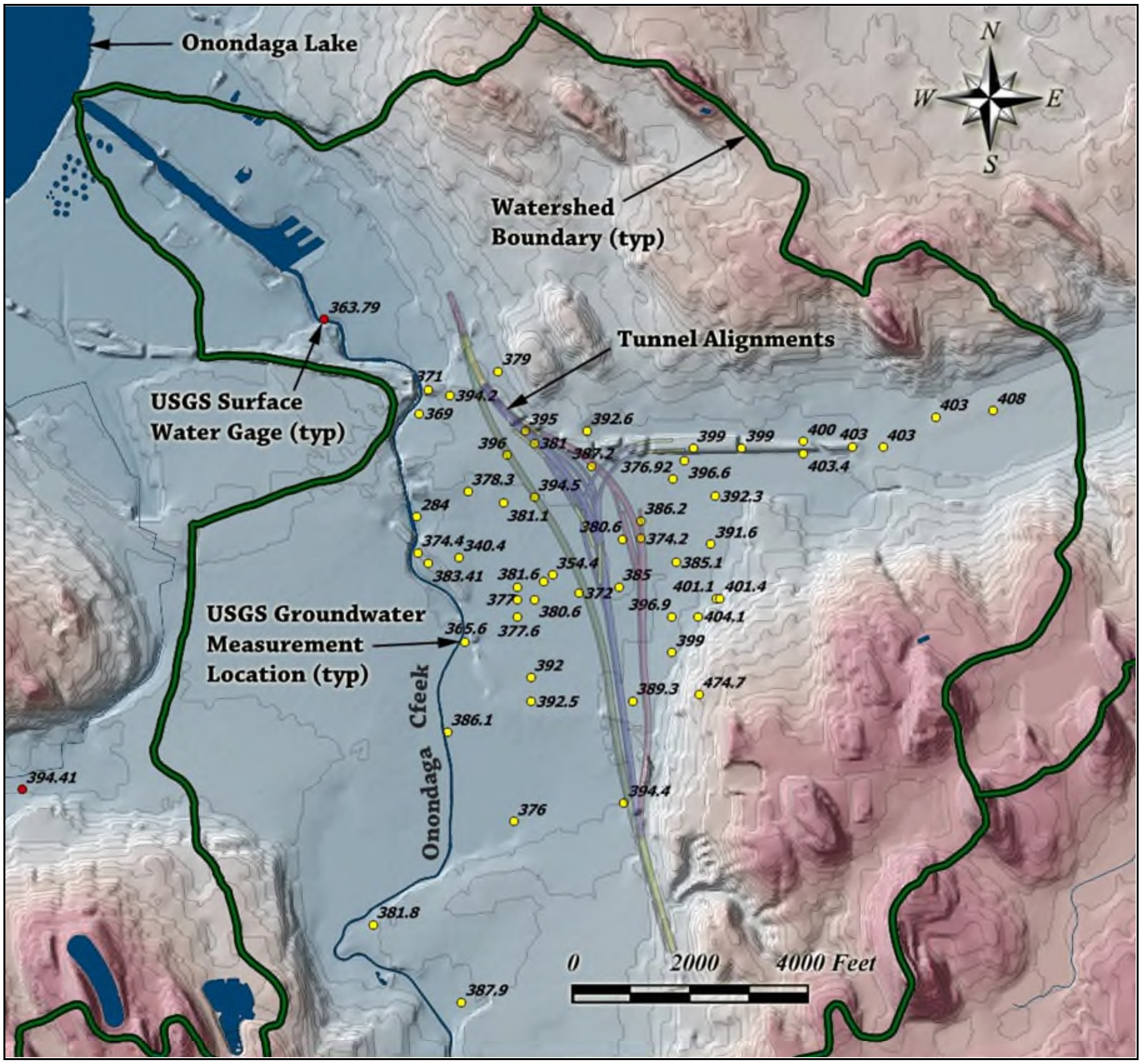


Figure 13: Groundwater Elevations and Watershed Boundaries

As Figure 13 shows, groundwater data locations are mainly located within the east-west valley in which the Erie Canal was located and in the Onondaga Creek valley. Overburden on the higher ground adjacent to these valleys is relatively thin and no wells were available in those areas. Groundwater levels in the valleys generally decline from the east downwards towards Onondaga Creek to the west.

As stated previously, Onondaga Creek and Onondaga Lake are the main groundwater discharge features in the system. There may also be withdrawals due to well and dewatering projects, but these are likely small and relatively unsubstantial, and were therefore not further considered. The principal source of recharge is infiltrating precipitation. Flux into or emanating from bedrock may also recharge or discharge the unconsolidated flow system; however, this was also considered to be unsubstantial and therefore not further considered.

As documented in their report of the groundwater study of the halite brine in the Onondaga Trough (Yager, 2007), the USGS calibrated model used an average value for groundwater recharge of 11 centimeters per year (4.3 inches per year) for urban areas. The Onondaga Lake Feasibility Study (Andrews, 2004) used a value for groundwater recharge of 6 inches per year around Onondaga Lake, except for highly paved areas along Onondaga Creek where a recharge rate 2 inches per year was used. The study further cited Winkley (1989), who estimated that 6 inches per year is the average groundwater recharge rate for Onondaga County. Thus, an average value of 4.3 inches per year, as used in the USGS study, is a reasonably representative value for recharge in the model study area of this evaluation.

The portion of the watershed east of Onondaga Creek and north of the proposed southern tunnel portals is approximately 5.2 square miles in area. At an average recharge rate of 4.3 inches per year, this equates to 1.65 cubic feet per second (cfs) of groundwater flow contribution to Onondaga Creek. The portion of this groundwater flow system located east of Concept T-5 is 3.4 square miles in area and would have an associated expected average flow of 1.07 cfs. This means that an average annual groundwater flow of 1.07 cfs, which is equivalent to 480 gallons per minute, flows through groundwater from east to west across the Concept T-5 alignment. During wet years, twice as much, or more, flow may result from recharge. All of this flow must be provided for, either by avoiding flow-carrying aquifer units or by conveying groundwater across a tunnel alignment. A greater amount of groundwater flow crosses the Concept T-6 alignment.

3.5 Salinity Data

As documented in the USGS studies on the halite brine in the Onondaga Trough underlying Onondaga Creek and Onondaga Lake (Kappel, 2005; USGS, 2000; Yager, 2007), the deeper aquifer within the trough is filled with brine and is overlain by waters of lower salinity. Figure 14 shows a generalized section of the geology within the trough and indicates that the substantial source of brine and high salinity groundwater may be the Salina Shale containing halite beds. The trough exposes these units approximately 10 miles to the south and groundwater flow then conveys the saline waters northward to Onondaga Lake.

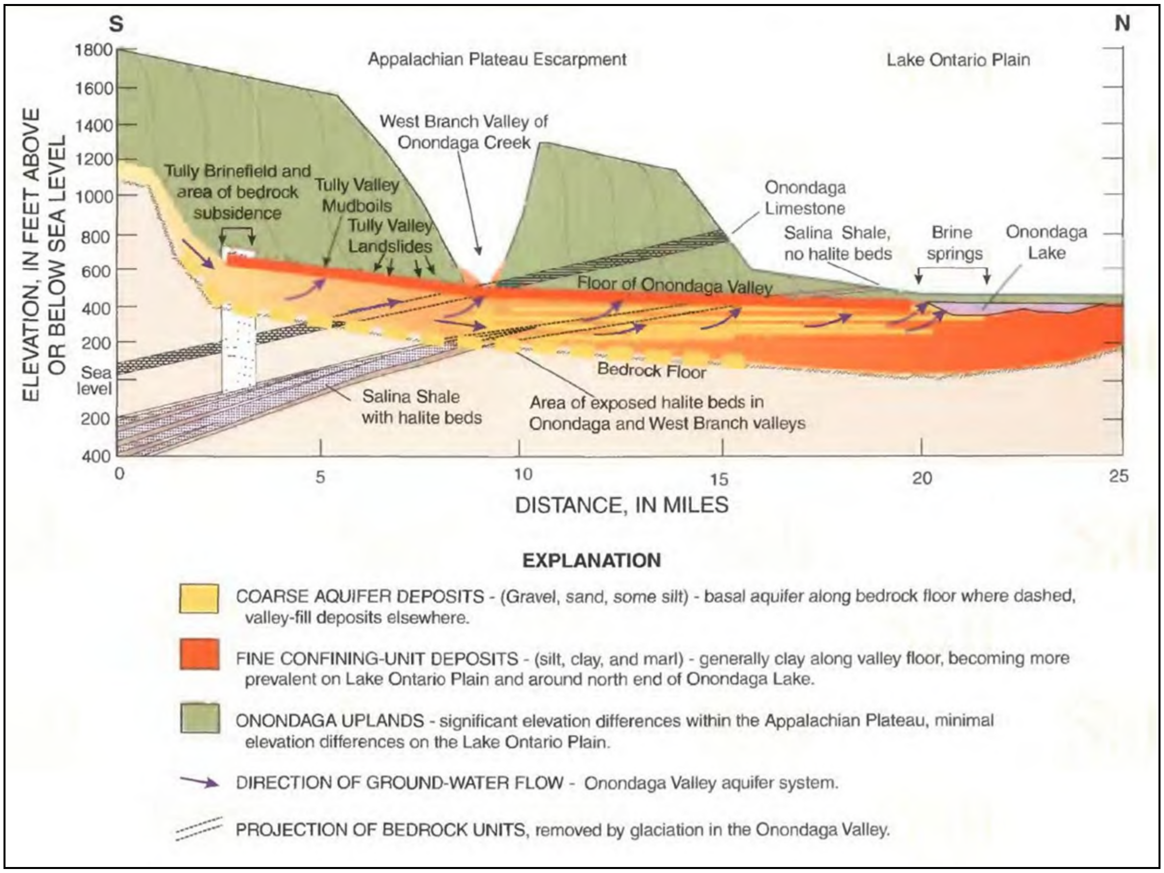


Figure 14: USGS Generalized Geologic Section along the Onondaga Trough (USGS, 2000)

The USGS studies were less informative regarding the distribution of salinity to the east of the Onondaga Trough, particularly in the East Syracuse Channel where most of the tunnel alignments are located. To the east and west of the trough, the Saline Shale deposits continue to rise to their outcrop south of Onondaga Lake. The USGS figure indicates that there are no halite beds in this portion of the deposits; however, the figure does not show whether halite deposits exist in outcrops within the East Syracuse Channel or whether such deposits may contribute to bedrock groundwater that may contribute to East Syracuse Channel.

Chloride concentrations in the sand and gravel aquifer of the East Syracuse Channel, as simulated with the USGS three-dimensional variable-density flow model (Yager, 2007), ranged from 50 to 170,000 mg/l, with lower concentrations predominant throughout most of the channel but increasing dramatically along the western edge where the channel discharges to the Onondaga Trough. However, little or no calibration data support exact concentration distributions within this region of the USGS three-dimensional variable-density flow model.

Water quality data are available from USGS at well locations in the vicinity of the East Syracuse Channel as shown in Figure 15 (USGS, 2016). These data, which are summarized in Table 1, indicate that elevated levels of sodium and chloride do exist within the Onondaga Trough (wells OD248, OD250, OD266, OD1805, OD1806 and OD1788). A comparison of

OD248 and OD250 as well as OD1805 and OD1806 indicates that concentrations are generally higher at greater depths.

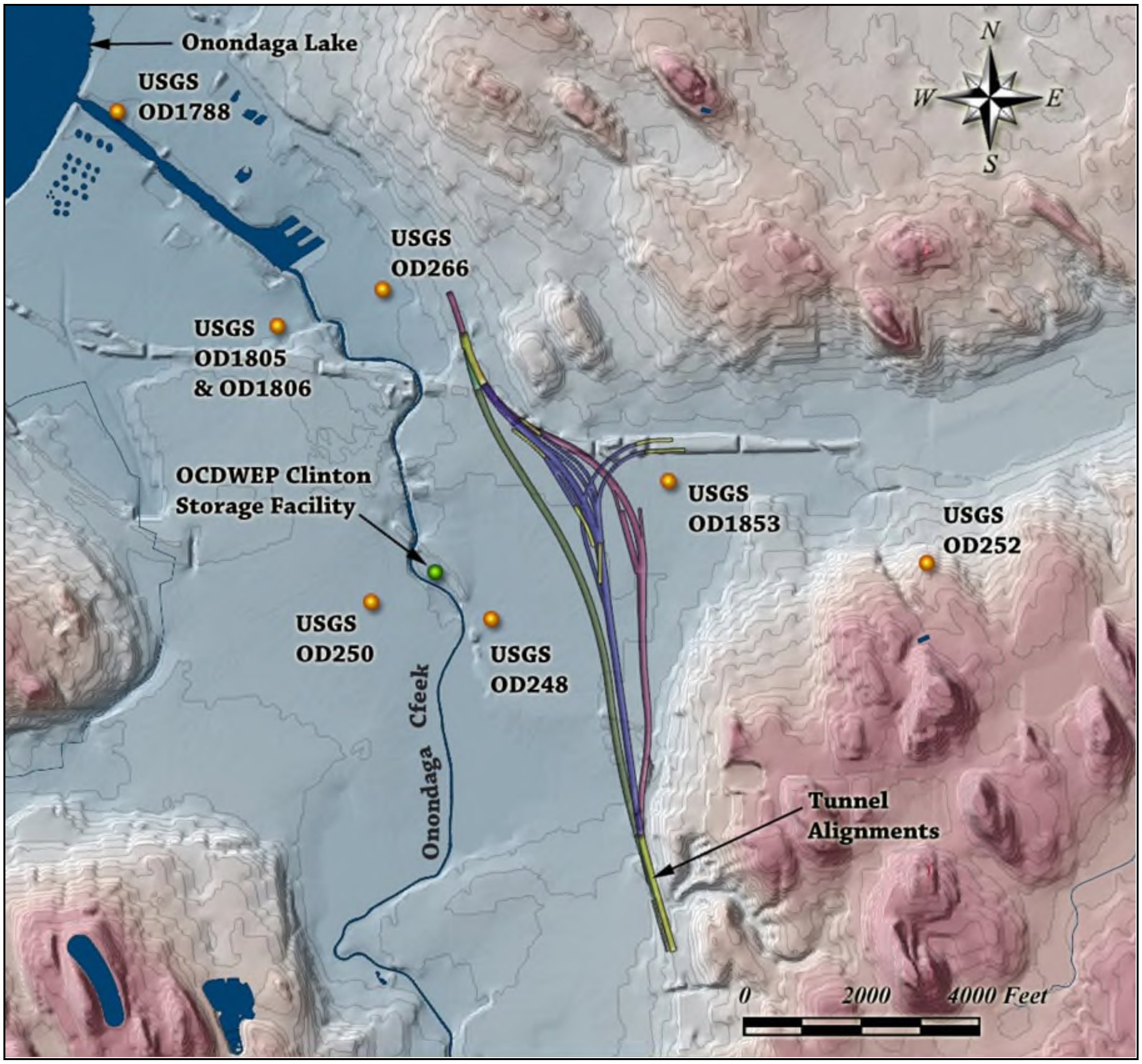


Figure 15: Wells with Water Quality Data

Table 1: USGS Water Quality Data

USGS Site Name	USGS Site Number	Well Depth (feet)	Date Sampled	Sodium (mg/l)	Chlorides (mg/l)
OD248	430237076090801	56	9/24/1954		2,090
OD250	430240076093501	132	3/18/1954		42,500
OD250	430240076093501	132	6/17/1957	26,000 (Na + K)	40,100
OD252	430246076072901	170	3/23/1954		21,200
OD266	430332076093201	240	4/13/1953	10	64
OD266	430332076093201	240	3/19/1954		310
OD1788	430402076103201	271	10/8/2003	63,000	97,900
OD1805	430326076095602	305	11/12/2002	69,500	117,000
OD1806	430326076095601	90	11/12/2002	46,500	74,800
OD1806	430326076095601	90	9/10/2004	60,000	101,000
OD1853	430300076082701	410	2/17/2006	29,900	47,100

Within East Syracuse Channel, there is only one well, OD1853, located at Syracuse University's Center of Excellence, which is 410 feet deep, more than 350 feet below the bedrock surface. However, sodium and chloride concentrations for this are elevated similar to those reported for wells within the Onondaga Trough. In addition, well OD252, located just south of the East Syracuse Channel and also screened in its underlying bedrock, has highly elevated chloride concentrations. For reference purposes, groundwaters that have a chloride concentration in excess of 250 mg/l or a total dissolved solids in excess of 1,000 mg/l are defined as saline (not fresh) groundwaters in New York (6 CRR-NY 700.1).

Onondaga County Department of Water Environment Protection (OCDWEP) provided information for various dewatering projects that the agency has conducted within Syracuse (Suryadevara, 2016). Of these projects, one provided information that is relevant to this analysis and is noted as "OCDWEP Clinton Storage Facility" on Figure 15. Chlorides and total dissolved solids data, as provided in the agency's geotechnical report (Brierley, 2011), are reported in Table 2 below. This information indicates fairly fresh groundwater conditions at shallow depths and elevated concentrations deeper.

Table 2: Clinton Storage Facility Water Quality Data

Well/Boring ID	Depth of Well Screen (feet)	Date Sampled	Chlorides (mg/l)	Total Dissolved Solids (mg/l)
BA10-5	37-42	6/29/2010	250	670
BA10-6	47-52	6/29/2010	300	900
HA-RTF-203	39-44	6/29/2010	390	1000
HA-RTF-207	94-99	6/29/2010	92000	130000
HA-RTF-212	34-44	6/29/2010	370	1500

Based on the data and information presented in this section, the actual salinity distributions and concentrations within the East Syracuse Channel are at present largely unknown. However, what is known is that high concentrations of salinity are present at greater depths within the Onondaga Trough and lower concentrations likely persist in most shallow areas, potentially due to infiltrating precipitation. It is also known that high salinity concentrations exist within the bedrock underlying the East Syracuse Channel and this bedrock groundwater may potentially recharge lower aquifer units within East Syracuse Channel.

3.6 Groundwater Flow Model

A four-layer groundwater flow model was designed to cover the model domain shown in Figure 16 below. The upper layer is mostly the unconfined water table layer composed of sands, silts, and fill materials. The second layer is a lower permeability layer, comprising mainly silts and clays, that semi-confines the third layer. The third layer is composed of sands and gravels as discussed in Section 3.3. The fourth layer is a low permeability layer overlaying bedrock composed of silts, clays, and fractured shales.

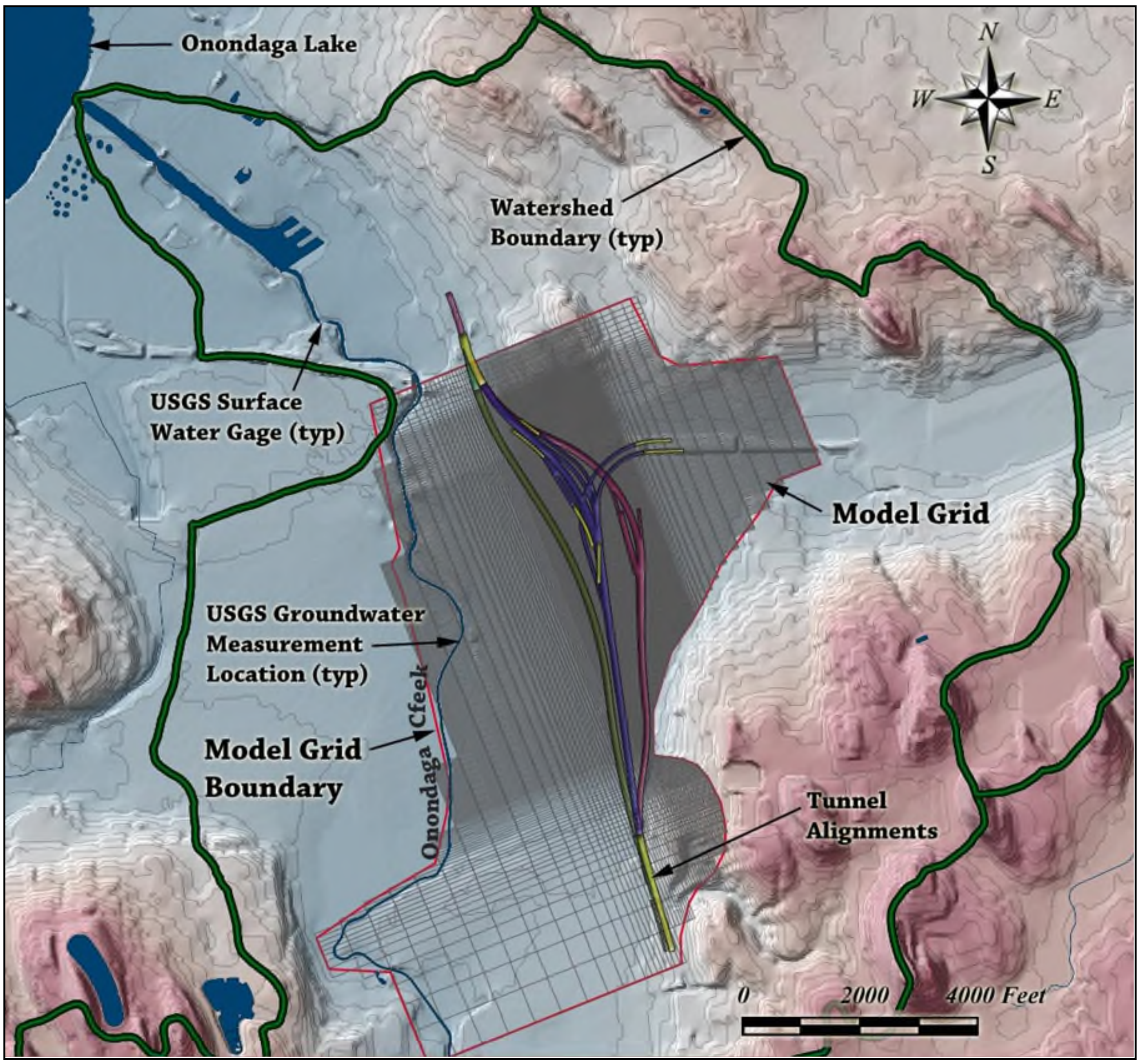


Figure 16: Groundwater Model Grid

The horizontal limits of the model were approximated at areas that were either judged to be parallel to groundwater flow or, where defining constant groundwater elevations, were judged to have a small effect on model results. Model spacing was set at 20 feet along the tunnel alignments in areas of principal groundwater flow and was progressively increased by about 30 percent to a maximum spacing of 635 feet.

For purposes of this concept-level evaluation, steady state conditions were simulated assuming average annual recharge and boundary head values as described above. Hydraulic conductivity was varied in accordance with ranges that would be expected for the hydrogeologic materials in each of the layers until a reasonable match was achieved between output results in model layer 3 and the observed USGS data displayed in Figure 10. A plot of these results is shown in Figure 17. This calibrated model was used for proposed groundwater evaluations in the following sections.

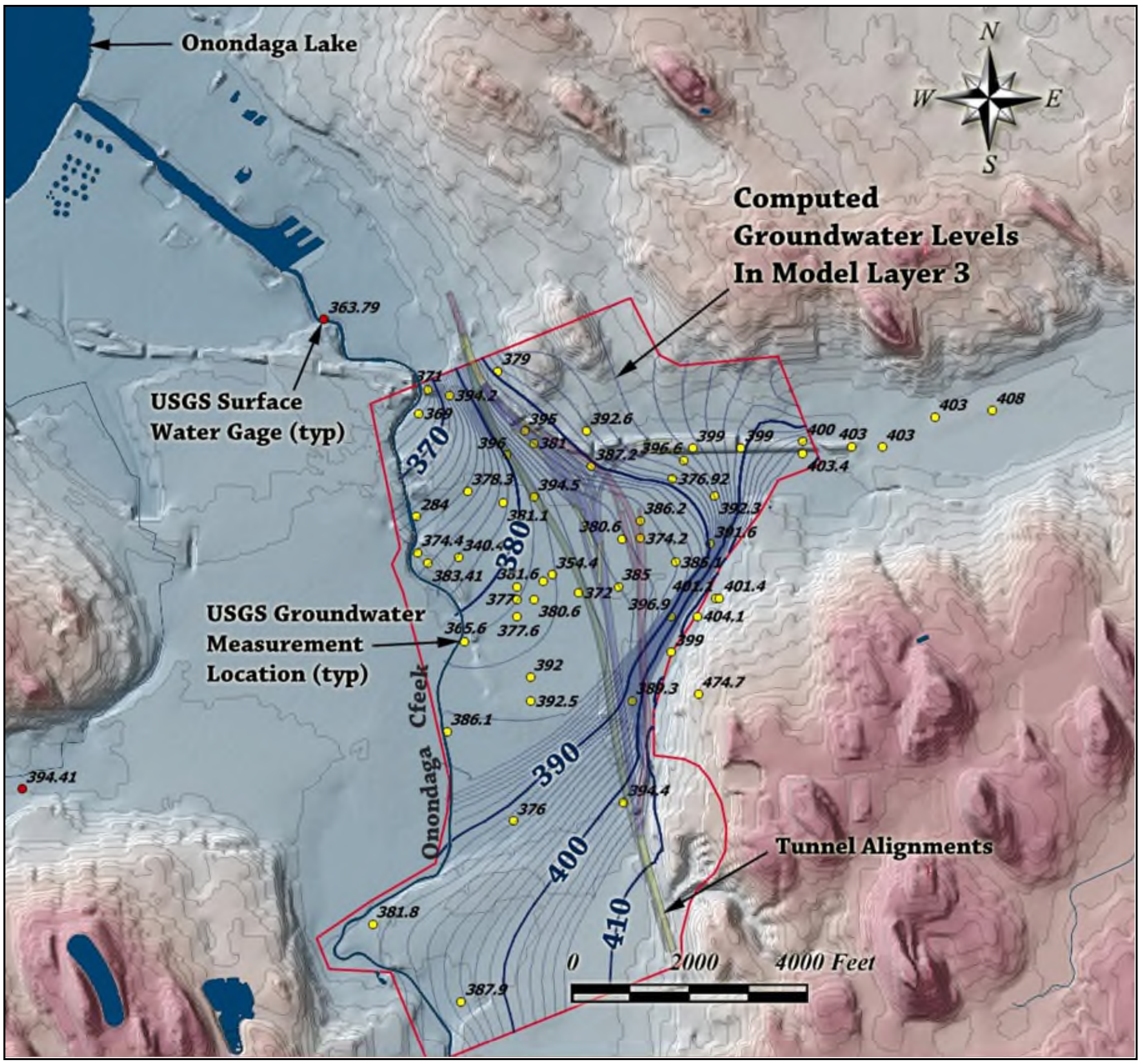


Figure 17: Groundwater Model – Concept Level Calibration

4.0 Concept T-5: Shallow (Cut and Cover) Tunnel

Concept T-5 consists of an approximately two-mile-long cut and cover tunnel from around East Kennedy Street in the south to Butternut Street in the north. This concept would be designed to meet interstate standards and would therefore carry the I-81 designation through the city. As such, the tunnel would be designed to have full connectivity with I-690. The southernmost portal of the tunnel proposed under Concept T-5 would be located about 600 feet south of Martin Luther King, Jr. East (formerly known as East Castle Street). From this point, the tunnel would follow the path of the existing I-81 viaduct underneath Almond Street. The alignment would veer westward around East Fayette Street, then continue in a northwestern direction until reaching the north portal, located in the vicinity of where Butternut Street crosses over I-81. Here, the tunnel would join the existing I-81 highway.

The segment of Almond Street above the tunnel would be reconstructed to serve local northbound and southbound traffic, and improvements would be made to enhance pedestrian and bicyclist safety and connectivity.

Concept T-5 also would reconstruct I-690 from approximately Leavenworth Avenue to Lodi Street, as well as interchanges along I-81 and I-690. The following interchange modifications would be included as part of Concept T-5:

- I-81/I-690 Interchange: New ramps would be built that would provide direct connections between eastbound I-690 and northbound I-81 and between southbound I-81 and westbound I-690, and the existing I-81/I-690 interchange ramps would be reconstructed to connect the elevated I-690 with the new I-81 tunnel. Some interstate-to-interstate ramp connections would be partially constructed underground, as separate cut and cover tunnels, to connect to the new I-81 tunnel. To accommodate the ramp entering and existing the tunnel, South McBride Street between East Washington Street and East Fayette Street would be permanently closed to vehicular traffic. Table 3, which lists the cut and cover tunnel connecting ramps and their associated lengths, shows that the majority of the connection ramps would be constructed above ground.
- I-81 from Interchange 20 to Interchange 23: This is common to all three tunnel concepts. A new travel lane in each direction would be provided on I-81 from I-690 to Hiawatha Boulevard to improve operations. Several non-standard highway features, such as narrow shoulders, sharp curves, and short acceleration and deceleration lanes, would also be corrected. The Court Street interchange (Interchange 21) would be reconstructed with an additional auxiliary lane to facilitate weaving movement in the southbound direction. The Route 370 (Onondaga Lake Parkway) on-ramp and Old Liverpool Road on-ramp to southbound I-81 would be consolidated into a single ramp, and the on-ramp to southbound I-81 from Genant Drive (between Spencer and Butternut Streets) would be closed because of its proximity to Interchange 20.
- I-81 Interchange 19 (Clinton Street/Salina Street) and Interchange 20 (Franklin Street/West Street): Interchanges 19 and 20 would be combined to accommodate the new connections between I-81 and I-690. This would involve replacing the existing off-ramps from southbound I-81 to West Street/Franklin Street (Interchange 20) and to Clinton Street/Salina Street (Interchange 19) with a single ramp that would serve Clinton Street

and Franklin Street. In addition, the existing on-ramps from Pearl Street (Interchange 19) and State Street (Interchange 20) would be reconfigured as a single ramp at Pearl Street.

- I-81 Interchange 18 (Adams Street/Harrison Street): Interchange 18 would be reconstructed as a partial interchange. The Adams Street ramps, which provide access to/from the south, would be reconstructed. These ramps would be about 4,500 feet long and begin near the southern I-81 tunnel portal and proceed over Martin Luther King, Jr. East; the New York, Susquehanna, and Western Railway; Burt Street; Taylor Street; and Jackson Street before reaching grade at about Adams Street. The reconstruction of the Adams Street ramps would introduce new structures (new ramp bridges would be constructed over these local streets). The existing ramp from Harrison Street to northbound I-81 would be removed because inclusion of this ramp would result in severing of local streets. Traffic destined for northbound I-81 would be able to use the reconstructed Interchange 13 on I-690 to access northbound I-81 as well as eastbound and westbound I-690 (see description of I-690 Interchange 13, below). The existing southbound I-81 exit to Almond/Harrison Street would be reconstructed, but would only serve southbound traffic from I-81. Eastbound I-690 traffic would be able to exit at the reconstructed I-690 Interchange 13 at Catherine Street, described below, rather than at Harrison Street as it does now.
- I-81 Colvin Street Entrance Ramp: The Colvin Street entrance ramp to northbound I-81 would be eliminated under Concept T-5. Because of the proximity of the reconstructed northbound I-81 exit ramp to Adam Street, it may be necessary to close the existing Colvin Street northbound entrance ramp due to ramp spacing and potential weaving conflicts. Elimination of the NB entrance ramp from Colvin Street would cause additional changes in travel patterns that would require additional modifications to local streets in that area.
- East Fayette Street Overpass: To accommodate interstate-to-interstate ramps entering and exiting the I-81 tunnel, East Fayette Street would need to be elevated from South Townsend Street to about Forman Avenue, as illustrated in Figure 18. This would allow East Fayette Street to remain open as a bridge over the ramp connections. However, due to the elevation difference between the elevated East Fayette Street and the at-grade local streets, the intersections at Almond Street and South McBride Street would not be accommodated.
- Butternut Street Overpass: This common element of all three tunnel concepts would involve the replacement of the bridge carrying Butternut Street over I-81 and the realignment of Butternut Street so that it would connect to Clinton and Franklin Streets in the Franklin Square neighborhood. The Butternut Street overpass must be rebuilt as part of the reconstruction of the I-81/I-690 interchange. Re-alignment of the Butternut Street bridge would allow the proposed ramp carrying traffic from eastbound I-690 to northbound I-81 to be constructed beneath the bridge.
- I-690 Interchange 11 (West Street): This is common to all three tunnel concepts. To improve safety on I-690 and the West Street ramps, the existing, free-flow Interchange 11 would be reconstructed. I-690 would pass above, rather than beneath, the West Street ramps, and the high speed ramps would be replaced with a new at-grade intersection, controlled by a traffic signal on West Street.
- I-690 Interchange 13 (Townsend Street/Downtown Syracuse): This existing partial interchange, with ramps on Townsend and McBride Streets, would be reconstructed as a full interchange on Almond Street, as shown in Figure 19. This interchange would also

provide access to northbound I-81 via a split from the I-690 westbound ramp. Due to the elevation difference between the eastbound I-690 exit ramp to Almond Street and South McBride Street, South McBride Street would be closed between Erie Boulevard and Burnet Avenue.

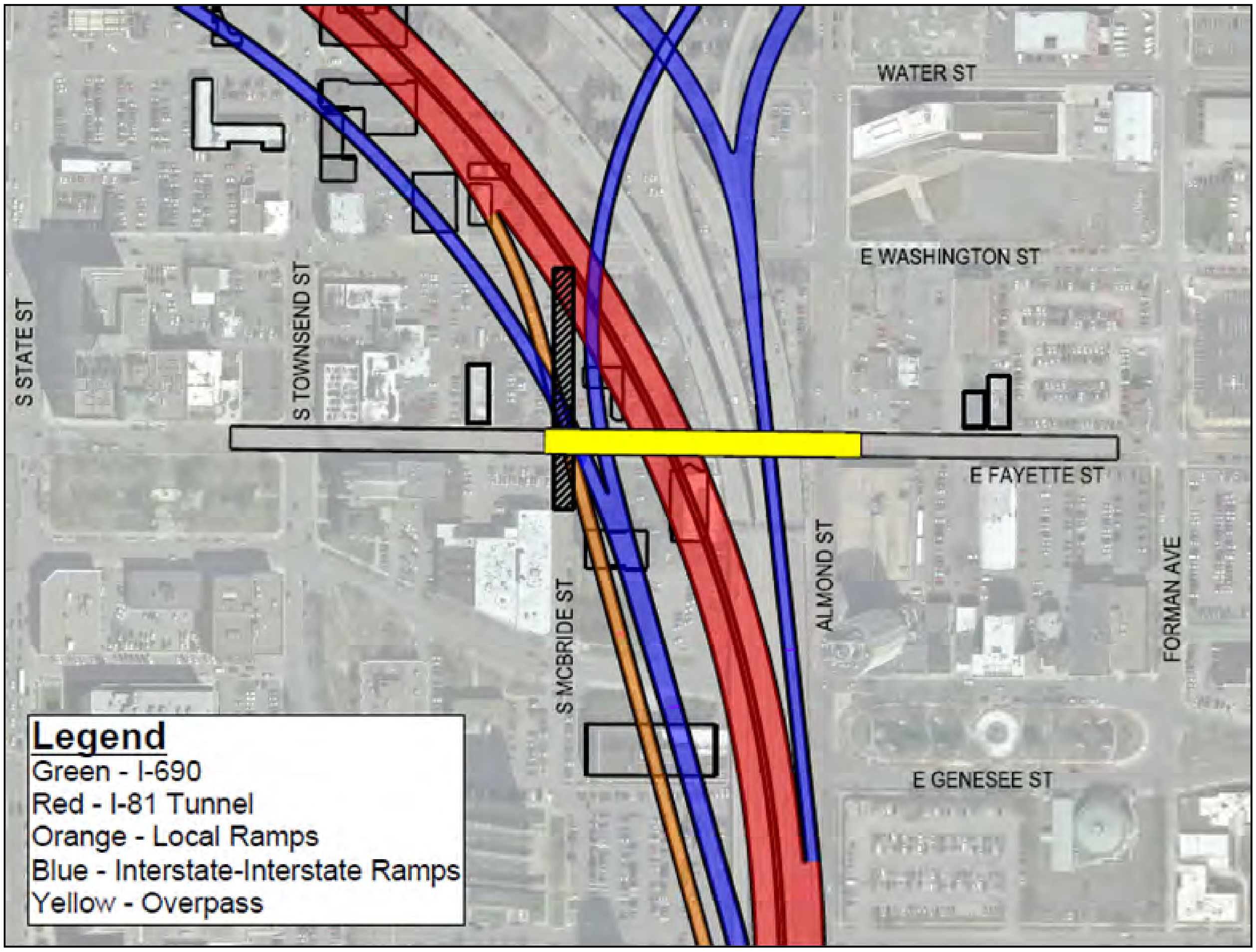


Figure 18: Concept T-5 - Fayette Street Overpass

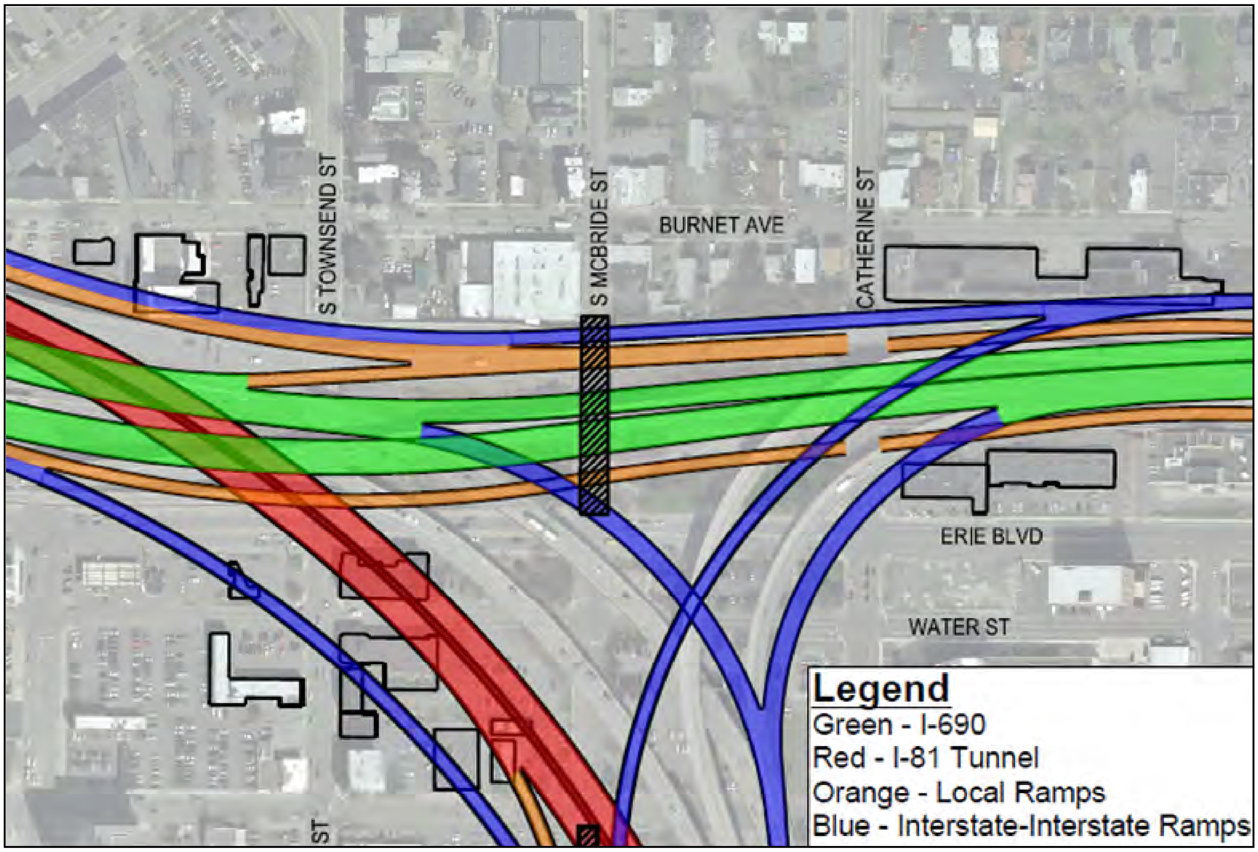


Figure 19: Concept T-5 - I-690 Almond Street Interchange

Table 3: Concept T-5 - Tunnel Connection Ramp Lengths

Connection Ramp	Total Length (miles)	Underground Length (miles)	Above-Ground Length (miles)
N I-81to W I-690	0.14	0.00	0.14
N I-81 to E I-690	0.16	0.00	0.16
N I-81 to W/E I-690	0.24	0.13	0.11
S I-81 to E/W I-690	0.06	0.00	0.06
S I-81 to E I-690	0.08	0.00	0.08
W I-690 to N I-81	0.80	0.00	0.80
E I-690 to S I-81	0.27	0.00	0.27
W I-690 to S I-81	0.63	0.00	0.63
E/W I-690 to S I-81	0.16	0.16	0.00
S I-81 to Harrison St.	0.29	0.25	0.04

Figure 20, a plan view of Concept T-5, depicts the cut and cover tunnel alignment from portal to portal. For clarity, the connecting ramps are not shown in Figure 20. The existing I-81 viaduct is shown in green. The I-81 tunnel would follow the existing I-81 property line under Almond Street from the south end of the viaduct to about East Fayette Street. Figure 21 presents a plan view of the Concept T-5 alignment with all the connecting ramps.

Figure 20: Concept T-5: Cut and Cover Tunnel Main Alignment – Plan View

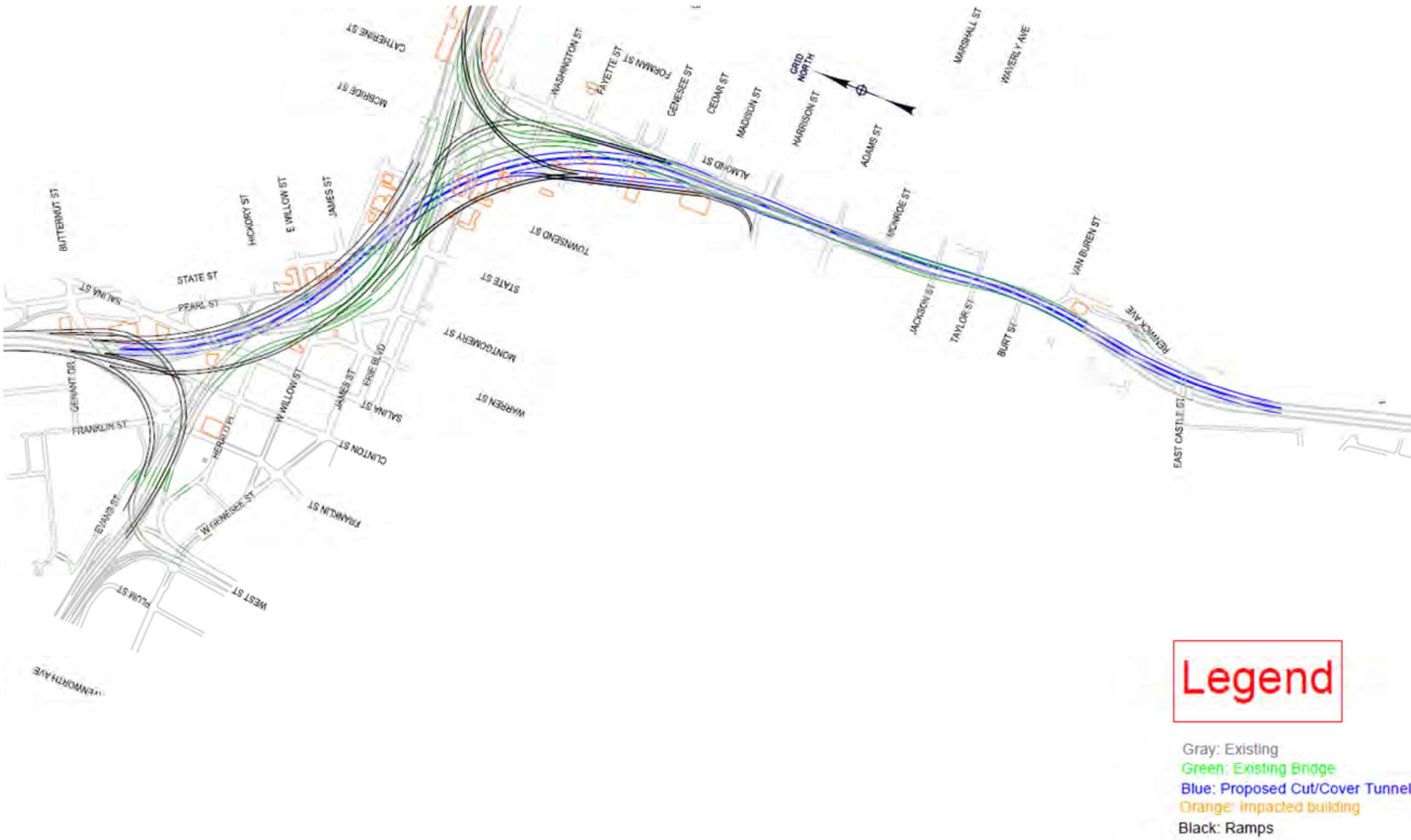


Figure 21: Concept T-5: Cut and Cover Tunnel Main Alignment and Connecting Ramps – Plan View

4.1 Geotechnical and Geological Subsurface Conditions

The City of Syracuse is located within Onondaga County on the border line between the lake plains on the north and the Alleghany plateau on the south. The physiography of the area is intensified by glacial action with outcropping edges of many of the stratigraphic units of Paleozoic rock series (Onondaga County Website).

The subsurface ground conditions along the Concept T-5 alignment were evaluated using borings performed in the 1960s by the New York State Department of Public Works (Figure 4). A generalized subsurface profile, presented in Figure 22, depicts the subsurface strata. The elevations datum in Figure 22 is NAVD88 (North American Vertical Datum of 1988), which is approximately the same as NGVD29 (National Geodetic Vertical Datum of 1929); the elevation difference between the two data is about 0.5 feet. The longitudinal profile of the Concept T-5 tunnel (roadway surface profile) is presented in Figure 22.

The subsurface conditions consist of manmade fill of variable thickness underlain by natural soils and bedrock. The subsurface strata for the Concept T-5 tunnel, beginning at the ground surface, are described below.

Fill: Fill Stratum is composed of loose to medium dense sand and gravel with some silt and clay mixed with construction and foreign material such as cinders and fragments of concrete. The thickness of Fill Stratum can be up to 50 feet, but it generally extends to a depth of about 5 to 15 feet below existing ground.

Soft Clay/Silt: This stratum consists of very soft to soft silt and clay with some peat, muck, and marl at some locations. When encountered, this stratum was observed below Fill Stratum, and its thickness ranged from a few feet to over 60 feet (approximately at the middle of the main tunnel alignment in the vicinity of Harrison Street).

Sand/Silt/Gravel: The Sand/Silt/Gravel Stratum consists of dense to very dense mix of sand, silt, and gravel and occasional weathered rock. This stratum was encountered throughout virtually all of the proposed tunnel alignment below Fill or Soft Clay/Silt Strata, and its thickness ranged from a few feet to over 60 feet around Cedar Street.

Weathered Rock: Weathered Rock stratum consists of weathered and decomposed shale mixed with sand, silt, and gravel. When encountered, this stratum was observed below Sand/Silt/Gravel Stratum and varied in thickness from a few feet to about 20 feet around Dyer Street. The determination of the top and bottom of this layer was difficult based on the available historic borings logs. The approximate depth to weathered rock and its approximate thickness are presented in Figure 22.

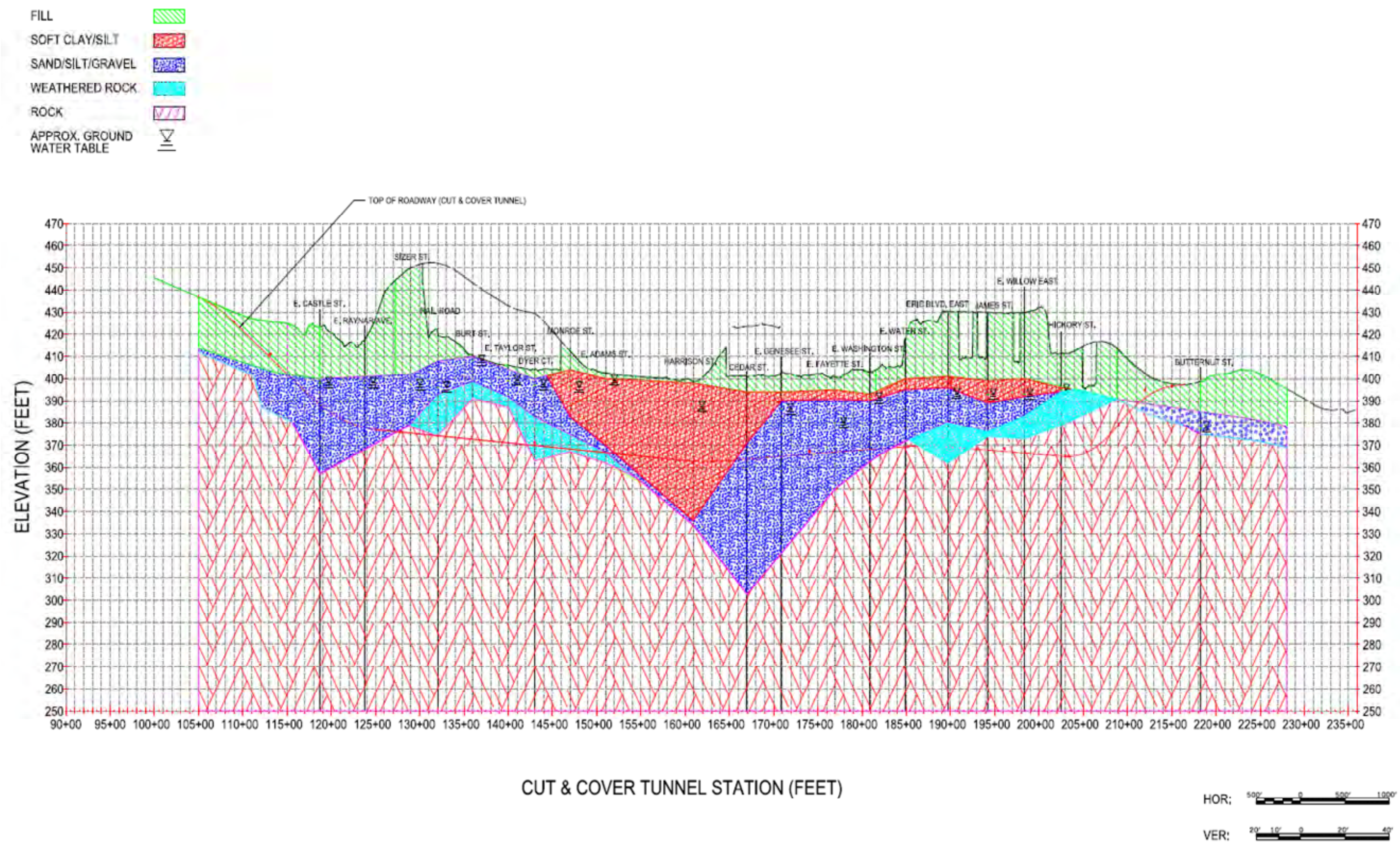


Figure 22: Generalized Geotechnical Subsurface Profile for Concept T-5

Bedrock: The Bedrock consists of shale and dolostone of Syracuse formation with occasional gypsum. The strength and weathering of the bedrock could not be quantified based on the available data. The depth of this stratum was determined based on rock cores obtained at the historic borings. This stratum was encountered below Weathered Rock or Sand/Silt/Gravel Strata. The depth to this stratum is the greatest around Cedar Street and about 100 feet. Based on available data, bedrock Stratum is shallower within the northern portion of the proposed tunnel alignment and deeper in the middle of the alignment.

Groundwater: The reported elevation of the groundwater at the time of borings (1960s) ranged from 375 to 410 feet. The approximate groundwater elevations are shown in the generalized subsurface profile in Figure 22. Artesian water head up to 7 feet above existing grade was reported at underlying bedrock about 0.75 to 1.0 miles east of the I-81 viaduct during subsurface explorations in 2015 (NYS DOT, 2016).

Seismicity: According to the 2008 Seismic Hazard Map, Onondaga County has a Peak Ground Acceleration (PGA) between 2 and 3% (%g) for earthquakes with a 10 percent probability of exceedance within 50 years. Based on historical records, the overall earthquake hazard ranking determined by the Planning Committee of Onondaga County is “low” (Onondaga County Website).

4.2 Vertical Roadway Alignment

The longitudinal portal-to-portal profile of the Concept T-5 invert (top of roadway surface profile) is presented in Figure 22 along with the generalized geotechnical profile. The proposed elevations of the tunnel invert at the south and north portals are approximately at 390 and 380 feet, respectively. The invert at its lowest point reaches elevation 365 feet, about 35 feet below ground surface, around Harrison Street. However, the deepest point of the tunnel would occur around Sizer Street, where the tunnel invert would be at elevation 375 feet and approximately 75 feet below ground surface, due to the existing I-81 embankment at this location.

The longitudinal profile shows that cut and cover tunnel excavation would be performed primarily in Fill, Soft Clay/Silt, and Sand/Silt/Gravel Strata. Some excavation in Weathered Rock and Bedrock would be required, especially between Sizer and East Adams Streets along the south portion of the alignment and along the portion north of Erie Boulevard.

Approach structures would be required at the south and north portals to facilitate transition between the existing grade and the cut and cover tunnel. The approach structures would be U-shaped and approximately 1,000 feet (0.19 miles) at the south portal and 480 feet (0.09 miles) at the north portal. The length of the cut and cover tunnel would be about 9,560 feet (1.81 miles). The total length of the underground alignment would be approximately 11,040 feet (2.09 miles). The approximate lengths of the approach structures and cut and cover tunnel are given in Table 4.

Table 4: Concept T-5 – Tunnel and Approach Structure Lengths

Tunnel Structure	Length in miles (feet)
South Portal Approach Structure	0.19 (1000)
Cut and Cover Tunnel	1.81 (9560)
North Portal Approach Structure	0.09 (480)
Total Underground Alignment Length	**2.09 (11040)**

4.3 Typical Tunnel Section

The tunnel would carry two travel lanes, with shoulders, in each travel direction (total of 4 lanes). The two travel directions would be separated by a wall. In addition, emergency egress and exits, which are required, would be separated from the tunnel by a minimum of a two-hour fire-rated construction enclosure/wall. A cross section of the cut and cover tunnel is presented in Figure 23 and the approximate section dimensions are summarized in Table 5.

Table 5: Concept T-5 - Tunnel Cross Section Geometry

Tunnel Type	Width (ft)	Height (ft)	Shoulder Width (ft)	Emergency Walkway Width (ft)	Barrier Width (ft)
Cut and Cover	84	30	4.0	4.0	1.5

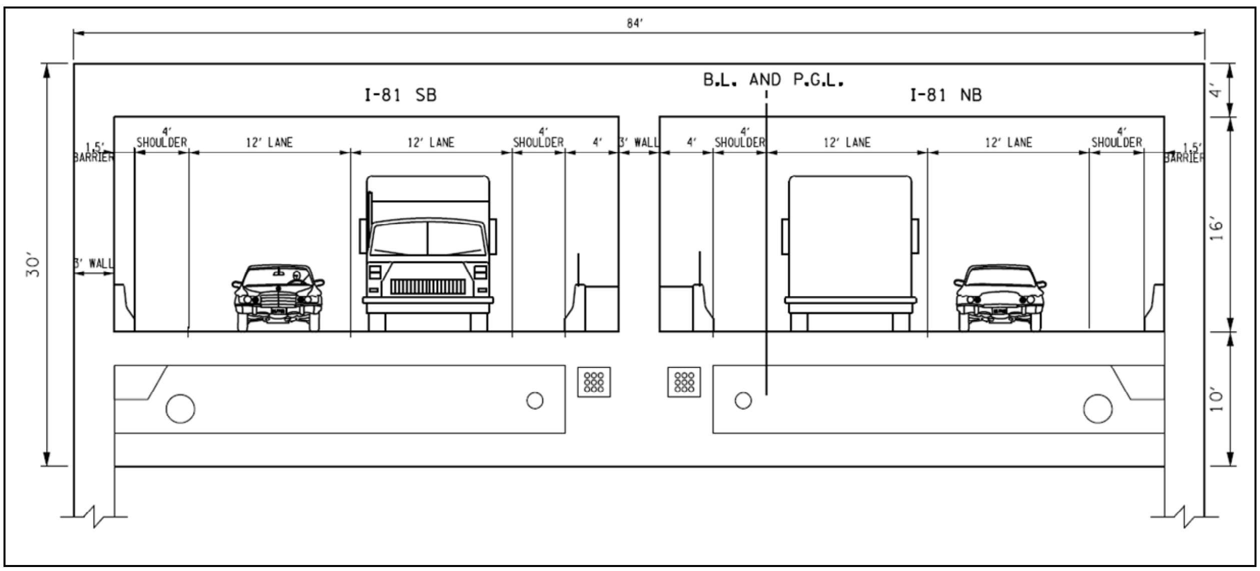


Figure 23: Cut and Cover Tunnel Section (Concept T-5)

The line representing the tunnel alignment in Figure 22 is the top of the tunnel invert (roadway surface). The top of the cut and cover tunnel is about 20 feet above this line and the bottom of the tunnel invert slab is about 10 feet below it.

4.4 Construction Method

To construct shallow tunnels in relatively soft soils, the cut and cover construction method can present a cost effective solution. Tunnels are considered shallow enough to employ cut and cover construction techniques when the depth to the invert slab is less than 80 feet. The depth to the tunnel invert for the proposed cut and cover tunnel shown in Figure 22 would be no more than 75 feet and typically less than 40 feet.

The cut and cover tunnel would be located primarily underneath Almond Street and below the existing I-81 viaduct and its connecting ramps. During construction, the existing I-81 viaduct and portions of the connecting ramps would have to be underpinned where cut and cover excavation is in close proximity or in conflict with the existing viaduct foundation elements. The existing viaduct is generally supported on steel or cast-in-place (CIP) piles to bedrock, except between Sizer Street to Burt Street, where the foundation consists of footings on bedrock (NYS 1964). Figures 20 and 21 present Concept T-5 in plan view (in black) relative to the existing viaduct (in green). These figures illustrate the approximate extent of underpinning work for the existing viaduct and the connecting ramps that would need to be performed prior to the cut and cover excavation for the tunnel construction. Figures 20 and 21 also show the properties (in orange) that would have to be acquired because they would be directly impacted by the cut and cover construction.

Given the proximity of the proposed cut and cover alignment to the existing I-81 viaduct, the depth of the proposed tunnel, and the subsurface ground conditions, a rigid and water-tight Support of Excavation (SOE) system would be used to minimize ground deformations during excavation, provide water tightness, and protect the viaduct and other adjacent structures. Appropriate SOE wall types are listed below. These walls would be approximately 3 feet in thickness, relatively water-tight, and rigid, and could also be used as the permanent walls of the final tunnel.

- Soldier Pile Tromie Concrete (SPTC) Wall
- Slurry Wall
- Secant Pile Wall
- Soil Mixing or Jet Grouting Wall

The preferred wall types for Concept T-5 would be the SPTC wall or slurry wall. Use of an SPTC or slurry wall would avoid the need for large scale dewatering of the site, which would also avoid inducing settlements on the surrounding buildings and facilities. Dewatering would need to be limited to the excavated areas and between the SOE walls. For the cut and cover tunnel, a top-down construction sequence as outlined below would be proposed.

- Phase 1: Site grading, demolition, utility relocation, instrumentation monitoring
- Phase 2: Existing structure protection (such as underpinning, ground improvement, etc.)
- Phase 3: SOE Installation. Support of excavation would consist of installation of three deep SOE walls with about 10 feet of embedment in bedrock. The SOE walls would be constructed on the sides and center of the cut and cover tunnel. Figure 24 shows

excavation using a clam bucket excavator for construction of a slurry wall for the Central Artery Tunnel Project in Boston.

- Phase 4: Excavation to about 5 feet below ground surface and installation of the deck beams over SOE walls. After installation of decking, the excavation could be backfilled, the roadway reconstructed and street traffic could resume.
- Phase 5: Excavation below the deck beams to the bottom of the tunnel roof slab and installation of lateral supports (internal struts). Dewatering of the excavation zone could be performed during this phase (dewatering should be limited to localized dewatering of the excavated areas and large scale dewatering should be avoided). The elevation of the roof slab would vary based on the tunnel depth as reflected in the longitudinal profile in Figure 22.
- Phase 6: Construction of the roof slab and tying it to the SPTC walls. The roof slab would be approximately 4 feet in thickness. Glory holes could be incorporated in the roof slab and used to facilitate mucking.
- Phase 7: Excavation underneath the roof slab to the bottom of the invert slab, and installation of one level of internal lateral braces.
- Phase 8: Construction of the invert slab and tying it to the SOE walls. The invert slab may be as thick as 10 feet at some locations to house the utilities required for the tunnel.
- Phase 9: Waterproofing and backfilling above the roof slab to street level.

Figure 24: Slurry wall construction at Central Artery Project in Boston, MA

Construction of the cut and cover tunnel in some locations would require excavation in the Weathered Rock or Bedrock Strata, as shown in Figure 22. Rock excavation could be accomplished by drilling and blasting where the tunnel encounters rock.

Approach structures would be used to connect the surface grade to the cut and cover tunnel. These structures would be U-shaped and consist of retaining walls on both sides and an invert slab. The depth to invert for the approach structures would be 30 feet or less. Where the bottom of the approach structures are above groundwater, soldier pile and lagging walls could be used instead of water-tight SOE walls. However, when the invert slabs of the approach structures are below groundwater, water-tight SOE walls such as SPTC or slurry walls would need to be employed.

The construction would proceed on a section by section basis. Following completion of any required service diversions, one side wall would be constructed first, then the second side wall. This would enable single lane occupations one side at a time. Ground surface would be protected by road plates when returning lanes to traffic. Minor speed restrictions also would be applied.

Approximately 16 major road and railroad crossings along the main alignment of Concept T-5 may be blocked off temporarily during construction. These crossings are listed below (from south to north).

1. Martin Luther King, Jr. East (formerly known as East Castle Street)
2. New York, Susquehanna and Western Railway Crossing
3. Burt Street
4. East Taylor Street
5. Jackson Street
6. Monroe Street
7. East Adams Street
8. Harrison Street
9. East Genesee Street
10. East Fayette Street
11. East Washington Street
12. East Water Street
13. Erie Boulevard
14. James Street
15. East Willow Street
16. North Salina Street

Crossings could be constructed using a number of options; however, the simplest approach would be a continuation of the cut and cover method. SOE works would involve nighttime and weekend closures of individual lanes of these roads. Weekend lane closures would be used to excavate and install temporary roadway decking and then resurface the road and return it to traffic.

The proposed cut and cover construction would require adjacent lane closures and traffic control. Therefore, the cost of traffic management has been incorporated into the cost estimates for Concept T-5. Proactive underpinning of existing nearby structures and ground treatment likely would be required. A ground improvement option could be considered for the railroad crossing where the cut and cover tunnel would pass under the existing tracks.

Other considerations regarding construction of the proposed cut and cover tunnel include the following:

a) **Community Disruption during Construction.** Open, deep excavation operations with the presence of large construction equipment and material lay down yards would temporarily sever streets, potentially closing them to vehicular, pedestrian, and bicycle traffic, for periods during construction. Figures 25A and 25B show similar cut and cover tunneling in urban environments. This method would require the use of heavy construction equipment (e.g., CAT 374F Large Hydro Excavator and Manitowac 777 400 ton Crawler Crane), which are commonly used during excavation. Figures 25C and 25D show the type of equipment generally used in urban tunnel construction.

A.

B.

C.

D.

A. Portland Westside CSO SOE Construction Adjacent to Neighboring Buildings
B. Seattle Alaskan Way Viaduct Construction through City Streets
C. CAT 374F Large Hydro Excavator
D. Manitowac 777 400 Ton Crawler Crane

Figure 25: Photos of Cut and Cover Tunneling and Equipment in Urban Environments

b) **Building Acquisition.** Based on the proposed alignment presented in Figures 20 and 21, approximately 35 buildings would have to be acquired under Concept T-5 as listed below:

1. 117 Butternut Street
2. 329 North Salina Street
3. 511-15 East Fayette Street
4. 319-325 North Salina Street
5. 301-319 North State Street
6. 215 State Street
7. 323-25 James Street
8. 122-124 Burnet Avenue
9. 421 East Water Street
10. 500 East Erie Boulevard
11. 511-519 East Washington Street
12. 603 East Fayette Street
13. 610 East Fayette Street (aka 601 East Genesee Street)
14. 309 S. McBride Street (aka 601 East Genesee Street)
15. 600 East Genesee Street
16. 400 Burnet Avenue
17. 701-09 East Erie Boulevard
18. 711-21 East Erie Boulevard
19. 212 Herald Place
20. 123-129 East Willow Street
21. 112-116 Burnet Avenue
22. 132 Burnet Avenue
23. 110 South McBride Street
24. 521-527 East Washington Street
25. 601 South Townsend Street
26. 110-112 South Townsend Street
27. 128 North Warren Street
28. 500 Renwick Avenue
29. 105 South Townsend Street / 500 Water Street
30. 109 South Townsend Street
31. 115 South Townsend Street
32. 117 North Townsend Street
33. 471-81 Oswego Blvd
34. 711 East Fayette Street
35. 713 East Fayette Street

c) **Noise and Vibrations**. Large equipment is required for SOE installation and excavations. For segments of the tunnel in rock, drilling and blasting would be employed. Such construction activities would generate noise and vibrations and require the installation of special types of monitoring devices on nearby structures during construction. Such monitoring devices may include seismographs (for recording vibration levels), total station prisms (for monitoring structure movements), crack meters (for monitoring existing and new cracks on building surfaces), and noise monitoring devices. Construction noise sources would include both stationary (e.g., compressors, power tools) and mobile (e.g., trucks, bulldozers) sources. Rock blasting and chipping generally emits the highest noise and vibration levels, and these would be anticipated during Concept T-5 construction.

d) **Disruption of services/access**. At critical roadway crossings, it would be necessary to implement lane closures, which would require temporary access. Temporary access over open excavation or decking would be required as shown in Figure 26, which depicts cut and cover tunnel construction similar to what would be proposed for Concept T-5. If possible, the flow of traffic would be severed one lane at a time. However, lane closures and temporary access roads would be anticipated at roadway crossings. The duration of lane closures would depend on the depth of excavation, construction complexity, adjacent structures, and facilities and traffic pattern of the crossing.

Figure 26: Temporary Access at Roadway Crossing for Pittsburgh North Shore Connector

e) **Easements**. Temporary and permanent easements (surface and subsurface) would be required for the implementation of Concept T-5. Permanent easements would consist of easements that envelop the cut and cover tunnel and related structures below the ground surface (subsurface easement) and easements that would provide space for the above ground facilities and future maintenance of the tunnel and related structures (surface easement). Temporary easements would be required to allow space for the contractor during construction.

4.5 Groundwater Control and Construction Dewatering

Groundwater control and construction dewatering would be required for all portions of the tunnel and approach sections extending below the groundwater table. Dewatering would be limited to the removal of water within tunnel excavation zones, which would be bounded by relatively impermeable SOE walls. This method would be required because dewatering outside of the excavation zones can induce short- and long-term ground and structure settlement. However, construction of SOE walls down to rock would inhibit the flow of groundwater from east to west, causing an increase in water table elevations (potentially flooding) to the east of the tunnel and a reduction in water table elevations west of the proposed tunnel.

To avoid inhibiting the natural flow of groundwater, equalization units would need to be constructed at required intervals. These units would consist of flow collection structures on the upgradient side of the tunnel, which would be connected to recharge structures on the downstream side. As indicated in previous sections, there is a substantial sand and gravel semi-confined aquifer unit in the central portion of the tunnel at depths of approximately 40 to 80 feet below the land surface. Furthermore, it is highly likely that the salinity in this aquifer is much greater than that of the shallow unconfined water table. Accordingly, from a permitting standpoint, it would be necessary to maintain a separation between the groundwater in the shallow and deep aquifer zones. In other words, groundwater collected in the shallow water table must be returned to the shallow water table and groundwater collected in the deep higher-salinity semi-confined aquifer must be returned to that aquifer.

For the shallow unconfined water table zone, an equalization unit consists of two manholes constructed at opposite sides of the tunnel and connected by a pipe below the tunnel invert. Perforated pipes along the longitudinal direction of the tunnel would be placed below the groundwater and parallel to the tunnel. These pipes would collect and draw the groundwater into the manhole so that the groundwater is equalized on both sides of the tunnel. An equalization unit within the semi-confined deep aquifer would be similar to the above except that instead of perforated pipes, wells would be constructed to collect and recharge groundwater and the cross drain pipe would be placed above the tunnel roof as shown in Figure 27. It is anticipated that construction dewatering would be recharged in the downgradient wells and/or perforated pipes as appropriate.

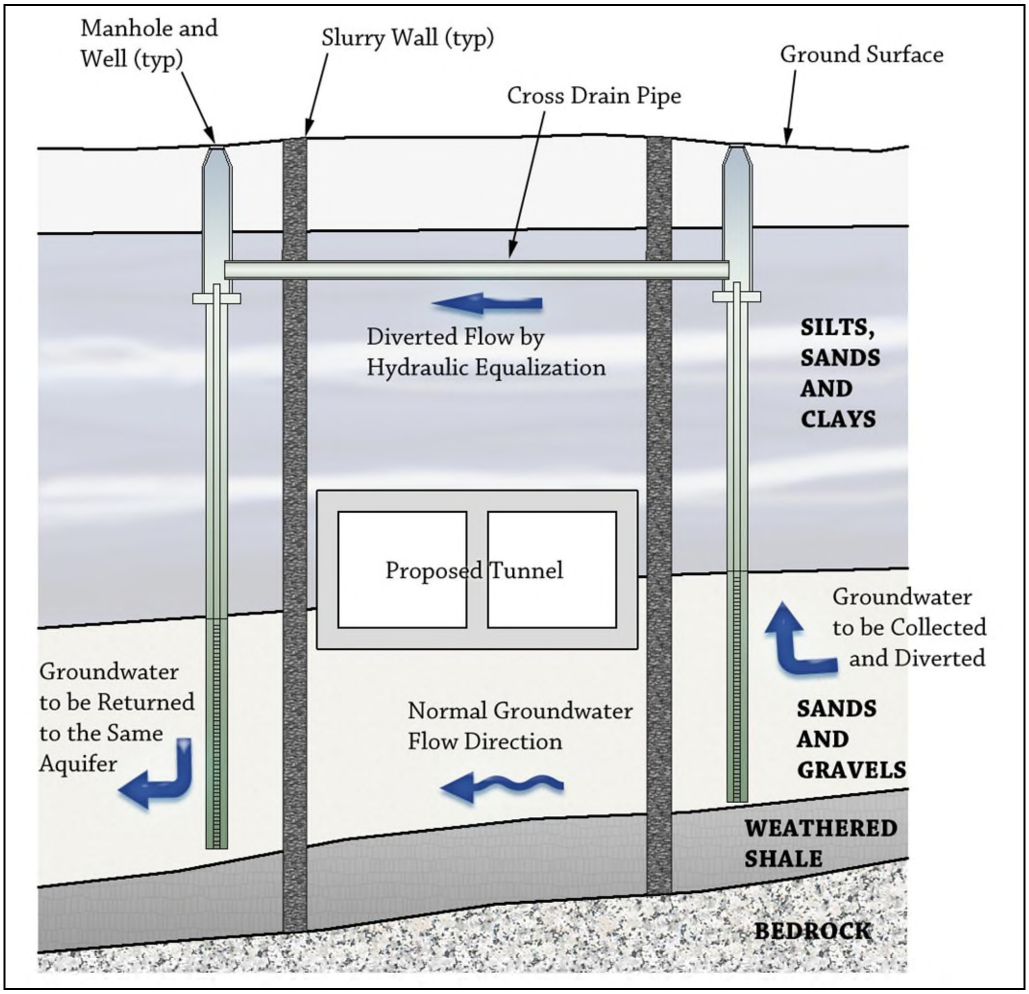


Figure 27: Equalization Well Concept

The downgradient recharge wells would be classified as Class V injection wells[1]. New York is a non-primacy state; thus, the United States Environmental Protection Agency (USEPA) Region 2 would be responsible for permitting this type of activity under their Underground Injection Control (UIC) program. The New York State Department of Environmental Conservation (NYSDEC) would be responsible for permitting the wells, construction dewatering, and recharge aspects of the concept. As of the date of this report, it is not known if the method here-described would be permitted by these agencies.

The groundwater flow model described previously was used to model the groundwater control system described above with the criterion that groundwater head (water table elevation) not be increased more than 0.1 foot on the upgradient side. The systems were designed to meet this criterion passively (without pumping); however, it is recognized that

[1] A Class V well is used to inject non-hazardous fluids underground. Fluids are injected either into or above an underground source of drinking water.

pumping could be required in certain or all cases in order to ensure appropriate control of groundwater flow. A groundwater monitoring system, consisting of an observation well network with telemetry that is reported in real time, would also be required to ensure that groundwater mounding is not occurring on the upgradient (eastern) side of the tunnel.

Long-term tunnel seepage would be collected in the internal tunnel drainage system and routed to sump drains. It would then be treated as stormwater runoff using manufactured treatment systems designed in accordance with the New York State Stormwater Management Design Manual (New York State Department of Environmental Conservation, 2010). Discharge would be pumped to nearby recharge structures or storm sewers as appropriate.

4.6 Protection of Adjacent Structures

Cut and cover tunnel construction, particularly in soft ground conditions, can cause ground movements, which have the potential to damage surrounding buildings and structures. Due to the proximity of the Concept T-5 tunnel to the existing I-81 viaduct, extensive underpinning and monitoring of the viaduct would be required. The existing I-81 viaduct is founded on cast-in-place (CIP) concrete piles or steel piles resting on bedrock, except for a segment of the viaduct between Sizer Street to Burt Street where footings are bearing on shallow rock. The design capacities of the concrete and steel piles are about 30 tons, according to the record drawings. The allowable bearing capacity of the shallow footings is about 5 tons per square foot (tsf) (NYS, 1964).

The underpinning of the I-81 viaduct foundation would generally follow this sequence:

- All the viaduct monitoring devices would be installed and baseline readings would be collected.
- The SOE walls would be constructed. If the limits of the tunnel (including the ramps) are outside the I-81 viaduct foundation footprint, concrete drilled shafts socketed into bedrock (minimum 5 feet) would be constructed in addition to the SOE walls for underpinning the viaduct.
- Jacking frames resting on the SOE walls and drilled shafts would be installed. Figure 28 shows plan and elevation views of an underpinning frame used to support and jack existing viaduct foundations for the Central Artery Tunnel in Boston. The underpinning frame was founded on the slurry walls used for excavation support and then used for jacking and unloading of the existing viaduct. The vertical loads of the viaduct were safely transferred to the slurry walls, which acted as load bearing elements. Figure 29 shows details of an underpinning design where the slurry walls used for cut and cover construction are outside of the viaduct foundation footprint. In this case, the underpinning frame was supported on slurry walls and drilled shafts. Figure 30 presents a picture showing jacking frames used for underpinning of a viaduct structure for Central Artery Tunnel Project in Boston, MA.
- The existing viaduct columns would be jacked, and the viaduct loads would be transferred to the SOE walls and drilled shafts.
- Existing viaduct foundations would be removed.
- Tunnel construction, as discussed in Section 4.4, would continue.

Figure 31 shows views of instrumentation and underpinning of an existing bridge of the Pittsburgh North Shore Connector. Picture A in this figure shows the strain gauges and total station systems used to monitor the stress changes and movements of the structure during underpinning. Picture B shows an underpinning beam that is rested on drilled shafts in an open excavation supported by lateral braces.

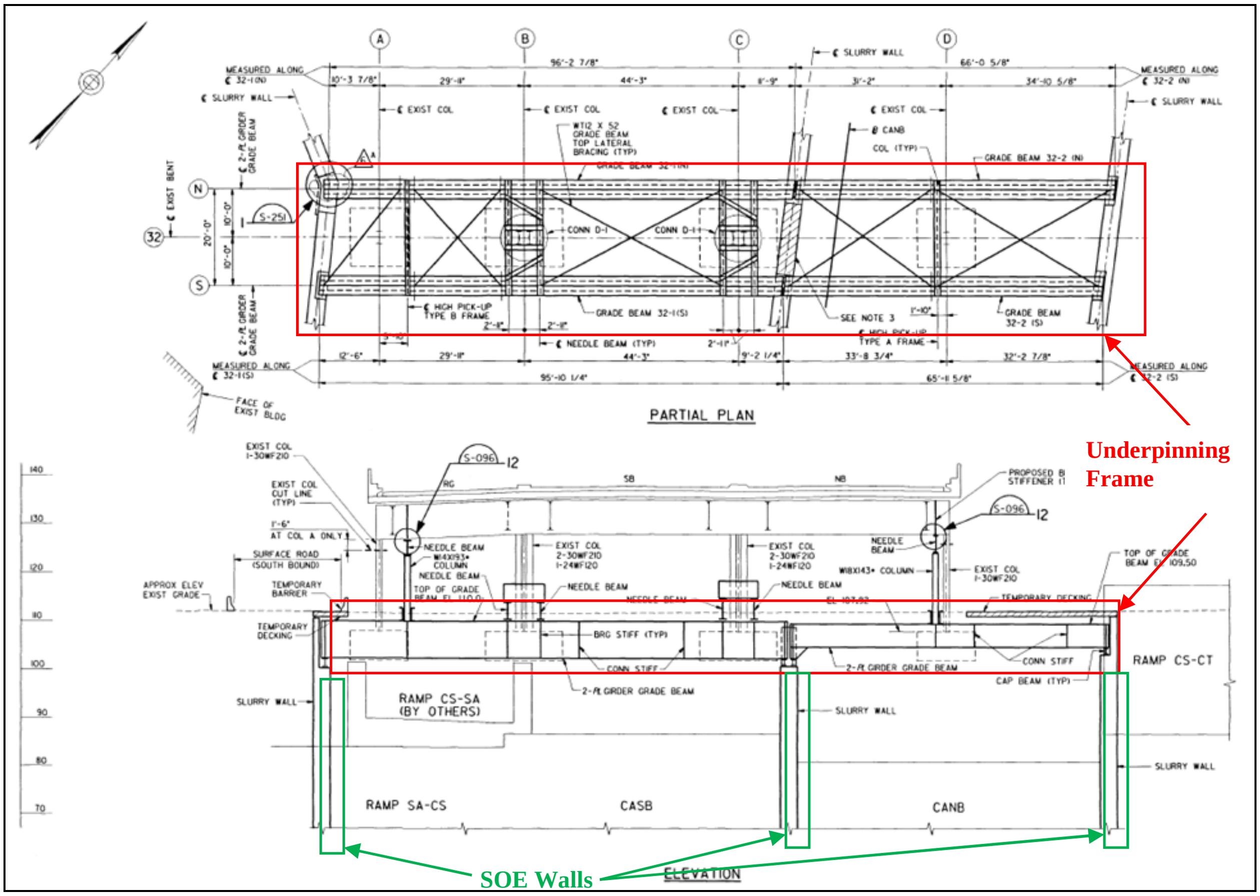


Figure 28: Underpinning of Existing Viaduct – Cut and Cover SOE Walls Used for Underpinning of the Viaduct for the Central Artery Tunnel Project in Boston (Massachusetts Highway Department, Central Artery Tunnel Drawings, 1996)

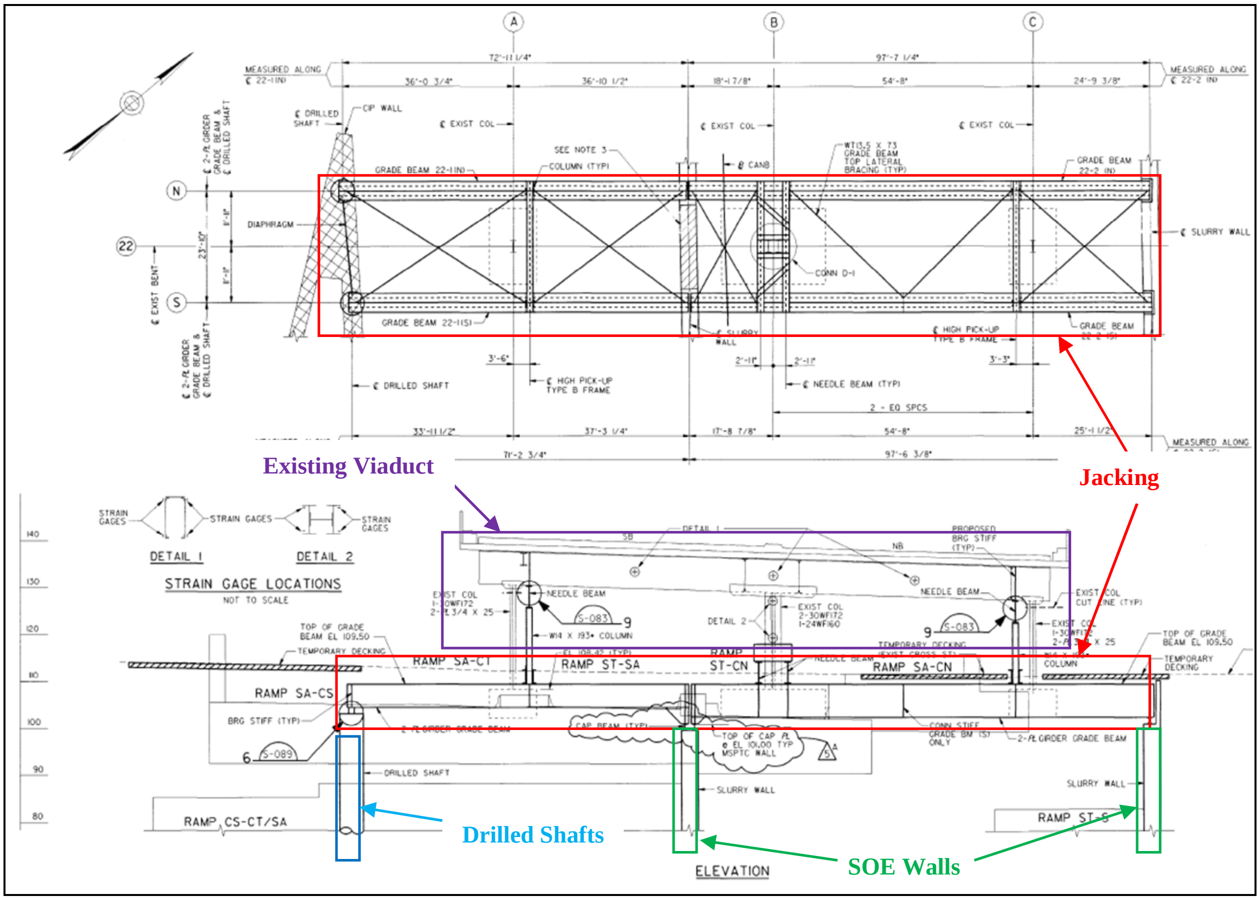
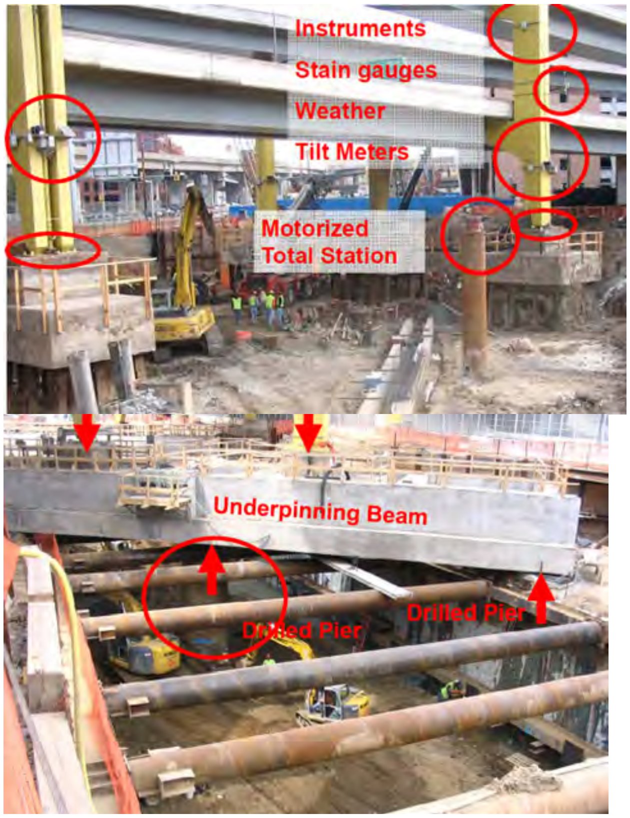


Figure 29: Underpinning of Existing Viaduct – Cut and Cover SOE Walls and Drilled Shafts Used for Underpinning of the Viaduct for the Central Artery Tunnel Project in Boston (Massachusetts Highway Department, Central Artery Tunnel Drawings, 1996)

Figure 30: Underpinning of Existing Viaduct – Central Artery Tunnel Project in Boston



A. B.

A. Instrumentation of Existing Bridge Underpinning

B. Bridge Underpinning over Cut and Cover excavation

Figure 31: Underpinning and Instrumentation of an Existing Bridge - Pittsburgh North Shore Connector Bridge

For Concept T-5, in addition to the existing I-81 viaduct, existing utilities, structures, and/or active roadways located within the impact zones would need to be underpinned to reduce ground and structure movements. Where the alignment of Concept T-5 would cross the existing New York, Susquehanna & Western Railway tracks, south of Burt Street (Figure 17), jet grouting could be used to underpin the tracks and support the ground. Figure 32 shows construction of jet grout columns for the underpinning of an existing building for North Shore Connector.

Figure 32: Jet grouting ground improvements for North Shore Connector

Depending upon the type of foundations, condition and age of the buildings, and impact of the proposed construction, some buildings would require underpinning. The type and extent of underpinning would be evaluated on a case-by-case basis for each building impacted based on its proximity to the excavation, depth of excavation, and the building's foundations.

4.7 Existing Utilities

Relocations of existing utilities would occur prior to the start of the cut and cover construction. Existing utility service would not be interrupted, and if temporarily relocated, would be restored upon completion of construction. Figure 33 illustrates the utility relocations before and after one of the cut and cover tunnels constructed for the Boston Central Artery project. Some of the utility manholes may also require underpinning. Each manhole would be evaluated independently depending on the condition of the manhole and the required depth of excavation. The utility lines anticipated along the alignment of Concept T-5 include water, gas, fiber optic, telephone, electric, combined sanitary sewer, and steam lines. The following major utilities were identified along Concept T-5:

- 34.5 KV Oil Cooled Electric Line crossing at Burt Street
- 48" Sanitary Crossing between MLK and the Railroad
- Steam Line Crossing at Taylor and Van Buren Streets, as well as line that runs parallel to Almond Street between Taylor and Van Buren Streets
- 66" Sanitary Crossing at Harrison Street
- 72" Sanitary Crossing at James Street
- 72" Sanitary Crossing at Willow Street
- 7.5' X 10.5' Sanitary Crossing at Erie Boulevard

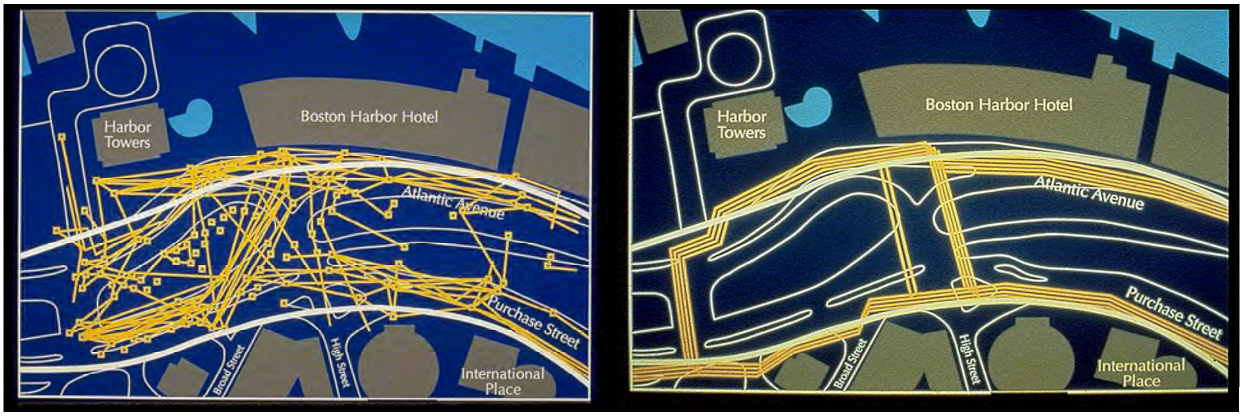


Figure 33: Utilities Before and After Cut and Cover Tunnel Construction at one of Boston Central Artery contracts.

4.8 Mechanical and Electrical Requirements and Ancillary Facilities

It is expected that a minimum of two ventilation buildings would be required at both portals of the tunnel, as illustrated in Figure 20.

- Electrical. Electrical power for the tunnels, ancillary facilities, and ventilation buildings would be provided via four independent utility incoming services, two at each ventilation building at or near both tunnel portals for redundancy. Stand-by diesel generators also would need to be provided rated to supply the maximum power demand for emergency lighting, pumps, ventilation fans, life safety, and communication devices in the tunnels, ancillary facilities, and ventilation buildings.
- Lighting. Tunnel lighting would use linear, continuous fluorescent, tunnel-rated luminaires throughout, with supplemental high intensity discharge luminaires as required for tunnel portal luminance adjustment in accordance with IESNA RP-22, "Recommended Practice for Tunnel Lighting" and CIE-88, "Guide for Lighting of Road Tunnels and Underpasses." The tunnel lighting system would be designed in accordance with IESNA RP-22.
- Ventilation. A ventilation system would be required to maintain acceptable air quality within the tunnel. The design of a tunnel ventilation system would be governed by fire safety measures or air quality. Tunnel ventilation, including jet fans and ventilation buildings, would be required for Concept T-5. The approximate locations of two ventilation buildings at the south and north tunnel portals of Concept T-5 are depicted in Figure 20. The tunnel ventilation system would manage emissions during day-to-day operations and remove smoke in case of a fire emergency. The proposed system would be configured so that there is a continuous air duct along the length of the tunnel. Along the air duct, dampers would be spaced for the purpose of extracting smoke and heat during a fire emergency. Both ends of the air duct would be connected to the tunnel ventilation buildings, where tunnel ventilation fans would be housed. Jet fans located in the tunnel would be used to manage the longitudinal air velocity and to prevent the movement of smoke and heat toward motorists. Ventilation for normal operations could be accomplished via vehicle piston effect (positive and negative pressure caused by the

vehicle movement in the tunnel) and hence mechanical ventilation would potentially not be required during normal operations. Emissions dispersion at the portals could require exhausting air from the tunnel before the exit portals. Ventilation for congested and standstill operations would be accomplished via the operation of the tunnel ventilation system. During normal, congested, and standstill operations, the ventilation system would be activated by an alarm from the carbon monoxide monitoring system or any other air quality monitoring device.

- Firefighting. An independent, multi-zone deluge sprinkler system would be employed for firefighting. This system would consist of a wet header pipe, heat traced and insulated where necessary, with normal closed deluge valves to dry sprinkler array over roadways. The standpipe system would consist of piping and hose valves housed in alarm cabinets adjacent to every egress door along the tunnel at intervals not to exceed the NFPA requirement of 275 feet. Fire pumps and fire department connections at both ventilation buildings, with a municipal hydrant located within 100 feet, would be required.
- Communications. Emergency telephones must be available in tunnels (at emergency exits or cross passages) and connected to an emergency power supply. Radio and mobile telephone coverage and communication means would be available to police, fire, and emergency personnel throughout the tunnel.
- Drainage. During construction, disposal and treatment of saline groundwater would be required. Long term tunnel drainage would include sump pump systems at the portals and low points. The drainage system would need to handle surface drainage and any water infiltration into the tunnel. Storm water control measures at the tunnel portals also would need to be implemented.

4.9 Maintenance of Pedestrian, Bicycle, and Vehicular Traffic during Construction

For Concept T-5, maintenance and protection of traffic programs would need to be developed to ensure that vehicular and pedestrian traffic flow is safely and properly maintained during construction. Figure 34 shows a view of a traffic diversion during cut and cover tunnel construction for the Seattle Alaskan Way Viaduct Replacement Program in Seattle. Traffic delays due to construction activities are common for cut and cover construction. Repair and maintenance of roadways also would need to be performed regularly.

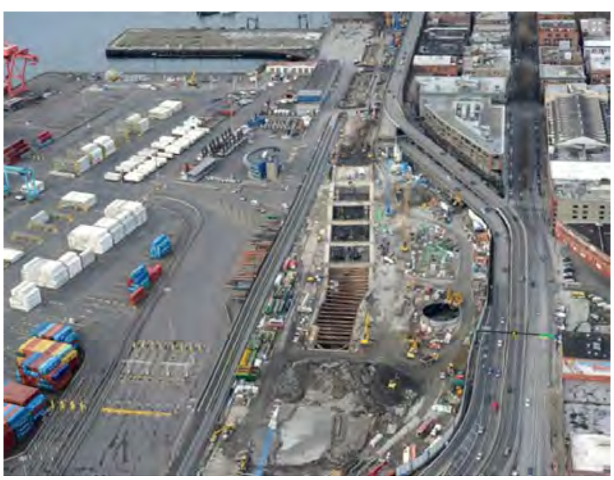


Figure 34: Re-routing of Traffic during Cut and Cover Tunnel Construction - Alaskan Way Viaduct Replacement Program, SR99 Re-route

4.10 Risk Identification and Mitigation

The risks associated with the Concept T-5 cut and cover tunnel are discussed below. Mitigation measures are also discussed.

- **Movements of the existing I-81 viaduct during underpinning and tunnel excavation**. As discussed in Section 4.6, Concept T-5 would be constructed underneath Almond Street and the existing I-81 viaduct for approximately the southern half of the alignment. The existing I-81 viaduct would stay active during the cut and cover tunnel construction. Considering the age of the viaduct (it was constructed in the early 1960s), its underpinning and the construction of a cut and cover tunnel underneath it would entail substantial risk and uncertainty. The construction procedure for Concept T-5, as discussed in Section 5.4, would require load transfer from the existing viaduct foundations to the proposed SOE walls and drilled shafts. The load transfer is a sensitive operation and its success relies heavily on the experience and workmanship of the contractor. Construction-induced movements must be minimized to reduce impacts on the active viaduct. Some level of structure movement would be inevitable during this process. To manage the risk associated with this operation, a rigorous instrumentation program and active monitoring of the structure would need to be implemented.
- **Settlements and movements of the surrounding structures, buildings, and utilities**. Depending upon their foundation systems and proximity to the excavation, underpinning of surrounding structures would be required before the start of construction. Settlements and movements of these structures would be expected during underpinning and cut and cover tunneling. Monitoring of the surrounding structures would be required during construction, and results of the monitoring would need to be used to modify the construction procedure or even to stop construction should recorded movements exceed alarm levels.
- **Environmental concerns with saline groundwater**. Groundwater in downtown Syracuse is known to be saline. The disposal of the groundwater during dewatering would follow state regulations.

4.11 Cost Estimate

An order of magnitude cost estimate range was prepared for Concept T-5 and is presented in Table 6. The cost estimate presented in this section is based on tunnel construction direct costs.

The major items included in the cost estimate are:

- Construction of the SOE walls for the cut and cover tunnel
- Underpinning of the I-81 viaduct and nearby structures
- Utility relocation and protection
- Maintenance of traffic
- Construction of ventilation buildings

- Tunnel finishes (ventilation, lighting, communication, fire suppression system, etc.)
- Construction of the dewatering system
- Tunnel operation and maintenance cost for 20 years (beyond interstate maintenance costs)

The major items not included in the cost estimate are:

- Above-ground interchange and connecting ramp construction
- Existing viaduct and other structure demolition
- Contingencies
- Escalation
- Property acquisitions
- Program management

The estimated construction duration of the tunnel portion of this concept is 4 years (48 months).

Table 6: Tunnel Concept T-5 – Order of Magnitude Direct Cost Estimate Range

Tunnel Alternative	Total Underground Length (ft)	Low Range Unit Cost ($/ft)	High Range Unit Cost ($/ft)	Low Range Total Cost ($)	High Range Total Cost ($)
T-5	11,040	110,800	136,200	1,223,232,000	1,503,648,000

5.0 Deep Tunnel Concepts (T-6 and T-7)

Two "deep bored tunnel" concepts, Concepts T-6 and T-7, were developed. These concepts would locate the tunnels as much as possible within deep bedrock strata to allow use of a Tunnel Boring Machine (TBM) and therefore avoid construction disruptions associated with cut and cover tunneling and minimize the settlements and movements to existing structures and utilities during construction. While both deep tunnel concepts consist of a bored segment in Bedrock Stratum, each would require cut and cover segments at the tunnel portals to link the bored segment to the ground surface.

Concept T-6

Concept T-6 would construct an approximately two-mile tunnel as shown in Figure 35. This concept would be designed to meet interstate standards and would therefore carry the I-81 designation through the city. As such, the tunnel would be designed to have full connectivity with I-690. The south tunnel portal would be located about 1,000 feet (0.19 miles) south of Dr. Martin Luther King, Jr. East (formerly E. Castle Street). From this point, the Concept T-6 tunnel would follow a path primarily underneath South Townsend Street, and make a westward turn around East Genesee Street. The tunnel would then continue in a northwestern direction until reaching the north portal, located approximately 800 feet (0.15 miles) north of Hickory Street, where the tunnel would join the existing I-81 highway.

Concept T-6 also would reconstruct I-690, from approximately Leavenworth Avenue to Lodi Street, as well as interchanges along I-81 and I-690. The following interchange modifications would be included in Concept T-6:

- I-81/I-690 Interchange: New ramps would be built to provide direct connections between eastbound I-690 and northbound I-81 and between southbound I-81 and westbound I-690 as illustrated in Figure 36. These new direct connections would facilitate interstate-to-interstate movement without use of the local street system. In addition to the missing connections, the existing I-81/I-690 interchange ramps would be reconstructed to connect the elevated I-690 with the new I-81 tunnel. Some interstate-to-interstate ramp connections would be partially constructed underground, as separate tunnels, to connect to the new I-81 tunnel. To accommodate the ramps entering and exiting the tunnel, East Willow Street, between Pearl Street and Warren Street, would be permanently closed to traffic. Table 7 summarizes the ramp lengths and the maximum depth-to-invert of the ramps. Table 7 shows that a substantial portion of the connecting ramps would be constructed below ground. Seven out of fourteen of these ramps would have underground segments with maximum depth-to-invert varying from 90 to 125 feet. Based on the depth to invert, cut and cover and Sequential Excavation Method (SEM) tunneling methods would be used for the construction of the ramps, as discussed in subsequent sections. Figure 37 depicts the layout of the new interstate-to-interstate ramps.
- I-81 from Interchange 20 to Interchange 23: This segment is common to all three tunnel concepts. A new travel lane in each direction would be provided on I-81 from I-690 to Hiawatha Boulevard to improve operations. Several non-standard highway features, such as narrow shoulders and tight curves, also would be corrected. The Court Street Interchange (Interchange 21) would be reconstructed with an additional auxiliary lane to facilitate weaving movement in the southbound direction. The Route 370 (Onondaga Lake Parkway) on-ramp and Old Liverpool Road on-ramp to southbound I-81 would be consolidated into a single ramp, and the on-ramp to southbound I-81 from Genant Drive (between Spencer and Butternut Streets) would be closed because of its proximity to Interchange 20.
- I-81 Interchange 19 (Clinton Street/Salina Street) and Interchange 20 (Franklin Street/West Street): Interchanges 19 and 20 would be combined to accommodate the missing connections between I-81 and I-690. The existing off-ramps from southbound I-81 to West Street/Franklin Street (Interchange 20) and to Clinton Street/Salina Street (Interchange 19) would be replaced by a single ramp serving Clinton Street and Franklin Street. In addition, the existing on-ramps from Pearl Street (Interchange 19) and State Street (Interchange 20) would be reconfigured as a single ramp at Pearl Street
- I-81 Interchange 18 (Adams Street/Harrison Street): The Adams Street ramps, which provide access to and from the south, would be reconstructed. These ramps, which would be about 4500’ long, would originate near the southern I-81 tunnel portal and proceed over Martin Luther King, Jr. East; the New York, Susquehanna, and Western Railway; Burt Street; Taylor Street; and Jackson Street before surfacing at about Adams Street. The reconstruction of the Adams Street ramps would introduce new structures (new ramp bridges would be constructed over these local streets). Due to the location of the tunnel along Townsend Street, the Harrison Street ramps, which provide access to and from the north, would be reconstructed along Townsend Street instead of Almond Street. The placement of these ramps would require the permanent closure of Townsend Street between Genesee Street and Harrison Street. In addition, these ramps would provide connectivity only to I-81 and would

not provide connectivity to I-690. Traffic currently using the existing Harrison Street on-ramp to access eastbound I-690 would need to use the new eastbound I-690 ramp from Almond Street (see below); motorists using the existing Harrison Street on ramp to access westbound I-690 would need to use another interchange, such as the West Street interchange or the Teall Avenue interchange. Similarly, eastbound I-690 traffic that can currently exit at Harrison Street to access Downtown would need to exit at another interchange, such as the West Street interchange or the Teall Avenue interchange.

- I-81 Colvin Street Entrance Ramp: The Colvin Street entrance ramp to northbound I-81 would be eliminated under Concept T-6. Due to the close proximity of the reconstructed northbound I-81 exit ramp to Adam Street, the Colvin Street entrance ramp would cause excessive weaving conflicts. Elimination of the northbound entrance ramp from Colvin Street would cause additional changes in travel patterns that would require additional modifications to local streets in that area
- Butternut Street Overpass: The replacement of the bridge carrying Butternut Street over I-81 and realignment of Butternut Street are common to all three tunnel concepts. The realigned Butternut Street would connect to Clinton and Franklin Streets in the Franklin Square neighborhood. The rebuilding of the overpass is necessary to allow the missing connection carrying traffic from eastbound I-690 to northbound I-81 to be constructed beneath the Butternut Street overpass.
- I-690 Interchange 11 (West Street): This improvement is common to all three tunnel concepts. To improve safety on I-690 and the West Street ramps, the existing, free-flow interchange 11 would be reconstructed. I-690 would pass over the West Street ramps, rather than under, and the high speed ramps would be replaced with a new at-grade intersection controlled by a traffic signal on West Street.
- I-690 Interchange 13 (Townsend Street/Downtown Syracuse): To allow for the reconstruction of the I-81/I-690 interchange, the westbound exit ramp from I-690, which is currently on Townsend Street, would be relocated to Almond Street. Similarly, the existing on-ramp to eastbound I-690 from McBride Street would be relocated to Almond Street as shown in Figure 38. Almond Street would remain a partial interchange with ramps only serving traffic to and from the east. The eastbound on-ramp also would serve motorists who currently use the existing on-ramp from Harrison Street to access eastbound I-690 as that movement would not be possible under Concept T-6 due to the new configuration of the ramps.

Table 7: Concept T-6 - Connecting Ramp Summary Information

Connection Ramp	Total Length (miles)	Underground Length (miles)	Above-Ground Length (miles)	Maximum Depth to Invert (feet)	Cut and Cover Length (miles)	SEM Length (miles)
N I-81 to W I-690	0.73	0.32	0.41	115	0.03	0.29
N I-81 to E I-690	0.46	0.25	0.21	115	0.01	0.24
N I-81 to W/E I-690	0.12	0.12	0.00	125	0.00	0.12
S I-81 to E/W I-690	0.07	0.00	0.07	N/A	N/A	N/A
S I-81 to E I-690	0.33	0.00	0.33	N/A	N/A	N/A
S I-81 to W I-690	0.14	0.00	0.14	N/A	N/A	N/A
S/N I-81 to W I-690	0.08	0.00	0.08	N/A	N/A	N/A
W I-690 to N I-81	0.32	0.00	0.32	N/A	N/A	N/A
E I-690 to N/S I-81	0.12	0.00	0.12	N/A	N/A	N/A
E I-690 to N I-81	0.45	0.00	0.45	N/A	N/A	N/A
E I-690 to S I-81	0.71	0.30	0.41	125	0.04	0.26
W I-690 to S I-81	0.81	0.61	0.20	120	0.04	0.57
S I-81 to Harrison St.	0.52	0.27	0.25	90	0.04	0.23
Harrison St. to N I-81	0.54	0.39	0.15	110	0.03	0.36
Total	**5.4**	**2.26**	**3.14**			

Figure 35: Concept T-6 – Plan View

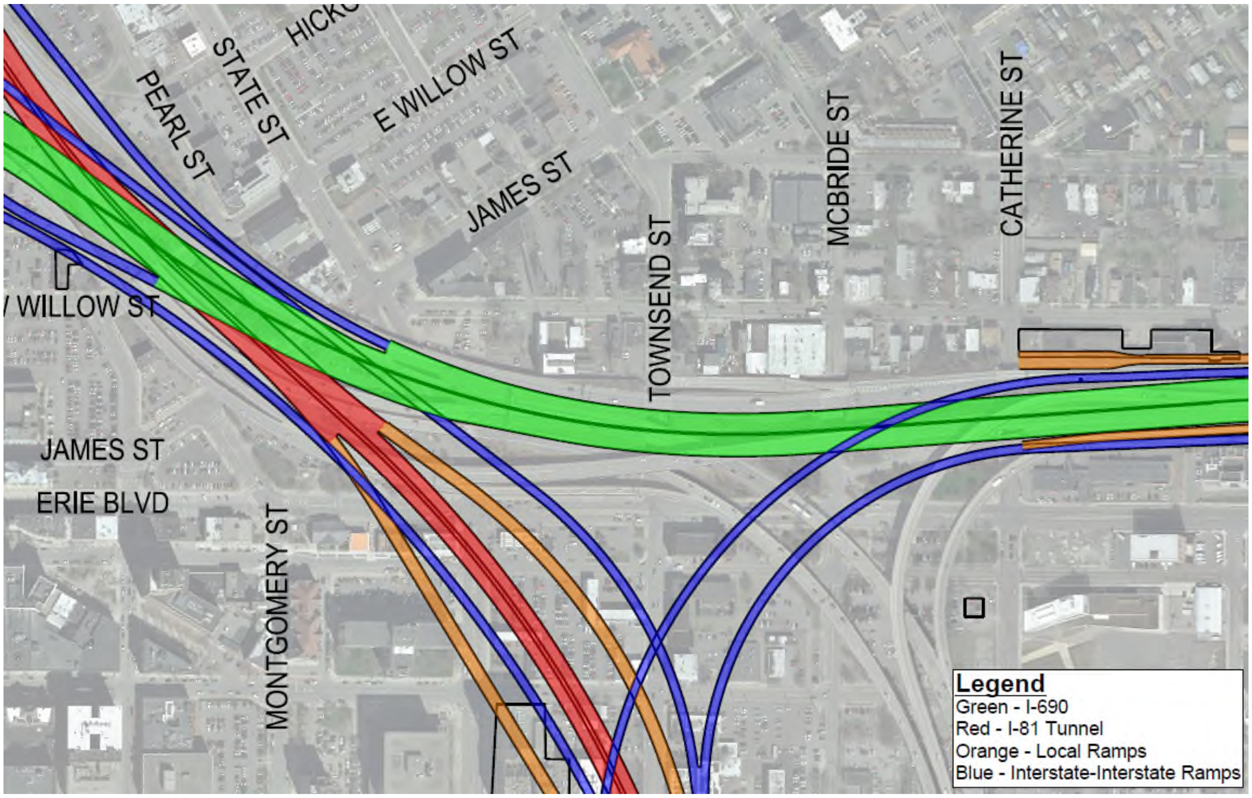


Figure 36: Concept T-6 - Main Interchange with Local and Interstate-Interstate Ramps

Figure 37: Concept T-6 – Plan View of Ramps

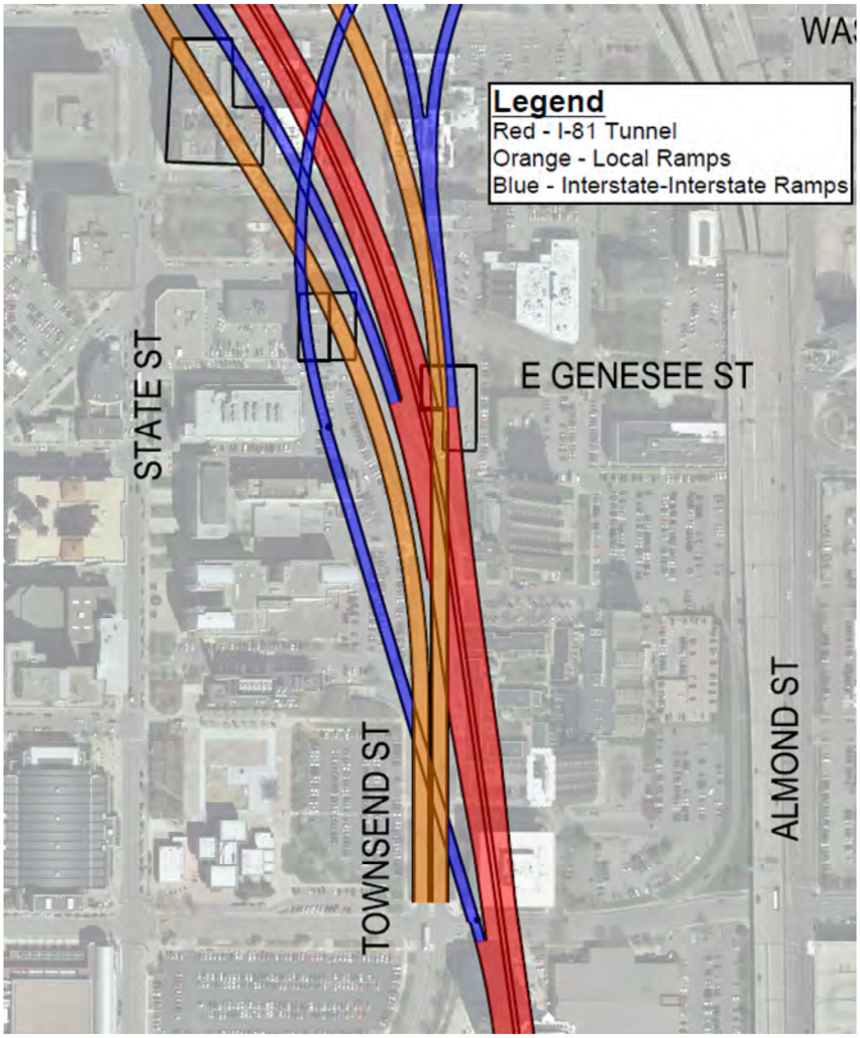


Figure 38: Concept T-6 - Townsend Street Ramp

Figure 39: Concept T-7 – Plan View

As illustrated in Figure 35, approximately 16 properties would have to be acquired as a result of the construction of Concept T-6, including the Verizon Building and Communications Tower. There also would be impacts in the form of construction-induced ground movements to Firefighter's Memorial Park, a local landmark, during construction of the tunnel (see Attachment 1). The buildings that would be acquired for Concept T-6 are as follows:

1. 117 Butternut Street
2. 329 North Salina Street
3. 319-325 North Salina Street
4. 400 Burnet Avenue
5. 212 Herald Place
6. 123-129 East Willow Street
7. 500 Renwick Avenue
8. 110 Almond Street
9. 901 North State Street
10. 909 North State Street
11. 915 North State Street
12. 471-81 Oswego Blvd.
13. 530 East Genesee Street
14. 444 East Genesee Street
15. 430 East Genesee Street
16. 411 East Fayette Street

Concept T-7

Concept T-7 (see Figure 39, Concept T-7 Plan View) would be designed as a high speed, non-interstate north-south "direct" tunnel through Downtown Syracuse and would not provide full connectivity with I-690. Concept T-7 would include the removal of the existing I-81 viaduct and the construction of a boulevard along Almond Street. The south tunnel portal would be located about 1,000 feet (0.19 miles) south of Dr. Martin Luther King, Jr. East (formerly E. Castle Street). From this point, the Concept T-7 tunnel would initially follow a path underneath South Townsend Street, but then would continue on a path farther west than the Concept T-6 alignment and pass more directly below the Downtown area. The tunnel would continue in a northwestern direction until reaching the north portal, located approximately 800 feet (0.15 miles) north of Hickory Street, where the tunnel would join what would be the former section of I-81 in the vicinity of Butternut Street.

Concept T-7 also would include the conversion and designation of I-481 as I-81 and a new I-690 interchange at Crouse and Irving Avenues. The following interchange modifications would be included in Concept T-7:

- I-481 conversion: Under this concept, I-81 would no longer pass through the city of Syracuse and I-481 would be converted to I-81. Work would include reconstructing and reconfiguring the southern I-81/I-481 interchange, the northern I-81/I-481 interchange, and other miscellaneous improvements along the I-481 corridor.

- I-81/I-690 Interchange: While Concept T-7 would sever I-81 through the city, the northern segment of existing I-81, north of I-690, would remain an interstate. Although the tunnel itself would not connect to I-690, the missing connections between I-690 and former I-81 would be provided. Under Option T-7, new ramps would be built to provide direct connections between eastbound I-690 and northbound former I-81 and between southbound former I-81 and westbound I-690 as illustrated in Figure 40. In addition to the missing connections, the former southbound I-81 to eastbound I-690 interchange ramp and the westbound I-690 to former northbound I-81 interchange ramp would be reconstructed. All interchange ramps would be constructed on elevated bridges.
- I-81 from Interchange 20 to Interchange 23: This is common to all three tunnel concepts and is the same as described above for Option T-6.
- I-81 Interchange 19 (Clinton Street/Salina Street) and Interchange 20 (Franklin Street/West Street): Interchanges 19 and 20 would be combined to accommodate the missing connections between I-81 and I-690. This would involve replacing the existing off-ramps from southbound I-81 to West Street/Franklin Street (Interchange 20) and to Clinton Street/Salina Street (Interchange 19) with a single ramp that serves Clinton Street and Franklin Street. In addition, the existing on-ramps from Pearl Street (Interchange 19) and State Street (Interchange 20) would be reconfigured as a single ramp at Pearl Street.
- I-81 Interchange 18 (Adams Street/Harrison Street): This interchange would be eliminated. Access to and from the south, currently served by the Adams Street ramps, would be replaced by an at-grade boulevard, including at-grade intersections with Martin Luther King, Jr. East and a new underpass where the boulevard would pass beneath the New York, Susquehanna, and Western Railway. The Harrison Street ramps, which currently provide access to and from the north, would be eliminated, and a new interchange at Crouse and Irving Avenues and new access points to former I-81 at either Catherine Street or at James/Pearl Street would be provided. I-690 traffic to and from the west, which can currently enter or exit the highway at Harrison Street, would need to use another interchange, such as the West Street interchange or the new Crouse-Irving Avenues interchange.
- I-81 Colvin Street Entrance Ramp: The Colvin Street entrance ramp to northbound I-81 would remain.
- Butternut Street Overpass: This is common to all three tunnel concepts and would include replacing the bridge carrying Butternut Street over I-81 and realigning Butternut Street to connect to Clinton and Franklin Streets in the Franklin Square neighborhood. This overpass would be rebuilt as part of the reconstruction of the I-81/I-690 interchange, which would shift the interstate and ramp locations. Re-alignment of the bridge would allow the missing connection carrying traffic from eastbound I-690 to northbound I-81 to be constructed beneath the Butternut Street overpass.
- I-690 Interchange 11 (West Street): This is common to all three tunnel concepts. To improve safety on I-690 and the West Street ramps, the existing, free-flow interchange 11 would be reconstructed. I-690 would pass over, rather than under, the West Street ramps, and the high speed ramps would be replaced with a new at-grade intersection, controlled by a traffic signal on West Street.
- I-690 Interchange 13 (Townsend Street/Downtown Syracuse): To allow for the reconstruction of the I-81/I-690 interchange, the existing partial interchange 13 would be reconstructed.

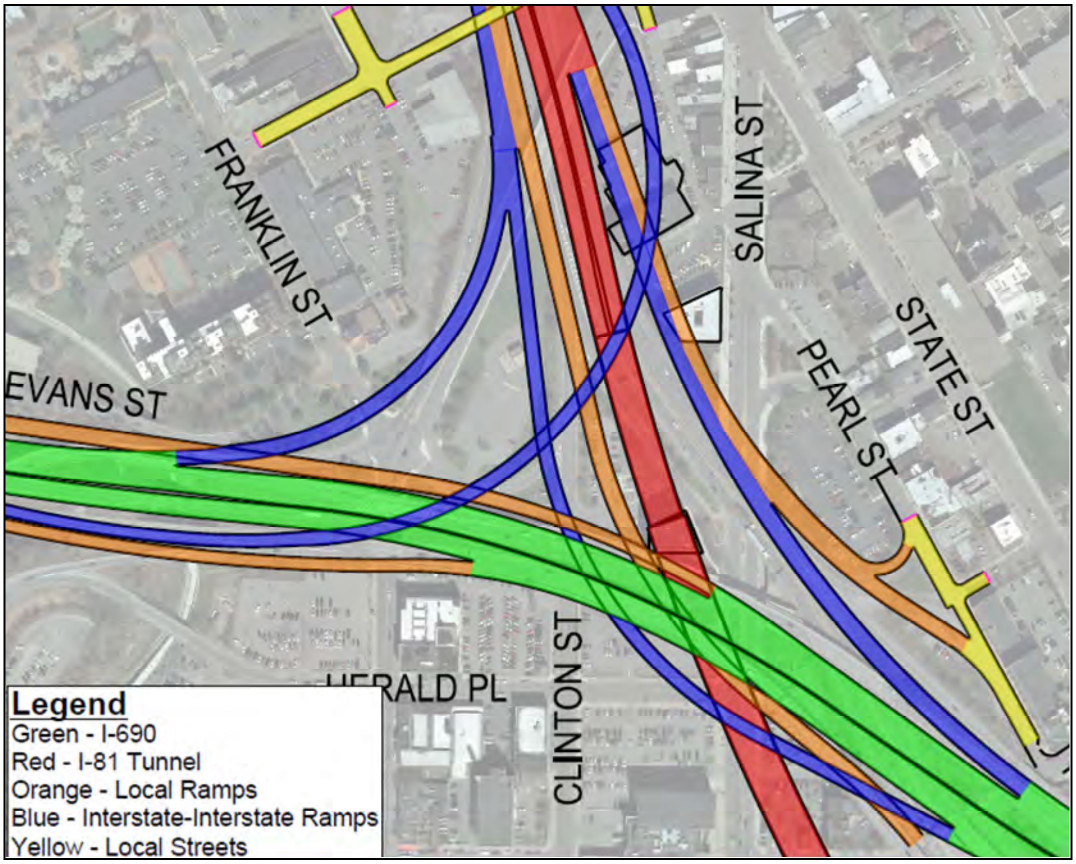


Figure 40: Concept T-7 – Main Interchange with Local and Interstate-Interstate Ramps

As illustrated in Figure 39, approximately 10 buildings would have to be acquired as a result of the construction of Concept T-7, as listed below:

1. 117 Butternut Street
2. 329 North Salina Street
3. 319-325 North Salina Street
4. 101 Lodi Street
5. 500 Renwick Avenue
6. 311 Genant Drive
7. 110 Almond Street
8. 901 North State Street
9. 909 North State Street
10. 915 North State Street

5.1 Geotechnical and Geological Subsurface Conditions

Limited subsurface geotechnical data were available along the proposed alignments of Concepts T-6 and T-7. Based on the historic borings performed in the 1960s by the New

York State Department of Public Works, rock elevation data collected from NYSDOT and USGS boring data, the subsurface ground conditions along the Concepts T-6 and T-7 alignments were evaluated and a generalized subsurface geotechnical profile was developed and presented in Figure 41. Similar to the subsurface profile presented in Figure 22 for Concept T-5, the elevation datum is in NAVD88, which is approximately the same as NGVD29. A comparison of the subsurface profiles for Concept T-5 (Figure 22) and Concepts T-6 and T-7 (Figure 41) suggests that the Bedrock Stratum, discussed in Section 4.1, is deeper along the majority of the southern half of Concepts T-6 and T-7 than it would be under Concept T-5.

Both Concepts T-6 and T-7 have similar longitudinal profiles (roadway surface), as presented in Figure 41. The approximate limits of the north and south cut and cover segments (including the approach structures) and the bored segments are also illustrated in Figure 41.

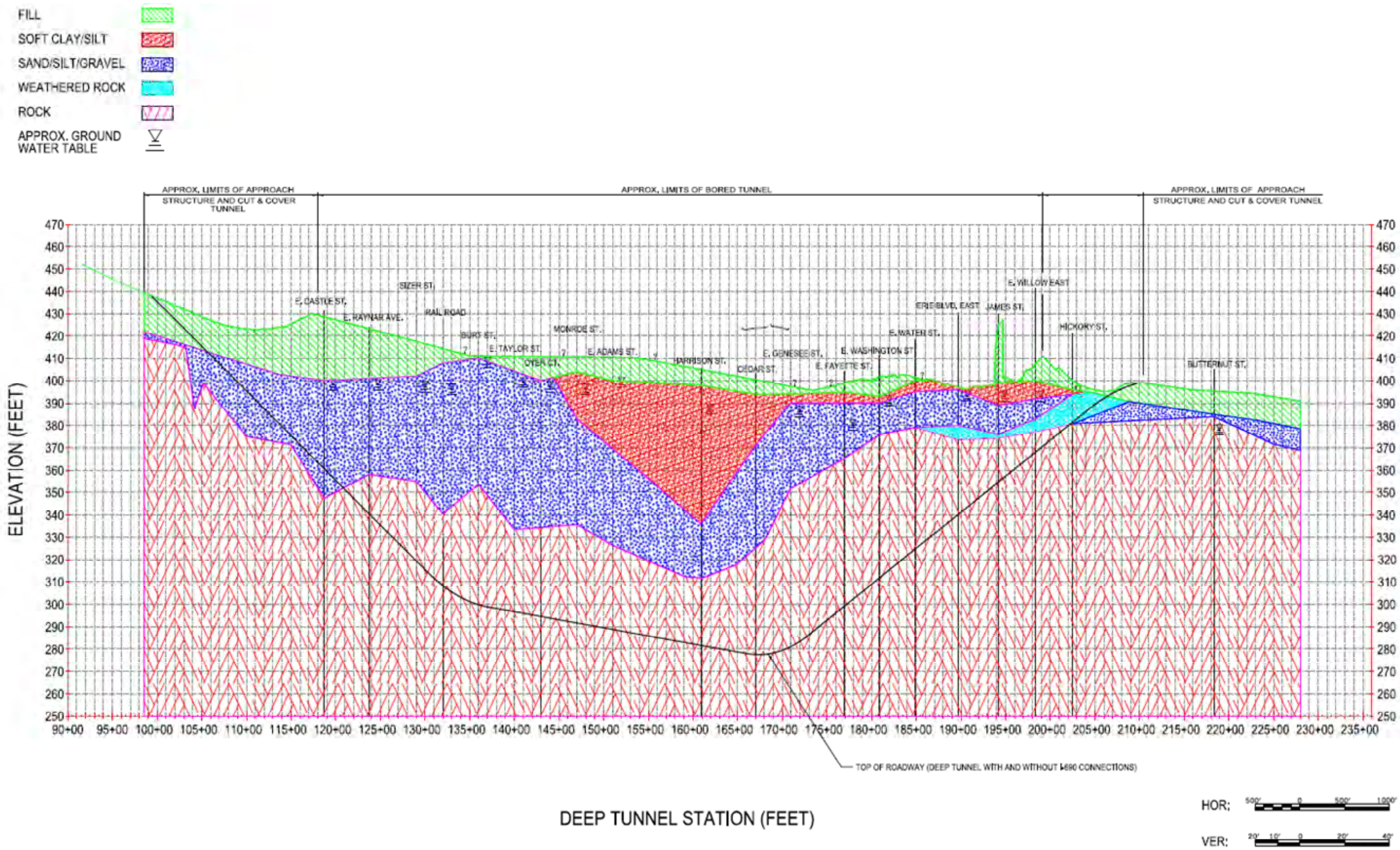


Figure 41: Generalized Geotechnical Subsurface Profile for Concepts T-6 and T-7

5.2 Vertical Roadway Alignment

The longitudinal portal-to-portal profile of Concepts T-6 and T-7 (roadway surface) is presented in Figure 41. The approximate elevations of the tunnel invert at the south and north portals are approximately at 440 and 400 feet (NAVD88), respectively. The tunnel invert at its lowest point reaches elevation 275 feet (NAVD88). The limits of the bored tunnel segment, shown in Figure 41, were established based on subsurface geotechnical conditions, depth to rock, and existing topography for launching and receiving a tunnel boring machine (TBM). Similar to Concept T-5, discussed in Section 5.0, Concepts T-6 and T-7 would require approach structures at the south and north portals to accommodate the transition between surface and cut and cover tunnels.

Table 8 summarizes tunnel segment lengths for Concepts T-6 and T-7.

Table 8 – Concepts T-6 and T-7 – Tunnel Segment Lengths

Tunnel Structure	Length in miles (feet)
South Portal Approach Structure	0.24 (1270)
South Cut and Cover Tunnel	0.14 (740)
Bored Tunnel	1.64 (8660)
North Cut and Cover Tunnel	0.07 (370)
North Portal Approach Structure	0.10 (530)
Total Underground Alignment	**2.19 (11570)**

5.3 Typical Tunnel Sections

The bored tunnel included under Concepts T-6 and T-7 would consist of two parallel tubes that would carry unidirectional traffic. Each tube would carry two lanes with shoulders and safety walks. Considering the geometrical requirements outlined by FHWA (2009), the assumed inside and outside diameters of the tubes would be 38 and 42 feet, respectively (assuming a lining thickness of 2 feet). A typical cross section for a two-lane bored tube is presented in Figure 42. The actual distance between the tubes would depend on the strength and quality of the rock in which they would be located; however, based on the information available, the assumed distance between the tubes is estimated at about 25 to 50 feet.

The cut and cover segments connecting to the bored segment of Concepts T-6 and T-7 would have a total width of about 159 feet at their connection to the bored tunnels. The width of the cut and cover segments and approach structures away from the connections to bored tunnels could be less than 159 feet and would be sufficient to accommodate four lanes of traffic (about 80 feet). The maximum width of the cut and cover segment (159 feet) was based on an assumption of 25 feet of rock between the twin tubes and 25 feet on each side of the tubes. The height of the cut and cover approaches would be about 30 to 40 feet (similar to the height of Concept T-5). Table 9 presents a summary of the cross-section dimensions of Concepts T-6 and T-7.

Table 9 – Deep Tunnel Cross Section Dimensions (Concepts T-6 and T-7)

Deep Tunnel Segments	Inside Diameter (ft)	Outside Diameter (ft)	Width (ft)	Height (ft)
Bored Segment	38	42	NA	NA
Cut and Cover Segment	NA	NA	80 to 159	30 to 40

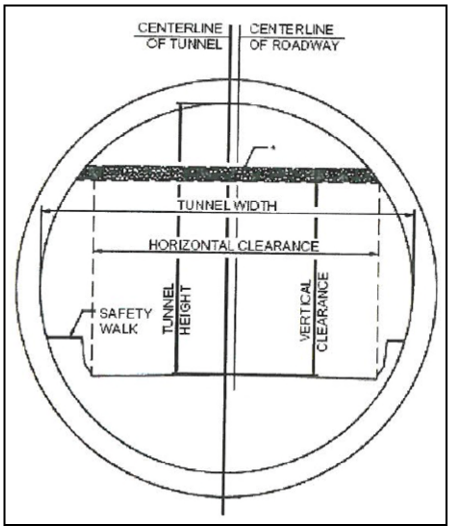


Figure 42: Typical Two-Lane Bored Tunnel Cross Section (FHWA, 2009)

5.4 Construction Method

The segments of Concepts T-6 and T-7 in bedrock (the approximate limits of the bored segments are shown in Figures 35, 39, and 41) would be constructed using a rock Tunnel Boring Machine (TBM). Tunnel boring is a mechanized process of excavation in hard rock. A TBM excavates rock using disc cutters mounted in the cutter head, which is at the front of the TBM. Hard rock TBM operation is a continual process of rock excavation that involves cutting the rock, removing the muck through conveyors, and providing temporary and/or permanent support and lining of the tunnel. TBMs are used to excavate circular cross section tunnels. The length of the bored segments is sufficient that TBM construction could be a cost effective solution for Concepts T-6 and T-7. Both tubes would be excavated using a single TBM.

TBMs typically have a shield (a large metal cylinder at the front of the machine) that is integrated with the machinery housed inside it. Depending on the type of geology and the required rate of advancement, the shield could be either single or double, as illustrated in Figure 43. In unstable geologies or where higher excavation speed is required, double-shielded TBMs are normally preferred. The single shield TBMs are more suitable in hard rock geology and are less expensive than double shielded TBMs.

To construct Concepts T-6 and T-7, a single-shielded TBM with a precast segmental concrete lining would be recommended. At the deepest point of the bored segment, the tunnel invert would be approximately at elevation 275 (Figure 41), about 125 feet below ground surface. This depth corresponds to a water pressure of about 3.5 bars, assuming ground water at 10 feet below ground.

Construction of the bored segments utilizing an Earth Pressure Balance (EPB) machine at shallower depths was considered and dismissed due to the presence of soft cohesive deposits (Soft Clay/Silt Stratum), lack of sufficient subsurface information, and the potential impacts in the form of movements and settlements on the existing structures.

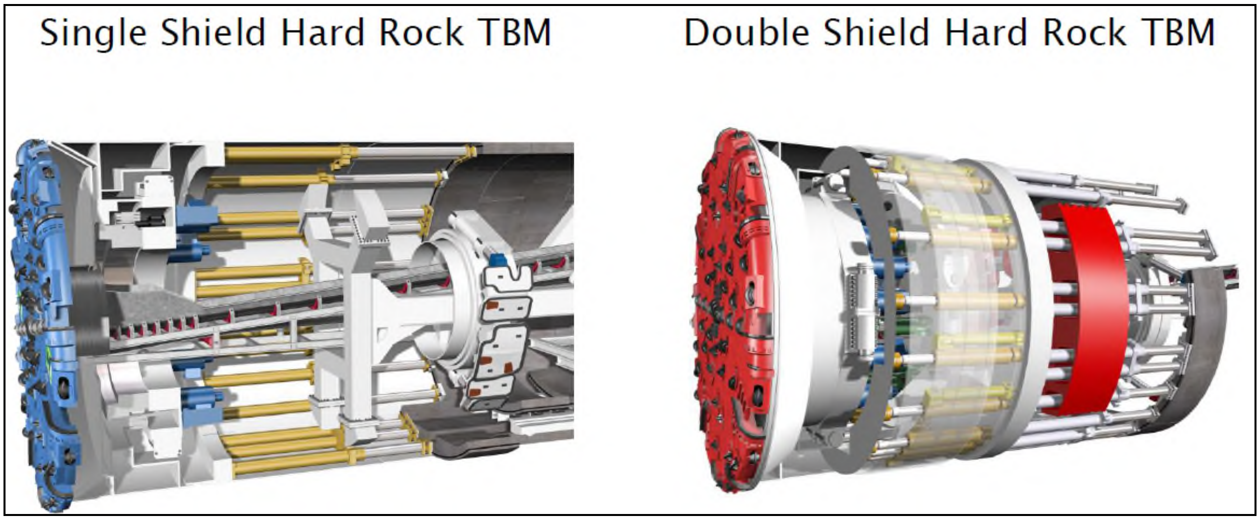


Figure 43: Single and Double Shielded Hard Rock Tunnel Boring Machines (Herrenknecht)

The construction of the cut and cover segments of Concepts T-6 and T-7 would be similar to the construction of Concept T-5 (discussed in Section 4.4). These cut and cover segments would include two SOE walls with 5 to 10 feet of embedment in Bedrock Stratum depending on the depth of the tunnel. The cut and cover segments of Concepts T-6 and T-7 would be wider than those of Concept T-5 at the connection between cut and cover and bored segments (159 feet versus 84 feet for Option T-5). The wider cut and cover segments would require construction of additional load bearing elements such as drilled shafts between the SOE walls to support the roof slab. The space between the SOE walls at the connection between the cut and cover and bored segments would be used as launching and receiving pits for the TBM.

U-shaped approach structures would be constructed to connect the surface area to the cut and cover segments of the deep tunnel. These structures would consist of retaining walls on both sides and an invert slab. The depth to invert for the approach structures would be 30 feet or less. Where the bottom of the approach structures are above groundwater, soldier pile and lagging walls, instead of watertight slurry walls, could be used. However, when the invert slabs of the approach structures would be below groundwater, relatively watertight SOE walls would be employed. For Concepts T-6 and T-7, waterproofing would be necessary, and a water collection system is assumed.

Water that enters the excavation during the boring operation would need to be collected and disposed.

The connecting ramps for Concept T-6 would be constructed using cut and cover and Sequential Excavation Method (SEM) methods. Cut and cover tunneling (including U-shaped approach structures) would be used from the ground surface to a depth where the tunnel depth-to-invert is about 40 feet below ground surface. The deeper segments of the ramp would be excavated using SEM. Table 7 summarizes the cut and cover and SEM lengths for the ramps with underground segments. As shown in Table 7, the majority of the ramps would be constructed using SEM. A typical tunnel cross section excavated by SEM is presented in Figure 44. The cross section of a SEM tunnel is different from the rectangular shape of a cut and cover tunnel. A transition structure would be constructed to connect the cut and cover segment to the SEM tunnel.

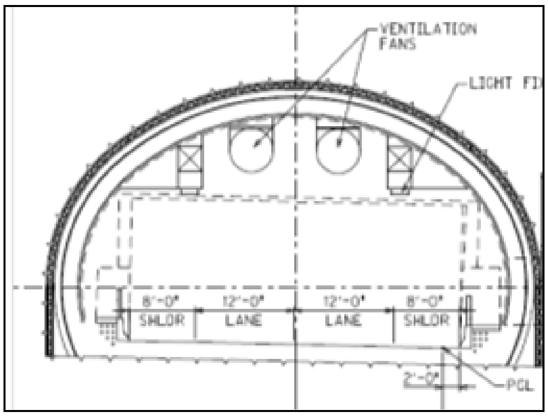


Figure 44: A Typical Tunnel Cross Section Excavated using SEM

Depth to top of competent rock in the vicinity of the north tunnel portal would be about 40 feet. Therefore, it is anticipated that the SEM tunneling for the ramps would be mostly in the Bedrock Strata. Drill and blast technique and mechanical excavation using a roadheader are commonly used techniques for tunnels excavated in rock by SEM. The drill and blast technique basically involves drilling a pattern of small diameter holes, loading them with explosives, and then detonating the explosives to remove the rock. The blasted and broken rock (muck) is then removed and the rock surface is supported so that the whole process can be repeated to advance the opening in rock. Figure 45 presents a photograph showing drill and blast operations.

Another commonly used approach for SEM tunneling in competent rock is the use of a roadheader. Excavation of a tunnel face with a roadheader results in an opening closer to the actual required section of the tunnel. The basic cutting tool for a roadheader is a large milling head mounted on a boom, which in turn is mounted on tracks or within a shield. Figure 46 shows excavation of a tunnel face using a roadheader. The final liner of a SEM tunnel typically consists of shotcrete or cast in place concrete. SEM tunneling is expected to be a slower process than TBM rock tunneling.

Figure 45: Drill and Blast Operations (SEM Tunneling)

Figure 46: Tunneling with a Roadheader (SEM Tunneling)

5.5 Groundwater Control and Construction Dewatering

Groundwater control and construction dewatering would be required for all cut and cover portions of the tunnel and approach sections extending below the groundwater table. Methods used in these areas would be identical to those described for Concept T-5, and the groundwater flow model described previously (Section 3.0) was modified to determine the number and placement of drainage and recharge structures required. Seepage during construction and long-term seepage would be collected, treated (as described previously), and discharged to nearby recharge structures or storm sewers.

5.6 Protection of Adjacent Structures and Utilities

The majority of the deep tunnels assumed under Concepts T-6 and T-7 would be constructed using a TBM, as noted in Figure 41 and Table 8, to reduce ground movements and distortion to adjacent structures and utilities. In addition, most of the below-ground ramps for Concept T-6 would be constructed using SEM, a technique that minimizes movements and distortion on nearby facilities and utilities. Surrounding structures and utilities would need to be protected as discussed in Sections 4.6 and 4.7.

5.7 Mechanical and Electrical Requirements and Ancillary Facilities

The tunnels constructed under Concepts T-6 and T-7 would be equipped with ventilation, lighting, communication, fire safety, and drainage as discussed in Section 4.8.

Considering the length of the deep tunnel under Concepts T-6 and T-7, it is assumed that two ventilation shafts, 25 feet in diameter, would be required at the approximate locations shown in Figures 35 and 39. Jet fans would be employed for ventilation purposes.

Cross-passages would be required to connect the north- and southbound tubes of the bored segments to facilitate evacuation. According to the U.S. National Fire Protection Association's standard, the cross-passages should be spaced no more than 800 feet apart. Assuming 8,660 feet of bored tunnel (Table 8), approximately ten cross-passages would be required for Concepts T-6 and T-7 with an estimated length of 50 feet for each cross-passage. The cross-passages would be constructed using SEM.

5.8 Maintenance of Pedestrian, Bicycle and Vehicular Traffic during Construction

During construction, efforts would be made to maintain pedestrian, bicycle, and vehicular traffic. The ability to maintain vehicular and pedestrian traffic flow during construction would likely be greater with Concepts T-6 and T-7 than with Concept T-5.

5.9 Risk Identification and Mitigation

- **Inadequate subsurface geotechnical and geological explorations**. The deep tunnel concepts (Concepts T-6 and T-7) and the methods of construction were established with inadequate subsurface geotechnical and geological information. A detailed subsurface exploration program would be required to modify the proposed alignments and determine ground characteristics for tunnel design and construction. Inadequate or different site conditions are often sources of delays, equipment malfunction, and contractual problems with deep bored tunneling. Variability of rock strength and weathering could be encountered during TBM and SEM tunneling, which may result in construction delays and additional costs. A thorough site investigation and development of a clear understanding of the rock and soil properties would need to be executed prior to the start of construction to reduce risks.
- **Encountering weathered rock and soft soils during tunnel boring**. Encountering weathered zones of rock or soft soils could slow down the advance rate of TBM tunneling and increase water intrusion. Zones with weathered rock and soft soils along the TBM alignment would need to be identified during subsurface exploration, and these ground conditions would need to be addressed with the proper selection of the TBM. Pre-excavation grouting could be used in fractured rock for both T-6 and T-7 concepts, which would increase both the cost and duration of construction.
- **Construction of deep connecting ramps**. Concept T-6 would require several ramps to maintain vehicular traffic connectivity. As discussed in this section, these ramps would have a maximum depth to invert of about 90 to 125 feet. Production rate for excavation of these ramps using SEM technique would depend heavily on the strength and joint characteristics of the rock. Construction delays could occur and different types of ground support measures would need to be employed to address variable rock condition.
- **Environmental concerns with saline groundwater**. Groundwater in downtown Syracuse is known to be saline. The disposal of the groundwater during dewatering would need to comply with local regulations, as discussed in Section 4.5.

5.10 Cost Estimate

Order of magnitude cost estimate ranges were prepared for Concepts T-6 and T-7 and are presented in Table 10 (for more detailed information, refer to **Appendix A**). The cost estimates presented in this section are based on tunnel construction direct costs.

The major items included in the cost estimate are as follows:

- Construction of the SOE walls for cut and cover segments and approach structures
- Excavation and lining of twin bored tunnels and cross passages
- Excavation and lining of connecting ramps (Concept T-6)
- Utility relocation and protection
- Maintenance of traffic

- Construction of ventilation shafts
- Underpinning of nearby structures
- Tunnel finishes (ventilation, lighting, communication, fire suppression system, etc.)
- Construction of dewatering system
- Tunnel operation and maintenance cost for 20 years (beyond interstate maintenance costs)

The major items not included in the cost estimate are as follows:

- Above-ground interchange and connecting ramp construction
- Existing viaduct and other structure demolition
- Property acquisitions
- Program management

The estimated construction duration of the tunnel portion of Concepts T-6 and T-7 is 3 years (36 months).

Table 10: Concepts T-6 and T-7 – Order of Magnitude Direct Cost Estimate

Option	Total Underground Length (ft)	Low Range Unit Cost ($/ft)	High Range Unit Cost ($/ft)	Low Range Total Cost ($)	High Range Total Cost ($)
T-6	11570	82,400	103,600	953,368,000	1,198,652,000
T-7	11570	65,300	80,000	755,521,000	925,600,000

6.0 Feasibility of Concepts

The feasibility of each of the three tunnel concepts was determined based on two factors: constructability and cost. Constructability was assessed based on the complexity of construction, construction duration, and other construction-related issues, such as the ability to maintain adequate traffic flow during construction. As previously discussed, estimated construction costs were developed for each of the three tunnel concepts; a concept that would cost over $2.35 billion is considered unfeasible.

The following summarizes the feasibility of the three tunnel concepts described within this report.

- **Concept T-5** is not feasible due to cost. Concept T-5's estimated cost is $3.1 billion, which includes construction direct costs, contingency, and escalation. As stated above, a construction cost of over $2.35 billion is unfeasible. While the construction of Concept T-5 is technically feasible, it would be highly disruptive and therefore undesirable. In addition to relocation of substantial utilities, Concept T-5 would require the underpinning of the viaduct, which is nearly 60 years old, and the surrounding buildings and roadways. This would be a risky operation with some unknowns (such as potential movements), adding difficulty to the construction and about four years to the construction duration. In addition, Concept T-5 would temporarily disrupt 15 major road crossings, listed below, as well as one railroad crossing.

- Martin Luther King, Jr. East (formerly known as East Castle Street)
- New York, Susquehanna and Western Railway Crossing
- Burt Street
- East Taylor Street
- Jackson Street
- Monroe Street
- East Adams Street
- Harrison Street
- East Genesee Street
- East Fayette Street
- East Washington Street
- East Water Street
- Erie Boulevard
- James Street
- East Willow Street
- North Salina Street

- **Concept T-6** is not feasible due to cost. Since the construction of Concept T-6 would be largely implemented underground, using a tunnel boring machine and sequential excavation method, it was determined to be feasible based on constructability. However,
  Concept T-6's estimated cost is \$2.6 billion, which includes construction direct costs, contingency and escalation. As stated above, a construction cost of over \$2.35 billion is unfeasible.

- **Concept T-7** is not feasible due to cost. Since the construction of Concept T-7 would be largely implemented underground, using a tunnel boring machine, it was determined to be feasible based on constructability. However, Concept T-7's estimated cost is \$2.5 billion, which includes construction direct costs, contingency, and escalation. As stated above, a construction cost of over \$2.35 billion is unfeasible.

In conclusion, Concepts T-5, T-6 and T-7, described within this report, are not considered feasible based on cost.

7.0 References

Andrews, Charles B. and Guy Swenson, "Onondaga Lake Feasibility Study Appendix D: Part A, Groundwater Flow to Onondaga Lake," Report prepared for Honeywell, November 2004.

CUGIR, Cornell University Geospatial Information Repository, "Digital Elevation Models (DEM) – New York State, Syracuse West 7.5-minute Quad," 10 meter raster, p29elu.dem.gz, http://cugir.mannlib.cornell.edu/bucketinfo.jsp?id=2262, Website accessed July 7, 2015.

CUGIR, Cornell University Geospatial Information Repository, "Digital Elevation Models (DEM) – New York State, Syracuse East 7.5-minute Quad," 10 meter raster, p30elu.dem.gz, http://cugir.mannlib.cornell.edu/bucketinfo.jsp?id=2263, Website accessed July 7, 2015.

Doucette, George, Personal communication: email regarding instructions and contents for New York State Department of Transportation Region 3 ProjectWise files containing DOT boring data within the project area, March 8, 2016.

FHWA – Federal Highway Administration (2009). Technical Manual for Design and Construction of Road Tunnels – Civil Elements. Publication No. FHWA-NHI-09-010.

Hopkins, Thomas Cramer, "Geology of the Syracuse Quadrangle," New York State Museum, Museum Bulletin 171, July 15, 1914.

Kappel, William M., and Todd S. Miller, "Hydrogeology of the Valley-Fill Aquifer in the Onondaga Trough, Onondaga County, New York," United States Geological Survey, Scientific Investigations Report 2005-5007, February 2005.

Kappel, William, Personal communication: email and transmittal of Google Earth file entitled, "GWSI_Wells_OnondagaCounty_NY.kml" containing basic well log data, April 11, 2016.

Kivlehan, John, Personal communication: emails containing transmittals of various project boring log data and other soils information, City of Syracuse Engineering Department, May 4, 2016.

Massachusetts Highway Department (1996). Central Artery Tunnel Record Drawings.

New York State Department of Transportation (2016). Memorandum, I-690 Viaduct – Beech Street to Teall Avenue, Final Embankment Foundation Settlement Assessment.

New York State Department of Public Works, Division of Construction (1964). Record Plans, F.A. Project No.I-81.

New York State Museum, "Bedrock Geology Shape Files, Finger Lakes Bedrock Sheet," 1:250,000, http://www.nysm.nysed.gov/research-collections/geology/gis, Website accessed May 3, 2016.

New York State Department of Environmental Conservation, "New York State Stormwater Management Design Manual," Prepared by: Center for Watershed Protection, August 2010.

NYS Orthos Online, "2012 6-inch Resolution 4-Band Orthoimagery Central Zone," http://www.orthos.dhses.ny.gov/, Website accessed February 27, 2016.

Onondaga County Website (http://www.ongov.net)

Parsons (2015). I-81 Viaduct Project Scoping Report dated April 2015. Submitted to U.S. Department of Transportation and New York State Department of Transportation.

Phillips, Margaret, Personal communication: email and transmittal of USGS well lithographic information, February 29, 2016.

Rickard, Lawrence V., and Donald W. Fisher, "Geologic Map of New York, Finger Lakes Sheet," New York State Museum and Science Service, Map and Chart Series Number 15, 1970.

Robison, Mary, PE, Personal communication: email transmittal of boring log data, City of Syracuse, City Engineer, May 4, 2016.

Suryadevara, Janaki, Personal communication: meeting and transmittal of various project data documenting boring log data and water quality data, Onondaga County, Department of Water Environment Protection, April 14, 2016.

USGS, National Water Information System: Mapper, Groundwater Sites, http://maps.waterdata.usgs.gov/mapper/, Website accessed February 28, 2016.

USGS, "Salt Production in Syracuse, New York ("The Salt City") and the Hydrogeology of the Onondaga Creek Valley," United States Geological Survey, Fact Sheet FS 139-00, November 2000.

Westcott, Douglas J, Personal communication: emails transmitting reports and drawings of boring logs for various buildings constructed by Syracuse University, April 14, 2016.

Winkley, Stephen J., "The Hydrogeology of Onondaga County, New York," Thesis, Syracuse University, Syracuse, New York, 1989.

Yager, Richard M., William M. Kappel, and L. Niel Plummer, "Halite Brine in the Onondaga Trough near Syracuse, New York: Characterization and Simulation of Variable-Density Flow," United States Geological Survey, Scientific Investigations Report 2007–5058, Reston, Virginia, 2007.

Yager, Richard M., Personal communication: email and transmittal to Timothy Ruga of bedrock digital elevation model and Modflow/SEAWAT model, July 30, 2015.

ATTACHMENT A

I-81 Viaduct Project - Bored Tunnel (T-5)
PROJECT SUMMARY BY COMPONENTS

WBS	Component	T-5 Tunnel Section	T-5 I-690 from McBride to Lodi	1 I-481/I-81 Southern Interchange	2 I-481/I-81 Northern Interchange	3 Misc. Improvements to I-481	4 Crouse Irving Interchange	5 Martin Luther King(MLK) Interchange	6 Former I-81 Northern Segment (Butternut To Hiawatha)	7 West Street Interchange	8 I-81 Viaduct & Almond Street	9 Main Interchange Area	10 I-690 Interconnect Ramps	Total
3.1	Enabling Projects	$ -	$ 2,000,000					$ 100,000	$ 10,000,000	$ 8,500,000	$ 10,000,000	$ 15,000,000	$ -	$ 45,600,000
3.2	Construction													
3.2.1	Maintenance of Traffic (MOT)	$ -	$ 2,280,000					$ 61,000	$ 6,768,000	$ 6,622,000	$ 8,941,000	$ 19,034,000	$ 1,500,000	$ 45,206,000
3.2.2	Demolition	$ -	$ 1,238,000					$ 65,000	$ 6,443,400	$ 3,408,000	$ 20,661,900	$ 18,568,633	$ -	$ 50,384,933
3.2.3	Embankment	$ -	$ 1,374,000					$ 75,000	$ 9,600,000	$ 5,500,000	$ 572,825	$ 7,832,500	$ -	$ 24,954,325
3.2.4	Elevated Structures	$ -	$ 11,671,000					$ -	$ 14,179,309	$ 19,440,279	$ 22,468,576	$ 104,924,597	$ 28,221,056	$ 200,904,817
3.2.5	Retaining Walls	$ -	$ 6,955,000					$ 75,000	$ 1,050,000	$ 2,375,000	$ 600,000	$ 6,180,000	$ -	$ 17,235,000
3.2.6	On Grade Highways	$ -	$ 7,764,000					$ 536,600	$ 16,708,213	$ 4,282,416	$ 4,194,530	$ 8,147,376	$ -	$ 41,633,135
3.2.7	Local Streets	$ -	$ -					$ 220,800	$ 8,300,994	$ 3,208,826	$ 6,224,034	$ 1,367,677	$ -	$ 19,322,331
3.2.8	Lighting, Signage, ITS, Signals	$ -	$ 4,065,000					$ 250,000	$ 12,400,000	$ 9,500,000	$ 4,070,000	$ 4,310,000	$ 1,600,000	$ 36,195,000
3.2.9	Landscaping/Streetscaping	$ -	$ 5,000,000					$ 100,000	$ 3,000,000	$ 4,000,000	$ 15,000,000	$ 4,000,000	$ -	$ 31,100,000
3.2.10	Storm Drains	$ -	$ -					$ 100,000	$ 15,000,000	$ 6,000,000	$ 5,405,709	$ 20,000,000	$ -	$ 46,505,709
3.2.11	Pedestrian Passage	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 202,878	$ -	$ -	$ 202,878
	Tunnel	$ 1,154,640,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,154,640,000
	Subtotal	$ 1,154,640,000	$ 42,347,000	$ -	$ -	$ -	$ -	$ 1,583,400	$ 103,449,916	$ 72,836,521	$ 98,341,452	$ 209,364,783	$ 31,321,056	$ 1,713,884,128
3.4	Evolution Allowance (Contingencies)	$ 461,856,000	$ 12,705,000	$ -	$ -	$ -	$ -	$ 476,000	$ 31,035,000	$ 21,851,000	$ 29,503,000	$ 62,810,000	$ 9,397,000	$ 629,633,000
	Subtotal	$ 1,616,496,000	$ 55,052,000	$ -	$ -	$ -	$ -	$ 2,059,400	$ 134,484,916	$ 94,687,521	$ 127,844,452	$ 272,174,783	$ 40,718,056	$ 2,343,517,128
3.5	Escalation	$ 510,703,000	$ 11,200,000	$ -	$ -	$ -	$ -	$ 220,000	$ 59,493,000	$ 36,618,000	$ 42,622,000	$ 105,255,000	$ 18,013,000	$ 784,124,000
	Project Total	**$ 2,127,199,000**	**$ 66,252,000**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 2,279,400**	**$ 193,977,916**	**$ 131,305,521**	**$ 170,466,452**	**$ 377,429,783**	**$ 58,731,056**	**$ 3,127,641,128**

I-81 Viaduct Project - Bored Tunnel (T-6)
PROJECT SUMMARY BY COMPONENTS

WBS	Component	T-6 Tunnel Section	T-6 I-690 from McBride to Lodi	1 I-481/I-81 Southern Interchange	2 I-481/I-81 Northern Interchange	3 Misc. Improvements to I-481	4 Crouse Irving Interchange	5 Martin Luther King(MLK) Interchange	6 Former I-81 Northern Segment (Butternut To Hiawatha)	7 West Street Interchange	8 I-81 Viaduct & Almond Street	9 Main Interchange Area	10 I-690 Interconnect Ramps	Total
3.1	Enabling Projects	$ -	$ 2,000,000					$ 100,000	$ 10,000,000	$ 8,500,000	$ 10,000,000	$ 15,000,000	$ -	$ 45,600,000
3.2	Construction													
3.2.1	Maintenance of Traffic (MOT)	$ -	$ 2,280,000					$ 61,000	$ 6,768,000	$ 6,622,000	$ 8,941,000	$ 19,034,000	$ 1,500,000	$ 45,206,000
3.2.2	Demolition	$ -	$ 1,238,000					$ 65,000	$ 6,443,400	$ 3,408,000	$ 20,661,900	$ 18,568,633	$ -	$ 50,384,933
3.2.3	Embankment	$ -	$ 1,374,000					$ 75,000	$ 9,600,000	$ 5,500,000	$ 572,825	$ 7,832,500	$ -	$ 24,954,325
3.2.4	Elevated Structures	$ -	$ 11,671,000					$ -	$ 14,179,309	$ 19,440,279	$ 22,468,576	$ 104,924,597	$ 28,221,056	$ 200,904,817
3.2.5	Retaining Walls	$ -	$ 6,955,000					$ 75,000	$ 1,050,000	$ 2,375,000	$ 600,000	$ 6,180,000	$ -	$ 17,235,000
3.2.6	On Grade Highways	$ -	$ 7,764,000					$ 536,600	$ 16,708,213	$ 4,282,416	$ 4,194,530	$ 8,147,376	$ -	$ 41,633,135
3.2.7	Local Streets	$ -	$ -					$ 220,800	$ 8,300,994	$ 3,208,826	$ 6,224,034	$ 1,367,677	$ -	$ 19,322,331
3.2.8	Lighting, Signage, ITS, Signals	$ -	$ 4,065,000					$ 250,000	$ 12,400,000	$ 9,500,000	$ 4,070,000	$ 4,310,000	$ 1,600,000	$ 36,195,000
3.2.9	Landscaping/Streetscaping	$ -	$ 5,000,000					$ 100,000	$ 3,000,000	$ 4,000,000	$ 15,000,000	$ 4,000,000	$ -	$ 31,100,000
3.2.10	Storm Drains	$ -	$ -					$ 100,000	$ 15,000,000	$ 6,000,000	$ 5,405,709	$ 20,000,000	$ -	$ 46,505,709
3.2.11	Pedestrian Passage	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 202,878	$ -	$ -	$ 202,878
	Tunnel	$ 872,440,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 872,440,000
	Subtotal	$ 872,440,000	$ 42,347,000	$ -	$ -	$ -	$ -	$ 1,583,400	$ 103,449,916	$ 72,836,521	$ 98,341,452	$ 209,364,783	$ 31,321,056	$ 1,431,684,128
3.4	Evolution Allowance (Contingencies)	$ 348,976,000	$ 12,705,000	$ -	$ -	$ -	$ -	$ 476,000	$ 31,035,000	$ 21,851,000	$ 29,503,000	$ 62,810,000	$ 9,397,000	$ 516,753,000
	Subtotal	$ 1,221,416,000	$ 55,052,000	$ -	$ -	$ -	$ -	$ 2,059,400	$ 134,484,916	$ 94,687,521	$ 127,844,452	$ 272,174,783	$ 40,718,056	$ 1,948,437,128
3.5	Escalation	$ 385,885,000	$ 11,200,000	$ -	$ -	$ -	$ -	$ 220,000	$ 59,493,000	$ 36,618,000	$ 42,622,000	$ 105,255,000	$ 18,013,000	$ 659,306,000
	Project Total	**$ 1,607,301,000**	**$ 66,252,000**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 2,279,400**	**$ 193,977,916**	**$ 131,305,521**	**$ 170,466,452**	**$ 377,429,783**	**$ 58,731,056**	**$ 2,607,743,128**

I-81 Viaduct Project - Bored Tunnel (T-7)
PROJECT SUMMARY BY COMPONENTS

WBS	Component	T-7 Tunnel Section	1 I-481/I-81 Southern Interchange	2 I-481/I-81 Northern Interchange	3 Misc. Improvements to I-481	4 Crouse Irving Interchange	5 Martin Luther King(MLK) Interchange	6 Former I-81 Northern Segment (Butternut To Hiawatha)	7 West Street Interchange	8 I-81 Viaduct & Almond Street	9 Main Interchange Area	10 I-690 Interconnect Ramps	Total
3.1	Enabling Projects	$ -	$ 750,000	$ 1,500,000	$ 50,000	$ 1,000,000	$ 100,000	$ 10,000,000	$ 8,500,000	$ 10,000,000	$ 15,000,000	$ -	$ 46,900,000
3.2	Construction												
3.2.1	Maintenance of Traffic (MOT)	$ -	$ 3,412,000	$ 3,947,000	$ 1,673,000	$ 7,993,000	$ 61,000	$ 6,768,000	$ 6,622,000	$ 8,941,000	$ 19,034,000	$ 1,500,000	$ 59,951,000
3.2.2	Demolition	$ -	$ 2,503,600	$ 960,500	$ 157,000	$ 6,503,775	$ 65,000	$ 6,443,400	$ 3,408,000	$ 20,661,900	$ 18,568,633	$ -	$ 59,271,808
3.2.3	Embankment	$ -	$ 7,200,000	$ 6,180,000	$ 600,000	$ 3,656,175	$ 75,000	$ 9,600,000	$ 5,500,000	$ 572,825	$ 7,832,500	$ -	$ 41,216,500
3.2.4	Elevated Structures	$ -	$ 21,928,932	$ 21,615,053	$ 29,950,011	$ 30,107,423	$ -	$ 14,179,309	$ 19,440,279	$ 22,468,576	$ 104,924,597	$ 28,221,056	$ 292,835,236
3.2.5	Retaining Walls	$ -	$ 100,000	$ 5,940,000	$ -	$ 7,810,000	$ 75,000	$ 1,050,000	$ 2,375,000	$ 600,000	$ 6,180,000	$ -	$ 24,130,000
3.2.6	On Grade Highways	$ -	$ 9,296,299	$ 10,567,061	$ 1,663,936	$ 11,325,232	$ 536,600	$ 16,708,213	$ 4,282,416	$ 4,194,530	$ 8,147,376	$ -	$ 66,721,663
3.2.7	Local Streets	$ -	$ -	$ -	$ -	$ 3,812,168	$ 220,800	$ 8,300,994	$ 3,208,826	$ 6,224,034	$ 1,367,677	$ -	$ 23,134,499
3.2.8	Lighting, Signage, ITS, Signals	$ -	$ 6,450,000	$ 9,110,000	$ 8,900,000	$ 11,100,000	$ 250,000	$ 12,400,000	$ 9,500,000	$ 4,070,000	$ 4,310,000	$ 1,600,000	$ 67,690,000
3.2.9	Landscaping/Streetscaping	$ -	$ -	$ -	$ -	$ 4,048,500	$ 100,000	$ 3,000,000	$ 4,000,000	$ 15,000,000	$ 4,000,000	$ -	$ 30,148,500
3.2.10	Storm Drains	$ -	$ 500,000	$ 500,000	$ 500,000	$ 562,500	$ 100,000	$ 15,000,000	$ 6,000,000	$ 5,405,709	$ 20,000,000	$ -	$ 48,568,209
3.2.11	Pedestrian Passage	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 202,878	$ -	$ -	$ 202,878
	Tunnel	$ 638,491,250	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 638,491,250
	Subtotal	$ 638,491,250	$ 52,140,831	$ 60,319,614	$ 43,493,947	$ 87,918,773	$ 1,583,400	$ 103,449,916	$ 72,836,521	$ 98,341,452	$ 209,364,783	$ 31,321,056	$ 1,399,261,543
3.4	Evolution Allowance (Contingencies)	$ 255,397,000	$ 15,643,000	$ 18,096,000	$ 13,049,000	$ 26,376,000	$ 476,000	$ 31,035,000	$ 21,851,000	$ 29,503,000	$ 62,810,000	$ 9,397,000	$ 483,633,000
	Subtotal	$ 893,888,250	$ 67,783,831	$ 78,415,614	$ 56,542,947	$ 114,294,773	$ 2,059,400	$ 134,484,916	$ 94,687,521	$ 127,844,452	$ 272,174,783	$ 40,718,056	$ 1,882,894,543
3.5	Escalation	$ 329,460,000	$ 12,559,000	$ 14,529,000	$ 9,174,000	$ 22,510,000	$ 220,000	$ 59,493,000	$ 36,618,000	$ 42,622,000	$ 105,255,000	$ 18,013,000	$ 650,453,000
	Project Total	**$ 1,223,348,250**	**$ 80,342,831**	**$ 92,944,614**	**$ 65,716,947**	**$ 136,804,773**	**$ 2,279,400**	**$ 193,977,916**	**$ 131,305,521**	**$ 170,466,452**	**$ 377,429,783**	**$ 58,731,056**	**$ 2,533,347,543**

T-5 Alternative Cost Summary

Description	Quantity	Unit	Rate	Total
Projectwide Items				
Geotechnical Instrumentation	1	LS	$20,000,000	$20,000,000
Utillity Re-locations	1	LS	$20,000,000	$20,000,000
Building Protection/Underpinning	1	LS	$30,000,000	$30,000,000
Maintenance of Traffic	1	LS	$15,000,000	$15,000,000
I-81 Viaduct Protection	1	LS	$50,000,000	$50,000,000
			SubTotal	**$135,000,000**
Cut and Cover Tunnel Structure and Approaches				
Install SOE Walls	300,000	CY	$1,000	$300,000,000
Excavate Soil	2,000,000	CY	$50	$100,000,000
Excavate Rock	95,000	CY	$500	$47,500,000
Haul Excavation	2,100,000	CY	$40	$84,000,000
Place Concrete for Structures	400,000	CY	$750	$300,000,000
Place Imported Backfill above Tunnel	500,000	CY	$75	$37,500,000
Construct Roadways, Guard Rail, Walkways, Ducts etc	11,000	LF	$1,000	$11,000,000
Interior Finishes - Wall Tiles etc	11,000	LF	$1,000	$11,000,000
Ground Improvement	5,000	CY	$1,200	$6,000,000
Install and Operate Dewatering System	1	LS	$15,000,000	$15,000,000
			SubTotal	**$912,000,000**
Ventilation Buildings				
South ventilation building	25,000	SF	$350	$8,750,000
North ventilation building	25,000	SF	$350	$8,750,000
			SubTotal	**$17,500,000**
Tunnel Systems				
Lighting	800,000	SF	$29	$23,000,000
Communication	800,000	SF	$6	$4,600,000
Intrusion Detection System	800,000	SF	$3	$2,300,000
SCADA System	800,000	SF	$8	$6,440,000
Drainage	800,000	LS	$8	$6,400,000
Inteligent Transportation Systems	1	LS	$3,000,000	$3,000,000
Fire Suppression System	800,000	SF	$23	$18,400,000
Tunnel Ventilation	1	LS	$25,000,000	$25,000,000
UPS Allowance	1	LS	$1,000,000	$1,000,000
			SubTotal	**$90,140,000**
			GRAND TOTAL	**$1,154,640,000**

T-6 Alternative Cost Summary

Description	Quantity	Unit	Rate	Total
Projectwide Items				
Geotechnical Instrumentation	1	LS	$11,000,000	$11,000,000
Utillity Re-locations	1	LS	$12,000,000	$12,000,000
Building Protection/Underpinning	1	LS	$9,000,000	$9,000,000
Maintenance of Traffic	1	LS	$5,000,000	$5,000,000
			SubTotal	**$37,000,000**
North and South Approaches				
South Approach				
Install SOE Walls	26,800	CY	$1,000	$26,800,000
Excavate Soil	474,000	CY	$50	$23,700,000
Excavate Rock	0	CY	$500	$0
Haul Excavation	474,000	CY	$40	$18,960,000
Place Reinforced Concrete	114,000	CY	$750	$85,500,000
Install and Operate Dewatering System	1	LS	$3,680,000	$3,680,000
North Approach				
Install SOE Walls	6,000	CY	$1,000	$6,000,000
Excavate Soil	63,600	CY	$50	$3,180,000
Excavate Rock	15,900	CY	$500	$7,950,000
Haul Excavation	79,500	CY	$40	$3,180,000
Place Reinforced Concrete	51,000	CY	$750	$38,250,000
Install and Operate Dewatering System	1	LS	$5,520,000	$5,520,000
			SubTotal	**$222,720,000**
Construct Twin Bored 38-Ft Diameter Tunnels				
Ground Improvement	40,000	CY	$1,200	$48,000,000
Excavation with TBM and Line 38-ft diameter tunne	17,320	LF	$10,000	$173,200,000
Muck handling and Disposal	890,000	BCY	$90	$80,100,000
Place Invert Concrete	8,660	LF	$750	$6,495,000
Roadway Finishes - Guard rail, Walkways, Tiles etc	800,000	SF	$20	$16,000,000
Mined Cross Passages	500	LF	$7,000	$3,500,000
			SubTotal	**$327,295,000**
Ramp Tunnel Construction by SEM				
Ramp 22x16 ft	12,000	LF	$14,000	$168,000,000
			SubTotal	**$168,000,000**
Ventilation Shafts				
South ventilation shaft	1	LS	$6,000,000	$6,000,000
North ventilation shaft	1	LS	$6,000,000	$6,000,000
			SubTotal	**$12,000,000**
Tunnel Finishes				
Lighting	1,000,000	SF	$29	$28,750,000
Communication	1,000,000	SF	$6	$5,750,000
Intrusion Detection System	1,000,000	SF	$3	$2,875,000
SCADA System	1,000,000	SF	$8	$8,050,000
Drainage	1,000,000	0	$8	$8,000,000
Inteligent Transportaion Systems	1	LS	$3,000,000	$3,000,000
Fire Suppression System	1,000,000	SF	$23	$23,000,000
Tunnel Ventilation	1	LS	$25,000,000	$25,000,000
UPS Allowance	1	LS	$1,000,000	$1,000,000
			SubTotal	**$105,425,000**
			GRAND TOTAL	**$872,440,000**

T-7 Alternative Cost Summary

Description	Quantity	Unit	Rate	Total
Projectwide Items				
Geotechnical Instrumentation	1	LS	$2,000,000	$2,000,000
Utillity Re-locations	1	LS	$2,000,000	$2,000,000
Building Protection/Underpinning	1	LS	$1,000,000	$1,000,000
Maintenance of Traffic	1	LS	$1,000,000	$1,000,000
			SubTotal	**$6,000,000**
North and South Approaches				
South Approach				
Install SOE Walls	26,800	CY	$1,000	$26,800,000
Excavate Soil	474,000	CY	$50	$23,700,000
Excavate Rock	0	CY	$500	$0
Haul Excavation	474,000	CY	$40	$18,960,000
Place Reinforced Concrete	114,000	CY	$750	$85,500,000
Install and Operate Dewatering System	1	LS	$500,000	$500,000
North Approach				
Install SOE Walls	6,000	CY	$1,000	$6,000,000
Excavate Soil	63,600	CY	$50	$3,180,000
Excavate Rock	15,900	CY	$500	$7,950,000
Haul Excavation	79,500	CY	$40	$3,180,000
Place Reinforced Concrete	51,000	CY	$750	$38,250,000
Install and Operate Dewatering System	1	LS	$500,000	$500,000
			SubTotal	**$214,520,000**
Construct Twin Bored 38-Ft Diameter Tunnels				
Ground Improvement	40,000	CY	$1,200	$48,000,000
Excavation with TBM and Line 38-ft diameter tunnel	17,320	LF	$10,000	$173,200,000
Muck handling and Disposal	890,000	BCY	$90	$80,100,000
Place Invert Concrete	8,660	LF	$750	$6,495,000
Roadway Finishes - Guard rail, Walkways, Tiles etc	800,000	SF	$20	$16,000,000
Mined Cross Passages	500	LF	$7,000	$3,500,000
			SubTotal	**$327,295,000**
Ventilation Shafts				
South ventilation shaft	1	LS	$6,000,000	$6,000,000
North ventilation shaft	1	LS	$6,000,000	$6,000,000
			SubTotal	**$12,000,000**
Tunnel Finishes				
Lighting	650,000	SF	$29	$18,687,500
Communication	650,000	SF	$6	$3,737,500
Intrusion Detection System	650,000	SF	$3	$1,868,750
SCADA System	650,000	SF	$8	$5,232,500
Drainage	650,000	SF	$8	$5,200,000
Inteligent Transportaion Systems	1	LS	$3,000,000	$3,000,000
Fire Suppression System	650,000	SF	$23	$14,950,000
Tunnel Ventilation	1	LS	$25,000,000	$25,000,000
UPS Allowance	1	LS	$1,000,000	$1,000,000
			SubTotal	**$78,676,250**
			GRAND TOTAL	**$638,491,250**