SECTION III

APPENDIX E

CUSTIS TRAIL TUNNEL STRUCTURAL ANALYSIS

LYNN STREET ESPLANADE PROJECT

FEASIBILITY STUDY:
CUSTIS PEDESTRIAN TRAIL TUNNEL
UNDER NORTH LYNN STREET

Prepared for the

Arlington County Department of Transportation
Mr. Tom Hutchings

Submitted by

ENGINEERS
PLANNERS
ECONOMISTS
Wilbur Smith Associates

(WSA)
June 27, 2006

Draft

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1.0 PROJECT DESCRIPTION

Wilbur Smith Associates (WSA) is involved on the North Lynn Street Esplanade project as a subconsultant to Toole Design Group and is responsible for evaluation of structural alternatives and preparation of conceptual structural designs during the NEPA process. This study report covers Task Item 2B, Custis Pedestrian Trail Tunnel under Lynn Street, as presented in the Task Order Proposal dated October 28, 2005. Under this proposal, feasible retaining wall and tunnel sections are to be identified and developed to a level sufficient to assess feasibility and rough construction costs. These alternatives are to be further evaluated based on constructability, maintainability and aesthetics.

Toole Design Group prepared a preliminary Trail Tunnel Plan and Tunnel Profile in April 2006 (see Attachment Nos. 1 & 2). The tunnel is located approximately 45 feet south of the existing at-grade trail crossing of Lynn Street and is 95 feet in length measured portal to portal. The tunnel trail surface is located approximately 18 feet beneath the existing pavement on Lynn Street. Open "tub" sections lead down to the portal entrances on both sides. These "tub" sections are between 80 and 100 feet in length and feature side walls up to 20 feet in height. According to information received from Toole Design Group, the proposed tunnel section is to be a minimum of 16'-0" wide by 12'-6" feet high. The Attachment No. 2 Tunnel profile allows for approximately 5 feet of fill above the tunnel roof to accommodate utilities and the Lynn Street pavement section.

Three tunnel alternatives are identified in this report. The first and most conventional alternative uses open excavation methods and is referred to as the Cut and Cover Tunnel Alternative. Due to the short length of tunnel, open excavation methods will likely provide the most cost effective solution if construction costs alone are considered. The alternative will be disruptive to traffic, utilities and other local services, however, and as such user costs could potentially be very large. There are multiple subsurface utilities in the existing North Lynn Street corridor. Under the Cut and Cover Alternative, existing utilities would have to be carefully supported and maintained or relocated for the duration of the construction.

Due to the potential for high user costs for the open excavation alternative, it was decided to consider and evaluate "trenchless" tunneling alternatives. These alternatives would allow construction to proceed beneath Lynn Street without disrupting traffic operations and possibly without disrupting existing utilities. Two trenchless tunneling methods were selected for further consideration; the Tunnel Jacking Alternative, and the Steel Tunnel Liner Alternative. The three alternatives described above are further described in Sections 6.0, 7.0 and 8.0 of this Report. A Conceptual drawing of the Cut and Cover Tunnel Alternative can be found on Attachment No. 3.

2.0 DATA SOURCES

Data sources for the project include the following:

- Lynn Street Esplanade Project: Survey, Conceptual Design & Related NEPA Tasks Scope of Work: October 28, 2005
- January 20 Project Meeting: Toole Design Group & Wilbur Smith Associates
- Directional Memorandum from Toole Design Group, Concept Design Structural Analysis, April 27, 2006
- Preliminary Trail Tunnel Plan and Tunnel Profile, Prepared by Toole Design Group, April 27, 2006
- Meeting with Northern Virginia Structure & Bridge Division and Wilbur Smith Associates, June 14, 2006
- Site Visit, Wilbur Smith Associates, October 2005 and June 2006
- Existing Lynn Street Bridge and Pedestrian Park Bridge As-Built Drawings (used for evaluation of utility locations and subsurface conditions)

3.0 DESIGN CRITERIA

For evaluation of alternatives, applicable design criteria for the design of structural components include the following:

- AASHTO Standard Specifications for Highway Bridges, 2002
- AASHTO Interim Specifications 2004, 2005
- AASHTO Design Specifications for Tunnel Liner Plates
- VDOT Modifications to AASHTO
- VDOT Road and Bridge Standards 2001
- VDOT Road and Bridge Specifications 2002
- VDOT Manual of the Structure and Bridge Division, Volume V, Part 2, Design Aids
- FHWA Road Tunnel Design Guidelines

4.0 SITE CONDITIONS

To assess site conditions, WSA acquired copies of the existing Lynn Street Bridge and Pedestrian Park Bridge plans including site borings and utility drawings and made two field visits to the site. WSA also studied new survey data prepared for Toole Design Group. It should be noted that there were no borings taken for this study. At this phase in the project, it was also was not possible to comprehensively identify all utilities, utility locations or other subsurface obstructions in the Custis Pedestrian Trail Tunnel corridor. As will be discussed throughout this report, it is recommended that a comprehensive geotechnical report be prepared should the Custis Pedestrian Trail Tunnel progress into further stages of conceptual design. For any further studies, it is also recommended that existing utilities and other obstructions in the corridor be fully identified both horizontally and vertically.

The existing Lynn Street Bridge and Pedestrian Park Bridge plans showed boring locations along the north abutment line some 100 feet to the south of the Tunnel corridor. These borings showed a layer of mixed fill materials consisting of sand, gravel, bricks and asphalt underlaid by Decomposed Granite Gneiss and Granite Gneiss. The Gneiss materials showed blow counts in the 20 to 50 range. Borings were terminated at a rock elevation consistent with the bottom of tunnel elevation. The boring data also indicated ground water elevations that would fall above mid-height of the tunnel per the Toole Design Group layout. While it is possible that these same subsurface conditions exist at the tunnel corridor location, site conditions could also vary dramatically even within the short distance noted. Again, a full geotechnical evaluation is needed based on at-site borings and materials evaluation.

The utilities in the Lynn Street Corridor were roughly identified based on the existing Lynn Street Bridge and Pedestrian Park Bridge plans. The Lynn Street Bridge as-built plans indicate that the bridge carries a 16” Gas Main, a 12” Water Main, two duct banks with electrical conduit (12 ducts and 5 ducts) and a 6” Sanitary Sewer Force Main. Survey files prepared prior to the Lynn Street Bridge construction indicate a slightly different series of utilities in the Lynn Street corridor and do not to indicate any utilities in the east/west tunnel corridor. The current survey files indicate that the proposed tunnel corridor directly conflicts with a Catch Basin and 6” Storm Drain along the west curbline of Lynn Street. It is anticipated that additional subsurface utilities and/or other obstructions do exist in the proposed tunnel corridor beyond those described above.

5.0 FEASIBLE DESIGN SOLUTIONS

A template of feasible tunnel options was identified based on the proposed tunnel geometry and the assumed subsurface profile and utility network. Cut and cover methods offer the most conventional approach to the tunnel construction. These methods are complicated, however, by complex maintenance of existing utilities in the corridor and maintenance of traffic on Lynn Street. Using open excavation methods, it will be necessary to expose all utilities and either support/maintain or relocate these during the tunnel construction. Assuming full vehicular traffic flow must be maintained during peak traffic periods, at-grade construction operations will have to take place at night. It will also be necessary to bridge over any open excavation to accommodate traffic.

Due to the complications described above, “trenchless” tunneling alternatives were identified that potentially could alleviate the maintenance of utility and traffic constraints listed above and speed construction. Options considered included Steel Tunnel Liner Plates, Pipe Jacking, Tunnel Jacking, Steel Ribs with Lagging and Hand Mining amongst others. More sophisticated tunneling methods using tunnel boring machines, and other mechanical boring methods were ruled out due to the small size of the project and high construction costs. For the purposes of this report, two feasible “trenchless” tunneling methods have been identified for further evaluation; Tunnel Jacking using a Concrete Box Section and Steel Tunnel Liner Plates. These methods were selected based on the size and scope of the project and their successful use on similar projects across the country.

To properly evaluate the feasibility and cost effectiveness of "trenchless" alternatives, a thorough design program needs to be followed. This program would begin with a geotechnical investigation that would include exploratory borings, test pits, in situ testing and laboratory studies. With "trenchless" tunneling methods, it is also important to establish a settlement monitoring program to assess impacts on adjacent road structures, buildings and other services during the construction. Discussions in this report should be considered as conceptual with the understanding that a thorough geotechnical program is required to verify the feasibility of the proposed alternative and allow for realistic identification of construction costs.

6.0 CUT AND COVER TUNNEL ALTERNATIVE

a. Description of Alternative

The Cut and Cover Tunnel Alternative consists of excavating an open trench for the tunnel construction. The trench would likely be excavated using driven soldier piles and timber lagging and would be approximately 24 feet in width. For this report, it is assumed that five lanes of traffic must be maintained on Lynn Street during peak traffic hours. As such, it is further assumed that work requiring lane closures will be done during nighttime hours and the open trench will need to be temporarily bridged to accommodate traffic during peak hours.

The open trench could either be staged in segments or span the full length of the tunnel. In either case, it will be necessary to bridge over at least portions of the trench during peak traffic hours to maintain traffic flow. Due to the length of span that needs to be accommodated, a temporary bearing seat will likely have to be constructed further complicating the soldier pile and lagging details. A schematic detail of the tunnel section during construction is presented in Attachment No. 3.

For maintenance of utilities, it will be necessary to first carefully trench out each utility line and establish a temporary support system that will be in place until the tunnel construction is completed and backfilled. In lieu of supporting the utilities in place, the utilities could be temporarily relocated and new lines established during backfilling operations.

The tunnel section itself could be constructed using either cast-in-place methods (using formwork set in place in the trench) or precast methods (where the box section would be fabricated offsite and dropped in place in segments). These segments would be sealed and waterproofed prior to backfilling. The retaining wall units or tub sections leading up to the tunnel portals could be similarly constructed using either cast-in-place or precast methods. The Toole Design Group Concept shows vertical retaining walls leading up to the tunnel portals. These walls reach 20 feet in height. A number of options exist to help "open" up these retaining walls to enhance sight distance and promote safety. The walls could be terraced or sloped to allow for additional openness.

The inner tunnel section or lining could be left as exposed concrete or could be painted or tiled to help lighten the interior of the tunnel. Tunnel lighting will also be required. Depending on the method of construction, it may also be possible to “vault” the ceiling to enhance the feeling of openness and promote better site distance. This vaulting is common with proprietary precast tunnel fabricators.

b. Constructability/Maintenance of Traffic & Utilities

The open trench used with this alternative allows for facilitated removal of materials when compared with the “trenchless” alternatives described below, particularly if the in-place material varies in consistency, contains highly irregular features, large boulders or rock outcroppings. These irregular features and rock could complicate or even rule out the “trenchless” methods. To identify the characteristics of the soil in the tunnel corridor and assess the feasibility of all discussed alternatives, a detailed geotechnical study is required. For the purposes of this report and for cost estimating, it will be assumed that subsurface material is similar in nature to that shown in the Lynn Street boring logs.

The open trench also allows for very controlled conditions facilitating the tunnel alignment, concrete placement, and waterproofing. Use of precast materials would even further enhance the quality of the sections being used. Depending on the elevation of groundwater, the construction of a subsurface drainage system would also be facilitated using open cut methods.

The biggest drawback to placement of the culvert by open trench methods is the inconvenience caused to traffic, utilities and other services. When comparing alternatives, the user cost and inconvenience associated with this alternative may not be defensible if other feasible alternatives can be identified.

c. Tunnel Maintenance

The open trench method of construction will allow for the greatest quality control in terms of placing and waterproofing the tunnel and retaining wall sections. As such, if properly designed, this method should result in the best overall service performance of all the alternatives presented.

A potential disadvantage of this alternative is the possibility of damage to the pavement and utilities due to improper backfilling, compaction and patching. As the pavement settles and cracks develop, water can get into the base, causing the pavement to deteriorate further. As such, extreme care should be taken for all backfilling operations.

d. Estimated Construction Costs

Pay items were identified for Cut and Cover Alternative based on the description given above. It is assumed that subsurface conditions will be similar to that shown on the Lynn Street Bridge borings. Rough quantity take-offs were developed and unit costs assigned based on historical cost data from VDOT and other sources. Unit costs were escalated based on the level of complexity and size of the project. Costs are based on 2006 dollars and no contingency is assigned in this report. It is our understanding that a contingency will be added by Toole Design Group in an overall construction cost summary.

The estimated construction cost for the Cut and Cover Alternative is $1.39M. A detailed breakdown of quantities and assumed unit costs is included with Attachment No. 4.

7.0 TUNNEL JACKING ALTERNATIVE (CONCRETE BOX SECTION)

a. Description of Alternative

The Tunnel Jacking installation, in simple terms, consists of constructing a concrete box tunnel structure adjacent to the facility at the desired depth and then “jacking” or horizontally pushing the preconstructed tunnel under the facility while simultaneously excavating the soil as the tunnel advances. This method allows construction to proceed without disrupting the traffic operations on Lynn Street and possibly without disrupting the existing utilities in the tunnel corridor.

The construction would begin with the excavation of a pit on either side of Lynn Street. A hydraulic jack device would be lowered into the pit which would bear on the back of the pit (which must be properly reinforced). A simple track is added to guide the concrete box into place. A box segment from 8 to 12 feet in length would then be lowered into the pit and the jacks operated to move the section forward. The jack rams are then retracted and a second box section is added. The process repeats until the entire operation is complete. The excavation and spoil removal process involved with this installation would require workers to be inside the box section during the jacking operations. The soil would be removed either mechanically or manually from the leading end of the box section.

Large diameter steel pipe sections may be used in lieu of the concrete box section noted above. These steel sections may be driven as casings or liners and may need to be further reinforced or strengthened after installation. It also may be possible to substitute a steam-powered hammer (similar to a pile driver) instead of a hydraulic jack. Similar to the jacking process, the hammering process would require the removal of displaced soil as the pipe or box moves into the embankment.

As stated above, the feasibility of this construction method must be established through a detailed geotechnical study which would include exploratory soil borings and other information related to the composition of the soil likely to be encountered. The jacking operations require that the soil be relatively uniform in composition and free from large boulders or rock outcroppings. The cover over the tunnel is another issue that will need to be addressed in detail, particularly due to the presence of existing utilities.

b. Constructability/Maintenance of Traffic & Utilities

The key advantage in constructability for this alternate is the minimization of disruption to utilities and vehicular traffic on Lynn Street. If user costs are considered, and further geotechnical studies show the jacking method to be feasible, the Tunnel Jacking Alternative could become cost competitive with the more conventional open trench methods.

Using jacking methods, the box sections are susceptible to damage if variations in pressure at the leading edge of the section are encountered. Obstructions or irregularities in the soil may also result in misalignment and voids. Groundwater in the bearing strata may also present difficulties, as saturated soil may flow into the pipe. This can lead to reduced soil densities above and around the pipe and result in settlements at grade.

c. Tunnel Maintenance

If soil can be adequately stabilized and groundwater controlled, the likelihood of street settlement above the tunnel can be reduced for this alternative versus open trench alternatives. Maintenance costs for Lynn Street pavement repairs should be minimal.

The jacking operations involved with this method are more likely to lead to damage and misalignment of the box section. As such, this alternative may require more concrete repair and general maintenance operations over time.

d. Estimated Construction Costs

Without a detailed geotechnical report and recommendations, it is difficult to assess the feasibility of the Tunnel Jacking Alternative and even more difficult to assess construction costs. The soil properties must be fully analyzed to assess if the limited amount of fill above the tunnel section is adequate and if the overall soil mass can be stabilized during jacking operations without problems with settlement. Soil stabilization techniques are available (soil grouting, ground freezing, soil nailing) but may be cost prohibitive.

Because of all of these unknowns, a cost estimate at this stage of design may be misleading and as such will not be included with this report. As stated earlier, straight construction costs will likely be higher for this alternative than for the Cut and Cover Alternative. If user costs are considered, however, it may be possible for the “trenchless” alternatives to be competitive.

8.0 STEEL TUNNEL LINER PLATE ALTERNATIVE

a. Description of Alternative

Steel liner plates are made up of small corrugated sections of steel plate that are bolted together to form a shell. The shell is installed to support the soil exposed by tunneling operations and is typically circular or elliptical in shape. Excavation methods are identical to those described for the Tunnel Jacking Alternative above. The difference between the two alternatives is that the steel liner plates are placed progressively as excavation advances versus being pushed ahead by jacking operations. Liner plates may act as a temporary liner or may serve alone as the permanent or primary liner. The corrugated section could be shotcreted or gunnited to give the lining the appearance of precast concrete.

The outside shape of the liner plate should fit closely to the excavated opening. If too much soil is removed, the annular space between the plates and soil should be backfilled promptly or temporary supports should be used and the space should be grouted.

Similar to the Tunnel Jacking alternative described above, the feasibility of this construction method must be established through a detailed geotechnical study. If it is found that soils are unstable or if soil will not remain in place long enough to excavate for the liner plate, the soil can be controlled by mechanical stabilization methods or other methods as described above (soil grouting, ground freezing, and soil nailing). Recent advances in soil stabilizing techniques have made the use of Tunnel Liner Plates more viable in recent years.

b. Constructability/Maintenance of Traffic & Utilities

The Tunnel Liner alternative features the same key constructability advantages as listed above for the Tunnel Jacking Alternative. The alternate potentially eliminates interference with traffic as well as inconvenience to and disruption to businesses, industry and utilities. Other advantages of the Tunnel Liner Alternative include less excavation, less backfilling and no need for expensive pavement repairs.

Problems associated with the Tunnel Lining alternative include deflection and deformation of the shell due to over-excavation of the bore and either a delay in backfilling or inadequate backfilling. The steel tunnel linings are also subject to abrasion damage and corrosion. With the open excavation procedures, care must be taken to prevent soil slough or rock falls prior to backfilling. The nature of the steel shell construction also leaves it more prone to problems associated with groundwater control and leakage.

c. Tunnel Maintenance

Similar to the Jacking Alternative above, the costs associated with future maintenance of Lynn Street due to settlement damage is reduced for this alternative. This requires effective stabilization of the soil during construction operations.

The nature of the steel shell construction leaves it more prone to problems associated with groundwater control than the better sealed concrete box options described above. The tunnel will have to be monitored for water leaks and the need for future sealing of these leaks is a possibility. Depending on how the steel liner is sealed, corrosion of the system may also become a maintenance issue. Unanticipated deflections have also been noticed with Tunnel Liners at loads below the theoretical design loads. Studies have found these deflections to be due to poor backfilling methods and other poor field installation problems.

d. Estimated Construction Costs

For this alternative, the same issues related to construction costs apply as stated above for the Jacking alternative.

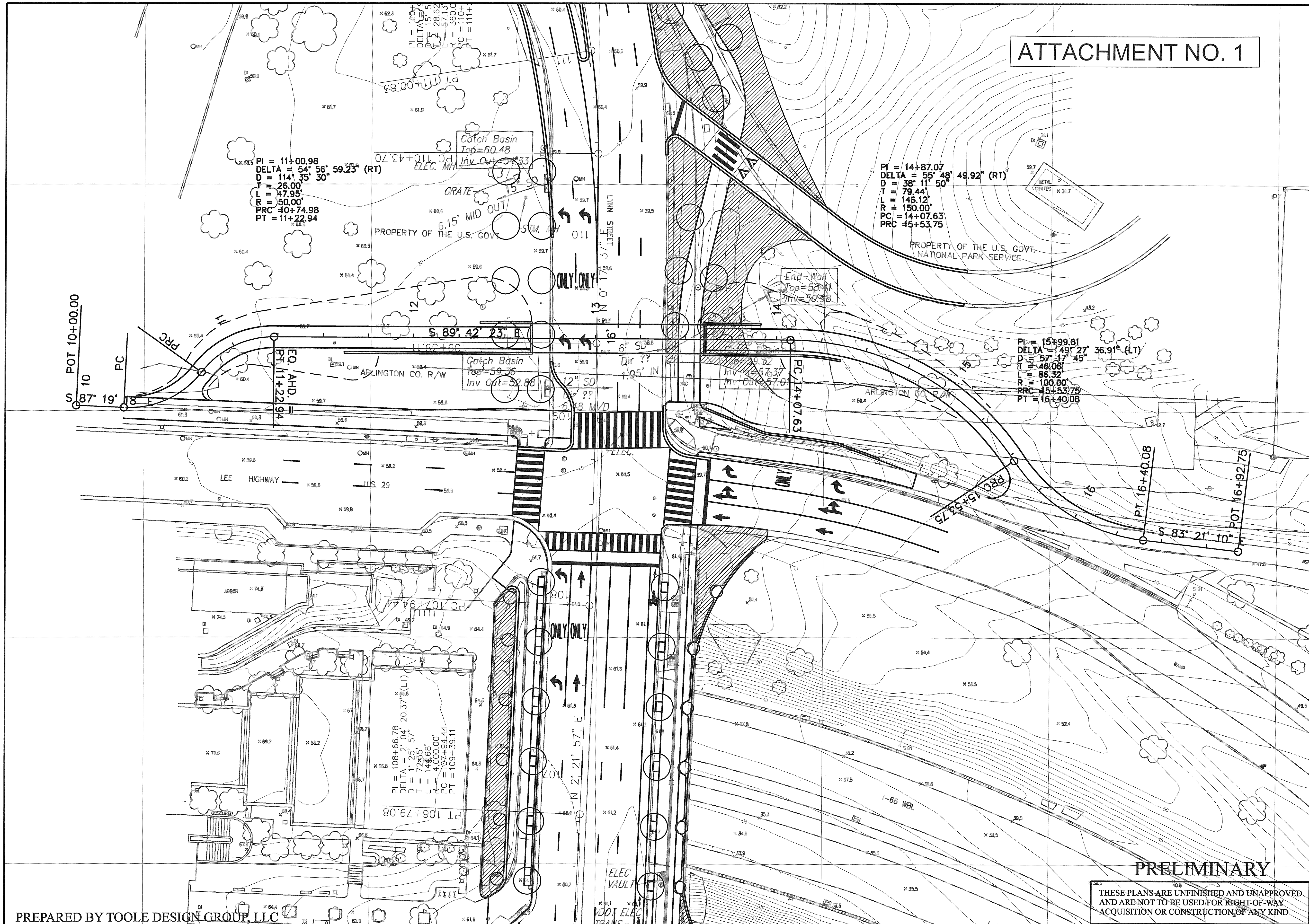
9.0 SUMMARY

One open excavation alternative and two "trenchless" tunnel alternatives are presented in this report. The open excavation alternative, or Cut and Cover Tunnel Alternative, is the most conventional and can be constructed without specialized methods. The cost estimate prepared for the Cut and Cover Alternative makes several broad assumptions that include; soil conditions and utilities are similar to those shown at the Lynn Street Bridge, five lanes of traffic must be maintained during peak traffic hours and a temporary bridging of the open trench will be required to maintain traffic. Construction costs for this alternative are estimated at $1.39M. It should be understood that this cost could vary greatly as further information is gathered for the tunnel corridor. A detailed geotechnical report and utility survey is required to better identify the costs associated with this and other alternatives.

Due to the short length of tunnel, open excavation methods will likely provide the most cost effective solution if construction costs alone are considered. The alternative will be disruptive to traffic, utilities and other local services, however, and as such user costs could potentially be very large. There are multiple subsurface utilities in the existing North Lynn Street corridor. Under the Cut and Cover Alternative, existing utilities would have to be carefully supported and maintained or relocated for the duration of the construction.

Two "trenchless" tunneling alternatives were identified with this report; the Tunnel Jacking Alternative, and the Steel Tunnel Liner Alternative. These alternatives would allow construction to proceed beneath Lynn Street without disrupting traffic operations and possibly without disrupting existing utilities. The feasibility of the "trenchless" construction methods cannot be established without performing a detailed geotechnical study which would include exploratory soil borings and other information related to the composition of the soil likely to be encountered. Because of the unknown nature of the costs associated with the soil conditions, a cost estimate at this stage of design may be misleading and as such is not be included with this report. Although straight construction costs will be higher for these alternatives compared with the open excavation alternative, user costs may be significantly less expensive due to less disruption to traffic on Lynn Street. If user costs are considered, it may be possible for the “trenchless” alternatives to be competitive if a detailed geotechnical report finds the options to be feasible.

ATTACHMENT NO. 1



PREPARED BY TOOLE DESIGN GROUP, LLC

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Approvals	Date
DESIGN TEAM SUPERVISOR	
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CHIEF WATER, SEWER STREETS BUREAU	
DEPARTMENT OF TRANSPORTATION	

Revisions	Date

Project Name and Location

LYNN STREET ESPLANADE

FROM 19TH STREET TO THE KEY BRIDGE

PROJECT NO. 87-05-3

TRAIL TUNNEL PLAN - 1

Designed: XXX
Drawn: XXX
Checked: XXX
Miss Utility Transmittal #:

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Plotted by:

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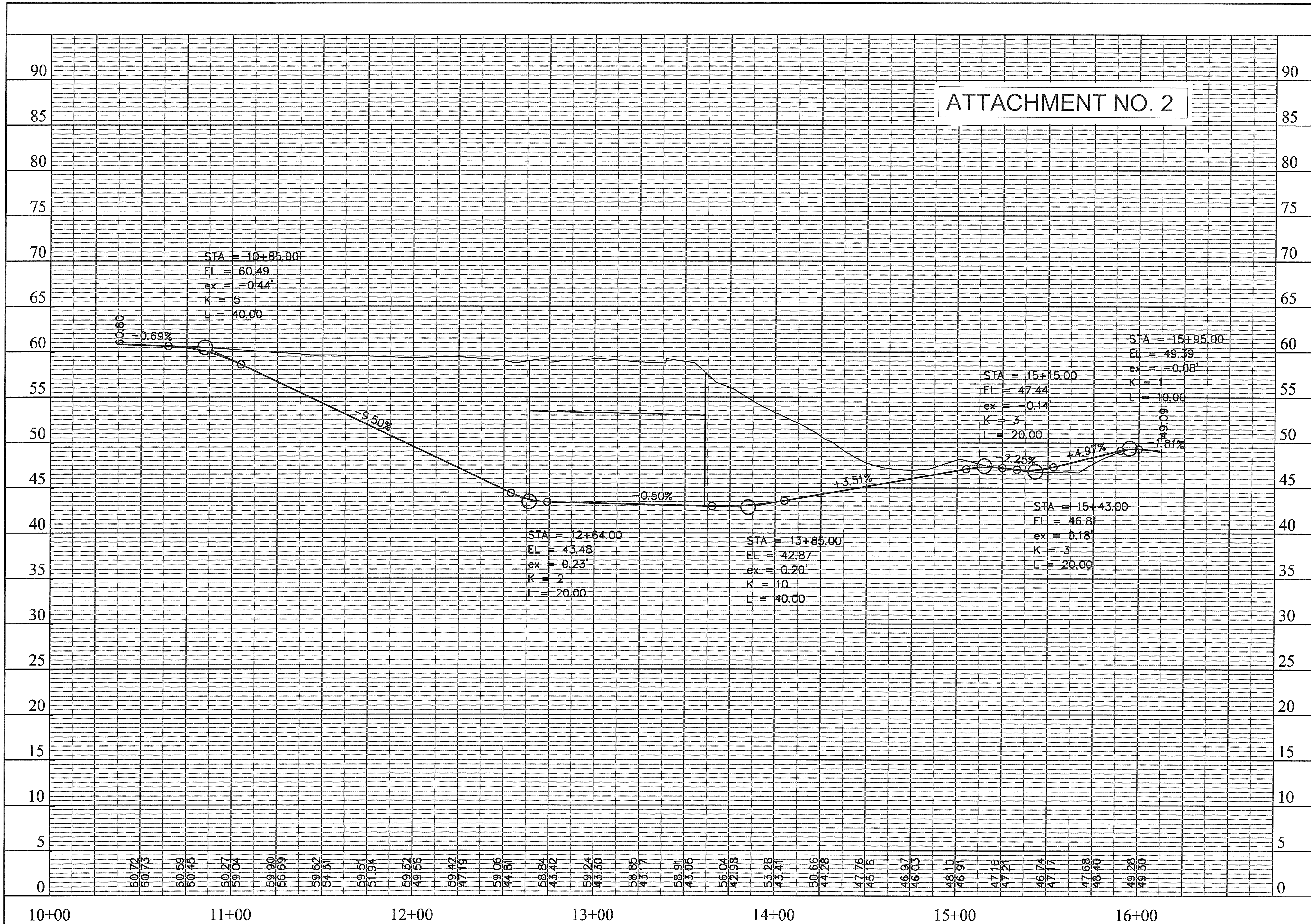
Sheet 7 OF X



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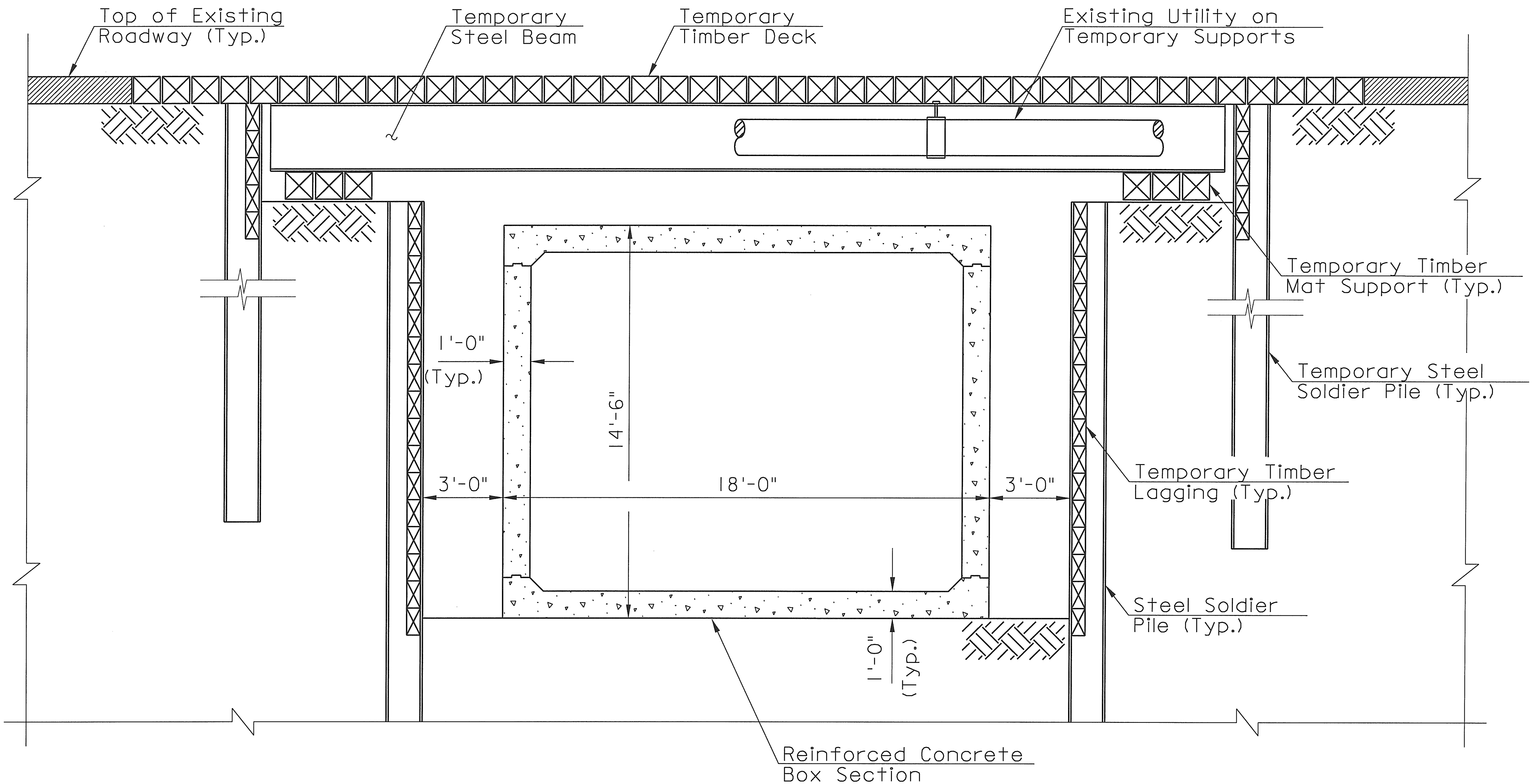
Sheet
7 OF X

ATTACHMENT NO. 3



CUT AND COVER TUNNEL ALTERNATIVE
(CAST-IN-PLACE CONCRETE BOX SHOWN)

ENGINEERS
PLANNERS
ECONOMISTS
Wilbur Smith Associates

ATTACHMENT 4

NORTH LYNN STREET ESPLANADE PROJECT

FEASIBILITY STUDY: CUSTIS PEDESTRIAN TRAIL TUNNEL UNDER NORTH LYNN STREET

COST ESTIMATE: CUT AND COVER TUNNEL ALTERNATIVE

ITEM	UNITS	UNIT COST	QUANTITY	COST
ROADWAY DEMOLITION (OVER UTILITIES)	SQ. FT.	$6.00	2,125	$12,750
SOLDIER PILE AND LAGGING WALLS	SQ. FT.	$25.00	6,100	$152,500
TEMPORARY SUPPORT OF UTILITIES				
16" GAS	LS	$60,000	1	$60,000
12" WATER	LS	$45,000	1	$45,000
6" SANITARY SEWER FORCE MAIN	LS	$30,000	1	$30,000
12 x ELECTRICAL DUCT BANK	LS	$20,000	1	$20,000
5 x ELECTRICAL DUCT BANK	LS	$10,000	1	$10,000
EXCAVATION	CU. YDS.	$20.00	2,824	$56,500
TEMPORARY BRIDGE SUPERSTUCTURE	SQ. FT.	$25.00	1,500	$37,500
CONCRETE BOX SECTION - TUNNEL	CU. YDS.	$1,250	230	$287,500
CONCRETE TUB SECTION - APPROACHES	CU. YDS.	$1,000	280	$280,000
WATERPROOFING MEMBRANE	SQ. FT.	$5.00	5,320	$26,600
TUNNEL LINING	SQ. FT.	$10.00	3,420	$34,200
TUNNEL LIGHTING	LS	$20,000	1	$20,000
SELECT BACKFILL	CU. YDS.	$150	520	$78,000
SPECIAL DRAINAGE SYSTEM	LS	$75,000	1	$75,000
LYNN STREET PAVEMENT MODIFICATIONS	SQ. FT.	$18.00	2,125	$38,250
RELOCATED CATCH BASIN & 12" STORM DRAIN	LS	$7,500	1	$7,500
MAINTENANCE OF TRAFFIC	DAY + LS	$500	200	$114,000
			TOTAL COST	**$1,385,300**