American Society of Civil Engineers
Tunnel Review Panel

DULLES CORRIDOR METRORAIL – PHASE 1
TYSONS CORNER SEGMENT

REPORT

to

Secretary of Transportation
Pierce R. Homer

Commonwealth of Virginia

July 2006

DISCLAIMER – Dulles Corridor Metrorail Tunnel Review Panel (TRP)

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I. EXECUTIVE SUMMARY

At the request of the Virginia Secretary of Transportation, the American Society of Civil Engineers (ASCE) formed a review panel, the Dulles Corridor Metrorail Tunnel Review Panel (TRP), to conduct an independent analysis of engineering options for the proposed alignment through the Tysons Corner area in phase 1 of the Metrorail extension to Dulles Airport and Loudoun County.

Recent advances in tunnel construction methods have made construction of large diameter tunnels feasible and cost effective. Tunnels of this size (40 feet or more in diameter) accommodate, in a single bore, both the tracks and station platforms of a full metro system that traditionally would be carried in two single-track tunnels with a train room spanning these tunnels at stations. Large diameter bored tunnels are currently being constructed in Europe and Asia using state-of-the-art earth pressure balance tunneling boring machines.

To assess the feasibility of the large diameter tunnel, the TRP reviewed the geology, the tunnel alignment, and physical limitations on the construction of the tunnel. On the basis of these reviews and evaluation of recent actual experience with improvements in tunneling technology, in the TRP’s opinion it is feasible to construct the Metrorail system through the Tysons Corner area using a large bore tunnel.

A review of the estimates and proposals, applying its collective experience and judgment, leads the TRP to believe that a figure of $2.5 billion would be a reasonable total cost to construct Phase 1 (temporarily terminating at the Wiehle Avenue Station in Reston) of the Dulles Metrorail extension, including the large bore tunnel through Tysons Corner. The TRP used a similar review of estimates and a proposal to assess the likely cost for the aerial alternative as $2.25 billion, noting that this exceeds the current program cost estimate of $2.1 billion for the same approach. The resulting difference in expected costs between the large bore tunnel and aerial alternatives for Phase 1 is approximately $250 million.

In the capital cost evaluations, other factors considered by the TRP include:

- Delays and Schedule Impact Costs – while the expected duration of the construction, installation and testing work under both alternatives is considered comparable, the start of the large bore tunnel solution will be delayed by up to one year to complete sufficient Preliminary Engineering and to secure approval of the documentation required under the National Environmental Protection Act (NEPA) and the equivalent State legislation. The inflationary effect on capital costs has been accounted for in the cost and pricing data above.

- Property Takings – less surface impact leads to fewer permanent, utility, and temporary construction easements for the large bore tunnel. This will substantially reduce cost - by at least $30 million.

- Roadway and Traffic Impacts During Construction – the aerial alternative generates serious negative traffic and business access impacts during construction of stations and line along Route 7, alongside Route 123, and in the construction of the line over Interstate 495 (the Capital Beltway), concurrent with the HOT Lane construction on I-495. The large bore tunnel, because it presents much less surface construction activity, has a much smaller impact on vehicular and pedestrian traffic in these zones. The tunnel does have substantial construction impact on the median of the Dulles Access Road at the two portal sites. This will generate heavy truck traffic for the temporary storage and removal of the very large quantity of tunnel muck, and then for delivery and staging of the pre-cast tunnel lining segments. Although these impacts have not been quantified, the TRP has concluded that they are potential sources of project risk, but they are manageable.

- Utilities – The aerial solution will require extensive utility relocation and support, especially along Route 7, with attendant costs and risks; the large bore tunnel solution will minimize this activity yielding a savings of up to $40 million that has been reflected in the capital cost and price data.

- Procurement Strategies – optimizing competition, establishing financial incentives, and risk-sharing in the procurement actions all have high potential for eliminating excessive contingencies from pricing and resulting in lower capital costs.

Non-Capital Cost Issues

- The expected life span of the tunnel is potentially twice that of the aerial structure (120 years versus 60 years).
- There are significant savings in operation and maintenance costs with the large bore tunnel alternative, estimated at $5 million per year (current dollars).
- Other life cycle cost savings favor the tunnel, but have not been calculated.

Long-term Economic and Business Impacts

Economic impacts have not been quantified, however the TRP believes that the large bore tunnel alternative will facilitate a more sustainable development path for Tysons Corner, enabling higher densities, a pedestrian-friendly environment, and other contributions to a transformation to a livable, urban-style community.

II INTRODUCTION AND BACKGROUND

A Description and Recent History of Project

The Commonwealth of Virginia has worked with the Federal Transit Administration (FTA), the Washington Metropolitan Area Transit Authority (WMATA), and local funding partners on various alignments and configurations of phase 1 of the Metrorail extension (from the East Falls Church station to the proposed Wiehle Avenue station, in Reston). The alternative that was advanced into preliminary engineering includes an alignment through Tysons Corner that is mainly aerial but includes a relatively short (0.4 mile) tunnel (under the Route 7 and Route 123 interchange). The commonwealth recently completed sufficient preliminary engineering on the entire phase 1 alignment in order to submit it to the FTA for approval to move into the procurement of a design-build contract under the New Starts funding appropriation.

A long-standing award under the Virginia Public Private Transportation Act named Dulles Transit Partners—a joint venture of Bechtel Corporation and Washington Group International—as the contractor for the execution of the final design and construction of the entire alignment from East Falls Church to the Loudoun County stations beyond Washington Dulles International Airport. This arrangement is to be modified only if the contractor and the commonwealth cannot achieve agreement on the price for the design-build execution. Dulles Transit Partners' engineering arm—Dulles Transit Engineers—has been preparing the National Environmental Protection Act compliance and the preliminary engineering documents on behalf of the commonwealth under a fee-for-service arrangement.

An independent evaluation was requested of the commonwealth by the Fairfax County Board of Supervisors. It is also supported by WMATA. These parties became aware of a tunneling technology applied in construction of tunnels in Madrid and Barcelona, Spain, that is expected to more effectively achieve some of their goals for the project than the aerial structure/short tunnel alternative that has been advanced into, and partially through, preliminary engineering.

In May 2006, Virginia Secretary of Transportation Pierce R. Homer announced the formation of the Dulles Corridor Metrorail Tunnel Review Panel to conduct the independent evaluation of a tunnel alternative for the Tysons Corner area in northern Virginia. The TRP was to be convened and led by the American Society of Civil Engineers (ASCE) and would consider the cost, schedule, and other project implications of the tunneling options.

ASCE is a leading professional engineering organization representing more than 139,000 members of the civil engineering profession worldwide. The Society has a strong commitment to protecting public health, safety, and welfare and is well qualified to provide support to the Commonwealth of Virginia on this project.

B Scope of Tunnel Review Panel Activity

ASCE agreed to lead the independent review of alignments through Tysons Corner and chartered the TRP to conduct this review. The task of the TRP was to examine available designs and cost estimates for the aerial structure and tunnel alternatives in the alignment through Tysons Corner (in the vicinity of East Falls Church Station on the Metrorail's Orange Line to the median of the Washington Dulles International Airport access highway, west of Tysons Corner). The examination was to include, but would not be limited to, tunnel construction costs and the related geology, life-cycle cost factors, schedule factors, right-of-way impacts, roadway and traffic impacts, and FTA cost effectiveness factors. (The latter was later removed because of changes occurring in FTA regulations.) The TRP was also to evaluate and critique risk management planning, including assigned contingencies in cost estimates. In addition, the TRP would identify any possible new solutions and would consider the economic and business impacts of the alternatives. The chairman of the TRP would keep the commonwealth's secretary of transportation informed on the progress of the TRP's work and would conduct an executive briefing approximately 60 days from the late May 2006 initiation of the review.

C Chartering of Panel

ASCE has selected TRP members who have professional experience in numerous areas of engineering that are pertinent to the independent evaluation of the aerial structure and tunnel alternatives for the Tysons Corner segment of the proposed Metrorail extension to Dulles Airport.

Panel Members

Robert S. O'Neil, P.E., F.ASCE, NAE, the president of Robert O'Neil and Associates in Potomac, Maryland. Mr. O'Neil, who served as the TRP's chair, has more than 40 years of experience in the planning, design, and implementation of major transportation projects, including urban transportation systems, highways, railroads, and other transportation-related facilities, both domestic and international. Included in his transit-related work are: the planning, design, and implementation of the Washington Metropolitan Area Transit System; the construction management of phase I of the Los Angeles rapid transit system; the design of the underground phase I section of the Taipei metro, as well as the designs of the Bangkok and Kuala Lumpur metro systems; the design of the train control and communications systems for the Baltimore and Miami, Florida, rail transit systems as well as the Baltimore light-rail system; and the design work for transit stations in Atlanta, for ventilation and bus maintenance facilities in Boston, and for bus maintenance facilities in New Jersey.

Brenda Bohlke, Ph.D., P.G., a principal of Myers Bohlke Enterprise. Dr. Bohlke has more than 30 years of experience in the planning, design, and construction of transportation and water infrastructure projects. She serves on the Board of Directors of the American Underground Construction Association (which was recently acquired by the Society for the Mining, Metallurgy, and Exploration), and has experience locally and worldwide, including work on the WMATA metro tunnels, the Singapore Deep Tunnel, the Sydney M5 motorway, and Boston's submarine outfall—work that entailed a variety of tunneling methods and contracting approaches. In 1996 she organized the forum on geotechnical baseline reports that has become the standard of practice in the underground industry. Recently Dr. Bohlke served as the project manager for the master planning for the expansion of the Panama Canal, and has served as the project manager for the preliminary engineering of the $4.5-billiion maglev system between Baltimore and Washington, D.C., which includes at-grade, aerial, and tunnel sections.

Young Ho Chang, P.E., M.ASCE, a principal and senior vice president of ATCS, PLC, an engineering firm based in northern Virginia with several offices in the Washington, D.C., metropolitan area. Mr. Chang has 19 years of experience in all aspects of transportation, including planning, traffic engineering, design, construction, and maintenance. He also specializes in local land use, zoning, and surface transportation. Mr. Chang has extensive knowledge of public-sector transportation projects at all levels of government, especially at the state and local levels. Previously, Mr. Chang served as the director of the Fairfax County Department of Transportation, where he oversaw the operation of a multimodal transportation agency.

Richard E. Gray, P.G., Hon.M.ASCE, a principal of DiGioia, Gray & Associates, LLC. Mr. Gray's specializations are in the areas of soil and rock mechanics, engineering geology, and foundation engineering. He has conducted numerous geotechnical studies of sites for such large industrial developments as steel mills, fossil-fuel power plants, hydroelectric power plants, and nuclear power plants; and has expertise in the design of tunnels, slopes, dams, and foundations. He has been responsible for numerous studies of subsidence, slope stability, seismicity, ground water, mineral evaluation, mine fires, acid mine drainage, expansive shales, and waste disposal and utilization.

Raymond E. Sandiford, P.E., M.ASCE, the chief geotechnical engineer for the Port Authority of New York and New Jersey. Mr. Sandiford specializes in heavy, underground, and foundation construction. He has more than 30 years of experience in design and construction that includes work involving foundations, tunneling (hard rock, soft ground, and microtunneling), bridges, waterfront structures, dredging, dredge disposal facilities, ground improvements, highway and aircraft pavement, rock slope stabilization, and deep shafts, and he has designed and supervised complex subsurface investigations and geologic interpretations. His contract experience includes traditional design, bid, and award contracts as well as negotiated design/build/operate and maintenance contracts.

Richard L. Tucker, Ph.D.., P.E., F.ASCE, NAE, the vice president of Tucker & Tucker Consultants, Inc., and the Joe C. Walter Jr. Chair Emeritus of the University of Texas at Austin. Dr. Tucker specializes in heavy construction, risk management, and cost. He has had considerable direct industry involvement in several of the world's largest firms and projects. He established a Construction Research Center in the Dallas-Fort Worth area. Under his supervision the Construction Industry Institute of the University of Texas at Austin developed improved construction productivity methods, foreman delay surveys, and design delay surveys; addressed constructability issues; established methods for evaluating design effectiveness, preproject planning, and industry benchmarking and metrics.

TRP Proceedings

The TRP activities comprised the following:

Face to Face Meetings
June 7 – 8, 2006
June 27 – 28, 2006
July 07, 2006 (partial)
July 18, 2006

Media briefings
June 12, 2006
July 10, 2006
July 31, 2006

Conference Calls
June 15, 2006
June 20, 2006
June 22, 2006
July 05, 2006
July 13, 2006
July 20, 2006
July 24, 2006

D Panel Approach and Assumptions

In establishing its approach to this effort, which was undertaken within very strict time constraints, the TRP established the following assumptions.

1. The TRP would not perform new analyses, but rather would focus on evaluating work done by others.

2. The commonwealth, or its successor in the owner role (likely the Metropolitan Washington Airport Authority), would ensure that the procurements optimize contracting methods and use methods to ensure optimal competition—for example, multiple large-bore tunnel contractors would be identified and encouraged to participate in the price competition and design-build or similar progressive delivery approaches would be used.

3. The structure of procurements would be developed on the basis of balanced allocation of risks and managed contingencies.

4. Cost elements for such soft areas as contingencies, overhead markups, and profit markups would be consistent with project risk and industry norms.

5. The development of final alignments and other elements of the facilities configuration would be strategically accomplished to minimize disruption of the FTA compliance process—for example, station facilities locations would be maintained generally in place.

6. The disposition of the very large volume of excavated tunnel material would be achieved through a proper balance of free market competition and preplanned reuse or disposal opportunities while minimizing the traffic impacts, trucking distances, and consequent roadway wear and tear.

7. The program management team would possess the requisite blend of skills, leadership ability, and knowledge to balance rigorous quality management with minimal duplication of effort, timely contract administration, effective technical decision making, and rapid dispute resolution.

8. The program would provide Metrorail service (no other modes were examined) and would adhere to WMATA technical and operating standards.

III DESCRIPTION OF ALTERNATIVES

A Development of Alternatives

Initially a suburban shopping area, Tysons Corner has become an urban business and commercial center with a steadily increasing residential population. To many, Tysons Corner is a satellite city grappling with all of the problems and opportunities of a central business district. In a typical transit solution for a central business district, new rail lines are constructed belowground to maximize surface development opportunities and minimize long-term impacts and restrictions on the community.

The extension of rail transit service to Washington Dulles International Airport was conceived as an at-grade rail line to be located in the median of the Dulles access road. At the request of concerned parties, it was decided that adequate service to the high-density Tysons Corner area could best be provided by routing the rail system through the Tysons Corner area.

The Commonwealth of Virginia worked with the FTA, the WMATA, and local funding partners on various alignments and configurations of phase 1 of the Metrorail extension, which would extend from the East Falls Church station to the proposed Wiehle Avenue station.

Earlier studies of the 4.2-mile segment through the Tysons Corner area included an aerial alignment with a short section of tunnel and a separate alternative for a twin-bore tunnel and station configuration similar to that in general use through the underground portion of the Metrorail system.

Because the 4.2 miles of the route through Tysons Corner include four stations and three large crossover sections, the standard Metrorail solution would include not only two train tunnels, but also seven station and track crossover chambers. At least four of the seven chambers would be constructed from the surface in excavations approximately 80 feet wide by 800 feet long. Two of these excavations would lie in the existing Route 7 roadway. Because of the tremendous impacts it would exert on traffic, utilities, and the community in general, this alignment was not pursued beyond the final environmental impact statement stage and was not advanced into preliminary engineering. The TRP agrees with this analysis, which concluded that this alternative is neither desirable nor economically feasible.

The alternative through Tysons Corner that was advanced into preliminary engineering is an alignment that is mainly aerial but includes a relatively short (0.4 mile) tunnel under the Route 7 and Route 123 interchange. The commonwealth recently completed preliminary engineering on the entire 11.6-mile phase 1 alignment, including the 4.2-mile section at Tysons Corner, extending from East Falls Church to Wiehle Avenue.

Late in the preliminary engineering phase WMATA and others initiated discussions on a new tunnel technique being used extensively in Europe, particularly in Spain. This tunnel approach—the Large Bore Tunnel (LBT) approach merited consideration as an alternative to the proposed aerial structure.

The LBT system provides for station platforms and crossover structures within a single large-diameter tunnel. Station access would be provided as four single entrances, one located at each station. Surface interruptions would be required for ventilation and emergency egress shafts as well. Vertical access at stations would be provided by means of elevators, thus mainstreaming access for disabled patrons.

This review will compare the features of the LBT concept with those of the proposed aerial alignment through Tysons Corner.

B Proposed Aerial Approach

In the current alternative for the 4.2-mile alignment through the Tysons Corner area the track structure would rise from the median of the Dulles access road, cross over the access road and the Dulles toll road, proceed as an aerial structure across Route 123 to the proposed Tysons East station, and then continue over the Capital Beltway to a second elevated station along Route 123. The alignment would then enter a short tunnel, turn, and enter a station in the median of Route 7.

The line would continue overhead in the median of Route 7 to a fourth station, proceed to the west, cross over the eastbound toll road and the eastbound access road, and return back to grade in the median of the access road. At times, the top of the elevated structure would rise as much as 70 feet above ground level. The Tysons West Station canopy is approximately 55 feet above the surface—in the median of Route 7—and all four stations would be at least partially elevated aboveground. (Tysons Corner Detail Map of the 4.2-mile segment through Tysons Corner is shown on Figure 1[1]**.** See Figures 2 and 3[2] for depictions of the aerial stations.)

C Large Bore Tunnel Alternative

Recent experience in Europe with very-large-diameter earth pressure balance boring machines prompted consideration of this technique for the 4.2-mile alignment through Tysons Corner. This consideration is central to the TRP's investigation.

[1] "Dulles Corridor Metrorail Project Web Site, Tysons Corner Detail map.

[2] "Dulles Corridor Metrorail Project (Phase I), Extension to Dulles via Wiehle Avenue; Preliminary Engineering and Costs", presentation to the Tunnel Review Panel from Dulles Transit Engineers on June 7, 2006, pages 12 and 16.

In the LBT approach, station platforms and transit crossover structures would be contained within the tunnel cross section. (See Figure 4[3]) Station entrances would be at street level and vertical access would be provided by a mezzanine just below (or possibly at) ground level. (See Figure 5)[4] Access from the mezzanine to the platform level would be provided by elevator. Rooms for systems operating equipment would be provided within the vertical access shafts. Separate smaller shafts would be required for tunnel ventilation and emergency access and egress. The number and locations of these shafts would be determined in the preliminary engineering phase. The shafts would terminate at or slightly above ground level, and would be unobtrusive. On completion of construction, the only discernible evidence of the Metro station would be the four entranceways to the mezzanines and the shuttle bus loops at the four entranceways.

[3] From Presentation made to the Tunnel Review Panel from Dr. G. Sauer Corporation on June 7, 2006.

[4] From Presentation made to the Tunnel Review Panel from Dr. G. Sauer Corporation on June 7, 2006.

Figure 1 – Aerial or Tunnel Rail Through Tysons Corner

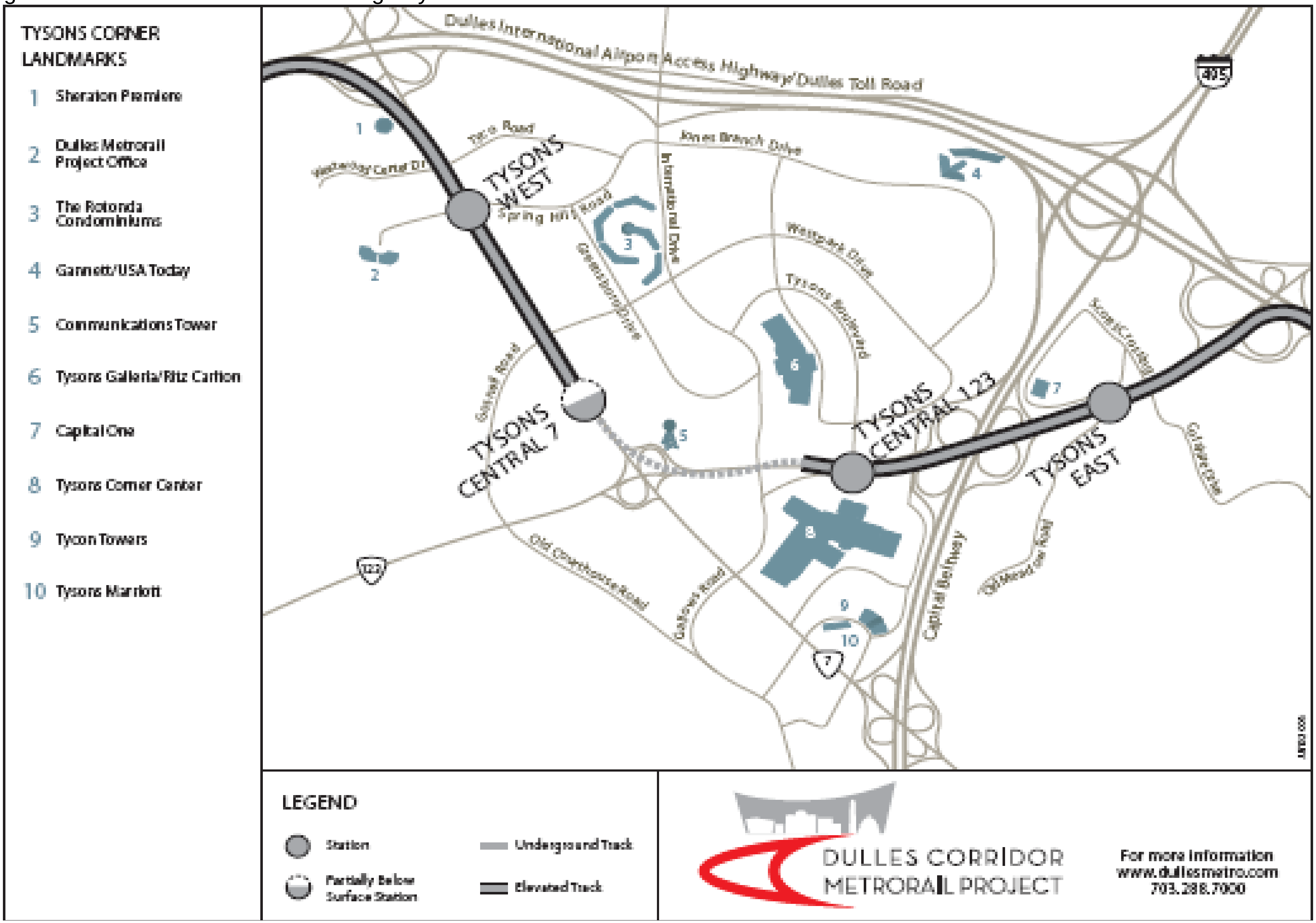


Figure 2 – Tysons West Aerial Station

Figure 3 – Tysons Central 123 Aerial Station

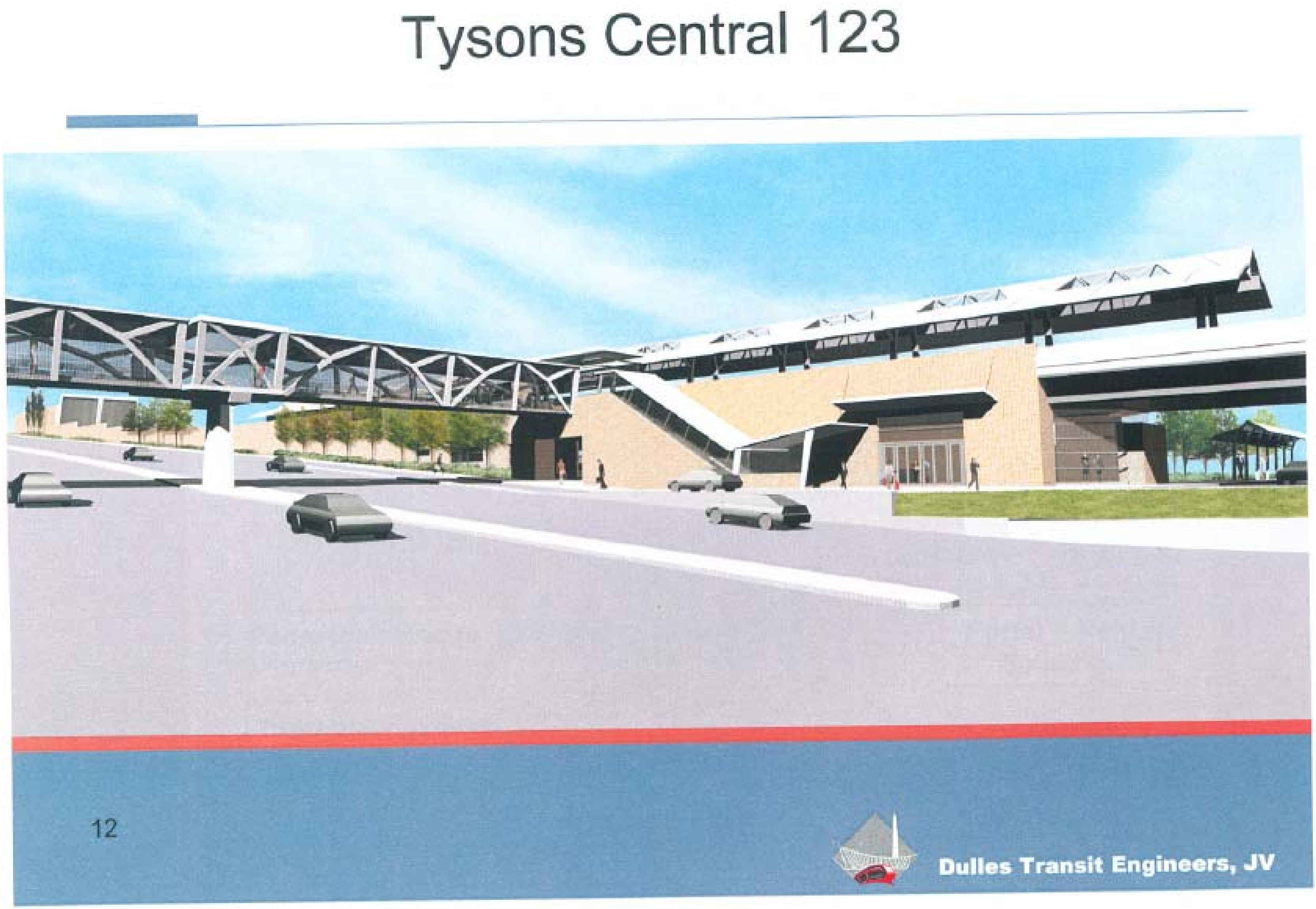


Figure 4 – Large Bore Tunnel Cross Section

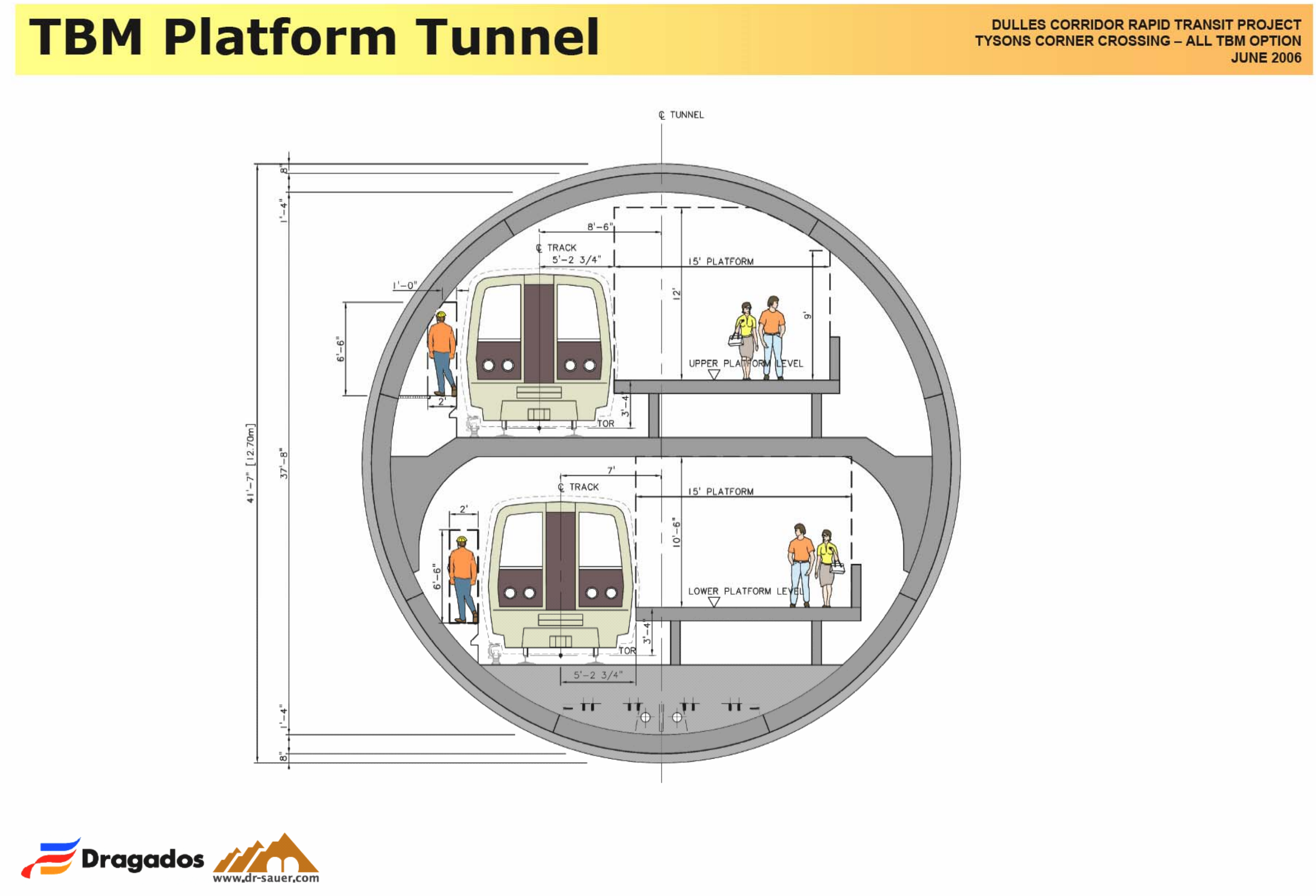
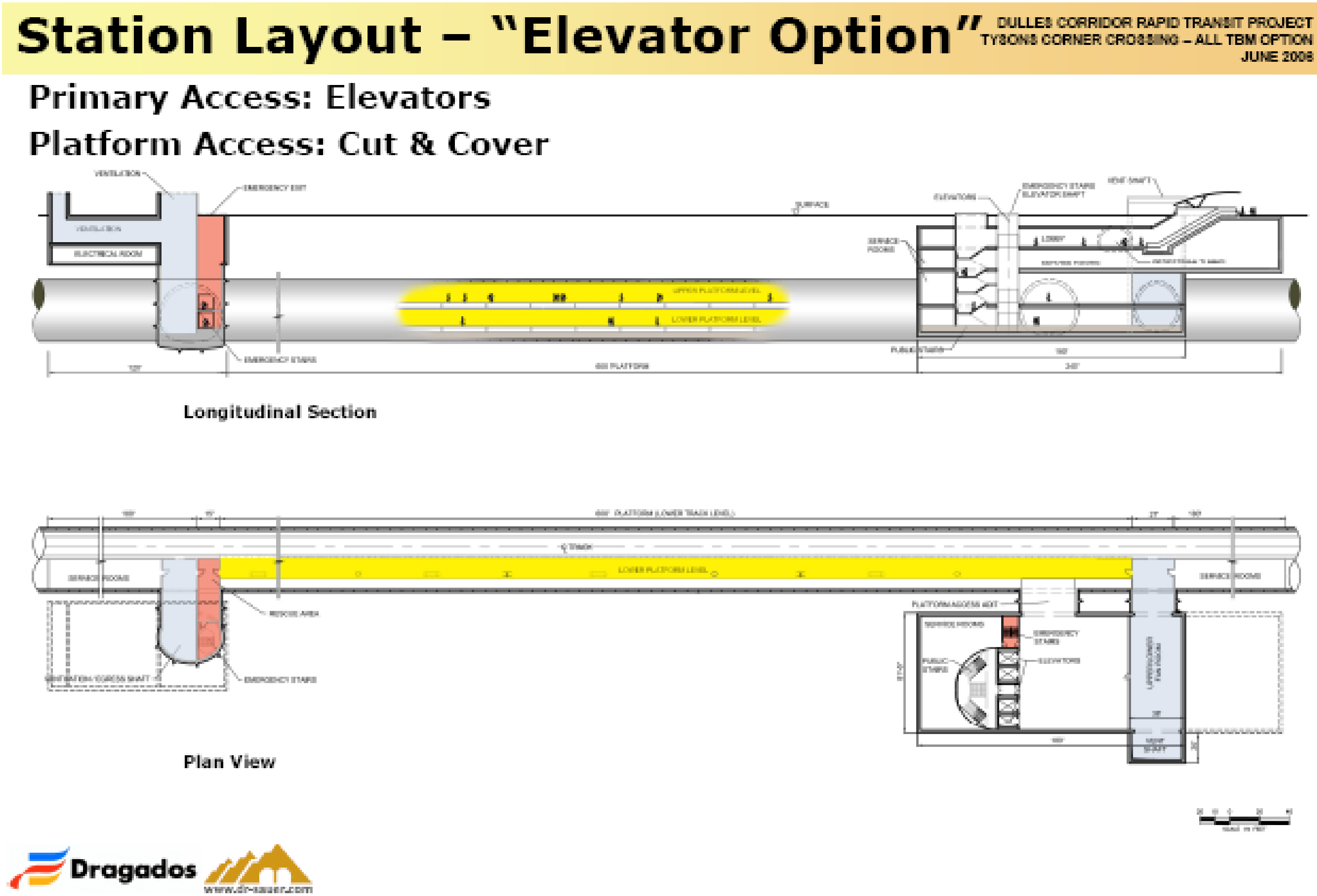


Figure 5 – Tunnel Alternative – Ancillary Station Facilities



IV GEOLOGY, CONSTRUCTION METHODS, RISKS, AND COSTS

A Geology

Tysons Corner is located in the Piedmont physiographic province. The rocks are metamorphic and predominately schist and gneiss with granite intrusives. Phyllite, slate, greenstone, diabase, quartzite, and soapstone may occur locally.

Extensive weathering has reduced the near surface metamorphic rocks to residual soils ranging from clay to silty sand. Weathering is facilitated by fractures, joints, and the presence of less resistant rock types. Consequently, the top of hard rock is often irregular. Lenses of hard rock may be present within the residual soil well above the general bedrock level.

Borings drilled for the current alternative provide some information on subsurface conditions that would be encountered by the proposed LBT and are adequate to evaluate the technical feasibility of the LBT alternative. In the western section of the alignment, many borings penetrated to the level of the LBT alternative. In the central section, very few borings were drilled to the level of the LBT's crown. In the eastern section, a number of borings reach the LBT level, but the coverage is not as good as it is in the western section.

No borings have been drilled to depths of one tunnel diameter below the proposed LBT invert level. If the LBT alternative is adopted, more subsurface information will be required in order to develop the design. A combination of borings and geophysics to define the top of hard rock should be considered for the required exploration program.

Rock coring has been performed in 54 borings to assess the nature and quality of the underlying rock along the transit corridor. Unconfined compression tests on the best quality rock encountered produced strengths ranging from 900 to 16,560 psi, with an average value of about 9,000 psi.

Where the existing borings reach the proposed LBT level they show an irregular top of rock. This would result in a mixed face (soil and rock) excavation by the tunnel boring machine. Much of the soil is described as decomposed rock because it still exhibits a relict rock structure. It would be best to anticipate mixed face excavation for the length of the large bore tunnel until additional subsurface information is obtained.

B Construction Methods

B 1 Proposed Aerial Approach

The proposed aerial approach consists of approximately 3.8 miles of aerial structure and 0.4 mile of tunnel. The aerial structure would include precast box beams and segmented structures bearing on concrete piers. The piers would be constructed on pile foundations.

The current alternative for the 4.2-mile alignment through the Tysons Corner area rises from the median of the Dulles access road, crosses over the access road and toll road, and proceeds in aerial structure across Route 123 to the Tysons East station, then over the Capital Beltway to a second elevated station along Route 123. The alignment would enter a short tunnel and turn into a station in the median of Route 7. The tunnel would be constructed using the New Austrian Tunneling Method (hand-mined tunnel with shotcrete initial liner/support).

The system would continue in the median of Route 7 to a fourth station, proceed to the west, cross over the toll road and the eastbound access road, and then proceed back to grade in the median of the access road. In places the top of the elevated line structure would be up to 70 feet above the surface. The Tysons West Station canopy would be about 55 feet above the surface in the median of Route 7. The horizontal alignment of the proposed 4.2-mile approach is shown in Figure 1.

Project risks in the current aerial and short tunnel alternative center on extensive surface construction, extensive utility work—particularly on Route 7, impacts on traffic, impacts on adjoining land takings, and the delicate staging of construction during heavy shopping seasons. Particular care would be required when leaving and returning to the median of the Dulles Access Road and crossing the Capital Beltway. All of these risks are typical of a project such as this and are considered manageable.

B 2 Large Bore Tunnel Alternative

The LBT alternative for the Metrorail extension through Tyson Corner has been proposed to take advantage of the advancing technology in mechanized tunneling within the past 5 to 10 years. During this time tunnel boring machine technology and machine performance have been advanced to:

- Increase the diameter by increasing the torque
- Increase the ability to manage higher water pressures at the tunnel face through improved gaskets and bearing design
- Improve the ability to excavate through a wider range of materials with advanced cutterhead design.

The size of the proposed large diameter bore—it features an approximately 42 foot outside diameter—is such that it will accommodate both Metrorail tracks in a stacked configuration (see figure 4), allowing for space for the platforms at the station locations. The large bore configuration has been reviewed by WMATA to ensure it will satisfy its standards for construction and operation.

B 3 Technological Advances in Tunneling

The earth pressure balance machine (EPBM) has revolutionized the tunneling industry by providing greatly improved control of the inflow of the ground and groundwater at the face when excavating below the groundwater table. This machine controls the outflow of the muck from the head of the machine and thus counterbalances the hydrostatic and earth pressures at the face of the advancing machine. By “balancing” the earth (and water) pressure at the face, the machine controls the rate and volume of material excavated, thereby controlling/limiting the settlement of the ground surface. This introduces both efficiencies and substantial safety improvement for the surface facilities and for the mining team excavating and supporting the tunnel.

The most recent advancement in the design of the EPBM is the significant increase in its diameter. In Madrid, EPBMs that are 49 feet in diameter and weigh in excess of 4,400 tons have been specified to construct a 2.5 mile highway bypass. Progress is expected to average about 36 feet per day. A 50 foot diameter EPBM will excavate a large-diameter tunnel for part of Barcelona’s metro system, using the same stacked track and station platform configuration proposed for the Tysons Corner LBT. The stations for the Barcelona metro will also be excavated as a breakout from the mainline tunnels. The Barcelona tunnel boring machine will traverse a wide range of geologic materials—from alluvial materials, conglomerates, limestones, and shales to granite intrusions.

Mixed ground conditions similar to those anticipated in the Tysons Corner project have been noted in the Singapore Deep Tunnel Sewer System tunnels where EPBMs were used to excavate much of the 48 miles of the tunnels, which are 20 feet in diameter. The mixed face conditions in Singapore involved both deeply weathered granites and alluvium over bedrock. In Portland, Oregon, EPBMs were designed to handle glacial deposits with boulders in silt and clay matrix for the sewer tunnel program. In the Miami, Florida, port tunnel project, LBT is planned under Biscayne Bay to provide direct freight transportation access to the port. The tunnel will be under substantial water pressure.

The tunnel through the Tysons Corner alignment would be excavated through mostly decomposed mica schists that have the characteristics of a dense silty sand that—on the basis of its in situ weathering characteristics—can behave as blocky ground. The irregular and variable penetration of weathering has resulted in an uneven soil-rock interface with resistant rocks or boulders and resistant rock pinnacles possibly present throughout the tunnel profile. The mixed face conditions will require the cutterhead design to include both soil picks and rock disk cutters. The LBT machines in current use have worked successfully in this mixed soil-rock profile.

B 4 Tunnel Vertical Alignment

As proposed by Dragados—the contractor constructing the LBTs in Spain—the Tysons LBT vertical alignment would be set within the available geotechnical boring profile. This vertical alignment is suboptimal with respect to the tunnel cover, geologic conditions, and alignment geometry. With respect to the cover, it should be noted that the preliminary vertical alignment data available for the large bore tunnel shows it is relatively shallow for a tunnel of this size, allowing little more than a tunnel diameter of cover in the western portions of the tunnel. Specifying a minimum cover to reduce risk to the performance of the EPBM, should be considered. With respect to the geology, the profile at this shallow depth consists primarily of decomposed rock with occasional resistant rock boulders, and resistant bedrock pinnacles occurring within the tunnel excavation. The geologic profile is characterized as a mixed face (mixed soil and rock) for much of the tunnel excavation. And finally, with respect to the vertical alignment, the profile could be improved by smoothing the subsurface alignment to increase the cover as well as improve the steering requirements for the tunnel boring machine.

We would expect that the LBT vertical alignment would be optimized as additional borings and geotechnical information are obtained during the preliminary engineering phase.

C Risks

Every major construction project has a number of risks associated with various facets of the project. Some of the risks associated with this project include:

- Ensuring competitive pricing
- Ensuring experienced program management and oversight
- Obtaining effective contractual terms and conditions and the resulting relationships
- Experiencing unforeseen conditions, whether geologic or man-made
- Controlling surface settlement and related impacts on utilities and structures
- Experiencing delays in tunneling: production, mucking, ring installation
- Experiencing site accessibility and traffic impacts
- Experiencing community and environmental impacts
- Encountering utility conflicts, relocation, and disruption
- Managing muck operations, disposal, and traffic
- Managing construction traffic, cranes, dust on Route 7 for aerial alternative for full project duration
- Operating a large-diameter tunnel boring machine in mixed face, which requires an experienced operating team skilled in all aspects of tunneling operations, including soil conditions; machine advance; control and steering of the machine; segment and lining erection; and muck conveyance
- Overseeing an experienced workforce skilled in the New Austrian Tunneling Method
- Ensuring overall project safety

Although this list is long and incomplete, containing and managing the risks on any project of this size and complexity in a densely populated and traveled corridor, can be accomplished by:

- Establishing a competitive pricing environment
- Appropriately allocating risks among the owner and design-build team members
- Contracting with highly qualified and experienced contractor teams composed of skilled staff dedicated to the project for the duration
- Conducting a risk assessment and management program in which all parties are engaged from the outset
- Conducting a thorough assessment of the site conditions, including geometries, geology, hydrology, and disclosing all of the information to all parties
- Implementing both internal and external communications programs
- Employing industry standards and good contract documentation
- Assigning experienced program managers

C 1 Proposed Aerial Approach

The proposed aerial structure would require continuous heavy construction activities on the ground surface, often at sites with restricted access and space and subject to environmental regulation. Each pier would require the installation of a number of piles in highly irregular soil and rock profiles, leaving some uncertainty in terms of the individual pile length. Foundation work at major highway crossings would be required. This type of heavy construction at the surface requires substantial risk-prone utility relocation and reconstruction as well as the very challenging control of vehicular traffic in a very congested area.

New Austrian Tunneling Method (NATM) technology has been used by WMATA to construct a number of soil tunnels within Metrorail system. NATM technology has its own risks, and requires a complement of experienced supervisory and tunnel staff on-site around the clock to implement changes to the advance and support sequence should geology or groundwater conditions change. Constructing a grouted pipe canopy support is slow but necessary for control of the surface settlement at the shallow depths near buildings. Instrumentation should be installed in advance of all tunneling activities.

C 2 Large Bore Tunnel Alternative

The major risks that can affect the schedule, cost, and stability of the LBT alternative lie in designing the machine in accordance with the local geology and groundwater conditions. It is particularly important for the machine to be capable of excavating a tunnel with the upper portion of the face in soils and the lower portion in rock, and to control the volume of soils excavated—and hence the surface settlement. Particular attention must be paid to the cutterhead design and the configuration and relative number of picks to disk cutters. These choices must take into consideration the specific range and variability of the materials and the necessary torque and thrust. The soil in the Tysons Corner area is generally relatively stiff silty sand with some cohesive properties. These conditions require an experienced machine operations crew and highly experienced supervisory engineers.

The LBT alternative would use a single pass lining consisting of bolted, precast concrete liner segments with permanent gaskets for water tightness. These would be erected in the tail of the TBM, and the annulus behind the rings would be grouted. Some movement of the ground around the annulus outside of the liner prior to grouting would result in minor surface settlement, which could be monitored through instrumentation set out in advance of the TBM. The TRP notes that the EPBM with the precast liner erection system provides considerably enhanced safety for tunneling work crews at and behind the tunnel face.

C 3 Muck Handling

The LBT alternative would produce 1.7 million cubic yards of excavated material (from the main tunnel bore), assuming a bulking factor of 1.5. Dragados estimates an average tunnel advance rate of 36 feet per day, which would produce approximately 3,300 cubic yards of muck per day for roughly 24 months. Movement of this amount of material from the tunnel portal in the median of the Dulles Access Road would constitute a significant challenge, but in the opinion of the TRP, is manageable.

C 4 Station Construction for the Large Bore Tunnel

The station locations for the LBT alternative would remain the same in number and location as the proposed aerial approach. The station access, ventilation shafts, and electrical and mechanical rooms would be constructed with ground surface penetrations and construction activities near those openings. These penetrations would be limited in extent and number at each of the stations, thus reducing the impact on the utilities, the local businesses, and right-of-way requirements. The proposed openings would allow for either escalator or elevator access to the underground station, and would be defined during preliminary engineering.

D Construction/Implementation Cost Estimates and Proposals

The TRP was charged with comparing and evaluating available cost estimates. Various stakeholders, contractor teams, and consultants have prepared capital cost estimates and proposals. The proposals, which carry greater weight in the view of the TRP, are:

1. Dulles Transit Partners' 'program cost estimate' for the current aerial solution is considered to be a proposal (see below), in the amount of $2.38 billion (in year-of-expenditure dollars)

2. An informal estimate offered by a group of reputable construction contractors and design consultants, including Dragados, has recently been formally and publicly submitted to the Commonwealth, in the amount of $2.0 billion (in year 2006 dollars).

The TRP has reviewed these and has attempted to make a rational and reasonable comparison based on its collective experience and judgment, within an appropriate order of magnitude.

The base cost estimate for the currently proposed aerial approach was prepared by STV Corporation for the Virginia Department of Rail and Public Transportation in the amount of $2.1 billion (year-of-expenditure dollars). This program cost estimate was made public and submitted in February 2006 to the Federal Transit Administration as part of the request for approval to proceed to Final Design.

Dulles Transit Partners is awaiting commencement of negotiations for the construction of phase I that is based on the aerial approach. The TRP determined that it should consider ‘project level cost estimates’ prepared by Dulles Transit Partners as commercial, opening prices in preparation for negotiations. The amount of Dulles Transit Partners’ proposal/estimate is $2.38 billion. The TRP considered that, applying its experience and judgment, this number might reasonably be brought to $2.25 billion in negotiations.

The $2.0 billion proposal recently presented to the Commonwealth for the large bore tunnel solution was characterized as a number from which some amount up to 10 percent might be deducted in the process of negotiation. This number is in year 2006 dollars. The TRP, applying their experience and judgment, deducted just 5% and added inflationary effects to mid-point of construction, soft costs, and unallocated contingency, yielding a phase 1 cost of $2.5 billion.

Other cost estimates (for the large bore tunnel solution) have been prepared by Dulles Transit Partners; the Washington Metropolitan Area Transit Authority; ARUP Corporation on behalf of the West*Group, a large Tysons Corner landowner/developer. The latter two are generally supportive of the TRP’s view of costs.

A review of the proposals and estimates—some very preliminary—lead the TRP to conclude that $2.5 billion would be a reasonable range of total cost for constructing phase I, including the large bore tunnel through the Tysons Corner area.

E Summary

On the basis of the evaluation of the information provided, and in the professional judgment of the TRP members, we identify the following issues for consideration by the Commonwealth of Virginia:

1. The TRP believes that construction of the LBT is feasible but that it would be prudent to evaluate the horizontal and vertical alignment to optimize the ground, geometry, and cover to the extent possible. The local geology would present some challenges regardless of which alternative is chosen, but it presents some opportunities as well. Case histories that discuss EPBM excavation of mixed face conditions should be reviewed—as should recent advances in EPBM technology.

2. The TRP encourages the Commonwealth (or the successor owner) to secure fully independent estimates for use in future program decisions on the project. TRP considers it inappropriate to seek project level/owners' cost estimates from the contractor team (Dulles Transit Partners) expected to perform the construction.

3. Through appropriate allocation of risks by contracts among the parties and use of contingency management strategies and incentives, the Commonwealth can reduce excessive contingencies.

4. The Commonwealth (or the successor owner) should, through appropriate contract language, ensure that the tunneling operations are staffed by individuals possessing the requisite levels of experience and technical expertise.

5. It is important to encourage opportunities for competition throughout the procurement including the tunnel portions. Note that there are three teams of bidders on the recent Miami Port Tunnel Project, which includes a significant EPBM LBT. TRP members' contact with other representatives of the tunneling industry indicates that there is strong domestic interest in the project.

V OTHER COST ISSUES

A Life Cycle, Operating, and Maintenance Costs

Life cycle comparisons between the aerial and LTB options include both tangible and intangible items. It is likely that the LBT would have a much longer expected life than the aerial configuration (possibly 120 years versus 60 years). However, the long time frame of either alternative negates the value of a present worth advantage of one over the other.

The most tangible issues for comparisons of the two options are those of operating and maintenance costs. Fortunately, WMATA has extensive historical data for both aerial and underground sections in its 30-year history of the 103-mile current system and has provided estimates for the two options for the 4.2-mile section.

Routine operational costs are expected to be comparable for the two options. Operational costs are dominated by personnel expenses and no significant differences are expected between the aerial and tunnel configurations. An informal analysis by WMATA staff and presented to the TRP, identifies 24 issues—11 of which present advantages for the tunnel configuration and 8 of which present advantages for the aerial configuration. The remaining 5 issues suggest no discernable differences. The differences are difficult to quantify, however, since much of the work will be accomplished by existing WMATA personnel.

More tangible differences occur in anticipated maintenance and rehabilitation costs for the 18,370 feet of the aerial (and at-grade transitions) versus the LBT subway sections. Some costs are similar for both options. Major cost differentials occur in structural rehabilitation, platforms, and systems.

Total costs have been estimated on an annualized basis for a 50-year life. The total annualized costs for the aerial structure are $7.17 million per year as compared to $2.30 million per year for the tunnel system. The difference of approximately $4.8 million per year would result in $240 million in savings for the tunnel system option over the 50-year life. Assuming a rate of five percent for the time value of money, a present worth of savings of the tunnel option would result in a value of approximately $100 million at the time of the project's completion (start of revenue service).

There are a number of less tangible issues favoring the tunnel option. The tunnel option would facilitate routine inspections, and train storage could be increased with the tunnel option. The tunnel would provide improved access for disabled patrons, particularly if elevators are used for the primary vertical access system. Although weather disruptions are erratic and unpredictable, they would have less impact on the tunnel option than on the aerial configuration. It is likely that routine utility maintenance unrelated to the transit systems would be disrupted less by the tunnel option than by the aerial option.

In short, it appears that tangible benefits from the tunnel option would amount to $4.8 million per year, or $100 million in present worth.

B Schedule

Adoption of the LBT approach would impact the schedule in a number of ways because it would require the preparation of a new preliminary engineering design, a new environmental assessment, an amended record of decision, a new cost benefit analysis, and new design-build contract documents. Because many of these activities are concurrent, it is their cumulative impact that will affect the overall project schedule.

The LBT design is sufficiently different from the present preliminary engineering design to require the preparation of a supplemental environmental assessment. An accelerated effort would be required to generate a new preliminary engineering design (to an approximately 50 percent level of definition) that is sufficiently detailed to support the environmental assessment process. The time required to prepare new preliminary engineering, prepare an environmental assessment, hold public hearings, and receive the record of decision and the FTA full funding grant agreement is estimated to be 10 months.

Upon the completion of the 50 percent preliminary engineering, an updated FTA compliant cost benefit analysis would be performed. This effort would be concurrent with the environmental assessment process and thus should not impact the overall project schedule.

The construction duration for the LBT alternative design is approximately the same as the proposed aerial alignment design: 48 months. A significant factor and critical path activity in the LBT schedule is the time required to fabricate and mobilize the tunnel boring machine. It would take between 12 and 15 months to design, fabricate, and then transport a machine to the site. It would be possible to reduce this time by approximately 4 to 6 months by locating and reconditioning a used TBM.

The TRP estimates that the cumulative impact on the schedule of all of these factors would extend the present project schedule by approximately 12 months.

C Rights-of-Way

Dulles Transit Partners calculated the right-of-way cost for the aerial alignment on the basis of a 95 percent complete preliminary engineering design. The right-of-way cost for the tunnel option is based on conceptual drawings; therefore some care should be exercised in concluding the difference between the two options until the tunnel option is more fully developed. On the basis of Dulles Transit Partners’ analysis, the right-of-way savings realized by choosing the tunnel option would be $25 million.

WMATA performed a spot review of Dulles Transit Partners' analysis and determined that the savings would be greater with the tunnel option. Their review shows $36 million in savings with the tunnel option. The increase in savings in WMATA's right-of-way estimate is primarily the result of the fact that less right-of-way would be required because utility relocation would not be as extensive. The TRP elected to use an average of approximately $30 million.

Because the cost estimate includes a 45 percent condemnation settlement additive as well as incremental property escalation to the base parcel cost, every dollar saved from reduced land acquisition has a multiplier effect on the total right-of-way estimate.

	Aerial Alignment	**Tunnel**	**Difference**
Right-of-Way Cost *(Prepared by DTP)*			
Parcel Cost	$58,973,190	$43,519,000	
Condemnation Settlement (45%)	$26,537,936	$19,583,550	
Subtotal	$85,511,126	$63,102,550	
Incremental Property Escalation (10%)	$8,511,113	$6,310,255	
Total	**$94,062,238**	**$69,412,805**	**-$24,649,433**
Right-of-Way Cost *(Prepared by WMATA*)*			
Total	**$94,062,238**	**$58,062,238****	**-$36,000,000**
* From a March 24, 2006, letter from J. Haggins to C. Carnaggio ** WMATA did not believe that the DTP cost included the savings from reduced property expenses resulting from reduced utility relocation.			

Although the time savings associated with fewer right-of-way acquisitions for the tunnel option was not reviewed, it is reasonable to believe that this will be realized. It is not known if these time savings will result in compression of the overall project schedule.

Right-of-way acquisitions should be carefully reviewed to take advantage of the opportunity to redevelop the land following construction. This is especially applicable to the tunnel option since land near the station area would command a premium price. In addition, air rights above the station areas may be considered for development, generating additional revenue.

D Roadway and Traffic Impact

The aerial alignment crossing of the Capital Beltway interchanges would require close coordination with the Capital Beltway's High Occupancy/Toll (HOT) Lanes project. At this time, the HOT Lanes project has not progressed sufficiently to indicate whether the proposed aerial alignment crossing requires modification. Therefore, the current aerial alignment plan is based on the existing configuration of the beltway. As currently planned, the widening of the beltway's outer loop roadway bridge over Route 123 is required. This would entail the closure of the median shoulder and lane shifts on the beltway's inner and outer loops. In addition, ramps at Route 123 would be reduced to 12 foot lanes with no shoulders.

Almost all of the aerial alignment along Route 123 is on the northwestern side. Therefore, most of the construction activities would take place behind the concrete barriers placed on top of the existing curb line. Trucks and other construction equipment would access the construction site from Route 123. The construction of piers and pier foundations would impact the cross streets and ramps in that corridor. In addition, at Tysons Boulevard, the right turn lane to Route 123 would be closed temporarily during the construction of the bus platform.

The aerial alignment would produce the greatest traffic impact along Route 7. Dulles Transit Partners has proposed a multiphase plan to handle the maintenance of traffic, and the service roads would be eliminated as part of this plan. The mainline Route 7 would be built to its ultimate cross section—that is, four lanes in each direction. Temporary concrete barriers would be placed along the outside edge of existing lanes in stage 1 to allow closure of the service roads and build a new Route 7 pavement section. These concrete barriers may limit sight distance at more than two dozen business entrances. The Virginia Department of Transportation also expressed concerns about the impact of the concrete barriers on snow removal operations.

Traffic Impacts	**Aerial**	**Tunnel**	**Comments**
I-495 HOT Lanes Project	More	Less	Potential impact may be significant
Route 123	Even	Even	Aerial - most of the work will be outside roadway. Right turn lane closure at Tysons Boulevard
Route 7	More	Less	Aerial – service drives eliminated.
Businesses Impacted	More	Less	Tunnel may impact up to 16 entrances fewer than aerial.
Businesses - Retail	More	Less	
Dulles Access Road (near Route 7)	Less	More	Portal construction, staging area and muck removal
Muck Removal	Less	More	Aerial – 0.27 M cu. yds. of muck Tunnel – 1.7 M cu. yds. of muck

The traffic impact on Route 7 resulting from the elimination of service roads, the location of concrete barriers, the frequent movement of construction equipment and trucks that are accessing the construction site from the road, and even the rubbernecking by motorists could prove significant. Work is progressing on a congestion mitigation plan that should reduce the traffic impact somewhat, depending on the strategies adopted and funding available. A particular concern is the holiday shopping season, when the need to maintain the construction schedule and the desire to serve retail customers could potentially conflict.

Even under the best of circumstances, maintaining access to businesses during utility relocation and aerial structure construction would be a challenge. The tunnel option offers much less disruption to the businesses along Route 7, especially those that are situated some distance away from the station areas, where some utility relocation would be necessary.

The portals for the tunnel option would be in the median of the Dulles access road and the I-66 connector road. The west tunnel portal in the median of the access road would most likely serve as the area for the construction operation, the material staging area, and the area for muck removal. It is estimated that approximately 1.7 million cubic yards of muck would be removed during the tunnel construction. This removal would require an around-the-clock operation involving several hundred truck-trips per day. Trucks would move on and off the median and merge with traffic on both the Dulles Access road and the toll road. Although the other phase 1 work taking place in the median would exert a significant impact on traffic, the tunnel construction would exacerbate the traffic impact.

The removal of muck would also present a challenge in terms of truck haul routes. One potential disposal location is in Lorton, Virginia, approximately 20 miles from the project site. Another site—at the future location of the rail service and inspection yard on the north part of the Dulles Airport property—may also become available.

The construction operation for the stations and the construction of the ventilation shafts should be analyzed further to determine the traffic impacts. With respect to Route 7 and Route 123, it is reasonable to believe that the roadway and traffic impacts of the tunnel option would be substantially less than those produced by the aerial option. With respect to the Dulles access road, the tunnel mucking and material handling activities would have significant impact on the roadway and traffic. Nevertheless these issues do appear to be manageable.

E Utilities

Utility relocation and coordination are critical components of the Dulles Corridor Metrorail Project. The utilities report prepared by Dulles Transit Partners and dated June 2006 notes that 28 separate utility companies would be affected by the aerial alignment. At this time, 183 conflicts have been identified—50 percent of them along the Route 7 roadway, 30 percent along the Route 123 roadway. Approximately 45 separate utility easements would be needed to accommodate the utility relocation, nearly 70 of which would be along the Route 7 corridor.

The traffic impact during the utility relocation required for the aerial option would be significant, especially in the Route 7 corridor. Maintaining the entrances to businesses would be challenging, as would maintaining the continuity of utility service during relocation.

	Aerial Alignment	Tunnel	Comments
Utility Conflicts	More	Less	50% of the conflicts along Route 7
Rights-of-way and easements required	More	Less	70% of the utility easements required along Route 7
Traffic Impact	More	Less	Service Drives to be closed
Businesses Impacted	More	Less	Entrances to businesses and possible service interruptions
Cost	$24.6 M	$4.0 M	
Utilities Underground	Yes	Partly	
Utility Corridor	Yes	No	

Under the proposed planned management approach to utility coordination for the project, Dulles Transit Partners would pay all labor and material costs involved in relocating utilities in conflict with the project.

Due to the preliminary nature of the tunnel option, the number of conflicts and their impacts have not yet been determined. However, there would likely be minimal conflicts at portal locations, at stations, and at ventilation and emergency egress shafts. The utility conflicts at these localized construction areas are not clear at this time although Dulles Transit Partners estimates that the utility relocation cost for the aerial and tunnel options is $24.6 million and $4 million, respectively.

It is reasonable to conclude that the areas of the highest impact and conflicts are along Route 7. The tunnel option would certainly decrease the number of conflicts and thus ease the relocation effort. This would also result in reduced right-of-way requirements.

F Summary

The TRP assesses that the cumulative financial effect of the factors considered in this chapter is as follows:

1. Operations and maintenance costs: present worth savings for the LBT solution of about $100 million, based on annual savings of $5 million.

2. Schedule impact costs: included in the estimated cost increase for the LBT approach

3. Rights-of-way: savings of approximately $30 million for the LBT

4. Roadway and traffic impacts: considerably reduced impacts through the project area and considerably increased impacts at the Dulles access road and on mucking haul roads for the LBT. These impacts are not quantified, but are acknowledged as sources of project risk.

5. Utilities: savings of an estimated $20 million to $40 million to be realized with the LBT option

In summary the approximate savings for the items in this chapter for the LBT alternative would be:

- $70 million of capital cost savings;
- $100 million of operations and maintenance cost savings ($5 million per year).

VI ECONOMIC AND BUSINESS IMPACTS

For the purposes of this report, the economic and business impacts are divided into short-term impacts and long-term impacts. Short-term impacts are defined as impacts that would occur during construction and are included in section D of chapter IV. This section of the report will describe in more detail the long-term economic and business impacts.

Although a number of studies have been conducted in an attempt to quantify the economic and business benefits of a rail system and specifically a tunnel system, this report presents information for both alternatives in more general terms.

A Proposed Aerial Approach

The proposed aerial alignment through the Tysons Corner area would consist primarily of an aerial structure and approximately 2,100 feet of tunnel at the interchange of Route 123 and Route 7. The proposed aerial structure would rise as high as 70 feet from the ground, and the pedestrian passageway and barrier walls would be visually obtrusive.

The aerial alignment would restrict future development in the Tysons Corner area to a much greater degree than would the tunnel alignment. Some of the visual drawbacks of the aerial structure could be mitigated through thoughtful design, but they could never be eliminated. The aerial structure would limit the opportunity to fully develop Tysons Corner, and might discourage developers and residents from embracing it as a prime residential area. The potential for development and future redevelopment—particularly the potential for the residential component of such development—would be significantly diminished by the aerial alignment.

B Large Bore Tunnel Alternative

The LBT option allows for a more fully integrated and more effective transit-oriented development of Tysons Corner. The tunnel option eliminates the need for a physical structure—and a visual impediment—through the heart of Tysons Corner. Development density would be increased in proximity to the station entrances, and it is possible that air rights could be secured at the station locations, further enhancing development potential. Other advantages of the tunnel option are:

- In accordance with the Fairfax County Comprehensive Plan, Route 7 could be reconstructed as a boulevard that would connect the two sides of the roadway and not act as a divider.
- Stations could be better integrated with businesses and offer direct access to major businesses.
- The architecture/urban form/development of adjacent parcels would not be confined, thereby providing a more fluid design for Tysons Corner.

- The pedestrian sense of scale would be preserved and thus would promote more pedestrian-friendly activities that would promote a more vibrant livable community.
- Parcels along the north side of Route 123 could be fully developed.

C Summary

Tysons Corner is often described as the central business district of Fairfax County, a county that boasts a number of successful business centers. When combined with the Dulles Corridor, this area is the second largest employment center in the entire Washington metropolitan area. In terms of tax revenue, Tysons Corner generates more tax dollars than any other single area in the county. Therefore, it is vital to the county, the region, and the state to select the approach to the Dulles Corridor Metrorail Project that will boost this success.

The aerial option could be completed more quickly and less expensively than the tunnel option. However, it is clear from many different perspectives that the tunnel option could promote better integrated development of Tysons Corner. The tunnel option could provide the impetus needed to transform Tysons Corner from an auto-dependent, pedestrian-hostile, business-and-retail-oriented edge city to an urban community that is pedestrian-friendly and enhanced by substantial residential fabric. Choosing the tunnel option would not in and of itself transform Tysons Corner, but it would facilitate a transformation.

With more attractive development in place and with more development density allowed by the tunnel alternative, it is reasonable to assume that the tunnel option would provide greater positive long-term economic and business impacts than the aerial option.

APPENDIX

ACRONYMS

ASCE	American Society of Civil Engineers
DAR	Dulles Access Road
DIAAH	Dulles International Airport Access Highway also known as Dulles Access Road (DAR)
DTE	Dulles Transit Engineers
DTP	Dulles Transit Partners
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPDM	Earth Pressure Balance Machines
FEIS	Final Environmental Impact Statement
FTA	Federal Transit Administration
LBT	Large Bore Tunnel
MOT	Maintenance of Traffic
MWAA	Metropolitan Washington Airports Authority
NATM	New Austrian Tunneling Method
NEPA	National Environmental Policy Act
OD	Outside Diameter
O & M	Operations and Maintenance
PE	Preliminary Engineering
PPTA	Virginia Public Private Transportation Act
ROD	Record of Decision
TBM	Tunnel Boring Machine
TRP	Tunnel Review Panel
VDOT	Virginia Department of Transportation
VDRPT	Virginia Department of Rail and Public Transportation
WMATA	Washington Metropolitan Area Transit Authority