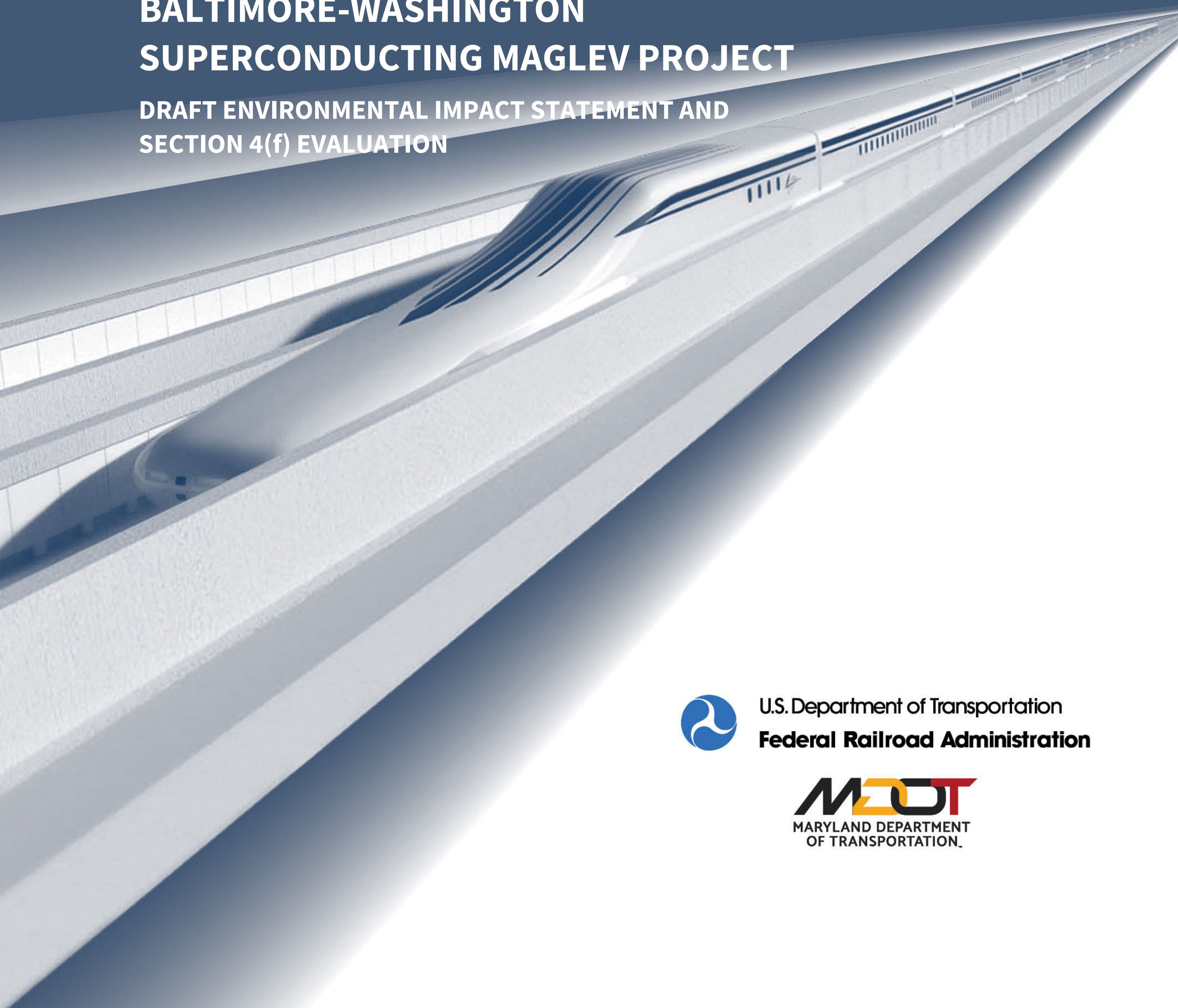
Appendix G10.

Electrical Coordination Technical Memorandum

Materials Provided by the Project Sponsor

BALTIMORE-WASHINGTON
SUPERCONDUCTING MAGLEV PROJECT

DRAFT ENVIRONMENTAL IMPACT STATEMENT AND
SECTION 4(f) EVALUATION



U.S. Department of Transportation
Federal Railroad Administration

MARYLAND DEPARTMENT
OF TRANSPORTATION

BALTIMORE-WASHINGTON SCMAGLEV PROJECT

ELECTRICAL COORDINATION TECHNICAL MEMORANDUM

REVISION: 1

DATE: OCTOBER 9, 2020

BWRR

BALTIMORE-WASHINGTON RAPID RAIL

BALTIMORE-WASHINGTON SCMAGLEV PROJECT

ELECTRICAL COORDINATION TECHNICAL MEMORANDUM

4.3 PRELIMINARY ENGINEERING

REVISION: 1

DATE: OCTOBER 9, 2020

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TABLES

APPENDICES

NOTES/REVISIONS FOR VERSION CONTROL

Revision 0: 2020-05-08

Revision 1: 2020-10-09

1. PURPOSE OF DOCUMENT

The purpose of this Technical Memorandum is to provide a summary of methodologies and analysis related to the energy consumption, sources of power, utility coordination plans and assumptions for the SCMAGLEV system-wide electrical power substation facilities and natural gas delivery points. The summary information also covers data on existing electricity infrastructure and planned capital improvements and upgrades by electric and gas utilities.

The primary electric utility providers in the Baltimore-Washington corridor are BGE and PEPCO; the primary natural gas providers are BGE and Washington Gas. BGE is Maryland's largest natural gas and electric utility, delivering power to more than 1.25 million electric customers and more than 650,000 natural gas customers in central Maryland. BGE and PEPCO are subsidiaries of Exelon.

PJM Interconnection is the regional transmission organization (RTO) that coordinates the movement of wholesale electricity in thirteen states including Maryland and the District of Columbia. BGE and PEPCO are Regional Transmission Operator (RTO) members of PJM. PJM is responsible for the planning, reliability and market coordination of the high voltage transmission network in the majority of the Northeast Corridor. PJM RTO installed generation is constantly monitored and reported. Publicly available parameters include:

Grand Total Installed Capacity	200,751 MW
Total Installed Renewable Capacity	12,800 MW

Details on fuel mix of installed capacity is included in Section 3.5 of this Memo.

BWRR is proposing to source the power needs of the Baltimore-Washington high speed train project utilizing a combination of wind power and purchased power, with an emphasis on renewable non-emission sources. PJM will be a key player in the approval process where wind power will be sited and inter-connected into the transmission system. PJM coordinates an extensive network of transmission lines throughout the State of Maryland.

2. ENERGY CONSUMPTION AND SOURCES OF POWER

2.1 POWER CONSUMPTION FOR OPERATIONS

Detailed power requirements for the Baltimore-Washington Project operations cannot be finally determined without final design and a final operating plan.

Power consumption for operations of the SCMAGLEV project includes the trains running consumption, substation power, passenger stations, the Train Maintenance Facility, the FA/EEs and other ancillary facilities of the Project.

2.2 POWER CONSUMPTION BY TUNNEL BORING MACHINES

During the construction phase, eight (8) tunnel boring machines (TBMs) will be operating for Alignment Alternative J, each requiring approximately 14 megawatts of power. Alignment Alternative J1 would have nine (9) TBMs. BGE and PEPCO are interested in providing this power from the grid based on the tunneling schedule. TBMs will use temporary standby generation facilities sited at each TBM launch site.

2.3 SOURCES OF POWER

The sources of power information is included in Section 3.6 of this Technical Memorandum.

3. ADDITIONAL DETAILS

3.1 GROUND DISTURBANCES ASSOCIATED WITH ELECTRIC POWER

The electric utility transmission and distribution power delivery points of interconnection to the mainline substations, passenger stations and TMF are shown on the drawings.

3.2 NATURAL GAS DELIVERY POINTS FOR STATIONS AND FACILITIES

The SCMAGLEV system will require natural gas to heat offices and work areas. Natural gas delivery points will include all ventilation buildings, maintenance facilities, and passenger stations. The design of the natural gas delivery network will be based upon the SCMAGLEV facility pressure and flow ratings of the connected loads. BGE and Washington Gas references and links are listed at the end of this memorandum. Proposed gas line connections are provided on the drawings.

3.3 EXISTING ELECTRICITY INFRASTRUCTURE

PJM is the Regional Transmission Organization (RTO) responsible for planning, reliability, and market coordination for the bulk power high voltage transmission network serving the District of Columbia and 13 states, including Maryland. For the SCMAGLEV project, PJM would perform Feasibility, System Impact, and Facilities studies in response to the BWRR application for network transmission service as an “Eligible Retail Customer”. PJM coordinates with BGE and Pepco to facilitate the required transmission line interconnections at 115kV and 230kV.

The Code of Maryland, COMAR 20.50.12.11, requires electric utilities to submit an annual performance report by April 1 of each year. In September 2019, the Public Service Commission of Maryland issued its “Order on Electric Reliability Performance Reports” based upon its review of the 2018 BGE and Pepco annual performance reports. The SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) results are shown in Table 3.1 below:

Table 3.1 SAIDI and SAIFI Ratings

BGE AND PEPCO RELIABILITY PERFORMANCE INDICES FOR 2018		
PERFORMANCE INDEX TARGETS AND RESULTS	**BGE**	**PEPCO**
SAIDI TARGET	162.6	109
SAIDI RESULTS	105.6	60
SAIFI TARGET	1.22	1.04
SAIFI RESULTS	0.99	0.8

Both BGE and Pepco met their safety standards; Pepco posted the best SAIDI and SAIFI results of all Maryland electric utility companies.

3.4 PLANNED CAPITAL IMPROVEMENTS / UPGRADES BY UTILITIES

As confirmed by the Public Service Commission, "PJM in its 2018 Regional transmission Expansion Plan (RTEP) authorized about $3 billion in system transmission improvement projects".[3] PJM annually prepares an RTEP based upon a 15-year forecast. Studies will be conducted by PJM to assess the impact of SCMAGLEV load on existing transmission infrastructure and existing capacity and energy contracts; this will be reflected in future PJM RTEPs.

The SCMAGLEV application for multiple commercial interconnections for natural gas will initiate the BGE and Washington Gas delivery design processes. Proposed gas connections are provided on the drawings.

3.5 ELECTRIC GENERATION SOURCES

PJM portrays its present portfolio of generation resources in the attached graphic on next page.

A link is listed below that portrays the dispersal of proposed renewable generation sites. PJM dispatches its generation portfolio in accordance with its market-based reliability and cost methodologies. The Public Service Commission of Maryland states, in Reference No. 3 below, that Maryland's power generation is 25% coal, 44.3% nuclear, 19.7% gas, 5.8% hydro, 4.9% renewable, and 0.3% oil.

3.6 SOURCE OF RENEWABLE POWER

BWRR is proposing to use renewable power sources for the Baltimore-Washington Project to the maximum extent possible. Details are included in Appendix A.

3.7 REFERENCES

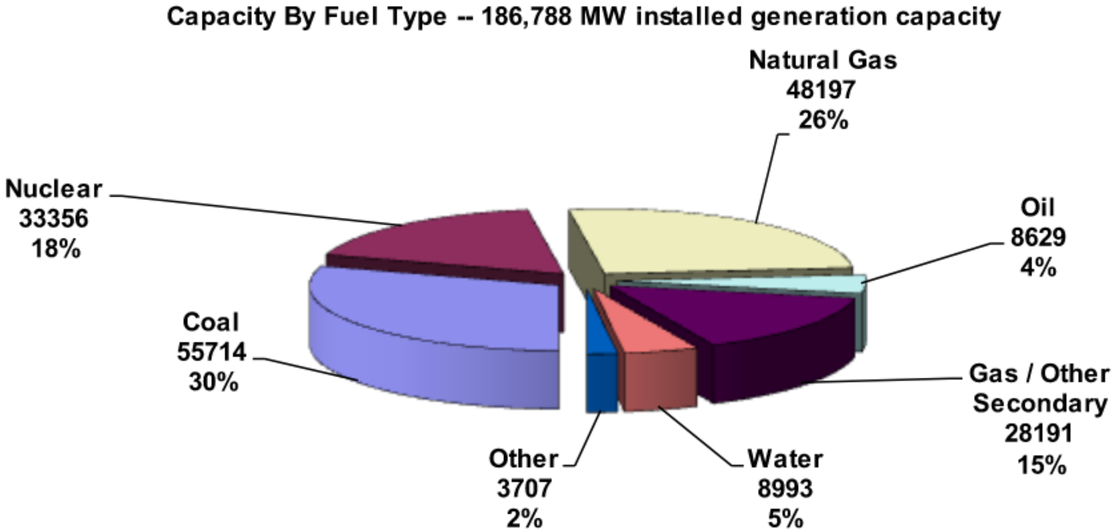
1. BGE, "Natural Gas and Electric Service Guide for Commercial, Industrial and Residential Customers", Baltimore, Maryland
2. Public Service Commission of Maryland, "Order on Electric Reliability Performance Reports", Order No. 89260, September 6, 2019
3. Public Service Commission of Maryland, "Ten-Year Plan (2019-2028) of Electric Companies in Maryland", December 2019

3.8 LINKS

1. PJM Realtime Generation Mix: https://www/pjm.com/markets-and-operations.aspx
2. PJM Proposed Renewable Projects: https://mapservices.pjm.com/renewables/
3. Washington Gas: https://www.washingtongas.com/safety-education/education/construction-processes
4. BGE: https://www.bge.com/MyAccount/Documents/combinedcustomerbooklet_single%20pages_rev102313.pdf

PJM RTO

(MidAtlantic, AP, ComEd, AEP, Dayton, Duquesne, Dominion, ATSI, DukeOK & EKPC Regions)



Effective 6/1/2019

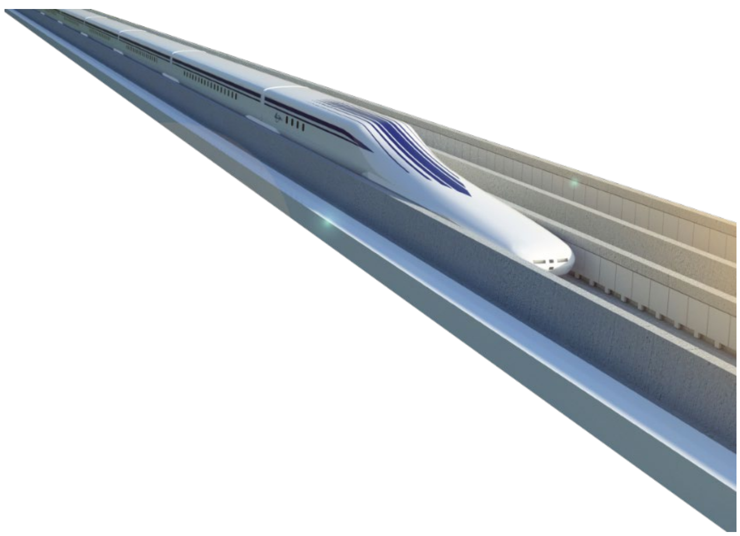
Fuel Type Group	Fuel Type SubGroup	Installed Capacity	External Purchases	External Sales	Total Capacity
Coal	Bituminous Coal	47309.8	1369.8	-95.8	48583.8
	Sub-Bituminous Coal	6319.4	717.0	-117.0	6919.4
	Waste Coal	2085.0			2085.0
Nuclear	Nuclear	33356.4	100.0	-454.7	33001.7
Natural Gas	Natural Gas	48196.7	180.0	-339.2	48037.5
	Natural Gas w/ Secondary	28190.7	165.0	-426.0	27929.7
	Other Gas	184.0			184.0
Petroleum	Distillate Fuel Oil	4064.5			4064.5
	Jet Fuel	11.0			11.0
	Kerosene	223.6			223.6
	Residual Fuel Oil	4194.2		-322.9	3871.3
	Petroleum Coke	136.0			136.0
Solid Renewable	Municipal Solid Waste	584.9			584.9
	Wood Waste	45.4			45.4
Liquid Renewable	Black Liquor	42.0			42.0
Gaseous Renewable	Landfill Gas	949.7			949.7
Other Renewable	Water	8993.4	385.0	-95.0	9283.4
	Wind	1198.6		-6.4	1192.2
	Solar	702.6			702.6
Demand Side	Demand Resource	9583.0			9583.0
	Energy Efficiency	3068.6			3068.6
External	R.E.C. Contract		252.0		252.0
Grand Total		199439.5	3168.8	-1857.0	200751.3

BALTIMORE-WASHINGTON SCMAGLEV PROJECT

ELECTRICAL COORDINATION TECHNICAL MEMORANDUM

Appendix A

RENEWABLE SOURCES OF POWER



BWRR
BALTIMORE-WASHINGTON RAPID RAIL

BALTIMORE-WASHINGTON SCMAGLEV PROJECT

RENEWABLE SOURCES OF POWER

1. Summary

The Baltimore Washington Rapid Rail is dedicated to sustaining our planet through utilization of renewable energy resources. Baltimore Washington Rapid Rail intends to source electricity required for the train operations to the greatest extent possible from renewable wind energy. SCMAGLEV operations will include substation power, passenger stations, the Train Maintenance Facility and other ancillary facilities of the Project. To match this need, BWRR intends to construct its own wind energy projects capable of providing enough power across viable wind resource locations in western Maryland in the wind rich area of the tristate, Maryland, Pennsylvania and West Virginia. Based on available wind data from National Renewable Energy Laboratory (NREL), viable wind resource areas have been identified having a minimum Wind Power Class 3, which is wind speed greater than 6.4 meters per second @ 50-meter height.

2. Background and Requirements

Detailed power requirements for the Baltimore-Washington Project operations cannot be finally determined without final design and a final operating plan.

For the SCMAGLEV Project, Section 2 of the Tech Memo includes information of power consumption and facilities requiring electrical power.

BWRR's mission is to provide a fast and efficient means of travel between Baltimore and Washington DC reducing the number of Vehicle Miles Traveled (VMT) and subsequently a drastic reduction of greenhouse gasses, positively effecting the environment. The SCMAGLEV Project intend to use non-fossil fuel based electric generation, to ensure the greenhouse gasses reduction. BWRR intends to eliminate the need for additional burning of fossil fuels to fulfill our train's energy requirements by installing renewable wind power plants to source the electricity needs. As a backup alternative to constructing our own wind power plants, if needed BWRR intends to procure energy with an emphasis on non-emitting sources from the marketplace. For example, Constellation Energy, BGE's parent company, provides such resources and has expressed serious interest.

3. Team Experience in Wind Power Development

BWRR's affiliate company, Synergics Wind Energy (SWE), has extensive knowledge and experience in the harnessing of wind energy to develop sustainable wind energy plants. Since 1980, Synergics group has planned, engineered, financed, constructed and operated over 60 renewable energy power projects worldwide. Their expertise covers the spectrum of complex issues critical to developing, financing, constructing and operating clean power projects in 10 states and 13 foreign countries. Synergics energy specialists work closely with local landowners, government and utilities, international lenders, investors and local private power companies as they face the challenge of establishing a framework for successful renewable energy development. Wind power projects developed by Synergics are operating successfully in Maryland and Pennsylvania.

Following wind projects developed by SWE are operating successfully in Western Maryland, supplying power to the grid making these projects financially rewarding for the counties, State of Maryland, landowners and investors.

Roth Rock Wind Energy Project

The 50 MW Roth Rock Wind Project is a success story of Synergics' project management which included engineering, permitting, procurement, financing and construction thru start-up, testing and commissioning of twenty Nordex N90/2500 Wind Turbines Generators for commercial operation on December 31, 2010 in Garrett County, Maryland. The project is located on Backbone Mountain. Nordex was responsible for logistics, shipping, transportation, un-loading, handling, mechanical erection and commissioning of the Wind Turbine components. The Roth Rock Wind Energy Project consists of 20 Wind Turbines along with a switchyard and project substation.

Fourmile Wind Energy Project

The 60 MW Fourmile Wind Energy project includes the complete development, permitting and construction of a wind farm facility including but not limited to engineering, procurement, and civil infrastructure construction and related work to support the installation, commissioning and testing of the Fourmile Ridge Wind Power Project located near Frostburg, Maryland. This facility consists of 16 – Nordex N100/2500 turbines, a collection system, switchyard and project substation interconnected to a 138 kV transmission line. The project is now owned by Exelon, the parent company of BGE and Constellation.

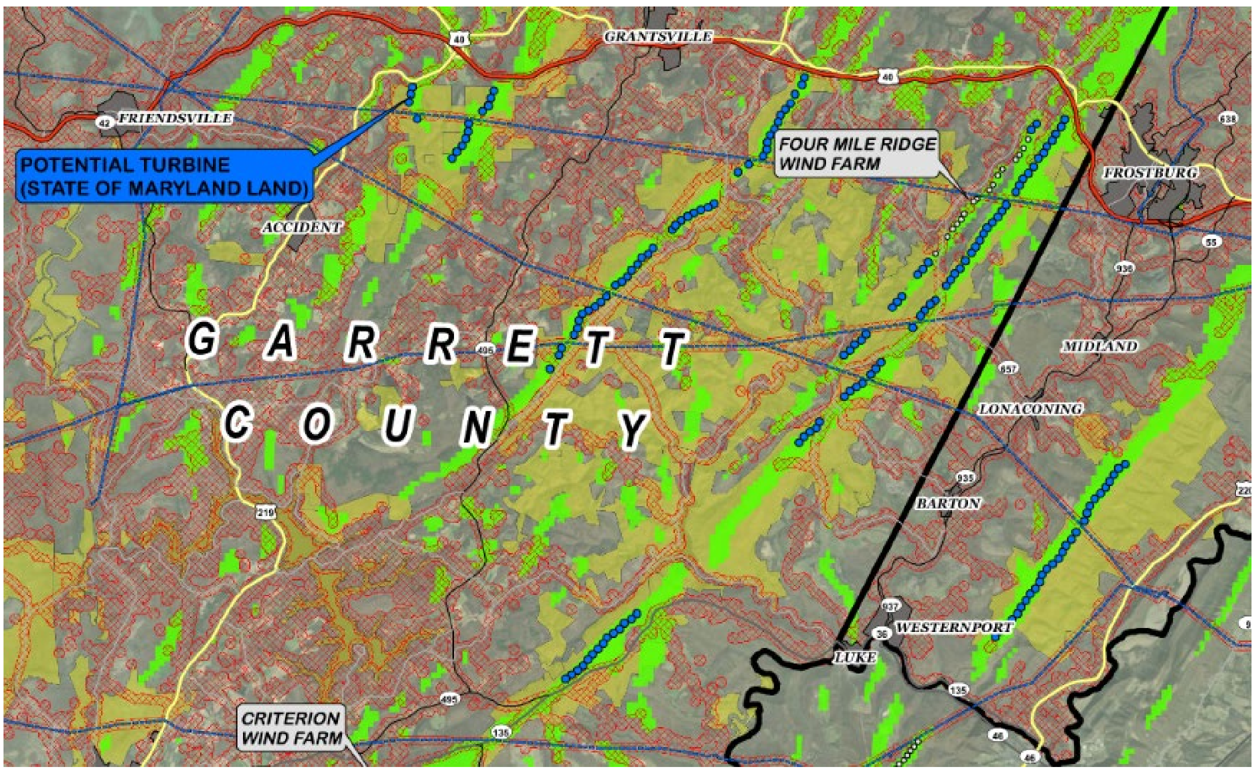
Chestnut Flats Wind Project

The 38MW Chestnut Flats Wind project includes the project development with Gamesa Energy. Gamesa did the permitting and construction of the wind farm facility, which is located in Logan Township, Blair County, northwest of Altoona, Pennsylvania. The project utilizes 18 G90 and one G87 Gamesa turbines with a rated capacity of two megawatts. Synergics negotiated the Power Purchase Agreement with

Delmarva Power and Light Company, a subsidiary of PHI, to sell the energy produced under a 20-year agreement. The project was later acquired by EDF RE in November 2011.

4. Plan to develop and construct BWRR's own wind capacity source

Western Maryland's mountainous region features land of high elevation and strong winds, making it a rich frontier for harnessing wind power and supplying it to the power grid. BWRR's renewable energy siting consultants Bennett Brewer & Associates (BBA) have studied the areas throughout western MD, and immediate surrounding states (Pennsylvania and West Virginia), and have identified viable build locations to harness wind energy (i.e. a viable build location being an area that is accessible for construction to a reasonable level and areas that have a consistent amount of wind energy allocated to the areas).



With the use of larger machinery on a contiguous tract of land, it is possible to have lessen environmental impact. Larger windmills in a condensed location scenario require lateral separation (3 rotor diameters or roughly 450m) between the turbines in a row on the same mountain ridge and a parallel separation (5-7 rotor diameters or roughly 750-1000m) between the turbines on adjacent mountain ridges.

Wind energy technology has evolved into larger and larger wind turbines with less installed cost, wider spacing and more power output. Below are the potential wind turbine generators that BWRR would consider utilizing for a western Maryland project.

Vestas V150-4.2 MW
Avg. Power: 4.2 MW
Rotor Diameter: 150 m
Approx. Acres per Turbine required: 22.23

GE 5MW-158 Cypress
Avg. Power: 5.3 MW
Rotor Diameter: 158 m
Approx. Acres per Turbine required: 24.67

Nordex N155
Avg. Power: 4.5 MW
Rotor Diameter: 155 m
Approx. Acres per Turbine required: 23.74

Siemens Gamesa SG 5.8-170
Avg. Power: 6.2 MW
Rotor Diameter: 170 m

Siemens Gamesa SG 5.0-145
Avg. Power: 5 MW
Rotor Diameter: 145 m
Approx. Acres per Turbine required: 20.78

5. Maryland Approval Process:

The MD Public Service Commission is the state agency that regulates gas, electric, telephone, water, and sewage disposal companies in Maryland. The Commission has the authority for supervision and regulation of activities by public service companies. Subject to the jurisdiction of the Commission are electricity suppliers as well. As a franchised railroad BWRR has the power to construct power generation for its facilities pursuant to its franchise and Certificate of Public Convenience and Necessity (CPCN).

In addition, most projects in Western Maryland would be 70MW or less qualifying them for an exemption from CPCN requirements under MD State Regulation § 7-207.1 which allows for a wind-powered generation facility (or any other energy generation project) to receive a CPCN exemption if:

- The generating station is land-based.
- The capacity of the generating station does not exceed 70 megawatts.
- The electricity that might be exported for sale from the generating station to the electric system is sold only on the wholesale market pursuant to an interconnection, operation, and maintenance agreement with the local electric company; and
- The Commission provides an opportunity for public comment at a public hearing

All four currently operating wind plants in Maryland received this exemption from the MD-PSC.

Each wind project BWRR has reviewed will have its own interconnection and substation, and would comply with above requirements, BWRR anticipates it will take 13 project sites.

6. State-Owned Viable Wind Power Locations

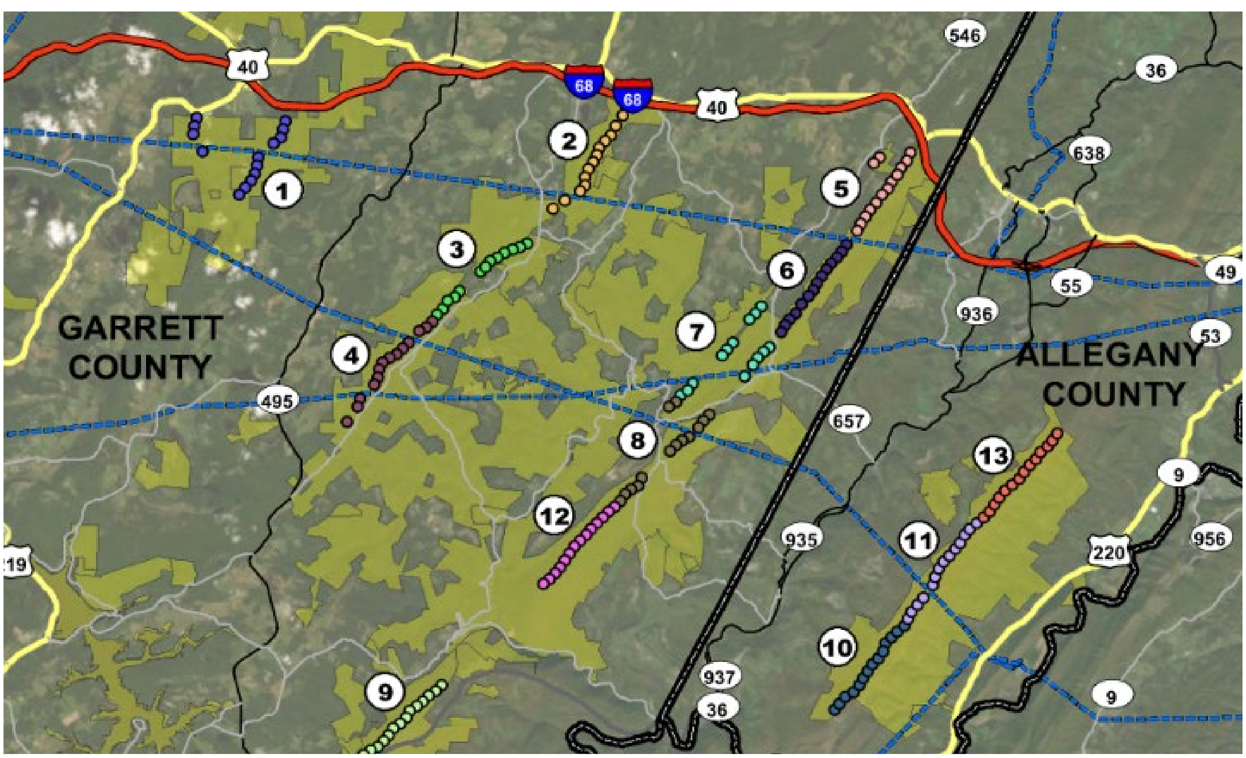
States are the largest owner of real estate in the tri-state area and the wind studies have shown that some of the best wind resources to be harnessed are on State owned mountain ranges. A study of existing wind turbine facilities in the tri-state area reveals that current operating turbine locations:

- Maryland Wind Turbines: 76 Locations
- Pennsylvania Wind Turbines: 781 Locations (780% more than Maryland)
- West Virginia Wind Turbines: 424 Locations (457% more than Maryland)

In all 3 states, many of the best wind resource lands are State owned lands.

7. Resolution

BWRR's consultants has completed preliminary review of potential wind power locations for western Maryland. In that study, we evaluated various possible turbine locations across several mountain ranges including utilizing only State land and establishing requisite setbacks. These locations have enough potential of wind development fulfilling BWWR's power needs for the Baltimore-Washington high speed train project.



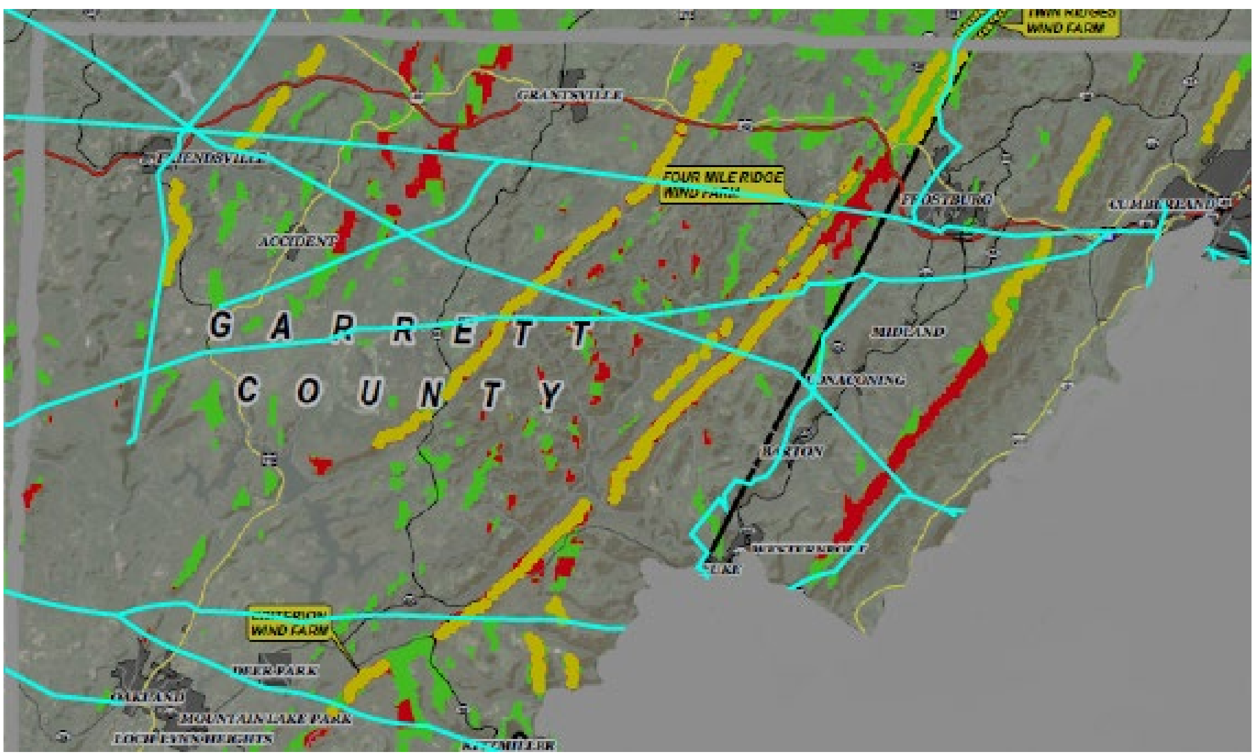
By capitalizing on the existing electricity transmission networks in the area, BWRR intends to provide their energy needs by wind power, produced by wind turbines designed, permitted and constructed in Maryland.

The primary electricity providers in the Baltimore-Washington corridor are BGE and PEPCO. BGE is Maryland's largest natural gas and electric utility, delivering power to more than 1.25 million electric customers and more than 650,000 natural gas customers in central Maryland. PEPCO provides safe and reliable energy service to approximately 894,000 customers in the District of Columbia and Maryland. Both companies are subsidiaries of Exelon.

PJM Interconnection is the regional transmission organization (RTO) that coordinates the movement of wholesale electricity in thirteen states to include Maryland and the District of Columbia. They are responsible for the planning, reliability and market coordination of high voltage transmission network in the majority of the Northeast Corridor. BGE and PEPCO are both part of PJM's system. As PJM will have an approval in the interconnection of wind power projects, BWRR will coordinate with PJM as part of the development process. As of now, PJM maintains an average of 1200 MW of wind power throughout their transmission locations.

PJM's already contains an extensive network of transmission lines throughout Maryland.

Transmission Lines in Western Maryland



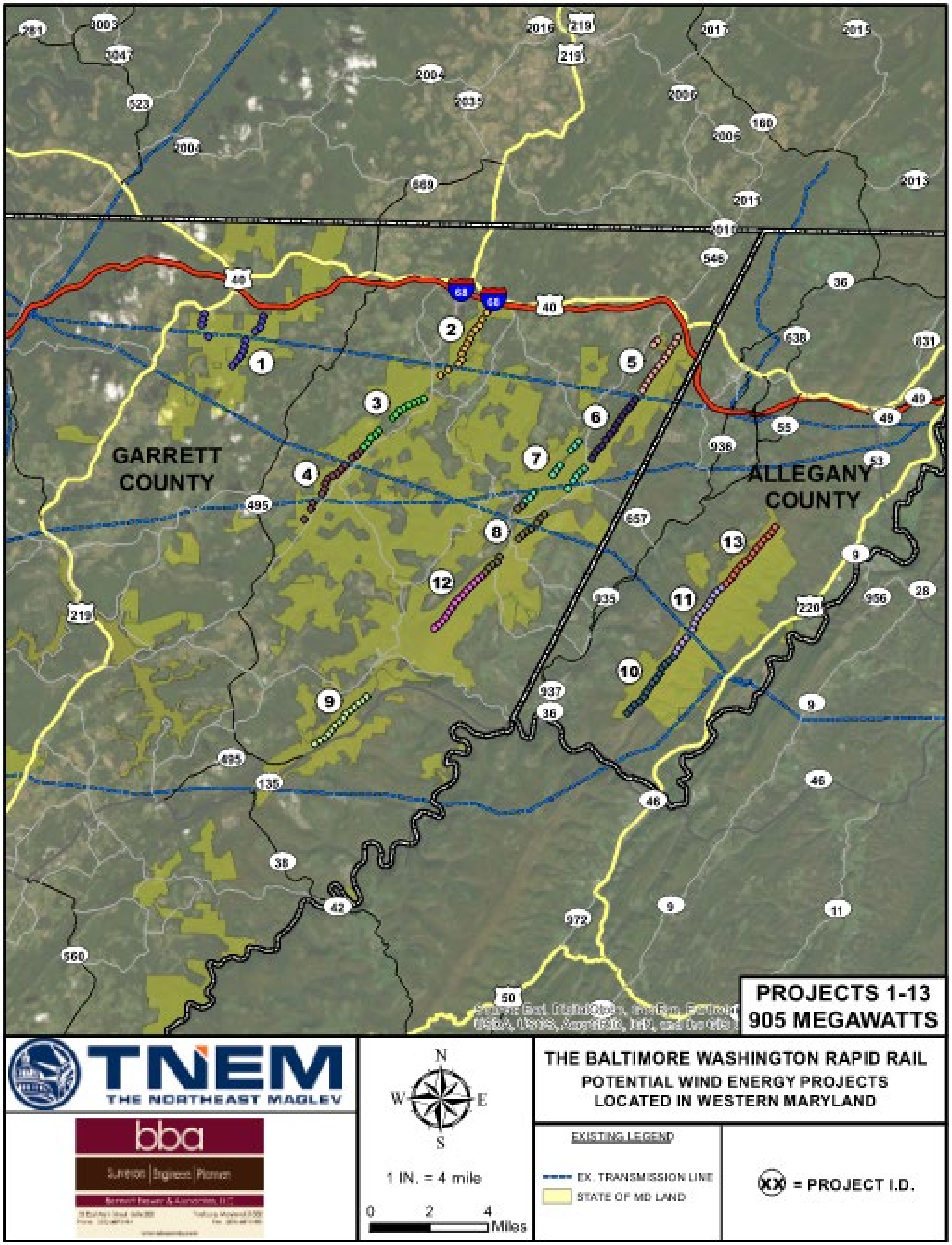
Link: hifld-geoplatform.opendata.arcgis.com/maps/edit?content=geoplatform%3A%3Aelectric-power-transmission-lines

<u>Exhibit 1</u> includes examples of potential viable wind projects.

Exhibit 1

This Exhibit includes the following maps of the proposed wind development program:

1. Overall Site Layout
2. West of Grantsville (Site 1)
3. North Savage State Forest (Site 2)
4. Mid- Savage State Forest (Site 3)
5. South Savage State Forest (Site 4)
6. North Savage River State Forest (Site 5)
7. Upper Mid Savage River State Forest (Site 6)
8. Mid- North Savage River State Forest (Site 7)
9. Lower Mid Savage River State Forest (Site 8)
10. North Backbone Mountain (Site 9)
11. South Dan’s Mountain (Site 10)
12. Mid Dan’s Mountain (Site 11)
13. South Savage River State Forest (Site 12)
14. North Dan’s Mountain (Site 13)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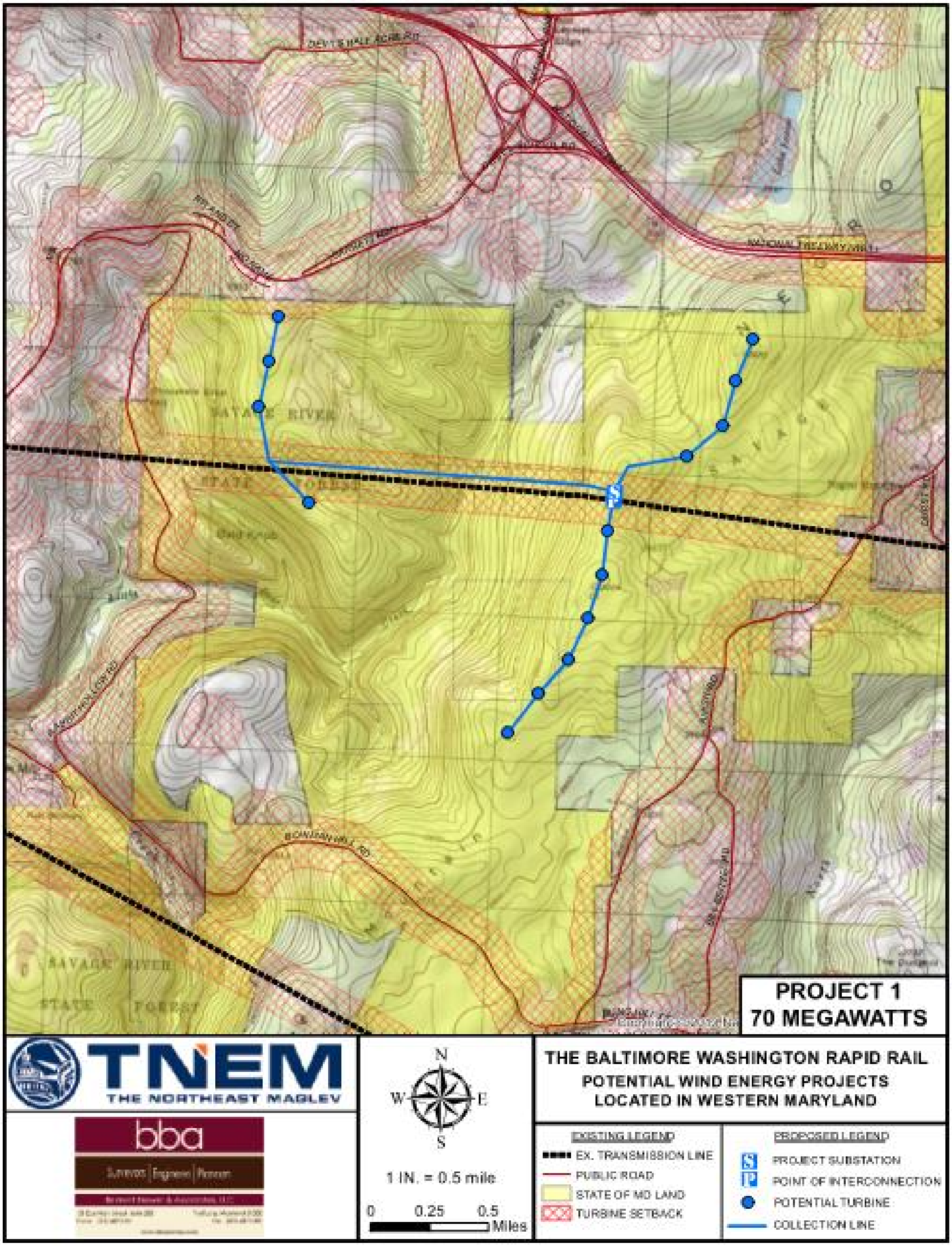
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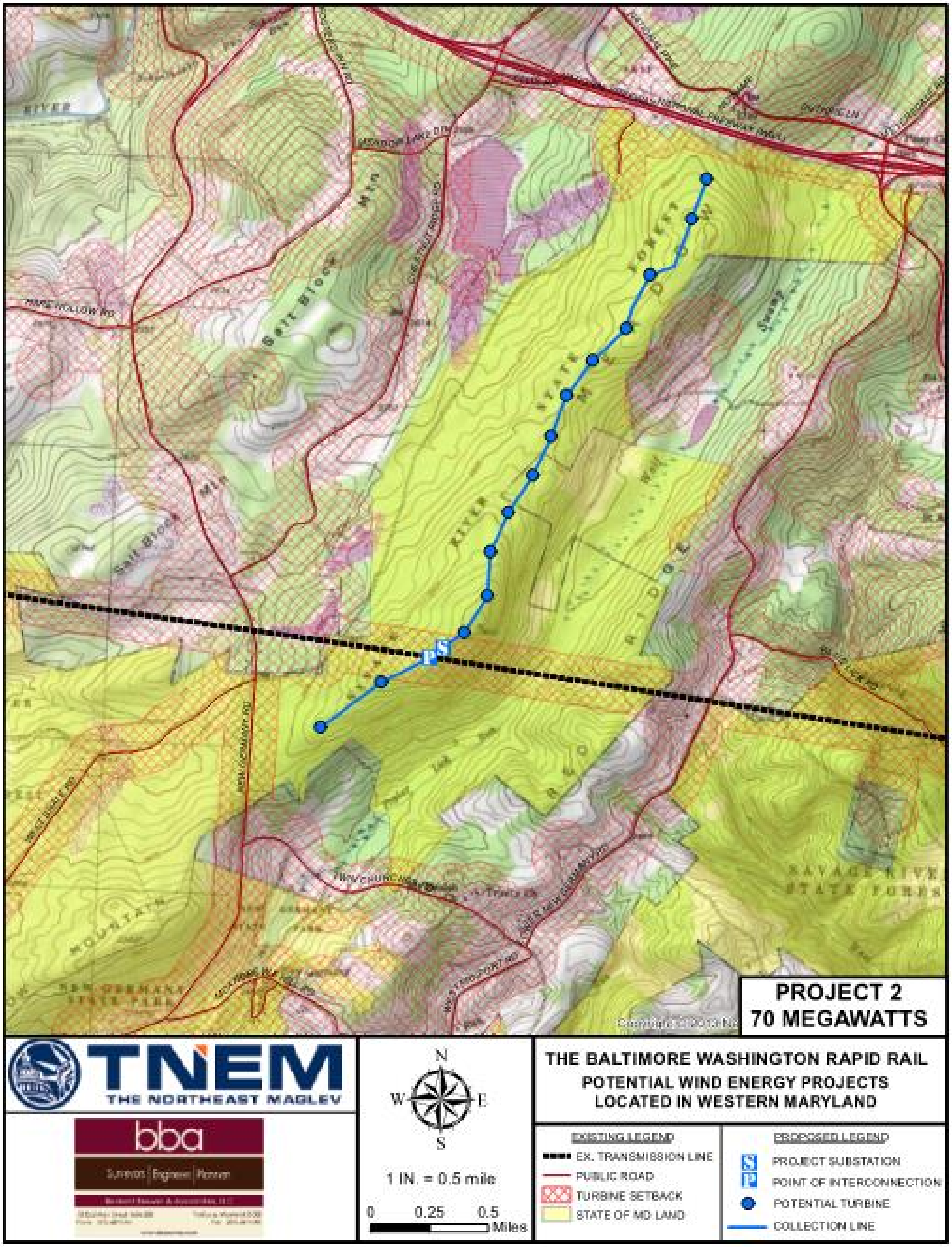

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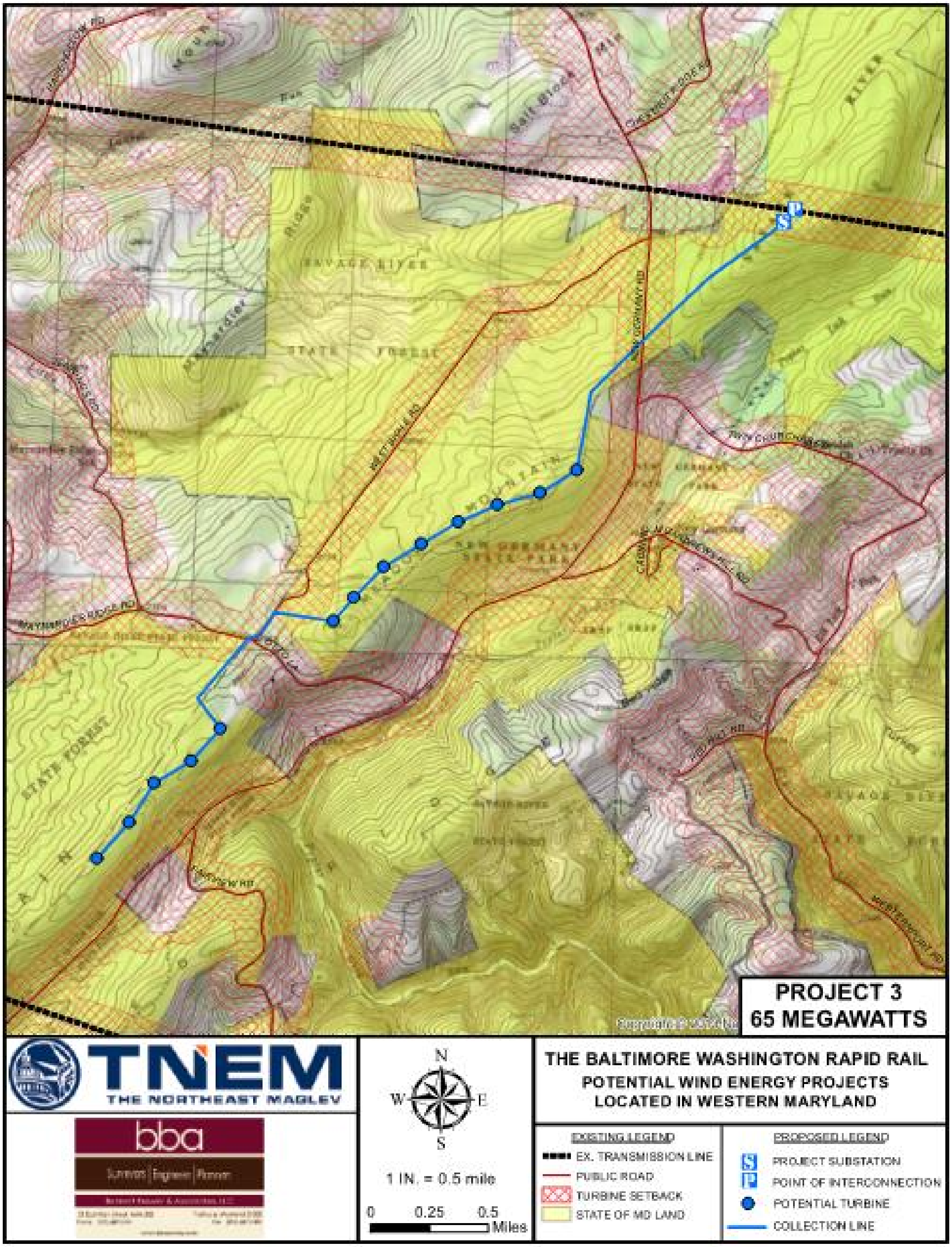
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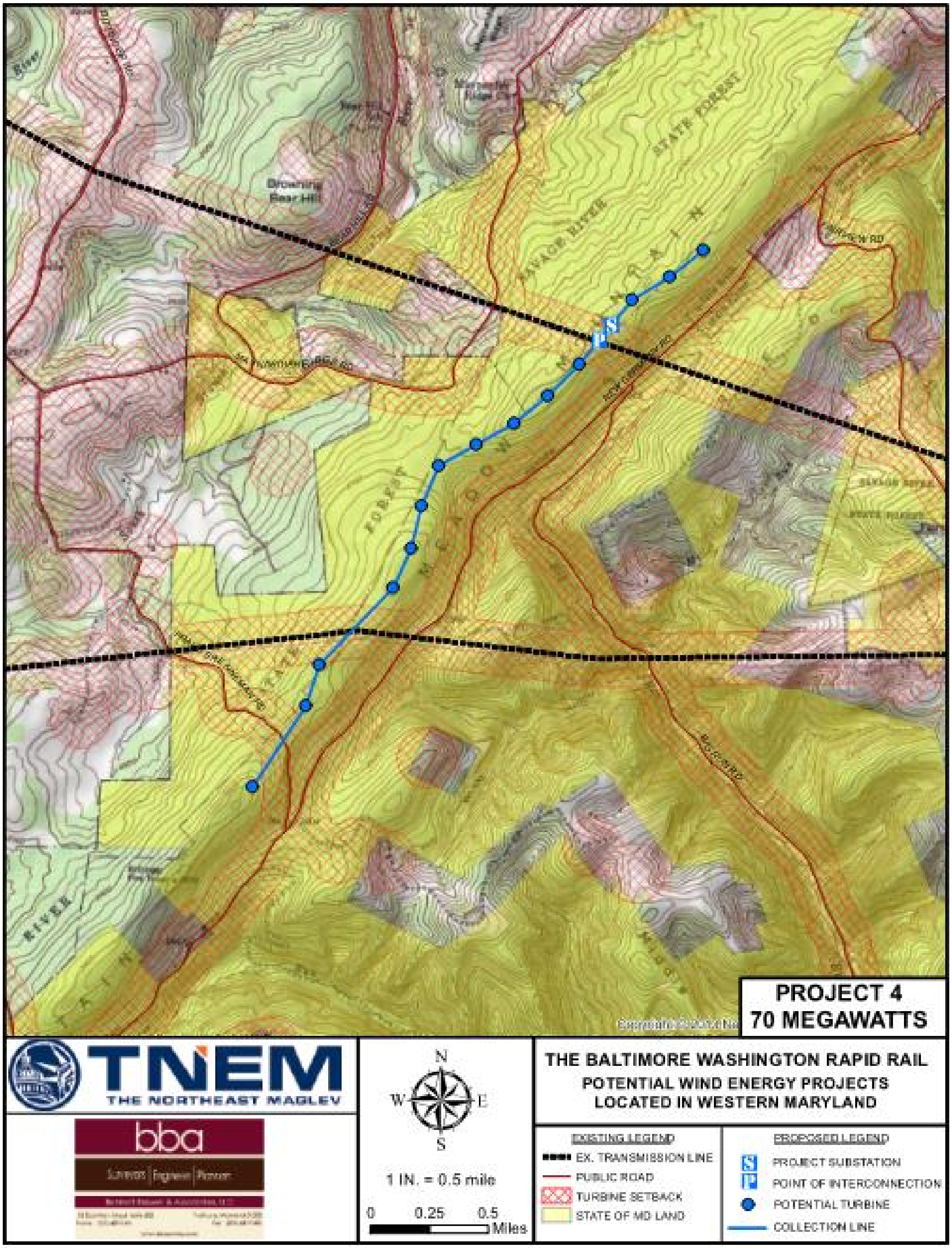

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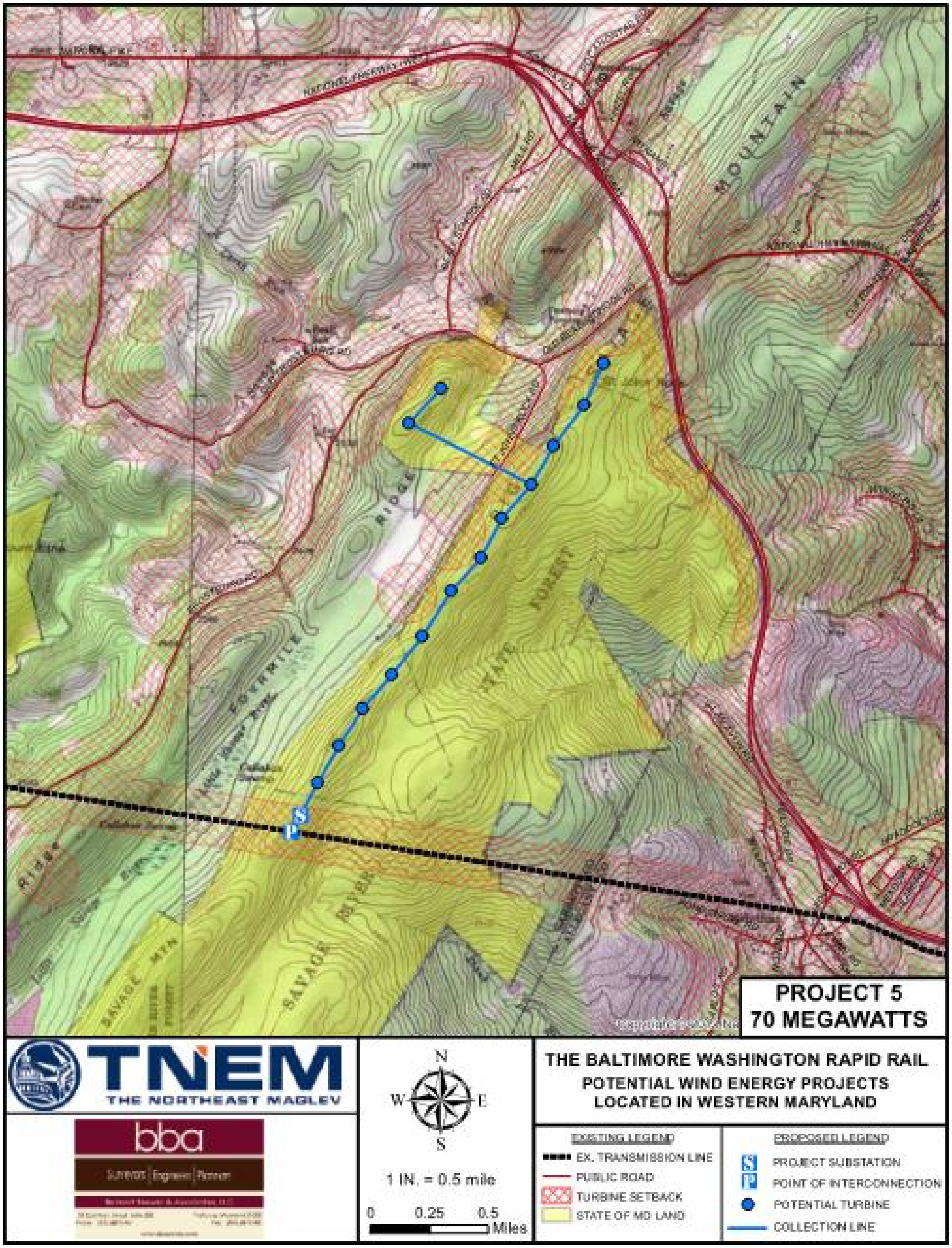
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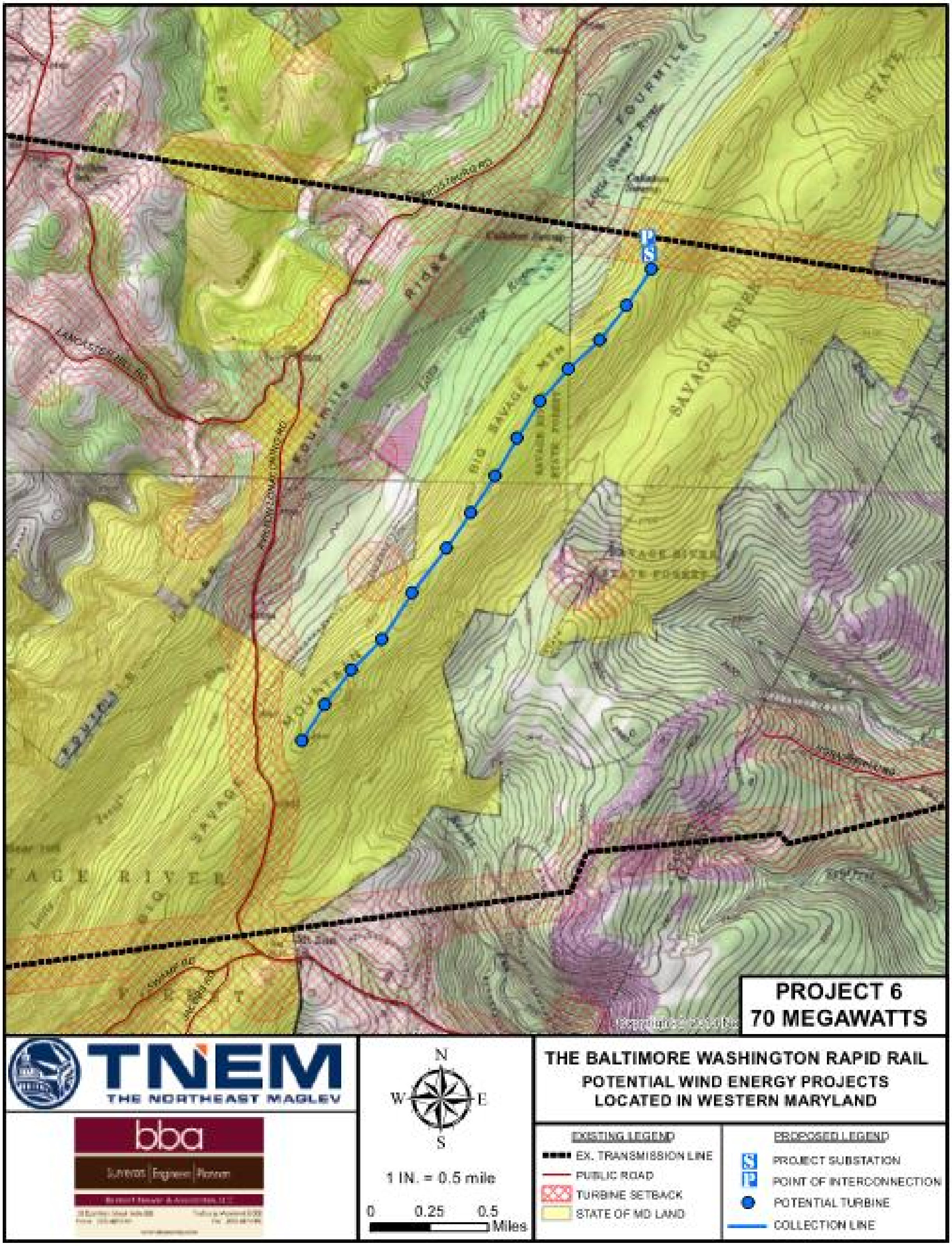
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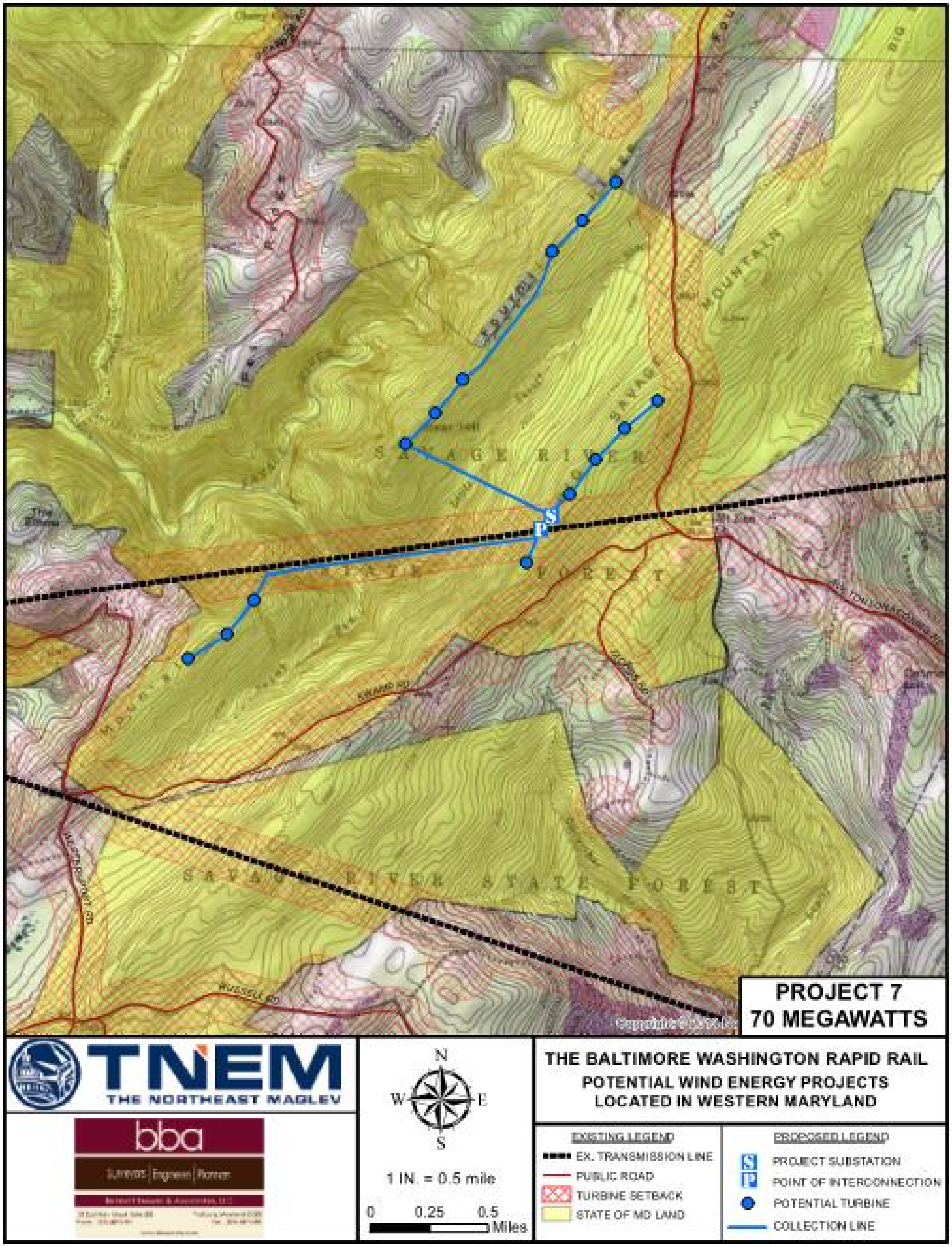
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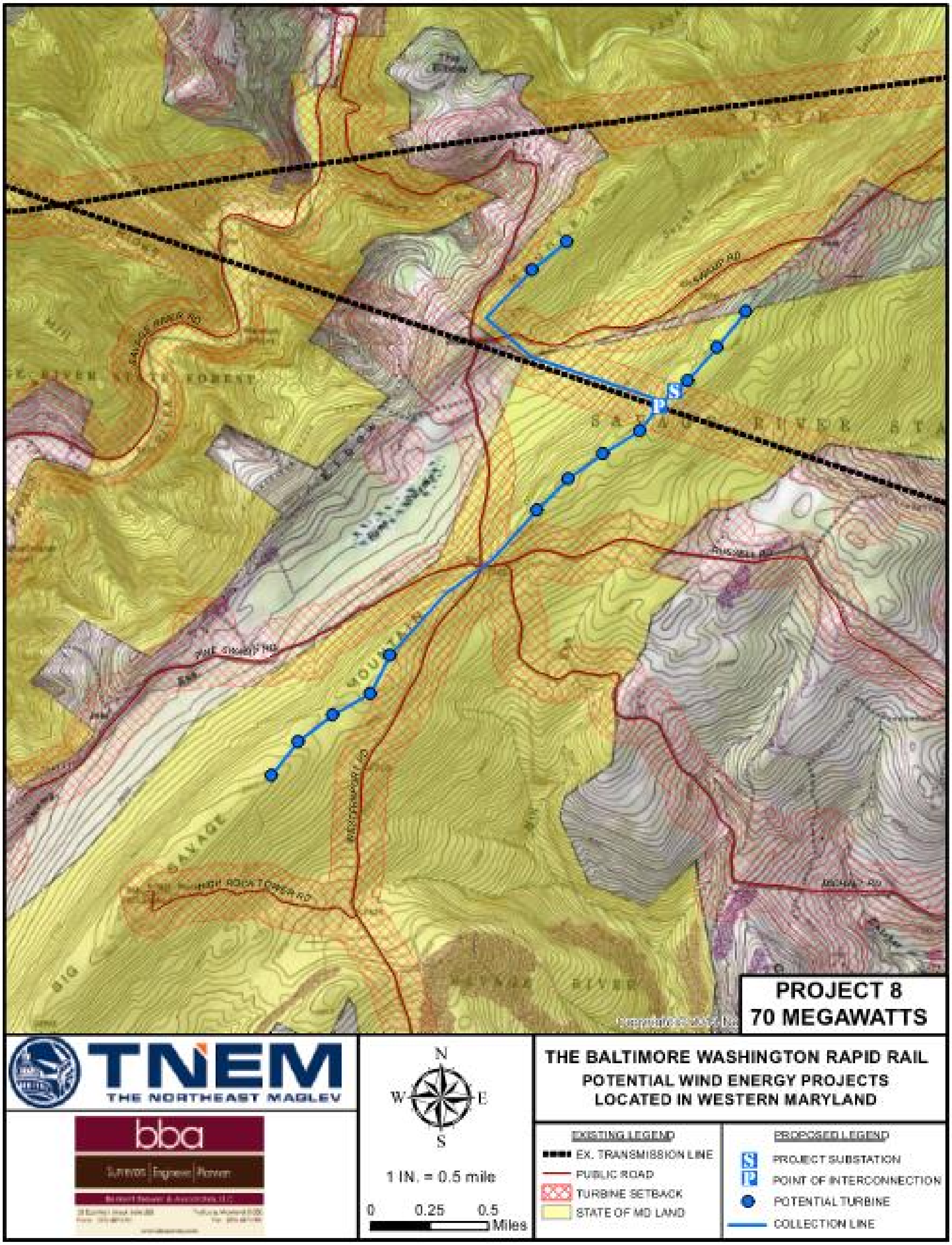
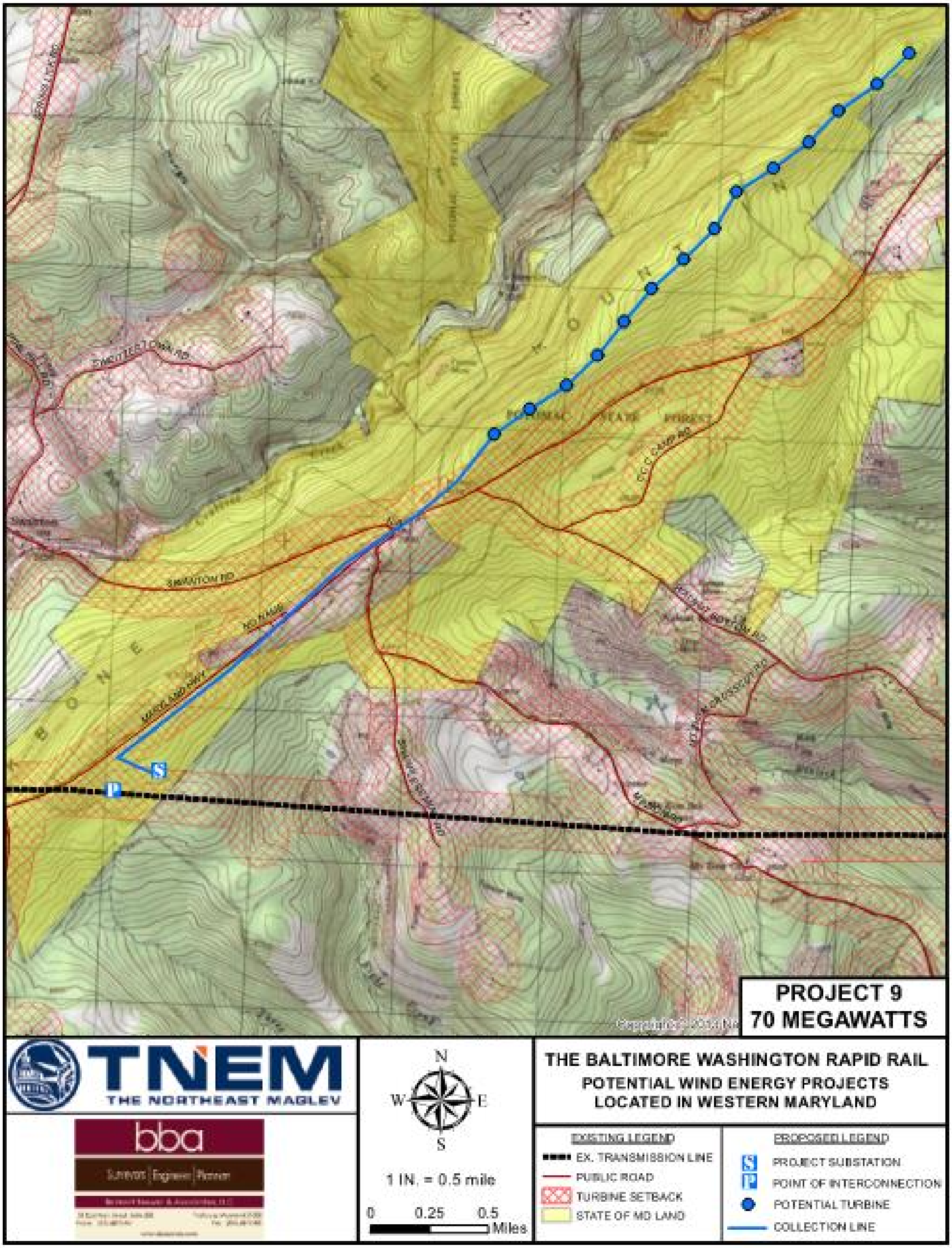
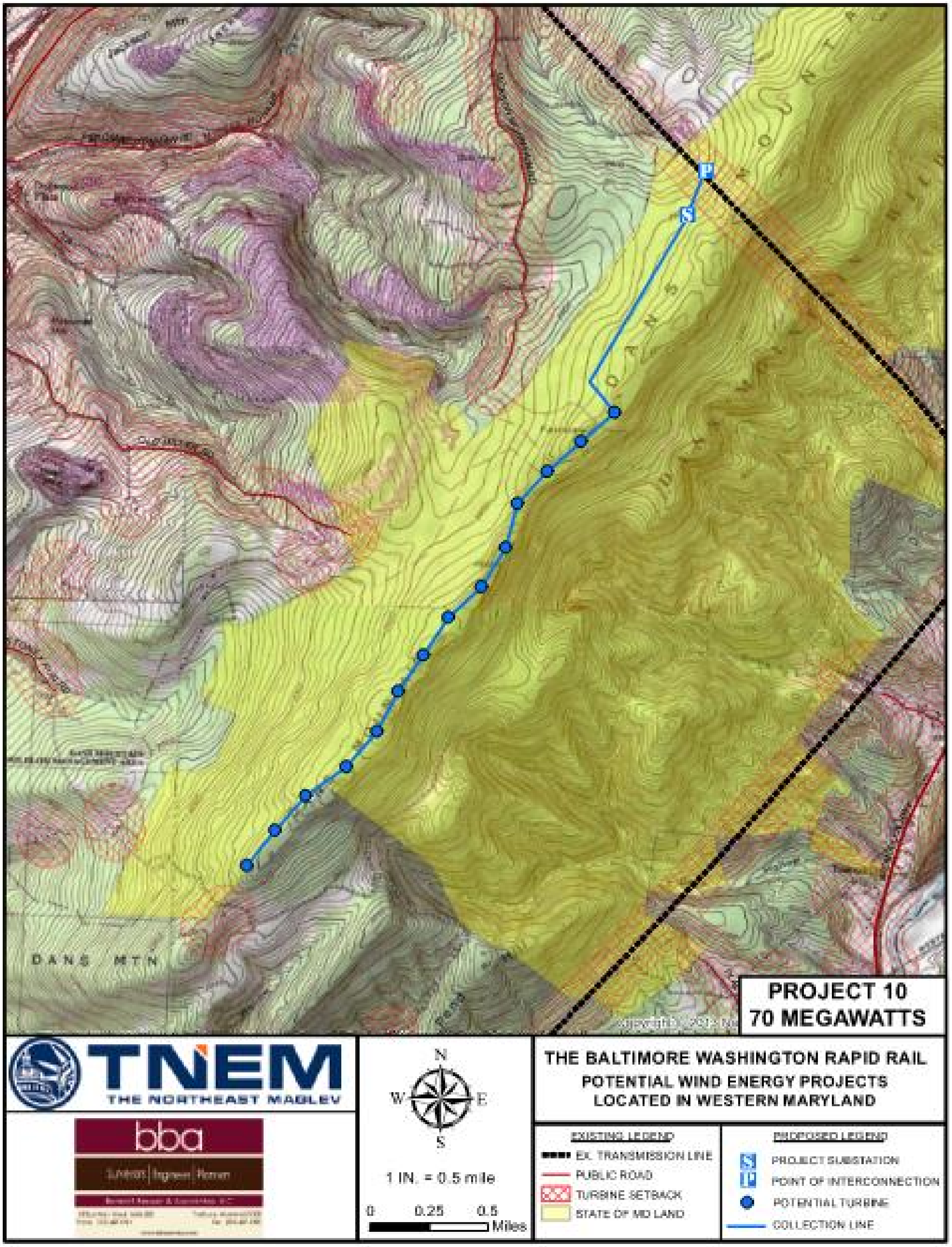
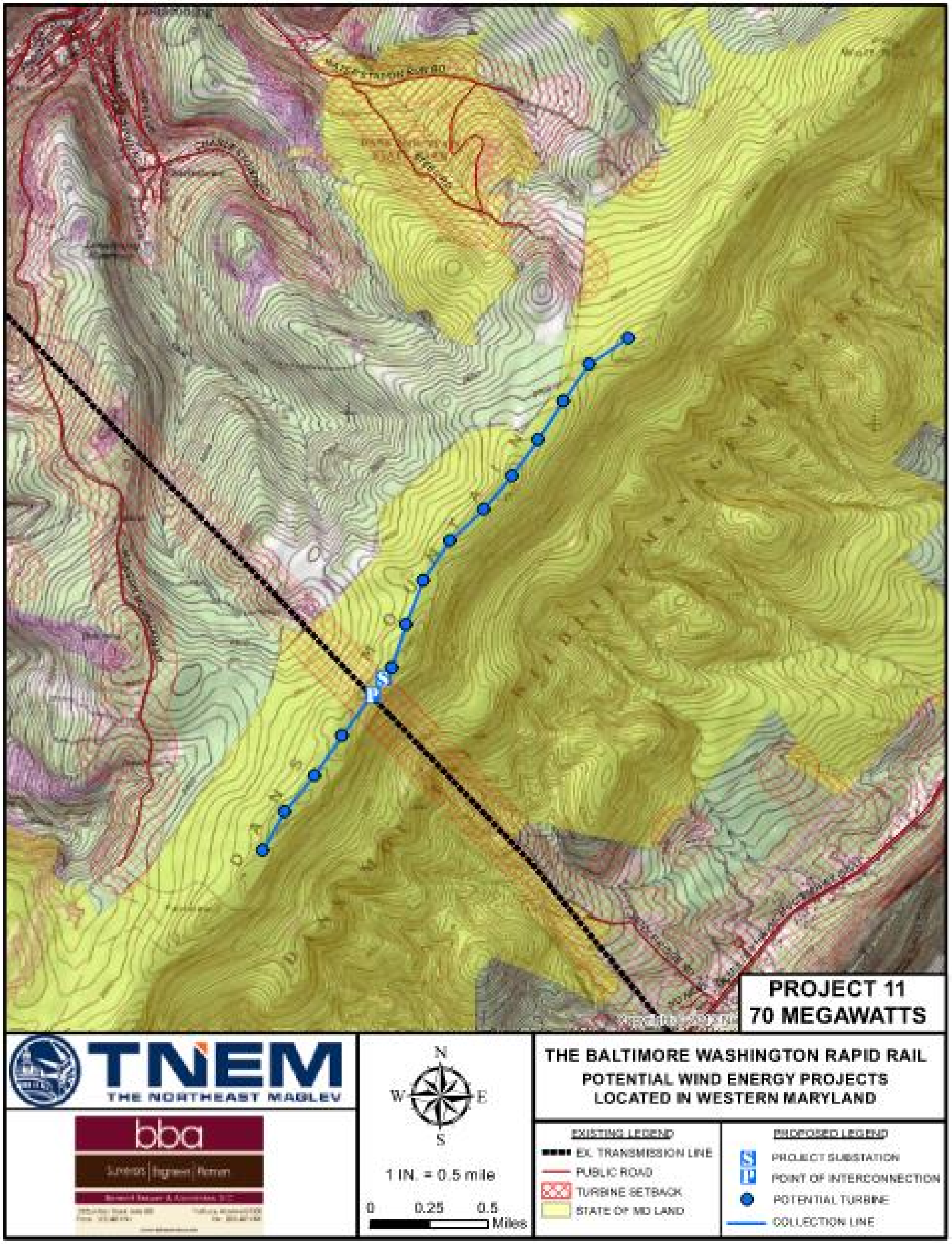
POTENTIAL TURBINE
COLLECTION LINE


PROJECT 8
70 MEGAWATTS
TNEM
THE NORTHEAST MAGLEV
bba
1 IN. = 0.5 mile
0 0.25 0.5 Miles
THE BALTIMORE WASHINGTON RAPID RAIL
POTENTIAL WIND ENERGY PROJECTS
LOCATED IN WESTERN MARYLAND
EXISTING LEGEND
EX. TRANSMISSION LINE
PUBLIC ROAD
TURBINE SETBACK
STATE OF MD LAND
PROPOSED LEGEND
PROJECT SUBSTATION
POINT OF INTERCONNECTION
POTENTIAL TURBINE
COLLECTION LINE


PROJECT 9
70 MEGAWATTS
TNEM
THE NORTHEAST MAGLEV
bba
N
W
E
S
1 IN. = 0.5 mile
0
0.25
0.5
Miles
THE BALTIMORE WASHINGTON RAPID RAIL
POTENTIAL WIND ENERGY PROJECTS
LOCATED IN WESTERN MARYLAND
EXISTING LEGEND
EX. TRANSMISSION LINE
PUBLIC ROAD
TURBINE SETBACK
STATE OF MD LAND
PROPOSED LEGEND
PROJECT SUBSTATION
POINT OF INTERCONNECTION
POTENTIAL TURBINE
COLLECTION LINE
SWANTON RD
MARYLAND HWY


DANS MTN
PROJECT 10
70 MEGAWATTS
TNEM
THE NORTHEAST MAGLEV
bba
N
W
E
S
1 IN. = 0.5 mile
0 0.25 0.5
Miles
THE BALTIMORE WASHINGTON RAPID RAIL
POTENTIAL WIND ENERGY PROJECTS
LOCATED IN WESTERN MARYLAND
EXISTING LEGEND
EX. TRANSMISSION LINE
PUBLIC ROAD
TURBINE SETBACK
STATE OF MD LAND
PROPOSED LEGEND
PROJECT SUBSTATION
POINT OF INTERCONNECTION
POTENTIAL TURBINE
COLLECTION LINE


PROJECT 11
70 MEGAWATTS
TNEM
THE NORTHEAST MAGLEV
bba
N
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W
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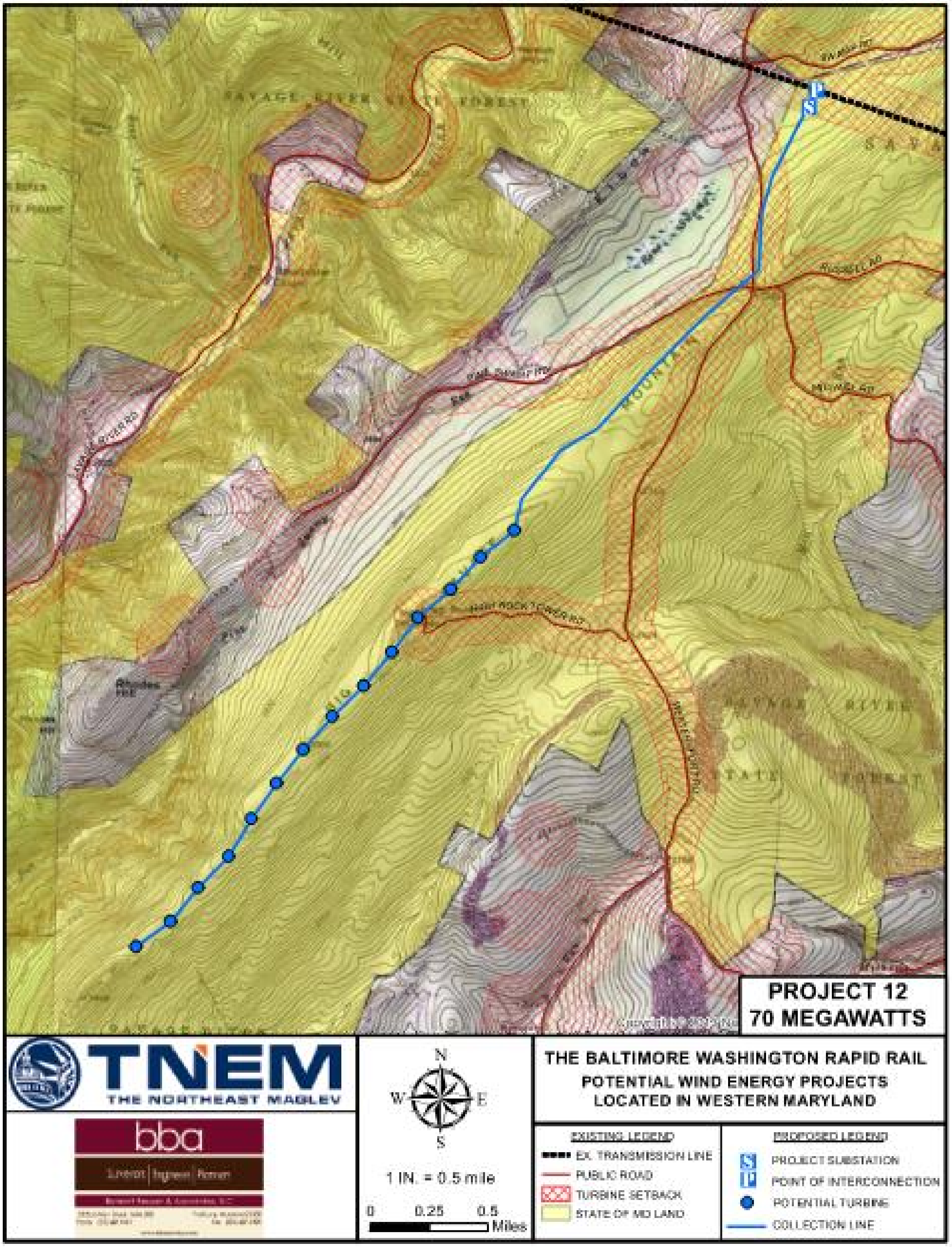
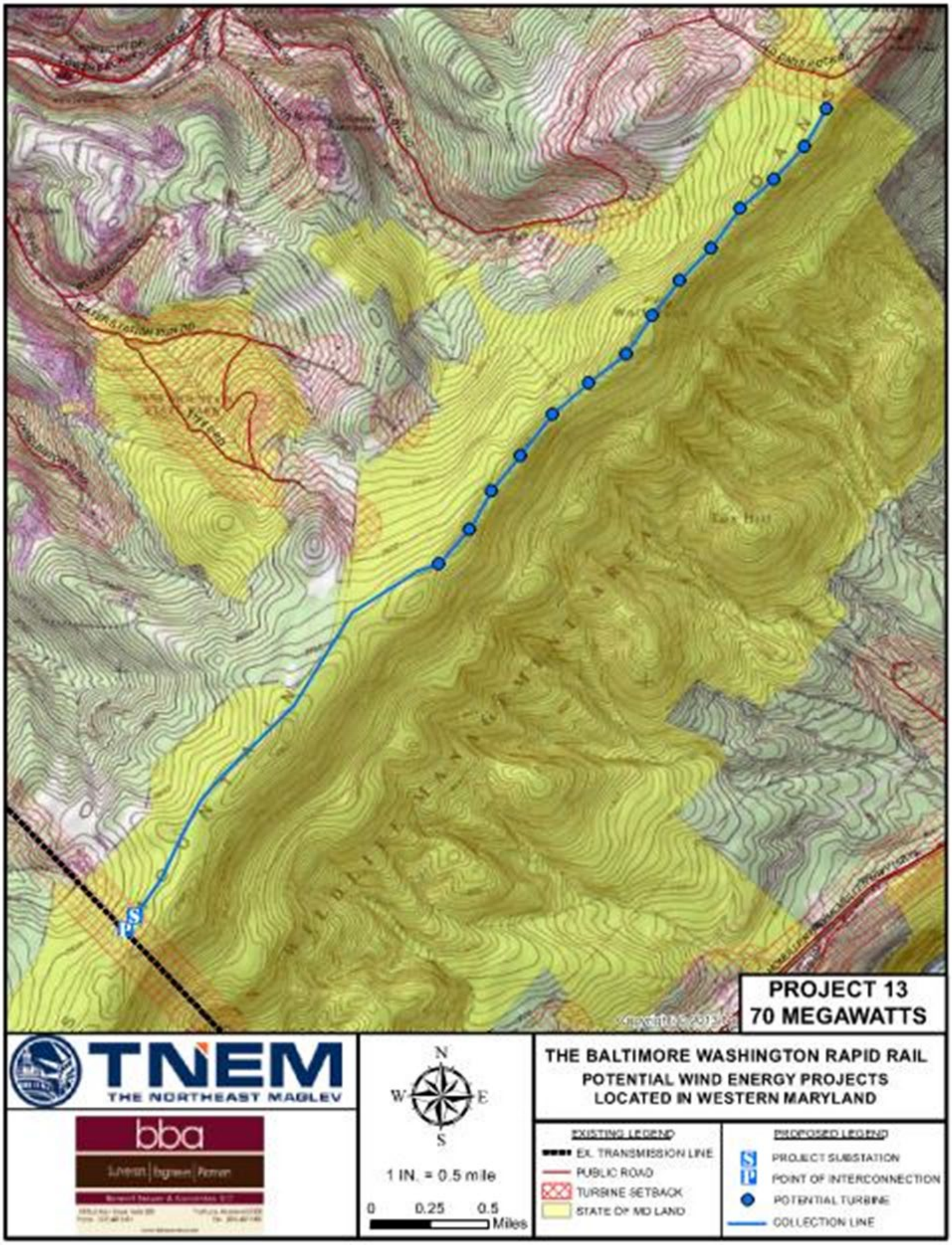
1 IN. = 0.5 mile
0
0.25
0.5
Miles
THE BALTIMORE WASHINGTON RAPID RAIL
POTENTIAL WIND ENERGY PROJECTS
LOCATED IN WESTERN MARYLAND
EXISTING LEGEND
EX. TRANSMISSION LINE
PUBLIC ROAD
TURBINE SETBACK
STATE OF MD LAND
PROPOSED LEGEND
PROJECT SUBSTATION
POINT OF INTERCONNECTION
POTENTIAL TURBINE
COLLECTION LINE



SAVAGE RIVER STATE FOREST
PROJECT 12
70 MEGAWATTS
TNEM
THE NORTHEAST MAGLEV
bba
N
W
E
S
1 IN. = 0.5 mile
0 0.25 0.5 Miles
THE BALTIMORE WASHINGTON RAPID RAIL
POTENTIAL WIND ENERGY PROJECTS
LOCATED IN WESTERN MARYLAND
EXISTING LEGEND
EX. TRANSMISSION LINE
PUBLIC ROAD
TURBINE SETBACK
STATE OF MD LAND
PROPOSED LEGEND
PROJECT SUBSTATION
POINT OF INTERCONNECTION
POTENTIAL TURBINE
COLLECTION LINE


PROJECT 13
70 MEGAWATTS
TNEM
THE NORTHEAST MAGLEV
bba
N
W
E
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1 IN. = 0.5 mile
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0.25
0.5
Miles
THE BALTIMORE WASHINGTON RAPID RAIL
POTENTIAL WIND ENERGY PROJECTS
LOCATED IN WESTERN MARYLAND
EXISTING LEGEND
EX. TRANSMISSION LINE
PUBLIC ROAD
TURBINE SETBACK
STATE OF MD LAND
PROPOSED LEGEND
S
PROJECT SUBSTATION
P
POINT OF INTERCONNECTION
POTENTIAL TURBINE
COLLECTION LINE

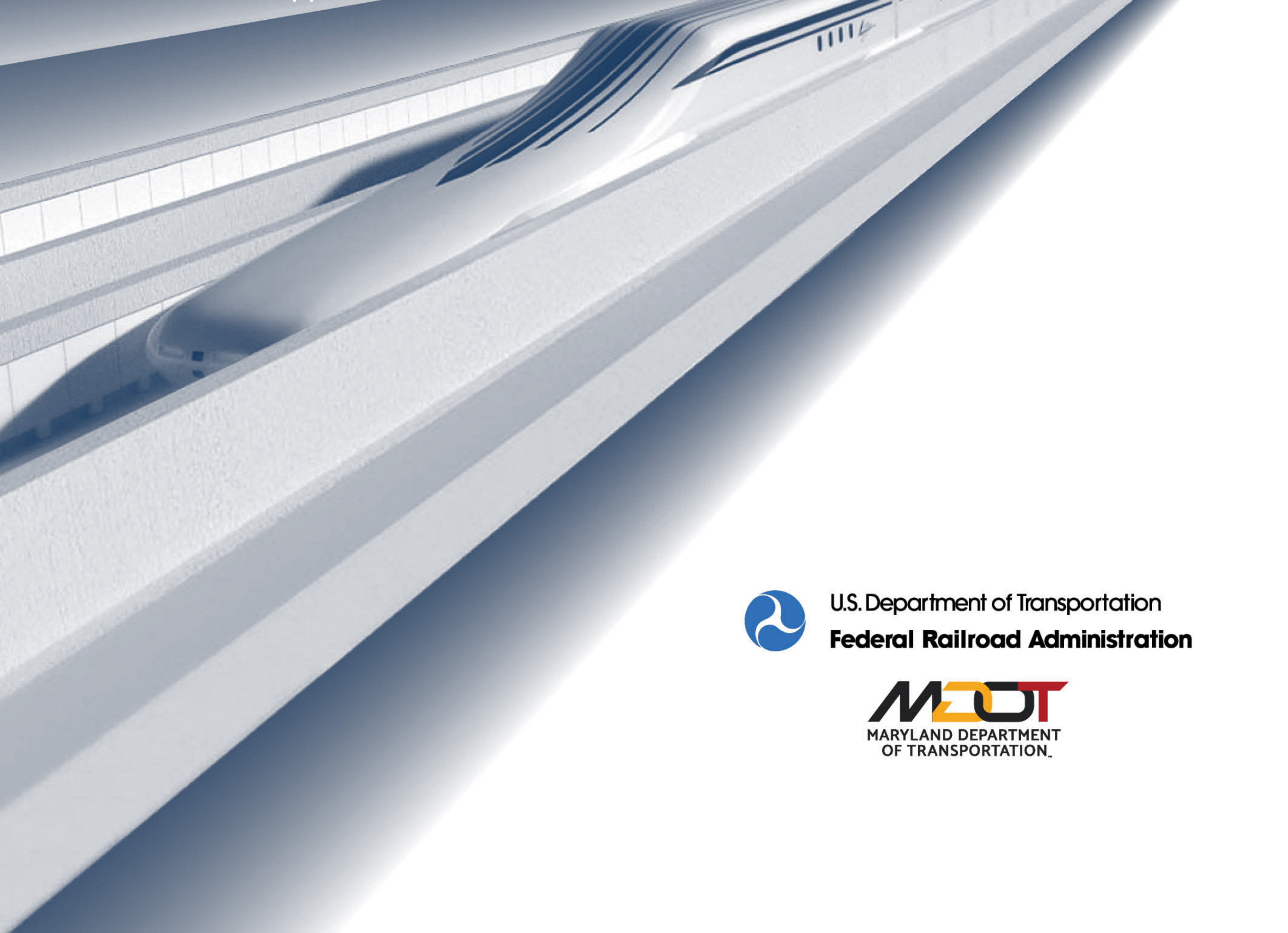
Appendix G11.

BWRRs Proposal for Preferred Alternative Selection

Materials Provided by the Project Sponsor

BALTIMORE-WASHINGTON SUPERCONDUCTING MAGLEV PROJECT

DRAFT ENVIRONMENTAL IMPACT STATEMENT AND SECTION 4(f) EVALUATION



U.S. Department of Transportation
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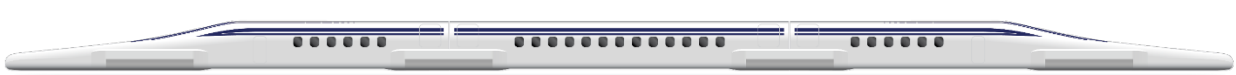
MARYLAND DEPARTMENT OF TRANSPORTATION

BALTIMORE-WASHINGTON SCMAGLEV PROJECT

Sponsor's Proposal for Preferred Alternate Selection

REVISION: 0

July 21, 2020



BWRR
BALTIMORE-WASHINGTON RAPID RAIL

Sponsor's Proposal for Preferred Alternate Selection

Comparative Evaluation of SCMAGLEV Alternatives

1.0 Introduction

NEPA requires that the environmental impact statement evaluate the applicant's proposal and reasonable alternatives. As a result of that analysis a Preferred Alternative is selected. The purpose of this memorandum is to document the proposal of the Project Sponsor (BWRR) and a discussion of the preferred alternative among the 12 end-to-end alternatives being evaluated in the SCMAGLEV DEIS.

The alternatives under consideration are as follows:

A. J Alignment – Cherry Hill – TMF BARC Option #1 (Sponsor's Proposal)
B. J Alignment – Cherry Hill – TMF BARC Option #2
C. J Alignment – Cherry Hill – TMF MD Route-198
D. J Alignment – Camden Yards – TMF BARC Option #1
E. J Alignment – Camden Yards – TMF BARC Option #2
F. J Alignment – Camden Yards – TMF MD Route-198
G. J1 Alignment – Cherry Hill – TMF BARC Option #1
H. J1 Alignment – Cherry Hill – TMF BARC Option #2
I. J1 Alignment – Cherry Hill – TMF MD Route-198
J. J1 Alignment – Camden Yards – TMF BARC Option #1
K. J1 Alignment – Camden Yards – TMF BARC Option #2
L. J1 Alignment – Camden Yards – TMF MD Route-198

The objective basis of this comparative evaluation is guided by BWRR's analysis of environmental impacts, the requirements of the SCMAGLEV technology, Congress's intent for the MAGLEV Deployment Program and the Project's Purpose and Need statement:

- NEPA requires an analysis of environmental impacts
- The technical requirements of the SCMAGLEV system have been incorporated in the current alternatives.
- The intent of Congress is that the maglev project be:
  - Revenue-producing and self-sustaining once built.
  - Consistent with the expressed intent of the Maglev Deployment Program, i.e., "to directly advance and result in construction of a maglev project."
- The Project's Purpose and Need Statement (P&N) states that the "[t]he purpose of the SCMAGLEV Project is to evaluate, and ultimately construct and operate, a safe, revenue-producing, high-speed ground transportation system that achieves the optimum operating

speed of the SCMAGLEV technology to significantly reduce travel time in order to meet the capacity and ridership needs of the Baltimore-Washington region."

The Project's purpose has been accepted by cooperating agencies and complies with their regulatory review requirements. In particular, the US Army Corps of Engineers requires "Section 10/404 permits" to choose among practicable alternatives where "practicable" means "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes" (23 CFR 230 – Section 404(b) (1) Guidelines). This permitting requirement reinforces the above-listed objectives.

The objectives listed below provide the criteria that allow alternatives to be differentiated. This provides an objective basis for a comparative evaluation and identification of a preferred alternative.

Practical objectives:

- Select an alternate that could feasibly result in the construction of the Project, while completely fulfilling NEPA requirements.
- Advance the Project towards construction and minimize capital costs to allow for the greatest economic opportunity and ridership.
- Minimize the duration of construction to ensure the earliest start of revenue service after the Record of Decision.
- Provide for a design that most efficiently controls operating costs of the SCMAGLEV system and, by so doing, will better enable reliable service and revenue to cover ongoing costs.
- Ensure project design and implementation will meet long-term ridership demand.

2.0 Methodology

To meet the above objectives through a comparative evaluation, criteria were developed for evaluation of the preferred alternative selection.

BWRR identified the following criteria:

1. Be able to reasonably mitigate any unavoidable environmental impacts including property and infrastructure as identified in Alternate Matrix (Appendix A).
2. Minimize construction cost.
3. Minimize duration of construction to achieve earliest start of revenue service.
4. Minimize Operation & Maintenance (O&M) cost.
5. Comply with Federal safety requirements, a specific objective of the Project's Purpose and Need.

The comparative evaluation of alternatives applies the relevant evaluation criteria with a rating as follows:

- **Achieves criteria.**
- **Does not achieve criteria** (i.e. does not meet one or more of the above objectives).

Each end-to-end alternative is a combination of the following three components:

1. Baltimore Station – Cherry Hill or Camden Yards
2. Trainset Maintenance Facility (TMF) – BARC Option #1, BARC Option #2, or Route 198
3. Alignment – J vs. J1

The evaluation is initiated with the Baltimore station components, followed by the TMF components. The alignment component evaluation is then based on the Baltimore station and TMF components which are clearly superior from an overall perspective. Rationale is provided to support the ratings.

Component evaluations are then compiled to support identification of the preferred end-to-end alternative being the best overall combination of components that can most effectively be advanced to construction, with least impact on the environment.

3.0 Comparative Evaluation of Alternatives

3.1 Baltimore Station Alternatives

Two station alternatives are under consideration in Baltimore:

- Camden Yards Station – an underground station located in Downtown Baltimore adjacent to the Baltimore Convention Center
- Cherry Hill Station – an elevated station located south of Middle Branch/Baltimore Harbor in the Cherry Hill section of Baltimore

In the table below, the two stations are assessed according to the methodology described in Section 2.0.

Criterion	Camden Yards	Cherry Hill
1. Reasonably Mitigate Impacts	**Does Not Achieve Criteria** Impacts during construction to CSX freight rail, MARC commuter rail, MTA Light RailLink, and vehicular traffic cannot be reasonably mitigated Historic District - Downtown Baltimore historic business and government buildings, and religious building would be lost and cannot be replaced. Loss of jobs and economic activity due to partial shutdown of the Baltimore Convention Center and other impacted business and governmental operations cannot be reasonably mitigated.	**Achieves Criteria** Temporary shutdowns to CSX branch line and MTA Light RailLink will be limited to nights and weekends

Criterion	Camden Yards	Cherry Hill
2. Minimizes Construction Cost	**Does not Achieve Criteria** Additional cost of $1.18 billion compared to Cherry Hill station (additional tunneling and underground station, with cut and cover construction in major city artery) Building/property acquisitions will add substantial cost compared to Cherry Hill (not included in the $1.18 billion cost differential above).	**Achieves Criteria**
3. Minimizes Construction Schedule	**Does Not Achieve Criteria** Requires time to acquire and demolish major buildings (Federal Reserve Bank, Bank of America building, section of the Convention Center, etc.), relocating a historic church, extended closure of critical CSX Howard Street rail tunnel, extended closure of MARC commuter rail train station, extended closure of MTA Light RailLink service, extended closures to I-395, Pratt Street and West Conway Street (*)	**Achieves Criteria** Requires temporary shutdowns for CSX two-trains-per-day branch line and MTA Light RailLink service Requires staged reconstruction with detours of West Patapsco Avenue, Annapolis Road, Cherry Hill Road, and Waterview Avenue
4. Minimizes O&M Costs	**Does Not Achieve Criteria** Extra O&M costs associated with underground station: ventilation systems, vertical circulation, fire & life safety, groundwater protection/grouting, etc.	**Achieves Criteria**
5. Complies with Federal Safety Requirements	**Achieves criteria**	**Achieves Criteria**

(*) Items in Section 3 of this table cannot be mitigated

Note: station construction is on the critical path for the start of revenue service.

Cherry Hill Station is BWRR's proposal and recommended preferred alternative in Baltimore. The Cherry Hill Station is an above ground station that is far less costly to construct in a shorter period of time, and less costly to operate and maintain. Additionally, there would be minimal disruption to the City of Baltimore during construction and during operations.

The Camden Yards station is not preferred for the following reasons: the cost is over $1.18 billion higher than the Cherry Hill station alternative, construction impacts are substantial and cannot be reasonably mitigated; traffic delays will impact the Downtown Baltimore economy during construction and difficult location will deter riders when service starts.

3.2 TMF Alternatives

Three TMF alternatives are being considered:

- BARC Option 1 (West) – located in Prince George's County on USDA property on the west side of the Baltimore-Washington Parkway
- BARC Option 2 (East) – located in Prince George's County on USDA and NASA property (leased from USDA) on a former airstrip on the east side of the Baltimore-Washington Parkway
- MD Route-198 – located in Anne Arundel County north of MD-198 on the east side of the Baltimore-Washington Parkway

In terms of construction sequencing, completing construction of the TMF in a timely manner is critical to starting revenue service. A fully functioning TMF is needed to assemble the SCMAGLEV trainsets and conduct system tests prior to starting service.

In the table below, the three TMF options are assessed according to the methodology described in Section 2.0.

Criterion	BARC 1 (West)	BARC 2 (East)	MD-198
1. Reasonably mitigate impacts	**Achieves Criteria** Requires about 33% more deforestation which can be mitigated through reforestation	**Achieves Criteria** Requires about 33% less deforestation than BARC 1 (West) Assumes that NASA concerns, below, can be resolved. If not, then <u>does not achieve criteria</u>: • Frequency interference • Vibration and light interference • Interference with the Spacecraft Magnetic Test Facility	**Does Not Achieve Criteria** Impacts that cannot be reasonably mitigated include: • diverting the Little Patuxent River • revising an irrevocable Conservation Easement • encroaching on Tipton Airport airspace (FAA Safety) • relocating critical aerial and underground BGE infrastructure • constructing 60m (200 foot) tall rail shops across from a residential development

Criterion	BARC 1 (West)	BARC 2 (East)	MD-198
2. Minimizes Construction Cost	**Achieves Criteria**	**Achieves Criteria**	**Does Not Achieve Criteria** Adds $250 million to cost to divert the river and construct 60m (200 foot) high shop buildings
3. Minimizes Construction Schedule	**Achieves Criteria**	**Does Not Achieve Criteria** Potential delay to start of revenue service from the baseline schedule if NASA frequency interference, electromagnetic interference concerns, vibrations and lighting concerns cannot be easily mitigated or resolved.	**Does Not Achieve Criteria** Conservation Easement revisions, diversion of Little Patuxent River, relocation of critical BGE underground and aerial infrastructure, relocation of Woodland Job Corps facility, and construction of 60m (200 foot) high shop buildings, FAA waiver for Tipton Airport airspace intrusion.
4. Minimizes O&M Cost	**Achieves Criteria**	**Does Not Achieve Criteria** Based on potential restrictions on O&M activities due to NASA constraints associated with frequency interference, electromagnetic interference, lighting and vibrations.	**Does Not Achieve Criteria** Increased operation costs due to an additional 10km (6 mile) distance for deadheading trains at the beginning and end of each service shift, compared to the BARC alternatives Increased maintenance costs associated with Little Patuxent River diversion through or adjacent to facility structure and 60m (200 foot) high shop buildings
5. Complies with Federal Safety Requirements	**Achieves Criteria**	**Achieves Criteria**	**Does Not Achieve Criteria** Inspection shop and Factory buildings will intrude into Tipton Airport airspace, violating Federal Aviation Regulation Part 77 – Surfaces – safety regulation of FAA

BARC Option 1 (West) TMF is BWRR's proposal and recommended preferred alternative. It achieves all the criteria outlined in Section 2.0 with no substantial mitigation requirements.

BARC Option 2 TMF (East) is not preferred due to protracted process to reach resolution with NASA on concerns raised (frequency interference, electromagnetic interference, lighting, and vibrations on NASA facilities) potentially constrain operation and maintenance of the system.

The MD-198 TMF location is not preferred due to intrusion into Tipton Airport airspace in violation of FAA requirements, substantial issues that will substantially delay the start of revenue service, diverting the Little Patuxent River, and substantial impacts that cannot be reasonably mitigated.

3.3 Alignment Alternatives

Two alignment alternatives are under consideration:

- Alternative J – generally follows along the east side of the Baltimore-Washington Parkway
- Alternative J1 – generally follows along the west side of the Baltimore-Washington Parkway

The two alignment alternatives are similar in the northern and southern tunnel portions of the route and at the passenger stations. They are differentiated by the viaduct portion in the center of the route, with Alternative J running through mostly federal properties on the east side of the Baltimore-Washington Parkway, and Alternative J1 running through federal, municipal and private properties on the west side of the Baltimore-Washington Parkway. Infrastructure and facility differences between the two alignment alternatives include:

- Locations and lengths of tunnel transition portals
- Locations and lengths of ramps connecting the alignments to the TMF alternatives
- Locations of MOW facilities and ramps associated with the MD-198 TMF
- Locations of substations and power distribution lines
- Numbers and locations of miscellaneous SCMAGLEV facilities
- Locations and sizes of stormwater management facilities

In the table below, the two alignment alternatives are assessed according to the methodology described in Section 2.0.

Criterion	Alternative J (BWP East)	Alternative J1 (BWP West)
1. Reasonably Mitigate Impacts	**Achieves Criteria**	**Does Not Achieves Criteria** ~ 30% more visual impacts to housing units ~ 29% more construction effect to residential properties within 200 ft of ROW and Truck Routes ~ County and City parks are impacted
2. Minimize Construction Cost	**Achieves Criteria**	**Does Not Achieve Criteria** Adds $440 million to cost, including approximately 6.2 km (3.85 miles) more tunneling and an additional FA/EE.
3. Minimizes Construction Schedule	**Achieves Criteria**	**Does Not Achieves Criteria** Additional tunneling will require longer schedule and cost.

Criterion	Alternative J (BWP East)	Alternative J1 (BWP West)
4. Minimizes O&M Cost	**Achieves Criteria**	**Does Not Achieve Criteria** Higher maintenance costs associated with additional tunnel length (ventilation, lighting, etc.) and one additional FA/EE facility. Higher energy consumption and cost associated with 4.1 km (2.5 miles) of climbing grade in acceleration and cruising zones, compared to 1.9km (1.2 miles) of climbing grade for Alternative J.
5. Complies with Federal Safety Requirements	**Achieves Criteria**	**Achieves Criteria**

Based on the above evaluation, Alternative J is BWRR's proposal and recommended preferred alignment.

Alternative J is by far the lower cost alternative with no substantial issues.

Alternative J1 is not preferred due to higher construction cost, and higher operating and maintenance costs.

4.0 Project Sponsor's Preferred Alternative

Based on the above evaluation and the Alternatives Comparison Matrix (Appendix A), **BWRR's proposal and recommended preferred end-to-end alternative is the combination of Cherry Hill Station, BARC 1 TMF (BARC West), and Alignment J**, identified as *Aggregated Alternative A* in the alternatives matrix provided in Section 1.0. This is the least impactful and lowest cost alternative to construct, operate, and maintain while also providing the earliest start to revenue service. This selection also meets the stated intent of the Maglev Deployment Program to advance to construction and produce a revenue stream while meeting the NEPA requirement of the least impact on the environment.

Appendix A: Alternatives Comparison Matrix

A. Alt J – Cherry Hill – TMF BARC #1 (Sponsor's Proposal)
B. Alt J – Cherry Hill – TMF BARC #2
C. Alt J – Cherry Hill – TMF MD Route-198
D. Alt J – Camden Yards – TMF BARC #1
E. Alt J – Camden Yards – TMF BARC #2
F. Alt J – Camden Yards – TMF MD Route-198
G. Alt J1 – Cherry Hill – TMF BARC #1
H. Alt J1 – Cherry Hill – TMF BARC #2
I. Alt J1 – Cherry Hill – TMF MD Route-198
J. Alt J1 – Camden Yards – TMF BARC #1
K. Alt J1 – Camden Yards – TMF BARC #2
L. Alt J1 – Camden Yards – TMF MD Route-198

Aggregated Alternative	A	B	C	D	E	F	G	H	I	J	K	L
Civil Infrastructure Cost ($B)	8.87	8.87	9.12	10.05	10.05	10.30	9.31	9.31	9.57	10.49	10.49	10.75
Delay to Start of Revenue Service (years)	0	5	5	3	5	5	1	5	5	3	5	5
Additional O&MCost	Base Cost	$	$	$	$$	$$	$	$$	$$	$$	$$$	$$$
Total Length (miles)	41.31	41.52	42.33	42.89	43.10	43.91	41.78	41.61	44.79	43.37	43.20	46.38
Tunnel Length (miles)	26.39	26.39	26.39	29.54	29.54	29.54	30.24	30.24	30.24	33.41	33.41	33.41
Viaduct Length (miles)	12.77	12.98	13.79	11.72	11.93	12.74	9.15	8.98	12.16	8.10	7.93	11.11
Portal Length (miles)	2.15	2.15	2.15	1.63	1.63	1.63	2.39	2.39	2.39	1.86	1.86	1.86
Spoils (Million Cubic Yards)	23.45	23.45	23.45	26.74	26.74	26.74	25.06	25.06	25.06	28.35	28.35	28.35
Zoned Business Acreage (facilities/station)	262.17	262.17	287.58	117.78	117.78	143.18	300.31	300.31	327.74	155.91	155.91	183.34
Zoned Business Acreage (Mainline)	10.75	10.75	10.75	2.16	2.16	2.16	19.03	19.03	19.03	10.45	10.45	10.45
Zoned Residential Acreage (Facilities/ Stations)	22.09	21.84	22.20	22.03	21.78	22.13	26.54	26.49	26.49	26.48	26.43	26.43
Zoned Residential Acreage (Mainline)	<0.1	<0.1	<0.1	0.00	0.00	0.00	4.63	4.63	4.63	4.62	4.62	4.62
Wetlands (based on NWI) (acres)	23.14	24.24	42.59	23.14	24.24	42.59	23.10	25.31	51.10	23.10	25.31	51.10
Floodplains (acres)	52.23	66.01	79.32	52.23	66.01	79.32	45.19	57.72	82.83	45.19	57.72	82.83
NPS Land (acres/%)	96.93/7.1	93.32/6.8	114.46/8.3	96.93/7.1	93.32/6.8	114.46/8.3	52.26/3.8	52.68/3.8	73.28/5.3	52.26/3.8	52.68/3.8	73.28/5.3
Patuxent Research Refuge (acres/%)	48.82/0.4	48.82/0.4	49.00/0.4	48.82/0.4	48.82/0.4	49.00/0.4	0/0	0/0	0/0	0/0	0/0	0/0
BARC (acres/%)	233.19/3.5	249.60/3.8	36.56/0.6	233.19/3.5	249.60/3.8	36.56/0.6	222.58/3.4	239.90/3.6	38.42/0.6	222.58/3.4	239.90/3.6	38.42/0.6
Fort Meade (acres/%)	22.56/0.4	22.56/0.4	22.56/0.4	22.56/0.4	22.56/0.4	22.56/0.4	6.93/0.1	6.93/0.1	6.93/0.1	6.93/0.1	6.93/0.1	6.93/0.1
Secret Service (acres/%)	10.04/2.0	16.12/3.3	10.44/2.1	10.04/2.0	16.12/3.3	10.44/2.1	0/0	6.06/1.2	0/0	0/0	6.06/1.2	0/0
NASA (acres/%)	15.08/1.2	15.08/1.2	15.08/1.2	15.08/1.2	15.08/1.2	15.08/1.2	0/0	0/0	0/0	0/0	0/0	0/0
County Park (acres/%)	0.23/<0.1	0.23/<0.1	0.23/<0.1	0.23/<0.1	0.23/<0.1	0.23/<0.1	72.15/8.8	72.48/8.8	88.35/10.7	72.15/8.8	72.48/8.8	88.35/10.7
Total Truck Trips (millions)	2.25	2.25	2.25	2.58	2.58	2.58	2.48	2.48	2.48	2.81	2.81	2.81
Construction Effect (Housing Units within 200 feet of ROW and Truck Routes)	660	650	650	613	603	603	852	836	907	805	789	860
Visual Impacts (housing units that would see the viaduct/facilities)	205	187	207	24	6	26	267	250	284	86	69	103

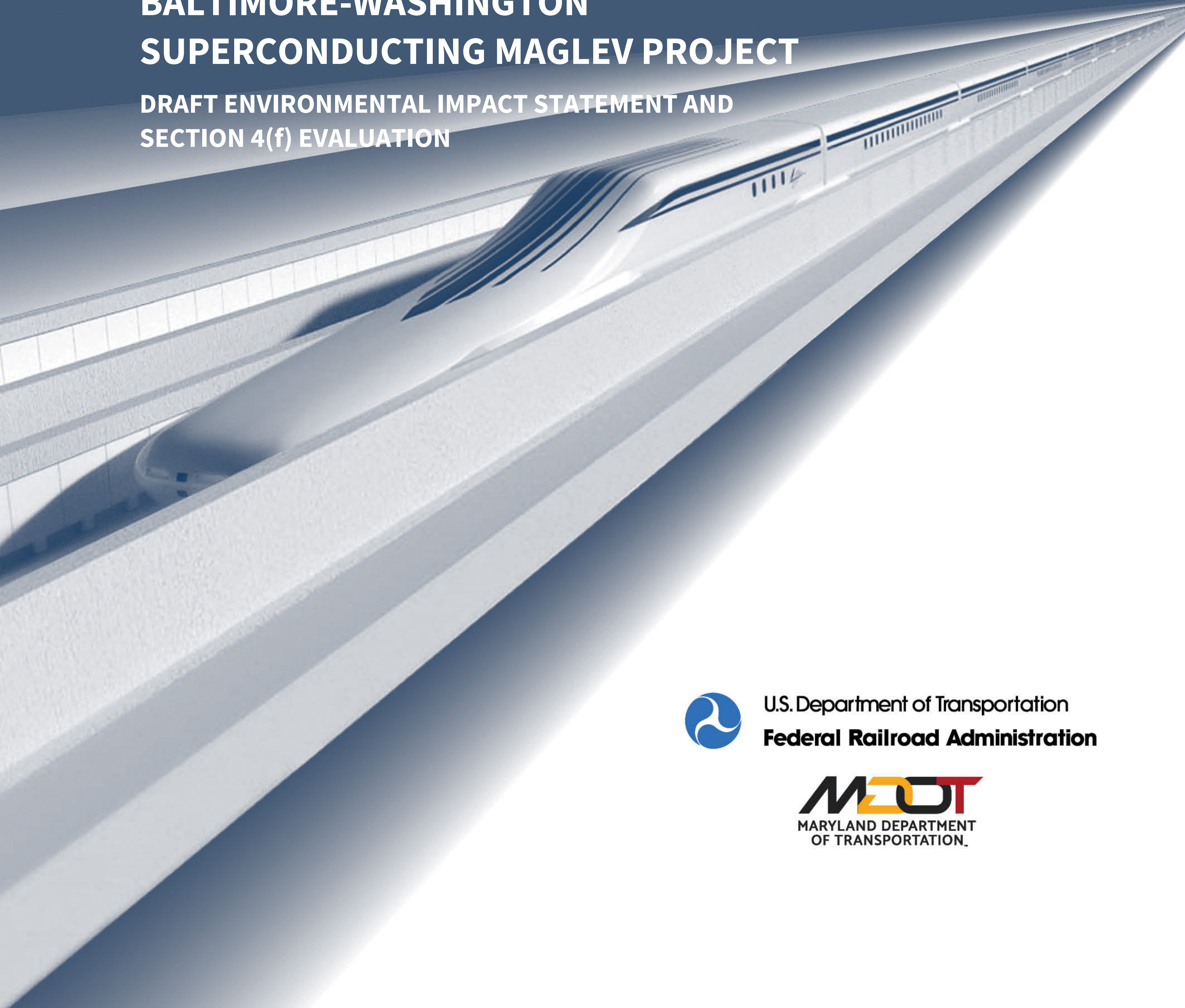
Appendix G12.

TMF Alternatives Assessment Comparison Memorandum

Materials Provided by the Project Sponsor

BALTIMORE-WASHINGTON SUPERCONDUCTING MAGLEV PROJECT

DRAFT ENVIRONMENTAL IMPACT STATEMENT AND SECTION 4(f) EVALUATION



U.S. Department of Transportation
Federal Railroad Administration

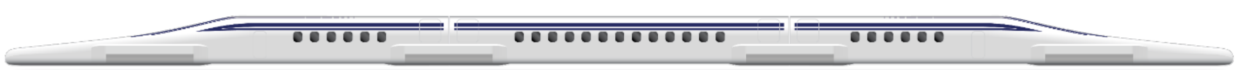
MARYLAND DEPARTMENT OF TRANSPORTATION

BALTIMORE-WASHINGTON SCMAGLEV PROJECT

TRAINSET MAINTENANCE FACILITY (TMF) ALTERNATIVES ASSESSMENT COMPARISON

REVISION: 5

DATE: December 10, 2020



BWRR

BALTIMORE-WASHINGTON RAPID RAIL

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Revision 3: 2020-08-18

Revision 3: 2020-10-09

File Name: BWRR 4.3 TMF Alternatives R4-20.10.09.docx

1. EXECUTIVE SUMMARY

This report presents the site and configuration options for the Superconducting Maglev (SCMAGLEV) Trainset Maintenance Facility (TMF), formerly called the Rolling Stock Depot (RSD), and explores the various considerations for the Washington, D.C. to Baltimore, MD project corridor. The evaluation in this report is based on the project sponsor's best assessments including environmental impacts. Final determination of environmental impacts will be made through the NEPA process.

The TMF is the home for the trainsets. All inspection, maintenance, repairs, and periodic or programmatic work is performed at the TMF. Light trainset servicing and cleaning is done at terminal stations during the operating day. Several hundred people will report to work at the TMF daily.

The Alternatives Report[1] evaluated two TMF locations along the Baltimore-Washington Parkway corridor using a 235-acre facility footprint. As recommended in the Alternatives Report, a subsequent TMF study was undertaken. BWRR considered the possible use of a reduced and disaggregated footprint (approximately 120 acres, later found not viable) to minimize impacts and allow additional sites to be considered. Eleven sites were studied, and the newly identified Patapsco Avenue site was selected along with a new layout within the existing MD-198 site as the two TMF sites to be studied in detail in the Draft Environmental Impact Statement (DEIS). However, a subsequent operational review conducted in the summer of 2019 concluded that the reduced and disaggregated footprints would not meet the operational and maintenance requirements of the fleet. Additional equipment, logistics, and time required for trainset maneuvers in the inefficient TMF layout would preclude completing required inspections and maintenance during the required six-hour nighttime maintenance window and introduce unacceptable operating risks.

A new site evaluation was conducted in the fall on 2019, based on a 180-acre TMF footprint as designed and currently under construction in Chubu, Japan. This site is 55 acres smaller than the 235-acre footprint considered in the Alternatives Report. In this assessment report fourteen sites are considered against key factors and operational considerations of overall size and shape, the ability to provide connecting ramps to the mainline, proximity to Washington DC, avoidance of residential impacts, and elimination or minimization of impacts that would be difficult or impossible to mitigate. These factors are consistent with the Purpose and Need for the project, specifically to achieve SCMAGLEV operational and safety metrics and to avoid, minimize and mitigate impacts to the human and natural environment.

Two locations, #4 Beltsville Agricultural Research Center (BARC) East and #5 BARC West are identified by BWRR as the alternatives for a TMF that best meet the BWRR project criteria, including no residential displacements. The proposed TMF sites on BARC land were developed avoiding the TMF site BARC objected to in the ARDS and incorporating other comments from the Alternatives Report. The BARC proposed sites are consistent with other non-agricultural uses on BARC property including buildings, a rail maintenance facility for WMATA, a new Bureau of Engraving and Printing facility, and many other uses. Additional non-agricultural uses of BARC are outlined in this report.

The MD-198 site (#10A) is the only other site that does not require residential displacements. However, there are increased costs, aviation safety, permitting, conservation easements and infrastructure challenges that are significant for the site. The BARC West, BARC East, and MD-198 alternatives are recommended by BWRR for further assessment in the DEIS, with the caveats noted above concerning MD-198 (#10A).

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[1] Baltimore-Washington Superconducting Maglev Project, Final Alternatives Report, November 2018. http://baltimorewashingtonscmaglevproject.com/images/document_library/reports/alternatives_report/SCMAGLEV_Alts_Report_Body-Append-A-B-C_Nov2018.pdf

2. PURPOSE

This report reviews options for the Trainset Maintenance Facility (TMF): its function and requirements, alternatives for siting a facility in the Baltimore-Washington corridor, and conclusions and Sponsor's recommendations for alternatives for inclusion in the Draft Environmental Impact Statement (DEIS).

3. BACKGROUND

The project is a high-speed public transportation system between Washington DC and Baltimore MD via a Superconducting Maglev (SCMAGLEV) train. The project requires new infrastructure, stations, and facilities to implement technology developed by Central Japan Railway Company (JRC).

The U.S. Federal Railroad Administration (FRA), in collaboration with Maryland Department of Transportation (MDOT) and Maryland Economic Development Corporation (MEDCO), is preparing an Environmental Impact Statement (EIS) to evaluate alternatives for the project pursuant to the National Environmental Policy Act (NEPA). The project sponsor is Baltimore Washington Rapid Rail (BWRR).

The November 2018 Alternatives Report (Alternatives Report) selected two alignment alternatives for further study in the Draft Environmental Impact Statement (DEIS):

- Alternative J – Baltimore-Washington Parkway East
- Alternative J1 – Baltimore-Washington Parkway West

The alignments are 53 to 56 kilometers (33 to 35 miles) long, depending on terminal station options, with approximately 75 to 83 percent of the alignment in underground tunnel, and the balance elevated on viaduct.

Alternatives J and J1 utilize the same TMF options, with variations to ramps connecting the TMF to the mainline. When the TMF is on the opposite side of the Baltimore-Washington Parkway from an alignment alternative, the connecting ramps cross over the Parkway on a bridge structure.

4. TMF DESCRIPTION

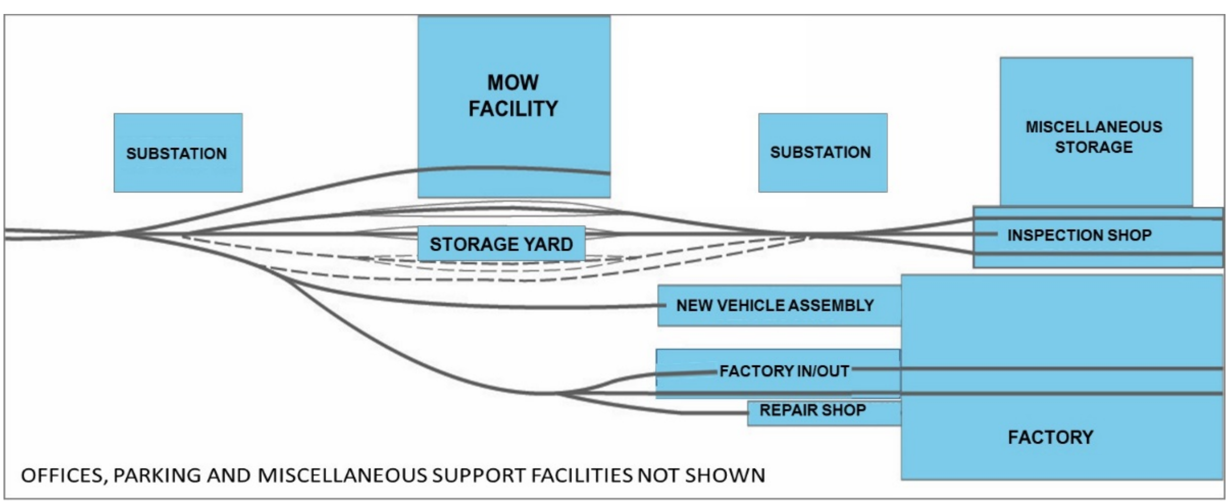
4.1 TMF COMPONENTS

The TMF serves as the home to the system's trainsets where they are stored, maintained, cleaned, inspected, repaired, and overhauled. Nearly 300 workers are employed at the TMF (This number has been estimated based on an evaluation of various other railroad requirements and will be refined as Project planning advances and operating details are finalized). See Figure 1 for a conceptual layout of TMF elements.

The TMF would house the following facilities:

- Storage yard, with guideways for staged trainsets
- Factory building where scheduled heavy maintenance work would be performed
- Inspection shop for performing daily inspections, daily service, and maintenance, etc.
- Repair facility for unscheduled repairs
- Factory "In/Out" shop for disassembling and assembling trainsets into individual coaches for major overhaul
- New vehicle assembly shop for assembling new component parts into complete trainsets and conducting major maintenance.
- Miscellaneous storage facility for materials used for inspection, maintenance, and repair of trainsets
- Two substations for train control and power supply within the TMF, each approximately five acres
- Miscellaneous support facilities (e.g., tire shop, battery shop, etc.)
- Parking for employees, material suppliers and guests
- Office space
- Maintenance of Way (MOW) facility, depending on TMF location

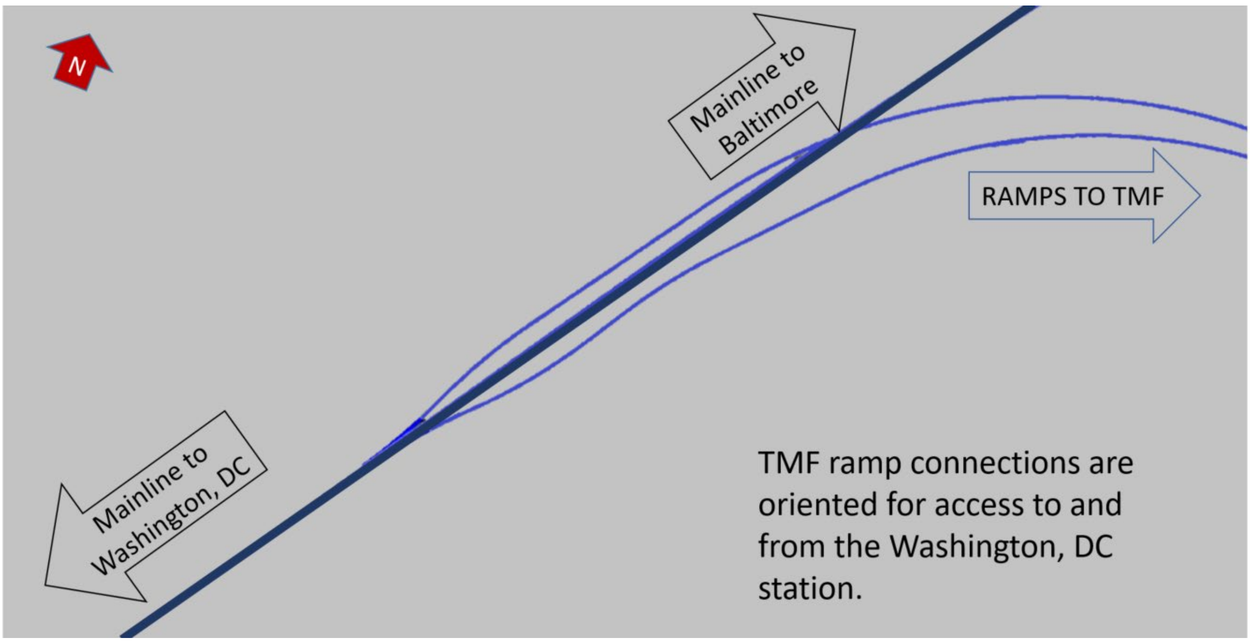
Figure 1. Conceptual Layout of TMF Elements



4.2 TMF RAMPS

Trains on the mainline access the TMF with ramps that connect to the Northbound and Southbound guideways. The turnouts on the mainline are oriented for trains traveling to and from the Washington, DC terminus station (Figure 2). Trains from the TMF that are going towards the Baltimore station would have to enter the mainline headed towards Washington and reverse direction to proceed Northward. Trains entering or exiting the mainline would operate at slow speed to maneuver the TMF turnouts.

Figure 2. TMF Ramp Configuration



The single guideway ramp structures are approximately 8.2 meters (27 feet) wide, supported on piers spaced at approximately 38 to 50 meters (125 to 164 feet).

The mainline guideway at the location of the TMF turnouts needs to be straight and have a profile grade of 0.3 percent or less, with no vertical curvature. The Northbound and Southbound ramps connecting the TMF to the mainline would have a minimum horizontal radius of 800 meters (2600 feet) and a maximum grade of 4 percent, however a reduced grade is preferred for one of the two ramps to facilitate towing of a disabled trainset.

Ramps within the TMF complex have a minimum horizontal radius of 800 meters and 0.0 percent vertical grade.

4.3 MOW FACILITY

Two MOW facilities are required between Baltimore and Washington, one in the Northern portion of the alignment and one in the Southern area. The MOW facility would have a total area of approximately 13 acres, with a maintenance garage for MOW equipment, a material storage facility, a crew building and a parking area. MOW equipment would be staged, inspected, and repaired in the garage.

Workers reporting to the crew building would be dispatched to perform nightly inspection and maintenance operations along the guideway. Ramps connecting the MOW facility to the mainline would allow maintenance vehicles access onto the guideways. A MOW facility co-located with the TMF would use the TMF ramps for mainline guideway access. Inspection and maintenance of the guideway would occur nightly between 11pm and 5 am, when no trains are allowed on the mainline guideways.

4.4 POTENTIAL TMF IMPACTS

The TMF has both day and night operations. Impacts associated with a TMF are described below.

Traffic. TMF personnel will work in various shifts and schedules with concentrated levels of traffic at normal shift change times. Truck traffic will consist of deliveries made to the material management facility generally during the day shift.

Light. Most of the trainset inspection, servicing and repair work would be performed within buildings at the TMF. Therefore, light and noise from the TMF would be kept to a minimum. Movement of trainsets between mainline, TMF work areas, and the storage yard would generally occur on evening and overnight shifts. Aside from the area lighting around the facilities, the most noticeable visual impact from operations may be from headlights of the trainsets and directional lighting throughout the facility, including the parking lot.

Coach lighting for trainsets while in the storage yard would be kept to a minimum. Yard lighting would be consistent with appropriate safety and security measures and combined with perimeter security. Directional lighting will be used to minimize offsite light impacts.

Noise. Noise impacts from the TMF would be minimal for equipment such as HVAC units, audible warning devices, etc. Trainsets would travel between the storage tracks and the inspection shop or factory on rubber tires, there is no steel on steel or catenary noise like a conventional trainset.

Safety and Security. Safety and security are key elements both to the entire rail operation, and to the TMF. The TMF facility would be designed and operated to protect both employee safety and to ensure the safe handling and storage of materials on site. As an element of the public transport network, the TMF would be made secure from encroachment or sabotage. The facilities would be designed with appropriate safety devices and procedures, directional lighting, and perimeter fencing. Security would be part of all plans, both during construction and during operation.

Onsite Storage. There would be a range of materials stored at the TMF, including trainset parts. Appropriate safety and material handling plans would be developed for all such materials. There would be regular truck traffic to support the material management function, including material deliveries, and outbound material for refurbishment or disposal.

Stormwater. Best management practices will be implemented during construction and continued through operations of the TMF site.

5. CONCEPTUAL ENGINEERING ALTERNATIVES (TMF)

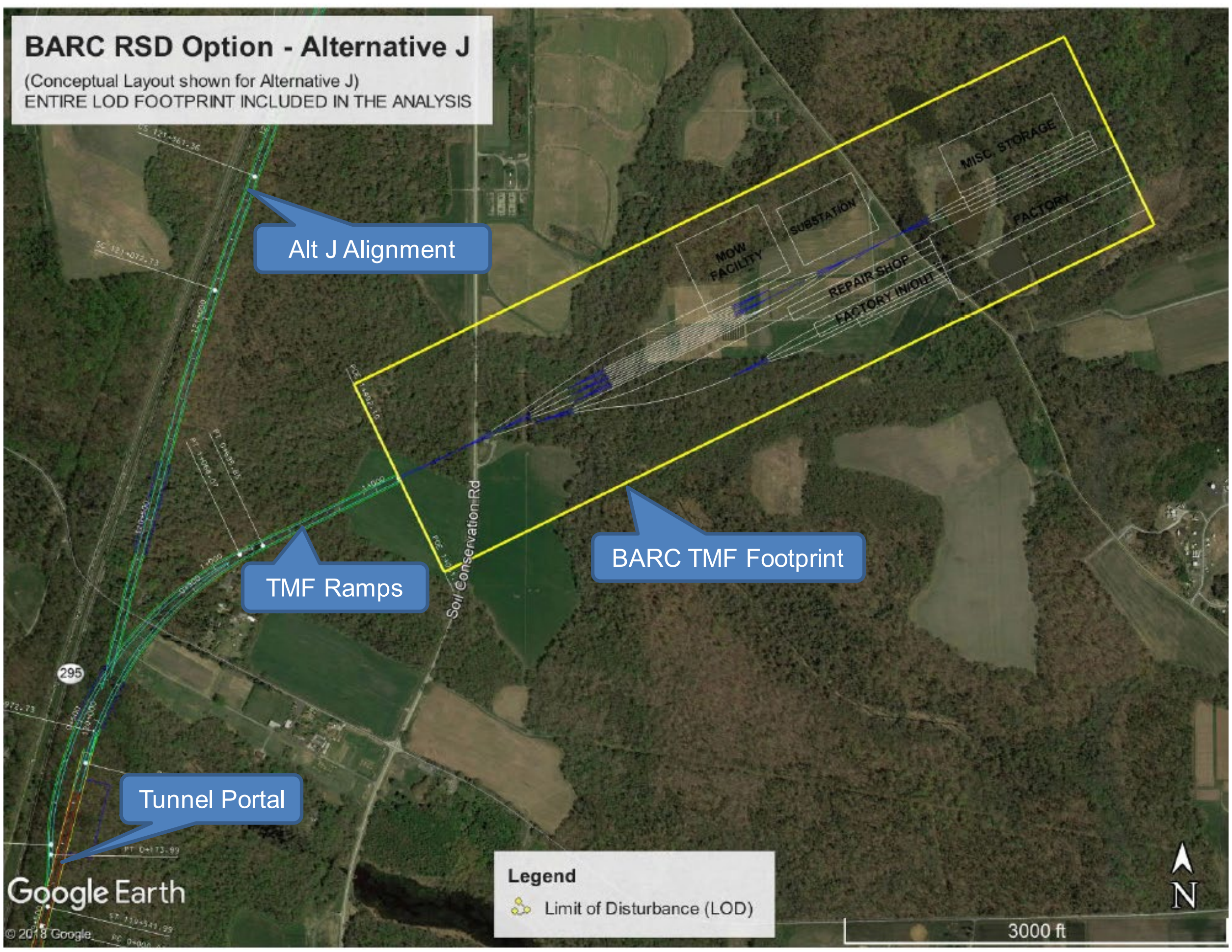
5.1 ALTERNATIVES REPORT

Studies conducted during conceptual engineering in support of the Alternatives Report used a 235-acre TMF footprint. The TMF footprint was applied to multiple locations along the two alignment Alternatives J and J1. TMF plans were developed and studied in the Alternatives Report for the following locations.

- Beltsville Agricultural Research Center (BARC) facility on the East side of the Baltimore-Washington Parkway, Prince George's County, MD. See Figure 3.
- North of MD-198 on the East side of the Baltimore-Washington Parkway, Anne Arundel County, MD. See Figure 4. (The footprint was slightly modified to avoid the Little Patuxent River).

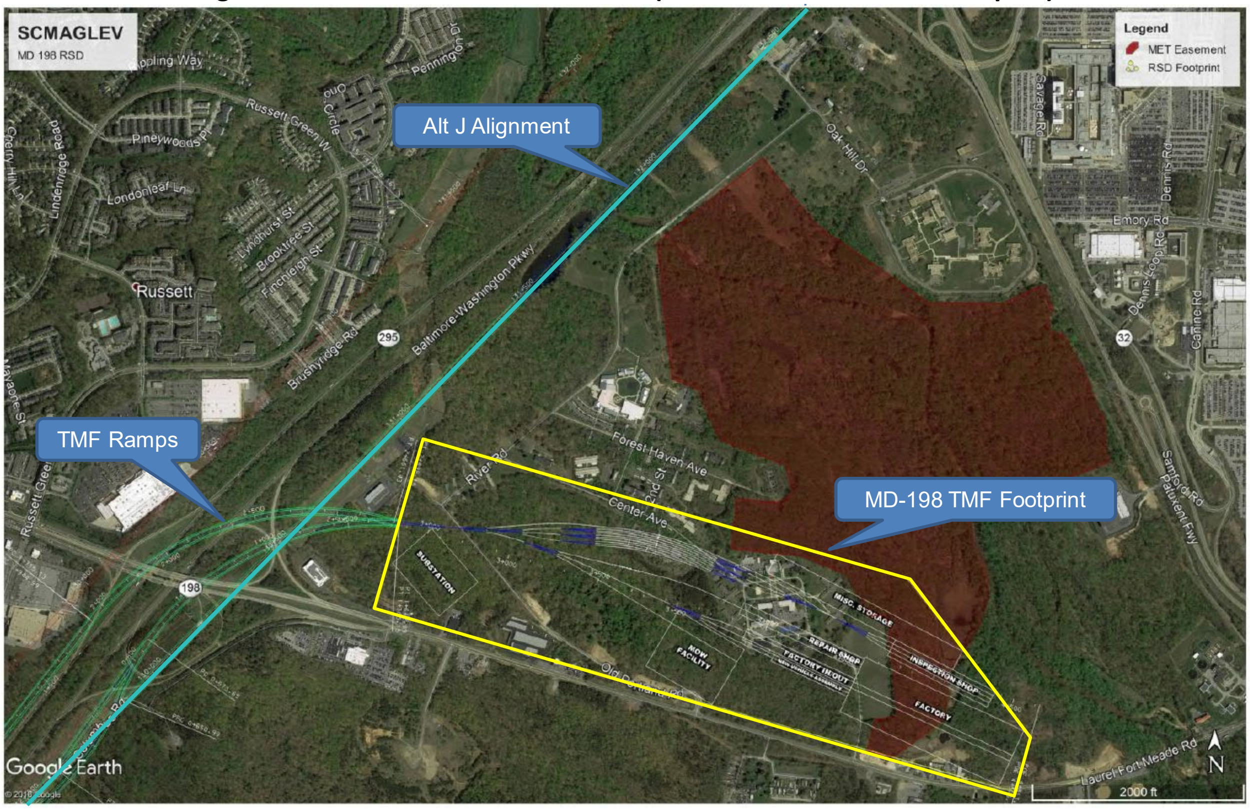
The Alternatives Report eliminated the original 235-acre BARC TMF location due to agency comments and concerns. The report retained the MD-198 alternative and outlined that further sites would be studied.

Figure 3. Original TMF Alternative at BARC (Eliminated in Alternatives Report)



Source: Alternatives Report (Nov 2018)

Figure 4. TMF Alternative at MD-198 (Retained in Alternatives Report)



Source: Alternatives Report (Nov 2018)

5.2 MODIFIED TMF LAYOUT

After the Alternatives Report was issued, BWRR explored options to reduce the site size of the TMF, including disaggregating the major operational elements onto separate parcels. If confined to approximately 120 acres, the reduced footprint and dispersed layout allowed additional sites to be considered. A total of eleven sites were explored along the Baltimore-Washington Parkway corridor for potential suitability. A location for the modified TMF layout with compatible land use was identified along Patapsco Avenue in the Cherry Hill area. That alternative is shown in Figure 5.

A smaller footprint was also explored at the MD-198 TMF site (Figure 6). The factory, inspection shop, repair shop and storage facility were combined into one building to reduce the overall footprint.

5.3 OPERATIONAL REVIEW

BWRR looked at other configurations for a TMF facility considering unique spatial limitations in certain locations. For example, could the various functions of a TMF be “disaggregated” to allow for a smaller footprint than Chubu’s streamlined layout. Specifically, BWRR considered disaggregated TMF layouts for the Patapsco Avenue and MD-198 TMF sites. Rather than arranging the storage yard and inspection shop in series, BWRR looked at whether trains could enter the storage yard and then switch back to enter the inspection shop, which was located further from the storage tracks than would be the case using the Chubu configuration.

An operational review was conducted with Japan Central Railroad (JRC) of the 120-acre reduced/disaggregated TMF. BWRR concluded the risk to efficient and reliable operations was simply too great to make a disaggregated TMF feasible. The trains would have to travel a longer distance from the storage tracks to the inspection shop adding a minimum of five minutes to each train movement between the storage yard and the inspection shop. This would add a total of two hours of travel time, thereby reducing revenue service hours since the required 6-hour maintenance window cannot be reduced. The addition of multiple switches and train movements also increased the risk that a technical malfunction would prevent timely inspections and maintenance.

The disaggregated layout also created inefficient material storage and handling since the inspection shop and factory share materials and equipment. At the Patapsco site, these were separated by approximately 1.7 kilometers (1.1 miles) and required bridging across a four-lane highway. The additional distance between maintenance operations required duplication of the shared resources and/or added travel time to retrieve resources that cannot be feasibly duplicated.

With extensive coordination with JRC BWRR determined that the layout of the Chubu TMF in Japan, which has been fully designed and is under construction, could be utilized for the Baltimore-Washington Project. It is approximately 180 acres and would result in a 24% reduction in size from the original proposal. The original layout at the MD-198 was dropped from consideration since the Chubu TMF layout was the most efficient and compact to have been designed. It requires 55 fewer acres than the original 235-acre MD-198 site in the ARDS report.

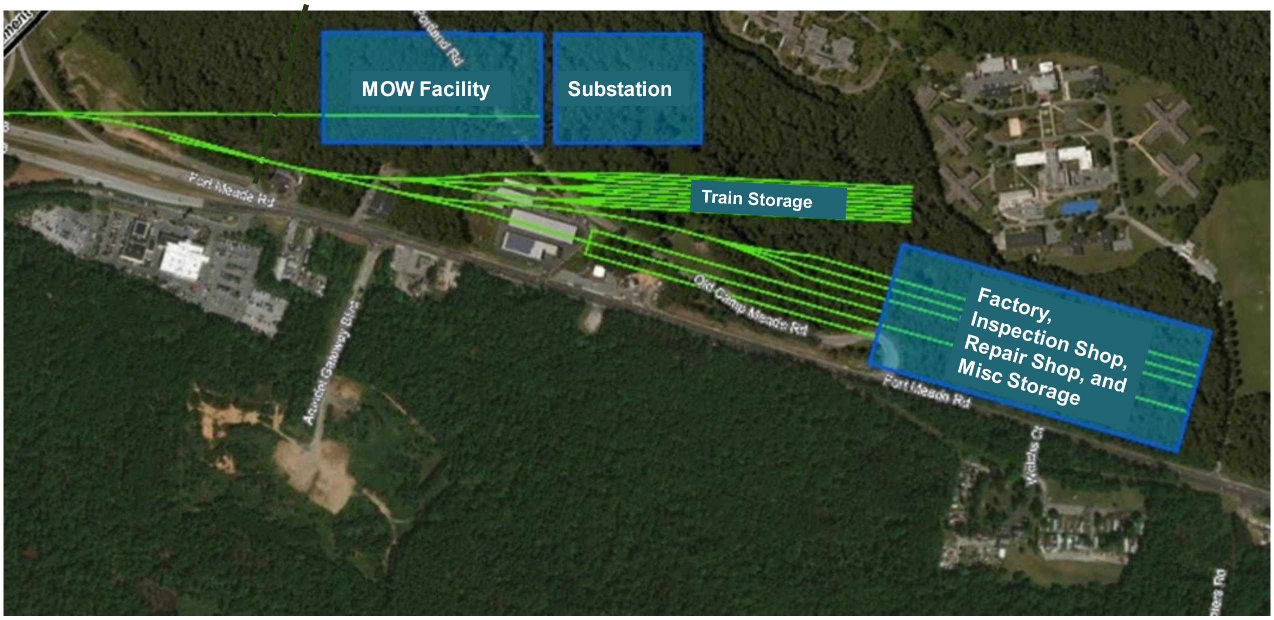
The Chubu TMF was designed based upon JRC's extensive experience with train operations and maintenance and is the smallest practicable size. JRC designed the Chubu TMF to allow trains to enter the facility directly from the mainline, and proceed immediately to the storage yard, from which individual trains can be moved into and out of the inspection shop. Similarly, trains can move to and from the assembly shop or factory directly from the mainline. This configuration minimizes the distance and time required for train movements, which is particularly important for ensuring that all necessary inspection and maintenance can be completed as expeditiously as possible, within the six hour window while maximizing the time available for revenue service operations.

It should be noted that JRC high speed trains operate at a very high standard for reliability and safety. JRC moves 150 million people a year on its system and the average passenger delay for a year is 20 seconds. In addition, there have been no fatalities since high speed rail operations began in 1964. In the United States, on-time performance between Washington DC and New York is defined as arriving within 30 minutes of scheduled time. According to the Department of Transportation there are 5,800 train car crashes each year in the United States, most of which occur at railroad crossings. These accidents cause 60 deaths and injure about 2,300, compared with zero on Japanese high-speed rail. Much of this is attributed to design, construction choices (viaducts and tunnels, no curves outside train geometry), and daily inspection and maintenance.

The operational inefficiencies produced by the disaggregated layout are similar for both the Patapsco and MD-198 TMF sites. Therefore, BWRR concluded that the only acceptable approach was to replicate the streamlined and thoroughly considered layout of the Chubu TMF.

Figure 5. Disaggregated TMF Site at Patapsco Avenue

Figure 6. Reduced TMF Site at MD-198



6. REDESIGNED TMF

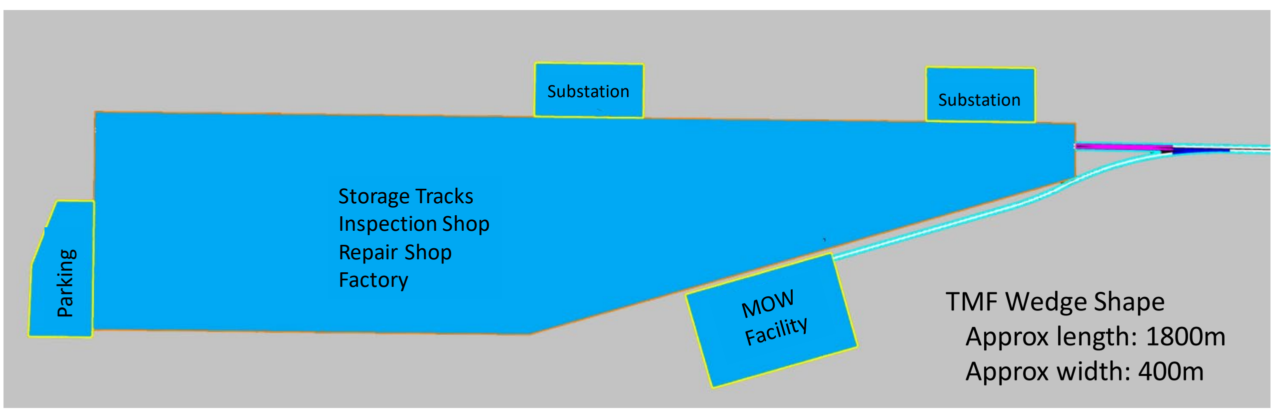
6.1 OPTIMAL TMF FOOTPRINT

Through additional coordination with JRC, and further evaluation of the facility layout and footprint, a 180-acre wedge shape was finalized with a length of 1800 meters (5,800 feet) and a width of 400 meters (1300 feet). This layout optimizes the operations for maintenance of the fleet. The footprint standardizes the TMF that is fully designed and is under construction in Chubu, Japan. The final TMF footprint is provided in Figure 7.

The 180-acre footprint is approximately 55 acres (24%) smaller than the original 235-acre site used in the Alternatives Report. The breakdown of the footprint is as follows:

- TMF wedge shape area of approximately 142 acres.
- Each substation of approximately 5 acres and enables the movement of different trainsets in the TMF.
- MOW facility of approximately 12 acres.
- Parking of approximately 6 acres.
- Ramps to the mainline of approximately 10 acres.

Figure 7. Final TMF Layout



The two substations would be optimally sited on the long side of the TMF, with one located near the entrance and the second substation approximately halfway along the length. For an optimal design, the parking area would be located with easy access to the roadway network, and the MOW facility would be positioned as close to the mainline as possible.

6.2 LOCATION CONSIDERATIONS

BWRR assessed fourteen (14) sites against the following key factors[2]:

- Sufficient size and shape for the 180-acre footprint
- Proximity to the Washington, D.C. terminus station, between D.C. and Baltimore
- Proximity to the mainline alignment with suitable geometry and orientation for TMF ramp connections
- Worker and material delivery access
- Avoidance of residential impacts

In response to agency input, an underground TMF alternative on BWI Airport property and a partially depressed TMF at MD-198 were explored. An underground TMF would require top down construction including the ramp connections to the mainline turnouts, resulting in temporary surface impacts over the full dimensions of the site. Additional permanent surface impacts would be imposed by a comprehensive system of ventilation and emergency egress facilities. According to engineering estimates, BWRR estimated the additional cost for construction would be over $1 billion compared to a conventional TMF on the surface. This additional cost results from several factors including, for example, the extensive excavation and movement of spoils, the need to construct walls and to cover the TMF, etc. Therefore, an underground TMF is not a reasonable or cost effective and economically infeasible.

Supported by this analysis, the TMF must be built above ground along a portion of the mainline alignment that is also above ground (viaduct). Both alignment alternatives have an elevated viaduct along the Baltimore-Washington Parkway, between Greenbelt and Fort Meade for Alternative J, and between Greenbelt and Maryland City for Alternative J1. Both alignment alternatives also have a short viaduct section around the Cherry Hill station alternative.

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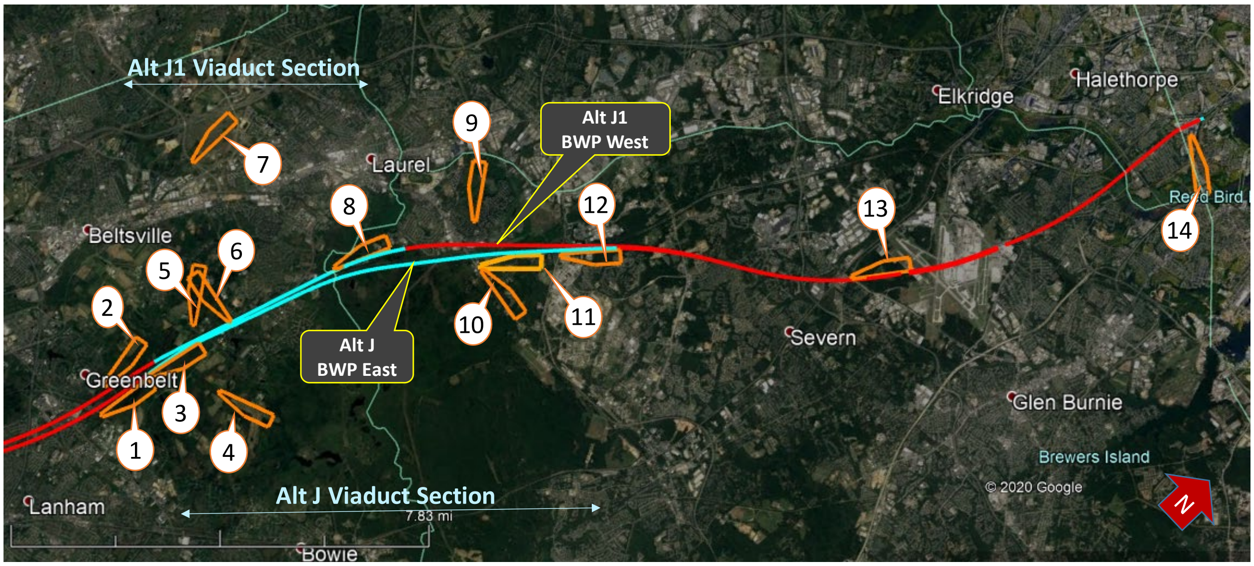
[2] Key factors were developed based on the subsequent operational analysis to ensure the TMF was located in an area along the alignment that meets the operational and maintenance requirements of the system.

7. TMF ALTERNATIVES

7.1 DESCRIPTION OF ALTERNATIVES

Using the 180-acre final footprint shown in Figure 7, a study was undertaken that included eleven sites that were previously evaluated plus three new locations that were subsequently identified, resulting in a total of fourteen sites shown in Figure 8 and assessed in Table 1.

Figure 8. TMF Site Alternatives



Each site is further described in Table 1.

All of the TMF sites are above ground and adjacent to a viaduct section of the mainline alignment, with the exception of Site #13, BWI Airport, and site #7. The MD-198 site was assessed two ways, #10A and #10B, with #10B excavated and depressed ~20m (66 feet) to avoid encroaching on Tipton Airport airspace.

TMF options on the West side of the Baltimore-Washington Parkway require TMF ramps to bridge over the Parkway to connect Alignment Alternative J. Similarly, TMF options on the East side of the Parkway require TMF ramps to cross over the Parkway to connect to Alignment Alternative J1.

7.2 EVALUATION CRITERIA

Table 1 provides information on each site, including ownership, surface characteristics, land use, feasibility of providing connecting ramps to the mainline, and impacts for each TMF alternative.

The first five columns in Table 1 provide site characteristics as described below.

- **Number (No.)** – Corresponds to numbers on Figure 8
- **Stationing** – Location along the Alternative J or J1 alignment
- **Location Descriptor** – Brief word identification
- **Property Owner** – Public or private owner
- **Characteristics / Land Use** – Surface characteristics such as woods, cropland, wetlands, rivers, and land use: residential, commercial, institutional parkland, etc. The elevation differential across the TMF footprint is provided.

The remaining columns provide additional details about each site that can be considered in an evaluation of alternatives. The following discussion describes the characteristics and how they are evaluated for consistency with the design criteria of the project.

- **TMF Ramps to Mainline** – Ramps that connect the TMF site to the Northbound and Southbound guideways on the mainline alignment.
    - Ramps that do not connect above ground were inconsistent with the design criteria adding additional cost on the order of $500 million, adversely impacting financial viability. Additionally, surface impacts associated with the construction of underground switchboxes, tunnel transition portals and ventilation facilities would pose substantial impacts.
    - Ramps in tunnel are therefore deemed **UNACCEPTABLE.**
- **Residential Impacts** – Direct impacts to residential properties by either the TMF or the TMF ramps.
    - Impacts to residences were considered **UNACCEPTABLE** and serious impediments based on the objective to avoid, minimize and mitigate impacts.
    - Impacts to residentially zoned properties that are not developed were considered **ACCEPTABLE**.
- **Wetland Impacts** – Wetland impacts quantified based on GIS data, supplemented by AECOM field studies, where available. The impacts noted are gross impacts and do not reflect mitigation, construction methods or post-construction impacts.
- **Parkland Impacts** – Impacts identified for areas that are designated as parkland.
- **Other Impacts** – Impacts to institutional facilities, major utilities, churches, cemeteries, transportation infrastructure, etc.
    - Completion of the TMF is a critical component of the project schedule as it is required to take delivery of the trainsets and commence assembly and testing.
    - Impacts were considered **UNACCEPTABLE** if the mitigation efforts required would add two or more years to the project schedule. The cost of overall construction would increase with a delay.

- **Cost Increment** – The additional cost of an alternative compared to all other alternatives due to site specific conditions, such as a requirement for underground construction.
    - Substantial cost increases were deemed **UNACCEPTABLE** due to a substantial adverse impact on the economic viability of the project.
- **Distance to Washington, DC Station** – The deadhead travel distance between the TMF and the Washington, DC terminal station. The operating assumption is that all revenue trains end their service at the DC station. The distance is important because a longer distance reduces time available for maintaining trainsets and guideway infrastructure during the 6-hour maintenance window.

Table 1. Evaluation of Fourteen Potential TMF Sites (180-acre footprint)

#	Stationing	Location Description	Property Owner	Characteristics / Land Use	TMF Ramps to Mainline	Residential Impacts	Wetland Impacts (acres)	Parkland Impacts	Other Impacts / Cost Differential	Distance to DC Station km (miles)
1	118+500	Greenbelt, MD East of BWP	BARC, NASA, Prince George's County	Woods, cropland Institutional - USDA facilities 18m (60 ft) elevation differential	Ramps would connect to mainline in tunnel Unacceptable	None	1	Yes	Relocate Explorer Rd	18.5 (11)
2	119+500	Greenbelt, MD West of BWP	BARC, Greenbelt	Greenbelt Forest Preserve Woods, cropland Institutional - USDA facilities 29m (95 ft) elevation differential	Ramps would connect to mainline in tunnel Unacceptable	44 acres zoned residential, not developed	4	Yes	Relocate access road to Northway Fields ballpark	19.5 (12)
3	121+000	BARC East Parallel to BWP	BARC	Woods, rivers, wetlands, cropland Institutional - USDA facilities 12m (40 ft) elevation differential	Ramps would connect to mainline in tunnel Unacceptable	None	34	No	Relocate Beaver Dam Rd	21 (13)
4[3]	121+000	BARC East	BARC, NASA	Airstrip, wooded, wetlands Institutional - USDA facilities 15m (50 ft) elevation differential	Ramps connect above ground to viaduct. No issue.	None	4	No	Relocate Springfield Rd Adjacent to NASA GGAO Ramps would be adjacent to BARC research fields may influence evapotransporation research, impacts to be assessed and mitigations to be developed in consultation w/BARC.	21 (13)
5[4]	121+500	BARC West	BARC, private	Woods, wetlands Institutional - USDA facilities: Several deteriorating buildings, 14 of which are slated for demolition per the recent EA (United States Department of Agriculture, 2020) 15m (50 ft) elevation differential	Ramps connect above ground to viaduct. No issue.	0.5 acre zoned residential, not developed	4	No	Relocate Entomology Rd Adjacent to DoS Beltsville Information Management Center Ramps in vicinity of BARC research fields may influence evapotransporation research, impacts to be assessed and mitigations to be developed in consultation w/BARC.	21 (13)
6	122+500	BARC West Perpendicular	BARC, GSA	Woods, wetlands Institutional - USDA facilities	East-West orientation of TMF requires ramps across US Secret Service Alt J1 ramps cross BW Parkway two times	None	11	No	Adjacent to DoS Beltsville Information Management Center Relocate US Secret Service training facility due to TMF ramp traversing through the middle of the campus. Unacceptable	22.5 (14)
7	124+000	Konterra, Beltsville, MD	PEPCO, Konterra Associates LLC	Open, disturbed 30m (100 ft) elevation differential	3 miles of ramps through residential and commercial areas	Ramps cross through several residential neighborhoods. Unacceptable	2	No	Site development is planned	24 (15)

[3] Alternative recommended for further study in the DEIS

[4] Alternative recommended for further study in the DEIS

#	Stationing	Location Description	Property Owner	Characteristics / Land Use	TMF Ramps to Mainline	Residential Impacts	Wetland Impacts (acres)	Parkland Impacts	Other Impacts / Cost Differential	Distance to DC Station km (miles)
8	127+500	Suburban Airport, Maryland City, MD	Commercial, Anne Arundel County	Woods, parkland Residential Former Suburban Airport site 14m (45 ft) elevation differential	Ramps connect above ground to viaduct. No issues	Over 50 homes Unacceptable	44	Yes	Relocate Brock Bridge Road Relocate Maryland City Wastewater Treatment Facility Relocate Maryland City Park ball fields	27.5 (17)
9	130+500	Russett, MD	Anne Arundel County, Private Owners	Woods, Wetlands 37m (120 ft) elevation differential	1 mile of ramps through residential and commercial areas	5 to 10 homes for TMF and ramps Unacceptable	23	No	Relocate Resurrection Roman Catholic Church Relocate Brock Bridge Rd	30.5 (19)
10A[5]	130+500	MD-198 East-West Laurel, MD	Federal Gov't (DC use) BGE Private	Woods, Wetlands, Commercial, Rivers Institutional Conservation easement 30m (100 ft) elevation differential	Ramps connect above ground to viaduct. No issues	None	32	Yes	Encroaches 10m (30 ft) into Tipton Airport airspace Oak Hill Conservation Easement 61m (200 ft) high shop next to residential area Relocate BGE critical infrastructure, relocate Job Corps Relocate Old Portland Rd	30.5 (19)
10B	130+500	MD-198 East-West Laurel, MD Same as Alternative 10A, except TMF depressed 20m (66 ft) to avoid Tipton airspace	Federal Gov't (DC use) BGE Private	Woods, Wetlands, Commercial, Rivers Institutional Conservation easement 30m (100 ft) elevation differential	Ramps are depressed in tunnel, with tunnel portals and switchbox in Patuxent Research Refuge Unacceptable	None	32	Yes	Avoids Tipton Airport airspace impact Oak Hill Conservation Easement 52m (170 ft) high shops next to residential area Relocate BGE critical infrastructure, relocate Job Corps Relocate Old Portland Rd Portal and switchbox in Patuxent Refuge Unacceptable Added cost of approximately $500 million for depressed TMF and ramps Unacceptable	30.5 (19)
11	130+500	MD-198 North-South Laurel, MD	Federal Gov't (DC use)	Woods, Institutional River valley Cemetery Conservation easement 24m (80 ft) elevation differential	Ramps connect above ground to viaduct. No issues	None	17	Yes	Historic Forest Haven Cemetery Oak Hill Conservation Easement Relocate critical BGE infrastructure Relocate Maya Angelou Academy / Youth Rehabilitation Services Department (DC) 61m (200 ft) high shops Relocate River Rd, Center Ave, Forest Haven Ave, Old Portland Rd Unacceptable	30.5 (19)
12	133+500	Fort Meade	Fort Meade (NSA Exclusive Use)	Institutional, Woods 29m (95 ft) elevation differential	OK for Alt J. Alt J1 is in tunnel, requires 3 mile long ramps to North portal	30 homes Unacceptable	0	No	Relocate multiple NSA facilities Relocate Connector Rd Unacceptable	33.5 (21)

5 Alternative recommended for further study in the DEIS

#	Stationing	Location Description	Property Owner	Characteristics / Land Use	TMF Ramps to Mainline	Residential Impacts	Wetland Impacts (acres)	Parkland Impacts	Other Impacts / Cost Differential	Distance to DC Station km (miles)
13	142+500	BWI Airport	State of Maryland	Airport, Woods 21m (70 ft) elevation differential	Ramps would connect to mainline in tunnel Unacceptable	Switchboxes for ramps would impact dozens of homes. Unacceptable	0	No	Relocate active BWI freight facilities Relocate planned new runway at BWI Relocate Mathison Way Unacceptable Requires underground facility, and underground ramps, with additional cost of approximately $1 billion Unacceptable	42.5 (26)
14	153+500	Patapsco/ Cherry Hill	Private commercial/ industrial CSX, MTA Residential Baltimore County	Developed area Parkland Utilities 18m (60 ft) elevation differential	Ramps would connect to mainline in tunnel Unacceptable	Hundreds of residences in 20 acres of Cherry Hill apartment buildings Unacceptable	0	Yes	Relocate CSX Relocate MTA Light Rail Relocate W. Patapsco Ave Southwest Area Park	53.5 (33)

7.3 EVALUATION OF ALTERNATIVES

Based on the evaluation provided in Table 1, all but three alternatives were found to have conditions that did not meet the design criteria for the project. The two BARC alternatives were found to have the least amount of impacts, and given both alternatives were located on BARC property it was determined to retain a third non-BARC alternative for purposes of study and comparison to the two BARC alternatives.

- Six alternatives did not allow connecting ramps to the viaduct section of the mainline: #1, #2, #3, #10B, #13 and #14
- Six alternatives impact existing residences: #7, #8, #9, #12, #13 and #14
- Six alternatives had other impacts of a severity that mitigation would be difficult or impossible: #6, #10A, #10B, #11, #12 and #13
- Two alternatives, #10B and #13, had an unreasonable cost penalty for all underground construction

Impacts to parks and wetlands were also assessed:

- Four sites have over 20 acres of wetland impacts: #3, #8, #9, #10A and #10B
- Seven sites impact parkland: #1, #2, #8, #10A, #10B, #11 and #14

The original MD-198 (#10A) location that was recommended for further study in the Alternatives Report was found to have multiple design, construction and property complications in the opinion of BWRR. The following impacts were identified (see Figure 9):

- Substantial elevation changes across the site resulting in a 60m high (200 feet or 20 stories) maintenance shop within a river valley and adjacent to a new residential development.
- Encroachment into the Tipton Airport airspace (Note: an EA is under review by the FAA to extend the airport's runway and expand the clear zones at both ends of the runway).
- Encroachment on the Oak Hill Conservation Easement that was created as part of a consent agreement with USEPA.
- Impacts to critical BGE infrastructure, including aerial and underground power lines feeding NSA and underground gas lines. BGE has stated it is unacceptable to impact power supply to NASA.

With the exception of mitigating airspace encroachment, the excavated and depressed version of the MD-198 site (#10B) does not eliminate these impacts. A depressed facility would add substantial cost (near $500 million).

Aside from the sites located on BARC property, the MD-198 site (#10A) is the only other site that does not require residential displacements. It is the only non-BARC alternative and so is retained for further discussion and comparison with the two BARC alternatives.

The Patapsco / Cherry Hill TMF location that was identified following the Alternatives Report is no longer considered viable with the final TMF footprint. The following impacts were identified:

- Substantial residential impacts.
- TMF ramps would not be able to connect to the mainline in a viaduct section, see Figure 10.

Figure 9. Alternative #10 MD-198 TMF

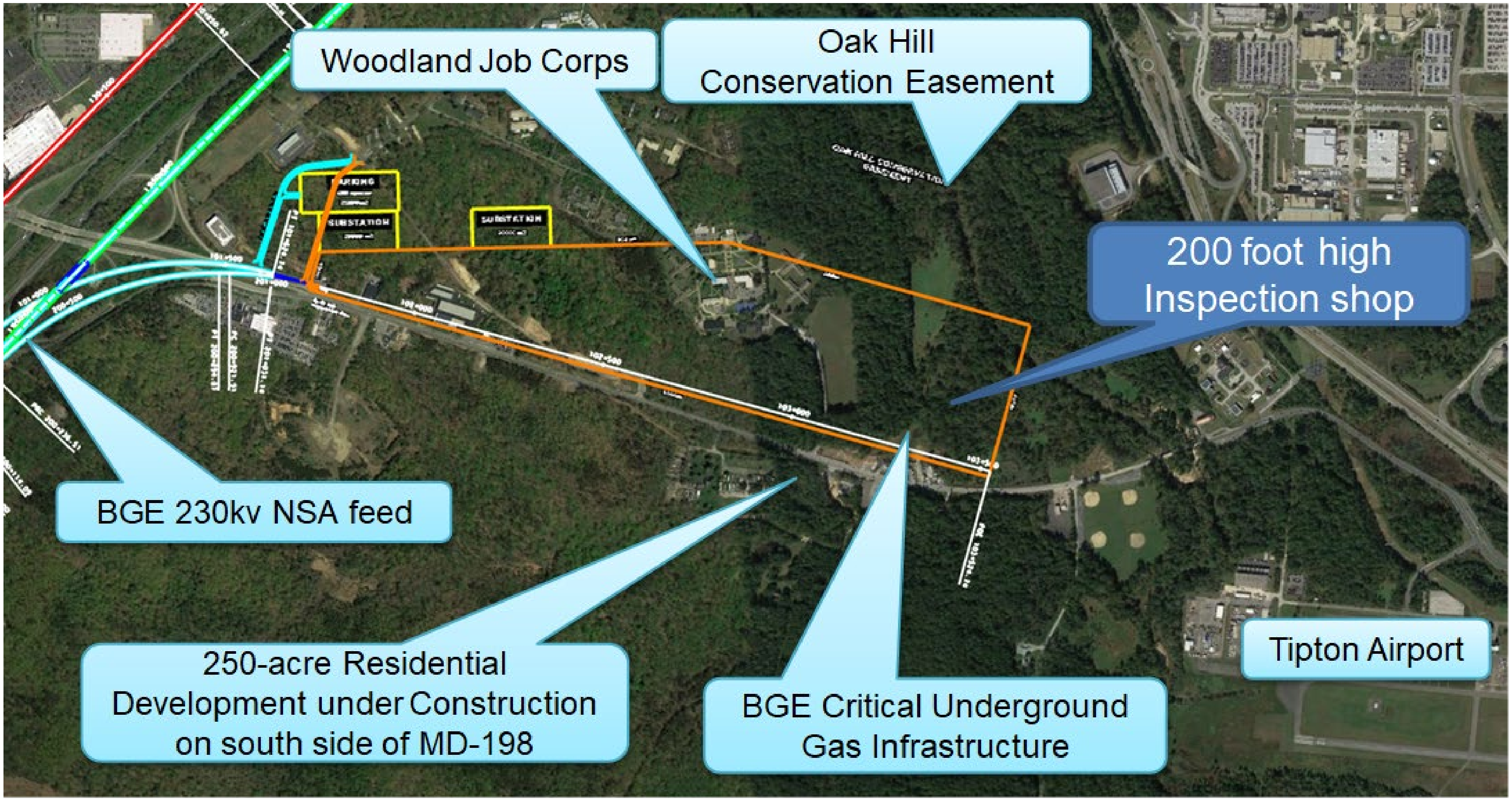
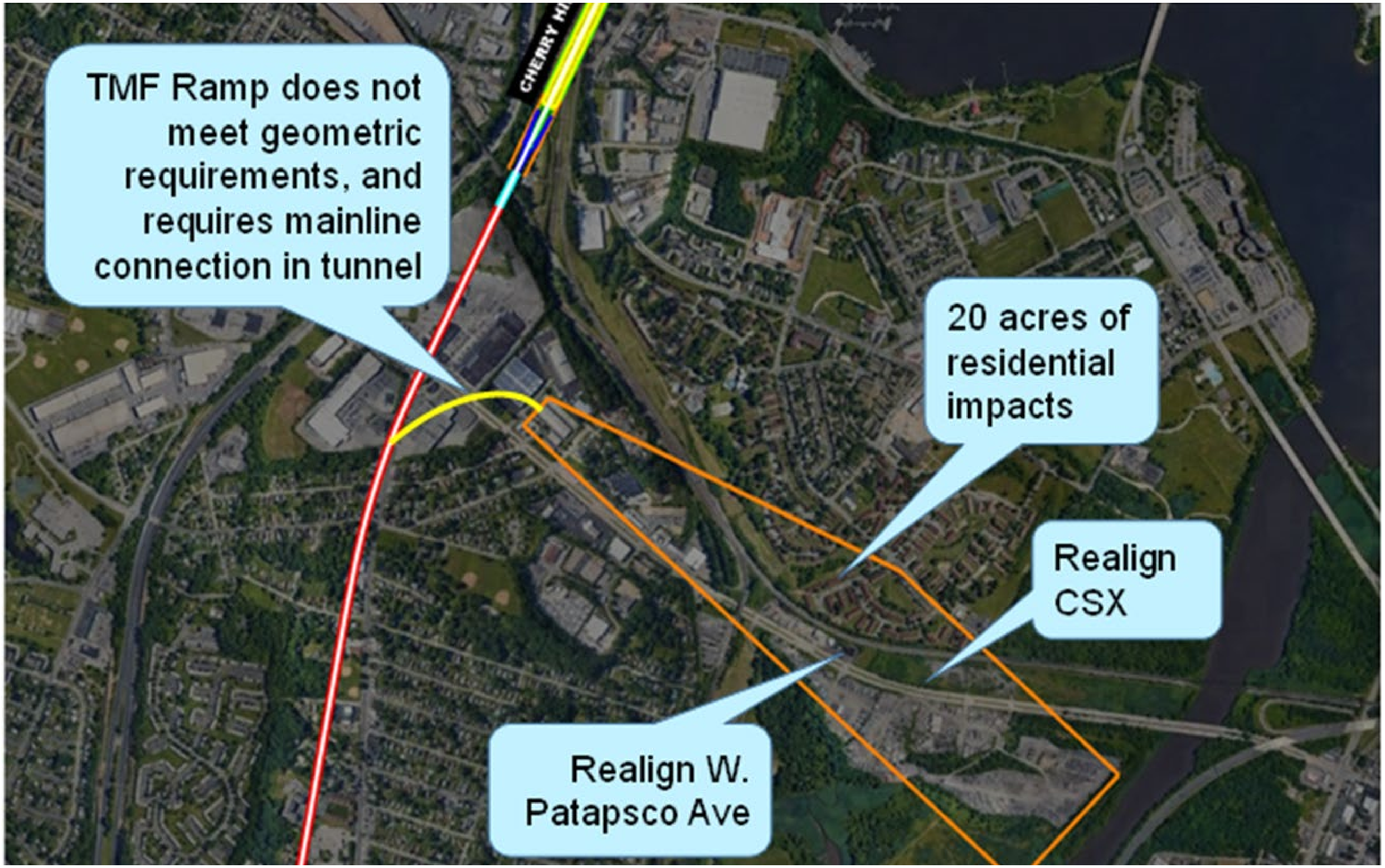


Figure 10. Alternative #14 Patapsco Avenue TMF



8. CONCLUSIONS AND RECOMMENDATIONS

Avoiding impacts to residential properties through this densely populated corridor presents the single biggest challenge to siting a TMF. Of the alternatives studied, two were found by BWRR to best meet the design criteria and a third, while containing multiple property, design and construction complications is retained for further review and comment in comparison with BARC alternatives in the DEIS:

- **#4 BARC East** – Located on the USDA BARC Eastern campus on land formerly used as an airstrip. Adjacent to NASA Goddard Geophysical and Astronomical Observatory (GGAO). NASA raised issues related to frequency interference, EMF, vibrations, and light impacts; BWRR believes these concerns can be mitigated. For example, the primary frequencies used by SCMAGLEV are outside the frequency range identified by NASA as a concern. BWRR believes additional concerns can be mitigated upon detailed review and discussion.
- **#5 BARC West** – Located on the USDA BARC Central Farm on forested land; adjacent to the Department of State (DoS) Beltsville Information Management Center and a residential area. In a discussion between BWRR and DoS on November 22, 2019, the DoS representative indicated there would be no concerns about potential interference from the TMF.
- **#10A MD-198 –** Located on the North side of MD-198 encroaching 10m (30 ft) into Tipton Airport airspace, requiring an FAA Safety Waiver, into the Oak Hill Conservation Easement, requiring a release or replacement of the conservation easement, with a 61m (200 ft) high shop next to residential area, which BWRR deemed a significant impact, requiring relocation of BGE critical infrastructure, which BGE has noted is not subject to relocation due to national security concerns, and relocation of Job Corps facilities, which are possible but difficult.

The BARC property sites are reasonable choices for full NEPA evaluation given BARC's ability to house a 180-acre facility without residential impacts and its proximity to the Washington, DC terminus station. It is similar to public uses currently occupying BARC (or former BARC) property and new proposed uses. Of note, BARC recently was issued a Finding of No Significant Impact for the demolition of 22 derelict buildings, 14 of which are within the TMF footprint. This highlights the fact that BARC West is not a pristine untouched habitat.

To help mitigate concerns expressed by BARC in the Alternatives Report, BWRR proposes to explore hardscaping mitigations such as engineered drainage management and "green roof" systems as well as solar panel installations on the approximately 100-acres of TMF roofs.

These mitigations would be beneficial to BARC for the following reasons:

- The project mainline will be constructed on an elevated viaduct, which may offer other opportunities for the study of vegetation control measures for grasses, low shrubs, and other flora located adjacent to cropland and transportation infrastructure.
- Possible use of TMF Site facilities to preserve 100+ acres of green rooftop for the study of:
    - Cropping efficiency, productivity, and quality using roofs and other hard infrastructure as a sustainable crop production system (See National Programs # 216 "Sustainable Agricultural Systems Research;" # 305 "Crop Production").
    - Soil biodiversity and nutrient retention on green-rooftop and other hard-infrastructure systems (See National Program # 212 "Soil and Air").

- Innovative green-rooftop technologies for stormwater storage and retention and improved watershed management (See National Program # 211 “Water Availability and Watershed Management”).

- Utilization of the TMF to construct a modern greenhouse over a portion of the site.
    - USDA would benefit from a large-scale facility for greenhouse research projects.

Figure #11 shows Alternative #4, BARC East, including a MOW facility, substations, parking facility, and connecting ramps to the Alternative J alignment. Figure #12 shows the same TMF connecting to the Alternative J1 alignment, with TMF ramps crossing over the Baltimore-Washington Parkway.

Figure #13 shows Alternative #5, BARC West, with the supplemental facilities and connecting ramps to the Alternative J alignment across the Baltimore-Washington Parkway. Figure #14 shows the TMF with ramps connecting to the Alternative J1 alignment.

Figure #15 shows Alternative #10A, MD-198, developed with the supplemental facilities and connecting ramps to the Alternative J alignment. Figure #16 shows the TMF with ramps connecting across the Baltimore-Washington Parkway to the Alternative J1 alignment.

Figure 11. Alternative #4 BARC East TMF with Alternative J Alignment

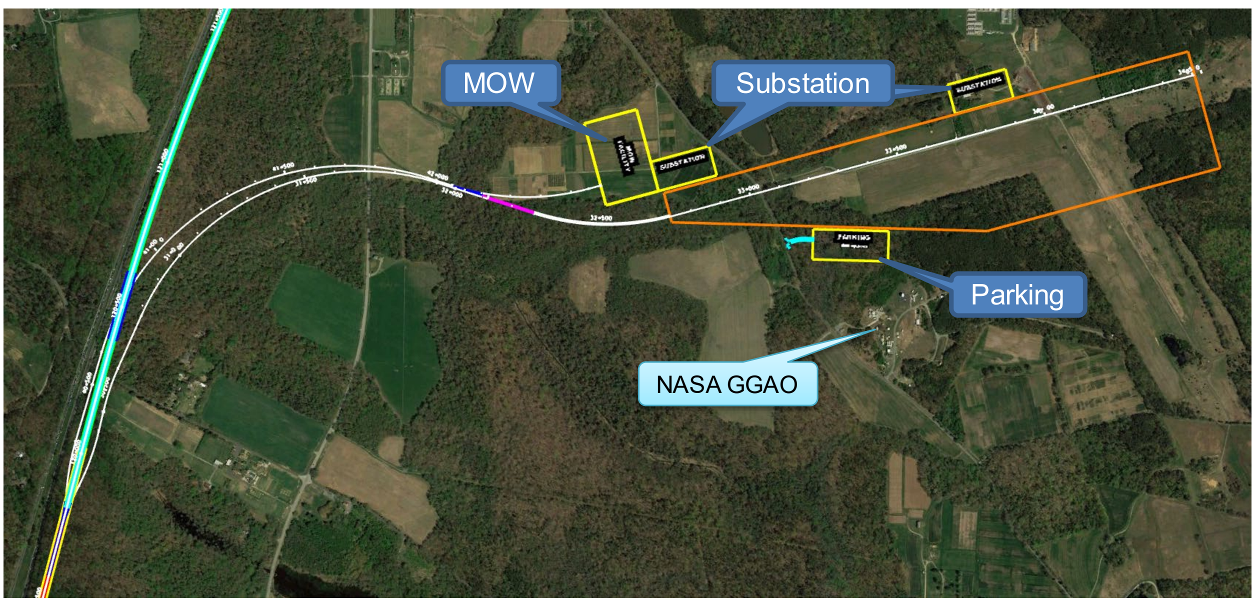


Figure 12. Alternative #4 BARC East TMF with Alternative J1 Alignment

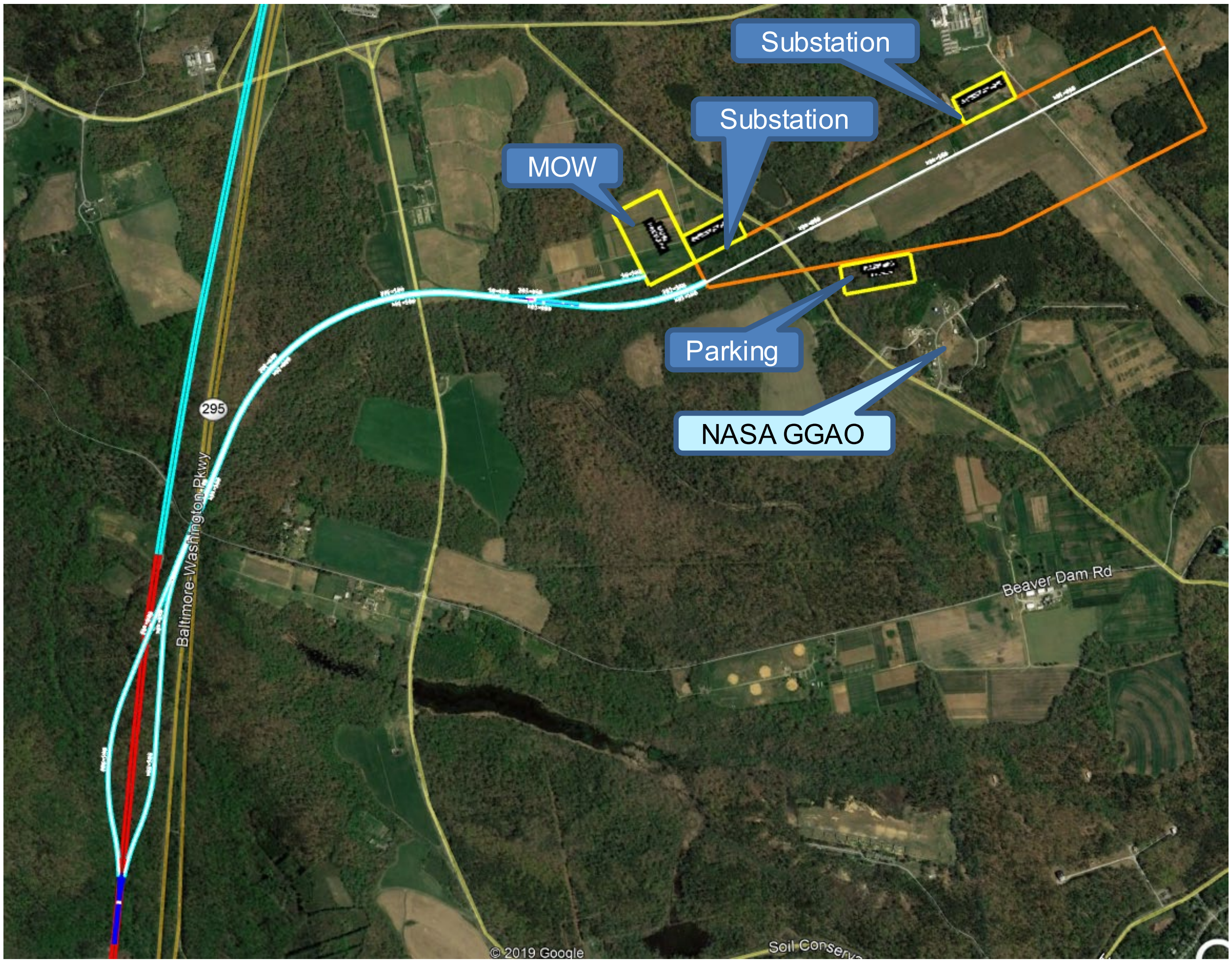


Figure 13. Alternative #5 BARC West TMF with Alternative J Alignment

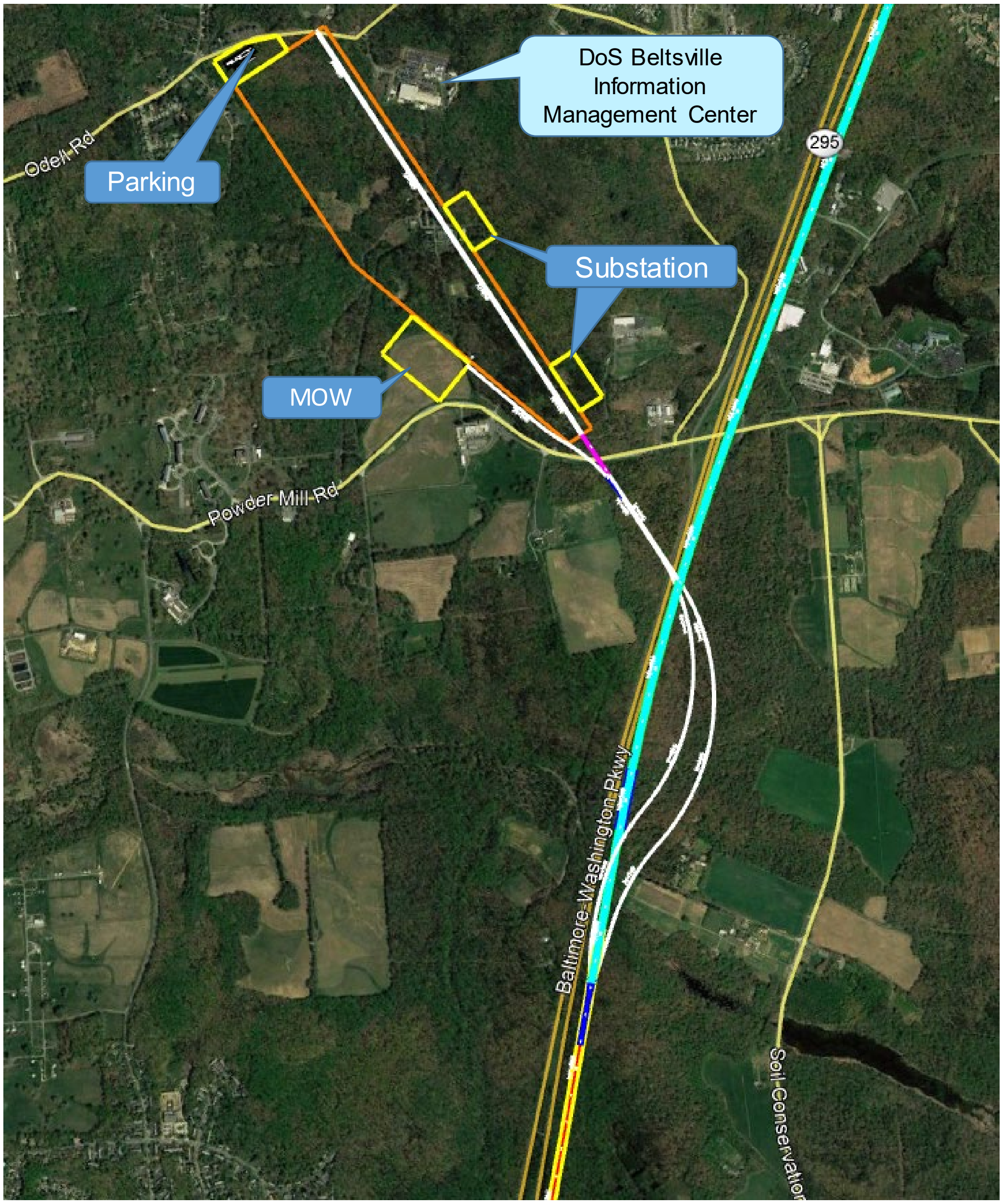


Figure 14. Alternative #5 BARC West TMF with Alternative J1 Alignment

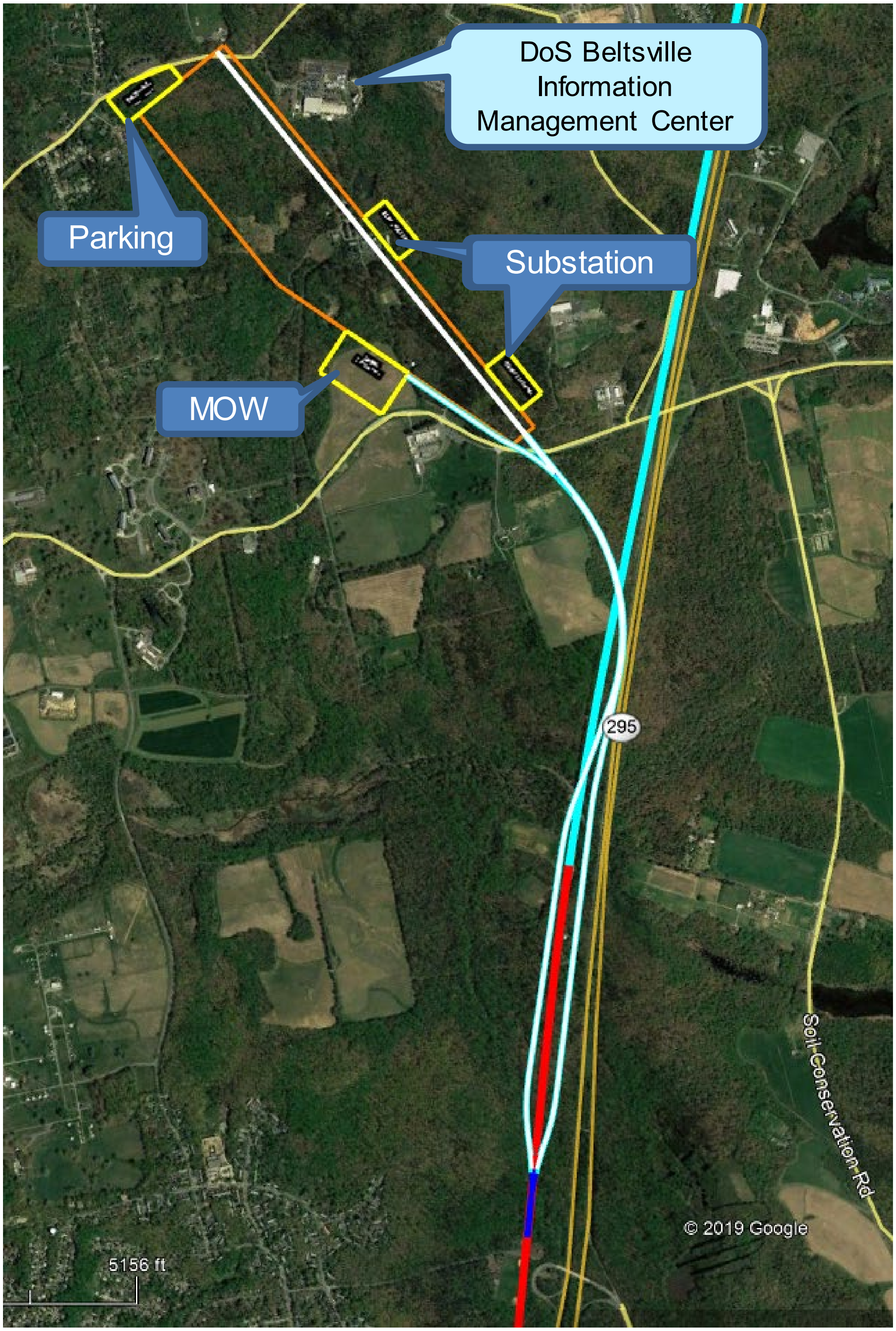
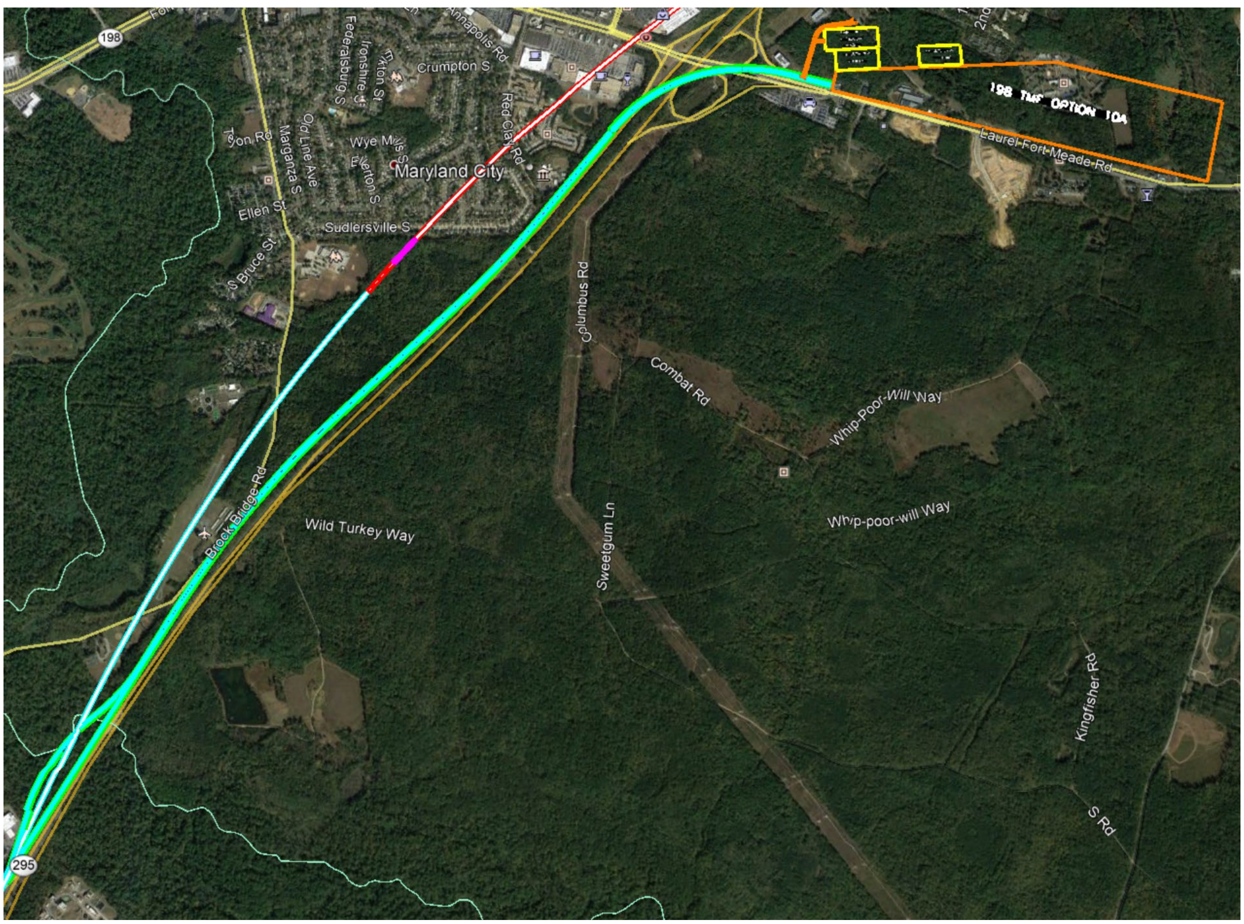


Figure 15. Alternative #10A MD-198 TMF with Alternative J1 Alignment

Figure 16. Alternative #10A MD-198 TMF with Alternative J1 Alignment



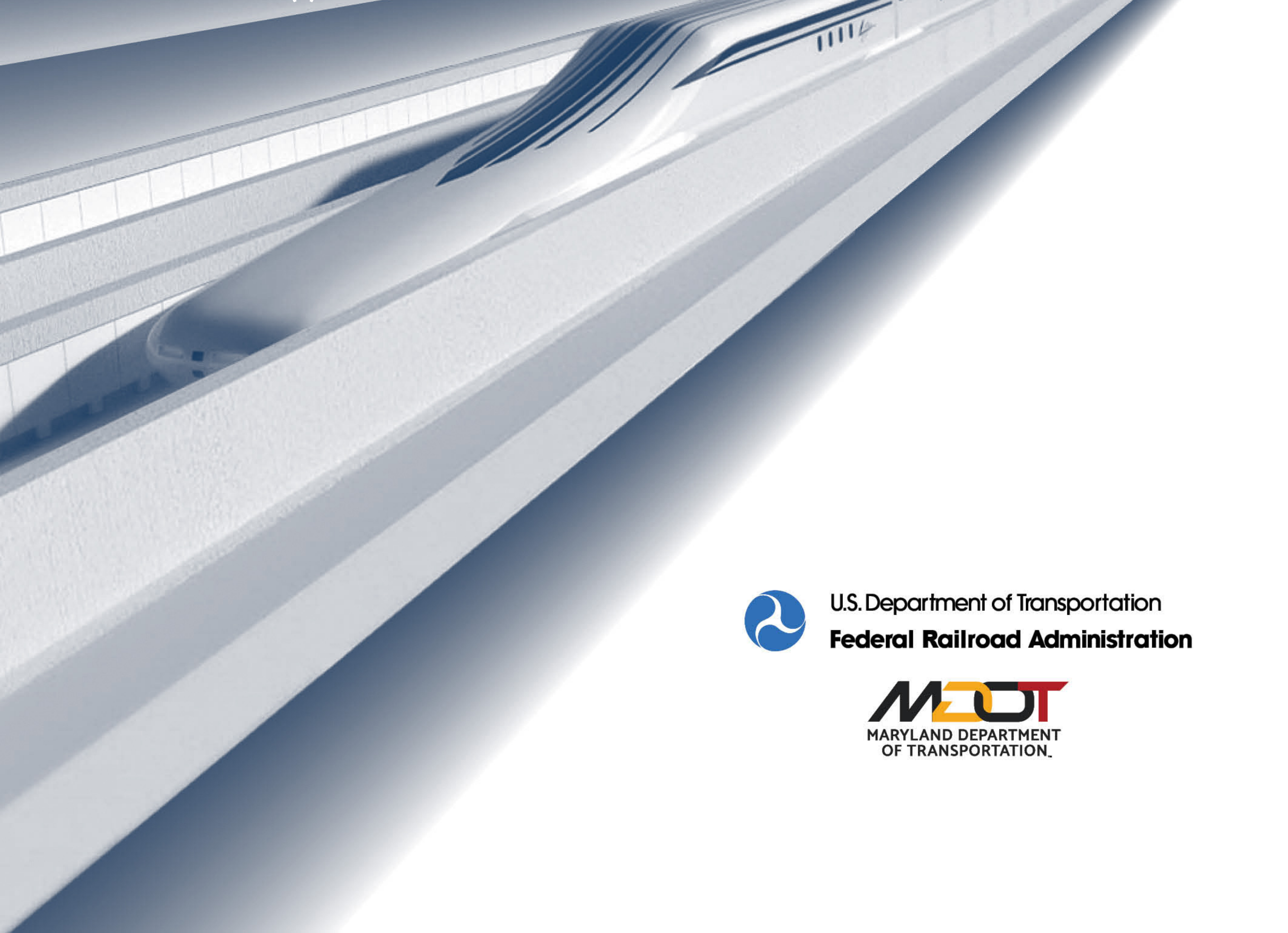
Appendix G13.

Preliminary Geotechnical Engineering Assessment Report

Materials Provided by the Project Sponsor

BALTIMORE-WASHINGTON SUPERCONDUCTING MAGLEV PROJECT

DRAFT ENVIRONMENTAL IMPACT STATEMENT AND SECTION 4(f) EVALUATION



U.S. Department of Transportation
Federal Railroad Administration

MARYLAND DEPARTMENT OF TRANSPORTATION

Baltimore-Washington SCMAGLEV Project Preliminary Geotechnical Engineering Assessment Report

Task: 4.3 Preliminary Engineering
Deliverable Name: Preliminary Geotechnical Engineering Assessment Report
Deliverable Description: Report

Revision 1, 2019-03-11

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TABLES & FIGURES

EXECUTIVE SUMMARY

The Northeast MAGLEV (TNEM) and Baltimore-Washington Rapid Rail (BWRR) are proposing a 60 km (37 mile) long superconducting magnetic levitation (SCMAGLEV) rail line between Washington, D.C. and Baltimore, MD. Two alignment alternatives are being considered and a preliminary ground investigation program was conducted in the spring-summer of 2018 to provide an initial assessment of anticipated ground conditions for construction. The program consisted of a total of 23 boreholes at approximately 3 km intervals along the alignment alternatives and was primarily performed by local Disadvantaged Business Enterprises (DBEs).

The results of the ground investigation program, summarized herein, confirm the entirety of the proposed alignment alternatives will be constructed within unconsolidated sediments of the Coastal Plain physiographic province. The material consists of Holocene-Pleistocene alluvium and terrace gravels, as well as Cretaceous sediments of the Potomac Group. The primary formations of the Potomac Group encountered are the Patuxent Formation, Arundel Formation, and Patapsco, which also represent important regional aquifers and aquicludes. The formations are fluvial in origin and consist of laterally discontinuous layers of sands, silts, and clays, with gravels. The Arundel Fm., primarily clays, acts as a barrier between the Patapsco and Patuxent aquifers. Pre-Cretaceous bedrock was encountered at depth at locations along the alignment in closest proximity to the Fall Line (boundary between the Piedmont and Coastal Plain physiographic provinces), corresponding to the Washington, D.C. and Baltimore Stations, as well as the central alignment segment. Limited temporary groundwater monitoring well installations suggest a fairly shallow groundwater table, indicating tunneling would occur almost entirely below the groundwater table.

The observed ground conditions permit preliminary considerations for design and construction, particularly with respect to top-down construction of stations, ventilation shafts, and Tunnel Boring Machine (TBM) tunnels. The high groundwater table and unconsolidated nature of the sediments impact the approach to support-of-excavation (SOE) for the top-down structures, with a need to prevent dewatering that could result in adverse impacts to existing structures by ground settlement. Tunneling is likely to be entirely within Potomac Group sediments and below the groundwater table. This indicates the need for a closed-face TBM capable of maintaining a pressurized face during excavation. The pressurized face prevents groundwater inflow, and hence dewatering of the sediments, minimizing both disturbance of the sediments as well as surface settlement.

The next phase of ground investigation will target the chosen alignment alternative with a higher quantity of boreholes and geotechnical material testing. This information, in additional to further illuminating the anticipated ground conditions along the alignment, will provide the data and ground parameters necessary for detailed design by the Design-Build (DB) contractors.

1.0 INTRODUCTION

The Northeast MAGLEV (TNEM) and Baltimore-Washington Rapid Rail (BWRR) are proposing a 37-mile (60 km) long superconducting magnetic levitation (SCMAGLEV) rail line between Washington, D.C. and Baltimore, MD. This Geotechnical Synopsis Report (GSR) summarizes the anticipated subsurface conditions during construction of the underground stations in Washington, D.C. and BWI Airport, the bored tunnels and cross-passages (if required), cut-and-cover tunnels, ventilation shafts, portal structures, viaduct structures, and the above-ground Baltimore Station. This report is intended to provide a general overview of soil/site conditions with the limited information collected during the preliminary ground investigation program. Additionally, preliminary discussions of construction considerations for major components of the alignment are discussed. The next phase of ground investigation, which will be far more extensive, will provide the testing data required for detailed design by the Design-Build (DB) contractors.

1.1 Purpose of Geotechnical Synopsis Report

This GSR is prepared for the Environmental Impact Statement. The objectives of the GSR are to:

1. Provide a preliminary evaluation of ground conditions, ground behavior, groundwater, in-ground obstructions, subsurface contamination, and gas conditions for the alignment.
2. Provide a summary of general construction considerations.
3. Provide a basis for preparing and executing the detailed ground investigation program along the preferred alignment alternative, including development of a Geotechnical Baseline Report (GBR).

1.2 Subsurface Investigations

The preliminary geotechnical boring program was executed by the local DBE Geotechnical firm BOTA Consulting Engineers, Inc. A total of twenty-three (23) borings were performed along the proposed alignment alternatives of the SCMAGLEV project (Figure 1). Prior to the start of drilling operation at each borehole, both Miss Utility and a Private Utility Locator were called to clear all underground utilities, notably electric line, gas line, waterline, sanitary sewer line, cable lines, communication lines, and others, within vicinity of the borehole. Where conflicts with utility lines were identified, the boreholes were offset to a safe distance before drilling operations began.

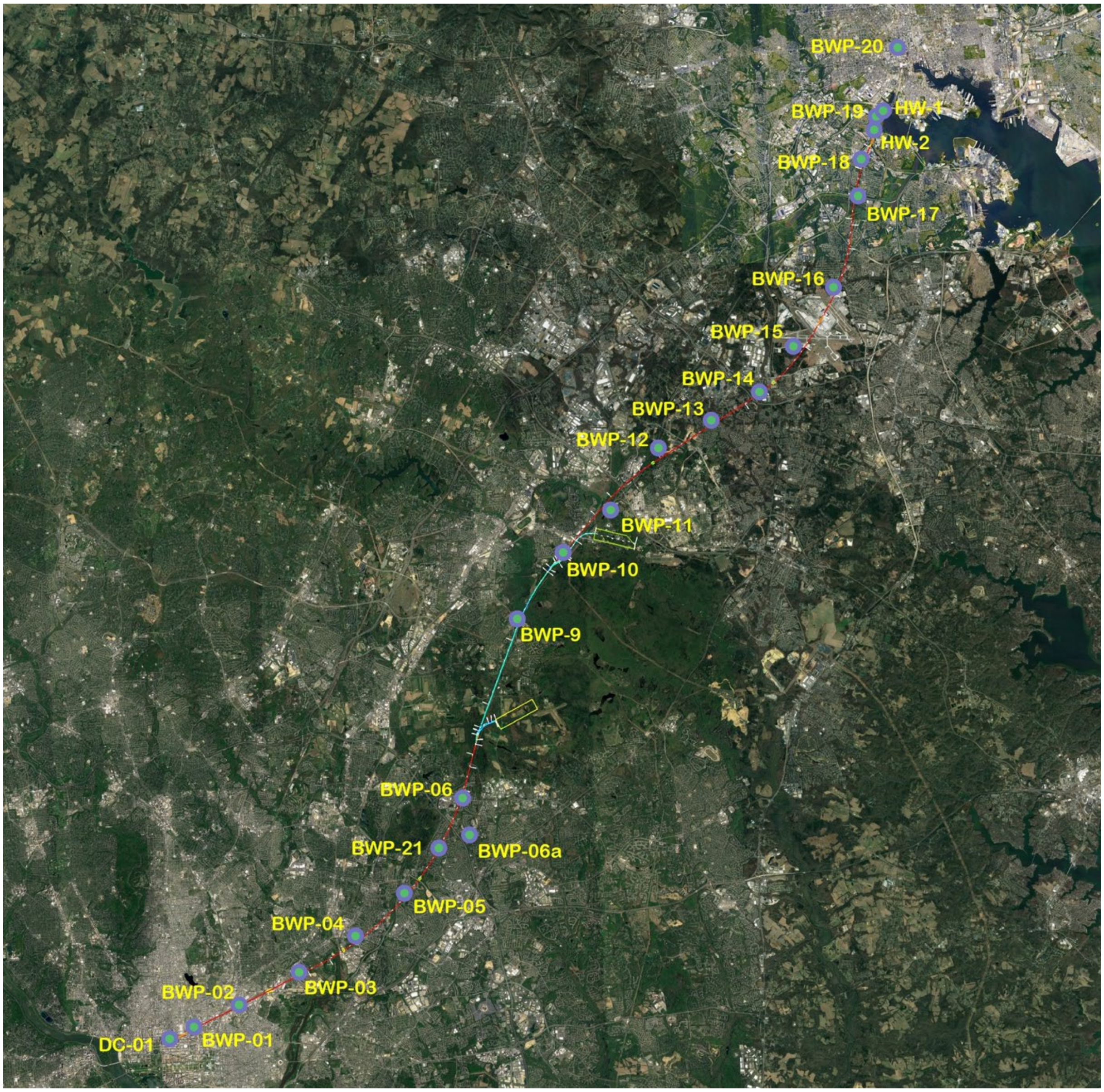


Figure 1. Plan view of boreholes from the Preliminary Ground Investigation Program

2.0 PROJECT DESCRIPTION

The SCMAGLEV Project is proposing a high-speed train system between Washington, D.C. and the City of Baltimore, approximately 60 km (37 mi) in length. This is the first leg of an envisioned route from Washington, D.C. to New York City. The SCMAGLEV system operates using a combination of electromagnetic levitation (support), propulsion and lateral guidance, rather than flanged wheels, axles and bearings as in conventional high-speed railways. The train system will cross several transportation corridors including interstate highways (I-95, I-195, MD295 Baltimore Washington Parkway, I-595, I-695, I-895), several state, city and local routes, and railroad lines, as well as the BWI Airport. All crossings will be grade separated. The project owner is the Northeast Maglev / Baltimore Washington Rapid Rail (TNEM / BWWR), with Louis Berger as the prime consultant and Gall Zeidler Consultants as the tunneling sub-consultant.

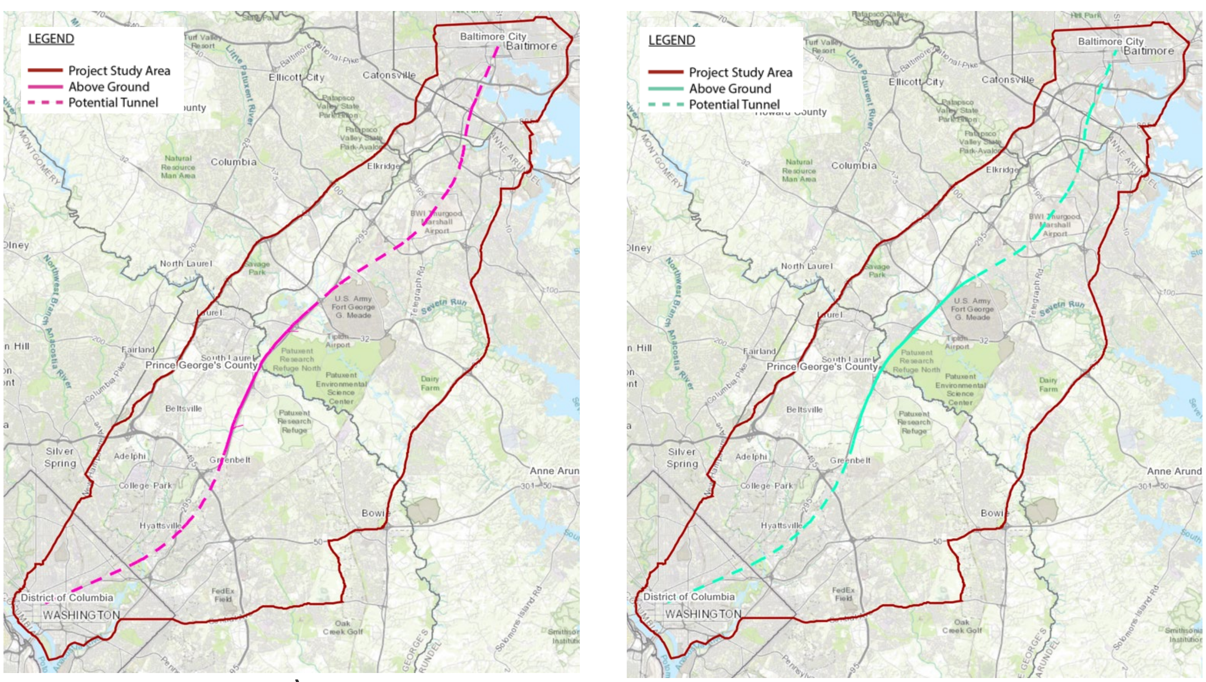
The project is in the preliminary engineering phase. An independent environmental review process was initiated in the fall of 2016 in accordance with the National Environmental Policy Act (NEPA), with a Record of Decision (ROD) anticipated in mid 2019.

2.1 Alignment Alternatives

The project is located in Washington, DC and Maryland, traversing a distance of approximately 60 km (37 mi) with three underground stations in Washington D.C., at BWI Airport and in Baltimore.

The SCMAGLEV system runs on an independent grade-separated right-of-way. The ultra-high speeds require relatively straight geometry with limited horizontal and vertical curvature. To accommodate the range of topographical and surface features, existing dense urban areas, utility mains, and existing structures, the proposed construction is expected to consist of below-ground (tunnel) for at over half of the route, and elevated structures (viaduct) for the remainder. The train system incorporates two main guideways, three stations, one rolling stock depot, electrical substations, right-of-way maintenance facilities, tunnel ventilation plants and emergency egress facilities.

The environmental review process initially identified several possible alignment alternatives which generally follow existing transportation corridors such as Baltimore Washington Parkway (MD 295), Amtrak Northeast Corridor, Washington, Baltimore and Annapolis Trail or a combination thereof, as shown in Figure 2. Alignment alternatives have since been further screened to two, which traverse the eastern and western sides of the BW Parkway. Overall, approximately 75% of the alignment is anticipated to be in tunnel and the remaining 25% is on elevated viaduct.



a) b)

Figure 2. a) Alignment alternative J Modified 1, and b) Alignment alternative J1 Option 5.

2.2 Elevation Datum

Elevations references in this report are reported in meters and based on the North America Vertical Datum of 1988 (NAVD88).

3.0 GEOLOGIC SETTING AND SUBSURFACE CONDITIONS

3.1 Regional Geological Setting

3.1.1 Washington, D.C.

A review of the published geological information indicates that the project rail alignment is geologically located in the Upland Deposits of the Atlantic Coastal Plain Physiographic Province. The Coastal Plain deposits are composed of sand, gravel, silt, and clay in well sorted and bedded fluvial deposits. The deposits are generally described as well-rounded cobbles and pebbles of gravel and quartz sand interbedded with layers of silt and highly plastic clay. Although the clay sediments appear to be very strong and over consolidated, these soils are unstable due to their inherent low residual shearing strength and the presence of fissures in their blocky structure. The clay and silt sediments are also known to be expansive and prone to shrink and swell due to the presence of montmorillonite as the predominant clay mineral.

3.1.2 City of Baltimore

The City of Baltimore lies within two physiographic provinces, the Piedmont Plateau and the Atlantic Coastal Plain. The North-Northeast trending Fall Line separates the two provinces, dividing the city in half. Most of the city is characterized by nearly level to gently rolling uplands, dissected by narrow stream valleys. The Baltimore segment of the proposed alignment alternatives, located in the eastern part of the city, is geologically situated entirely within the Atlantic Coastal Plain. Hilly areas and steep side slopes border the deeper stream valleys, particularly along the Fall Line, concentrating the flow of water in these watersheds into fast-moving, high-energy streams. Elevations range from sea level, where the Patapsco River is a tidal estuary, to as much as 146 m on the ridge on the Piedmont Plateau in the northwestern part of the city. These ridges descend gradually to the Coastal Plain in the south and east, where hilltop elevations average about 76 m.

City of Baltimore is underlain by the Baltimore Gneiss, a series of Pre-Cambrian quartzo-feldspathic, migmatite domes. Unconformably atop the bedrock are sediments of the Lower Cretaceous Potomac Group, which are overlain by younger sediments consisting primarily of sand and gravel and minor amounts of silt and dark clay.

3.2 Subsurface Materials Along Alignment Alternatives

The regional geology along the proposed alignments is dominated by unconsolidated sediments Holocene to Pleistocene in age, Cretaceous Potomac Group sediments, and bedrock. With the alignments situated East of the Fall line, construction activities will primarily fall within sediments of the Potomac Group, which includes the Patapsco Formation (Fm.), Arundel Fm., and Patuxent Fm. (Glaser, 1969). The results of the preliminary geotechnical investigation, discussed herein, provide insight to the general stratigraphy and geotechnical properties of materials along the proposed alignments.

3.2.1 Fill

Fill deposits in the project area are unconsolidated soils that have been deposited by the activities of man. These soils will be encountered at the ground surface at the shaft sites and in general over the entire land surface along the proposed alignment alternatives. Fill deposits are highly variable in extent and composition, including all types of locally derived soils. Fill ranges from fine-grained to coarse-grained material and can contain fragments of construction debris, including wood, concrete, metal, cinders, and trash in varying amounts depending upon location.

Fill is more frequently granular than fine-grained and will typically be saturated unless its elevation is above the normal range of groundwater levels. Perched groundwater conditions above normal piezometric levels due to trapping of surface water infiltration can exist in fine-grained Fill soils. Permeability of the Fill will vary significantly based on its specific composition.

3.2.2 Alluvium

Holocene alluvium occurs within and along the floodplains of fluvial bodies encountered along the proposed alignments. Pleistocene alluvium is present within Washington, D.C. and consists of loose to dense silty sands with gravels and stiff lean clays. Borings show the thickness of this unit between 24 and 28 meters.

3.2.3 Terrace Deposits

Terrace deposits consist of interbedded sand, gravel and silty-clay. These sediments are Pleistocene in age and are encountered adjacent to streams crossing the proposed alignment alternatives, particularly through Prince George’s County.

3.2.4 Potomac Group

The Potomac soils were previously overlain by several hundred feet of soil deposits that were later eroded away. The fine-grained cohesive soils are hard and over-consolidated, and the coarse-grained cohesionless soils are dense to very dense. The primary formations that constitute the Potomac Group are the Patapsco/Arundel Fm. and the Patuxent Fm.

3.2.4.1 Patapsco Formation

The Cretaceous aged Patapsco Formation unconformably overlies the Arundel Fm. and consists of highly colored and variegated clays, sandy clays, and silts.

3.2.4.2 Arundel Clay

The Arundel Clay is a dense, low-permeability dark gray to maroon, massive lignitic clay and silt unit that also serves as the confining unit between the Lower Patapsco Aquifer system and the Patuxent Aquifer System. Identification is based mainly on the presence of dark grey clays and an overall higher proportion of clay and silt to sand compared with the Patuxent Fm. The Arundel Fm. unconformably overlies the Patuxent Fm. Borings show the thickness of this group (Patapsco Formation and Arundel Clay) between 13 and 86 meters.

3.2.4.3 Patuxent Formation

The Cretaceous-age Patuxent formation lies unconformably on the igneous and metamorphic bedrock along the proposed alignment alternatives. The Patuxent is comprised of permeable sand inter-bedded with low permeability silt and clay layers. The fluvio-deltaic deposits of the Patuxent are separated from the unweathered bedrock by an irregular saprolitic layer of varying thickness that reflects the undulating surface of the basement rock. Borings show the thickness of this formation between 6 and 54 meters.

3.3 Bedrock

The Maryland Coastal Plain physiographic province is underlain by basement rock consisting of Precambrian to Paleozoic crystalline rocks, as well as Mesozoic sedimentary and volcanic rocks. The overlying Cretaceous-age Potomac Group sediments often sit upon a saprolitic layer of weathered bedrock. Overall, the basement rock dips to the east-southeast at an approximate rate of about 13.26 m/km near the fall line, becomes gentler at approximately 5.68 m/km in southern Maryland, and increases in gradient to approximately 16.10 m/km thereafter (Hansen & Edwards, 1986). Locally, the bedrock surface is irregular. A general map of the elevation of the bedrock surface beneath the Coastal Plain sediments of Maryland is shown in Figure 3 below. This figure also includes an overlay of the approximate proposed alignment alternatives.

Bedrock shallows within 100 m of depth at segments of the proposed alignment alternatives that are closest to the Fall line, with an eastward deepening of bedrock at those segments that move easterly away from the Fall Line. Typically, a zone of weathered bedrock and saprolite of varying thickness was encountered in the upper part of the bedrock, with potential boulders of the bedrock material encountered in a Washington, D.C. borehole (DC-01). It is anticipated that the bedrock level will be at approximately -24 m El. in Washington, D.C., and about -22 m El. towards Baltimore. However, additional boreholes must be drilled to confirm these depths/elevations. This assessment is based on a limited number of borings and cannot account for local irregularities in the bedrock. A more constrained assessment of bedrock surface elevations will be determined from the next phase of ground investigations.

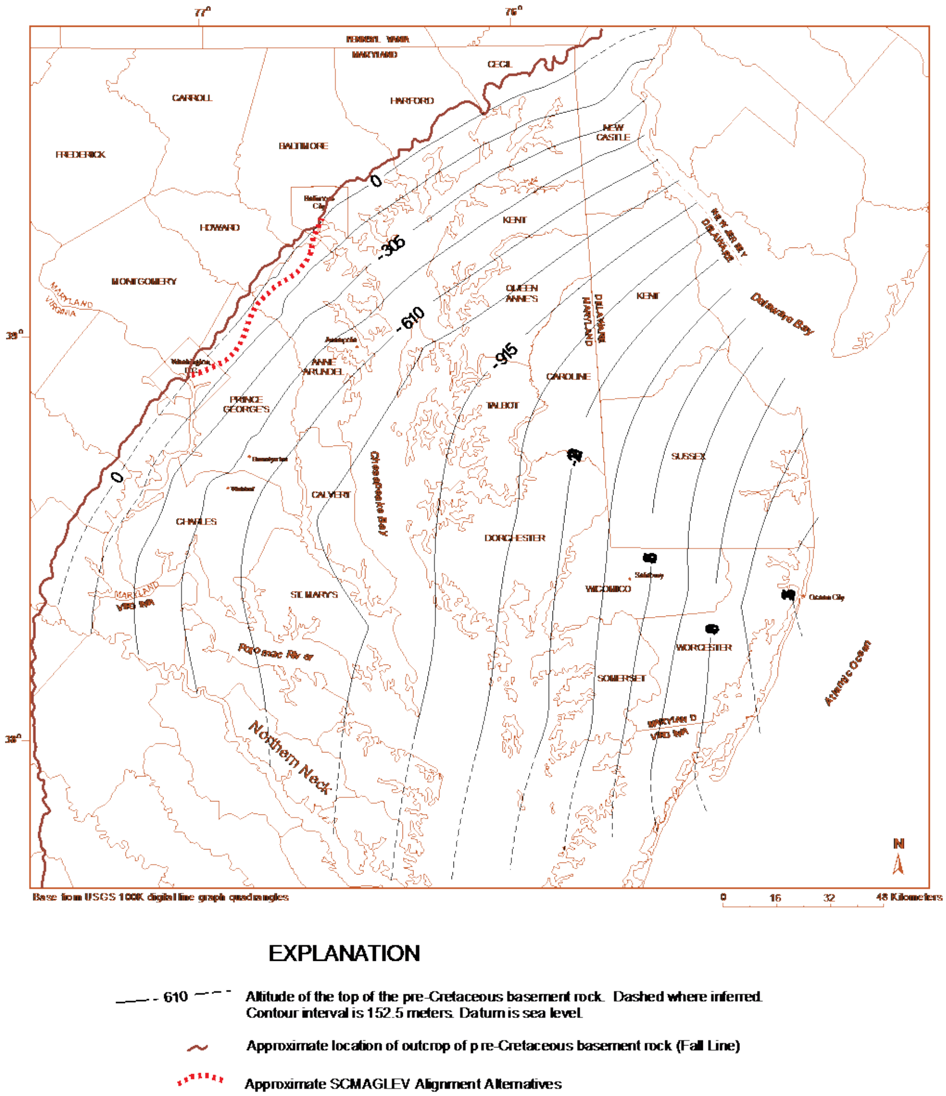


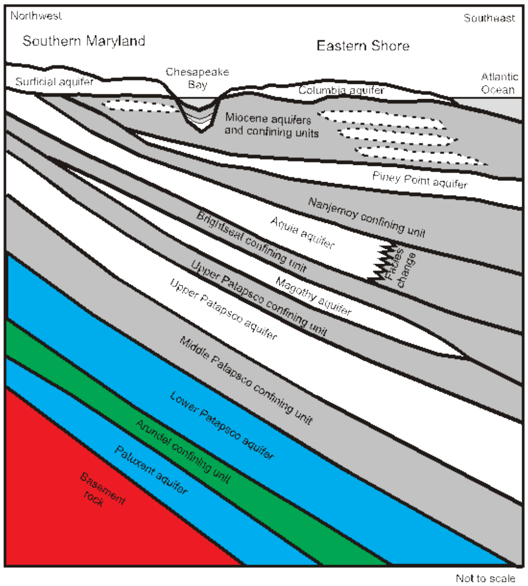
Figure 3. Altitude of the top of the pre-Cretaceous basement rock (after Hansen & Edwards Jr., 1986).

3.4 Groundwater

3.4.1 Groundwater Aquifer Systems

The Coastal Plain physiographic province of Maryland consists of unconsolidated sedimentary layers that serve as natural aquifers for eastern and southern areas of Maryland. As previously discussed, the sediments consist of sand, gravel, silt and clay that overly pre-cretaceous bedrock that ranges in age from Precambrian to Jurassic. The overlying sediments constitute a series of aquifers and confining units that serve as important freshwater sources for Maryland.

Tunnel sections for the proposed SCMAGLEV alignment alternatives will be through Cretaceous sediments of the Potomac Group (Figure 4). Three aquifer systems are present within the Potomac Group likely to be impacted by construction activities, including tunneling: 1) Upper Patapsco aquifer system, 2) Lower Patapsco aquifer system, and 3) Patuxent aquifer system. Each aquifer is separated by a confining unit, typically consisting of impermeable fine-grained sediment layering (Staley et al., 2009; Calis & Drummond, 2008).



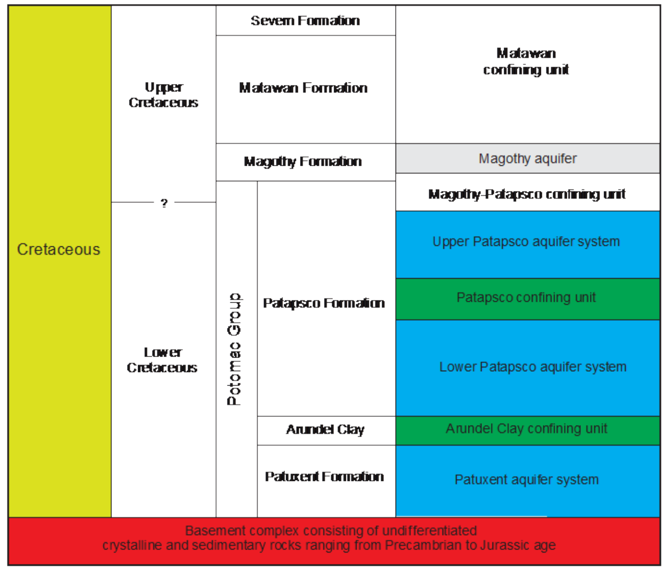


Figure 4. Schematic cross section of major hydrogeologic units in the Maryland Coastal Plain physiographic province with a reduced geologic time scale highlighting the age of the stratigraphic units to be encountered by the proposed SCMAGLEV alignment alternatives (after Drummond and Bolton, 2010).

3.4.2 Upper & Lower Patapsco Aquifer System

The Upper & Lower Patapsco aquifer system is of considerable importance as a water supply to Maryland's western shore, with a combined total use between the two permitted at approximately 70 Million gallons/day (Mgal/day) (Andreasen et al., 2013). The Upper and Lower aquifers are separated by the Patapsco confining unit, which consists of clays interbedded with fine quartz sand. The thickness of the confining unit varies with potential for gaps at thinner points of the bed through which hydraulic connectivity between the Upper and Lower Patapsco aquifer systems is possible. Confining unit thickness varies from approximately 5 m in Anne Arundel County to 88 m in Queen Anne's County. Hydraulic properties for the Upper and Lower Patapsco Aquifers and the Patapsco Confining Unit are summarized in Table 1.

Table 1. Hydraulic Properties for the Patapsco Aquifer System (Andreasen et al., 2013).

Unit	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Storage Coefficient
Upper Patapsco Aquifer	0.6 – 282.9	12.2 – 45.7 (Vertical)	8.4×10^{-5} – 0.0096
Patapsco Confining Unit	-	1.8×10^{-7} – 4.5×10^{-7} (Vertical)	-
Lower Patapsco Aquifer	1.1 – 337.0	1.2 – 38.1 (Horizontal) 2.5 – 64 (Vertical)	8.6×10^{-5} – 0.025

3.4.3 Patuxent Aquifer System

The Patuxent Aquifer system is a critical source of water on Maryland's western shore for Anne Arundel, Charles, Prince George's, and Cecil Counties. As of 2011 approximately 33 Mgal/d were permitted for use form the Patuxent aquifer system with the highest quantities from Anne Arundel county (18.8 Mgal/d), Baltimore County (7.78 Mgal/d) and Prince George's County (4.45 Mgal/d) (Andreasen et al., 2013). Available aquifer hydraulic properties are summarized in Table 2.

Table 2. Hydraulic Properties for the Patuxent Aquifer System (Andreasen et al., 2013).

Unit	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Storage Coefficient
Arundel Confining Unit	-	1.8×10^{-7} (vertical)	-
Patuxent Aquifer System	.6 – 621.6	0.6 – 58.5 (horizontal)	3.4×10^{-5} – 0.0012

3.4.4 Subsurface Gases

Radon is a commonly encountered gas within sediments and groundwater of the Coastal Plain. Radon is a gas produced by the radioactive decay of radium, which is a daughter element of Uranium. Radon, with a half-life of 3.8 days, produces its own daughter elements, including polonium. It is the production of radon daughter elements within one's lungs, due to breathing in radon gas, that constitutes the primary health risk (Otton, 1992). Uranium is present within all rocks in varying concentrations, and hence is also present within the unconsolidated sediments sourced from the rocks, including the Potomac Group and coastal plain alluvial deposits.

The Environmental Protection Agency (EPA) recommended levels for radon are <4 picocuries per liter (pCi/L) (US Environmental Protection Agency, 2016). The Maryland Department of Health maintains a database of radon levels measured in homes in Maryland between 2005 and 2016. Radon is present within Coastal Plain sediments; however, the overall recorded values are just above or below the EPA recommendations. Furthermore, the TBM pressurized face, in combination with a water-tight segmental lining and constant ventilation ensure no accumulation of radon during construction and during the post-construction lifespan of the structures.

The next phases of ground investigation, in addition to evaluating the radon content of sediments and groundwater along the project alignment, will also test for the presence of other gases such as methane and hydrogen sulfide. Additionally, future ground investigation efforts will search for the presence of contaminants within the surface and sub-surface that would be encountered during construction and tunneling.

3.5 Seismic Activity

Based on a review of 2018 United States Geological Survey (USGS) National Seismic Hazard Maps (Peterson et al., 2018), and Earthquake Hazard Maps for Maryland (Reger, 1999) the study area is located in an area of the United States with a low probability of seismic activity. The USGS identifies the eastern United States as a "Stable Continental Region" (SCR) because of its location in the center of a tectonic plate. Based on this geologic setting, the potential for seismic hazards has been deemed as low.

3.5.1 Recent Earthquake Activity (1990 – Present)

Maryland has experienced a number of earthquakes since 1990, all with magnitudes <3.0 which classify as minor (Maryland Geological Survey, 2010). This does not include earthquake epicenters located in surrounding states, which achieve magnitudes up to 5.8 (2011 Mineral, VA earthquake). The latest recorded earthquake in Maryland was recorded on November 11, 2017 and was classified as magnitude 1.5 (Intensity I).

4.0 GROUND CHARACTERIZATION

This section provides background information, definitions and explanations for the characterizations of the soil, bedrock and groundwater. Soil profiles are provided in Appendix C and D and geotechnical data report in Appendix F.

4.1 Soils

The soil deposits encountered in the underground excavations are heterogeneous. Soil descriptions are based on visual logging of cores and samples, Standard Penetration Test (SPT) and laboratory testing. The soils consist of interlayered layers and lenses of fine- and coarse-grained materials as classified by the Unified Soil Classification System (USCS).

For the purposes of this report, layers of soil materials have been identified based on grain size distribution and standard penetration test data. Soil units identifying:

a. Fill/Unconsolidated sediments
b. Mostly very stiff/hard clay/silt with very dense sand layer
c. Mostly very dense sand with very stiff/hard clay/silt layer

Distribution of Materials along the tunnel horizon (7.6 m above tunnel crown to 7.6 m below tunnel invert) identifying:

a. Predominantly Coarse-Grained Soils defined as soils with less than 50 percent passing the No. 200 Sieve and including soils classified as SC, SM, SP, SP-SM, SM-SC and GP.
b. Predominantly Fine-Grained Soils – defined as soils with more than 50 percent passing the No. 200 Sieve and including soils classified as CH, CL, CL-ML and ML.

4.2 Bedrock

Underlying the soils, the SCMAGLEV Alignment is located along a bedrock profile of varying depth. Bedrock along the SCMAGLEV alignment consists of metamorphic rock, in the form of gray gneiss, slightly to highly weathered (Appendix C and D). Overall, the rock Total Core Recovery (TCR) and Rock Quality Designation (RQD) indicate expected improving quality with increasing depth into bedrock as related to the degree of weathering decreasing with increasing depth. Bedrock will be encountered along the tunnel in the Washington, D.C. Station area which is slightly to moderately weathered.

Based on the lab test results, compressive strength of bedrock is between 124 to 284 MPa (estimated using Point Load Strength Index). Also, splitting tensile strength of bedrock is between 3.8 to 17.5 MPa. Rock abrasivity was assessed by means of Cerchar Method. Results show the abrasivity of bedrock is between 0.73 to 4.56 CAI which put the rock in low abrasive to extreme abrasive classes (BOTA Consulting Engineers, 2018) Rock testing is summarized in Table 3 below.

Table 3. Summary of bedrock lab testing results

Borehole	Splitting Tensile Strength (MPa)	Est. Compressive Strength (MPa)
DC-01	3.8	-
BWP-01	5.3	-
BWP-17	17.5	284.0
BWP-19	11.2	165.5
BWP-20	6.9 – 11.9	145.5 – 165.5
HW-01	-	124.1
HW-02	-	16.7

4.3 Groundwater

Estimated groundwater levels have been estimated on the geological and geotechnical alignment profiles (Appendix C and D) using a combination of field observations and installed piezometers. However, given the large distances between the exploratory boreholes, local variations in the groundwater are expected and a thorough groundwater monitoring program will be an important component of the next phase of geotechnical investigation, particularly with respect to seasonal fluctuations of the groundwater table.

5.0 EXISTING STRUCTURES

The buildings along the alignment are primarily commercial and residential. The commercial buildings consist predominantly of one- and two-story masonry and concrete structures with a few light one-story steel frame structures that house office and retail space. The residential buildings include high rises and single-family homes.

1. *Carnegie Library, Washington, D.C.* – Listed on the National Register of Historic Places, Carnegie Library has a shallow foundation system with continuous wall type foundation and local ground improvement under heavy columns on spread footings with stepped widening. This makes the structure sensitive to settlement and dewatering.

2. *Baltimore-Washington International Airport (BWI)* – BWI Airport serves over 25 million passengers annually. Tunneling will occur beneath critical infrastructure including runways and terminal facilities. The terminals include shallow pile support (approximately 12 m long) foundation system.

3. Other Construction Activities – Construction activities by other will potentially be taking place along the alignment while tunneling is occurring. In addition to surface activities, this also includes construction of the:

    - *Northeast Boundary Tunnel Project (NEBT)* – The NEBT is a 7 m diameter, 8,230 m long Combined Sewer Overflow (CSO) tunnel that is part of DC Water's Clean Rivers Project. The tunnel crosses above the MAGLEV alignment and construction is anticipated through 2023.

    - *Maryland Purple Line* - The Maryland Purple Line Project is a 26 km light rail line that will extend from Bethesda in Montgomery County to New Carrollton in Prince George's

County. The alignment is typically at-grade with minor stretches of elevated structures and a short underground section. Construction is anticipated to be completed by 2021.

6.0 PRELIMINARY DESIGN CONSIDERATIONS

6.1 Stations (Alignment Alternative J Modified 1 and J1 Option 5)

6.1.1 Washington, D.C. Station Alternatives (Mt. Vernon East & Mt. Vernon West)

6.1.1.1 Subsurface Conditions

The Mt. Vernon West Washington, D.C. Station alternative box construction would proceed through Fill, middle-Pleistocene alluvium, potentially Cretaceous Potomac Group sediments, weathered bedrock, and pre-Cambrian gneissic bedrock. Bedrock would potentially be encountered between -24 m El. and -37 m El. The unconsolidated sediments consist of very dense silty sands and very stiff/hard lean clays. Weathered bedrock horizon may include boulders of partially weathered material.

The Mt. Vernon East Washington, D.C. Station alternative would proceed through Fill, middle-Pleistocene alluvium, potentially Cretaceous Potomac Group sediments, weathered bedrock, and potentially pre-Cambrian gneissic bedrock. The bedrock would be encountered at approximately -20 m El. primarily at the western end of the station construction. The unconsolidated sediments consist of medium to very dense silty sands (SM), clayey sands (SC), hard sandy silts (ML) and a thick bed of very stiff lean clay (CL). Sandy gravels (GPS) are also likely to be encountered atop bedrock.

Groundwater levels within Washington, D.C. are encountered at approximately 3 to 5 m below ground level.

6.1.2 Baltimore-Washington International Airport Station

6.1.2.1 *Subsurface Conditions*

Station box construction will likely proceed through sediments of the Patapsco Fm. consisting of medium dense to dense sands (SP) and stiff silts (ML) with bands of stiff to hard lean clay (CL). Groundwater level is anticipated to be about 10 m below the existing grade level corresponding to an approximate elevation of +37 m El.

6.1.3 Cherry Hill Station, Baltimore, MD

6.1.3.1 Subsurface Conditions

The Cherry Hill Station alternative for Baltimore will be constructed atop very loose silty sands (Fill), dense to very dense silty sands (SM), thickly layered hard lean and fat clays (CL, CH) and very hard sandy silts (ML) and silty sands (SM). The silty sands sit unconformably atop gneissic bedrock at approximately -26 m El. Groundwater table is encountered at approximately 3.5 m (11.5 ft) below ground level.

6.1.4 Camden Yards Station Alternative, Baltimore, MD

6.1.4.1 Subsurface Conditions

The proposed Camden Yards Station would be constructed within the sand facies of the Potomac group with dense silty/clayey sands and potentially lenses of stiff clays and gneissic bedrock. Groundwater level likely sits at 3 to 5 m below ground level.

6.2 Tunnels & Shafts

Tunnel construction will be in water-bearing soils both above and below the groundwater table. Because tunneling will take place through built-up areas, control of ground losses and surface settlement to minimize damage to structures, buried utilities and streets along the alignment is a primary consideration for the selection of the tunneling method. The following sections discuss the general anticipated geological and geotechnical conditions anticipated along TBM runs for both alignment alternatives.

6.3 Alignment Alternative J Modified 1

6.3.1 Sta. 100+400 (Washington, D.C. Station) to Sta. 104+250 (Ventilation Plant & Substation)

6.3.1.1 Subsurface Conditions

The geology consists of unconsolidated fill and middle-Pleistocene alluvium, Potomac Group sediments, weathered bedrock (saprolite) of varying thickness, and Pre-Cambrian gneissic bedrock. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm. The saprolite is likely a very dense medium to coarse-grained silty sand with bedrock fragments and potentially weathered boulders. Gneiss bedrock is moderately to slightly weathered with slight to moderate fracturing.

Tunneling will proceed through a mixed face of bedrock and saprolite moving north from the Washington, D.C. station into the very dense sands of the Patuxent Fm. within which it will remain. The sediments likely to be encountered are classified as ML, SW, SM, and SC and are primarily medium to fine grained sands and silts, with potential localized clay lenses. Both alignment alternatives will excavate within the groundwater table.

6.3.2 Sta. 104+250 (Ventilation Plant & Substation) to Sta. 108+150 (Ventilation Plant)

6.3.2.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed primarily through dense sands and silty sands of the Patuxent Fm. The sediments likely to be encountered are classified as SM, CL, and ML and are primarily fine to coarse grained silty sands, with stiff to hard lean clay lenses. Both alignment alternatives will excavate within the groundwater table.

6.3.3 Sta. 108+150 (Ventilation Plant) to Sta. 112+950 (Ventilation Plant)

6.3.3.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed through dense sands and silty sands of the Patapsco Fm. and Patuxent Fm., with the majority of the run within a clay-rich zone of the Patapsco Fm. The southern end of the run will be through a mixed face of the Patapsco Fm. clays and Patuxent Fm. sands, into a long stretch within the Patapsco Fm./Arundel Fm. where the soils will be primarily hard to very hard lean clays (CL) and fat clays (CH) with lenses of sandy silts (ML). The northern portion of the run will encounter mixed face conditions again with Patapsco Fm. clays and Patuxent Fm. dense to very dense silty sands. Both alignment alternatives will excavate within the groundwater table.

6.3.4 Sta. 112+950 (Ventilation Plant) to Sta. 119+450 (Portal)

6.3.4.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed through dense sands and silty sands of the Patapsco Fm. and Patuxent Fm., with the majority of the run within a clay-rich zone of the Patapsco Fm. The southern end of the run will be through a mixed face of the Patapsco Fm. and Patuxent Fm. sands/silty sands and fully within the Patapsco Fm., with hard to very hard lean clays (CL) and fat clays (CH) with lenses of sandy silts (ML), until reaching the portal. Both alignment alternatives will excavate within the groundwater table.

6.3.5 Sta. 135+000 (Portal) to Sta. 141+600 (Ventilation Plant)

6.3.5.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL), fine to coarse grained, very dense sands (SW, SP), and very hard silts (ML). The Patapsco Fm. silty sands (SM) are fine to medium grained, very dense. Both alignment alternatives will excavate within the groundwater table.

6.3.6 Sta. 141+600 (Ventilation Plant) to Sta. 146+500 (Ventilation Plant & Substation)

6.3.6.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL), fine to coarse grained, very dense sands (SW, SP), and very hard silts (ML). The Patapsco Fm. silty sands (SM) are fine to medium grained, very dense. Both alignment alternatives will excavate within the groundwater table.

6.3.7 Sta. 146+500 (Ventilation Plant & Substation) to Sta. 151+100 (Ventilation Plant)

6.3.7.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL) and fat clays (CH) of the Arundel Fm. Both alignment alternatives will excavate within the groundwater table.

6.3.8 Sta. 151+100 (Ventilation Plant) to Sta. 153+200 (Portal)

6.3.8.1 Subsurface Conditions

The geology consists of unconsolidated fill, Cretaceous Potomac Group sediments, and weathered bedrock (saprolite). Tunneling will likely proceed through very hard lean clays (CL) and fat clays (CH) of the Arundel Fm., with local lenses of very dense, fine to medium grained sands (SP-SM). Tunneling may encounter weathered bedrock consisting of very dense, fine to medium grained silty sands (SM) and hard to very hard silts with rock fragments. Both alignment alternatives will excavate within the groundwater table.

6.4 Alignment Alternative J1 Option 5

6.4.1 Washington, D.C. Station

6.4.1.1 Subsurface Conditions

The Washington, D.C. Station construction will proceed through Fill, middle-Pleistocene alluvium, potentially Cretaceous Potomac Group Sediments, weathered bedrock, and potentially pre-Cambrian gneissic bedrock (depending upon selected station alternative). The unconsolidated sediments consist of very dense silty sands and very stiff/hard lean clays. Weathered bedrock horizon may include boulders of partially weathered material.

6.4.2 Sta. 100+400 (Washington, D.C. Station) to Sta. 104+250 (Ventilation Plant & Substation)

6.4.2.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed primarily through dense sands and silty sands of the Patuxent Fm. The sediments likely to be encountered are classified as SM, CL, and ML and are primarily fine to coarse grained silty sands, with stiff to hard lean clay lenses. Both alignment alternatives will excavate within the groundwater table.

6.4.3 Sta. 104+250 (Ventilation Plant) to Sta. 108+150 (Ventilation Plant)

6.4.3.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed primarily through dense sands and silty sands of the Patuxent Fm. The sediments likely to be encountered are classified as SM, CL, and ML and are primarily fine to coarse grained silty sands, with stiff to hard lean clay lenses. Both alignment alternatives will excavate within the groundwater table.

6.4.4 Sta. 108+150 (Ventilation Plant) to Sta. 112+900 (Ventilation Plant)

6.4.4.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed through dense sands and silty sands of the Patapsco Fm. and Patuxent Fm., with the majority of the run within a clay-rich zone of the Patapsco Fm. The southern end of the run will be through a mixed face of the Patapsco Fm. clays and Patuxent Fm. sands, into a long stretch within the Patapsco Fm. where the soils will be primarily hard to very hard lean clays (CL) and fat clays (CH) with lenses of sandy silts (ML). The northern portion of the run will encounter mixed face conditions again with Patapsco Fm. clays and Patuxent Fm. dense to very dense silty sands. Both alignment alternatives will excavate within the groundwater table.

6.4.5 Sta. 112+900 (Ventilation Plant) to Sta. 119+950 (Portal)

6.4.5.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed through dense sands and silty sands of the Patapsco Fm. and Patuxent Fm., with the majority of the run within a clay-rich zone of the Patapsco Fm. The southern end of the run will be through a mixed face of the Patapsco Fm. clays and Patuxent Fm. sands and fully within the Patapsco Fm., with hard to very hard lean clays (CL) and fat clays (CH) with lenses of sandy silts (ML), until reaching the portal. Both alignment alternatives will excavate within the groundwater table.

6.4.6 Sta. 128+500 (Portal) to Sta. 134+950 (Ventilation Plant) and to Sta. 141+600 (Ventilation Plant)

6.4.6.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL), fine to coarse grained, very dense sands (SW, SP), and very hard silts (ML). The Patapsco Fm. silty sands (SM) are fine to medium grained, very dense. Both alignment alternatives will excavate within the groundwater table

6.4.7 Sta. 141+600 (Ventilation Plant) to Sta. 146+500 (Ventilation Plant & Substation)

6.4.7.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL), fine to coarse grained, very dense sands (SW, SP), and very hard silts (ML). The Patapsco Fm. silty sands (SM) are fine to medium grained, very dense. Both alignment alternatives will excavate within the groundwater table.

6.4.8 Sta. 146+500 (Ventilation Plant & Substation) to Sta. 151+100 (Ventilation Plant)

6.4.8.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL) and fat clays (CH) of the Arundel Fm. Both alignment alternatives will excavate within the groundwater table.

6.4.9 Sta. 151+100 (Ventilation Plant) to Sta. 153+200 (Portal)

6.4.9.1 Subsurface Conditions

The geology consists of unconsolidated fill, Cretaceous Potomac Group sediments, and weathered bedrock (saprolite). Tunneling will likely proceed through very hard lean clays (CL) and fat clays (CH) of the Arundel Fm., with local lenses of very dense, fine to medium grained sands (SP-SM). Tunneling may encounter weathered bedrock consisting of very dense, fine to medium grained silty sands (SM) and hard to very hard silts with rock fragments. Both alignment alternatives will excavate within the groundwater table.

6.5 Soil Stickiness

The cohesive nature of the excavated fine-grained materials is expected to impact excavation and spoils handling. Where significant quantities of fine-grained materials are present, handling difficulties such as clay lumping, balling and sticking must be expected. The excavated clay will be sticky, tend to clog the cutting wheel and air lock doors, and will be difficult to remove from the face and clog the spoils handling system. Preliminary ground investigation results along the alignment suggest large spans of tunneling within the Patapsco/Arundel Fm. that are rich in lean and fat clays and pose a great potential for stickiness.

Clay lumping, balling and sticking will require the use of conditioners and/or the use of water jets within the chamber to mitigate problems related to clay "stickiness." The excavated clay is likely to be slick and difficult to handle in the presence of water. The application of foam, bentonite, polymers or other conditioners can assist in reducing the "stickiness" and "slickness" of the clay. Efficient separation of the fines from the bentonite in the slurry separation plant must also be considered.

6.6 Soil Abrasion

Excavation and handling of the clays, sands, gravels, cobbles and boulders will abrade and wear the cutter head, the excavation chamber and the muck removal system. When tunneling tools are subject to excessive wear, penetration and thus the advance rate decreases. The tools have to be replaced during a maintenance interval, which leads to very high costs due to unplanned downtimes. With the help of wear prediction models, the wear of tools in dependency of the tunnel alignment geology could be investigated. Since at preliminary geotechnical boring program, no test has been done about soil abrasivity, it is recommended to do some tests like Soil Abrasion Testing (SAT) to help having more information regarding soil abrasivity along the tunnel alignment.

6.7 Ground Support in Tunnels

6.7.1 Tunnel Lining

A one-pass tunnel lining system, consisting of precast concrete segments, double gasketed for water control, bolted and dowelled together to form a continuous circular lining, will be the standard ground support. The double gasketed system provides redundancy and a means for effecting leak repair to prevent leakage of groundwater into the tunnel. The gasketed precast concrete tunnel lining installed by the TBM during excavation serves as the final lining. The permanent lining must be capable of resisting degradation when in contact with the anticipated natural soil and groundwater conditions. Short term (construction loading) and long-term conditions shall be considered in liner design. Also, anticipated soil behavior, like swell potential of fat clays/over consolidated clays and its impact on lining should be considered in segmental lining design.

6.7.2 Backfill Grouting

To minimize ground loss and reduce settlements, the void between the TBM excavation and the tunnel lining must be completely filled. The grout is installed through the tail of the shield as the tunnel is advanced. For adequate filling of the void, a grout pressure will be required in excess of the surrounding soil and water pressures, and grout volume must be placed behind the tail seals at a rate consistent with the excavation advance.

6.7.3 Break-outs and break-ins with TBM

Excavation out of the shaft into the ground (referred to as "break-out") required ground treatment to control groundwater flows, to stabilize soils, to minimize ground losses that would risk failure of the tunnel or excavation, and prevent unacceptable movement of existing structures and utilities.

7.0 CONSTRUCTION CONSIDERATIONS

7.1 TBM Excavation

Tunnel boring machine (TBM) selection will be important to addressing anticipated geologic conditions. Given groundwater and soil conditions an Earth-Pressure Balance Machine (EPBM) or Slurry Shield will likely be required for the majority of the tunnel alignment. Within the Washington, D.C. Station tunnel segments a mixed-face TBM (slurry-shield type) will likely be required to address the variable ground conditions consisting of gneissic (granitic) basement rock, dense/hard sediments, and high groundwater pressures.

7.1.1 Closed Face TBMs

The use of pressurized closed-face TBMs – either earth pressure balance (EPB) or slurry shield – with a one-pass gasketed segmental lining installed in the tail shield is required for tunneling. Without the application if a positive pressure to the face and around the shield, the soils will run, flow, and ravel. When operated effectively, closed face TBMs apply a positive pressure to the tunnel face and around the tunnel shield. This reduces the risk of soil inflows and groundwater flooding the tunnel, while minimizing ground losses that can result in surface settlements. This reduction in surface impacts is critical, as previously discussed, as tunnel construction proceeds beneath developed commercial and residential areas along the alignment. Generally, an EPB TBM operates more efficiently in finer grained soils whereas a slurry shield TBM is more efficient in coarser grained soils. The grain size distribution charts from the preliminary ground investigation are provided in Appendix B. A more detailed assessment will be needed with the next phase of ground investigation and selection of the type of TBM to be used will ultimately be the decision of the Design-Build Contractor.

For the pressure at the face and around the periphery of the shield to be effective in controlling ground loss, it must mobilize the internal friction within the soil mass. This supports the soils and prevents ground and groundwater movement towards the face and the shield. Fluctuations in the pressures applied will occur as the ground conditions and the compositions of the spoil or fluid within the working chamber of the TBM change.

For an EPB TBM, proper conditioning of the spoil within the excavation chamber is required so that it will act as a viscous fluid supporting the face. TBM operation that produces low support pressures can result in runs, caving and progressive instability of soils, particularly coarse-grained material in the face and should be avoided. High support pressures can result in excessive torque requirements for the cutting wheel. Arching of the spoil at the entrance to the screw conveyor inhibits discharge and should also be avoided. Fluctuations in the support pressure at the face as a result of changing ground conditions must be expected and planned for.

For a slurry shield TBM, the face pressure must be maintained by the use of bentonite slurry. It will be necessary to vary the density and constituents of the slurry and consider fluctuations in the types of soils being excavated and in groundwater conditions.

For the Washington, D.C. Station construction, a closed-face TBM with mixed face capabilities (e.g. slurry shield-type) will be required to account for tunneling through anticipated variable soil and rock-face conditions. The TBM would be designed to address ground conditions at the station including the presence of hard gneissic bedrock, very dense/hard sediments and high groundwater pressure.

7.2 Shaft Excavation & SOE

The methods of excavation are anticipated to use heavy excavation equipment such as backhoes or excavators, to excavate the very dense and stiff soils which may contain gravel, cobbles and boulders. The impact of dewatering must be considered with selection of shaft excavation method. For many, if not most locations along the alignment, any dewatering could result in settlement and adverse impacts to adjacent structures and should not be allowed. Additionally, the project construction will be within important aquifers of the Maryland western shore (see Section 3.4) and potential for adverse impacts needs to be carefully considered.

Sheeting by the use of sheet piles to reduce water infiltration into excavation and maintain excavation stability could be considered as well. Sheeting should be installed using high frequency oscillatory hammers to reduce/control vibrations. The D&B contractor should also consider the use of jet grouting to control water infiltration as well as silent pilers (for example GIKEN) to control vibrations in installing sheeting for deep excavations, shafts, etc.

7.2.1 Anticipated Ground Behavior for Support Installation and Shaft Excavation

Excavations for the shaft can be achieved using conventional excavation equipment such as track mounted hydraulically operated backhoes or excavators. Suitable drilling equipment can be used to drill holes for installation of the soldier piles for the initial support system. Heavy excavation equipment will be required to excavate the very dense soils containing gravel, cobbles and boulders, ground that has been grouted, and artificial fill. Abandoned and functioning utilities will also be found in the fill that the Design-Build Contractor will be required to relocate or remove, where necessary.

For general ground conditions at shaft locations, refer to geological/geotechnical discussion of alignment in Section 6.0 of this document, and the geological and geotechnical profiles for the alignment alternatives (Appendix C, D).

7.2.2 Pile Drilling

Drilling for piles must penetrate the dense to very dense soils. The holes will be subject to caving and deviation unless proper precautions are undertaken. Instability of drilled holes for piles will occur when

holes encounter granular soils containing sand, gravel, cobbles and/or boulders both above and below the water table. Where caving occurs, it will result in large backfill quantities. Casings, water and polymers, or slurry will be required to control the caving. The Design-Build Contractor must utilize appropriate drilling techniques, control the drilling rate and limit the number of passes down the hole to limit caving, and have casing and different types of drilling tools available at the job site for rapid use.
Deflection of the drilling tool when it encounters obstructions in fill (up to 1 meter in size), cobbles and boulders will cause deviations of holes. A coring bit should be available to drill through materials that will deflect the drill tool. Core drilling, backfilling of holes and re-drilling will be necessary to correct deviations and these activities will slow down the rate of advance of the holes.

Additives and slurries introduced into the borings to prevent caving must be effective over the full range of ground and groundwater chemistries anticipated in this project.

7.2.3 Slurry Wall Panel Installation

Reinforced concrete slurry wall (or diaphragm wall) panels forming straight walls along the sides of the excavations can provide an effective initial ground support system and groundwater cutoff for shaft excavation. To be effective, the slurry wall depth must be sufficient to provide a groundwater cutoff adequate to prevent inflow to the excavation and groundwater movements or the shaft bottom improved by grouting to be less permeable.

Hydromills, hydrofraises and clamshells with chisels are possible tools that can be used for slurry wall construction. By using bentonite slurry, the sidewall stability of the excavation can be maintained with control of slurry density used to avoid loss of slurry into the formation through the open zones. Because of the ground conditions, the excavation of panels will be subject to misalignment and remedial actions will be required when the panels are out of alignment. Over-excavation can occur where open zones, boulders or hard, dense, cemented zones are encountered that cause the mechanical excavator to drift out of alignment (and re-excavation is required to maintain panel verticality criteria). Over-excavation can also result if excessive slurry loss or insufficient slurry density causes sidewall instability and ground is lost into the excavation. These issues will lead to greater than anticipated excavation volumes.

7.2.4 Shaft Excavation

The methods of excavation are anticipated to use heavy excavation equipment such as backhoes and excavators, to excavate the very dense soils which may contain gravel, cobbles and boulders.
The excavated materials include both fine and coarse-grained deposits with particle sizes ranging from less than No. 200 sieve to granular material containing sands, gravels and cobbles and occasional boulders. Exposed soil conditions within the shaft excavation will vary. Changes will be gradational or abrupt, and will occur across the exposed surface as the excavation progresses. At D.C. station, shaft excavation will encounter the bedrock. For rock excavation, drill & blast (if allowed) or other appropriate methods would be considered.

For excavation carried out by a sequential excavation and support method, i.e., soldier pile and lagging and in the absence of groundwater, exposed wall heights should be limited such that they stand long enough to permit placement of lagging prior to sloughing of the soils. Lagging should be installed in a timely manner. Unsaturated sand, silt, silty sand, and clayey sand which are moist or have some apparent cohesion will ravel (within an hour) from unsupported sidewalls. Gravel, gravelly sand, poorly graded sand and silty sand above the groundwater table will ravel rapidly (within a few minutes) and running conditions should be anticipated. Flowing conditions must be anticipated in gravelly sand, poorly-graded sand, and well-graded sand below the water table or in the presence of semi-perched groundwater. Unsupported fine-grained soils will squeeze into the excavations, particularly where seepages from ground water occur.

When ground is exposed, raveling and ground loss will occur if lagging is not placed promptly. For an excavation supported by soldier piles and lagging, the migration of soils and the piping of fines from the soils through the lagging must be prevented by measures such as placement of filter materials behind the lagging in areas where raveling or water seepage (due to residual inflows, groundwater inflow or broken utilities) persists. Where relatively impermeable lagging (i.e. shotcrete) is used, effective drainage must be provided to reduce pressure on the support system.

7.3 Mined Cross Passages

7.3.1 Subsurface Conditions

One Washington, D.C. Station alternative would potentially require the construction of cross passages between twin tail tunnels with station platforms. Preliminary ground investigation boreholes suggest the cross passages would likely to be excavated through dense to very dense water saturated silty sands of medium to coarse grained size. The sediments are Holocene alluvium atop the pre-Cretaceous bedrock. However, the fully establish conditions, additional exploratory borings at the approximate location of each cross passage will be necessary to investigate site specific geotechnical conditions related to the soils, and groundwater present.

7.3.2 Groundwater

The range of groundwater levels is shown on the geologic and geotechnical profiles in Appendix C and D. The soils exposed in the cross passages will be below the groundwater table. For construction, the groundwater level at each cross-passage location will be established by the Design-Build Contractor.

7.3.3 Ground Improvement

Ground treatment is required to minimize groundwater inflows and prevent the ground from raveling, running and flowing in soils below the water table and in the presence of semi-perched groundwater. Ground treatment, e.g., jet grouting, permeations grouting (chemical or cement grout), must be performed prior to breakouts for the cross-passage excavations to improve the ground strength, to stabilize the ground around the existing tunnels; to increase stand up time for the excavation and allow installation of ground support; and, to control or limit groundwater inflows during excavation. An additional method that could be used is ground freezing, which will serve to stabilize soils and cut-off ground water inflow during excavation. Dewatering is not an option for soil stabilization, as it would likely induce settlement of adjacent surface structures. The Design-Build Contractor must consider groundwater conditions as well as surface access for ground treatment at each cross-passage site.

7.3.4 Method of Excavation

Methods of excavation and initial support for the cross passages must stabilize the mined excavations and limit surface settlement to avoid damage to existing surface structures, utilities and the main tunnels.

To achieve these goals, the methods must prevent soil losses and groundwater inflows. These will deprive the tunnel support system of the passive ground reaction necessary for stability and cause instability at the face of the cross-passage excavation. Use of the Sequential Excavation Method (SEM), utilizing pre-support and a heading and bench method of excavation is anticipated for the cross-passages. Where finer grained soils below groundwater are encountered at the bottom of the excavation the invert should be stabilized by means of crushed rock or a mud slab.

7.3.5 Break-outs and Break-Ins at Tunnel/Cross Passage Connections

As well as ground treatment to stabilize the ground at tunnel break-outs and break-ins, the tunnel lining must be given additional support over a length of tunnel sufficient to maintain the shape and stability of the lining. This support would likely be in the form of a steel breakthrough frame emplaced prior to initiation of break-through. This is critical to maintaining the segments in compression, which ensures stability of the lining and prevents groundwater inflow.

7.4 Soil Disposal and Handling

The large volumes of soils anticipated to be produced during excavation will require development of thorough plans for testing and disposal of the materials, which will be the responsibility of the Design-Build contractors. This includes considerations for treating the spoils if required (i.e. bentonite removal from slurry) as well as proper storage and disposal of any potentially contaminated ground. Preliminary disposal sites and disposal haul routes have been identified and are shown in Appendix E. The haul routes were selected to minimize impact of truck traffic to local communities while getting the trucks to main highways as efficiently as possible.

8.0 STRUCTURE PRELIMINARY FOUNDATION EVALUATIONS

Preliminary geotechnical data obtained from 23 boreholes show the subsurface has relatively uniform stratification and consists mostly of loose to medium (dense) sand to medium to stiff clay locally mixed with topsoil and fill in the upper 5-10 meters underlain by alternating/intercalated layers of very dense sand (SP/SW), silty sand (SM), Clayey Sand (SC), gravel (GP), locally with boulders, and very stiff-hard Silt and Clay, over bedrock gneiss which is typically hard and sound.

Depth to bedrock ranges from about 50 m. below the existing grade corresponding to approximate elevation of El.-30 m near Washington DC station; between the elevations El.-15 m. and El.-30 m in Greenbelt, MD area and about 30m. below the existing grade in Baltimore area with elevations in between El.-5 m and El.-8 m.

The boring logs and detailed description of each strata along with laboratory test results are presented in Geotechnical Data Report (BOTA Consulting Engineers, 2018).

8.1 Structure (Viaduct) Foundations

Preliminary engineering data suggested the elevated structures would be supported on 45m. (150 feet) span single pier reinforced concrete viaducts. Data obtained from the project's structural engineer show the following loads (Table 4) based on AREMA LFD (Load Factor Design) directives.

Table 4. Factored loads acting on 150-foot spaced viaduct pier

Load Combination Groups	Axial Load on Pier Base (P)	Axial Load on Pile Group (P)	Longitudinal Shear (Vx)	Transverse Shear (Vy)	Moment due to Transverse Force about Longitudinal Axis (Mx)	Moment due to Longitudinal Force about Transverse Axis (My)
I: 1.4 (DL + 5/3 LL + E)	9196 k	10893 k	0	0	0	0
IA: 1.8 (DL + LL + E)	11449 k	13630 k	0	0	0	0
II: 1.4 (DL + E + W)	8467 k	10164 k	91 k	140 k	7496 k.ft	4195 k.ft
III: 1.4 (DL + LL + E + 0.5W+WL+LF)	8904 k	10601 k	1051 k	112 k	8196 k.ft	85670 k.ft
VIII: 1.4 (DL + LL + E + Ice or Snow)	9067 k	10764 k	0	0	0	0

The soils in the upper 3 – 6 m (10-20 ft) generally do not carry the characteristics of a bearing strata to support the structure foundations. Also, the current and future urban development plans do not allow large foundation footprint areas. Considering the (large) magnitude of loads, stringent settlement/deflection criteria, unsuitable/low bearing soils, a deep foundation system was evaluated and selected. Of the deep foundation support because of large loads bearing ability, little or no vibrations during installations, drilled shafts were selected and recommended.

Different sizes of drilled shafts between 1.2 m (4 ft) and 3 m (10 ft) diameter were evaluated. The estimated drilled shaft capacity in compression, and the estimated settlements for each pile group is given in Table 5.

Table 5. Nominal Drilled Shaft Capacity and estimated settlements for different shaft sizes

Pile Diameter ft.(m)	Pile Length, ft. (m)	Axial Compression (tons)	Settlement in. (mm)	Settlement to failure in. (mm)	Comment
4 (1.2)	115 (35)	1,600	0.60 (15)	0.60 (15)	NG. Marginally safe
5 (1.5)	100 (31)	1,800	0.52 (13)	0.70 (18)	OK
6 (1.8)	120 (37)	2,800	0.65 (16)	0.80 (20)	OK
10 (3.0)	105 (32)	3,400	1.00 (25)	1.20 (31)	OK

It is likely that 1.5 m (5 ft) diameter, approximately 30.5 m (100 ft) long reinforced concrete drilled shafts, spaced minimum 4.6 m (15 ft) center-on-center, would adequately resist the viaduct structural loads.

8.2 Station Foundations

DC Station is to be located approximately 150 feet below the existing grade, the approximate bottom elevation of the station building is El.-100 feet (Apr. El.-31 feet). At this depth/elevation, the subgrade would consist of very dense silty sand/ hard clay over bedrock gneiss at shallow depths. A mat foundation is recommended to support the station structure. For conceptual/preliminary engineering the mat could be designed using an allowable bearing capacity of 10 tsf (tons square foot) and using a coefficient of subgrade reaction of 150 tons/ft^3.

The mat would need to be tied down to bedrock gneiss to resist hydrostatic forces.

8.3 Cut-and-Cover Tunnel and Portal Foundations

Both preferred alignments have two portals for the TBM (exit/entry) and transition cut-and-cover zones. Based on the review of the recent boreholes and the geological setting of the alignment (Appendix C, D and BOTA Consulting Engineers, 2018) a mat foundation is recommended for all portal structures. Generalized subsurface and geotechnical conditions are summarized below.

8.3.1 Alignment J modified 1

8.3.1.1 Sta. 118+810 to Sta. 119+441 (Cut-and-cover)

The subgrade would consist of alternating layer of dense, very dense sand and very stiff-hard clay. A mat foundation would support the portal foundation. A mat can be designed using an allowable bearing capacity of 2.5 tsf (tons per square foot) and a coefficient of subgrade reaction of 130 pci (pounds cubic inch, using 12 in. by 12. plate) at or below El. +37 m (el. +120 ft). There would be a long-term settlement of less than 13 mm (0.5 in.). Groundwater would be encountered at the foundation bottom elevation. Temporary groundwater pumping would be required. Long-term resistance to uplift forces is not likely required as the head would be about 9 m as the deadweight of the structure would resist uplift forces.

8.3.1.2 Sta. 119+441 to Sta. 119+950 (Tunnel Portal area)

Similar subgrade to section 8.3.1.1, but is less dense. The subgrade would need to be over-excavated 1.0m, and exposed surface as well as excavated soils would be re-placed in maximum 0.2 m lifts and each lift be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat foundation can be designed using an allowable bearing capacity of 1.5 tsf and a coefficient of subgrade reaction of 100 pci (using 12 in. by 12. plate) at or below El. +46 m (El. +150 ft).

8.3.1.3 Sta. 134+150 to Sta. 134+985 (Tunnel Portal Area)

The subgrade would consist of dense sand and stiff clay except the upper 1.5 m. Because of disturbance of the near-surface soils and surface disturbance, the foundation subgrade the upper 1.5 m of the exposed soils must be excavated and re-placed in maximum 0.2 m lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat foundation would support the portal foundation. A mat can be designed using an allowable bearing capacity of 1.5 tsf and a coefficient of subgrade reaction of 100 pci (using 12 in. by 12. Plate) at or below El. +71 m (el. +230 ft). There would be a long-term settlement of about 13 mm (0.5 in.).

Groundwater would likely be encountered at the foundation bottom elevation. Temporary groundwater pumping would be required. Long-term resistance to uplift forces is not likely required as the head would be less than 3 m and the deadweight of the structure would resist uplift forces.

8.3.1.4 Sta. 134+985 to Sta. 135+234 (Tunnel Cut-and-cover)

The subgrade would consist of very dense Sand and hard Clay/Silt. A mat foundation would support the portal foundation. However, because of disturbance of the near-surface soils, the foundation subgrade the upper 0.3m of the exposed soils must be excavated and re-placed in two lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat can be designed using an allowable bearing capacity of 3.0 tsf and a coefficient of subgrade reaction of 130 pci (using 12 in. by 12. Plate) at or below El. +53m (el. +170 ft). There would be a long-term settlement of about 13 mm (0.5 in.)

Groundwater would likely be encountered at the foundation bottom elevation within 10 feet. Temporary groundwater pumping would be required. Long term resistance to uplift forces is not likely required as the head would be less than 3 m. The deadweight of the structure would resist uplift forces.

8.3.2 Alignment J1 option 5

8.3.2.1 Sta. 119+520 to Sta. 119+941

The subgrade would consist of alternating layer of dense, very dense Sand and very stiff-hard Clay. However, because of disturbance of the near-surface soils, the foundation subgrade the upper 0.5m of the exposed soils must be excavated and re-placed in maximum 0.2 m lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat foundation would support the portal foundation. A mat can be designed using an allowable bearing capacity of 2.5 tsf and a coefficient of subgrade reaction of 120 pci (using 12 in. by 12. Plate) at or below El. +28 m (el. +92 ft). There would be a long-term settlement of about 13 mm (0.5 in.).

Groundwater is within 3 m of the foundation bottom. Temporary groundwater pumping would be required. Long-term resistance to uplift forces is not likely required as the head would be about 4.6 m. and deadweight of the structure would resist uplift forces.

8.3.2.2 Sta. 119+941 to Sta. 120+230 (Tunnel Portal area)

Similar subgrade to section 8.3.2.1, but is less dense. For uniform subgrade, an over-excavation of 1.0 m, and re-placing of excavated granular soils would be required. Backfill should be made in maximum 0.2 m lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A foundation support can be used with an allowable bearing capacity of 1.5 tsf and a coefficient of subgrade reaction of 100 pci (using 12 in. by 12. plate) at or below El. +36 m (El. +118 ft).

8.3.2.3 Sta. 127+505 to Sta. 128+830

The subgrade would consist of very dense sand and very stiff/hard clay and silt. However, because of disturbance of the near-surface soils, the foundation subgrade the upper 0.5 m of the exposed soils must be excavated and re-placed in maximum 0.2m lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat foundation would support the portal foundation. A mat can be designed using an allowable bearing capacity of 2.5 tsf and a coefficient of subgrade reaction of 130 pc1 pci (using 12 in. by 12. plate) at or below El. +60 m (el. +196 ft). There would be a long-term settlement of less than 13 mm (0.5 in.).

Groundwater would likely be encountered at the foundation bottom elevation. Temporary groundwater pumping would be required. Long-term resistance to uplift forces is not likely required as the head would be about 3 m and the deadweight of the structure would resist uplift forces.

9.0 BUILDING AND UTILITY PROTECTION MEASURES

Disturbance of the ground as a result of tunneling can result in the settlement of existing structures (identified as buildings, utilities and other structures such as embankments and ramps) that are close to the construction activities. Settlement criteria that provide protection to the existing structures along the alignment will need to be developed in the project specifications. To meet these criteria and to demonstrate they are being met, the Contractor should:

- Evaluate ground movements caused by tunneling excavation
- Determine where structure protection is needed
- Design appropriate protection measures
- Monitor ground movements during construction to assure that the protection measures are sufficient to meet the criteria, and if necessary carry out remedial and/or additional protection measures. The monitoring program will monitor:
    i. Ground movements and settlements caused by each tunnel as it approaches and passes beyond each monitoring station.
    ii. Ground movements and settlements caused by cross passage excavations
    iii. Confirmation that the settlement effects due to construction have ceased.
    iv. Perform pre- and post-construction surveys to confirm the structures have not been damaged.

In addition to the grouting required for the protection of structures, ground treatment by means of permeation grouting with chemical or other suitable grout should be utilized by the contractor, particularly at sensitive locations such as beneath Carnegie Library, BWI Airport, etc.

9.1 Pre-Construction Surveys

Surveys of existing buildings and structures that may impacted by construction activities shall be conducted prior to the start of construction. The surveys will document the pre-construction conditions of the buildings and structures with high-definition photos and video that will allow a clear assessment post-construction if construction activities adversely impacted the structures. The pre-construction survey is typically complemented with the installation of optical crack gages on existing cracks and relevant instrumentation for monitoring settlement and vibrations during construction.

9.2 Construction Vibration

A Noise and Vibration Control Plan is prepared by each contractor for submission, which will include studies documenting baseline noise and vibration levels prior to the start of construction and tunneling. Remediation measures will be determined to address situations where noise and vibration levels have been exceeded. Noise and vibration monitoring points shall be established along the alignment during construction and tunneling operations with daily monitoring and additional monitoring if necessary in response to public complaints. Vibration limits are imposed to minimize the possibility of physical damage to buildings and to minimize annoyance to the public.

9.3 Instrumentation

An extensive program shall be emplaced during construction and tunneling operations to monitor for surface settlements. This includes an Alert Notification System that will generate messages to responsible personnel when data collected by an instrument is determined to be outside the established tolerances. Tolerance levels are established based on thresholds for buildings, roads and other sensitive structures to ensure remediation measures can be implemented immediately upon surpassing a tolerance level. Instrumentation would likely include Borehole Extensometers, Inclinometers, Tunneling Diameter Measure Device, Structure Monitoring Points, Ground Monitoring points, Utility Monitoring Points, Grid Crack Gauges, Tiltmeters, and Survey Instruments.

10.0 REFERENCES

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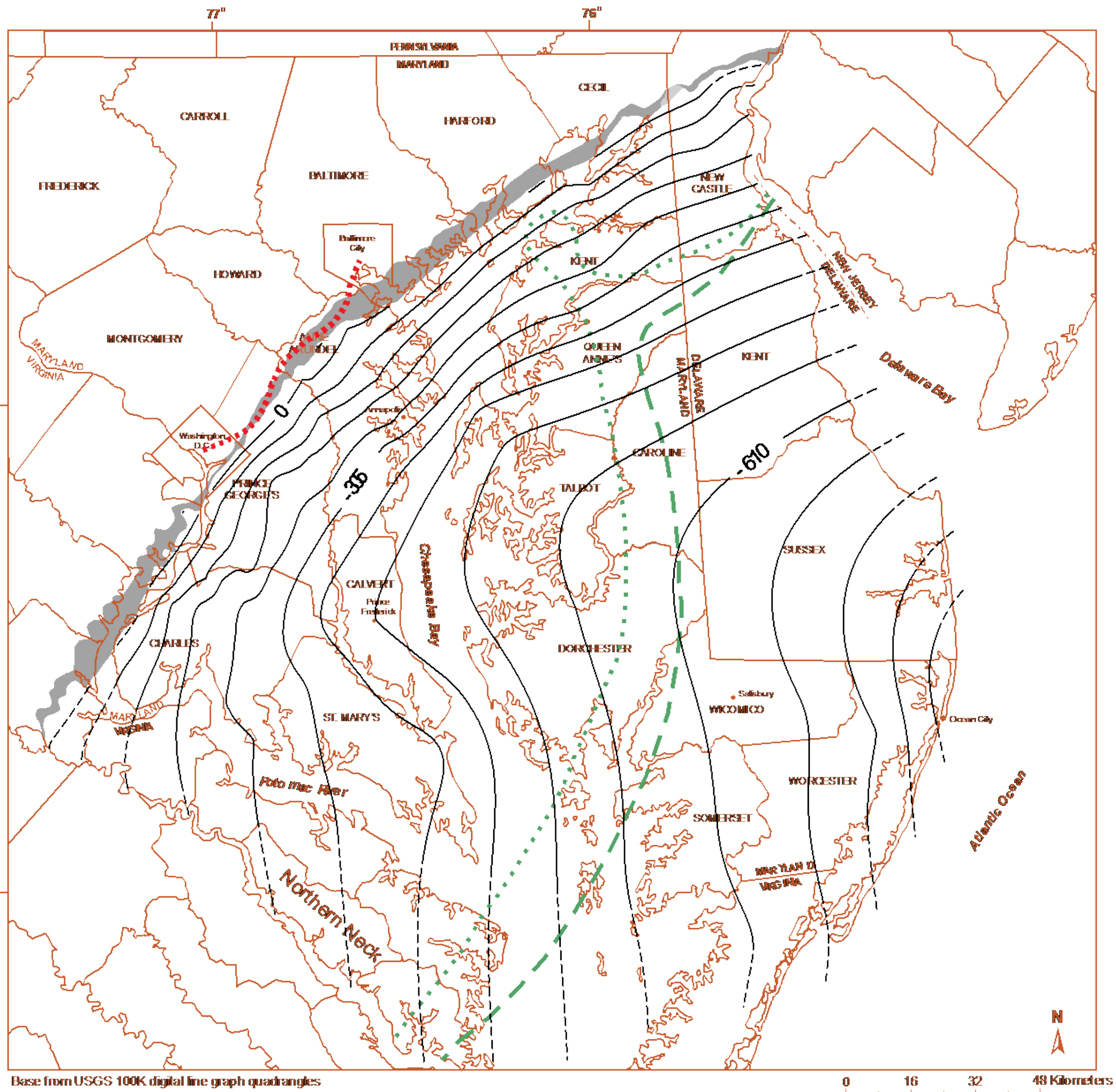
APPENDIX A: MAPS OF MARYLAND AQUIFERS



EXPLANATION

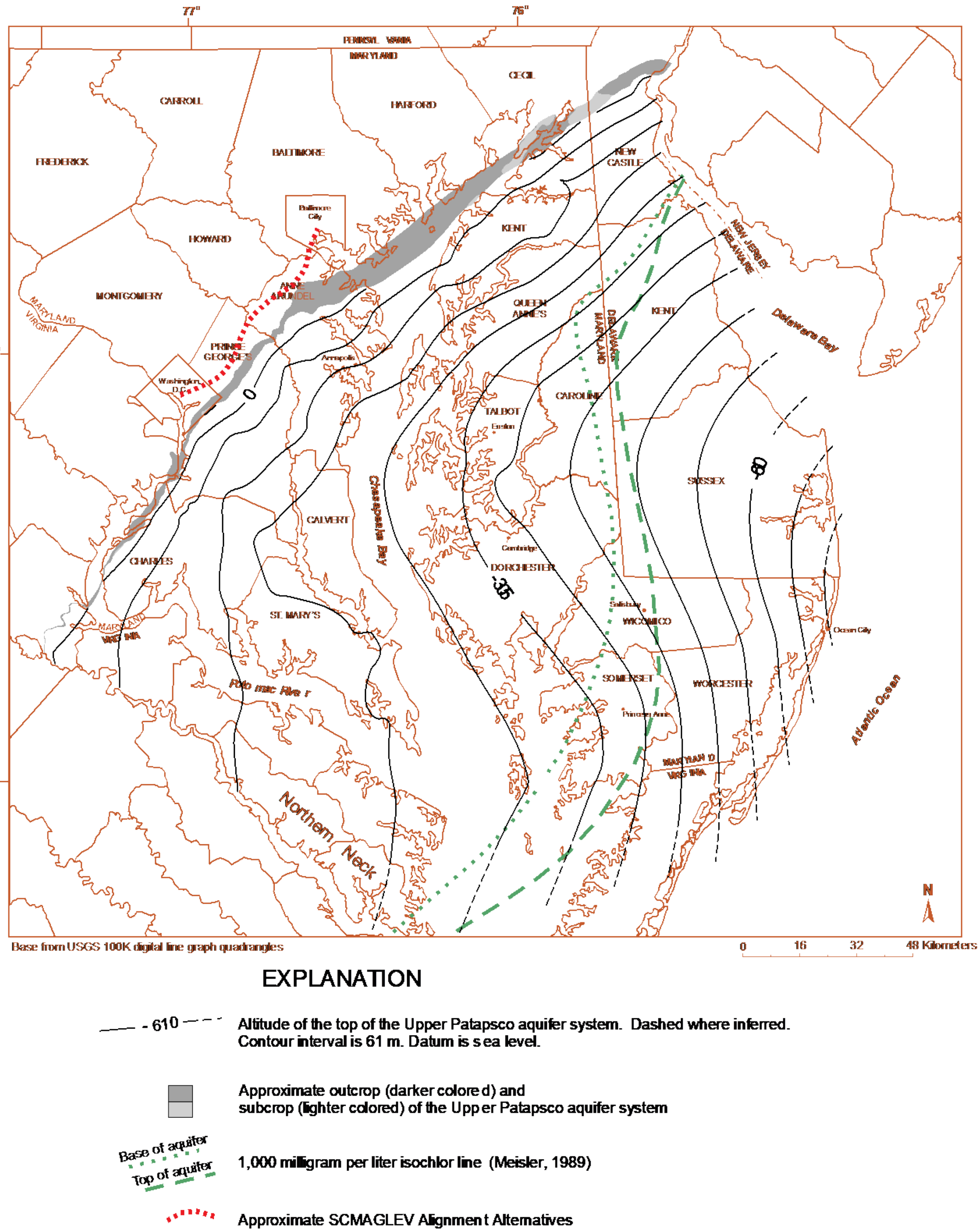
- 610 — Altitude of the top of the Lower Patapsco aquifer system. Dashed where inferred. Contour interval is 61 meters. Datum is sea level.

Approximate outcrop (darker colored) and subcrop (lighter colored) of the Lower Patapsco aquifer system

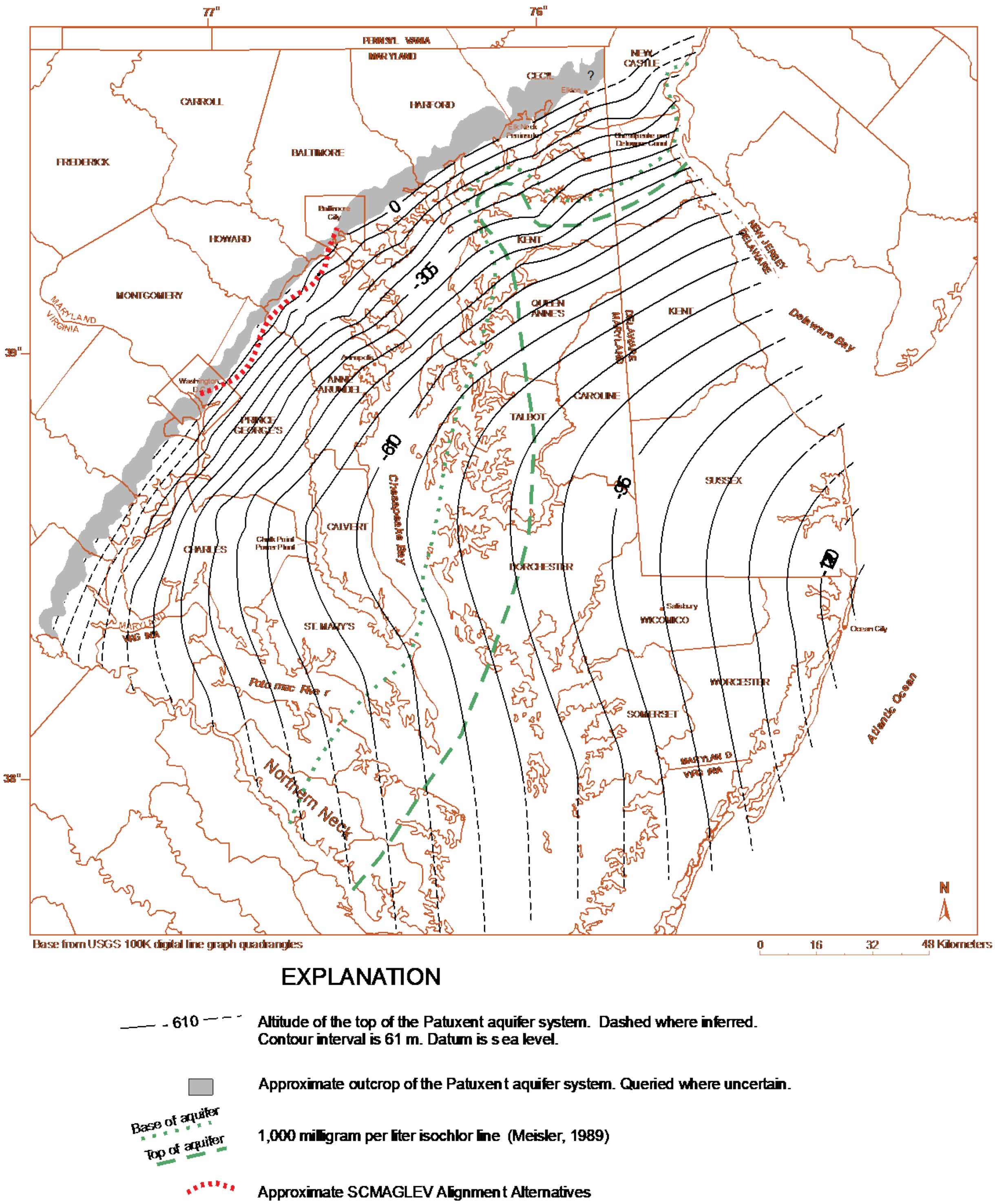
Base of aquifer / Top of aquifer — 1,000 milligram per liter isochlor line (Meisler, 1989)

Approximate SCMAGLEV Alignment Alternatives

Altitude of the top of the Lower Patapsco aquifer system (after Andreasen et al., 2013)

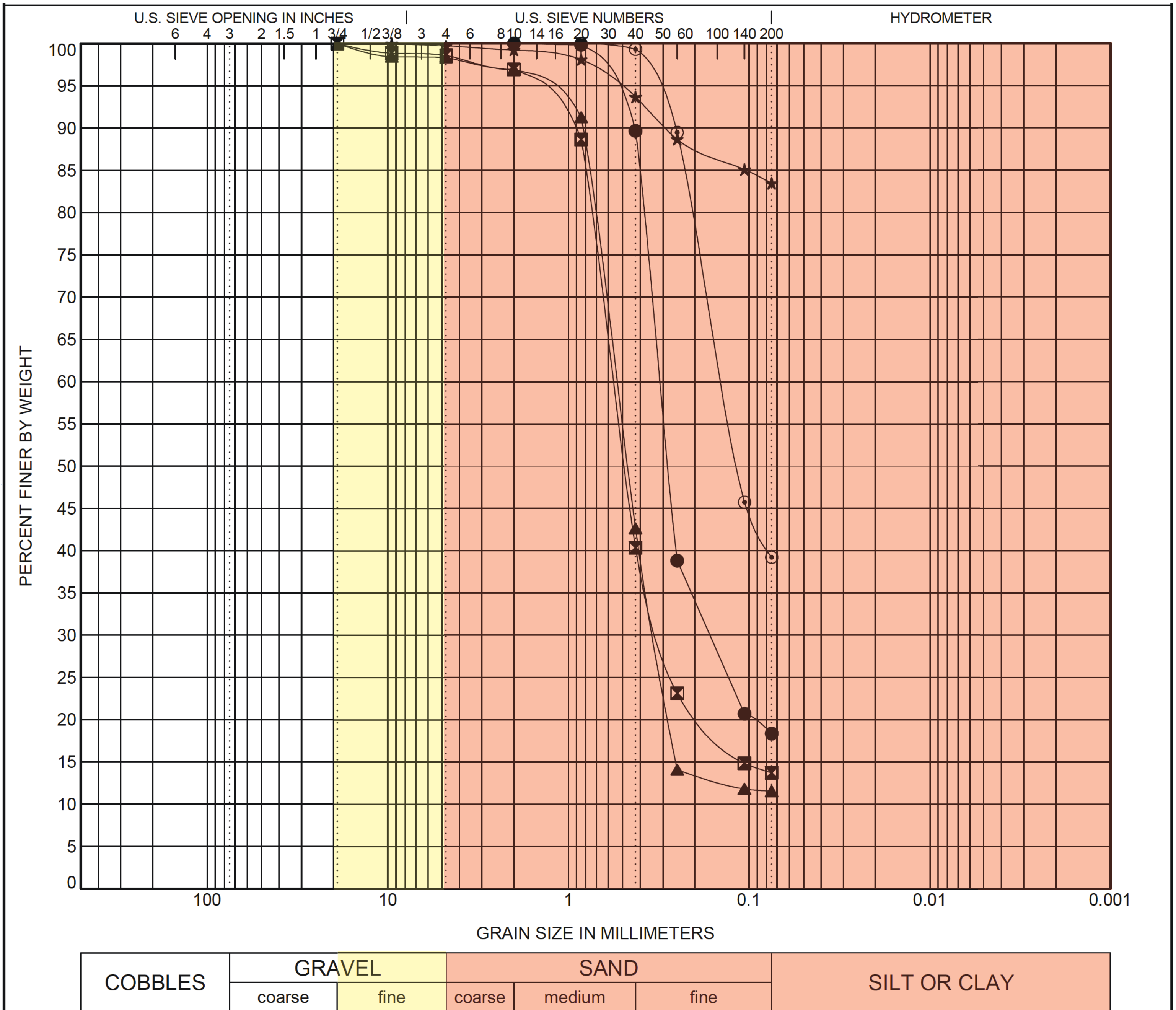


Altitude of the top of the Upper Patapsco aquifer system (after Andreasen et al., 2013)



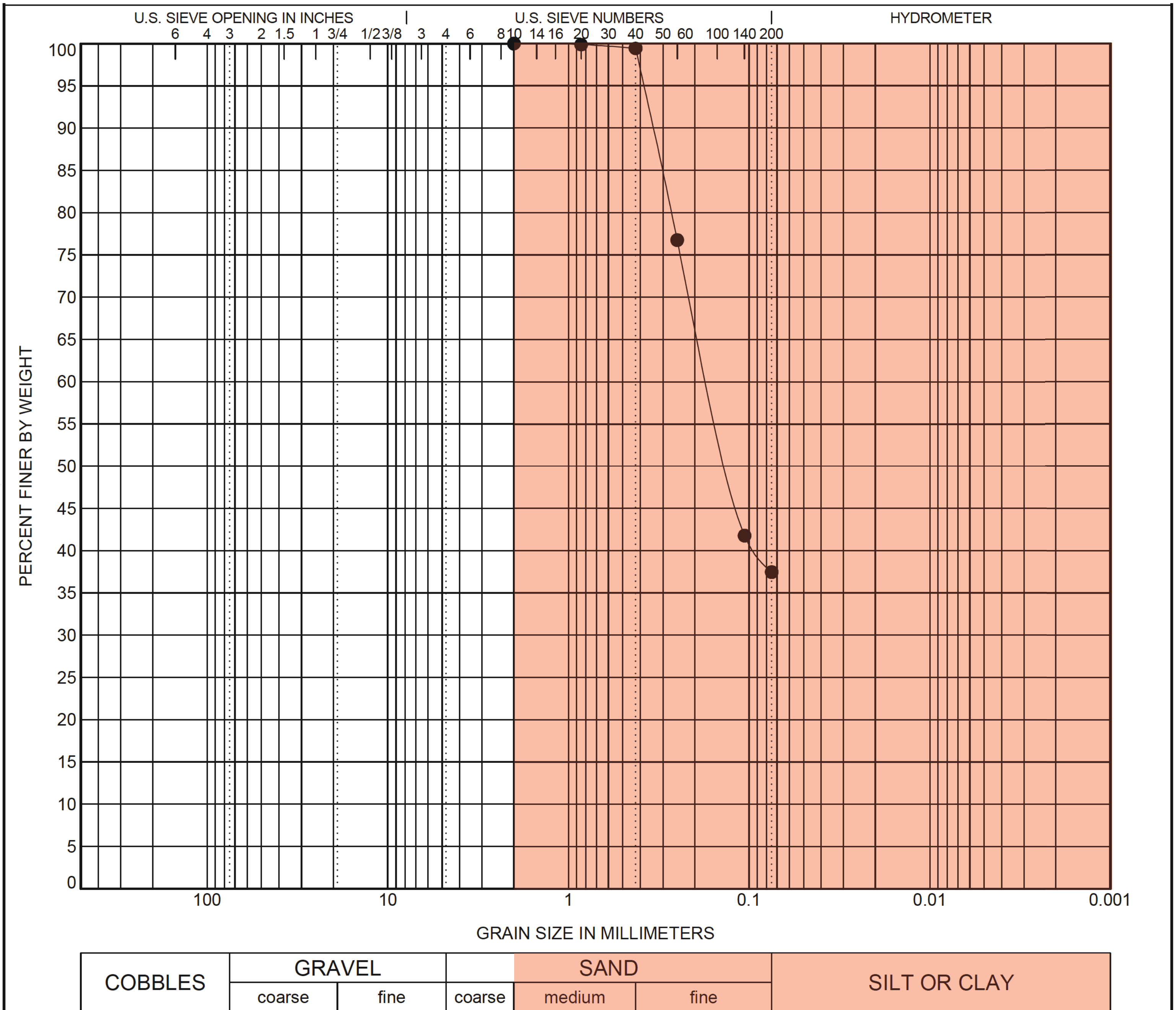
Altitude of the top of the Patuxent aquifer system (after Andreasen et al., 2013)

APPENDIX B: GRAIN SIZE DISTRIBUTION PLOTS



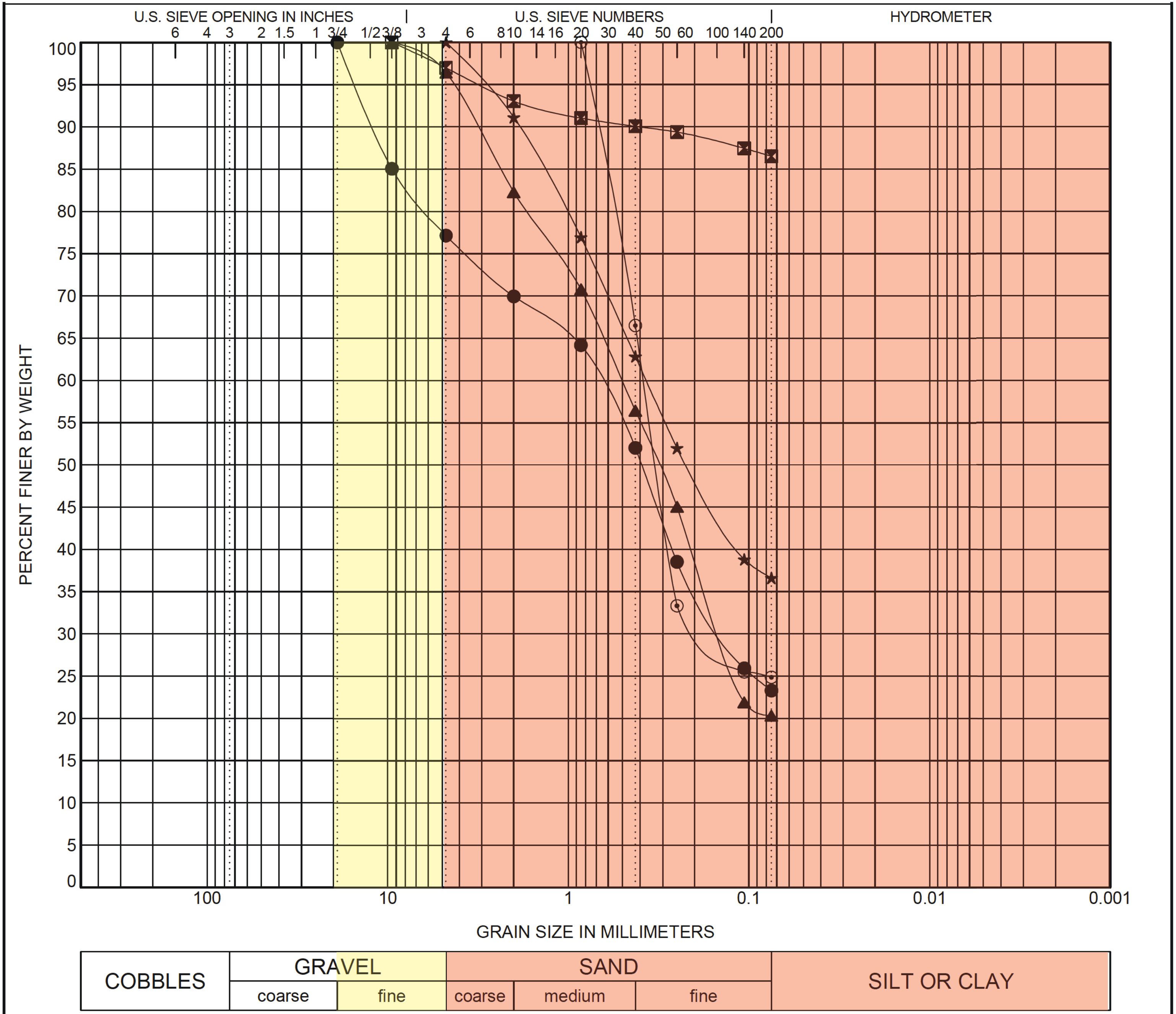
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-10**	**148.5-150**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊠	**BWP-11**	**33.5-35**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
▲	**BWP-15**	**30-31.5**	**POORLY GRADED SAND with SILT(SP-SM)**	**NP**	**NP**	**NP**	**20.44**	**53.64**
★	**BWP-15**	**80-81.5**	**SILT with SAND(ML)**	**NP**	**NP**	**NP**		
⊙	**BWP-15**	**135-136.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-10**	**148.5-150**	**2**	**0.312**	**0.165**		**0.0**	**81.6**	**18.4**	
⊠	**BWP-11**	**33.5-35**	**19**	**0.564**	**0.309**		**1.4**	**84.9**	**13.7**	
▲	**BWP-15**	**30-31.5**	**19**	**0.545**	**0.336**		**1.7**	**86.8**	**11.5**	
★	**BWP-15**	**80-81.5**	**9.5**				**0.3**	**16.2**	**83.5**	
⊙	**BWP-15**	**135-136.5**	**0.85**	**0.14**			**0.0**	**60.8**	**39.2**	



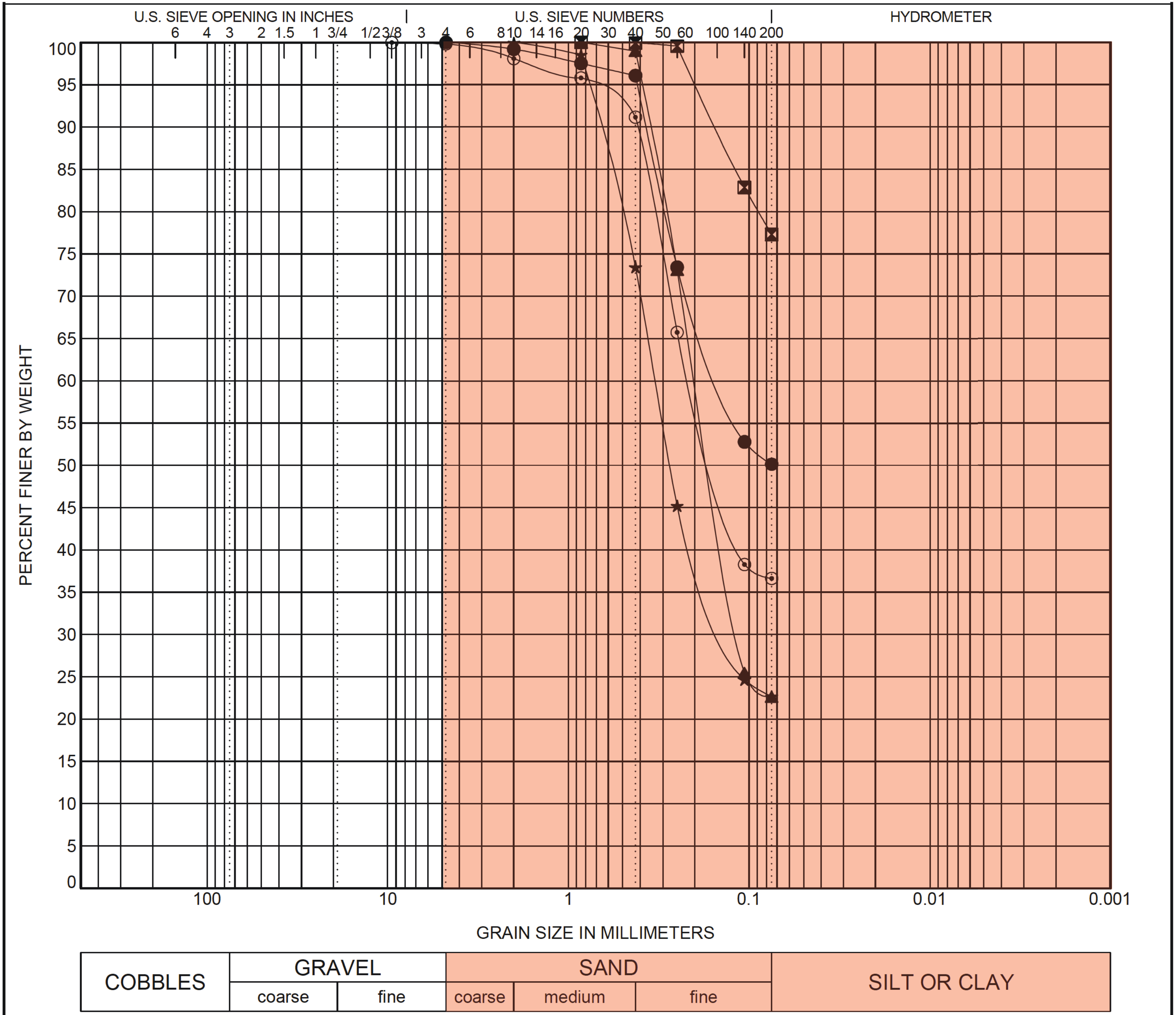
SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
● **BWP-15**	**200-200.5**	**CLAYEY SAND(SC)**	**37**	**23**	**14**		

SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **BWP-15**	**200-200.5**	**2**	**0.166**			**0.0**	**62.6**	**37.4**	



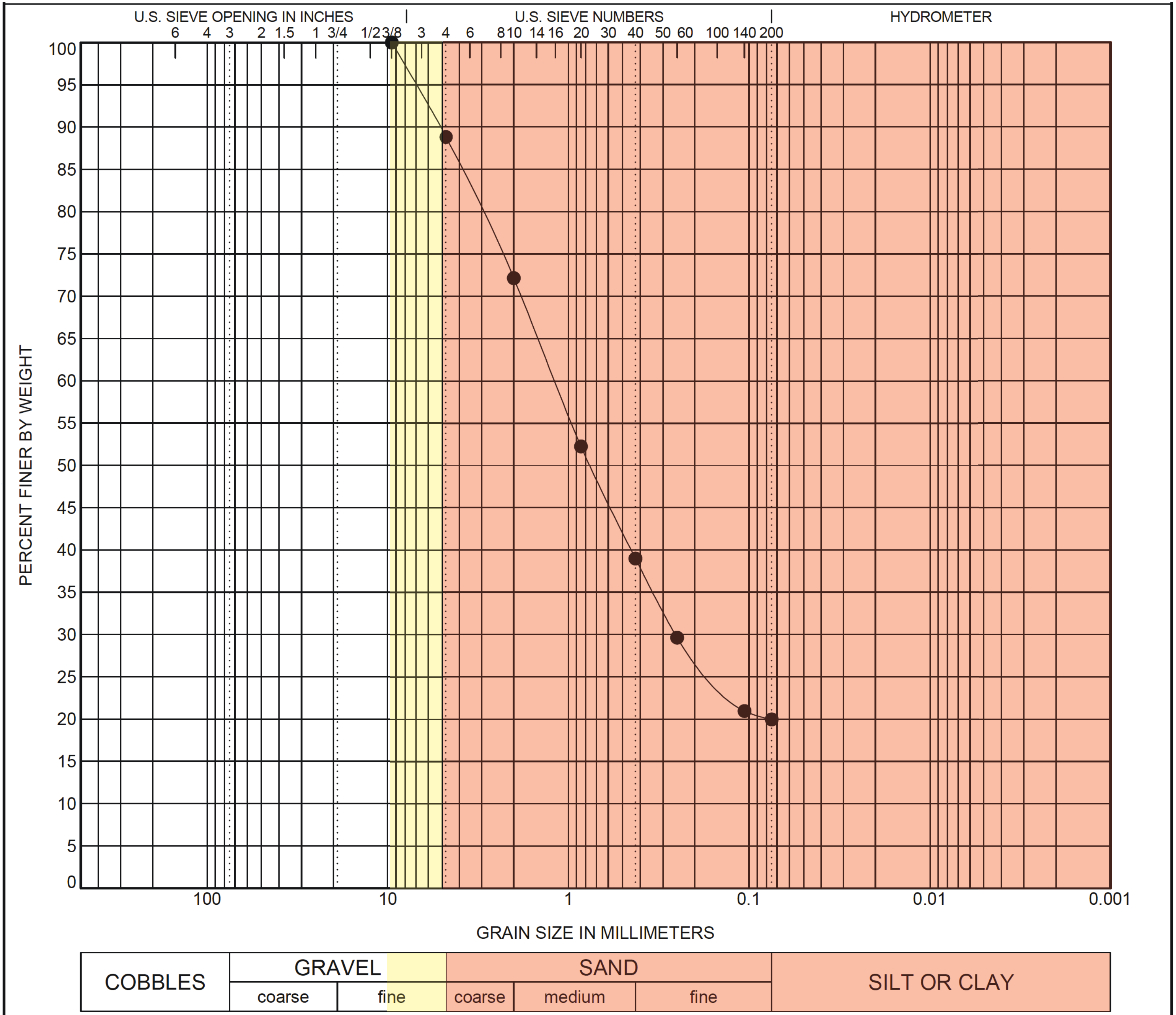
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-1**	**33.5-35**	**CLAYEY SAND with GRAVEL(SC)**	**37**	**21**	**16**		
⊠	**BWP-1**	**78.5-80**	**SILT(ML)**	**NP**	**NP**	**NP**		
▲	**BWP-1**	**111-112.5**	**CLAYEY SAND(SC)**	**39**	**22**	**17**		
★	**BWP-1**	**137-138.5**	**CLAYEY SAND(SC)**	**40**	**23**	**17**		
⊙	**BWP-3**	**83.5-85**	**CLAYEY SAND(SC)**	**39**	**23**	**16**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-1**	**33.5-35**	**19**	**0.669**	**0.14**		**22.9**	**53.9**	**23.3**	
⊠	**BWP-1**	**78.5-80**	**9.5**				**3.0**	**10.5**	**86.5**	
▲	**BWP-1**	**111-112.5**	**9.5**	**0.504**	**0.143**		**3.6**	**76.1**	**20.3**	
★	**BWP-1**	**137-138.5**	**4.75**	**0.369**			**0.0**	**63.4**	**36.6**	
⊙	**BWP-3**	**83.5-85**	**0.85**	**0.383**	**0.174**		**0.0**	**75.1**	**24.9**	



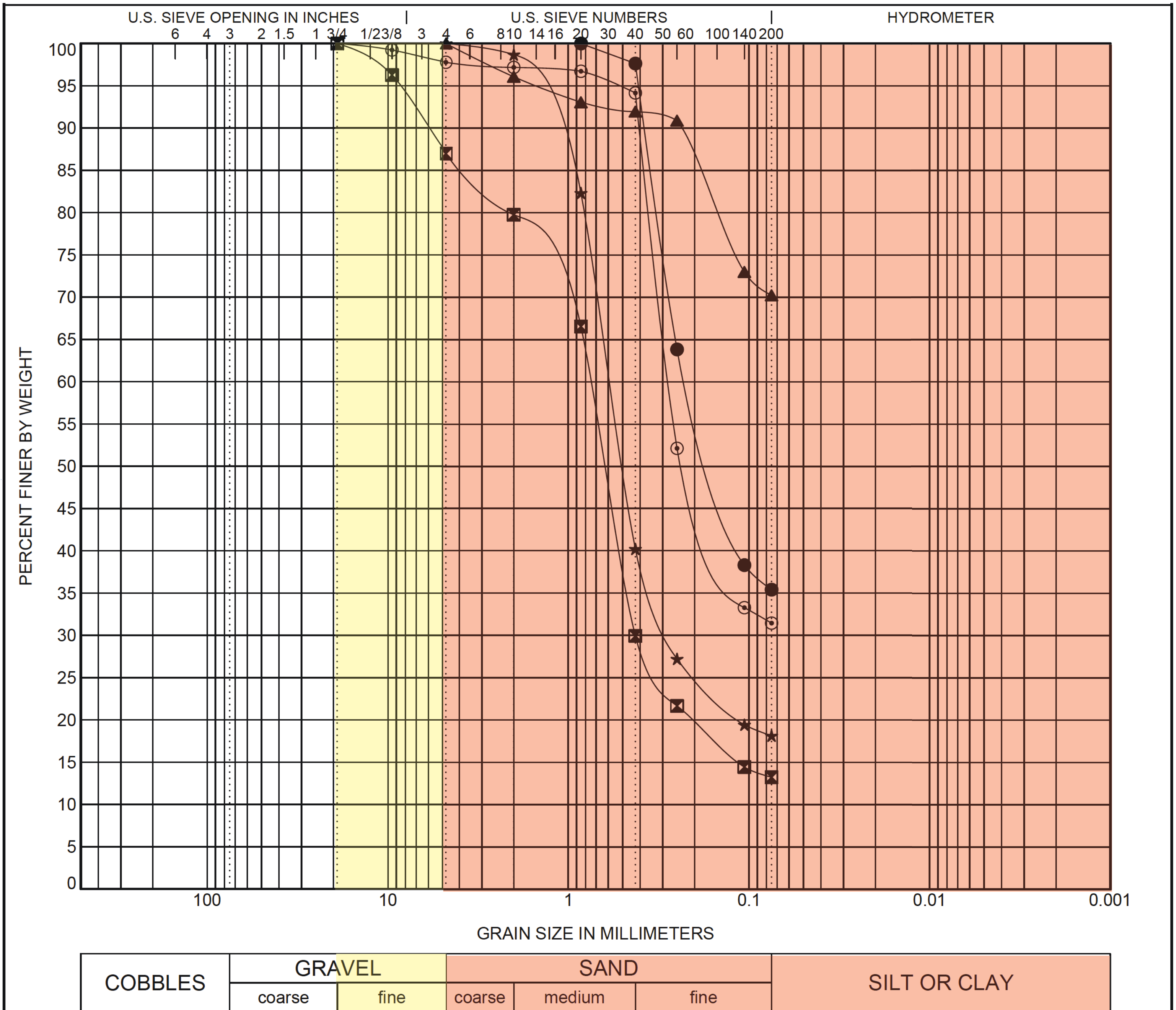
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-3**	**138.5-140**	**SANDY LEAN CLAY(CL)**	**38**	**21**	**17**		
⊠	**BWP-3**	**188.5-190**	**FAT CLAY with SAND(CH)**	**54**	**21**	**33**		
▲	**BWP-3**	**224.5-226**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
★	**DC-1**	**53.5-55**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊙	**DC-1**	**78.5-80**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-3**	**138.5-140**	**4.75**	**0.143**			**0.0**	**49.9**	**50.1**	
⊠	**BWP-3**	**188.5-190**	**0.85**				**0.0**	**22.7**	**77.3**	
▲	**BWP-3**	**224.5-226**	**0.85**	**0.197**	**0.115**		**0.0**	**77.4**	**22.6**	
★	**DC-1**	**53.5-55**	**4.75**	**0.33**	**0.133**		**0.0**	**77.3**	**22.7**	
⊙	**DC-1**	**78.5-80**	**9.5**	**0.209**			**0.2**	**63.2**	**36.6**	



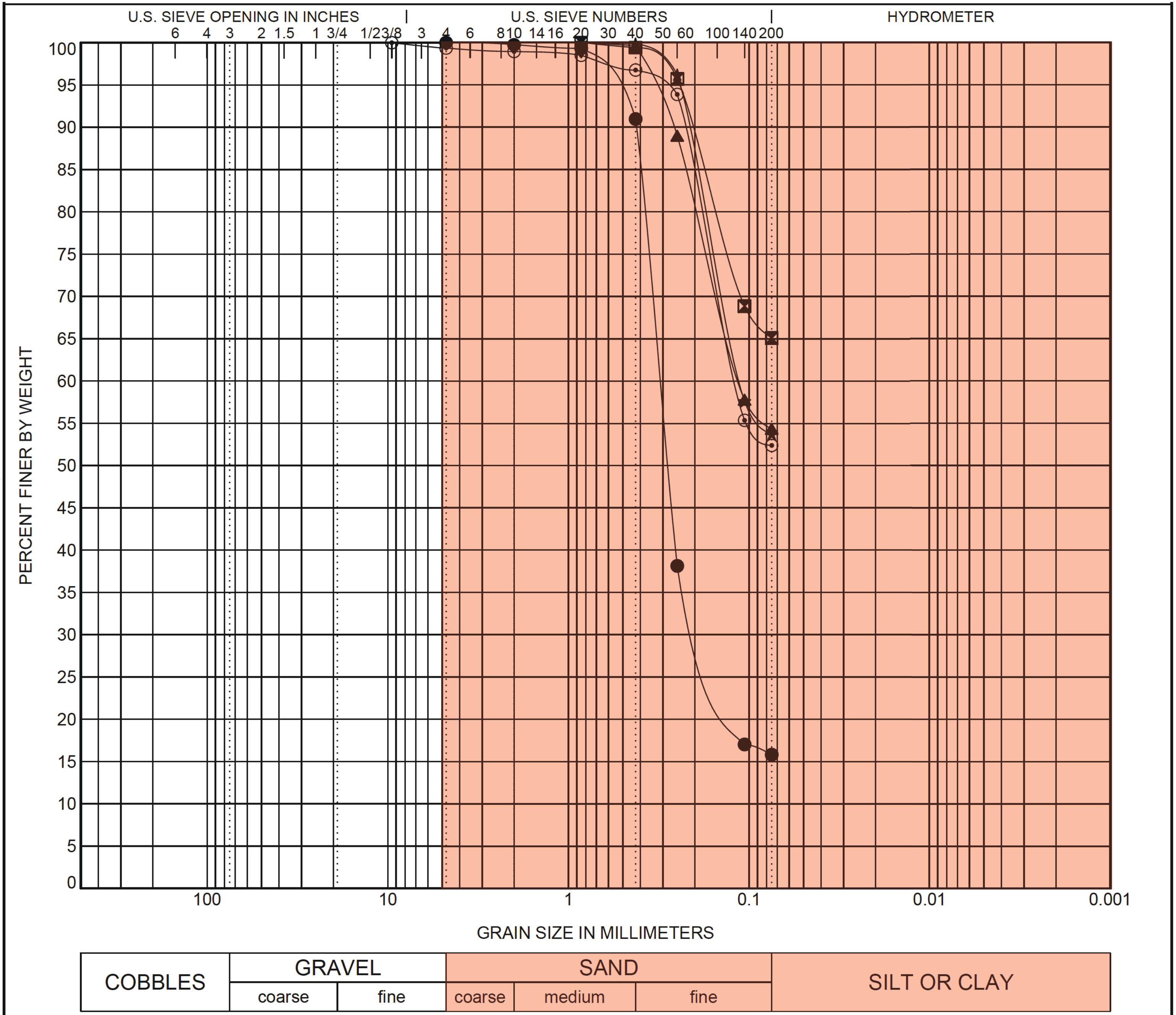
SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
● **DC-1**	**118.5-120**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **DC-1**	**118.5-120**	**9.5**	**1.185**	**0.255**		**11.2**	**68.9**	**20.0**	



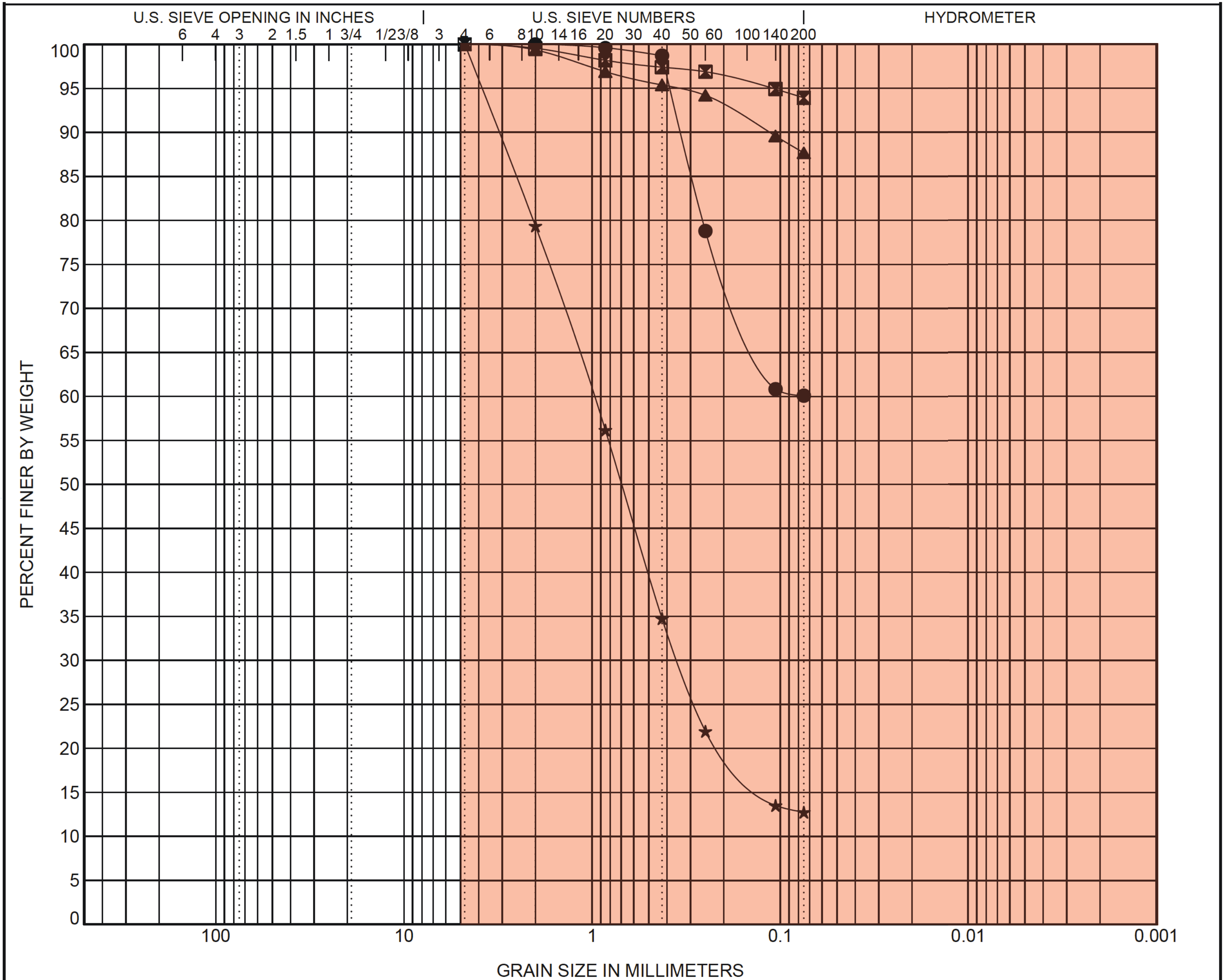
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-2**	**68.5-70**	**SILTY SAND(SM)**	**40**	**27**	**13**		
⊠	**BWP-2**	**123.5-125**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
▲	**BWP-2**	**183.5-185**	**SILT with SAND(ML)**	**39**	**26**	**13**		
★	**BWP-3**	**248.5-250**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊙	**BWP-3**	**303.5-305**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-2**	**68.5-70**	**0.85**	**0.22**			**0.0**	**64.6**	**35.4**	
⊠	**BWP-2**	**123.5-125**	**19**	**0.751**	**0.426**		**13.0**	**73.7**	**13.2**	
▲	**BWP-2**	**183.5-185**	**4.75**				**0.0**	**29.8**	**70.2**	
★	**BWP-3**	**248.5-250**	**4.75**	**0.589**	**0.28**		**0.0**	**81.9**	**18.1**	
⊙	**BWP-3**	**303.5-305**	**19**	**0.276**			**2.2**	**66.3**	**31.4**	



	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-3**	**348.5-350**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊠	**BWP-12**	**19-21**	**SANDY SILTY CLAY(CL-ML)**	**23**	**17**	**6**		
▲	**BWP-12**	**39-41**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		
★	**BWP-12**	**64-66**	**SANDY SILTY CLAY(CL-ML)**	**22**	**17**	**5**		
⊙	**BWP-12**	**184-186**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		

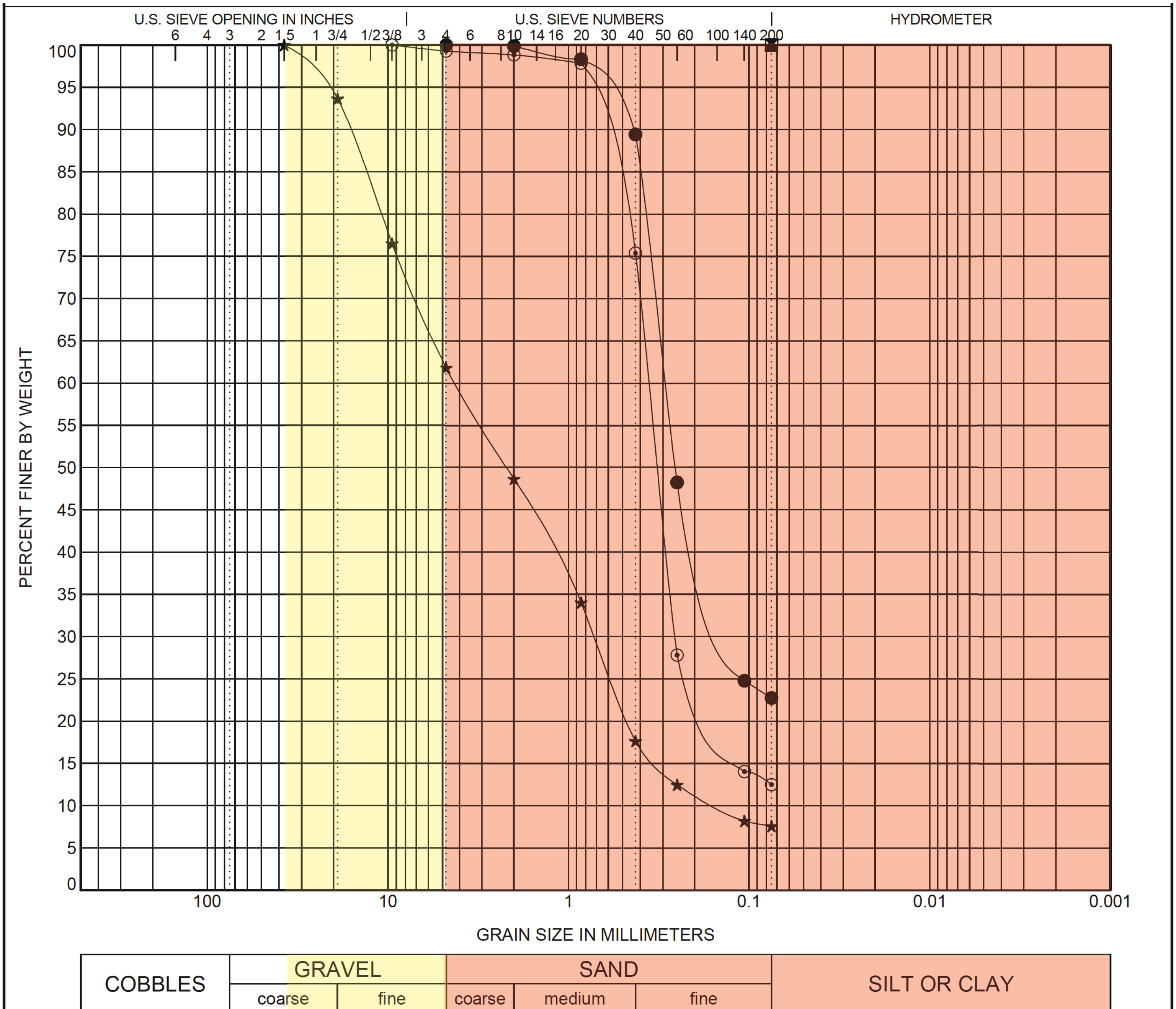
	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-3**	**348.5-350**	**4.75**	**0.311**	**0.18**		**0.0**	**84.2**	**15.8**	
⊠	**BWP-12**	**19-21**	**0.85**				**0.0**	**34.9**	**65.1**	
▲	**BWP-12**	**39-41**	**0.85**	**0.113**			**0.0**	**45.6**	**54.4**	
★	**BWP-12**	**64-66**	**0.85**	**0.112**			**0.0**	**46.2**	**53.8**	
⊙	**BWP-12**	**184-186**	**9.5**	**0.117**			**0.7**	**46.9**	**52.4**	



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

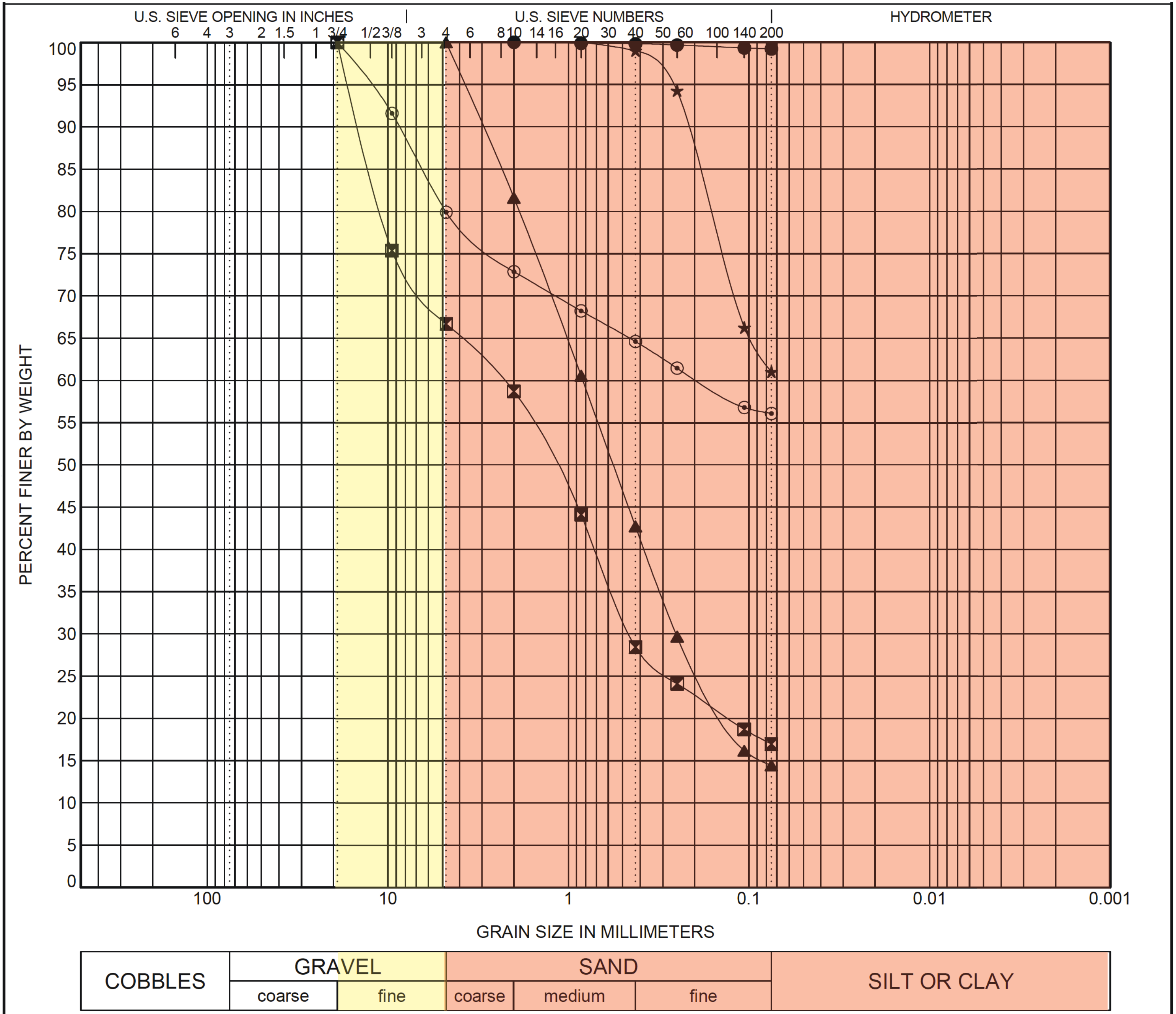
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-14**	**19-21**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		
⌧	**BWP-14**	**84-86**	**SILT(ML)**	**NP**	**NP**	**NP**		
▲	**BWP-14**	**134-136**	**SILT(ML)**	**NP**	**NP**	**NP**		
★	**BWP-20**	**99-101**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-14**	**19-21**	**2**				**0.0**	**39.9**	**60.1**	
⌧	**BWP-14**	**84-86**	**4.75**				**0.0**	**6.1**	**93.9**	
▲	**BWP-14**	**134-136**	**4.75**				**0.0**	**12.3**	**87.7**	
★	**BWP-20**	**99-101**	**4.75**	**0.978**	**0.349**		**0.0**	**87.2**	**12.8**	



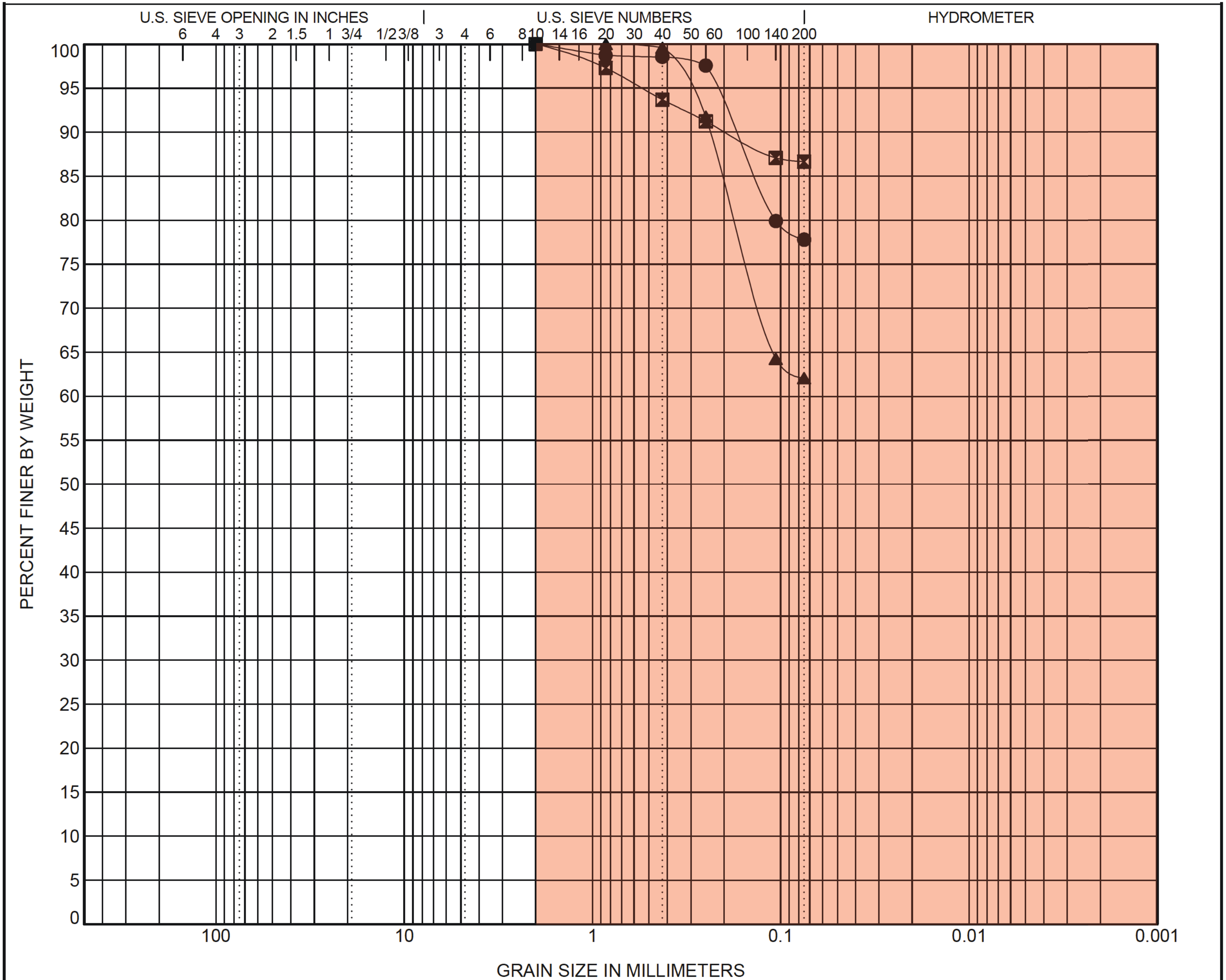
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-6A**	**33.5-35**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊠	**BWP-6A**	**53.5-55**	**LEAN CLAY(CL)**	**33**	**18**	**15**		
▲	**BWP-9**	**55-56.5**	**LEAN CLAY(CL)**	**34**	**18**	**16**		
★	**BWP-9**	**105-106.5**	**POORLY GRADED SAND with SILT and GRAVEL(SP-SM)**	**NP**	**NP**	**NP**	**0.80**	**27.76**
⊙	**BWP-9**	**165-166.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-6A**	**33.5-35**	**4.75**	**0.291**	**0.128**		**0.0**	**77.3**	**22.7**	
⊠	**BWP-6A**	**53.5-55**	**0.075**				**0.0**	**0.0**	**100.0**	
▲	**BWP-9**	**55-56.5**	**0.075**				**0.0**	**0.0**	**100.0**	
★	**BWP-9**	**105-106.5**	**37.5**	**4.215**	**0.717**	**0.152**	**38.2**	**54.2**	**7.6**	
⊙	**BWP-9**	**165-166.5**	**9.5**	**0.358**	**0.256**		**0.7**	**86.8**	**12.5**	



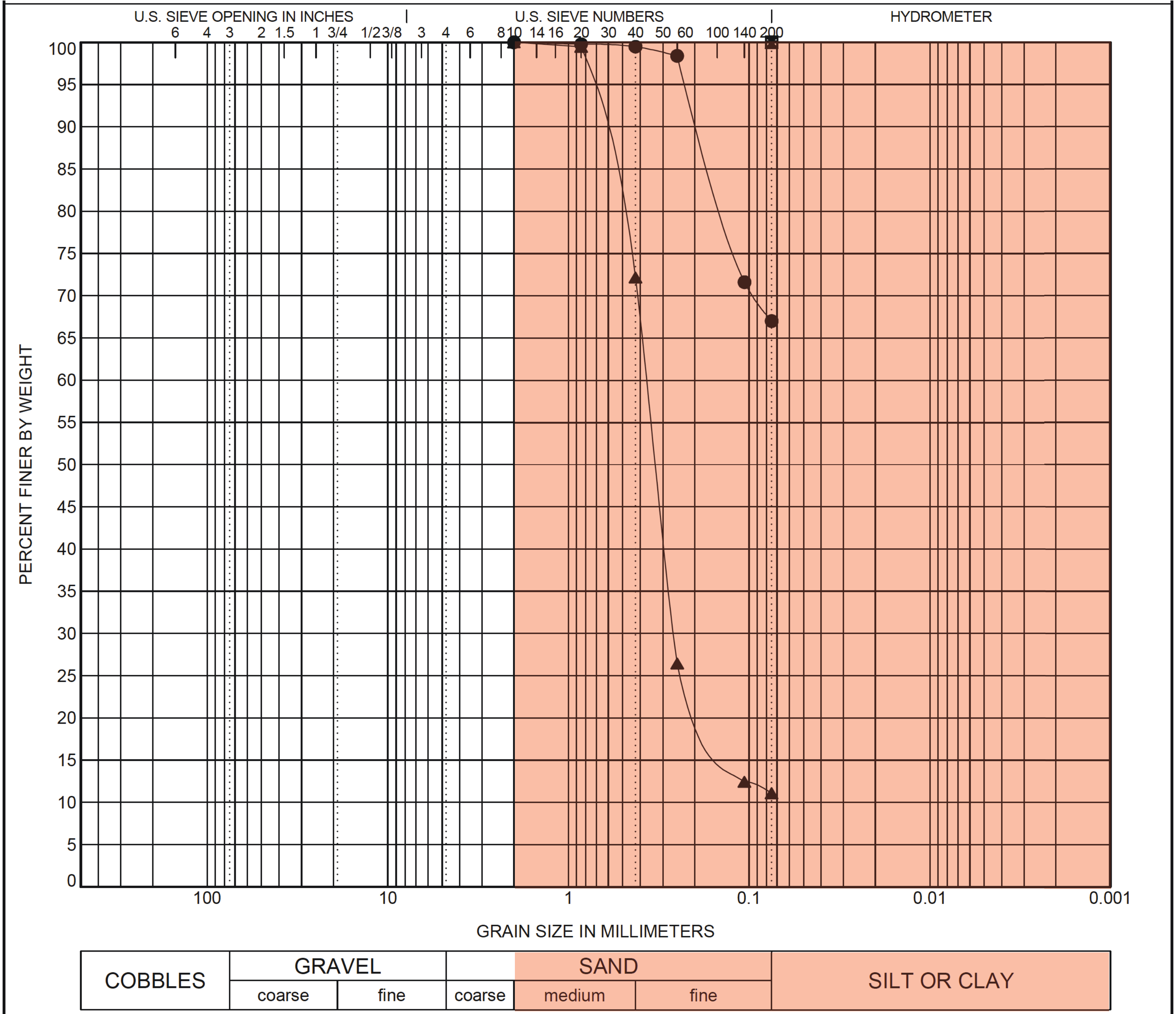
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-6A**	**83.5-85**	**SILT(ML)**	**NP**	**NP**	**NP**		
⊠	**BWP-17**	**130-131.5**	**CLAYEY SAND with GRAVEL(SC)**	**45**	**22**	**23**		
▲	**HW-1**	**74-76**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
★	**HW-1**	**84-86**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		
⊙	**HW-1**	**24-26**	**SANDY SILT with GRAVEL(ML)**	**40**	**31**	**9**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-6A**	**83.5-85**	**2**				**0.0**	**0.8**	**99.2**	
⊠	**BWP-17**	**130-131.5**	**19**	**2.299**	**0.456**		**33.3**	**49.7**	**17.0**	
▲	**HW-1**	**74-76**	**4.75**	**0.831**	**0.253**		**0.0**	**85.6**	**14.4**	
★	**HW-1**	**84-86**	**0.85**				**0.0**	**39.0**	**61.0**	
⊙	**HW-1**	**24-26**	**19**	**0.191**			**20.1**	**23.8**	**56.1**	



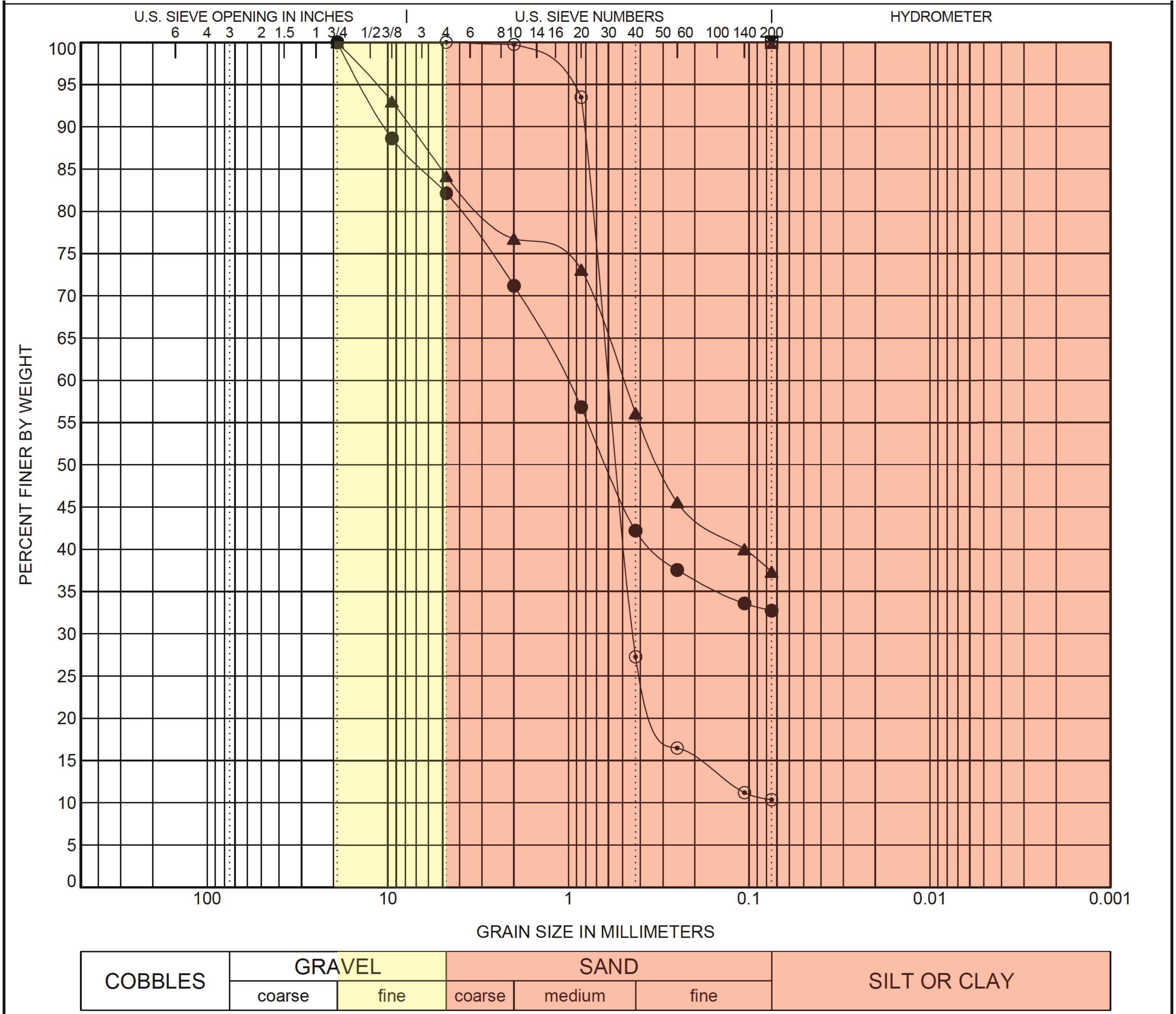
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**HW-1**	**54-56**	**LEAN CLAY with SAND(CL)**	**29**	**18**	**11**		
⊠	**HW-2**	**39-41**	**LEAN CLAY(CL)**	**37**	**21**	**16**		
▲	**HW-2**	**79-81**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**HW-1**	**54-56**	**2**				**0.0**	**22.2**	**77.8**	
⊠	**HW-2**	**39-41**	**2**				**0.0**	**13.4**	**86.6**	
▲	**HW-2**	**79-81**	**0.85**				**0.0**	**37.9**	**62.1**	



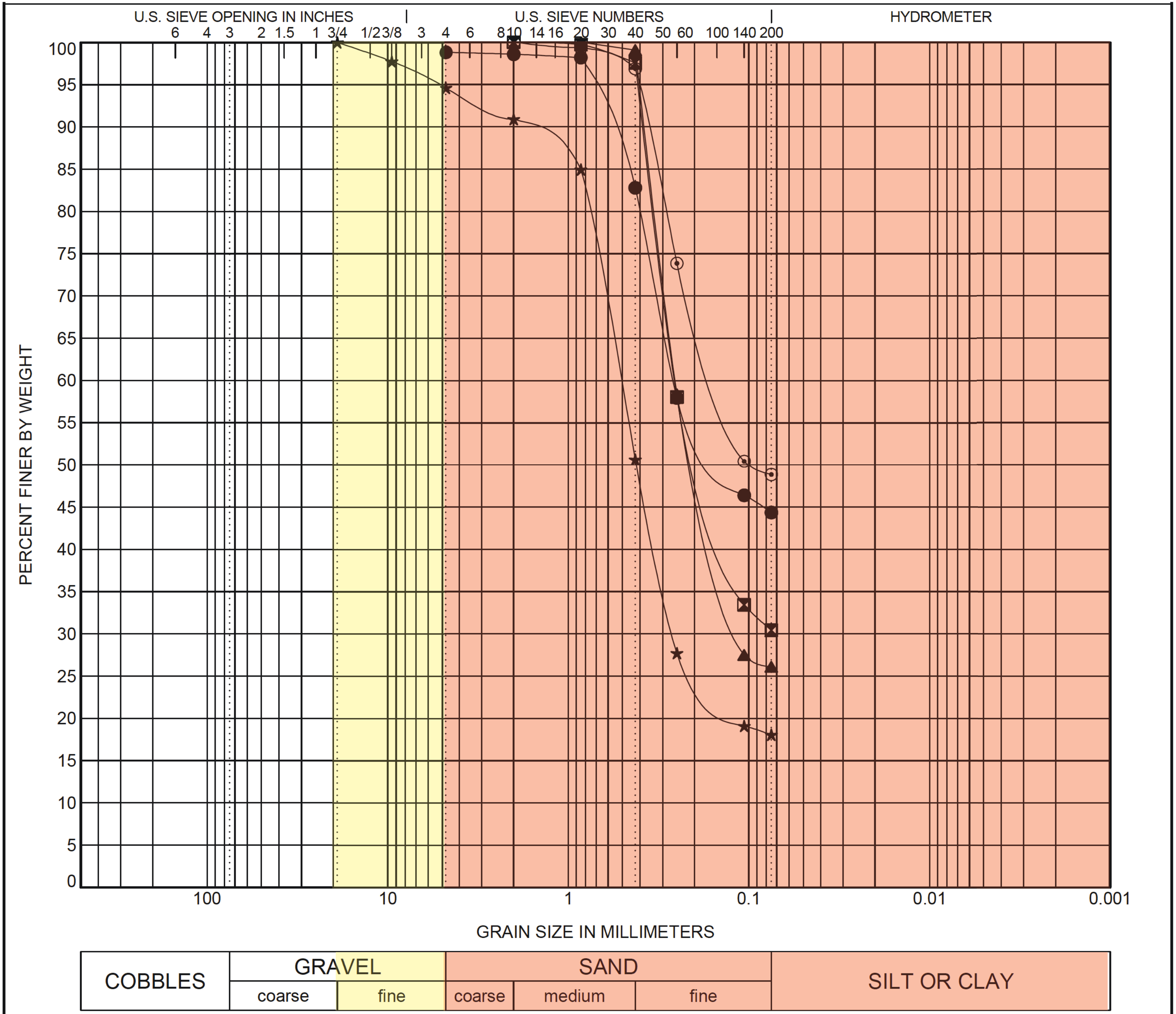
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-4**	**168.5-170**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		
⊠	**BWP-4**	**188.5-190**	**LEAN CLAY(CL)**	**39**	**20**	**19**		
▲	**BWP-6**	**23.5-25**	**POORLY GRADED SAND with SILT(SP-SM)**	**NP**	**NP**	**NP**	**3.24**	**6.51**
★	**BWP-6**	**68.5-70**	**LEAN CLAY(CL)**	**43**	**21**	**22**		
⊙	**BWP-10**	**203-205**	**SILT(ML)**	**35**	**27**	**8**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-4**	**168.5-170**	**2**				**0.0**	**33.0**	**67.0**	
⊠	**BWP-4**	**188.5-190**	**0.075**							
▲	**BWP-6**	**23.5-25**	**2**	**0.369**	**0.261**		**0.0**	**88.9**	**11.1**	
★	**BWP-6**	**68.5-70**								
⊙	**BWP-10**	**203-205**								



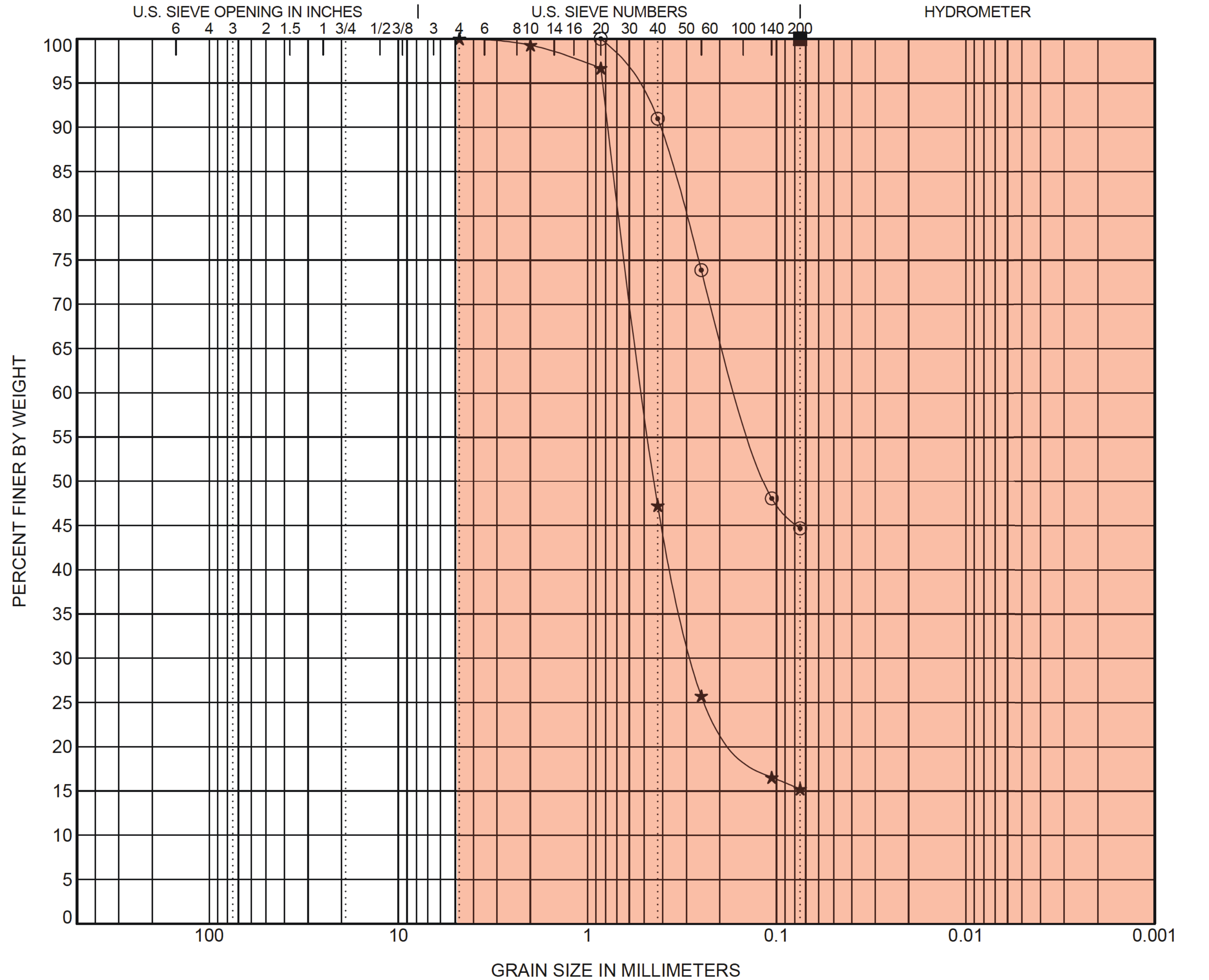
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-11**	**73-75**	**SILTY SAND with GRAVEL(SM)**	**NP**	**NP**	**NP**		
⊠	**BWP-11**	**108-110**	**SILT(ML)**	**36**	**27**	**9**		
▲	**BWP-11**	**138-140**	**SILTY SAND with GRAVEL(SM)**	**NP**	**NP**	**NP**		
★	**BWP-11**	**173-175**	**SILT(ML)**	**35**	**27**	**8**		
⊙	**BWP-13**	**34-36**	**POORLY GRADED SAND with SILT(SP-SM)**	**NP**	**NP**	**NP**	**4.95**	**9.28**

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-11**	**73-75**	**19**	**1.026**			**17.9**	**49.4**	**32.7**	
⊠	**BWP-11**	**108-110**								
▲	**BWP-11**	**138-140**	**19**	**0.498**			**15.8**	**46.9**	**37.3**	
★	**BWP-11**	**173-175**								
⊙	**BWP-13**	**34-36**	**4.75**	**0.599**	**0.437**		**0.0**	**89.6**	**10.4**	



	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-13**	**54-56**	**CLAYEY SAND(SC)**	**38**	**22**	**16**		
⊠	**BWP-13**	**74-76**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
▲	**BWP-13**	**104-106**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
★	**BWP-13**	**129-131**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊙	**BWP-13**	**164-166**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

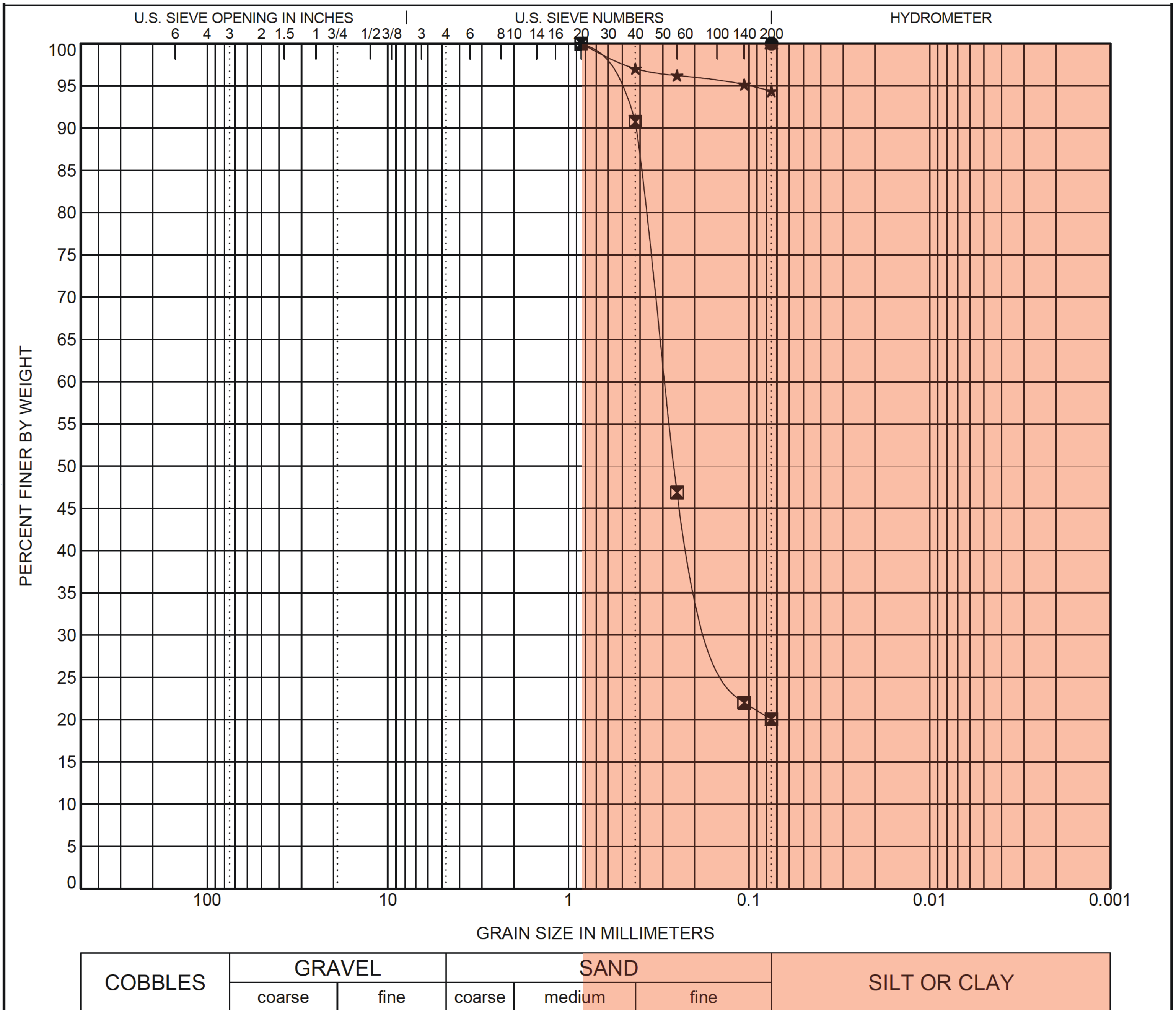
	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-13**	**54-56**	**4.75**	**0.261**			**1.2**	**54.5**	**44.3**	
⊠	**BWP-13**	**74-76**	**2**	**0.257**			**0.0**	**69.6**	**30.4**	
▲	**BWP-13**	**104-106**	**0.85**	**0.255**	**0.114**		**0.0**	**73.9**	**26.1**	
★	**BWP-13**	**129-131**	**19**	**0.513**	**0.264**		**5.4**	**76.5**	**18.1**	
⊙	**BWP-13**	**164-166**	**2**	**0.15**			**0.0**	**51.2**	**48.8**	



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

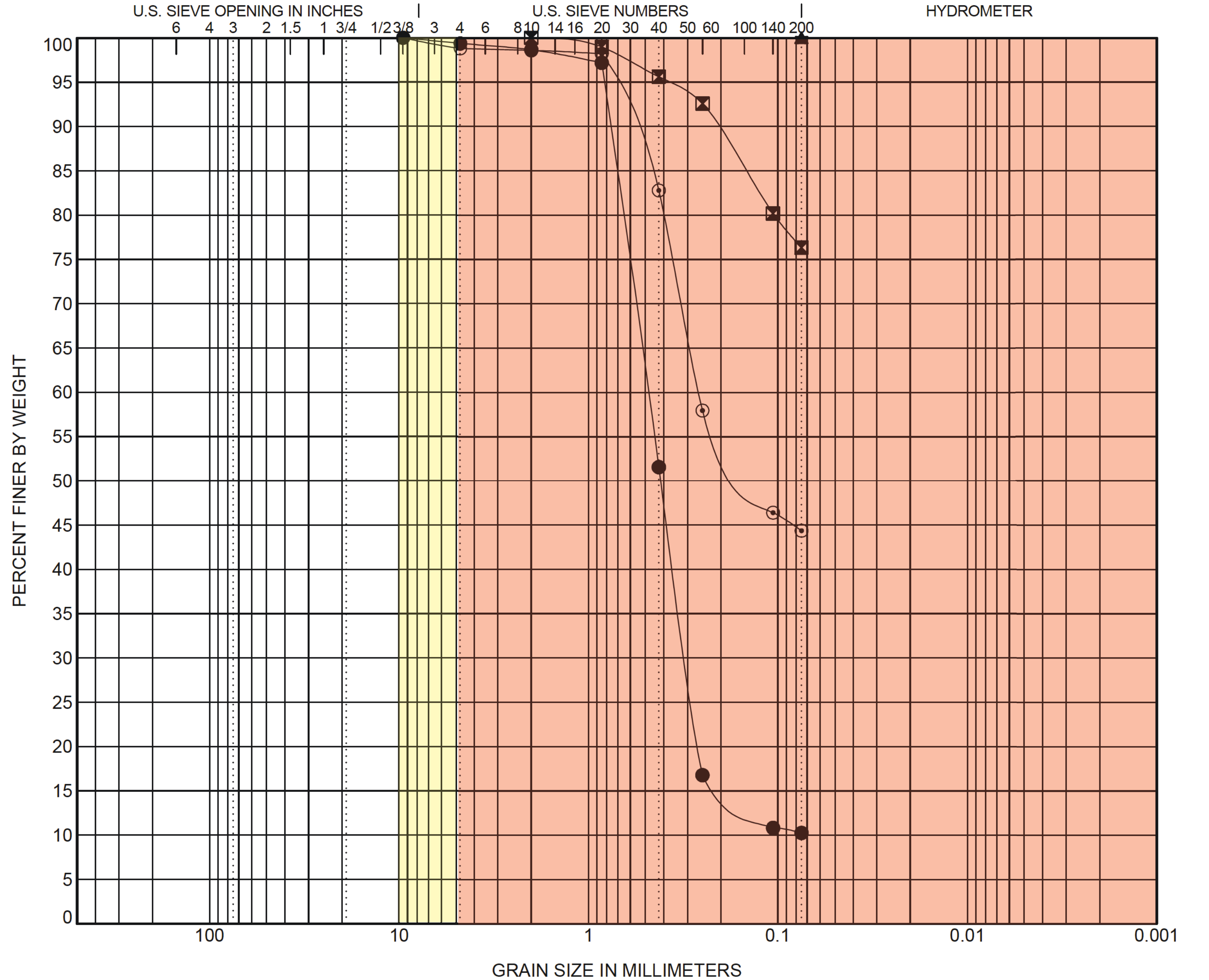
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-13**	**179-181**	**LEAN CLAY(CL)**	**29**	**18**	**11**		
⊠	**BWP-16**	**40-41.5**	**LEAN CLAY(CL)**	**30**	**18**	**12**		
▲	**BWP-16**	**65-66.5**	**SILT(ML)**	**36**	**27**	**9**		
★	**BWP-16**	**95-96.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊙	**BWP-16**	**115-116.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-13**	**179-181**								
⊠	**BWP-16**	**40-41.5**								
▲	**BWP-16**	**65-66.5**								
★	**BWP-16**	**95-96.5**	**4.75**	**0.508**	**0.278**		**0.0**	**84.8**	**15.2**	
⊙	**BWP-16**	**115-116.5**	**0.85**	**0.158**			**0.0**	**55.3**	**44.7**	



	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-16**	**127-128.5**	**SILT(ML)**	**35**	**26**	**9**		
⊠	**BWP-16**	**155-156.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
▲	**BWP-16**	**165-166.5**	**SILT(ML)**	**36**	**27**	**9**		
★	**BWP-16**	**210-211.5**	**LEAN CLAY(CL)**	**44**	**21**	**23**		
⊙	**BWP-18**	**30-31.5**	**LEAN CLAY(CL)**	**41**	**23**	**18**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-16**	**127-128.5**								
⊠	**BWP-16**	**155-156.5**	**0.85**	**0.293**	**0.14**		**0.0**	**79.9**	**20.1**	
▲	**BWP-16**	**165-166.5**								
★	**BWP-16**	**210-211.5**	**0.85**				**0.0**	**5.6**	**94.4**	
⊙	**BWP-18**	**30-31.5**								



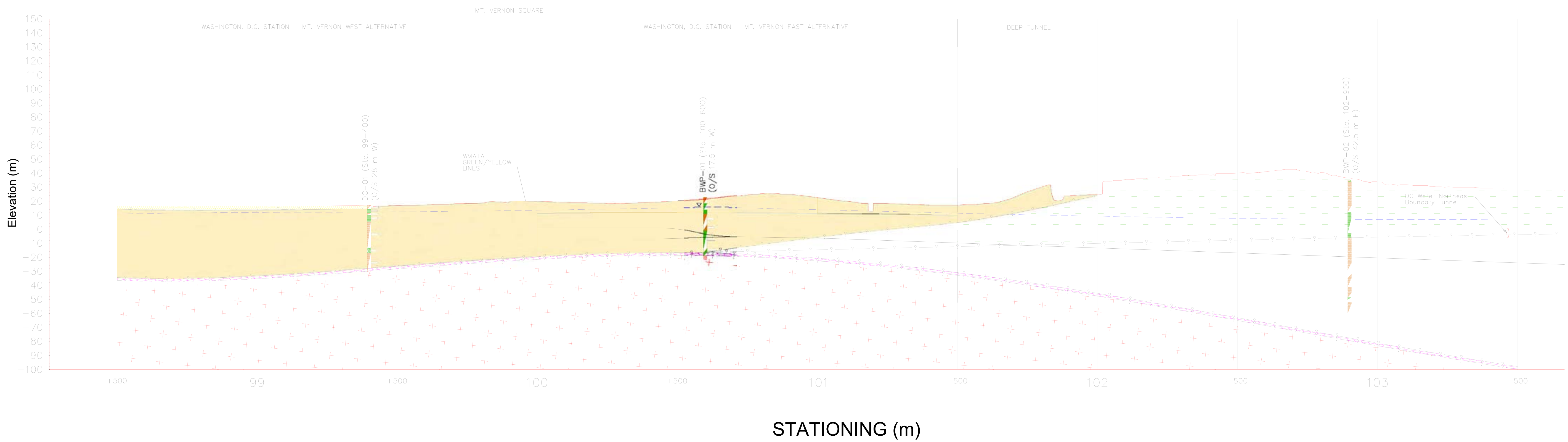
COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-18**	**70-71.5**	**POORLY GRADED SAND with SILT(SP-SM)**	**NP**	**NP**	**NP**	**3.04**	**7.58**
⊠	**BWP-18**	**100-101.5**	**LEAN CLAY with SAND(CL)**	**33**	**20**	**13**		
▲	**BWP-18**	**110-111.5**	**LEAN CLAY(CL)**	**37**	**23**	**14**		
★	**BWP-18**	**140-141.5**	**SILT(ML)**	**35**	**27**	**8**		
⊙	**BWP-18**	**156-158**	**CLAYEY SAND(SC)**	**34**	**19**	**15**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-18**	**70-71.5**	**9.5**	**0.483**	**0.306**		**0.6**	**89.1**	**10.3**	
⊠	**BWP-18**	**100-101.5**	**2**				**0.0**	**23.7**	**76.3**	
▲	**BWP-18**	**110-111.5**								
★	**BWP-18**	**140-141.5**								
⊙	**BWP-18**	**156-158**	**9.5**	**0.261**			**1.2**	**54.5**	**44.3**	

APPENDIX C: GENERALIZED GEOLOGICAL PROFILES WITH RESPECT TO ALIGNMENTS

Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock		Groundwater Level
					Unit Boundary
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater		Ground Surface
					Tunnel Track Level



DATE	REVISIONS	No	DESIGNED: TO DRAWN: TO CHECKED: KT APPROVED: VG

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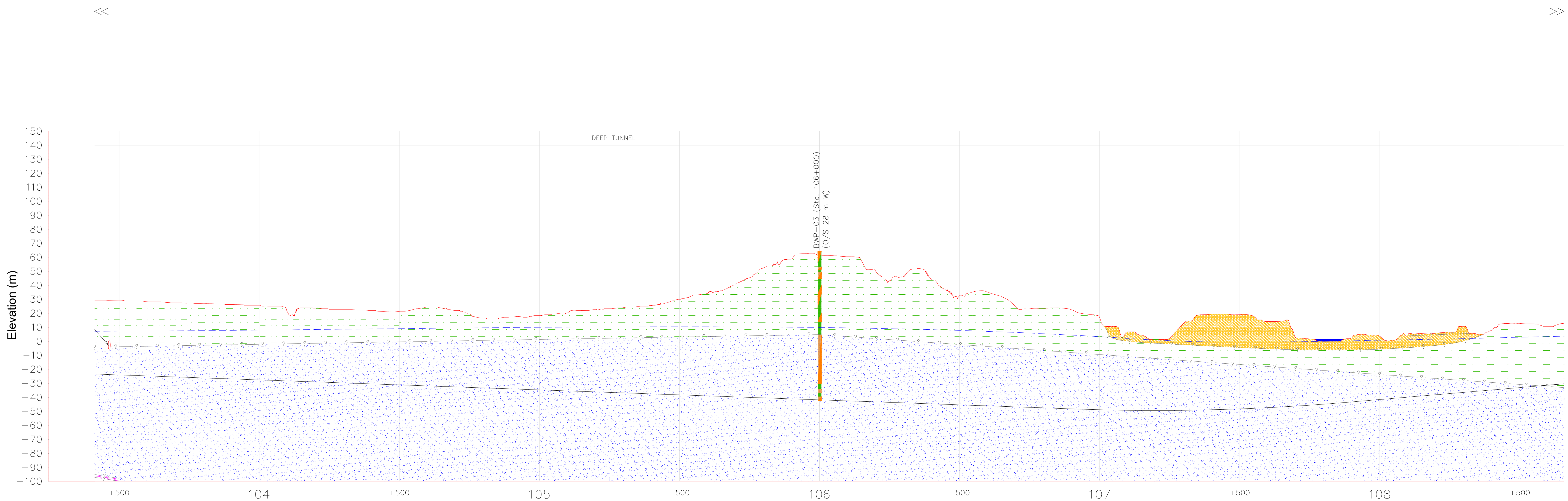
PROJECT NAME:
BALTIMORE-WASHINGTON SCMAGLEV PROJECT
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 98+500 TO STATION 103+500

SCALE:
CONTR. No.
FILE NAME: 0661 BWMLV
ISSUE
DRAWING No.: GP-01
REV 0
DATE: 12/04/2018
SHEET No. 1 OF 12

Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock		Groundwater Level
					Unit Boundary
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater		Ground Surface
					Tunnel Track Level



STATIONING (m)

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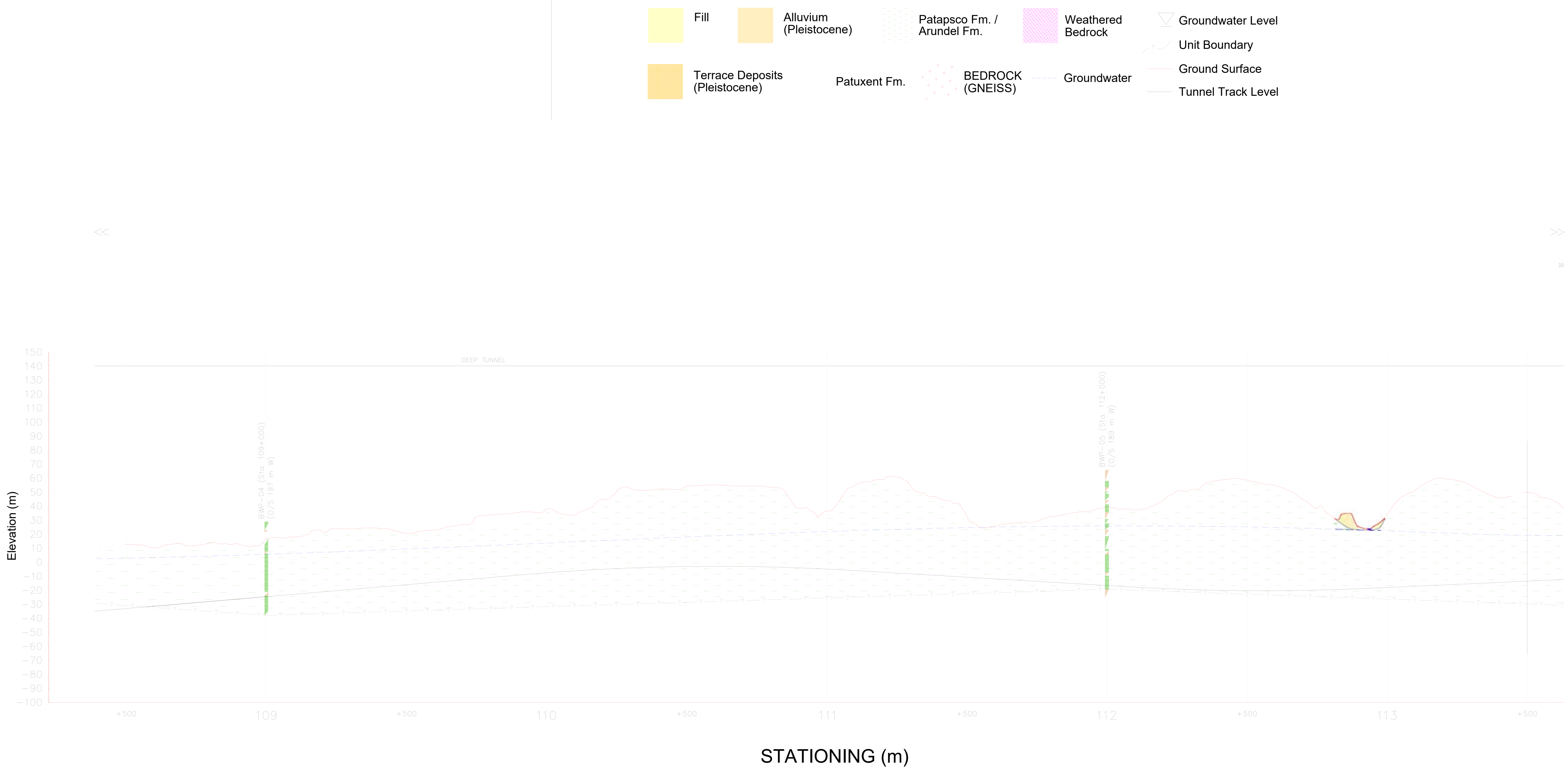

DESIGNED: TO	PROJECT NAME: BALTIMORE-WASHINGTON SCMAGLEV PROJECT ADVISORY SERVICES CONTRACT	DRAWING TITLE: GEOLOGIC LONGITUDINAL SECTION ALIGNMENT ALTERNATIVE J1 OPTION 5 STATION 108+500 TO STATION 113+500	SCALE:	CONTR. No.
DRAWN: TO			FILE NAME: 0661 BWMLV	ISSUE
CHECKED: KT			DRAWING No.: GP-03 REV 0	SHEET No. 3 OF 12
APPROVED: VG	PROJECT No.: 0661 BWMLV		DATE: 12/04/2018	

DATE | REVISIONS | No

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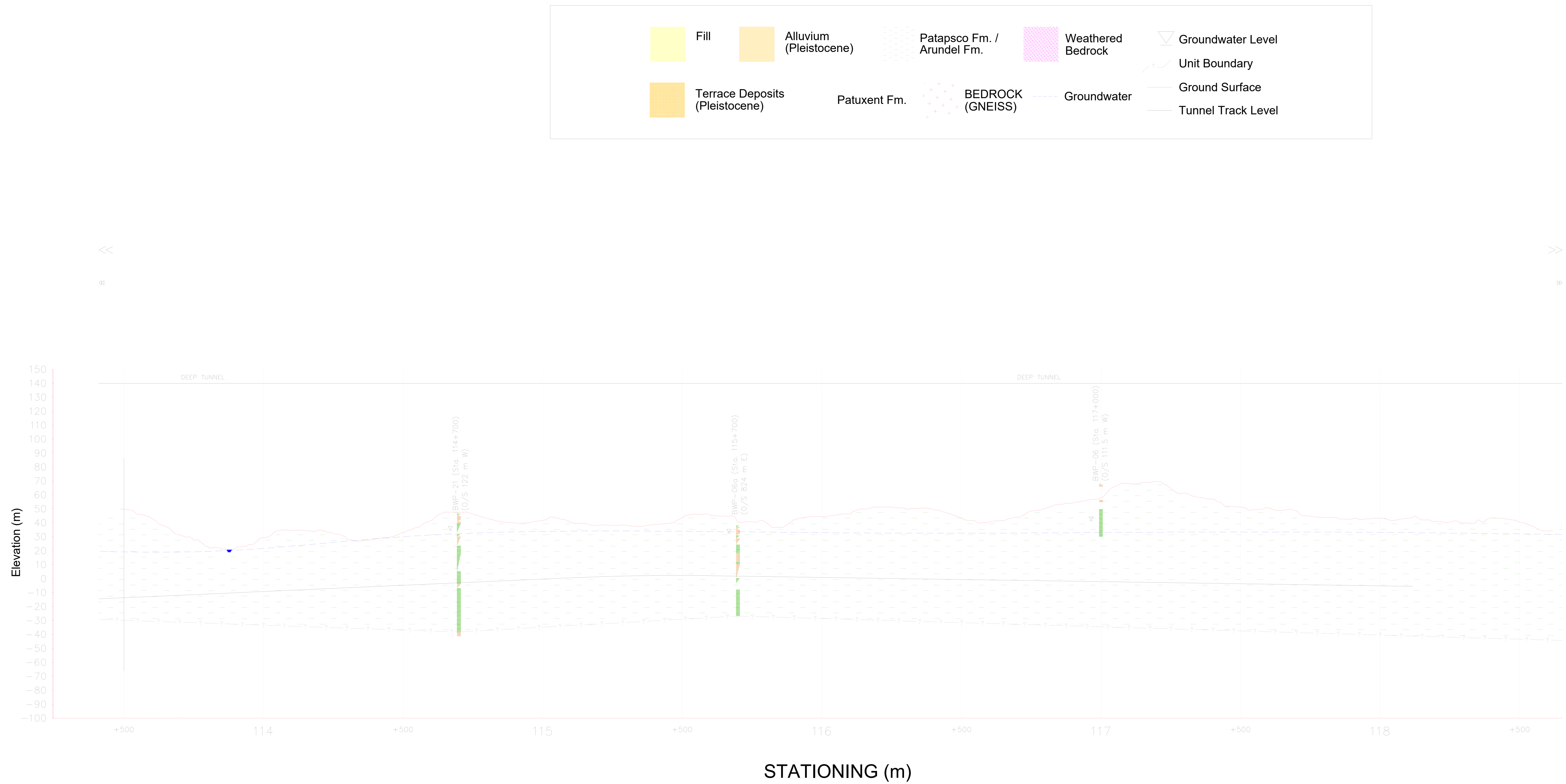

DESIGNED: TO DRAWN: TO CHECKED: KT APPROVED: VG	PROJECT NAME: BALTIMORE-WASHINGTON SCMAGLEV PROJECT ADVISORY SERVICES CONTRACT PROJECT No.: 0661 BWMLV	DRAWING TITLE: GEOLOGIC LONGITUDINAL SECTION ALIGNMENT ALTERNATIVE J1 OPTION 5 STATION 113+500 TO STATION 118+500	SCALE: FILE NAME: 0661 BWMLV DRAWING No.: GP-04 REV 0 DATE: 12/04/2018

DATE	REVISIONS	No

CONTR. No.

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SHEET No. 4 OF 12

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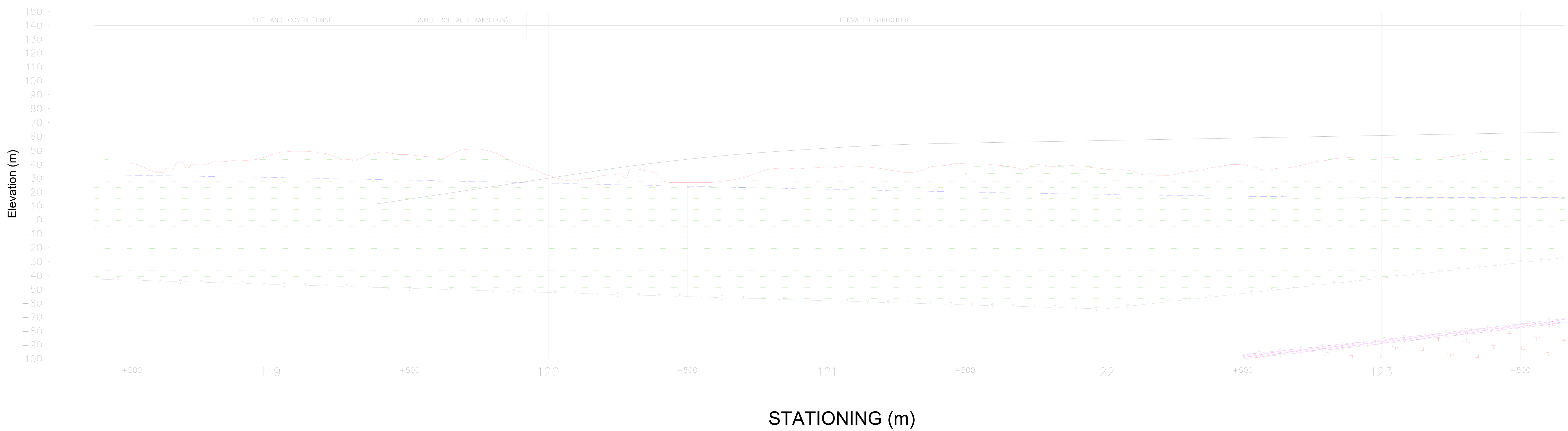
Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater

- Groundwater Level
- Unit Boundary
- Ground Surface
- Tunnel Track Level



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APPROVED: VG

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PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 118+500 TO STATION 123+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-05
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 5 OF 12

Fill

Alluvium (Pleistocene)

Patapsco Fm. / Arundel Fm.

Weathered Bedrock

Groundwater Level

Unit Boundary

Terrace Deposits (Pleistocene)

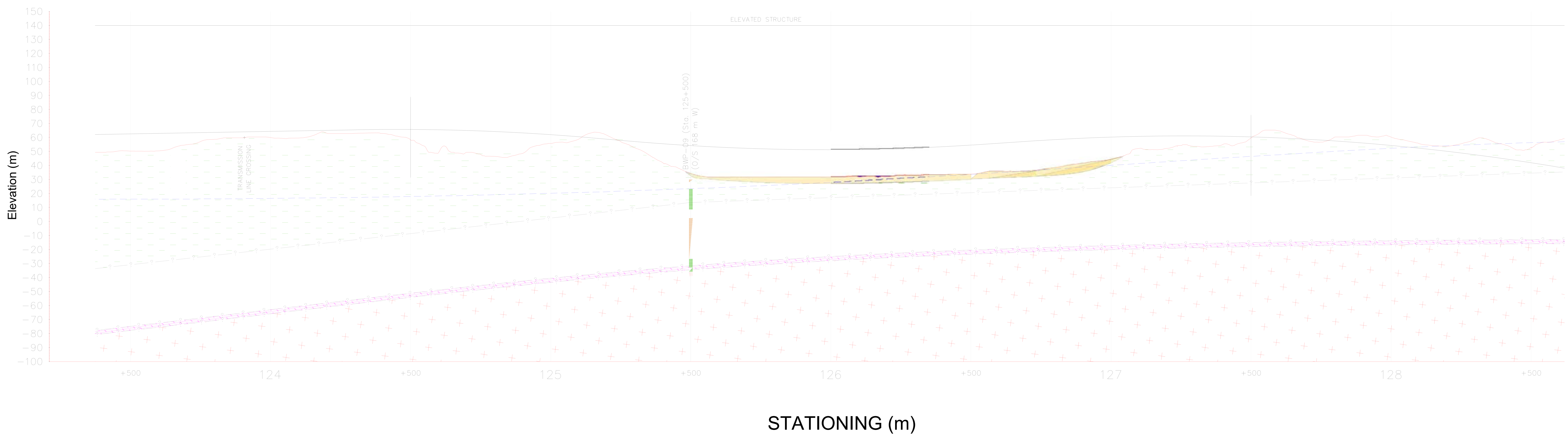
Patuxent Fm.

BEDROCK (GNEISS)

Groundwater

Ground Surface

Tunnel Track Level



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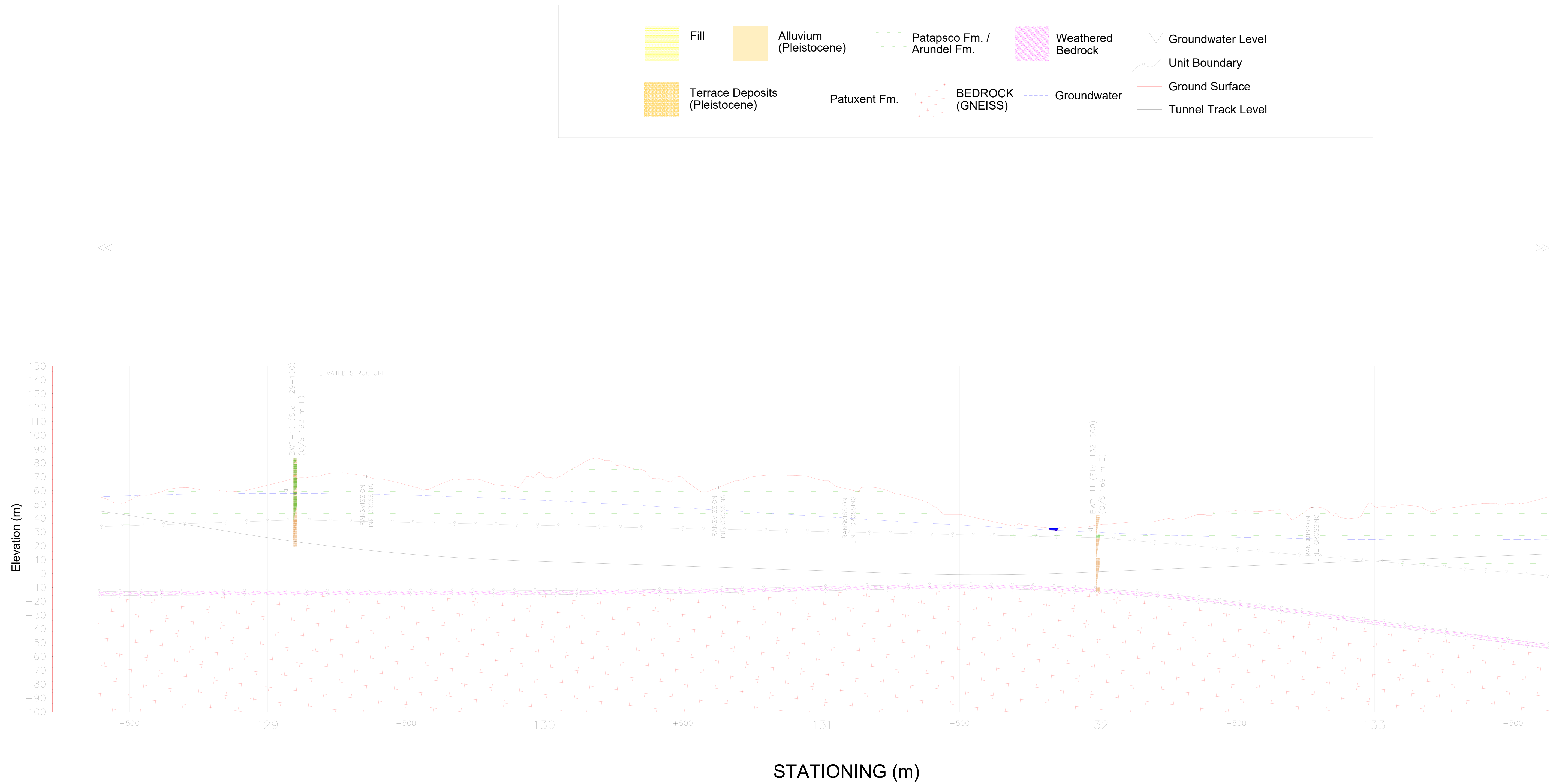
PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 123+500 TO STATION 128+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-06
REV 0
DATE: 12/04/2018

CONTR. No.
ISSUE
SHEET No. 6 OF 12



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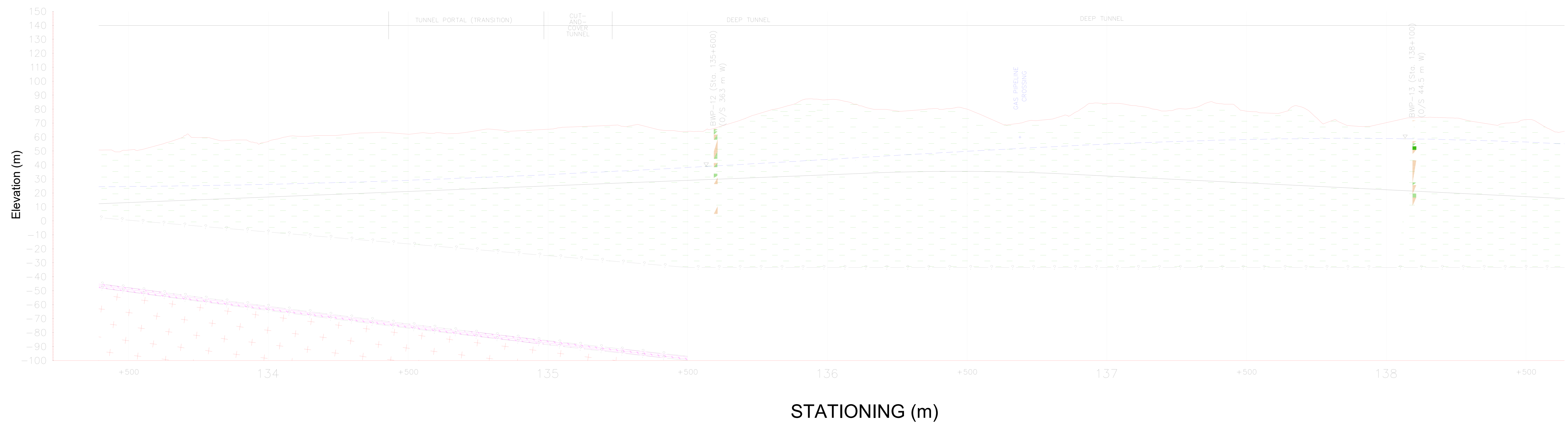
PROJECT No.: 0661 BWMLV

DRAWING TITLE:

GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 128+500 TO STATION 133+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-07
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 7 OF 12

Fill
Alluvium (Pleistocene)
Patapsco Fm. / Arundel Fm.
Weathered Bedrock
Groundwater Level
Unit Boundary
Terrace Deposits (Pleistocene)
Patuxent Fm.
BEDROCK (GNEISS)
Groundwater
Ground Surface
Tunnel Track Level



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SCALE:	CONTR. No.
FILE NAME: 0661 BWMLV	ISSUE
DRAWING No.: GP-08 REV 0	
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Fill
Alluvium (Pleistocene)
Patapsco Fm. / Arundel Fm.
Weathered Bedrock
Groundwater Level
Unit Boundary
Ground Surface
Tunnel Track Level
Terrace Deposits (Pleistocene)
Patuxent Fm.
BEDROCK (GNEISS)
Groundwater

STATIONING (m)

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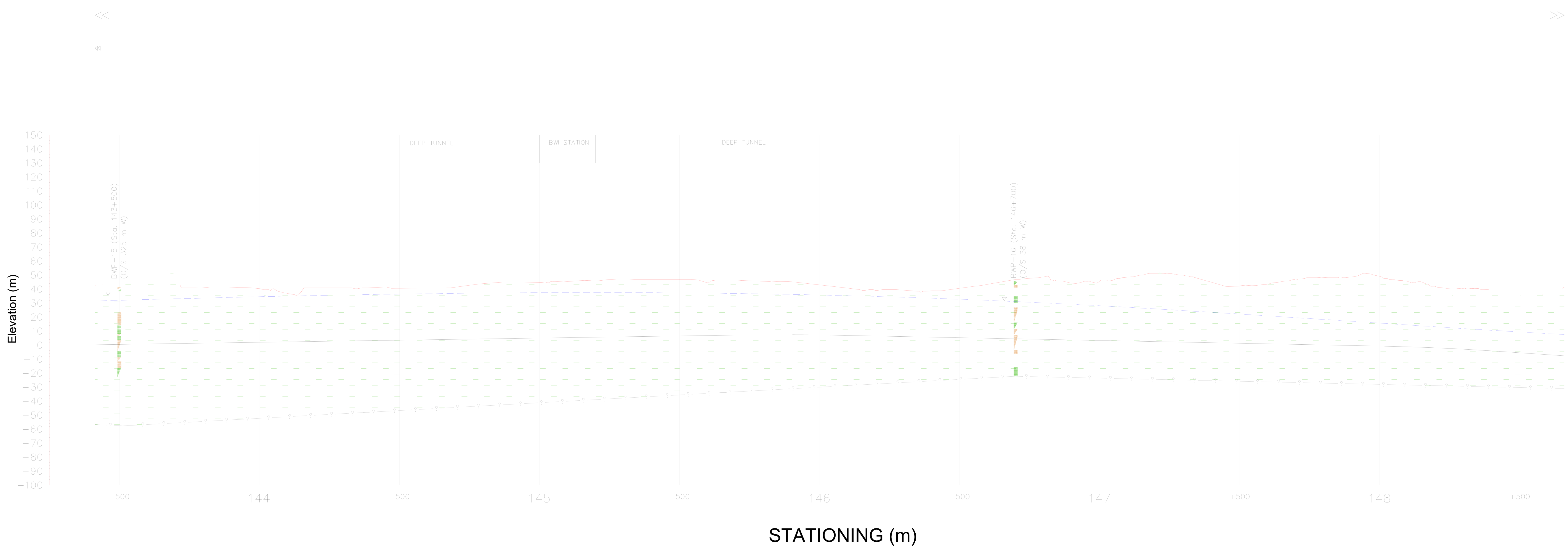
PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 138+500 TO STATION 143+500

SCALE:
CONTR. No.
FILE NAME: 0661 BWMLV
ISSUE
DRAWING No.: GP-09
REV 0
DATE: 12/04/2018
SHEET No. 9 OF 12

Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock	Groundwater Level
				Unit Boundary
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater	Ground Surface
				Tunnel Track Level



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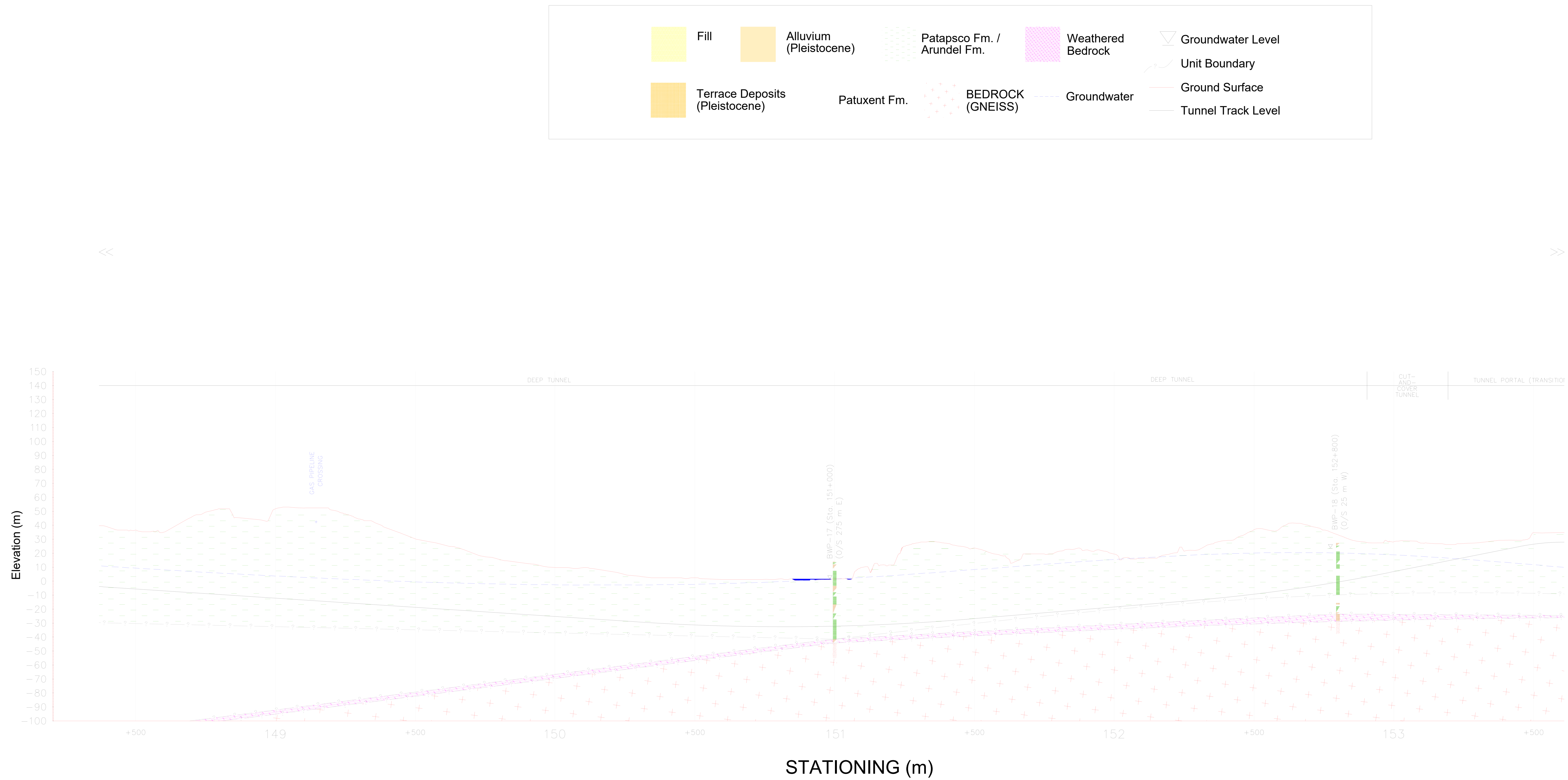

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			APPROVED: VG

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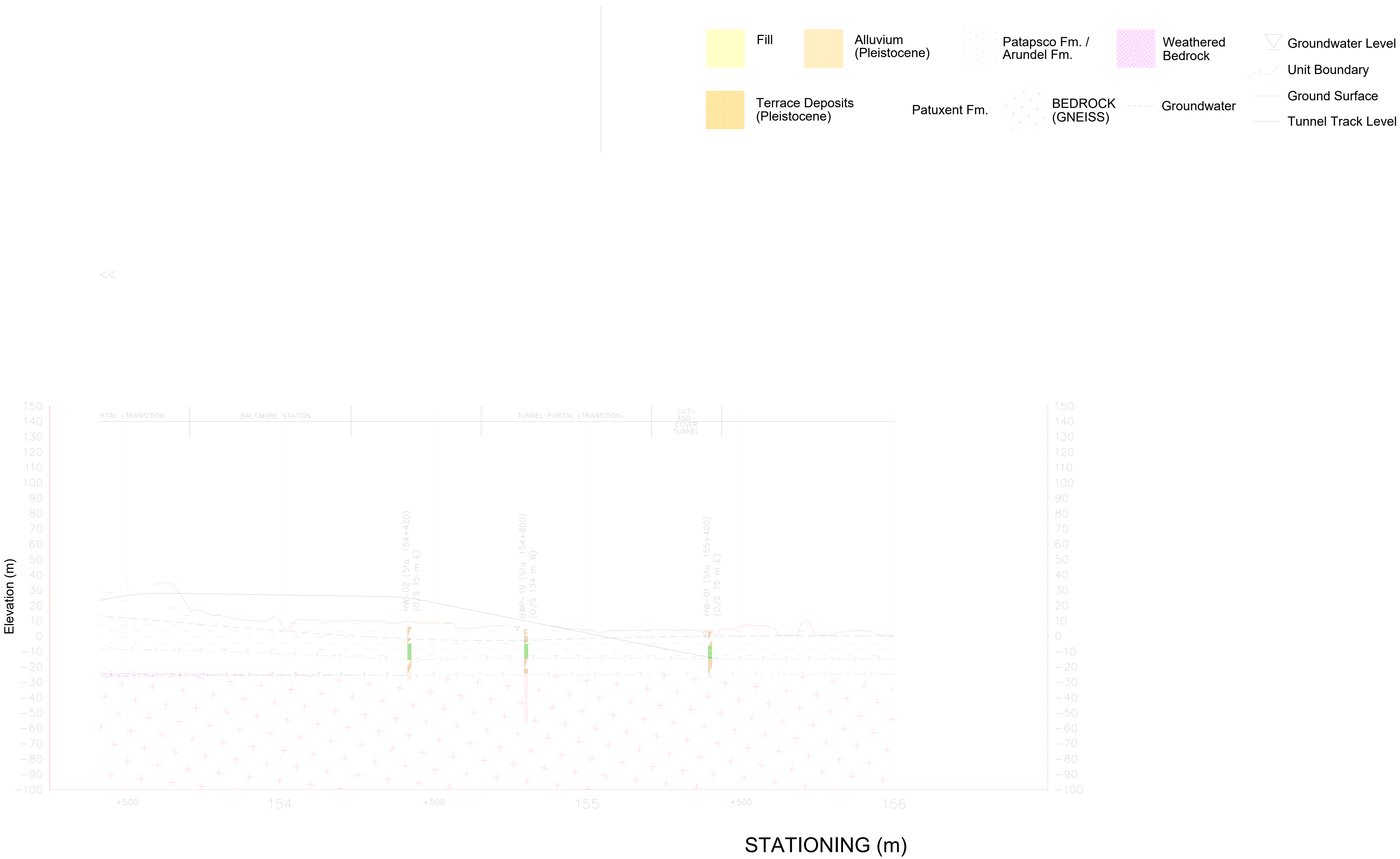
PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 148+500 TO STATION 153+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-11
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 11 OF 12



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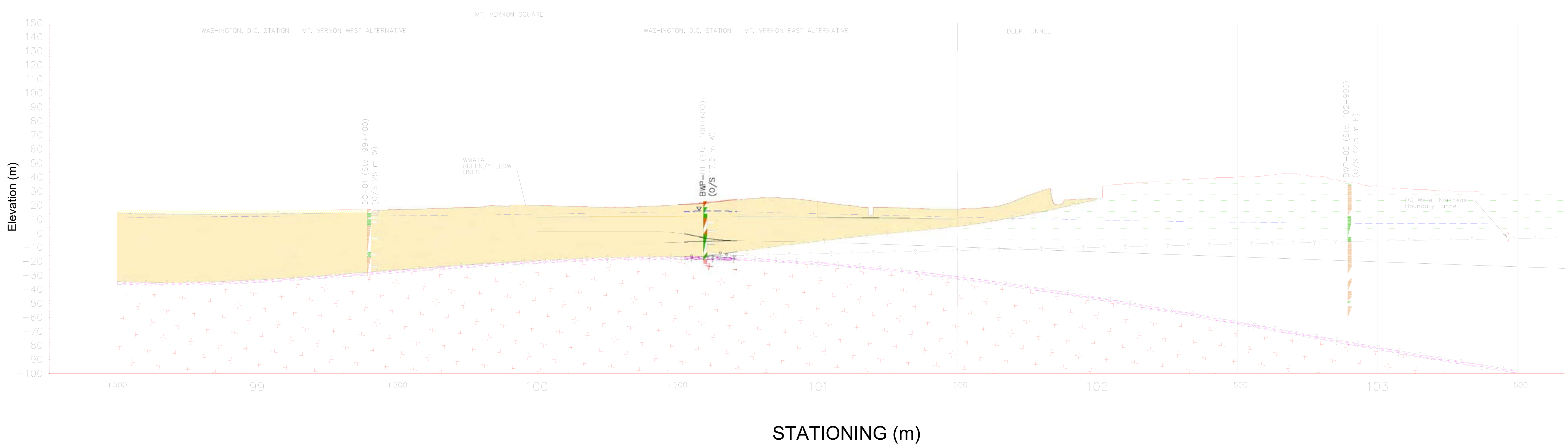
Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock	Groundwater Level
				Unit Boundary
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater	Ground Surface
				Tunnel Track Level



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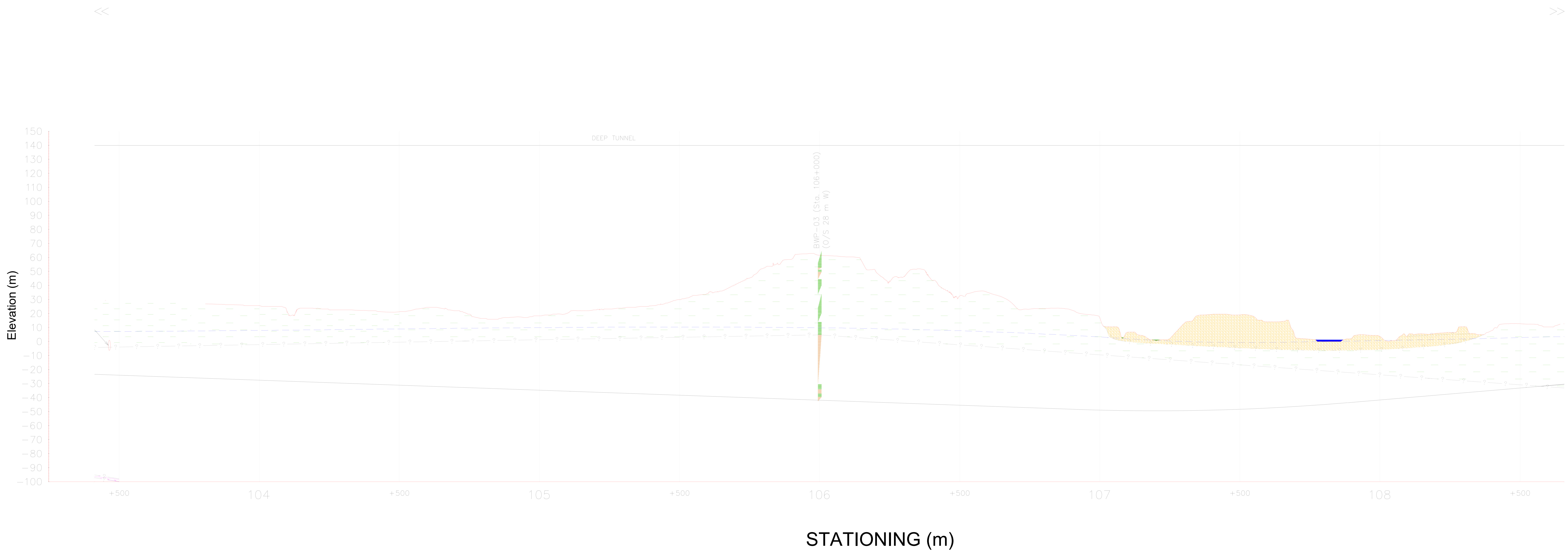
Fill
Alluvium (Pleistocene)
Patapsco Fm. / Arundel Fm.
Weathered Bedrock
Groundwater Level
Unit Boundary
Ground Surface
Tunnel Track Level
Terrace Deposits (Pleistocene)
Patuxent Fm.
BEDROCK (GNEISS)
Groundwater



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DRAWN: TO		
CHECKED: KT		
APPROVED: VG	PROJECT No.: 0661 BWMLV	

DATE | REVISIONS | No

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FILE NAME: 0661 BWMLV
ISSUE
DRAWING No.: GP-014
REV 0
DATE: 12/04/2018
SHEET No. 2 OF 12

Fill

Alluvium (Pleistocene)

Patapsco Fm. / Arundel Fm.

Weathered Bedrock

Groundwater Level

Unit Boundary

Terrace Deposits (Pleistocene)

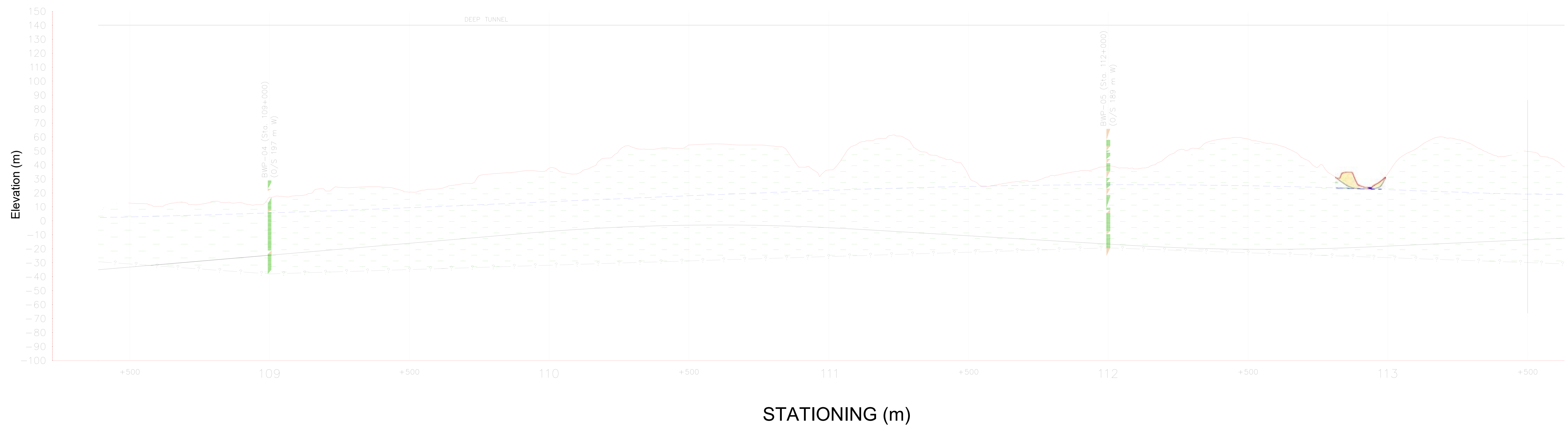
Patuxent Fm.

BEDROCK (GNEISS)

Groundwater

Ground Surface

Tunnel Track Level



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APPROVED: VG

PROJECT NAME:
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ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 108+500 TO STATION 113+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-15
REV 0
DATE: 12/04/2018

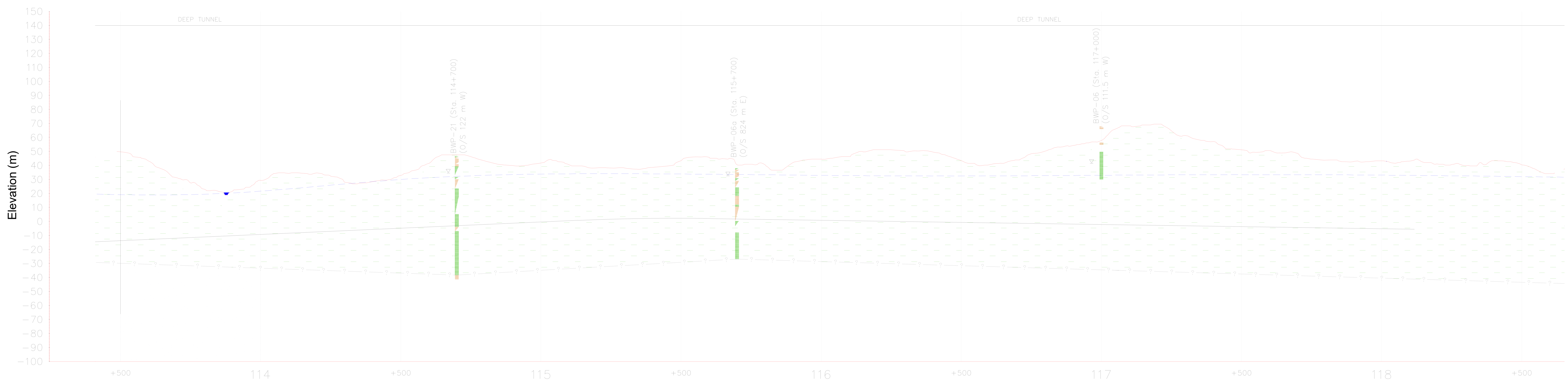
CONTR. No.
ISSUE
SHEET No. 3 OF 12

Fill | Alluvium (Pleistocene) | Patapsco Fm. / Arundel Fm. | Weathered Bedrock | Groundwater Level

Unit Boundary

Ground Surface

Terrace Deposits (Pleistocene) | Patuxent Fm. | BEDROCK (GNEISS) | Groundwater | Tunnel Track Level



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CHECKED: KT
APPROVED: VG

PROJECT NAME:
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ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 113+500 TO STATION 118+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-16
REV 0
DATE: 12/04/2018

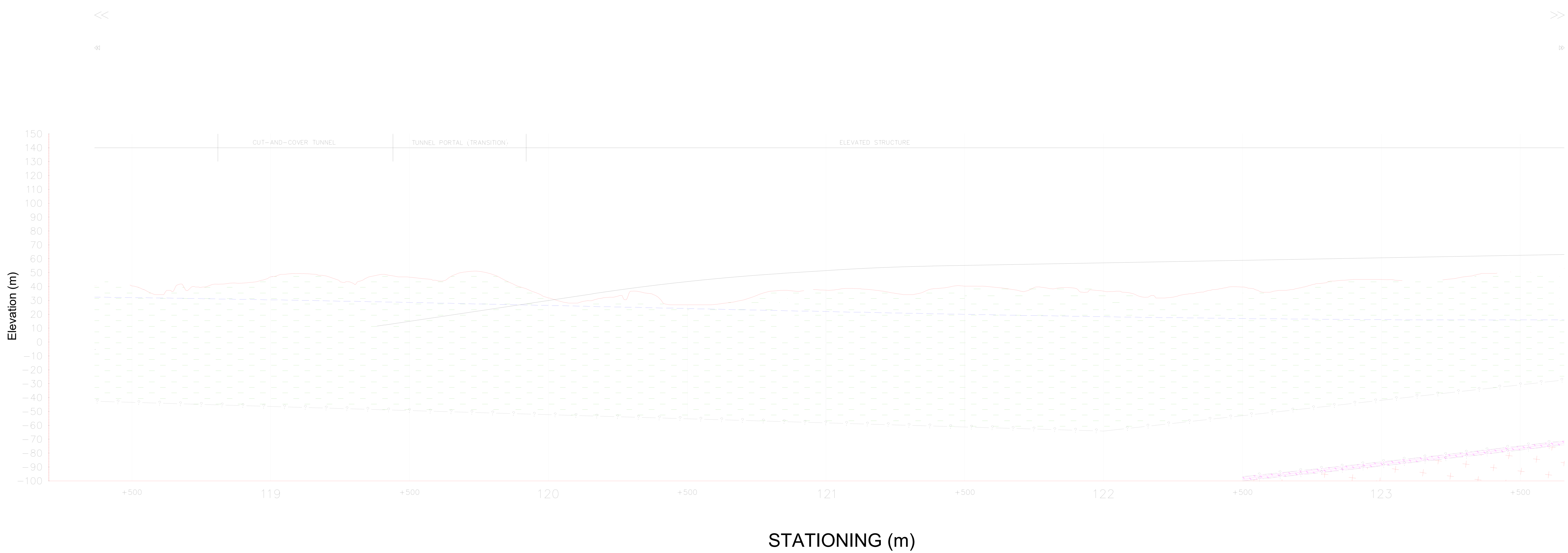
CONTR. No.
ISSUE
SHEET No. 4 OF 12

Fill | Alluvium (Pleistocene) | Patapsco Fm. / Arundel Fm. | Weathered Bedrock | Groundwater Level

Unit Boundary

Ground Surface

Terrace Deposits (Pleistocene) | Patuxent Fm. | BEDROCK (GNEISS) | Groundwater | Tunnel Track Level



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DATE	REVISIONS	No

DESIGNED: TO
DRAWN: TO
CHECKED: KT
APPROVED: VG

PROJECT NAME:
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ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

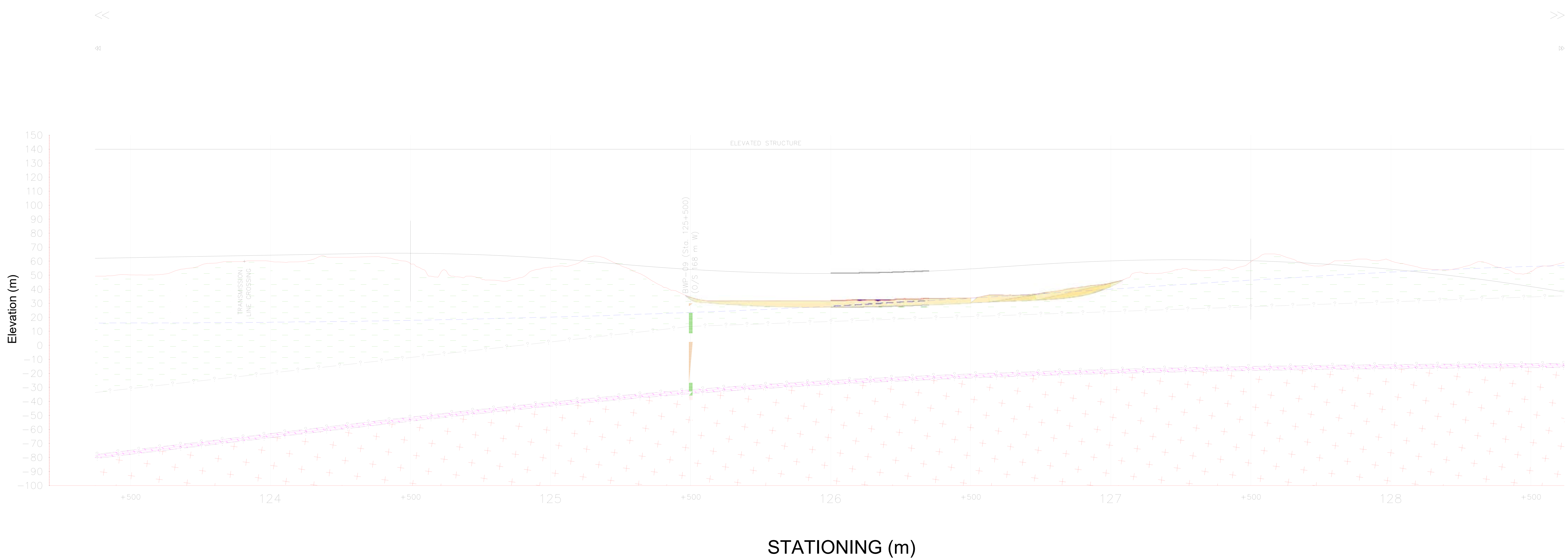
DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 118+500 TO STATION 123+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-17
REV: 0
DATE: 12/04/2018

CONTR. No.
ISSUE
SHEET No. 5 OF 12

Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater

Groundwater Level
Unit Boundary
Ground Surface
Tunnel Track Level



DATE	REVISIONS	No

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DRAWN: TO
CHECKED: KT
APPROVED: VG

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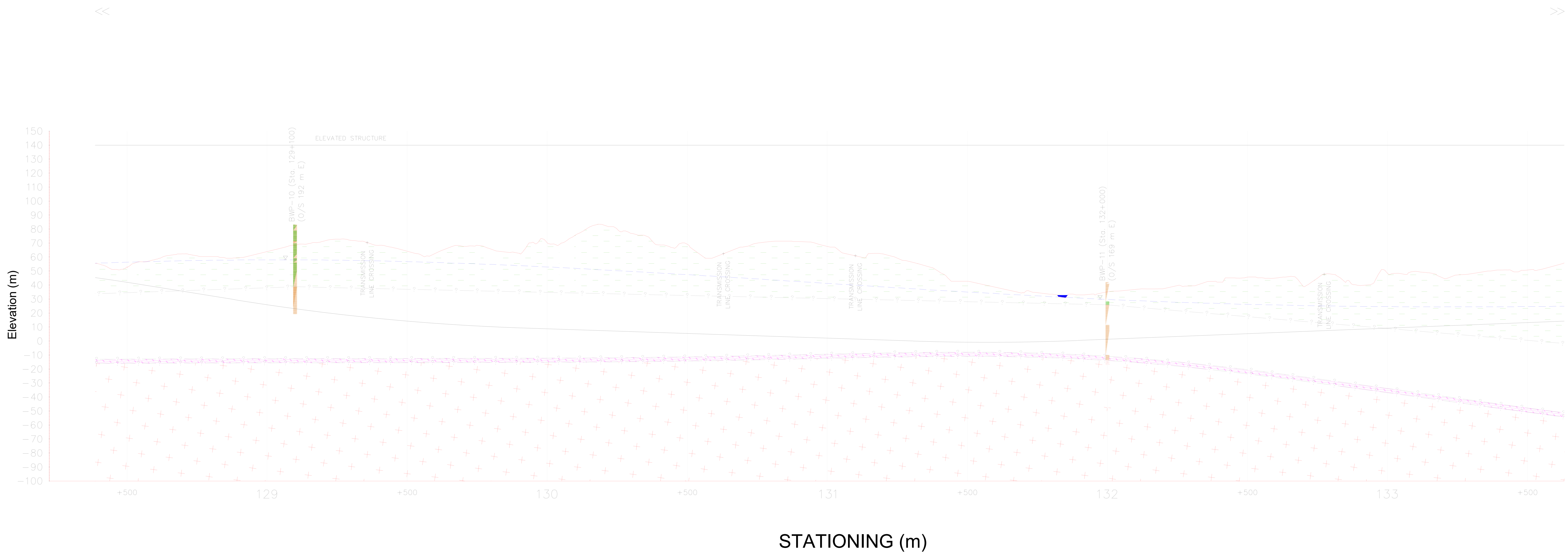
PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 123+500 TO STATION 128+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-18
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 6 OF 12

Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater

Groundwater Level
Unit Boundary
Ground Surface
Tunnel Track Level



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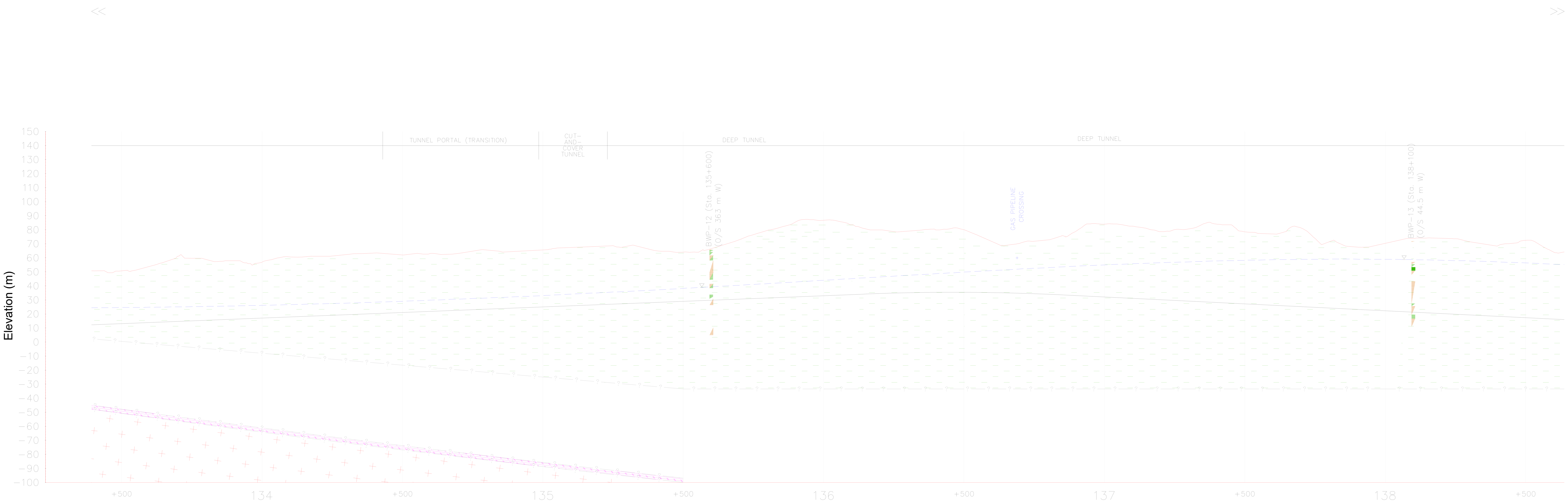
Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock	Groundwater Level
				Unit Boundary
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater	Ground Surface
				Tunnel Track Level



STATIONING (m)

DATE	REVISIONS	No	DESIGNED: TO DRAWN: TO CHECKED: KT APPROVED: VG	PROJECT NAME: BALTIMORE-WASHINGTON SCMAGLEV PROJECT ADVISORY SERVICES CONTRACT PROJECT No.: 0661 BWMLV

Gall Zeidler Consultants
Geotechnics | Tunnel Design | Engineering

44345 Premier Plaza, Suite 210; Ashburn, Virginia 20147;
Phone: 703 726 2700; Fax: 703 726 6999; www.gzconsultants.com

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 133+500 TO STATION 138+500

SCALE:	CONTR. No.
FILE NAME: 0661 BWMLV	ISSUE
DRAWING No.: GP-20 REV 0	
DATE: 12/04/2018	SHEET No. 8 OF 12

Fill

Alluvium (Pleistocene)

Patapsco Fm. / Arundel Fm.

Weathered Bedrock

Groundwater Level

Unit Boundary

Ground Surface

Terrace Deposits (Pleistocene)

Patuxent Fm.

BEDROCK (GNEISS)

Groundwater

Tunnel Track Level

STATIONING (m)

DATE	REVISIONS	No	DESIGNED: TO DRAWN: TO CHECKED: KT APPROVED: VG	PROJECT NAME: BALTIMORE-WASHINGTON SCMAGLEV PROJECT ADVISORY SERVICES CONTRACT PROJECT No.: 0661 BWMLV	DRAWING TITLE: GEOLOGIC LONGITUDINAL SECTION ALIGNMENT ALTERNATIVE J MODIFIED 1 STATION 138+500 TO STATION 143+500

SCALE:	CONTR. No.
FILE NAME: 0661 BWMLV	ISSUE
DRAWING No.: GP-21	REV 0
DATE: 12/04/2018	SHEET No. 9 OF 12

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Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater

Groundwater Level
Unit Boundary
Ground Surface
Tunnel Track Level

STATIONING (m)

Gall Zeidler Consultants Geotechnics | Tunnel Design | Engineering 44345 Premier Plaza, Suite 210; Ashburn, Virginia 20147; Phone: 703 726 2700; Fax: 703 726 6999; www.gzconsultants.com	DESIGNED: TO DRAWN: TO CHECKED: KT APPROVED: VG	PROJECT NAME: BALTIMORE-WASHINGTON SCMAGLEV PROJECT ADVISORY SERVICES CONTRACT PROJECT No.: 0661 BWMLV	DRAWING TITLE: GEOLOGIC LONGITUDINAL SECTION ALIGNMENT ALTERNATIVE J MODIFIED 1 STATION 143+500 TO STATION 148+500	SCALE: FILE NAME: 0661 BWMLV DRAWING No.: GP-22 REV 0 DATE: 12/04/2018 CONTR. No. ISSUE SHEET No. 10 OF 12

DATE	REVISIONS	No

Fill

Alluvium (Pleistocene)

Patapsco Fm. / Arundel Fm.

Weathered Bedrock

Groundwater Level

Unit Boundary

Ground Surface

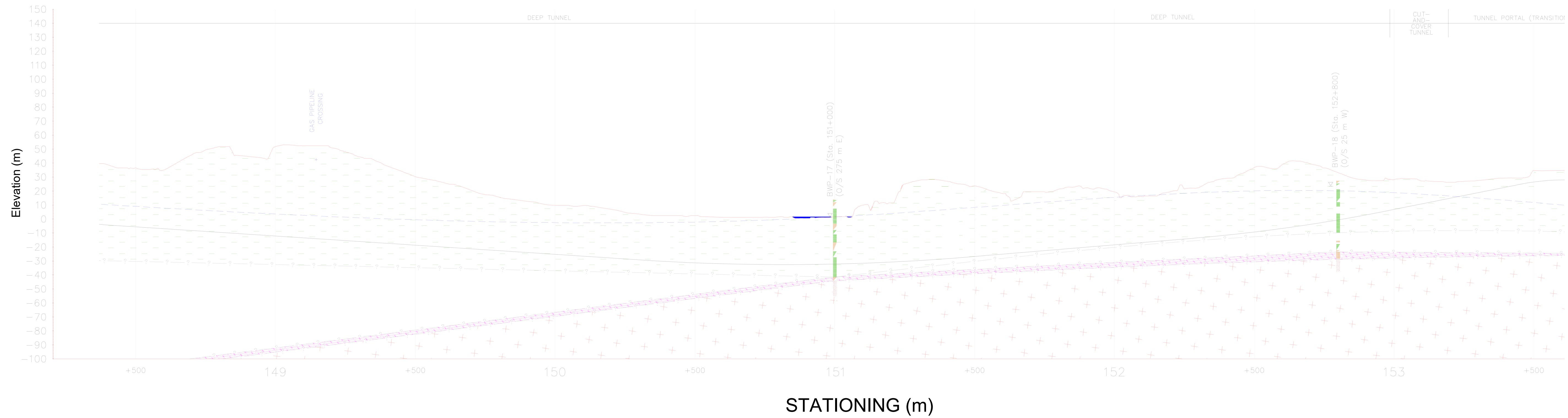
Tunnel Track Level

Terrace Deposits (Pleistocene)

Patuxent Fm.

BEDROCK (GNEISS)

Groundwater



DESIGNED: TO DRAWN: TO CHECKED: KT APPROVED: VG	PROJECT NAME: BALTIMORE-WASHINGTON SCMAGLEV PROJECT ADVISORY SERVICES CONTRACT PROJECT No.: 0661 BWMLV	DRAWING TITLE: GEOLOGIC LONGITUDINAL SECTION ALIGNMENT ALTERNATIVE J MODIFIED 1 STATION 148+500 TO STATION 153+500	SCALE: FILE NAME: 0661 BWMLV DRAWING No.: GP-23 REV 0 DATE: 12/04/2018

DATE	REVISIONS	No

CONTR. No.

ISSUE

SHEET No. 11 OF 12

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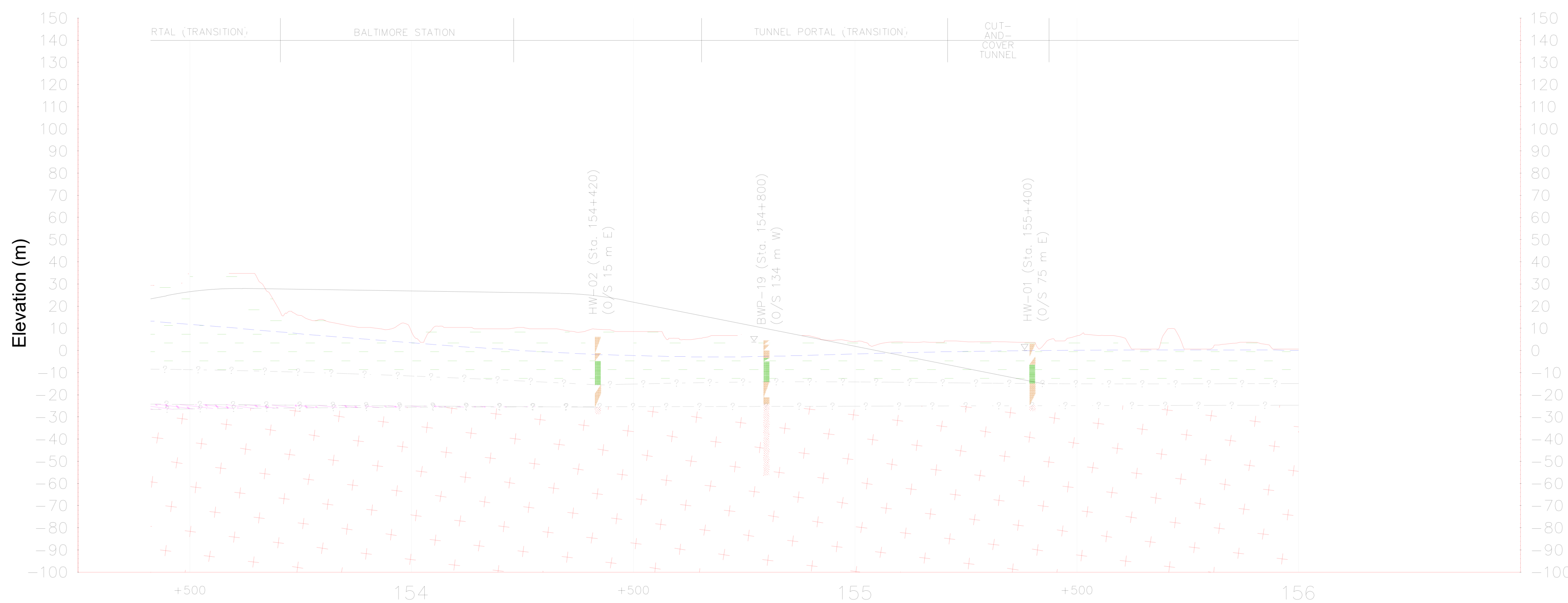
Fill	Alluvium (Pleistocene)	Patapsco Fm. / Arundel Fm.	Weathered Bedrock	Groundwater Level
				Unit Boundary
Terrace Deposits (Pleistocene)	Patuxent Fm.	BEDROCK (GNEISS)	Groundwater	Ground Surface
				Tunnel Track Level



STATIONING (m)

Gall Zeidler Consultants
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Phone: 703 726 2700; Fax: 703 726 6999; www.gzconsultants.com

DATE	REVISIONS	No

DESIGNED: TO
DRAWN: TO
CHECKED: KT
APPROVED: VG

PROJECT NAME:
BALTIMORE-WASHINGTON SCMAGLEV PROJECT
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

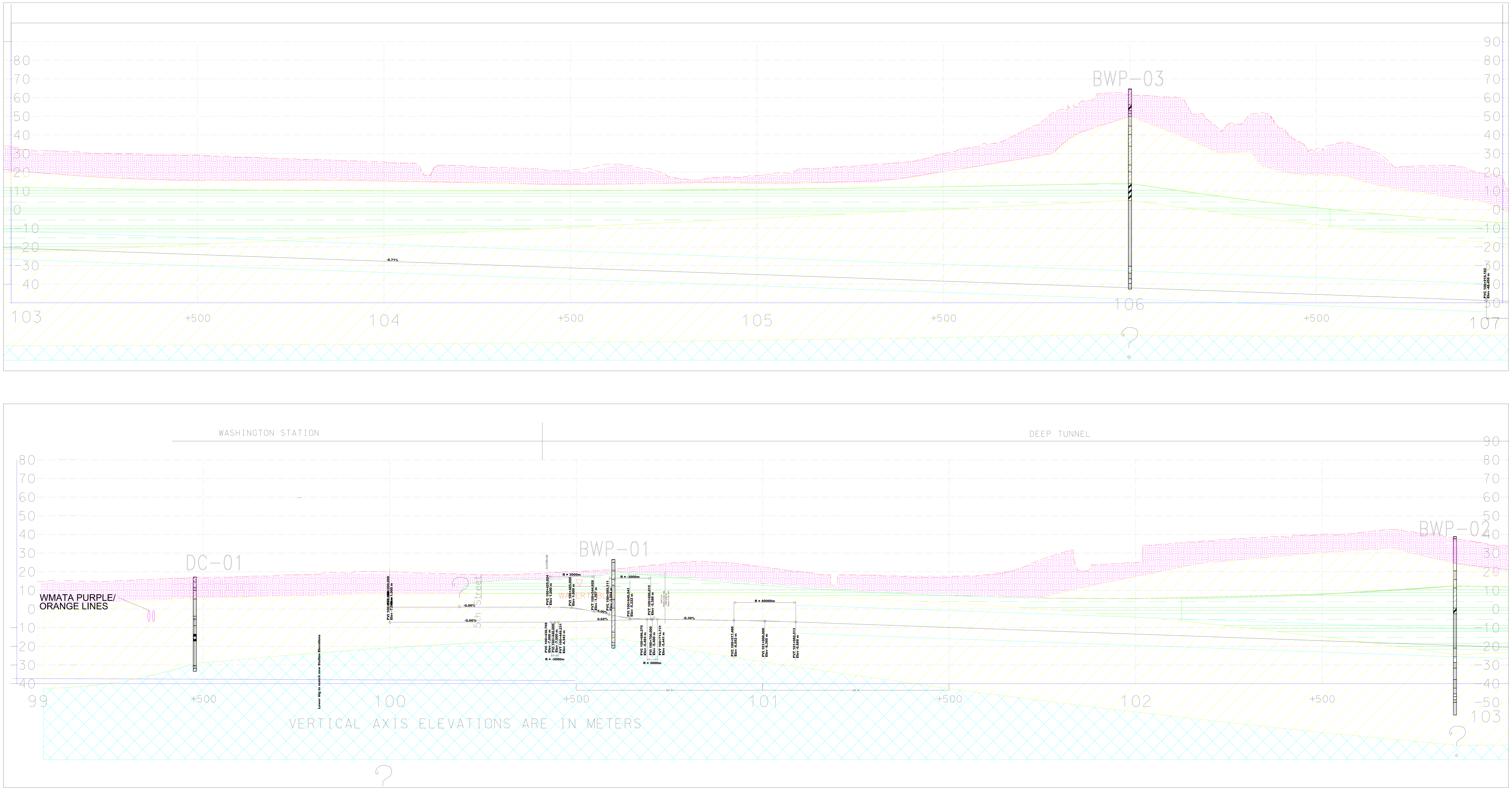
DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 153+500 TO STATION 156+000

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-24
REV 0
DATE: 12/04/2018

CONTR. No.
ISSUE
SHEET No. 12 OF 12

APPENDIX D: GENERALIZED GEOTECHNICAL PROFILES WITH RESPECT TO ALIGNMENTS

GEOTECHNICAL PROFILE WITH RESPECT TO ALIGNMENT J1 OPTION 5



LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

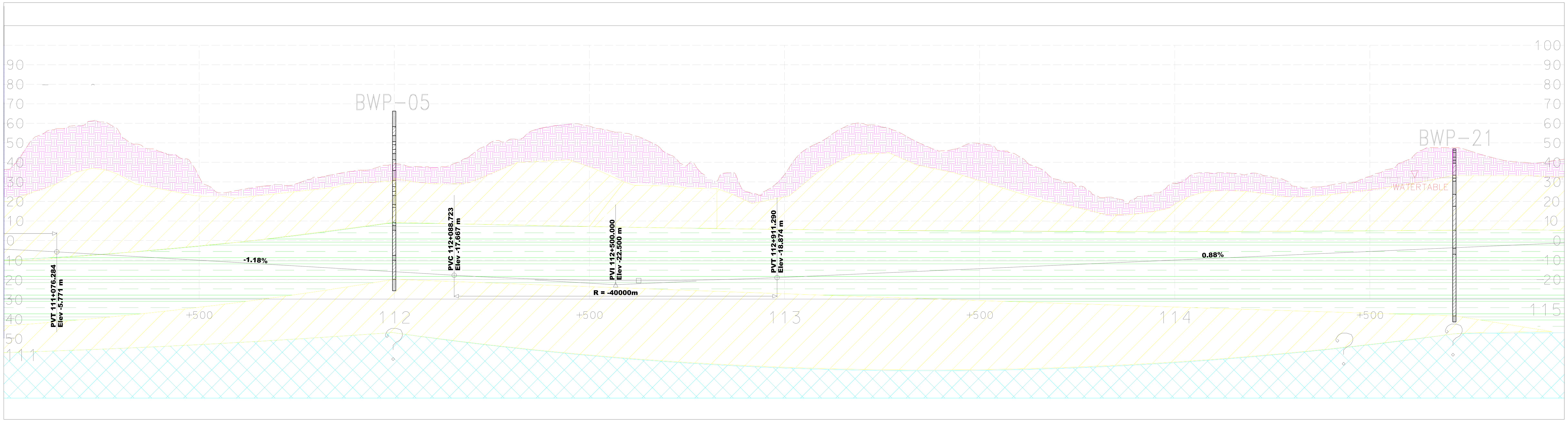
BWRR BALTIMORE-WASHINGTON RAPID RAIL

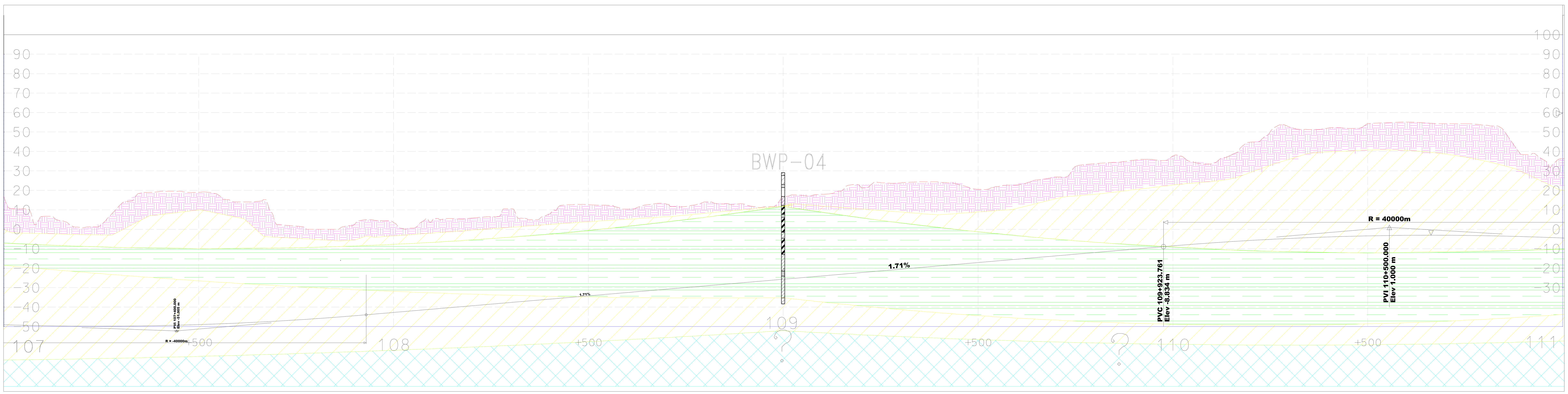
TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1A





LEGEND

FILL/UNCONSALIDATED SEDIMENTS

MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER

MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER

BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

BWRR BALTIMORE-WASHINGTON RAPID RAIL

TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1B

LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

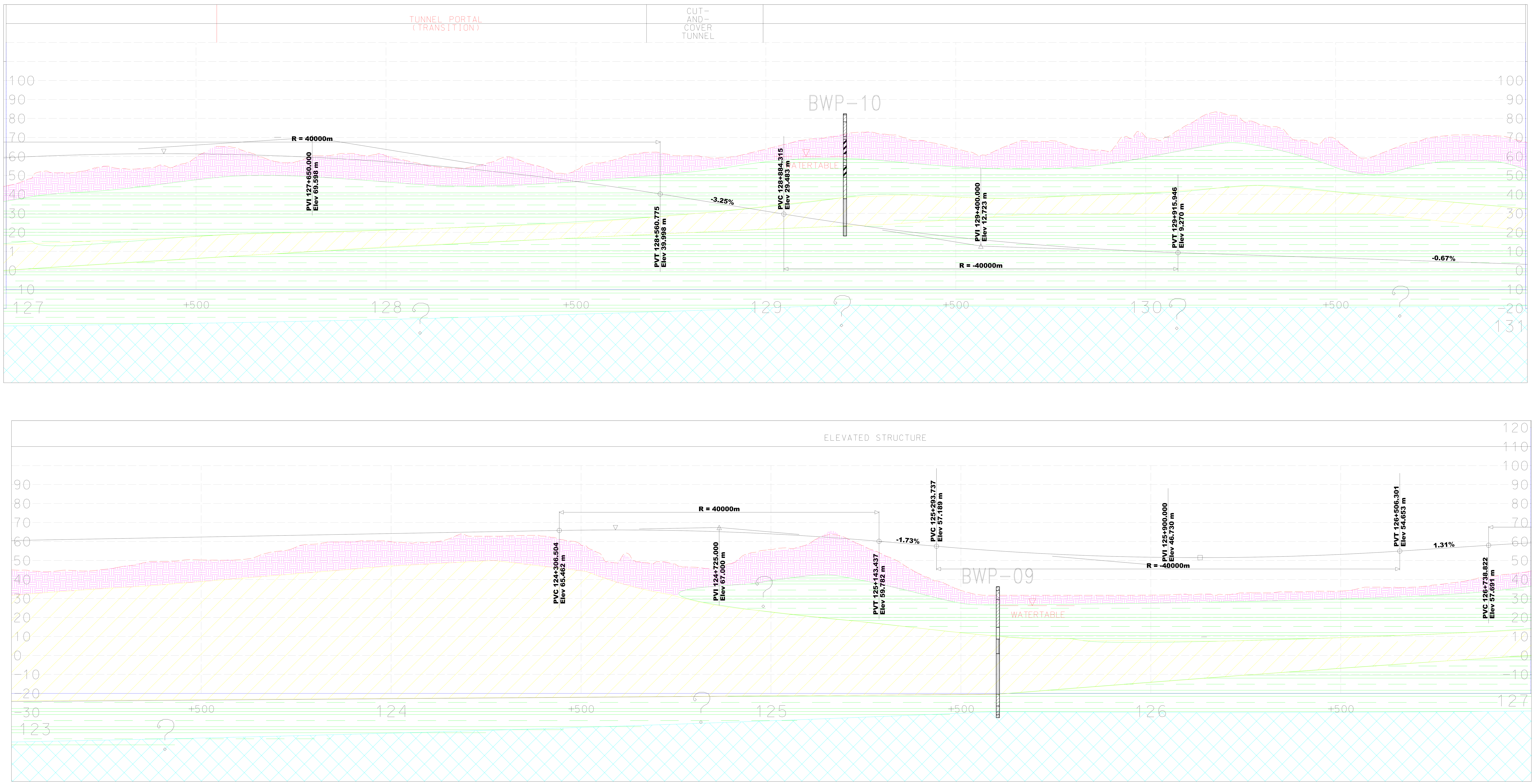
PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1C

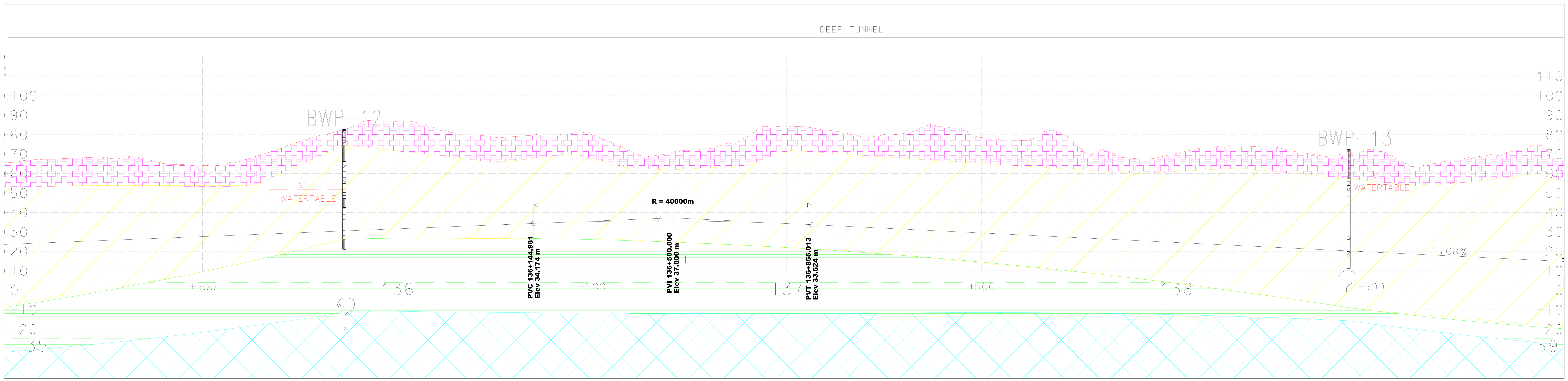


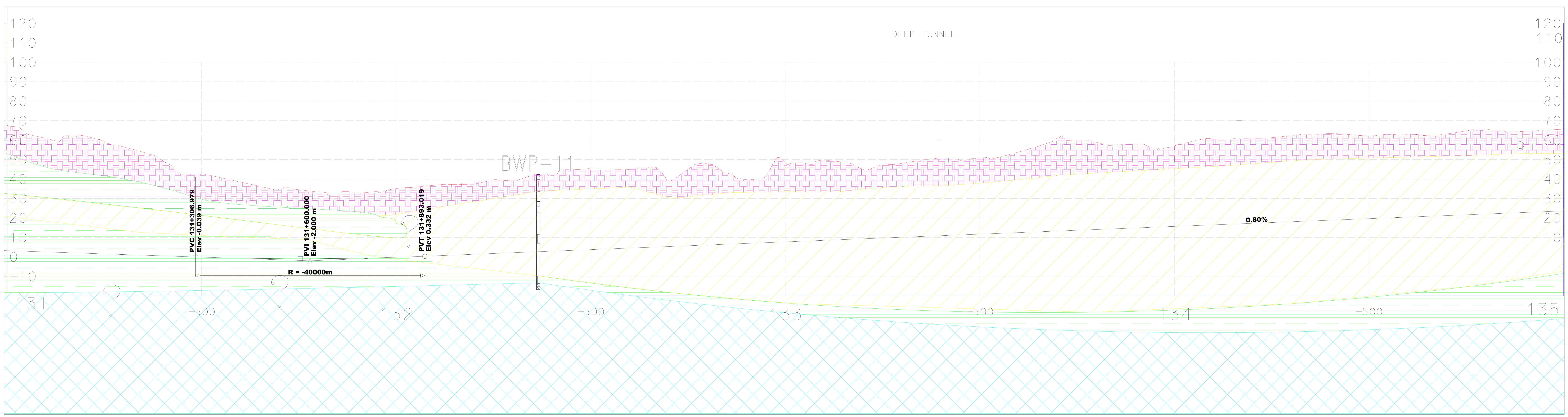
LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1D



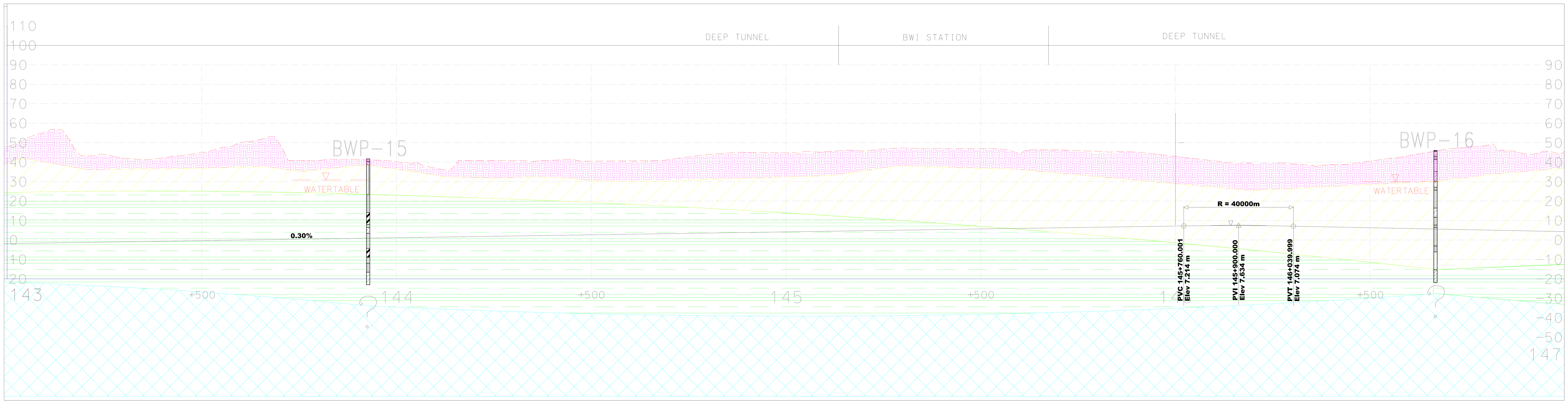


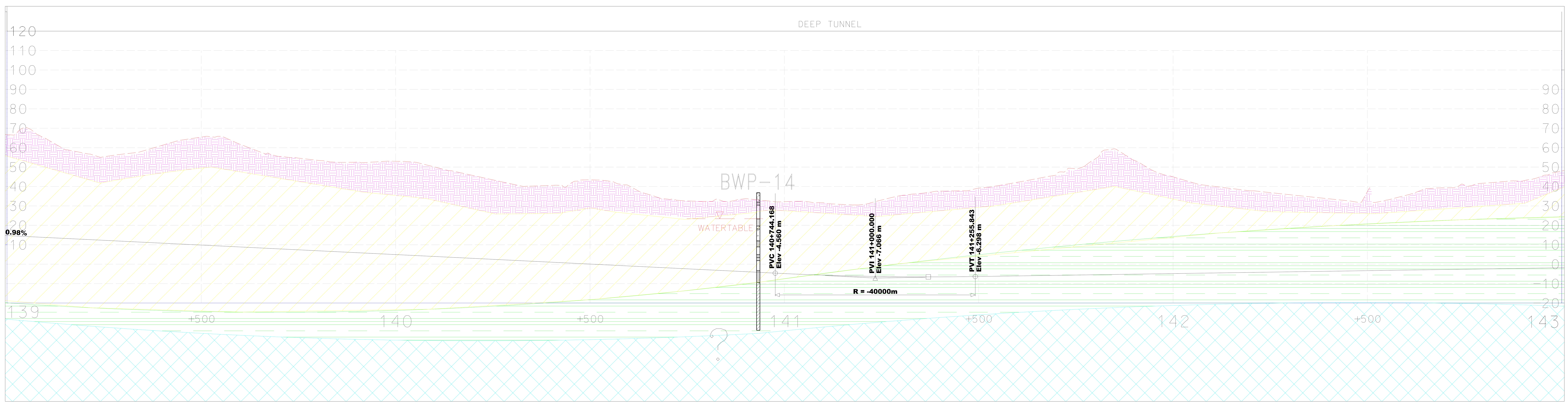
LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1E





LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1F

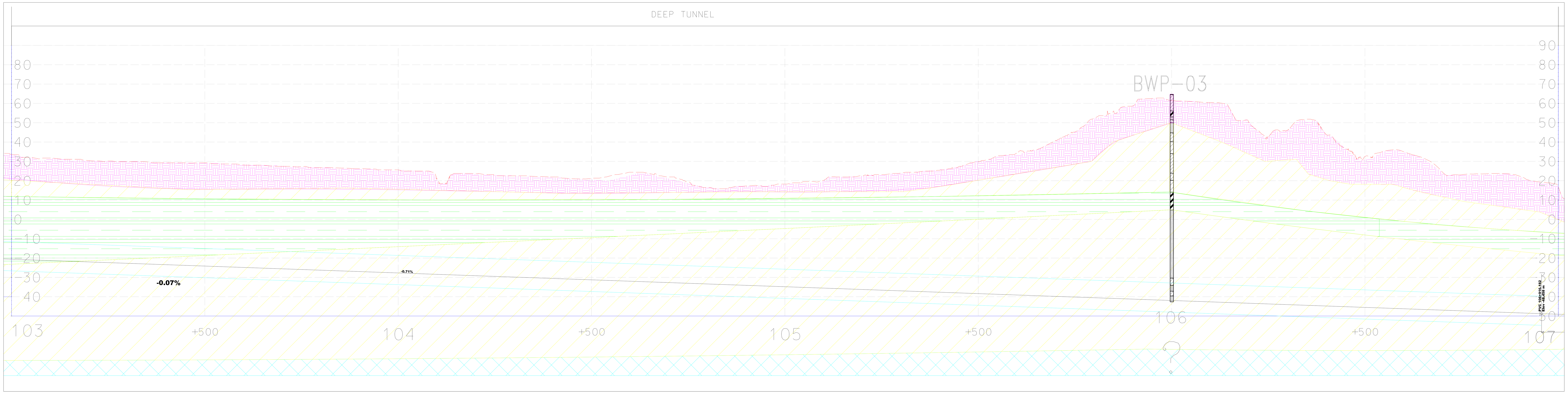
LEGEND

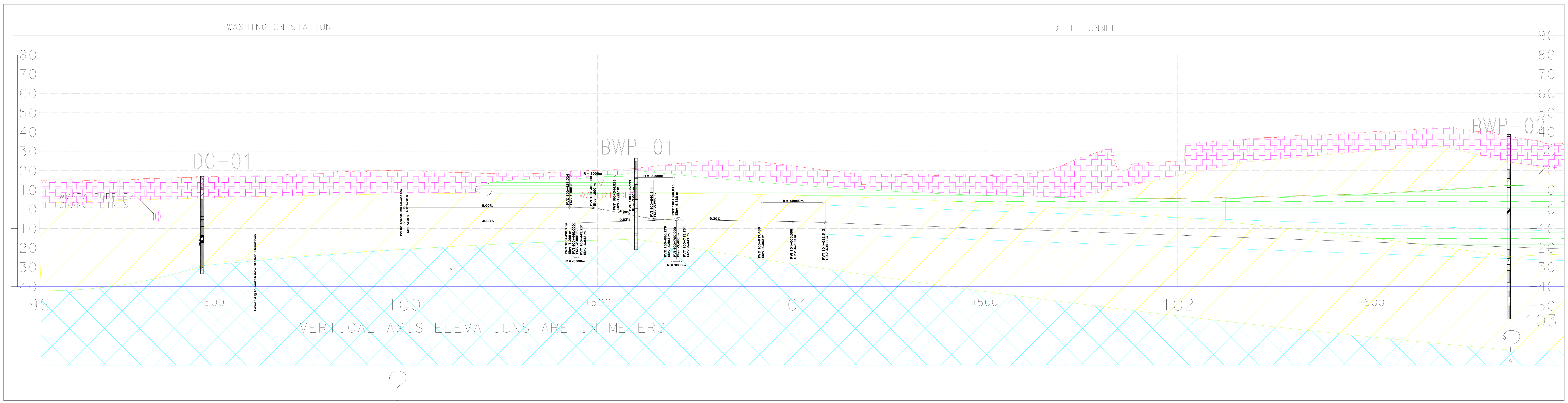
- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1G

GEOTECHNICAL PROFILE WITH RESPECT TO ALIGNMENT J MODIFIED 1





LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

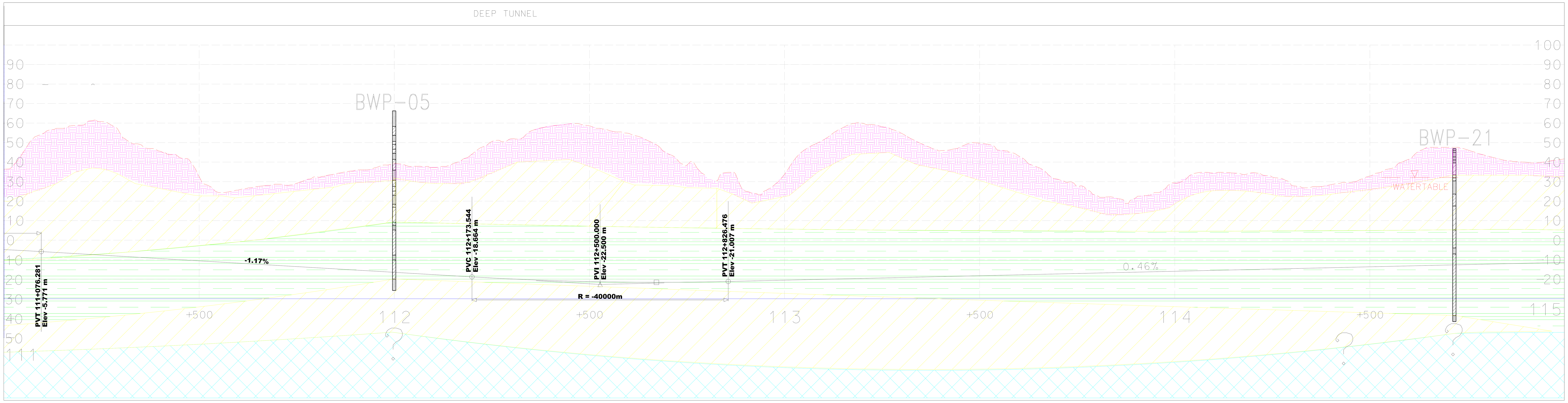
BWRR BALTIMORE-WASHINGTON RAPID RAIL

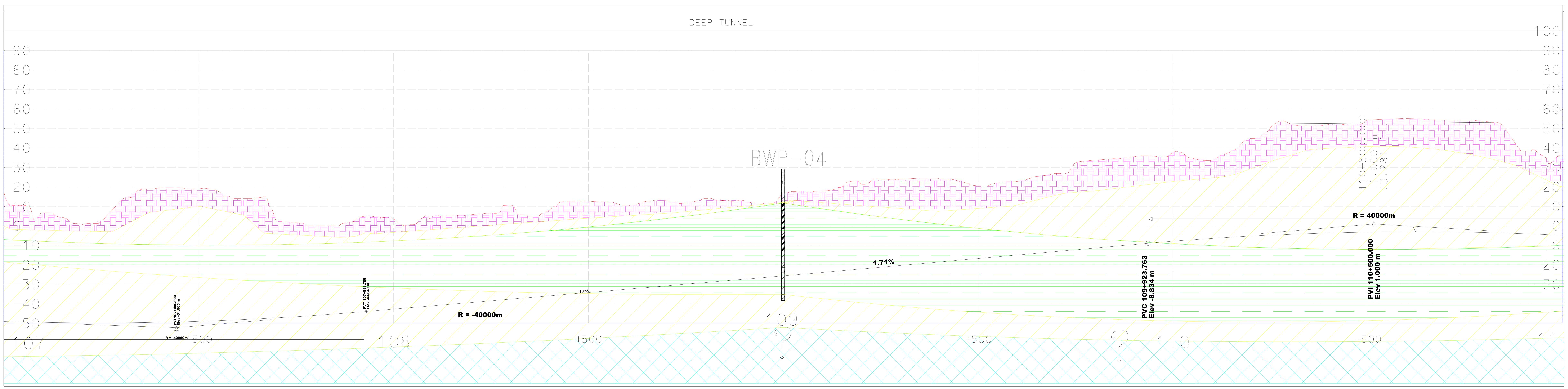
TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1A



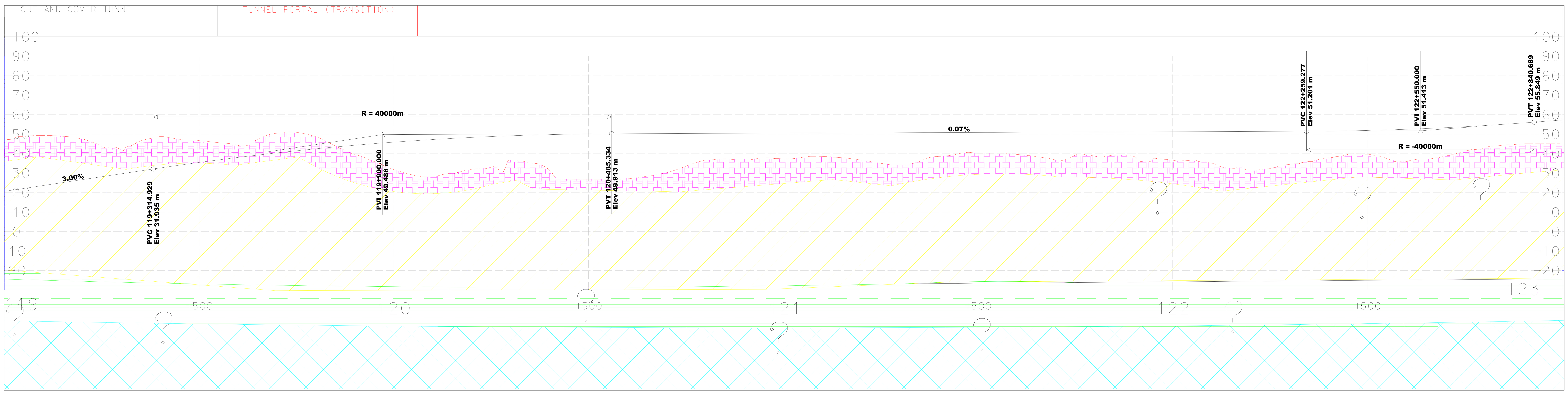


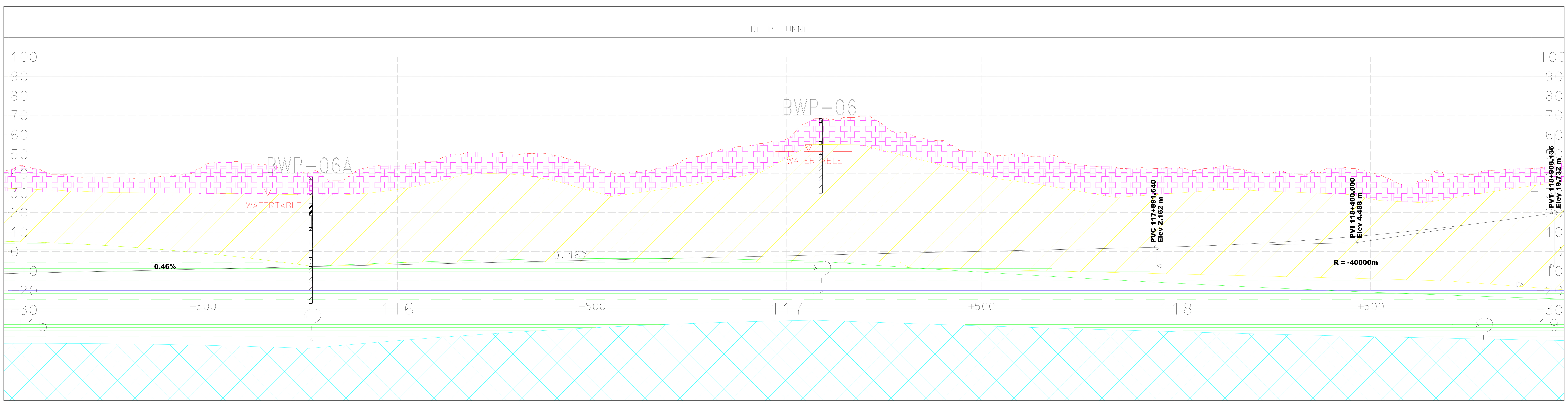
LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV	BWRR BALTIMORE-WASHINGTON RAPID RAIL · TNEM THE NORTHEAST MAGLEV	Generalized preliminary subsurface stratification based on 22 boreholes	Louis Berger	FIGURE 1B





LEGEND

FILL/UNCONSALIDATED SEDIMENTS	MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER	BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

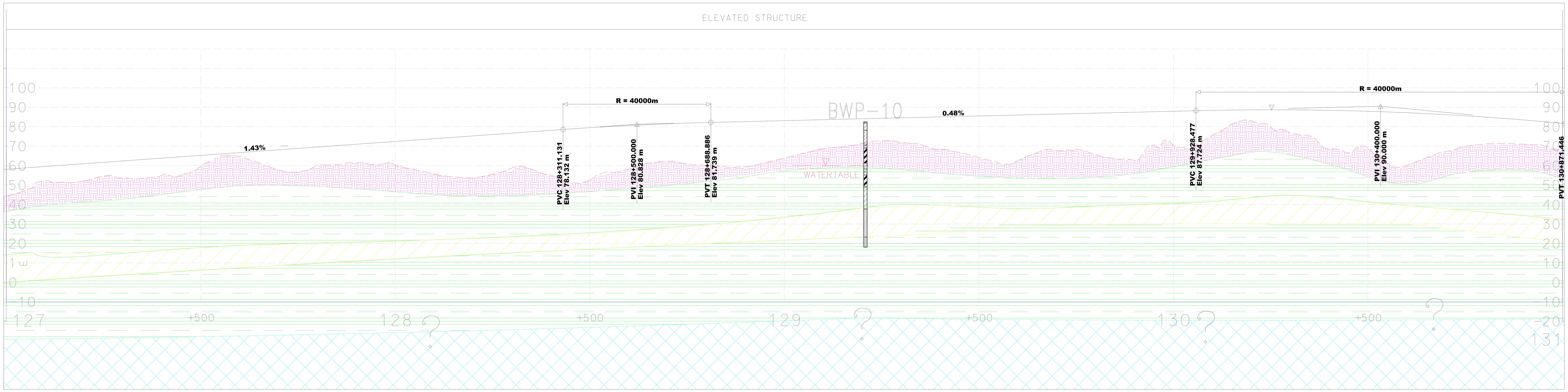
BWRR BALTIMORE-WASHINGTON RAPID RAIL

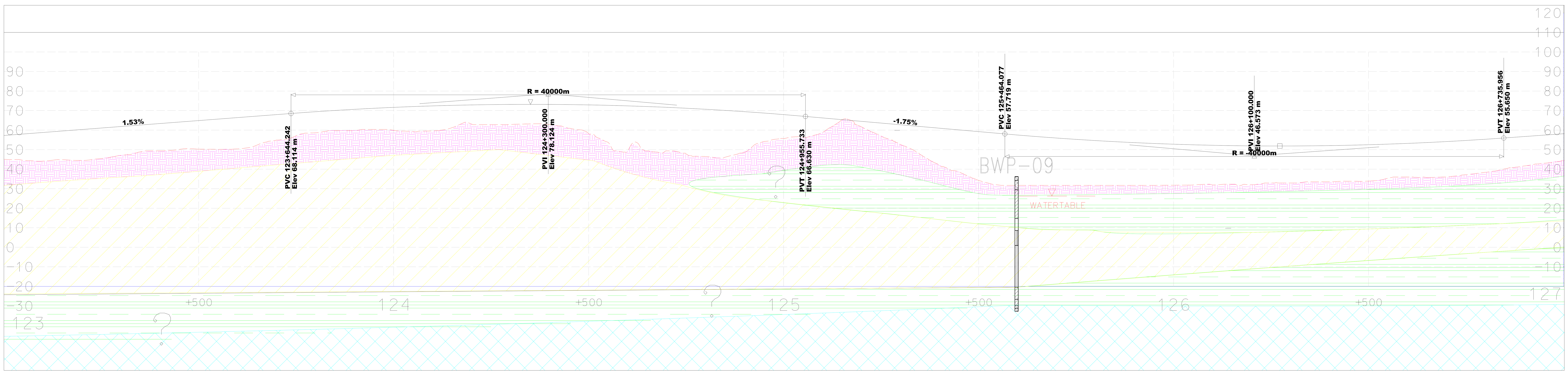
TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1C



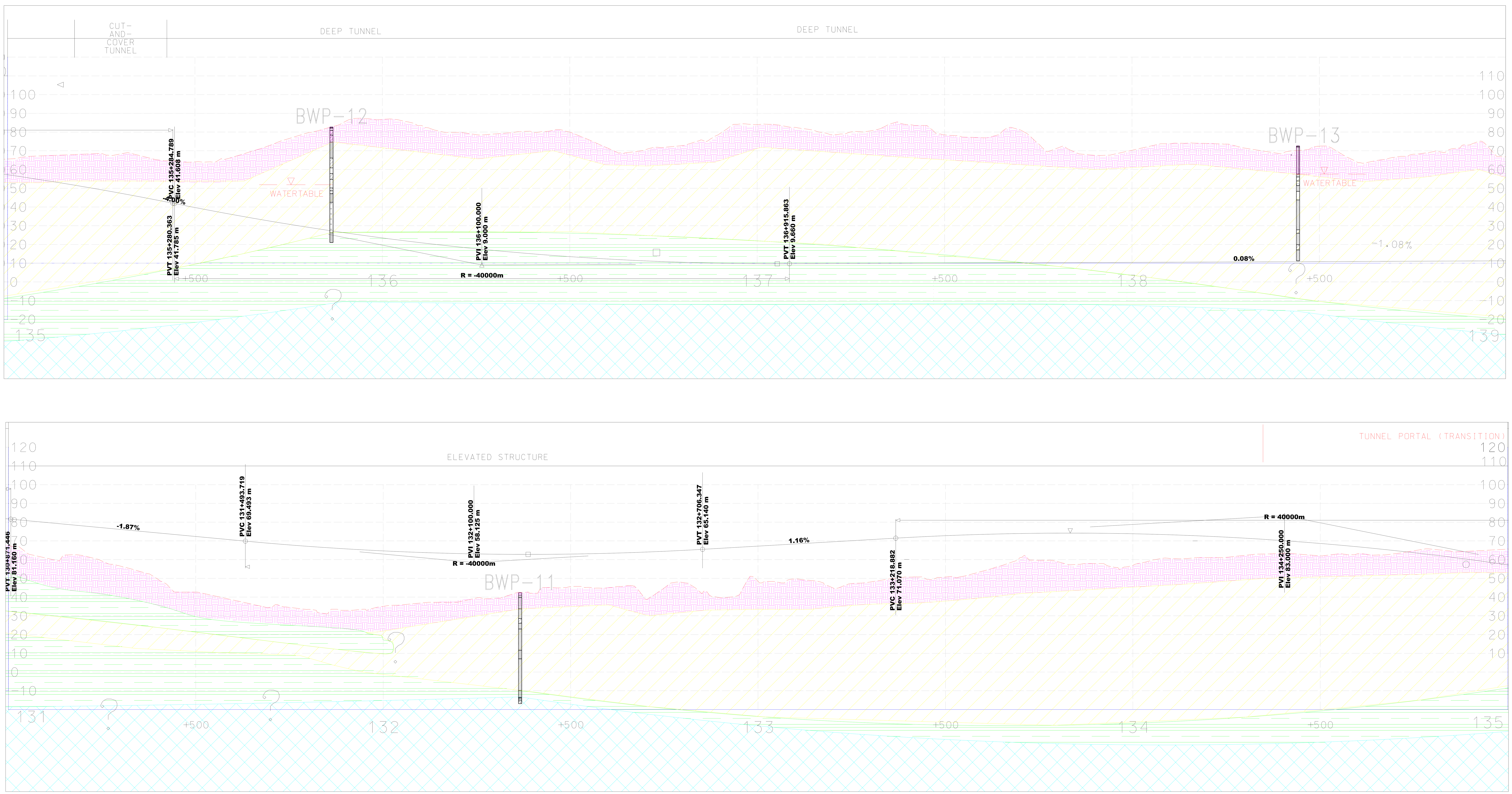


LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1D



LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

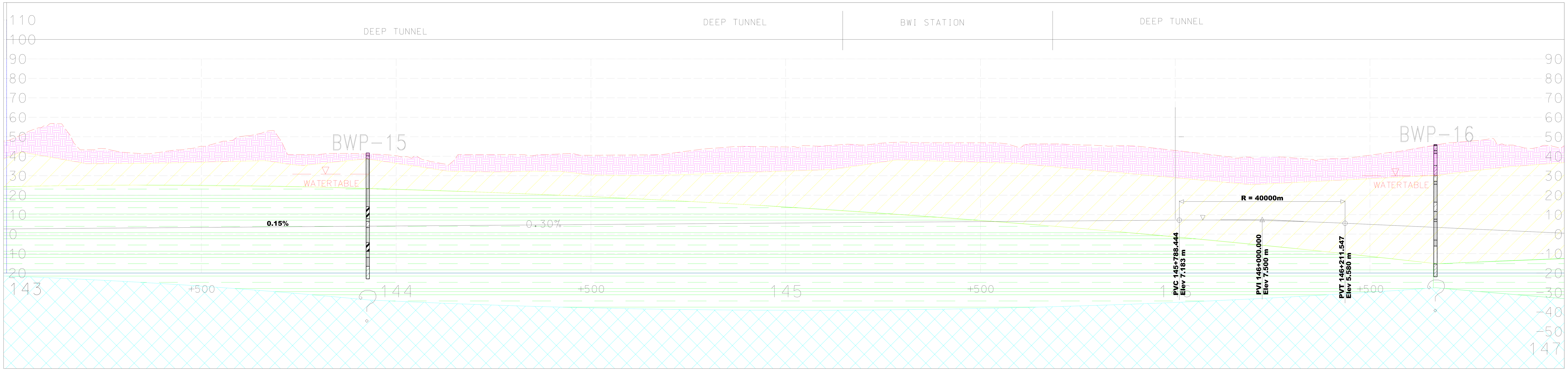
PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

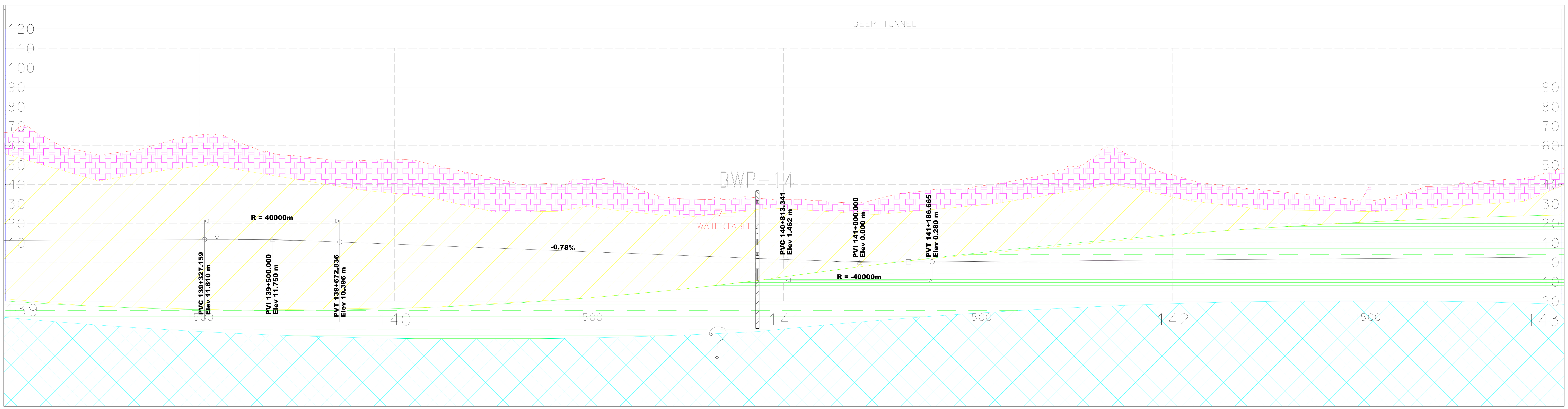
US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1E





LEGEND

FILL/UNCONSALIDATED SEDIMENTS

MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER

MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER

BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

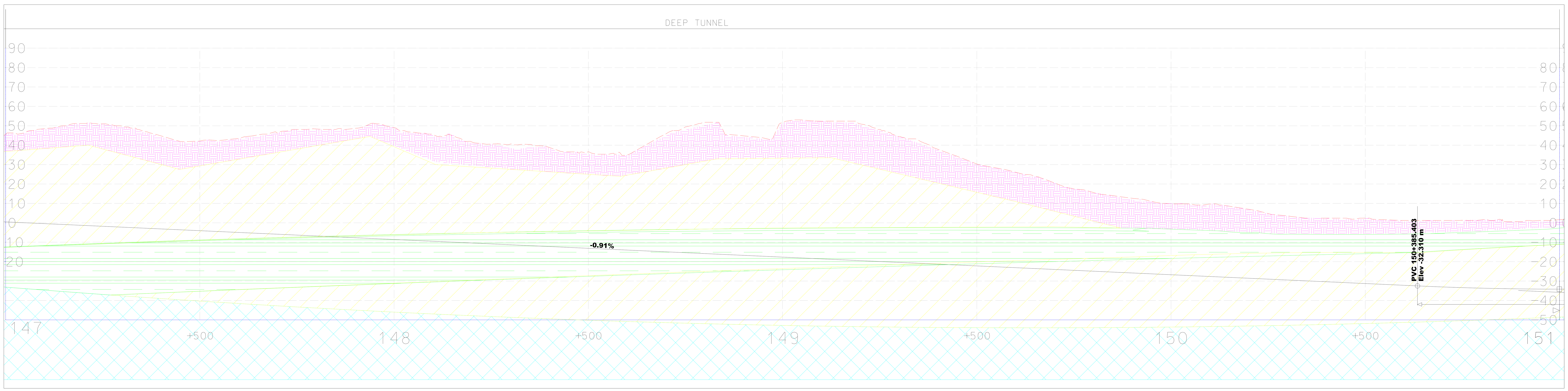
BWRR BALTIMORE-WASHINGTON RAPID RAIL

TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1F



LEGEND

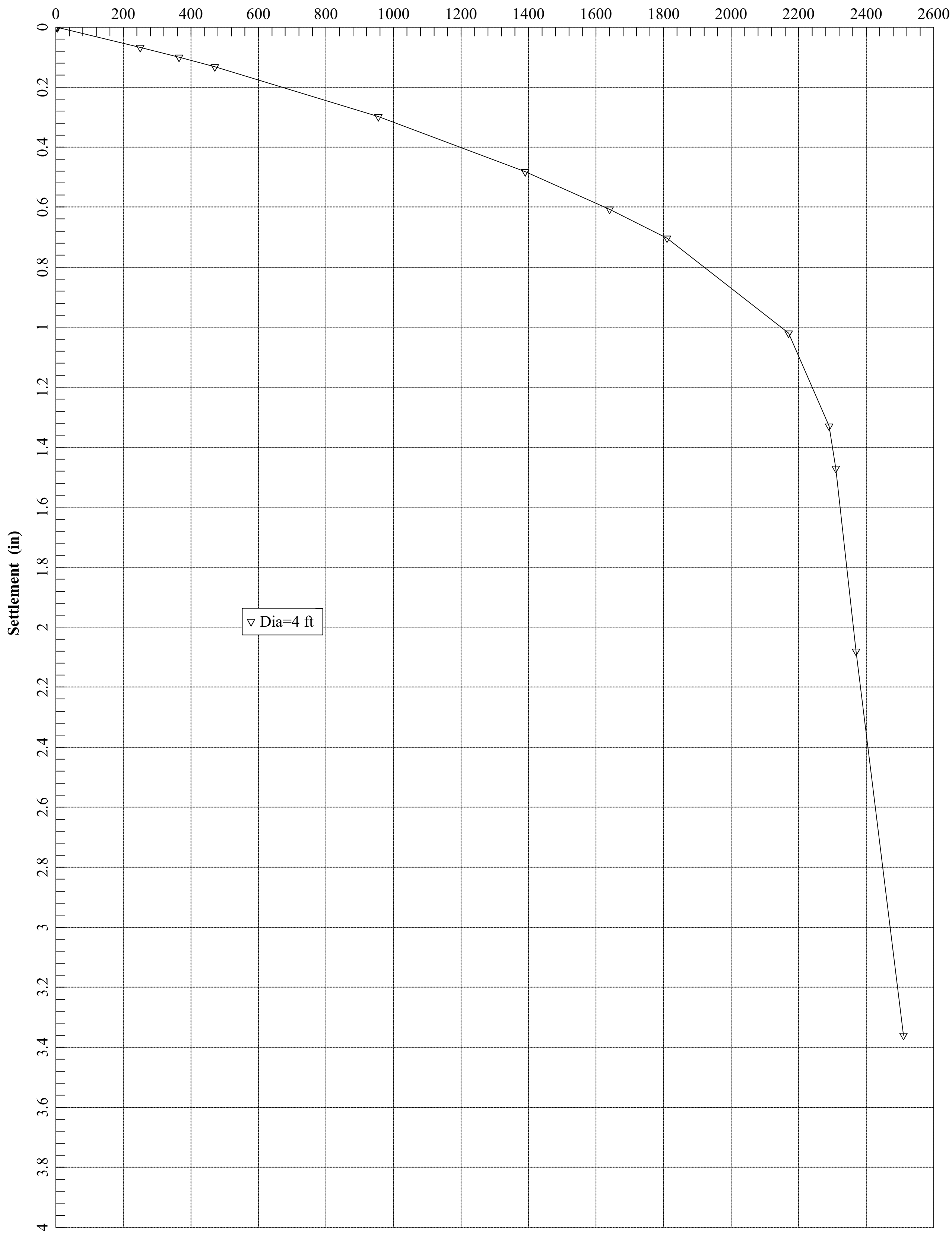
- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

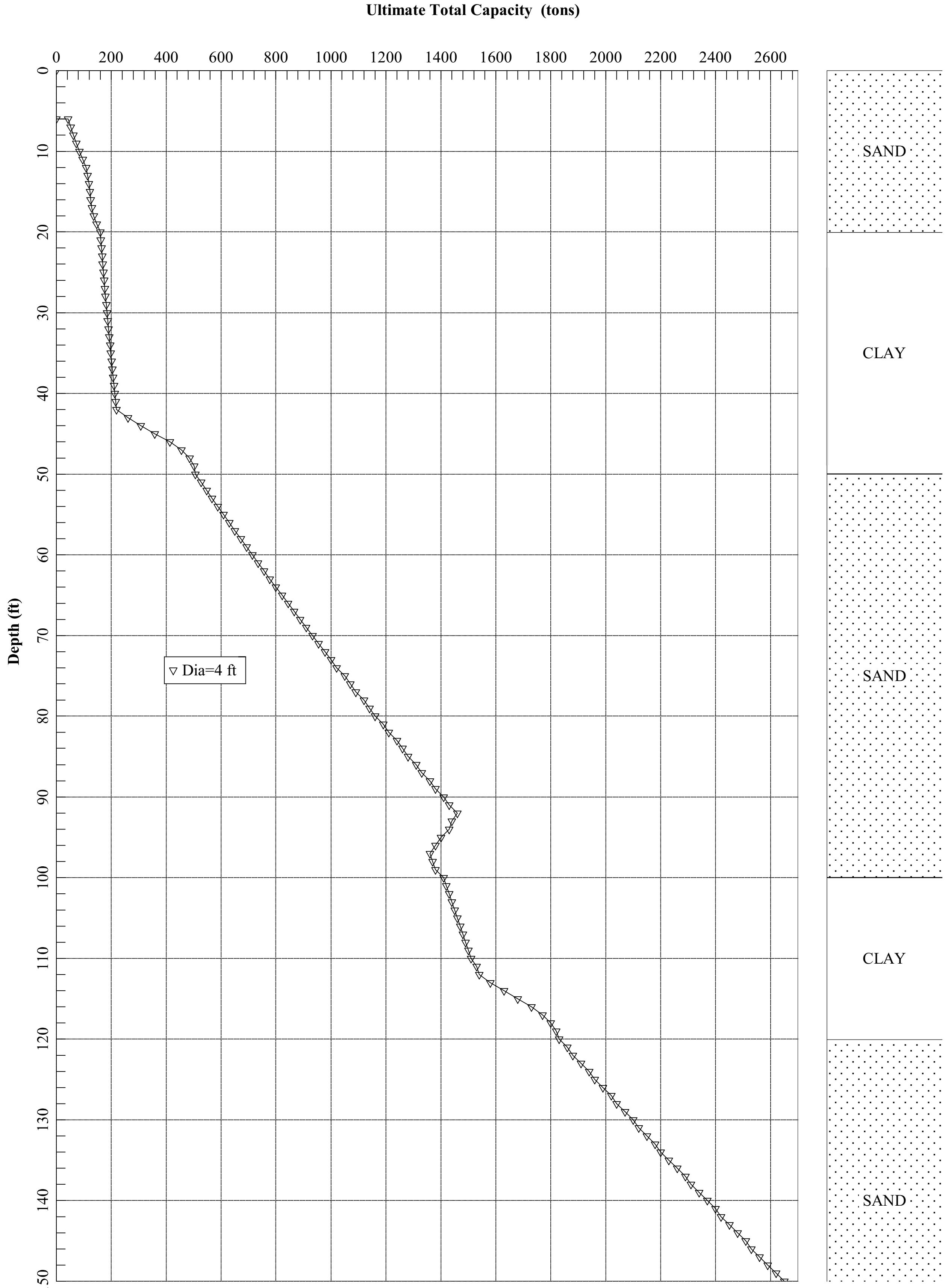
US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1G

APPENDIX E: DRILLED SHAFT CAPACITY ANALYSIS

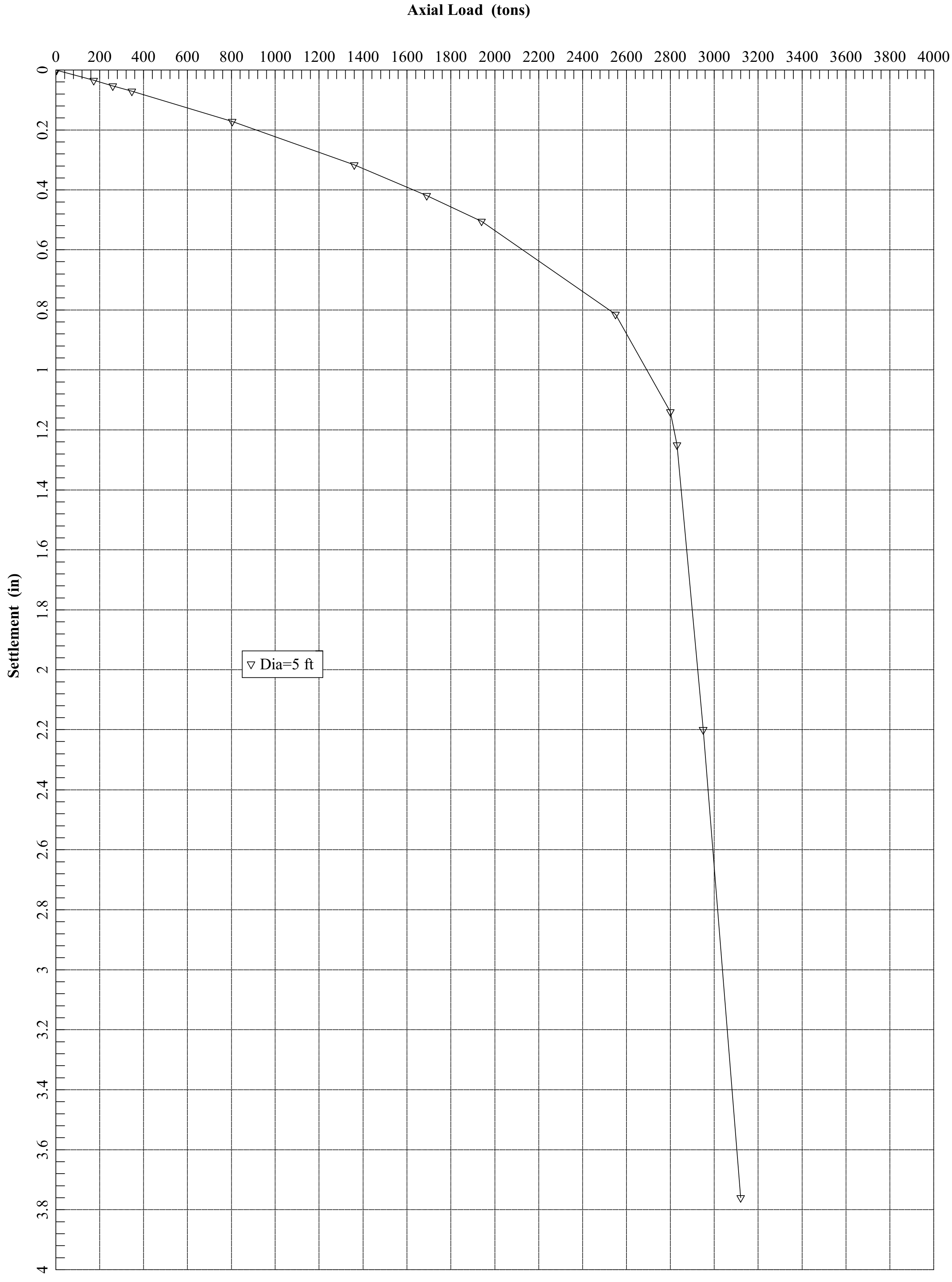
MAGLEV 4 FT DIA. DRILLED SHAFT, SETTLEMENT VS. LOAD
Axial Load (tons)

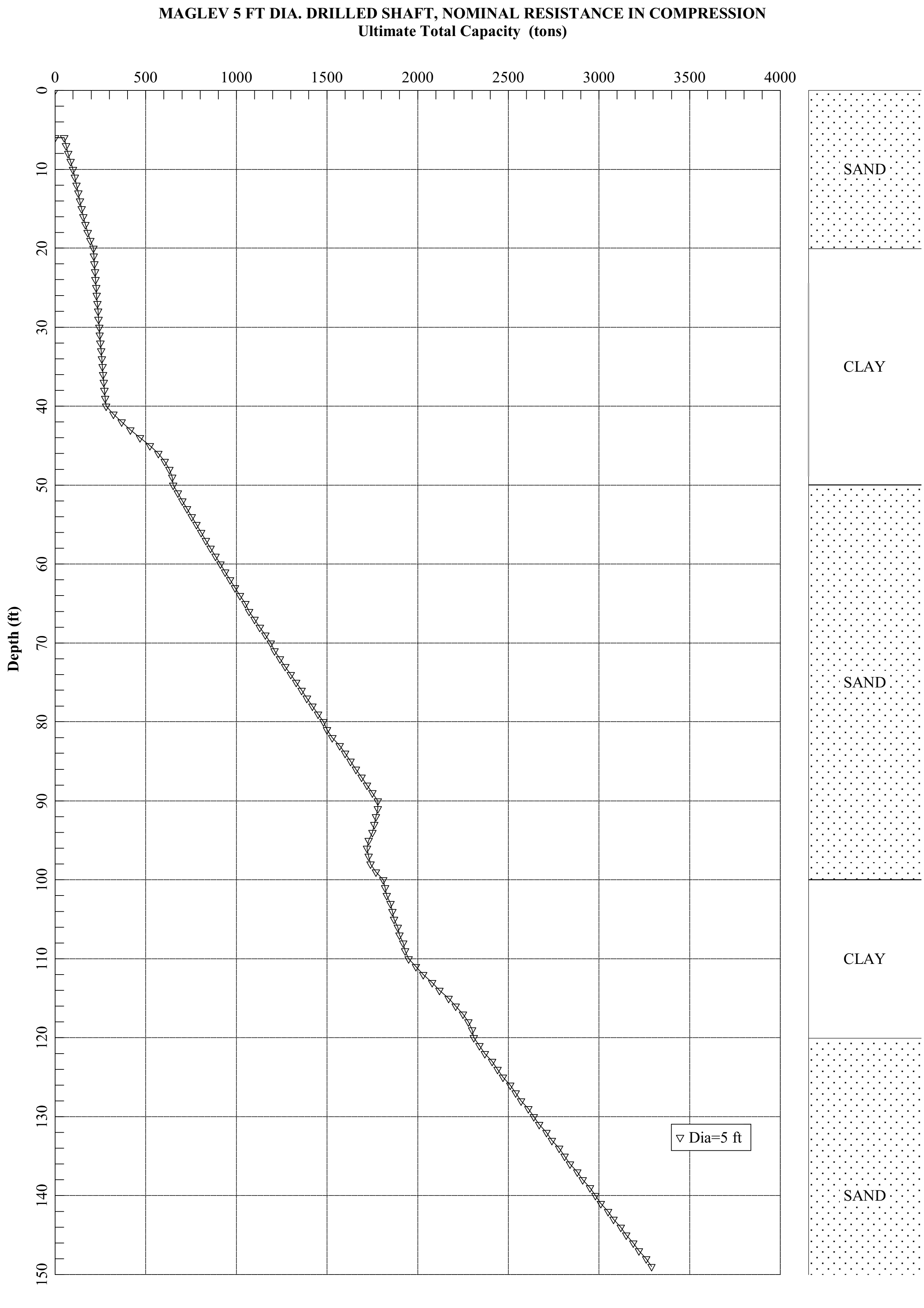


MAGLEV 4 FT DIA. DRILLED SHAFT, NOMINAL RESISTANCE IN COMPRESSION

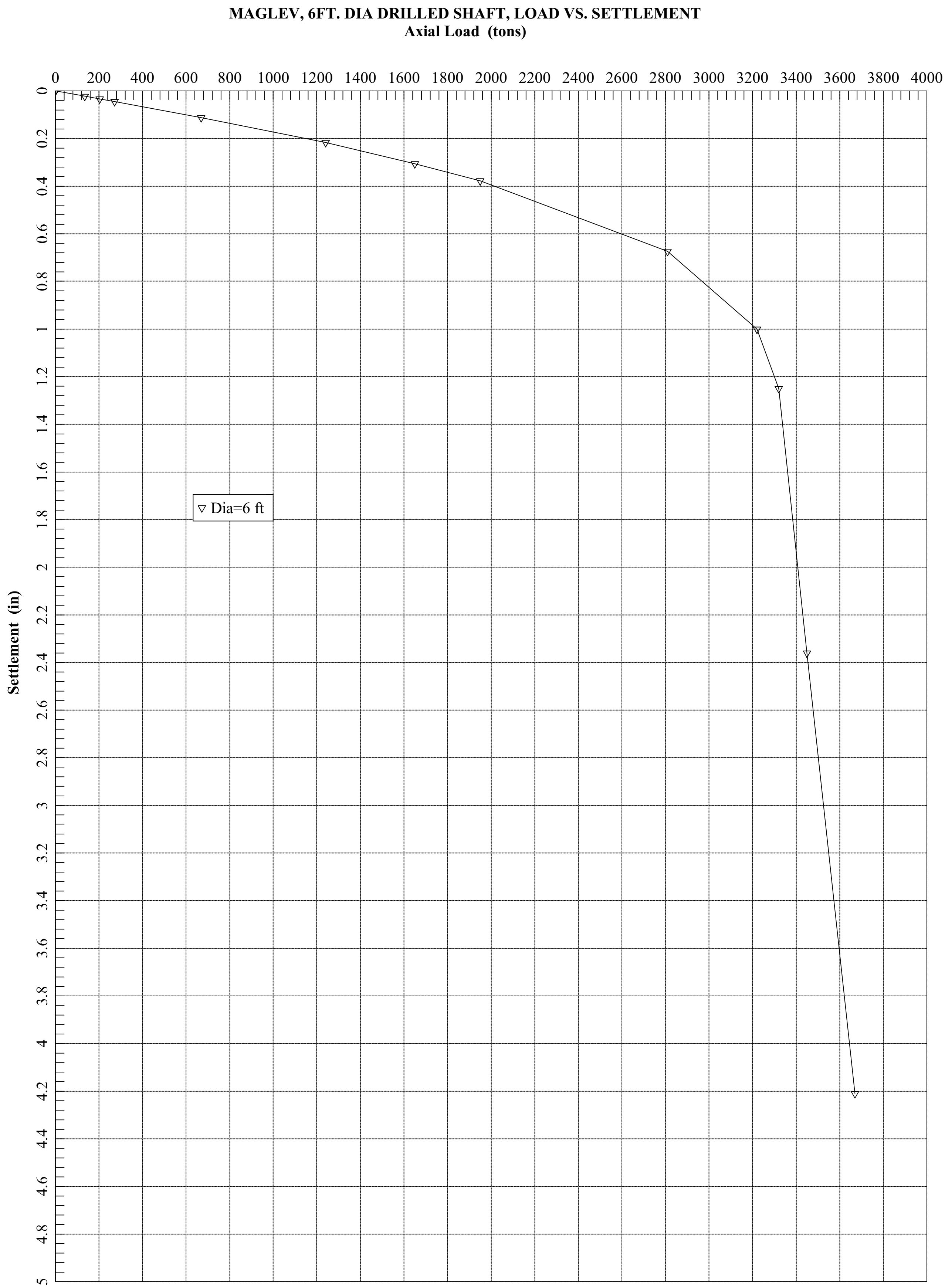


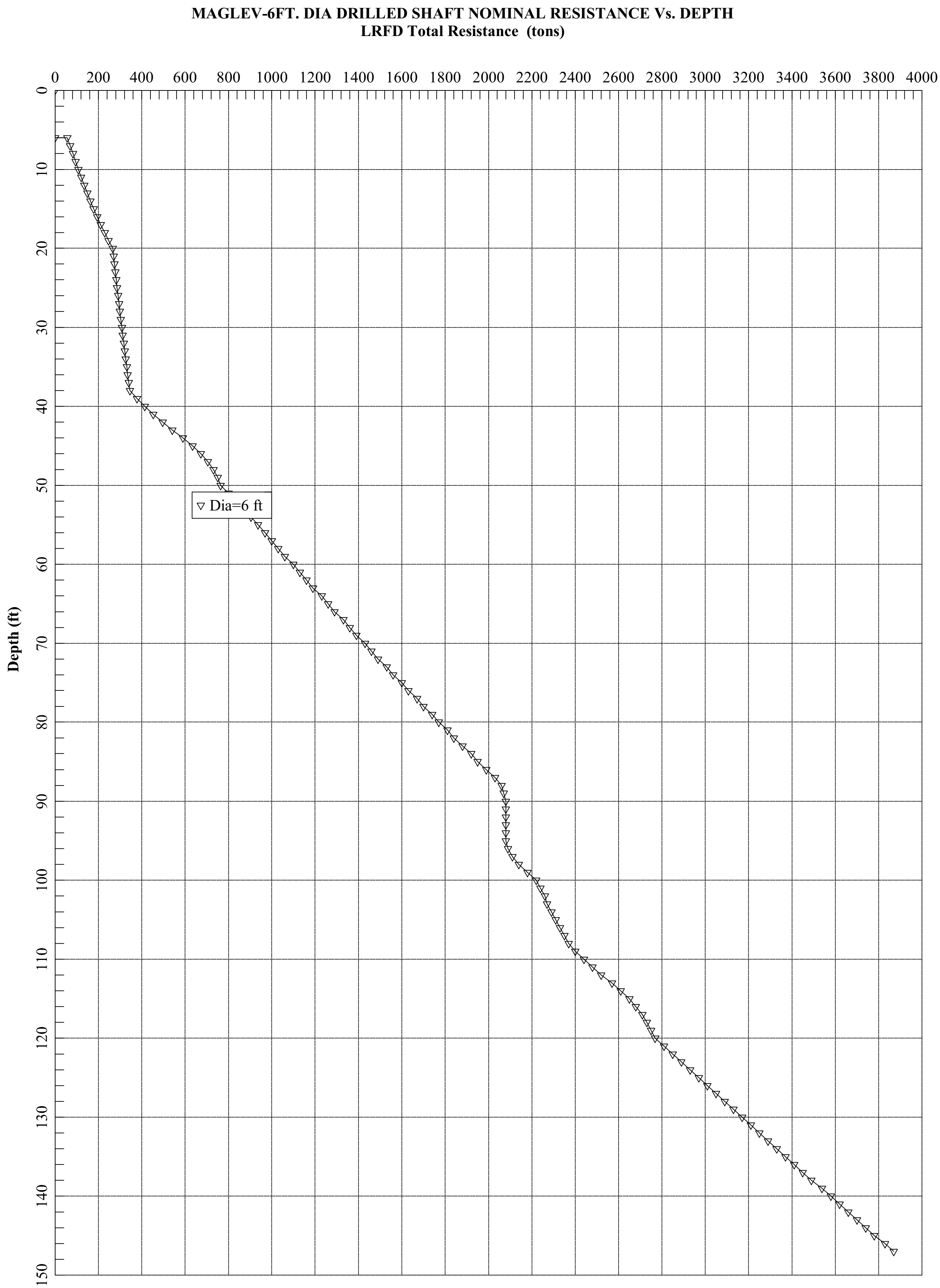
MAGLEV 5 FT DIA. DRILLED SHAFT, SETTLEMENT VS. LOAD



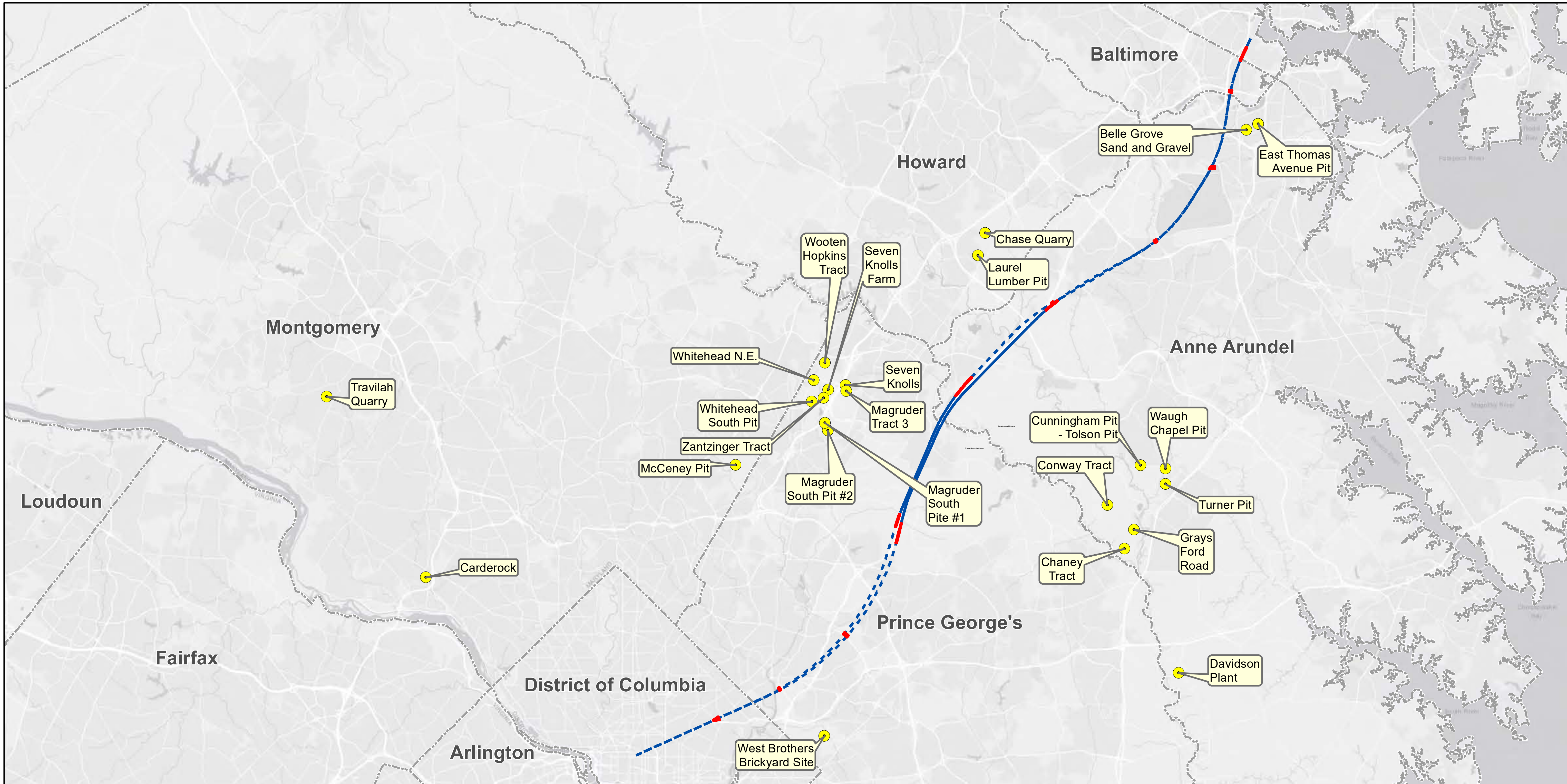


MAGLEV 5 FT DIA. DRILLED SHAFT, NOMINAL RESISTANCE IN COMPRESSION
Ultimate Total Capacity (tons)
0
500
1000
1500
2000
2500
3000
3500
4000
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Dia=5 ft
SAND
CLAY
SAND
CLAY
SAND


MAGLEV, 6FT. DIA DRILLED SHAFT, LOAD VS. SETTLEMENT
Axial Load (tons)
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000
Settlement (in)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5
Dia=6 ft


MAGLEV-6FT. DIA DRILLED SHAFT NOMINAL RESISTANCE Vs. DEPTH
LRFD Total Resistance (tons)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
Depth (ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Dia=6 ft

APPENDIX F: SOIL DISPOSAL ROUTES



Active Mining Locations
Laydown Area
Elevated Structure
Deep Tunnel
County Boundary

Sources: ESRI (2017), BWRR (2017)

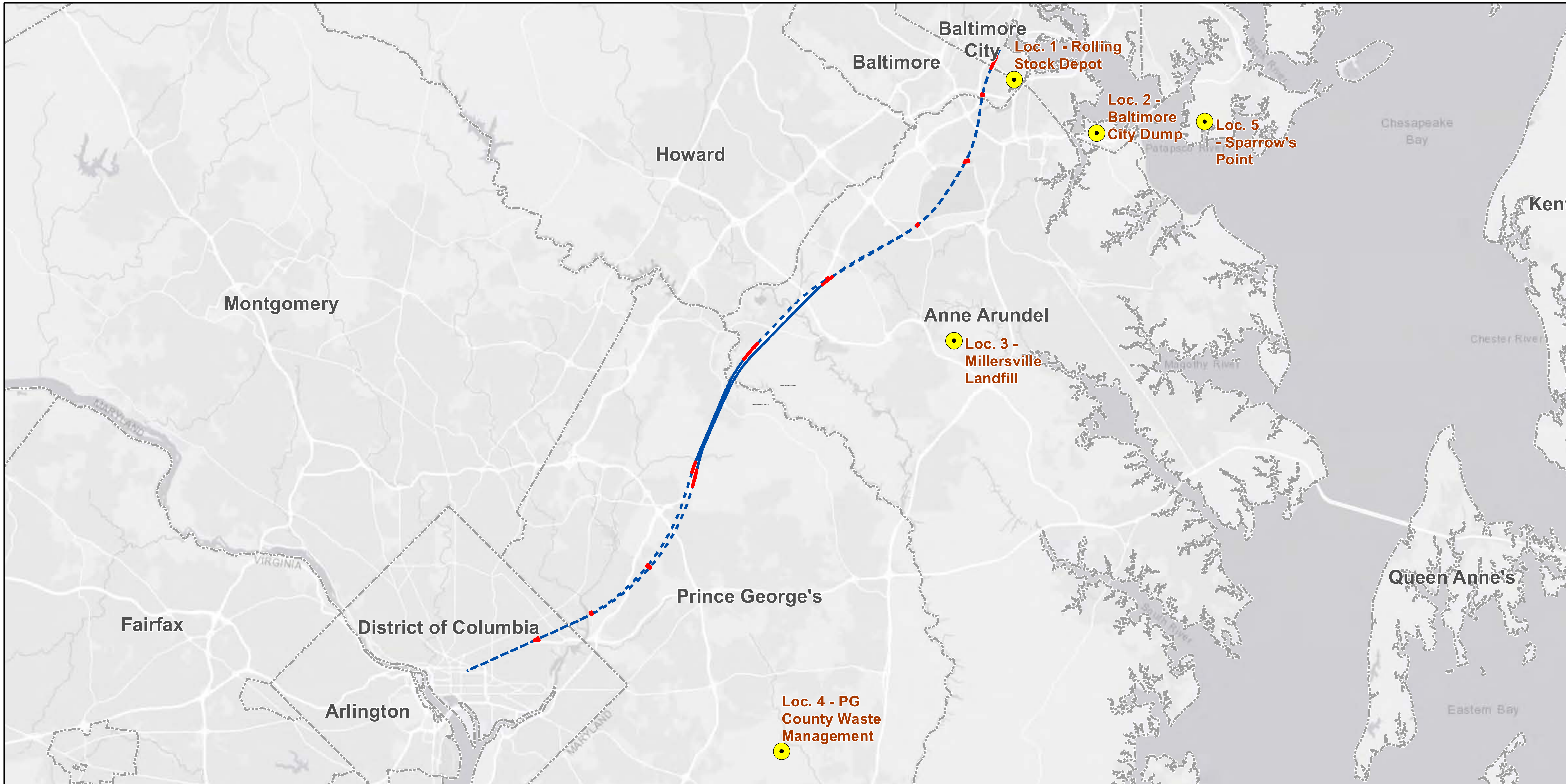
Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

November 07, 2018

Potential Other Spoil Disposal Sites

BWRR Louis Berger

0 2 4 6 8 Miles
N



- Potential Spoil Site
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

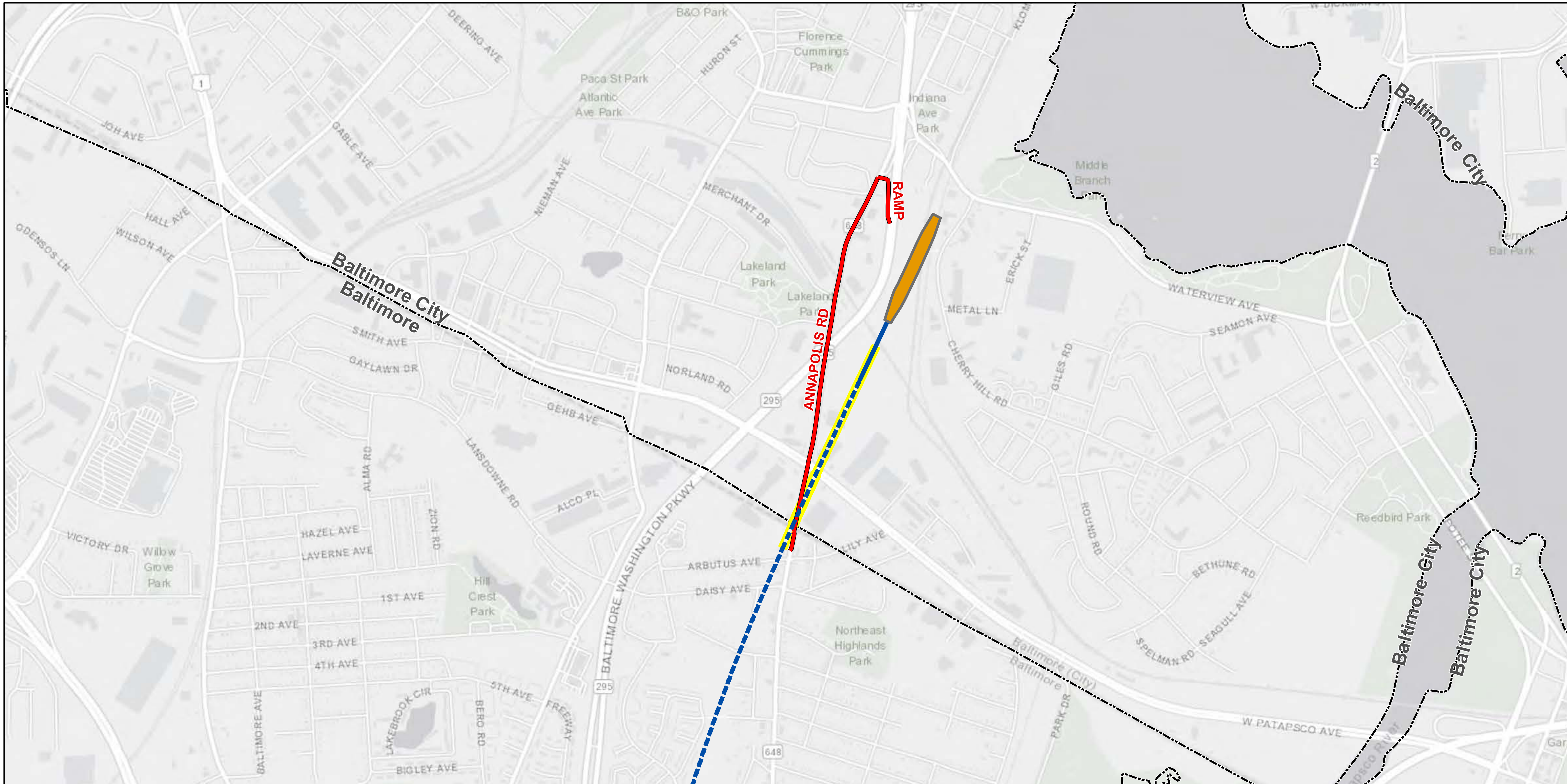
Proposed Spoil Destinations

BWRR Louis Berger

0 2 4 6 8 Miles

N

Cherry Hill Portal
Proposed Haul Route



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

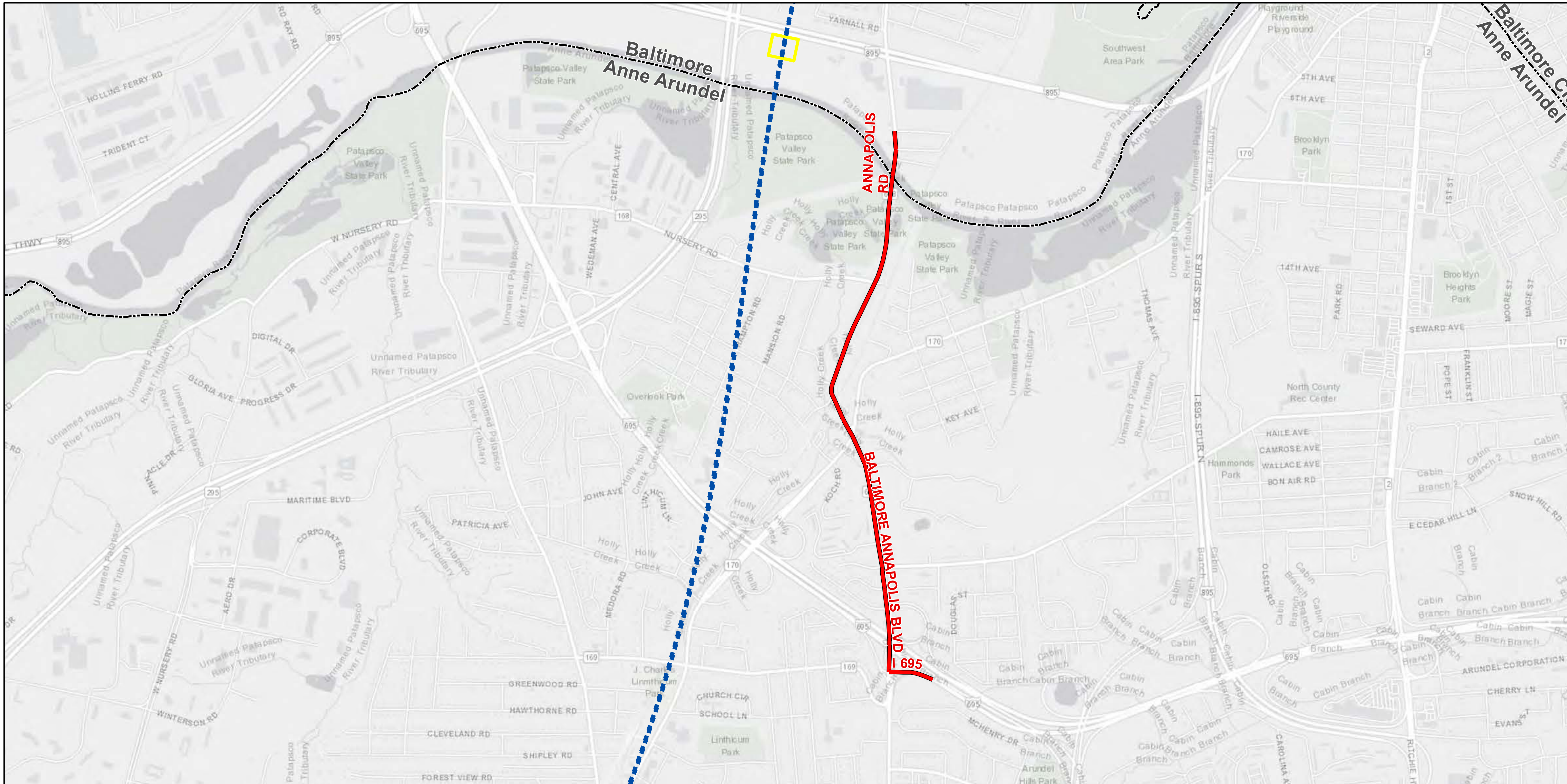
Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

BWRR
Louis Berger

0 0.25 0.5 Miles

N



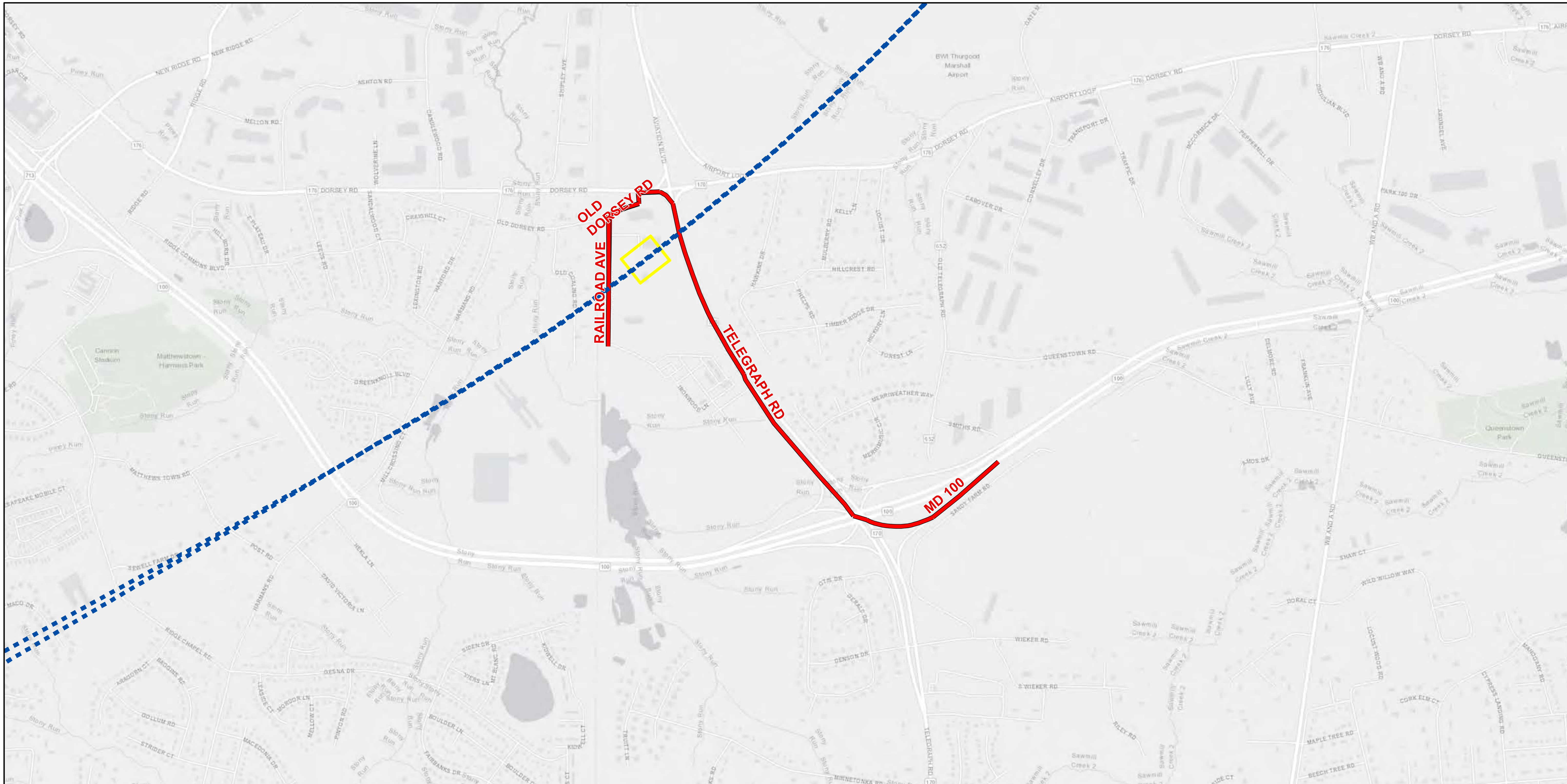
Truck Route	Sources: ESRI (2017), BWRR (2017)	
Laydown Area	Coordinate System: NAD 1983 StatePlane MD (feet) Datum: North American 1983	
Elevated Structure	October 22, 2018	
Deep Tunnel		
County Boundary		

I-895 Vent Plant
Proposed Haul Route

BWRR Louis Berger

0 0.25 0.5 Miles

N

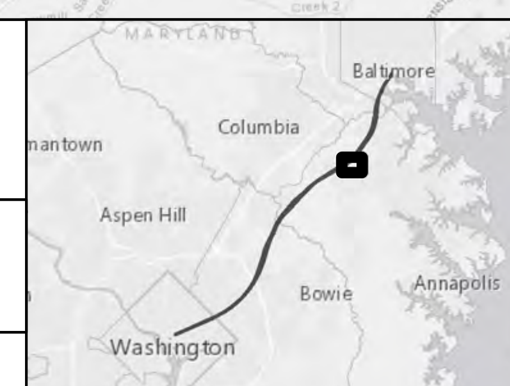


Truck Route
Laydown Area
Elevated Structure
Deep Tunnel
County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

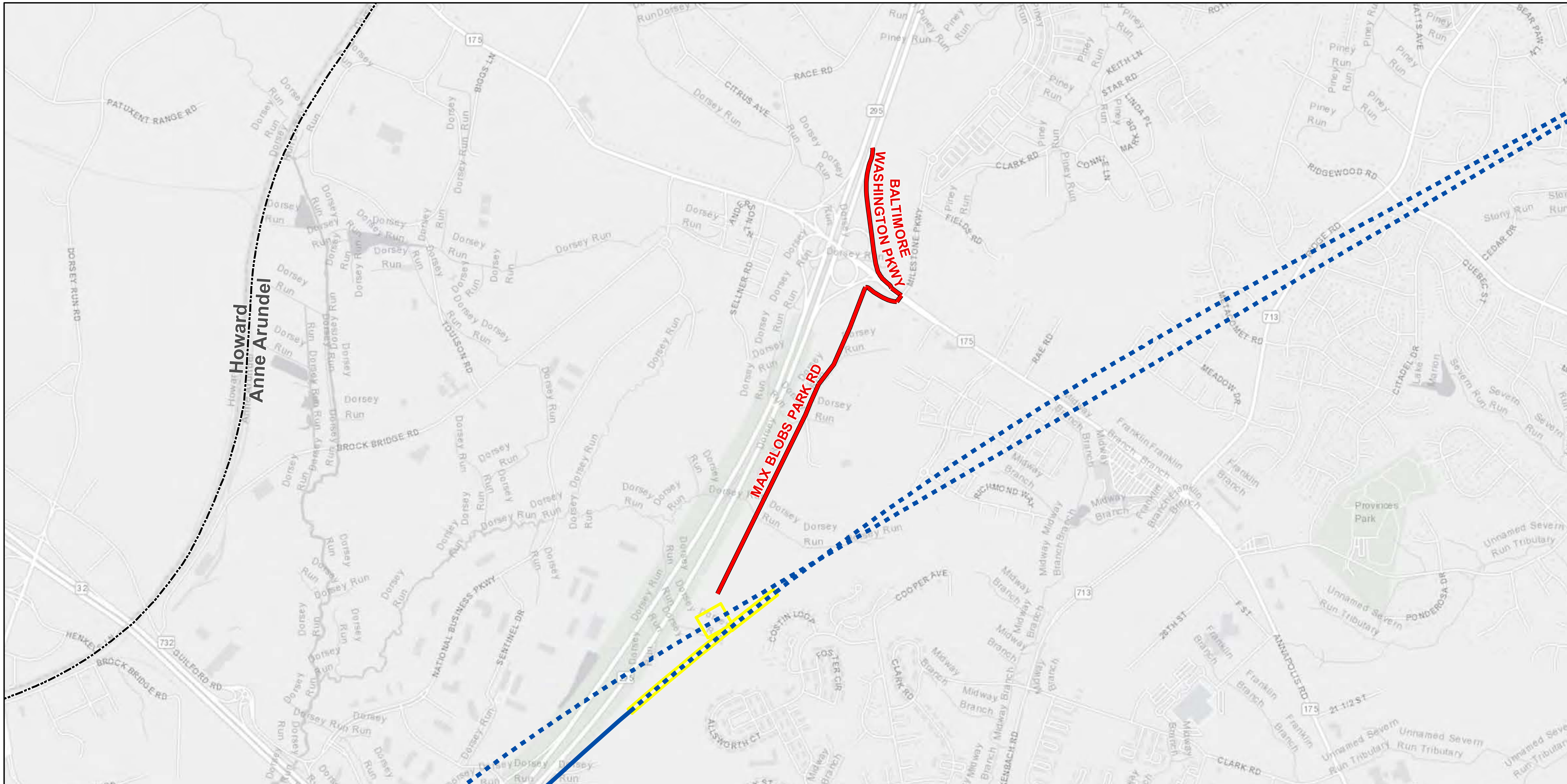
October 22, 2018



Harmans Vent Plant
Proposed Haul Route

BWRR
Louis Berger

0 0.25 0.5 Miles
N



Truck Route

Laydown Area

Elevated Structure

Deep Tunnel

County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System:
NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

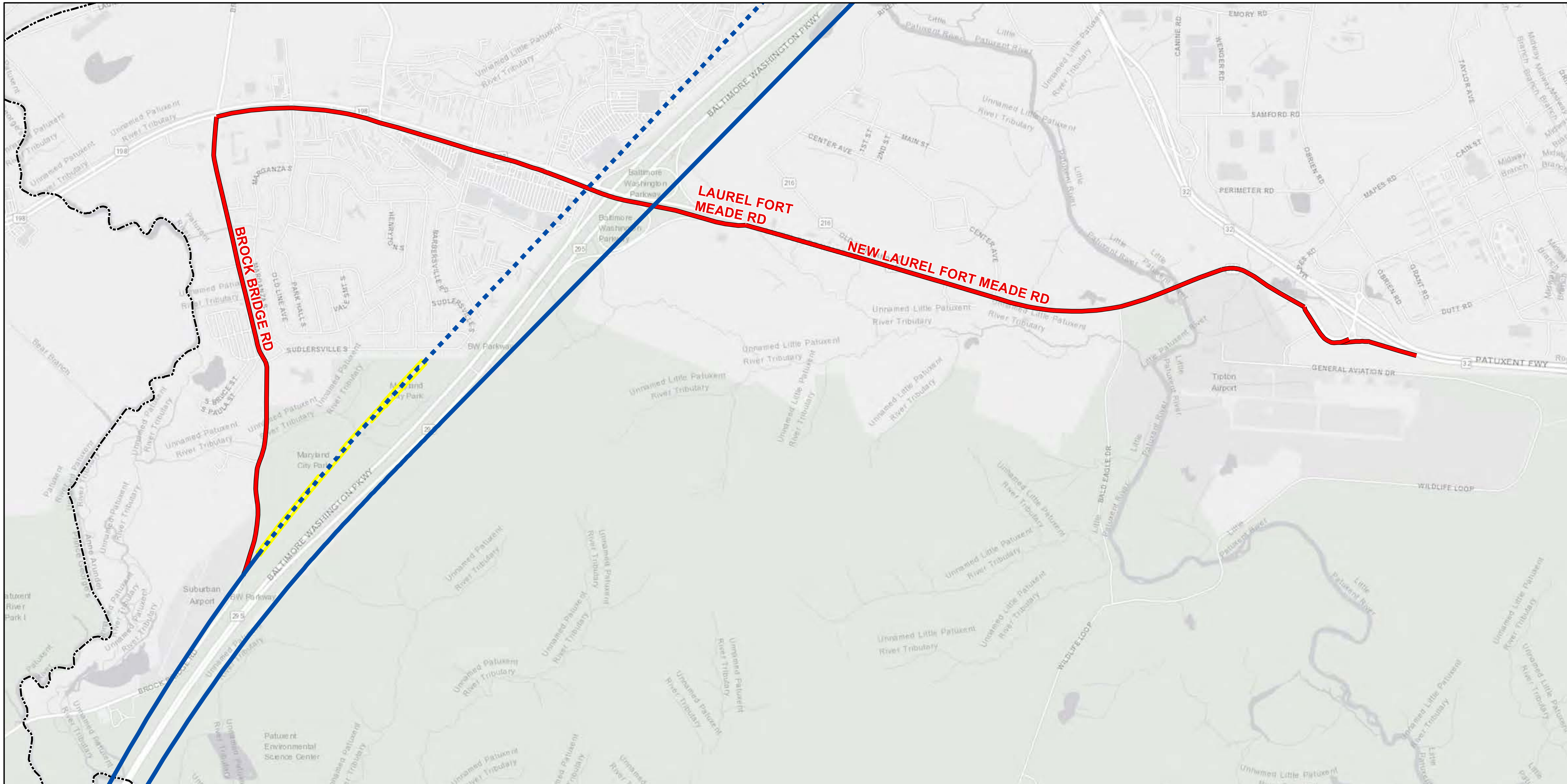
NSA Vent Plant/Portal Proposed Haul Route

BWRR

Louis Berger

0 0.25 0.5 Miles

N



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017),
BWRR (2017)

Coordinate System:
NAD 1983 StatePlane MD (feet)
Datum: North American 1983

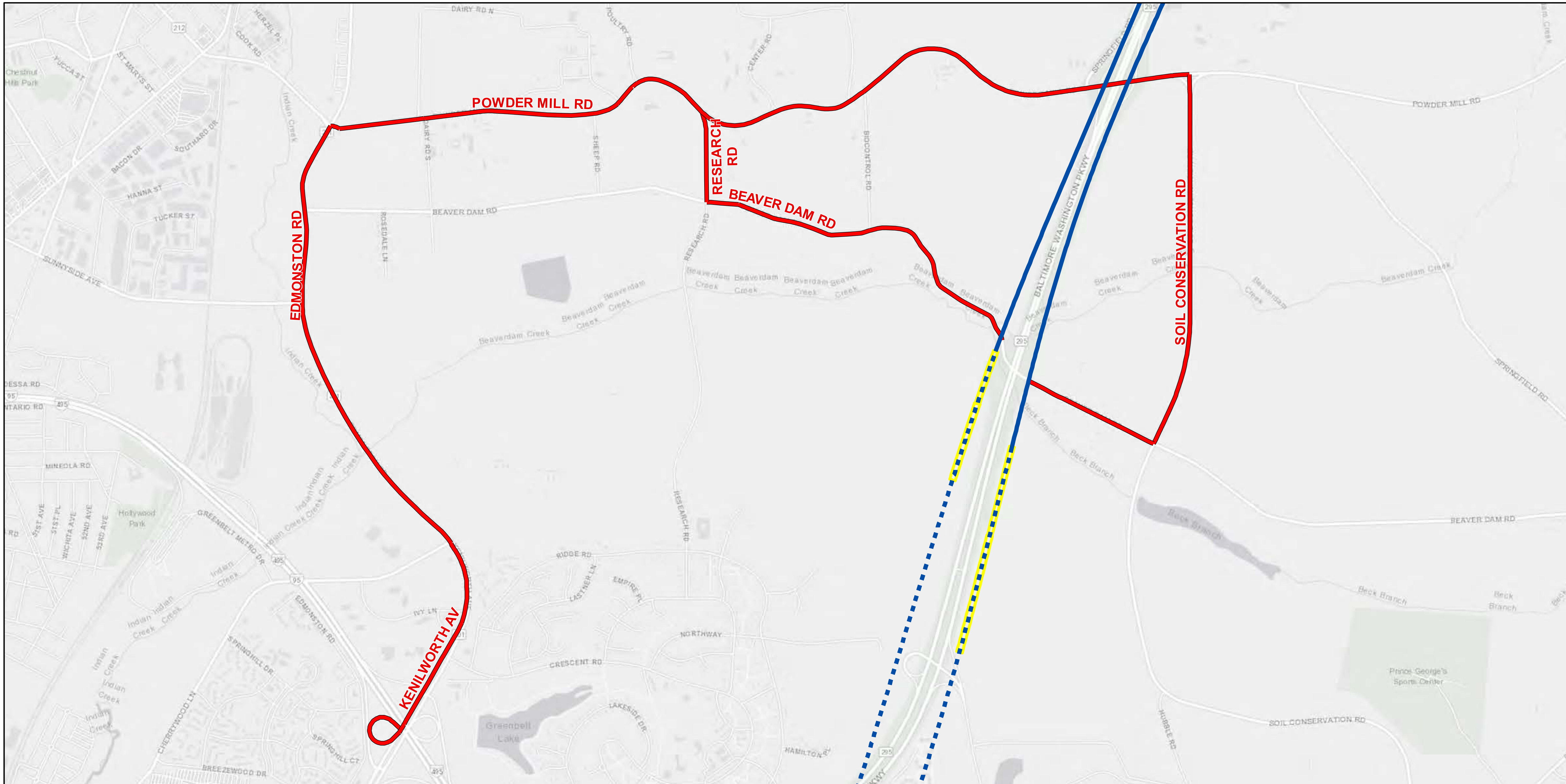
October 22, 2018

Maryland City Portal
Proposed Haul Route

BWRR Louis Berger

0 0.25 0.5 0.75 Miles

N



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System:
NAD 1983 StatePlane MD (feet)
Datum: North American 1983

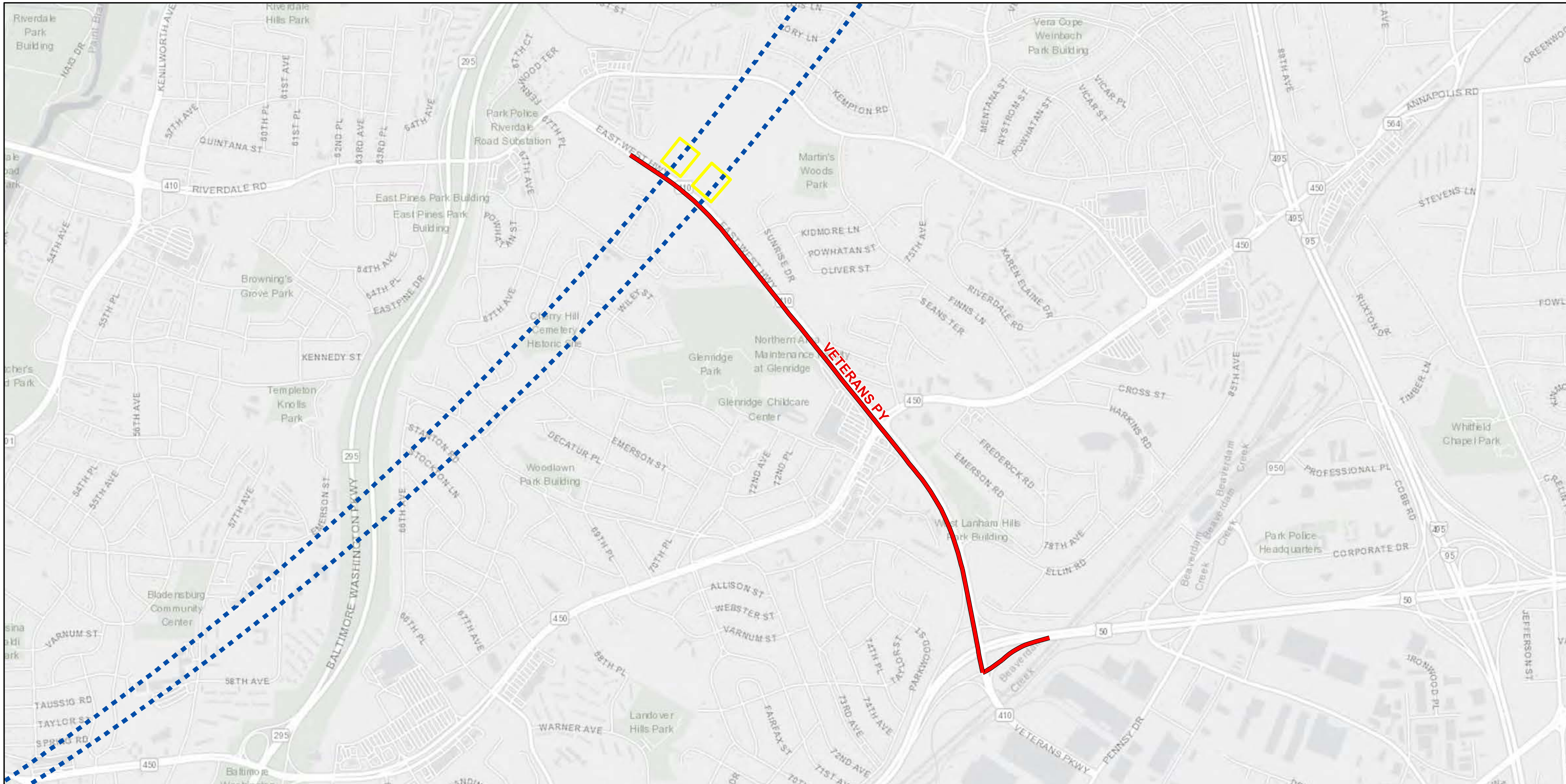
October 22, 2018

BARC Portal
Proposed Haul Route

BWRR Louis Berger

0 0.25 0.5 0.75 Miles

N

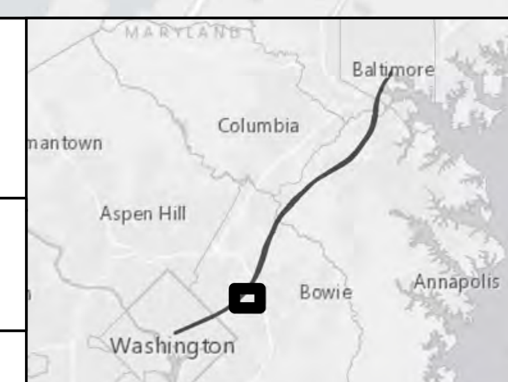


Truck Route	
Laydown Area	
Elevated Structure	
Deep Tunnel	
County Boundary	

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

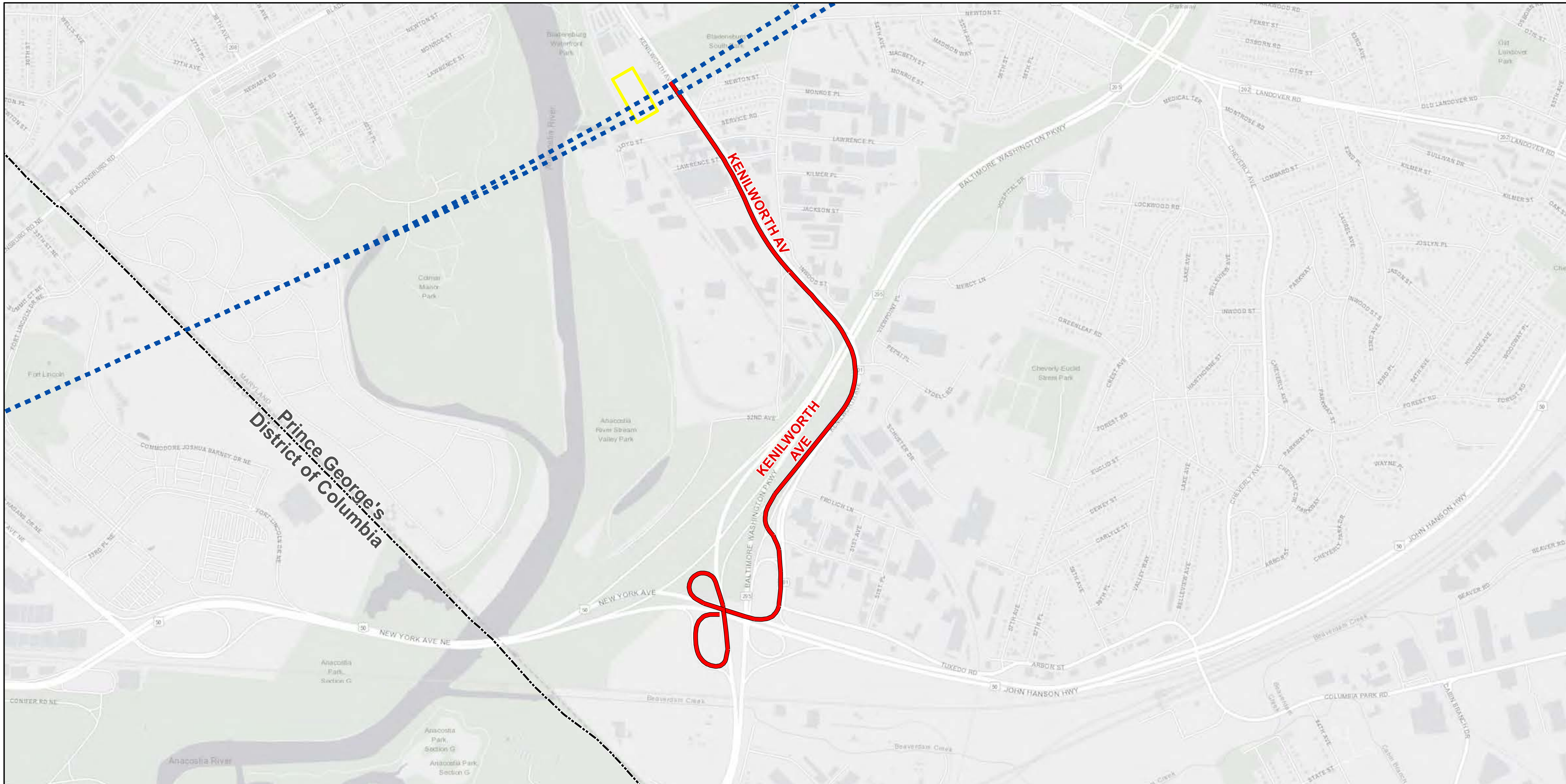


MD410 Vent Plant Proposed Haul Route

BWRR Louis Berger

0 0.25 0.5 Miles

N



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017),
BWRR (2017)

Coordinate System:
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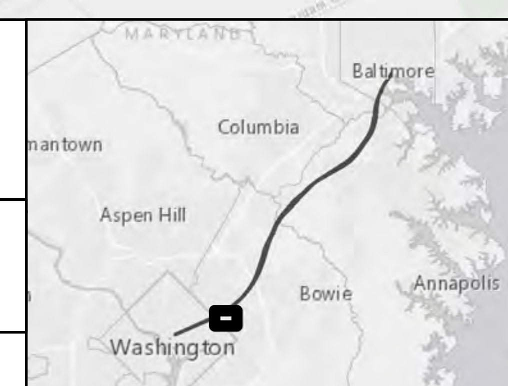
Datum: North American 1983

October 22, 2018

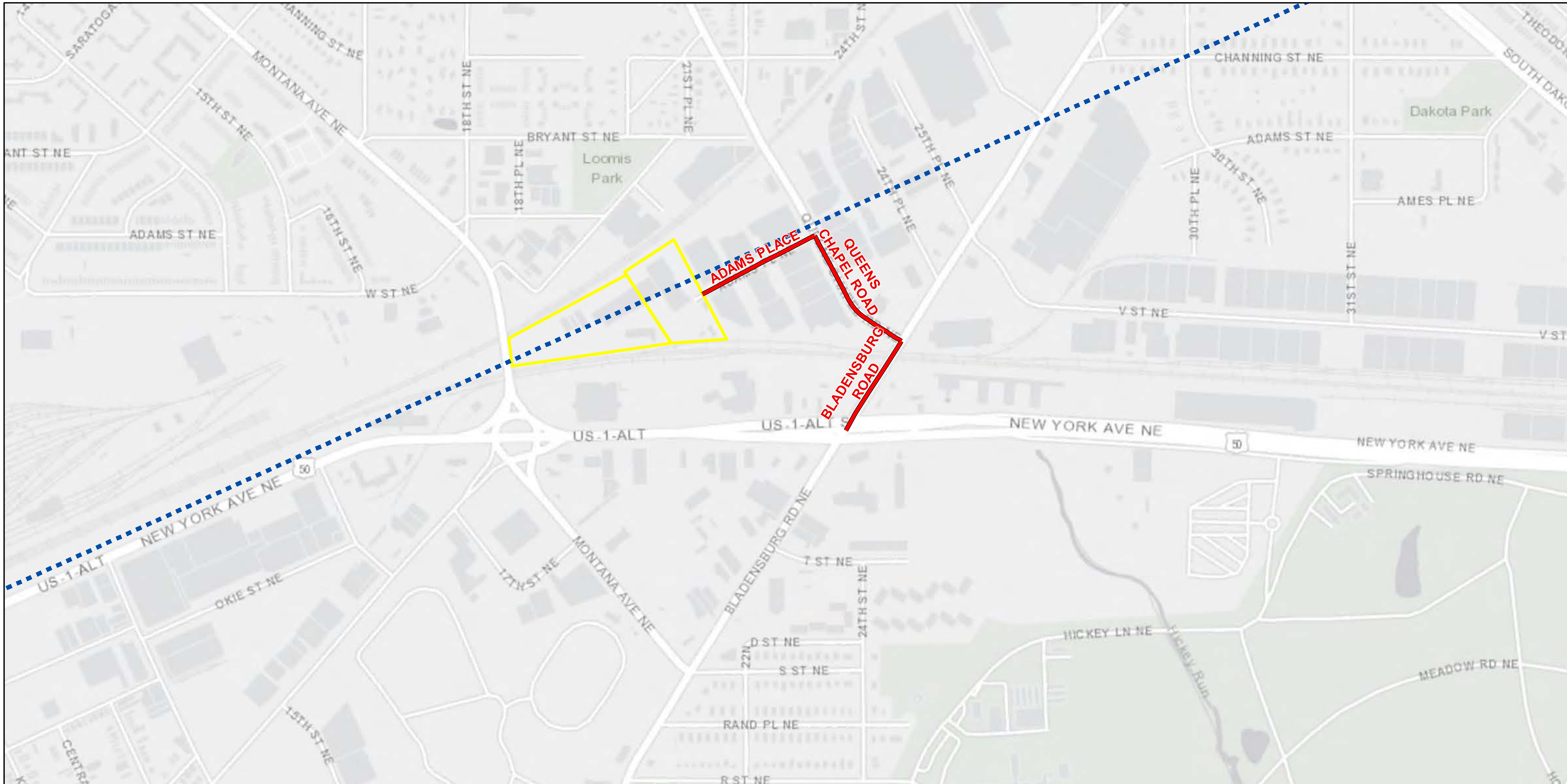


WSSC Vent Plant
Proposed Haul Route

BWRR Louis Berger

0 0.25 Miles

N



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

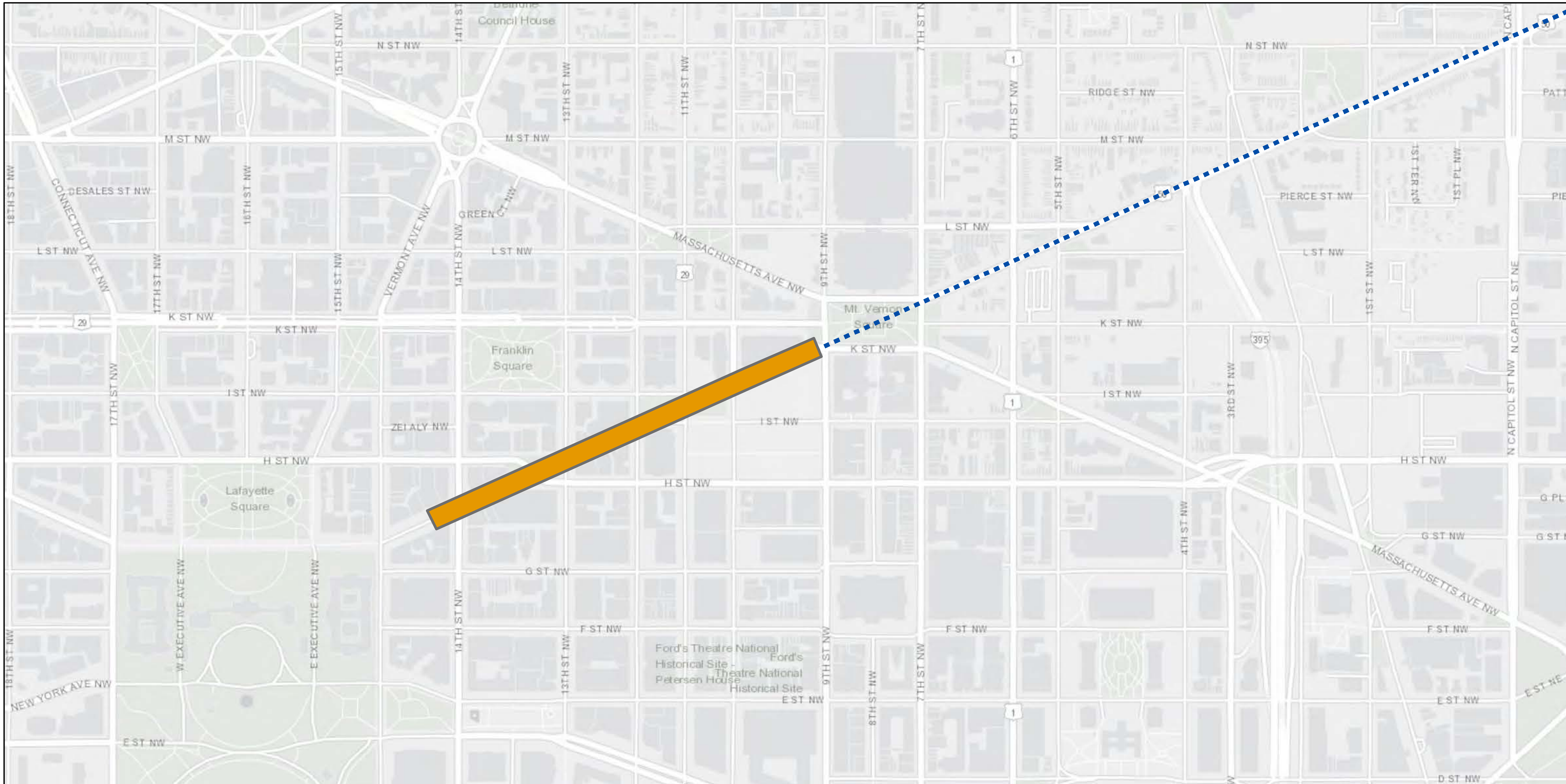
Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

DC Surplus Vent Plant
Proposed Haul Route

BWRR Louis Berger

N



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

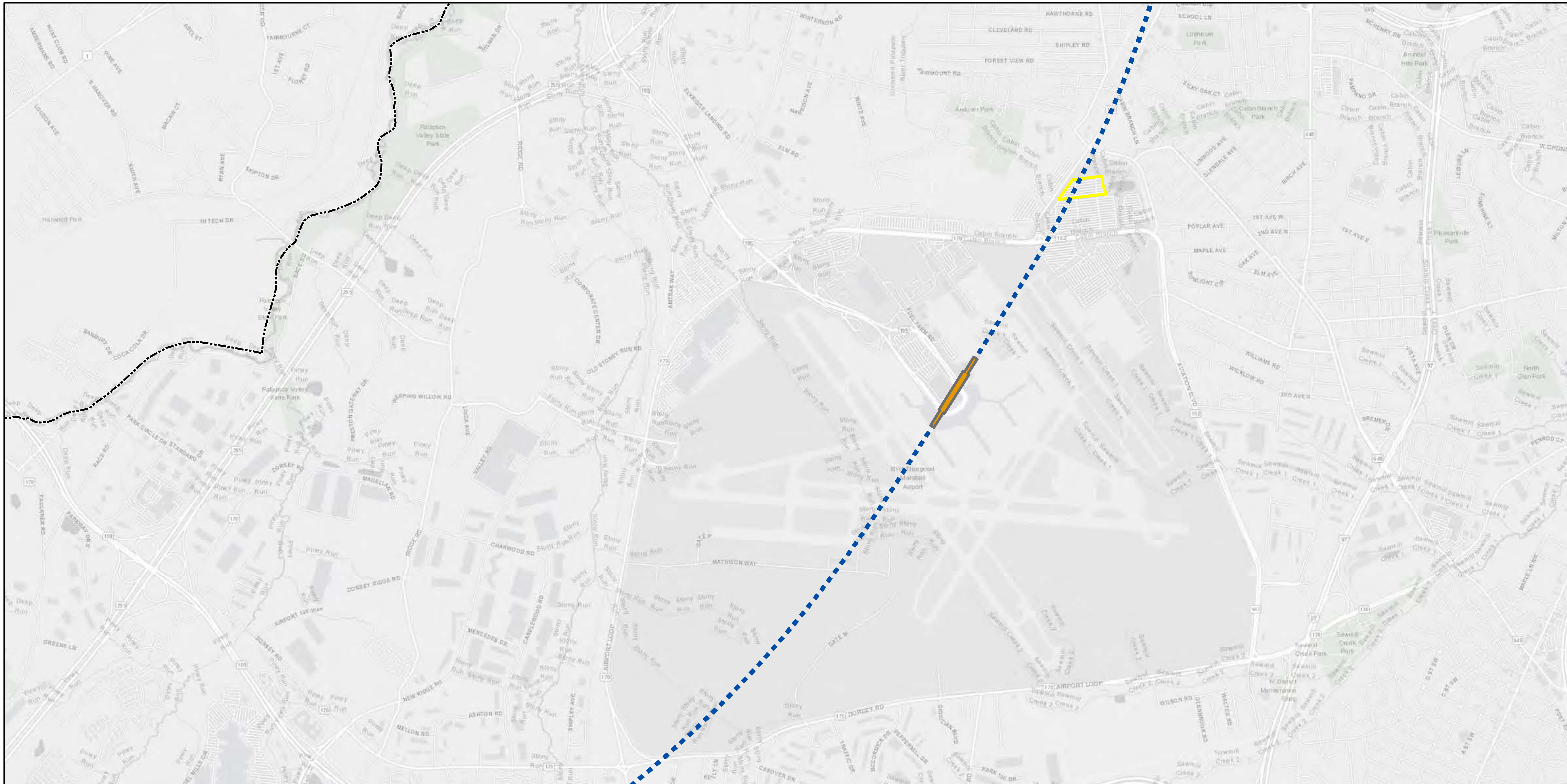
October 22, 2018

DC Station
Proposed Haul Route

BWRR Louis Berger

0 0.25 Miles

N

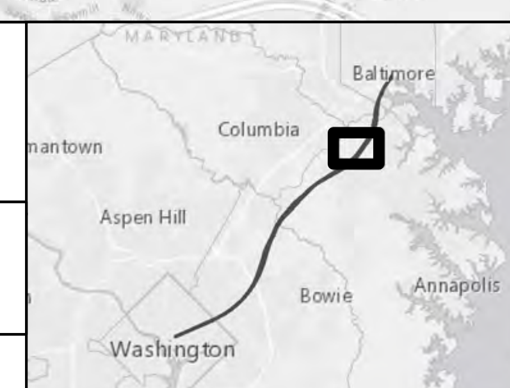


- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017),
BWRR (2017)

Coordinate System:
NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018



BWI Airport
Proposed Haul Route

BWRR Louis Berger

0 0.25 0.5 0.75 1 Miles
N

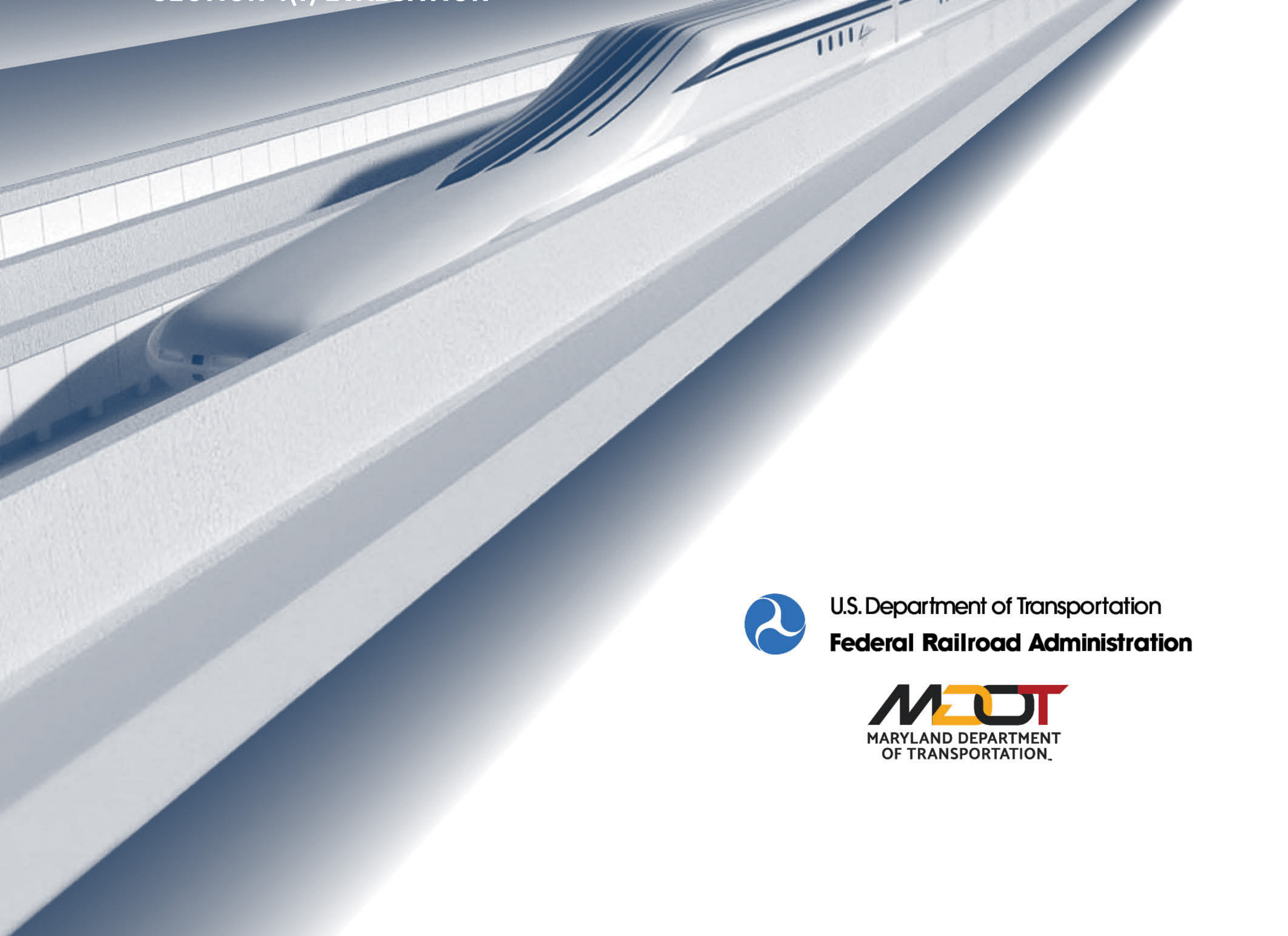
Appendix G14.

Public Transportation Impacts Memorandum

Materials Provided by the Project Sponsor

BALTIMORE-WASHINGTON SUPERCONDUCTING MAGLEV PROJECT

DRAFT ENVIRONMENTAL IMPACT STATEMENT AND SECTION 4(f) EVALUATION



U.S. Department of Transportation
Federal Railroad Administration

MARYLAND DEPARTMENT OF TRANSPORTATION

BALTIMORE-WASHINGTON SCMAGLEV PROJECT

PUBLIC TRANSPORTATION IMPACTS TECHNICAL MEMORADUM

4.3 PRELIMINARY ENGINEERING

REVISION.: 1

DATE: FEBRUARY 12, 2020

WSP

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TABLES

FIGURES

NOTES/REVISIONS FOR VERSION CONTROL

Revision 0: 2018-12-19

Revision 1: 2020-02-12

File Name: LB 4.3 SCMAGLEV Public Transportation Rev1

1. EXECUTIVE SUMMARY

This report assesses if the construction of the SCMAGLEV system would affect any existing bus routes operated by the Washington Metropolitan Area Transit Authority (WMATA), the Regional Transportation Agency of Central Maryland (RTA), the Maryland Transit Administration (MTA), the National Security Agency (NSA), the Department of Defense (DoD), Partners in Care, and the BWI Business Partnership. This assessment also includes the effect on existing light rail and commuter rail routes that are operated by the MTA.

The assessment determined that the SCMAGLEV station would affect 6 WMATA lines within Washington D.C., 8 MTA lines in Cherry Hill, 18 MTA buses in Camden Yards, the Baltimore Light RailLink routes, and the Camden Line of MARC Train Service.

The J Alignment would affect two WMATA lines, one RTA line, one BWI Business Partner shuttle, one Partners in Care shuttle (an NSA shuttle), and one DoD shuttle.

The J1 Alignment would affect one WMATA line and one RTA line.

2. PROJECT OVERVIEW

The Project involves the construction and operation of a revenue-producing high-speed SCMAGLEV system between downtown Washington, D.C. and downtown Baltimore, MD with an intermediate stop at BWI Airport, as seen in Figure 1.

Figure 1. Project Location

The Project addresses key challenges along the segment by alleviating traffic in one of the most congested regions in the country. The Project will provide reliable connectivity for the Baltimore-Washington travel market, offering a 15-minute service between the two cities that will be highly integrated into the existing transportation infrastructure. Construction of the alignment would temporarily impact public transit services crossing the alignment. The corridor has approximately 35 bus services and shuttles that cross the proposed alignment. These services are identified in Section 3.0 with potential mitigation plans described in Section 4.0. Alternative transit services that could be offered both during the construction of the alignment, and as a permanent addition to current public transit services, are identified in Section 5.0.

3. IDENTIFICATION OF IMPACTS

3.1 ASSESSMENT

This project will affect several modes of public transportation from Washington, D.C. (Washington), along the alignments, to Baltimore, MD. Understanding the modes affected will be key to lessening the impacts on normal daily commutes. These impacts are temporary, but would cause minor disruptions in service, including detours and/or delays, from an increase in traffic and congestion. An assessment of services showed that buses, both near the stations and along the alignment, will be the most impacted mode of public transportation. The tables below illustrate the routes that are affected by each alignment, as well as by each station. They also include information on the various public and private agencies offering service, a description of the location of the route, as well as the town and county closest to the route. Service is provided by a variety of agencies including WMATA, RTA, MTA, NSA, DoD, Partners in Care, and the BWI Business Partnership.

3.2 IMPACTED ROUTES

Table 1 summarizes bus routes that would be affected by the construction of the Mount Vernon Square East Station in Washington. These include the Georgia Avenue MetroExtra, Georgia Avenue – 7th Street, Convention Center – Southwest Waterfront, and East Capital Street lines. The Georgia Avenue MetroExtra line operates during rush hour and morning time from Monday to Sunday. The East Capitol Street line operates from Monday to Sunday during rush hour, morning and evening with extra service Monday to Saturday evening. These routes will need to detour as designated by WMATA. No major deviations in the route are anticipated with the construction of this station. Mount Vernon Square East Station construction detour plans have also been developed that WMATA can choose to follow. Two other WMATA routes might experience short-term affects from construction due to the routes traveling next to the 5th and 6th Street proposed station and underground parking areas.

Table 1. Mount Vernon Square East Station

County	Alignment	Town/District	Agency	Routes
Washington	J, J1	Mount Vernon Square	WMATA	<u>Crosses Construction Path:</u> 7th and New York Ave: 79,70, 74 New Jersey Ave and New York Ave: 96 <u>Travels adjacent to Construction Area</u> 5th and 6th Streets south of New York Avenue: D4 and P6

Table 2 summarizes bus routes and light rail routes that would be affected by the construction of the Cherry Hill Station in Baltimore. Affected bus routes include the CityLink Yellow line and several LocalLink lines that provide access to adjacent neighborhoods and downtown Baltimore. The impact also includes the MTA-operated Baltimore Light RailLink that provides passengers access to communities throughout the Baltimore metropolitan area. Bus routes adjacent to Patapsco Avenue and Annapolis Road will need to detour as designated by the MTA. No major deviations in the route are anticipated with the construction of this station. Cherry Hill Station construction detour plans have also been developed that the MTA can choose to follow. The construction of the Cherry Hill Station would also impact the Hunt Valley—BWI Marshall and Hunt Valley—Cromwell routes of the Baltimore Light RailLink. Construction of the SCMAGLEV Cherry Hill Station would impact rider access to the Cherry Hill Station of Light RailLink.

Table 2. Cherry Hill Station

County	Alignment	Town/District	Agency	Routes
Baltimore	J, J1	Cherry Hill	MTA	Waterview Avenue: LocalLink 26,69,70,71
Baltimore	J, J1	Cherry Hill	MTA	Patapsco Avenue: CityLink Yellow (YW) and LocalLink 29,71,73,75
Baltimore	J, J1	Cherry Hill	MTA	Annapolis Road: LocalLink 71, 73, 75
Baltimore	J, J1	Cherry Hill	MTA	Baltimore Light RailLink: Hunt Valley—BWI Marshall, Hunt Valley—Cromwell

Table 3 summarizes bus routes, light rail routes, and commuter rail routes that would be affected by the construction of the Camden Yards station in Baltimore. Affected bus routes include CityLink lines Brown, Green, Navy, Yellow, and Silver as well as several LocalLink lines. Four Commuter Buses would also be affected. These lines primarily provide routes to the Convention Center and would need to detour as designated by the MTA. No major deviations in the route are anticipated with the construction of this station. Camden Yards Station construction detour plans have also been developed that the MTA can choose to follow.

The MTA-operated Baltimore Light RailLink and MARC Train Service would also be impacted. The construction of the SCMAGLEV Camden Yards Station would impact rider access to the Camden Yards Station of Light RailLink. Construction of the station would impact the Hunt Valley—BWI Marshall and Hunt Valley—Cromwell routes of the Baltimore Light RailLink as well as the Camden Line of the MARC Train Service.

Table 3. Camden Yards Station

County	Alignment	Town/District	Agency	Routes
Baltimore	J, J1	Camden Yards	MTA	Convention Center: CityLink Yellow, Brown, Green, Navy, and Silver, LocalLink 51,54,65,67,76,94,103,120,154,160, Commuter Bus 320,410,411,420
Baltimore	J, J1	Camden Yards	MTA	Baltimore Light RailLink: Hunt Valley—BWI Marshall, Hunt Valley—Cromwell
Baltimore	J, J1	Camden Yards	MTA	MARC Train Service: Camden Line

Table 4 summarizes bus routes that would be affected by the construction of the J Alignment from Washington to Baltimore, excluding stations. These include the RTA's Town Centre Laurel/Arundel Mills line, the WMATA Laurel Express and BWI Thurgood Marshall Airport line, an NSA shuttle from the NSA headquarters to the Savage MARC station, the LINK shuttle from BWI Amtrak/MARC station to NSA Visitor Control Center (VCC), and the NSA Laurel – Fort Meade shuttle. The RTA lines operate Monday to Sunday during rush hour, morning and evening. The Link shuttle operates weekdays from 5:45 a.m. to 5:55 p.m. and arrives every 35 minutes. The NSA shuttle also only operates during the weekdays. These routes crossing the alignment would need to detour as designated by the RTA, WMATA, DoD, and private shuttle operators. The Alignment J construction detour plans have also been developed that WMATA, RTA, DoD, and private shuttle operators can choose to follow.

Table 4. J Alignment (Excluding Stations)

County	Town/District	Agency	Routes
Prince George's County	Laurel	WMATA	Powder Mill Road: 87, B30
Prince George's County	Laurel	RTA	197/Laurel Bowie Road: 301
Anne Arundel County	Laurel	BWI Business Partnership	32/Patuxent Freeway: Link Shuttle
Anne Arundel County	Laurel	Partners in Care	32/Patuxent Freeway: PIC NSA Shuttle
Anne Arundel County	Laurel	DoD	32/Patuxent Freeway: NSA Shuttle
Anne Arundel County	Russett	RTA	198/Laurel Fort Meade Road: 502

Table 5 summarizes bus routes that would be affected by the construction of the J1 Alignment from Washington to Baltimore, excluding stations. These include the RTA Laurel – Arundel Mills line, and the WMATA Laurel Express, the WMATA BWI Thurgood Marshall Airport line. The RTA line operates from Monday to Sunday during rush hour, morning and evening. The WMATA Laurel Express operates weekdays only during rush hour and evenings. The service to the airport is available Monday to Sunday during rush hour, morning and evening, and arrives every forty minutes. These routes that cross the alignment will need to detour as designated by the RTA and WMATA. The Alignment J1 construction detour plans have also been developed that WMATA and RTA can choose to follow.

Table 5. J1 Alignment (Excluding Stations)

County	Town/District	Agency	Routes
Prince George's County	Laurel	WMATA	Powder Mill Road: 87, B30
Prince George's County	Laurel	RTA	197/Laurel Bowie Road: 301

4. MITIGATION

4.1 MITIGATION PLANS

Mitigation for the affected routes listed above would be at the discretion of the relevant authority providing service. The bus routes would be redirected with minor detours based on the construction detour plans. Detour plans have been developed that the operating authority can choose to follow. Access to some light rail or commuter rail stations would be disrupted by the temporary severing of the lines that the stations service as a result of construction. The relevant authorities that operate those lines would be expected to offer riders a service such as free shuttles to connect riders between affected stations.

In addition to mitigation, an effort should be made to assist the transit agencies with the following services:

- Minimize congestion around the proposed stations,
- Provide alternative routes through and around station locations,
- Preserve current ridership and minimize disruptions to public transportation service,
- Educate transit ridership of modifications to service and expected delays,
- Optimize safety and convenience to the traveling public, and
- Maintain economic stability within the impacted areas.

5. PERMANENT CHERRY HILL TRANSIT SERVICE

5.1 SHUTTLES

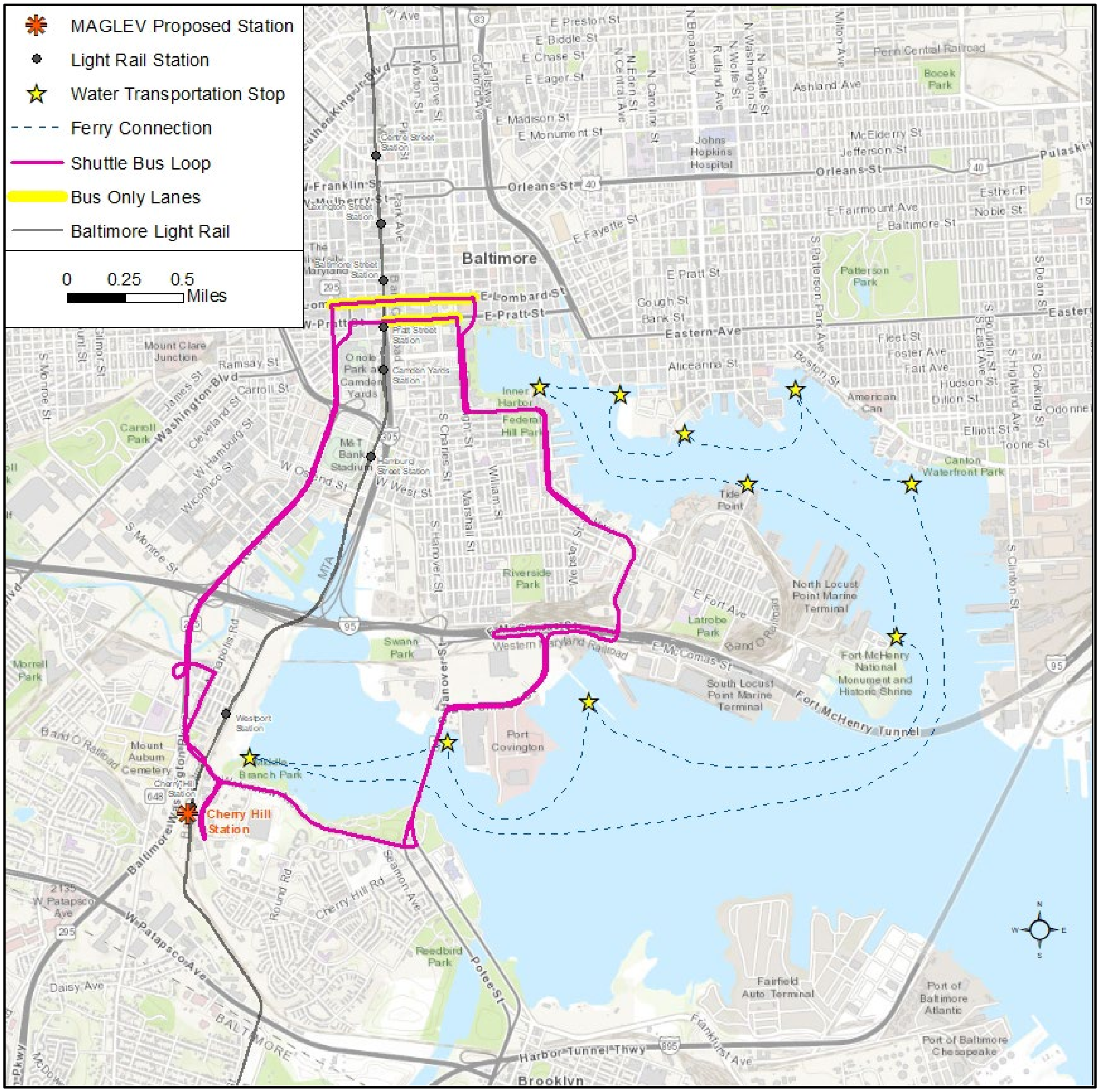
In order to provide more transit options between Cherry Hill and Inner Harbor, a shuttle bus loop was created. The shuttle could operate from 5 a.m. to 11 p.m., matching the SCMAGLEV operations with potential stops along Russell, Pratt, Lombard, and Light Streets, Key Highway, and a stop or two at Port Covington. Travel time from Cherry Hill to Inner Harbor would be 10-15 minutes depending on traffic. Assuming the city agrees, the buses should have full access to the existing bus lanes along Pratt and Lombard Streets to minimize delays when driving through the downtown area. Figure 2 below shows the proposed bus loop.

5.2 WATER SHUTTLE

A proposed high-speed water shuttle could potentially operate between the Cherry Hill waterfront and the Inner Harbor, with a dock adjacent to Light Street. This shuttle could provide express and local service. Frequent express service from the Cherry Hill waterfront direct to Inner Harbor would have approximately 12 and 15-minute travel times, based on a service speed of 32 knots (30-m.p.h.). Additional neighborhoods with water access could be added as stations in the future for a local service. Figure 2 shows the proposed ferry water stops and connections.

There are several examples of high-speed commuter ferries in the U.S. The Massachusetts Bay Transportation Authority (MBTA) operates the MBTA Harbor Express which provides commuter services between Hingham, MA and Hull, MA to Downtown Boston, and Boston Logan International Airport with high speed ferries that have a capacity of up to 150 passengers (MassDOT, 2017). The SeaStreak is a privately-operated ferry company that offers commuter services to and from Manhattan and New Jersey with high speed catamarans that have a capacity of up to 600 passengers and crew. Service speeds can be up to 39 knots (Workboat, 2018). The Golden Gate Ferry is operated by the Golden Gate Bridge Highway and Transportation District and operates seven catamarans for commuter routes from Larkspur, Sausalito, and Tiburon, to San Francisco. Three of the boats can carry up to 450 passengers while one can carry up to 750 passengers. Four of the catamarans have a service speed of 36 knots (GGBH&TD, 2020). A similar commuter service could potentially provide additional transit opportunities for the Cherry Hill Waterfront.

Figure 2. Shuttle Bus Loop and Ferry Connections



6. REFERENCES

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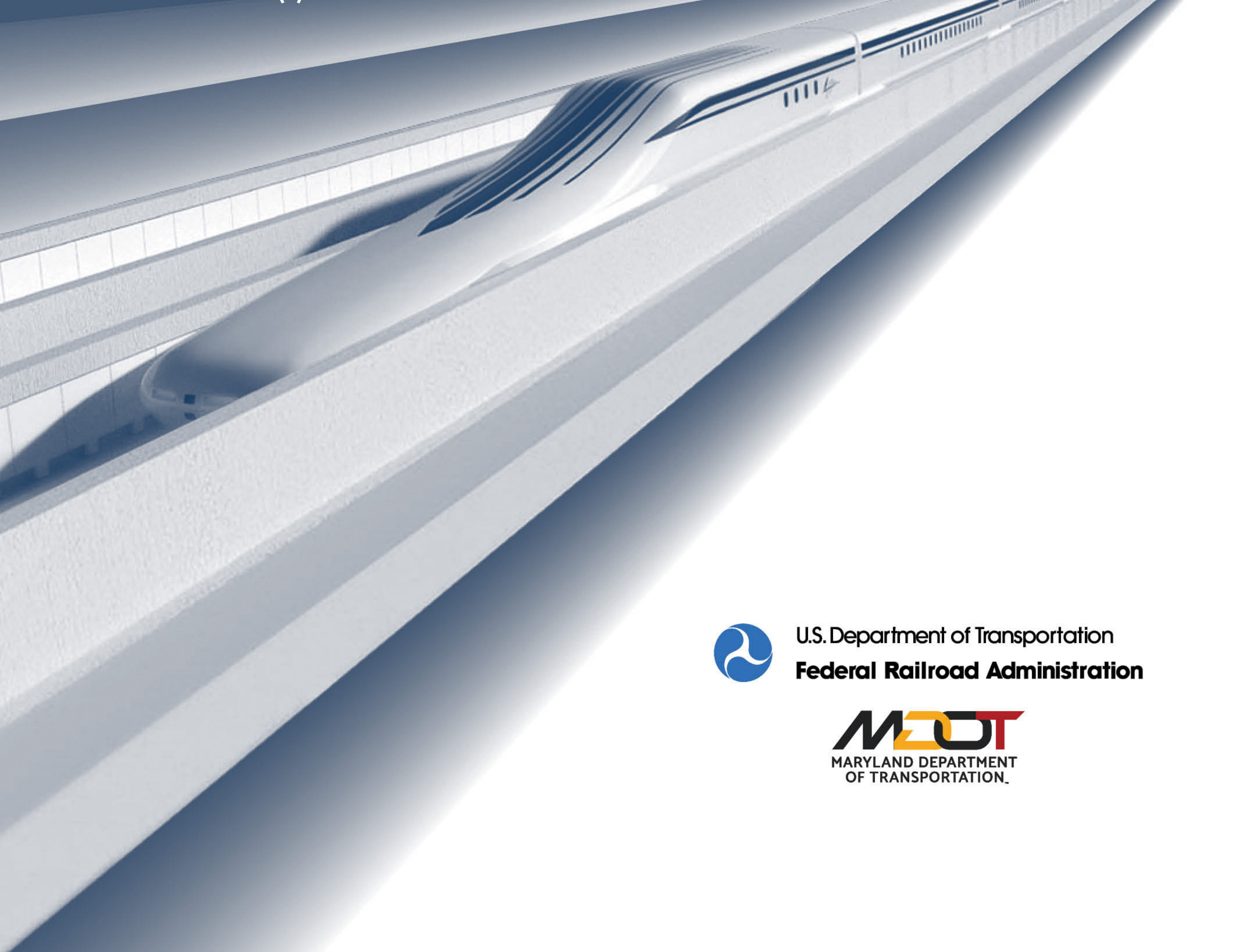
Appendix G15.

Operations and Maintenance Memorandum

Materials Provided by the Project Sponsor

BALTIMORE-WASHINGTON SUPERCONDUCTING MAGLEV PROJECT

DRAFT ENVIRONMENTAL IMPACT STATEMENT AND SECTION 4(f) EVALUATION



U.S. Department of Transportation
Federal Railroad Administration

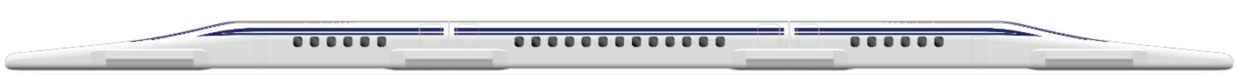
MARYLAND DEPARTMENT OF TRANSPORTATION

BALTIMORE-WASHINGTON SCMAGLEV PROJECT

OPERATIONS AND MAINTENANCE MEMORANDUM

REVISION: 1

Date: DECEMBER 10, 2020



BWRR

BALTIMORE-WASHINGTON RAPID RAIL

BALTIMORE-WASHINGTON RAPID RAIL

Baltimore Office
6 South Gay Street
Baltimore, MD 21202
(443) 759-8360

Memorandum

To: Shreyas Bhatnagar

From: Furqan Siddiqi

Re: Task #5

Date: **December 10, 2020**

This memo addresses FRA's data request #5, Annual O&M costs.

Based on a call with FRA on January 28, 2020, FRA agreed to accept an O&M staffing analysis in lieu of proprietary O&M cost information.

As such, BWRR is issuing this memo dated December 10, 2020, regarding SCMAGLEV operational economic estimates.

Memorandum

DATE: December 10, 2020

TO: Furqan Siddiqi and Kris Frederes, BWRR

FROM: Larry Pesesky

SUBJECT: SCMAGLEV Operational Economic Estimates

This memorandum presents the results of WSP's operational employment and operational economic impacts for the Baltimore-Washington SCMAGLEV project. The methodologies used to conduct the analyses precede the estimates.

Estimated Operational Impacts

Methodology

Direct employment for SCMAGLEV operations and maintenance was estimated by assessing the functional requirements of the various elements of the project once constructed. Preliminary estimates of staffing by function are assumed as follows (these numbers have been based on an evaluation of various other railroad manpower requirements and will be refined as Project planning advances and operating details are finalized):

- General Management & Administration – 40-50
- Security – 60-70
- Railway/Stations Operations – 290-310
- Rolling Stock Depot/Maintenance of Way – 300-320
- Total – 690-750

To estimate the net growth in jobs, labor income, gross regional product, and sales associated with operating and maintaining SCMAGLEV, an input-output modeling system (IMPLAN) was used. IMPLAN is a widely used and accepted input-output modeling tool. IMPLAN allows the user to generate area-specific multipliers that take into account inter-industry linkages and the relationships between industries and consumers across 440 sectors.

IMPLAN estimates the following effects associated with operations and maintenance spending.

- Direct: jobs, income, sales, and gross regional product created directly from the expenditures, such as hiring construction workers.
- Indirect: jobs, income, sales, and gross regional product created by secondary activity related to the expenditures, such as the jobs generated in the professional services industry in support of the larger construction project.
- Induced: jobs, income, sales, and gross regional product created by additional spending through the economy. These are the employment effects that occur when employees spend their wages in other industries, for example, retail purchases.

The employment and economic effects are calculated in IMPLAN using capture rates provided by IMPLAN based on trade-flows data and models.

Results

Operation and maintenance expenditures will generate permanent jobs in the rail industry and its supplying industries. Household spending by workers in the rail industry and supplier industries will generate additional jobs throughout the region. The operations and maintenance economic benefits (direct – the 690-750 listed above, indirect, and induced) are summarized in Table 1.

Table 1. Estimated Operations & Maintenance Economic Benefits

Employment	Gross Regional/Domestic Product (million)	Economic Output or Sales (million)
1,350 -2,080	$115-$145	$330 - $520