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USACE / NAVFAC / AFCEC **UFGS-31 71 19 (November 2022)**

Preparing Activity: USACE **New**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2025
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11/22

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SECTION 31 71 19

TUNNEL AND SHAFT EXCAVATION IN ROCK - MECHANICAL
11/22

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NOTE: This guide specification covers the requirements for tunnel excavation for underground construction by mechanical excavation using Tunnel Boring Machine (TBM), roadheader, or hydraulic rock breaker. This specification is currently for use in tunnel excavation in bedrock conditions. For mixed-face or soft ground tunneling conditions (i.e., soil-like conditions), revise specification to account for anticipated ground conditions for appropriate equipment selection and methods of ground support and groundwater control. The term "mining" is often used synonymously with "excavation" for underground construction applications. Where the construction of an underground cavity is the primary purpose, the term "excavation" is more appropriate, and is used herein.

For localized ground conditions including fault zones or other specialized ground conditions, revise specification to account for rock characterization conditions identified in the Geotechnical Baseline Report or other geotechnical design documents where the rock mass is characterized. This specification can be modified for micro-tunneling applications; however, exercise care for Execution requirements. This section was originally developed for USACE Civil Works projects.

For underground construction and tunnel excavation requiring drill and blasting methods, include guide specification 31 23 00.00 TUNNEL EXCAVATION - BLASTING.

For projects on a naval facility, consult with local NAVFAC office, and NAVSEA on requirements.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing

this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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PART 1 GENERAL

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NOTE: For USACE: Consult with Subject Matter Experts (SME) from the Geotechnical Engineering, Structural Engineering, Engineering Geology, and Materials Community of Practice or District Office that have completed a similar type of underground construction project, while editing this section, to be appraised of recent, specific requirements, guidance, excavation methods, lessons learned, or understandings for the subject project.

Consult with or have Specification reviewed by Subject Matter Experts in Underground Construction for projects involving Tunnel Excavation as a primary component of a project, or where Underground Construction issues are particularly challenging. For a Tunnel Excavation project in the vicinity of a dam or levee, Subject Matter Experts in Dam and Levee Safety must review the Specification.

There are likely decisions and/or requirements of other agencies, the Safety Manual, and/or internal offices/divisions/ branches, which could have an influence upon a project's underground construction specifications. Some of these issues may be: concerns from federal, state, and local jurisdictions and agencies; public use of federal, state and/or local properties near or adjacent to the project; evaluations of acceptable construction vibrations, noise and/or pressures affecting individuals or reaching nearby structures; natural resource impact reviews, negotiations and/or requirements; constraints on the excavation means and methods; pre-construction inspections; special studies to facilitate lower cost of the bids or to encourage more bid submissions; the acquisition strategy for the payment for the project; and, other concerns specific to the project. Depending on the acquisition strategy, a Design Bid Build or Design Build will require adequate up-front planning and tailoring of specifications depending on strategy

This Tunnel Excavation guide specification covers the construction of underground facilities by means of mechanical excavation by Tunnel Boring Machine (TBM), or other mechanical excavation such as roadheader or hydraulic breaker, and includes mucking. The details on excavation are typically covered by a separate Rock Excavation specification depending on the contract mechanism used. Tailor this specification for your specific project needs

The following minimum requirements for project information will be indicated on the project drawings:

1. Surface elevations, existing and proposed, with reference datums provided for vertical and horizontal coordinates.

2. All utilities, whether trenched, buried, at the surface or overhead to distances well beyond the project's boundary limits;

3. Spatial location and record of all soil and rock borings and test pits, instrumentation, geologic mapping, and geophysical surveys including soil and rock classifications and the pertinent engineering properties. For example, this data may include, but is not limited to, weathered rock, material strength, bit drops, circulation loss, voids, ground water observations, SPT, Recovery, RQD, RMR and Q System rock mass classification systems, lab testing results, permeability, stratigraphy, geologic features and structure, faults and other significant discontinuities, and topsoil thickness encountered in borings and mapped surface exposures. (NOTE: This is a list of examples of data pertinent to the tunnel design that may be provided in the project drawings or GBR/GDR but does not include all possible engineering properties or conditions of soil and rock that characterize a specific site.);

4. Hazardous gases, such as methane are a concern. As well as coal seams, coal lenses, abandoned gas/oil wells, or gas lines shown on the appropriate drawings.

5. Reference to project Geotechnical Data Report (GDR), Geotechnical Interpretation Report (GIR) and/or Geotechnical Baseline Report (GBR) for additional site characterization information not contained on the project drawings.

6. Location and limits of hard material, whether rock or concrete, or other building materials;

7. Excavation or demolition limits, and clearing, stripping and grubbing limits, and tolerances of excavation;

8. Location of borrow and disposal area, if located on Government property; or on site (as some sites may or may not remain government property, and disposal sites may be under control of project partners);

9. Hydrological, hydraulic and impoundment data, where applicable;

10. Details of all rights-of-way within the project boundaries; and

11. History of relevant construction, earthwork, and any environmental conditions of potential concern at the site.

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NOTE: Typical Measurement and Payment language is to be inserted into the Measurement and Payment specification section. This is typical language used that will need to be tailored for the project needs.

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1.1 METHOD OF MEASUREMENT

Tunnel support for the various support categories must be measured and paid by the individual components comprising each support category (e.g., Rock Bolts, Dowels, High-Capacity Anchors, Steel Arch Ribs, Welded Wire Fabric, Shotcrete, Reinforced Concrete), under their respective specification or special provision section.

Tunnel Excavation must be measured by the[meter][cubic meter][linear foot][cubic yard] excavated in accordance with the 'B' line payment limit shown on the Drawings. Tunnel drainage must be measured and paid under Section 01 20 00 PRICE AND PAYMENT PROCEDURES.

1.2 BASIS OF PAYMENT

The accepted quantities measured as specified above must be paid for at the contract unit price for the pay items listed below.

Pay Item	Pay Unit
Tunnel Excavation	[Meter][Cubic Meter][Linear Foot][Cubic Yard]

Payment for Tunnel Excavation must constitute full compensation for all excavation, scaling, scaling reports, rock support, removal, hauling and disposal of excavated materials, air monitoring and ventilation and illumination, instrumentation and stability monitoring, survey control, control of water and groundwater inflow including groundwater testing, supply of potable water, safety, supervision and management coordination, control and oversight of said work, and all other work necessary for completion of the tunnel in accordance with the Contract Documents.

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NOTE: The coordination with other federal, state,

and local jurisdictions and agencies, the public, and private entities must be completely resolved before finalizing the specifications. A project's excavation and/or foundation requirements, for which, dense materials are being removed, may require navigation, highway, structural and/or other regulations and codes to be followed. Depending upon the proximity of public-use areas, private residences or businesses, and the project's location within a county or township, various accommodations will need to be required for the protection of the public, and the safety of private entities regarding local laws, regulations, and ordinances. Avoiding natural resource impacts may overlay other measures and require seasonal or daily time limitations; special observers for some or all the underground construction work; special studies or monitoring; and other potential considerations.

Agency coordination will vary by project. Be certain that all government stakeholders have been involved with planning of the project and approved of all requirements for the specifications. List those important navigation or safety stakeholders.

It is essential that the agency/service person, using these Guide Specifications to prepare Plans and Specifications, coordinate with the planners and environmental compliance specialists within their agency/Service to ensure that all appropriate restrictions and mitigation measures for hazards associated with tunnel excavation and underground construction are incorporated into the Plans and Specifications. Failure to comply with the requirements of applicable Federal or state laws and regulations could result in project delays or stoppages, as well as the potential for increased project costs.

****

1.3 SCOPE

This work consists of excavation and disposal of all material within the rock tunnel limits indicated on the plans, in accordance with these specifications and in conformity to the lines, grades, stations and tolerances shown on the plans or as established in the field by the Contracting Officer. Also included is the initial design support and tunnel reinforcement requirements for the rock tunnel to maintain the inherent strength and control deformations of the ground surrounding the tunnel opening. In addition, the work also includes geotechnical instrumentation for monitoring rock displacement and water management in the tunnel, including but not limited to: furnishing, installing, and monitoring of instrumentation and optical survey targets in the tunnel, collection and interpretation of data and furnishing all other necessary material, equipment and labor incidental to such work, [furnishing of optical survey targets][furnishing of weirs and flumes to measure ground water inflow and outflow], including installation and monitoring of instruments in accordance with the specifications. The Contractor's qualified staff must monitor all geotechnical instrumentation and

interpret the data obtained from them, performed in a timely manner to ensure that potential safety issues are identified and effectively mitigated. The data must be made available to the Contracting Officer upon request or otherwise required per specification.

1.4 RELATED WORK SPECIFIED ELSEWHERE

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NOTE: These specifications for related work specified elsewhere are not all inclusive. Add and remove specifications as needed for the project.

List any specifications that are related, such as Earthwork, Excavation, Soil and Rock Anchors, Temporary Environmental Controls, Shotcrete, Natural Resources, are typical specs related depending on the project.

The specifications without numbers listed below presently do not have a corresponding UFGS Guide Specification. The designer will need to write a project-specific specification to address those features of work, if needed.

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Section 01 20 00 PRICE AND PAYMENT PROCEDURES
Section 01 35 26 GOVERNMENT SAFETY REQUIREMENTS
Section 01 33 00 SUBMITTAL PROCEDURES
Section 02 32 13 SUBSURFACE DRILLING AND SAMPLING
Section 03 30 00 CAST-IN-PLACE CONCRETE
Section 03 37 13 SHOTCRETE
Section 31 00 00 EARTHWORK
Section 31 23 06.00 BLASTING - SURFACE
Section 31 68 13 SOIL AND ROCK ANCHORS
Section 31 73 19 TUNNEL AND SHAFT GROUTING
[Section XX XX XX GEOTECHNICAL AND STRUCTURAL INSTRUMENTATION]
[Section XX XX XX GEOTECHNICAL DATA]
[Section XX XX XX GROUNDWATER TREATMENT SYSTEM]
[Section XX XX XX REINFORCING STEEL]
[Section XX XX XX SURVEYING AND LAYOUT]
[Section XX XX XX TEMPORARY ELECTRICAL SYSTEMS]
[Section XX XX XX TEMPORARY LIGHT AND POWER]
[Section XX XX XX TUNNEL AND SHAFT DEWATERING]
[Section XX XX XX TUNNEL EXCAVATION SUPPORT]

1.5 REFERENCES

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NOTE: Add and remove references as needed for the project. Reference the appropriate state and local laws, regulations and ordinances concerning blasting where the project is to occur.

This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D2487	(2017; E 2020) Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D5434	(2012) Field Logging of Subsurface Explorations of Soil and Rock
ASTM D6032/D6032M	(2017) Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core

INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

ISEE PSBS	(2017) ISEE Performance Specification for Blasting Seismographs

U.S. ARMY CORPS OF ENGINEERS (USACE)

EM 385-1-1	(2024) Safety -- Safety and Occupational Health (SOH) Requirements
EM 1110-1-1804	(2001) Engineering and Design -- Geotechnical Investigations
EM 1110-2-1009	(2018) Engineering and Design -- Structural Deformation Surveying
EM 1110-2-2901	(1997) Engineering and Design -- Tunnels and Shafts in Rock

1.6 RELATED ATTACHMENTS AND SPECIFICATIONS

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NOTE: Geotechnical Data Report (GDR) and Geotechnical Baseline Report (GBR) Importance. Project-specific site data should be presented in Geotechnical Data Report (GDR); design interpretations of the expected subsurface conditions and expected behavior should be presented

in the Geotechnical Baseline Report (GBR). GDR/GBR data must be consistent with information presented in the project specifications and drawings without conflict. Agencies may require different types of documents; there may be a Geotechnical Interpretive Report (GIR).

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"Geotechnical Data Report" (GDR) dated [_____], prepared by [_____].

"Geotechnical Baseline Report" (GBR) dated [_____], prepared by [_____].

"Geotechnical Interpretive Report" (GIR) dated [_____], prepared by [_____].

1.7 DEFINITIONS

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NOTE: Delete definitions that will not be used in the specification text for a specific project. A complete list of frequently used tunneling terms can be found in Appendix B of the EM 1110-2-2901 and other references. Recommend only including definitions not already referenced in the EM and definitions to further define the work on the specific project in the specification. It may be necessary to add definitions depending on what the Earthwork and/or Excavation specifications for the project have terms for Rock, Weathered Rock, Sound Rock, Voids, or Sediment. The same rock classification terms and definitions used in design should be carried through construction to avoid ambiguities and conflict.

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[1.7.1 Green Concrete

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NOTE: If no concrete placement is expected on the project, then delete this definition. There needs to be limits on vibrations when there is green concrete because of the strength loss due to vibrations while curing. Involve the Structural Engineer project development team members in these determinations.

****

Concrete that has undergone initial setting but has not hardened to design strength. Green concrete also includes the materials of shotcrete or cementitious grouts. Note the paragraph Green Concrete.

]1.7.2 Vibrations

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NOTE: Velocity units are expressed in centimeters per second (cps) or inches per second (ips). Tailor this for project purposes. Frequency of vibration is also a factor of potential concern to be measured with PPV.

****

Vibrations are the result of various wave forms emanating from the source. Peak particle velocity (PPV) and associated frequencies are defined as the maximum absolute value of the three ground vibration velocities measured in the three mutually perpendicular directions along the vertical, longitudinal, and transverse plane over the period of a record by a seismograph, capable of producing a permanent record and capable of internal dynamic calibration. Peak, total vector-sum particle velocity is the peak value over the full-time history of each time-unit's value of the square-root sum of the squared, component velocities.

1.7.3 Initial Support

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NOTE: In addition, the initial support systems indicated on the drawings for additional openings in the tunnel, must form part of the Permanent Support.

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The support system installed after an excavation advance within the tunnel forward area to minimize ground deformation and loosening and to maintain stability and safety of the opening. Provide initial support to minimize ground movement and loosening and to maintain stability of the opening prior to construction of the permanent rock reinforcement/support and tunnel lining. Initial support generally refers to all elements of rock support required to provide a safe, stable rock excavation at all times during construction. Initial support measures include but may not be limited to [_____],[rock bolts and dowels for rock reinforcement], [shotcrete lining], [steel ribs], [timber blocking], (cribbing), (lagging), (chemical grout), [spiling or forepoling], [steel straps], [lattice girders], [welded wire fabric], [shotcrete], and [pre-reinforcement].

1.7.4 Additional Support

May include rock bolts and dowels, crib and lagging, steel straps, spot-holds, steel sets, steel liner plates, chemical grout, shotcrete and pre-reinforcement spiling in addition to the initial support types and quantities for the support categories as shown on the Contract Drawings to stabilize rock and provide water control. Install additional ground support measures as conditions warrant for local stabilization and safety during tunneling operations.

1.7.5 Final Lining

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NOTE: Tailor this paragraph to the type of final lining for the project, this may be a cast-in-place or precast reinforced concrete liner, steel liner that is backfilled with contact grout, or left unlined, maybe with shotcrete or reinforced (steel fiber) shotcrete or other.

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[Cast-in-place reinforced concrete, steel] lining that is placed after the tunnel has been excavated and supported with initial support. Backfill concrete and contact grout are also included in the final lining.

1.7.6 Design (Excavation) Line

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NOTE: This nomenclature should be defined during the development of the plans and specifications as it will be specific for each project.

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A line defined as that completed excavation surface/line within which no unexcavated material must remain. Only shotcrete, structural steel rib supports with limited blocking, rock bolts or dowels, including bearing plates and metal hardware, and tie rods may extend beyond the design line as shown on the Drawings. The minimum concrete cover over these elements is shown on the Drawings. Embedments shown on the Drawings within the design line must be placed as shown. The Contractor may select the size of the excavated opening provided that finished minimum excavation tolerances are maintained and the design line requirements and diameter constraints given in this section are satisfied.

1.7.7 A-line (Theoretical Excavation Line)

The A-line, shown in the contract drawings, is the line within which unexcavated material must not be permitted to remain.

1.7.8 B-line (Pay Line)

The B-line shown in the contract drawings is the outside limit to which measurement for payment for excavation must be made. Excavation beyond the B-line must be avoided and will be at the Contractor's expense unless approved by the Contracting Officer.

1.7.9 Heading

A wall of unexcavated rock at the advance end of a tunnel (synonymous with the term "Face"). Also use to designate either a small tunnel or a small tunnel driven as part of a larger tunnel.

1.7.10 Face

The position of the underground works that has been advanced the furthest for the respective section of the overall construction sequence adopted for the tunnel, adit or shaft. Also referred to as "Working Face" or "Heading."

1.7.11 Fissure Grouting

Is the drilling and grouting of holes, including in advance of the face being excavated, in order to seal off water passages or solidify discontinuities or other areas of jointed or fractured ground intercepting the underground works, which if left untreated could lead to instability of the tunnel excavation. Also referred to as "Pre-Grouting."

1.7.12 Forward Area

Is that area within which the initial ground support is to be installed behind the heading in the vicinity of the face, also referred to as spilling or forepoling (depends on rock mass conditions, stand up time, and heading advance rate).

1.7.13 Intermediate Jacking Station

A fabricated steel cylinder fitted with hydraulic jacks that is incorporated into a pipeline between two pipe segments. Its function is to distribute the jacking load over the pipe string on long drives.

1.7.14 Length of Advance Interval

Length of the unsupported span of exposed ground opened up during one excavation increment (depends on rock mass conditions, stand up time, and heading advance rate).

1.7.15 Overbreak

The amount of ground unintentionally removed beyond the pay line, or B-Line. Minimize overbreak, reduce excessive rock removal or over-excavation.

1.7.16 Micro-Tunneling

Trenchless construction of small diameter tunnel used to construct utility tunnels from approximately 0.5 to 4m 1ft 8in to 13ft 1in in diameter and remotely operated.

1.7.17 Over-Excavation

Excavation of ground beyond the theoretical excavation line, or A-Line.

1.7.18 Pipe Jacking

A one-pass tunneling method by which a pipe string with the leading edge directly behind the TBM is pushed forward as the tunnel advances and will serve as the tunnel support and carrier pipe.

1.7.19 Probe Hole

An exploratory hole drilled in advance of an excavation to explore ground conditions or water infiltration conditions. Supplemental probe holes are those installed in addition to the probe holes shown on the Drawings or required herein and at the direction or approval of the Contracting Officer.

1.7.20 Scaling

Consists of barring, wedging, and picking to remove loose, shattered, or unstable pieces of rock around the heading advance. Individual pieces not in accordance with the specified tolerance must also be removed during scaling. Scaling may be performed manually or with mechanical equipment depending on tunnel configuration and safety considerations.

1.7.21 Shotcrete

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NOTE: EM 1110-1-2907 Rock Reinforcement, Chapter 6 Surface Treatment provides guidance on shotcrete (wet and dry mix) applications.
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Mortar or concrete conveyed through a hose and pneumatically projected

at high velocity onto a surface.

1.7.22 Staged Excavation

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NOTE: Advancing multiple headings is often performed in poor ground or for larger final tunnel dimensions, where a top (left and/or right) heading is advanced, supported, then the other heading or bench removed, potentially also removing the center support system separating the headings.
****

Sequence of excavation by which the final excavation is divided into a group of smaller drifts, also referred to as slashes and cuts, or top heading and bench.

1.7.23 Support Type

Method of excavation and initial ground support defined in the Drawings for use at a particular location.

1.7.24 Tights or Underbreak

Projections of rock in a tunnel inside the minimum excavation profile (A-line) that need to be removed prior to placement of lining.

1.7.25 Tunnel Boring Machine (TBM)

A mechanized, shielded machine that is steerable, guided, and articulated. The TBM may be operated and steered either from within the machine or remotely.

1.7.26 Backfill Tunnel Grouting

Filling the annular space between the pipe string and the excavated ground.

1.7.27 Water Sheet and Drain Hose

Sheeting and drain hose used to collect and pan off ground water from areas at either the excavated surface behind the shotcrete lining or to collect and drain seepage through the shotcrete lining.

****
NOTE: The following restrictions apply to tunnel excavation methods using Tunnel Boring Machine (TBM) only. Tunnels may be excavated and supported using a continuous or incremental excavation-observation-support approach to provide the necessary and justifiable levels of ground control and permanent stabilization.
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1.7.28 Adit

A horizontal passage for the purpose of access or drainage. Supplemental to the main tunnel heading and typically shorter in length.

1.7.29 Roadheader

A mechanical excavator consisting of a rotating cutterhead mounted on a boom; boom may be mounted on wheels or tracks or in a tunnel boring machine.

1.7.30 Hydraulic Breaker

Hydraulic operated rock breaker, also known as a percussion hammer or hydraulic impact breaker, mounted on heavy duty excavator or backhoe with point tools selected for impact rock breakage in tunnel or rock slope excavation.

1.7.31 Reverse Circulation Drill

Method of drilling using combined rotary drill and pneumatic reciprocating piston (hammer) action, with dual wall drill rods consisting of an outer drill rod with an inner tube. Hollow inner tubes allow drill cuttings to be transported back to the surface. Can be used for shaft excavation in rock within certain limits of maximum shaft diameter.

1.7.32 Stand-Up-Time

The amount of time the tunnel will support itself without any added support structures. The time that elapses between the exposure of rock or soil in a tunnel excavation and the beginning of noticeable movements of the ground.

1.8 RESTRICTIONS

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NOTE: Revise these requirements to accommodate project-specific constraints based upon variables such as ground conditions, locations of adjacent structures, construction vibration criteria, ordnances, or other requirements.

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The use of a staged excavation approach with integral, concurrent initial support and permanent stabilization of the tunnel periphery is fundamental to the successful execution of the project and recognizes that tunnel spans of different dimensions must be developed in variable and fractured rock mass conditions.

Do not begin tunnel excavation until the following conditions have been met:

1. Required submittals as listed in Paragraph SUBMITTALS have been made and the Contracting Officer has reviewed and approved the submittals.

2. Pre-construction inspections near the tunnel excavation have been completed by the Contractor and pre-construction documents have been provided to Contractoring Officer.

3. Installation of geotechnical and structural instrumentation for surface structures and ground near the tunnel excavation alignment have been completed and initialized by others.

4. All issues related to health and safety have been met and all

submittals have been made in accordance with OSHA requirements, EM 385-1-1, and other applicable codes and regulations of Federal, State, and local agencies having jurisdiction.

5. Required personnel with qualifications specified in paragraph TUNNELING PERSONNEL are available on site to perform work.

6. Temporary construction power substation has been installed and tested in accordance with the Division 16 specifications.

7. Installation of all vibration monitoring and air quality equipment with required background monitoring completed.

1.9 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

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NOTE: The following Submittal requirements are for tunnel excavation using any excavation methods and should be included in all project specifications.

Several other considerations include Tunnel and Confined space rescue team training and setting up an independent emergency communication lines within the tunnel. The requirements for safety will need to comply with EM 385-1-1 and additional requirements included in safety section. If the local fire department is not trained in confined space tunnel or mine rescue, they may have to be trained in confined space tunnel/mine rescue procedures prior to excavation of tunnel or a private specialty company can be hired for rescue services as required by local, state, and federal work ordinances.

Haul routes for muck disposal can also be an issue in densely populated areas. Haul routes may need to be coordinated with local and state officials as required by local ordinances.

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Power Supply Requirements and Anticipated Power Source(S); G, [_____]

Dust Suppression System; G, [_____]

Muck Removal System; G, [_____]

Method and System For Maintaining Line And Grade; G, [_____]

Pre-Construction Surveys; G, [_____]

****

NOTE: The section below should be used when excavating near vibration sensitive equipment.

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SD-03 Product Data

Manufacturer's Specifications; G, [_____]

Seismographs; G, [_____]

Roadheader; G, [_____]

SD-05 Design Data

Tunnel Excavation Plan; G, [_____]

Ventilation Plan; G, [_____]

SD-06 Test Reports

Daily Records

Drilling Logs

Post-Construction Surveys; G, [_____]

Individual Vibration Monitoring Report; G, [_____]

SD-07 Certificates

Certification from the Roadheader Manufacturer; G, [_____]

Tunneling Superintendent and Supervisors; G, [_____]

Professional Engineer or Professional Geologist; G, [_____]

TBM Operators and Mechanics; G, [_____]

Vibration Monitoring Specialty Firm; G, [_____]

Structural Condition Assessment Inspection/Evaluation Technician; G, [_____]

Roadheader; G, [_____]

SD-10 Operation and Maintenance Data

Manuals for Operation and Maintenance; G, [_____]

1.10 COORDINATION

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NOTE: The following paragraph can be used if working with multiple stakeholders/owners.

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Underground construction methods will be in the vicinity of the [existing lock, railroad, and highway, and river barge, train, hospital highway traffic, utilities and businesses] and their operation will not be impeded or delayed beyond that which has been coordinated with TVA, U.S. Coast Guard, U.S. Army Corps of Engineers - [_____] District, [_____] environmental or natural resources offices, [_____] Department of Transportation, local government entities, [[_____] Railroad, regional or local utilities, and/private businesses]. Include a coordination and traffic control with the appropriate authorities that mitigates navigation and traffic delays.

Coordinate, through the Contracting Officer, with other Contractors working onsite to minimize work stoppages during tunnel excavation.

1.11 LIABILITY

Compliance with provisions in the contract will not relieve the Contractor of their responsibility for damages or injuries caused by, related to, or arising out of tunneling or associated activities. The Contractor assumes all liability and hold and save the Government, its agents, officers, and employees harmless for all claims for personal injuries, property damage, or other claims arising out of or in connection with, under this contract.

PART 2 PRODUCTS

2.1 SAFETY EQUIPMENT

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NOTE: This section requires tailoring for the specific project design, geology, and site conditions.
****

a. Provide safety equipment and monitoring instruments according to requirements of Safety and Health Plan in accordance with Section 01 35 26 GOVERNMENT SAFETY REQUIREMENTS, to be included in the Materials Handling Plan as required in Section 01 33 00 SUBMITTAL PROCEDURES.

b. Provide personal protective equipment for protection against respirable dust, and all other protective measures that may be deemed necessary for dust control as per Federal Requirements. Submit the details of the Dust Suppression System.

c. All rock reinforcement, including spiling and other ground support in accordance with the requirements set forth in Section 31 68 13 SOIL AND ROCK ANCHORS and 03 37 13 SHOTCRETE.

d. Lattice girders and shotcrete lining must be in accordance with the requirements of [Section XX XX XX TUNNEL EXCAVATION SUPPORT], and Section 03 37 13 SHOTCRETE.

e. Steel sets must be in accordance with the requirements of [Section XX XX XX TUNNEL EXCAVATION SUPPORT], and [Section XX XX XX REINFORCING STEEL].

f. Shotcrete materials must be in accordance with the requirements of Section 03 37 13 SHOTCRETE.

g. Water sheet and drain hoses as part of temporary construction measures to drain off local water inflows:

(1) . PVC sheet, or approved equal by the Contracting Officer, for application at exposed ground surface or shotcrete surface.

(2) . Flexible PVC hose with end couplings as required

2.2 PROBEHOLE DRILLING EQUIPMENT

A continuous probe must be maintained at [_____] meters [_____] feet, or least [_____] tunnel diameters ahead of the tunnel face. If the probing results indicate the presence of poor ground requiring the installation of pre-reinforcement, the Contractor must adjust as necessary to achieve the required excavation profile prior to excavating through the anticipated poor ground. During the probing operation the Contractor must monitor and measure the amount of in-flowing water.

Probe hole drilling equipment must be capable of drilling a minimum [_____]-inch diameter holes through sound and decomposed rock [and concrete]. Provide all necessary probe hole drilling personnel, equipment, and accessories.

****

NOTE: Designer of record to provide input on the flow pressures for packer tests. Consideration must be taken by reviewing other available data such as piezometers, pressure cells, rock mass features.

****

The drill must be suitable for drilling in wet ground conditions, highly sheared or fractured zones, and through fault gouge. The drilling equipment must be capable offsetting packers in the hole against a pressure of [_____] kg/cm^2 [_____] psi.

2.3 ROADHEADER

****

NOTE: The following Submittal requirements for Roadheader should only be included if this method of mechanical excavation will be employed on the project.

****

Conform to Section 01 33 00 SUBMITTAL PROCEDURES. Submit for review at least sixty (60) days before the start of excavation with the roadheader(s) the following:

a. Make and model number, manufacturer's specifications, and manuals for operation and maintenance.

b. Certification from the roadheader manufacturer that the proposed machine(s) can excavate the anticipated rock conditions as described in the Contract Documents at a rate sufficient to meet the project schedule.

c. Power supply requirements and anticipated power source(s).

d. Details of dust suppression system.

e. Details of muck removal system.

f. Details of method and system for maintaining line and grade.

g. For refurbished (used) machines, in addition to the information required herein, submit the following additional information: maintenance record(s) and description of last three (3) projects, including rock types excavated, advance rates, total operated hours, and rebuild records of major components.

2.4 TUNNEL BORING MACHINE (TBM)

****

NOTE: Accurate TBM performance estimation is critical for construction schedule and cost development for any mechanical tunneling. The selection of an appropriate TBM for excavation conditions at a site depends on rock properties, rock mass characterization and machine specifications anticipated along the tunnel alignment. TBM parameters including thrust and

power, as well as cutter disk spacing and layout together with the anticipated rock material properties and rock mass characteristics are main parameters used for TBM performance estimation. Therefore, these key parameters should be quantified carefully along any tunnel alignment for any type of hard rock TBM projects. These conditions should be defined in the project GDR/GBR and/or GIR. The impact of these factors on TBM performance cannot be understated. Significant detail should be given to joint and fracture systems within the rock mass. The fracture systems should be classified and quantified by using fracture class designation system. Orientation of discontinuities via alpha angle and distance between the planes of weakness should be quantified and used to make correlation between the geology present along the alignment and the rate of penetration for the selected TBM. These results can be modeled in several different tunnel penetration prediction models. Rock fracture index (RFI) should be introduced and used as an adjustment factor for fractured rock mass conditions. Typical Rock Mass Classifications systems used include RMR, Q, and GSI.

Specific technical considerations for the use of TBMs include geological parameters (rock type, rock alteration, rock strength, rock abrasivity, durability, groundwater inflows), discontinuities in the rock mass (joints, fractures, bedding, shears, faults), depth of cover and the potential for overstressing/rock bursts, site access and terrain, portal locations, TBM constraints, minimum tunnel size, tunnel support requirements, contractor and labor experience, and project schedule demands. A thorough evaluation of the anticipated ground conditions should be performed as part of the investigation and the design decision to utilize TBM excavation techniques. Minimum specifications for TBMs are necessary in order to prevent the incorrect type of TBM from being used. Appropriate geotechnical investigations are essential in order to provide critical information on the anticipated subsurface conditions for careful planning and design of the proposed tunnel alignment.

TBMs offer high rates of tunnel excavation progress that can be run around the clock, which is a unique economic advantage recognized for tunneling projects where timing is a critical component of the project. TBMs are most appropriately applied in homogeneous rock conditions that are conducive for excavation, including very strong rock varying from 150 MPa to 250 MPa (21,755 to 35,300 psi).

One of the key considerations for the use of TBMs is the depth of rock cover along the tunnel alignment and the potential for overstressing. Overstressing will occur under the following conditions:
1) High rock cover.

2) Low/moderate rock strength.
3) High in situ stresses.

Evaluation of the uniaxial compressive strength and in situ stresses should be included in the tunnel investigation program. Estimates of rock strength can be made by field observations at bedrock outcrops, and rock alteration and joint spacing can be measured in the field. Drilling programs can collect in-situ samples for laboratory testing of rock block or core samples.

The vertical alignment for TBMs is typically kept below a maximum grade of 3 percent; otherwise, special braking systems must be incorporated in the TBM design. Horizontal alignments also have similar limitations, with typical minimum radii of curvature of about 250-300 meters 820-954 feet.

Project schedule and procurement are probably the two biggest issues regarding TBM selection. Early or on-time completion is critical for major tunneling projects due to the large amount of infrastructure and manpower associated with their construction. Some projects may mandate the use of TBMs in order to provide an overall shorter construction schedule. Typical procurement and building time for new TBMs is typically over a calendar year.

The minimum requirements for the application of TBMs on any given tunnel project should be based on the following:
1) Distribution of main rock types, strength, quality, and durability.
2) Quantification of number and extent of major fault and shear zones.
3) Presence of weak rock units and potential for overstressing and squeezing conditions.
4) Installation requirements for initial tunnel support.
5) Final support and lining requirements.

The main disadvantages for the use of TBMs for tunneling projects are as follows:
1) Limited to use for relatively straight tunnels where radius of curvature may be restricted
2) TBMs are typically not considered to be appropriate for long, deep tunnels, where extensive lengths may be subject to overstressing due to low rock strengths and/or high in situ stresses.

Geological mapping and evaluation should be considered the first step in tunnel planning and design. This work can comprise a desk review of existing literature and historical reports and investigations. The key requirement is the identification of rock mass characteristics and engineering properties critical to tunnel design. Consideration should be given to structural

discontinuities such as faults along the tunnel alignment and then, field proofing/mapping of suspected features. The key lessons learned from past tunneling projects where TBM were utilized are that every tunnel project and site location is unique in terms of geology, access, terrain/cover, experience of candidate contractors and project completion demands. TBMs offer key project schedule benefits regarding production which is a unique economic advantage recognized and utilized when selecting TBM excavation methods.

****

The TBM will be a fully shielded machine built or rebuilt by an established TBM manufacturer with at least 10 years' experience manufacturing or rebuilding TBMs.

The TBM must have the following specific characteristics, capabilities, and equipment:

a. Configured to excavate to the dimensions indicated on the Contractor's shop drawings and designed to advance through all anticipated ground conditions as detailed in the GBR.

b. Full-circle shield, for the entire length of the TBM and tail that will continuously and fully support the ground as the TBM advances.

c. Ability to steer TBM and trailing equipment to maintain line and grade within the specified tolerances.

d. Full-face cutterhead. Select cutter types, changeability, and configuration as required to excavate through the anticipated ground conditions.

e. TBM performance specifications, including cutterhead rotation horsepower, must be specified based upon anticipated ground conditions (e.g., lithology and in-situ rock stress conditions) along the proposed tunnel alignment.

f. The tail of the shield must have a sealing system that prevents soil from flowing into the shield and tunnel through the joint between the tail of the shield and the first jacked pipe if required by anticipated ground conditions.

g. When starting and stopping TBM, provide equipment and implement procedures to avoid high voltage fluctuations on the power distribution system.

h. TBM must be equipped with suitable safety systems in accordance with applicable OSHA requirements.

i. Equip TBM with laser target system to permit accurate monitoring of line and grade.

j. Maintain an inventory of spare parts and wear items recommended by the TBM and trailing systems manufacturers to ensure continued functioning of TBM and all essential systems.

2.5 PIPE JACKING SYSTEM

****

NOTE: Depending on the project design, include language for the pipe jacking system, as needed. Delete if pipe jacking for tunnel liner installation is not required.

****

Provide a pipe jacking system with the following features:

a. Has the main jacks mounted in a jacking frame located at the jacking portal.

b. Has a jacking frame which successively pushes a string of connected pipes following the TBM towards the receiving portal.

c. Has sufficient capacity to push the TBM and pipe string through the ground. Incorporate intermediate jacking stations, if necessary.

d. Develops a uniform distribution of jacking forces on the end of the pipe by use of spreader rings and packing, measured by operating gauges.

e. Provides and maintains a lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.

f. Use thrust reactions for pipe jacking that are adequate to support the jacking pressure developed by the main jacking system. Special care must be taken when setting the pipe guide rails at the jacking pit to ensure correctness of the alignment, grade, and stability.

****

NOTE: Expansive grouts were introduced as an alternative rock breakage method but were not used extensively in mining due to low productivity rate and cost per excavation volume ratios. Expansive grouts can be used to induce fractures in saturated conditions. Effectiveness is generally determined by water content, ambient temperature, and borehole diameter. Expansive grouts can have low efficiencies and take a long time to set and expand to induce rock breakage. Depending on access line drilling can be performed with an air track or hydraulic hammer drilling set ups. Localized small breaks can be done with a rotary hammer drilled line patterns.

Expansive grout is utilized to eliminate fly-rock, noise, blast or mechanical excavation vibration, and structural damage related to air blast overpressure or mechanical excavation. It does not require special permits, or special blasting certifications. Expansive grouts are typically used in specialized ground condition conditions that necessitate its use (examples: rock excavation adjacent to embankment structures or grout curtains, or in close urban environments where blasting techniques would exceed local variances on peek particle velocities and/or

vibration and dust.

To best utilize this technique bedrock information should be collected regarding rock type, grain size, planes of weakness, foliation, strength, cementation, fracture spacing, rock mass characterization and engineering parameters. Test panels to specifically develop expansive grout excavation techniques could be utilized and finalized prior to critical excavation in environmentally sensitive near critical structures at the site.

A hydraulic splitting machine is another mechanical means of excavation that utilizes predrilled patterns in the rock. It is comprised of two parts: a splitter and a power station. The splitter consists of a power cylinder with multiple pistons or wedges (based on a machine model) that apply pressure into a bore hole wall, pushing the rock toward a free face. The power station consists of a hydraulic pump, hydraulic pipe, and control panel. These can be utilized locally in critically sensitive areas in place of expansive grout techniques.

****

PART 3 EXECUTION

****

NOTE: This specification is for use for tunnel excavation. For mixed face tunneling conditions, revise specification to account for anticipated ground conditions. This specification requires a Geotechnical Baseline Report (GBR) that defines the ground properties, conditions, and behavior related to tunnel excavation, support, and constructability along the tunnel alignment, portals, or along separate tunnel segments that is expected. The Geotechnical Data Report (GDR) contains all the testing and rock mass characterization data used to characterize the conditions and behavior of the ground along the tunnel alignment to establish the base line conditions for the project. The GBR defines what constitutes a differing site conditions for claim resolution per the frameworks of the contract.

****

3.1 GENERAL

****

NOTE: This paragraph should agree with the designations under paragraph SUBMITTALS.

****

a. Care must be exercised to minimize overbreak, to prevent immediate or subsequent rock falls from within the tunnel or from portal areas and other rock slopes outside the tunnel, and to preserve the integrity of

the rock outside the limits of tunnel excavation.

b. Clean working conditions must be always maintained inside the tunnel. All muck, slush grout, grout spills, and any other material not required for tunneling must be removed from the tunnel in a timely manner.

c. Detailed construction sequencing must be the responsibility of Contractor, consistent with the requirements of these Specifications, and those shown on the Contract Drawing and in agreement with the approved submittals.

d. Perform work in a manner that minimizes safety hazards and exposure of personnel and equipment to hazardous and potentially hazardous conditions in accordance with specified safety requirements and Contractor's Safety and Health Plan.

e. Minimize ground movement at the tunnel face and in the surrounding excavation, and prevent ground loss, subsidence, and movement in surface features, overlying structures, and utilities above and around the vicinity of the tunnel excavation.

f. Provide additional face and excavation stabilization by means of discretionary ground support wherever ground conditions dictate.

g. In case of stoppages for any reason, maintain qualified personnel on-duty to monitor conditions that may threaten stability of the heading.

h. If monitoring of ground vibrations indicate that vibration levels are exceeding response levels as defined under paragraph titled Ground Vibration and Deformation Effects Monitoring, and [Section XX XX XX GEOTECHNICAL AND STRUCTURAL INSTRUMENTATION] then adjust procedures for excavation and initial support installation in accordance with the accepted Contingency Plan to reduce the levels to within acceptable limits.

****

NOTE: The need to maintain enough tunnel support materials/equipment will vary per project. Define this quantity during design phase and incorporate in GBR. The following paragraph should be tailored for the specific project requirements.

****

i. Maintain enough shotcrete materials at the tunnel face, ready for immediate application, during the entire excavation period. Excavation will not be permitted without this requirement being met or as approved by the Contracting Officer.

j. As the excavation progresses, the Contracting Officer will perform inspection, [photogrammetry,LiDAR scanning] and geologic mapping or other documentation of the exposed tunnel sections. This mapping will be accomplished after excavation and either before or in conjunction with support installation. The Contractor must provide cleaning of the heading and completed crown and sidewalls and a safe means of access to these areas to allow this mapping. Mapping of the crown and sidewalls will be conducted for documentation of the actual geologic conditions encountered and assessment of rock mass characteristics of

the heading. The Contractor must assume that this inspection and mapping will be performed once each shift for a period of minimum [20] minutes in each heading. Lighting, ventilation, and access will be provided for close inspection of the face. Where necessary the excavated surfaces may need to be cleaned by air or water jets to provide surfaces suitable for mapping, as directed by the Contracting Officer; provided, however, such cleaning will be minimal in areas where softer materials can be gouged out to depths greater than three inches. The Contractor must cease operations to the extent necessary to permit such mapping as directed by the Contracting Officer. Such work will be coordinated by the Contracting Officer in a manner to avoid undue disruption to Contractor's operations.

k. Establish and maintain surveyed tunnel station markers throughout both lined and unlined excavated tunnel. Placed station markers indicating the tunnel stationing at 15.24 meters50 feet intervals by spray painting the rock or shotcrete surface in a color to contrast with background. Intermediate station markers will be made at 3.05 meters 10-foot intervals with visible paint marks located at or near tunnel spring-line.

l. Sequence and direction of tunneling to be as shown on the Drawings and as reviewed by the Contracting Officer.

m. Temporary niches or adits, temporary or future pump sump pits and other temporary openings:

(1) . Excavate these temporary openings conforming to excavation and support criteria of this Specification and as reviewed by the Contracting Officer.

(2) . Seal all temporary openings with [27.58 MPa][4,000-psi] 28-day strength concrete in accordance with the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE when no longer needed, before Contract completion and as reviewed by the Contracting Officer.

n. Survey:

(1) . Contractor is responsible for the development and implementation of a surveying program capable of satisfying all survey and accuracy requirements. This program is subject to the review of the Contracting Officer prior to the commencement of the work. The review does not release the Contractor of liabilities associated with or dependent on this part of the work.

(2) . Design and implement a functional underground network and determine all required measurements and the required accuracy of each measurement including horizontal angles, zenith angles, azimuth angles, distances, and height differences. Include analysis of required redundancy and measure of internal reliability associated with each planned observation.

(3) . Design and implement a functional surface control network, stations, positions, measurements, and accuracies. Measurements may include Global Positioning System (GPS) vectors, horizontal angles, zenith angles, azimuth angles, distances, and height differences. Include analysis of required redundancy and measure of internal reliability associated with each planned observation.

(4) . Obtain survey information prior to completing the last [_____] meters [_____] feet of the tunnel excavation. Adjustments to line and grade to the tunnel over the last 30.48 meters100 feet may be necessary to meet project requirements. The purpose of conducting the survey is to obtain the true centerline alignment in 3-dimensions to locate the connections as shown on the drawings. Vertical and horizontal alignment must be taken along both invert/sidewall construction joints. The center point on the invert is assumed as the dividing line between both invert/sidewall joints.

(5) . Obtain start point alignment for the survey from the surface at [_____] data for alignment consisting of at least 2 benchmarks with known elevation and geographic coordinates enabling tie-in to [NAVD88] elevation and the [_____] State Plane Coordinate System, respectively.

(6) . Perform in-tunnel survey to an accuracy of one-half-inch in the horizontal and vertical dimensions. Record sufficient survey points to enable the complete horizontal and vertical profile of tunnel alignment to be detailed. Some tunnel alignment curves may not necessarily be circular arcs; they may be based on complex parabola or other geometric shape forms.

(7) . Assume that station of benchmarks or survey monuments are as indicated in historical documents. All new survey stationing must reference these stations.

(8) . A survey was completed on [_____]. This information is available and must be reviewed by the Contractor, prior to conducting the tunnel survey.

(9) . Shaft centerline is the basis of all tunnel stationing up and down station of the shaft centerline.

(10) . Calibration and data processing:

a. Calibrate all survey instrumentation as required and as recommended by instrument manufacturer. Submit all calibration records to the Contracting Officer.

b. Data reduction must incorporate calibrations and meteorological correction, and reduction of measurements to the ellipsoid and thence to the [_____] State Plane Coordinate System. Correct distance measurements by electro-optical distance measurement instrument (EODMI) for scale, cyclic error, zero error, and meteorological effects. Correct azimuth angles using the Laplace correction and include the deflection of the vertical components on angles and azimuth measurements.

c. Data regression processing must include least squares adjustments, as required. Employ data outlier detection. Determine horizontal and vertical confidence intervals.

3.2 TEMPORARY SYSTEMS

****

NOTE: Review applicable consideration in EM 385-1-1 and/or consult with a safety professional with

tunneling background. Ensure groundwater conditions and overall regime through rock mass is well understood by tunnel reach and rock type. The safety requirements for the contract should be specified in Section 01 35 26 GOVERNMENTAL SAFETY REQUIREMENTS. This specification section below can be tailored to remove some items if they will be included in Section 01 35 26.

****

1. Provide, operate, and maintain a complete backup generator systems for all tunnel ventilation, lighting and dewatering systems.

2. Provide, operate, and maintain a complete groundwater control/ treatment system to collect water from within the tunnel and shaft and suitably treats it before discharge in accordance with the requirements of [Section XX XX XX TUNNEL AND SHAFT DEWATERING].

3. Water entering the tunnel from all sources must be controlled, managed, and disposed of in a manner to prevent damage to the tunnel and surrounding property and in accordance with all Federal, State, and local regulations.

4. Design, furnish, install, operate, and maintain a temporary lighting system in all underground and other working areas in strict compliance with all applicable Federal, State, and local regulations and industry standards.

5. The system must provide a minimum light level in accordance with OSHA requirements and EM 385-1-1. In case of failure of the lighting system, provide an emergency lighting system in all work areas in strict compliance with all applicable Federal, State, and local regulations, and industry standards.

6. Design, furnish, install, operate, and maintain temporary ventilation during all phases of construction complying with all applicable Federal, State, local regulations, and industry standards. Operate and maintain the entire temporary ventilation system. Details of the Contractor's ventilation system must be presented to the Contracting Officer for his agreement at least 60 days prior to its installation.

7. Two battery-operated handlamps of 20-Watts minimum power must be provided and maintained at each working face and portal for emergencies and inspection of the work.

8. Electric heaters or radiators having exposed coils or elements must not be allowed in the tunnels.

9. All main electrical cables installed within the tunnels must comply with all applicable Federal, Municipal, and Local Requirements.

****

NOTE: Designer will need to ensure safety requirements in specification at a minimum follow OSHA/EM 385-1-1/MSHA.

****

10. Provide additional floodlighting and ventilation locally as required at active ground support installation, shotcrete, and other locations,

and provide portable floodlighting and ventilation equipment, as needed, for localized construction operations. Equipment for short-term use may be battery-operated.

11. For Contract requirements regarding temporary construction power, refer to [Section XX XX XX TEMPORARY LIGHT AND POWER] [and] [Section XX XX XX TEMPORARY ELECTRICAL SYSTEMS].

12. In all parts of the Underground Works, the atmosphere inhaled by those present must contain not less than 19.5% nor greater than 23.5% of oxygen and must not contain a concentration of contaminates such as gases, vapors, and dusts greater than is safe for the health of the construction personnel, considering the effects of exposure time, temperature, humidity, and the combined effects of several contaminants. The concentration of inflammable contaminants must not exceed 10 percent of the lower explosive limit (minimum explosive concentration).

13. Use of wet drilling methods. Carry out drilling using hollow bits with continuous water feed to reduce dust. Always wear suitable protective equipment.

14. The Contractor must be responsible for obtaining all information necessary to determine what concentrations of contaminants are harmless, without prejudice to the adoption of such lower figures as may be stated by competent authorities or directed by the Contracting Officer. The atmosphere inhaled by the workmen and other authorized persons in all parts of the tunnel must not contain more than 5 ppm of nitrous fumes (measured as NO2) for longer than 10 minutes after each blast, 30 ppm of nitrous fumes as an absolute maximum, 50 ppm of carbon monoxide as an absolute maximum, 5,000 ppm of carbon dioxide as an absolute maximum, or for other contaminants. The Safety Professional must field calibrate air quality monitoring instrumentation in accordance with manufacturer's recommendations.

15. In all parts of the Underground Works, throughout the period in which materials producing contaminants are used, and at such time as may be necessary to maintain the standard of purity of air required in this subsection, clean fresh air must be supplied by forced ventilation, using an exhaust system at the face or other method as agreed by the Contracting Officer, at a rate not less than the greater of the following:

****
NOTE: OSHA 29 CFR 1926.800(k)(2) requires each employee working underground have at least 200 cu ft (5.7 m3) of fresh air per minute. OSHA 29 CFR 1926.800(k)(3) addresses minimum velocity of air.
****

a. [_____] cubic meters[_____] cubic feet per hour per person present in a tunnel;

b. [_____] meters[_____] feet per hour per kilowatt of combustion-engine generated power operating simultaneously in the heading.

16. The Contractor must take special measures to minimize the effect of fumes. These measures must include the use of efficient and properly maintained exhaust smoke washers (scrubbers) for all internal

combustion engines in the tunnel. Gasoline engines must not be permitted in the tunnel.

17. Notwithstanding any requirements of this subsection the method of ventilation and treatment of fumes or airborne particulate matter, must be submitted to the Contracting Officer. The Contractor must provide, maintain, and use as directed by the Contracting Officer, an instrument approved by the Contracting Officer to measure the velocity of air, and an approved gas detector. Maintenance of the gas detectors must include the supply of all detector tubes.

3.3 PUBLIC MEETINGS

****
NOTE: Communicate with the project manager and stakeholders about whether specific requirements for a meeting or multiple meetings are needed. It may be necessary to advertise the meeting in a local newspaper and specify the meeting room capacity. Several planning meetings with stakeholders will need to take place during design and the need and content of the public meetings determined and this specification tailored appropriately.
****

Fifteen calendar days prior to commencing tunneling operations, provide the approved Project Manager, Tunneling Superintendent and Vibration Specialist, to attend a public meeting to be conducted on an evening to be determined by the Contracting Officer. This meeting will inform the public about the anticipated tunneling and underground construction operations. The Project Manager and Tunneling Superintendent must make a short presentation on tunneling and underground construction. [The Vibration Specialist must make a presentation explaining the potential impacts tunneling activities may have on nearby structures.] Answer any questions pertaining to public concerns that may impact the public.

3.4 TUNNELING PERSONNEL

3.4.1 Tunneling Superintendent and Supervisors

****
NOTE: The nomenclature of tunneling "supervisors" could vary based on geographic location. Foreman, Shifters or Walking-Boss are common terms for supervisor.
****

Submit for approval the qualifications. Perform the work under the direct supervision of an experienced tunneling superintendent and tunneling supervisors with experience requirements in accordance with Section [_____], or as directed by the Contracting Officer. In addition, the Tunneling Superintendents' experience must include at least one project of a comparable size to this Project within the previous ten years (or as approved by the Contracting Officer). Duties of the tunneling superintendent and tunneling supervisors will include the requirements set forth in Section [____]. Substitutions for the tunnel superintendent during the Contract period will not be made without prior written acceptance by the Contracting Officer. Substitute personnel must have the same qualifications specified herein for the position to be held.

Tunneling superintendents and supervisors must have a minimum of 15 years of comparable experience in supervising the excavation and support of tunnels in similar ground using the similar construction methods and must have all necessary licenses and permits required by local agencies or others having jurisdiction. Supervisors and superintendents must have experience on at least two projects with full face hard [roadheader, TBM] excavation. Tunneling must not be performed unless the tunneling superintendent, supervisors, drillers, and miners meeting the above experience requirements are on site and in actual supervision of this portion of the work.

The following duties are also part of the responsibilities of tunneling supervisors and superintendents:

a. Supervising excavation to ensure safety and quality of construction.

b. Meeting daily [at the start of each shift] with the Contracting Officer or the Contracting Officer's designated representative at the tunnel face to discuss ground conditions encountered and corresponding excavation and support requirements including additional initial support and keeping records thereof.

c. Devising and implementing additional initial support measures as required by ground conditions or as directed by the Contracting Officer, coordinating remedial measures when ground loss at mined tunnel heading or instability of mined tunnel occurs, or appears likely to occur.

****

NOTE: Nomenclature of these positions may vary depending on geographic area. The level of experience of the TBM Operator (and Mechanics) should be a function of the size and complexity of the project. Ten years should be a minimum for most small projects.

****

3.4.2 TBM Operators and Mechanics

TBM operators and TBM mechanics must have at least [ten] years (or as approved by the Contracting Officer) of demonstrated experience in operating bedrock TBM(s).

3.4.3 Professional Engineer or Professional Geologist

****

NOTE: A licensed professional must be used, that may vary on the state, since some do not license Engineering Geologists or Geotechnical Engineers. Tailor this section appropriately for your project needs. There could be different functions for the different positions, with the geologist expert in defining the rock conditions and understanding the design requirements, while providing input in design of tunnel and underground support. Expertise in both design and construction aspects of the work is needed - how that's accessed might be different whether Design Build or Design Bid Build.

****

Contractor's Professional Engineer or Professional Geologist must be a licensed Civil Engineer, Geotechnical Engineer, Geologist, or Engineering Geologist in the State of [_____] with a minimum of 10 years' experience designing underground excavations and constructing such excavations, installing slope stabilization support, designing tunnel and underground support, evaluating rock mass properties, and groundwater conditions for large underground excavations. The Civil Engineer, Geotechnical Engineer, Geologist, or Engineering Geologist must have worked on a minimum of two projects with full face hard rock tunnel excavation. Tunneling must not be performed unless the Civil Engineer, Geotechnical Engineer, Geologist, or Engineering Geologist meeting the above experience requirements is on site and in actual supervision of this portion of the work. Submit for approval the qualifications.

The Contractor's Professional Engineer or Professional Geologist as defined above will:

****

NOTE: Depending upon the nature of the Contract, the Contractor's Professional Engineer or Professional Geologist may provide geologic mapping or other services previously specified as responsibilities falling under the Contracting Officer. The designer should determine which party will be responsible for providing these services.

****

a. Provide inspection of excavations and evaluate rock and groundwater conditions during construction.

b. Perform pre-construction and periodic site visits throughout construction to assess site conditions.

c. Update the excavation, dewatering plans, rock support, and rock mass characterization as construction progresses to reflect changing conditions and changes in contract rock support based on in-situ conditions observed.

d. Submit a written Monthly Excavation Status Report that informs the Contractor and Contracting Officer of the status of the excavation and provide an accounting of the Contractor's adherence to the plans and address present or potential problems or issues with ongoing construction.

e. Be available to meet with the Contracting Officer and Government representatives throughout the Contract duration.

3.4.4 Vibration Monitoring Specialty Firm

****

NOTE: This requirement is a new format from previous specifications. The firm is submitted for approval, having the appropriate experience and the firm must have on staff the Vibration specialists and Seismograph Technicians, typically a firm is subcontracted by the Contractor and having multiple

experienced people approved allows them to have flexibility on supporting the site work. The people coming to the project or responding to the work must be within the group approved but does not need to be a single person anymore.

****

Retain the services of a vibration monitoring specialty firm that specializes in the prediction, monitoring, and control of ground vibrations. The firm must have experience conducting installation of seismographs for vibration monitoring and communicating vibration results. The firm must have on staff at least [_____] Vibration Specialists that specialize in vibration monitoring and analysis. The firm must have on staff at least [_____] Seismograph Technicians that have five years or more experience with seismograph installation and vibration monitoring. Submit resumes for all personnel and for the firm for approval citing, in additional to other pertinent data, experience, training, and education, at least 60 days prior to the commencement of work. The Seismograph Technicians must be persons capable of setting up the seismographs at designated locations, effectively recording the work, and appropriately interpreting results. The Vibration Specialists must interpret the seismograph records to ensure that the seismic data must be effectively utilized in the control of operations with respect to the existing structures. The Seismograph Technicians must supervise the placement, operation, and maintenance of the seismographs. The Contracting Officer may require the Vibration Specialists and Seismograph Technicians to be present during the production tunneling work.

3.4.5 Structural Condition Assessment Inspection/Evaluation Technician

****

NOTE: This may be required for shaft/portal construction. Depending on proximity of the tunnel it may be needed to document condition of structures and ground in proximity to the work. Designers will need to determine if this is necessary.

****

****

NOTE: Five years is the minimum experience requirement, depending on the project it might be necessary to increase the minimum if there is a special concern or sensitive structures, consult with USACE SME to help determine.

****

Pre and Post Construction structural inspections must be performed by technicians with at least [five] years' experience in pre-construction and post construction surveys in the State of [_____]. [The inspections must be done under the supervision of a professional engineer and be stamped by the engineer]. Submit a copy of the qualifications and certificates to the Contracting Officer.

****

NOTE: The paragraph below should be used when Tunnel Boring Machine (TBM) excavation techniques are required.

****

3.5 PRE-CONSTRUCTION DOCUMENTS

****

NOTE: The following submittal requirements are for tunnel excavation using Tunnel Boring Machine (TBM) and should only be included if this method of excavation will be employed on the project.

****

Training certifications and/or resumes of TBM operators and mechanics, experienced in operating and maintaining TBMs suitable for the Project conditions, at least 60 days before TBM assembly or excavation commences.

Sequence and methods for mobilizing each TBM to Assembly Chamber, launching TBMs in Starter Tunnels, partial or complete disassembly, backing up and re-assembling TBMs and re- launching in Starter Tunnels for subsequent tunnel drives, as applicable.

Contingency plan for providing additional initial support of tunnel sidewalls and advancing TBM if rock mass has insufficient bearing capacity to support required gripper pressure.

3.5.1 Tunnel Excavation Plan

3.5.1.1 General

The following documents must be submitted to the Contracting Officer at least 60 days prior to commencing excavation:

1. A scale drawing of proposed tunneling operations. The drawing must include detailed working drawings of mobilization, proposed methods, and sequence of excavating and disposing of materials for each portion of the work, ventilation, illumination, identification of known shears/faults/weak rock, survey control, type and location of vibration and stability-related instrumentation, installation of ground support including placing of shotcrete, steel sets and rock reinforcement, dimensions for excavation and types of equipment to be used.

2. Drawings and details of the initial support of all excavations.

3. Procedures for the control and disposal of groundwater and water supplied for use during tunneling.

4. Methods and equipment for measuring and recording groundwater inflow. Methods, equipment, guidelines, and criteria for the use of fissure grouting must be proposed by the Contractor in his method statement as required in Section 31 73 19 TUNNEL AND SHAFT GROUTING.

5. Instruments for monitoring air quality.

6. The following records of work accomplished must be submitted to the Contracting Officer within one day of the installation of any geotechnical instrumentation measuring tunnel convergence:

a. A list of instruments installed, including instrument identification numbers, calibration, elevation, orientation, stationing, offset, and initial coordinates as applicable to each instrument or installation.

b. Drawings showing details of installed instruments. All dimensions and materials used must be fully identified.

c. A statement describing the procedure used for the installation of each instrument.

7. A method statement of the proposed tunneling operations. This method statement must include details of the Contractors proposed tunnel-logging system such as the NGI "Q" system or Rock Mass Rating (RMR) system for determining ground support, as defined in the GBR, in concert with guidelines provided in Chapter 7 Design of Initial Support, EM 1110-2-2901. The report must present details of proposed methods and sequences of excavating and disposing of materials for each portion of the work, probing ahead of the tunnel face, pre-grouting, ventilation, illumination, placing shotcrete, steel sets and rock reinforcement, surveying, monitoring, and construction equipment to be used.

8. Catalog cuts of excavation, drilling, mucking and transportation equipment to be used.

9. Contingency Plan for the excavation and support of the tunnels in the event that monitoring of excavation operations in accordance with Section [_____] and monitoring of ground deformations in accordance with [Section XX XX XX TUNNEL INSTRUMENTATION] indicate vibrations or movements exceeding threshold values defined in the drawings. Refer to EM 1110-2-1009 for further guidance on instrumentation.

10. The following Survey Details must be submitted to the Contracting Officer for approval:

d. Manufacturer's address, phone number and name of the contact person.

e. List and description of special modifications if there are changes.

f. Description of instrument's operational principle.

g. Plans or diagrams of instrument.

h. Maintenance requirements.

i. Reading procedures, including sample data, and data processing calculations.

j. Complete data on all tests done to calibrate instruments or verify accuracy.

11. Working Drawings - The following must be submitted in accordance with the specifications:

k. Drawings and details of the initial and permanent reinforcement and/or support of all excavations.

l. Procedures for the control [, treatment]and disposal of groundwater and water supplied for use during tunneling.

m. Methods and equipment for measuring and recording groundwater inflow. Methods, equipment, guidelines, and criteria for the use of fissure grouting must be proposed by the Contractor in a method statement as

required in Section 31 73 19 TUNNEL AND SHAFT GROUTING.

12. Instruments for monitoring air quality and ventilation.

13. The following records of work accomplished must be submitted to the Contracting Officer within 24-hours of the installation of geotechnical instrumentation measuring tunnel convergence and any other devices to monitor tunnel stability:

n. A list of instruments installed, including instrument identification numbers, calibration, elevation, orientation, stationing, offset, and initial coordinates as applicable to each instrument or installation.

o. Drawings showing details of installed instruments. All surveyed locations, dimensions and materials used must be fully identified.

p. A statement describing purpose and the procedure used for the installation of each instrument.

14. Complete working drawings and system description of proposed equipment, materials, and method for handling water within the tunnel, measurement of pumped water, and disposal methods.

3.5.1.2 Roadheader

Submit for review at least sixty (60) days before the start of excavation with the roadheader(s)the following:

1. Make and model number, year manufactured, manufacturer's specifications, and manuals for operation and maintenance.

2. Certification from the roadheader manufacturer that the proposed machine(s)can excavate the anticipated rock conditions as described in the Contract Documents at a rate sufficient to meet the project schedule.

3. Power supply requirements and anticipated power source(s).

4. For refurbished (used) machines, in addition to the information required herein, submit the following additional information: maintenance record(s) and description of last three (3) projects, including rock types excavated, advance rates, total operated hours, and rebuild records of major components.

5. Roadheader Shift Report: Prepare a roadheader shift report for each shift in which the roadheader(s) was operating and submit to the Contracting Officer for review by noon the following day in a form and format acceptable to the Contracting Officer. The following minimum information should be included with these reports:

a. Time and position of cutter/pick changes.

b. Identification of all roadheader downtime, including classification and duration. Categories of downtime identified should include roadheader repair, cutter/pick changes, installation of initial support, groundwater inflow, gas inflow, power outages and electrical repair, muck disposal delays, mechanical repairs, alignment survey, grouting, routine maintenance, or other category as described by the Contractor.

6. Contingency Plan for additional initial support of pillars with signs of instability or if excessive ground deformations are detected. Contingency Plan must include a backup roadheader. Contingency Plan for the excavation and support of the tunnels if monitoring of excavation operations and monitoring of ground deformations in accordance with [Section XX XX XX GEOTECHNICAL AND STRUCTURAL INSTRUMENTATION] indicate vibrations or movements exceeding threshold values defined in the drawings.

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NOTE: If the XX XX XX TUNNEL EXCAVATION SUPPORT Specification will be used, the proceeding section can be deleted.
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NOTE: The following Submittal requirements for Roadheader should only be included if this method of mechanical excavation will be employed on the project.

Prediction of roadheader performance plays a significant role in the plan of tunnel and underground construction in regard to cost, schedule, and excavation assessment. The roadheaders advancement rates underground are influenced by rock strength, abrasivity, rock mass discontinuities, rock type, brittleness, machine specifications (rotary rotation speeds and teeth or pick metal type, and weight and power of roadheader machine) combined with the time to install rock support and muck out. Roadheader performance results illustrate that rock mass properties have a considerable impact on the applicability and rate of the roadheader advancement. Several models demonstrate and accurately predict the roadheader performance as a function of rock mass properties. The very low vibration emissions and precise profile of a roadheader excavation may facilitate excavation near embankment infrastructures or vibration sensitive infrastructure. Dust, and associated mitigative measures should be considered carefully as well. The higher susceptibility of this excavation method in regard to the rock and rock mass characteristics does imply a significant risk potential to the application of this method in regard to the variability of the excavated rock mass. For these reasons a comprehensive site GBR should be performed during the site characterization process outlined in USACE 1110-1-1804 and utilized with this specification.
****

3.5.2 Ventilation Plan

Provide, operate, document, and maintain for the duration of tunnel construction operations a temporary ventilation system and air quality monitoring system which conforms to the requirements of all federal,

state, and local regulations in accordance with EM 385-1-1. Remove system(s) from the site when work is completed.

3.5.3 Pre-Construction Surveys

****

NOTE: During design consult with the adjacent businesses/stakeholders/jurisdictions to determine what Pre-Construction Survey needs to be conducted and whether access is allowed, or special considerations are needed. This needs to be outlined in the specifications for a proper bid to be made for the scope. It is important to include the entire Project Development Team in design to ensure all project features of importance are documented before tunnel construction.

Special attention should be given to clear identification of Real Estate property and boundary information in support of design and construction.

****

Prior to the commencement of construction, conduct a Pre-Construction Survey of any nearby buildings, structures, and utilities within [_____] meters [_____] feet from the construction area, or otherwise delineated by plan drawing, that may potentially be at risk of vibration damage to document pre-existing conditions. The survey extent and method used must be acceptable to both the Contractor's insurance company and the Contracting Officer. The Contractor is responsible for any damages or injuries resulting from construction. Submit all Pre-Construction Surveys 60 calendar days before the start of work. There will be no construction allowed until the Pre- Construction Survey is submitted and approved by the Contracting Officer. Provide owners of surveyed features a copy of their feature's Pre-Construction Survey results before or with the notice of work commencement. Notify owners and occupants of local buildings prior to the commencement of work. Perform the following when conducting Pre-Construction Surveys:

a. Each [Civil Works] structure must be documented (including high resolution photography and/or videotaping) as to its construction, foundation type, condition, and closest distance to excavation. The general condition and all observable defects of each structure must be documented. This includes measurements of the defects.

b. The facilities that may be impacted by construction must be addressed by the Contractor for safety and continued operation during the tunnel program.

c. Freestanding structures (such as retaining walls) must be inspected on the exterior and on the interior if connected to a structure. All concrete walks, driveways, or adjacent structures must be inspected for cracks, level condition, holes, and defects.

d. Industrial structures, silo/elevators and special facilities, and office space must be described relative to their present condition and tolerance to vibration. Besides the inspection of walls, columns and stairwells, the Contractor must survey the work areas and structures for distress.

e. Survey the current condition of above and underground utilities to include water, power, gas, sewer, and communication lines, and any associated above-ground connections to said underground utilities such as fuel tanks and hard connections to structures.

f. An inspection of accessible structures must be made and a list of all structures, which could not be surveyed or refused to allow survey, must be completed. The dates of possible subsequent surveys and physical constraints prohibiting the survey must be documented. The requirement to perform Pre-Construction Surveys is not an indication of Right-of-Entry by the Contractor. Any Right-of-Entry associated with Pre-Construction Surveys, monitoring during construction and Post-Construction surveys are the responsibility of the Contractor. In the event a property or properties identified as significant or intended to be included in the Surveys and monitoring are not included because access was denied, indicate this occurrence including the points of contact, dates contacted, and any reasons provided for denial of access (if given.)

g. Certify that the survey was prepared prior to the start of any construction under this Contract. Submit a copy of the Pre-Construction survey in conjunction with the Tunnel Excavation Plan.

3.6 RECORD KEEPING

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NOTE: The paragraph below applies to all excavation techniques.
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3.6.1 Daily Records

Maintain daily records as excavation progresses and one copy of such records must be submitted to the Contracting Officer before 12:00 PM of the following workday. Keep such other records as deemed necessary. The following data must be included in the daily record for each tunnel heading:

1. Station of tunnel heading faces at start and end of each work shift.

2. Type, quantity, and location of initial support and additional initial support installed. Draft Geologic mapping and excavation records that comply with EM 1110-1-1804 Appendix B and C.

3. Evaluation of in-tunnel monitoring results.

4. Probe hole records in accordance with Drilling Logs paragraph of this Section.

5. Number of workers employed per shift for each workday categorized by union trade, idle equipment, active equipment, and site visitors.

6. Water inflow measurements.

7. Air quality Measurements.

8. Vibration Monitoring Measurements.

9. Tunnel Deformation Monitoring Measurements.

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NOTE: The section below should be used when Tunnel Boring Machine (TBM) excavation techniques are required.
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10. Daily shift reports on TBM operation and performance data must be prepared commencing on the first day of TBM assembly and cover a continuous period until the TBM(s) are removed from the tunnel. One copy of the shift reports, signed by Contractor's representative, must be provided to the Contracting Officer before 12:00 PM the following workday. Use manual and automatic recording data collection systems in accordance with [Section XX XX XX GEOTECHNICAL AND STRUCTURAL INSTRUMENTATION]. Include the following information, as a minimum, in the shift reports for each tunnel heading excavated by TBM:

a. TBM performance information, including stations of each advance of the TBM, the TBM clock time at the start and end of each shift.

b. For each shove or stroke of the TBM, the date, time, and tunnel station at start of shove, the duration and length of shove.

c. TBM and excavation system downtime, including classification, details, and duration. Iinclude the impact on excavation progress. Categories of downtime may include, but not be limited to, TBM repair, cutter head changes, installation of initial support, groundwater inflow, gas inflow, power outages and electrical repair, downtime of backup equipment, muck disposal system delays, hydraulics repair, gripper problems, alignment survey, probe hole drilling, waiting time due to lack of grout, and routine maintenance.

d. Cutter head changes, including time, date, and reason for replacement, cutter position, or number.

e. TBM clock record of utilization and penetration rates.

f. Air quality and gas monitoring data. Line and grade survey reports.

g. Water inflows, if any, with locations and estimates of rates.

h. Overbreak

i. Any other geological and/or unusual features such as faults, shears, crushed or soft zones, and raveling areas.

3.6.2 Drilling Logs

The drillers are required to keep precise drilling logs on each probe hole to show the depth and position of the geological features. At minimum, each drilling log must include:

a. Borehole designation and location station number;

b. Borehole depth, groundwater depth, inclination, azimuth, and diameter;

c. Elevation of top of borehole;

d. Depth(s) of geologic structural features, e.g., voids, gouge or mud

seams, soft weathered or altered zones, Ocher iron-stained intervals, changes in rock chip color, and other features encountered in the probe hole;

e. Relative penetration rates;

f. Start and end times of drilling;

g. List hole misalignment;

h. Soft seams within the rock and sudden feed pressure changes on the drill;

i. Seepage and groundwater flow from the borehole; and

j. Drill make, model, and serial number.

k. If qualitative descriptors are used (e.g., soft, moderately hard, hard, very hard, decomposed, highly weathered, moderately weathered, slightly weathered, unweathered), ensure consistency between drill operators in logging using these terms. [Log soil and rock in accordance with ASTM D2487, ASTM D5434, ASTM D6032/D6032M.] Submit an example of the Drilling Logs with the Tunnel Excavation Plan. Copies, both hard and electronic PDFs, of these drilling logs must be provided within 24 hours to Contracting Officer.

3.6.3 Post-Construction Surveys

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NOTE: Pre- and Post-Construction Inspections and the Structural Inspection/Evaluation Specialist would only be required if there are structures or facilities requiring such inspections. Eliminate the paragraphs referencing Pre- and Post-Construction Inspections and the Structural Inspection/Evaluation Specialist if the project does not have a requirement for these inspections.
****

Post-Construction Survey must be conducted at any structure previously surveyed during pre-construction and locations where a reasonable notice of damage from construction has been provided. Post-Construction surveys will be conducted by, or under the supervision of, the Structural Inspection/ Evaluation Specialist, who will also sign and date each survey. The survey extent and method used must be acceptable to both the Contractor's insurance company and the Contracting Officer. The post-construction surveys must be conducted within a week of the notice of damage. The Contractor is responsible for any damages or injuries resulting from construction. Submit a copy of all post-construction surveys within two business days of the on-premises surveys to both the structure's owner and the Contracting Officer.

3.6.4 Probe Hole Drilling

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NOTE: The design team must evaluate expected ground conditions including but not limited to: zones of intensely jointed rock mass due to faults, shears, or other structural dislocations, rock types,

weathering profiles, groundwater regime, other pertinent geological information available from the site investigations to determine the adequate length of probing ahead of tunnel. This information must be included in the Geotechnical Baseline Report as a recommendation.

Insert gallons per minute (gpm) based upon results of any packer tests performed, or other estimates of water inflow. In lieu of available project data assume nominal amount of water on the order of 15-20 gpm. The inflow information must be included in the GBR and/or GDR.

The number of supplemental probe holes expected for the project must be determined during design phase and clearly listed as a recommendation in the GBR.

****

a. The Contracting Officer must be informed 24 hours prior to any probing activities in the tunnel so that a government representative be present during the probing. The results of probing ahead, along with any proposed amendments to excavation profile, sequence or support must be submitted to the Contracting Officer immediately upon completion of the probing.

b. Probe holes must be drilled to provide advance warning of any abnormal inflow of water or degradation in rock quality, which might occur. Probe hole locations and extent of hole drilling is shown on the Drawings and will be modified as needed in the field as approved by the Contracting Officer. The Contracting Officer may direct supplemental probe holes to be drilled based on ground conditions. Exploratory probe holes may also be required to explore the nature of subsurface formations or following grout operations to investigate the effectiveness of the grouting program.

c. If the inflow of water from the probe hole exceeds [_____] gpm, supplemental probe holes will be required, at the direction of the Contracting Officer, to probe the extent and character of the ground, and/or to drain the water, and/or for use as grout holes. If directed by the Contracting Officer, grout the face of the tunnel heading in accordance with 31 73 19 TUNNEL AND SHAFT GROUTING.

d. Probe holes must be drilled to a minimum of [_____] meters [_____] feet measured along the drilled hole and will overlap to maintain at least one hole a minimum of [_____] meters [_____] feet ahead of the plane of the tunnel face at all times. The Contracting Officer may reduce the drilling length based on ground conditions.

e. During probe hole drilling, the Contractor will stop at a minimum of each 3.05 meters10 feet of hole advance to measure water flow and water pressure. The Contracting Officer may waive this requirement on a hole-by-hole basis if little or no water is encountered.

f. Probe hole must be terminated [_____] meters [_____] feet beyond the first groutable feature, as determined by the Contracting Officer.

g. Probe holes must be sealed by grouting through a packer close to the first water producing feature to prevent water flows into the tunnel

while the tunnel face is advanced.

****
NOTE: Depending on the project the probe holes may be incidental to the work and no additional time or payment will be required as in this paragraph. If the Contracting Officer directs the Contractor to do probe hole drilling outside of the contracting payment procedures, then it would be compensated. Tailor this paragraph for your project requirements.
****

h. If, in any section of the tunnel excavation, drilling is directed by the Contracting Officer for supplemental probe holes, other operations will be suspended or modified as may be necessary to permit such drilling; and the Contractor will not be entitled to any compensation for delay nor will the Contractor be entitled to any extension of time, such stopping of work being deemed an ordinary delay to be expected during construction operations.

i. Follow format requirement in the paragraph DRILLING LOGS.

3.7 GROUND VIBRATION AND DEFORMATION EFFECTS MONITORING

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NOTE: Incorporate requirements for a data acquisition system and real time monitoring in certain sensitive areas on project-specific basis as needed.
****

3.7.1 General Tolerance

The instruments must be installed as close as practicable to the locations [shown on the Drawings] [or as established in the field by the Contracting Officer]. The Contractor must submit to the Contracting Officer for consent, all final instrument locations prior to their installation. Where instruments are shown on the contract drawings to be installed in clusters, the Contractor must install all instruments shown within a [_____] mm [_____] in. radius

3.7.1.1 Availability of Data

The Contractor must monitor all instruments and provide data obtained to the Contracting Officer within a maximum of [24 hours] after taking the readings unless otherwise directed by the Contracting Officer.

Instrument monitoring data must not be disclosed to third parties and must not be published without the prior written approval of the Contracting Officer.

3.7.1.2 Instrument Installation Sequence

Optical survey targets must be installed following scaling and within [_____] meters [_____] feet of the advancing tunnel face.

3.7.1.3 Installation Requirements

The Contractor must assign an instrument identification number to each instrument. Each instrument identification number must be permanently affixed to a suitable material, such as the stamping of a brass tag. The tag must be attached to the instrument or must be secured at the instrument location.

Optical survey targets must be installed as shown on the drawings.

3.7.1.4 Protection of Instruments

Full responsibility must be borne by the Contractor for protecting the instruments from damage caused by construction operations. Damaged instruments must be promptly replaced or repaired, as directed by the Contracting Officer, at the expense of the Contractor.

The instruments must be clearly marked and protected to avoid being covered by shotcrete. Access must be maintained to permit reading of instruments. Shotcrete applied around instruments must be removed immediately.

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NOTE: Depending on the project, this section will vary and need to be tailored for the monitoring locations and thresholds specifically. The designer should engage necessary subject matter experts for various disciplines - Structural for concrete and Mechanical/Electrical for related equipment (powerhouses or locks).

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3.7.2 Vibration Control Monitoring

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NOTE: Vibration monitoring may be required for underground construction using mechanical excavation means. Consult with the Structural, Mechanical, and Electrical Engineers as appropriate on the project in developing the vibration thresholds. The paragraph's narrative is a generic description for most projects, where the nearest structure/facility is: Standard Construction Timber Frame, Brick, and Concrete Buildings; Lock Monoliths; Powerhouse Switchyard; Highway and Railroad Bridges; Buried Utilities; and Wells and Aquifers. Some projects may require assessment by a trained experienced vibration specialist or structural engineer of lower allowable vibration criteria at critical or historic or special structures or facilities or structures with continuous occupants. Ground vibrations can cause the occupants of structures to become physically uncomfortable at levels well below the allowable vibration levels to avoid damage to the structure itself. Projects a with a Powerhouse and Electrical Power Relay Equipment or Pipelines, besides those with continuous occupants, should be evaluated for lower allowable vibration criteria. Some projects could utilize the assessment by a

trained experienced vibration specialist or structural engineer to include higher allowable vibration criteria for those projects where typical structures/facilities are more than twice the distance of the closest approach from construction to: Steel and Reinforced-Concrete Structures; Mass Concrete Monoliths; and Cured Shotcrete. The specification writer must include a limitation of the allowable vibration.

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Vibration monitoring must conform to current industry standards and use equipment developed for that purpose. Peak particle velocity must be used as the unit of measure. Begin seismic vibration monitoring at least four weeks prior to the commencement of any mechanical excavation anticipated to induce excessive ground vibrations to determine background levels on adjacent roads, and the [_____]. Permanently mount the seismograph to record seismic events for a 24-hour period daily. Submit the background vibration monitoring reports and the baseline vibrations levels determined from the data for approval at least two weeks prior to the commencement of mechanical excavation anticipated to induce excessive ground vibrations. The peak particle velocity of each component must not be allowed to exceed current local, State and Federal vibration limits, whichever is more stringent, and never exceed the safe limits of the nearest structure subject to vibration damage.

3.7.3 Measuring and Recording Instruments

Submit seismographs for approval. Provide up to [_____] seismographs capable of sampling rates of 15,000 samples per second or higher that meets ISEE PSBS. The 15,000 samples per second accuracy is required to acquire reproducible vibration readings. The units must be self-contained except for external geophones and microphones. The seismograph must be capable of providing a printout or downloading the data to a portable device for off-site printing. The units must be programmed with specific data for each site of seismograph placement, which includes seismograph location, geophone burial or mounting method, calibration signal, date, time, and closest distance to the excavation. The seismographs and geophones must be placed on and secured to sound bedrock, buried in virgin soil, or affixed to mass concrete foundations or to other structures where vibration data is needed. Include the raw data values from the seismograph of vibration.

3.7.4 Seismograph Locations

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NOTE: This paragraph will vary depending on the project, the designer should determine what structures need to be monitored. It may be necessary to require one or two extra seismographs that are placed at the Contracting Officer's direction.

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Install seismographs at locations approved by the Contracting Officer. These locations are subject to change as the project progresses.

3.7.5 Individual Vibration Monitoring Report

Provide the original digital results of vibration monitoring in the form of peak readings and frequencies for each monitoring period, provide the Contracting Officer with access to the online data available immediately after data is collected. Submit the vibration monitoring reports. Data recorded for each monitoring period must include the following:

a. Identification of instrument used and location.

b. Name of qualified observer and interpreter.

c. Distance and direction of recording station from excavation area.

d. Type of ground at recording station and material on which the instrument is sitting.

e. How the geophone is anchored, if peak acceleration is greater than 0.2 g to prevent decoupling of the sensor.

f. Maximum particle velocity in each component direction.

g. A dated and signed copy of seismic records with their supporting information.

3.7.6 Convergence Monitoring Construction Requirements

3.7.6.1 General Tolerance

The instruments must be installed as close as practicable to the locations shown on the Drawings or as established in the field as approved by the Contracting Officer. The Contractor must submit to the Contracting Officer for consent, all final instrument locations prior to their installation. Where instruments are shown on the contract drawings to be installed in clusters, the Contractor must install all instruments shown within a [_____] mm [_____] in. radius.

3.7.6.2 Availability of Data

The Contractor must monitor all instruments and provide data obtained to the Contracting Officer within a maximum of 24 hours after taking the readings unless otherwise directed by the Contracting Officer.

Instrument monitoring data must not be disclosed to third parties and must not be published without the prior written approval of the Contracting Officer.

3.7.6.3 Protection of Instruments

Full responsibility must be borne by the Contractor for protecting the instruments from damage caused by construction operations. Damaged instruments must be promptly replaced or repaired, as directed by the Contracting Officer, at the expense of the Contractor.

The instruments must be clearly marked and protected to avoid being covered by shotcrete. Access must be maintained to permit reading of instruments. Shotcrete applied around any instrument must be removed immediately.

3.7.7 Rock Damage Control

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NOTE: Tailor this paragraph to the specific site conditions that may affect underground construction.

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The rock formations are known to contain geological features including variable weathering, alteration, fracturing and shearing, voids, weathered joints, and gouge seams. Rock cores recovered during site exploration drilling investigations disclose the site's geological conditions and are available for review by the Contractor. The Contractor is encouraged to review the [Geotechnical Data Report, Geotechnical Baseline Report, other reports provided with bid documents or made accessible], the drill core, drill core photographs, cut slopes or outcrops, and all geotechnical and structural information available before planning and conducting tunnel excavation operations.

****

NOTE: The section below should be used when Roadheader mechanical excavation techniques are required on the project.

A Roadheader is more economical for shorter tunnels rather than using/mobilizing a TBM and where Drill and Blast excavation is not allowed.

A Roadheader is a hybrid mechanical excavator and consists of a boom-mounted rotating cutting head with a conveyor for broken rocks, crawler tracks move the entire machine forward into the rock face. High mobility, advance rates, reliability, low rock disturbance, safety, and small labor force for deployment, staging area footprint, are some of the advantages of Roadheader.

The power density ratio provided by the small diameter cutting drum gives the Roadheader an edge over other mechanical excavation techniques. Recent advances have made Roadheaders more efficient in hard rock tunneling. Increases in machine weight, size, automation, and remote control, cutterhead and boom positioning, advances in hydraulic and electrical systems, muck pick and loading systems, and cutter head design are the biggest developments in Roadheader which make them economical choices in some underground excavation scenarios.

Boom-type Roadheaders are small size (up to 30 tons), mid-size (between 30 and 70 tons) and large size (between 70 and 120 tons). Several rock properties affect the cutting force of a Roadheader. Uniaxial Compressive Strength (UCS), Brazilian Tensile Strength (BTS), quartz content, Ratio of UCS to BTS, and Cone indenter hardness, tangent Young's modulus, density, porosity, static elasticity modulus, shore scleroscope hardness, specific energy, rock quality designation, Rock mass cuttability index, Cercher abrasivity index, Schmidt

Hammer rebound hardness, and point load strength, are some of the parameters of rock that are found to influence Roadheader performance.

Cutting performance is a term used to illustrate the influence of cutting rate and cutter wear in different geological conditions. The prediction of cutting performance for any type of excavating conditions, or rock formation in which the machine is deployed, is one of the main factors determining the economics of a mechanized excavation operation. The instantaneous cutting rate or ICR has widely been applied and modified for specific rock types. Progress over a construction shift or on hourly basis is also taken as a performance metric tracked on the job. Machine selection is performed on the basis of tunnel dimensions and ground conditions which in turn, determine production rate and bit consumption. Deployment of the Roadheader is mainly dependent on how effectively the performance rating is geologically investigated. Accordingly, if not selected as per geological conditions anticipated the consequences can be economically costly leading to claims and scheduling implications.

Despite the advantages, the Roadheader has some disadvantages such as high pick consumption rate in very abrasive rocks, making excavation uneconomical due to frequent bit changes with increased machine vibrations and maintenance costs. Exposure to silica or rock dust continues to be a major risk to the health of workers. Dust particles such as coal dust, silica dust and other finely powdered materials, can damage lungs and airways.

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3.8 ROADHEADER EXCAVATION

The roadheader(s) must excavate the tunnel(s) to the minimum excavation size as shown on the Drawings or as approved by the Contracting Officer, to provide the required lining thickness indicated on the Drawings within the size, alignment and grade tolerances specified. The roadheader(s) must be maintained and utilized to handle the various ground conditions as described in the GBR and sustain advance rates that will permit completion of the work within the allowable schedule. Minimize the loss of ground ahead of and around the roadheader and always provide support of the excavation. Use a dust control system.

Install the rock support and initial support system as close behind the excavation operation as possible. The face must not extend more than [_____] meters [_____] feet in front of the nearest installed support.

The tunnel must be excavated by a mobile fully articulated boom excavating machine, commonly known as a "road header". The excavating machine must meet the following requirements:

1. Must be a [25] ton or heavier machine with a minimum horsepower of [150] HP to the cutter head.

2. Be equipped to excavate to the "A" or over excavation lines shown on the above drawings with capability to quickly adjust excavation size to meet varied support requirements.

3. Be equipped with a gas-detection devices and warning system.

4. Be of such a configuration that structural-steel adit supports or rock reinforcement may be installed at or near the heading ahead of the main body of the machine where required.

5. Be designed so that the entire machine and its trailing equipment may be backed out through the structural-steel supported reaches of the adit or any other restricted reaches so designed to provide free access for passage of men, equipment, and materials to the face to perform ground support or excavation tasks. To assist in backing excavating equipment out of the adit, partial disassembly of the machine is acceptable. However, the capabilities of backing the equipment out of the adit and providing free access to the adit heading must be provided in a manner that maintains the integrity of the machine and trailing equipment during removal from the adit and reinstallation in the adit.

6. Be equipped to remove muck with high water content from adit invert in areas of high water inflow and in standing water.

7. Be equipped so that adit drainage inflow of water in the vicinity of the machine, as deep as 0.61 meters2 feet, will not stop the operation of the tunneling machine.

8. Be designed to provide for adequate ventilation for all workmen in vicinity of the machine and its trailing equipment.

9. Be capable of maintaining its correct alignment and grade at all times.

10. Be capable of wetting the face of the excavation and cutter head for effective dust control.

11. Excavation of quartzo-feldspathic bedrock lithologies are expected to result in higher than normal wear on the cutter and fracturing of carbide cutter tips.

****

NOTE: While it has been demonstrated that roadheaders have been used in conglomerates, sandstones, granite, quartzite and diabase, these formations are particularly hard for roadheader tunnel excavation. Roadheader is most efficient in low to medium hardness rock. Use in hard rock and highly abrasive rock should be expected to result in low-production excavation rates. Equipment is limited by a shorter life of tools and increased cutting tool cost.

****

3.9 REQUIRED MUCKING

Required mucking operations must adhere to the detailed plan for muck handling.

****
NOTE: The section below should be used when Tunnel Boring Machine (TBM) excavation techniques are required.
****

Provide a mucking system for handling and transporting the excavated rock from the tunnel face, through the TBM backup system, the tunnel and shaft, and on the surface, to the muck stockpiling area, with the capacity to sustain peak hourly penetration, peak shift, and peak daily advance rates. Ensure the mucking system does not restrict any of the other operations including handling and erecting of initial support system materials.

For rail mucking systems, a track with ties and ballast or direct fixation system will be maintained for safe operation of trains. Do not allow the head of the rails to be submerged in water or covered with tunnel muck or other debris. Upon completion of excavation of the tunnel, remove all such trackwork prior to placement of final lining.

For conveyor mucking systems, the tunnel must be immediately cleared of all spillage and other debris to maintain a safe and clear personnel egress and evacuation route throughout the tunnel. Do not store tunnel muck on the mucking conveyor when not in use. In the event the conveyor mucking system is repaired, all replaced parts and components must be removed from the tunnel to minimize safety hazards.

3.10 SCALING

****
NOTE: Typically, a level of scaling is required for each project to remove loose, unstable rock prior to mucking operations or prior to required bolting application, shotcrete, or other methods of stabilization before carrying out additional excavation operations.
****

A program of frequent inspection and scaling must be maintained in all portions of the tunnel. Immediately after excavation advancement, the roof and walls of rock excavations must be inspected by experienced and suitably equipped scalers who must dislodge and scale down all loose and unstable rock. Scale any loose and unstable or unsafe appearing material remaining on the tunnel periphery at the portal areas as the excavation proceeds. No separate payment will be made for scaling.

****
NOTE: The section below on grouting should be used when Tunnel Boring Machine (TBM) excavation techniques are required, and high groundwater conditions are anticipated or unstable geologic materials (such as fault zones, karst, or other unstable geologic conditions) and grouting is used to control water inflow to the tunnel heading or stabilize ground conditions. The anticipated volume of water as indicated in the Geotechnical Baseline Report should be specified in the section below.
****

3.11 GROUTING

Conduct pre-excavation and post-construction grouting in accordance with Section 31 73 19 TUNNEL AND SHAFT GROUTING and as shown on the Contract Drawings.

If groundwater exceeds [_____] liters per minute (lpm) gallons per minute (gpm) during probe hole advancement during tunnel construction the Contractor's Engineering Geologist or Geotechnical Engineer will submit a grouting and excavation plan or establish protocols for excavation if certain inflows exceed threshold lpm gpm values prior to tunnel excavation. The Contracting Officer must be informed of the implementation of the grouting plan if groundwater inflows exceed excavation plan established inflow thresholds.

****
NOTE: The section below should be used when Roadheader excavation techniques are required.
****

3.12 MAINTAINING PILLAR STABILITY

****
NOTE: The use of rock pillars as an excavation support means in tunneling is expected to have limited application. Historically, pillars have been used in mining applications. Delete this section if rock pillars are not anticipated on the project.

In addition to pillar stabilization using rock dowels, a narrow pillar may be designed to be stabilized/widened by a heavily reinforced concrete section. Modify as applicable to project conditions.
****

Install additional rock dowels in pillars where the pillar width measured at springline is less than or equal to [_____] meters [_____] feet. Install dowels as shown on the Contract Drawings.

****
NOTE: The section below should be used when Tunnel Boring Machine (TBM) excavation techniques are required.
****

3.13 INITIAL SUPPORT

****
NOTE: A UFGS for TUNNEL EXAVATION SUPPORT is being developed. The designer will need to include Initial Support as listed here and Permanent support. Often the contractor will be responsible for designing their own initial ground support types and may not be defined in the GBR or specs. Alternatively, the GBR may give conceptual initial support types (spacing, type, lengths) to bid on but give multiple support Types that may be applied along different alignment stationing depending on

the geologic conditions. Tailor this section as appropriate

****

3.13.1 Support Classes and Support Class Ranges

All stations indicating limits of typical support classes referenced herein or as shown on the Contract Drawings are only approximate and may vary due to the geological and hydrological conditions encountered in the field. Tunnel excavation support classes, as shown on the Contract Drawings, are the minimum to be installed and adjusted above and beyond the said minimum based on the actual ground conditions encountered and be determined in the field in consultation between Contractor and the Contracting Officer. Each support class defines installation of a specific initial support system. The support elements are as specified in [Section XX XX XX TUNNEL EXCAVATION SUPPORT] and as shown on the Contract Drawings.

3.13.2 Initial Support Measures

Initial support measures have been derived based on anticipated ground conditions and the need to provide stabilization of the tunnel openings under this Contract. Excavation and support measures delineated hereafter are typical and will be supplemented by additional initial support measures as required by ground conditions encountered or as directed by the Contracting Officer. Expect to install additional ground support across weak or open geological features to minimize ground deformation. Damage is defined as the loosening of rock behind final lines and grades, opening of joints in the excavation or rock block displacement. If any damage occurs to the final excavation that requires remediation, it must be the responsibility of the Contractor to provide a timely, recommended corrective action to the Contracting Officer and demonstrate that the methods employed did not cause the damage.

To minimize ground movement; the initial support must be installed following each heading and as close to the working face as practical in accordance with [Section XX XX XX TUNNEL EXCAVATION SUPPORT].

****

NOTE: Verify that a Geotechnical Baseline Report has been prepared for the project and has been referenced in Section Related Attachments and Specifications.

****

a. Ground support guidelines for the tunnel excavation are shown on the Drawings and provided in the GBR. In addition to the ground support shown on the contract plans, the Contractor must install such ground support as necessary to always ensure the stability of the excavation and the safety of the construction personnel. Ground support installed by the Contractor without agreement or instruction from the Contracting Officer must be for the Contractors convenience and at the Contractor's expense.

b. The ground support must be installed as soon as practicable after tunnel excavation to minimize loosening or movement of the surrounding ground. The Contractor must be responsible for providing confirmation

that the ground support system has produced a stable excavation. The support layouts shown on the contract drawings are a guide only and must be modified as required in the field based on geologic conditions exposed during tunnel excavation.

c. The approval of the proposed excavation and support sequence by the Contracting Officer or failure to call attention upon improper or inadequate application of the related excavation sequence or tunnel support, pre-support, or face support or to require respective change must not relieve the Contractor of responsibility for the integrity of the tunnel support or the proper execution of the work.

d. Lengths of excavation rounds shown on the contract drawings are maximum values and may have to be reduced due to the ground conditions encountered.

e. Pneumatically projected concrete, either fiber reinforced Shotcrete or plain Shotcrete must comply with provisions set forth in Section 03 37 13 SHOTCRETE.

f. Rock reinforcement for tunnel excavation must comply with 31 68 13 SOIL AND ROCK ANCHORS.

g. Steel arch ribs, liner plates and additional ground support elements must comply with [Section XX XX XX TUNNEL EXCAVATION SUPPORT].

3.14 EXCAVATION SEQUENCE FOR TUNNELS

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NOTE: This is a placeholder for an excavation sequence. Depending on the project design and site conditions each project will require a specific excavation sequence. Example language: "Tunnel excavation must be accomplished in either a full face or top heading and bench format as indicated on the contract drawings. All initial support must be applied or installed prior to tunnel heading advance."

****

3.15 GROUND SUPPORT SYSTEM TYPES

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NOTE: Ground support systems are often referred to as "categories" of ground support types. These categories are applied throughout a tunnel alignment in various zones as defined by the geologic conditions encountered as part of the pre-design investigations. See the Geotechnical Baseline Report for anticipated ground conditions.

****

[_____] ground support categories have been developed for the stabilization of the main tunnels as defined in [Section XX XX XX TUNNEL EXCAVATION SUPPORT].

An estimate has been made as to the lengths of each of the ground support categories required to stabilize the tunnel. The estimated lengths are shown on the contract drawings and presented in the Geotechnical Baseline

Report (GBR). Actual stabilization requirements may vary from those estimated based on the geologic conditions encountered. In accordance with Section 01 35 26 GOVERNMENTAL SAFETY REQUIREMENTS, the Contractor must be responsible for the safety of the work and for accomplishing the initial and permanent stabilization of the tunnel opening.

3.16 EXCAVATION FOR TRENCHES AND SUMPS

Excavation for trenches and sumps must conform with 31 00 00 EARTHWORK and as shown on the contract drawings.

****

NOTE: Excess Excavation section is applicable to mechanical excavation using roadheader. It should not be expected that the excess excavation section will be applicable to TBM excavation methods.

****

3.17 EXCESS EXCAVATION

****

NOTE: The type/class of shotcrete used to fill overbreak areas in the tunnel should be defined by the designer in early stages of the development of the bid documents. Similarly, the type of material used to fill overbreak in tunnel invert must also be defined during early stages of the project design.

****

Excavation outside of the B-Line shown on the drawings must be filled with Class I,II, III Shotcrete in accordance with Section 03 37 13 SHOTCRETE, or as directed by the Contracting Officer, at the expense of the Contractor. Overbreak excavation in the tunnel invert must be filled with [compacted crushed rock, lean concrete], or as directed by the Contractor Officer, at the expense of the Contractor.

3.18 TOLERANCES

The tunnels must be excavated in accordance with the A-line dimensions shown on the Drawings. No unexcavated rock or other material must protrude within the A-line.

3.19 CONTROL OF WATER

****

NOTE: This section will likely be incorporated into a future UFGS for Tunnel Dewatering. This section will need to be heavily tailored for your project needs. Adhere to the current version of the ETL 1110-2-586 DEWATERING: Methods, Installation, and Performance Monitoring. The project may develop a Diversion and Care of Water specification that is included in the front-end specifications and this language may be included there.

Beyond safety considerations of ice accumulation around portals and shafts, ice formation can create havoc with tunnel drainage and related rock subdrain systems in unheated area subjected to freezing

conditions (e.g. near portals). This has been a critical issue for prior USACE underground facilities during construction.

****

The Contractor is responsible for control of water in the tunnel during construction and must take all means necessary for such control. Control of water must include but not be limited to, furnishing, installing, operating, and maintaining pumps and other equipment including temporary measuring devices must as per (b) below, constructing temporary ditches and drains and keeping ditches and drains free to carry all water to sumps or other disposal areas; and disposal of all water, tested as required, draining, or pumped from the tunnel. Disposal of water must conform to all applicable Federal, State, and local laws. [Treatment of groundwater is required if determined to be contaminated.]

3.19.1 Automatic Measuring Devices

Automatic measuring devices must be furnished by the Contractor and must be employed to measure the flow rate of water coming out of the tunnel portals. Water piped in for construction operations and water exiting at the portals must be separately measured. The difference between the total flow rate out of and the total flow rate into the tunnel must be considered the rate of groundwater inflow to the tunnel. This rate of flow must be measured and recorded on a [daily basis, [_____] hour basis] for information only.

3.19.2 Fissure Grouting

Fissure grouting must mean grouting carried out in the rock mass surrounding the Underground Works to stem water flows emanating from fissures in the rock where if left un-stemmed the inflows could initiate instability. Pressure grouting must be carried out when instructed by the Contracting Officer and, where necessary the Contractor must carry out lugeon permeability tests to establish the extent of the fissure to delineate zones that will take grout. Further requirements are detailed in Section 31 73 19 TUNNEL AND SHAFT GROUTING.

3.20 PERMANENT TUNNEL DRAINAGE

A drainage geotextile must be installed on the walls and crown of the excavation behind the shotcreted surface at locations where actual flows of water are encountered and at other locations as shown on the Drawings or as may be required to the satisfaction of the Contracting Officer. The drainage geotextile may be accompanied by drill holes installed into the rock face at discrete locations to capture concentrated seepage flow. The installation must comprise full coverage for ground support in accordance with [Section XX XX XX TUNNEL EXCAVATION SUPPORT].

The drainage membrane must be fixed and sealed to the approval of the Contracting Officer so that the placing of shotcrete does not block or obstruct the drainage geotextile. Geotextile must be installed in accordance with Section [_____] and Waterproof Membrane must be installed in accordance with Section [_____].

-- End of Section --