SECTION 02416
TUNNEL EXCAVATION BY MICROTUNNEL BORING MACHINE (MTBM)

PART 1 GENERAL

1.1 DESCRIPTION

A. The work includes furnishing and installing cased tunnels by microtunneling methods where indicated to install water intake pipes without open excavation and installation of specified appurtenances as shown on the Drawings.

B. For the purpose of this section, microtunneling is defined as the trenchless installation of a pipe by jacking the pipe behind a remotely controlled steerable, laser-guided, microtunnel boring machine (MTBM).

C. The microtunneling work is the installation of two microtunnels. The first extends from Big Sand Wash Reservoir to a construction access shaft. The second extends from the construction access to a portal in the valley below Big Sand Wash Dam. The tunnels lengths are approximately 560 feet and 500 feet, respectively. The tunnels are mainly 100 feet below ground level.

D. The two microtunnel operations may be undertaken from inside the construction access shaft. Alternatively, the downstream tunnel may be driven from the downstream portal and the upstream tunnel driven from the construction access shaft.

E. The pipe for upstream tunnel will be launched and will be installed by microtunneling from the shaft wall toward the lake. The lake will be lowered so that the MTBM enters into a dry excavation on the floor of the lake.

F. The CONTRACTOR shall use the geotechnical information provided in the Geotechnical Baseline Report (GBR) and Geotechnical Data Report (GDR) to plan and execute this work. Core from the exploratory borings drilled for this Project is available and may be examined by the CONTRACTOR or his representative.

1.2 QUALIFICATIONS

A. The CONTRACTOR and his field superintendent shall demonstrate and document their qualification for this Project by their experience on projects of similar type, scope, and/or complexity.
1. The CONTRACTOR and field superintendent shall have completed three microtunneling projects comparable to the size and scope of this Project or the installation of 2,000 feet of conduit ranging from diameter from 52 inches or larger in the last 5 years using microtunneling equipment manufactured by Iseki, Soltau, Herrenknecht, or Akkerman.

2. The CONTRACTOR and field superintendent shall have completed at least one prior drive of 1,000 or more feet.

3. The MTBM operator/technician that will be utilized must show as minimum the qualifications in Article QUALIFICATIONS.

4. The CONTRACTOR and field superintendent may submit other information not called for that he deems pertinent in demonstrating his qualifications for review by the OWNER and CONSTRUCTION MANAGER.

1.3 DEFINITIONS

A. Work Plans and Shop Drawings: Are detailed descriptions, together with Drawings, calculations, specifications, operation manuals, method statements, schedules, and any other documents detailing the CONTRACTOR’s plans for tunneling.

B. Microtunnel Boring Machine: A tunneling machine to be used with pipe jacking having provisions for remote operation, steering control and face control.

C. A slurry machine is an MTBM with a bulkhead behind the face of the machine to form a plenum chamber. Bentonite slurry or other medium is introduced into the plenum chamber under appropriate pressure to stabilize the face and to be mixed with material excavated by the rotary cutter wheel. The resultant slurry is removed by a slurry pumping system.

D. Slurry System: Transportation of excavated material in a slurry flow matched to excavation rate. System balances groundwater pressures and separates soil from slurry at the end of the process.

E. Jacking System: A system of hydraulic jacks in the jacking shaft that push the string of pipe. The capacity of jacks and extension rate is synchronized with excavation rate of the machines.

F. Intermediate Jacking Station: Hydraulic jacks installed at intermediate locations in the pipe string to allow selective shoving of discrete segments of the total pipe.
G. Laser: An optical system projecting a beam onto a target in the head of the MTBM to provide guidance for steering the MTBM.

H. TV: A television system that monitors the progress and alignment of the MTBM and pipe string.

I. Controls: The system, which synchronizes excavation, removal of the excavated material, and jacking of pipe to maintain overall balance to provide complete and adequate ground support at all times.

J. Obstructions: Objects or portions of objects located within the cross-sectional area to be excavated by the MTBM that stop forward progress. Object may be one of the following:

1. Zones of rock with a maximum Unconfined Strength of 10,000 psi.
2. Metal.
4. Large tree trunks or extensive pieces of wood.

1.4 QUALITY ASSURANCE

A. In addition to the provision of operational data referred to elsewhere in this specification, the CONTRACTOR shall comply with the following:

1. Only qualified microtunneling contractors accepted by the CONSTRUCTION MANAGER are authorized to perform the microtunneling work.
2. The CONTRACTOR shall establish and maintain quality control for operations under this section to provide compliance with the Contract requirements and maintain records of quality control for materials, equipment, and construction operations.
3. The CONTRACTOR shall keep and maintain at the construction site a complete set of field drawings for recording as-built conditions. It shall have marked or noted thereon all field information, properly dated, recording as-built conditions. This set of field drawings shall be kept up-to-date during the course of the Project and turned over to the CONSTRUCTION MANAGER at the end of the Project.

PART 2 PRODUCTS

2.1 TUNNELING EQUIPMENT

A. The tunneling machine selected shall be designed for excavating and installing pipe from a jacking pit through the geologic materials as described in the site
GBR report. The CONTRACTOR must read the GBR and take this information into account in planning and executing the underground construction on this Project.

B. The CONTRACTOR shall use pressurized slurry microtunneling methods. Microtunneling equipment shall be closed pressurized face, steerable, laser guided, articulated tunnel shield of a suitable type so as to exert continuous, controllable pressure at the tunnel heading to prevent groundwater inflows and soils movements into the heading.

C. The MTBM shall have a reversible cutterhead drive system to minimize rotation of the pipe during installation.

D. MTBM shall be a suitable type as manufactured by Herrenknecht, Iseki, Soltau, or Akkerman and shall be capable of fully supporting the face both during the excavation and shutdown; shall have the capability of positively measuring in the plenum chamber face the external groundwater pressure at shutdown and the earth pressure and the slurry pressure when operating.

E. The MTBM shall apply slurry pressure at the MTBM face to stabilize the excavation and maintain a continuously monitored pressure level slightly in excess of normal hydrostatic pressure.

F. MTBM shall be capable of being operated in a manner that will prevent loss of ground during tunneling and shall be steerable and capable of controlling the advance of the heading to maintain line and grade within the tolerances specified.

G. The MTBM shall have a spoil transportation system that has the capacity for removal of spoil in balance with excavation and advance. The spoil separation system shall have sufficient capacity to remove solids from the flow while the system is excavating spoil, and operate in such a manner that recirculated or excess fluid can be discharged safely and with negligible remaining fines.

H. The MTBM shall be capable of excavating, crushing and transporting in the slurry system the rock describe in the GDR and GBR.

I. Amount of over cut provided on the MTBM cutter head shall be compatible with the soil conditions, stiffness characteristics of selected pipe, and joint system at the designed maximum jacking loads.

J. The microtunneling equipment shall employ a spoil removal system with a pressure balance system that is capable of equalizing pressures between the
tunnel face and the microtunneling machine head to depths of 90 feet of hydrostatic head.

K. MTBM shall have a guidance control system using a laser which is monitored continuously and accurately observes the boring machines vertical and horizontal displacement from the laser beam datum which has been accurately set to the required alignment and grade of the tunnel under construction.

L. The MTBM shall have the ability to articulate and be steered to correct vertical and horizontal deviations from the required alignment by the remote activation steering jacks to maintain the tunnel machine alignment within the Contract Specifications.

M. The MTBM shall have the ability to continuously display and record the position of the MTBM relative to the laser line.

N. The MTBM shall have the means to inject lubricant over and around the rear of the MTBM and subsequent pipes for pipe jacking.

O. Have an overall control system that enables remote control and recording of all the main operating functions of the system from the surface of the main operation shaft.

P. Power generation plant shall be engineered by the manufacturer to provide a guaranteed sound pressure level rating at full load not exceeding 75 dBA at 50 feet in any direction when installed on open ground as the only reflective surface. Each component contributing to overall sound level shall be acoustically engineered and attenuated as required to achieve the guaranteed maximum sound pressure level.

2.2 STEEL CASING PIPE

A. All steel casing pipe shall conform with Section 02501, WELDED STEEL PIPE, SPECIALS, AND FITTINGS.

B. CONTRACTOR Design: In addition to the requirements indicated herein, the CONTRACTOR shall design the steel casing pipe with the following minimum requirements:

1. External Loads: The maximum ground cover and hydrostatic loads as indicated in these documents.
2. Steel casing pipe ends shall be uniformly supported so that jacking loads are evenly distributed around the entire pipe joint.
3. Jacking Loads: The CONTRACTOR shall provide calculations of the allowable jacking force based on the external loads, a factor of safety of 3.0, and potential angular deviations at joints between adjacent pipes. This allowable jacking force shall not be exceeded during tunneling.

4. Casing OD: 74.5 inches.

5. Minimum steel casing pipe thickness, considering manufacturing under-tolerance, shall be 3/4 inch.

6. Grout/lube holes (1-1/2 inch to 2 inch) shall be provided as indicated on the Drawings.

7. Suitable spiders or stulls shall be provided in the pipe for transportation and site handling.

C. Dimension Tolerances: As required in the manufacturing specifications and as modified below:

1. Straightness: The maximum allowable straightness deviation in any 10-foot length shall be 1/8 inch. Deviation of the entire length shall not exceed 3/8 inch in any 40-foot length.

2. Pipe Ends: The end of the pipe shall be perpendicular to the longitudinal axis of the pipe within 1/16 inch per foot of diameter, with a maximum allowable deviation of 1/4 inch, measured with a square and straight edge across the end of the pipe. Pipe ends shall align within 0.05 inch for the entire circumference before welding begins.


D. Field Joints: Connect steel casing pipe at CONTRACTOR’s option as follows:

1. Permalok: Steel casing pipe as specified herein with Type 5 joints as manufactured by Permalok Corporation, St. Louis, MO, (314) 524-1900, FAX (314) 524-5702. Field weld joints after jacking into tunnel using 1/4-inch PJP groove weld to prevent leakage.

2. Steel casing pipe with CJP field welded butt-joints; as specified herein.

E. Welding (Shop and Field):


2. Inspection: Full-time CWI.

3. See Section 02501, WELDED STEEL PIPE, SPECIALS, AND FITTINGS, for further information.

F. Coating and Lining: As specified in Section 09910, STEEL PIPE COATING AND LINING.
G. Factory Pressure Testing: No factory hydrostatic testing of steel casing pipe is required.

PART 3 EXECUTION

3.1 SUBMITTALS REQUIREMENTS FOR MICROTUNNELING OPERATIONS

A. The CONTRACTOR shall submit to the CONSTRUCTION MANAGER for review, plans, details and data including compliance with the requirements of these Contract Drawings. Such review shall not be construed to relieve the CONTRACTOR in any way of responsibilities under the Contract. CONTRACTOR shall not commence work on any items requiring a Tunneling Work Plan or other submittals until the submittals have been reviewed and accepted by the CONSTRUCTION MANAGER.

B. The following submittals related to the microtunneling work are to be submitted for review complete, where appropriate or required, with working Drawings showing details of the proposed method of construction and the sequence of operations to be performed during construction.

C. Submittals shall be made in accordance with Contract requirements.

D. All CONTRACTOR submittals requiring structural design shall be signed by a suitably experienced professional civil or structural engineer registered in the State of Utah.

E. The review of the CONTRACTOR submittals by the CONSTRUCTION MANAGER shall not be construed in any way as relieving the CONTRACTOR of his/her responsibilities under this Contract.

3.2 CONTRACTOR SUBMITTALS FOR MICROTUNNELING OPERATIONS

A. The CONTRACTOR shall provide the following submittal information and Shop Drawings in accordance with the requirements of the Contract.

B. CONTRACTOR’s Experience: The experience of CONTRACTOR’s proposed personnel or operators not previously submitted as part of the pre-qualification or bid process or those that have changed.

C. MTBM: The following information shall be provided and certified by the MTBM manufacturer.

2. MTBM general arrangement Drawings.
3. Cutter head configuration(s) including Drawings.
4. MTBM capabilities for dealing with anticipated ground conditions.
5. A statement of the operating parameters within which the CONTRACTOR proposes to operate the machine together with confirmation from the equipment manufacturer that these are appropriate for the conditions on the Project.
6. Arrangement Drawings and technical Specifications of the MTBM and trailing equipment (include any modifications).
7. A copy of the manufacturer’s operational manual for the machine.
8. Grade and alignment control system.
9. Specific gravities and viscosities proposed for the slurry.
11. Interrogation period for data recording.
12. Stock of spare parts for MTBM system to be available on site.
13. Details of proposed soil separation methods, including calculations for the system capacity to handle flows.
14. Details of proposed slurry system, pump locations and slurry pipe diameters and calculations to demonstrate system capabilities at all distances and changes of elevation to and from the tunneling machine.
15. The submittal shall include a detailed description, with a readily understandable visual representation, of all MTBM operations functions as seen by the operator, including what each function means and what is the normal operating range for that function.

D. Pipe and Pipe Jacking:

1. A detailed method statement for the proposed microtunneling and recovery of the MTBM.
2. Proposed pipe materials, joint design, and wall thickness.
3. Welding requirements of Section 02501, WELDED STEEL PIPE, SPECIALS, AND FITTINGS.
4. Pipe design calculations demonstrating that the pipe selected has been designed to support the maximum anticipated external load, the anticipated jacking forces, and hydrostatic forces.
5. CONTRACTOR’s calculation of proposed allowable jacking force on the pipe(s).
6. Calculations of anticipated jacking forces including graphical plot of distance versus jacking force for each drive.
7. Plan of locations of interjacks.
8. A specification for the interjacks.
10. Peak jacking force that can be applied by the jacking system (max cut off level).
11. CONTRACTOR’s lubricating plan, mixture, pumping pressures, and volumes.
12. Frequency and location of lubrication ports in MTBM and pipes as shown on the Drawings.
13. Layout of tunneling and ancillary equipment at the shaft and, if appropriate, the downstream portal sites.
15. MTBM “Hole-Out” of the shaft and, if appropriate, the downstream portal. This shall include a detailed step-by-step description, all calculations, detail drawings for methods of controlling groundwater and hydrostatic pressures.
16. Pipe storage arrangements on site.
17. A certificate of compliance from the pipe manufacturer, endorsed by the CONTRACTOR, with all parts of this specification.
18. Test reports on pipe as required. Mill test reports or independent testing laboratory reports regarding the entire casing pipe mechanical.

E. Lake Bottom Construction: This submittal shall describe and illustrate all construction required to dewater the lake bottom excavation; manage the lake during construction operations, complete the microtunnel excavation into the lake bottom excavation; perform the open cut excavation; construct the intake structure; and construct the pipeline connecting the tunnel and intake structure.

F. Shaft for Microtunneling:

1. Shaft design.
2. Shaft construction.
3. Arrangement and location of tunneling equipment in the shaft.
4. Design of thrust blocks for microtunneling.
5. Details of launch seals and any pipe clamping devices.
6. Plan for dewatering and keeping shaft dry.
7. Plan to backfill the shaft.

G. Contingency Plans:

1. Detailed contingency plans are required for the following:
   a. High jacking forces.
   b. Damaged pipe.
   c. Obstruction(s).
   d. Settlement.
   e. Loss of line or grade.
   f. Major mechanical breakdown.
g. Stoppage of jacking.
h. Leakage.

H. Tunnel Monitoring:

1. Procedures for monitoring tunnel operation.
2. Reporting forms in detail with explanation for all aspects of monitoring.

I. Other Submittals:

1. Safety Procedures. Complete information on CONTRACTOR’s proposed safety plan for personnel conducting the tunneling and appurtenance installation. The plan shall include provisions for lighting, ventilation, air quality monitoring, underwater operations, and electrical safety. All OSHA, Federal, State, county, city, or local regulations/laws shall be followed.
2. Grouting plan at launch.
3. Details for grouting the annular space after pipe has been installed including injection pressure and method of controlling grout pressures.
4. Power generation plant sound rating data shall be submitted. Sound level rating data shall be based on actual tests of an identical unit or a similarly packaged unit of equal capacity with calculated corrections submitted for review. Manufacturer’s test procedure, equipment, and reporting shall conform to SAEJ1074, Engine Sound Level Measurement Procedure or ANSI/ASME PTC36, Measurement of Industrial Sound. Submit unweighted sound pressure levels in the eight octave frequency bands centered at 63 Hz through 8,000 Hz and the overall A-weighted sound pressure level.
5. CONTRACTOR shall provide complete information on facilities for treating water pumped from or drained from the tunnel and shaft system. These facilities shall have the capacity to treat up to 500,000 gallons of water per day for discharge in compliance with Section 01581, Compliance With Laws And Regulations.

3.3 CONTRACTOR EXPERIENCE

A. Only qualified microtunneling contractors as approved by the CONSTRUCTION MANAGER or OWNER will be allowed to perform the microtunneling operations in these Contract Documents.

B. Supervision: Each jacking shift shall be supervised by at least one person with previous experience of the work. Application for acceptance of named supervisors shall be made to the CONSTRUCTION MANAGER prior to the commencement of work.
C. Operation: System operators shall be experienced personnel with prior knowledge and ability in the proper operation of the systems being employed. Application for acceptance of named operators shall be made to the CONSTRUCTION MANAGER prior to the commencement of work.

D. CONTRACTOR shall provide evidence of OSHA certification for site safety representative and personnel responsible for air quality monitoring.

E. An experienced grouting contractor is required. The CONTRACTOR shall provide suitable evidence of the grouting contractor's qualifications for this work.

3.4 CONSTRUCTION

A. The CONTRACTOR shall be responsible for the structural design and integrity of all temporary works for shafts, tunneling, construction methods, and other methods that are carried out by the CONTRACTOR in order to complete the work. The CONTRACTOR shall submit full details of such structural designs, and of any associated construction methods for the CONSTRUCTION MANAGER for review and acceptance.

B. The CONTRACTOR shall plan, schedule, and execute the excavation of tunneling works in accordance with the Specifications and Drawings.

C. All personnel employed by the CONTRACTOR in the execution of tunneling works shall be experienced and competent in their respective tasks, and shall work only under the direct control of a suitably experienced supervisor.

D. Shop Drawings. All pipe installation by microtunneling shall be completed in accordance with the Shop Drawings and accepted submittals.

E. The MTBM utilized shall meet the specified requirements of this section.

F. Shafts: The following are particular requirements of microtunneling:

1. The CONTRACTOR shall have the sole responsibility for allowing adequate space to meet CONTRACTOR operational requirements for tunnel construction and to accommodate the installation of pipe casings, MTBM, and jacking devices and for the subsequent construction of any permanent structures indicated on the Drawings.

2. Construction techniques required to provide access for microtunneling shall be such as to ensure the safety of the work.

3. The shaft shall conform to applicable local safety standards, OSHA standards, trenching and shoring standards.
4. Construct the shaft support system to the necessary size, shape, and depth to allow construction of the facilities in accordance with the Drawings and the geotechnical conditions.

5. The shaft ground support systems shall be designed by the CONTRACTOR’S professional engineer licensed in the State of Utah. The CONTRACTOR’S professional engineer shall observe and monitor the work and provide the CONSTRUCTION MANAGER a separate signed and sealed certificate affirming that the ground support systems are being appropriately implemented, when requested by the OWNER.

6. The CONTRACTOR shall provide a concrete working slab or plug for the shaft bottom to meet the requirements of tunnel and pipeline construction.

7. The CONTRACTOR shall install thrust block(s) to resist the anticipated jacking pressures.

8. All work excavating, shoring and bracing, and microtunneling shall be executed such that settlement is minimized, the in-place casing shall have full bearing against earth, and no voids or pockets are left in any portion of the work.

9. The CONTRACTOR shall provide for all dewatering to be sure that the shaft is maintained in a dry condition during all tunneling preparation and operation. He/she shall maintain temporary drainage facilities of adequate size, with standby pumps and adequate backup power for emergency use, to collect and dispose of water that enters the shaft excavations.

10. The CONTRACTOR shall provide a sump and pump for each shaft excavation to remove seepage that enters the excavation. Pumping from sumps shall not result in boils, softening of the ground, or loss of fines. Sumps, sub-drains, drain blankets, wells, and well points shall be installed with suitable filters or screens so that fines are not removed from the formation.

11. The CONTRACTOR shall dispose of all water removed from shaft excavations in accordance with all applicable permits and regulatory requirements. Dispose of contaminated groundwater in accordance with all applicable permits and regulatory requirements.

12. The CONTRACTOR shall take all measures necessary, including the provision of a hold back system on the tunnel pipe as installed, to take account of the effect of external hydrostatic pressure exerting a force on the MTBM and tunnel pipe and tending to push the pipe back into the jacking shaft unless restrained.

13. Remove shaft support from the ground surface a minimum of 10 feet below the ground surface during backfilling of the shaft.

14. Material for backfilling the shaft shall be as indicated on the Drawings.
G. Health and Safety:

1. All work, including ventilation requirements, shall conform to the requirements of OSHA. Perform all work in accordance with the current applicable regulations of the Federal, State, and local agencies. In the event of conflict, comply with the more restrictive applicable requirements.

2. Gas testing shall be performed by competent personnel within the confines of the valve shaft and the tunneling alignment. Performed in accordance with any local, State or Federal guidelines.

H. Control of Line and Grade:

1. The CONSTRUCTION MANAGER will establish a baseline and benchmarks from the control system in the plans. The CONTRACTOR is required to check the control system at the beginning of the Contract period and report any error or discrepancies immediately to the CONSTRUCTION MANAGER.

2. The CONTRACTOR shall use these baselines and benchmarks to furnish and maintain all reference lines and grades for tunnel construction. Use these lines and grades to establish the exact starting location of the tunnel.

3. All surveying work carried out to establish or check the laser alignment for the tunneling work shall be carried out by an independent and suitably experienced Professionally Licensed Surveyor (PLS) licensed in the State of Utah.

4. The CONTRACTOR shall submit to the CONSTRUCTION MANAGER copies of field notes used to establish all lines and grades, however, the CONTRACTOR remains fully responsible for the accuracy of the work and the correction of it, as required.

5. If the CONTRACTOR should need to reset the laser alignment once a tunnel drive has commenced, prior to recommencing tunneling to the changed laser alignment, he shall inform the CONSTRUCTION MANAGER of such change and explain the magnitude of and reason for the change.

3.5 INSTALLATION

A. Microtunneling General: No work shall commence on the microtunneling phase until all the design and construction submittals have been reviewed and finally commented upon in writing, in accordance with the submittals procedure contained in this Contract Document, by the CONSTRUCTION MANAGER. The CONTRACTOR is solely responsible for the performance...
of the equipment and means and methods selected for construction of the works. The CONSTRUCTION MANAGER’s review of submittal signifies only that the construction process is compatible with the overall objectives of the Project.

B. MTBM:

1. The MTBM shall be designed, configured, and operated so as to prevent both surface heave and loss of ground during microtunneling. The MTBM advance rate and the volume of material excavated shall be monitored and adjusted, as required, to avoid loss of ground, over-excavation, and surface heave.

2. The pressure applied by the MTBM at the tunnel face shall be maintained at all times between the measured active earth pressure and the estimated passive earth pressure. Pressure applied at the tunnel face to balance the groundwater shall be maintained at a level slightly in excess of normal hydrostatic pressure and shall be monitored continuously.

3. MTBM shall be capable of fully supporting the face both during the excavation and shutdown; shall have the capability of positively measuring the slurry pressure at the face; shall apply pressure at the MTBM face to stabilize the excavation and maintain it at a level slightly in excess of normal hydrostatic pressure; and shall be monitored continuously.

4. The MTBM shall be remotely operated, laser-guided, and monitored continuously by the operator. A display showing the position of the machine in relation to design line-and-grade and other operational data shall be provided, as a minimum, at the operation console to allow the operator to monitor face pressure, roll, inclination, laser position, steering attitude, rate of advance, installed length, thrust force, and cutterhead torque.

5. The MTBM shall have an articulated shield that is steerable in both vertical and horizontal directions to maintain line and grade within the specified tolerances. The cutterheads shall have reversible drive system so that it can rotate in either direction to minimize rotation of the MTBM or roll of the pipe during tunnel installation.

6. The MTBM shall be operated within the parameters proposed by the CONTRACTOR and accepted in the submittals.

7. The MTBM shall be operated within the parameters by the CONTRACTOR and accepted in the submittals.

8. All groundwater encountered during the excavation of the tunnel shall be pressure balanced by the MTBM, no loss of water or slurry shall be permitted.
9. Regular checks shall be made by the CONTRACTOR, in conjunction with the CONSTRUCTION MANAGER, to compare the volume of material removed with the calculated volume of the jacking/tunneling to provide a safeguard against excessive loosening or loss of material beyond the pipe dimensions or lining. Allowance shall be made for any material removed with the water from the jacking/tunneling operation.

C. Jacking System:

1. The MTBM shall be provided with a main jacking station at the jacking shaft capable of exerting uniform load to the pipe ring and at a speed commensurate with the speed of excavation advance. The jacking hydraulic circuit shall be set to relieve pressure at the maximum safe working capacity of the pipe as stipulated by the CONTRACTOR in his submittal.
2. The jacking system, including any intermediate jacks used, shall be capable of monitoring the jacking pressure, the rate of advancement, and the distance jacked.
3. The CONTRACTOR shall determine the number, location, and capacity of intermediate jacking stations to ensure completion of the drive. A welded closure of the intermediate jacking stations shall be completed prior to placement of the cement mortar lining.
4. A backstop wall shall be provided behind the main jacks. This wall shall be constructed so as to be normal (square) with the proposed pipe alignment and shall be designed to support the maximum obtainable jacking pressure. The CONTRACTOR shall design the backstop to transfer the jacking loads to the shaft wall and into the surrounding ground without causing damage to shaft structure.
5. Special care should be taken when setting pipe guide rails in the shaft to ensure correctness of the alignment.
6. The jacking system provided by the CONTRACTOR shall be capable of providing a sustainable jacking force equal to the CONTRACTOR required maximum jacking force plus 20 percent.
7. The main and intermediate jacking stations shall be designed to exert uniform load to the pipe ring and to push the pipe forwards at a speed commensurate with the speed of excavation advance.

D. Jacking Pipe:

1. Inspect all pipe prior to lowering into the shaft or jacking excavation to ensure that no defective materials are being used. Pipes delivered with visible damage in excess of the limitations specified, shall not be used.
Damaged or defective pipe shall be marked with a permanent marking as rejected and shall be promptly removed from the job.

2. Each pipe section shall be jacked forward as the excavation progresses in such a way to provide complete and adequate support to the surrounding ground at all times.

3. Pipe that has been damaged during installation shall be repaired in place if possible. Any repairs to damaged pipe shall be subject to a detailed procedure being provided by the pipe manufacturer and being accepted by the CONSTRUCTION MANAGER.

4. Seal weld all joints after the pipe is in final position and annulus grouting completed.

5. Test the completed pipe hydrostatically as directed by the CONSTRUCTION MANAGER. Seal weld areas of infiltrating water after the pipe in drained.

6. Apply the cement mortar lining.

E. Lubrication:

1. Lubrication shall be applied to the external surface of the pipe to reduce skin friction and the annular space created by the overcut shall be filled with a lubricant suitable for the particular ground conditions to be tunneled.

2. A lubrication system shall be provided to inject an approved lubricant at the rear of the tunneling shield and as required along the pipe length to lower the friction developed on the sides of the pipe during jacking. The lubrication system shall be such that it can automatically be controlled from the operators cabin and controlled volumes of lubricant can be injected by the MTBM operator at selected locations along the tunnel. Such volumes of lubricant pumped, including the location of injection, shall also be automatically recorded.

3. The lubricant injection points shall be no less than three per 25-foot length of pipe to be installed.

4. The CONTRACTOR shall at all times monitor both the volumes, pressures, and location of grout/lubrication injection points to ensure that the annulus around the pipe is completely filled with approved lubricant.

F. Microtunneling Alignment Control and Inspection:

1. The alignment tolerance of the constructed tunneling shall not deviate from the required vertical alignment by more than plus or minus 3 inches or from the required horizontal alignment by more than plus or minus 6 inches.
2. Should the tunnel alignment be outside the above tolerance requirements, then the MTBM shall be returned to the plane line and/or grade at a rate of not more than 1 inch per 25 feet of tunneling.

3. Steering corrections made to the tunnel alignment shall be carried out in such a manner that the joint angle of any two adjacent pipes or segments does not exceed allowable limits.

4. The laser to the laser guidance system shall be mounted in a manner that isolates it from effects of movement by the jacking forces and protects it as much as possible from accidental impacts.

5. The CONTRACTOR shall check the laser primary control for the tunneling system against an above ground undisturbed reference at least every 3 days or not greater than 300-foot intervals of tunnel constructed, whichever is more frequent.

6. In addition the laser alignment for tunneling control shall be checked each shift against local survey marks.

7. After installation of jacked pipe, the CONTRACTOR shall provide the CONSTRUCTION MANAGER with safe, ventilated and lighted access to the casing for visual inspection of the line and grade of the completed casing.

G. Slurry and Lubricant:

1. Bentonite: Shall be high swelling montmorillonite clay or other product as accepted by the CONSTRUCTION MANAGER. High yield bentonites containing additives to artificially increase the resulting viscosity when mixed with water are not acceptable. Neat bentonite without additives shall be high quality Wyoming bentonite or similar.

2. Polymers: Polymers used as pipe lubricant or additive to bentonite or slurry water shall be non-toxic and compatible for use in a municipal raw water reservoir.

3. The use of slurry additives other than bentonite or polymer will require the acceptance of the CONSTRUCTION MANAGER.

4. The slurry parameters shall be maintained by the CONTRACTOR within those proposed and accepted in the submittals.

H. Soil Handling and Removal:

1. The CONTRACTOR shall provide with the MTBM a separation plant suitable to accommodate the types and volumes of excavated materials anticipated to be encountered by the MTBM. The separation plan shall be so designed as to efficiently clean the excavated soil from the slurry for disposal and return the slurry back to the cutting face for reuse. As an additional storage, slurry lagoons will be permitted, but if used all
material from these lagoons shall be cleaned through the separation plant before removal from site.

2. The CONTRACTOR shall pay particular attention and shall take all necessary steps, including the use of polymers and/or hydro-cyclones and centrifuge devices in his separation plant, to enable the efficient cleaning of the slurry when tunneling in the fine claystone materials.

3. The CONTRACTOR shall transport and dispose of all excess excavated materials properly away from the construction site in such a fashion that trucks and other vehicles do not create a dirt nuisance on roads and pathways. CONTRACTOR shall secure the required permits and promptly remove and disposal of any spillage.

4. Slurry to be removed from the site shall be pumped into tanker trucks and disposed of at acceptable facilities in accordance with current State regulations for disposal of these materials.

I. Tunnel Grouting:

1. As soon as jacking for each tunnel has been completed and the pipe is in its final position, the “annulus” around the pipe at the jacking shaft junction shall be grouted to seal off water and soil entry into the shaft.

2. The annular space around the installed pipes shall, as early as reasonably possible after completion of each tunnel, (and all intermediate jacking stations for a pipe jacked tunnel closed) be filled with an approved cement grout. The lubricant within the annular space shall be displaced by the cement grout. The CONTRACTOR shall take steps prior to and during grouting to prevent water flow and pressure from the reservoir body flowing into this annulus.

3. Grout Connections: The CONTRACTOR shall provide Grout/Lubrication ports within the pipe wall with no fewer than three holes per 20 feet of pipe and spaced no closer than 120 degrees apart. Grout/lubrication ports are to be 1-1/2 inches to 2 inches with check valves installed. Grout hole placement shall be equally spaced along the axis of the pipe and the grout connections through the casing pipe are to be plugged.

4. Grout to Exterior Casing Annulus: Grout for displacing bentonite and filling the void between the pipe and the soil shall consist of portland cement, water and fluidizers as required to produce a satisfactory pumpable grout with a minimum 7 day compressive strength of at least 500 psi. The CONTRACTOR shall demonstrate such strength by suitable testing on site.

5. The pressure and the volume of grout shall be controlled by the CONTRACTOR to avoid pipe damage and displacement of the pipe and soil. Grout pressure shall be controlled so as to avoid deformation of the
casing pipe and avoid movement of the surrounding ground. The order of grout hole connection and the grouting time at each connection shall be selected to place the maximum annular backfill.

6. The CONTRACTOR shall give the CONSTRUCTION MANAGER 24 hours notice of his intention to grout. The volumes of grout used shall be recorded by the CONTRACTOR. The CONTRACTOR shall keep a detailed record for the grouting work, including, as a minimum, the following information which shall be available to the CONSTRUCTION MANAGER.
   a. Time and duration of grouting work.
   b. Details of grout mix.
   c. Point of injection and depth of the hole.
   d. Quantity of grout and pressure applied.

7. The CONTRACTOR shall take steps prior to and during grouting to prevent water flow and pressure from the reservoir flowing into this annulus and to ensure that the annulus between the tunnel exterior and the ground is filled with and sealed by grouting. Water influx around the tunnel pipe and/or into the shaft will not be permitted.

8. All grouting shall be undertaken by an approved grouting contractor.

J. Tunnel Safety and Ventilation:

1. CONTRACTOR shall provide adequate ventilation at all tunnels and shafts and shall design the ventilating system to include such factors as the volume required to furnish fresh air and the volume to remove dust and vapor, which may impact the laser guidance system. The ventilation system should be designed considering all internal combustion equipment that may be used in and near the shaft.

2. All work areas, including shaft access, ladders, and microtunneling operation activities (above and below the surface) shall be lighted with sunlight or a sufficient number of electric lights to ensure proper work safety and visibility.

3. Underground works, whether completed or under construction shall be kept clear of water, slurry, lubricant, hydraulic oil, and excavated material.

K. Lake Bottom Construction:

1. The CONTRACTOR shall provide removable bulkheads or other suitable and approved devices, in the lake end of the tunnel to ensure that the works are protected from flooding.
2. CONTRACTOR shall provide to the CONSTRUCTION MANAGER a detailed description, including drawings and sketches as appropriate, of the methods and equipment he proposes to use.

L. Additional Requirements:

1. The CONTRACTOR shall provide suitable launch seals (a specially designed seal which fits on the shaft wall and through which the MTBM and pipe passes) to avoid excessive inflow of groundwater, ground, slurry, or lubricant around the pipe and into the jacking shaft as pipe is jacked.

2. The dual seals to be used shall be designed to resist the hydrostatic and other forces at the seal location. A backup/emergency seal system, such as an inflatable seal, shall be used in conjunction with the dual rubber seal. Grout injection ports at a minimum of 30-degree radial spacings shall be incorporated in the design. The CONTRACTOR shall provide details of his proposals for CONSTRUCTION MANAGER’s review.

3. Whenever there is an emergency or stoppage of work which may potentially endanger the tunnel excavation, surface facilities or adjacent structure, the CONTRACTOR shall undertake the tunneling operations with a full work force based upon 24 hours a day, including weekends and holidays, without intermission until the emergency or potentially hazardous conditions no longer jeopardize the stability and safety of the work. Twenty-four hours per day, 7 days per week shall be required on the microtunneling work if jacking forces in the main jacks reach 75 percent of the anticipated (submitted and accepted) jacking forces.

4. If such difficulties with the microtunneling operation are encountered or there is a significant change in the rate of progress, the CONTRACTOR shall notify the CONSTRUCTION MANAGER’s on-site representative immediately. Within 16 hours of the difficulty, the CONTRACTOR shall provide a written report to the CONSTRUCTION MANAGER describing the details of the difficulty and the actions that were taken or are proposed to be taken to deal with the problem.

5. The CONTRACTOR shall be responsible for monitoring ground movements associated with the work and making suitable changes in the construction methods to control ground movements and prevent damage or detrimental movement to the work and adjacent structures and/or pavements. The CONTRACTOR shall monitor progress when the MTBM is under the surface of the water to ensure no settlement and heave occurs.

6. The CONTRACTOR shall comply with the Contract requirements regarding access and pollution of the lake. He shall ensure that
minimum quantities of slurry and lubricant are introduced into the reservoir in accordance with good industry practice.

3.6 MONITORING OF TUNNEL OPERATIONS

A. Monitored Parameters: The CONTRACTOR is required when operating the slurry MTBM to monitor a number of operating parameters both for the machine operating functions and also for other issues such as slurry parameters, etc., as described below.

B. Provision of Monitored Data: The CONTRACTOR is reminded of the importance that is placed under the Contract in properly monitoring the works. Should the CONSTRUCTION MANAGER consider that the tunneling is not being properly monitored, or that the monitoring data required under the Contract, as described below, is not being provided adequately or in a timely manner to the CONSTRUCTION MANAGER, he shall have the right, but not the duty, to stop payment until such monitoring, or its reporting, are acceptable to the CONSTRUCTION MANAGER.

C. Automatically Recorded Information:

1. The CONTRACTOR shall record all parameters from the MTBM that are routinely interrogated and recorded. These include the following which typically present the information in real time on the operator’s console:
   a. Tunnel distance.
   b. Advance speed (on some machines).
   c. Cutter head torque.
   d. Cutter head rpm and direction.
   e. Jacking force, including all IJS loads.
   f. Steering jacks extensions (for each steering cylinder).
   g. Steering jacks pressures (for each steering cylinder).
   h. Laser relative to target vertical.
   i. Laser relative to target horizontal.
   j. Yaw.
   k. Roll.
   l. Pitch.
   m. Machine face pressure.
   n. Slurry volumes charge.
   o. Slurry volumes discharge.
   p. Slurry feed line pressure.
   q. Slurry discharge line pressure.
   r. Slurry pump performance (sometimes).
2. All of the above shall be measured at a maximum of each 3 feet of pipe length installed.

D. Hand Recorded Information:

1. If the MTBM utilized does not automatically record the major operator parameters described above or for the additional parameters not automatically recorded, a hand record shall be kept by the CONTRACTOR.

2. The log, hand scribed on paper, will be taken at intervals of no more than 10 minutes apart with a minimum of four readings of all the parameters listed per pushed pipe section.

3. Where the operating system data is not automatically recorded by a computer, the hand log shall be accompanied by a VHS video recording of the TV image at the operator’s console. Video shall show a real-time clock that matches the time scale used in the log. Indicators in the tunneling machine being viewed by the VHS recorder shall indicate when the tunneling machine is excavating and the number of the pipe joint that is being pushed.

4. As a minimum, the hand log shall consist of the following:
   a. Position of the tunneling machine in relation to the design line and grade.
   b. Jacking forces exerted on the pipe at each jacking station.
   c. Date, start time, and finish time.
   d. Earth pressure.
   e. Slurry pressure.
   f. Position of the steering jacks.
   g. Inclination.
   h. Cutterhead torque.
   i. Slurry flow rates in both the supply and return lines.
   j. MTBM face pressure.
   k. Hydraulic pressure (on hydraulic motor machines).
   l. Lubricant volume (from an automatic lubrication system).

5. All of the above shall be measured for each pipe length installed.

E. Manually Measured On Site:

1. The following are required to be recorded:
   a. Slurry specific gravity (SG) (using a mud balance).
   b. Slurry viscosity (using a Marsh Funnel).
   c. Slurry volumes in charge and discharge systems if not automatic.
   d. Bentonite type.
   e. Excavated volume of material removed from site per pipe.
f. Lubricant mix (for bentonite mixing purposes only).
g. Lubricant pressure.
h. Mix water pH (for bentonite mixing only).
i. Settlement monitoring in various forms.
j. Pipe Damage: Typically all of the above are to be measured at a maximum of each 10 feet of pipe length.

F. CONTRACTOR Reporting Requirements:

1. The CONTRACTOR shall provide to the CONSTRUCTION MANAGER complete and orderly records, if a form acceptable to the CONSTRUCTION MANAGER, of all of the above in accordance with the following:
   a. Shift printouts of MTBM and hand recorded data or hand records for each shift’s tunneling provided early the next shift in a timely manner. The written logs shall be submitted to the CONSTRUCTION MANAGER once per day. The videotape shall be submitted to the CONSTRUCTION MANAGER each week.
   b. A final report collating all of the above information at the end of each drive.
   c. An electronic copy of the MTBM records at the end of each week or at the end of each drive, whichever is sooner.
   d. Any video recordings of TV screens associated with hand logs shall be submitted to the CONSTRUCTION MANAGER each week or at the end of each drive, whichever is sooner.
   e. In addition, summary of the manually recorded records should be complied at the end of each drive.

3.7 COMMUNICATIONS

A. A two-way “Leaky Cable” Radio Communications System between any manned location within the tunnel, shaft bottom, and the operation room shall be installed, used, and kept in operation by the CONTRACTOR at all times; such as Tunnel Radio of America, Corvallis, OR (541) 758-5637, or equivalent.

B. A closed circuit TV system shall be installed by the CONTRACTOR in the MTBM operation room in full view of the operator to monitor all operations within the shaft and at the shaft bottom. The CCTV shall have the ability to zoom in/out and pan onto the various operations being performed at the jacking operation.
3.8 FIELD TESTS AND INSPECTIONS

A. The CONSTRUCTION MANAGER will witness field tests specified in this section.

B. Perform field tests and provide labor, equipment, and incidentals required for testing. Be able to produce evidence, when required, that each item of work has been constructed properly in accordance with the Drawings and Specifications.

C. The CONTRACTOR in the presence of the CONSTRUCTION MANAGER shall check each tunnel run for infiltration, in no case will more than 1 gallon of water per hour leak per 500 feet of pipe installed. All leaks shall be repaired prior to installing cement mortar lining.

D. The CONTRACTOR shall undertake an as-built survey of each completed tunnel using an instrument or pipe laser in the presence of the CONSTRUCTION MANAGER to determine the as-built line and grade.

E. The CONTRACTOR shall provide the CONSTRUCTION MANAGER, in a form acceptable to the CONSTRUCTION MANAGER, and as-built drawing of each tunnel showing in detail the installed vertical and horizontal alignment.

F. The CONTRACTOR or his acoustical consultant shall measure and report statistical sound pressure levels from the power generation plant once each week during the nighttime minimum ambient sound level period. Sound pressure levels shall be measured within 50 feet of the adjacent residential properties closest to the power plant. Sound pressure levels shall be A-weighted and representative of the statistical level exceeded 50 percent of the time. Sound measuring equipment shall conform to ANSI S1.4 and shall be calibrated before each measurement.

END OF SECTION