ground improvement/treatment must be provided in advance of this feature. The TBM must be launched with limited backup equipment; and then, once sufficient tunnel has been constructed, the trailing equipment gantries can be erected. Once the gantries have been installed and the shaft logistics are rearranged, tunneling becomes more efficient and progress is anticipated to be faster after initial startup.

Daily and weekly maintenance of the TBM are required. In addition to regular maintenance, it is possible to plan major maintenance stops, and an allowance of 4 calendar weeks has been included for each tunnel drive between shafts and at vent shafts. There is a residual risk that unplanned stoppages requiring major maintenance or repair might also be required, and an allowance of 4 calendar weeks has been included for unplanned stoppages for each tunnel drive. The entry to the shafts and exit from shafts will limit tunnel production as there is no tunnel footage gained on the schedule. An allowance of 2 calendar weeks has been included to receive a TBM into a shaft, and an allowance of 6 calendar weeks is included to exit a vent shaft and advance 600 feet from that shaft.

Environmental documentations and permit conditions will be issued as a part of the contract documents. All bidders are required to review and incorporate such requirements prior to submitting the bids. Using the information described above, the following is a summary of the conceptual tunnel construction schedule components.

Launch TBM to 600 Feet Fully Assembled	24 weeks
Drive 200 Feet per Week to Next Shaft	Varies
Planned Maintenance	4 weeks
One Unplanned Intervention	4 weeks
Launch TBM to 600 Feet from Shaft	6 weeks
Drive 200 Feet per Week to Next Shaft	Varies
Planned Maintenance	4 weeks
One Unplanned Intervention	4 weeks
Arrival at Reception Shaft	2 weeks
Disassemble and Remove	12 weeks

11.4 Safety

11.4.1 Levee Failure and Shaft/Tunnel Flooding

It is unlikely that the shafts and tunnels will be inundated by a breach of the levee because the shaft collars will be formed on elevated fill pads (except the shafts at IF). However, due to the low lying nature of the shaft sites, other supporting systems may be affected adversely by a flood. To address this possibility, secondary levees are planned around the perimeter of the elevated shaft pad construction areas at the shaft sites to create a protected area adjacent to the elevated pads. These secondary levees provide some level of flood protection, but are not high enough to protect against severe flooding. At IF, all four tunnel shafts are protected by a levee equal in height to the elevated fill pads at the other shaft sites.

To help mitigate flooding issues and provide life safety for workers, it is assumed that the emergency standby generators and other life-critical systems such as ventilation will be sited on the elevated pad, above severe flood inundation levels. Additional analyses are required during design of the tunnels to determine the correct elevations for shaft tops and temporary works at each shaft site, including the protective levee at the IF.

11.4.2 Tunnel Classification

All tunnels constructed in California are required by law to obtain a tunnel classification from the State of California Division of Mines and Tunnels.

There are active natural gas fields beneath the anticipated alignment for the tunnels. As these gas fields are present near the proposed tunnel alignment, it is anticipated that the State of California Division of Occupational Safety and Health (Cal/OSHA) might classify the tunnels as “potentially gassy.” This classification requires high levels of precautions related to tunnel construction safety. The TBMs are required to be equipped with gas monitoring equipment that automatically shut down the TBM if gas is detected. It is also likely that special ventilation requirements, as well as special access and egress requirements, are imposed by Cal/OSHA (at a minimum). Additionally, all equipment used in the tunnels needs to be intrinsically safe.

11.4.3 Tunnel Ventilation System

Tunnel ventilation requirements defined by Cal/OSHA, including the minimum amount of fresh air supply and its flow velocity, are presented in the California Code of Regulations. Cal/OSHA requires that at least 200 cubic feet per minute of fresh air per person working underground be provided. Additionally, a minimum air velocity of 60 feet per minute (fpm) is required to dilute any contaminated gas present within the tunnel. Certain activities within tunnels, such as welding, require higher minimum air velocities.

Contractors usually provide more air flow than required by Cal/OSHA (e.g., approximately 100 fpm) in order to avoid work interruptions due to gas concentrations building up beyond allowable thresholds. This practice reduces the risk of work shutdowns and mandatory tunnel evacuation until the contaminant is diluted by the ventilation system to a concentration below the safe limit.

Cal/OSHA also sets requirements for the ventilation hardware used. Systems including steel ducts and explosion-proof fans capable of reversing the direction of air travel are required. The contractor usually designs the ventilation system when developing the means and methods for the work.

11.4.4 Tunnel Interventions

Certain operations for maintenance and repair of the TBM require work to be performed under high water inflow, high groundwater pressures, unstable ground conditions, or any combination of these factors. Where these operations are pre-planned at a particular location, it might be possible to construct a safe haven (such as at a vent shaft)by ground improvement to maintain stable conditions with reduced water inflow and under atmospheric conditions. Once a TBM reaches these areas, pressures at the face of the TBM can be reduced without inducing ground loss or excessive deformations. This allows maintenance activities to be undertaken at atmospheric pressure, which is safer and less expensive than personnel working in hyperbaric conditions.

It is likely that there are occasions where these operations cannot take place at a predetermined location. The TBMs should be designed to maximize maintenance and repair work performed from the TBM interior. For events where interventions are needed from the exterior, the equipment and procedures in place shall ensure that the work is performed safely, with minimum delay.

11.4.5 Other Tunneling Issues

Tunneling operations have additional impacts that need to be considered, including traffic, noise, lighting, vibration, dust and air quality, and tunnel water treatment and disposal. For additional information, environmental commitments are identified in the Public Draft EIR/EIS, Appendix 3B. Treatment and disposal of construction water from the tunnel requires permitting according to current NPDES and Regional Water Quality Control Board regulations.

11.4.6 Ground Improvement

Ground improvement is required to facilitate construction of the permanent structures, tunnel, and shafts; facilitate groundwater control at the locations of the shafts; prevent development of undesired ground movements; and potentially provide predefined zones for TBM maintenance interventions. The types of ground improvement that should be considered during future design activities include jet grouting, permeation or compaction grouting, and ground freezing. Site-specific geotechnical investigations are needed to design the extent and type of ground improvement that may be required.

11.4.7 Behavior Under Seismic Events

The preliminary design ground motions for the tunnels and shafts have an average annual recurrence interval of 1,000 years, as discussed in Section 3.0, “Overview of Conveyance Option.” The tunnels and shafts must be able to withstand the design ground motions while maintaining continuous operation of the system. All structural systems shall be considered as Essential Facilities per California Building Code, which means the key systems shall remain operational after the maximum considered earthquake. Also, as noted in Section 3.0, the typical seismic responses/damages of tunnels are expected to be less than those for above-ground structures. Special design considerations will be implemented to address the shaft-tunnel connection to account for the differences in structural stiffness and ground strain between the two elements.

The conceptual design of the segment liner considered ground strains associated with three types of deformation resulting from earthquake motions:

- Axial extension and compression due to seismic wave propagating along the tunnel.
- Bending due to wave action perpendicular to the tunnel.
- Ovaling due to shear waves propagating normal to the tunnel.

The preliminary and final design will further evaluate the seismic performance based on detailed geotechnical data.

11.5 Maintenance Considerations

Maintenance requirements for the tunnels have not yet been finalized. Some of the critical considerations in terms of maintenance include evaluating whether the tunnels need to be taken out of service for inspection and, if so, how frequently this is required. Typically, new water conveyance tunnels are inspected at least every 10 years for the first 50 years and more frequently thereafter. In addition, the equipment that the facility owner needs to put into the tunnel for maintenance needs to be assessed so that the size of the tunnel access structures can be set. Equipment requirements such as trolleys, boats, harnesses, camera equipment, communication equipment, and ventilation need to be assessed prior to finalizing shaft designs.

Maintenance activities are expected to include, at a minimum, periodic inspection of the tunnels by remotely operated vehicles and removal of sediment that accumulates in the tunnels. Additional study is required to determine the frequency and extent of sediment removal activities.

Note that permanent power for maintenance is not anticipated at the Main Tunnel shafts; therefore, portable power is required during maintenance operations.

11.6 Engineering Analysis

During preliminary design, engineering analyses are required to confirm the constructability and cost of the selected vertical and horizontal alignments, shaft locations, and construction methodology selected for the tunnel and shafts.

Recommended engineering analyses include (but are not limited to):

- Anticipated geotechnical conditions.
- Anticipated ground behavior.
- Evaluation of soil abrasiveness.
- Corrosion evaluation.
- Earth and groundwater loads on tunnel support.
- Groundwater treatment/improvement feasibility analyses.
- Seismic motions and deformation.
- Internal pressure loads on tunnel lining.
- Handling loads during segment erection and transportation.
- Gasket design based on contact pressure, gap width, and offset anticipated.
- Concrete segment joint design.
- Segment leakage analysis and design.
- Tunnel lining tension design with potential scaled testing.
- Tunnel infiltration/exfiltration analysis.
- Evaluation of need for secondary lining or membrane due to internal tunnel pressures.

- Tunnel to shaft connection during normal operation and seismic conditions.
- Lateral earth pressures for shaft design.
- Shaft bottom stability.
- Shaft area settlement calculations.
- Tunneling-induced settlement calculations.
- Operation/ventilation requirements for tunnel dewatering and filling.
- Resource availability.
- Access and enabling works requirements.