SAN BERNARDINO VALLEY
A REGIONAL WATER AGENCY
SINCE 1954

# BOARD OF DIRECTORS WORKSHOP -

# RESOURCES/ENGINEERING

# TUESDAY, JULY 11, 2023 - 2:00 P.M.

**PUBLIC PARTICIPATION**

Public participation is welcome and encouraged. You may participate in the July 11, 2023, meeting of the San Bernardino Valley Municipal Water District in-person, or online and by telephone as follows:

**Dial-in Info: (877) 853 5247 US Toll-free**
**Meeting ID: 824 9230 9440**
**PASSCODE: 3802020**

**https://sbvmwd.zoom.us/s/82492309440**

If you are unable to participate online or by telephone, you may also submit your comments and questions in writing for the District's consideration by sending them to comments@sbvmwd.com with the subject line "Public Comment Item #" (insert the agenda item number relevant to your comment) or "Public Comment Non-Agenda Item". Submit your written comments by 6:00 p.m. on Monday, July 10, 2023. All public comments will be provided to the Chair and may be read into the record or compiled as part of the record.

**IMPORTANT PRIVACY NOTE: Participation in the meeting via the Zoom app is strongly encouraged. Online participants MUST log in with a Zoom account. The Zoom app is a free download.**
**Please keep in mind: (1) This is a public meeting; as such, the virtual meeting information is published on the World Wide Web and available to everyone. (2) Should you participate remotely via telephone, your telephone number will be your "identifier" during the meeting and available to all meeting participants; there is no way to protect your privacy if you elect to call in to the meeting.**

**SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT**
380 E. Vanderbilt Way, San Bernardino, CA 92408

**BOARD OF DIRECTORS' WORKSHOP - RESOURCES/ENGINEERING**

**AGENDA**

**2:00 PM Tuesday, July 11, 2023**

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**CALL TO ORDER**
Chairperson: Director Hayes
Vice-Chair: Director Harrison

**1) INTRODUCTIONS**

**2) PUBLIC COMMENT**
Members of the public may address the Board regarding any item within the subject matter jurisdiction of the Board; however, no action may be taken on off-agenda items except as authorized by law. Each speaker is limited to a maximum of three (3) minutes.

**3) DISCUSSION AND POSSIBLE ACTION ITEMS**

3.1 Project Status Update on the Feasibility Study for the Foothill Pipeline Crossing at City Creek (30 min) - Page 2
Staff Memo - Project Status Update on the Feasibility Study for the Foothill Pipeline Crossing at City Creek
Draft Feasibility Study Report-Foothill Pipeline Tunnel (03-03-2023)

**4) FUTURE BUSINESS**

**5) ADJOURNMENT**

PLEASE NOTE:
Materials related to an item on this Agenda submitted to the Board after distribution of the agenda packet are available for public inspection in the District's office located at 380 E. Vanderbilt Way, San Bernardino, during normal business hours. Also, such documents are available on the District's website at www.sbvmwd.com subject to staff's ability to post the documents before the meeting. The District recognizes its obligation to provide equal access to those individuals with disabilities. Please contact Melissa Zoba at (909) 387-9228 two working days prior to the meeting with any special requests for reasonable accommodation.

SAN BERNARDINO VALLEY | A REGIONAL WATER AGENCY SINCE 1954

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**DATE:** July 11, 2023

**TO**: Board of Directors' Workshop - Resources/Engineering

**FROM**: Leo Ferrando, Assistant Chief Engineer
Mike Esquer, Sr. Project Manager
Aaron Jones, Senior Engineer

**SUBJECT:** Project Status Update on the Feasibility Study for the Foothill Pipeline Crossing at City Creek

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**Staff Recommendation**

Staff recommends that the Board of Directors (BOD) consider authorizing Staff to negotiate with AECOM to provide a proposal for final design services, including plans and specifications (i.e., construction bid documents). Staff will bring AECOM's proposal for final design services back to the BOD for consideration.

**Summary**

Since 2006 Valley District has been actively working to protect the portion of the Foothill Pipeline that crosses City Creek Channel. The City Creek Channel has been eroding and head-cutting for the last several years between Highland Avenue and Base Line Road in the City of Highland. Staff released a Request for Proposal (RFP) for a Tunneling Feasibility Study of the Foothill Pipeline Crossing at City Creek (Project). The BOD approved awarding AECOM the consulting contract for $435,500 in December of 2021. AECOM has since completed the feasibility study, and Staff will provide an update and recommendations on the following steps to the BOD.

**Background**

San Bernardino Valley constructed the 78-inch diameter Foothill Pipeline in the 1970s, one of the Valley's primary water supply pipelines. A portion of the existing pipeline that crosses under City Creek has become exposed in recent years during significant storm events, which increases the potential of a major pipe failure. In recent years, temporary measures have been implemented to help mitigate the erosion and scour over the pipeline. The interim measures have included the construction of Gabion walls along the channel sides and placing boulders on top of the pipeline to protect the pipeline's structural integrity and encasement. This has allowed for studies and research to be conducted so that a permanent solution could ultimately be implemented.

Scour studies have been performed by West Consultants for the Foothill Pipeline at City Creek, and by Engineering & Hydrosystems Inc. for the Metropolitan Water District of Southern California (MWDSC) Inland Feeder Pipeline at City Creek. Both reports indicated that a scouring depth in the 15 to 25 feet range is possible. Separately, the United States Army Corps of Engineers (USACE) has been planning for modifications to City Creek to reduce the channel velocity and scouring depth. However, the timing of these improvements is still being determined by the USACE and could be several years away. Therefore, as recommended by staff, the BOD approved a contract with AECOM to prepare a feasibility study to assess the viability of potential relocation options for the Foothill Pipeline crossing at City Creek.

As part of AECOM's scope, the following reports have been prepared for San Bernardino Valley:

- Feasibility Study for the Foothill Pipeline Crossing at City Creek
- Geotechnical Investigation Report
- Biological Technical Memorandum
- Aquatic Resources (Jurisdictional) Delineation Report

Two primary alignments were analyzed for their feasibility, including a tunnel alignment below the creek and a pipe bridge alignment above the creek. Both options would remedy the potential creek scouring concerns and better protect the pipe at the crossing. The tunnel option would consist of approximately 600 lineal feet of an approximately 9-foot diameter tunnel casing installed approximately 50 feet below the creek bottom with the 78-inch diameter Foothill Pipeline routed inside the tunnel. The launch and receiving shafts for the tunnel installation would be located outside City Creek, and no major construction activities would be required within the San Bernardino County Flood Control District (SBCFCD) right-of-way or the USACE jurisdiction. The pipe bridge option would consist of an approximately 380-foot long by 13-foot wide prefabricated steel truss utility bridge installed over the creek. Due to the required span and weight of the pipeline and water within, the bridge would require intermediate support directly in the middle of the creek, as well as abutment supports at both sides of the creek. The pipe bridge alternative would have significant impacts within the SBCFCD right-of-way and USACE jurisdiction, and it could be a difficult and lengthy process to get approved by the regulatory agencies. It is recommended to move forward with the tunnel alignment for the final design of the project.

In addition to alignments, AECOM also evaluated several different trenchless construction methodologies for the proposed tunnel alignment of the Foothill Pipeline crossing City Creek, including the Sequential Excavation Method (SEM), Shielded Tunneling, Pipe Jacking, and Microtunneling. The trenchless construction methodologies presented above are viable options for the proposed alignment, but each has advantages and disadvantages. Staff will provide more details on the risks and potential hazards for each alternative during the update presentation to the BOD.

Furthermore, a conceptual-level opinion of the probable construction cost was developed for both the tunnel alignment and pipe bridge options. A summary of the total estimated construction cost for all alternatives evaluated is detailed in the table below. Design phase services were not included as part of the estimated costs.

*Table: Alignment Alternative Construction Cost Summary*

| Alternative | Estimated Construction Cost |
|---|---|
| **Open Pipe Jacking** | $15.1M |
| **Microtunneling** | $16.1M |
| **Shield Tunneling, Rib & Lag** or **Steel Plate** | $15.3M - $15.9M |
| **Sequential Excavation Method (SEM)** | $16.8M |
| **Pipe Bridge** | $15.3M |

The open pipe jacking tunnel construction has the lowest estimated construction cost, with the SEM tunnel construction having the highest estimated construction cost.

**District Strategic Plan Application**

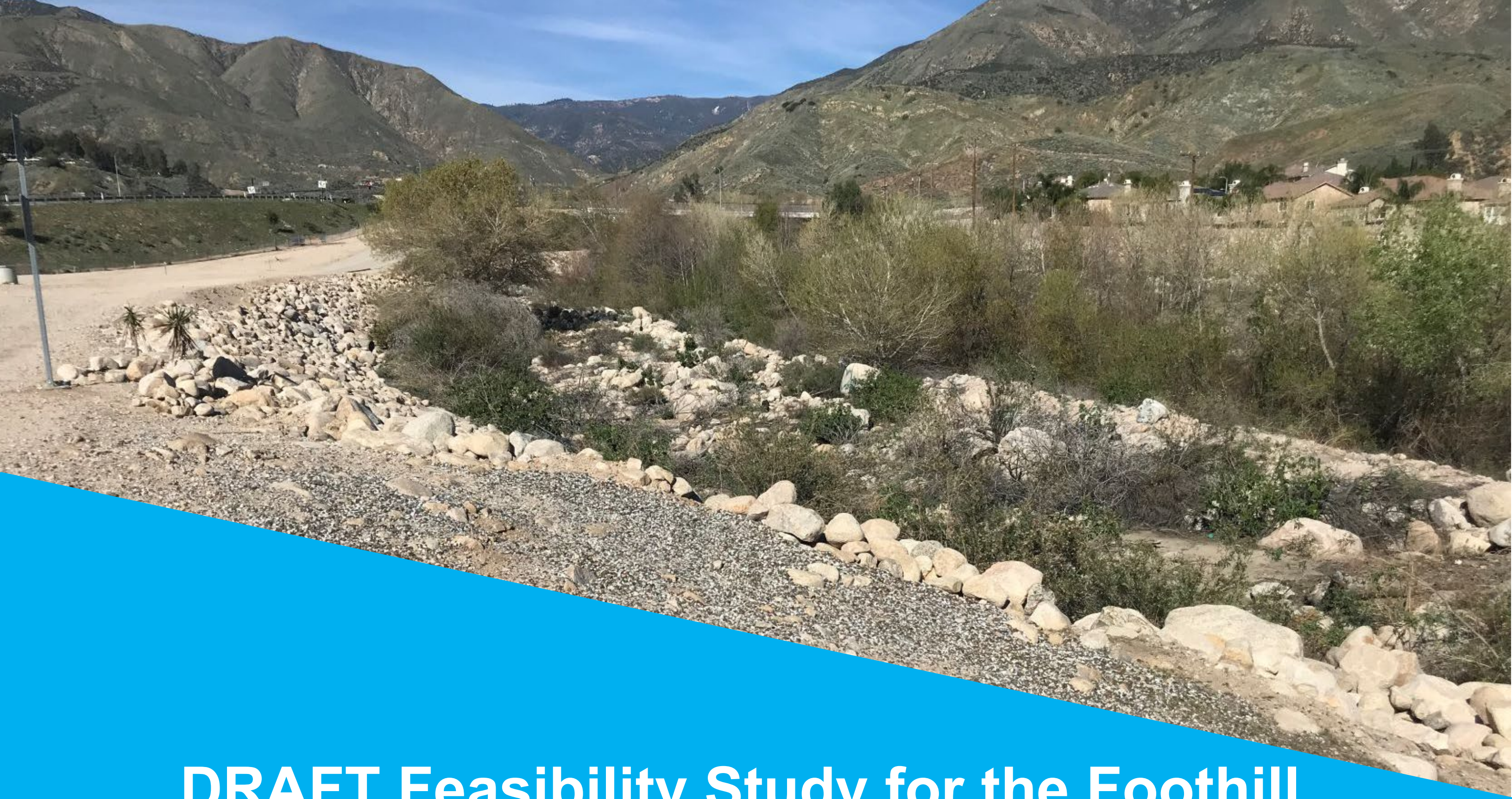
This Project will enable San Bernardino Valley to provide a resilient and reliable water supply to our service area for future generations.

**Fiscal Impact**

The approved budget for the feasibility study was $435,500. Costs associated with this Project will be shared with San Gorgonio Pass Water Agency per Reach 1 Repayment terms (18.33%). Future costs, including final design and construction, are yet to be determined and, once available, will be included in the future State Water Contracts Fund Budget for consideration by the Board of Directors.

**Attachment:**

Draft Feasibility Study for the Foothill Pipeline Crossing at City Creek



# DRAFT Feasibility Study for the Foothill Pipeline Crossing at City Creek

San Bernardino Valley Municipal Water District
380 E Vanderbilt Way
San Bernardino, CA 92408

AECOM Technical Services, Inc.
300 South Grand Avenue
Los Angeles, California 90071

March 3, 2023

AECOM Project Number: 60677279

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AECOM
300 South Grand Avenue
Los Angeles, CA 90071
www.aecom.com

March 3, 2023

Mr. Aaron Jones, E.I.T., M. Eng.
Associate Engineer
San Bernardino Valley Municipal Water District
380 E. Vanderbilt Way
San Bernardino, CA 92408

Subject: Feasibility Study Report
Foothill Pipeline Crossing at City Creek
Highland, CA

Dear Mr. Jones:

As part of the Design Professional Services Agreement between AECOM and the San Bernardino Valley Municipal Water District, Job Number 1604, dated January 26, 2022, AECOM is pleased to present for your consideration the attached Feasibility Study Report summarizing the conceptual-level design for the Foothill Pipeline crossing at City Creek.

Sincerely,

**AECOM Technical Services, Inc.**

____________________________________

Bryan C. Paine, P.E.
Project Manager

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# Table of Contents

## Tables



## Figures

## Appendices

# List of Acronyms and Abbreviations

| | |
|---|---|
| AWWA | American Water Works Association |
| bgs | below ground surface |
| CMC | cement-mortar coating |
| CML | cement-mortar lining |
| 3D | three-dimensional |
| DigAlert | Underground Service Alert of Southern California |
| EVWD | East Valley Water District |
| ft/s | feet per second |
| GIR | Geotechnical Investigation Report |
| MTBM | microtunneling boring machine |
| MWD-IF | Metropolitan Water District of Southern California's existing 144-inch-diameter Inland Feeder |
| MWD | Metropolitan Water District of Southern California |
| psf | pounds per square foot |
| RCP | Reinforced concrete pipe |
| RCRA | Resource Conservation and Recovery Act |
| SBCFCD | San Bernardino County Flood Control District |
| SEM | sequential excavation method |
| TBM | tunnel boring machine |
| USACE | United States Army Corps of Engineers |
| Valley District | San Bernardino Valley Municipal Water District |
| WSP | welded steel pipe |

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# EXECUTIVE SUMMARY

The San Bernardino Valley Municipal Water District (Valley District) owns and operates the 78-inch Foothill Pipeline. The Foothill Pipeline crosses underneath the City Creek flood control channel in the City of Highland near the intersection of Highland Avenue and California State Highway 330. The Foothill Pipeline is a critical infrastructure component for the Valley District, which provides water to a large portion of the District's service area. The Valley District wants to ensure that the pipeline is protected through the creek crossing and does not become exposed during scour events, which could cause the pipe to be damaged from traveling rocks and debris. Given the current depth of the pipeline at City Creek (10 to 15 feet below existing grade) and the potential scour depth in the creek (15 to 25 feet below existing grade) the existing Foothill Pipeline crossing could be exposed during a severe scour event that would occur during a larger storm.

In light of the foregoing, the Valley District elected to issue a feasibility study to determine the viability of potential relocation options for the Foothill Pipeline crossing at City Creek. Two primary alignments were analyzed for their feasibility, including a tunnel alignment below the creek and a pipe bridge alignment above the creek. Both options would remedy the potential creek scouring concerns and better protect the pipe at the crossing. The tunnel option would consist of approximately 600 lineal feet of an approximately 9-foot diameter tunnel casing installed approximately 50 feet below the creek bottom with the 78-inch diameter Foothill Pipeline routed inside the tunnel. The launch and receiving shafts for the tunnel installation would be located outside City Creek, and no major construction activities would be required within the San Bernardino County Flood Control (SBCFCD) right-of-way or United States Army Corp of Engineers (USACE) jurisdiction. The pipe bridge option would consist of an approximately 380-feet long by 13-feet wide prefabricated steel truss utility bridge installed over the creek. Due to the required span and weight of the pipeline, the pipe bridge would require an intermediate support directly in the middle of the creek, as well as abutment supports at both sides of the creek. The pipe bridge alternative would have significant impacts within the SBCFCD right-of-way and USACE jurisdiction and could be particularly difficult to get approved by the regulatory agencies. Also, it will impact the natural creek view aesthitics for the residents that live along City Creek. Resultantly, it is recommended to move forward with the tunnel alignment for the final design of the project.

Several different trenchless construction methodologies were considered for the proposed tunnel alignment of the Foothill Pipeline crossing at City Creek, including Sequential Excavation Method (SEM), Shielded Tunneling, and Pipe Jacking. SEM involves the sequential excavation of ground material followed by immediate application of shotcrete for support, typically entailing an ovoid-shaped tunnel cross section. Shielded tunneling involves a steerable forward shield with hood that extends beyond the excavating face for ground stabilization. The material at the face is excavated by a digger arm and removed via an internal conveyor belt. Pipe jacking involves the use of hydraulic jacks to push segments of casing pipe through the ground while the face is excavated manually or with a tunnel boring machine. Pipe jacking can take the form of either microtunneling or open-face pipe jacking. All of the trenchless construction methodologies presented above are viable options for the proposed Foothill Pipeline tunnel alignment, but each has its own advantages and disadvantages. It is difficult to propose a single tunneling method for the construction of the City Creek tunnel, and it is recommended to allow the contractor to use any of the tunneling options discussed above. The contractor's selected tunneling method will likely be based on its own expertise, equipment availability, and cost.

A conceptual level opinion of probable construction cost was developed for both the tunnel alignment and pipe bridge options. For the tunnel alternative, costs for each of the three tunneling methodologies (SEM, shielded tunneling, and pipe jacking) were developed. The pipe bridge alignment had the lowest cost at $15.3M. The various trenchless methodologies for the tunnel alignment ranged from $15.6M to $19.2M, with open-face pipe jacking being the least expensive and SEM being the most expensive.

# 1. INTRODUCTION

The Foothill Pipeline is a 78-inch-diameter welded steel water pipe, constructed in the mid-1970s, that crosses under City Creek. A portion of the pipeline within the creek has become exposed due to scouring of the creek bed. The San Bernardino Valley Municipal Water District (Valley District) has decided to replace the pipeline beneath City Creek and investigate the feasibility of installing the relocated pipeline on a pipe bridge over the creek or within a new carrier pipe inside a casing at a deeper location to protect it from potential damage and failure. The relocated pipeline will be approximately 700 feet long and 70 to 100 feet deep. Geomorphologic and streambed erosion studies indicate that 15 feet to 25 feet of scour could occur during a major storm event. The new pipeline will need to be below the expected storm scour and under the Metropolitan Water District of Southern California's (MWD) existing 144-inch-diameter Inland Feeder (MWD-IF).

The purpose of this report is to evaluate alignment and construction alternatives for the Foothill Pipeline that are viable and meet the requirements of the Valley District and other regulatory agencies. This report develops a recommended alignment that minimizes impacts to existing facilities; and considers scour development in City Creek, existing geotechnical conditions, and separation requirements from the MWD-IF. The report also assesses the feasibility and risk of trenchless construction methods by comparing and evaluating several trenchless and tunneling technologies and their implementation in the project design. The report identifies necessary regulatory permits and the requirements needed to successfully obtain such permits. Finally, a comparison between conceptual-level construction cost and schedule of these trenchless technologies is provided.

# 2. GEOTECHNICAL INVESTIGATIONS SUMMARY

A geotechnical investigation was performed by AECOM to provide geotechnical information to support an evaluation of the viable alignment and construction alternatives for the Foothill Pipeline. The investigation included the following;

- Review of the pertinent geologic literature and data from previous investigations
- Drilling and logging of three sonic borings to depths of 110 feet below ground surface
- Downhole suspension P-S velocity logging
- Installation of monitoring wells in each of the three borings
- Geotechnical laboratory testing of selected soil samples recovered from the borings
- Assessment of geologic and seismic hazards at the project site

One of the three sonic borings was done on the west side of city creek in the vicinity of where the launch shaft will be located and the other two borings were done on the east side of the creek, near where the receiving shaft will be located. The findings of the geotechnical investigation were presented in a Geotechnical Investigation Report (AECOM, 2023). The following paragraphs of this section provide a summary of the key geotechnical findings presented in that report.

The project site is at the northern edge of the San Bernardino Basin, an alluvial filled valley that lies between the San Bernardino Mountains on the north and the Riverside Badlands on the south. The basin is predominantly filled with alluvial channel and alluvial fan deposits consisting of eroded material shed from the southern side of the San Bernardino Mountains. City Creek is a 7.5-mile (12.1-kilometer) tributary of the Santa Ana River that drains a southwest-facing slope of the San Bernardino Mountains. The geologic hazards that could potentially impact the project are Strong Ground Shaking, Fault Rupture, Liquefaction, Flooding, and Scour.

The ground at the Foothill Pipeline includes artificial fill and alluvium, as described in the following paragraphs.

**Artificial Fill (af):** In the immediate vicinity of the project, native materials are overlain by artificial fill on both sides of the City Creek channel. On the eastern side of City Creek, artificial fill forms a levee that is approximately 50 feet wide at its crest and about 15 to 20 feet high. On the western side of City Creek, a wide fill pad lies between State Route 330 and the channel. This fill pad is estimated to be approximately 15 to 20 feet thick in the vicinity of the project. The fill on both sides of the channel consist of gravelly sands and sandy gravels with some cobbles.

**Alluvium:** The active City Creek channel is mapped by Morton and Miller (2006) as late Holocene wash deposits (Qw) and the alluvium to the east and west of the active channel is mapped as middle Holocene alluvial fan deposits (Qyf3). The wash deposits (Qw) overlie the alluvial fan deposits (Qyf3). The following paragraphs summarize the published description of these units from Morton and Miller (2006), and summarizes their characteristics, as encountered in the three borings that were drilled and logged at the project site.

Morton and Miller (2006) describe the Holocene Wash deposits (Qw) as very young wash deposits (late Holocene), consisting of unconsolidated sand and gravel in active washes of axial-valley streams, with fresh flood scours and channel-and-bar morphology. The wash deposits are subject to localized reworking and introduction of new sediment during flooding. In places, especially in the upper reaches of some drainages, the deposits contain boulders several meters across that were deposited by flash floods. The alluvial fan deposits (the Qyf3 alluvial unit) is described by Morton and Miller (2006) as young alluvial-fan deposits, Unit 3 (middle Holocene), that are slightly to moderately consolidated silt, sand, and coarse-grained sand to bouldery alluvial-fan deposits that have slightly to moderately dissected surfaces.

All three of the AECOM borings encountered, the Holocene wash deposits and the Holocene alluvial fan deposits. In the AECOM boring that was done in the vicinity of the Launch Shaft, the wash deposits were about 20 feet thick. They generally consisted of dry, silty sand with gravel and cobbles, up to 6 inches. In the borings that were advanced on the east side of the creek, the wash deposits were about 20 to 25 feet thick and were were described as gravel with sand and sand with gravel. On the east side of the creek the wash deposits included cobbles up to ~8 inches and a couple of large boulders (>4 to 5 feet) were encountered in the borings. Based on observations of boulders at the surface in the creek bed, it appears that boulders up to about 8 feet in maximum dimension are characteristic of the wash deposits in the vicinity of the project. The base of the wash deposits are at an elevation of about 1413 feet on the west side of the channel, near the launch shaft and about 1400 feet on the east side of the channel, near the receiving shaft. The wash deposits likely thicken beneath City Creek and it is speculated that the contact with the underlying alluvial fan deposits could be at an elevation of 1375 feet or lower.

Groundwater levels were measured from the monitoring wells installed by AECOM for this study. On the western side of the channel, near the proposed launch shaft, groundwater was not encountered to the total depth of the monitoring well which is 110 feet below ground surface. Thus groundwater at and near the launch shaft is presumably below an elevation of 1338 feet. During drilling of the borings and in the monitoring wells installed along the east side of City Creek, near the receiving shaft, groundwater was encountered at an elevation of approximately 1349 feet.

Groundwater conditions along the proposed tunnel reach, away from the shafts and the exploration borings are not known. It is likely that the groundwater table encountered at an elevation of about 1348 feet on the east side of City Creek, gradually deepens to an elevation below elevation 1338 on the west side of City Creek. However, there is also some possibility that depending on the depth of the base of the wash deposits (Qw) below City Creek (the elevation of the Qw/Qyf3 contact), and the elevation of the proposed tunnel, that the tunnel could potentially intersect the wash deposits. Considering that the generally coarse wash deposits (Qw) are highly permeable, that the generally finer grained alluvial fan deposits (Qyf3) have substantially lower permeability, and that City Creek continually flows year round, it is likely that there is perched groundwater on the Qw/Qyf contact. Consequently, intersection of the Qw/Qyf3 contact by the tunnel could result in the tunnel encountering perched groundwater.

# 3. ALIGNMENT EVALUATION

## 3.1 Topographic Survey

As part of the alignment evaluation, AECOM subcontracted with Psomas to conduct aerial topographic mapping; field topographic surveying; and right-of-way, property line, and easement research and plotting for the project. Survey control was established within the project limits using a combination of global navigation satellite system and conventional surveying. The benchmark for the survey is based on the County of Los Angeles Vertical Control (North American Vertical Datum of 1988). The field survey provided detailed information regarding surface features present at the project site, including structures and buildings; utilities and equipment; access roads; trees and vegetation; and all other ancillary features. Psomas provided a digital terrain model of the topographic survey that was converted into a three-dimensional (3D) existing ground surface using AutoCAD Civil 3D. The 3D surface and corresponding surface feature mapping were used in the evaluation of the proposed pipeline alignment.

## 3.2 Existing Utility Investigations

As part of the alignment evaluation, AECOM conducted existing utility research for the project area and immediate surroundings. AECOM contacted the Underground Service Alert of Southern California (DigAlert) to identify potential existing utilities and their respective owners. The DigAlert report identified the following utility owners that have facilities in the project area or its immediate surroundings:

- AT&T
- East Valley Water District (EVWD)
- City of Highland
- Verizon
- MWD
- County of San Bernardino Public Works
- Southern California Gas
- Southern California Edison

AECOM contacted each utility owner to verify the presence of facilities in the project area. Record drawings, atlas maps, or GIS information were requested from owners who stated that they did have facilities in the project area. The information provided by the utility owners was used to develop a utility base map in CAD for the project site. This base map was used in the alignment evaluation to determine which existing utilities would be affected by the pipeline relocation. The existing utilities are identified in the proposed pipeline alignment figures included in Appendix A.

## 3.3 Existing Site Conditions and Constraints

The proposed alignment for the relocated Foothill Pipeline will need to cross the existing City Creek. A recent scour analysis performed by West Consultants for City Creek indicated that the potential scour depth could be 25 to 80 feet deep. The proposed pipeline must be placed below this depth to ensure that it is protected during large storm events. Any ground disturbance, such as excavation for tunnel shafts or utility bridge abutments, will need to take place outside of the San Bernardino County Flood Control right-of-way and United States Army Corps of Engineers (USACE) jurisdictional limits—for example, in the Valley District or MWD properties adjacent to City Creek.

The project is near a residential community in the City of Highland, with several homes relatively close to the proposed alignment location. Noise and vibration from construction activities will need to be considered and addressed for the selected alignment, to ensure that adjacent property owners are not substantially affected by the construction.

The existing Foothill Pipeline is a critical infrastructure component for the Valley District and cannot be taken offline for an extended period of time. Therefore, the proposed relocation of the pipeline at City Creek will need to be phased appropriately to ensure minimal downtime of the existing Foothill Pipeline and avoid any prolonged disruption of water delivery by Valley District.

MWD owns and operates the 144-inch Inland Feeder Pipeline that under City Creek. The proposed relocation of the Foothill Pipeline will need to cross the existing Inland Feeder in the creek. The proposed alignment will need to consider and minimize any impacts to the existing Inland Feeder, and must be designed in accordance with MWD requirements for large-diameter pipeline crossings.

## 3.4 Alignment Alternatives

AECOM performed an alternative analysis for two potential alignments for the Foothill Pipeline crossing at City Creek. One alternative was for an underground tunnel alignment and the other was for an aboveground pipe bridge alignment. The analyses for each of these alternatives are presented in detail in the following sections.

### 3.4.1 Tunnel

The conceptual layout for the proposed tunnel alignment is identified in Figure A1 in Appendix A. The construction will be by a two pass method where a tunnel or casing pipe will be constructed first and the carrier pipe will be installed inside with spacers and the space between the carrier pipe and the tunnel will be filled with cellular grout. The alignment would consist of approximately 600 feet of tunnel construction underneath City Creek. The tunnel would need to be approximately 100 feet deep at the launch and receiving shafts, and approximately 50 feet deep at the center of the crossing under City Creek. The top of the tunnel casing would be approximately 20 feet below the invert of the MWD-IF, which would be acceptable to MWD. The proposed alignment is routed in such a manner as to not impact the existing Foothill Pipeline, thereby allowing the existing pipeline to remain in service during construction of the proposed tunnel.

The launch shaft for the tunnel construction would be on the western side of City Creek in the relatively flat and open property that is currently owned by MWD. The receiving shaft would be on the eastern side of City Creek in the existing Valley District property adjacent to the existing Valley District turnout facility. Both shafts would be outside of the County right-of-way and USACE jurisdiction. The tunnel would be constructed from west to east, using the available space within the MWD property for tunnel construction equipment staging and pipe material storage. A temporary access agreement would need to be developed between Valley District and MWD to allow Valley District to use the property for construction of the tunnel and pipeline.

At the launch and receiving shafts, the pipeline would be routed vertically upward to meet the elevation of the existing Foothill Pipeline. Manways and air/vac valve assemblies will be provided at these locations to allow for access into the carrier pipe for inspection or maintenance, and to remove any accumulated air in the pipeline. The tunnel will have a slight upslope in the eastward direction to help facilitate tunnel construction, and to provide a means to drain the carrier pipe to one end of the tunnel via a proposed blow-off assembly.

A conceptual-level opinion of probable construction cost for the potential tunnel methods is provided in Section 9 of this report. The proposed tunnel alignment is advantageous because it avoids any ground disturbance in City Creek and does not impact the existing MWD-IF. In addition, all required ground disturbance work will be outside the County right-of-way and outside USACE jurisdictional limits. The major disadvantage of the tunnel alignment is the slightly higher construction cost when compared to the pipe bridge alternative.

### 3.4.2 Pipe Bridge

The conceptual layout for the proposed pipe bridge alignment is identified in Figure A2 in Appendix A. The alignment would consist of approximately 350 feet of a prefabricated steel truss pipe bridge over City Creek. AECOM contacted Contech Engineered Solutions to prepare a conceptual-level design of the pipe bridge. The pipe bridge would be 13 feet wide and 10 feet tall, with a grated access deck running the entire length of the bridge for inspection and maintenance of the pipeline. Due to the required length of the bridge span and the weight of the pipeline, an intermediate pier support would be required for the bridge at the center of the span within the creek. Abutments would also be required on either end of the bridge for support. The bridge abutments and central pier support would be constructed of reinforced concrete and likely founded on concrete piles drilled into existing bedrock material.

A conceptual-level opinion of probable construction cost for the pipe bridge alignment is provided in Section 9 of this report. The proposed pipe bridge alignment has several inherent disadvantages. Due to the limitations in the available span of the prefabricated bridge structure, significant ground disturbance would be required in City Creek and in the County right-of-way and USACE jurisdictional limits for construction of the bridge abutments and intermediate pier support. The placement of a pier support in City Creek is unfavorable from a hydraulic perspective and would require significant analysis and vetting with regulatory agencies to obtain approval. In addition, the intermediate pier support would need to be near the existing MWD-IF, which would require detailed coordination with MWD. The pipe bridge has a relatively lower construction cost when compared to the tunnel alignment; however, additional costs associated with permitting approval and regulatory coordination would be required during the final design phase. From an inspection and maintenance perspective, placing the pipeline aboveground would also be advantageous compared to the tunnel alternative because it would be easier to access and maintain from the pipe bridge.

### 3.4.3 Recommended Alignment

A summary of the proposed advantages and disadvantages of the tunnel and pipe bridge alignments is provided in Table 3-1. Based on the associated advantages and disadvantages for each alternative, the tunnel alignment option is recommended for the proposed Foothill Pipeline crossing at City Creek. The tunnel alignment was selected over the pipe bridge alignment because of the required ground disturbance needed to construct the pipe bridge in City Creek, the County right-of-way, and USACE jurisdiction. The process of seeking and receiving regulatory approval for permanent features in City Creek would be a highly involved process, which would increase project schedule and cost. It is therefore recommended to move forward with the tunnel alignment, which avoids impacts to City Creek.

### Table 3-1 Alignment Alternative Analysis Summary

| Alignment Alternative | Advantages | Disadvantages |
|---|---|---|
| Tunnel | • No ground disturbance in County right-of-way or USACE jurisdiction<br>• No impact to MWD-IF<br>• No impact to City Creek hydraulic capacity<br>• No risk of vandalism or pipe damage<br>• No impairment to existing visual aesthetics of site | • Relatively high construction cost<br>• More complex construction means-and-methods required<br>• More difficult to maintain and inspect pipeline |
| Pipe Bridge | • Relatively low construction cost<br>• Less complex construction means and methods required<br>• Easier to maintain and inspect pipeline | • Requires ground disturbance in County right-of-way and USACE jurisdiction<br>• Intermediate pier footing requires close coordination with MWD-IF<br>• Intermediate pier in creek and abutments in County right-of-way and USACE jurisdiction will require involved regulatory approval process<br>• Hydraulic capacity of existing City Creek will need to be verified and maintained<br>• Potential risk of vandalism or pipe damage<br>• Impact on existing visual aesthetics of site |

Notes:
MWD-IF = Metropolitan Water District of Southern California's existing 144-inch-diameter Inland Feeder
USACE = United States Army Corps of Engineers

# 4. CARRIER PIPE DESIGN

## 4.1 Steel Pipe Design

The proposed relocation of the Foothill Pipeline crossing at City Creek will be 78-inch internal diameter welded steel pipe (WSP) with cement-mortar lining (CML) and cement mortar coating (CMC). The proposed wall thickness for the 78-inch carrier pipe was determined in accordance with methodology from American Water Works Association (AWWA) *Manual of Water Supply Practices – M11, A Guide for Steel Pipe Design and Installation* (AWWA M11). The pipeline was designed for both internal and external pressure, as well as earth and traffic loading. The detailed piping calculations are provided in Appendix B. The resulting minimum pipe wall thickness was determined to be 0.50 inches. The proposed piping will have a minimum 0.5-inch CMC and 0.75-inch CML, in accordance with AWWA C205. The corresponding outside diameter of the pipeline is 81.50 inches. The pipeline will have double-welded lap joints outside of the tunnel and either double-welded lap joints or full-circumference butt-welded joints inside the tunnel.

## 4.2 Connections to Existing Foothill Pipeline

The proposed 78-inch WSP will connect back to the existing Foothill Pipeline at both the western and eastern side of City Creek, as shown in Figure A1 in Appendix A. The eastern connection will include a 78-inch fabricated steel cut-in tee that is connected to the existing 78-inch Foothill Pipeline with butt-strap joint connections. The fabricated steel tee will have a crotch-plate-type outlet reinforcement, in accordance with AWWA M11. The portion of the existing Foothill Pipeline to the north of the proposed connection point must remain in-place to connect to the existing turnout facility; therefore, a tee is being provided for the eastern connection point in lieu of an elbow. The western connection will consist of a 78-inch fabricated steel elbow that will connect directly in line with the existing Foothill Pipeline via another butt-strap joint connection. The fabricated fittings for both connections will be completely encased in reinforced concrete.

## 4.3 Operation and Maintenance Considerations

To provide access to the proposed Foothill Pipeline in the tunnel crossing, a 60-inch, pressure-rated manway will be installed at the top of the vertical section on each side of the creek, as identified in Figure A1 in Appendix A. The manway will extend up to existing grade elevation and will be designed so that it may be unbolted to allow for personnel and equipment to enter the 78-inch WSP for inspection or cleaning. A minimum 12-inch blow-off assembly will also be provided on the lower end of the tunnel and tapped near the bottom of the 78-inch WSP. The blow-off will be routed upward to existing grade and will allow for the removal of water from inside the tunneled portion of the pipeline. To remove entrained air at the high points of the pipeline, a minimum 10-inch combination air/vac valve assembly will be provided at each manway.

## 4.4 Abandonment of Existing Foothill Pipeline

Once the proposed tunnel alignment is constructed and the new carrier pipe is installed and connected to the existing Foothill Pipeline, the portion of the existing foothill pipeline in City Creek can be abandoned in place as shown in Figure A1 in Appendix A. The existing pipeline can be cut on the western side of the creek at the proposed connection to the new 78-inch WSP. At the eastern side of the creek, the existing pipeline will be cut after the connection to the existing turnout facility. It will be necessary to install a permanent bulkhead on the end of the existing 78-inch WSP to remain to keep that portion of the Foothill Pipeline in service. The portion of piping to be abandoned in City Creek will be completely filled with cellular concrete or sand-cement slurry.

## 4.5 Cathodic Protection

The project Geotechnical Investigation Report (GIR) identified on-site soils that are classified as moderately to highly corrosive for buried metals and concrete. It is recommended that some form of cathodic protection be provided for the proposed 78-inch WSP and steel casing. The proposed 78-inch WSP will have electric continuity with the existing Foothill Pipeline to ensure that the existing cathodic protection system for the Foothill Pipeline is imparted onto the proposed 78-inch WSP. A cathodic protection test station can be provided at either end of the proposed pipeline to monitor the electric potential of the proposed pipeline. The annular space between the tunnel casing and carrier pipe will be filled with a non-conductive grout mixture to prevent metallic contact between the two pipes. Rubber isolators will also be positioned at the end of the casing spacers to prevent metallic contact. A separate cathodic protection system in the form of either galvanic anode or impressed current can be provided for the steel casing pipe. A separate test station should be provided to monitor the electric potential in the casing pipe. It will be necessary to further develop the cathodic protection system during final design.

# 5. TUNNEL EVALUATION

## 5.1 Preliminary Tunnel/Casing Design

The cross section or initial tunnel size is a function of the 78-inch carrier pipeline diameter. There is little difference in the cross section area of the initial tunnel for any of the alternatives. The diameter of the proposed carrier pipeline is 78 inches. Typically, a 12-inch annular clearance is considered between the carrier pipe and the initial tunnel/casing; this space will be filled with grout after the carrier pipe is installed. Based on these assumptions, the cross sections of the tunnel for the alternative are likely similar to those shown in Figure 1.

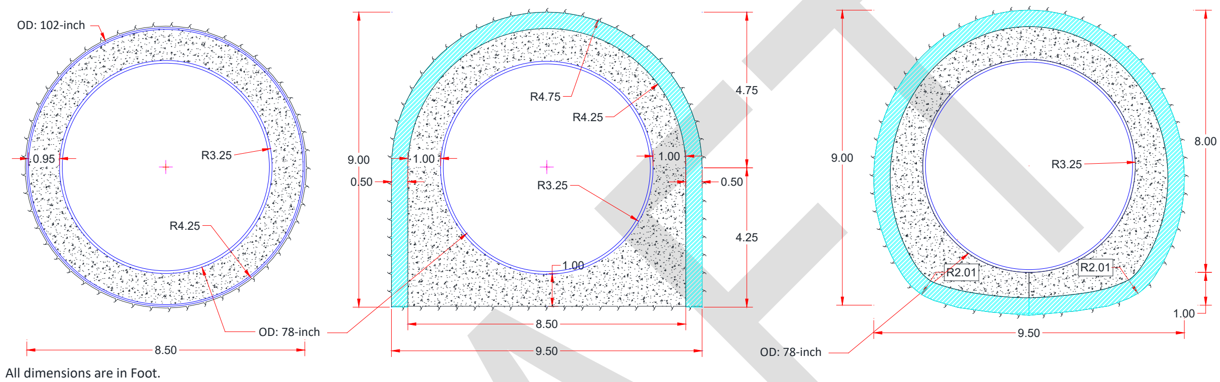


**Figure 1 Tunnel Cross Sections -Circular Tunnel (Pipe Jacking, TBM) , Horseshoe (Ribs & Lagging), and Ovoid (SEM) -Shaped Tunnels**

## 5.2 Tunneling-Induced Settlement

The ground movements associated with tunnel excavation can be estimated with either semi-empirical methods or numerical modeling methods. In general, semi-empirical methods are simpler, allow for greater repeatability of calculations, and provide direct estimates of slope and curvature of the settlement trough; numerical modeling methods are more sophisticated and are generally used where there are structures that may be affected by the construction. Modeling provides more accurate results for complex problems and allows a more in-depth understanding of soil-structure interaction. Modeling is generally used where structures may be affected by construction; such is the case for this project, where tunneling may adversely affect MWD's Inland Feeder Pipeline.

### 5.2.1 Settlement Impact on MWD Inland Feeder

The effect of tunneling-induced settlement on the existing MWD-IF pipeline was evaluated by performing 3D modeling using FLAC3D. FLAC3D is a 3D explicit finite difference program for geotechnical engineering and rock mechanics computations.

The detail modeling inputs are summarized in Table 5-1. The stress-strain behavior of the soil was approximated by using elastic moduli derived from in-situ shear-wave velocities measured during the geotechnical investigation. Considering the uncertainty of soil conditions underlying the creek bed and the sensitivity of the existing pipeline to tunneling-induced settlements, the analysis was run on the conservative side. Figure 2 indicates potential ground loss at the MWD-IF, based on 0 and 10 percent over-excavation.

**Table 5-1 Soil Properties for FLAC 3D Modeling**

| Material | Vs[1] (ft/s) | Poissons' Ratio ($\nu$) | Dry Unit Weight (pcf) | Shear Modulus (psf) | Young's Modulus (psf) | Bulk Modulus (psf) | Cohesion (psf) | Friction Angle (°) |
|---|---|---|---|---|---|---|---|---|
| Af | 700 | 0.3 | 130 | 1.98E+06 | 5.15E+06 | 4.29E+06 | 850 | 30 |
| Qw | 900 | 0.35 | 115 | 2.90E+06 | 7.82E+06 | 8.69E+06 | 500 | 40 |
| Qyf3 | 800 | 0.35 | 117 | 2.33E+06 | 6.28E+06 | 6.98E+06 | 250 | 30 |

Notes:

[1] Minimum shear wave velocity (Vs) were assumed for modeling purposes.

ft/s = feet per second
psf = pounds per square foot

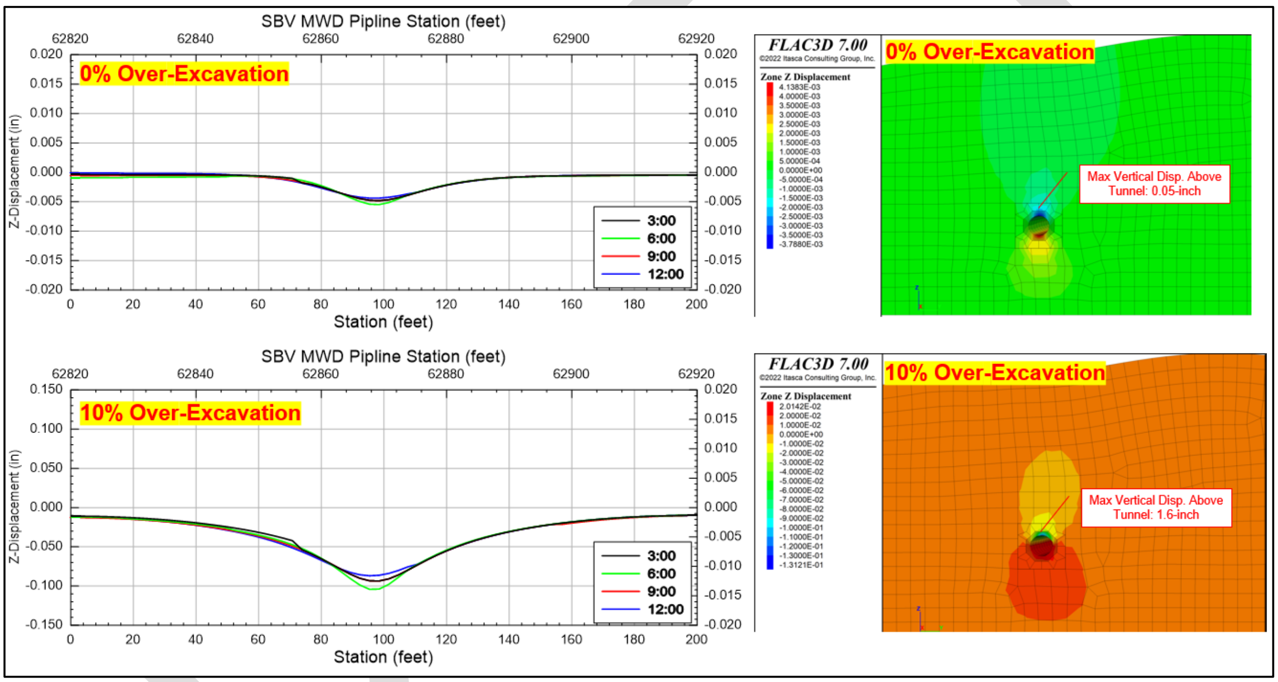


**Figure 2 Results of Settlement Analysis using FLAC 3D**

## 5.2.2 Effect of Shaft and Tunnel Construction on USACE Levee Integrity

The tunnel alignment and shaft locations were selected to minimize the impacts to existing facilities. Both launching and receiving shafts are as far as possible from the side slope boundaries of City Creek.

A full surface monitoring program should be put in place for the creek banks and existing utilities along the tunnel excavation alignment. Settlement can result from shaft excavation, tunneling, dewatering, and flooding. Borehole extensometers are commonly used in field monitoring programs to measure settlement. The most important utility in the vicinity of the proposed tunnel alignment is the existing 144-inch-diameter Inland Feeder (MWD-IF) and the existing 78-inch water pipeline. To monitor the settlement close to these utilities, rod extensometers can be used to measure the ground movement at the utility depth during the construction.

### 5.2.3 Settlement Monitoring Scheme

Settlement can result from excavation, tunneling, dewatering, and flooding. Borehole extensometers are commonly used in field monitoring programs to measure settlement. To secure the targets of the extensometer, the borehole is typically backfilled with cement-bentonite grout. Extensometers are commonly used to measure settlement and monitor small displacements of soil or rock along the axis of a borehole. In this project, control of settlement is important to avoid damage to existing facilities (i.e., underground utilities) adjacent to and crossing the tunnel alignment. To monitor the settlement close to these MWD-IF and 78-inch water pipeline, rod extensometers can be used to measure the ground movement at the utility depth during the construction.

The primary instrument for monitoring lateral subsurface deformations is the inclinometer. There are two types of inclinometer systems: the portable, traversing probe system; and the dedicated, in-place sensor system. Both systems require the use of inclinometer casing. In-place inclinometer systems are installed when continuous monitoring is required for construction control and safety. Inclinometers are used to ensure that the deflections of walls are within design limits, to check for ground movement that may affect adjacent buildings, and to verify that struts and ground anchors are performing as planned. An in-place monitoring system is recommended to allow continuous monitoring of the shafts during tunneling.

For this project, settlement in the MWD-IF pipeline, 78-inch Valley District, and 20-inch EVWD water pipelines during the tunnel construction and settlement is important, as is lateral displacement monitoring around the shafts. For this reason, it is recommended that an extensometer be installed on the west side just before the existing MWD-IF. A multi-point extensometer can measure the displacement at 5 feet below the MWD-IF and 5 feet above the tunnel crown.

A utility monitoring point may be installed on the existing 78-inch Valley District and 20-inch EVWD water pipelines at the intersection with the tunnel. Inclinometers are also suggested at both shafts. Figure 3 shows the recommended location of instruments in the shaft and along the tunnel alignment.

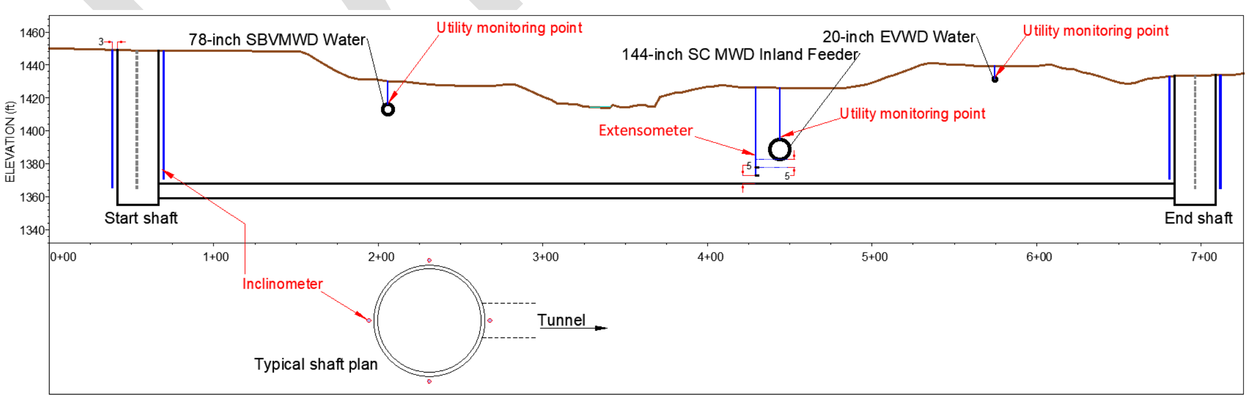


**Figure 3 Location of Instruments in the Shaft and along the Tunnel Alignment**

# 6. TUNNELING FEASIBILITY

The Foothill Pipeline Project will consist of temporary excavations for launching and receiving shafts, which will be set approximately 700 feet apart on either side of City Creek. The tunnel constructed between them will be approximately 90 feet deep. The surficial debris, organic materials, and deleterious materials will be removed and disposed of outside the construction limits.

## 6.1 Shaft Design and Construction

The launch shaft will be on the western side of City Creek and the receiving pit will be on the eastern side of City Creek. Both shafts could be excavated by either the sequential excavation method (SEM), with wire mesh and shotcrete or bolted-steel segments, or shoring systems of predrilled soldier piles and lagging or secant piles could be used. Considering ground conditions in the initial 40 feet, which has a high percentage of cobbles and boulders, pile driving or fluid-based pile drilling methods will be difficult. SEM with shotcrete and mesh, steel-bolted segments, or a hybrid of both will probably be the preferred method of shaft construction. However, the contractor will ultimately be responsible for finalizing a design, means, and methods of temporary shaft construction that meet the requirements of the their tunneling method and the permanent-works specifications.

Circular launching shafts 30 to 35 feet in diameter are likely in this type of geology and depth, and the shaft requirements will be similar for all tunneling methods. The receiving shaft may be 20 to 25 feet in diameter. Figure 4 shows an example of a shaft with shotcrete and steel-bolted segments.

**Figure 4 Shotcrete and Steel-Bolted Segments Supported Shaft**

Due to the ground conditions in City Creek, both the secant pile and SEM methods of shaft construction have some advantages and disadvantages. Table 6.1 compares these two methods.

**Table 6-1 Comparison of Shaft Alternatives**

| Item | Greater Advantage | |
|---|---|---|
| | **Secant Pile** | **Shotcrete/Steel Segments** |
| Ground control | √ | |
| Groundwater control | √ | |
| Cobble and boulder | | √ |
| Flexibility | | √ |
| Cost | | √ |
| Advance rate | √ | |
| Safety | √ | |

## 6.2 Tunnel Design, and Construction Alternatives

The new carrier pipeline will be installed using a two-phase method involving the construction of a tunnel to act as a casing to the steel carrier pipe. The annular space between the carrier pipe and the tunnel will be filled with grout. The first-phase tunnel could be constructed using any of several methods, determined by the anticipated ground conditions, the need to control settlement, and the need to minimize the possibility of ground and groundwater inflows into the tunnel. Control of settlement is important to avoid damaging existing facilities adjacent to and crossing the tunnel alignment. The tunnel alignment was selected to be as far as possible below the MWD-IF but above the groundwater table to minimize the risk of ground loss and surface settlement due to raveling and flowing ground conditions. However, the risk of raveling and flowing ground conditions cannot be entirely ruled out due to the possible presence of perched groundwater from City Creek in the wash deposits (Qw).

The selection of appropriate tunneling methods for the anticipated ground conditions will be the responsibility of the tunnel designer and the contractor. Potential tunneling methods include SEM, which typically entails an ovoid-shaped excavation that is initially supported by shotcrete and lattice girders. Shielded tunneling and pipe jacking with initial support provided by reinforced concrete pipe (RCP), steel pipe, ribs and lagging, or steel-bolted liner plates are also potential methods. SEM, involves sequential excavation with application of shotcrete, providing immediate support. In a shielded tunnel, the excavation is supported initially by a shield and subsequently the placement of rib and lagging or steel liner plates. For pipe jacking, the ground is immediately supported by the shield and a pipe, and any overcut is filled with a supporting lubrication fluid that is later replaced by grout.

Free-flowing perched water may also be hazardous to all the open face tunneling methods, if accompanied by raveling ground conditions

### 6.2.1 SEM Tunneling

SEM, also known as New Austrian Tunneling Method (NATM), was developed in the 1960s and is used in various ground conditions at various depths. For SEM, the surrounding rock or soil of a tunnel is typically integrated with a shotcrete liner into an overall support structure; thus, the ground formations will themselves be part of the supporting structure. Key elements of SEM tunneling include: (1) a typically ovoid-shaped tunnel is sequentially excavated and supported; (2) immediate ground support is provided by a thin coat of fast-setting shotcrete (flashcrete); (3) shotcrete is applied, reinforced with fiber or welded-wire fabric, and steel arches (lattice girders); and (4) ground reinforcement (e.g., soil nails or spilling) is installed for pre-support of the next excavation round. Monitoring of deformations during excavation is essential, providing real-time feedback regarding the effectiveness of ground support; this allows for additional support to be installed when needed.

Figure 5 explains the basic SEM philosophy and depicts a typical SEM soft-ground excavation scheme.

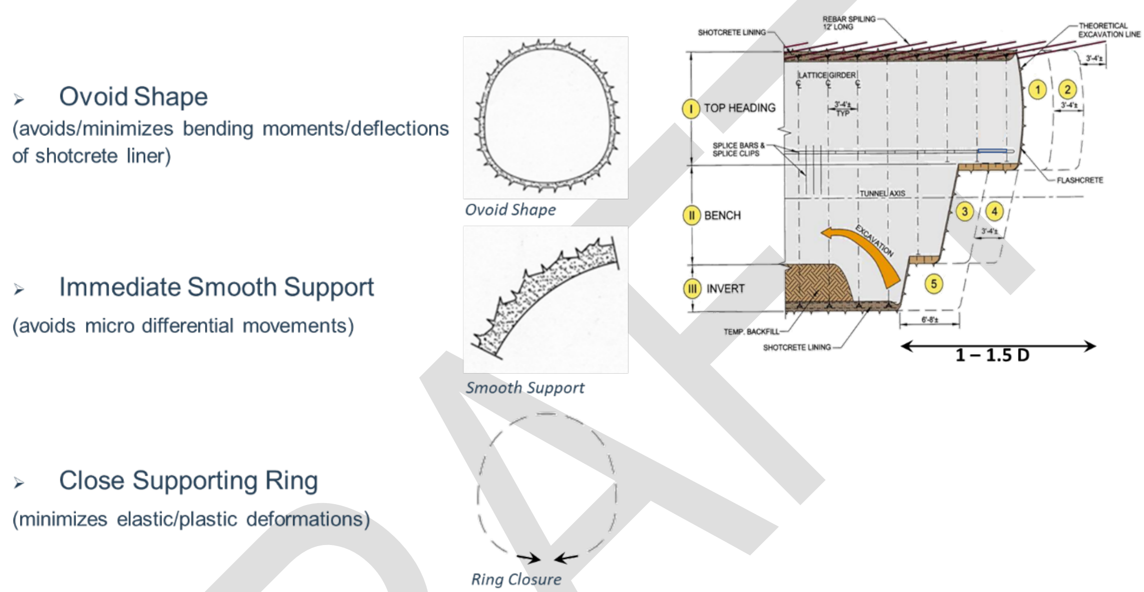


**Figure 5 Basic SEM Philosophy and Typical SEM Soft-Ground Excavation Scheme**

## Excavation and Loading Equipment

Depending on the type of the soil, different methods of mechanical/mannual excavation and loading equipment would be used for small-size SEM tunneling on this project. Figure 6 shows typical equipment used for SEM tunneling. An advantage of this method is that large boulders may be removed/broken up without causing major delays. Excavated material can be transferred to the shaft by rubber-wheeled vehicles and removed by a crane.

| Backhoe | Loader | Drum cutter |
|---|---|---|

**Figure 6 Example of Small-Size Excavation/Loading Equipment**

Figure 7 shows different stages of excavation in SEM tunneling in a small-diameter tunnel. Depending on the stand-up time of the soil, the tunnel can be excavated in one stage or multiple stages (top heading and bench). Pre-grouted tunnel face could change stand-up time and sequence of the tunnel excavation.

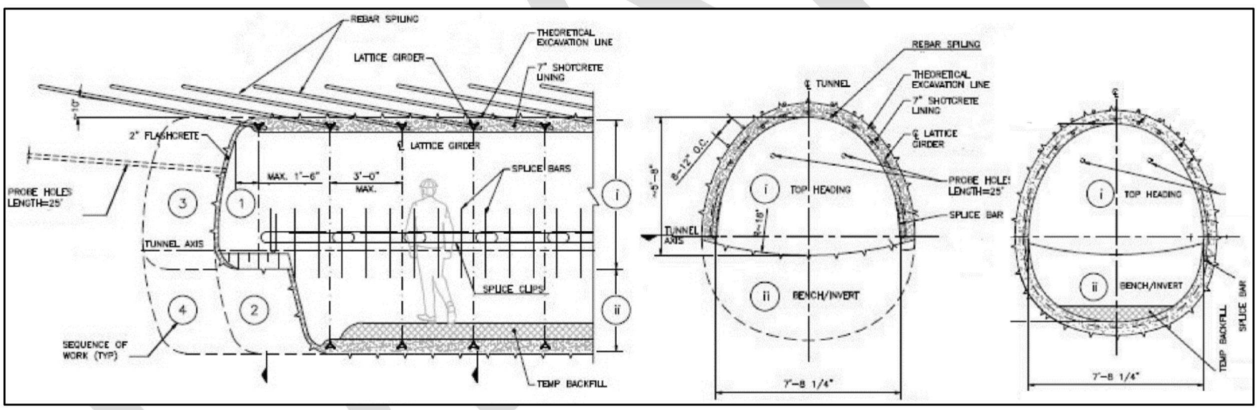


**Figure 7 Different Stage of Excavation in SEM Tunneling in a Small-Diameter Tunnel**

## Initial Ground Support (Pre-Support)

SEM support systems include pre-support by forepoling with rebar or grouted spiling, followed by application of shotcrete reinforced with wire mesh and lattice girders. Ring closure, achieved by extending shotcrete to the invert, provides a semi-ridged confinement to minimize potential settlements. Figure 8 shows some examples of support systems in SEM tunneling.

| Steel set and spiling | Steel set and shotcrete | Lattice girder and spiling |
|---|---|---|

**Figure 8 Example of Support System in SEM Tunneling**

In suitable ground conditions where the excavated face is stable and fully excavated, and where a horseshoe-shaped tunnel profile is excavated, the initial support may be steel ribs and lagging. This is an alternative to SEM, but overexcavation of the tunnel profile may increase the amount of settlement. Strict supervision is required on site to limit overexcavation and to ensure the proper placement and expansion of the ribs and lagging. Like SEM, boulders may be easily removed using this method, but this support method is not suitable for raveling ground or water and ground flows.

### 6.2.2 Shielded Tunneling

The Shielded (Shield) tunneling method includes a steerable tunneling shield which advances during the excavation cycle by thrusting off the initial tunnel support system. The shield may be bulkheaded and have a rotating cutter wheel for excavation using a conveyor and wheeled muck skips to transfer the spoil to the shaft (Figure 9 A) or in manual excavation shield (Figure 9 B) it may have an extended hood beyond the excavating face. In this case, the angle of repose of the excavated material at the face will be controlled by sand shelves and an operator inside the shield during excavation. In either method, access to the face for removing boulders is possible.

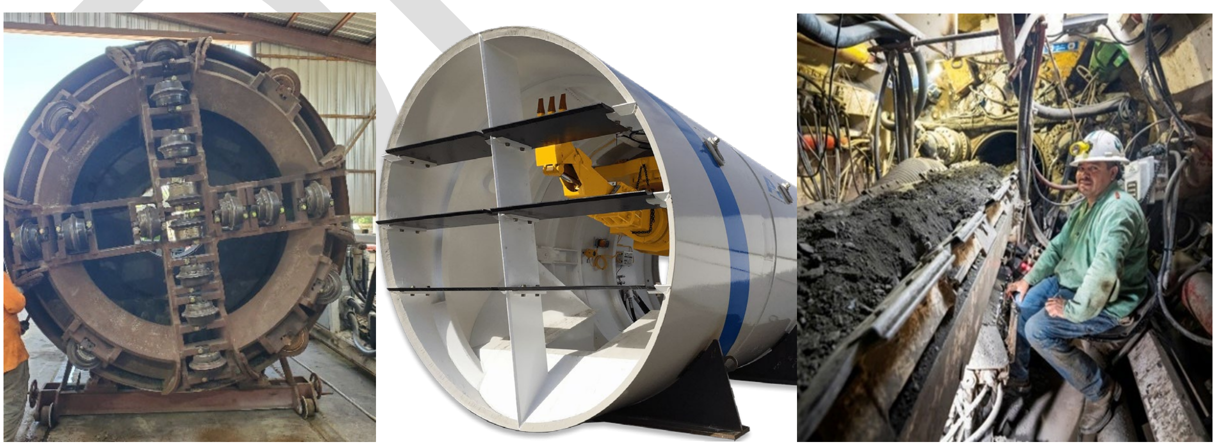

**Figure 9 A - Open Shield with cutter Disc B Open Shield with excavation arm C- Conveyor muck transfer**

In this method the shield advance cylinders will thrust against the bolted-steel liner plates (Figure 10 A) or rib and lagging (Figure 10 B) which provide initial temporary support to conventionally open-face excavated tunnels. The liner plates are of a weight and size that can be handled without heavy lifting equipment but are designed to take the ground loads. They may be gasketed to provide a seal to limit water and flowing ground. In larger diameters, steel ribs may be installed to provide additional support. During construction, as the overburden loads are transferred through the ring, slight ring deformation may be seen; if required, contact grouting may be carried out and steel ribs may be added. Spoil is generally removed by conveyor and by muck cars on rail tracks. Like SEM, this is an open-face method, and face instability would require grouting to stabilize the ground. Liner plates are typically set every 2 feet and 4 to 6 feet for rib and lagging, depending on ground stability. Overcut is kept to a minimum to reduce settlement. This system is better used above the water table in consolidated grounds of clay and silt or weak rock. The steel plates or rib and lagging are only an initial support and act as the casing in a two-phase method; a carrier pipe will be installed inside, and the annular space between will be grouted.

**Figure 10 A-Steel-Bolted Liner Plate Tunnel Support B- Rib and Lag Tunnel Support**

### 6.2.3 Pipe Jacking

Pipe jacking is another trenchless construction method that uses hydraulic jacks installed in the launching shaft to push pipes or casings through the ground while the face is excavated with a mechanized tunnel boring machine (TBM). Today, it is one of the most accurate of the tunneling methods and is used as a one- or two-pass method of installing carrier pipe. Pipe jacking has two main variations: (1) open-face pipe jacking and (2) microtunneling. Either could be potential construction methods on this project. Open-face pipe jacking (Figure 11) is normally performed using an open shield with a powered rotating cutter wheel or, in some cases, a roof-mounted backhoe or roadheader arm. The open face may also have doors that can be closed to stop ground from entering the shield in an uncontrolled manner; however, because these doors will not control groundwater flow, this method is typically only suitable above the groundwater or in dewatered ground conditions. The pipe jacking method may be used with RCP or steel pipe between 60- and 120-inch inside diameter and straight drive lengths not exceeding 1,000 feet. The jacking system is set up in the launching shaft (Figure 12), and 10- to 20-foot lengths of pipe are advanced into the ground as excavation at the face continues. The shield's overcut, typically ½-¾-inch, is filled with lubricant to help reduce jacking loads and settlement. If boulders are encountered, in a stable face or a grouted stabelized face (i.e. permeation grouting), it is possible for workers to access the face to break up and remove them. The advantage of pipe jacking is the excavated tunnel is supported at all times and the overcut around the pipes from the excavation is filled with a supporting lubrication fluid which is replaced by grout at the end of the drive so limiting any settlement.

Figure 9 Open-Face Pipe Jacking Shield with Iris Doors

Figure 102 Pipe Jacking Shaft Set-Up

### 6.2.4 Microtunneling

Microtunneling is also a pipe jacking method but is remotely controlled, closed-face, steerable method with which jacking pipes may be installed on straight or curved alignments of 2,000 to 3,000 feet between shafts with the use of intermediate jacking stations. Microtunneling is suitable for nearly all ground conditions, including rock and raveling ground below the water table. It is the most sophisticated of the trenchless pipe installation methods, having an accuracy of 2 inches on line and grade. Casings or jacking pipes are jacked from the launching shafts to the receiving shaft where the microtunneling boring machine (MTBM) is retrieved. To reduce friction during jacking, bentonite lubrication is injected into the overcut around the outside of the pipes through ports in the casing or pipe which reduce the tunneling-induced settlement. Figure 13 shows a schematic of a microtunneling system.

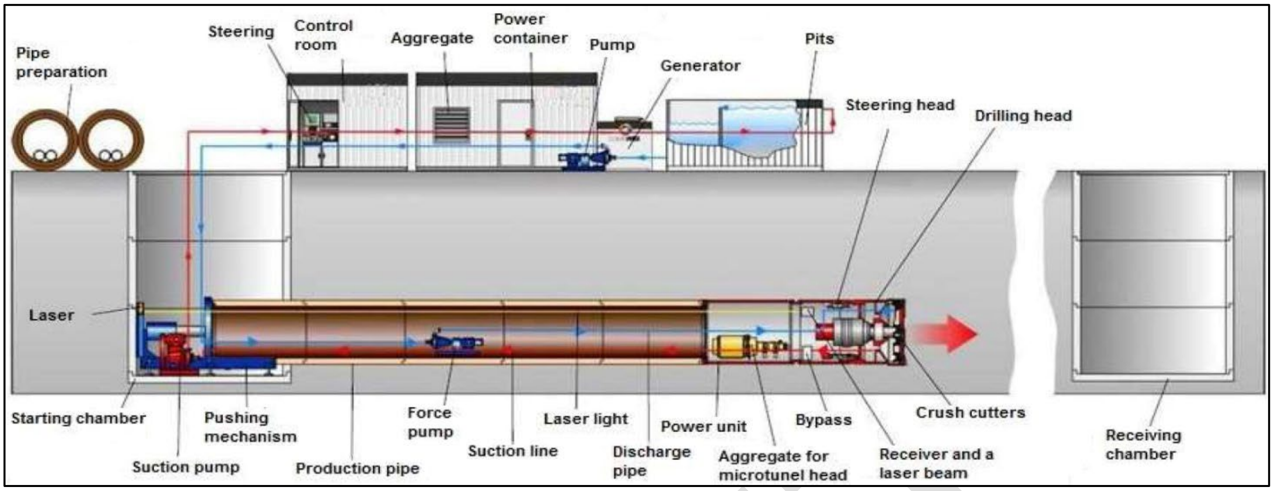


Figure 113 Schematic of Microtunnel Boring Machine Project

MTBM's advance rate is typically faster than those of other potential tunneling methods. The excavated ground is transported to the surface normally by a circulating fluid slurry system. This system also provides pressure at the face to control groundwater pressures; the slurry on the surface passes through a separation plant, where the excavated solids are removed. The slurry fluid is then recirculated to the MTBM. Microtunneling is a closed-face pressurized system that is generally not used above the water table in high permeability ground due to risk of loss of returns and frac-outs. MTBMs greater than 72 inches typically have access to the face through a door in the pressure bulkhead. This access may be used at atmospheric pressure when above the water table, but a pressurized airlock allows access to change cutters and enables removal of obstructions when below the groundwater table.

## Casing Pipes

Steel or concrete casing pipes could be used along the tunnel alignment as a permanent tunnel support system, designed to support overburden soil pressure, groundwater hydrostatic pressure, seismic forces, and surcharge loads due to traffic and construction activities. The jacking pipe must also resist jacking forces applied during excavation and advancing the MTBM. The friction between casing and soil is reduced by introducing a fluid lubricant on the outside of the pipe in the overcut of the shield. Jacking pipes have a safety factor of 3 to calculate the maximum force that may be applied to them during installation. Depending on the tunnel application, length, and diameter, different types of pipes (casing) are available, including reinforced concrete, steel, and fiberglass. Figure 14 shows steel and RCP used for microtunneling. In this project, a 102-inch-diameter casing pipe would be suitable. Steel pipe could be jointed with Permalok or by butt welding.

|  |  |
| --- | --- |
| Steel pipe | Concrete pipe |

Figure 124 Suitable Jacking Pipes for Microtunneling

For pipe jacking, the shaft must take the thrust loads; it typically has a thrust wall built at the shaft bottom to allow these thrust loads to be applied inside the shaft to the surrounding ground.

### 6.2.5 Carrier Pipe Installation

Once the tunnel is completed or casing pipe is installed, the carrier water pipes will be installed. The carrier pipes will have casing spacers installed on every 10 feet of pipe, along with polyvinyl chloride grouting pipes, as shown on Figure 15. The annular space between the outside of the steel carrier pipe and the inside of the casing pipe will be filled with grout. In seismic areas, a lightweight cellular grout is recommended. The carrier pipes may be installed by welding them in the shaft and pushing them into the casing pipe on rollers fitted to the spacer system. An alternative generally used on long and curved drives involves carrying the carrier pipes inside the casing and welding them in position from each end.

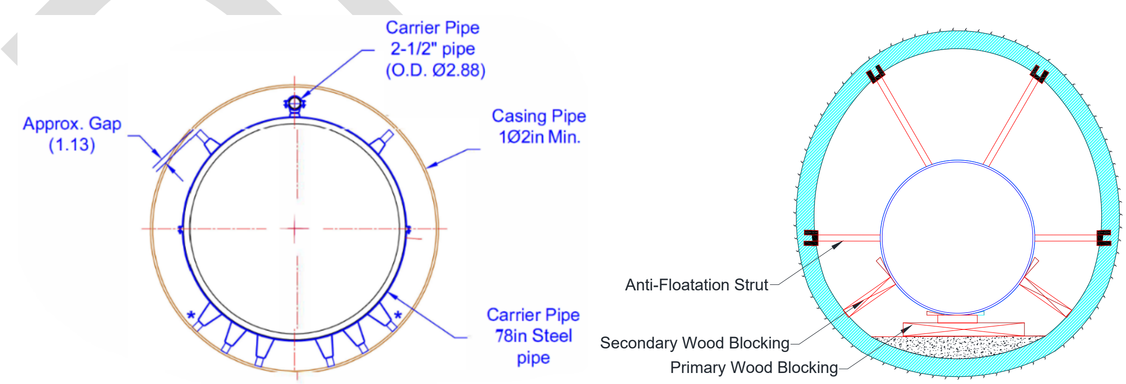


Figure 135 Carrier Pipe Spacers

### 6.2.6 Ventilation

All tunnels large enough for a worker to enter must be equipped with ventilation, and gas detection, in accordance with the requirements of the California Division of Occupational Safety and Health. Hazardous gas such as carbon monoxide, carbon dioxide, and hydrogen sulfide, and explosive gases such as methane may be found mixed with dust from the excavation. Tunnels must have efficient ventilation systems during construction and operation, with air blown to the tunnel heading from the surface through a ducting system. The capacity of the fan will be calculated based on the cross section area of the tunnel, number of personnel, method of excavation, type of equipment, and potential existence of natural hazardous gases.

### 6.2.7 Summary and Discussion

The SEM which involves installing wire mesh and shotcrete, Shield tunneling with rib and lagging, or steel liner plate; and open-face pipe jacking and microtunneling—have advantages and disadvantages.

One of the advantages of using microtunneling, is that it causes minimal disruption to the environment and typically causes the least settlement. However, because it is a closed face method, any problems at the face will be more difficult to access, requiring entry through the bulkhead door to change cutter tools or remove obstructions. A significant disadvantage of microtunneling above the water table in permeable ground is the potential loss of slurry circulation, which can cause a “fracout” and potentially make it impossible to excavate until circulation is regained. Remote control in microtunneling naturally leads to greater safety for the operator, because a person can operate the MTBM from the surface without having to enter the tunnel excavation. The operator is therefore safe from any hazards such as gases or ground failure. During microtunneling, the ground and groundwater pressure at the cutting face are monitored, so there is less likelihood of overexcavation causing ground settlement. Microtunneling drive lengths are determined by diameter, pipe material, and ground conditions. For diameters greater than 72 inches, drives of more than 3,000 feet are now possible with curved alignments. Microtunneling is suitable as a tunneling method below the water table in unstable, flowing ground conditions.

Open face pipe jacking with face closure doors is an alternative to microtunneling where ground conditions are suitable in above the water table and not suitable as a method below the water table in raveling or flowing ground conditions. In this method the excavated material is transported by conveyor belt from head chamber to muck cars and then to the shaft . In suitable ground conditions, it may offer a lower-risk, lower-cost option to use in permeable and impermeable ground above the water table.

SEM is carried out in a sequence of open excavations, with each section being supported by initial placement of wire mesh; shotcrete; and, if required, lattice girders. Typically, the ground needs to be self-supporting until the initial support is placed. If the face is unstable and flowing with water, then additional support such as roof spiles and /or dewatering or grouting may be required to stop uncontrolled ground loss. In this project, with the tunnel likely above the groundwater, SEM is a suitable method; however, the risk of perched water flows needs to be recognized because that could cause increased settlement due to ground loss in the excavation face. SEM is more flexible in terms of the length and shape of the excavation. It is also affected less by cobbles, boulders, and abrasive soil conditions. However, SEM tunneling personnel must be underground, resulting in a lower level of worker safety due to the potential for unstable ground, exposure to hazardous gases, and groundwater flows.

In conventional tunneling methods, excavation is normally carried out from an open shield with excavators; or in partially bulkheaded shields with powered, rotating cutter heads. Initial support consists of rib and lagging, or bolted-steel liner plates. In this case, the support is installed directly behind the excavation shield, and the shield can advance forward by applying thrust from the cylinders to the tunnel support to advance the shield during an excavation cycle. Any delay in the placement of the support could lead to increased settlement. A disadvantage of conventional tunneling is that rib and lagging is not waterproof, so water can flow from the excavated ground into the tunnel. It is therefore not suitable for raveling or flowing ground. However, bolted-steel liner plates may be gasketed, providing a partial seal to groundwater, and may be used in some unstable ground conditions.

For all the above-discussed tunnel methods, it is necessary to determine the geotechnical and hydrogeological risks of the ground carefully.

It is difficult to recommend one tunnel method over another for the construction of the City Creek tunnel, because of the advantages and disadvantages outlined above for each method. No single method is clearly the best; if contractors are left to decide the method, it is likely that they will decide based on their own expertise, cost estimate, and their available equipment.

It is likely that microtunneling will not be cost competitive due to the short drive length, large diameter, and the high cost of equipment. The risk of lost circulation below creek bed is also high in this method. SEM, conventional tunneling, and open-pipe jacking are all similar in having risks, advantages, and disadvantages; any of these methods are technically suitable.

## 6.3 Ground Treatment and Dewatering

According to the geotechnical investigation data presented in GIR, the unknown condition below the creek may raise the risk of mixed-face conditions in the mid-section of the tunnel, with the possibility of cobbles and boulders. The tunnel alignment was selected deep enough to be below the cobbles and boulders and to be above the groundwater table, minimizing the risk of water flow causing settlement. In the case of presence of perched water under the creek or an unlikely event of water table rising above the proposed tunnel level, and in the presence of cobbles and boulders, there is a risk of raveling ground conditions. If uncontrolled, this could cause settlement of existing utilities, in particular the Inland Feeder Pipeline. In these conditions, microtunneling is likely the best method to excavate and control settlement. If SEM, conventional tunneling, or open-face pipe jacking were being used in these conditions, then deep dewatering or ground treatment may become necessary to prevent ground loss and potential settlement of utilities. If these conditions exist at the shaft locations, ground treatment or dewatering methods could be required to complete construction of both shafts.

### 6.3.1 Grouting

Various methods of grouting including jet grouting, compaction grouting, soil mixing, and permeation grouting are available to improve ground condition before/after/during the construction. For this project, permeation grouting is likely the best method to stabilize the gravel and boulder conditions. Permeation grouting uses flowable grouts to fill voids. It permeates granular soils or cracks and joints in rock; improves the strength properties of the ground; and reduces water flow to the excavation. Permeation grouting is used to create barriers to groundwater flow, underpin foundations, provide excavation support, and stabilize and strengthen granular soils. Permeation grouting may also be carried out around existing MWD-IF to improve the surrounding soil and reduce the risk of settlement during tunneling. Permeation grouting may be carried out from the surface in advance of tunneling or from inside the tunnel by drilling ahead of the tunnel-excvation face.

For shaft excavation by SEM, permeation grouting increases the stability of the shaft during excavation—especially in the upper part, which contains very young wash deposits with cobbles and boulders.

### 6.3.2 Dewatering

The tunnel alignment was selected to be above the groundwater table, but in case of any changes in the depth of water table or if perched water flows into the tunnel or shaft, permeation grouting and deep dewatering from the surface are options. In order to avoid the need for dewatering due to unexpected water table raise or increase in perched water, it is recommended that construction be scheduled to take place during dry summer months. If the water table elevation increases into the tunnel level, localized pumping from a sump in the shafts is another option for dewatering the working area.

## 6.4 Spoils Transportation and Disposal

Ground disposal will depend on the analytical results of the excavated spoil. Based on the level of contamination, there are two categories of spoil:

1. **Non-hazardous:** This consists of clean, uncontaminated soil, or soil with low level of non-hazardous contamination. Non-hazardous soil is mostly disposed in regular Class III landfills.

2. **Hazardous:** This consists of contaminated soil that is impacted by petroleum hydrocarbons (gas or diesel), volatile organic compounds, metals, polychlorinated biphenyls, and other regulated constituents.

Depending on the nature and level of contamination, **hazardous** soil must be disposed of in special designated landfills or disposal facilities in accordance with Non-Resource Conservation and Recovery Act (RCRA). Prior to disposal, a composite sample of the excavated soil will be analyzed by a certified environmental laboratory. The analytical results will determine which specific disposal facility can accept the excavated soil.

Table 6-2 shows the disposal facilities that may be used for different levels of contamination and potential haul routes.

**Table 6-2 Potential Spoil Disposal Sites and Haul Routes**

| Type of Soil | Facility Name | Facility Address |
|---|---|---|
| Non-Hazardous Class III | Environmental Management Technologies | 1456 S. Gage Street<br>San Bernardino, CA 92408 |
| Non-Hazardous Class III | Azusa Land Reclamation | 1211 W. Gladestone Street<br>Azusa, California 91702 |
| California Hazardous – Non-RCRA | Hec Hayward Environmental Consulting | 9852 Crescent Center Drive #801<br>Rancho Cucamonga, CA 91730 |
| California Hazardous – Non-RCRA | Clean Earth | 121 Main Street<br>Riverside, CA 92503 |
| RCRA Hazardous | Environmental Management Technologies | 1456 S. Gage Street<br>San Bernardino, CA 92408 |

Note:
RCRA = Resource Conservation and Recovery Act

# 7. RISK ANALYSIS

Risk identification involves determining and documenting risks that may affect the project. In this section, the risks of environmental and geotechnical hazards during construction were identified and analyzed for tunneling construction. Additional hazards affecting the pipeline during operation that have not been considered include strong ground shaking, fault rapture, liquefaction due to long-term seismic activity, and corrosion.

## 7.1 Risk Identification

Risk identification involves determining and documenting risks that may affect the project.

### 7.1.1 Flooding and Scour

Geomorphologic and streambed erosion studies indicate that 15 to 25 feet of scour could occur during a major storm event. This could affect shaft construction and tunneling by causing damage to construction equipment and temporary construction-related installations on the surface.

### 7.1.2 Groundwater

The groundwater table in Boreholes 1 and 2 was encountered at elevations 1,340 feet and 1,350 feet, respectively. The invert of the tunnel will be above this elevation, at approximately 1,360 feet. However, because the groundwater table seasonally fluctuates, it could be higher at the time of construction. Furthermore, there is also the possibility of encountering pockets of perched groundwater during tunneling.

### 7.1.3 Cobbles and Boulders

The depth of the tunnel can be designed to mostly avoid cobbles and boulders, but there is still the risk of encountering such oversized materials, which tend to cause problems of over-excavation for both open-faced as well as closed-face TBMs.

### 7.1.4 Abrasive Soil

Based on the GIR, cobbles and boulders in the wash deposit (Qw) are of strong abrasive granite. Most likely, the sandy soil below has the same granitic origin, with a high quartz content, and is also abrasive. Tunneling through these soils decreases the cutting tools' life. Therefore, open-faced as well as closed-faced TBMs must provide the possibility of accessing the face for tooling changes. If groundwater is present, then it is likely that a closed-face tunneling method will be required, with access to the face under compressed air.

### 7.1.5 Tunneling-Induced Settlement

Control of settlement is important to avoid damaging existing structures (i.e., underground utilities) adjacent to and crossing the tunnel alignment. The tunnel alignment was selected to be above the groundwater table, minimizing the risk of ground loss and surface settlement due to raveling and flowing ground conditions. Microtunneling has more ground control to prevent/reduce settlement, but there is always a risk of settlement due to operator error during excavation. Existing infrastructure adjacent to/above the proposed tunnel includes MWD's existing 144-inch-diameter Inland Feeder (MWD-IF), Valley District's 78-inch  water pipe, EVWD's 20-inch water pipe, and City Creek boundaries). The tunneling crew's experience is of paramount importance to avoid damage to these structures and should be part of the contractor's qualifications.

### 7.1.6 Safety during Construction

It is anticipated that the City Creek tunnel will be classified as non-gassy, but equipment-generated emissions and dust are a hazard to workers, especially in confined spaces. Ventilation during construction has an important role in protecting the health and safety of workers.

### 7.1.7 Stability

Risks of unstable ground excavation can be correlated to reliability of support installed during tunneling (casing vs. rib & lagging vs. shotcrete & lattice girder), and control of the tunnel face (open vs. closed face).

## 7.2 Hazard Frequency and Severity

Hazard frequency is the number of times that a hazard might occur during construction time; and the severity of a hazard event is related to the effect or magnitude of the damage that the hazard can cause. Depending on the type of hazard, damage could be an onsite fatality, or destruction or damage to existing structures or utilities, site equipment, or completed construction, any of which will cause additional cost and probable delay in the project.

In this study, the frequencies of major hazard-related failures are determined based on the likelihood of the occurrence. The probability and severity of risks in this project are defined in Table 7-1 and Table 7-2, respectively.

**Table 7-1 Probability of Hazards**

| Level | Descriptive Word | Definition |
|---|---|---|
| 1 | Improbable | Probability of occurrence cannot be distinguished from zero |
| 2 | Remote | Not likely to occur in system life cycle, but possible |
| 3 | Occasional | Likely to occur sometimes in system life cycle |
| 4 | Probable | Likely to occur several times in system life cycle |
| 5 | Frequent | Likely to occur repeatedly in system life cycle |

**Table 7-2 Impact of Hazards (Consequence)**

| Level | Descriptive Word | Definition |
|---|---|---|
| 1 | Very Low | Problem can be solved during the shift<br>No major delay |
| 2 | Low | No risk of damage<br>Makes delay or occasional downtimes |
| 3 | Medium | No serious damage<br>Construction stops for a short time |
| 4 | High | Can damage the structure and equipment<br>Construction stops until troubleshooting |

| Level | Descriptive Word | Definition |
|---|---|---|
| 5 | Very High | Severe damage in the tunnel structure or equipment<br>Construction stops for a long time |

## 7.3 Risk Evaluation

A risk-ranking evaluation is based on a matrix in which the axes are the consequences and probability. The combination of consequence (severity) and probability creates a risk ranking. Risk matrices are tools that allow the categorization of risk. Most matrices employ probability and consequence as their x and y axis, and therefore it is generally accepted that risk = probability times consequence. The purpose of the matrix is to reduce the risk into ranges or bands of equal risk—e.g., high, medium, or low risk.

A type of risk matrix that is visually represented as a table or a grid, a five-by-five risk matrix has five categories each for probability (along the X axis) and impact (along the Y axis), all following a scale of low to high. The first step is to assign a numeric value from 1 to 5, 1 being the lowest, for each of the categories under probability and impact. The value of the probability is multiplied by the value of Impact to determine the risk level. The numeric values for each risk level are defined as follows.

- 1 to 4: Low – no further action may be needed; maintaining control measures is encouraged
- 5 to 9: Medium – may be considered for further analysis
- 10 to 16: High – must be reviewed in a timely manner to carry out mitigation
- 17 to 25: Very High – must implement a stop order and take immediate action

These bands are often allocated colors: red for the highest risks to green for the lowest, giving rise to the term "Heat Map." A widely used definition of risk involves the multiplication of probability and impact. In this application, a five-by-five matrix is designed to monitor contract status (Table 7.3). Table 7.4,show the degree of risk of the hazards during construction in SEM tunneling, Shield tunneling,open pipe jacking, and Microtunneling based on the five-by-five risk matrix.

**Table 7-3 Five-by-Five Risk Matrix and Criteria**

| Probability/ Impact | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | 1 × 1 | 1 × 2 | 1 × 3 | 1 × 4 | 1 × 5 |
| 2 | 2 × 1 | 2 × 2 | 2 × 3 | 2 × 4 | 2 × 5 |
| 3 | 3 × 1 | 3 × 2 | 3 × 3 | 3 × 4 | 3 × 5 |
| 4 | 4 × 1 | 4 × 2 | 4 × 3 | 4 × 4 | 4 × 5 |
| 5 | 5 × 1 | 5 × 2 | 5 × 3 | 5 × 4 | 5 × 5 |
| Legend | | Low<br>1 to 4 | Medium<br>5 to 9 | High<br>10 to 16 | Very High<br>17 to 25 |

## Table 7-4 Risks during Construction by Tunneling methods

| Hazards | Probability | Impact | | | | Risk | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SEM | Shield Tunneling | Pipe Jacking | | SEM | Shield Tunneling | Pipe Jacking | |
| | | | | Open | Microtunnel | | | Open | Microtunnel |
| Groundwater | 4 | 4 | 4 | 3 | 1 | 16 | 16 | 12 | 4 |
| Flooding and scour | 2 | 3 | 3 | 3 | 3 | 6 | 6 | 6 | 6 |
| Cobble and boulder | 3 | 2 | 2 | 4 | 5 | 6 | 6 | 12 | 15 |
| Abrasive soil | 5 | 1 | 1 | 3 | 3 | 5 | 5 | 15 | 15 |
| Settlement | 3 | 4 | 4 | 3 | 3 | 12 | 12 | 9 | 9 |
| Safety | 3 | 4 | 4 | 1 | 1 | 12 | 12 | 3 | 3 |
| Stability | 4 | 3 | 4 | 3 | 2 | 12 | 16 | 12 | 8 |
| | | | | | Total | 69 | 73 | 69 | 60 |

| Legend | |
|---|---|
| Low | 1-4 |
| Medium | 5-9 |
| High | 10-16 |
| Very High | 17-25 |

In SEM and open shield tunneling, there is a higher risk of groundwater inundation, safety, and ground stability, along with four high-risk hazards. The most important of these risks is face instability and tunneling-induced settlement and their impact on the existing utilities. These two risks could intensify in the presence of groundwater or perched water inflow and jeopardize the safety of tunneling crew due to ground instability at the face. In microtunneling abrasive soil and the existence of cobbles and boulders could impact the project with high risk, but groundwater in open pipe jacking could worsen the face instability. Having face doors and face access to change tools and remove the boulders in open pipe jacking will reduce the risk.

The recommended tunnel profile is evaluated to be deep enough to avoid most cobbles and boulders and at least 15 feet below the inland feeder but above the groundwater table (based on latest measurements). The pipe jacking methods reduce the risk of ground instability since the tunnel excavation is fully supported by the casing pipe being installed at the jacking shaft as excavation occurs to avoid tunnel collapse and damage to existing utilities. With open-face pipe jacking the excavation face may be physically closed with iris type doors, but groundwater can not be controlled and will enter into the shield and could cause face instability. Therefore, upgrade tunneling is recommended so that groundwater will flow out of the tunnel to the shaft to be removed by pumping. The advantage of open-face pipe jacking is the open access to the face to remove boulders and replace tooling. The disadvantage of the method is the limitations on work in unstable, flowing, or raveling ground conditions; and that the maximum drive length is around 1,000 feet, but this is not a factor on this project.

The most serious risk for microtunneling is the potential for lost circulation when operating in permeable ground above the water table, but the risk of face instability due to ground water or pearched water will be low. Any boulders in the tunnel alignment may also cause delays if a face intervention was required. This can be mitigated by having disc cutters for cutting the boulders and face access through the MTBM; if the groundwater is below the alignment, boulder removal and tooling changes are easily carried out without the need for compressed air. Soil abrasiveness is not a serious threat, because of the short length of the tunnel. However, if the cutting tools get damaged by cobbles and boulders, the wear in the cutterhead will increase. Based on the GIR, no boulders were encountered in the Qyf3 deposits in any of the boulders. It can be concluded that the probability of boulders at the proposed tunnel level is low.

# 8. REGULATORY AGENCY REQUIREMENTS

## 8.1 Surface Water and Biological Resources

This section summarizes the laws, regulations, and agencies applicable to regulatory permitting for water resources and biological resources. Other environmental topics, such as air quality and cultural resources, and not included below.

A summary of the permits and fees required for the construction of the Foothill Pipeline is provided in Table 8-1, followed by detailed descriptions of the regulations and permit requirements for each permit listed. Note Table 8-1 is for the Federal and State regulatory agencies; other local agencies are not included here but are described at the end of this section.

**Table 8-1 Summary of Regulatory Permits Anticipated for Construction of the Foothill Pipeline (Tunnel and Bridge Alternatives)**

| Agency | Law, Regulation, Permit Type | Applicable Fee / Other Information |
|---|---|---|
| **FEDERAL** | | |
| Regulatory Division<br>USACE Los Angeles District | **CWA Section 404 Permit**<br>(a) Tunnel – no 404 anticipated<br>(b) Bridge - Section 404 Nationwide Permit (NWP) No. 58 for Utility Line Project[1] | No fee; $100 if USACE decides to require a Standard Individual Permit (SIP). Need to comply with NWP General Conditions and SPL Regional Conditions<br>Duration: 45 days for NWP No. 58; Over 120 days for a Standard Individual Permit. |
| Civil Works Division<br>USACE Los Angeles District | **Section 408 Permit**<br>(a) Tunnel – no 408 required<br>(b) Bridge – no 408 required | The official USACE levees begin downstream (south) of the Project within City Creek. There are no levees in the Project area; thus, no Section 408 Permission is anticipated.<br>Duration: Variable. |
| U.S. Fish and Wildlife Service | **FESA Compliance**<br>(a) Tunnel – no Section 7 or 10 required<br>(b) Bridge – Section 7 likely applicable | No fee anticipated for Section 7 Consultation.<br>Federal Endangered Species Act – Section 7 Consultation (Biological Opinion) or Section 10 Habitat Conservation Plan (HCP) and Incidental Take Permit (ITP).<br>Duration: Section 7, approximately 120 days; Section 10, up to a year or more. |
| **STATE** | | |
| Regional Water Quality Control Board (RWQCB) | **CWA Section 401 Water Quality Certification**<br>(a) Tunnel – no 401 anticipated; recommend | General Order (2020) for NWP No. 58 is applicable if criteria are met (e.g., exempt from CEQA). If does not meet General Order, then individual 401 Certification required. |

| Agency | Law, Regulation, Permit Type | Applicable Fee / Other Information |
| --- | --- | --- |
| Santa Ana Region (8) | agency coordination before construction.<br>(b) Bridge – 401 required; at least 90 days; “401 Rule” may apply so need pre-application meeting.<br>**Porter Cologne Water Quality Control Act – Waste Discharge Requirement** – Not Applicable. | Fee based on acreage of impact (temporary and/or permanent impacts) within waters of the State (Discharge Area x $24,366).<br>Fee Range from < 0.10-acre to 1.00-acre shown below:<br>**Low Impact Discharges**<br>**(< 0.10-acre, < 300 linear feet)**<br>_Appl Fee $2,734; Project Fee = $0<br>Annual Fee = $365<br>**0.10-acre**<br>_Appl Fee = $2,734; Project Fee = $0<br>Annual Fee = $2,297<br>**0.50-acre**<br>_Appl Fee = $2,734; Project Fee = $9,449;<br>Annual Fee = $2,297<br>**1.00-acre**<br>_Appl Fee = $2,734; Project Fee = $21,632;<br>Annual Fee = $2,297<br>Duration: 90 days. |
| California Dept. Fish and Wildlife (CDFW)<br>Inland Desert Region, Region 6 | **CFGC Section 1600 *et seq.* Streambed Alternation Agreement**<br>(a) Tunnel – no SAA required<br>(b) Bridge – SAA required; at least 90 days. | Agreement Fee Range for Standard Agreement (5 Years or Less):<br>Fee of $699.75 (project costs less than $5,000) to<br>Fee of $6,236.00 (project costs $350,000 or more).<br>Duration: 90 days. |
| California Dept. Fish and Wildlife (CDFW)<br>Inland Desert Region, Region 6 | **CFGC CESA (Sections 2050–2115)**<br>(a) Tunnel – no CESA Compliance required<br>(b) Bridge – CESA Compliance may be required given future conditions | Would assume a state-listed species is present or very likely to occur.<br>Permit Fee Range for ITP:<br>Project Cost ≤$100,000.00; $7,503.75 to<br>Project Cost ≥$500,000.00; $37,517.25<br>California Endangered Species Act – Incidental Take Permit (ITP) – Not anticipated but potential for future applicability if SBKR is present.<br>Duration: Variable. |

[1] NWP 58 – Utility Line Activities for Water and Other Substances is a newly issued NWP effective March 15, 2021; https://www.spl.usace.army.mil/Missions/Regulatory/NWP-Reissuance/.

## 8.2 County of San Bernardino

The San Bernardino County Flood Control District (SBCFCD) manages the regional flood protection functions for San Bernardino County. A SBCFCD Flood Control Construction Permit from the San Bernadino County Public Works is required when any work or access is proposed within SBCFCD property or a SBCFCD maintained facility. Since the proposed tunnel alignment will cross underneath City Creek, which is SBCFCD owned facility, a Flood Control Construction Permit will be required from SBCFCD for the project. In addition, some minor construction activities may be required for the tunnel alignment within the creek, including installing and maintaining the required settlement monitoring equipment for the existing MWD-IF. For this proposed work, a Temporary Access Permit from SBCFCD will be required to perform temporary (i.e., non-permanent) work within City Creek.

To obtain these permits with the SBCFCD the final project construction documents will need to be submitted to SBCFCD for review and approval. In addition, a County inspector will need to be present during the portions of the construction that is within the SBCFCD right-of-way. The County has the right to stop all work within City Creek at any time during construction if it deems the work will compromise the integrity or function of the flood control facility. No work will be permitted within the channel during rain events. The SBCFCD states that the permit review and approval process can take anywhere from three to six weeks to complete. The SBCFCD charges permit fees for filing, review, and inspection that vary based on the scope of the project.

The proposed tunnel alignment will be routed in a different alignment from the existing Foothill Pipeline through City Creek. This new alignment will require a new or revised easement agreement between Valley District and SBCFCD to provide Valley District with the right to access City Creek for maintenance and operation of the pipeline and tunnel in the future.

## 8.3 Metropolitan Water District of Southern California

The MWD owns and operates the 144-inch Inland Feeder Pipeline that runs in City Creek. The proposed tunnel alignment for the new 78-inch WSP will need to cross underneath the existing Inland Feeder pipeline. The crossing will need to be designed in accordance with the MWD's *Guidelines for Improvements and Construction Projects Proposed in the Area of Metropolitan's Facilities and Rights-of-Way* (MWD 2018). The pertinent requirements from the MWD guidelines include the following:

- MWD facilities within MWD's rights-of-way, including pipelines, structures, manholes, and survey monuments, must be protected from damage by the project proponent or property owner, at no expense to MWD. The exact location, description, and method of protection must be shown on the project plans.
- Utility lines crossing MWD's pipelines must be as perpendicular to the pipeline as possible. Cross-section drawings, showing proposed locations and elevations of utility lines and locations of MWD's pipelines and limits of rights-of-way, must be submitted with utility plans, for all crossings.
- Utility crossings installed by jacking, or in a jacked casing or tunnel under/over a MWD pipeline, must have at least 3 feet of vertical clearance between the outside diameter of the pipelines and the jacked pipe, casing, or tunnel.
- If utilities are installed in a jacked casing or tunnel, the annular space between the utility and the jacked casing or tunnel must be filled with grout. Provisions must be made for grouting any voids around the exterior of the jacked pipe, casing, or tunnel.
- Detailed jacking, tunneling, or directional boring procedures must be submitted to MWD for review and approval. The procedures must cover all aspects of operation, including but not limited to dewatering, ground control, alignment control, and grouting pressure. The submittal must also include procedures to be used to control sloughing, running, or wet ground, if encountered. A minimum 10-foot clearance must be maintained between the face of the tunneling or receiving pits and outside edges of MWD's facility.

- Detailed drawings of shoring for jacking or receiving pits must be submitted to MWD for review and written-approval.

- MWD must review any proposed installation of impressed-current cathodic protection systems on pipelines crossing or paralleling MWD's pipelines to determine any potential conflicts with MWD's existing cathodic protection system.

# 9. OPINION OF PROBABLE CONSTRUCTION COST

A preliminary opinion of probable construction cost for both the tunnel alignment and pipe bridge alignment was developed. For the tunnel alignment, costs were developed for pipe jackings construction options (open and Microtunneling) as well as for shield tunneling and SEM construction options. A summary of the total estimated construction cost for all alternatives are detailed in Table 9-1. The pipe bridge has the lowest construction cost with the SEM tunnel construction being the highest construction cost. A detailed cost estimate illustrating the individual line item breakdowns is provided in Appendix C. This estimate is based on recent projects in the area and on the conceptual level basis of design presented in this feasibility report. The total estimated cost for each alternative includes a 10% design development contingency and a 20% construction contingency, which is consistent with an AACE Class 4 estimate.

**Table 9-1 Alignment Alternative Construction Cost Summary**

| Alternative | | Total Construction Cost |
|---|---|---|
| **Open Pipe Jacking** | | $15.1M |
| **Microtunneling** | | $16.1M |
| **Shield tunneling** | **Rib and Lag** | $15.3M |
| | **Steel Plate** | $15.9M |
| **Sequential Excavation Method** | | $16.8M |
| **Pipe Bridge** | | $15.3M |

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