memo

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3/3/2022

ABOUT INDEPENDENT TECHNICAL REVIEWS (ITRs) FOR DELTA CONVEYANCE DESIGN AND CONSTRUCTION AUTHORITY (DCA)

Independent technical reviews (ITRs) are third-party evaluations of a project's engineering and design work for the purposes of providing expert input on specific technical aspects of a proposed project. It is important to note that ITRs ***do not*** *represent a decision on a project or process, nor do comments/opinions in the document consider anything other than technical information. ITRs are a best practice for industries that engage in complex, technical work such as large-scale public infrastructure projects.*

DCA enlisted world-renown engineers with specific expertise for each ITR conducted during the development of the preliminary conceptual plans for the proposed Delta Conveyance Project.

These ITR teams were tasked by the DCA with review and input on major aspects of the proposed project as outlined in the introduction section of each ITR report.

The following information is contained in each ITR:

- Name and association of ITR team members
- Technical aspects of the proposed project that are being reviewed
- Observations and technical recommendations of the ITR team
- DWR and DCA's response to the recommendations of the ITR Team

ITRs address technical processes and are merely one point of consideration for DCA and/or the Department of Water Resources in considering the proposed design and possible approval of the proposed project. There are many factors that must also be weighed when considering whether to approve the proposed Delta Conveyance Project, such as the outcome of environmental impact analysis in compliance with the California Environmental Quality Act that includes consideration of the proposed project and alternatives ability to meet the project objectives, and required compliance with other laws and regulations, such as the Endangered Species Act and Delta Reform Act.

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May 29, 2020

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DELTA CONVEYANCE INDEPENDENT TECHNICAL REVIEW PANELS (ITR)
DWR AGREEMENT NO. 4600013418, TASK ORDER ITR-04

TUNNELING AND SHAFTS ITR PANEL REPORT – MEETING 1
MAY 13 TO MAY 15, 2020

Dear Sir:

This letter report presents the findings of the Delta Conveyance Tunneling and Shafts Independent Technical Review (ITR) Panel from its May 13 to 15, 2020 Skype meeting. In addition to the ITR Panel, representatives from the Department of Water Resources (DWR), the Delta Conveyance Office (DCO), Jacobs Engineering (Delta Conveyance Authority's (DCA's) Engineering Design Manager (EDM), and ICF (DWR's Environmental Services Contractor) participated in the meeting. The meeting agenda is included as Appendix 1. A daily listing of meeting attendees is included as Appendix 2. Appendix 3 presents a discussion on handing and processing the Reusable Tunnel Material (RTM). Appendix 4 presents information on potentially handing and processing excavated tunnel material transported via slurry pipelines, while Appendix 5 presents selected information on the characteristics of selected long drive tunnels. Appendix 6 presents information on other considerations regarding the O&M shafts. (Note: the ITR Panel did not have the opportunity to visit the site prior to the meeting.)

Due to the size of this letter report an index with hyperlinks is provided to facilitate access to the Panel comments/considerations in the body of the report and to supplemental information in the appendices.

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Appendices

EXECUTIVE SUMMARY

The following are the ITR panels key recommendations for consideration. The reader is referred to Section 10. Summary, Key Conclusions and Recommendations for reasons, other recommendations, and details of- and for- the recommendations.

Reach Lengths:

- TBM reaches from 14 to 15 miles are practical and have been achieved in the industry. However, TBM maintenance must be performed on a regular basis.
- Providing surface access for TBM maintenance every 4 to 6 miles for major repairs in free air is recommended, which aligns generally with the EDM's current approach.
- A prudent approach is to equip TBM equipment in a manner that allows for underground Safe Haven development for early and routine cutterhead checks and unanticipated TBM maintenance issues. This would likely include compressed air entry and/or grouting or freezing from the TBM.

Proposed Corridors and Alignments:

- The geotechnical data reports should be expanded for the Eastern Corridor and should include soil profiles for each tunnel reach in addition to what was previously generated for the Central Corridor. The current and next phase of programs should focus on exploration at critical locations along the Eastern alignment.
- The alignment reaches in the two corridors should be further optimized considering the geotechnical, environmental and community challenges; hydraulics, schedule, and oil & gas well exploration program.
- A detailed risk-based cost estimate/schedule should be performed along both corridors for an impartial comparison as input to the final selection decision of corridor/alignment.
- The ITR recommends raising the tunnel alignment by a half a diameter to one diameter (if possible) as there are benefits in terms of shallower shafts, tunnel and TBM operations (especially, for interventions for machine maintenance). The impact of up to one diameter raise is unlikely to adversely affect the liner design for net internal pressure, but it is understood that raising the tunnel could impact other aspects of the vertical alignment and should be carefully weighed as to its advantages and disadvantages.

Overall Construction Sequence and Schedule

- Provide clarification of logic required to develop the borrow pits for the construction of the Maintenance Shaft pads.
- Check the availability of a stable power supply in light of rolling blackouts, which are of high probability in the Delta during warmer months.

Tunnel Lining Design and Constructability Considerations:

- Provide probabilities or percent operating time for surge events, steady state gravity event, etc. and tie into engineering judgment as to how much net pressure must be designed for.
- Require in areas of net internal pressure that the TBM operate with face/shield/grout pressures that balance groundwater pressure plus an increment of earth pressure to balance the net internal pressure and lock in stresses around liner as segments are installed.

- Recommend further investigation into benefits of longitudinal bolts/dowels on liner for carrying internal pressure and potential (negative) effects, and if used, radial bolt/reinforcing connection (designed to prevent cracking).

Reusable Tunnel Material (RTM) Handling and Identified Re-uses:
- Verification of the practicability of the RTM transport, handling and processing is critical to the success of the project as currently presented and it is concluded that further investigations need to be conducted to assess and develop alternatives for high capacity drying. It is recommended that full-scale trials be carried out.
- Issues with respect to transporting the excavated tunnel material in a slurry form via temporary pipelines for drying at the RTM processing facility and/or delivery to settlement ponds are described in Appendix 4.

Contracting and Packaging:
- Design-build contracting approach is appropriate for the tunnels and shafts.
- Consider using best value for contractor selection where the technical proposal is scored separately from the price.
- Investigate taking the work associated with the RTM out of the Tunnel and Shaft contracts and contracting it separately in one or more contracts.
- The ITR Panel does not recommend a separate contract for manufacture of the segmental lining and does not recommend pre-purchase of the project's Tunnel Boring Machines.

Understanding and Satisfying O&M:
- The minimum requirements for mandatory O&M Shafts need to be defined in terms of minimum spacing (e.g. 4 to 6 miles seems tied to tunneling not O&M), type of equipment used, duration and extent of maintenance activity, operational controls, and seasonal demand constraints, to provide a better determination of the minimum spacing, diameter, and height above existing ground surface required for each O & M Shaft.

Other Relevant Topics:
- Modern tunneling technology with pressurized TBMs (earth pressure balance or slurry TBMs) combined with a coordinated program of ground and TBM monitoring has proven to mitigate concerns related to tunneling with large diameter TBMs and/or at shallow depth adjacent to, or below structures.

1.0 INTRODUCTION

Prior to the May 2020 Meeting, the ITR Panel was provided with the following documents:

A. DCA Tunnel Alignments Map - dated March 27, 2020
B. DCA Drawings: Central Corridor Combined-Optimized - dated April 2, 2020
C. DCA Drawings: Eastern Corridor Combined-Optimized - dated April 2, 2020
D. DCA Long TBM Tunnel Drives Technical Memorandum (Draft) - dated November 15, 2019

E. DCA Conceptual Tunnel Lining Evaluation Technical Memorandum (Draft) - dated February 20, 2020
F. DCA Shaft Conceptual Design Technical Memorandum (Draft) - dated March 27, 2020
G. DCA Seismic Design Criteria Technical Memorandum (Draft) - dated April 15, 2020
H. DCA Field Work Execution Plan (Draft) - dated August 20, 2019
I. DCA Central Bid Item Schedule (Preliminary) - dated April 10, 2020
J. DCA Eastern Bid Item Schedule (Preliminary) - dated April 10, 2020
K. DCA Dec. 2019 Tunnels and Shafts ITR Panel Memorandum (Final) - dated January 31, 2020 and DCA Presented Responses to Items
L. DHCCP Draft Pipe-Tunnel Option Geotechnical Data Report - dated April 2013 **
M. DHCCP Isolated Conveyance Facility – East: Geotechnical Data Report – dated July 2010
N. DHCCP Reusable Tunnel Material (RTM) Testing Report (Final) – dated March 2014
O. Bouldin Island Geotechnical Data Report (GDR) (Final) – dated May 2018. EDM Field Work Plan Comments - All to be addressed

Comments by DCO on the following documents:

- EDM Long TBM Tunnel Drives TM
- EDM Tunnel Lining Evaluation TM
- EDM Shaft TM
- EDM Field Work Plan

** including Appendices L.1 to L.8

The ITR panel reviewed the above documents and developed responses to the following eight categories in the form of ideas, suggestions or recommendations followed by commentary on the benefits or challenges associated with each concept or consideration.

Specific feedback requested from the Panel in advance of the First Meeting were:

1. Proposed Tunnel Reaches - Drive Lengths/Shafts/Logistics Concerns
2. Comments on Proposed Corridors and Alignments
3. Overall Construction Sequence and Schedule
4. Tunnel Lining Design and Constructability Considerations
5. Reusable Tunnel Material (RTM) Handling and Identified Re-uses
6. Contract Packaging Approach
7. Recommendations Related to Understanding and Satisfying O&M Needs
8. Other relevant topics

Definitions:

Reach: Length between the launch shaft and the retrieval shaft.
Drive: Length between shafts (launch, intermediate or retrieval).

2.0 "Proposed Tunnel Reaches - Drive Lengths/Shafts/Logistics Concerns"

2.1 Reach Lengths

Issue:
Reach lengths up to 14 to 15-miles as a single TBM heading, are practical so long as regular maintenance is performed on the new TBM.

- Large diameter rock tunnel reaches have been driven over 15miles and provide acceptable evidence that a single, serviced, new TBM can drive over 15 miles (see Appendix 5). Rock projects require stronger, heavier TBM mechanical components and design as compared to a soft ground machine. Maintaining face pressure during the drive, cutter tool replacement and maintenance while under face pressurized conditions will be required in soft ground. Cutterhead maintenance and repairs while under "free air" conditions along the drive length will be required, as with rock machines.
- TBM manufacturers will guarantee the main bearing for a minimum of 20,000 working hours, which by far exceeds the time to dive a 15-mile tunnel reach.
- Appendix 5 includes information on the Tokyo Ring Road (51 ft. Diameter) & the Caracas Guarena Guatire project (27 ft. Diameter). The Tokyo Ring Road EPBM drives (2) are both 5.72 miles long. The Caracas EPBM project had a reach of 9.4 miles.
- TBM Maintenance includes a host of activities. The primary focus of the ITR was on the cutting head/face tools of the TBM. All panel members agreed that maintenance would be required throughout the TBM operation, and that access for free-air maintenance at an interval of 4-6 miles will likely be required if ground conditions are assessed to be abrasive. Panel members agreed that key elements of the TBM, such as the main bearing, should last the entire reach, and further that if for some reason these major elements fail, there is no way to predict where that failure will occur.

Benefits:

- Fewer contracts to manage, TBMs to purchase, fewer performance consuming learning phases to overcome and machine launch sites.

Challenges:

- Size of the contracts (Contract values above $2B will limit competition).
- Logistical operation and maintenance of TBM (i.e. fresh bentonite to the face needs 2-3 hrs pumping, long travel times from portal to heading, etc.)

Delay risk associated with a major TBM breakdown outside of a pre-planned maintenance shaft/safe haven.

2.2 TBM Maintenance Shafts

Issue:

Provide real estate for the shaft site, access to the shaft site, and necessary permitting for TBM maintenance at intervals of 4-6 miles between launch and receiving shafts. Contractor can determine what type of access to provide.

- ITR was split on "the best" way to do this. Some believed contractors would build a shaft, while others would use ground improvement. Both methods would work, and both depend on the overall approach chosen.
- ITR agreed that if a shaft is required for permanent access (see section 8.0 below) then putting it in the Tunnel Contract and having the Tunnel Contractor build it makes sense, as it will serve dual purposes. However, ITR also agreed that the 80 ft. diameter shafts as presented, are too large.

Benefits:

- The Contractor is in the best position to determine the appropriateness of a TBM maintenance shaft, or safe haven, depending on the type/design and operation of the TBM.
- Allows full access for maintenance and personnel (some of whom might not be able to work in hyperbaric intervention) to replace and/or refurbish TBM cutterhead (CH), plenum chamber, seals and bearings, and tail seals. Access can be provided before the TBM arrives, a significant benefit to schedule.
- Contractor determines size required (diameter or safe haven space), and the means and methods; potential cost savings.
- If the contractor chooses to use a safe haven, a number of proven ground modification methods exist including grouting, soil/cement mixing and freezing.

Challenges:

- The shafts as proposed are large and require significant fill to build, for example the time required for consolidation of fill requires early installation of fill and/or ground treatment.
- Determining optimum size during design vs. obtaining ROW (Right of Way); e.g. smaller diameter shafts that provides access around TBM may be a plan of one contractor for his means and methods but not another.
- Commonly used approach is for the designer to show the permanent structure required for O&M and allow the contractor to select means and methods of construction and shaft dimensions.

2.3 TBM Maintenance within Tunnel

Issue:

Provide capability for drilling through ports within the TBM for ground treatment (e.g. freezing, grouting) ahead of the face to create a safe haven from within the tunnel where surface access ROW is anticipated to be restricted. This is a tunneling industry standard of practice.

Benefits:

- The plan would allow for access to the cutterhead in the event repairs are needed, between the pre-planned TBM maintenance locations.

Restricted access and lack of permission to install safe havens from surface would be done from TBM.

Challenges:

- Time required for creation of safe haven in tunnel heading.
- Difficulty in uniform treatment of ground with grouting to provide a secure/safe environment during construction.
- It is possible that freezing cannot be done from within the TBM using liquid nitrogen (not allowed in the tunnels in Europe), therefore, it may have to be done with much more complicated Calcium Chloride Brine techniques which requires more time to freeze and complicated in-and-out-flow tubes.

2.4 Safe Haven 1 Mile from Launch

Issue:

Allow contractor the option to construct a TBM safe haven within 1 mile from the long-reach the launch shafts by providing pre-acquired/approved real estate.

- If an early CH check is required, compressed air intervention or safe heaven near or adjacent to the launch shaft is more common and cost effective.

Benefits:

- Early check of TBM operational parameters confirm/disprove contractor's assumptions in terms of cutter head wear, cutting tool lifetime, etc.
- Cutting tool can be changed/modified to reflect performance.

Challenges:

- Pros and Cons of surface ground treatment vs from TBM
- Environmental restriction, construction approval for real estate and access
- Economic advantage of an extra shaft is questionable if not further used as O&M maintenance shaft.

2.5 Additional Suggestions for Long Tunnel Drives

Issue:

- Figure 1 of the December 2019 ITR Panel Report is a table of case histories for long tunnel drives, which provides their justification for longer tunnel drives without required TBM maintenance shafts. Suggest that the DCO or DCA request the case histories provided in the Figure (i.e. table and/or literature references with salient TBM drive features, TBM machine characteristics, tunneling conditions, etc.). Our findings are included in Appendix 5.
- Look at "State of the Art" procedures for cutting tool changing while under face pressure. These procedures include robotic arms for tool handling, accessible

cutterhead spokes for changing tools in free air. Cutting tool design using high wear abrasion resistant materials, additional wear plating and soil conditioning to improve wear resistance to the cutting tools and cutterhead structure.
Benefits: Provides additional justification for reach and drive lengths contemplated.
Challenges:

3.0 "Comments on Proposed Corridors and Alignments"

3.1 Central versus Eastern Tunnel Alignments

Issue:

The panel is not prepared at this point to identify a preferred corridor and the Eastern Alignment should continue to be developed. The panel does recognize the importance of optimization of the alignment in terms of logistics of TBM assembly, servicing, supplies and other tunneling operations.

Benefits:

- Eastern alignment has the advantage of better access, and better geology at shallower depths. If there is less peat and denser r soils, this is favorable in terms of higher average unit weight, and therefore, higher earth pressure at lower depth. However, if there is more coarse- grained sand or gravel (especially SP and/or GP – depending also on mineralogy (Quartz or Calcium)), this is not favorable for TBM wear (either EPB or slurry). A lower water table goes both ways, less confinement on lining but lower TBM intervention pressure for same depth.
- For the Central alignment, MWD/DWR/State own or control the majority of the property along this corridor, which in certain situations could afford surface access for safe havens, if required (e.g., level roads). Also, the RTM from the Reach 3 tunnel drive can be disposed of on Bouldin Island, and if it was important to reduce the overall schedule, the very long 14-mile drive for Reach 2 (the critical path) could be cut in half by adding a second heading to the north from Bouldin Island.
- ITR report dated January 31, 2020 recommended a “Far East” alignment”, not the Eastern alignment currently under consideration. Therefore, some of the conclusions and recommendations in the January 2020 report may be applicable to the Eastern alignment. However, that panel did recommend not pursing the Central alignment due to “logistical” or access concerns.
- Central alignment is about 2.3 miles shorter than the Eastern, but costs are reportedly about the same.
- It should be emphasized that no fatal flaw was identified by this panel for either of the two alternative alignments under considerations. Less favorable aspects

identified in the maintenance/reception shaft siting evaluations can be mitigated as part of the risk-based cost estimate and alignment evaluation/selection.

- With regard to tunnel excavation, the ground conditions along the Central alignment are generally favorable, especially for EPBM, and similar is expected for the East alignment, but if more coarse coarse-grained soils it would be slightly less favorable for EPBM but more favorable for slurry TBM; however, a shallower depth will be an advantage for both.
- ITR panel has not had opportunity to visit sites, and no clear preference at this time. A detailed, cost/schedule-based risk analysis needs to be carried out to better evaluate the two alignments (discussed below).

Challenges:

- Bringing the Eastern alignment site exploration up to the level of the Central. It should be emphasized that the exploration on the Eastern alignment need not be as comprehensive as the Central to make decisions about alignment options if the program focuses on the critical elements (i.e., river channels, levies, rail crossings, low cover areas),
- Consider geotechnical exploration techniques, which have a potential for optimizing subsurface conditions information (e.g. geophysical techniques):

Consider capability of seismic refraction/reflection techniques, gravitometer surveys, etc. for locating the top of denser soils, or bottom of peat deposits.

  - Project has performed in-hole suspension shear wave velocities which should be the reference for evaluating soil stiffness, for both static loadings around a TBM (using G/Gmax relationships) as well as for seismic ground motions due to earthquakes.

3.2 Vertical Alignment

Issue:

- The ITR recommends raising the tunnel alignment by a half a diameter to one diameter (if possible) as there are benefits in terms of shallower shafts, tunnel and TBM operations (especially, for interventions for machine maintenance). The impact of up to one diameter raise is unlikely to adversely affect the liner design for net internal pressure, but it is understood that raising the tunnel could impact other aspects of the vertical alignment and should be carefully weighed as to its advantages and disadvantages. Raising the alignment more than one diameter could adversely impact the segment design and similarly should be weighed against its advantages and disadvantages.

Benefits:

- Reduces shaft depth.
- Improves ability to perform TBM maintenance at lower pressure (preferably invert elevation at or below 3.5 bar groundwater head).
- Reduces TBM wear (tools and cutterhead wear, especially machine seals)

• Hyperbaric interventions can be better executed (shorter duration for pressurizing/depressurizing crews, reduced health risk for staff).

Challenges:
• Consider ground conditions (e.g., liquefaction), ship channel cover requirements (or consider use of inverted siphon), and effective ground load on lining system to resist internal pressure from surge.
• Raising the alignment will reduce the confining pressure. As an example, tunnel depths on the order of 110 ft to springline would provide sufficient earth pressure to equal the factored surge pressure when the at rest earth pressure, Ko=0.5 (appropriate for 30-degree effective friction). If the soils are over consolidated, an upper bound of Ko=1, the tunnel depth to balance is reduced by half, 55 ft (see notes for background).
    o For saturated soil unit weight of 120 pcf.
    o Maximum surge is from the "no IF" hydraulic model case and occurs within Reach 2 (other Reaches have lower surge pressure).
    o Δ head = surge elevation @ +37' – GWT @ -5' = about 42 ft head or 18 psi; with load factor: 1.2 x 18 psi = 22 psi)
    o For the surge pressure, a load factor less than the typical 1.6 can be considered (for surge, 1.0-1.2 is commonly used in hydro design depending on conservatism incorporated in resisting elements and the probability of occurrence – approximately one event per year).
• The potential need for designing a segmental lining in which dowels and/or bolts can take a portion of the tension will depend on the height of ground cover as well as the ground conditions (average unit weight, Ko, and GWT).
• Over pressuring the face and shield gap and tail void grout, above Ko and approaching overburden pressure, to obtain higher confinement may not provide additional confinement due to soil creep.
• Stockton deep water ship channel and EBMUD aqueduct are issues that have a major impact on the tunnel depth.
• Softer bedding of segments within lower density soil requires more reinforcement

4.0 "Overall Construction Sequence and Schedule"

4.1 Production Rates

Issue: The assumed tunnel production rates are reasonable
Benefits: • The assumed production rates are reasonably conservative (i.e. the winning contractors will likely have higher production rates).
Challenges: • Not clear where "rehab/recondition" time is at each TBM maintenance shaft

- Check the schedule for TBM pass through the maintenance shaft, and where appropriate, include on the schedule
- Tunnel production rate to be clearly defined (penetration rate is more TBM related, advance rate is more logistically related). What interruptions/stoppages are foreseen?
- The longer the reach the more impact due to wrongly estimated production rates
- TBM drive always on the critical path of a project
- Production rates depending on impact of gas and oil wells as well as on logistical site-installation and experience of TBM contractor and also RTM concept.

4.2 Schedule Logic

Issue:
Clarify the logic used for time required to develop the material supply and construction of the shaft pads.

Benefits:
- Potential improvements to the construction schedule

Challenges:
- Identify source/time to deliver at South Forebay.
- 2-years for maintenance shafts – show logic (particularly if they require RTM).

4.3 RTM Mass Balance

Issue:
The Panel recommends checking the mass balance logic with RTM at the South Forebay

Benefits:
- Improved construction schedule

Challenges:
- Eastern Alignment – generating RTM well after Forebay is "done"
- Central Alignment – tunnel done long before Forebay (run out of RTM?)
- Balance – seems like need more RTM early, but need to discard excess RTM later

4.4 Concurrent Tunnel Drives

Issue:
All 5 Tunnel Drives Concurrent

Benefits:
- Improved planning

Challenges:

- This produces a tremendous volume of RTM "tidal wave" due to interdependence of RTM
- Different types of TBM (EPB or slurry) require totally different logistic concepts (excavated tunnel material handling, servicing of TBM, O&M, etc.)
- Check availability of stable supply of electrical power (e.g. due rolling blackouts)
- Public traffic restrictions which also have impacts on TBM performance (e.g. due to community-imposed restrictions on delivery trucks, etc.)

4.5 Other Possible Schedule Considerations

Issue:

The construction start date and completion date for the project does not appear to be fixed and or driven by any sort of external mandate, but the use of RTM for construction of the Southern Forebay does.

If extending the overall duration of the project is feasible, consider changing the sequence for the Reach 3 and Reach 4 tunnels, to allow Reach 4 to be completed prior to tunnel excavation commencing for Reach 3. Excavated tunnel material from Reach 3 could be transported through/via Reach 4 conveyors to the Southern Forebay RTM facility for treatment and ultimately use at the building the site.

Benefits:

- Excavated tunnel material removal directly to the Southern Forebay location, in time for construction of forebay (Reach 4 would be done).
- Substantially reduced need for trucking/rail and or other transport (and associated upgrades) for Reach 3.

Challenges:

- Total project duration would be extended by several years.
- Moves two tunnel contracts into a linear path, and any delays on Reach 4 would impact the Reach 3 Contractor's ability to complete their work (due to inability to transport excavated tunnel material).

5.0 "Tunnel Lining Design and Constructability Considerations"

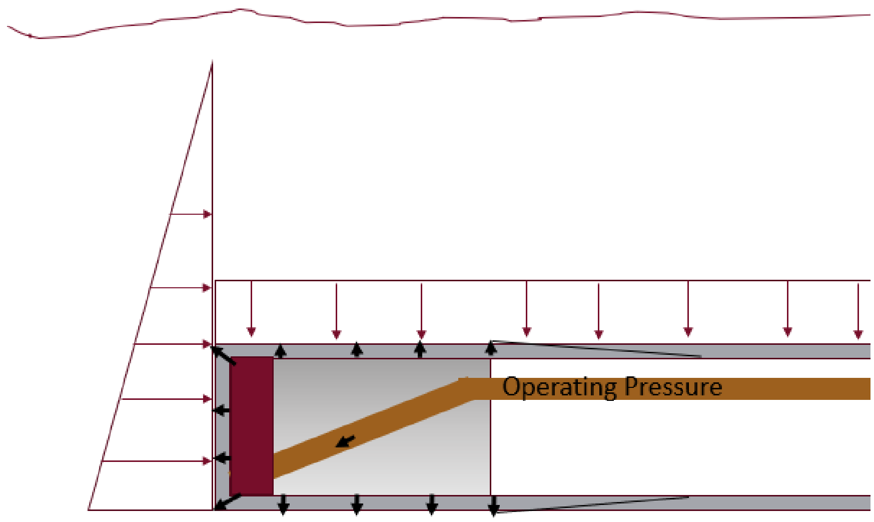
5.1 Lining Design for Net Internal Hydraulic Surge Pressure

Issues:

- Pre-stress lining with specified operation of pressurized TBM to compensate for differential water pressures in tunnel.
- Current hydraulic analysis gives maximum heads during surge of up to 42 feet above natural groundwater levels for a 36-ft I.D. tunnel. The internal pressure will be balanced by groundwater pressures plus effective soil pressures acting against the tunnel lining and by hoop stresses in the lining. Pressurized tunneling (EPB or slurry balance) will develop pressures on the shield perimeter due to injection of

slurry or conditioned muck in the overcut gap which balance with the face pressures. Pressures on the tunnel lining develop due to grouting of the annulus at pressures higher than the face/shield pressures.

- Earth pressure cells on the shield perimeter and grout pressures at the tail are used to confirm the pressures, and borehole extensometer/vibrating wire-piezometer combinations monitor the ground response.
- The TBM pressures should exceed the pressures due to any loosening ground loads and will pre-stress the lining and minimize tensile hoop stresses in the lining during surge events.
- Maintaining upper face/shield pressures at groundwater + ~ 1 bar for a 40 ft O.D. tunnel, along with pressurized grouting around the lining would reduce pressures to: 42 –14.77/(62.4/144) = 42 – 34 = 8 ft head = 3 psi, significantly reducing tensile hoop stresses in the segmental lining. A shield pressure of approximately 1.5 bars in excess of groundwater would compensate for the full 42 ft of differential internal pressure including a load factor of 1.2 so that there is no tensile stress within the lining.
- Recommend plotting the differential heads under operation as well as during surges.
- Evaluate radial displacement and tangential strains due to differential pressure.
- Determine cracking strains and strains that could cause opening of a joint. Consider effect of adjacent dowels on interaction between rings. Evaluate key segment piece with respect to shear transfer (consider placing key at springline locations to deal with potential loss of ring continuity at the crown; the crown is the most vulnerable portion of the lining – region of relatively low thrust).
- Prevent potential failure mechanism where tensile crack can form and propagate in location without any reinforcement, such as between a bolt pocket and the steel cage: Connect bolt pocket to reinforcement or provide embedment length of bolt pocket.
- Conduct tests of segments and connections between segments. Consider ways to simulate ground loads around liner during test with bands or in buried earth.
- Opening of radial joints more than allowable gap would allow flow in between the gaskets.
- Consider secondary grouting especially where excessive ground loss has occurred.
- Specify operating the TBM face/shield pressure at or near at rest earth pressure (Ko) to reduce ground disturbance and to maximize the resting earth pressure.
- Estimate probabilities of or percent operating time for surge events, steady state event and length affected
- Connections: Design longitudinal dowels to carry some portion of the net internal pressure (by shear)



Benefits:

- Increases the effective ground load on the lining system and to improve the overall stiffness of the surrounding ground and maximizes confining pressure, thereby reducing the risk of segment joint opening and leakage or segment damage from internal pressure due to surge (or tension).
- Tied into engineering judgment as to design for net internal pressure and assessment of risk.

Structural details of the connections for net tension case is required as well as a realistic analysis of soil-structure interaction using reasonably conservative soil stiffness (derived from a combination of lab data and values from shear wave velocity with appropriate adjustments for strain).

Challenges:

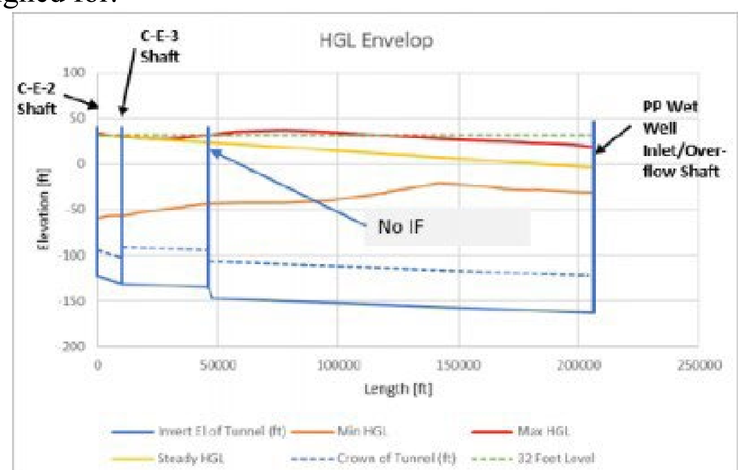
- Prescriptive elements of the lining design and operating pressure requirements need to be specified and enforced during construction.
- Structural design requires close coordination with hydraulic analyses and should be Reach specific, considering the local GWT and surge pressure.
- Structural:
    - Weighing the amount of confinement obtained from depth of cover vs. raising the alignment (see 3.2 above)
    - Benefits of single vs. double gaskets and allowable gasket gap; a second gasket is often used just to provide even loading/seating on thick segments for concentric thrust on circle as well as radial joint surfaces.
    - Radial bolts weighing pros and cons of “leave in vs. take out”.
    - Prevent cracking at connections (steel fiber).
    - Variation in shop drawings for each contract package
    - EBMUD issues concerning security of their aqueduct and a segmented liner design and consideration of various acceptable mitigation measures to EBMUD (net internal pressure design solution varied near aqueduct).9
    - Loss of confinement due to settlement, ground loss or soil creep

- Consideration of secondary grouting to check or lock in confinement
- Single-component vs. double-component grouting (recommend two component).

Comment:
Please note that the seismic memo regarding tunnel design for seismic and fault movement needs to be revised to include references by Hashash et al. (2001) and the Chapter 4 of the MCEER-FHWA (2006) report. Also, with respect to EBMUD issues possible approaches include a secondary liner under Mokelumne Tunnel. A hazards analysis for consequences of various leaky liner scenarios could be performed to demonstrate capability of a single pass segmental lining.

5.2 Other Design Issues related to Net Internal Pressure

Issue:
Consider providing probabilities or percent operating time for surge events, steady state gravity event, etc. and tie into engineering judgment as to how much net pressure must be designed for.



Consider benefits of using longitudinal dowels to transfer stresses in adjacent segments to help carry net internal pressure and in 3 D analysis.
Consider not using radial bolts/consider removing, that way O&M doesn't have to worry about them. Radial bolts can be a source of cracking if indeed, some of the internal pressures are carried by the liner rather than the ground. If required, best to let the longitudinal dowels do the work. Steel fiber will help prevent cracking, but just avoid the bolts if possible.

Benefits:

- Provides level of risk understanding.
- Saves costs and schedule in design and construction.

Challenges:

- Reduce tensile stresses and strains, and the potential for cracking of the lining during surge events.
- Provide reinforcement design that is efficient and prevents tensile failure mechanism.
- Finding most beneficial segment ring design in terms of providing high ring-stiffness (i.e. lesser segments per ring) and low sensitivity to ring deformation (i.e. high degree of segment symmetry (X+0 instead Y+1) avoiding instable of using a smaller keystone.
- Cannot count on an assumed effective earth pressure unless the lining is pre-stressed. Maintain consistent pressures on the TBM, not dropping pressures to ground water pressures between shoves (specify minimum operating and resting pressures).
- Provide reinforcement design where concentrated tensile cracking cannot occur and are limited to in size, as specified for water retaining structures.
- With time, if bolts were to corrode: Check that during a surge, any opening of joint would be small or the load would be transferred to adjacent segments, and the strains would not be high enough to decompress the gasket.
- Design and modeling of effective ground load to resist internal pressure.
- Proof of concept must show clear benefits over risks.

Note:
For SDLAC PDWF 10% of time, internal pressure is 25 psi; PWWF 1% of time is 41.4 psi. In addition to DC Water with no internal steel, reference, Aguas Argentina, SDLAC modeling, flood control tunnels in Europe. Also, please note that 17 psi net for SBOO in San Diego is incorrect. Correction to memo Section 3.5.2 net internal differential of 3 bar, 89 ft of head x 0.43 = 38.7 psi = 2.7 bar. Not .43 ft/psi, but .43 psi/ft

6.0 "Reusable Tunnel Material (RTM) Handling and Identified Re-uses"

6.1 Perform an RTM Testing Test Program

Issue:
ITR recommends a test program be established to confirm the assumptions for mechanical drying and to confirm feasibility of mass drying and the rate to do so.

- The mass balance approach to the project (e.g. using RTM for levies and berms) relies on processing schemes to work effectively and is critical to project success
- The approach contemplated has never been done before, a philosophy that is contrary to the other major decisions on the project (e.g. Reaches, O&M requirements, etc.).
- A delay in the ability to process the excavated tunnel material into RTM appears to impact the entire program.

Benefits:

- Improved cost and schedule certainty.

- Confidence in the overall design approach.
- Identifies issues/fatal flaws (if any) early.

Challenges:

- Full scale testing programs take time and effort to scope and execute, often far more time that "originally envisioned".
- Finding suitable tunnel material, from another project, or from the Delta area will require identifying a source, then contracting for delivery of a large volume of excavated tunnel material (foam, water, polymer, etc.) with proposed equipment for both mechanical and natural processing of the RTM.
- Testing program, if thorough, will need to address the suitability and "dryability" of slurry tunnel material as well.
- Testing program will need a facility (e.g. lab or field space), with all that's necessary to "run a mechanical dryer" at full speed.

6.2 Consider Natural Processing and Other Ideas

Issue:

ITR identified several other ideas for the RTM work:

- Evaluate the practicality of pumping the excavated tunnel material in a slurry pipeline to the RTM processing facilities.
- Incorporate climate and potentially large shelters (e.g. Sheds) to enhance performance of natural processing (e.g. spread, and dry);
- Identify if local developer and or landfills/quarries could use the material for future fill/projects.
- Consider steps to "partially process or reduce moisture" along the conveyor system of an EPB/Transfer belt.
- Look into case histories, such as SBOO (San Diego) where more than half of spoils were CH/CL/ML and the other SM, SC, SP, GM, GC, GCB used surfactants and bentonite respectively. The CH/CL/ML material were used for structural fill for housing development nearby in the South Bay.
- Engage with companies that provide "slurry processing equipment' to determine if they can produce suitable customized equipment for this application. (See Appendix 4).

Benefits:

- Potential for reduced volume of mechanical drying.
- More flexibility in resolving the RTM surplus management

Challenges:

- Available disposal sites will/may change (e.g. land use changes, developers' needs change, etc.)
- Specification and testing requirement considering possible changes in regulatory and environment statutes for disposal or reuse of RTM.
- How to deal with oil/gas contaminated tunnel material.

Conditioning of excavated tunnel materials to suitable RTM end use.

7.0 "Contract Packaging Approach"

7.1 Design Build for Tunnels and Shafts

Issue:
ITR considers design-build contracting approach appropriate for the tunnels and shafts.

Benefits:
- Large complex projects can merit the design-build approach.
- Potentially starts the tunnel and shaft construction work sooner than if bid-build.
- Provides early contractor engagement on design development.
- Allows for cleaner best-value determination (price and approach together)
- Highly unknown risk factor of RTM better controlled by early planning with contractors; risk shifting to the contractor side

Challenges:
- Require change in California Law
- Could add costs not currently contemplated (e.g. risk allocation, etc.).
- Institutional resistance within DWR.
- Developing the RFQ/RFP and the evaluation process are difficult and time consuming.
- Incorporating prescriptive elements of the precast segmental lining design.

7.2 Combine the Northern Drives

Issue:
ITR Consider advantage of one contractor for both Reaches 1 and 2

Benefits:
- Operation out of the double shaft would not require sequencing and handover and potential delay of start-up of a separate contractor.
- Site does not have to be broken into two construction yards
- Facilities for support, supply and excavated tunnel material removal can be consolidated

Challenges:
- Larger contract: may be advantageous for some JVs; however, would be significantly larger than the $2B recommended limit for contact size.

7.3 Best Value - Contractor Selection

Issue:

Consider using best value for contractor selection where a technical proposal is scored separately from the price. Gain and pain contract model in order to motivate the contractors to keep time (and cost) plan.

Benefits:

- For the long tunnel drives proposed the risks are high. An experienced Contractor proposing highly qualified personnel and employing superior equipment should be recognized for the lower risk profile.
- Avoiding cheap and under-equipped TBM (which have a key role)
- Contractors being kind of shareholders of the project success

Challenges:

- Developing the RFQ/RFP and the evaluation process are difficult and time consuming.
- Changes to CA law.
- Adequate bid assessment

7.4 Alternate Contracting Plans

Issue:

ITR discussed the following ideas for carving scope out of the proposed Tunnel and Shaft Contracts.

- TBM Procurement (early before the Tunnel Contracts are let);
- Project-wide Segment Manufacturing/Supply;
- One or two contracts established for the processing and transport of excavated tunnel material and RTM.

The ITR does not recommend early TBM Procurement or a project-wide Segment Contract. Primary reasons are that both elements of the work are intimately related to the tunnel design and the construction means and methods.
ITR does recommend that one or more separate contracts associated with treatment of excavated tunnel material into RTM be considered.

Benefits:

- Obstacles to permits, etc. taken out of big money, linear schedules of tunnel contractors
- Would attract "earthwork and material processing" contractors;
- Could include the "Borrow production" as part of the contract (e.g. advance of tunnel contracts):
- Creates flexibility for RTM supply, which could de-couples the inter-dependence of tunnel reaches (on the rest of the program).
- Removes substantial "pass through" work from each Tunnel Contract, which will help keep each contract under the $2B threshold.
- Could simplify the sequence at the South Forebay, particularly if RTM and levy building were in the same contract.

Challenges:

- Permits, handover issues innovation to tunnel contractor
- RTM contractor dictates price for TBM contractors
- RTM contractor to be experienced with handling of tunnel material of both TBM types EPB and slurry
- RTM contractor being the bottle neck of logistical chain of the whole project

8.0 "Recommendations Related to Understanding and Satisfying O&M Needs"

8.1 Spacing & Size of Inspection and Maintenance Shafts

Issue:

The ITR recommends the minimum requirements for mandatory O&M Shafts be defined in terms of minimum spacing (e.g. 4 to 6 miles seems tied to tunneling not O&M), type of equipment used (e.g. ROV equipment was discussed as well as rubber tired/human entrance), duration for such an inspection, anticipated maintenance activity (e.g. removal of sediment was mentioned), operational controls (e.g. it was mentioned it will take 2 weeks to un-water the tunnel), and seasonal demand constraints (e.g. duration tunnel can be dry). This will provide a better determination of the minimum spacing, diameter, and height above existing ground surface required.

The ITR panel agrees that at some point, the tunnels will need to be inspected and will need reasonable access for future maintenance. However, limited work to date has been done on how that will occur, and little consideration appears to have been given to logistics, equipment, and purpose of such inspections. Further, the approach contemplated (dedicated facilities at eight, or more, locations along the alignment) seems more significant (capital expenditure) than the ITR has seen in the industry for what could be a once-in-25-year event.

- Water/wastewater industry has no standard for tunnel inspection, in either process to use or duration between inspections. Several agencies ITR members work with do not inspect their tunnels, and do not have plans to do so. A few agencies which ITR members have worked with perform inspections in 30 to 50-year intervals, whereby a major shutdown (months, not weeks) occurs. The time period is less a function of "access points" and more a function of the planning, staffing, seasonal demand, equipment procurement, and data collection effort required for inspection of tens of miles of tunnel. See Appendix 6 as some case histories for consideration.
- This is a significant issue in terms of cost and schedule impact on the project, because the shafts (shown below) require a tremendous amount of fill and ground improvement to address the 200-year flood design criteria.
- The shaft design contemplated what will appear as hills where they do not currently exist, which will change the horizonal view/existing conditions along the tunnel alignment. This seems contrary to the tunneling approach, which is typically considered a way to minimize or eliminate impacts to the ground surface along the alignment. Accordingly, this may be difficult to permit.
- Investigate the maximum practicable length that an ROV can efficiently survey a tunnel and then evaluate whether the maximum distance between O&M shafts can be designed to match this length. It is noted that the Snowy Mountain tunnel in Australia

utilizes a 12km (7.5mile) single pass ROV to inspect their tunnels (built in 1960's). If the underwater inspection single pass length is determining the distance between O&M access shafts, then the EDM could more thoroughly research the current practicable single pass length of ROV inspections in order to determine whether one, or more, intermediate shafts could be eliminated.

- Instead of designing O&M pads around service shafts, evaluate the practicability of designing containment dikes around such service shaft of sufficient height to resist the 200-year design flood elevation and with sufficient contained volume that when dewatering the tunnel for maintenance supplemental siphon pumps could be used to drain a useful volume of tunnel water to accelerate the dewatering process.
- While the ITR Panel was not provided with a detailed dewatering plan for the tunnel, if the DCA desires to dewater the tunnel more rapidly than currently planned, then the EDM could evaluate the option of providing water holding ponds at O&M shafts selected to assist in dewatering the tunnel using temporary syphon pumps. Possibly borrow from such ponds could provide fill for the construction of the pads.

Benefits:

- Documents decision process and criteria for O&M Shaft needs by separating hydraulic design issues (surge pressure mitigation and dampening benefits) and constructability issues (TBM maintenance shaft) from O&M requirements
- Possible savings in costs for increased spacing and for use of smaller diameter shafts and possible installation by drilling rather than shaft sinking.
- Possible reduction in fill required at all the sites.

Challenges:

- Safety and risk issues associated with entry, ventilation, and equipment access.
- Keeping with standard of care as related to other projects.

8.2 Inspection of Segmentally Lined Tunnel

Issue:

ITR is not aware of any other segmentally lined tunnels where bolt pockets created either tripping hazard or a concern over catchment for sediment. However, if sediment within segment bolt pockets remains a concern, ITR is aware of one or two projects in North America where bolt pockets were filled, so a detail could be worked out if needed.

With respect to hydraulics, diameter is large compared to other projects with filled bolt pockets or no bolt pockets.

Ideas to Consider:

- Sediment within segment bolt pockets issues can be assessed by comparison to other tunnels using precast segment to determine if filling is needed
- Determine if tripping hazard exists by having O&M staff visit a BGS tunnel under construction.
- Optimus system or other systems without bolt pockets could be considered. TRex (Denver) UNWI (Sacramento) both have 12 ft. ID tunnels without pockets, also

Interceptor Sewer Projects along the Seine River including Chantiers Interceptor (13 ft. at 3 bar)

- Can fill pockets of invert with concrete patch or pre-cast insert if determined the need to do so exists.
- DC Water and LACSD did not require bolt pocket filling

9.0 "Other Relevant Topics"

9.1 Oil/Gas Wells along tunnel alignment

Issue:

- Locating abandoned oil/gas wells prior to tunneling, and adjusting alignment to avoid (1) zones of concentrations of wells, (2) known well locations or known circles of uncertainty

Benefits:

- Prevent risk of gas inflows due to intersecting well during tunneling
- Prevent delay required to abandon well intersected in the tunnel.
- Avoid oil/gas (hydrocarbon-)contaminated tunnel material

Challenges:

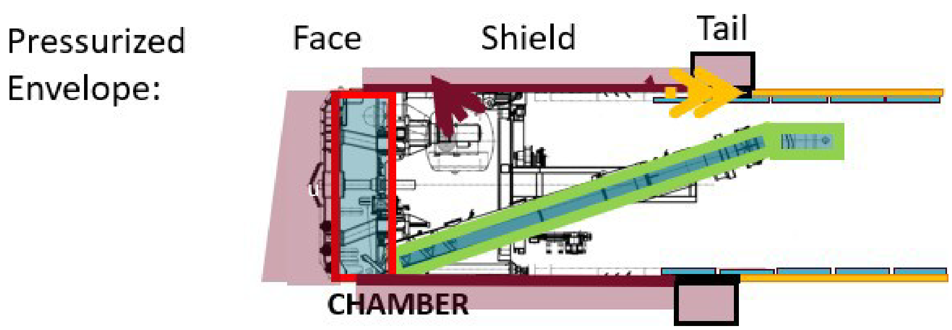
- On LA Metro jobs in 90's, probe holes were drilled ahead of the face, usually on maintenance shift, for magnetometer surveys in locations with oil fields. This is more difficult with Pressurized-TBMs and will delay tunnel if a well is encountered. On several current tunnel projects, magnetometer surveys are being conducted in casings installed with horizontal directional drilling (HDD) or to tunneling. With current technology, three HDD holes are being used for magnetometer surveys above the crown of a single 20-ft-diameter tunnel.
- How can information be obtained that will allow magnetometer surveys with HDD to be employed in limited areas rather than over long reaches of tunnel? Depends on:
  - Ability to locate abandon wells, well fields, and areas that can be cleared of wells.
    - Availability of records: More recent well installations along the alignment may have more information on their location and procedures used for abandonment. Define uncertainty of location for known wells, potential for unknown wells in a field.
  - As noted by project personnel: Consider remote sensing, aerial recon, to \determine if there is any surface expression of abandoned wells or well support facilities.
  - Conduct surface magnetometer surveys that might help pinpoint an abandoned well, recognizing that the surveys are limited in the depth that they can sense, and that many anomalies will be due to debris.
- Coordinate with Cal Gen for requirements for re-abandoning wells that cannot be avoided. Recognizing a low probability of encountering a well, as well as the

difficulty in determining that all reaches of the alignment have been cleared of wells, consider investigating current or developing technologies for sensing a well ahead of the TBM with instrumentation on the cutterhead so that advance can be stopped before a well is intersected, thereby preventing the hazard of gas flow into the tunnel.

9.2 Pressurized Tunneling to Control Surface Ground Movements and Protect Adjacent Structures

Issue*:*

- Controlled Tunneling with Pressurized TBMs



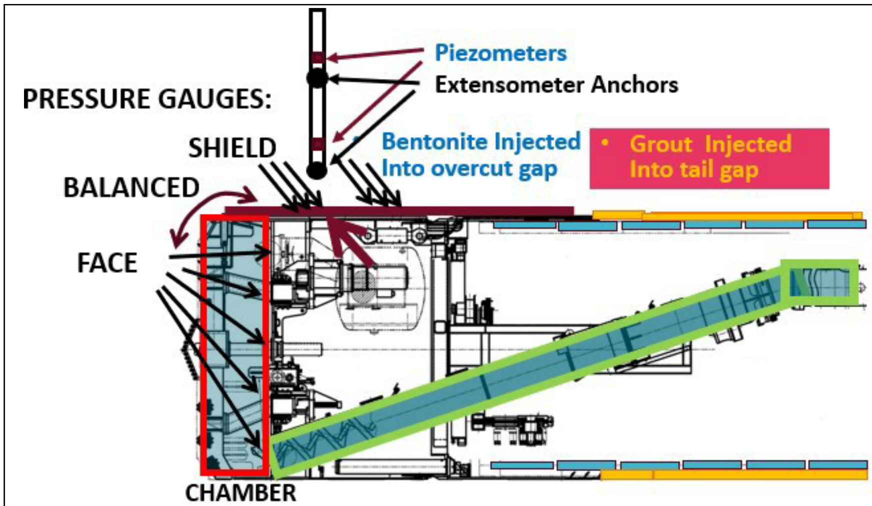
i. Pressurized TBM, either Earth Pressure Balance (shown) or Slurry Balance. Balance groundwater pressures & prevent inflow of sands & silts into face.

ii. Fill & pressurize gaps to prevent ground loss into gaps around shield and tail.

iii. Provide consistent monitoring & control of TBM throughout the drives.

iv. Use well engineered gasketed segmental concrete tunnel lining. Use a well-engineered geotechnical monitoring program coordinated with key TBM operating parameters, such as pressures and volumes injected around the TBM.

v. Be sure to consistently EPB-chamber in order to achieve totally chamber filling for comprehensive face pressure control



Integrated Program: **Geotechnical Monitoring** around **advancing TBM**
Correlated in real time with **key TBM operating parameters**

Benefits:

- Demonstrated on projects that pressurized tunneling prevents damage to structures and can be accomplished with reduced cover without surface impacts:
- Allow adjusting vertical alignment to reduce groundwater pressures that must be balanced and allow interventions into TBM chamber at less than 3.5 bars pressures so that high pressure hyperbaric interventions with mixed gas are not required.
- Controlled tunneling is required and is to be demonstrated throughout TBM drive to respond to 3rd Party concerns.
- Monitoring and hold points approaching and passing beneath facilities, such as EBMUD facilities to ensure that control is achieved.
- Experience: The SR-99 project in Seattle employed a larger diameter (57.5 ft) earth pressure balance TBM which was advanced below critical structures with low ground cover depth to tunnel diameter ratios and successfully mined 8,000 ft of tunnel in glacial soils near or under 300 building in downtown Seattle with no damage. Surface settlements were on the order of 1to 2.5 mm (near or below ability to measure). The TBM passed ft below the pile tips of the Highway 99 Viaduct with no settlement of the bents. The drive was completed with settlements less than 1 mm in non-cohesive sands with low fines content and with cover reducing from one to 0.6 diameters.
- As demonstrated on SR-99, requirements for ground improvement measures are reduced, and the potential issues associated with their use\are eliminated by proper TBM operation (i.e., face, shield and tail fully pressurized within predetermined ranges, and volume monitoring to confirm void filling and excavated tunnel material balance, thereby preventing ground loss.
- Experience with pressurized tunneling in glacial sands and clay in Toronto and in medium-dense alluvial soils in Los Angeles showed similar control was

achieved with settlements on order of 1 to 2.5 mm at covers of one diameter (20 ft for 20-ft diameter earth pressure balance TBMs.
Challenges: • Selection of experienced Contractors with proven performance (possible use of best value selection process), enforcing Specifications, and demonstrating performance throughout the tunnel drive, including in test sections at start up, and monitoring and coordination with TBM operations along alignment and prior to excavation under critical structures. • Different TBM types provide different face pressure control quality; depending on contractors' experience with various TBM types slurry-TBM supposed to have a better controllable, more precisely and safer (face)pressure keeping system

9.3 TBM Early Procurement

Issue: TBM Pre-purchase: **Not recommended**.
Benefits: • Can improve schedule
Challenges: • Significantly increases Owner's risk (Contractor can blame Owner for all machine related problems). • If Contractor purchase of TBM, desirable to be available when launch shaft has been constructed. • Features required or recommended by owner can be included in Contractors contract documents rather than in purchase agreement with manufacturer. • TBM type choice only obvious if geology would be obvious, which is not the case here

10.0 SUMMARY - KEY CONCLUSIONS AND RECOMMENDATIONS

The Tunneling and Shafts ITR Panel is pleased with the quality of the current conceptual designs for the tunneling and shafts, and offers the following summary, key conclusions and recommendations:

Reach Lengths:

<u>Summary</u>

- TBM reaches from 14 to 15 miles are practical and have been achieved in the industry

- The ITR panel is only aware of two comparable long drive, large diameter soft ground TBM case-history; i.e., the Tokyo Ring Road, 5.78 miles by 51.6 ft OD and Caracas Guarena Guatire EPBM, 9.4 miles by 27ft OD.
- Current industry experience and technology is that major TBM maintenance on the cutterhead wear plates and cutting tools should be anticipated every 4 to 6 miles.

Key Conclusion and Recommendations

- Provisions for spacing of surface access of TBM maintenance every 4 to 6 miles is recommended, which is in keeping with the EDM's current approach.
- A prudent approach and in keeping with industry standard of practice is to make provisions for underground Safe Haven development for early and routine Cutterhead checks and unanticipated TBM maintenance issues, such as the requirements for equipping the TBM with compressed air entry, ability to grout or freeze from the TBM and is the tunnel contractors' responsibilities.

Proposed Corridors and Alignments:

Summary

- The geotechnical information is much more developed on the Central alignment including detailed geotechnical reports and developed alignment profiles with geologic stick logs.
- In the EDM's presentation on May 13, noted that tunneling ground conditions appeared slightly more favorable on the East Alignment using a five-scale screening matrix in terms of better geologic conditions shallower depth and thickness of peat, and a deeper groundwater table. Also, based on the December 2019 ITR panel report an alternative far Eastern alignment was preferred in terms of access to the site and stability of the surface soils, therefore, potentially requiring less site improvement.
- While the East Alignment is 2.3 miles longer the capital costs of each are about the same.

Key Conclusions and Recommendations

- The soils from the data provided thus far are not appreciably different from an TBM excavation rate and machine wear standpoint.
- East Alignment has better access.
- Central Alignment has better RTM disposal access (on-site at Bouldin Island), and MWD/DWR/State own or control majority of the property along the tunnel alignment.
- Geotechnical data reports should be expanded for the Eastern Corridor and should include soil profiles for each tunnel reaches as well as the Central Corridor. The current and next phase of programs should focus on exploration at critical locations along the Eastern alignment.
- The alignment Reaches in the two corridors should be further optimized/refined considering the geotechnical, environmental and community challenges; hydraulics, schedule, and oil & gas well exploration program.
- A detailed risk-based cost/schedule estimate should be performed along both corridors for final decision making.
- The ITR recommends raising the tunnel alignment by a half a diameter to one diameter as there are benefits in terms of shallower shafts, tunnel and TBM operations (especially, for interventions for machine maintenance). The impact of up to one diameter raise is unlikely to adversely affect the liner design for net internal pressure, but raising the tunnel more than one diameter could impact the segment design and should be carefully weighed as to advantages and disadvantages.

Overall Construction Sequence and Schedule:

Summary

- Production rates and schedule are reasonably conservative with respect to tunnel drives.

Key Conclusions and Recommendations

- Provide clarification of logic required to develop the borrow pits for the Maintenance Shafts pad construction.
- The RTM for South Forebay requires a check on the mass balance logic.
- Check the availability of a stable power supply due to rolling blackouts, which are probable in the Delta during warmer months.
- Slurry and EPB TBM's require different logistics, equipment, and have advantages and disadvantages. A comprehensive comparison between EPB and slurry TBMs in regard to influence of geotechnical conditions, logistics, site accessibility, excavated tunnel material/and ensuring RTM, and performance rates should be undertaken prior to finalizing the design.
- For the Central alignment, RTM from the Reach 3 tunnel drive, is understood to be allowed to be stockpiled on Bouldin Island. If it is important to reduce the overall schedule, the 14-mile drive for Reach 2 (the critical path) could be cut in half by adding a second heading to the north from Bouldin Island.

Tunnel Lining Design and Constructability Considerations:

Summary

- Hydraulic analysis for transient conditions indicated that the tunnel lining will experience a net internal pressure; i.e., the total internal pressure minus the ambient external groundwater pressure.

Key Conclusions and Recommendations

- The avoidance of using continuous hoop steel within the precast concrete segment across segment joints designed to carry internal pressure is preferred as the precedence for such an application in this diameter is limited and the detailing is quite complex.
- Provide probabilities or percent operating time for surge events, steady state gravity event, etc. and tie into engineering judgment as to how much net pressure must be designed for. Clarify/provide (stations) as to where net internal pressure occurs.
- Require in areas of net internal pressure that the TBM be operated in pressurized conditions to lock in stresses around liner as segments are installed.
- Recommend further investigation into benefits of longitudinal bolts/dowels on liner for carrying internal pressure and potential (negative) effects and need for radial bolts in the same function
- Recommend a structural "balancing of load" or second gasket on liners, which provide the additional benefits of possible gas intrusion from surrounding ground. Balancing gaskets to distribute load is standard of practice for thick liners to keep installation, erection, and final position loads concentric. For gas/water considerations a combined EDM and bentonite strip gasket are also common in -practice.

Reusable Tunnel Material (RTM) Handling and Identified Re-uses:

Summary

- Handling of RTM excavated tunnel materials is major area of risk in terms of efficient schedule and contracting logistics, acceptable reuse, and permitting,

Key Conclusions and Recommendations

- Establish a test program to confirm the assumptions for mechanical drying and to confirm feasibility of mass drying and the rate to do so.
- Evaluate the practicability of transporting the excavated tunnel materials in a slurry form via temporarily pipelines and to process the slurry into RTM, to confirm suitability of Slurry TBM and compare with conveyor transport.
- Investigate the interest/market for RTM by developers.

Contracting and Packaging Approach:

Summary

- The packaging of separate tunneling contract by Reaches of less than about $2 billion is currently underway by the EDM.

Key Conclusions and Recommendations

- Design-build contracting approach is appropriate for the tunnels and shafts.
- Consider advantage of one contractor for both Reaches 1 and 2 for more efficient use and elimination of schedule conflicts at the single site for launching and servicing the two TBM drives.
- Consider using best value for contractor selection where the technical proposal is scored separately from the price.
- Smaller separate contracts for infrastructure development (access, bridge improvements, docks, pads, ground improvement, power, and other utilities) should be investigated/developed.
- Separate contracts for Early TBM Procurement or a project-wide Segment manufacture/supplier are not recommended.
- Consider separating RTM work (transport and conditioning of excavated tunnel material into RTM) into one or more separate contract(s) to a specialist company, or companies.

Understanding and Satisfying O&M:

Summary

- Access to inspect the Delta Conveyance tunnel is required and the needs are undergoing documentation by the DCO.

Key Conclusions and Recommendations

- The minimum requirements for mandatory O&M Shafts should be defined in terms of minimum spacing (e.g. 4 to 6 miles seems tied to tunneling not O&M), type of equipment used (e.g. ROV equipment was discussed as well as rubber tired/human entrance), duration for such an inspection, anticipated maintenance activity (e.g. removal of sediment was mentioned), operational controls (e.g. it was mentioned it will take 3 weeks to un-water the tunnel), and seasonal demand constraints (e.g. duration tunnel can be dry). This will provide a better determination of the minimum spacing, diameter, and height above existing ground surface required.

Other Relevant Topics:

Summary

- The tunneling alignments face challenges crossing under stakeholders' right-of-way.

Key Conclusions and Recommendations

- Modern tunneling technology with pressurized TBMs (earth pressure balance or slurry TBMs) combined with a coordinated program of ground and TBM monitoring has proven to mitigate concerns related to tunneling at shallow depth adjacent to, or below structures.

11.0 NEXT ITR PANEL MEETING

The participants agreed that at this point it would be premature to set a firm date for the next Tunneling and Shafts ITR Panel Meeting.

12.0 CLOSURE

This was a productive meeting. The Tunneling and Shafts ITR Panel acknowledges the efficiency with which the First Meeting was organized and conducted, and also the hospitality afforded to all. We compliment the presenters and facilitators, and also note the willingness of individuals from all parties to present findings and opinions, and to provide technical and strategic leadership to the project.

Respectfully submitted,

Dale E. Berner   Dan Adams   Edward Cording   Doug Harding

Gregg Korbin   Ulrich Rehm   Jon Kaneshiro

Appendix 1: Daily Agendas

Delta Conveyance Project
Tunnels and Shafts ITR Panel - Meeting No. 1
May 13-15, 2020

SKYPE-
TIME 8:00 AM Start each day

Meeting Goal and Objectives

1. Develop Common Understanding of Project's Tunnel and Shaft Approaches in Order to Recognize and Comment on Critical Issues
    - Delta Conveyance Overview; Investigated Project Alignments/Tunnel Conveyance Needs/Features; Single Pass Tunnel Liner/Depth and Profile/General Construction Sequencing; Hydraulics and Operational Considerations; Geotechnical Overview and Planned Data Gathering
2. Thoroughly Investigate Critical Project Issues:
    - Be able to summarize and evaluate technical topics presented including recommending future analyses, assessing solutions, commenting on the progress of engineering work, and recommending prioritization of future work.
3. Tunnels and Shafts ITR Feedback on Proposed Approach, Reaches and Designs
    - Focus on DWR Identified Questions:
        - Proposed Tunnel Reaches - Drive Lengths/Shafts/Logistics Concerns
        - Comments on Proposed Corridors and Alignments
        - Overall Construction Sequence and Schedule
        - Tunnel Lining Design and Constructability Considerations
        - Reusable Tunnel Material (RTM) Handling and Identified Re-uses
        - Contract Packaging Approach
        - Recommendations Related to Understanding and Satisfying O&M Needs

Day 1 AGENDA for May 13, 2020

8:00- 8:10 Introductions (including introductions of panel members) - Safety Moment – *Dale Berner*

8:10- 8:15 Opening Remarks – *Tony Meyers*

8:15- 9:30 **Delta Conveyance Project Overview Presentations**

- Delta Conveyance Overview *(John Caulfield)*
- Investigated Project Alignments & Reaches/Tunnel Conveyance Needs/Features *(John Caulfield)*
- Geotechnical overview/Depth/Profile/General Construction Sequencing *(John Caulfield)*
- Hydraulics and Operational Considerations – *(Tony Naimey)*

9:30-9:45 Questions - *All*

9:45-10:00 Break - *All*

10:00-12:15 **Tunnel and Shaft Construction Approach Presentations**

- Shaft Siting Criteria/Locations - *(G. Bradner)*
- Shaft Functions & Layouts/Work Activities/Logistics and Construction Methods/Safety – *(Steve Dubnewych)*
- TBM Considerations & Drive Lengths – *(Steve Dubnewych)*
- Tunnel Lining - Single Pass/Preliminary Cross Sections/Precast Segment Sizes –
  - Loading Cases /" Hoop Stresses" Segment Design – *(Steve Dubnewych)*
- Precast Facilities – Supply, Production and Transportation Considerations – *(Jim Lorenzen)*
- Road/Rail/Barge/Power Improvements - *(Jim Lorenzen)*

12:15- 12:45 Lunch Break - *All*

12:45-2:45 **Tunnel and Shaft Construction Approach Presentations (cont.)**

- Schedule - Assumptions/Early Works/Contract Packages/Advance Rates - *(Martin Ellis)*
- Reusable Tunnel Material (RTM) –
  Quantities/Handling/Spreading/Storage/Drying Assumptions/Reuse – *(Shaun Firth)*
- Construction Safety Considerations (gas/flooding/etc) – *J. Caulfield*
- Permanent Facilities –
  Shaft Sites/Instrumentation/O&M Considerations/Inspection and Access Needs - *(Jesse Dillon)*

2:45-4:30 Questions and Discussions - *All*

Day 2 AGENDA for May 14, 2020

1. ITR Panel Review and Discussions – *ITR Panel and Selected DCA and DCO Reps*
2. Summary Recommendations and Presentation Preparation – *ITR Panel and COWI*

Day 3 AGENDA for May 15, 2020

10:30- 12:00 ITR Panel Summary Presentation – *ITR Panel*

Adjournment (noon)

Appendix 2: Lists of Daily Attendees

Wednesday (5/13/2020)

- Graham Bradner
- Carolyn Buckman
- John Caulfield
- Dan Adams
- Jesse Dillon
- Doug Harding
- Steve Dubnewych
- Edward Cording
- Martin Ellis
- Andrew Finney
- Gregg Korbin
- Anthony Meyers
- Ulrich Rehm
- John Bednarski
- Tony Naimey
- Jay Arabshahi
- James Lorenzen
- Ryan Phil
- Shaun Firth
- Jon Kaneshiro
- Dale Berner
- Christoffer Brodbaek
- Valerie Sazo
- Darryl Hayes

Friday (5/15/2020)

- Praba Pirabarooban
- Jesse Dillon
- Anthony Meyers
- Darryl Hayes
- Arasan Singanayaham
- Carolyn Buckman
- Marcus Yee
- Dan Adams
- Doug Harding
- Ulrich Rehm
- Jon Kaneshiro
- Gregg Korbin
- Edward Cording
- Dale Berner
- Christoffer Brodbaek
- Valerie Sazo
- Phil Ryan
- Tony Naimey
- Steve Dubnewych
- Kathryn Mallon
- Janet Barbieri
- Hong Lin
- Terry Krause
- John Caulfield
- Joh Bednarski
- Shaun Firth
- Graham Bradner
- Steve Minassian

Appendix 3: RTM Processing Considerations

The ITR Panel views the excavated tunnel material handling and RTM processing as being critical activities that merit further evaluation.

The ITR Panel is concerned that the excavated tunnel material heating screw device presented for decreasing the moisture content of the excavated tunnel material may very likely not work efficiently. The panel is concerned that cohesive spoil which is planned to be reduced in water content, may change its consistency to the point where it may clog the processing equipment.

Given the spoil properties in the DCA presentation slide no 77 in terms of water content – the increase by approx. 10% of natural water content (from 31% to 41,5%) through operation is related for example to an EPB application with FIR (foam injection rate) of approx. 60% and FER (foam expansion rate) of approx. 12 which are average reasonable numbers. If one were to only assume more sticky conditions which would realistically change the FIR to approx. 100% and the FER to 7-8, the spoil water content could increase by approx. 30% as some TBM driver may do in order to protect their TBM; which would require far more drying activities by the screw dryer (or by a natural stock piling).

In one panel member's opinion is that it is not possible to adequately reduce the water content satisfactorily either in an TBM screw conveyor or along the tunnel on the conveyor belt, because one cannot deliver sufficient lime powder into a screw conveyor. Furthermore, the use polymers to dry the excavated tunnel material do not work properly and produce unacceptable environmentally conditions. Additionally, while some panel members believe that it is worth contacting selected manufactures to evaluate the practicability of design the mechanical RTM processing equipment to be positioned within the length of the bored tunnel drive; while other panel members advise that such an approach is not practicable and not worth evaluating.

The situation for a slurry excavated tunnel material is comparably challenging, i.e. depending on the amount of fines content of the natural ground the residual water content of separated spoil from filter presses or hydro cyclones lies within 30-40% which is close to the assumption of the DCA whereas this is related to separated highly cohesive filter cakes only. One will get the other separated fractions of gravel, sand and silt separately with various water contents but for using it as reclamation material you will have to mix the separated fractions again in order to get a suitable material for reclamation purposes which can be difficult. This would be a further argument to contract the spoil handling separately to an experienced contractor.

Additionally, the power requirements for a 40-foot EPBM draws approx. 6-7 MW whereas the slurry TBM requires a bit less (some 5-6 MW – without slurry pumps) just for the shield machine and back up – but also requires the use of a number of slurry pumps along the length of the tunnel.

Regarding the length of the longest reach of 14-15 miles, the panel believe that this as possible but would require the talents of a world-class tunnel contractor. Therefore, it is not only the engineering of the TBM that has to be world-class but also the technical support during tunneling and the innovative approaches for outstanding long reaches.

Appendix 4: Considerations for Handling Slurried Excavated Tunnel Material

One or more of the tunneling contractors may select the use of a Slurry TBM, or a contractor using a EPBM TBM may elect to convert the excavated tunnel material into a slurry (as described in the following discussion) if the excavated tunnel material is allowed to be used (or disposed of) as a beneficial fill material, instead of converting the excavated tunnel material into material for levee construction.

The following write-up contains selected consideration on means and methods for liquefying of EPB excavated material (EM) with the variable density (VD) TBM:

The VD TBM uses a slurrifier box (or flushing box, see figures below) at the outlet of the screw conveyor to mix the EM from the face with additional Bentonite slurry that has to be provided along the whole tunnel length. This EM-slurry should have a density of maximum 1,3t/m^3 otherwise, pumping along the tunnel gets problematic as the slurry requires slurry pumps of some 800kW-1MW each every approx. 1-1,3km intervals. The proper mixing process of EM and slurry in the slurryfier box depends on the composition of the EM; the more cohesive it gets the higher the risk to plug the outlet of the slurrifier box. Another critical point in the case of the spoil being conditioned with foam (which is state of the art for EPBM); which would then very likely re-foam in the slurrifier box due to the high energy potential generated by the slurry being flushed into the box which could cause, beside an increase in slurry-air-bubble-volume, also cavitation in the slurry pumps. This is one of the reasons why a VD TBM might utilize a conveyor belt instead of a slurry pipeline.

The stone crusher shown in Fig. 2 between the screw and a slurriyfier box is only needed if bigger stones are expected (which shouldn't be the case for the Delta); which also could become a critical point in terms of spoil flow jam in case of cohesive ground.
Thus, a pumped slurry would have a density of approx. 1,3 t/m^3 of which approx. a third would be of solids and 70% of the slurry would have to be separated before disposing of the EM (possibly as a fill material). IF the EM were to be used for levee construction then the separated soil components would have to be re-mixed in order to achieve best soil-composition for compaction. Slurry pipelines may be supported by steel struts along the surface which might require solid concrete foundations each 20-30m (see figures below)er, or alternately the temporary slurry transport pipeline, and booster pumps, could be designed to float on the breaded river channels. Furthermore, EM treatment requires special knowledge of earth moving, mixing and handling and electric power.

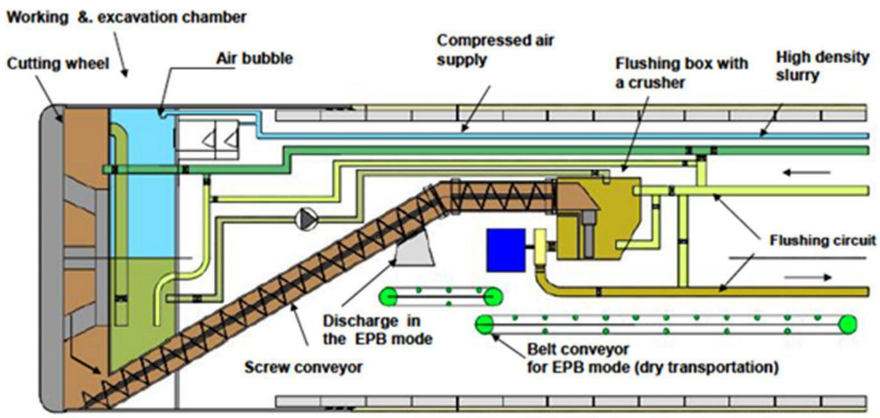


Fig. 1 Variable-density TBM

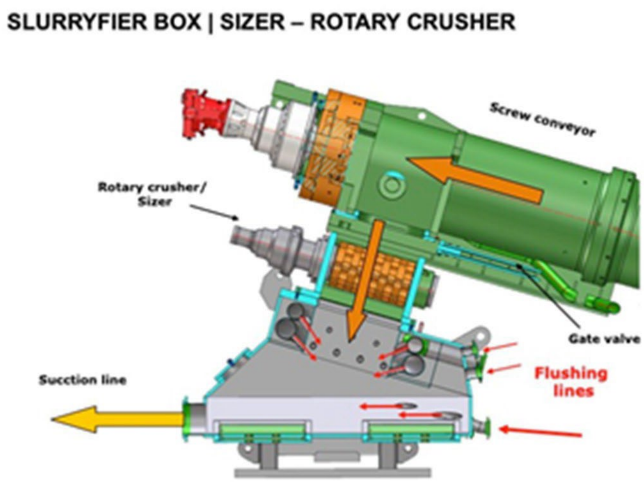


Fig. 2: Slurryfier-box with stone crusher

Fig. 3: Slurryfier-box with stone crusher for 7m diameter TBM (Kuala Lumpur)

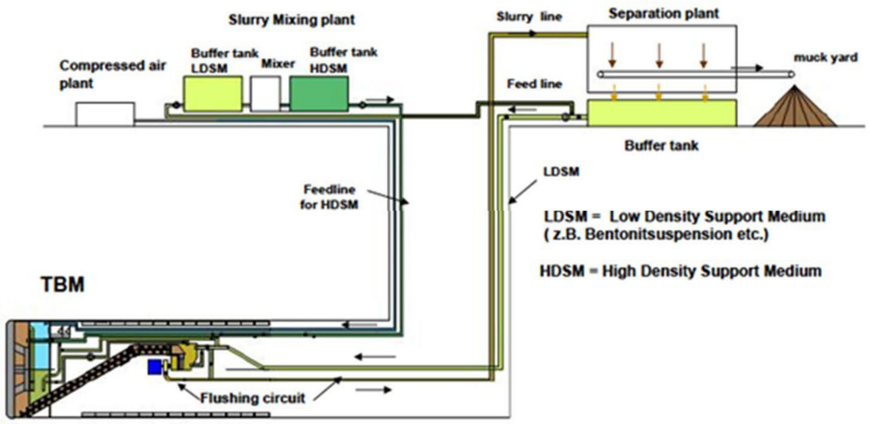
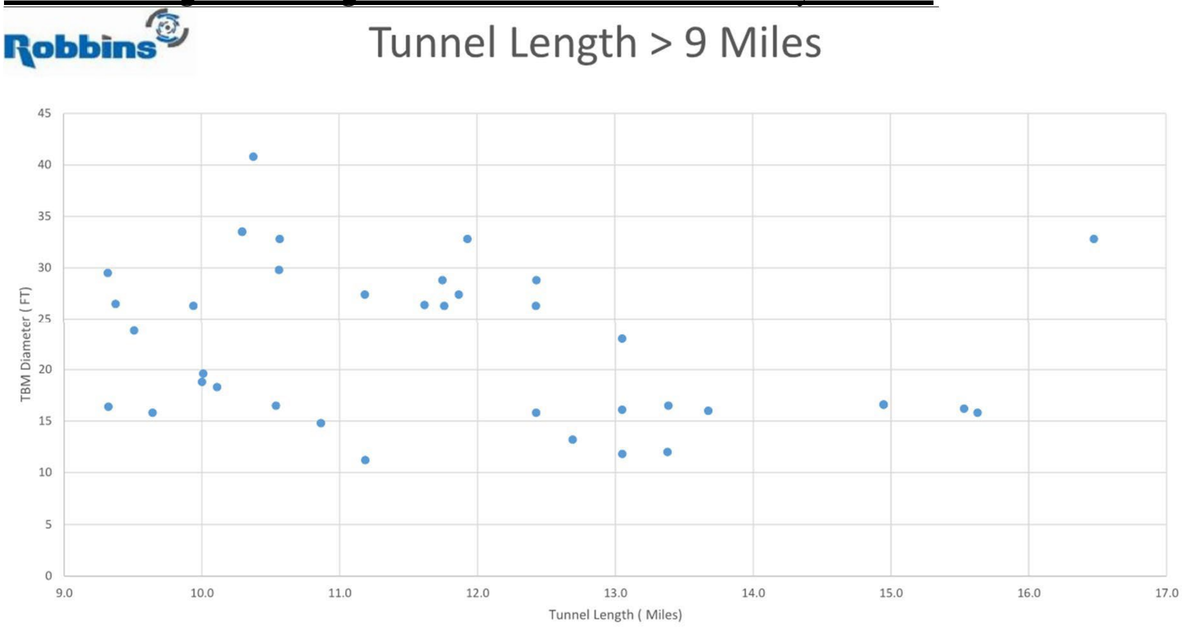


Fig. 4: Principal logistical effort for VD TBM (Kuala Lumpur)

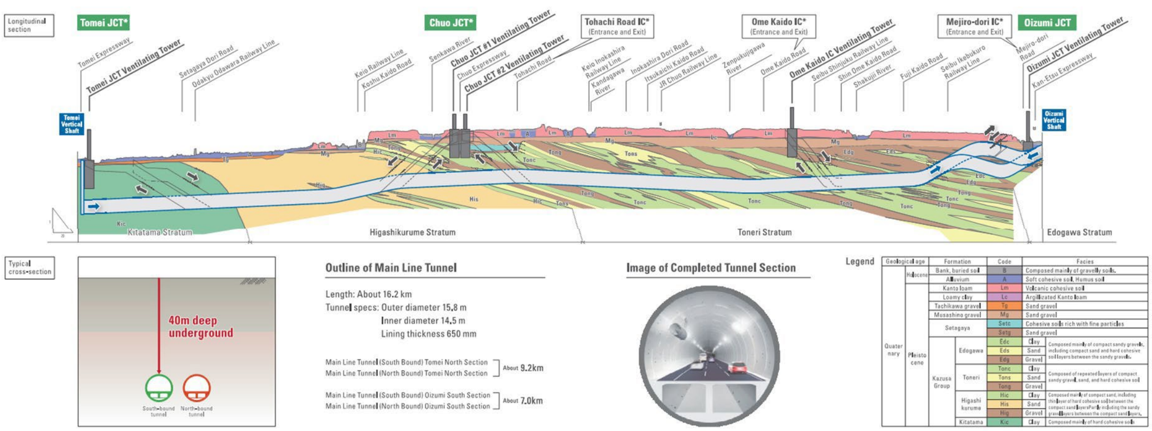
Fig. 5: Elevated slurry lines through Berlin/Germany

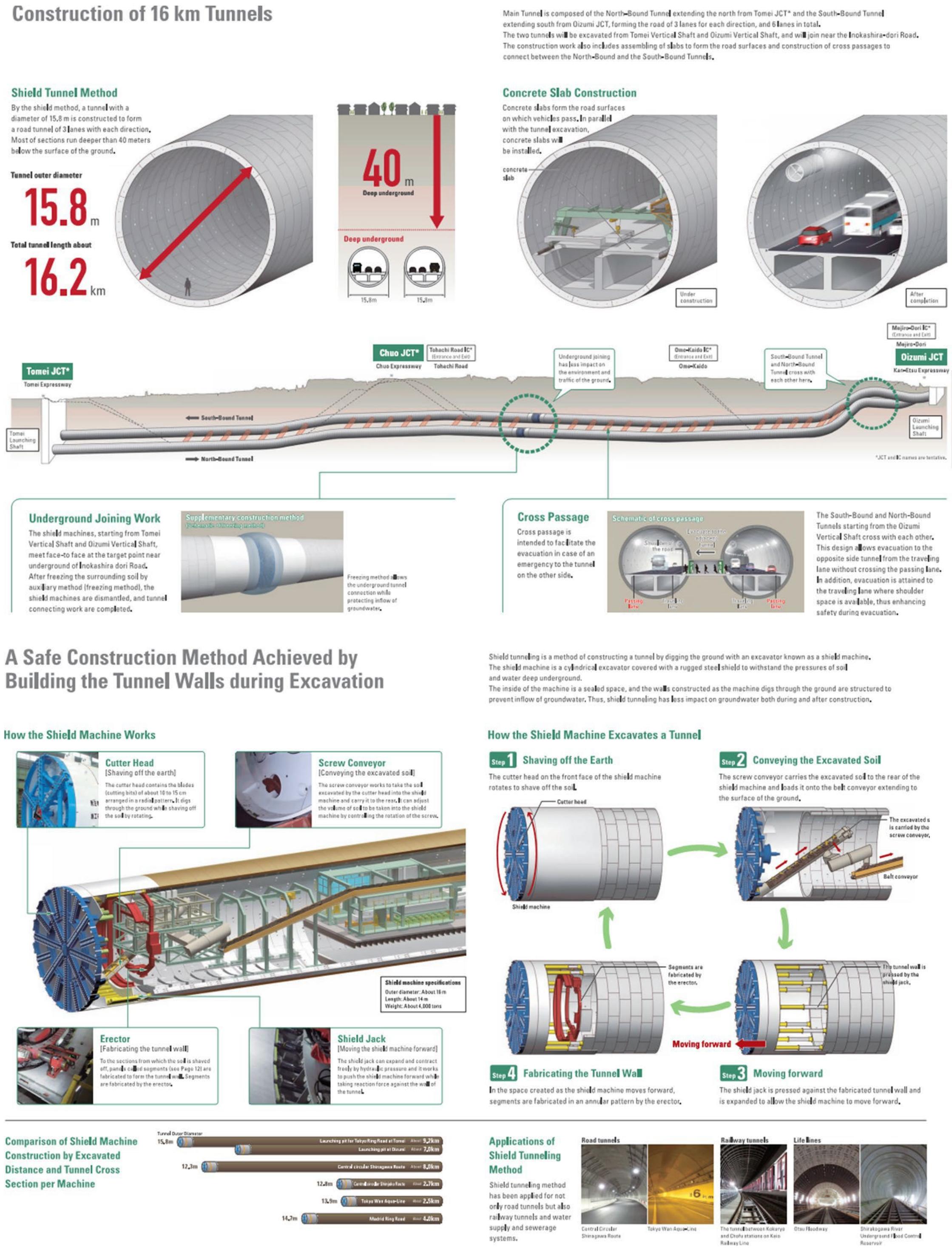
Appendix 5: Presentation of Selected Existing Long Drive Tunnels

Table of Long-Drive Large Diameter Tunnels thru Rock by Robbins



Abstract of Selected Information on the Tokyo Ring Tunnel Project Under Construction




Construction of 16 km Tunnels
Main Tunnel is composed of the North-Bound Tunnel extending the north from Tomei JCT* and the South-Bound Tunnel extending south from Oizumi JCT, forming the road of 3 lanes for each direction, and 6 lanes in total.
The two tunnels will be excavated from Tomei Vertical Shaft and Oizumi Vertical Shaft, and will join near the Inokashira-dori Road.
The construction work also includes assembling of slabs to form the road surfaces and construction of cross passages to connect between the North-Bound and the South-Bound Tunnels.
Shield Tunnel Method
By the shield method, a tunnel with a diameter of 15.8 m is constructed to form a road tunnel of 3 lanes with each direction. Most of sections run deeper than 40 meters below the surface of the ground.
Tunnel outer diameter
15.8 m
Total tunnel length about
16.2 km
40 m
Deep underground
Deep underground
15.8m
15.8m
Concrete Slab Construction
Concrete slabs form the road surfaces on which vehicles pass. In parallel with the tunnel excavation, concrete slabs will be installed.
concrete slab
Under construction
After completion
Tomei JCT*
Tomei Expressway
Chuo JCT*
Chuo Expressway
Tohachi Road IC*
(Entrance and Exit)
Tohachi Road
Underground joining has less impact on the environment and traffic of the ground.
Ome-Kaido IC*
(Entrance and Exit)
Ome-Kaido
South-Bound Tunnel and North-Bound Tunnel cross with each other here.
Mejiro-Dori IC*
(Entrance and Exit)
Mejiro-Dori
Oizumi JCT
Kan-Etsu Expressway
Tomei Launching Shaft
South-Bound Tunnel
North-Bound Tunnel
Oizumi Launching Shaft
*JCT and IC names are tentative.
Underground Joining Work
The shield machines, starting from Tomei Vertical Shaft and Oizumi Vertical Shaft, meet face-to face at the target point near underground of Inokashira dori Road. After freezing the surrounding soil by auxiliary method (freezing method), the shield machines are dismantled, and tunnel connecting work are completed.
Supplementary construction method
Freezing method allows the underground tunnel connection while protecting inflow of groundwater.
Cross Passage
Cross passage is intended to facilitate the evacuation in case of an emergency to the tunnel on the other side.
Schematic of cross passage
The South-Bound and North-Bound Tunnels starting from the Oizumi Vertical Shaft cross with each other. This design allows evacuation to the opposite side tunnel from the traveling lane without crossing the passing lane. In addition, evacuation is attained to the traveling lane where shoulder space is available, thus enhancing safety during evacuation.
A Safe Construction Method Achieved by Building the Tunnel Walls during Excavation
Shield tunneling is a method of constructing a tunnel by digging the ground with an excavator known as a shield machine.
The shield machine is a cylindrical excavator covered with a rugged steel shield to withstand the pressures of soil and water deep underground.
The inside of the machine is a sealed space, and the walls constructed as the machine digs through the ground are structured to prevent inflow of groundwater. Thus, shield tunneling has less impact on groundwater both during and after construction.
How the Shield Machine Works
Cutter Head
[Shaving off the earth]
The cutter head contains the blades (cutting bits) of about 10 to 15 cm arranged in a radial pattern. It digs through the ground while shaving off the soil by rotating.
Screw Conveyor
[Conveying the excavated soil]
The screw conveyor works to take the soil excavated by the cutter head into the shield machine and carry it to the rear. It can adjust the volume of soil to be taken into the shield machine by controlling the rotation of the screw.
Shield machine specifications
Outer diameter: About 16 m
Length: About 14 m
Weight: About 4,000 tons
Erector
[Fabricating the tunnel wall]
To the sections from which the soil is shaved off, panels called segments (see Page 12) are fabricated to form the tunnel wall. Segments are fabricated by the erector.
Shield Jack
[Moving the shield machine forward]
The shield jack can expand and contract freely by hydraulic pressure and it works to push the shield machine forward while taking reaction force against the wall of the tunnel.
How the Shield Machine Excavates a Tunnel
Step 1 Shaving off the Earth
The cutter head on the front face of the shield machine rotates to shave off the soil.
Cutter head
Shield machine
Step 2 Conveying the Excavated Soil
The screw conveyor carries the excavated soil to the rear of the shield machine and loads it onto the belt conveyor extending to the surface of the ground.
is carried by the screw conveyor.
Belt conveyor
Segments are fabricated by the erector.
Moving forward
Step 4 Fabricating the Tunnel Wall
In the space created as the shield machine moves forward, segments are fabricated in an annular pattern by the erector.
Step 3 Moving forward
The shield jack is pressed against the fabricated tunnel wall and is expanded to allow the shield machine to move forward.
Comparison of Shield Machine Construction by Excavated Distance and Tunnel Cross Section per Machine
Tunnel Outer Diameter
15.8m
Launching pit for Tokyo Ring Road at Tomei About 9.2km
Launching pit at Oizumi About 7.0km
12.3m
Central circular Shinagawa Route About 8.0km
12.8m
2.7km
13.9m
Tokyo Wan Aqua-Line 2.5km
14.7m
Madrid Ring Road 4.0km
Applications of Shield Tunneling Method
Shield tunneling method has been applied for not only road tunnels but also railway tunnels and water supply and sewerage systems.
Road tunnels
Railway tunnels
Life lines
Central Circular Shinagawa Route
Tokyo Wan Aqua-Line
Otsu Floodway

Comparison of Shield Machine Construction by Excavated Distance and Tunnel Cross Section per Machine

For additional information about the Tokyo Ring Road project, please see the May 17, 2017 TunnelTalk article entitled: 'Mega TBMs begin Tokyo ring road drives', as well as the following three associated references:

- Tokyo Bay highway engages eight mega TBMs – *TunnelTalk,* August 1994
- Tracking the world's mega-TBMs – *TunnelTalk,* May 2016
- Mitsubishi TBM business consolidation – *TunnelTalk,* May 2015

Appendix 6: Other Considerations and Case Histories Regarding O&M Shafts

As noted, in Section 8.1, the need for Operations and Maintenance Shafts for tunnels varies by type of tunnel and Owner's requirements and programs. It is understood that the DCO is weighing the needs of the program and comparing to demands of other water projects in the industry. The following are some additional thoughts that the ITR panel is offering for the DCO to consider for information, when assessing the needs for the Delta Conveyance Project.

Tunnels in general, and water tunnels especially, have a longer life cycle than other conveyance facilities (e.g. pipelines, pump stations, aqueducts). They are typically designed to account for corrosion, and as such maintenance can be expected to be minimal with proper details in the design. This is particularly true for tunnels through mountains which have long (e.g. over 10 miles) distances between access points. Examples include the North Fork Stanislaus Hydroelectric Project (ca. 1989) which has access intervals at about 11 miles or MWD's San Jacinto tunnel (ca. 1930) with access at about 13 miles. It is noted with this second example that MWD inspections are every 5 years, because San Jacinto required it as the original 1930's grouting program did now work so well. But now they have Inland Feeder so they can have longer shutdowns for repair.

Interceptor sewer tunnels, have less life expectancy, and typically will have manhole spacings of 500 to 2000 ft, mainly drops and tie-ins. The added benefit of this spacing is for hazards of sewer gases during inspections and due to maintenance required associated with sewerage. But for long crossings of rivers or mountains Owner's accept limited access and they will accept larger spacings. Recent examples include King County's Brightwater interceptors, St. Louis Deer Creek Sanitary Sewer Overflow (SSO), and Austin Downtown tunnel SSO where there is limited access

Effluent outfall tunnels are long by sewer design standards, and like mountain tunnels, do not have access, i.e., shaft access due to the ocean. Ventilation during a manned inspection (if ever) carry significant safety risk, but nevertheless, the O&M manuals typically addressed such scenarios of dewatering and manned inspection, in the unlikely event they are ever needed. As an example, the Sanitation Districts of Los Angeles (SDLAC) inspected their existing outfall by ROV several decades ago, and it was lost; likely stuck in a diffuser. The entire length of the existing outfall, about 70 years old had never been inspected by humans. The new tunnel under construction now, will provide the redundancy needed to inspect the existing outfall.

Consideration of size of equipment to access the tunnel for inspection is an important aspect. The SDLAC 18 ft ID by 7-mile-long tunnel has a 12 ft diameter lid at the drop shaft. Restrictions at fault crossings and the connection to the drop shaft is 16 ft. Maximum anticipated equipment was on the order of 10 ft.

Appendix 7: Table of Considerations and Requested Responses

DCA Response to May 2020 Tunnel Independent Technical Review Panel Recommendations

Item	ITR Recommendation	DCA Response
2. Proposed Tunnel Reaches		
2.1	Reach lengths up to 14 to 15 miles as a single TBM heading are practical so long as regular maintenance is performed on the new TBM.	Agree. Regular maintenance shafts have been added at approximately 4 to 6 mile intervals.
2.2	Provide real estate for the shaft site, access to the shaft site, and necessary permitting for TBM maintenance at intervals of 4 - 6 miles between launch and receiving shafts. Contractors can determine what type of access to provide.	Agree. For purposes of CEQA, proposed designs have been included. Note: These shafts also serve as access points and surge relief during long term operations.
2.3	Provide capability for drilling through ports within the TBM for ground treatment ahead of the face to create a safe haven from within the tunnel where surface access may be restricted.	Noted. Will study implementation during detailed design. Does not affect conceptual design.
2.4	In response to previous recommendations to allow the tunneling contractor the option to construct a TBM safe haven within 1 mile from the long-reach launch shafts by providing pre-acquired/approved real estate, this ITR Panel recommends compressed air intervention or safe heaven near or adjacent to the launch shaft is more common and cost effective.	Noted. Will investigate methods to provide safe haven and maintenance access from within tunnel for unplanned events which include an early intervention at 1 mile. See above.
2.5	Additional Suggestions: a) Review case histories of long drive implementations. b) Review procedures for cutting tool changing while under pressure.	Noted. Will follow up.
3. Proposed Corridors & Alignments		
3.1	a) The panel is not prepared to identify preferred corridor and the Eastern Alignment should continue to be developed. The panel does recognize the importance of optimization of alignment in terms of logistics of TBM assembly, servicing, supplies and other tunnel operations. b) The alignment Reaches in the two corridors should be further optimized/refined considering the geotechnical, environmental and community challenges; hydraulics, schedule, and oil & gas well exploration program	a) Noted. DCA is responsible for preparing conceptual designs for all alternatives identified by the DWR and addressing areas such as logistics to accommodate the work. b) Noted.

DCA Response to May 2020 Tunnel Independent Technical Review Panel Recommendations

Item	ITR Recommendation	DCA Response
3.2	The ITR recommends raising the tunnel alignment by a half a diameter to one diameter as there are benefits in terms of shallower shafts, tunnel and TBM operations (especially, for interventions for machine maintenance). The impact of up to one diameter raise is unlikely to adversely affect the liner design for net internal pressure, but raising the tunnel more than one diameter could impact the segment design and should be carefully weighed as to advantages and disadvantages.	Noted. Will study in detailed design. Current tunnel depth controlled by surge analysis and the resolution passed by the Port of Stockton for minimum separation below San Joaquin River.
4. Overall Construction Sequence and Schedule		
4.1	The assumed tunnel production rates are reasonable	Agree.
4.2	Clarify the logic used for time required to develop the material supply and construction of the shaft pads.	Noted. DCA team has reviewed and is comfortable with their current logic.
4.3	The panel recommends checking the mass balance logic with RTM at the South Forebay.	Noted. DCA team has reviewed and is comfortable with their mass balance calculations.
4.4	Review the schedule for concurrent tunneling operations	Noted. DCA team is confident in current sequence but will also review and confirm in the detailed design phase.
4.5	Other Schedule Considerations a) The construction start date and completion date of the project does not appear to be fixed and or driven by any sort of external mandate but the use of RTM for construction of the Southern Forebay does. b) If extending the overall duration of the project is feasible, consider changing the sequence for the Reach 3 and 4 tunnels to allow Reach 4 to be completed prior to tunnel excavation commencing for Reach 3. Excavated material from Reach 3 could be transported through/via Reach 4 conveyors to the Southern Forebay RTM facility for treatment and utlimiante use at the site.	a) Noted. DCA team has reviewed the schedule and has appropriately sequenced the work at Twin Cities and construction of the embankments at the Southern Forebay. b) Disagree. This change would require a launch shaft on Bacon Island for the Central alignment which is not feasible from a logistics perspective and is not necessary for the Eastern alignment as there is ample supply of material for the Southern Forebay embankments from the existing configuration.
5. Tunnel Lining Design and Constructability Considerations		
5.1	Lining Design for Net Internal Hydraulic Surge Pressure	Noted. Comments will be addressed during detailed design. They do not affect the concept design required for CEQA analysis.
5.2	Other Design Issues Related to Net Internal Pressure	Noted. Comments will be addressed during detailed design. They do not affect the concept design required for CEQA analysis.
6. Reusable Tunnel Material (RTM) Handling and Identified Re-Uses		
6.1	Perform an RTM Testing Program	Agree. Test program will be conducted to validate design assumptions.
6.2	Consider Natural Processing and Other Ideas	Noted. Will be evaluated further in design phase. For conceptual design, we believe we have the right balance of mechanical and natural drying to minimize construction area, reduce air emissions, and manage risks.
7. Contract Packaging Report		

DCA Response to May 2020 Tunnel Independent Technical Review Panel Recommendations

Item	ITR Recommendation	DCA Response
7.1	ITR considers design-build contracting approach appropriate for the tunnels and shafts	Noted. Will conduct contracting alternatives analysis during future design phase. Does not affect Conceptual Engineering Report.
7.2	Consider advantage of one contractor for both Reaches 1 and 2	Noted. Will conduct contract packaging alternatives analysis during future design phase. Does not affect Conceptual Engineering Report.
7.3	Consider using best value for contractor selection where a technical proposal is scored separate from the price. Gain and pain contract model in order to motivate the contractors to keep time and cost plan.	Noted. Will include in contracting alternatives analysis described above.
7.4	The ITR does not recommend early TBM procurement or project wide segment contract. ITR does recommend that one or more separate contracts associated with treatment of the excavated tunnel material into RTM be considered.	Noted. Will include in contract packaging analysis described above.
8. Recommendations Related to Understanding and Satisfying O&M Needs		
8.1	a) The ITR recommends the minimum requirements for mandatory O&M shafts be defined in terms of minimum spacing, type of equipment used, duration for such an inspection, anticipated maintenance activity, operational controls, and seasonal demand constraints. b) The imported soils are a significant issue in terms of cost and schedule impact on the project.	a) Noted. Additional work will be done to optimize permanent shaft diameter and pad size needed for operations access. Shafts currently shown are of size and location to facilitate tunnel construction. b) Noted. We will study methods to reduce the amount of fill required at shaft site. Currently, this fill prevents artesian flooding during shaft excavation but we may be able to reduce the working platform area to reduce overall volume of imported soil needed.
8.2	ITR is not aware of tunnel project where bolt pocket created a tripping hazard or concern over catchment of sediment. ITR is aware of other projects where the bolt pocket was filled.	Noted.
9. Other Relevant Topics		
9.1	Recommend locating abandoned gas/oil wells prior to tunneling and adjusting alignment to avoid zones of concentration of wells, known well locations, or known circles of uncertainty.	Agree. Gas well studies will be conducted as part of future field work efforts and gas surveillance requirements will be in the contract specifications.
9.2	Pressurized tunneling has been demonstrated on projects to prevent damage to structures and can be accomplished with reduced cover without surface impacts.	Noted. Will study in detailed design. Current design accommodates various types ofmachines.
9.3	TBM Pre-purchase not recommended.	See Comment 7.4