County of Marin

Alto Tunnel Investigation and Cost Estimates Update – 2017

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Distribution

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Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

1.1 Project Description

In 2009, the County of Marin commissioned a corridor study of three specific bike/pedestrian routes connecting the city of Mill Valley and the town of Corte Madera. The Alto Tunnel route (see Figure 1), which follows the route of the former Union Pacific Railroad alignment and would include reopening the Alto railroad tunnel, was one of the alternates studied. In 2010, Jacobs Associates (now McMillen Jacobs Associates) prepared two cost estimates: one to reconstruct the Alto Tunnel with a multi-use pathway, using costs obtained from the then-recent reconstruction of the Cal Park Tunnel; the other to fill and permanently close the tunnel. In 2016, McMillen Jacobs Associates was retained by the County of Marin to perform an investigation into the tunnel and use the obtained information to update the cost estimates completed in 2010. This report provides a summary of the investigation and the updated cost estimates. The "do-nothing" alternate, i.e. leaving the tunnel as is, remains a third option.

1.2 Definitions

There are several terms used in this study that are unique to the tunnel construction industry. Definitions of selected tunneling terms are given below.

Face:	Location in tunnel where excavation is taking place.
Ground Support:	General term for the materials installed to stabilize the ground around a shaft or tunnel excavation.
Initial Support:	Any combination of ground support elements installed prior to installation of a final lining, including steel sets, shotcrete, spiling, etc.
Roadheader:	A piece of construction equipment that consists of a rotary cutterhead equipped with picks that are attached to a hydraulically operated boom, which in turn is mounted on a base frame.
Spiling or Forepoling:	A mining technique used to advance an excavation in caving ground by driving poles, slabs, or sheathing into the ground ahead of the excavation or simultaneously with it.
Stand-up Time:	A general term describing the length of time the tunnel is anticipated to remain stable without any support.
Steel Set:	Structural steel member used for ground support, curved to match the theoretical shape of the tunnel or shaft excavation and uniformly blocked or expanded to the excavated surface.
Top Heading and Bench:	Method of excavating a tunnel face by excavating, stabilizing, and supporting the upper portion of the tunnel first and then excavating and supporting the lower portion of the tunnel.

1.3 Report Organization

This report is organized into the following sections:

- Section 2.0 summarizes the previous studies performed for Alto Tunnel.
- Section 3.0 presents a chronology of work performed at the tunnel, as well as an interpretation of the existing conditions at the tunnel.
- Section 4.0 summarizes the work performed for this investigation, and the existing conditions of the Alto Tunnel.
- Section 5.0 presents the known historical conditions and results of the investigation.
- Section 6.0 presents the functional design criteria for the tunnel rehabilitation, as well as the approach to such rehabilitation.
- Section 7.0 presents a conceptual approach for filling and permanently closing the tunnel.
- Section 8.0 presents cost estimates for both rehabilitating and for filling and permanently closing the tunnel.
- Section 9.0 summarizes the tunnel feasibility study.
- The appendices include photos, tunnel rehabilitation figures, and the feasibility study level cost estimate.

1.4 Quality Assurance

This memorandum was prepared by Carol Ravano, Shawn Spreng, and staff members of McMillen Jacobs Associates. Technical review was provided by David Crouthamel of McMillen Jacobs Associates.

1.5 Limitations

This technical memorandum was prepared based on a limited assessment of the Alto Tunnel by drilling five boreholes and laser scanning where possible. Personnel entry into the Alto Tunnel for an internal inspection was not made; therefore, an assessment of the anticipated condition of the tunnel interior was developed based on the laser scan results, previous inspection reports, and comparisons with other tunnels of similar construction, condition, and age.

2.0 Previous Studies

Several studies and observations have been produced for the Alto Tunnel and the nearby Cal Park Hill Tunnel that are pertinent to the current feasibility study. These documents are summarized below.

- **Mill Valley to Corte Madera Bike and Pedestrian Corridor Study – Appendix B Tunnel Feasibility Study.** This work was completed in April 2010 and consisted of the following:
  - Functional design criteria to frame the Alto Tunnel rehabilitation technical requirements.
  - A feasibility-level cost estimate for reopening the Alto Tunnel and developing it for bicycle/pedestrian use, based on the construction bids for the Cal Park Hill Tunnel Rehabilitation.
  - A feasibility-level cost estimate for filling and permanent closure of the tunnel.
- **Alto Tunnel Scoping Study, Volume I—Background Information.** This document contains a detailed history of the tunnel and summarizes all reference materials available at the date of the scoping study. This work was completed in August 2001.
- **Alto Tunnel Scoping Study, Volume II—Engineering Summary and Proposed Supplemental Investigation**. This document provides a summary of the tunnel's condition for each reach of the tunnel. This work was completed in August 2001.
- **An Alto Tunnel Primer.** John Palmer, a member of the Scott Valley Homeowners' Association, prepared a series of articles describing the Alto Tunnel history, the technical studies completed through 2003, and his opinion of the issues associated with reopening the tunnel.
- **Cal Park Hill Tunnel Documents.** The Cal Park Hill Tunnel was built in 1884 as a single-track railway tunnel. In 1924, it was widened to accommodate a double track and was converted back to a single track before it was closed. It has been rehabilitated for use as a pedestrian and bike pathway by the County of Marin, and as a commuter rail transportation corridor by the Sonoma Marin Area Rail Transit Agency (SMART). The Cal Park Hill Tunnel original construction was similar to that of the single-track Alto Tunnel, and both tunnels were constructed in the same year.
  - Cal Park Construction Contract Documents (including design drawings, specifications, and geotechnical reports) and construction observations were considered in the development of the Alto Tunnel feasibility study.

3.0 Existing Conditions

3.1 Chronology

The following is a summary chronology of Alto Tunnel events pertinent to this tunnel investigation.

1884	The Alto Tunnel was constructed by Northwestern Pacific Railroad serving the Corte Madera to Sausalito communities. The 2,173-foot-long tunnel has a cross section 16 feet wide by 20 feet high. A single narrow-gauge track served the railroad. The Northwestern Pacific Railroad (RR) was a joint venture of Southern Pacific RR and Santa Fe RR.
1929	Southern Pacific RR became the sole owner of the Alto Tunnel.
1940	The Corte Madera–Sausalito line was closed to passenger rail traffic. Freight traffic continued along the line.
1950–1960s	Construction of homes adjacent to the railroad right-of-way on the Mill Valley side.
1971	The Corte Madera–Sausalito line and the Alto Tunnel were closed to freight rail traffic. At the time of the tunnel closure, heavy bulkheads were built at each end of the tunnel to prevent further access.
1972	The Golden Gate Transit District attempted to purchase the railroad's right-of-way, including the Alto Tunnel, for use as a commuter rail line. Community concerns over land ownership, right-of-way, noise, and rail safety prevented the purchase.
	Kaiser Engineers evaluated the condition of the tunnel for Golden Gate Transit and expressed its concerns about continued deterioration of the tunnel supports. Its recommendations were not implemented.
Late 1970s	The County of Marin purchased additional right-of-way from Southern Pacific RR.
1975	A lean concrete plug, approximately 124 feet long, was installed 170 feet south of the North Portal to improve stability and security.
1977	A private party offered to purchase the tunnel to use as a commercial enterprise. However, the sale was not successful because of fee title issues.
1979	Southern Pacific RR sealed the Alto Tunnel.
1981	A portion of the tunnel near the South Portal collapsed and caused a large depression adjacent to Underhill Road. The depression destroyed a residence and underground utilities.
	Some of the old rail right-of-way, excluding the Alto Tunnel, was converted to multipath use.
	The County of Marin hired the firm of Copple Foreaker Associates to study the tunnel in anticipation of its possible purchase from Southern Pacific. The Foreaker Study, as it came to be known, described the tunnel as being in an advanced state of decay because of moisture and neglect.
1982	A depression and a portion of the tunnel were backfilled with gravel. In total, 400 feet of the tunnel was filled with concrete or gravel. The Foreaker Study was updated to reflect the backfill work to fill the depression and tunnel. The dates of these events have not been confirmed.

1983	The County of Marin and the Northwestern Pacific Railroad Company entered into a 15-month option wherein the County would purchase a 1-mile portion of the railroad right-of-way. The agreement was completed in part.
1990	Northwestern Pacific Railroad Company sells a portion of the railroad property at the south end of the tunnel to the Mr. and Mrs. Michael Casey.
1994	The Marin County Department of Parks and Open Space hired Brady and Associates to explore the possibility of developing a bike path and reconstructing the Alto Tunnel.
2000	Safe Routes Marin showed interest in evaluating the possibility of utilizing the Alto Tunnel as part its bike master plan.
	The Marin County Department of Public Works researched and verified both the County's and the railroad's current rights-of-way. The portions of the tunnel still controlled by the railroad included the 275-foot portion from the South Portal north, and the 490-foot section from the North Portal south.
2001	The Congestion Management Agency of the Marin County Department of Public Works commissioned a new feasibility study from the firms of Quincy Engineering, Jacobs Associates, and Parikh Consultants to evaluate the Alto Tunnel for its possible conversion to pedestrian and bicycle use.
	An inspection team confirmed that access to the tunnel interior was blocked by a concrete plug.
2008	Marin County Department of Public Works commissioned the Corte Madera to Mill Valley Corridor Study to evaluate bicycle and pedestrian routes connecting Corte Madera and Mill Valley.
2010	Marin County commissioned Jacobs Associates to produce the Mill Valley to Corte Madera Bike and Pedestrian Corridor Study – Appendix B Tunnel Feasibility Study, which produced a feasibility level cost estimate for reopening the Alto Tunnel and developing it for bicycle/pedestrian use, based on recent construction bids for the Cal Park Hill Tunnel Rehabilitation.
2016–2017	McMillen Jacobs Associates was retained by Marin County Department of Public Works to perform a limited investigation into the tunnel to refine the 2010 feasibility level cost estimates for tunnel reconstruction and multi-use pathway construction and for filling and permanently closing the tunnel.

4.0 2017 Investigation

McMillen Jacobs Associates completed a limited investigation to gain visual access and perform laser scanning of the Alto Tunnel interior to determine its current condition and update cost estimates for tunnel reconstruction and pathway construction, as well as for filling and permanently closing the tunnel. The scope of work included drilling five boreholes into the tunnel from the public right-of-way (ROW) in two locations, as shown in Figure 2 and summarized in Table 1, and placing a down-hole scanning device into the tunnel to scan the tunnel interior for evaluation of the tunnel supports for distortion, collapse, and frequency of occurrence. There was no personnel access into the tunnel interior.

Table 1. Summary of Investigation Boreholes

Location	Boring No.	Date Completed	Ground Surface Elevation	Hole Length	Coordinates
Underhill Site	Borehole 1	02/22/2017	145 ft	120 ft	37.914705° N, -122.524281° W
	Borehole 2	02/15/2017	147 ft	330 ft	37.914722° N, -122.524289° W
Chapman Site	Borehole 3	03/28/2017	325 ft	380 ft	37.917164° N, -122.525717° W
	Borehole 4	03/17/2017	325 ft	238 ft	37.917198° N, -122.525770° W
	Borehole 5	03/14/2017	324 ft	363 ft	37.917220° N, -122.525808° W

Local homeowners and the community were informed of the investigation work through two public meetings that were held in January 2017. Approval for right-of-entry was obtained by an agreement with Union Pacific Railroad. An encroachment permit was filed for the Alto Tunnel Study with the City of the Mill Valley, and permission to install monitoring wells was permitted by the Marin County Environmental Health Services. The drilling locations are shown in Figure 3 and Figure 4.

On February 6, 2017, drilling commenced for the investigation at the Underhill Site. Drill Tech Drilling and Shoring (DrillTech) performed the borehole drilling and casing using a Klemm 806 double-head drill rig to drill the hole and simultaneously place a 5-1/2-inch steel outer casing for the length of the borehole. A slightly larger hole with a 7-5/8-inch steel casing was used in the overburden soils in the top 0 to 15 feet of the holes. Each of the five boreholes was drilled at an angle to penetrate the tunnel at locations spaced approximately 300 feet apart along the historical tunnel alignment. Subsurface conditions encountered in all five borings were similar, with the driller noting up to 15 feet of soil underlain by variably soft to hard Franciscan Complex rocks. All boreholes successfully penetrated the tunnel. A camera and light were advanced to the bottom of each borehole through the installed casing. Video was recorded at the bottom of the borehole to investigate the structure of the tunnel and material encountered within the cavity. During the initial investigation, it was discovered that Borings B-1, B-2, and B-3 terminated in collapsed rubble.

After completion of the drilling project, a concrete Christy box well-monument was constructed at the ground surface to cover and protect each borehole.

On April 18, 2017, McMillen Jacobs and its scanning subconsultant Renishaw deployed a C-ALS Cavity Profiler to the bottom of each borehole through the installed casing. The cavity profiler provided video imagery as well as a three-dimensional (3-D) model of survey data points of the tunnel interior encountered at each borehole. Because collapsed material was found in the crown of the tunnel in B-1, B-

2, and B-3, scanning was not possible; however, the boreholes were surveyed for alignment. An intact tunnel interior was observed in Boreholes B-4 and B-5. The known and inferred conditions of the tunnel are shown on Figure 1 in Appendix B; a discussion of the findings can be found in Section 4.2. Examples of the cross sections observed in Borehole B-4 are shown in Figure 3 of Appendix B. Photos of the drilling process are shown in Appendix A.

5.0 Tunnel Condition

5.1 Known Historical Conditions

The North Portal of the Alto Tunnel is located between Tunnel Lane and Montecito Drive. Several residences are located immediately adjacent to the portal structure. The inactive rail bed is overgrown with vegetation and is poorly drained. Access to the tunnel is prevented by a steel bulkhead at Station 277+61.9. The tunnel was originally supported by redwood timber (10 by 14 inches) sets in a 7-segment configuration spaced 1 to 5 feet apart. Wood lagging, spanning between the sets along both sides and the crown of the tunnel, consists of split redwood approximately 2 inches thick and 5 to 8 inches wide. As the 7-piece sets deteriorated, they were replaced by 5-piece sets of similar dimensions. It was reported that in the 300 feet of tunnel north of the South Portal, 7-piece sets were also replaced with 5-piece sets.

There is a 30.9-foot-long concrete portal barrel, constructed in the 1950s, at the north end of the tunnel. South of the barrel, there are 139 lineal feet of gunite over either steel sets, timber sets, or timber and steel sets. The documents that we have reviewed do not give a definite description of the method of installation or of the materials used in this section. The gunite may have been placed over the original timber sets; newer steel sets may have been placed and the existing timber sets removed; or the timber sets may have been left in place between the newer steel sets. Additional investigation should be performed in this section to confirm what materials are present. Because of the inadequate drainage, approximately 18 inches of standing water were present in this section during the 2001 investigation. In 1975, a 125-foot-long lean concrete "plug" was placed between approximately Stations 275+92 and 274+68. This plug was placed to increase the stability of this section of tunnel and the ground above it, and for security purposes. There is a remnant wooden bulkhead at the north end of this plug, which was visible during the 2001 investigation. To the south of the concrete plug, there is reported to be an approximately 170-foot-long zone of uncompacted backfill material. However, based on a review of the historical documents, it is not possible to definitively determine if the backfill material is present. The scan in the tunnel performed in 2017 also was unable to confirm the presence of the fill. For estimating purposes, it has been assumed that the fill is in place, and the timber sets are intact in this fill area.

5.2 Results of 2017 Investigation

5.2.1 North Portion

Boreholes B-4 and B-5 allowed laser scanning of the Alto Tunnel's northern portion; these scans confirm that the tunnel is intact in these sections, with 7-piece sets at those locations. The scan at B-4 extends between approximately Stations 268+00 and 270+00 and shows 7-piece timber sets spaced at approximately 4 feet on center, with no noticeable distress or deformations. There are approximately 2 to 3 feet of standing water in this portion of the tunnel. Boring B-5 terminated close to the tunnel side wall at approximate Station 271+30, so only a single line scan could be performed at this location. The line scan indicates that the tunnel is open at this location. Standing water was not observed at B-5. Discrete cross sections taken from the laser scan are shown in Figure 3 of Appendix B.

Based on the results of the laser scanning at B-4 and B-5, as well as previous information that indicates that the northern portion of the tunnel is generally in good rock (as evidenced by the lighter support originally installed here), we have assumed for the base-case cost estimating purposes that the tunnel is intact with no significant failures between the assumed southern extents of the uncompacted fill at approximately Sta. 272+98 and the central portion of the tunnel at approximately Sta. 267+00. This is shown schematically on Figure 2 in Appendix B.

In order to evaluate the effect of a range of potential ground conditions on the cost estimates, a sensitivity analysis assuming reasonable best-case and worst-case scenarios was performed. For the northern half of the tunnel, the best-case scenario is similar to the base case, except that intact timber sets are assumed to be in place instead of the potential uncompacted fill. The worst-case scenario assumes that everything not shown to be intact (i.e. visual at the north portal, and the observed extents of scans at B-4 and B-5) is collapsed.

5.2.2 South Portion

Videos of Borings B-1, B-2, and B-3 reveal that all three boreholes terminate in collapsed rubble material. There was no significant gap between the rubble and the intact rock and/or timber supports. This indicated that the tunnel is completely filled with collapsed material at these locations. Since there was no measurable void present, scanning was not performed at these borings. The boreholes were accurately measured with gyroscopic surveying equipment, and it was confirmed that they broke through the tunnel and encountered rubble at approximately the theoretical tunnel crown location.

Based upon document review, the southern half of the tunnel is known to be in worse condition than the northern half. We know this because the geology is generally weaker, and heavier supports were installed during original construction. During an inspection into the tunnel in the 1970s, a few small localized collapses were found in this half, as well as one moderate collapse approximately 900 feet north of the south portal. The collapses revealed by the drilling indicate that the condition of the tunnel has deteriorated since it was last entered in the late 1970s. For base-case cost estimating purposes, it has been assumed that the entire southern half of the tunnel, south of Station 267+00, is either filled with collapsed material or significantly distressed. This is shown schematically on Figure 2 in Appendix B.

Best and worst-case scenarios were also assessed for the southern half of the tunnel. Here, the worst-case scenario is similar to the base case, except that there is an additional 100 feet of assumed collapsed material adjacent to the observable scan at B-4. The best-case scenario assumes that portions of the tunnel not observed to be collapsed are intact. It was assumed that each observed collapse is 100 feet in extent. The south portal area is known to be collapsed and filled, and was thus not changed.

6.0 Tunnel Reconstruction and Pathway Construction

This 2017 report includes only the Alto Tunnel portion (Segment 8) of the full Alto Tunnel corridor route. The full Alto Tunnel corridor route, and costs to develop the full route including pathway approaches to the tunnel, are discussed on pages 2-47 to 2-70, Chapter 4, and Appendix L of the 2010 Mill Valley-Corte Madera Corridor Study. This report does not discuss or provide costs for other segments of the route or the pathway approaches to the tunnel because no new information or evaluations of those segments were conducted as part of this scope of work.

6.1 Tunnel Repair Types

The basic tunnel reconstruction design would be to line the entire tunnel, from portal to portal, with a wide flange steel section, either W6 or W8, spaced from 3 to 5 feet apart, depending on the existing conditions in the tunnel, with shotcrete applied over and between the steel sets. Based on the information gathered during the investigation and an analysis of previous studies, as outlined in Section 4.0, five different tunnel repair types have been developed. These repair types and a table showing their locations are shown in Appendix B.

The new tunnel would have a clear opening 11.5 feet wide and over 14 feet tall. The new tunnel size was selected so that the new steel sets could be placed within the old, intact timber sets. This eliminates the high cost and risk associated with tearing out old timber supports, many of which are likely in distress, to stand new supports of a similar size to the original sets. The proposed tunnel size is taller and slightly wider than Cal Park's 11.4-foot-wide wide bicycle/pedestrian tunnel.

Five different repair support types (see Table 2) have been defined to address the range of tunnel conditions anticipated:

- Type 1 – North Portal barrel and in the section with gunite over steel or timber sets: W6x25 steel sets at 4-feet on center (o.c.); shotcrete. Annular space between sets and existing gunite would be backfilled with low strength concrete.
- Type 2 – Concrete plug section; the plug would be excavated using a small roadheader: W6x25 steel sets at 4-ft o.c.; shotcrete.
- Type 3 – Inferred intact northern portion of tunnel between Sta 272+98 and 267+00: W8x35 steel sets at 5-ft o.c.; shotcrete. Annular space between new sets and existing timber supports would be backfilled with low strength concrete. In area of potentially uncompacted fill, the fill would be mucked out prior to set placement.
- Type 4 – Collapsed and inferred not intact sections with limited rock and debris: Excavate through portions of the tunnel partially filled with rock and debris; place shotcrete as initial support prior to placement of steel sets. W8x35 steel sets at 3-ft o.c.; shotcrete. Annular space between new sets and temporary shotcrete would be filled with low strength concrete.
- Type 5 – Collapsed and inferred not intact sections with extensive rock and debris: Excavating through portions of the tunnel filled with rock and debris using channel spile presupport in crown, continuous wood lagging elsewhere, potentially using top heading and bench method; W8x35 steel sets at 3-ft o.c.; shotcrete.

In areas where the steel sets are placed within a larger opening (Types 1, 3, and 4), stayform (expanded wire mesh) would be installed on the back flange of the steel set and shotcrete would be applied over the stayform. After the shotcrete shell is formed, the annular space between the stayform and the original tunnel would be backfilled with low strength concrete. A similar process was performed in the Cal Park Tunnel. Types 2 and 5 tunnel support are not within larger openings; therefore, the shotcrete would be applied directly over the substrate. In all support types, the shotcrete thickness would be a minimum of 4 inches thick between steel sets. The shotcrete section thickens at the steel set to encapsulate the steel set with a minimum of 2 inches of cover for corrosion protection purposes. Below the tunnel springline, additional shotcrete would be placed between the steel sets and troweled to produce a smooth and uniform surface to minimize injury potential for pathway users.

Table 2. Tunnel Rehabilitation Repair Types

Repair Type	Steel Set Size and Spacing	Excavation/Initial Support	Low Strength Concrete Backfill
1	W6 x 25 @ 4-ft o.c.	None necessary.	Yes
2	W6 x 25 @ 4-ft o.c.	Roadheader through low-strength concrete.	No
3	W8 x 35 @ 5-ft o.c.	Excavate through uncompacted fill. No initial support anticipated.	Yes
4	W8x 35 @ 3-ft o.c.	Excavate through limited collapsed rock and debris; use shotcrete as initial support.	Yes
5	W8 x 35 @ 3-ft o.c.	Excavate through extensive collapsed rock and debris, cemented pea gravel; use spiling as pre-support.	No

6.2 Tunnel Amenities

The following sections describe the tunnel amenities assumed for cost estimating purposes.[1] These amenities and the general tunnel operation are similar to what are in place at the Cal Park pedestrian tunnel. Details are shown on Figure 6 in Appendix B.

6.2.1 General Description

The proposed pedestrian/bicycle path tunnel would have the following general characteristics:

- The 2,173-foot-long tunnel would be converted from a single-track rail tunnel with current interior dimensions of approximately 16 feet wide by 20 feet tall to a bicycle/pedestrian tunnel with interior clear dimensions of approximately 11.5 feet wide by 14 feet tall.
- The existing intact timber sets in the tunnel would not be removed; a smaller diameter bicycle/pedestrian tunnel would be constructed inside the larger diameter tunnel.
- The entire length of the proposed bicycle/pedestrian tunnel would be lined with steel sets with shotcrete and wire mesh lagging. The annulus (space) between the smaller diameter

[1] The costs to construct the pathway approaches to the tunnel are included in the Mill Valley/Corte Madera 2010 report and not included in this report.

bicycle/pedestrian tunnel and the existing timber-lined tunnel would be backfilled with a low-strength concrete.

6.2.2 Ventilation and Lighting

Natural air ventilation is sufficient for the normal tunnel usage. Natural ventilation relies on weather (wind, temperature, and pressure difference due to elevation) to maintain air flow. Historically, tunnels shorter than about 2,500 feet and with noncombustible elements and usage can be ventilated naturally. However, a ventilation system would be installed to address the emergency scenario of a maintenance vehicle or fire in the tunnel. For cost estimating purposes, this system would comprise:

- Twelve fans spaced at 200 foot intervals
- Movement of 3,000 cubic feet per minute (CFM) per vane axial fan providing 15 feet per minute of air movement through the tunnel

Low energy lighting would be provided just outside the portals as well as throughout the length of the tunnel. Lighting would have a backup power supply.

6.2.3 Safety and Security

In addition to ventilation and lighting, the following safety and security provisions are used for cost estimating purposes:

- Radio communications (leaky coaxial cable, cell phones if possible) for public safety in the tunnel
- Emergency call stations at portals and at 200-foot increments in the tunnel
- A system for user notice when maintenance, emergency vehicle, or another blockage is present in tunnel
- Security cameras at portals and at approximately 300-foot increments in the tunnel
- Lockable portal gates
- Bollards at portals to block unauthorized vehicle entry
- Anti-graffiti coating of portal structures and tunnel walls (optional)

6.2.4 Fire Prevention and Suppression

The following fire safety provisions are used for cost estimating purposes:

- Fire alarm pull stations at portals and at 200-foot increments in the tunnel
- Sprinkler system in the tunnel
- 1,000 gpm fire hydrants on the portal sides of the emergency access turnarounds and wet-standpipe fire hose connections at 200-foot increments in the tunnel

6.2.5 Emergency Access

The following incident response provisions are recommended but are not included in this cost estimate (see 2010 Mill Valley to Corte Madera Corridor Study, Segments 7 and 9a, Figures 2-24 and 2-28):

- A 20-foot-wide traffic corridor from street to portals: 12-foot-wide paved path with 4-foot-wide compacted earth shoulder on either side.
- Overhead clearance of 13 feet minimum
- A 16-foot-wide shunt or hammerhead vehicle turnaround as close as possible to each portal (225 feet from North Portal, 150 feet from South Portal)
- Pull-off parking near the portals for emergency vehicles

7.0 Alto Tunnel Filling and Permanent Closure

If the Alto Tunnel is not reconstructed with a multi-use pathway, it could be left as is (the "do-nothing" alternate) or the tunnel could be filled and permanently closed. The latter option was considered in response to community members and elected officials, who asked, in the context of the 2010 Mill Valley/Corte Madera Corridor Study, that this option be investigated should the reconstruction/pathway not be pursued and it is later deemed necessary to improve future stability of the tunnel and surrounding areas. Therefore, the 2010 cost estimates were updated for backfilling the tunnel with a stable material and permanently closing the tunnel. This Investigation and Cost Estimate Update makes no assumptions, evaluations, or findings about *who* would be responsible for the cost of stabilizing the tunnel, nor about *who* would be liable for any future land or building movement.

For purposes of the cost estimate, a staged approach to filling the tunnel was assumed, whereby the largest voids would be filled with relatively low-cost, controlled-low-strength-material (CLSM), followed by higher cost material with higher mobility to fill the smaller voids in the collapsed and inferred not intact sections. Secondary, and possibly tertiary rounds of drilling, verification, and grouting would be required to ensure all voids are filled. This process is shown in Figures 8 and 9 in Appendix B. It is assumed that standing groundwater in the central portions of the tunnel would be incorporated into the cement backfill during the placement process. Standing water at the north portal would be pumped out, treated if necessary, and disposed of in accordance with local regulations.

The following describes the approach of the tunnel filling process for cost estimating purposes. The first phase of backfilling would place CLSM into the intact northern half of the tunnel through existing boreholes B-4 and B-5. CLSM would be pumped until the tunnel and borings are filled. Next, a low viscosity grout such as neat cement would be pumped into the collapsed and inferred not intact sections in the southern half of the tunnel through existing boreholes B-1, B-2, and B-3. Grout would be pumped until the tunnel and borings are filled. Next, a bulkhead would be constructed at the north portal, and the northern 170 feet of tunnel would be backfilled with CLSM. Prior to construction of the bulkhead, a pipe with injection ports would be installed along the tunnel crown for contact grouting.

The second phase of backfilling would be targeted at verifying that the tunnel is backfilled and filling any remaining voids. A series of 5-inch-diameter secondary grout holes would be drilled to intercept the tunnel. The boreholes would be videoed to determine the extent of remaining voids. If extensive voids (>1 cubic yard) are found, the voids would be filled with CLSM. If no voids or only small voids are found, the boreholes would be filled with grout to refusal. Following secondary grouting, the pre-installed pipe at the North Portal would be grouted to fill any remaining voids.

If no large voids are found during the second phase of backfilling, then the operation is complete. If extensive voids are discovered and filled during secondary grouting, then a tertiary round of boreholes would be drilled and grouted, in a similar manner as described for secondary grouting.

8.0 Feasibility Level Cost Estimate

This 2017 cost estimate update includes only the Alto Tunnel portion (Segment 8) of the full Alto Tunnel corridor route, which is further discussed in the 2010 Mill Valley-Corte Madera Corridor Study on pages 2-47 to 2-70. Cost estimates to develop pathway approaches are discussed and provided in Chapter 4 and Appendix L of the 2010 Mill Valley-Corte Madera Corridor Study. Cost estimates for the other segments of the Alto Tunnel route were not updated as part of this effort because no new information or evaluations of those segments were conducted as part of this scope of work.

8.1 Estimate Methodology

An opinion of probable construction cost was developed for both the Alto Tunnel reconstruction with multi-use pathway, as well as the backfilling and permanent closure option, and are presented in Appendix C. The estimates are based on the figures in Appendix B. The estimate for tunnel reconstruction with multi-use pathway are for in-tunnel work only; improvements outside the tunnel are not included. Pathway improvement costs outside the tunnel are identified in the 2010 Mill Valley/Corte Madera Corridor Study.

The scope of work and work sequence for the tunnel reconstruction and multi-use pathway construction includes:

- Establishing work laydown areas; the specific locations have not been identified but a lump-sum cost has been added to the estimate for this purpose
- Excavating, re-supporting, and relining collapsed sections of the tunnel
- Re-supporting and relining non-collapsed sections of the tunnel
- Paving a smooth invert
- Installing tunnel utilities and fire / life safety systems
- Backfilling the exploratory boreholes from the surface
- Site restoration of the laydown areas

The scope of work for the backfilling and permanent closure of the tunnel includes:

- Establishing work laydown areas at the North Portal of the tunnel, and at strategic borehole locations along the tunnel alignment.
- Placing a controlled low strength material into the larger voids in the tunnel by pumping it through the existing boreholes
- Placing a fluid grout (assumed cement-based) into the collapsed and inferred not intact sections of the tunnel
- Drilling secondary boreholes from the surface along the tunnel alignment
- Performing secondary grouting (assumed cement-based) along the alignment to fill additional voids not filled during the initial phase of backfilling/grouting
- Drilling tertiary boreholes from the surface to verify complete ground filling (estimate assumes no additional tertiary grouting).

- Site restoration of the laydown areas

For each element of work making up the project, a takeoff was performed that quantified the amount of work and materials required for that element in such terms as cubic yards of excavation, steel supports, cubic yards of shotcrete, grout, etc. A cycle time analysis was performed to determine the likely rate at which the task could be executed based on a specific crew size and equipment spread handling the relative amounts of each type of material required. In this fashion, the cost of performing each discrete task was tabulated in terms of labor, equipment, material, and subcontract costs. The construction cost estimate is based primarily on production rates calculated for conditions specific to this contract.

Resource rates for labor, equipment, materials, and subcontracts are detailed in the cost estimates in Appendix C. Labor wage rates for the estimate are based on current prevailing wage rate determinations for Marin County, published by the State of California. These rates are segregated into base wages and fringes to calculate applicable payroll taxes.

The construction equipment used in the estimate is based on the US Army Corps of Engineers Construction Equipment Ownership and Operating Expense Schedule – Region VII, which covers the Southwest Region. Recent budgetary vendor quotes for steel rock support, shotcrete, etc. are used in this estimate. For other items, a combination of sources such as RS Means or recent cost data from similar projects is used with adjustments as appropriate. Subcontractor pricing and production rates are primarily taken from recent contractor budget quotes for minor subcontractor items, and escalated and prorated costs for similar work performed on the Cal Park Hill Tunnel.

This project is estimated assuming the contract would be a design-bid-build delivery. Indirect costs are calculated and added to the direct cost using this basis of contract delivery. The general conditions costs are detailed as part of the Indirect Costs in the estimate. The Indirect Costs include items such as Equipment Ownership/Mobilization, Field Supervision, Bonds Insurance and Taxes, and Contractor Markup. Local and State Sales Taxes are also included where applicable.

The construction estimate is reported in June 2017 dollars. Escalation is added to the base estimate at a rate recommended by McMillen Jacobs (3%) based on surveys of construction trends, and computed to the midpoint of construction for each activity indicated.

This estimate was prepared in conformance with the Association for the Advancement of Cost Engineering’s Cost Estimate Class 3 recommendations (AACE, 1997); however, it should be cautioned that significant portions of the tunnel have not been observed. The design definition is now recommended at 20%, and McMillen Jacobs recommends the owner carry a minimum of 20% for design allowance to accommodate any changes as the design is completed.

The following assumptions were made for the cost estimates:

- All work is estimated on a single 8-hour shift, 5-day workweek.
- The estimates assume no utility conflicts.
- The contract would be fixed-price, lump-sum, using a design-bid-build delivery.
- A disposal site is located within two hours of the site.
- Potential water discharged from the tunnel would be treated and discharged into a local sewer.

- Sufficient potable water is available at each site.

The following exclusions were made for the cost estimates:

- All sewer discharge fees are excluded.
- All required permits and easements would be obtained prior to bidding the contract.
- Adjacent pathway improvements were not included.

8.2 Estimate Summary

8.2.1 Alto Tunnel Reconstruction and Multi-Use Pathway Construction

A summary of the estimated cost of reconstruction of the Alto Tunnel and Multi-Use Pathway Construction is given in Table 3.

Table 3. Summary of Estimated Cost of Alto Tunnel Rehabilitation

PROJECT COST	OPINION OF PROBABLE COST (Millions)	
	Base Case	Best to Worst Case Range
PROJECT CONSTRUCTION COSTS		
Subtotal Construction Cost	$25.0	$22.3 – $26.9
Escalation	$0.5	$0.4 – $0.7
Contingency	$5.0	$4.5 – $5.4
Total Construction Costs with Contingency	**$30.4**	**$27.2 – $33.0**
PROJECT DEVELOPMENT COSTS		
Survey, Technical Studies, & Engineering Design (15%)	$4.6	$4.1 – $4.9
Environmental Analysis, Documentation, & Permits (10%)	$3.0	$2.7 – $3.3
Project Administration (10%)	$3.0	$2.7 – $3.3
Construction Management (10%)	$3.0	$2.7 – $3.3
Design Services During Construction	$1.3	$1.3
Allowance to Address Right of Way Issues[1]	$1.5	$1.5
Total Project Development Costs	**$16.4**	**$15.0 – $17.6**
TOTAL ESTIMATED PROJECT COST	**$46.8**	**$42.1 – $50.5**

[1] A placeholder allowance developed by others.

8.2.2 Alto Tunnel Filling and Permanent Closure

A summary of the estimated cost of filling and permanently closing the Alto Tunnel is given in Table 4.

Table 4. Summary of Estimated Cost to Fill and Permanently Close Alto Tunnel

PROJECT COST	OPINION OF PROBABLE COST (Millions)
PROJECT CONSTRUCTION COSTS	
Subtotal Construction Cost	$4.49
Escalation	$0.02
Contingency	$0.90
Total Construction Cost with Contingency	**$5.41**
PROJECT DEVELOPMENT COSTS	
Survey, Technical Studies, and Engineering Design (15%)	$0.81
Environmental Analysis, Documentation, and Permits (10%)	$0.54
Project Administration (10%)	$0.54
Construction Management (10%)	$0.54
Design services during construction	$0.40
Allowance for ROW permitting	$0.25
Total Project Development Costs	**$3.08**
TOTAL ESTIMATED PROJECT COST	**$8.5**

9.0 Summary

Our limited investigation into the interior of the Alto Tunnel reveals that the condition of the southern portion of the tunnel has deteriorated since it was last inspected in the late 1970s, with all three borings in the southern half intercepting collapses. The two borings penetrating the northern portion of the alignment encountered open tunnel with no apparent signs of deformation. The cost estimates are based on these observations, as shown on Figure 2 in Appendix B.

Preliminary designs for the reconstruction of the Alto Tunnel and construction of a multi-use pathway were developed. A new tunnel interior cross section similar to the Cal Park pedestrian tunnel cross section was chosen so that the new tunnel supports could be placed within the existing, intact supports without first removing them. Five support types were developed to accommodate different existing tunnel conditions and support types. The appurtenant fire/life/safety, and operations and maintenance features within the finished tunnel are assumed to be similar to what was installed at Cal Park. A separate design for the complete filling and permanent closure of Alto Tunnel was also developed. A new opinion of probable cost was prepared based on the inferred tunnel conditions and the reconstruction and permanent closure designs. The preliminary level estimate of construction costs, assuming a 20% contingency to reflect design definition and current uncertainties, is approximately $46.8 million in 2017 dollars to rehabilitate the tunnel, and $8.5 million to backfill and permanently close the tunnel.

10.0 References

Association for the Advancement of Cost Engineering (AACE). August 1997. Cost Estimate Classification System, AACE International Recommended Practice No. 17R-97.

Jacobs Associates. 2009. Task 4.1. Geotechnical Study.

Jacobs Associates. 2001. Alto Tunnel Scoping Study. Prepared for Marin County Department of Public Works.

Palmer, John. 2003. An Alto Tunnel Primer.