George Miller Regional Trail
A San Francisco Bay Trail Segment in Steep Terrain

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Synopsis: A new segment of the San Francisco Bay Trail was recently constructed to provide safe and easy access to an exceptionally scenic area of shoreline hills west of Martinez, California. The new paved multi-use trail follows the alignment of a 1.7-mile-long section of old county road previously closed due to numerous significant slope stability and drainage issues. Because of the history of instability at the site, geotechnical engineering input from Cal Engineering & Geology was given high priority throughout the planning and design process. Identifying the significant geotechnical challenges and addressing them early contributed greatly to the successful implementation of the project.

Project Background

The San Francisco Bay Trail is a planned 500-mile multi-use trail around the entire San Francisco Bay. The goal of the Association of Bay Area Governments (ABAG) San Francisco Bay Trail Project is to build a continuous shoreline pedestrian and bicycle path as close to the San Francisco Bay margin as feasible. To date 343 miles of trail have been completed. The Bay Trail passes through all nine Bay Area counties, 47 cities, and across seven toll bridges.

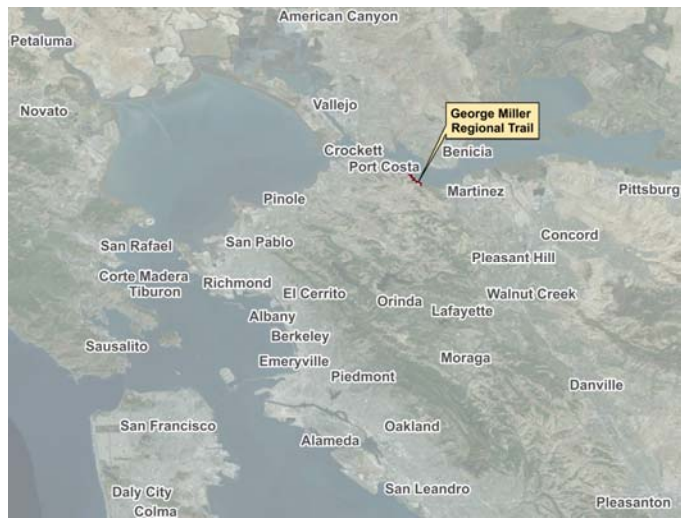

Figure 1. Project location

A new paved 1.7-mile-long segment of the Bay Trail has been completed in Contra Costa County west of Martinez along the steep hillslopes of the East Bay Regional Park District's (EBRPD) Carquinez Regional Shoreline. (Figure 1) The new trail was dedicated in November 2014 and named in honor of retired U.S. Congressman George Miller in appreciation of his almost four decades of work and support for this project. Completion of this trail segment closed a critical gap in the San Francisco Bay Trail system and offers trail users safe and easy access to an exceptionally scenic area. In addition, the George Miller Regional Trail links the communities of Crockett and Port Costa with the county seat of Martinez providing a convenient route for bicycle commuters.

Figure 2. A large landslide at Station 176 closed Carquinez Scenic Drive permanently in 1983.

The George Miller Regional Trail was built along the alignment of a closed section of Carquinez Scenic Drive. This concrete-paved road, constructed in about 1914 by the California Highway Commission, was the first improved road to link east and west Contra Costa County. The narrow road winds in and out of steep hillslopes on the south side of the Carquinez Strait between the historical towns of Crockett and Martinez. Over the years the road has been particularly difficult and costly for the County to maintain. Much of the roadway embankment was affected by progressive downslope creep and sliding, the upslope cuts failed regularly, and drainage features were inadequate. In 1983, as a result of damage from several large landslides and due to the overall deterioration of the roadway, a 1.7-mile-long section of Carquinez Scenic Drive was permanently closed to traffic. (Figure 2)

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Despite the lack of maintenance, hazardous conditions, locked gates, and warning signs, local hikers and cyclists continued to use the closed portion of Carquinez Scenic Drive because it was the only access to this scenic area and because alternate routes connecting the communities of Crocket and Port Costa with Martinez were many miles out of the way and in some cases extremely steep.

In early 2002, the ABAG San Francisco Bay Trail Project awarded a grant to the Contra Costa County Public Works Department to develop a plan to convert the closed section of Carquinez Scenic Drive to a multi-use hiking and cycling trail. Cal Engineering & Geology was retained to carry out a preliminary geotechnical investigation of the site, develop design alternatives, and, in partnership with Alta Planning + Design, prepare a planning study and development plan that refined the conceptual design, identified funding sources, and incorporated public input.

Preliminary Geotechnical Investigation

Much of the focus of the preliminary geotechnical investigation was to identify and characterize all existing and potential stability problems along the proposed trail alignment. All notable upslope and downslope failure areas along the alignment were identified and mapped. (Figure 3) Other relevant features such as the condition of the existing roadway pavement and drainage facilities were also systematically documented.

The significant embankment failure areas identified are listed below to give an indication of the extent of the stability issues at the site:

Station 128: A 300-foot-wide embankment failure with loss of outer lane and 10-foot-high headscarp. Failure of embankment and underlying older landslide material.

Station 154: A 100-foot-wide embankment failure with loss of both lanes and up to a 12-foot-high headscarp. Failure of embankment and underlying older landslide material.

Station 161: A 200-foot-wide embankment failure with loss of outer lane and up to a 15-foot-high headscarp. Failure of embankment and underlying older landslide material.

Station 172: A 50-foot-wide embankment and slope failure with loss of 3 feet of outer lane and a 10-foot-high headscarp. Failure is within the 150-foot-wide previous failure of downslope area. Failures are possibly a consequence of previous removal of slope toe by railroad.

Station 176: A 200-foot-wide embankment and slope failure with complete loss of 100 feet of road embankment and up to an 18-foot-high headscarp. Failure is possibly a consequence of previous removal of the slope toe for railroad construction.

Station 191: A 50-foot-wide embankment failure with loss of outer lane and up to a 15-foot-high headscarp. Failure of embankment and underlying colluvial material.

The significant upslope failures areas included the following:

Station 162: A 50-foot-wide slope failure. Earthflow-type failure onto road.

Station 167: A 50-foot-wide slope failure. Earthflow-type failure onto road.

Station 176: A 150-foot-wide cut slope failure with flow of material onto road. Veneer-type failure of weathered rock cut. Failure material consisted of fine material up to large boulders. Potential for future failure.

Station 191: A 250-foot-wide cut slope failure with deposition of material onto road. Raveling-type failure of weathered rock cut. Failure material consisted of fine material. Potential for future raveling.

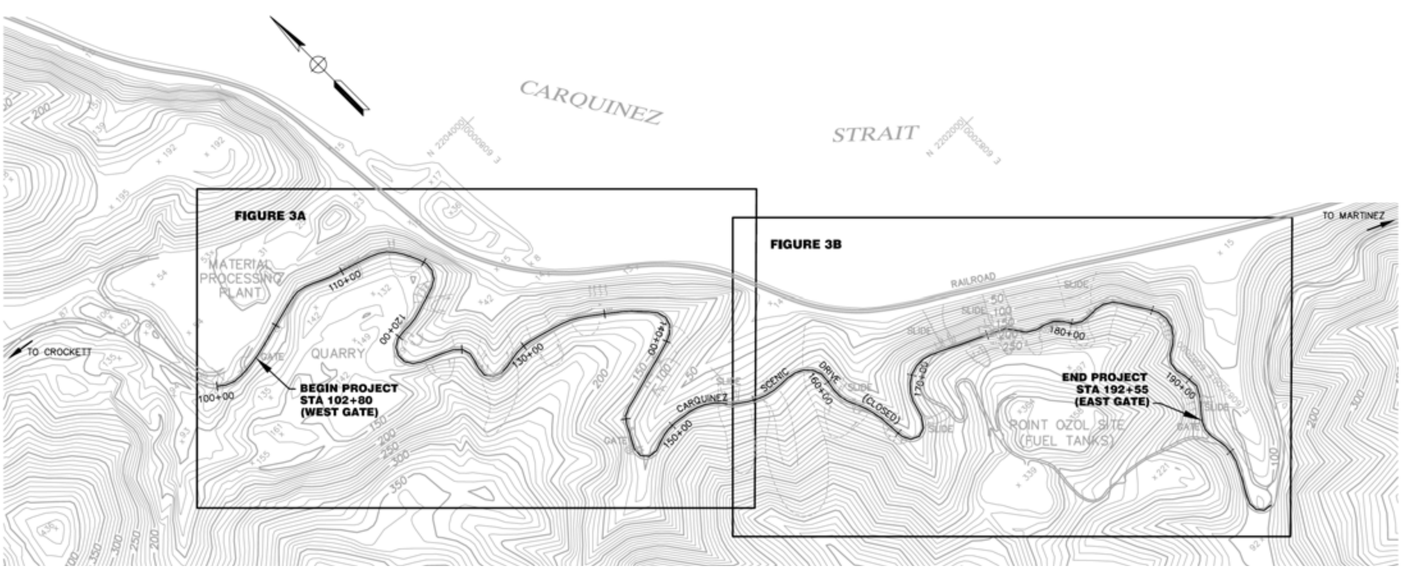

Figure 3. Carquinez Scenic Drive alignment

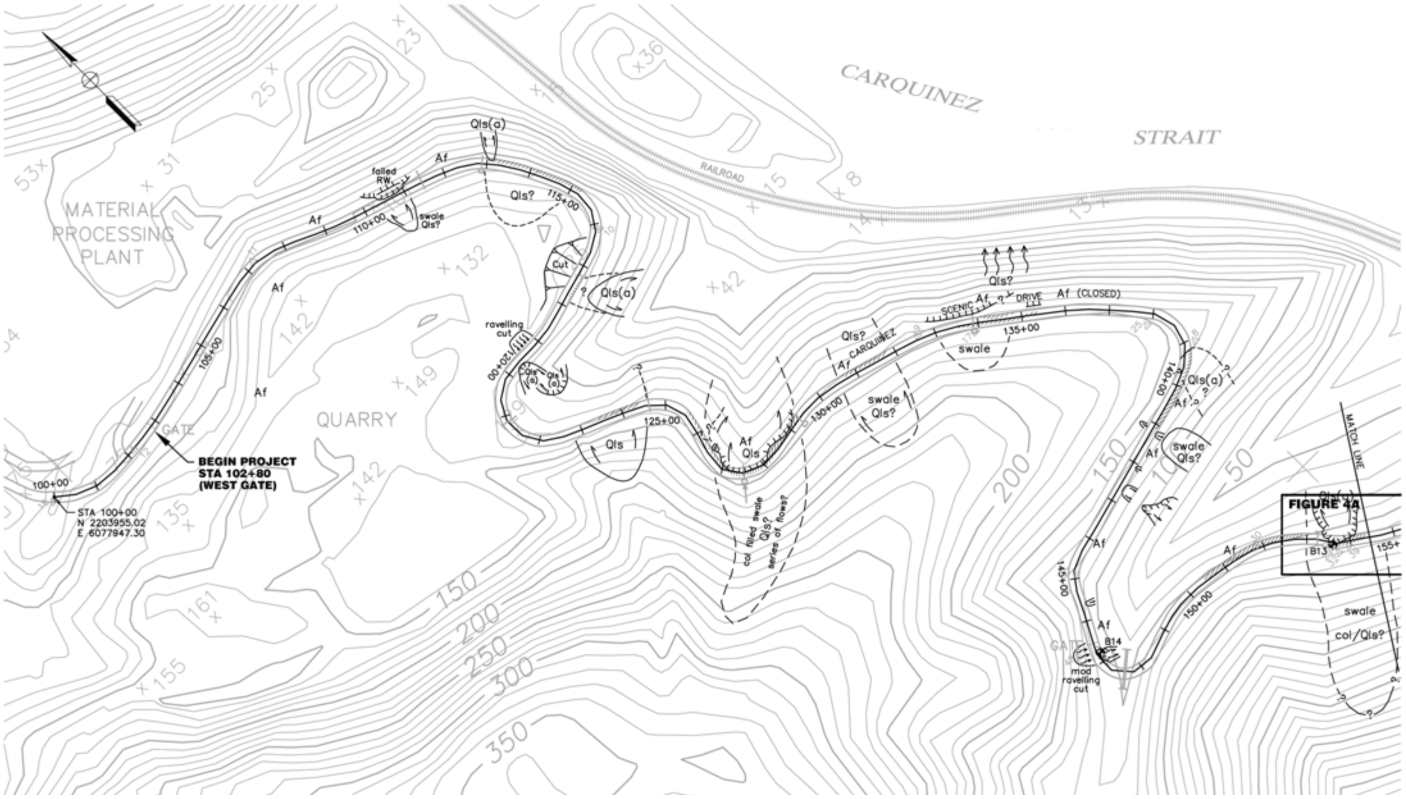

Figure 3A. Geologic mapping of the northwestern half of the trail

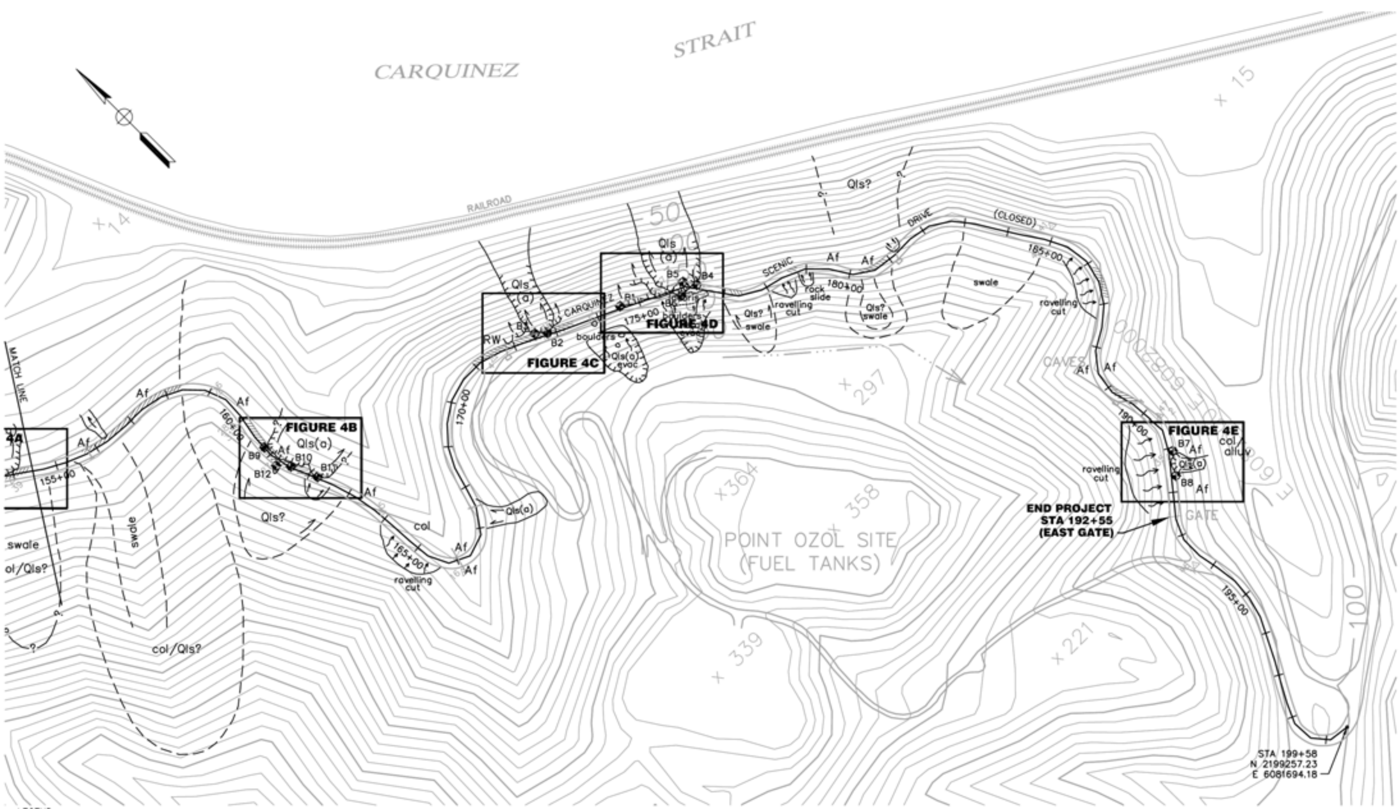

Figure 3B. Geologic mapping of the southeastern half of the trail

Subsurface investigation for this project was confined to the County's right-of-way and particular care needed to be taken to ensure that drilling activities did not present a hazard to the heavily-used main line railway located below along the shoreline at the base of the hills.

Fourteen test borings were drilled at six embankment failure locations. The test borings ranged in depth from 4 to 37 feet below ground surface. Based on field and laboratory testing of soil and rock samples, preliminary geotechnical design parameters and recommendations were provided for the development of stabilization design alternatives.

Design Alternatives

With the preliminary geotechnical investigation completed, CE&G developed a comprehensive conceptual-level design for the 1.7-mile-long multi-use trail project. This design was intended for planning and costing purposes. Along much of the alignment basic standard designs were sufficient to adequately categorize the anticipated scope of work and costs. However, for the more significant embankment and upslope failure areas more detailed site-specific design alternatives needed to be developed and evaluated. Design alternatives included embankment reconstruction where possible and retaining walls of various types and configurations at the steeper sites.

At the most challenging locations, such as at Station 176, the design alternatives included hybrid structures such as segmental retaining walls supported by cast-in-drilled-hole concrete pile foundations, soldier pile and lagging walls laterally supported with steel tie beams connected to an upslope row of soldier piles, and a steel viaduct structure supported on pile foundations with tieback anchors to allow landslide debris to flow underneath. (Figures 4A, 4B, and 4C)

In all cases the design alternatives, while making use of up-to-date geotechnical engineering practices, were intended to be buildable primarily with conventional construction materials, methods, and equipment and only a minimal amount of specialty contracting. The intent was to present alternatives that could accomplish the design objectives with minimal construction cost uncertainty. These conceptual-level design concepts and engineer's estimates were used by the County and then EBRPD to secure grant funding and later as a solid starting point for developing the final project plans, specifications, and estimate for the project.

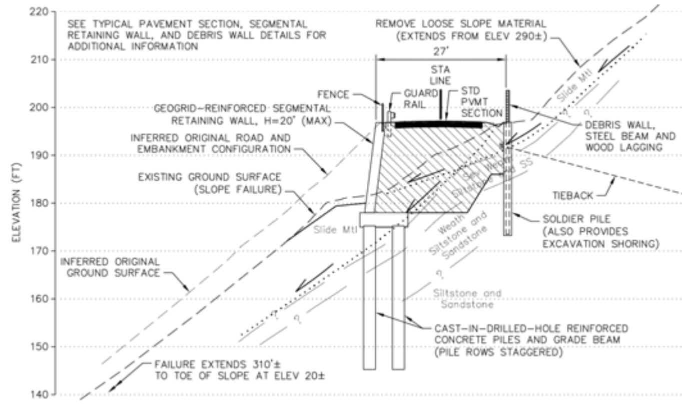

Figure 4A. Conceptual design alternative for Station 176 showing geogrid-reinforced segmental retaining wall supported by cast-in-drilled-hole reinforced concrete piles and grade beam

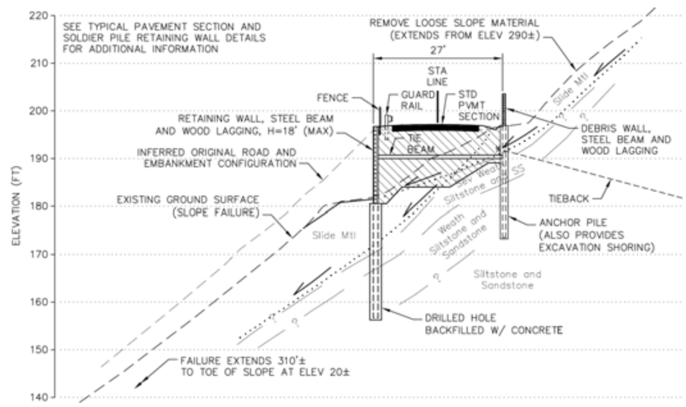

Figure 4B. Conceptual design alternative for Station 176 showing a soldier pile and lagging retaining wall laterally supported with steel tie beams connected to an upslope row of anchor piles with tieback anchors

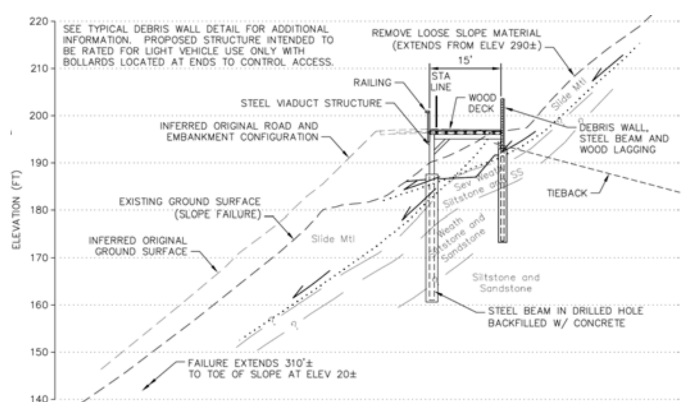

Figure 4C. Conceptual design alternative for Station 176 showing a steel viaduct structure supported on pile foundations with tieback anchors to allow landslide debris to flow underneath

Final Geotechnical Investigation and Design Efforts

In 2011, the EBRPD retained Nolte Vertical 5 and CE&G to complete the final geotechnical investigation, develop the preliminary and final design of the trail, obtain environmental clearance, and prepare construction documents.

Since addressing the slope stability issues at the site was the most significant cost element of the project, a value engineering process was used to help select the design alternative(s) to develop in the design phase. The value engineering activity involved over a dozen participants including representatives of the EBRPD, Nolte Vertical 5's civil and structural engineers, CE&G's geotechnical engineers, as well as cost estimators and construction managers. Through this process the group came to the conclusion that it would be most efficient and cost effective if all the significant failure areas could be mitigated using the same basic design concept. The consensus was that the design concept that was versatile enough for all locations was soldier pile and lagging retaining walls for embankment stabilization and reconstruction and soldier pile and lagging debris walls to protect the path from upslope failures. To meet the design criteria of low required maintenance, concrete rather than wood lagging was to be utilized.

As proposed in the earlier conceptual-level design, the extensive areas of distressed roadway embankment crest would be reconstructed with geogrid-reinforced fill and, where necessary, toe support would be provided by cast-in-drilled-hole concrete piles.

A geotechnical design challenge arose when it was determined that tieback anchors originally planned for the retaining structure at steep Station 176 could not be utilized because the time and cost associated with obtaining the needed easement. CE&G determined that if a light-weight material such as geofoam was used for wall backfill, the need for tieback anchors could be eliminated. This allowed the soldier pile and lagging retaining wall system chosen for the other slide repairs to be a viable and appropriate option at the Station 176 site.

Figure 5. Portable hydraulic drilling rig situated on 1.25H:1V slope at large landslide at Station 176 (same view as Figure 9)

Figure 6. Truck-mounted drilling rig equipped with hollow stem augers

Another innovative design was used to address the possibility that at some locations downslope failures could retrogress and widen, threatening the trail embankment on either side of completed soldier pile and lagging retaining walls. At some susceptible retaining wall sites additional soldier piles would be installed to beyond the limits of concern. These piles would be fully backfilled to the ground surface but only low strength concrete backfill was specified for the upper portion of the pile so that, if the need arose, the backfill could be removed and retaining wall lagging installed.

After the design and layout of the retaining and debris walls became more defined, CE&G began the challenging final subsurface investigation program. A total of 33 test borings were advanced through bedrock using hollow-stem augers and rock core barrels with truck-mounted, track-mounted, and portable hydraulic drill rigs. (Figures 5 and 6) The program entailed a total of 10 days of drilling. Often, two drilling teams worked simultaneously at either end of the project.

At Station 176, the location of the largest slide, access to the site was extremely difficult and drilling crews had to excavate steps by hand 25 feet up the steep landslide debris to the drilling pad. Care was taken to not destabilize the 6-foot-diameter boulders that littered the slope above and not to allow debris to fall down the slope to the busy railroad line 200 feet below.

In total, the subsurface investigations for this project involved drilling and logging 1,380 feet of soil and rock (over a quarter mile) with over 1,000 SPT and Modified California samples collected and reviewed.

Funding and Construction

Funding sources for design and construction of the George Miller Regional Trail included a TIGER II grant, Contra Costa Transportation Authority Measure J Pedestrian/Bike funds, SAFETEA grants, EBRPD Measure WW funds, and San Francisco Bay Trail Project funding via the State Coastal Conservancy.

Construction of the project was carried out by Top Grade Construction between July 2013 and October 2014 with Parsons Brinckerhoff providing construction management services. (Figures 7, and 8) Final construction costs for the project were $5.7 million.

Cal Engineering & Geology was retained to provide engineering support during construction, which included the observation and documentation of 385 piles that were drilled to construct the debris walls, stabilization piles, and retaining walls. There were no significant changes made to the design during construction.

Figure 7. Installation of steel soldier piles at Station 176

Figure 8. Light weight geofoam backfill is being placed behind the retaining wall at Station 176

Figure 9. Completed retaining and debris walls at Station 176 (same view as Figure 5)

Conclusions

Completion of the George Miller Regional Trail is significant because of the positive social and environmental impacts provided to the local community and the San Francisco Bay Area as a whole. The new facility provides safe and easy access to an exceptionally scenic area of shoreline open space and once again links the communities of Crockett, Port Costa, and Martinez. (Figures 9, 10, and 11)

Because of the history of ground instability at the site, the lead agencies on this project, Contra Costa County Public Works Department and then the East Bay Regional Park District, gave a high priority to developing long-term solutions to these problems. Involving a geotechnical engineering firm to lead the initial planning efforts and again to participate in an active and significant capacity throughout the design and construction phases meant that geotechnical challenges were properly characterized and addressed early and remained in clear focus throughout the process. This proactive and interactive approach to geotechnical engineering involvement certainly contributed greatly to the successful implementation of this project.

Figure 10. Celebrating the opening of the George Miller Regional Trail in November 2014. George Miller in center of photograph

Figure 11. Members of the public enjoying the newly completed trail