WHITE PAPER

A Storm Drain Success Story: Two Tunnels and a Landslide

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Abstract

Discover the challenges and the innovations associated with a storm drain project sporting a construction cost of $15.1 million along San Ramon Canyon in the affluent coastal city of Rancho Palos Verdes in Los Angeles County. The east side of the canyon was suffering from cyclical deposition of soil from the active Tarapaca Landslide, which resulted in 30-foot vertical slopes that filled the canyon and allowed large rain events to deliver sediment and floodwater to 25th Street below. More than 250 homes were in harm's way and access was threatened to both 25th Street and Palos Verdes Drive East (PVDE) switchbacks.

The Harris Team developed an elegant solution using trenchless technology, which required two tunnel s and a gravity buttress fill design to divert the collected stormwater to the ocean at the bottom of the coastal bluffs, shore up a deficient drainage system downstream and mitigate the runoff inspired transport of debris from an active landslide.

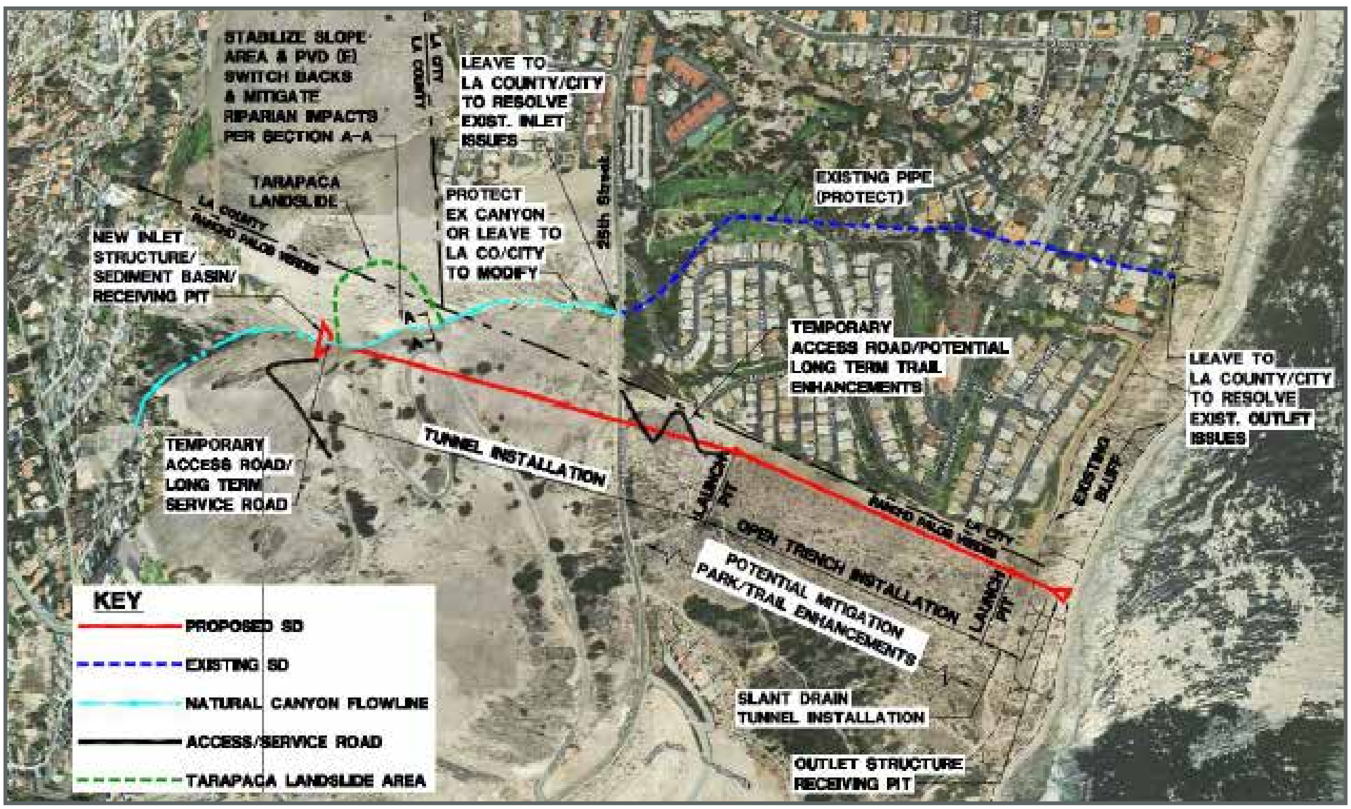

Figure 1. Location overview map.

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The focus of this paper will include the design and construction of the following critical project elements:

- **Lower Tunnel** (300' long, 80" hand-mined tunnel in solid bedrock at 38% grade atop a 150' high Pacific Ocean coastal bluff)
- **Upper Tunnel** (2,000-foot long 80-inch rib and lagging tunnel though a dormant landslide at 14% grade that was as much as 90-feet deep below PVDE)
- **Inlet and Outlet Structures** (requiring CIDH piles with grade beams and tieback anchors)
- **Access Road and Gravity Buttress Fill** (restoring the natural canyon while maintaining access)

1. Introduction

After years of planning and coordination with the County and City of Los Angeles it became clear to the City of Rancho Palos Verdes staff that if this $15.1 million San Ramon Canyon Drainage Improvement Project was going to be built, they would have to take the lead themselves. This included obtaining $9.4 million in funding from an Integrated Regional Water Management Storm Water Flood Management Grant, Proposition 1E, designing and constructing the largest public works project that the city had ever undertaken. The project became all the more urgent after the flooding that was experienced during the winter of 2010, as shown in Figure 2.

Figure 2. Flooding on 25th Street/Palos Verdes Drive South (PVDS) during a January 19th, 2010 storm.

The project included significant canyon grading to form a stabilizing buttress fill adjacent to the Tarapaca Landslide (see Figure 3) and 100-year plus storm drainage diversion system (see Figure 4). The project included some unique and innovative elements to protect more than 250 homes that were directly downstream and two of the region's major arterials, namely 25th Street/Palos Verdes Drive South, which was being regularly flooded downstream, and Palos Verdes Drive East (switchbacks) directly to the west, which had slopes that were being undermined at a rate of up to five feet per year.

Figure 3. Tarapaca Landslide east of San Ramon Canyon and Palos Verdes Drive East (switchbacks).

The steep San Ramon Canyon watershed consists of 184 acres (Figure 5—Hydrology Map) and produces a 100-year storm peak flow rate of 262 cubic feet per second (cfs),

Figure 4. Overview of San Ramon Canyon Storm Drain looking downstream.

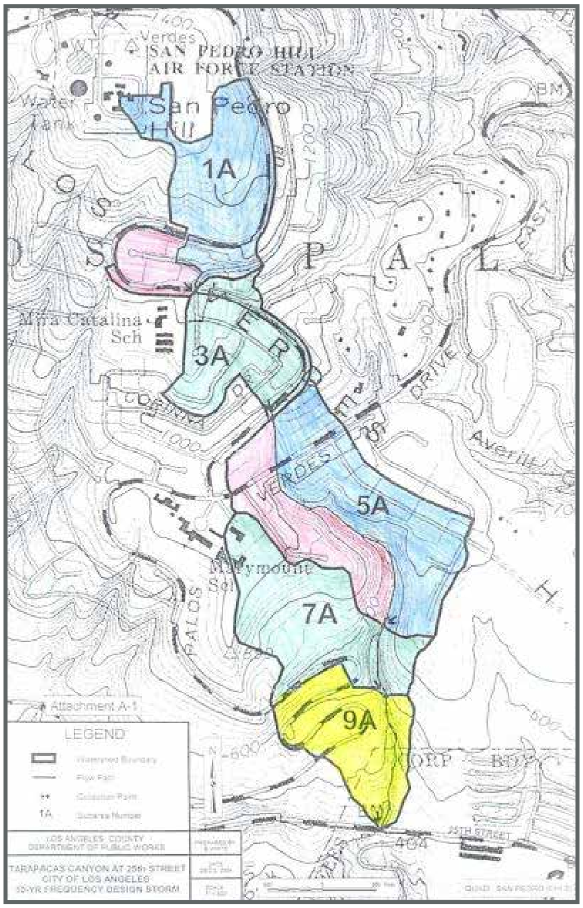

Figure 5. San Ran Canyon hydrology map.

which includes a percentage increase burn and bulk factor as required in Los Angeles County in the event the storm event follows after a wild fire in the natural canyon.

2. Proposed 54-Inch Diameter Welded Steel Pipe Mainline

A 48-inch diameter welded steel pipe mainline was required to convey the 100-year storm flows, however through a value engineering process the pipeline was upsized to a 54-inch diameter welded steel pipe because it was determined that the increase in pipe costs would more than offset the related annular space grouting costs and would also provide a superior level of protection with the potential to add a rehabilitative liner many years in the future without reducing the 100-year level flood protection.

The somewhat unconventional use of steel pipe for the storm drain mainline was determined to be the most appropriate material because of the high velocities anticipated which would be in excess of 54 feet per second (fps) and would also be heavily laden with sediment and cobbles up to 8-inch in diameter. Other pipe materials that were considered included reinforced concrete pipe (RCP), High Density Polyethylene (HDPE) pipe and HOBAS (fiberglass) pipe, but were all eliminated from consideration due to their inability to resist long-term scouring in combination with shattering impacts from bouncing cobbles. Cobble and sediment were decided to be included in the flow, rather than separated from the flows, as part of the project's "Returning the River to the Sea" design approach. More specifically, there was no room to fit the tradition large sediment basin to yield clean water at the upstream inlet of the system and, with the prevailing 6% creek profile grade at the inlet and narrowness of the existing canyon, such a large "level" basin would be difficult to build. Thus, natural sediment (8-inch cobble and smaller) was allowed to continue to the beach, just the same as the natural creek process that has occurred for thousands of years before the surrounding land was developed, allowing the replenishment of sand and cobbles at the beach. This also eliminates a considerable amount of maintenance by not having to remove reoccurring sediment from an upstream inlet structure (see Figure 6).

2. Tunnel #1—Downstream 300-Foot Long Jacked Steel Sleeve Tunnel

The 80-inch diameter steel sleeve tunnel (see Figure 8) was excavated through solid bedrock via a Rotohead excavator (see Figure 7) at a steep slope (38% profile grade) within the 150-foot high coastal bluff along the Pacific Ocean. Once the steel sleeve was jacked into place then the 54-inch diameter steel storm drain pipe could be installed, with the annular space grouted. A top-down tunneling method was required because of environmental concerns (limiting impacts and equipment on the beach) and due to limited access on the beach (the only access point was from White Point-Royal Palms Beach approximately three quarters of a mile to the southeast).

Figure 6. Completed upstream inlet structure.

Figure 7. Lower tunnel Rotohead excavator.

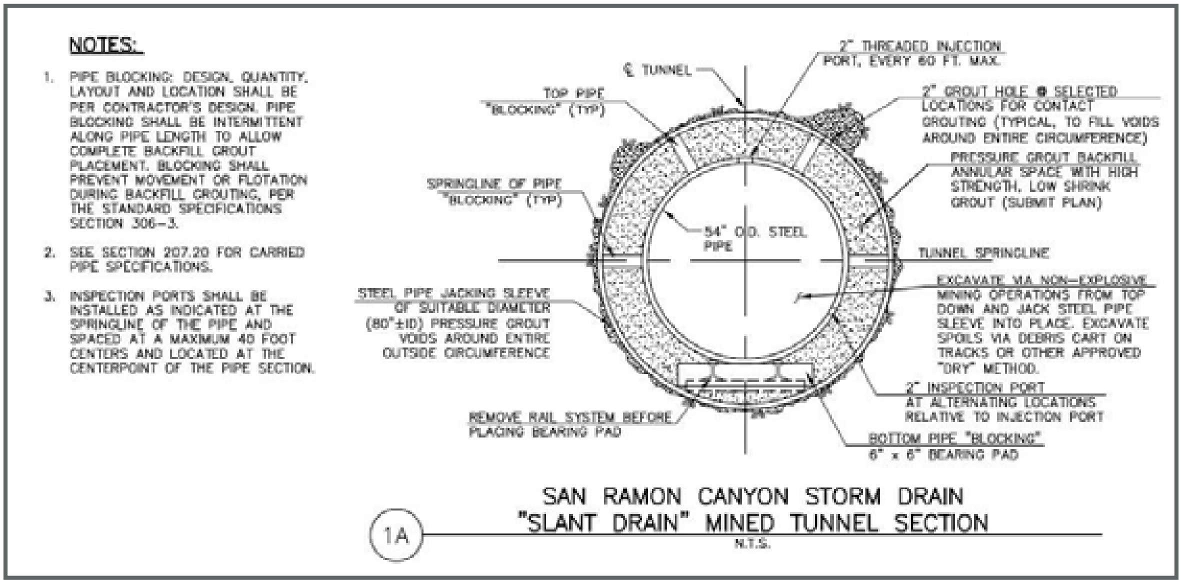

Figure 8. Typical lower tunnel trench cross section.

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It was anticipated that a hand-mine tunnel method, similar to the recently completed successful McCarrell Canyon Storm Drain project to the northwest, would be utilized. However, the methodology was left open to the contractor who chose a Rotohead system instead to speed up production. Other factors that contributed to the jacked steel sleeve method included:

- **Short Length** (conducive to jacking due to non-excessive friction forces);
- **Installation Direction** (the environmental sensitive beach below had limited access which drove the requirement to construct from the top-to-bottom, and most tunneling methods utilizing hydraulic systems require a bottom-to-top installation direction to allow drilling mud pipe conveyance systems to be drained, extended and re-pressurized as the drilling head moves forward); and
- **Bedrock Conditions** (the varying bedrock hardness, which ranged from ancient landslide deposits to hard basalt, thus it is preferred to position an operator who can directly see the tunnel face and can react to varying bedrock material conditions and modify methods in real time.)

Figure 9. Lower tunnel launch pit 150-feet above the Pacific Ocean (with Catalina Island beyond).

3. Tunnel #2—Upstream 2,200-Foot Long Rib and Labbing Tunnel

The 80-inch diameter rib and lagging tunnel (see Figure 10) was excavated through a dormant landslide via a Rotohead excavator (see Figure 11) at a fairly steep slope (14% profile grade) for a distance of 2,200-feet

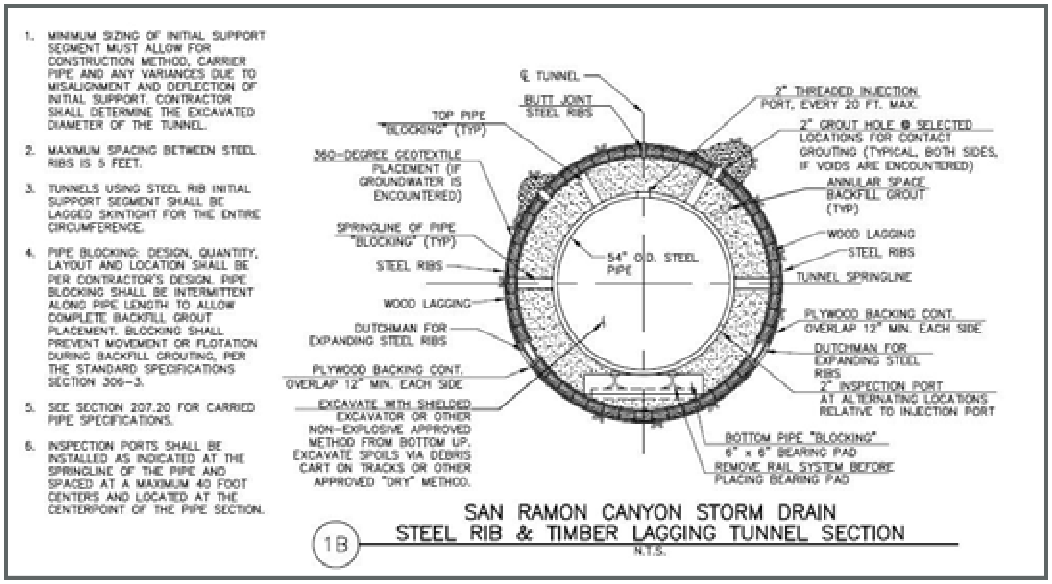

Figure 10. Typical upper tunnel trench cross section.

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Figure 11. Upper tunnel Rotohead excavator as it emerges into the upstream inlet structure.

Figure 12. Completed upper rib and lagging tunnel prior to installation of the 54-inch storm drain pipe.

Figure 13. Upper tunnel launch pit just below PVDS/25th Street.

Figure 14. San Ramon Canyon bottom looking upstream with barren Tarapaca Landslide soil on the right.

that was as much as 90-feet below PVDE (switchback roadway). The rib and lagging system requires a sophisticated TBM with hydraulic expanders at the tail end to allow the “W”-beam ribs to be fitted with a “Dutchman” expander that is bolted into place and effectively presses the rib and lagging (consisting of 3-inch thick x 5-inch wide x 5-feet long Douglas pine boards) into the surrounding soil. Once the entire rib and lagging tunnel was placed (see Figure 12), then the 54-inch diameter steel storm drain pipe could be installed, again with the annular space grouted. The preferred bottom-up tunneling method was utilized (see launch pit in Figure 13) facilitating the removal of spoils (on the return trip down). Each return trip back up included an otherwise empty muck cart loaded with another complete set of rib and lagging materials. The rib and lagging method was chosen because the length of tunnel and amount of friction anticipated in the irregular rocky soil would have prevented the use of a jacked sleeve installation, even with the addition of multiple mid-system jacks that create an “inch-worm” effect and a bentonite lubrication system.

4. Tarapaca Landslide Stabilization

The Tarapaca Landslide consisted of a 30-foot high near vertical eroded slope (see Figure 14 and previous Figure 3) that continued to slough into the canyon bottom and then be carried downstream during major storm events. The slide area was stabilized by introducing an engineered fill, complete with sub-drain mainline and "fingers" (see Figure 16). The canyon bottom was then lined with a rip rap rock, which included smaller rock fill in the interstices to allow a four wheel drive maintenance vehicle to access the entire length, and the adjacent slopes were landscaped with native plants and irrigated (see Figure 15). The landslide itself (surface and underlying soils) was "off limits" due to private ownership and as such will either require future grading by the landowner or left to simply "heal" through years of corrective erosion and localized settling.

Figure 15. San Ramon Canyon adjacent to Tarapaca Landslide with rip rap rock bottom and landscaping in progress.

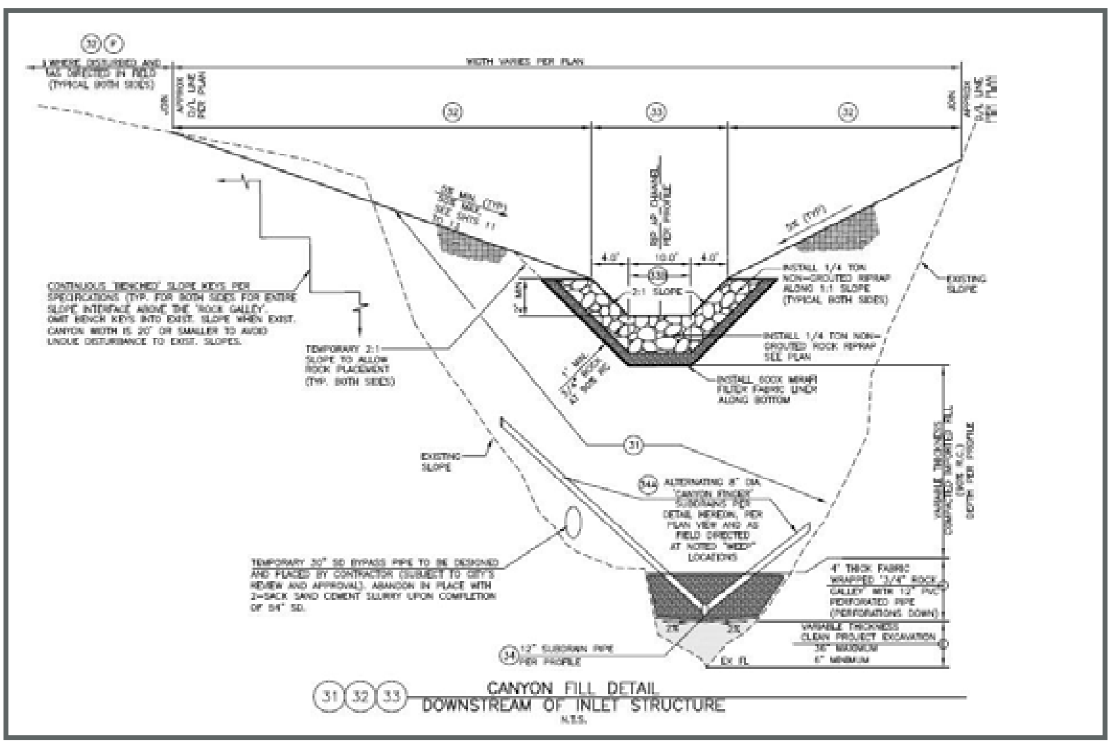

Figure 16. Tarapaca Landslide buttress fill typical section (looking upstream).

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5. Environmental Clearances

The environmental clearances for the project included:

- U.S. Army Corp of Engineers (Section 404 of the Clean Water Act)
- California Department of Fish and Wildlife (1602 — Streambed Alteration Agrement)
- California Coastal Commission — Federal consistency determination
- Los Angeles Regional Water Quality Control Board — 401 certification
- City of Rancho Palos Verdes — CEQA lead agency

The environmentally conscious design also included provisions for protecting the beach during construction via extensive Best Management Practices (BMPs) to avoid contamination during construction. Note the natural canyon above serves as a "bio-swale" to infiltrate low flows from the hilltop residences.

6. "Project Numbers" Summary

Table 1. San Ramon Canyon Storm Drain "Project Numbers".

PHASE	BEGIN	END
Project Study Report and Pre-Design	April 2009	June 2011
Design Phase	July 2011	October 2012
Bid Phase	December 2012	January 2013
Construction Phase	April 2013	September 2014

LINE ITEM	TRUE COST (% CHANGE)	ENGINEER'S ESTIMATE
Original Construction Bid	$15,140,000 (-1.7%)	$15,400,000*
Post Award Value Engineering **	-$422,676 (-2.8%)	
Project Change Orders***	+$731,874 (+5.6%)	
Final Construction Costs	**$15,449,198**	

Pre-Construction Soft Costs	$950,919	
Construction Soft Costs	$1,350,995	
Total Project Cost =	**$17,751,112**	

NOTES:
*Engineer's (base) estimate (without a 10% contingency)
**Value engineering in pipe material & outlet structure shoring/construction yielded net credits to the city
***Change orders included approximately +$600k to enhance PVDE roadway and drainage (not in original design), +$260k in changes related to the original design and a <$130k> credit to cover city staff weekend/OT work.

7. Additional Project Highlights and Innovations:

Additional highlights and innovations for the San Ramon Canyon Storm Drain project include:

- Saving costs per a value engineering suggestion by the contractor to replace the proprietary "snap together" steel storm drain pipe that was specified with a more economical and readily available steel pipe that required field welding. This resulted in a $315,334 credit to the city.
- Saving costs per a value engineering suggestion by the contractor to replace the soldier piles/ slope anchor outlet structure shoring with a more economical and easier to install soil nail system to shore up the bluff at the tunnel outlet point (see Figure 17). This resulted in a $107,342 credit to the city.
- Constructing an aesthetically pleasing outlet structure at the beach (see Figure 18), which is well camouflaged even a short distance down the beach.
- Creating an improved maintenance access road/trail to the beach below 25th Street in the sloped area where the long tunnel launch pit was situated (see Figure 19).
- Creating a significant maintenance access road from PVDE (switchbacks) to the inlet structure in San Ramon Canyon (see Figure 20).
- Savings realized by the net positive (credits to city) change orders on project allowed the City to add drainage and roadway paving improvements along the entire length of PVDE (switchbacks).

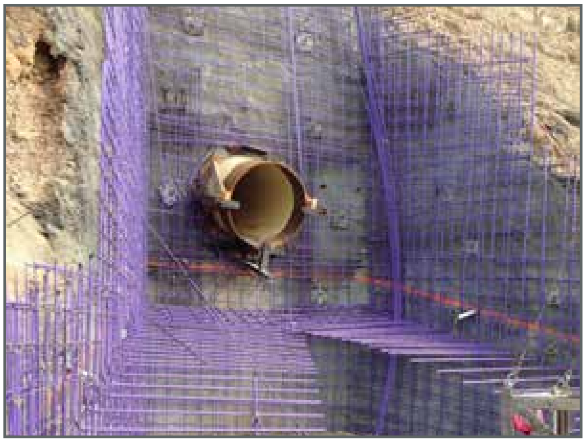

Figure 17. Outlet structure under construction with soil nail shoring system visible.

Figure 18. Outlet structure completed.

Figure 19. Completed maintenance access to the beach below 25th Street/PVDS.

8. Conclusion

The San Ramon Canyon Storm Drain in Rancho Palos Verdes presented some unique engineering challenges and provided an opportunity to significantly benefit the local community through improved flood protection and safer access to the entire Palos Verdes Peninsula. Designing and successfully constructing a storm water diversion tunnel to the beach with net positive change orders (credits to city) is a proud accomplishment for City staff and Harris & Associates design team. The recent APWA 2014 Project of the Year Award is icing on the cake. With a potential "El Nino" storm system predicted to be looming in the 2014-15 winter season it is reassuring to have these improvements in place. It is the presenter's goal to share the lessons learned and project innovations so that they hopefully inspire a "can do" attitude for other engineers who might be considering a similar storm drain diversion project that requires tunneling in a coastal bluff setting.

Figure 20. Completed maintenance access to the San Ramon Canyon inlet structure.

About the Author

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Randy ensures that water and traffic go where they should, often with breathtaking results. One example is his team's work on the picture-perfect Sunset Strip Beautification Project, which earned Outstanding Community Improvement Project Awards from the American Society of Civil Engineers' LA Section and at the state level Region 9.

Drawing on three decades of experience for 50 public agencies, Randy specializes in storm drain, roadway and sewer design projects—shepherding them from the competitive proposal stage, to PS&E preparation stage, and through construction.