Cliff Tunneling for Storm Water Diversion

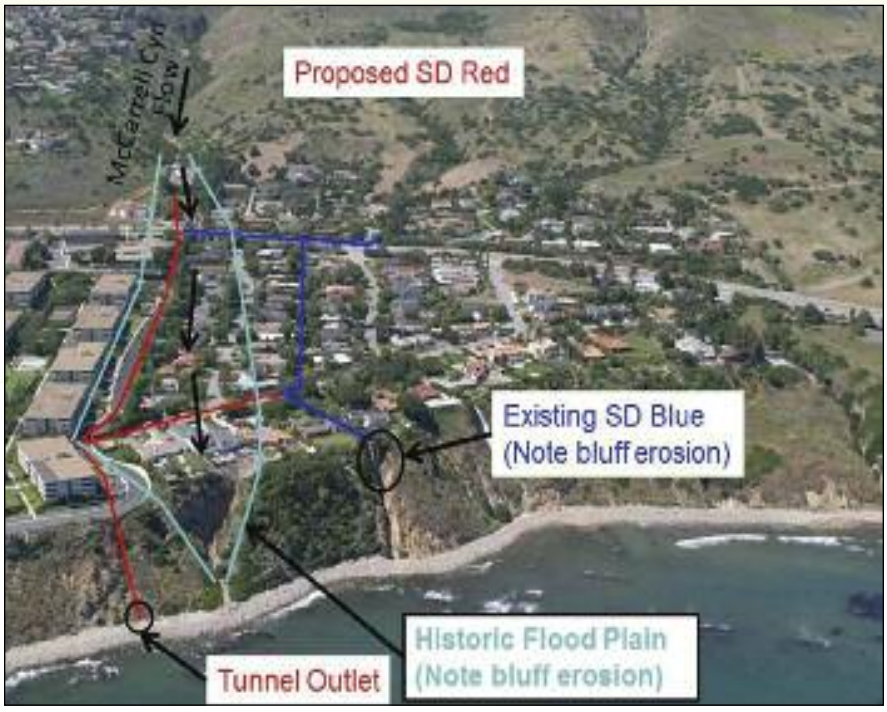
Randall Berry, PE
Harris & Associates

Some said the $7.5-million McCarrell Canyon Storm Drain System could not be constructed, but City of Rancho Palos Verdes staff and the Harris team rose to the challenge to complete this system that is essentially "returning the river to the sea."

The proposed 100-year storm drainage system in the City of Rancho Palos Verdes includes some unique and innovative elements to stop the erosion of coastal bluffs – erosion that jeopardized multi-million-dollar homes that were built within the historical flood plain. (See Photo 1.) The project became all the more urgent after the flooding that was experienced during the winter of 2005.

California's steep McCarrell Canyon watershed consists of 340 acres and has a 100-year storm peak flow rate of 630 cubic feet per second (cfs). The affected downstream areas that were in harm's way (due to reoccurring flooding and sediment deposition) include Palos Verdes Drive (South), which is the primary roadway access into the Palos Verdes peninsula where there are single-family residences, Bay Club condominiums, and Saint Peter's Presbyterian Church.

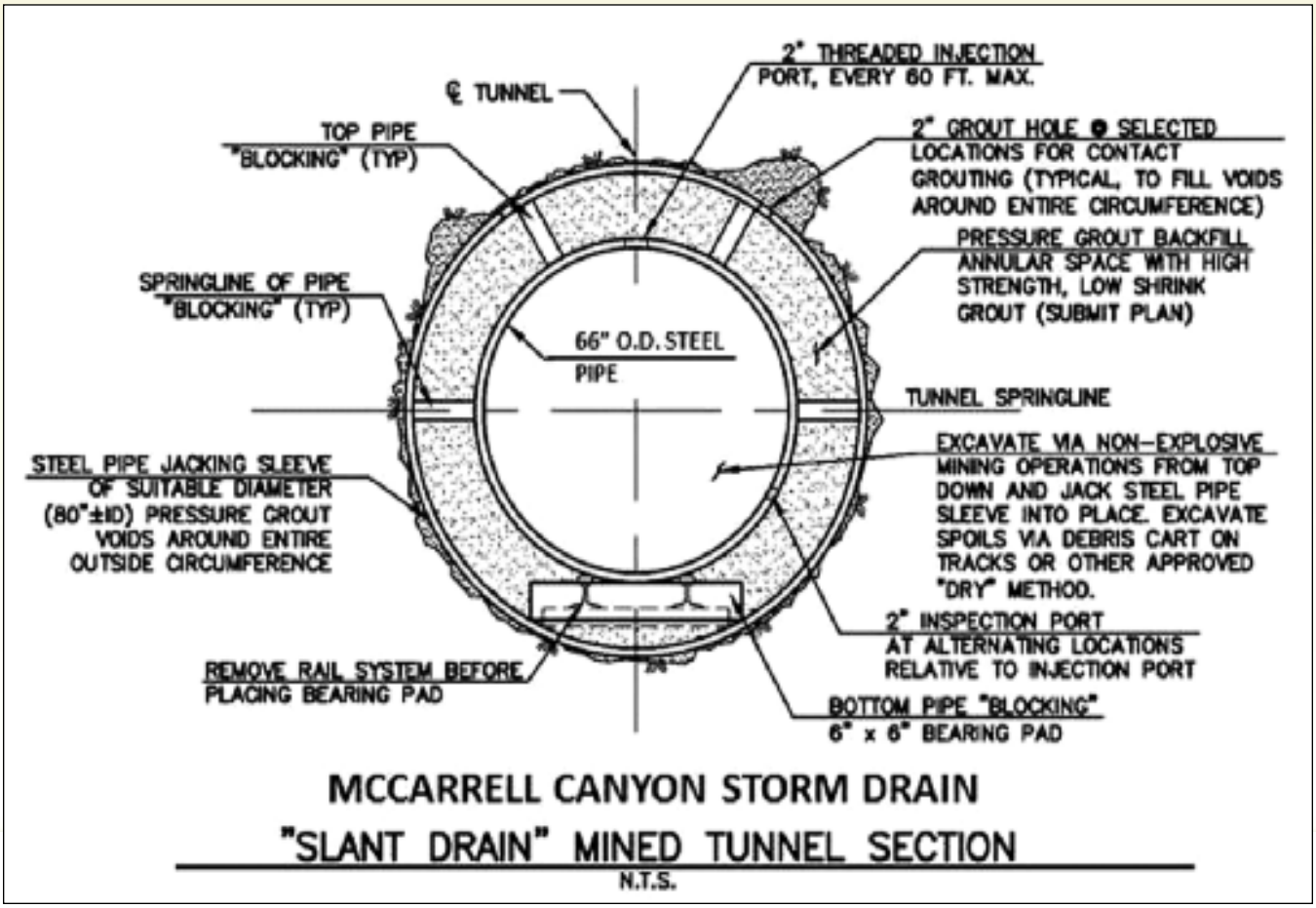
Proposed Welded Steel Pipe Mainline: A 66-inch-diameter welded steel pipe mainline was required to convey the 100-year storm. Though a somewhat unconventional choice, steel pipe was determined to be the most appropriate material for the storm drain mainline because of the high velocities anticipated (in excess of 45 feet per second) and water that would be heavily laden with sediment and cobbles. Other pipe materials were considered but eliminated from consideration due to their inability to resist long-term scouring in combination with shattering impacts from bouncing cobble.



McCarrell Canyon Storm Drain System with Historical Flood Plain in Light Blue

Proposed Hand-mined Tunnel: An 80-inch-diameter tunnel was required (at a 40% profile grade within the 150-foot-high coastal bluff to the Pacific Ocean) to allow the installation of the 66-inch storm drain pipe. 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 (all equipment had to traverse approximately a half mile along the beach below the bluff from the adjacent Abalone Cove Beach).

Several factors led to the recommenda-



Typical Tunnel Trench Cross Section

tion to utilize a traditional hand-mined tunnel method, including:

- Installation Direction: The requirement to construct from top to bottom. ("Wet" tunneling methods 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.)
- Bedrock Conditions: The significantly varying bedrock hardness, which ranged from very soft weathered shale to very hard basalt. (A tunnel contractor noted that if the multi-million-dollar tunnel boring machine were to get stuck there is a considerable chance that it could not be retrieved, in which case he would go out of business. Also, a person working at the tunnel face can react to varying bedrock material conditions and modify methods in real time.)
- Length of tunnel: The tunnel is 300 feet long. (Tunnel contractors indicated short length did not justify mobilizing an expensive tunnel boring machine.)

Tunnel Geotechnical Investigation: The tunnel portion of the geotechnical investigation included three vertical borings that extended 31.5 feet, 60 feet and 120 feet deep, respectively, directly over the proposed tunnel alignment. The 2.4-inch-diameter cores were removed intact and stored for study and mapping purposes. The three borings in combination with mapping of the exposed bluff face allowed a cross-section to be developed and the creation of a 3D extrapolation of the soil conditions.

Monitoring Soil Movement during Tunnel: Two primary sources of potential movement were monitored during the tunneling operations to protect the adjacent Bay Club condominiums: 1) Inclinometer: Two inclinometers were utilized between the launch pit and the condominiums to monitor potential horizontal movement adjacent to the launch pit shoring on the top of the bluff. Geokon Model 6400 inclinometer casings were installed to a depth of 40 feet, and the City's geotechnical inspector utilized a specialized probe and "read out" unit to determine if any horizontal movement occurred. The project specifications included strict requirements on allowable movement and project remediation/shutdown operations should movement occur. 2) Extensometer: Two extensometers were

Constructed upstream inlet being tested during a January 2010 storm

Constructed downstream outlet in January 2010

utilized at the one-third points directly over the tunnel alignment to monitor potential vertical movement within the bluff due to tunneling. The project specifications included strict requirements on allowable movement and project remediation/shutdown operations should movement occur.

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

- Protecting the public's interest by gaining critical public input

Outlet structure under construction with 24-inch-diameter soldier piles visible

via multiple public outreach meetings and City Council meetings, and addressing public concerns via detailed contract requirements to limit hours of work, aggressive dust control and daily coordination during construction.

- Protecting the bluff and working operations on the beach by utilizing a "Geobrugg" rock fall protection system and installing two 24-inch-diameter soldier piles to a depth of 45 feet, which allowed a key to be cut at the toe of the bluff and temporary shoring at the tunnel outlet point.
- Constructing a customized outlet structure tucked into the beach and bluff and also matches the bluff in color.
- Protecting adjacent existing utilities through the use of an electronic utility detection survey during the design phase that located existing utilities both horizontally and vertically to an accuracy that was better than most of the existing record drawings, which allowed a design that avoided utility impacts.
- Using "Permalok" welded steel pipe with an epoxy exterior coating and mastic interior liner to minimize field welding and improve production, which also included velocity reducer rings in the 40% "slant drain" tunnel portion of the mainline pipe to dissipate energy from the flows (slowing the flow from 65 fps to 45 fps) as they are conveyed to the bottom of the bluff.
- Constructing 1,925 linear feet of open trench to install the 66-inch diameter "Permalok" steel pipe mainline at a prevailing grade of 7% from the system inlet to the tunnel.
- Jacking and boring 30-feet of mainline pipe at a depth of 16 feet to protect an eight-foot-high retaining wall at the Bay Club / Saint Peter's Church property line.

Conclusion: The McCarrell 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 tunnel to the beach with only minor change orders is a proud enough accomplishment for the City and Harris & Associates design team on its own, but the added fact that it was successfully tested the very next rainy season in what was estimated to be a 100-year storm made the achievement all the sweeter. It confirmed that the $7.5-million expense was a timely investment that prevented what would likely have otherwise resulted significant property damage due to the January 2010 storm.