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Hollywood Water Quality Improvement Project construction

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ABSTRACT: This paper describes the history leading up to the project, the construction methods, significant events and the principal elements of the system. The project setting, community involvement and environmental aspects are a large consideration for this project located in the heart of the Hollywood Hills under the famous Hollywood sign. The work is taking place in an environmentally sensitive area adjacent to the Upper and Lower Hollywood Reservoirs, which supply the drinking water for 500,000 people. The Department has placed a high emphasis on community involvement to facilitate construction, including building of a dedicated access road to minimize the construction traffic through the neighborhood. The project consists of two world-class size 30 million gallon storage tanks, a 10-foot diameter 6,000 foot long bypass tunnel, a 6-foot diameter 1,200 foot long utility tunnel, underground connection to the existing Weid tunnel and associated piping and mechanical facilities.

1 HISTORY

The Los Angeles Department of Water and Power (the Department) is the agency that built the 238 mile Los Angeles – Owens River Aqueduct in the early 1900's under supervision of chief engineer William Mulholland. This water coupled with that from the Colorado River Aqueduct has enabled the City of Los Angeles to grow from 100,000 population at the beginning of the 20^{th} century to over 3 million – the second largest city in the United States. The Hollywood Water Quality Improvement Project is being built on a segment of the Aqueduct at the Hollywood Reservoir to meet new water quality standards imposed by the State of California Surface Water Treatment Rule.

2 PROJECT DESCRIPTION

The Hollywood Water Quality Improvement Project (HWQIP) consists of a $80 million program of two large underground water storage tanks and a system of tunnels and regulator station.

2.1 *Setting*

The HWQIP is located in the Hollywood Hills residential neighborhood of the Santa Monica Mountains, approximately seven miles northwest of downtown Los Angeles.

2.2 *Neighborhood*

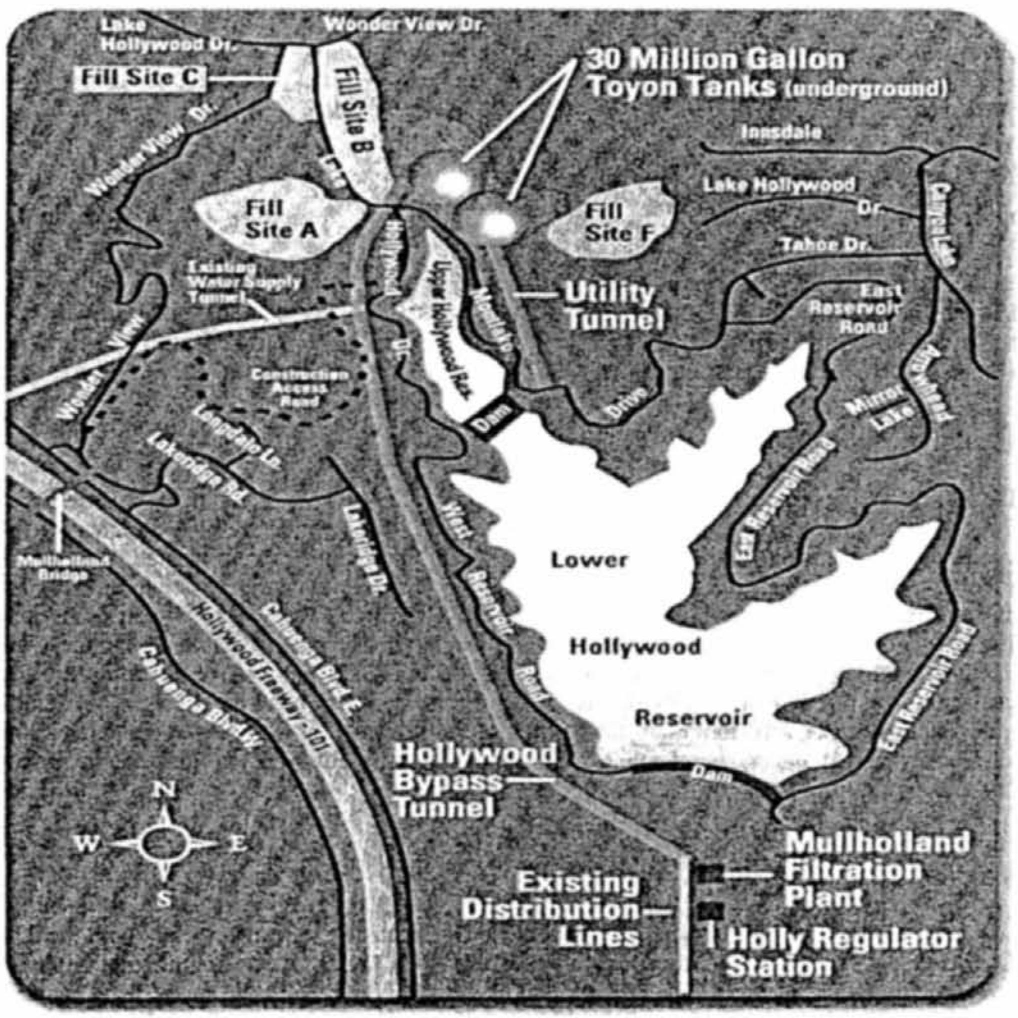

Figure 1. Map of Project Site

The neighborhood includes famous influential people. To address their concerns, the Department entered into a formal mediation process with the Coalition to Preserve Open Reservoirs (CPOR), an organization of community, environmental, and public interest groups, with a common concern of preserving the environment surrounding the Hollywood Reservoirs. Community representatives from CPOR worked with the Department to identify impacts of the project all the way from the conception through Environmental Impact Report through design and throughout the construction.

2.3 *Reservoirs*

The Hollywood Reservoir Complex is composed of two reservoirs, the Upper Hollywood reservoir and the Lower Hollywood Reservoir. The HWQIP consists of the construction and operation of facilities and structures required to bring the two reservoirs into compliance. The project allows the reservoirs to remain in service as storage reservoirs to meet peak demands and maintain system reliability.

2.4 *Tanks*

The two new underground water storage tanks provide 60 million gallons of storage capacity. These tanks are named after a local native plant called the Toyon. Each tank is 385 feet in diameter and 40 feet high. There is a North Tank and a South Tank. Each tank is fed by duplicate inlet and outlet valves and lines, allowing the Department to use either or both tanks in any configuration. The operators are able to take water from either of the two main lines to keep the water in the tanks from becoming stagnant. The tanks are built of reinforced concrete and will be wrapped with steel strand cable to provide horizontal prestressing of the tank walls. Vertical prestressing is provided by embedded threadbars.

2.4.1 *Shoring System & Slurry Wall*

A soldier pile and tieback anchor system was contructed to provide temporary shoring support to protect adjacent utilities and roadways. A structural slurry wall comprises a portion of the shoring system constructed to provide below ground area shoring for building of the concrete Toyon Tanks located at the west side of the South Tank and at the Inlet/Outlet Vault. This slurry wall is a requirement of the contract to provide an impervious barrier between the Upper Hollywood Reservoir and the tank site.

2.4.2 *Excavation*

A one million cubic yards of soil and rock excavation is required to facilitate construction of the tanks, a portion of which are slope cuts, and the remainder within the shoring system. The excavated material was placed in fill sites on the property adjacent to the tank sites.

2.4.3 *Fill Sites*

Three separate fill disposal areas have been constructed at the north end of the Hollywood Reservoir Complex. These general areas consist of moderately steep, hilly terrain with residential areas surrounding the ridge tops. One million cubic yards of material excavated from the tanks site were placed in these canyon areas selected jointly by the DWP and the adjacent property owners. The final grading of the fill sites utilized a technique called landform Grading. Landform Grading incorporates variable gradients and rolling contours to simulate natural contours of the area. Native vegetation was planted on the slopes. 150,000 cubic yards of material is reserved for backfilling and covering of the tanks when they are completed.

2.5 *Tunnels*

There are six tunnels on the project. They are the North Tank Overflow Tunnel, South Tank Overflow Tunnel, Storm Sewer Outfall, Utility Tunnel, Bypass Tunnel, and the Weid Connection Adit.

2.5.1 *Jacked Bores*

The North Tank Overflow Tunnel, South Overflow Tunnel, and the Storm Sewer Outfall are short pipe-jacked bores ranging from 100 to 150 feet in length under Montlake Drive between the tank site and the Upper Hollywood Reservoir. The Overflow Tunnels were driven using an Akermann pipe-jacking system with a 72-inch steel casing. Following the hole-through, the tunnels were lined with 54-inch diameter steel pipe.

2.5.2 *Utility Tunnel*
The Utility Tunnel is 1200 linear feet long by 6-feet diameter using steel ribs and wood lagging. The tunnel houses a 30-inch diameter steel suction line, a 24-inch diameter PVC tank drain line and an 18-inch diameter PVC subdrain line. The pipelines were backfilled with light-weight cellular concrete. The Utility Tunnel allows for gravity drainage of the groundwater at the foundation through the 18-inch diameter line and for draining the main storage tanks through the 24-inch line. The Utility Tunnel also permits the existing Hollywood Pump Station to drain water from the tanks.

2.5.3 *Bypass Tunnel*
The purpose of the Bypass Tunnel is to route water from the Toyon Tanks around both the Upper and Lower Hollywood Reservoirs to a regulator station below Mulholland Dam. This allows the Department to supply water directly to the public without using water from the open reservoirs in compliance with the State Rule. The Bypass Tunnel also provides the connection to the existing Weid Tunnel that supplies the reservoirs. The Weid Tunnel is connected to the Bypass Tunnel through a shaft and adit. The Bypass Tunnel alignment is located on the west side of both Upper and Lower Hollywood reservoirs, 150 to 680 feet from the shoreline of the reservoirs. The southerly terminus of the Bypass Tunnel will be at the South Exit Shaft, located below existing Mulholland Dam adjacent to the existing Mulholland Pumping Station. The purpose of this tunnel is to bypass the Hollywood Reservoir Complex which will allow treated water to flow directly into the distribution system without first passing through the open reservoirs where it is exposed to possible contamination.

2.5.4 *Weid Connection*
The Weid connection consists of a 112 foot deep shaft and a 100 foot long connecting adit to the Bypass tunnel.

2.6 *Hollywood Regulator Station*

The regulator station is a series of valves and piping that reduces the water pressure to prevent over pressurization of a service zone.

3 CONSTRUCTION METHODS

3.1 *Tank Shoring & Excavation*

The tank excavation required shoring from the top level of the tanks to 60 foot depth. The shoring system on the reservoir side of the site consists of strucural concrete slurry wall with tie-back anchors.

The contractor used crawler crane equipped with a clamshell bucket to excavate the soil. A 15-ton heavy-duty chisel was used to break resistant sandstone layers and to form the bedrock key.

Figure 2. Excavation Using Clam

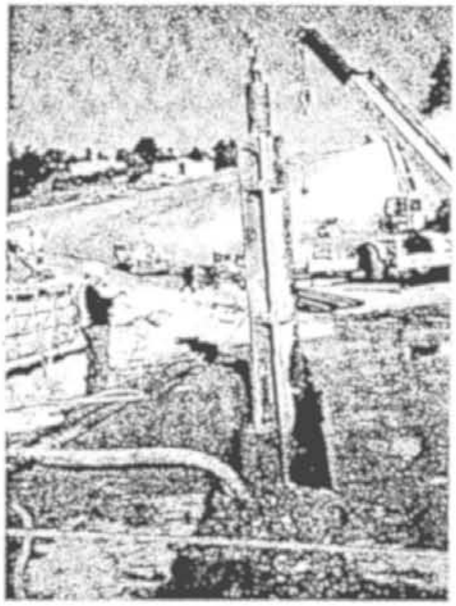

Figure 3. Chiseling in Operation

The slurry wall has 20 individual panels, each 20 feet long and up to 80 feet deep, corresponding to the depth to bedrock.

The slurry wall is suppored by 216 tiebacks installed during the downward excavation for the tanks. The strand tiebacks are grouted and tensioned up to 200% of the design rating. The tieback operation was performed from May 5[th] to Aug 14[th] 1999.

The remaining shoring wall was constructed with 207 soldier piles and tiebacks and lagged with shotcrete. After drilling to the tip elevation of each hole, each pile was seated plumb in the pre-bored hole, encased with lean tremie concrete from the tip to the bottom level of the final excavation. Each solder pile contains a series of pre-fabricated beam pockets welded onto the center flange and web of the soldier pile.

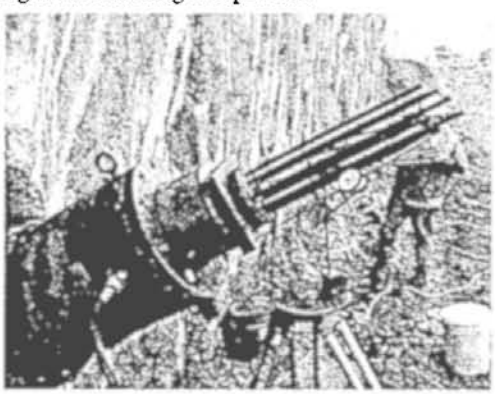

Figure 4. Tensioning Tieback

Figure 5. Slurry Wall and Tiebacks

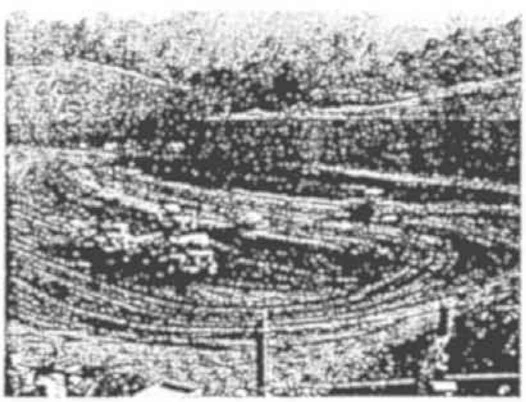

Figure 6. Tank Site Excavation

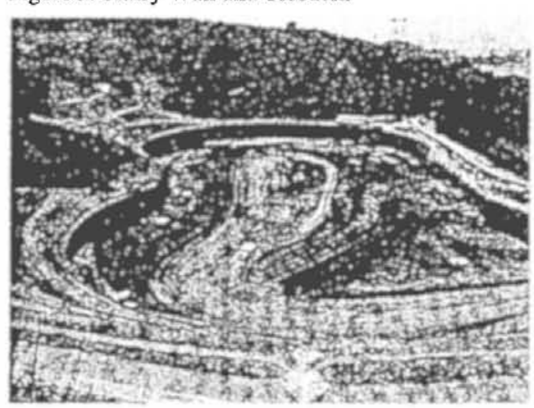

Figure 7. Excavation

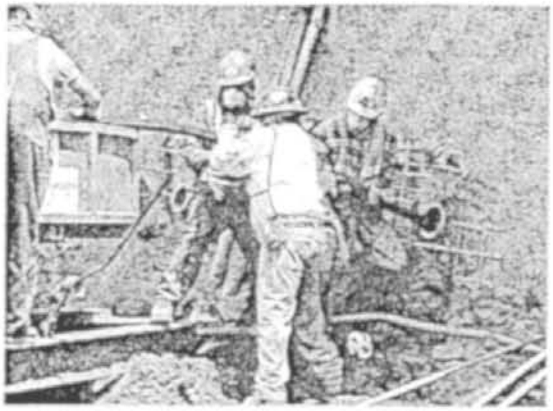

Figure 8. Installing Tieback

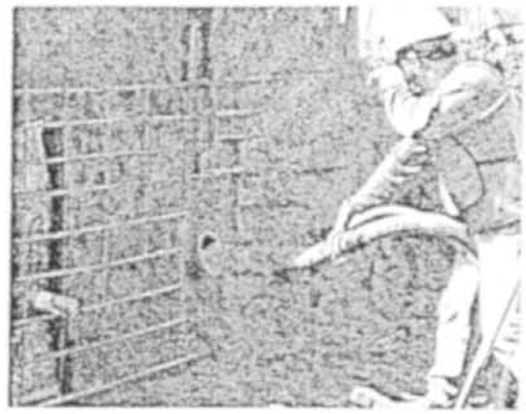

Figure 9. Shotcrete

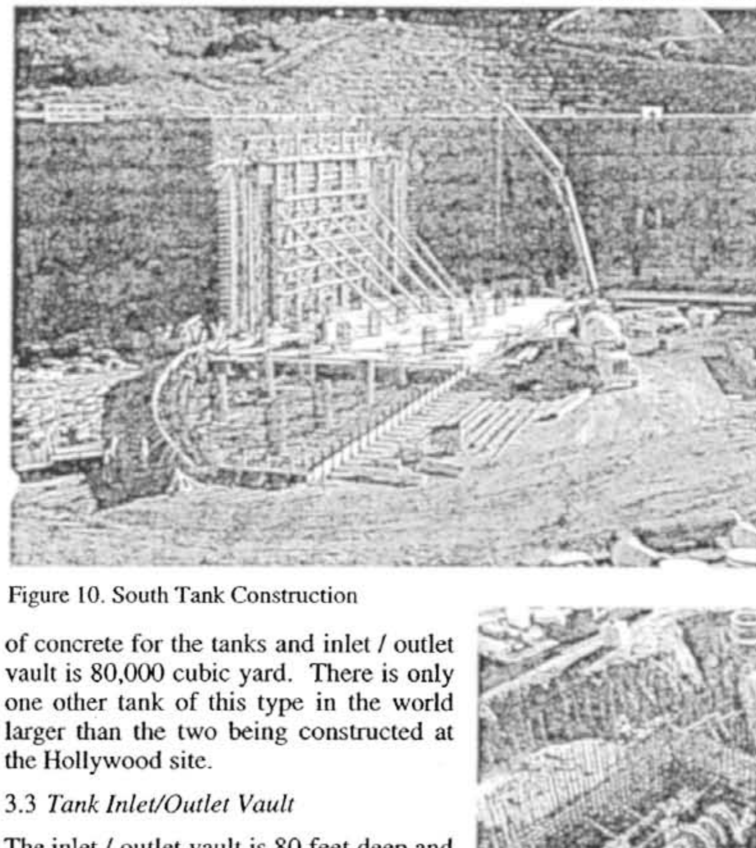

Figure 10. South Tank Construction

The excavation for the tanks was done using a CAT D10 dozer and CAT 637 scrapers.

At the completion of each lift of excavation, a minimum of 3-inch thickness shotcrete was applied as lagging between the soldier piles. The soldier wall contains 1490 tiebacks installed during the excavation for the tanks.

3.2 *Concrete Tank Structures*

The majority of the construction cost is in the tanks. The total quantity of concrete for the tanks and inlet / outlet vault is 80,000 cubic yard. There is only one other tank of this type in the world larger than the two being constructed at the Hollywood site.

3.3 *Tank Inlet/Outlet Vault*

The inlet / outlet vault is 80 feet deep and houses 15 major butterfly and check valves for controlling flow of the water in and out of the tanks through the Bypass Tunnel and the Utility Tunnel. The piping and valves were installed prior to construction of the concrete walls of the vault.

Figure 11. Inlet / Outlet Vault Valves

3.4 *Hollywood Regulator Station*

The Hollywood Regulator Station is being constructed in a very constricted work site in a residential area below Mulholland Dam. The primary difficulty with the construction is the tight conditions, close neighbors and the many existing utilities that have to worked around. This work has to be done in phases and the connections to the live supply lines can only be done in a window from December 15th through March 30th in each season.

3.5 *Jacked Bores*

Two of the jacked bores under Montlake Drive have been completed. The tunneling was done from the tank side of the roadway and exited on at the edge of the Upper Hollywood Reservoir. An Akkerman 5000 series machine was used for the bores. The pump unit provided hydraulic power and the jacking thrust to push the 78" steel casing from the jacking pit. The tunnel boring machine was equipped with a wheel to excavate ahead of the jacked pipe. The excavated material was conveyed from the face and discharged into the muck car. The muck car transported in and out of the tunnel by an electric power unit. The steel casing was jacked as sections of ground was excavated.

As with all of the tunnels, Cal-OSHA conducted a tunnel pre-construction safety meeting. The north overflow tunnel was begun on June 8, 1999 and completed on June 30th. The TBM was then moved to the South Tank Overflow Tunnel portal location on the same day and set up. Mining of the South Tank Overflow Tunnel started mining on July 7, 1999 and was completed on July 12th After the pipe jacking was completed, grout was pumped behind the steel casing to achieve full contact with the ground. Concrete encased guide rails were installed in the invert of the casing. The 54" ID Pipe sections were pushed into the steel drive casing from the tank site toward the reservoir. Each section of the pipe was then welded from the inside of the pipe.

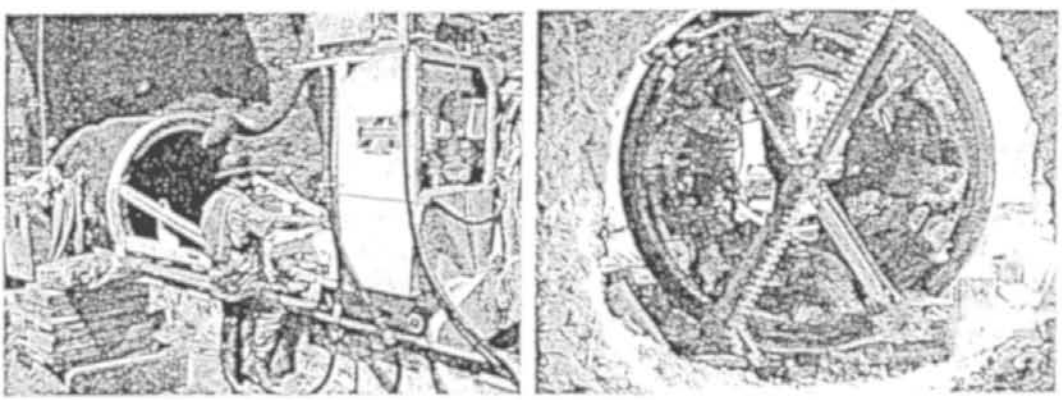

Figure 12. Akkerman Jacking System

3.6 *UtilityTunnel Tunnel Boring Machine & Support*

The Utility Tunnel Access Structure construction was started on March 16, 1999 and completed by April 14, 1999. Conventional soldier piles and wood lagging was used to support the access structure. The Utility Tunnel was excavated with a Tunnel Boring Machine manufactured by Bill Taylor. The mucking system was Akkerman battery powered locomotive and muck cars. A generator located on the top of the shaft powered the TBM. The TBM was delivered to the site and lowered down into the Access Structure on April 15, 1999 and tunneling began on April 20, 1999. The main gear of the TBM broke down the next day. After consulting with the manufacturer's representative and installing new parts, the contractor decided to retrieve the TBM entirely and return it to the manufacturer for modifications. The TBM returned to the site on May 5, 1999 with the main drive gear completely rebuilt, and modifications to the cutterhead including new style teeth.

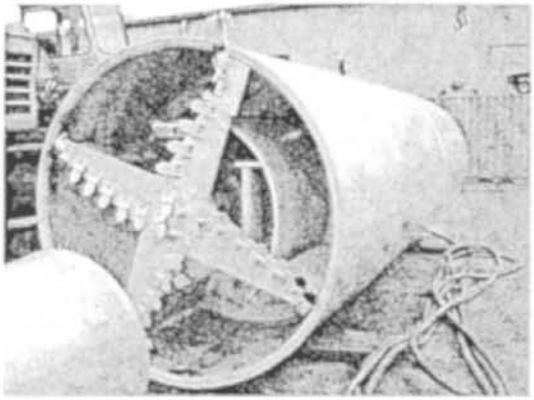

Figure 13. Utility Tunnel TBM

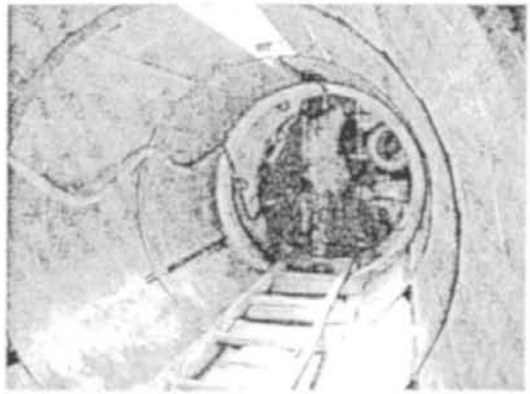

Figure 14. Ribs and Lagging

Figure 15. Cutterhead with Ripper Teeth

Mining operations resumed on the 6th of May. Excavation was very slow, and it became apparent that there were still problems with the cutterhead. Continuing modifications to the TBM were required several times during production, and teeth were constantly being broken by resistant well-cemented sandstone lenses. After placing set 182, the TBM was deflected off line by a large sandstone lense and became frozen in place at station 19+39. After seven days of hand mining, the TBM was freed and tunnel mining resumed. The TBM hit five tieback strands from the tank shoring during the last 100 feet of mining. The TBM holed-through into the south tank excavation on August 20, 1999 at 9:50 am. The line and grade were right on target. The total production time of mining was 63 days and the total down time was 42 days. Twenty days of the 42 were attributable to cutter problems created by the sandstone lenses. The tunnel initial support was composed of steel ribs and 5-foot wood lagging boards.

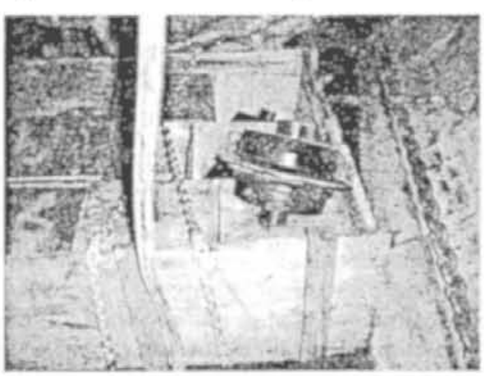

Figure 16. Disc Cutters

Figure 17. Worn Ripper Teeth

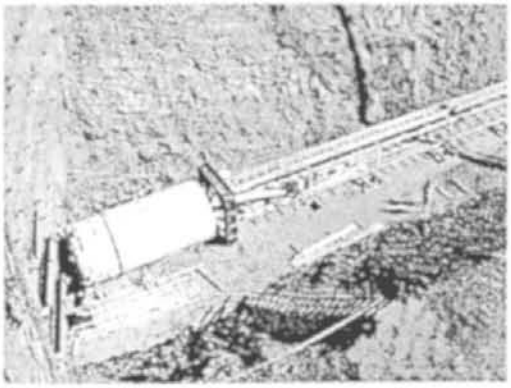

Figure 18. TBM at the Portal

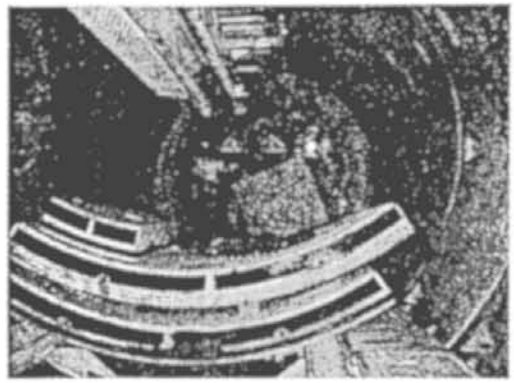

Figure 19. Building a Segment Ring

3.7 *Bypass Tunnel*

The Bypass Tunnel was mined through the Topanga Formation composed of soft and hard siltstone, sandstone and shale. Harder Conglomerate and Basalt were found toward the end of the tun-

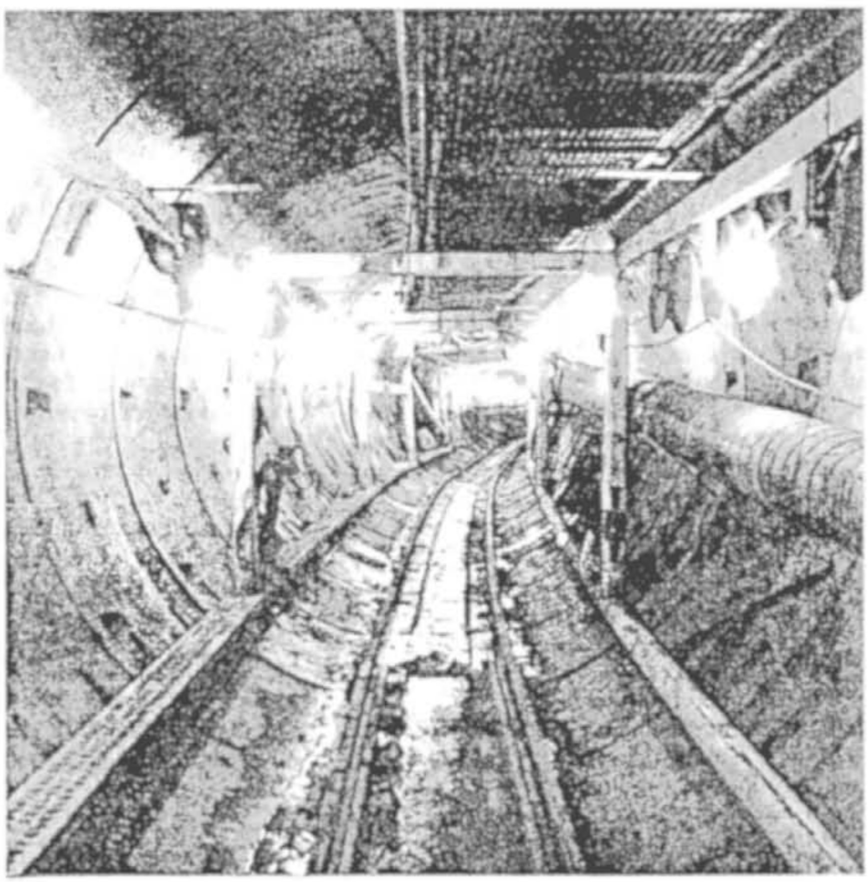

Figure 20. Bypass Tunnel Interior

nel that contained more ground water than the shales and sandstones. The tunnel depth ranges from 30 to 375 feet. The entire alignment is lies below the water table and water inflows up to 4,000 gpm were anticipated. A LOVAT model RM 131RL/SE Earth Pressure Balance TBM was selected for excavation. The tunneling system selected by the contractor is designed to be able to handle both soft, squeezing ground and the hard rock with potential ground water.

This machine can be equipped with either ripper teeth for the softer rock or roller disc cutters for hard rock. The ripper teeth were first installed to mine softer rock near the portal and they were replaced with the disc cutters when the ground was found to be too hard for the rippers.

Bolted, gasketed precast concrete segments were used as the initial support to seal off ground water from getting into the tunnel. The overcut annular space was filled with a sand - cement grout immediately following the TBM.

The Bypass Tunnel portal is located inside the north tank construction area. The Bypass Tunnel invert is approximately 15 feet below the bottom of the tanks. A structural steel frame thrust block was constructed for the initial mining. Five false sets were built between TBM pushing rams and the thrust block as a starter tunnel. The false sets and thrust block were removed after the mining progressed enough distance to where the segments could withstand pushing pressure.

Mining for the Bypass Tunnel began on July 28, 1999. There was no major problems encountered during mining. The mining has progressed to 90% as of January 10, 2000 and is forecast to finish two weeks ahead of schedule. The tunnel excavation fell approximately one month behind schedule due to hydraulic drive problems at start up. Once up and running, tunnel excavation has averaged 60 feet per day, working two 10 hour shifts.

4 EVENTS

4.1 *Slurry Leak*

During the excavation for slurry panel # 11, an abandoned 30-inch diameter steel pipe that fed directly into the upper Hollywood Reservoir was hit. This drained 7,000 gallons of Bentonite slurry into the drinking water reservoir. Concrete was immediately placed in the panel and plugged the leak. The Department's emergency procedures for incidents impacting the reservoir were followed. The Department back-flowed the water into the upper reservoir and flushed the local drinking water lines, which prevented any of the Bentonite from reaching the public. The Bentonite was precipitated in the reservoir and since it is inert and not hazardous, caused no further problems. The Department mobilized their on-call diving contractor who found the end of the old pipe and installed a plug. The remaining work was then completed on the slurry wall.

4.2 *Probing & Grouting*

The contractor proposed the use of an Earth Pressure Balance tunnel boring machine to eliminate the specified use of probe hole drilling and pre-excavation grouting. This proposal was accepted by the tunnel management team. The benefits of the EPB combined with the utilization of the bolted gasket tunnel shoring segments minimized the quantity of water in the tunnel.

4.3 *Utility Tunnel Lagging Change*

Following purchase of the required fire-retardant lagging for the Utility Tunnel, it was discovered that the treatment would not meet the water quality requirements for a drinking water facility. The contractor was required to replace the fire-retardant treated lagging with ordinary wood lagging and a change order was produced to compensate for the extra cost.

4.4 *Utility Tunnel DSC*

The rock that the Utility Tunnel TBM became stuck in was found to be more massive than that described in the contract documents. The site investigation cores cut across the bedding planes of the sandstone and did not show the nature of the individual layers. This was discovered while hand mining around the TBM shield to free it. A change order was produced to compensate the contractor for the extra cost of dealing with the massive sandstone.

5 COMMUNITY & ENVIRONMENTAL

Dealing with the community was a very important part of the design and construction of the HWQIP. The community was involved in every aspect of the project, including the basic concept of buried tanks, purchasing of the property, the final disposition of the property as open space and the construction impacts. A few of the issues related to the community are covered in the following sections.

5.1 *Oak Trees*

The site contains coast live oak trees that range in age to 200 years. Several of these trees had to be removed to make room for the tanks. One of the major trees was successfully transplanted to a fill site at great effort and expense. During the embankment work on one of the fill sites, one of the oaks to be saved had to be removed. This created a considerable amount of controversy with the neighbors, resulting in a modification of the project planting plans to replace the lost oak tree and provision for an additional riparian zone.

5.2 *Grading*

A modification to the fill sites was made during construction to facilitate the removal of a temporary bridge and restoration of the main fill area at an earlier time. This was accommodated by the community with the agreement to change the tank backfill stockpile and a reduction in height in another fill site. It took over one year to come to an agreed grading plan for the fill sites that would accommodate the majority of the community's concerns and to incorporate the additional riparian zone agreed to as a result of the loss of an oak tree.

5.3 *Outreach*

Throughout the construction life of the project, bi-monthly meetings were held with the community representatives to keep them informed of construction progress and issues. These meetings were invaluable in maintaining good relations and preventing potential problems.

6 CONCLUSION

The Hollywood project is a good example of a successful heavy construction project in a potentially controversial setting. The Los Angeles Department of Water and Power has been able to design and construct the project with the community's involvement throughout the entire process to minimize problems. This is especially remarkable in Los Angeles where recent tunneling has been fraught with bad press.

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