TUNNEL 26 TRACK REHABILITATION AND WALL STABILIZATION PROJECT

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ABSTRACT

In order to increase speed and reduce maintenance expenditures in the 7,369-foot-long single track tunnel, Southern California Regional Rail Authority (SCRRA) decided to renew the entire track structure and stabilize the walls. Tunnel 26 is located on the Ventura Subdivision in California, and is currently operated and maintained by SCRRA. Rail traffic consists of SCRRA commuter, AMTRAK passenger, and UPRR freight trains.

Subgrade and ballast were very muddy and wood ties were severely deteriorated, and for years train speed had been 25 MPH or less.

There was a 16-day suspension of train operations between September 29, 2000 and October 16, 2000 to perform the tunnel rehabilitation work. The contractor performed most of the rock bolting activities prior to the 16-day outage, during nightly windows between 10:00 PM and 5:00 AM.

The primary elements of the work included:

a) Installing rock bolt liner stabilizers and extensometer anchor pins to monitor wall movements
b) Removing existing pumps and installing new sump pumps with an upgraded drainage system
c) Removing and replacing existing track structure with new CWR, wood ties, OTM, and ballast
d) Excavating and removing all ballast and loose material and over-excavating and removing soft areas

The project was completed safely, on schedule, under budget, and with a great deal of coordination and support by all stakeholders. Speed through the tunnel was increased to 50 MPH, improving service and decreasing maintenance costs along this portion of the corridor.
INTRODUCTION

Tunnel 26 is 7369-feet long and is located on the Southern California Regional Rail Authority (SCRRA) Ventura County Line between Mileposts 441.2 and 442.6, which is between Chatsworth and Simi Valley Stations, (See Figure 1, Metrolink System Map). The rail line runs approximately east-west between Los Angeles County and Ventura County, roughly paralleling California Highway 118, and under the Santa Susana Pass. The track horizontal alignment through the tunnel is tangent. The crest is located near the middle of the tunnel, and the grade falls 1.0% at the east half and 0.1% at the west half. Southern Pacific Railroad (SPRR, now UPRR) owns the tunnel, and Metrolink, the operating entity of SCRRA, took over maintenance and operational responsibilities in 1995. However, all operation, maintenance, and construction services are performed by outside contractors.

A total of 50 trains operate daily on this Ventura Subdivision Line: 29 Metrolink trains, 10 AMTRAK trains, and 10 UPRR trains. Track speed through the tunnel is currently 50 MPH for commuter traffic and 40 MPH for freight. It must be noted that prior to the Tunnel rehabilitation work in the year 2000, the speed limit was 25 MPH. Access to the tunnel portals is through City of Los Angeles Department of Parks property on the east end, and Simi Valley Department of Parks on the west end, (See Photo 1). Some short sections of access to the portals also run through private property. Sidings are located at Hasson, 0.8 miles west of the tunnel, and at Chatsworth, 3.5 miles east of the tunnel.

The tunnel carries three separate fiber optic lines, two in wall-mounted conduits and the third in a direct burial line covered with shotcrete, (See Photo 2).

Top-of-rail clearance is 21-feet 4-inches to 21-feet 9-inches at tunnel centerline, and 16-feet total width below spring line. This clearance is ample for all existing commuter and AMTRAK trains, and allows for Plate F freight traffic. Consideration has been given in the past
(SPRR/UPRR files) for improving the top-of-rail clearance to permit the passage of 20-foot 3-inch double stack trains, however, this would require a maximum 11-inch vertical clearance improvement.

No ventilation or walkways exist in the tunnel. Temporary lighting has been installed during track maintenance work, but is always removed after the work is complete because of a serious and continuing vandalism problem.

**TUNNEL HISTORY AND CONDITIONS**

The tunnel was constructed in 1904, with timber sets, and was lined with concrete in 1922. It is not clear if the 1904 construction program intended the timber sets to be the final tunnel lining, or if the sets were dimensioned to allow a later placement of an overlay concrete or brick lining as was the later norm. The dimensions of the finished timber sets in Tunnel 26, 17-foot width and 20-foot 7-inch height, seem to indicate that an overlay lining was contemplated, given the clearance standards of the era. Certainly, tunnel fires were (and still are) common in timber-supported tunnels, and the economic consequences of a fire in such a long tunnel are very severe, taking the line out of service for months if not longer. Concrete or brick liners were mostly placed for fire abatement and reduced maintenance cost rather than their improved support capacity. We assume that a concrete lining was contemplated and this may explain why so little attention was apparently paid to cribbing the void behind timber sets and thereby, reducing long-term loosening loads on the timber supports. In 1922, SPRR placed a reinforced concrete liner over the timber supports.

A major track structure renewal project was executed in 1972. This project included a complete renewal of the track structure, limited excavation of the subgrade rock, and the installation of impervious plastic sheeting that was immediately perforated and was not effective. The 1972 project was executed during a 6-day track outage (dead track construction). After the 1972 work, the speed was 40 MPH. Records show that within a short period, however, the new ballast was fouled and became muddy and track maintenance once again became a problem. By 1979, there were localized failure spots that resulted in 25 MPH restrictions. This was corrected by
daytime spot undercutter work and the 40 MPH was re-established. Sump pumps to improve drainage and control seepage-related ballast pumping and related track instability were installed in 1980 and 1998. These sump pumps have helped, but they are frequently disabled by vandalism.

The 1972 date was a key to establishing the life of the wood ties; by 2000 they were all within a few years of failing. By 1992, the ballast was again very wet and the surface was poor, the speed for all trains was 25 MPH. By 2000, there were several episodes of temporary 10 MPH speeds until hand labor could be used to replace clusters of failed ties.

A 1992 geotechnical exploration program (Reference 1), performed as part of a double stack clearance study, confirmed that the tunnel was originally supported with timber sets (referred to as bents on some drawings) on a four-foot spacing, consistent with SPRR Standards. The timber supports mimic the approximate shape and dimension of the excavated perimeter, a straight-legged horseshoe, but because of the overbreak, due to blasting and ground loosening, a significant void remained between the back of the timber sets and the excavated perimeter. Continuous lagging boards were nailed to the back face of the timber sets to prevent small to medium size rock from falling onto the track, in effect forming a protective canopy, but not a ground support system. An attempt was sometimes made to bridge the void between the sets and excavated perimeter with timber cribbing (blocks and wedges) so that the ground loads (continually loosening rock) would be transmitted to the timber sets.

**TUNNEL AND OPERATIONAL CONDITIONS IN 2000**

136 lb CWR, wood ties, few steel ties, and gage rods existed prior to the 2000 Track Rehabilitation Project. Much of the rail and ties were corroded and deteriorated and needed to be replaced. There were a total of 75 pumps, at approximately 100’ intervals, in 4-foot-deep sump holes that dump water to through-tunnel drain pipe affixed to the sidewall. Some of the pumps were damaged and non-functional and needed to be upgraded.
A speed restriction of 25 MPH had been in place for years due to heavy invert seepage combined with soft shale and sandstone that produced very soft and muddy subgrade and fouled ballast section. Continuous maintenance efforts, especially in the rainy season, were required to maintain track conditions and the minimum speed restrictions.

**Floor and Subgrade Conditions**

The original method of blast excavation left an invert with a “wavy” profile that ponds the seepage entering from localized springs in the invert. The occurrence of soft shale beds, combined with this ponded seepage, results in softening of the subgrade that is exacerbated by the high cyclic loading inherent from a thin ballast section and heavy axle loads. This softening not only results in fouling of the ballast and loss of track geometry, but also undermines the liner footings, potentially leading to structural problems with the liner. Two extreme cases of this became apparent early on the life of the tunnel, and SPRR constructed a heavily reinforced concrete invert slab that both sealed the softened subgrade and provided lateral support to the liner footings.

The “eggshell” liner allows for continued loosening of the ground around the liner, especially in the areas of weaker ground (shale), precisely where the bearing capacity of the liner footings are at risk from the aforementioned seepage-related softening of the subgrade.

In order to stabilize the tunnel and replace the seriously deteriorated track elements (fouled ballast and decayed ties), (See Photo 3), these conditions would have to be considered in the implementation of a complete track structure renewal program in 2000.

**Liner and Ground Conditions**

The 1992 geotechnical exploration program relied heavily on the data obtained from hundreds of 1-3/4-inch probe holes drilled through the concrete liner and to bedrock in back of the liner, similar probe holes through the ballast into subgrade, and the excavation of small test pits in the tunnel invert. Logs of this testing confirmed the thickness of the concrete liner as shown on the
Design Drawings, but also showed that significant voids (average 20-inches) existed behind the liner, some partially filled with decayed timber support material and/or collapsed ground. Similarly, the invert probes noted areas of deep pockets containing a mixture of ballast, saturated silty soil, and free-standing water. These latter areas were the locations of severely fouled ballast, wet and deteriorated ties, mud volcanoes, and required constant maintenance efforts to maintain stable track geometry.

Our 1999 inspection confirmed the 1992 observations and noted that almost all of the seepage water entering the tunnel originated in the subgrade and the very lowest part of the sidewalls, and not from the upper sidewalls or crown. The great majority of the hundreds of probe holes drilled in the sidewalls and crown in the 1992 exploration program remained dry, indicating that groundwater has been drawn down to the base of the liner over the years. This is common in old tunnels because the tunnel acts as the regional sump, depressing the groundwater table in the immediate vicinity of the tunnel. Unfortunately, the “sump” only lowers the water table to the bottom of the tunnel, allowing springs located in natural rock joints to saturate the invert at the critical ballast-subgrade horizon. Localized springs were noted by the work crews in the 1972 track structure replacement project. The combination of locally-soft shale beds, irregular subgrade surface profile produced by the original excavation “waviness”, subgrade springs, and the high cyclic loads transmitted to the invert by rail traffic results in a significant softening of the subgrade and pumping of saturated silt and clay into the ballast section, (See Photo 4). With regards to the liner sidewalls and crown, neither the 1992 nor the 1999 explorations found any indications of liner structural distress, only minor seepage-related deterioration of the concrete surface, and very locally of the rebar where the latter had less than 1-inch of concrete cover.

**DESIGN PHASE**

**Design Options**

The design recommendations included the installation of untensioned, cement-grouted rock bolts (dowels) for ground support and liner wall support at areas of weak soil/rock, (See Figure 2). The rock bolts/anchors were recommended to be installed in those critical sections where a
combination of soft and saturated subgrade extending below the adjacent liner footings was known or suspected to exist.

A comprehensive analysis was conducted to determine the best track structure improvements program. Both steel and concrete ties were considered and rejected. UPRR steel ties in northern California tunnels were investigated and some spot steel ties were tried in the tunnel. Under the wet conditions there, signal voltage could not be maintained. Some abrasion of the bottom of the concrete ties in wet conditions was experienced. Due to the probability that there would be some recurring wet spots and the relatively thin ballast section, concrete ties were rejected. The concept is that another whole track renewal project will be done in 25 to 30 years, and it would be the same with any type of tie.

It was decided to use new 136 lb CWR with Pandrol plates and galvanized clips; the pre-plated ties facilitated rapid assembly of the track and the galvanizing was an effort to reduce corrosion induced stress fractures of the clips. The pre-plated ties were an advance quality control.

Replacement of the track structure would not result in a long-term improvement in rail operations (increased speed, reduced track maintenance) through the tunnel unless the invert seepage could be controlled and the existing areas of soft subgrade removed and stabilized from further deterioration. Three options to accomplish this were considered, all including removal of existing pockets of soft, saturated subgrade prior to replacing the track structure:

- **Option 1** - Placing a very thick ballast-subballast section that effectively reduced the dynamic load on the subgrade and at the same time formed a drainage ditch off the sides of the track structure.
- **Option 2** - Excavating deep drainage ditches off the end of ties on both sides for the entire length of the tunnel, possibly requiring the use of pre-cast concrete box liners as gutters.
- **Option 3** - Placement of a thinner ballast-subballast section along with deep sumps drained by trash pumps emptying into a through-tunnel drain pipe affixed to the
sidewall. The sumps not only de-water the subgrade pockets, but also work as deep draw down wells that can locally lower the water table below the subgrade level.

Option 1 was not feasible because of clearance restrictions inherent in raising the top-of-rail one-plus feet; deep clearance notching or total crown removal and replacement with a thinner arch liner would have been both technically and economically challenging, to say the least.

Option 2 would run the significant risk of de-stabilizing the tunnel liner since it required deep excavation below the liner footings, thereby entailing significant cost not only in the construction of the drainage ditches, but also the stabilization (tiebacks, minipiles, etc.) of the liner along its entire length on both sides.

Option 3 appeared to be the most efficient and cost-effective solution, especially given the live-track or short outage work window under consideration, and was selected for final design studies in early 2000.

**Design Layout**

The removal of ballast and subgrade material down at least to the level of the base of the liner footings was required as part of the track structure renewal project. The effect of this removal of material from in front of the liner footings was evaluated by a Finite Element Analysis (PLAXIS). Several rock and soil strength parameters were assigned to the subgrade rock and soil units encountered in the 1992 exploration program and the estimated liner convergence determined due to excavation and earthquake loading calculated both with and without rock anchor liner stabilization. Even without the installation of grouted rock anchors in the liner sidewalls or through the footings, maximum displacements are tolerable. However, this analysis was only valid for excavation down to, but not below, the base of the liner footings.

The Option 3 program required the excavation of pockets of soft, saturated subgrade potentially extending below the level of the footings in certain critical areas identified by the 1992 and 1999 explorations. Furthermore, passage of the equipment used to remove the ballast (scrapers,
loaders/trucks) would also likely soften this saturated and soft silty material to levels significantly below the adjacent liner footings. Since the length and depth of this potential undermining of the footings could not be accurately predicted, it was decided to stabilize the liner with grouted rock anchors prior to removing the track structure and soft subgrade in those critical sections of the tunnel. Two alternatives were evaluated for the placement of the liner anchors. Placement of the grouted rock anchors horizontally in the lower sidewalls was structurally efficient, however, the general occurrence of wide voids (average 20-inches) behind the liner sidewalls meant that the liner would have to be grouted prior to anchor installation. Although grouting of the liner was considered to be beneficial for other reasons, the cost however would be substantial (actually as much as the entire track structure renewal project). The second alternative, which was selected, was to install the grouted rock anchors at a steep angle through the liner footings (within the footprint of the wall thickness) which were poured directly on subgrade. The rock anchor consists of a 15-foot-long #11 (metric 35) grade 75 threadbar grouted into a 4-inch diameter hole, and installed on 4-foot centers on both sides. The specific location of the areas requiring the liner stabilization was noted on the design drawing.

In addition to the complete track rehabilitation program, Option 3 also required the enhancement of the drainage of the invert with the use of drilled sumps located in areas of significant seepage. The sump consisted of a 12-inch-diameter hole drilled and cased with factory-slotted pvc to a depth of 4 feet below top-of-tie. A self-actuating trash pump maintains the level of seepage within inches of the bottom of the sump and pumps the water into a 6-inch-diameter through-tunnel drain pipe emptying at both portals.

**Engineering, Operation, and Bidding Considerations**

The preferred Option 3 included a complete track rehabilitation program, drainage improvements, and wall stabilization of Tunnel 26. The primary work elements of the “Tunnel 26 Track Rehabilitation/Wall Stabilization Project” were: 1) install rock bolt liner stabilizers and extensometers anchor pins; 2) remove existing pumps and save for reinstallations; 3) suspend train operations for 16 days; 4) remove CWR, OTM, wood and steel ties, and gage rods and dispose off right-of-way; 5) excavate and remove all ballast and loose material, and over-
excavate and remove soft areas; 6) drill and case new deep sumps; 7) install and roller compact
sub-ballast and ballast; 8) distribute pre-plated 8’ ties; 9) install new CWR; 10) dump final
ballast and surface track; 11) thermally adjust and weld CWR; 12) remove all excavated material
including muck and old ballast and dispose off the right-of-way. (References 2 & 3)

The design team evaluated several feasible work plans, prepared cost analysis alternatives, and
conducted several meetings with internal and external stakeholders. A final design (PS&E) was
completed and the final bid document was advertised in May 2000. Only two (2) bids were
received. The successful low bidder was awarded the contract in July 2000. Construction began
the first week of August focusing on installing rock bolting and performing the required
preparatory work during a nightly window between 10:00 PM and 5:00 AM. The Contractor
submitted the approved work plan to the Engineer with the following major work elements
which had to be completed prior to the 16-day outage:

✓ Complete significant amount of rock bolting.
✓ Resolve all outstanding issues regarding utilities, permits, access, staging and laydown
areas.
✓ Conduct daily safety meeting and job briefing.
✓ Unload and stockpile pre-plated ties at portals.
✓ Stockpile ballast and OTM at portals.
✓ Install a set-out track.
✓ Establish Survey controls.
✓ Install air management system to comply with CAL OSHA and MSHA requirements.
✓ Install temporary lighting to support construction activities.
✓ Establish project support at each portal: communications, 24-hour emergency project
telephone list, office, and first aid station.
✓ Prepare portable pumps.

The design team provided a continuous coordination with the operating department and the other
impacted rail carriers during the initial construction phase of this project. In order to mitigate the
impact of the full 16-day full closure of this very busy rail corridor, the design team conducted
several “brain-storming” meetings with Metrolink Operating, Sales & Marketing, and Passenger Services departments. In addition, extensive effort and coordination were required with all impacted stakeholders: UPRR, AMTRAK, and Caltrans. An alternate construction method to perform all proposed improvements during nightly 5-hour windows was presented and evaluated. In addition to the engineering and construction deficiencies of this alternative, it would have caused a greater operating impact for a long period of time. It would have required approximately one year to complete with significant amount of engineering, construction, and agency costs. Therefore, the approximately 2-month nightly windows and the 16-day outage schedule were approved by all stakeholders. Metrolink conducted a comprehensive and effective public outreach program to prepare the passengers for this important project, and coordinated with AMTRAK and UPRR the busing and the freight detouring requirements.

CONSTRUCTION PHASE

Installation of Rock Anchors

The installation of the rock anchors was performed in nightly 6-hour windows in the two (2) months preceding the track outage during which the actual track renewal work would be performed. This was critical to success of the latter work since the rock anchor placement activities consumed many equivalent days to perform and would interfere with the movement of track removal/replacement activities. The rock anchors (650) were placed through the lower sidewalls with drills mounted on rail-mounted push carts and low-railers pushed by car movers, (See Photos 5 & 6). After drilling the holes, the latter were filled with non-shrink grout and the anchors with spacers pushed into the holes. Some minor re-grouting was performed to ensure that the entire length of anchor was covered with grout. No plates were affixed to the anchors because ample anchorage was obtained with the sidewall due to the adherence of the grout to the length of hole in the concrete liner. Anchorage tests in the soft subgrade rock were performed by de-bonding the upper 5 feet of anchor (in the concrete liner portion of the hole; and pull-testing the bottom 10 feet of the anchor (grouted into the soft rock subgrade). A total of 5 anchors were tested, with negligible movement measured at any of the anchors.
Track Structure Removal, Subgrade Preparation, and Installation of Sumps

Existing alignment, grade, and superelevation of the track was the final design specification. Therefore, the Contractor installed survey reference markers on north sidewall every 50 feet prior to the 16-day outage.

At 11:00 PM on September 30, 2000, the track was removed out of service between Chatsworth and Simi Valley Stations. The 16-day outage had just begun. The Contractor installed a ventilation system at the west Portal, (See Photo7), and after a comprehensive safety meeting and job briefing, Metrolink Signal crews disconnected track wires and signal devices, and the Contractor forces began to remove track sections and complete final rock bolting segments. The Contractor pulled spikes, cut rail into strings and pulled out of the tunnel. Dump trucks, vacuum trucks, loaders/backhoes, speed swings, forklifts, and Vermeer “Asphalt Type” Grinders were used for the track removal and the excavation and hauling activities. It was found that the pavement grinders provided a very smooth subgrade to work with in addition to being able to load directly into trucks, (See Photos 8, 9, & 10).

Excavation required the complete removal and disposal of existing rail, ties, tie plates, ballast, fines, and waste in preparation for installing new ballast and sub-ballast. Steel ties and gage rods were also removed and delivered to the Metrolink Taylor Yard. Contractor was responsible to locate and secure designated areas for all disposed material. All work inside the tunnel was in compliance with Metrolink and government rules and regulations (lights, air quality monitoring, air handling, etc.). All excavated material were stockpiled at the pre-designated staging areas, and then placed into trucks for disposal off the railroad right-of-way. Up to 12” of mud and muck was discovered in the tunnel floor, (See Photos 11 & 12), and the contractor brought in 2 Vermeer Grinders, one on each end of the tunnel to expedite the rock removal process. In addition, old pvc pipes and decayed filter fabric material was discovered during the excavation of the tunnel floor. Vacuum trucks were used to assist in pumping out the water from alongside the tunnel sidewalls, (See Photo 13). Contractor performed on-going survey control and monitoring services to ensure accuracy and compliance with design parameters. It took approx.
10 days, during the 16-day track outage, to complete the installation of all of the rock bolting system, remove all track elements, remove rock material to the bottom of the sidewall footings, and prepare the tunnel floor for the installation of the new track structure, (See Photo 14).

During the removal of track structure and subgrade preparation, existing pumps, which were installed in 1998, were kept in service (by an explicit contract specification). This continual removal of water during the subgrade excavation, replacement, and compaction was vital to achieving a quality job. Therefore, only damaged pumps were replaced and reinstalled, and a total of 75 pumps, at approx. 100’ intervals, were protected in place and/or relocated and reinstalled in 4-foot-deep sump holes prior to placing the new track structure, (See Photo 15). The area of subgrade adjacent to the sumps was graded and/or pumped with a vacuum truck to remove soft subgrade and/or to channel seepage water toward the sumps. The sumps were connected to the pre-existing 6-inch pvc through-tunnel drain pipes, one each running downgrade toward the respective portals. At the completion of the track renewal project drainage from the sumps was about 5 gpm at the west end of the tunnel, and less than 2 gpm at the east end, and a recent inspection (2003) measured similar amounts of drainage.

**Track Structure Replacement**

Ballast “Center Type” dump trucks with blades entered from both ends of the tunnel, spreading and rolling ballast to approx. 3” below grade. Filter fabric was rolled and placed in the soft mud critical areas only. CWR was placed into the tunnel at the side of the track bed. The Contractor brought in and placed the pre-plated ties with front end loaders. Track was laid on the pre-plated ties, and additional ballast was dumped and spread to the design elevation, (See Photo 16). The Contractor de-stressed and completed 10 field welds. Final surfacing, dressing, brooming, and testing were performed during the 14th day of this track outage. The Contractor also removed from the tunnel all temporary and construction material and equipment.

Track was made available for a test train on the 15th day, and the track was put back in service one day ahead of schedule.
FUTURE PROPOSED SEISMIC/SAFETY UPGRADES

The success of the 2000 Track Structure Renewal Project, both technically and financially, allowed Metrolink to fund the immediate design of a Seismic and Safety Upgrade Program, as well as the installation of a permanent lighting system, that also had the beneficial effects of improving the maintenance environment in the tunnel, and providing the necessary liner strengthening required in any future liner notching for Plate H clearances. This program has been designed and is currently awaiting funding.

A permanent lighting system above the tunnel spring line that is protected with modern impact-resistant plastic fixtures was installed last year, and paid for with the money saved from the track rehab work. In addition, the future proposed improvements include the installation of a compacted ballast or gravel walkway surface that smoothes the existing ballast surface off the end of tie. These improvements will be considered a part of a much larger seismic and safety upgrade of the tunnel in the near future.

CONCLUSION

The engineer’s estimate for this project was $2,559,750. The low bidder price was $2,476,750. Due to field design changes and the excellent working relationships and cooperation between the contractor and the design/construction management team, the project was completed without any change orders, and the construction cost was approx. $400,000 less than the awarded contract.

The creative design and construction ideas coupled with the support of the Metrolink engineering leadership and the cooperation of the experienced contractor all contributed to the successful completion of this project. This was indeed a True Team Successful Effort!
TUNNEL 26 REFERENCES

The following information was found in SPRR and Metrolink files regarding the condition of Tunnel 26:


2. Metrolink Project File for “Track Rehabilitation/Wall Stabilization Project”, Contract No. C3048-00, including static and seismic analysis of tunnel liner, design and as-built drawing of rock bolt liner support and sump pump installation, track structure replacement including tunnel invert cleanup, field notes and photos of rock bolt and invert cleanup work, 2000.

3. “Enlargement and Rehabilitation of Mainline Railroad Tunnels in Western USA”, G. Millar, H.W. Parker, and P.M. Godlewski, 1991 Rapid Excavation and Tunneling Conference Proceedings, SME/ASCE. Discusses methodology and cost of various live-track tunnel repair and stabilization programs, including grouting, rock bolting, etc.

In addition to this documented information, conversations with SCRRRA engineering and maintenance officials have been helpful in assessing the history of defects observed in the liner and tunnel invert. Although undocumented, several members of the current SCRRRA staff and the authors of this report inspected Tunnel 26 immediately after the 1994 Northridge earthquake, and their observations have been taken into account in the seismic evaluation section of the report.
TYPICAL SECTION
LINER STABILIZATION

NOT TO SCALE

#1 ROCK BOLT LOCATIONS
AREAS OF SOFT SUBGRADE
BOTH SIDWALLS: 4'-6" C-C

STATIONS: 1288+00 TO 1293+00
1300+00 TO 1305+00
1308+00 TO 1313+00
1311+00 TO 1315+00
TOTAL: 600 ROCK BOLTS

#1 SUMP LOCATIONS
SOUTH SIDWALL

SUMP LOCATIONS WILL BE DETERMINED IN THE FIELD. THEY WILL BE LOCATED IN AREAS WHERE SPRINGS ARE ENCOUNTERED IN THE LINTERN ALONG THE UPLAND SIDE OF CONCRETE INVERT SLABS.

DETAIL A

NOT TO SCALE