PCCP Rehabilitation: Optimizing System Performance and Leveraging Drought Management Opportunities

The Metropolitan Water District of Southern California (MWDSC) is undertaking a comprehensive, proactive program to rehabilitate aging prestressed concrete cylinder pipe (PCCP) in one of the nation's largest water distribution systems. Implementation of MWDSC's PCCP rehabilitation program has coincided with one of the most severe droughts in California history. As a result, MWDSC is investigating a wide range of system modifications to enhance its ability to deliver water reliably to its member agencies. MWDSC's program may be of value to other municipal agencies embarking on PCCP management programs and/or implementing drought management solutions.

PCCP Rehabilitation

PCCP has been used throughout the water industry for nearly 70 years. Introduced in North America in the early 1940s, PCCP was considered a viable alternative to welded steel pipe because of its often lower initial cost and ability to be designed for many combinations of internal water pressures and external soil loads. Approximately 30,000 mi of prestressed pipe was installed in the United States and Canada from the 1960s to the 1980s.
Over time, water agencies throughout the United States and several other countries have observed that, under certain conditions, PCCP has an elevated risk of failure in comparison with other types of pipes. A research paper presented data collected on PCCP failures and discussed possible causes (AWWA Research Foundation, 2008). PCCP's vulnerability stems from the potential for its prestressing wires to deteriorate under a range of service conditions unique to each PCCP line (internal operating pressure, external soil corrosivity, stray current interferences from nearby cathodic protection systems, and properties of the pipe materials).

Multiple prestressing wire breaks, especially if located in proximity to each other, can significantly reduce the pressure capacity of a pipe segment, which can lead to a rupture with little or no warning. In some instances, these ruptures have been catastrophic. Impacts have included interruption of service, costly emergency repairs, minor to significant property damage, and threat to life and safety.

As the risk of PCCP failures became better understood, water utilities began implementing strategies to monitor and inspect PCCP and to repair and replace at-risk pipe segments. Agencies with major programs now span the United States, from the Washington Suburban Sanitary Commission on the East Coast (WSSC 2013, 2012) to the San Diego County Water Authority on the West Coast (SDCWA 2014, 2013a, 2013b). The challenges associated with implementing a PCCP rehabilitation program vary significantly depending on the pipeline diameter, local alignment conditions, and level of local development.

MWDSC's PCCP lines were installed more than three decades ago. During the intervening years, land development throughout Southern California has surrounded MWDSC's pipeline alignments, creating significant rehabilitation challenges. Examples include continuous adjacent developed property (commercial and private), multiple municipal boundaries, railroads, major drainage features such as the Los Angeles River, an international airport, and the buried infrastructure of a fully developed urban community (water, sewer, natural gas, oil, telecommunications, and power).

A regional wholesaler, MWDSC delivers water to 26 member agencies serving 19 million people living in a 5,200-mi² service area encompassing parts of Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura counties. Collectively the member agencies serve the residents and businesses of more than 300 cities and numerous unincorporated communities. MWDSC's distribution system encompasses five water treatment plants and an extensive distribution pipeline network, summarized in Table 1.

In 1989, MWDSC began performing internal PCCP inspections that included visual and sounding inspections to identify the extent of damage or deterioration. In 1996, MWDSC initiated a formal condition assessment/reliability program to aggressively inspect PCCP lines.

During 14 years of monitoring, MWDSC identified trends of deterioration and observed a consistent correlation between wire-break development and corrosive soils.

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<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Overview of MWDSC's pipeline distribution system</th>
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<tbody>
<tr>
<td><strong>Asset</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>Entire system</td>
<td>&gt;830 mi of large-diameter pipelines</td>
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<td>PCCP portion of system</td>
<td>27 pipelines, total length ~163 mi, diameters 42-201 in. (80% are ≥78 in.)</td>
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MWDSC—Metropolitan Water District of Southern California, PCCP—prestressed concrete cylinder pipe
stray current, and previous severe wire breaks. Throughout this period, MWDSC repaired individual distressed pipe segments in which the risk had reached unacceptable limits. MWDSC estimated that continued repair of PCCP lines on an as-needed basis, until the last PCCP section was repaired, would result in a projected total cost (without consideration of inflation or increased access difficulty) exceeding $5.5 billion. The magnitude of this repair cost became the basis for MWDSC to aggressively proceed with a proactive master planning program for pipeline rehabilitation.

MWDSC'S PCCP REHABILITATION PROGRAM

The first step in developing the long-term rehabilitation program was to review all existing PCCP that was in service in the distribution system. MWDSC staff created a system to objectively rank and prioritize PCCP on the basis of risk. Building on several reference sources—including reports published by the AWWA Research Foundation (2008), the Water Environment Research Foundation (2007), and the Water Research Foundation (2012)—MWDSC implemented a two-step screening process to identify and prioritize PCCP rehabilitation. MWDSC prescreened and scored all existing PCCP lines for factors indicative of a shortened service life. MWDSC then evaluated each PCCP line against three “consequence” factors that reflected the impacts of failure: pressure, criticality, and location. MWDSC assigned weights and developed a total consequence score for each pipeline.

The result of the analysis was the identification of five pipelines with the overall highest risk: the (1) Second Lower Feeder, (2) Sepulveda Feeder, (3) Rialto Pipeline, (4) Calabasas Feeder, and (5) Allen-McColloch Pipeline, as shown in Figure 1. MWDSC developed a plan for the long-term rehabilitation and replacement of the five at-risk pipelines (MWDSC 2014). This work is anticipated to take 20 years. MWDSC’s PCCP management strategy also includes (1) continuing regular inspection and monitoring, (2) monitoring stray currents and installing drain stations where necessary, and (3) performing individual segment repairs where risk is judged to require immediate action.

BALANCED APPROACH FOR SECOND LOWER FEEDER PROJECT

After identifying the Second Lower Feeder as the highest-priority line, MWDSC engaged Black & Veatch to perform the preliminary design of the initial rehabilitation program work. The Second Lower Feeder, shown in red in Figure 1, consists of 39 mi of 78- and 84-in. diameter potable water pipeline. The pipeline conveys water from MWDSC’s Robert B. Diemer water treatment plant (Orange County) and terminates in the Palos Verdes Reservoir (Los Angeles County). The scope of the Second Lower Feeder rehabilitation is summarized in Table 2.

The Second Lower Feeder is a primary transmission pipeline delivering potable water to MWDSC’s central pool service area, which covers the major population centers of Los Angeles and Orange counties. Therefore, thorough consideration of the impacts on member agencies served...
by the Second Lower Feeder and the affected associated facilities is of paramount importance. A basic tenet established early in development of the overall rehabilitation program can be summarized in MWDSC's commitment to its member agencies:

- Close coordination with member agencies will identify acceptable downtime for construction.
- Out-of-service time will be minimized.

Through initial planning and preliminary design, the MWDSC-consultant project team identified an overall rehabilitation effort for the Second Lower Feeder with an estimated construction cost of $480 million implemented through 13 construction contracts completed over 20 years (MWDSC 2015). The rehabilitation will result in a transmission pipeline with a renewed service life of more than 50 years. Because it is the first element of a larger rehabilitation program, MWDSC is using the Second Lower Feeder project to establish overall PCCP rehabilitation program standards and common methods for design as well as communication with stakeholders.

Developing an overall rehabilitation/repair approach. MWDSC evaluated three potential methods for restoring the service life of PCCP: (1) replacing PCCP segments with new pipe, (2) inserting steel cylinders as a liner inside an existing PCCP segment, and (3) strengthening existing PCCP segments by installing carbon fiber lining.

As part of the preliminary design, the project team performed additional research and analysis to select the optimal repair method from the three previously identified options. Evaluation criteria were capital cost, impact on MWDSC and member agency operations during construction, constructability, hydraulic considerations, schedule, environmental and community impacts, and durability. These analyses yielded a preferred rehabilitation strategy of relining the PCCP with steel cylinders.

The fully developed and urbanized project area did not allow much opportunity to consider pipeline replacement as a viable alternative. However, in selected locations, installation of a new steel pipeline (and abandonment of the existing PCCP) was recommended as the most cost-effective solution. Existing section-izing valves and flowmeters will be replaced, and new isolation points will be installed for future operations and shutdowns that are more convenient. Key pipeline appurtenances will be replaced, including relocation of air/vacuum valves to above-grade locations and replacement of primary system control valves.

Identifying and developing access sites for construction purposes. The Second Lower Feeder pipeline is divided into 10 reaches by line valves, allowing MWDSC to isolate a portion of the pipeline for maintenance and inspection. The preliminary design identified numerous excavation sites that would be needed to efficiently do the relining work. The site selection process included site visits to ensure that sensitive locations such as schools and hospitals were avoided to the greatest extent possible; preliminary investigations to identify geotechnical issues, hazardous site locations, environmentally sensitive locations, and proximity to critical public facilities; and development of typical access-site layouts.

Critical design considerations that affect the overall cost of rehabilitation are the location and spacing of

| TABLE 2 Overview of Second Lower Feeder rehabilitation scope |
|-------------|-------------|
| **System function** | Potable water transmission from Robert B. Diemer water treatment plant (primarily Colorado River water) to MWDSC's central pool area |
| **Length** | 39 mi of 78-in. and 84-in. diameter pipeline |
| | 9.0 mi of 84-in. CMLC steel pipe |
| | 5.3 mi of 84-in. PCCP |
| | 24.7 mi of 78-in. PCCP |
| **Central pool distribution** | Backbone pipeline delivering potable water to six interconnections: Orange County Feeder, South Coast Feeder, Cross Feeder, Sepulveda Feeder, Palos Verdes Feeder |
| **Member agency turnouts** | 15 turnouts delivering potable water to nine member agencies |
| **Line valves and meters** | 10 line valve and flow meter installations will be rehabilitated |
| | Three new line valve installations will be constructed |
| **Jurisdictions** | Fully urbanized alignment crossing >20 jurisdictions in Los Angeles and Orange counties |

CMLC—cement-mortar lined and coated, MWDSC—Metropolitan Water District of Southern California, PCCP—prestressed concrete cylinder pipe
PCCP access sites. First, the project team identified controlled-access sites, which are required for construction entry into constrained sections of the existing PCCP. Selection of these sites was driven by specific features that severely limit access to relining operations (such as construction under the San Gabriel River, as shown in Figure 2) and as a result of restrictive surface features (such as construction through the Long Beach Airport property). The remaining access points were then selected to allow the maximum construction length possible from each access site while considering the construction difficulty associated with the pipeline alignments, bends, fittings, and appurtenances.

Addressing unforeseen seismic issues. The original construction of the Second Lower Feeder included an alignment selection near the Diemer plant. This section of the pipeline was recently identified as at risk during a seismic event. Second Lower Feeder rehabilitation provided the opportunity to investigate alternatives and incorporate seismic risk mitigation into the rehabilitation plan. Construction of a new welded steel pipe segment to replace the PCCP in this location was recommended.

Maximizing knowledge from existing system operations. The existing Second Lower Feeder has been operating successfully for more than 30 years. The experience gained from this extended operation identified a number of design modifications that are being incorporated into the rehabilitation project.

- **Expanded isolation facilities.** The rehabilitated Second Lower Feeder will incorporate three additional line valve installations to expand MWDSC's ability to isolate, dewater, and inspect the pipeline in the future.

- **Turnouts—dual feed provisions.** New isolation facilities are being strategically located to enable continued service to member agencies from either side of a line valve. This new configuration will minimize impacts on member agencies by allowing service to continue while one section is dewatered.

Coordinating requirements of member agencies and government jurisdictions. Project development included contract packaging and prioritization that provided a framework for implementation. As discussed above, MWDSC established standards to ensure that a reliable water supply is maintained to member agencies while rehabilitation of the Second Lower Feeder is underway.

The pipe alignment crosses a number of jurisdictions and governing agencies on its journey from the Diemer water treatment plant to the Palos Verdes Reservoir. Identification and coordination of jurisdiction-specific requirements will be key to project success. The project team held preliminary meetings with jurisdictions and agencies to review the wide range of requirements that will affect design and construction. MWDSC is particularly sensitive to member agency concerns related to street impacts and is committed to scheduling rehabilitation work to coordinate with local moratoriums on street improvements.

Continued coordination will further define requirements and constraints. For example, balancing the conflicting requirements of limiting working hours for construction on city streets (particularly in residential areas) with traffic considerations and the need to minimize the duration of any outages in supply to member agencies will be key areas of focus.

**Drought management coordination**

As California remains gripped by a severe drought, MWDSC, through its comprehensive drought response program, is investigating new ways to deliver water specifically to portions of the distribution system routinely supplied by the State Water Project (SWP). The drought response program and the pipeline rehabilitation program are being coordinated, where appropriate, to maximize the overall capabilities of MWDSC’s system.

MWDSC's water supply, treatment, and distribution system is a complex network of pipelines, pump stations, pressure control structures, hydroelectric facilities, water treatment plants, and storage reservoirs. Within MWDSC's service area, the distribution system normally operates on gravity flows. The ongoing drought
has resulted in severe restrictions on SWP allocations, requiring MWDSC to minimize the use of SWP water whenever possible and to optimize its use of Colorado River resources, local supplies, and storage reserves.

The Greg Avenue Pump Station Improvements Project is one component in MWDSC's drought response program and an example of how MWDSC would send Colorado River Aqueduct (CRA) water into portions of the system traditionally served by the SWP.

In the preliminary phase of the project, the project team evaluated several alternatives to achieve increased capacity from the existing distribution system by rerouting flows from other parts of MWDSC's transmission system to accomplish the desired goal of conveying 100-150 ft3/s of flow into western Los Angeles using existing distribution system pipelines and infrastructure.

MWDSC is evaluating the possibility of reversing the flow of the Sepulveda Feeder (the second pipeline to be rehabilitated under MWDSC's long-term PCCP rehabilitation program). The Sepulveda Feeder normally uses gravity to convey SWP water into the Los Angeles area. Conveying CRA water via the Sepulveda Feeder would require pump station(s) and pressure beyond the existing pipeline pressure class. However, relining the Sepulveda Feeder (as part of the PCCP rehabilitation program) would allow for increased pressure capability, making the alternative operating scenario viable and enabling MWDSC to convey CRA water deeper into its system.

SUMMARY

MWDSC's PCCP rehabilitation program will yield many benefits. A proactive program (planned rehabilitation rather than reactive repairs) minimizes the risk of service interruptions and a catastrophic PCCP failure. Continued monitoring of existing PCCP while the rehabilitation program is moving forward will help focus the repair activities and refine the risk-based approach. The ultimate performance benefit is enhanced overall reliability to deliver water to member agencies.

In addition, the implementation of a managed rehabilitation program will provide significant construction savings in contrast to the costs associated with segment-by-segment PCCP repairs. Moreover, the program will mitigate risks of catastrophic failures to individuals, property, schools, airports, and other entities. PCCP rehabilitation, in conjunction with the drought response program, will provide MWDSC with the opportunity for expanded system operational flexibility to ensure reliable water delivery during drought conditions.

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