Planning, Communication Make Conduit Rehabilitation Project Go Smoothly

Steve Frank

As much as 7 in. (178 mm) of concrete in the roof of the old box conduit at the Metro Wastewater Reclamation District South Plant had corroded away from the original 14-in. (356-m) roof thickness leaving the lower rebar reinforcing mat visible in places.

Add hydrogen sulfide to a reinforced concrete box conduit for 30 years, and you have a formula that has the potential to produce a catastrophic failure.

The 12-ft by 9-ft (3.7-m by 2.7-m) box conduit was put in service in the Metro Wastewater Reclamation District (Metro; Denver) South Plant in 1976 to carry primary effluent from four 150-ft-diameter (45.7-m-diameter) primary clarifiers to eight nearby aeration basins and 10 secondary clarifiers. As operated in 2005, the conduit was conveying as much as 144 mgd (545,000 m^3/d) of primary effluent during peak flows.

The original operating concept for the old, unlined box conduit called for it to be operated submerged — that is, to be full of flow all the time. The submerged condition prohibited growth of the airborne *thiobacillus* organism, which generates sulfuric acid, a key component in the corrosion of concrete structures.

After a few years of operation, however, Metro's Operations Division lowered the flow level to reduce excessive cycling of downstream pumps. This operating change exposed the top few feet of the conduit and enabled corrosion to occur.

"The South Primary Effluent Conduit was 1050 linear ft [320 linear m] of reinforced, cast-in-place concrete that was exposed to hydrogen sulfide corrosion for almost 30 years," said Orin Padgett, the Metro project manager for what became the South Primary Effluent Conduit Rehabilitation Project.

"Following the collapse of an adjacent reinforced concrete pipe on the plant site in 1999, the Metro initiated an assessment of the South Primary Effluent Conduit and other plant conduits and pipelines," Padgett said.

Metro's treatment facility serves most of metropolitan Denver. It comprises two co-located plants rated for a combined design flow of 227 mgd (859,000 m^3/d), using a 30-day average, and is the largest wastewater treatment facility in the Rocky Mountain West. The plants treat an average of about 130 mgd (492,000 m^3/d).

TROY GOTTSCHALK (METRO WASTEWATER)

Orin Padgett, the Metro District's project manager, and Tim Volz of URS Corp. (Denver) inspect microbiologically-induced corrosion damage in the poured concrete box conduit that Metro rehabilitated.

Speedy Assessment

Metro called upon URS Corp. (Denver) to conduct the emergency assessment of conduits. The inspection confirmed their worst fears.

"We found significant deterioration of the [South Primary Effluent Conduit] roof and upper sidewalls," said Bill Wemmert, a URS engineer. As much as 7 in. (178 mm) of concrete had corroded away from the original 14-in.-thick (356-mm-thick) roof.

"At most locations, we found exposed reinforcing steel across the entire roof and portions of the sidewalls," Wemmert said. "The lower reinforcing mat had completely separated from the roof at one location."

The inspection concluded that the conduit, located 10 ft (3 m) below a concrete-paved plant thoroughfare, was in danger of collapsing. The result would have had significant safety, operational, environmental, and regulatory impacts on a facility that in 2005 won its second Platinum Award from the National Association of Clean Water Agencies (Washington, D.C.) for operating 10 years without a numerical discharge permit violation.

Metro and URS immediately began studying alternatives to rehabilitate the South Primary Effluent Conduit. Representatives from Metro's Operations and Engineering departments were at the table.

Fortunately for Metro, a comprehensive facilities plan was under way. It provided the long-range planning necessary to kick off a 10-year, $600 million repair, rehabilitation, and upgrade program. The plan includes details about a major upgrade of the South Plant scheduled for the near future — about half of the conduit that needed rehabilitation would remain in service and require a 50-year design life, while the other half could be completely reconfigured in the next 10 to 15 years.

The design Metro ultimately accepted called for using 500 ft (152 m) of fiberglass-reinforced pipe (FRP) in the part of the conduit run that required a 50-year design life, as well as hydroblasting and shotcreting the 500-ft (152-m) run that had to last 10 to 15 years. *Shotcreting* refers to a process of spraying concrete or mortar onto a surface.

Meticulous Planning

As planning commenced, two huge issues loomed. One was the location of the conduit in the middle of the plant. The second was the need to plan and execute a significant flow bypass from the South Plant primary clarifiers through four temporary bypass pumping locations (stations) to the South Plant aeration basins.

Simply shutting down the South Plant to complete the project was not an option. The conduit rehabilitation team would have to design and build a temporary bypass that would enable the South Plant to continue operating flawlessly while repairing corroded conduit.

The construction documents restricted bypass pumping to 79 days between Labor Day and Thanksgiving. Historical records showed that the Labor Day–Thanksgiving window was most desirable because flows and loadings are lower and more stable then than at any other time of year. Average flows, minimum flows, normal peak flows, the potential effects of rainstorms or snowstorms, and myriad other factors had to be considered, not only for sizing the bypass but for operations during construction.

"The toughest thing was ensuring that the bypass pumping operation was sized right," said

STEVE FRANK (METRO WASTEWATER)

Norm Klapper, sales representative for Process Equipment Corp. (Boulder, Colo.) demonstrates the 11.2-ft (3.4-m) fiberglass-reinforced pipe used in the conduit rehabilitation. Each section weighs about 13,000 lb (5900 kg).

ORIN PADGETT (METRO WASTEWATER)

A Stanek Constructors Inc. (Denver) employee guides the first piece of fiberglass-reinforced pipe into place. Metro used 500 ft (152 m) of fiberglass-reinforced pipe in the design for the part of the conduit run that required a 50-year design life.

Metro operations specialist Craig Barnes, a 26-year veteran. "The possibility of wet weather surges sent us to our historical records. Peaking factors were used to help size the bypass pumping facility."

"We had to make sure during design that we would have enough capacity, because the bypass operation design would not let us make any equipment changeouts for something like a pump failure," Barnes said. "That proved valuable when hurricanes Katrina and Rita hit the Gulf Coast, because we could never have gotten another pump anywhere after those storms hit."

"A key to our success was our MOPs [methods of procedure] process," Barnes said. "We believe in them so much they're part of our bid specs."

A construction MOP is a preformatted planning tool. It outlines tasks and responsibilities for a shutdown or other operational interruption. "It helps contractors understand my constraints and how their actions are likely to affect my permit compliance," Barnes said. "It also helps contractors be more realistic in organizing their tasks. Their job is to meet schedule; mine is to minimize the risk to our operations."

Barnes said MOPs also help Metro and its contractors see potentially conflicting activities among several parallel projects. A MOP was created for every shutdown or any other step or activity that might affect operations. The work outlined in the MOPs was evaluated both for possible conflicts and for complimentary opportunities with work in other concurrent projects.

"Lots of details were thought about and covered up-front with plans and contingencies for the contingencies," Wemmert observed. Metro's Engineering Department and URS made sure Metro's Operations group was part of every decision, he said.

Construction Begins

On June 22, 2005, Metro awarded Stanek Constructors Inc. (Denver) the $6.9 million construction contract. Stanek began mobilizing equipment onsite July 7 and soon faced its first challenge — the load limit on the existing conduit roof.

"The deteriorated state of the existing conduit roof made it necessary to impose a load [weight] limit on removing the soil from it," Wemmert said. The contractor had to use smaller, lighter excavating equipment because heavy equipment could collapse the conduit.

The contractor's second challenge was working within the limited space available. Room for excavated soil, construction offices, bypass pumps and pipes, the new conduit pipe, other materials and supplies, and equipment was at a premium. Numerous existing pipes for potable water, plant water-chlorinated, waste activated sludge, raw sludge, stormwater, and secondary scum removal had to be temporarily relocated prior to excavation of the conduit. These utilities were bypassed through temporary, aboveground high-density polyethylene (HDPE) pipes ranging in size from 4 to 12 in. (100 to 300 mm).

"Stanek had a big shoring challenge because of the proximity of the conduit to digester No. 2, which was full," Padgett said. "It was critical that the soil supporting the digester not shift at all. Trenching and shoring had to be implemented so the soil stayed in place."

A concurrent project to build two new 1.8-million-gal (6.8-million-L) anaerobic digesters was under way at the other end of Metro's "digester row" at the same time. Capacity was tight, and taking digester No. 2 off-line was not an option, Barnes said.

Stanek solved the shoring problem with soldier beams and crossbeams. Cutting the roof and upper sidewalls off the old conduit began in September. But the distance between crossbeams created another problem — getting the replacement conduit pipe into the old conduit.

"FRP isn't new, but this is a different use for this material," Padgett said. "In addition to being corrosion-resistant throughout the pipe wall, it also offered some other advantages," including the ease and speed of joining pipe sections.

Quick and easy joining was important because of the abbreviated timeframe in which the job had to be completed. To accommodate the shoring openings, the manufacturer made the pipe in 28-ft (8.5-m) lengths — the FRP has an inside diameter of 11.2 ft (3.4 m).

The FRP was nested inside the undamaged lower sidewalls and floor of the old conduit and

STEVE FRANK (METRO WASTEWATER)

Last year, the Metro Wastewater Reclamation District (Denver) rehabilitated more than 1000 ft (305 m) of a reinforced concrete conduit with fiberglass-reinforced pipe. The project also required a 50-mgd (189,000-m³/d) bypass operation.

strapped into place with steel cables to keep it from floating during backfilling operations. Low-strength concrete slurry was piped in as backfill in the pipe bedding zone to keep the FRP from slumping and deforming.

Bypass Basics

As the trench was being opened and the roof and upper sidewalls of the old conduit were being wet-sawed away, pump subcontractors Wagner Rents (Denver) and Godwin Pumps (Bridgeport, N.J.) were busy installing the 13 10-mgd (38,000-m³/d) bypass pumps at four locations (pump stations) and 20,000 ft (6100 m) — almost 4 mi (6.4 km) — of 18-in. (450-mm) HDPE pipe that would carry 50 mgd (189,000-m³/d) of flow during the bypass.

The concept of plant operation during the project called for baseloading the South Plant to process 50 mgd (189,000 m³/d). This kept the hydraulic load as constant as possible, which kept pump cycling to a minimum, put less start–stop wear and tear on the bypass pumps, and reduced the chances of a malfunction.

The three in-service South Plant primary clarifiers, which each hold about 230,000 ft³ (6500 m³), had one bypass pumping station. (One primary clarifier was dewatered and kept out of service throughout the project.) The fourth bypass pumping station was used to pump flow from the 10 North Plant primary clarifiers to the South Plant aeration basins to help maintain the steady 50-mgd (189,000-m³/d) hydraulic load. The bypass pumping operation began Sept. 25.

Quick Change

All the advance planning and MOP creation paid off when the flows to the South Plant aeration basins had to be changed in a single 24-hour period.

Part of the scope of work for the Primary Effluent Conduit Replacement Project included rehabilitating and cleaning the South Plant's aeration basin influent conduit. This task was included in the scope because the reduced flows — 50 mgd (189,000 m³/d) versus up to twice that flow normally — presented a good window of opportunity to work on the aeration basins. To do this work, four of the eight aeration basins would have to be out of service at the same time.

Stanek installed a temporary bulkhead that allowed rehabilitation and cleaning of half the aeration basin influent conduit at a time. To complete the rehabilitation and cleaning of the second half, the four operating aeration basins had to be taken out of service at the same time the four previously out-of-service aeration basins were brought on-line.

The changeover from the first four basins to the second four basins had been planned and scheduled as a weeklong process. It required redirecting the bypass piping from the first four basins to the second four, which entailed cutting the HDPE discharge pipes one at a time and reattaching another discharge pipe that had been preassembled and set in place to direct flow to the second group of four basins. Godwin Pumps performed the reattachment using all flanged HDPE connections.

When the time came for the changeover, Godwin Pumps told Metro that because of high-priority hurricane-related work in the Gulf Coast region, the changeover crew could only be available for 24 hours.

"We seeded the four 'A-basins' and put them in service during that 24-hour period," Barnes said. "This operation was a huge departure from what we had anticipated, and there were a few rough spots, but it worked."

Taking all eight basins in the South aeration basin complex out of service for 24 hours took

a 50-mgd (189,000-m^3/d) chunk out of Metro's processing capabilities. To accommodate that change, the excess flow was sent to the North Plant.

"We knew it was coming, so we optimized our North [Plant] primaries for maximum BOD [biochemical oxygen demand] removal before and during the changeover," Barnes said. "We also adjusted our solids inventory in the North [Plant] to accommodate the excess flows and loads from the South [Plant]."

In such a complex project, there are many opportunities for things to go wrong. Barnes said it is almost impossible to overstate the importance of constant, good communication among all the parties to help prevent such things from happening.

"We talked all the time with the [Metro] project manager, the resident engineer, and the contractor's superintendent," Barnes said. "We reviewed data on a daily basis."

"But it was also important to keep our own staff informed," Barnes said. "We wrote specialized procedures for this job for the operations staff. We didn't want anybody wondering what was supposed to happen on their shift."

Sweet Success

The project finished on time and with few change orders. Bypass pumping ended Nov. 17, a week before Thanksgiving. The trench where the FRP was installed was refilled and covered, the 500 ft (152 m) of the project that received the shotcrete treatment was finished, permanent utility pipelines were installed, and the project reached substantial completion on March 3, 2006.

"The success of the project was due in large part to regular progress meetings, detailed plans concerning any activity that might impact plant operations, and bypass pumping redundancy, all of which had as their objective minimizing plant operational risks and incorporating safety considerations for the health and safety of the workers," Padgett said.

"I'm really proud of the way this team pulled together," said Steve Rogowski, Metro's operations and maintenance director. "This was a model project."

One last item: Metro's more than 11-year record of having no numerical discharge permit violations remains intact.

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