Developing an Approach to Diagnosing & Correcting Capacity Problems on Distribution Infrastructure

Julian Deleon, Edward Sierra, and Willie Shelton

Water distribution capacity problems on existing transmission mains are often easy to correct but difficult to troubleshoot and diagnose. This is usually the case because water distribution systems are looped, allowing water to feed from multiple directions. The aim of this article is to provide a general guide to field practitioners for correcting water distribution problems on existing infrastructure.

Usually, the first indication of capacity problems arises from several customers complaining of low water pressure. In addressing these problems, we have implemented a procedure to systematically investigate, analyze, and correct these problems. To illustrate this procedure, here is an actual example:

The City of Riviera Beach Utility District contracted the installation of approximately 9,000 feet of 16-inch ductile iron pipe (DIP) water main. The project included directional drilling under the C-17 canal and under Interstate Highway 95. The directional drilling included the installation of 16-inch HDPE pipe.

This new 16-inch water main was expected to provide additional capacity to increase service pressures and flow to the western communities, but after the project was placed in service, district staff members found that complaints of low water pressure continued from those communities.

Using the district's Infowater Hydraulic Model, the engineering section evaluated the pipeline capacity and generated a rating curve for flow versus pressure at targeted locations where pressure gauges had been installed. The district's distribution division located the 11 butterfly valves on the 16-inch pipe line and ensured that the valves were all in the open position. The procedure usually employed to verify the state of the valve includes closing back three turns and then re-opening the valve.

District staff proceeded by installing pressure gauges at the air relief valves by using a T-fitting to retain the functionality of the air relief valve and minimize the number of taps required on the pipe. After the gauges were installed, staff members isolated the 16-inch main from one end and conducted a series of fire flow tests. The purpose of isolating the line from one end was to ensure that no looping condition would exist—a necessary constraint to determine the actual conveyance capacity of the pipe system.

With the water treatment plant at a steady pressure setting, static elevation differences were accounted for in the calculations. The 16-inch water main was stressed at a flow rate of 1,600 gallons per minute. Staff members measured a dynamic loss of 25 pounds per square inch (psi) for the entire 9,000 feet of pipe. Using the Infowater hydraulic model, we computed a theoretical loss at this flow rate of only 6 psi.

Julian Deleon is a district engineer for the City of Riviera Beach Utility District, Edward Sierra is the district director, and Willie Shelton is a water/wastewater superintendent with the district.

Using the hydraulic model, we determined that the district's 16-inch water main was behaving as though it were a 10-inch water main, or as if the H/W pipe roughness "C" had a value of 30. These values were indicative of gross field problem.

In an effort to locate a possible blockage or pinpoint the problem in 9,000 feet of pipe, we measured residual pressures along the transmission main and plotted these measurements, as shown on Figure 1. As can be noted from the figure, relative to distance, we had excessive losses on the C-17 directional drill and the Interstate 95 directional drill segments.

Table1: Procedure for Troubleshooting Field Problems

1. Install pressure gauges along the pipe. Rather than installing new taps, the utility worker can install at the ARVs using a "T" fitting.
2. Isolate one end of the pipeline to ensure flow in only one direction.
3. Under static conditions, account for all elevation differences by reading the pressure gauges.
4. Extract a predetermined flow rate from a fire hydrant. If the pipe is greater than 12 inches, staff members should use two diffusers connected to the same hydrant to generate sufficient flow to stress the line.
5. After Step 4 is in a steady-state condition, record the residual pressures along the pipe system.
6. Plot the residual pressures versus the gauge distances as illustrated in Figure 1. Use this chart to locate steep declining hydraulic gradient.
7. Use an engineering table or a hydraulic model to determine calculated residual pressures and compare to the measured values from Step 5.
8. Once the problem has been pinpointed, cut the pipeline and inspect with the traditional tools. If the pipe segment in question is too long, the user should tap the pipe and install gauges to close in on the problem as needed.

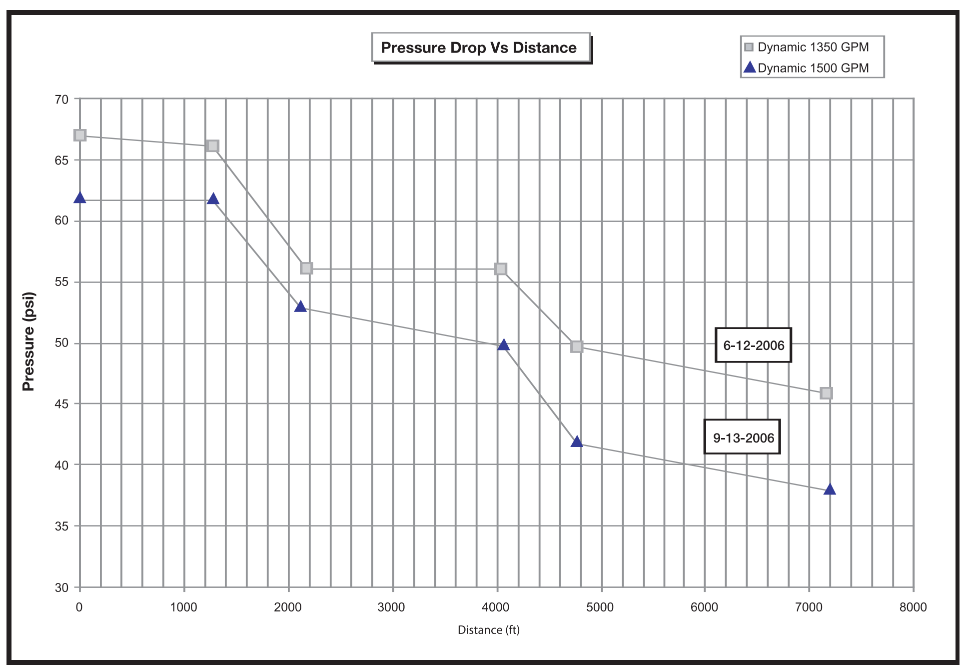
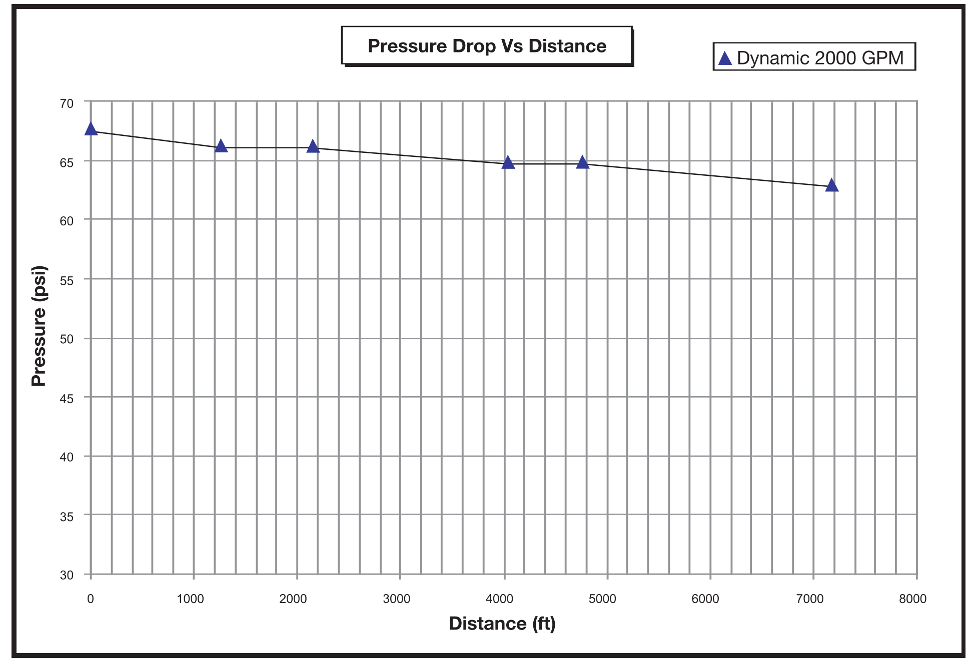


Figure 1

Figure 2



Next, staff members requested and examined the field report and drill log for the directional drilling. We found that the project specifications had maximum allowable entry and exit angles of 15 degrees for the HDPE pipe. According to the drill log, the drilling contractor had at times exceeded 25 degrees. The utility staff theorized that the pipe had possibly buckled due to the tighter entry and exit angles, but we knew that an actual inspection had to be conducted to be conclusive about the transmission problems.

The HDPE pipe was scheduled for an inspection, and the staff proceeded by removing one of the valves to insert a camera. Upon inspection of the valve assembly, we discovered that the contractor had installed the 16-inch butterfly valve following the DIP fusion to the HDPE pipe. This valve installation problem proved to be the transmission problem; thankfully, no buckling had occurred as initially theorized.

In essence, a butterfly valve opens inside the pipe diameter. Since the inner diameter of the 16-inch HDPE pipe was 14.75 inches and the valve was sized for a true 16-inch DIP pipe, the butterfly valve, which depends on the inner pipe diameter for its successful operation, was only partially functional.

This problem was not initially recognized by our water distribution staff because the valve actually had five working turns available out of the full 32 turns for a full open or close state. Staff members were not able to find this valve problem because they only closed back three turns on the valve to determine whether the valve was actually in the open status and assumed everything else was acceptable. The same valve problems were found at the HDPE I-95 crossing. We corrected these problems by simply changing the butterfly valves to gate valves.

While the solution was fairly simple, the problem was extremely difficult to pinpoint for an entire run of 9,000 feet of pipe. Obviously, it would be uneconomical to inspect or camera all 9,000 feet, and this is where the use of a hydraulic model made a significant difference in troubleshooting the measured field conditions in comparison to the calculated conditions. The valve having only five working turns out of 32 was also extremely abnormal and unexpected. The contractor installing butterfly valves where the pipe diameter changed was also a troubling problem.

Because of transmission problems in moving water to the western sections of the city, our consultants had recommended the construction of a second water treatment plant to the west of the city with an estimated capital cost of $7 million. At the time of this recommendation, no one realized that we had gross transmission problems with our existing infrastructure.

The Infowater Hydraulic Model was used as a tool by the district's engineering section to evaluate the existing infrastructure and compute system capacity. Our hydraulic model is fully integrated with the GIS system, which is important because it eliminates replication and maintains database normalization. The cost for the modeling software was approximately $9,000.

From this experience, we have now implemented procedures to test new pipeline facilities to ensure that they perform to their rated capacity. As can be noted from Figure 2, our system has greatly improved after the described corrections were implemented, and we avoided the construction capital costs of a second water treatment plant with its annual operations and maintenance costs.

When troubleshooting field problems, the procedure outlined in Table 1 can be employed on any pressurized pipeline system, including force mains.