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Hydraulic Model Helps Save Money on Sewer System

A hydraulic capacity analysis is helping the city of South San Francisco save money on improvements to its aging sewer system by pinpointing the biggest bottlenecks. By knowing where the most serious deficiencies are, city decision makers can identify the improvements that will have the greatest effect on increasing the system's capacity.

A computer analysis of the system's performance during a five-year, six-hour storm graphically illustrated the variations in flow through the system as the storm passed through. This made it possible to identify a few choke points, such as the capacity of the city's two pumping stations, whose upgrade would solve the majority of the problems west of U.S. 101.

"Having this information was helpful in planning improvements because some of the changes were not intuitive and might have been given a lower priority," said Ken Metcalf, Capital Projects Coordinator for South San Francisco.

South San Francisco shares its wastewater treatment facility with the neighboring city of San Bruno. The treatment plant, known as the South San Francisco/San Bruno Water Quality Control Plant (WQCP), currently receives flows from these two cities as well as portions of Daly City and Colma.

The existing system consists of a sanitary sewer network of approximately 90 miles of 6-inch through 33-inch pipes. The backbone of the sewer system, west of U.S. 101, consists of the trunk sewers, generally 8 inches in diameter and larger, which were designed to convey wastewater to one of two pump stations, the San Mateo pump station or the Shaw Road pump station. These stations intercept the city's sanitary sewer flows and provide conveyance, via existing force mains, to the treatment plant.

Wet Weather Flows

Much of the sewer system in South San Francisco was built during the area's rapid growth in the 1930s through the 1950s. The system experiences relatively high flows during the wet weather season. During some storm events, the pump stations have allowed flows to back up into the sewer system.

The City of South San Francisco is under a "cease and desist" order from the State Regional Water Quality Control Board issued in August 1997. The order requires the city to make improvements to its collection system and treatment practices to capture storm water inflows and cease overflows to the San Francisco Bay.

The city hired Carollo Engineers to design an expansion of the existing 9 mgd WQCP to 13 mgd. As part of the cease and desist order, the company was also hired to conduct a separate Infiltration and Inflow Study (INI). The study was used to evaluate the hydraulic capacity of the existing sewer collection system and to provide recommendations about how to mitigate the surcharging and overflows caused during rainfall events.

One of the first tasks for the Carollo engineer assigned to the project, Tony Akel, was to establish the current flow criteria for the sewer system. By examining historical records, he concluded that the highest measured wastewater flows occurred during the wet weather season, usually between November and March.

Akel supplemented this data with two temporary flow monitoring programs performed during subsequent years to get more precise flow data. He used flow monitoring equipment that recorded velocity of flow and depth measurements at six-minute intervals throughout the duration of the monitoring program. He recorded sixteen storm events with total rainfall averaging between 0.04 inches and 1.31 inches. Flow then was estimated using a combination of historical data, monitoring program data, and judgment.

For the study, Akel decided that a five-year, six-hour storm would provide a realistic simulation of the system under typically heavy rainfall conditions.

The next step was to create a computer hydraulic sewer model to identify the deficiencies in the system during a five-year, six-hour storm. The software Akel used for this was Hydra™, from Pizer Incorporated, Seattle, Wash. Hydra models the hydraulics in municipal storm, sanitary, and combined sewer systems.

"Although there is an abundance of sewer analysis software, I prefer Hydra because it is reasonably priced, easy to use and is integrated with AutoCAD," Akel said. "Also, this program stores the collection system data such as pipe size, pipe length, pipe inverts, manhole rim elevations, and so on in a dBase file format (.dbf) which will allow the client to convert it to other engineering software applications or hydraulic models in the future."

Akel created a digital model of the collection system showing the network of pipes, the two pump stations, and the treatment plant. He also identified 10 drainage basins in the study area to help understand the operations of the sewer system and to establish flow characteristics experienced by the sewer trunks and sub-trunks. The next step was loading the sewer model with rainfall amounts generated by the five-year, six-hour storm.

Akel then ran the analysis to evaluate the ability of the existing collection system to handle peak wet weather flows. In this analysis, a 48-hour diurnal flow pattern was routed through the city's sewer collection system during a five-year, six-hour storm, with an estimated peak flow of 26.5 mgd. As a comparison, he also simulated the system's performance during peak dry weather flows with the same flow pattern and an estimated peak flow of 6.9 mgd.

Analysis Results

The capacity analysis showed several deficiencies in the system during the five-year peak wet weather flows. The San Mateo pump station, with a capacity of 14.4 mgd, was adequate for the peak dry weather flows. However, during the peak wet weather flows, the analysis showed the station backing up into the 27-inch interconnect between the two pumping stations, and continuing into the Shaw Road station. This coincided with the city staff's observations of occasional overflows upstream of the pump station during significant storm events.

Similarly, the Shaw Road pump station's capacity of 15 mgd was shown to be inadequate to handle the peak wet weather flow. The analysis also showed other problems including the interconnect between the two pump stations due to its relatively flat slope. There were additional deficiencies in the sewer trunks in drainage basin 7 (the Linden trunk and the Airport Blvd. trunk), which experienced overflows during the design storm scenario. The analysis also indicated deficiencies in several sub-trunks in the system.

Akel used the results to prepare a list of recommended improvements to the system. He suggested approximately a dozen modifications, ranging from increasing the size of certain pipes to increasing the capacity of the pumping stations. He prioritized the improvements to address the biggest bottlenecks first so that early modifications would have the greatest effect on reducing overflows.

The biggest bottleneck, according to the hydraulic analysis, was the San Mateo pump station. Akel's recommendation was to replace the existing pumps at the station with four new pumps for a total capacity of 27 mgd. Next, he recommended replacing the pumps at the Shaw Road pump station with five new ones for a total capacity of 31.25 mgd. Other recommendations were the construction of a 24-inch parallel relief sewer to serve an area of recent residential development and a new 27-inch interconnect between the two pump stations.

Akel acknowledges that Metcalf's role was critical to the success of this project.

"Mr. Metcalf was a central element of the project team, as he provided invaluable assistance in extracting voluminous historical flow records and maintenance records. I greatly enjoyed working with Mr. Metcalf who exhibited exemplary, prompt, and courteous professionalism."

City officials are now using the information in the Carollo report to apply for grant funding from the state regional water quality control board.

Conclusion

For South San Francisco, the hydraulic analysis provided more than a way to prioritize improvements. It gave officials an understanding of the sewer system that they could not get any other way.

"The hydraulic model allowed us to take the system apart layer by layer and gain insights into its performance that we could not get simply by driving around and seeing what happens during a storm," Metcalf said. "We are now making decisions based on a realistic simulation of an unusually heavy rainfall, giving us confidence that after the improvements are made, the system should be free of overflows."

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