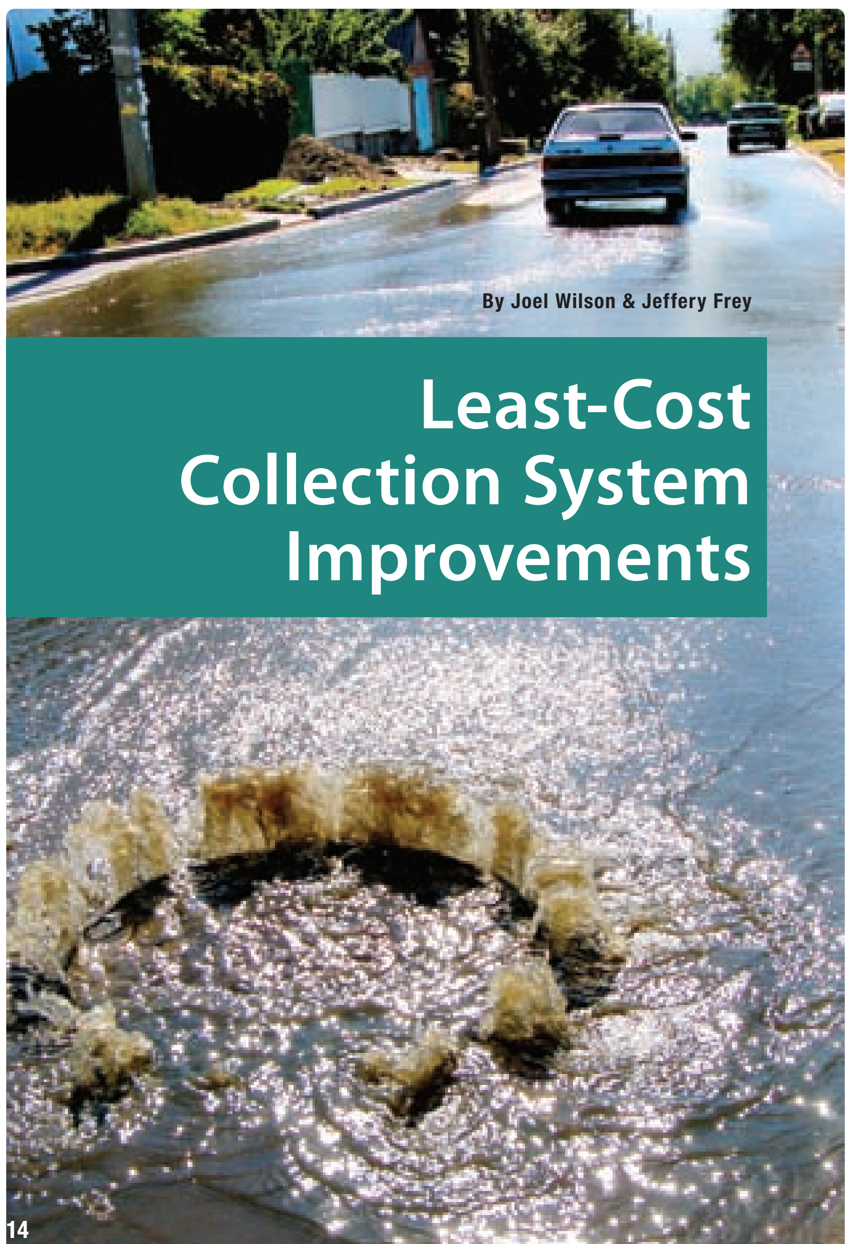
EDITOR'S FOCUS

Least-Cost Collection System Improvements

By Joel Wilson & Jeffery Frey

Minimizing the overall cost of conveyance and treatment capacity upgrades and lifetime system operation

Water utilities are investing billions of dollars to improve existing collection systems and reduce the frequency of sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs). Whether a utility is driven by SSO or CSO reduction or simply the need to upgrade its collection system, proper planning and sizing of capital improvement projects is the key to achieving cost-effective and affordable solutions.



Innovative Optimization Approach

Planning collection system improvements is a daunting task made more challenging if there are insufficient resources and time pressures to undertake a proper analysis. The challenge is the sheer number of options and combinations of options that should be considered to identify a solution that meets the required hydraulic performance criteria at near-minimum cost.

Factors to consider could include: location and size of new gravity or pressure sewer mains; location and size of new storage facilities; location and capacity of new or upgraded pump stations; capacity of new or upgraded treatment plants; and level of effort and funds to spend on reducing infiltration and inflow (I/I).

Collection system planners and modelers tackle the problem with a trial-and-error approach by creating trial solutions and simulating each solution's performance in a calibrated wastewater model. The shortcoming of this approach is that the planner can investigate only a limited number of combinations of options and likely does not come close to achieving the best hydraulic or most cost-effective solution.

Following the release of the U.S. Environmental Protection Agency's SWMM5 collection system modeling software in 2005, Optimatics and global consultant CH2M HILL teamed up on an Australian government-funded project to create the foundation technology that led to the development of wastewater optimization software.

The software is used to evaluate improvement options, operational protocols and system rehabilitation alternatives for wastewater collection systems based on hydraulic performance and life-cycle cost analysis. It is a "big-picture" planning tool used to find the best mix of improvement options such as storage capacity, treatment plant capacity, conveyance capacity, real-time control settings and sewer separation. The following is a case study of a recently completed project.

Coastal City Case Study

In 2008, Optimatics completed a detailed optimization study of a high-growth sewershed for a large coastal city and developed a solution with a total life-cycle cost savings of 25% compared to the cost of the city's previous master plan solution (hereafter referred to as the baseline solution). Based on the success of this first project, the city decided to license the optimization software in house and jointly work with Optimatics to undertake a citywide optimization project that is now nearing completion.

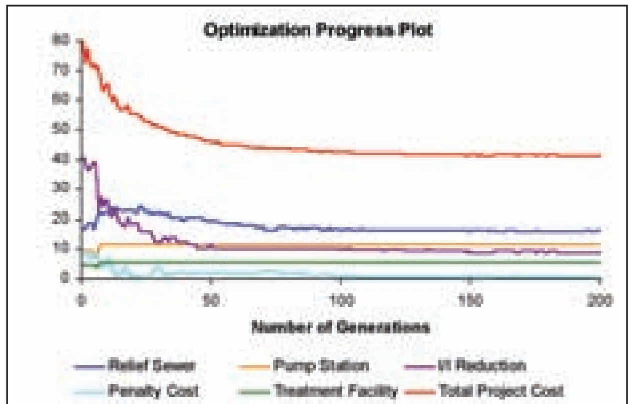
The city currently services 220,000 customers and anticipates a 40% growth in population by 2060. Based on an earlier study of the high-growth sewershed, the city's proposed strategy was to relieve the existing trunk sewer network by pumping flow directly to the existing treatment plant via a new, more direct sewer alignment than is currently in place. In the latest study, the optimization was formulated to include the improvement options evaluated in the city's master plan together with additional ideas for sewer, force mains and pump stations.

The team identified the range of allowable improvement options—replacement and parallel gravity sewer, new force mains, in-system storage, pump station upgrades and treatment plant expansion—to enable the system to satisfy the goal of not more than one overflow occurrence every six months, based on a 17-year-long time series analysis. Unit costs for each of these improvement options were developed, as well as hydraulic performance constraints such as minimum and maximum velocity.

The optimization software evaluates numerous combinations of improvement options by creating thousands of trial solutions and running each one in the hydraulic model while monitoring hydraulic performance and total solution cost simultaneously (see Figure 1). Distributed computing enables the optimization run to be completed efficiently by utilizing many processors in parallel.

After successful preliminary runs made sure the hydraulic model and optimization software were linked and in working order, the optimization

Figure 1. Optimization Search Plot Showing Progress on Reducing Solution Cost



developed several near-optimal solutions with differing characteristics. The project team discussed the advantages, disadvantages, risks and practicalities of the different solutions, and the city voiced its preferences. The final, near-optimal solutions were approximately 25% less in total cost compared to the total estimated cost of the baseline solution, and they met the performance criteria of just one overflow occurrence in six months under design-storm conditions.

The selected solution consisted of: a new gravity sewer; a new force main; new pump stations; flow diversion from existing pump stations to the new force main; and a reduction in operating costs for one existing pump station. The key differences between the optimized solution and the baseline solution were:

- The optimization pump station and force main configurations significantly reduced the capital and operating costs of pump stations.
- Additional flow was diverted into the new force main and pumped directly to the treatment plant, thereby avoiding costly upgrades to existing gravity sewers, pump stations and force mains.
- Wet-weather storage within the system, which was included in the baseline solution, was not selected in the optimized solution because it was more cost-effective to increase the diameter of the new force main and reduce dry-weather operating costs.

By using optimization, the city was able to identify a planning strategy that will save millions of dollars in future capital and operations investment.

Planning for Uncertainties

One of the greatest challenges facing water utilities when developing wastewater planning strategies is to find solutions that are cost-effective in the short term and provide the desired level of service for the design life of the infrastructure. Uncertainties in future population forecasts, climate change impacts, rates of system deterioration and accuracy of hydraulic model calibration can have a significant impact on planning solutions.

The approach being used for recent optimization projects enables greater engineering input by improving the efficiency with which modeling can be completed and planning scenarios evaluated. Optimization scenarios that demonstrate solution sensitivity to key assumptions help to: indicate aspects of solutions that have little dependence on the assumptions and can be implemented with confidence; identify opportunities where a small amount of additional investment can be made to achieve a greater level of contingency in the future; and show which assumptions have a significant impact on short-term works projects so utilities can focus investment into further data collection where it is important.

The real value in optimization is not in finding a single, absolute optimal solution but rather in having an efficient planning tool for options analysis and scenario evaluation that can be used to help develop robust, cost-effective and highly defensible planning strategies. WWD

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