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Project Summary

Alternative Sewer Studies

This report provides new design and operational information on two of the most effective and widely applied alternative sewer systems—small-diameter gravity and pressure sewers. The information provided here will help system designers and operators avoid or rectify problems resulting from sulfides and downhill hydraulics that could otherwise represent major impairments to the successful application of these technologies.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Small communities in need of new or expanded sanitary sewers are faced with a severe financial burden. Low population densities and unfavorable geological situations increase per capita costs of conventional sewers, which often account for up to 80% of the total capital costs of a new wastewater management system.

Conventional sewers are expensive. To insure that raw sewage flows freely, conventional sewer systems use large-diameter pipes set in the ground at minimum slopes. Pumping stations are often required as well. Extensive excavation is usually necessary to achieve the desired slopes. Flat terrain, high groundwater, and waterfront areas all add to construction costs and difficulties. Finally, infiltration and inflow (I&I) of extraneous water cannot be eliminated entirely in large pipes. The added wastewater volume and solids mean that the treatment plant must have a greater capacity than would be required to treat only the dry weather flow.

Alternative approaches to sewering that address some of the problems encountered with conventional systems can reduce collection and treatment costs. Three types of alternative sewers are discussed below:

- pressure sewers
- vacuum sewers
- small-diameter gravity (SDG) sewers

Discussion

Alternative sewers offer the dual advantages over conventional sewers of small-diameter pipes and a greater ability to follow the natural topography without risk of clogging, which reduces excavation and construction costs. Furthermore, all three of these sewers provide reduced I/I.

The two major types of pressure sewer systems are grinder pump (GP) and septic tank effluent pump (STEP). These two systems differ in the onsite equipment, layout, and quality of the wastewater conveyed to the pressure sewer. In GPs, solids are ground to a slurry and discharged through pressure lines. In STEPs, wastewater from a home first flows into a septic tank from which treated effluent is pumped to pressurized lines.

Vacuum sewers use a central vacuum source to constantly maintain a vacuum on small-diameter collection mains. Periodically, the pressure differential created by the vacuum source draws a slug of sewage from a holding tank at each home into the line. When sufficient volume of sewage is collected at a central vacuum station, it is pumped to the treatment plant or main interceptor.

Like the STEP system, a small-diameter gravity (SDG) sewer is used with individual septic tanks. Because solids are removed by the septic tank, pipes of 4 in. in diameter can be used at very shallow slopes without risk of clogging. The effluent requires little or no pumping, generally flowing by gravity to the treatment facility.

Despite their many advantages, several concerns have been raised about alternative sewers. The most important of these potential problems are:

- Excess sulfide generation, and
- Two-phase flow in pressure and SDG sewers

Sulfide generation affects all types of sewers. The problem manifests itself in unpleasant odors and corrosion produced by hydrogen sulfide. Years of experience have gone into the design of conventional sewer systems to minimize sulfide generation. Experience with sulfides in conventional sewer systems has raised two main concerns about alternative systems: (1) That the septic effluent in SDG and STEP systems may be more prone to sulfide generation, and (2) that the anaerobic nature of the pressure and the SDG sewers may contribute to sulfide generation.

Two-phase flow refers to a hydraulic problem of particular concern in pressure systems. In downhill sloping sections of pressure sewers, gas bubbles present in the pipeline can adversely affect flow. The typical solution is to install air-release valves at summits within the pipeline. However, in many cases this technique does not work efficiently, and additional steps must be taken to solve the problem.

Conclusions

Although a significant number of pressure and SDG sewers have been designed and constructed, there remain some significant gaps in understanding the technology. These studies provide some insights into two of the major technology gaps. The major conclusions are as follows:

1. GP systems can produce sulfides at a rate of three to four times that of STEP systems and about twice that of conventional sewer force mains because of the high organic strength of the wastewater.
2. STEP systems show unexplained losses of sulfide and gains in dissolved oxygen based on analyses performed in this study and previous data for septic tank effluents.
3. Both pressure systems (i.e., GP and STEP) can be expected to have some sulfide concentration in their wastewaters, with values varying from 1 to 14 mg/L based on this study.
4. GP sulfide concentrations will generally increase in the direction of mainline flow, but random locations of service lines and branches may mask this trend
5. Concentrations of sulfides in pressure sewers cannot yet be quantifiably predicted because of the empirical nature of the available equations and their derivation from weaker conventional wastewaters.
6. SDG sewers should not be designed to minimize pipe sizes, to flow full for substantial periods, or to proliferate substantial inundated sections of mainline if sulfide minimization is desired.
7. For conventional gravity sewers, equilibrium sulfide concentrations result from long pipe segments of relatively uniform conditions. Applying the equilibrium equation for conventional gravity sewers to SDG sewers results in concentrations comparable with those observed in SDG sewers. These concentrations are much lower than the higher levels reported to occur in septic tanks.
8. Because of the phenomenon of conclusion No. 7, SDG sewers appear to be capable of producing terminal wastewater sulfide concentrations lower than those of pressure sewers.
9. Conventional placement of air-release valves at high points of a pressure sewer system does not preclude the entrainment of air, which results in headlosses greatly exceeding design calculations.
10. In downhill runs where the pressure main intersects the dynamic hydraulic grade line (HGL), a hydraulic jump is formed that generates gas bubbles that pass on to downstream segments of the main.
11. Placement of sewage-type automatic air-release valves at points at least 14 pipe diameters below hydraulic jump locations was effective in removing entrapped air and reducing headlosses to near theoretical levels.
12. Backpressure sustaining valves were found to be inadequate for control of downhill hydraulics in the pressure sewer because of high capital cost, intensive maintenance requirements, and unreliable operation.
13. On downhill runs with irregular terrain that provide numerous opportunities for the formation of smaller hydraulic jumps, standpipes were shown to be inexpensive and reliable. The standpipes used large-diameter downlegs to prevent the escape and conveyance of air bubbles into the downstream segment of the mains and automatic air-release valves at their summits to expel the trapped gases.
14. Soil absorption beds were successfully used for the vented gases from the air-release valves to prevent hydrogen sulfide odors.

Recommendations

The designer needs improved capability to predict sulfide concentrations in pressure and SDG sewers. Toward this end, comprehensive studies of sulfides should be made from the septic tank to the terminus of a number of these systems to identify the gains and losses of sulfide concentration, to quantify the mechanisms responsible, and to develop predictive equations. Once this goal is accomplished, a study should be undertaken to develop a corrosion-based methodology for evaluating the alternatives of designing a transition station or modifying a receiving conventional sewer. Such a methodology would provide a quantitative solution to one of the major design obstacles in the design of pressure and SDG sewers that terminate at larger conventional sewers.

A need also exists for more quantitative assessment of the requirements for, location of, and design and operating and maintenance requirements for air-release valves in pressure and SDG sewer systems. Further assessment is also needed for soil absorption and other low-maintenance odor control methods appropriate for these alternative sewers.

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