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Combined Sewer Overflow Technology Fact Sheet

Maximization of In-line Storage

DESCRIPTION

This fact sheet describes technologies designed to maximize the in-line storage capability of combined sewer systems, thus reducing the frequency and/or severity of Combined Sewer Overflows (CSOs).

Sewer systems that convey both sanitary sewage and storm water through a single pipe are referred to as combined sewer systems (CSSs). In dry weather, the CSS is able to convey all flows to the wastewater treatment facility. During periods of heavy rainfall, however, the capacity of the CSS may be exceeded and an untreated combination of sewage and storm water may discharged directly into a nearby receiving water. These overflow instances are called Combined Sewer Overflows, or CSOs.

CSOs contain untreated domestic, industrial, and commercial wastes. Contaminants include suspended solids, biochemical oxygen demand (BOD), oils and grease, toxics, nutrients, floatables, pathogenic microorganisms and other pollutants. CSOs often contribute to exceedances of water quality standards and can result in threats to public health, aquatic species, and aquatic habitat.

Under the U.S. Environmental Protection Agency (EPA)'s CSO Control Policy, discharge permits issued to communities with CSSs are expected to include "nine minimum controls." The nine minimum controls are measures that can reduce the magnitude, frequency and impacts of CSOs without significant construction or expense. Maximization of storage in the collection system is one of the nine minimum CSO controls.

In-line storage capacity is typically obtained through the use of control measures downstream from a point where excess capacity exists. Typical control measures include:

- Inspection of the collection system and removal of obstructions.
- Maintenance, repair and replacement of tide and control gates.
- Installation and adjustment of regulators.
- Reduction/retardation of inflows.
- Upgrade/adjustment of pumps.
- Real time monitoring.

These control methods are discussed in more detail below:

Collection system inspection and removal of obstructions

Collection system inspection involves investigation of pipes and inflow points to determine where sediments, debris, and other obstructions are preventing the system from operating as designed. Removal of obstructions can reduce CSO volume by increasing the amount of storage capacity in the system. Sediments and small obstructions can be removed by sewer flushing; large obstructions are often removed manually. Routine inspection ensures that obstructions are identified and removed quickly.

Tide and control gate maintenance, repair and replacement

Tide gates are designed to reduce or prevent receiving water from flowing back into the sewer outfall during high tide. Proper maintenance is essential for the tide gate to function as designed. Leaks and cracks that allow flow to pass alter design performance and reduce available in-line storage.

Flap style tide gates are commonly used to resist tidal influences. These gates are typically hinged stainless steel doors attached to the outfall, opening and closing dependent on the relative pressure applied by CSO flows or tidal influence.. While simple in construction and operation, typical flap gates are subject to fouling and sticking and require appreciable hydraulic heads to operate against their own weight (WEF, 1989). Commonly encountered problems with typical flap gates include warpage, corrosion, and the tendency to become stuck in one position (U. S. EPA, 1993).

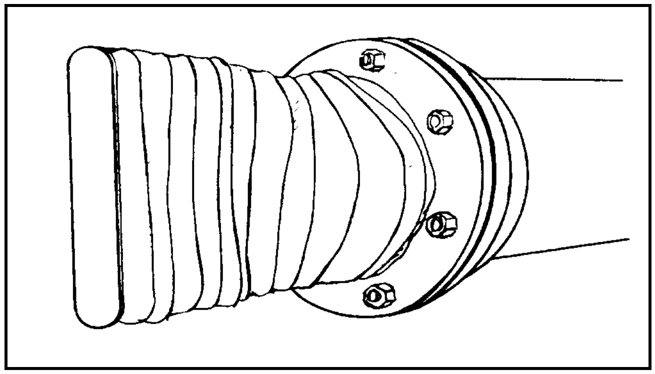
Elastomeric tide gates may be considered when installing or replacing a tide gate. An elastomeric tide gate is a positive pressure device that forces CSO flows to open an otherwise collapsed rubber-based valve. Elastomeric tide gates can overcome many of the problems encountered by typical flap gates. They are designed to open with smaller head requirements and to close over larger debris. A typical elastomeric check valve appears in Figure 1.

The use of flap gates and elastomeric tide gates allows greater retention volume in the collection system by minimizing tidal inflows. The benefits of these devices are greater at outfalls with significant tidal influence.

Regulator Installation and Adjustment

Regulators control the amount of flow to a downstream point and provide an outlet for flows in excess of the sewer capacity. Adjustment of regulator settings, proper regulator maintenance and increasing a regulator outlet to the interceptor are control measures that can ensure optimal system performance and maximize in-line storage.

A vortex valve is used to discharge high flows through a spiral action valve while leaving low flows untouched. Vortex valves have been used to divert flows to CSO treatment facilities, control flow out of storage facilities, and replace failed mechanical regulators (U.S. EPA, 1993). Since the flow through the vortex value is constant during storm events, it serves to dam high flows. Obstructions to flow such as trash and debris pass through the vortex, reducing maintenance costs over traditional valves.



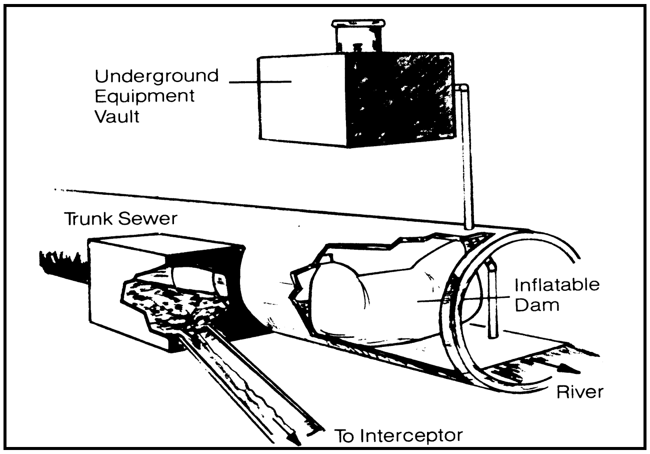
Source: WEF, 1989.

FIGURE 1 TYPICAL ELASTOMERIC CHECK VALVE

Inflatable dams are popular control measures whereby a rubberized fabric device is inflated and deflated to control flows and maximize storage in designated points in the combined sewer system. Inflatable dams are usually activated by automatic sensors that measure flow levels at specified points in the system. Generally, very little maintenance is required for inflatable dams. The air or water supply used to inflate the dam, however, should be inspected regularly. A typical inflatable dam appears in Figure 2.

Many other mechanical regulators are designed to operate under the control of gravity. These devices are semiautomatic and mechanically variable, depending on flow. Because these systems are activated by float mechanisms or pressure plates, they require little maintenance, and they eliminate the need for power sources.

As conditions change with system demands over time, regulator adjustment ensures an optimal routing of flows in the combined sewer system. Regulators in areas of growth may need to be



Source: WEF, 1989.

FIGURE 2 TYPICAL INFLATABLE DAM

adjusted to allow additional flows beyond the intended discharge (U. S. EPA, 1995). Increasing regulator outlet to the interceptor can be allowed if sufficient capacity exists in the downstream interceptor or the wastewater treatment plant.

Reduction/Retardation of Inflows and Infiltration

The reduction or retardation of inflows and infiltration (I&I) lowers the magnitude of the peak flow passing through the collection system, helping to prevent the occurrence of CSO events.

Inflows are wet weather flows resulting from the entry of storm water directly into the CSS. Examples of inflows include parking lots and surface roads containing storm water inlets, and roof and sump drains connected to storm water inlets, either directly or from sheet flow over impervious surfaces. Infiltration is that flow that enters the CSS through joints, cracks and manholes as a result of wet weather events. Infiltration can also enter the system from leaking tide gates.

Inflows can be reduced by detaining or infiltrating storm water runoff at the point of generation (e.g. onsite ponds, tanks, infiltration trenches, porous pavement), in regional detention facilities, and by disconnecting or blocking roof, sump pump and perimeter drains. Commercial devices that retard the rate of inflow can also be installed. They include storm water inlet flow restriction grates and piping, and hydrobrakes. Before installing such devices, care should be taken to ensure that sufficient drainage is provided to prevent upgradient flooding.

I&I studies can be performed to determine the extent and severity of CSS capacity reduction impacts. Manhole inspection, smoke testing and television inspection are common methods of measuring I&I. Infiltration can be corrected through sewer repair, relining and replacement, and root control in areas with mature or aggressive trees.

Upgrade and Adjustment of Pumps

Upgrading/adjusting a lift station pump can result in additional in-line storage in upgradient portions of the system, if sufficient hydraulic downgradient capacity is available. Effects of the additional pumping rates on the ability of the wastewater treatment plant to treat increased flows must first be determined.

Raising Existing Weirs and Installation of New Weirs

Raising existing weirs and installing new weirs utilizes in-system storage by controlling discharge in the overflow conduit. By controlling discharge, the CSO volume and frequency are typically reduced. The installation of weirs can be implemented in stages so as to reduce the risk of surcharging. Masonry bricks, concrete blocks and stop logs are commonly used media for weir construction.

System of Real-time Monitoring/Network

A computerized system to control regulators can be set up to maximize in-line storage. In ‘real-time’ systems, flow and precipitation data are measured by sensors throughout the system. The collected data is transferred immediately from the measuring device to a central control computer through a communications system. The controlling computer uses the data as input for system operations. The control center then automates control of gates, pumps and other regulators based upon the analysis. The process allows for the instantaneous change of control settings in response to changing precipitation and flow conditions throughout the service area.

APPLICABILITY

Implementation of control measures that maximize in-line storage can result in the lowest cost additional storage alternative. In-line storage is appropriate for systems with limited space for other types of controls. Construction disruption is minimized, and available storage can include any part of the system with potential to contain additional CSO volume. Potential for the greatest performance improvements will be found in systems where trunk and interceptor lines can handle additional flow volumes. Additional treatment of combined flows can be realized via settling of sediments within the system. Access to areas where increased detention and settling is to occur is important as sediments must periodically be removed.

Monitoring and modeling systems are frequently used tools to determine available storage locations. Hydraulic monitoring of the system provides necessary information on flow characteristics. Computer modeling of rainfall and flow data can simulate system response to event conditions and, thereby, assist planners in determining the most appropriate areas for maximizing in-line storage.

ADVANTAGES AND DISADVANTAGES

Limitations of in-line storage include: the potential for backing flows (surcharging) into basements or streets; the amount of additional flows the system can detain; and increased operation and maintenance requirements.

Before applying an in-line storage control measure, the hydraulic grade line must be evaluated in order to determine the effect of the proposed measure on the system. The hydraulic grade line is an imaginary line obtained by adding the force of the flow (pressure head) and the elevation of the flow relative to the outfall discharge (elevation head) at a given point in the collection system. A serious potential for surcharging flows into basements or streets exists without proper hydraulic evaluation of proposed in-line storage measures. If a computer model is used, the maximum height of the hydraulic grade line should be specified so that control measures designed to maximize in-line storage do not cause surcharging of the system.

Combined sewer systems must maintain minimum flow velocities in order to transport solids and sediments to the wastewater treatment facility. This may limit the increase in the volume of flows that can be detained with additional control measures. Effects of each in-line storage measure should be evaluated before implementation to determine the effect on the conveyance of dry weather flows to the wastewater treatment facility, and on other existing and proposed controls.

Most control devices have routine operation and maintenance requirements. With increased volume, additional solids and debris will collect in the trunk and interceptor lines. Therefore, maintenance requirements for the system usually increase with control measures designed to maximize in-line storage.

By reducing the volume of CSOs released to receiving water, maximization of in-line storage reduces the adverse impact of BOD, TSS, nutrients, and other contaminants.

Surcharging of the collection system is a possible limitation of maximizing in-line storage. The likelihood of surcharging, and the associated public health risks, must be evaluated before implementing control measures to maximize in-line storage. Flooding problems can be avoided through effective monitoring efforts, hydraulic modeling, and/or physical barriers such as disconnection of basement sump pumps and perimeter drains.

PERFORMANCE

The performance of maximizing in-line storage for CSO control can be examined through a series of case study examples outlined below.

Cleveland, Ohio Area

The Northeast Ohio Regional Sewer District began using an automated control system for its combined sewer system in 1972 and has expanded the system over time. The current system comprises sensing elements, field control elements, communication equipment, and a central control center. A network of 25 rain gauges, 24 remote level monitors, 56 remote flow monitors, and local level monitors at the regulators comprise the sensing system. Data collected from these devices are sent via modem or radio to a central control facility. The entire system is connected by a central computer which operates on a local area network of personal computers. Twenty-nine automated regulators, all which have distributed control with programmable logic controllers (PLCs), are used to control the amount of flow in various portions of the system. This system was augmented by physical in-line changes, whereas fixed weirs were replaced by gates and inflatable dams. The PLCs use the sewer levels, gate positions, and dam pressures as variables to compare with fixed points. By comparing the variables and fixed points, the amount of available storage and CSO discharge is determined. In-line storage is maximized by adjusting controlling regulators based on current system conditions.

Results of the Cleveland area real time monitoring and control system have proven to be efficient in achieving significant reductions in overflow. Interceptor capacities have been maximized by utilizing in-line storage, and reductions in BOD(5) and TSS discharges to the environment have proven to be cost effective through the operation of automated regulators. Less than one percent of capital improvement funds since 1972 have been spent on real time control systems (Hudson, 1994).

On average, the automated system has prevented about 2 MGD of untreated flow from entering the environment every day. In 1994 approximately 950,00 lbs. of BOD(5) and 6.7 million lbs. of TSS were captured. The operating cost for storage of these parameters were $0.15 and $0.16 per pound, respectively.

Boston, Massachusetts Area

In 1993, the Massachusetts Water Resources Authority (MWRA) completed a System Optimization Plan (SOP) for Boston and three other nearby CSO communities. The SOP identifies relatively simple structural or operational modifications that can reduce CSO frequency and volume. The SOP projects are designed to be low in cost and easy to implement.

Recommended improvements included raising weir elevations, repairing regulators, constructing regulators and weirs, plugging and abandoning certain overflow pipes, and replacing or repairing tidegates.

The MWRA recommended SOP measures at 103 locations. As of June 1997, approximately 95% of SOP projects have been completed (Parker, 1997). The MWRA SOP analyzed the projected volume and percent reduction as modeled for each optimization project. It also analyzed the cost/benefit ratios for each project. The MWRA estimates that SOP improvements would reduce the volume of CSOs (including treated CSOs) by over 25% (MWRA, 1993).

Norwalk, Connecticut

The City of Norwalk, CT, eliminated untreated CSO discharges in 1980 by separating some outfalls and bringing all remaining flows to the wastewater treatment plant (WWTP). Like many old combined sewer systems, Norwalk has large diameter connecting and interceptor lines. Utilization of the maximum capacity in the system allows for the greatest treatment of CSS flows at the WWTP. This is accomplished through regulation of the plant’s main gate. Existing in-line storage capacity is utilized to hold as much flow as possible until the storm event passes. Operators use rain gauges and monitoring of a large siphon at the main interceptor junction to assist in regulating the plant’s main gate. Regular maintenance and cleaning of sewer lines after storm events ensure that the greatest possible volume of flow is stored in the collection system.

During certain storm events, excess flow not handled by the WWTP enters a CSO treatment facility that provides micro screening and disinfection. Flows entering the micro screening units pass through spacings of 33 microns up to 256 microns, depending on volume of flow. All flows are then routed through the WWTP chorine contact chamber for disinfection. The CSO treatment facility averages 30 per cent BOD(5) and TSS removal, with some smaller storm event removals of up to 50 per cent.

The Norwalk WWTP is undergoing an upgrade to biological nutrient removal (BNR). The plant treatment capacity will be increased from 20 MGD to 30 MGD per day. As this facility comes on-line, maximization of in-line storage will allow maximum treatment of wet weather events to the BNR facility. Since the existing CSO treatment facility provides only the equivalent of primary treatment, significant water quality improvements will be obtained by maximizing treatment to the WWTP.

COSTS

Techniques to maximize in-line storage are most cost-effective in trunks and interceptors with mild slopes and large storage capabilities.

Capital and O&M costs vary considerably based the on characteristics of the system and the type of control measure implemented. Ancillary costs may include traffic rerouting and traffic control plans, proper ventilation requirements, and post construction monitoring.

Some in-line storage measures do not require capital improvements. In Norwalk, CT, for example, no capital costs are involved with regulation of the main control gate. Expensive replacement of drum screens and associated O & M at the CSO treatment facility is reduced by maximizing in-line storage. O & M for the collection system does increase as a result of the operational modification.

A comparison of costs for control measures implemented by various communities appears in Table 1.

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ADDITIONAL INFORMATION

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TABLE 1 COST COMPARISON FOR CONTROL MEASURES

Control Measure	City	Unit	Capital Cost	Annual O & M
Regulator Installation (Inflatable Dams)	Washington D.C.	per dam	$1,219,000[1]	N/A
Pump Installation	San Francisco, CA	gpd	$0.10-$0.11 gpd[2]	N/A
Install Raised Weir's	Boston, MA Area	per weir	$3,250 brick & mortar [3] $12,050 formed concrete[3] $18,100 stop logs [3]	N/A
Real Time Monitoring System	Cleveland, OH Area	per unit	$264,000 auto regulators[4] $12,900 remote level monitor[3]	automated regulator $11,975[3] rain gauge $2,830[3] flow and level monitor $3,270[3]
	Philadelphia, PA	system	$1,906,000[5]	N/A
Collection System Inspection	Norwalk, CT		None	reduction in O & M for microscreening devices; increase in O & M for collection system
Tide Gate Replacement	Boston, MA Area	per gate	$24,100[3]	N/A

ENR = 5750

[1] Average cost per dam of 12 dams installed at 8 sites; complete cost includes all monitoring equipment
[2] Used to convey flows from CSO treatment facilities to WWTP as conditions allow
[3] Typical cost; costs vary by site
[4] Average bid cost of automated regulators (usually inflatable dams) in Southerly WWTP district; costs vary by site
[5] System = 1 central computer, 8 computer controlled regulators, level measuring devices at 53 regulators, 22 rain gages, flow metering at 18 stations, several other level devices

Sources: AMSA 1994, Hudson 1996, Metcalf & Eddy 1993, Northeast Ohio Regional Sewer District 1997, Treffeisen 1997.

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