September/October 2011

Environmental Science & Engineering MAGAZINE

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New CSO treatment shaft technology replaces cancelled tunnel project

By Kurt Giberson

A large CSO tunnel project in Dearborn, Michigan, proved to be uneconomical because of geotechnical challenges, and was cancelled in 1995. However, a solution to the untreated overflows was still needed, so a multi-year process was initiated to re-evaluate every design solution and potentially develop new alternatives.

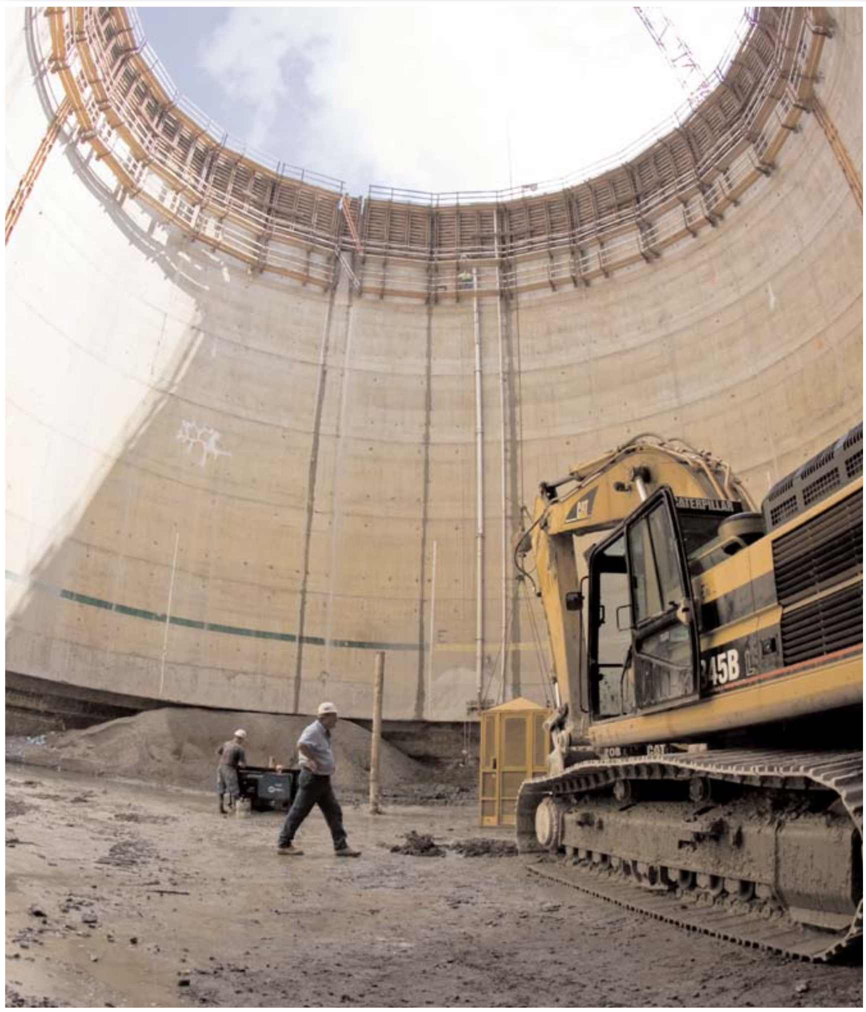
Various tunnel systems were reviewed, as well as sewer separation, which had always been the highest cost alternative. Retention treatment basins, which had been rejected, due to land constraints, were looked at again. Also, a downspout disconnect program was launched to reduce roof top run-off contributions to the sewer system.

A joint feasibility study with an adjacent community was also conducted to see if a shared tunnel would reduce costs through its economy of scale (680 million litre volume). The joint tunnel was a tough option, as it would require complex controls to minimize surging and was a high construction risk due to poor rock conditions. Also, since it only provided capture capacity, there was a possibility that costly screening and disinfection facilities would be required in the future. These challenges, plus minimal cost savings, led to a decision to pursue other options.

It was during this lengthy analysis that a very different alternative gained attention. The new concept, referred to as a "treatment shaft," provides integrated combined sewer overflow (CSO) multi-treatment in a single vertical shaft. This design concept solved many of the hydraulic and regulatory issues facing the project, and was eventually adopted as the primary CSO control alternative.

Treatment shaft features

In addition to the complete capture of CSOs for the vast majority of storms, the patented "Treatment Shaft Technology" also provides high-rate flow-through treatment of overflows beyond its storage capacity, including skimming, settling, screening and disinfection of flow rates in excess of 52,868l/s. (Figure 1).



The treatment shafts are constructed using the sinking caisson construction method.

A key feature of the treatment shaft design is its low hydraulic head loss and low upward velocity that promotes settling of suspended organic and inorganic solids. During the peak hourly average flow rate of the 10 year, one hour design storm, upward velocity within the shaft is less than 30 millimetres per second. This drops dramatically after the peak hourly average so that one hour later it is only 3 millimetres per second.

Head loss through the entire treatment shaft is only 0.18 metres (with fine screening) during the peak five minute average of the 10 year, 24 hour design storm. This also drops dramatically afterward.

Treatment shafts can also work with a variety of disinfection methods. If disinfection is not required, the design still provides capture volume, skimming, settling and screening, all within a compact footprint that is only about 15% of surface storage (Figure 2).

Horizontal raked bar screens (5 millimetre spacing) are used on the effluent side. The horizontal configuration ensures that all flows, high or low, are screened with minimum velocities through the screens. The entire flow is in contact with the screens, achieving a highly efficient perpendicular flow path. During a treated overflow event, the screens are continually raked by a hydraulically driven system.

All materials collected during operation automatically end up at the bottom of the shaft. They are pumped back to the treatment plant after the storm event, without additional handling or the use of trash containers. All maintenance of the horizontal raked bar screens can be performed top side.

A robust, automated flushing system at the conical bottom of the shaft, using jets designed with computerized fluid dynamics, provides cleaning of the facility in preparation for the next storm event. The jets create a swirl effect that re-suspends settled materials and scours the cone-shaped bottom, followed by dewatering with small pumps to deliver the captured flows to the treatment plant within 24 to 48 hours. The jets can use the combined sewer water within the shaft, or a potable water source, if additional flushing is required.

Comparison to traditional alternatives

Common flushing systems for basins, such as tipping buckets, are unable to fully scour the bottom surface. This can result in odour problems and require time-consuming manual cleaning. In tunnels, the typically flat slope promotes settling of materials that are not removed by later storm events. Over time, significant loss of capture volume can occur, again requiring manual cleaning. The automated flushing process and conical bottom of treatment shafts eliminate these problems.

Another advantage over tunnels is in surge control. Tunnel design often requires complex modeling to determine potential surging during filling. As tunnels fill rapidly during large storm events, tremendous hydraulic forces occur that can cause dramatic surges and grade line elevations, as well as structural damage. Computer modeling required to predict such phenomena is complex and can be expensive. Surge control structures and monitoring systems are then needed to avoid these undesirable effects, adding substantial cost to a tunnel system.

Treatment shafts resolve these issues, because their large diameter and configuration act as a surge control structure. Lower head losses in treatment shafts also help eliminate the need for booster pump stations, often required for tunnels and basins.

Figure 1. Patented Treatment Shaft Technology.

Figure 2. If disinfection is not required, the design still provides capture volume, skimming, settling and screening, all within a compact footprint.

The compact footprint of treatment shafts means that far less surface area is required for siting, compared to retention basins. In terms of their land requirements, they are only 15% of the size of basins of the same volume. The upward flow of the effluent discharge allows for the use of the horizontal raked bar screens, which require no surface building. This means that the entire system (shaft, screens, disinfection and control systems) can be placed under the shaft cover, with virtually no surface presence noticeable to the public. With a concrete cover, the top can be used for a variety of secondary purposes, from parking to recreation.

Physical model study

Prior to final design, a one-nineteenth scale physical model (Figure 3) was constructed at the University of Michigan - Ann Arbor, to test the expected perform-

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Figure 3. One-nineteenth scale physical model.

Figure 4. Sinking caisson construction method.

ance of treatment shafts. The study confirmed that the shaft itself introduces only 0.126 metres of head loss, during the peak flow rate of 52,868 litres/sec. This ensures successful gravity operation during flow-through operation. Also, the very low velocities through the structure provide negligible flow inertia. This eliminates the potential for undesirable surges.

The hydraulically efficient horizontal raked bar screens add only 0.051 metres of additional head loss. Minor modifications to the upstream sewer system can be included in projects, so that no net additional head loss occurs. This eliminates the need for booster pump stations.

Construction projects

Four major projects based on this new design are currently being constructed to control CSOs in Dearborn, Michigan. The first of these projects became operational in December of 2010, and the second came on line in 2011. Construction costs for these projects were 30-50% lower than comparably sized alternatives. Treatment shafts are expected to reduce capital costs by over $100 million (USD). Ongoing operations and maintenance will be less complex than basins or tunnels.

The treatment shafts are constructed through soft clay and into limestone rock, using the sinking caisson construction method (Figure 4), to depths up to 52 metres. One of the largest of the shafts controls peak flows of 53 cubic metres per second. This project has a diameter of 29 metres and a capture volume of 25.7 million litres to provide 10 minutes of disinfection contact time for the peak hourly design flow rate.

Conclusion

Treatment shafts are now proving that they can provide significant benefits. As such, this CSO alternative is now being considered by many cities across Canada and the US.

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