5. White Papers

5.1 Infiltration/Inflow Reduction White Paper

The Capacity Assurance Program Plan (CAPP) project was developed to meet the Metropolitan Sewer District of Greater Cincinnati (MSDGC) Interim and Global Consent Decree mandates regarding assurance of capacity to control sanitary sewer overflows (SSOs). The project is based on the results of the hydraulic model used in the Capacity Assessment Report (CDM, October 2004). That report documented development of a calibrated system-wide model and identified areas of the system with limited hydraulic capacity to convey present (June 2003) flows and those from the 2025 build-out community during periods of significant wet-weather conditions. CAPP builds upon the capacity assessment by developing capital improvement projects to improve the conveyance capacity.

The extent (number, size) of the capital improvement projects is directly related to the capacity necessary to convey the peak wastewater flow rates. Peak flows are inherently related to the amount of rainwater unintentionally captured in the sanitary sewers. The capacity assessment allowed for this inadvertent rainwater by including infiltration and inflow (I/I) factors in the system-wide model. One alternative considered to relieve the capacity restraints is the reduction of the I/I of non-sewage waters.

The purpose of this document is to provide a framework for evaluating the effectiveness of I/I reduction as a potential alternative for capacity relief. The document is presented in three major sections:

- A summary of past MSDGC stormwater I/I removal programs
- A summary of industry experience with I/I reduction programs
- A recommended approach for future MSDGC evaluation of I/I reduction potential

Past District Stormwater I/I Removal Experience

The MSDGC stormwater removal program is particularly important because it is an early, and continuing, effort to address a major factor in capacity limitations, i.e., the stormwater inadvertently carried in sewers designed for only sanitary wastes. Prior to 1991, MSDGC efforts to identify and remove sources of I/I were hindered by the fact that MSDGC did not have a practical way to enforce I/I removal on private property. MSDGC had the authority, through the Rules and Regulations, to enforce the removal; however, MSDGC relied on the various municipal leaders to work with the property owners. In 1991, MSDGC began a new, more effective program for removing I/I from sanitary sewers (Zande 1997).

MSDGC worked with the state legislature to amend state law to allow a municipal agency to pay for improvements on private property. The Board of County Commissioners, the body that governs MSDGC, voted to allow up to $3,000 per property for removal of these I/I sources from private property.

MSDGC expanded the I/I source identification program in 1992 to emphasize areas with identified SSOs. This corresponded with the issuance of the Director's Final Findings and

Orders by the Ohio Environmental Protection Agency (OEPA), dated September 22, 1992. Section 2D of these Orders directed MSDGC to develop a plan that included:

> "…. a fixed-date compliance schedule for (1) completing a program for investigation and minimization of precipitation-dependent inflow and infiltration affecting separate sanitary sewers subject to overflows;"

MSDGC initiated the rainfall-derived I/I (RDI/I) Removal Program with a pilot study in the village of Mariemont in the eastern part of Hamilton County. Mariemont was an area that had SSOs and had experienced considerable basement backups due to the surcharging of the sanitary-only sewer.

The Mariemont project began with smoke testing followed by dye testing of all connections that smoked. This was quickly changed to smoke testing followed with dye testing of all downspouts, driveway drains, and area drains. In addition, any inlets on storm sewers that crossed the sanitary sewer were smoke and dye tested. Manhole inspection was also a part of this program, but no flow monitoring was done with this project.

This pilot program was then expanded to include all areas with active enumerated SSOs.

In 1992, the first year of the program, 604 unauthorized connections were identified, and 345 were corrected at a cost of $361,770. By 1998, the totals were 18,864 identified and 11,678 removed at a cost of $11,317,530.

I/I identification and removal focused on inflow in the beginning of the program; this focus changed to infiltration as the I/I effort matured. Flow monitoring was utilized and MSDGC began to investigate infiltration sources such as sump pumps, foundation drains, and lateral integrity. The Matson Area in Deer Park was the pilot project for this next step.

MSDGC found a close correlation between the capacity and maintenance of the storm sewer system and the inflow into the sanitary sewer. The stormwater flows into houses in areas where the storm sewer system (or lack of storm sewer system) causes street flooding or flooding around the houses. The stormwater flows into depressed driveways under the houses, through window wells around the houses, and through cracks between the foundation and the soil surrounding the foundation.

The funds expended on the I/I identification and removal effort to date has been effective in removing flow from the system. The amount of flow effectively removed from the MSDGC system is difficult to quantify since pre- and post-flow monitoring was not conducted as part of the RDI/I Removal Program. The intent was to use the available funds to identify and eliminate the sources of the I/I as a first step. The program to date has resulted in a reduction in customer calls reporting basement backups in the targeted areas such as Mariemont in the Little Miami Basin. To date, SSOs have not been eliminated with the work completed. The current I/I removal program is dramatically scaled back from the initial efforts, but is still ongoing, identifying connected downspouts, driveway drains, and area drains that must be removed.

Overview of I/I Reduction Experience Elsewhere

I/I is the encompassing term that includes both groundwater infiltration and RDI/I. I/I is undesirable because it occupies pipe and treatment capacity that ideally should be reserved to convey and treat only sanitary flow. I/I control was an essential element of the construction grants program that funded the early construction under the Clean Water Act.

The traditional methodology for I/I control involves finding the sources of I/I, then sealing out the unwanted water. Utilities often employ flow monitoring and maintenance programs to identify sub-basins with relatively high I/I and then allocate source detection resources to identify potential sources. Based on the I/I severity and type of defects found the analyst is then challenged to determine the appropriate level of I/I reduction that can be cost-effectively implemented.

To compound the difficulty, utilities recognize that pre- and post-monitoring to evaluate the effectiveness of I/I reduction efforts are usually inconclusive. Multiple studies yield a wide range of the impacts from rehabilitation programs designed to target I/I sources. Repeatable and accurate flow monitoring of the dynamic wastewater conveyance systems is difficult due to varying rates of storm patterns, complex hydraulics, sewer deterioration, groundwater tables, and operational changes, among others. Furthermore, over a period of months or years after an I/I reduction program is introduced, new I/I sources may appear due to deterioration or illicit attempts to remove drainage waters.

I/I Control Effectiveness

In 2003, the Association of Metropolitan Sewerage Agencies (AMSA) surveyed municipalities across the country to gather information on the factors that publicly owned treatment works (POTWs) consider when sizing their wastewater conveyance and treatment systems for peak wet weather flows. The report (AMSA, 2003) documented a specific question: "Has I/I reduction been an effective control alternative?" The results indicated a varied perception of I/I rehabilitation effectiveness. The following is excerpted from the report:

> "Fifty-two percent of respondents (39 of 75) indicated that I/I control has been an effective peak flow control strategy; 17 percent (13 of 75) believed I/I removal to be effective, yet insufficient data exist to support that conclusion. Among those who believe I/I reduction to be effective, the most common methods for measuring its relative success were reduced customer complaints/service calls in historic problem areas (64 percent; 25 of 39), post rehabilitation flow monitoring (49 percent; 19 of 39), and lower observed peak flows at the POTW (41 percent; 16 of 39). Twenty-one percent of respondents (16 of 75) do not believe I/I reduction to be an effective strategy, as determined by the absence of reduced customer complaints/service calls (69 percent; 11 of 16), post-rehabilitation monitoring (25 percent; 4 of 16), and no observed change in flow recovery to normal after rainfall events (25 percent; 4 of 16). Several respondents (10 percent; 8 of 75) do not know either way if I/I reduction has been an effective strategy."

Results of source detection programs are often unreliable. Programs incorporating closed-circuit television (CCTV) inspection are highly dependent upon operator experience and the antecedent moisture conditions in the soil. CCTV can document sump pump discharges and contribution of leaking laterals and foundation drains if CCTV activities are completed after

a rainfall with wet antecedent moisture conditions or a during snowmelt. Smoke testing results are also often confounded by the antecedent soil conditions.

Spot repairs or limited slip lining are seldom effective because of water migration. As defects are repaired, the water migrates to the next infiltration source thereby reducing the effectiveness of the repair. Water Environment Federation's (WEF) *Existing Sewer and Evaluation and Rehabilitation* (WEF, 1994) cautions that "consideration has to be given to the "fluid" nature of the I/I sources, particularly if rehabilitation is limited to specific components in the total system."

I/I enters the wastewater conveyance system from three primary sources: collection lines, manholes, and service lines. The opportunity for I/I is related to the length of the sewer lines and the number of junction points. Percentages of city-owned versus privately owned sewer footage vary, but approximately 50 percent of the wastewater conveyance system is privately owned (private laterals). In areas of high-density housing, 75 percent of the infiltration can result from the service connection (WEF, 1994). A significant amount of I/I sources are traditionally found on private property. Without an aggressive, enforceable program to locate and repair these private property defects, often at homeowner expense, a significant portion of the I/I sources remain. The Lower Paxton Township Authority (LPTA) found that its I/I rehabilitation program removed about 30 percent of the total measured I/I from the mainline but shifted the extraneous flows to the service laterals. LPTA estimated that I/I in service laterals increased from 60 to 80 percent compared to pre-mainline rehabilitation flows. It predicts an overall 60 percent reduction when the service lateral rehabilitation is completed (Rowe, 2004).

Over time, I/I increases as wastewater systems deteriorate. Incorporating a reduction in I/I in the planning recommendations necessitates including sufficient future system-wide inspection, connection construction diligence, and continual system repair (operation and maintenance costs) to sustain the anticipated I/I control.

Inflow/infiltration Reduction Evaluation Recommendations

For capacity planning purposes, the CAPP initially recommended that I/I contributions be assumed to remain constant at the levels included in the capacity assessment models. In general, no reduction in I/I was anticipated since there is little evidence that significant I/I sources can be found and repaired in a manner that results in sustainable reduction in peak flow rates. Thus, the assumption of no reduction in I/I rates builds a reasonable amount of conservatism into the analysis. CAPP also acknowledged that sustaining the current level of I/I requires continued investment in rules enforcement and system inspection and repair.

The initial CAPP recommendation allowed that there are exceptions to the assumption that I/I cannot be reduced in a manner that is both reliable and sustainable. CAPP recommended incorporating I/I reduction into project sizing only where all of the following conditions are met:

- The nature of I/I sources has been identified. This could require extensive source detection program, or could involve identification of a known major source (e.g., a missing manhole lid in a stream invert).

- The cost to remove the identified sources of I/I is included in the project cost.
- A program and funding is identified to continue long-term source detection and repair to ensure additional sources of I/I do not occur.

CAPP recommendations for each basin called for I/I management activities. The Wet Weather Improvement Plan has consolidated these multibasin recommendations into an MSDGC-wide recommendation for continued I/I exclusion, detection, and repair. CAPP best professional judgment also recommends adaptive management approaches for those areas experiencing extremely high I/I. Each of the recommended CAPP basin analyses still call for I/I management, but the funding for these programs is excluded from the basin plans in favor of MSDGC-wide programs. The following text summarizes the MSDGC-wide programs anticipated as an essential part of the CAPP basin recommendations.

Continued I/I Exclusion, Detection, and Repair

CAPP recommends that MSDGC continue an aggressive program of I/I exclusion, detection, and repair in order to protect both the existing capacity and the recommended capacity enhancements against future growth in peak flows resulting from increased I/I. Logic and experience both demonstrate that I/I will increase with infrastructure aging unless aggressive programs are implemented to exclude, detect, and repair defects the permit leakage. The I/I exclusion, detection, and repair program might include:

1. Connection restrictions
    1.1. Review and recommendations for municipal servicing requirements
    1.2. Review and recommendations for municipal plumbing inspections
    1.3. Review and recommendations for sewer design standards
    1.4. Review and recommendations for sewer construction inspection
2. I/I detection
    2.1. Flow monitoring programs
        2.1.1. Review WWTP influent records
        2.1.2. Rotating sewershed monitoring
    2.2. CCTV inspection program
    2.3. Evaluation of storm sewer system for capacity and adequate maintenance
    2.4. Follow-up inspection in areas with increasing I/I
3. I/I exclusion
    3.1. Rehabilitation of deteriorating sewers
    3.2. Enforcement of rules prohibiting rainwater connections
    3.3. Disconnection of observed illicit connections

Adaptive Management for Extremely High I/I

CAPP recognized that some sub-areas of the MSDGC service area experience inordinately high RDI/I. These areas are characterized in the system-wide model with high calibrated, or extrapolated, "R" factors[1]. Statistical evaluation (see Exhibit 1) of the calibrated "R" factors indicated that "R" values above 20 can be considered extraordinarily high. Since an "R"

[1] The MSDGC System-Wide Model uses a triple unit hydrograph method to calculate wet weather flows. The "R" factors in this method are roughly related to the percentage of rainfall that enters the sewer system.

factor of 20 would be appropriate for a low-density development area served by combined sewers, such that an "R" value in a separated sewer system would be unexpectedly high.

Field observations in some of the areas with high "R" values have reported connected downspouts, foundation drains, and catch basins. Many of the high "R" value areas are located near the border between combined sewer service areas and separated sewer service areas. Given that these transition areas were often developed during a period when the industry (engineers, plumbers, inspectors, and contractors) were transitioning from the past practice of single pipe (combined) systems to the then-new practice of two-pipe systems, it is likely that the construction in these areas may have included numerous connections that are currently disallowed in separated sanitary systems. Construction of such illicit connections may continue if plumbers and contractors fail to recognize the "borders" between combined and separate sanitary sewer areas.

Because many designated separated sanitary sewers respond to rainfall like combined sewer systems, failure to curb the high RDI/I in these systems would result in high wet weather flows during large storms. Attempts to provide full secondary treatment to these dilute flows would likely be unsuccessful, even if they could be conveyed to the treatment works.

Recognizing the futility, as well as the expense, of conveying and treating extremely high RDI/I to treatment, CAPP is recommending that projects serving areas with extremely high "R" values be postponed until after site-specific research can identify effective means of addressing the excess flows. An adaptive process for handling these flows will include:

1. Verify the high infiltration and inflow values
    1.1. Verify the model R value is representative
        1.1.1. evaluate how well the model calibration point reflects the area draining to the constraint point
        1.1.2. identify corroborating indicators of high infiltration and inflow
    1.2. Perform additional flow monitoring and model refinement if needed to refine the area to be subjected to further RDII investigation
2. Investigate the source of confirmed high RDII values
    2.1. Review construction plans and applicable municipal rules for connections during the period when the sewersheds were developed
    2.2. Perform additional flow monitoring if necessary to isolate the high RDII areas
3. Evaluate the potential for RDII reduction strategies
    3.1. Strategies to be considered may include:
        3.1.1. Sewer rehabilitation
        3.1.2. Private lateral rehabilitation
        3.1.3. Storm sewer improvement
        3.1.4. Ordinance enforcement actions
        3.1.5. Ordinance revision
        3.1.6. Re-designation of the area as a combined sewer service area
    3.2. Review RDII reduction performance in other similar areas (e.g., areas with similar sources of high "R" values)
    3.3. Perform target research/demonstration projects to test RDI/I reduction strategies
4. Perform sanitary sewer evaluation surveys in the high RDII areas, selectively using:
    4.1. Smoke testing

4.2. CCTV inspection, including side camera lateral inspection
4.3. Yard surveys
4.4. House surveys

5. Evaluate storm sewer system, selectively using:
   5.1. CCTV Inspection
   5.2. Yard Surveys
   5.3. House Surveys
   5.4. Calculation of design capacity
   5.5. Flow monitoring
6. Develop refined projects to relieve surcharge and/or overflows, considering:
   6.1. Re-designation of the area as a combined sewer service area, with development of appropriate regulation structures and controls
   6.2. Identification of the area as a sewer system reconstruction area where all sewers, including private laterals, will be systematically inspected and repaired or replaced as appropriate
   6.3. Implementation of RDI/I reduction measures
   6.4. Sizing and implementing capacity improvements to convey and treat residual RDI/I

I/I identification and removal is an ongoing effort as the MSDGC sewer system ages and more flow enters the system. A comprehensive and aggressive I/I identification and removal program such as the one outlined above should be undertaken in areas with extremely high I/I rates. Although industry, and MSDGC, experience with I/I reduction has been disappointing, there is a need research, test, develop and implement effective means of I/I reduction in order to avoid growth in sewer system capacity problems. This effort is essential to evolving a sustainable, cost-effective and long-term solution for sanitary sewers capacity relief.

References

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