Appendix E-4 – Inflow and Infiltration Reduction in Sanitary Sewers

INFLOW AND INFILTRATION REDUCTION IN SANITARY SEWERS

D.1 Introduction to RDII in Sanitary Sewers

A properly designed, operated and maintained sanitary sewer system is meant to collect and convey all of the sewage that flows into it to a wastewater treatment plant. Rainfall dependent infiltration and inflow (RDII) into sanitary sewer systems has long been recognized as a major source of operating problems that cause poor performance of many sewer systems including system overflows. The extent of infiltration also correlates with the condition of aging sewers.

The three major components of wet-weather wastewater flow into a sanitary system – base wastewater flow (BWWF), groundwater infiltration (GWI), and RDII are illustrated in Figure D-1 and are discussed below.

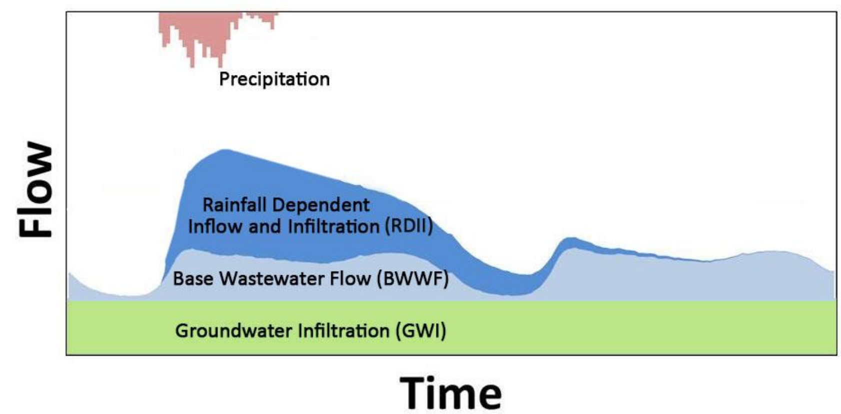

Figure D-1: Three components of wet-weather wastewater flow

BWWF, often called base sanitary flow, is the residential, commercial, institutional, and industrial flow discharged to a sanitary sewer system for collection and treatment. BWWF normally varies with water use patterns within a service area throughout a 24-hour period with higher flows during the morning period and lower during the night. In most cases, the average daily BWWF is more or less constant during a given day, but varies monthly and seasonally. BWWF often represents a significant portion of the flows treated at wastewater treatment facilities.

GWI represents the infiltration of groundwater that enters the collection system through leaking pipes, pipe joints, and manhole walls. GWI varies throughout the year, often trending higher in late winter and spring as groundwater levels and soil moisture levels rise, and subsiding in late summer or after an extended dry period.

GWI and BWWF together comprise the dry-weather flow (DWF) that occurs in a sanitary sewer system. Because the determination of GWI and BWWF components of DWF is not an exact science, various assumptions related to the water consumption return rates and wastewater composition during early morning hours are typically used to help estimate these flows components.

RDII is the rainfall-derived flow response in a sanitary sewer system. In most systems, RDII is the major component of peak wastewater flows and is typically responsible for capacity-related SSO and basement backups. Snowmelt may also cause RDII flows. RDII flows are zero before a rainfall event, increase during the rainfall event, and then decline to zero sometime after the rain stops. For cases with less than saturated antecedent moisture conditions, surfaces and soils may take up some of the rainfall early in the event before a response is observed and, if the event is small enough, there may not be a sanitary system response. The maximum amount of rainfall that does not produce a response in the system is termed the “initial abstraction.”

Figure D-2 depicts various pathways of RDII into sanitary sewer systems in both public right-of-way and private property. “Inflow” is the water that enters the sanitary sewer system directly via depressed manhole lids and frames, downspouts, sump pumps, foundation drains, area way drains and cross-connections with storm sewers. Although direct connections such as downspouts, sump pumps, foundation drains, and areaway drains are no longer common design practices, they still exist and contribute to inflow in many older sanitary systems. Inflow typically occurs shortly after a rainfall starts and stops quickly once it stops. Inflow is typically the major component of the RDII peak flow and often contributes to limitations in conveyance system capacity. Therefore, reducing inflows can reduce the peak wastewater conveyance above the design flow rates and consequently capacity related problems in operating sewer systems.

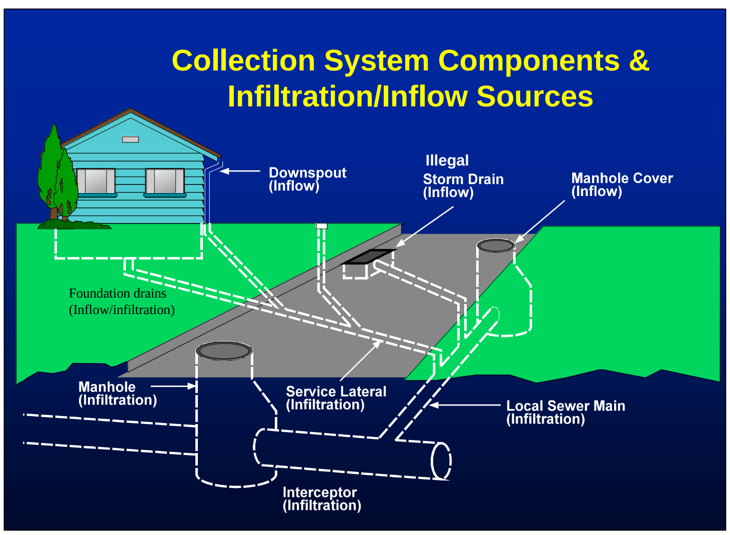

Figure D-2: Pathways of infiltration and inflow into sanitary sewer systems.
(Courtesy of EPA Publication: Computer Tools for Sanitary Sewer System Capacity Analysis and Planning, EPA/600/R-07/111).

Rainfall-derived infiltration (RDI) refers to rainfall runoff that filters through the soil before entering a sanitary sewer system through damaged pipe sections, leaky joints or poor manhole connections. These defects can occur in both the public right-of-way portions of the sanitary sewer system or in individual service laterals on private property. Infiltration processes typically extend beyond the end of rainfall and takes some time to recede to zero after the storm event. A system may experience a fast RDI response, a slow RDI response, or both.

In areas characterized by soils with high percolation rates, RDI can quickly enter shallow service laterals and sewer system defects, contributing significantly to the peak wet-weather response. RDI is typically the major component of the total RDII volume, especially during periods of high antecedent soil moisture conditions when the recession limb of the wet-weather response can last for several days after the wet-weather event. Aging sewer systems with numerous structural defects experience higher levels of infiltration. Therefore, sewer rehabilitation priorities can be determined by the level of infiltration in a subsystem. In addition, addressing aging sanitary sewer system should help reduce total RDII volume in a subsystem.

The rainfall response of a sanitary sewer system is quite complex. Various factors control RDII responses in addition to the rainfall (volume, intensity, and duration) and antecedent moisture conditions, including depth to groundwater, depth to bedrock, land slope, number and size of sewer system defects, type of storm drainage system, soil characteristics, and type of sewer backfill. Further, RDII responses can vary greatly due to spatial rainfall distributions over a sewershed.

D.2 RDII Reduction Benefits and Challenges

Reducing and managing RDII to sanitary sewer systems has been a major industry priority which requires significant effort, time and money. As regulations of wet-weather overflows and other wet weather discharges continue to develop along with increased fiscal constraints, regulators have increasingly turned their attention to effectively removing excessive RDII from collection systems. Numerous communities around the country established RDII reduction programs in the 1970s – primarily to address capacity issues in their sewer systems which were in relatively better condition compared to today. Since then, the industry has been gaining progressively deeper knowledge of do's and don'ts in implementing RDII reduction and management programs which has resulted in the development of a wide range of successful practices. Significant knowledge has been gained in RDII source detection approaches as well as a better understanding of the role private property RDII reduction to achieve meaningful capacity improvements. Industry experts have been grappling with reasons why different agencies have achieved widely varying results in RDII reduction effectiveness and whether the industry can reach a consensus on best practices for achieving and documenting consistent RDII reductions.

Despite the uncertainties in the levels of reduction achieved, source reduction of wet-weather flows through RDII reduction continues to be a high interest topic with wastewater utilities and regulators. The interest in tackling RDII in sanitary sewers is ever growing and RDII reduction is taking center stage in many wet-weather programs. Attachment 1 provides additional information about some of the many flow reduction programs throughout the country.

In recent years, many of these programs have been approached from the context of an asset management framework with the emphasis being to assure aging sewer assets are repaired/rehabilitated/replaced to manage the risk of failure and to assure the intended level of service is delivered. This leads to the convergence of the rehabilitation of aging sewers to extend the design life and the reduction of excessive RDII to restore the capacity of those same sewers. While the early RDII removal program goals were toward capacity recovery, the most recent programs are more balanced in achieving both broader infrastructure renewal goals and cost-effective removal of RDII through sewer rehabilitation.

In a slowly but steadily developing trend, communities and regulatory agencies are taking an holistic approach by first cost-effectively reducing RDII through rehabilitating sewers in poor structural condition and removing inflow and then determining the supplemental storage and conveyance infrastructure needs to establish the parameters for the required improvements in system capacity. This approach allows for the alignment of the dual objectives of renewing aging infrastructure while reducing RDII.

Estimating the amount of potential RDII reduction takes into account many factors and is very site-specific as it depends on the complexity of the rainfall response of a sanitary sewer system as described in the previous section. In many cases, sewer laterals that connect individual buildings on private properties to sewer mains are a major source RDII. Effective RDII reduction on both private properties and public right-of-ways (R/W) is needed to achieve impactful RDII reduction and help minimize the supplemental infrastructure needs of a wet-weather program. Well-designed pilot studies can help develop system-specific RDII reduction programs that focus on both private property and R/W efforts. Table D-1 shows estimated RDII reductions for various types of rehabilitation programs based on national experience in RDII reduction programs as well as industry observations. Note that the statistics for the higher levels of rehabilitation are increasingly dependent on unique system-specific RDII characteristics and distributions.

Table D-1: Estimated RDII Reductions from Sewer Rehabilitation

Level of Rehabilitation	Volume Reduction	Peak Flow Reduction
Point Rehabilitation in Public R/W	15 – 30%	0 – 10%
Point Rehabilitation in Public R/W and Private Property	25 – 50%	0 – 20%
Comprehensive Rehabilitation in Public R/W	30 – 60%	10 – 35%
Comprehensive Rehabilitation in Public R/W w/ Point Repair of Service Lines	35 – 70%	15 – 40%
System-Wide Comprehensive Rehabilitation	>70	> 50

There are numerous industry publications and sewer agency reports that address the effectiveness of public and private RDII reduction projects and programs. A sampling of these documents is included as Attachment 2 of this appendix. In addition, Three Rivers Wet Weather (3RWW) prepared two documents that included an examination of the effectiveness of private and public efforts to reduce I/I as summarized below.

- **3RWW Feasibility Study Working Group, *Guidelines for Performance of Source Flow Reduction Cost-Effectiveness Analysis*, Document 013, Appendix C, March 2011** – This Technical Research Summary Paper is included as Attachment 4 of this appendix. It summarizes six regional and six national publications that report on the effectiveness of RDII reduction. The paper concludes that 70 percent reductions in RDII are possible on a subsystem level, but that the success rate cannot be relied upon when translated to another proposed project. The paper recommends that "source flow reduction estimates be predicated flow isolation studies and micro level analysis via the CEP tool". The Cost Effectiveness Program (CEP) Tool is describe in the main body of this report, and is a Present Worth based tool for source flow reduction alternative analysis.

- **3RWW Feasibility Study Working Group, *"Private Sector" / Lateral Subcommittee*, February 2013** – This document includes discussion of the potential effectiveness of several private lateral control programs in Western Pennsylvania. Of the eight programs evaluated, only three have collected or plan to collect flow data that documents "pre-" and "post-" program wet weather flow responses. Of the two programs with available data, the flow analysis performed did not identify any measurable and conclusive flow reduction attributable to the lateral program.

In addition to these resources, the Water Environment Federation (WEF) has created and is maintaining the Private Property Virtual Library (PPVL). The PPVL is a growing library of case studies from private property-related programs at wastewater utilities. It is intended to be a resource for utilities seeking information or advice about private property programs. The library includes information gathered from successful private property programs targeting: sanitary lateral repair or replacement; RDII source detection and elimination; lateral condition assessment; privately owned pump station operation and maintenance; and sewer easements. The WEF PPVL also provides many relevant references related to RDII reduction programs.

The references above avoid representing the RDII reduction programs as either "successful" or "failed or unsuccessful". They do however emphasize that there are a wide range of estimates of RDII reduction effectiveness and varying metrics and variables go into the determination of those estimates. As such, sewer rehabilitation goals should focus on: 1) addressing the aging sewer system and its repair/rehabilitation/replacement (R/R/R) needs in both private and public sewers; and 2) achieving effective reduction in excessive RDII through focused sewer rehabilitation. This approach will allow the extension of the sewer infrastructure service life and the reduction of excessive RDII to the extent that can be practically achieved in an existing system. In effect, you will be able to show program outcomes are positive and help minimize the overall supplemental infrastructure needs to meet wet-weather program goals.

A review of these references indicates that a long term commitment for establishing and sustaining a private property RDII reduction program is essential for its success. Following are key considerations for a successful private property program:

1. *Private Property Program Needs Assessment* – frame the program drivers and anticipated outcomes;

2. *Policy and Legal Issues* – establish conditions such as understanding of limits of ownership, legal basis for what is illicit flow, use of public funds and right of access;

3. *Funding* – determine funding mechanisms and who pays for what.

4. *Public Outreach* – establish a plan to communicate with the public, the most critical factor in the success of the program.

5. *Implementation* – address the location of sewer defects, rehabilitate and repair and demonstrate the effectiveness of the program.

D.3 Sewer Rehabilitation Approaches and Methods

Typically, a focused sewer system evaluation survey (SSES) is performed to determine the scope of sewer rehabilitation required. This often involves use of a densely arrayed network of flow monitors to determine the sources and severity of extraneous flows. The monitoring is generally followed by detailed manhole inspection, use of acoustical inspection technologies, close-circuit television inspections or relatively new/emerging technologies (e.g., sonar, laser, ultrasonic and infrared), smoke testing, flow isolation and other techniques to gather adequate information regarding sewer conditions to guide rehabilitation efforts. The industry references at the end of this section include an overview of the various flow monitoring and field investigation methods for determining the scope of rehabilitation required. There are also numerous articles, and conference presentations that discuss approaches and methods for monitoring and analysis of RDII. A sampling of these articles is included in Attachment 3.

Once an area is identified as a contributor of high RDII and thus designated as a rehabilitation priority, there are three general sewer rehabilitation approaches that can be used:

- Rehabilitate all sewers including service laterals located within the public right-of-way and on private property;
- Rehabilitate only sewers located in public rights-of-way; or
- Repair structural defects in pipes and manholes and remove major inflow sources identified.

The first and second approaches are considered "comprehensive rehabilitation." A comprehensive rehabilitation approach consists of rehabilitating every foot of sewer line to eliminate all potential points of entry for RDII.

Experience has shown that the greatest cost/benefit ratios can be achieved by comprehensive rehabilitation of those sewersheds area with the greatest level of deterioration. Benefits may be reduced significantly for sewersheds with lower levels of extraneous flow.

The third approach is point rehabilitation, which repairs localized defects identified from inspection and focuses on SSOs resulting from structural and maintenance problems rather than RDII. However, there is the potential to identify specific defects that are significant sources of RDII. This approach does not include rehabilitating the laterals, and thus is not as effective in reducing RDII as the comprehensive approach.

Because of the time and cost required, and the uncertainty in peak flow reductions provided, sewer system rehabilitation is best used as one part of an overall program that also includes other capacity improvement options, such as relief sewers and pumping station upgrades. However, rehabilitation is an important part of all utilities' ongoing O&M programs to prevent high levels of RDII and to ensure that the sanitary sewer system continues to operate as designed.

When considering rehabilitation, lifecycle costs and benefits should be considered. Sanitary sewer systems continually deteriorate over time. While generally accepted design life for the materials used to construct sewers is on the order of 20 to 30 years, these sewers are called on to provide service for 50 years and longer. While comprehensive rehabilitation approaches previously described have higher initial costs, the collection system is revitalized both structurally and hydraulically, and the service life of the sewers can be extended significantly. A point-repair approach is less costly, but it may not adequately control system deterioration. In addition, migration of infiltration from the repaired defect to defects not addressed by the point repair approach may significantly reduce the effectiveness of this approach in reducing RDII. The potential need for a continuing series of spot repairs may be more costly and less effective than a comprehensive rehabilitation approach.

The best approach will vary from system to system, and pilot rehabilitation projects that include pre- and post-rehabilitation flow monitoring to determine the RDII reduction success of different approaches within each system are recommended. The validity of these RDII reduction assumptions is critical to the success of the recommended sewer improvements program.

Pipeline and Manhole Repair, Rehabilitation and Replacement - The most widely used rehabilitation techniques involve liners, but also include panel systems and coatings. Replacement can be accomplished through either conventional open-cut or trenchless methods, which are techniques that minimize soil disruption. Most trenchless techniques use the old pipe as a guide or require a carrier pipe. Various trenchless methods are listed under pipeline replacement and pipeline rehabilitation in Figure D-3.

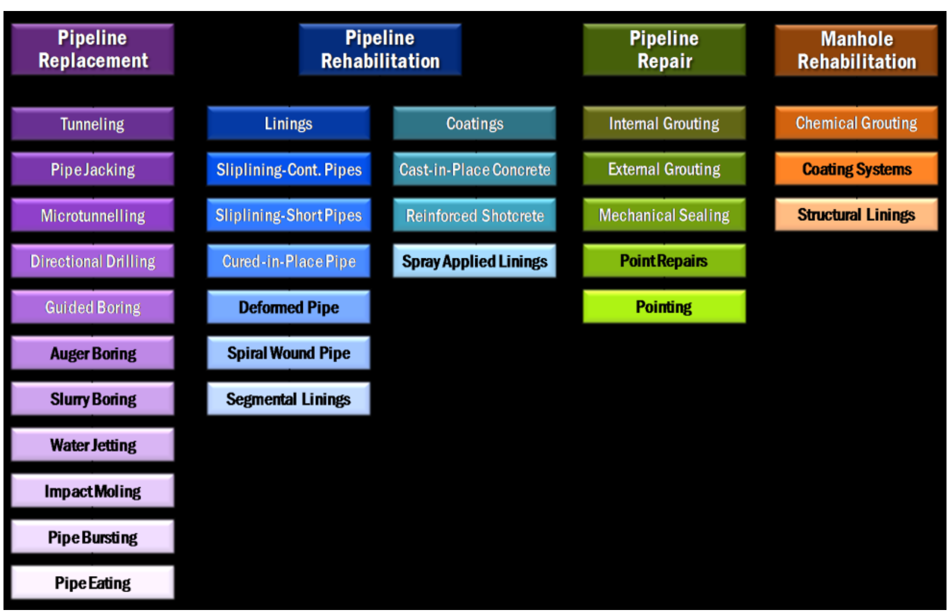

Figure D-3: Sewer System Rehabilitation Techniques

Reporting on Efficacy of RDII Reduction Programs - Periodic reporting on program effectiveness to the program stakeholders is necessary. Governance boards that approve funding or otherwise authorize implementation will likely scrutinize the quantitative program results and how they were accomplished. Thus, it is important to consider reporting needs when establishing the supporting flow monitoring and modeling efforts, program controls, pre- and post-improvement data collection/management methods and reporting protocols.

The following references provide guidelines and tools for: setting sewer condition assessment and rehabilitation priorities; evaluating cost-effectiveness using a return on investment approach; pre- and post-sewer rehabilitation flow monitoring; RDII characterization; data evaluations; and documentation. The EPA references provide free software tools and methodologies for setting sewer condition and rehabilitation priorities, properly characterizing RDII under pre-and post-sewer rehabilitation conditions and statistical means to determine the reduction levels from rehabilitation efforts. The WEF/ASCE reference provides a method of evaluation of sewer rehabilitation effectiveness using documentation, quality assurance and return-on-investment.

1. 2012 EPA Publication http://nepis.epa.gov/Adobe/PDF/P100G00U.pdf
2. 2007 EPA Publication http://nepis.epa.gov/Adobe/PDF/P1008BBP.pdf; http://www2.epa.gov/water-research/sanitary-sewer-overflow-analysis-and-planning-ssoap-toolbox.
3. WEF/ASCE Manual of Practice, FD-6 Existing Sewer Evaluation and Rehabilitation

Attachment 1
Flow Reduction Program Information

Large Sewer Authorities with Frequently Cited Flow Reduction Programs

- East Bay Municipal Utilities District (EBMUD) – serving eastern side of San Francisco Bay
- Hampton Roads Sanitation District (HRSD) – Southeast Virginia
- Massachusetts Water Resource Authority (MWRA) – metropolitan Boston area
- Metropolitan Council Environmental Services (MCES) – St, Paul, MN
- Milwaukee Metropolitan Sewerage District (MMSD) – Milwaukee, WI
- Renewable Water Resources (ReWa) – Greenville, SC

Example Program Descriptions in Publications

Water Environment Federation (WEF), A Regional Approach to Private Property I/I Mitigation, Hubbard, Phil; Wilson, Christopher; Proceedings of the WEF, Collection Systems 2012, January 2012, pp. 599-609

WEF. A Tale of Two Programs - A Comparison of Two Regional Private Property I/I Abatement Programs, Hubbard, Phil; Flogel, Jerome; Stahr, Richard; Scarano, Jeff; Lukas, Andy, Proceedings of the WEF, WEFTEC 2012: Session 11 through 20, January, 2012, pp. 1168-1181

WEF. Coordinating Regional Efforts to Protect Valuable Assets: Working Cooperatively with Satellite Municipalities, Jensen, Debra; Simmons, Thomas, Proceedings of the WEF, Collection Systems 2009, January, 2009, pp. 95-106

WEF. Development of Milwaukee MSD's Private Property Infiltration and Inflow Control Program, Gonwa, Willie; Simmons, Thomas F.; Schultz, Nancy U., Proceedings of the WEF, Collection Systems 2004, January, 2004, pp. 237-266

ReWa (Renewable Water Resources), Inflow & Infiltration Reduction: A System-Wide Sewer Rehabilitation Program, January, 2012

Massachusetts Water Resources Authority (MWRA), MWRA Annual Infiltration and Inflow (I&I) Reduction Report for Fiscal Year 2014, August, 2014

Metropolitan Council Environmental Services, Ongoing Infiltration/Inflow Reduction Program 2014 Procedure Manual, July, 2013

Hampton Roads Sewer District, Regional Wet Weather Management Plan – Annual Update, Volume 5, Issue 1, February, 2013

Attachment 2
Effectiveness of Public and Private RDII Reduction Projects and Programs

WEF. A Regional Approach to Private Property I/I Mitigation, Hubbard, Phil; Wilson, Christopher; Proceedings of the WEF, Collection Systems 2012, January 2012, pp. 599-609

Water Project Showcase. A Simplistic Approach to Dependent Infiltration, crain, Jason; Baldwin, Jennifer; and Morgan, Holly, September, 2014, pp. 20-22

King County, Washington. Pilot Project Report - King County Regional I/I Control Program, October, 2004

North American Society for Trenchless Technology (NASTT), Successful I/I Reduction: Four Documented Cases, Miles, Wayne, NO-DIG 2006 Conference Proceedings, Paper F-1-02, March, 2006

East Bay Municipal Utility District. Revised Final Flow Modeling and Limits Report, September, 2012

WEF. Holistic Sewer Rehabilitation — Measures of Effectiveness, Batman, Shelton, Paul J.; Shelton, James W.; Travis, John Paul; Proceedings of the WEF, WEFTEC 2011: Session 41 through 50, January, 2011, pp. 2448-2461

WEF. How Effective is Collection System Rehabilitation?, Dent, Shawn; Ohlemutz, Rolf; Wright, Leonard; Sathyanarayan, Priya; Proceedings of the WEF, Collections systems 2004, January 2004, pp. 139-152

WEF. How Much Water Weight Have You Lost? Quantifying Rehabilitation Effectiveness in the Collection System, Campbell, Shannon Jay; Zhang, Zhiyi; Brooks, Jason, Proceedings of the WEF, Collection Systems 2011, pp. 849-863

WEF. Less Leaks, More Capacity, Dawood, Tony H.; Nicholson, Mike; Water Environment and Technology Magazine, November 2012, pp. 37-39

WEF. Making Sense of I/I Reduction Case Studies: We're Swimming in Data, But What Does It All Mean?, Oriol, Heidi G.; Tran, Jenny H.; Kepke, Jacqueline T.; Cunningham, Richard; Proceedings of the WEF, Collections Systems 2013, January 2013, pp. 92-116

WEF. Method to Verify I/I Reduction to Obtain Moratorium Relief, Kurz, George E.; Colvett, Kevin; Proceedings of the WEF, Collection Systems 2009, January 2009, pp. 643-654

WEF. MSD St. Louis – Bonfils I/I Removal Pilot Study – Bust or Lucky Strike, Beck, Gary S.; Moore, Gary; Proceedings of the WEF, Collection Systems 2013, January 2013, pp. 606-624

WEF. Realistic I/I Reduction: What Can We Really Remove?, Oriol, Heidi G.; Tran, Jenny H.; Kepke, Jacqueline T.; Cunningham, Richard; Proceedings of the WEF, WEFTEC 2013: Session 10 through Session 19, January 2013, pp. 1054-1078

ReWa (Renewable Water Resources), Inflow & Infiltration Reduction: A System-Wide Sewer Rehabilitation Program, January, 2012

WEF. Achieving Infiltration/Inflow Removal Goals with a Comprehensive Approach, Kunay, Jonathan; Ross, Paul E., Proceedings of the WEF, WEFTEC 2012

WEF. Unique Performance Based I/I Reduction Contract Exceeds Goal, Bible, David, Proceedings of the WEF, Collection Systems 2007, January 2007, pp. 644-651

WEF. Achieving Infiltration & Inflow Removal Goals with a Comprehensive Approach, Kunay, Jonathan; WEFTEC 2014, Workshop Presentation: Establishing Sound Pre- and Post-Sewer Rehabilitation I/I Assessment Goals and Strategies, 2014, pp. 1-35

WEF. WERF: Peak RDII Flow Reduction: Case Studies and Protocol, Merrill, M. Steve; Lukas, Andy; Proceedings of the WEF, WEFTEC 2004, Session 41 through Session 50, January 2004, pp. 485-502

EPA. http://nepis.epa.gov/Adobe/PDF/P100G00U.pdf

Attachment 3
RDII Monitoring and Analysis Approaches and Methods

WEF. A Process of Elimination – A New Entrant in Sewer Evaluatins Removes Unlikely I/I Sources First, Saving Resources for Priority Areas, McGillis, Rich; Barton, John M.H. and Kamalesh, Joseph, Water Environment and Technology Magazine, August 2014, pp. 66–69

WEF. A Summary of Footing Drain Flow Studies: Residential Footing Drain Flows and Their Role as a Significant Cause of SSOs and Wet Weather I/I, Stonehouse, Marc C.; Hilbers, Grant; TenBroek, Mark J., Proceedings of the WEF, WEFTEC 2003, Session 41 through Session 50, January 2003, pp. 491-519

WEF. Basin Size is the Magic Knob for Controlling Costs of RDII Reduction Projects, Stevens, Patrick, Proceedings of the WEF, Collection Systems 2012, January 2012, pp. 774-783

WEF. Basin Size Optimization Forecasts Savings of 190 Million for PRASA, Keefe, Peter; Doble, Alejandro; Rowe, Reggie; Quinones, Adamaris; Perez, Juan, Proceedings of the WEF, WEFTEC 2009: Session 21 through Session 30, January 2012, pp 1431-1439

WEF. Building a Better Business Case for Funding Sewer Rehabilitation, Miles, Wayne; Moyer, Jack; Ridge, Joe, Proceedings of the WEF, Collection Systems 2004, January 2004, pp 558-566

WEF. Convey Your Storm Water and Plug Your Holes! A Proven Means of I/I Reduction with Private Property Improvements and Trenchless Sewer Rehabilitation, Fallara, C. Timothy, Proceedings of the WEF, Collection Systems 2013, January 2013, pp. 45-73

WEF. Evaluation of Life-Cycle Costs and Cost/Benefit Analysis in Comparing Sewer Replacement Versus Sewer Rehabilitation, Killips, John; Gamble, Chad, Proceedings of the WEF, Collection Systems 2013, January 2013, pp. 537-549

WEF, Evaluation of Sewer System Rehabilitation via Flow and Storm Data Analysis, Zhang, Z., Proceedings of the WEF, Collections Systems 2011, January, 2011, pp. 333-344

WEF. Find and Fix Rehabilitation Program Producing I/I Reduction Successes for City of Suffolk, VA,: Ziesemer, Craig; Frie, Shelly; Holloway, Dan; Donnelly, Matthew; Moran, Jarrett; Rowe, Reggie, Proceedings of the WEF, Collections Systems Conference 2011, January 2011, pp. 355-360

WEF. Hydraulic Model Methodology for Evaluating Sewer Rehabilitation Projects, Bechara, Alberto; Kokorian, Vahe; Chioke, Uche; Ahmad, Rasheed, Proceedings of the WEF, WEFTEC 2011: Session 81 through Session 90, January 2011, pp. 5939-5954

WEF. If I Had This To Do Over - A Twelve Step Program to Successfully Measure Sewer Rehabilitation, Stevens, Patrick L., Keefe, Peter N., Proceedings of the WEF, Collection Systems 2011, January 2011, pp. 731-758

WEF. Making Sense of Private RDII from Footing Drains, Sherman, Benjamin J; Perala, Pete; Stonehouse, Marc C., Proceedings of the WEF, Collection Systems 2006, January 2006, pp. 214-225

WEF. Measuring Successful Rehabilitation, Keefe, Peter; Kimbrough, Hal, Proceedings of the WEF, WEFTEC 2002: Session 1 through Session 10, January 2002, pp. 518-522.

WEF. Sewer System Rehabilitation Guidelines – More Bang for Your Buck, Germain, Rudolph St.; Becker, Joseph; Mansour, Sal; Cruice, Kevin P., Proceedings of the WEF, WEFTEC 2003: Session 61 through Session 70, January 2003, pp. 353-362.

WEF. WERF INFR4R12-Sewer Lateral Electro Scan Field Verification Pilot, Lukas, Andy; Flogel, Jerome; McMullin, Julie; Plier, Andrew; Skipper, Gary, Proceedings of the WEF, Volume 13, Number 12, January 2013, pp.4635-4657.

Attachment 4
Three Rivers Wet Weather Feasibility Study Working Group
Source Flow Reduction Cost Effectiveness Analysis
Appendix C – Technical Research Summary Paper

Feasibility Study Working Group
Document 013 (completed)
Guidelines for Performance of
Source Flow Reduction Cost-Effectiveness Analysis

Appendix C
Technical Paper Research Summary
March 3, 2011

This FSWG Document 013 Appendix C presents an overview of Source Flow reduction experiences in Separated Sanitary Sewer Systems as reported in National Technical Journals, and local engineering reports. To prepare this paper, the Proceedings for the WEF Collection Systems Annual conferences since 2001 were searched and papers presenting findings of various projects were reviewed and summarized. In addition, Demonstration Project Summary Reports included on the 3 Rivers Wet Weather, Inc. website were also downloaded and summarized as were internal technical memorandum specific to parallel replacement. Those papers that were on point have been listed and findings are summarized below.

Overview

The effectiveness of Source Flow Reduction as an alternative to contain/convey/store/treat has been the subject of much controversy for many years on both a local and national level. A review of the available literature uncovers an issue replete with apparent contradiction ranging from highly successful to woefully unsuccessful project findings. Varying project analytic techniques including pre-project scope evaluations (i.e. defect or flow based rational), flow monitoring, variant hydrologic conditions, measures of success, rehabilitation methodology, extent of rehabilitation (i.e. public vs. private) and a myriad of other factors combined render definitive conclusions on effectiveness of source flow reduction difficult. What can be concluded is that, for the most part, properly planned rehabilitation projects have demonstrated a significant level of success in terms of reduction of RDI/I flows as measured by flow monitoring at the subsystem level. Quantifying the success rate in a manner that can be relied upon and translated to a proposed project is another matter entirely. The literature clearly indicates success rates in excess of 70% on a subsystem level appear to be achievable. For properly scoped projects, that is projects based on flow based analysis as opposed to “search and fix” methods, higher success rates can be anticipated.

Most projects base their estimates of success on pre- and post-project flow monitoring findings at a specific bottom of shed site. However, in many instances comparative hydrologic regimes and/or volumetric precipitation and antecedent groundwater conditions are not discussed. As a consequence representations of source flow reduction success are difficult to ascertain and verify. Additionally some projects address peak rates of flow while others address volumetric removal. Given inherent monitor inaccuracy and the simple “in nature” volatility of peak flow rates, any representation of flow reduction based solely on monitored flow rates should be viewed with a jaundiced eye. For those instances where single site monitoring is utilized to assess effectiveness a “standardization” approach involving use of pre- and post-project monitoring and evaluation for either the 10 year or 5 Year return Storm Q_p has been suggested.[1] [2]. Later variations include the use of calibrated SWMM H&H models to "project" the 5 Year Return Storms and compare the projected storm parameters to establish effectiveness.[3]

The following paragraphs provide a brief synopsis of each of the articles or Reports reviewed pursuant to this document:

In Search of Valid I/I Removal Data: The Holy Grail of Sewer Rehab?
WERF: Predictive Methodologies for Determining Peak Flows After Sanitary Sewer Rehabilitation ,Lukas, and Merrill - Brown and Caldwell, Palmer, R.and Van Rheenan, N.- University of Washington

Synopsis: This technical paper presented a proposed research project and recommendations for a standardized protocol for analyzing and reporting on I/I removal effectiveness. The paper also presented findings for two studies utilizing the suggested protocol. The intent of the protocol is to provide a mechanism whereby "actual" effectiveness could be measured on a standardized basis (Peak Rate of flow for a stated Design Return Storm) and "predicted" based on implementation of the various methodologies available. For the two projects analyzed using the proposed protocol RDI/I reduction of 17% was projected for wholesale mainline replacement. This projection is increased to 67% with inclusion of laterals RDI/I reduction. In a third basin, where only 20% of the laterals were replaced, projected reduction was 50% for the design storm (once in 10 Year Peak Hour flows.) Volumetric reductions were not addressed).

Water Environment Federation, Collection Systems 2007
Update on a Nationwide I/I Reduction Project Database, Andy Lukas, Brown and Caldwell

Synopsis: This paper is a follow up to the prior paper that addressed standardization of reporting on I/I removal effectiveness. Twenty Four (24) projects are reported to be included in the data base used to develop the concept. No actual detail of rehabilitation techniques or approaches implemented is provided. The use of the peak hour flow rate for the 5 Year Return Storm (Q_{P5YR}) as a datum for comparison of effectiveness is suggested. The paper also presents and discusses eight (8) "Normalization" techniques which the author suggests "…*can be much more useful as they provide a way to include several variables that affect the outcome of the project.*" This analysis includes a number of "scatter graphs" to illustrate the normalization technique effectiveness. Of note is the conclusion: "…*Scatter is again apparent in this presentation. The consistent scatter of these graphs point to percent removal as a poor method of comparing project results.* The paper concludes with: "*The author strongly encourages system owners to invest in gathering and reporting I/I project work according to the WERF protocol.*"

[1] "In Search of Valid I/I Removal Data: The Holy Grail of Sewer Rehab? WERF: Predictive Methodologies for Determining Peak Flows After Sanitary Sewer Rehabilitation", Lukas, and Merrill - Brown and Caldwell, Palmer, R. and Van Rheenan, N.- University of Washington
[2] Water Environment Federation, Collection Systems 2007,"Update on a Nationwide I/I Reduction Project Database ",Andy Lukas, Brown and Caldwell
[3] Collection Systems 2004, Water Environment Federation, "How Effective is Collection System Rehabilitation?", Dent, S, Wright, L. and Sathyanarayan,P. – Carollo Engineers, Rolf Ohlemutz – Vallejo Sanitation and Flood Control District

3 Rivers Wet Weather Demonstration Project Allegheny County, PA
Lennon, Smith, Souleret Engineering Inc, Township of Scott, PAINTER'S RUN PHASE IA
May 2003

Synopsis: This project involved implementation of a "parallel replacement" approach in a residential collector subsystem involving only the "wettest" subunits of the project area. The rehabilitation work scope for this project was based on flow isolation studies directed at finding and isolating subunits that contribute elevated base infiltration rates under non-storm wet weather conditions. Less than 50% of the mainline footage was replaced with new sanitary sewers while the "old" sewer was converted to a neighborhood subsurface drain line. Implementation of a parallel replacement program yielded significant RDI/I flow reductions and eliminated chronic SSO's and basement flooding. Inflow reductions exceeding 90% and infiltration reductions exceeding 70% were reported based on analysis and comparison of pre and post project flow monitoring.

3 Rivers Wet Weather Demonstration Project Allegheny County, PA
KLH Engineers, Inc., Township of Shaler Little Pine Creek Pilot Program, Final Report
July 2004 Revised June 2006 Revised October 2006

Synopsis: The rehabilitation work scope for this project was based on CCTV inspection findings. A combination of pipe replacement (1%), lining (38%) and joint sealing (16%) of about 55% of the total footage of mainline comprising this predominantly residential system is reported to have produced Dry Weather flow reduction of 94%, Max Wet Weather I/I reduction of 57%, Maximum Total I/I reduction of 64% and discrete storm flow reductions ranging from 34 to 70%. These findings are based on paired comparisons of similar sized pre- and post rehabilitation storms ranging in size from 0.04 to 0.14 inches of volume. Monitored flow rates ranged from 0.054 mgd to 0.035 mgd. There is no indication the QA/QC was performed on the flow data. Given the every low precipitation and flow rates reported conclusions derived are problematic.

3 Rivers Wet Weather Demonstration Project, Allegheny County, PA
Gateway Engineers, Inc., Borough of Bridgeville, Report for 3 Rivers Wet Weather Demonstration Program, Pesavento Drive Rehabilitation Project
May 30, 2006

Synopsis: This project reports on implementation of a project selected for convenience to attempt to demonstrate the effectiveness of lining. Lining of 75% of the total mainline footage comprising this predominantly residential system, and removal of two sump pumps, is reported to have produced 47% volumetric reduction on a per edu basis. The conclusions are based on a single comparative event analysis.

3 Rivers Wet Weather Demonstration Project, Allegheny County, PA
Chester Engineers, Bethel Park Municipal Authority, Ruthfred Acres Area Phase II Sanitary Sewer Replacement Project, Contract 2001-02
September 2003

Synopsis: This project involved In-trench replacement of 100% of the mainline footage and all man. Flow monitoring included three months of pre-construction monitoring between February through April 1999 and three months post-construction February through April 2003. Flow monitor QA/QC analysis is indicated. In trench replacement of 100% of the mainline footage and all manholes is projected to have produced a 70% storm I/I flow reduction for a one year return storm.

3 Rivers Wet Weather Demonstration Project, Allegheny County, PA
Hunting Ridge Area Wye Grouting Project, Brown, J, (Municipal Authority of the Township of South Fayette) and Loehlein, M (Camp Dresser McKee, Inc.)
September 2001

Synopsis: This program focused on flow reduction associated with gel grouting of service laterals and wye connections. A test basin was selected and laterals air/pressure tested to check integrity. The project resulted in 94% of wyes and service laterals being grouted. Flow monitors were installed and maintained for upstream, downstream, and control basins. Monitors were maintained for 1 year prior and six months after project completion. QA/QC data analysis was performed. Flow data analysis concluded that there were no discernable flow reductions associated with this program "…there was no quantifiable wet weather benefit as a result of the rehabilitation efforts".

Water Environment Federation, Collection Systems, Inc. 2010
Implementation Challenges of Public and Private Source Control to Eliminate SSOs
Pressman et.al. Malcolm Pirnie, Inc., Hazen and Sawyer,

Synopsis: This technical paper discussed prior efforts involving primarily ("find and fix") defect repairs as a method of source reduction and subsequent engineering evaluations of two possible additional alternatives. Regarding the implemented "find and fix" defect repair option it was concluded that "*The effectiveness of removing I/I through these improvements is inconclusive*". The two additional alternatives evaluated, but apparently yet to be implemented, included*: "Conduct public and private I/I removal and any necessary storm improvement to convey additional flow" and "Construct new gravity sewer to convey peak flows*…". Projections of flow reduction are presented however findings are not indicated. The engineering analysis concluded that *"private source removal and phased 'rehabilitation'* was the recommended approach.

Collection Systems 2007 Water Environment Federation.
Unique Performance-Based I/I Reduction Contract Exceeds Goal
Bible, D – ARCADIS U.S., Inc.

Synopsis: This technical paper discussed the outcome from a "find and fix" …"performance based construction contract" that reports on flow reduction as computed based on a 5 year, 24 hour storm event. Limited pre (7 months) and post (6 months) flow monitoring provided the data base for evaluating reductions. As shown in the performance table 4 of 6 sites demonstrated increases in the 5 year flows while 2 show flow reductions. Nonetheless, overall a 41% reduction was claimed. No analysis or discussion of precipitation for the monitoring periods was presented so climatic impact is unknown.

Collection Systems 2007, Water Environment Federation
70 Percent I/I Reduction – Sweet Home, Oregon Aims High with Collection System Management Best Practices, Scarano, J. Brown and Caldwell

Synopsis: This technical paper presents a largely theoretical computation of Peak flow reductions based on projected 5 year return storms computed via H&H models. Five years of flow monitor data was collected including use of DataGator meters. The flow data was used "*to develop hydrologic models to predict theoretical peak hour flows"* and to assess post rehabilitation modeling. *Hydrologic calibrations were developed for the pre- and post-construction monitors…"* A series of projects involving CCTV based rehabilitation of 8 percent of its collection system and over 9 percent of the service laterals was completed is 2003 -2004 Three types of rehabilitation projects were implemented: full (all pipe), mainline only, and lateral only. Rehabilitation techniques/methodologies are not indicated. . Peak flow reductions ranging between 11 % and 88% are "predicted". Flow reduction associated with rehabilitation of "mainlines only" is projected at 11%, for full rehabilitation it is projected to be 88%, and for laterals only averaged 18%. No actual flow volume reductions are presented.

Collection Systems 2004, Water Environment Federation
How Effective is Collection System Rehabilitation?
Dent, S, Wright, L. and Sathyanarayan, P. – Carollo Engineers
Rolf Ohlemutz – Vallejo Sanitation and Flood Control District

Synopsis: This technical paper presents findings of a pilot program that included comprehensive rehabilitation of both mainlines and mainlines and laterals in 5 test basins. Pre and post flow monitoring/model calibration to establish findings was considered acceptable in only two of the five test basins. A calibrated SWMM H&H model was used to "normalize" the data and project the 5 Year Return storm volume and rate of flow reductions. The test basin wherein only service lateral rehabilitation was completed was found to be equally as effective as the basin with both lateral and mainline rehabilitation and lesser cost (i.e. more cost effective.). The projected 5 Year storm reductions associated with a comprehensive rehabilitation program averaged 28% for Peak Flow Rate and about 30% for design storm volume.

Pleasant Hills Flow Reduction Analysis
Lennon, Smith, Souleret Engineering, Inc.
Internal Communication July 2010

Synopsis: This technical memorandum documented the methodology used to determine percent capture in the C-11C subarea of Pleasant Hills using pre (February 1997 through July of 1999) and post (January 2003 through December 2009) construction hourly flow data. This memorandum included details on the procedures used for data QA/QC, Storm Deconstruction, RTK analysis and Design Storm comparison and summarized the results for both RDII Storm Response peak flow and volume. Flow Monitor data is quantified / qualified as follows:

Monitor C-11C QA/QC Data Quality Breakdown		
	Pre Construction	Post Construction
Meter Months of Data	26	75.75
Type 1 Data	93%	86%
Type 2 Data	4%	1%
Type 3 Data	3%	13%

RTK processing was performed using the 3RWW PM Team RTK Calculator tool. 3RWW PM Team design storm time series and distributions for the 1, 2, 5 and 10 year storms were processed using average RTK values for both winter and summer months. Comparative tables presenting the monthly and seasonal RTK values are presented below.

Regression Analysis Monthly Summary							
	Pre Construction			*Post Construction*			*RDII Response % Reduction*
	Storm Count	*RDII Response Volume for 1 Inch of Rainfall (inches)*	R^2	*Storm Count*	*RDII Response Volume for 1 Inch of Rainfall (inches)*	R^2	
Overall	*40*	*0.0741*	*0.8261*	*95*	*0.0322*	*0.4207*	*57%*
Winter	*19*	*0.0902*	*0.871*	*39*	*0.039*	*0.5489*	*57%*
Summer	*16*	*0.0638*	*0.752*	*45*	*0.0222*	*0.5304*	*65%*
January	*1*	*NA*	*NA*	*2*	*0.059*	*1*	*NA*
February	*0*	*NA*	*NA*	*2*	*NA*	*NA*	*NA*
March	*7*	*0.0761*	*0.8727*	*4*	*0.0527*	*0.9060*	*31%*
April	*4*	*0.0824*	*0.8556*	*8*	*0.0526*	*0.7385*	*36%*
May	*5*	*0.0767*	*0.9734*	*8*	*0.0928*	*0.8557*	*NA*
June	*10*	*0.049*	*0.4354*	*17*	*0.0284*	*0.5557*	*42%*
July	*3*	*0.0247*	*0.9077*	*10*	*0.0159*	*0.942*	*36%*
August	*3*	*0.0701*	*0.9999*	*15*	*0.0208*	*0.6535*	*70%*
September	*1*	*NA*	*NA*	*5*	*0.0207*	*0.9597*	*NA*
October	*1*	*NA*	*NA*	*11*	*0.0425*	*0.6378*	*NA*
November	*5*	*0.0895*	*0.9257*	*8*	*0.0697*	*0.7248*	*22%*
December	*1*	*NA*	*NA*	*4*	*0.1057*	*0.3309*	*NA*

Regression equations for each month were used to calculate RDII volume based on one inch of rainfall. As shown in the Table RDII volume reductions ranged from 22% to 70%. The results of the design storm comparison for RDII peak flow rate and volume using the seasonal RTK values are shown in the following tables. As shown, a range of 27% to 44% RDII volumetric reduction and 16% to 53% peak flow rate reduction was achieved.

Design Storm RDII Peak Flow Comparison 10 Year Storm Event			
Season	***Pre- Construction RDII Peak Flow (MGD)***	***Post- Construction RDII Peak Flow (MGD)***	***% Difference***
Summer	*3.04*	*1.43*	*53%*
Winter	*1.68*	*1.42*	*16%*

Design Storm RDII Volume Comparison 10 Year Storm Event			
Season	***Pre- Construction RDII Volume (MG)***	***Post- Construction RDII Volume (MG)***	***% Difference***
Summer	*0.74*	*0.41*	*44%*
Winter	*0.83*	*0.60*	*27%*

Table 8 shows the average monthly R value representing the capture percentage from the RTK analysis. The table indicates that average RDII capture reductions on a monthly basis range from 28% to 59% for months where multiple monthly data sets were available for averaging.

Total R Value Monthly Average Percent Reduction			
	Pre-Construction Average R	***Post-Construction Average R***	***Percent Reduction***
June	*3.6%*	*2.6 %*	*28%*
July	*2.4%*	*1.0%*	*58%*
August	*4.1%*	*1.7%*	*59%*
October	*2.6%*[1]	*3.5%*	*-35%*
November	*4.6%*	*2.4%*	*49%*
December	*8.1%*[1]	*4.8%*	*41%*
January	*NA*	*4.9%*	*NA*
February	*5.3%*[1]	*7.4%*	*-40%*
March	*6.7%*	*4.0%*	*40%*
April	*6.5%*	*4.0%*	*38%*

[1] *Indicates only one month of data available for analysis*

GWI reduction was analyzed by unitizing flow per inch of rainfall as shown in Table 9. Comparing average annual unitized GWI data for individual years indicates a 47% reduction in GWI when comparing average GWI volume per inch of rainfall.

Summary and Conclusions

SUMMARY

With very few exceptions, much of the RDI/I source reduction literature reports on projects that are based on macro scale pre-program (basin or sub-basin) wide assessments of infiltration and inflow. Although the intent of these programs is source flow reduction few were predicated on pre-program micro analysis of the origin of RDI/I flow. Although the rehabilitation work scope was performed at the subunit level the hydrologic analytic methods typically do not consider or focus on subunit measured flows.

If anything history has demonstrated that source flow reduction based on "search and fix" for observed structural defects is not a successful basis for predicting or achieving source flow reduction success. As a result there is a prevailing belief that source flow reduction is "hit or miss". This thinking has pervaded regulatory philosophy to the detriment of regional hydrology.

CONCLUSIONS

The FSWG has indicated its desire to establish guidance type flow reduction estimates for sanitary sewers for the various types of rehabilitation identified. After discussion it has been concluded that broad based representations of achievable flow reduction at the macro level cannot be reasonably presented (i.e. that is forward projections of reduction achievable absent detailed micro level analysis). Alternatively, it is recommended that source flow reduction estimates be predicated on flow isolation studies and micro level (i.e. subunit) analysis via the CEP Tool (see FSWG Document 013 Appendix B). The CEP Tool provides an overall summary estimate of source flow reduction potential based on rehabilitation technology evaluated (see the attached/following CEP Tool example Option Summary sheet; Parameters and Methods table; and Construction Methods table. Note that the Construction Methods table shows the default GWI and RDII removal percentages for the Tool's various standard construction methods). This CEP Tool summary estimate should be compared to the macro level flow reductions presented herein and an engineering judgment of achievability made based on the comparison as to the reasonableness of the estimate.

Option Summary

Municipality A

	gallons	dollars
Starting Storage	2,000,000	$6,100,000

250 TOTAL SUBUNITS

Option	Subunits: # To Be Rehabilitated	Subunits: # of Overrides	Percent I/I Removed	Remaining Storage Volume (gallons)	Capital Construction Costs (Dollars): Storage Remaining	Capital Construction Costs (Dollars): Construction	Capital Construction Costs (Dollars): Total	PW Volume Remaining Value (Dollars): O&M Storage	PW Volume Remaining Value (Dollars): Treatment	PW Volume Remaining Value (Dollars): Total Treat + Store	Capital and PW Total $
Trenchless Rehabilitation	32	0	37.07%	50,120	250,360	6,665,875	6,916,235	1,474	78,687,928	78,689,402	$85,605,637
Inlrench Rehabilitation	32	0	48.63%	0	0	12,774,939	12,774,939	0	64,526,983	64,526,983	$77,301,922
Full Parallel Rehabilitation	38	0	50.46%	0	0	13,624,389	13,624,389	0	62,379,922	62,379,922	$76,004,311
Partial Parallel Rehabilitation	36	0	44.75%	0	0	11,805,656	11,805,656	0	69,383,731	69,383,731	$81,189,387
Ph Partial Parallel Rehabilitation	37	0	48.17%	0	0	12,939,138	12,939,138	0	65,182,273	65,182,273	$78,121,411
IntTrnk Grout Collect Full Par	38	0	47.59%	0	0	8,815,234	8,815,234	0	65,894,937	65,894,937	$74,710,171

SELECTED SUBUNITS FOR SIX OPTIONS

STORAGE REQ'TS

Present Worth calculations based upon 30 years and Net Earnings of 3.00%

Parameters and Methods

Default Information Values

POC # A-01

Misc. Parameters

Avg. Service Lateral Length	35	Linear Feet / Structure
New Pipe Infiltration	100	gpimd
PersonsPerEdu	2.50	PPH
GalPerPersonsPerDay	65	gpcd
TandTSurcharge	$4.04	per 1,000 gal (over limit)
TandTAllowable	600	gpimd

Storage Parameters

StorageCost	$3.00	per gallon
OandMCost	$1.00	per 1,000 gallons
BaseFixedCost	$100,000	
StorageRequired	0	gallons

Present Worth

Years	20
Net Earnings Pct.	0.50
Factor	18.99

Infiltration Parameters

Gwi Factor	1.10	
Spring GWI Distribution Factor	1.00	
Summer GWI Distribution Factor	0.50	
Fall GWI Distribution Factor	0.80	
Winter GWI Distribution Factor	0.75	
Design Storm Volume	2.50	MG
Annual RDII Volume	25.00	MG
Annual RDII SafetyFactor	1.00	

Construction Methods

Segment Type	Method	Gwi Removal Pct %	Rdii Removal Pct %	$ Improved Main Cost	$ Unimproved Main Cost	$ Improved Service Cost	$ Unimproved Service Cost	$ Traps/Tees Reinstate $ Per Structure	Service Lateral Replace Percent %
collector	FullParallel	75.00	75.00	235.00	200.00	65.00	40.00	600.00	100.00
collector	Intrench	30.00	30.00	175.00	125.00	0.00	0.00	0.00	0.00
collector	PartialParallel	50.00	50.00	235.00	200.00	0.00	0.00	0.00	0.00
collector	PhasedPartParallel	65.00	65.00	235.00	200.00	65.00	40.00	600.00	60.00
collector	Trenchless	15.00	15.00	65.00	65.00	0.00	0.00	0.00	0.00
interceptor	Intrench Int	75.00	75.00	270.00	220.00	0.00	0.00	0.00	0.00
interceptor	Trenchless Int	60.00	60.00	125.00	125.00	0.00	0.00	0.00	0.00
trunk	Intrench Trunk	75.00	75.00	195.00	145.00	0.00	0.00	0.00	0.00
trunk	Trenchless Trunk	60.00	60.00	105.00	105.00	0.00	0.00	0.00	0.00