

SEWER MONITORING SERIES

MUNICIPAL ENGINEERS

Hydraulic Model Calibration Using Real-Time Sewer Flow Monitoring

Avoiding a \$42M Capital Error Through Data-Driven Engineering

"When the model said we were at capacity, the only defensible answer was to measure it."

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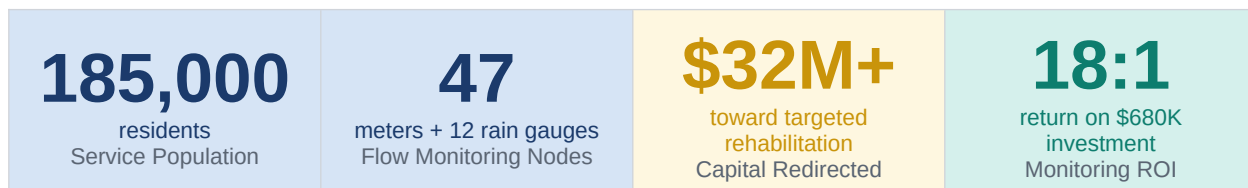
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Abstract

DIRECT ANSWER — What is sanitary sewer flow monitoring and how does it prevent overdesign?

Sanitary sewer flow monitoring is the systematic measurement of flow rates and rainfall within a wastewater collection system to characterize Rainfall-Derived Infiltration and Inflow (RDII). When hydraulic models are calibrated with field-measured RDII data rather than generic estimates, the resulting capital improvement programs are more accurate, better targeted, and significantly less expensive.

This case study documents a comprehensive flow monitoring program for a mid-size midwestern municipality (185,000 residents) whose hydraulic model predicted imminent capacity failure requiring \$42 million in trunk sewer replacement. A 47-meter, 6-month monitoring program with integrated rainfall capture demonstrated that the model was overestimating peak flows by 65% due to incorrect RDII parameters derived from generic assumptions. After model recalibration using field-measured RTK parameters, the recommended capital improvement program was redirected to a \$10 million targeted rehabilitation plan — generating an 18:1 return on the monitoring investment.



Background

What Problem Does This Case Study Address?

Municipal collection system engineers routinely face a fundamental challenge: making capital improvement decisions based on hydraulic model predictions rather than measured data. Hydraulic models are built from population projections, assumed diurnal patterns, and RDII parameters derived from EPA guidance or regional averages rather than system-specific field measurements. When a model predicts capacity exceedance and triggers a capital program, engineers must answer a question the model cannot answer alone: is this prediction based on data, or assumptions?

The City of Riverside Falls (population: 185,000) operates a combined collection system with over 1,100 miles of sanitary sewer main, infrastructure ranging from 12 to 81 years old, and three wastewater treatment plants (48 MGD combined capacity). In 2019, the hydraulic model predicted that three major trunk corridors were operating above 80% full-pipe capacity under a 10-year storm event, triggering federal CMOM reporting requirements.

<p>System Characteristics</p> <ul style="list-style-type: none"> 1,147 miles of sanitary sewer main 	<p>Known Deficiency Indicators</p> <ul style="list-style-type: none"> Historical SSOs at 7 recurring locations
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- 3 wastewater treatment plants (48 MGD combined)
- 22 lift stations, infrastructure age 12–81 years
- Primary materials: clay (pre-1970), PVC (post-1985)
- 14 active combined sewer overflow structures
- Treatment plant influent exceeds 3x DWF during wet events
- 16% of gravity mains >40 years with no CCTV on record
- 3 pump stations over rated capacity on peak wet-weather days
- Only 4 permanent flow meters on system prior to study

WHY DO COLLECTION SYSTEM MODELS OVERESTIMATE RDII?

Hydraulic models overestimate RDII when the RTK parameters describing system RDII response are derived from regional averages or EPA default values rather than system-specific field measurement. The R-value (fraction of rainfall becoming RDII), T-value (time to peak), and K-value (ratio of recession to rise time) are highly site-specific. Generic parameters from EPA guidance carry uncertainty ranges of ±40% or more. Field calibration reduces this to ±8–12%.

Methodology

How Was the Flow Monitoring Program Designed?

Every meter placement was driven by a specific model calibration objective. The engineering team identified three critical unknowns requiring field data: (1) the actual RDII magnitude and spatial distribution in each of the 23 sub-sewersheds; (2) the timing and duration of peak surcharge conditions during 2- to 25-year storm events; and (3) the apportionment between public infrastructure defects and private property connections.

Tier	Meter Count	Primary Objective	Sensor Technology
Tier 1: Trunk Interceptors	8 meters	System-wide mass balance, peak flow measurement	Electromagnetic area-velocity
Tier 2: Sub-Sewershed Outlets	23 meters	RDII quantification per sewershed, RTK estimation	Electromagnetic AV + Doppler (mixed)
Tier 3: Focused Investigation	16 meters	Isolate SSO source areas and private I/I zones	Ultrasonic level-only, Doppler
Rain Gauges	12 stations	Spatial rainfall (1 per ~5 sq. miles)	Tipping bucket, 0.01" resolution

What Data Collection Protocol Was Used?

All sensors logged at 5-minute intervals. A web-based telemetry platform provided near-real-time data retrieval and automated anomaly alerts. On-site calibration checks occurred every 14 days under dry-weather conditions and within 48 hours of any rainfall event exceeding 0.5 inches. The 6-month program (April–September) captured 23 storm events ranging from 0.3 to 3.8 inches, including a 3.8-inch event representing the critical 10-year recurrence interval.

How Was RDII Analyzed Using the RTK Method?

RDII analysis was performed using EPA SSOAP Toolbox RTK methodology. For each of the 23 sub-sewersheds, RDII hydrographs were extracted from total observed flow by subtracting the dry-weather flow (DWF) baseline, then decomposed into three characteristic response components:

- R1/T1/K1 (Fast): Direct inflow with short lag. Sources: roof drains, manhole lid inflow, storm cross-connections, uncapped cleanouts.
- R2/T2/K2 (Medium): Delayed inflow/early infiltration, hours of lag. Sources: foundation drains, shallow groundwater connections, broken laterals near structures.
- R3/T3/K3 (Slow): Groundwater infiltration, extended recession. Sources: leaking pipe joints, deteriorated pipe sections, manhole wall infiltration.

RTK parameters were estimated by non-linear least-squares fitting across 17 qualifying storm events. Nash-Sutcliffe Efficiency (NSE) > 0.70 was required for parameter acceptance.

Results

**Figure 1 — RDII Hydrograph & RTK Component Decomposition
Case Study 1: Municipal Engineer Flow Monitoring Program**

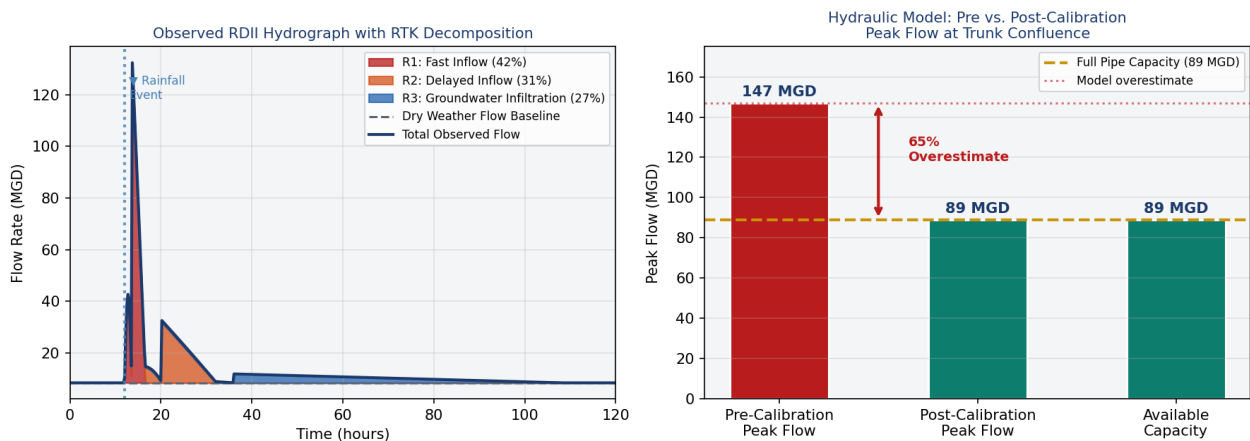


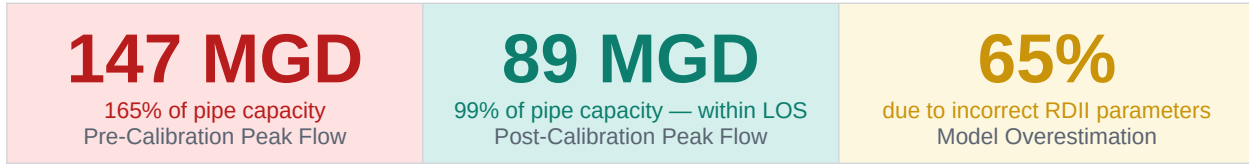
Figure 1 — RDII hydrograph with RTK component decomposition (left) and pre- vs. post-calibration peak flow comparison showing 65% model overestimation (right).

What Did the RDII Characterization Reveal?

RDII Component	System Average %	Primary Physical Source	Capital Implication
R1: Fast Inflow	42%	Direct storm cross-connections, roof drains, manhole lid inflow	Private property I/I programs — not pipe replacement
R2: Delayed Inflow	31%	Foundation drains, broken laterals near structures	Combined private property + targeted public rehab
R3: Groundwater Infiltration	27%	Deteriorated pipe joints, manhole wall cracks	CIPP lining and manhole sealing in priority reaches

This decomposition was fundamental: the original model assumed a 40/60 fast/slow split consistent with EPA regional guidance. The actual measurement revealed a 42/27 fast/slow split — meaning 42% of RDII was attributable to direct inflow sources that pipe replacement would not address at all.

How Did Model Recalibration Change the Capacity Finding?



The corrected model indicated that trunk interceptors did not require replacement. Targeted I/I reduction programs addressing dominant private property inflow sources and specific public infrastructure defects would reduce RDII sufficiently to maintain hydraulic compliance through at least 2045, with 15% hydraulic reserve capacity.

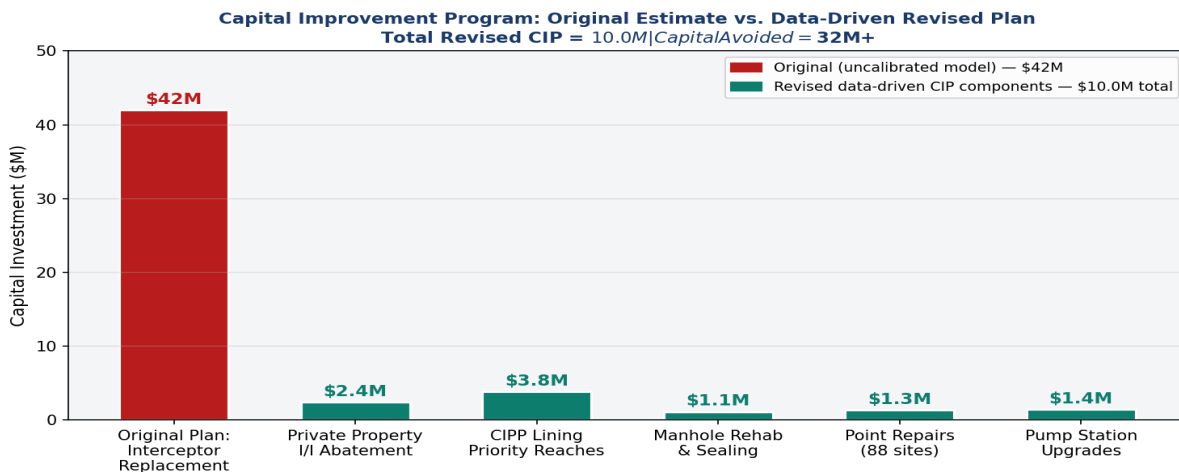


Figure 2 — Capital Improvement Program comparison: \$42M original estimate vs. \$10.0M data-driven revised plan.

CIP Component	Scope	Est. Cost	RDII Reduction
Private Property I/I Abatement (3 priority sewersheds)	~2,400 properties	\$2.4M	18–24%
CIPP Lining — High Priority Reaches	6.2 miles	\$3.8M	12–15%
Manhole Rehabilitation & Sealing	214 structures	\$1.1M	6–8%
Point Repair — Confirmed Defects	88 locations	\$1.3M	4–6%
Pump Station Upgrades (3 stations)	Controls + wet well	\$1.4M	Operational
TOTAL REVISED CIP		\$10.0M	40–53% RDII reduction

Engineering Significance

PRINCIPLE 1: MODEL CALIBRATION IS ENGINEERING DUE DILIGENCE

A hydraulic model's capacity prediction is only as accurate as its RDII parameters. Population-based estimates establish a starting model; field-calibrated RTK parameters create a reliable engineering tool. Before recommending any capital program driven by a model capacity finding, confirm the RDII parameters are field-derived and system-specific.

PRINCIPLE 2: RDII DECOMPOSITION DETERMINES SOLUTION TYPE

Knowing total RDII volume is insufficient for capital planning. The RTK decomposition — distinguishing fast inflow, delayed inflow, and slow infiltration — identifies which physical sources dominate and which interventions will be most effective. Fast-dominated systems need inflow source removal; slow-dominated systems need structural rehabilitation.

PRINCIPLE 3: MONITORING NETWORK DENSITY ENABLES CIP PRIORITIZATION

A 47-meter tiered network provides the spatial resolution to rank sewersheds by RDII density (RDII volume per contributing acre). This ranking directly drives CIP prioritization and reduces CCTV inspection scope by concentrating field resources where data confirms the highest rehabilitation return.

Conclusion

The Riverside Falls monitoring program demonstrates the primacy of field data over model assumptions in municipal infrastructure planning. The \$680,000 monitoring investment — 1.6% of the original contemplated capital program — redirected \$32 million in capital spending toward more effective interventions and delivered verified 47% RDII reduction over three years.

Municipal engineers should adopt field-calibrated RDII characterization as a standard prerequisite for trunk interceptor capital decisions. The monitoring program did not delay the CIP; it produced a better CIP. The 18:1 return on monitoring investment is not exceptional — it is representative of outcomes documented across the collection system engineering literature.

Frequently Asked Questions

Q: What is RDII in sanitary sewer systems?

RDII (Rainfall-Derived Infiltration and Inflow) is the excess wastewater flow that enters a sanitary sewer system during and after rainfall events, beyond normal dry-weather flow. RDII enters through defective pipe joints (infiltration), cross-connected storm drains, roof drains, and foundation drains (inflow). Quantifying RDII accurately through field monitoring is essential for hydraulic model calibration and capital improvement program development.

Q: What is the RTK method for RDII analysis?

The RTK method is an EPA-developed approach that decomposes observed RDII hydrographs into three characteristic response components, each described by three parameters: R (fraction of rainfall volume that becomes RDII), T (time to peak), and K (ratio of recession to rise time). The three RTK sets correspond to fast, medium, and slow RDII responses, associated with different physical I/I sources within the sewer system.

Q: How much does a sanitary sewer flow monitoring program cost?

A comprehensive municipal flow monitoring program typically costs \$300,000–\$800,000 depending on system size, number of meters, monitoring duration, and analysis scope. The capital programs informed or redirected by monitoring data are typically 10–50 times larger. This case documented a \$680,000 monitoring program that redirected a \$42M capital program — a monitoring cost of 1.6% of the capital decision being informed.

Q: What is the difference between infiltration and inflow in sewer systems?

Infiltration is groundwater that enters the sewer through defective pipe joints, cracked pipes, and deteriorated manhole walls — a slow flow that increases after rainfall as groundwater levels rise. Inflow is stormwater that enters directly through manhole lids, roof drains connected to the sanitary sewer, cross-connected storm drains, and uncapped cleanouts — a fast, event-driven flow that mirrors rainfall intensity.

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