Abstract
The EPA’s conclusion (EPA Report: EPA/600/R-12/690) that a need existed for the “prioritization of sub-sewersheds for field investigations to support condition assessment” produced a new requirement for I&I detection capability. Everyone agreed with the EPA regarding the “sub-sewershed” recommendation, but when looking at real world conditions, hundreds of independent flow studies confirmed that 80% of I&I resided in just 20% of the collection network and according to the EPA’s latest report, it was the I&I in the upper reaches of this 20% of the system that needed to be exposed.

Conventional Doppler-type flow meters, while able to measure flows in larger basins (2-4 miles) where wastewater levels remain at heights satisfactory for covering their “bottom-sitting” sensors, have proven themselves incapable of providing the necessary high resolution monitoring required for micro detecting I&I in the smaller diameter pipes (8”-12”) within the sub-sewersheds that make up 85% of almost every collection system. This shortcoming presented itself as an opportunity for developing a solution not currently available with conventional I&I detection flow monitoring methods. If it was now deemed important to isolate the I&I hiding in the upper reaches of the network, the time had arrived for developing a more technologically advanced and cost-efficient solution capable of pinpointing sources of I&I down to micro-basins comprised of just a few manholes.

Advancing I&I Detection Technology
In order for consulting and utility engineers to increase their success rate in pinpointing the 20% of the collection network responsible for contributing 80% of the I&I, an advanced technology (referred to as I&I Micro Detection or iTracking) needed to be developed that was not only cost-efficient but also had the capability to accurately monitor the low flows found in the upper reaches of every wastewater conveyance system.

Thanks to recent advances in digital technology, locating exact areas of I&I have now become possible through the seamless integration of low cost sensors, wireless connectivity and high-powered analytical software. iTracking’s capability to locate and measure I&I after just a single rainstorm is only one of its many advantages. Its patented technology also eliminates the need for confined space entry, repetitive maintenance and on-site data retrieval in addition to having the ability to negate the requirement for costly and labor intensive nighttime flow isolation.
**I&I Micro Detection (iTracking)**

*What municipalities and utilities are ultimately interested in accomplishing is NOT to measure each gallon of I&I but to quickly and cost-efficiently PINPOINT those areas within the collection network responsible for contributing the greatest influx of rain and groundwater.*

This is exactly what iTracking Micro Detection technology is designed to achieve; locate inflow and infiltration down to an adjacent pair of manholes simply, safely, quickly and inexpensively. The key to iTracking is a seamless integration of low-cost sensors, wireless connectivity and automated analytical software delivering results where present technologies fall short. iTracker® Wi-Fi and cellular-enabled smart level sensors simply and safely record wastewater levels from 0 – 100% pipe ID between dry day periods and wet weather events and then convert those changes in level to volumetric differences in flow through the use of cleverly developed algorithms embedded within the iTracking I&I Micro Detection software program. With the simple click of a button, bar graphs, pie charts and operating performance reports are clearly presented detailing the contribution of I&I for each mini and micro-basin within the area under investigation.

In many instances, the problem is pinpointed down to an adjacent pair of manholes without the requirement for expensive monitoring equipment, confined-space entry, repetitive maintenance or “in the road” data retrieval. The time period to pinpoint faulty infrastructure can be as quick as a single rain event. This one storm approach is the biggest factor in delivering a successful and cost saving I&I detection study.

**Converging on Inflow & Infiltration**

in most situations, sub-sewersheds are configured in a serial pattern and one must be capable of subtracting flows from each mini or micro-basin (sub-sewershed) from the one directly above it. Not an easy task to accomplish with presently available I&I detection methods. iTracking solves the “subtraction” problem by adding a powerful series of volumetric differentiation algorithms to the I&I discovery process. With just the “click of a button”, iTracking allows for the independent analysis of micro-basins all the way down to a single pair of adjacent manholes.

I&I Micro Detection is achieved by strategically placing a group of iTracker smart level sensors upstream of a regional flow meter allowing for changes in wastewater volume to be observed in mini and micro-basins down to 1/10” of flow. iTracking’s unique ability to isolate mini and micro segments of a basin from one another ultimately results in determining the volume of I&I residing within each individual piping segment. Custom developed algorithms have the ability to convert level readings to flow in gpm thereby resulting in being able to subtract flows in any micro basin from the one directly upstream of it. By simply repeating the process, areas of I&I can be micro-detected down to a set of adjacent manholes.
Zeroing in on the Problem
By increasing the number of measurement points, iTracking Micro Detection has the ability to reveal the location of I&I after only a single storm event. Strategically placed iTracker smart sensors provide the high resolution required for pinpointing the 20% of the faulty infrastructure responsible for the majority of I&I all the way down to adjoining sets of manholes. iTracker sensors are installed from the street level without the need for confined-space entry and sensor calibration is accomplished in 5 minutes using any Wi-Fi enabled mobile device.

Mini-Basin I&I Detection
Micro-Basin I&I Detection

Having discovered that mini basin 1 is responsible for 30% of total I&I, iTracker sensors are relocated creating (4) micro basins within mini basin 1.

*iTracking analytics immediately discover that micro basin 1C, comprised of adjacent manholes 1B - 1C, is contributing 75% of the I&I within all of mini basin 1.*

**Performance Analysis**

A critical step for successful I&I evaluation studies and RDII modeling of wastewater collection systems is the ability to decompose all of the collected dry and wet weather performance data into base wastewater discharge volume, groundwater contribution and extraneous amounts of volume due to the effects of rain-derived inflow and infiltration. The analytical process of determining base, groundwater and I&I contributions can then be utilized to determine the sources and quantities of flows within the network. Additionally, the resulting analytics will determine whether the generation of excessive RDII and groundwater flow components are the cause of SSOs and other operational problems.
With conventional flow monitoring methods, once the data has been collected and transferred to a software analysis program, the tedious and time-consuming process of analyzing the information and creating reports begins. Not so with iTracking. ITracking’s advanced analytical programs perform each operation automatically within the time span of a few minutes.

After downloading of sensor data to the iTracking software program and the simple click of a button, proprietary algorithms perform the functions necessary for producing a wide array of charts, graphs and reports describing the exact state of the collection infrastructure as it relates to the effects of both groundwater and Rain-Derived Inflow and Infiltration (RDII).

**Results with the Click of a Button**

After downloading of smart sensor data to the auto-analysis software program, proprietary algorithms convert each measurement of volumetric change to actual volume in gallons per minute. Then with the simple click of a button, charts, graphs and reports are automatically created describing the exact state of the infrastructure as it relates to Inflow & infiltration.

Smart algorithms embedded within the auto-analysis software program calculate mathematical factors representing increases in flow between dry weather days and wet weather events for each mini and micro-basin under investigation. Simple to understand bar charts depict “at a glance” the sites most responsible for contributing the highest volumes of storm water related I&I along with graphs depicting base flows, groundwater contributions and total I&I volume.

*High visualization bar graphs, developed for each set of collection basins under investigation, instantly highlight all Major, Mini and Micro-Basins responsible for the greatest influx of I&I.*
Hydrographs report exactly what is transpiring within the collection system on a 5, 10 or 15-minute incremental basis. Micro I&I Detection analysis programs start off at the major basin level and then drill down to greater detail as areas and sub-areas of I&I are identified providing a complete understanding of collection system performance. These functions include Rainfall Analysis, Base Flow Analysis, Groundwater Analysis, Dry vs. Wet Day Analysis, Peak RDII and Capacity Analysis.

Consolidated analysis reports are also generated detailing the effects that both dry and wet weather have upon specifically designated areas within the wastewater collection network under investigation. Location, volume and treatment cost data are clearly organized and presented for every sub-sewershed undergoing investigation.
Summary and Conclusions
In case after case, extensive SSES studies have confirmed that 80% of inflow & infiltration originates in just 20% of the collection system. Portable flow meters, while able to measure flows in larger basins (2 – 4 miles) where wastewater levels remain at heights satisfactory for covering their “bottom-sitting” sensors, have proven themselves incapable of providing the necessary high resolution monitoring for micro-detecting I&I in the upper reaches (8” – 12” diameter pipes) making up 85% of almost every collection system.

A newly developed I&I Micro Detection technology, referred to as iTracking, seamlessly integrates intelligent low-cost sensors, wireless connectivity and auto-analytical software to deliver 40 to 60 times the I&I detection capability of conventional flow monitoring methods. In most instances, after a single storm event, the problematic infrastructure is pinpointed down to mini and micro-basins without the requirement for expensive monitoring equipment, confined-space entry, repetitive maintenance or hazardous “in the road” data retrieval.
Proving the Technology: Jefferson County, Alabama

Working with Hazen & Sawyer's Engineering Team, iTracking’s I&I Micro Detection ability was recently proven in a Pilot Project initiated by Jefferson County, Alabama (Feb., 2018).

The area selected for the Pilot by Jefferson County and the Hazen & Sawyer Engineering Team as being one of the basins responsible for contributing the greatest amounts of I&I was designated as "Turkey Creek TK2B". It was decided to initially place (14) iTracker® sensors within the 22 linear miles comprising the TK2B basin. The project was scheduled for completion in three phases during what was to be a 6-month Pilot Project. What ultimately resulted was that with only (14) iTracker® sensors, the Pilot was completed in 3-1/2 months with actual man-hours expended on all three phases (including developing analytical reports) totaling just 48 hours.

**PHASE I:** On February 7th and 8th of 2018, fourteen iTracker sensors weighing just under 2 lbs., without the requirement for confined-space entry, were installed at strategic locations along the 22-mile TK2B basin. On average, it took 20-30 minutes to locate each manhole and 15 minutes to install each sensor. The entire installation process was completed in less than 10 hours.

**PHASE II:** On March 16 after a few rain events, data was simply and safely collected from each monitored site via smartphone Wi-Fi connectivity. Data from the 14 sites was imported into the iTracking® analytical software program in order to determine those basins responsible for contributing the greatest amounts of I&I. With the click of a button, a bar graph (see Graph 1) was automatically developed detailing RDII, Groundwater, Base and Total I&I contributions in gpm for each monitored site. It was quickly determined that Mini-Basin 7004-002 was responsible for the highest volumes of Rain-Derived I&I (RDII).
Below is a summary of the results of Phases I and II detailing the calculated RDII volume for each mini and micro basin over the study period.

SITE 7004-002  RDII 1,802,958.00 Gal. (27.41% of Total)
SITE 7004-101B  RDII 1,081,097.00 Gal.
SITE 7004-004  RDII  712,714.10 Gal.
SITE 7004-059D  RDII  709,952.10 Gal.
SITE 7004-034  RDII  693,073.70 Gal.
SITE 7004-007  RDII  459,706.70 Gal.
SITE 7004-102  RDII  333,006.80 Gal.
SITE 7004-258  RDII  208,402.90 Gal.
SITE 7004-006B  RDII  206,988.80 Gal.
SITE 7004-092  RDII  160,326.70 Gal.
SITE 7004-057A  RDII  135,448.00 Gal.
SITE 7004-085  RDII  111,967.00 Gal.
SITE 7004-060  RDII  81,513.11 Gal.

In order to prove the I&I Micro Detection capability of iTracking’s technology, Site 7004-002 exhibiting the greatest volume of RDII was scheduled to be divided into 11 micro-segments for the next evaluation period (Phase III).

**PHASE III:** In order to further isolate the source of I&I entering the system, (11) iTracker sensors were strategically located upstream of Site 7004-002. It was quickly concluded that an area directly upstream of 7004-002 consisting of only 4 manholes alongside a creek was responsible for contributing the majority of RDII (see Graph 2). iTracker sensors were placed in each of the (4) manholes making up the 870 feet of micro-basin 7004-002. Evidence of major infiltration was discovered along the 7004-002 15’ ID micro-basin with the majority entering between two adjacent manholes (002 and 003). Cameras were immediately dispatched and it was quickly determined that the large volumes of I&I were due to faulty laterals entering the 7004-002 micro-basin between manholes 002 and 003.

With just 48 hours of actual field and analytical reporting time expended and the ability to obtain concrete results after single storm events, Jefferson County, in conjunction with Hazen & Sawyer, were able to quickly and cost-efficiently evaluate 22 miles of collection system piping all the way down to (14) mini and micro-basins in just a 3-1/2 month period.