If I Had This To Do Over…

Observations from RDII (Rainfall Dependent Infiltration/Inflow) Reduction Projects

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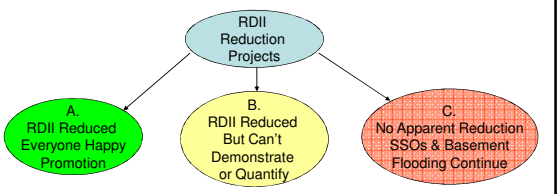
ADS

Agenda

1. Fate of RDII Projects – An Overview
2. Basin Size Affects the Rehabilitate/Replace Decision
3. Getting More Knowledge from Flow Metering.
4. Discussion of Agency Approaches

Fate of Sewer RDII Reduction Projects



Followed Recipe
Plan for Post-rehab
Extremely Lucky

'Toilet Paper is Not as High in the Trees as it Used to be'

Do Not Try to Measure

Forensic RDII Reveals Twelve Stumbling Blocks

No Rain-based Criteria
Did Not Address Private Sources
Did Not Control Basin Size
Rely on Smoke Testing Only
Rely on CCTV only
Piecemeal Repair (find & fix)
Repaired only Manholes
Repaired only Mainlines
Use Poor Rehab Technology
Upstream Restricted Sewer

National Perspective

- WERF Project (99-WWF-8) studied I/I removal programs around the US.
- Unsuccessful because:
  - Data were not generated or archived suitably
  - Data were incomplete or unreliable
  - Mismatch of methods and procedures for evaluating I/I
  - Lack of uniformity of methods among agencies

The Tell-Tale Language of Failed Post-rehab

Conclusions by Consultant for City of Cedar Lake

"Due to the inequality of the conditions in Post-rehab flow monitoring versus Pre-rehab flow monitoring ...the magnitude of improvements made to the collection system cannot be measured. Given equal antecedent conditions in Post-rehab versus Pre-rehab, significant improvements will be clearly evident. Therefore, this comparison does not show the totality of the improvements made to the collection system".

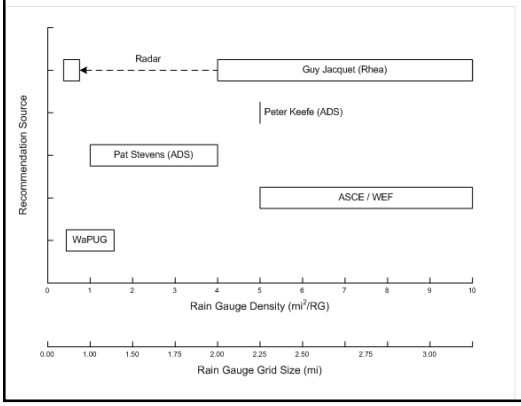
12 Stumbling Blocks to Measurement

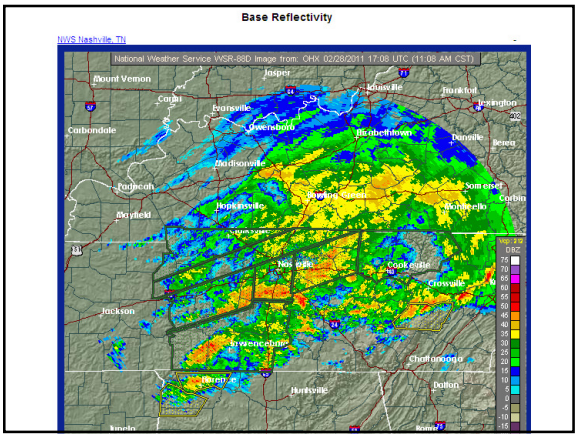
1. Rain Gauge Strategy
2. Basin Size
3. QA/QC Touchstones, Scattergraphs & Q vs. i
4. Metering Depth Technology
5. Duration
6. Season
7. Rainfall Data Frequency
8. Tight Subtractions
9. Method of Calculating RDII
10. Dynamics of Sewers (restricted)
11. Control Basin
12. Site Hydraulics at Metering Manhole

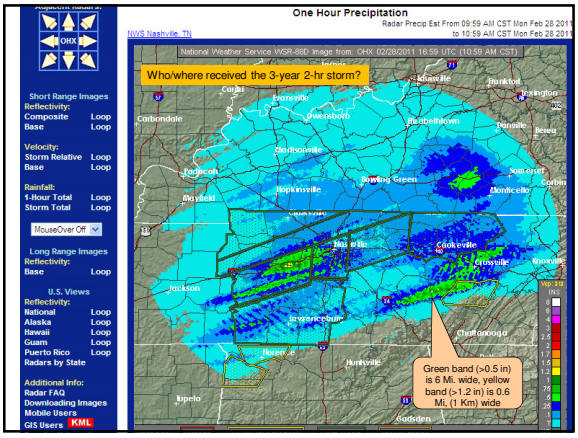
Stumbling Block #1
Rain Gauge Strategy

- Don't rely on RG at the airport
- 1 -2 Mi^2/RG in convective storm season or in hilly area.
- 3 -4 Mi^2/RG in cyclonic/frontal storm season.
- Place RGs in grid not by sewershed.
- Never Less than Two (always assume one will fail)

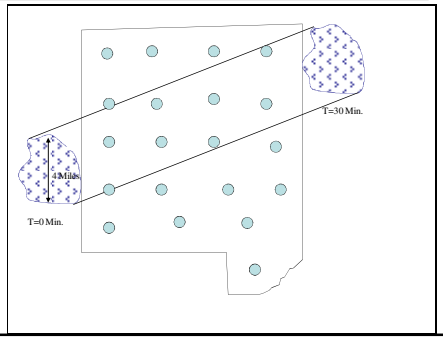
Recommended Densities

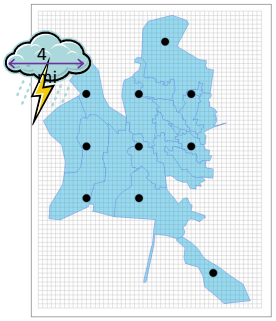






More intense rainfall has narrower foot prints, often less than 2 miles wide. Gauges should be ~ 2 miles apart to capture both the direction and boundary of footprint.





Rain Gauge Density:

4-9 mi^2 / RG

Rain Gauge Grid Size:

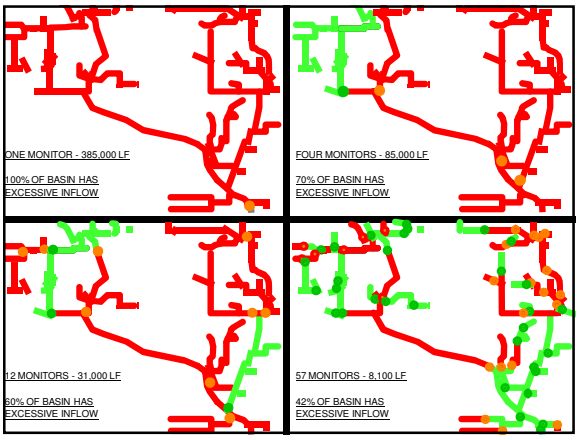
2-3 mi grid

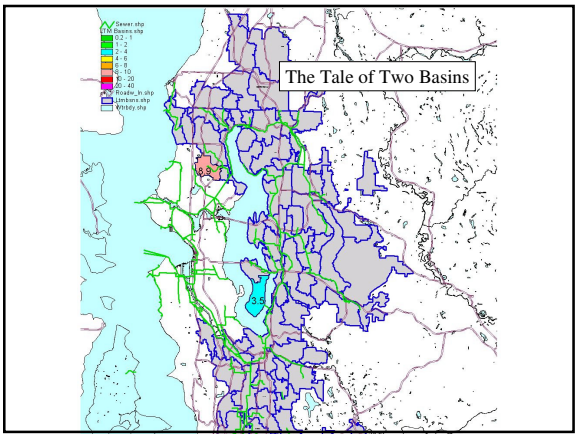
Recommended Quantity:

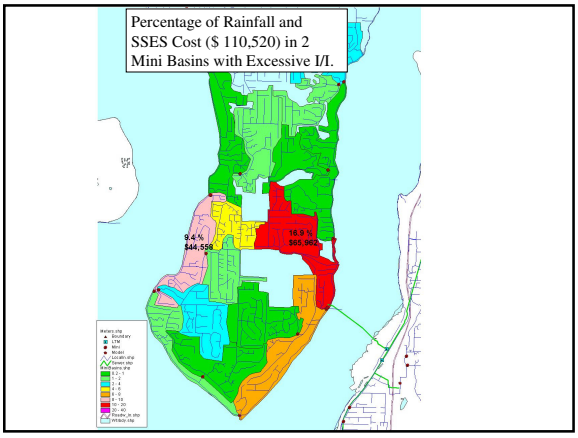
10

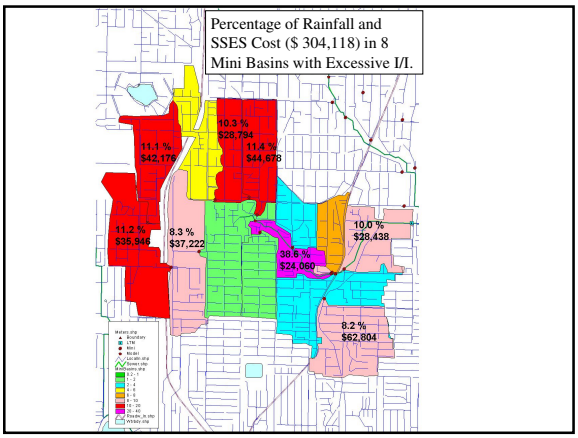
Stumbling Block #2
Basin Size is an Important Variable

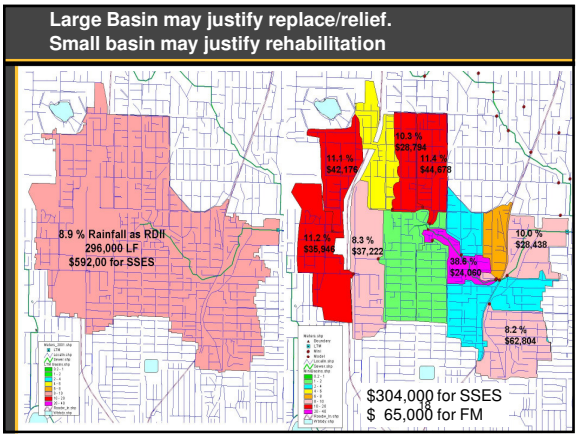
- Meter Basins Should be Small and Uniform in Size
- Small Basins Isolate RDII (80/20 Rule)
- Small Basins Change the location of apparent problems
- Smallest Amount and Cost of Rehabilitation
- Easier to Demonstrate Improvement



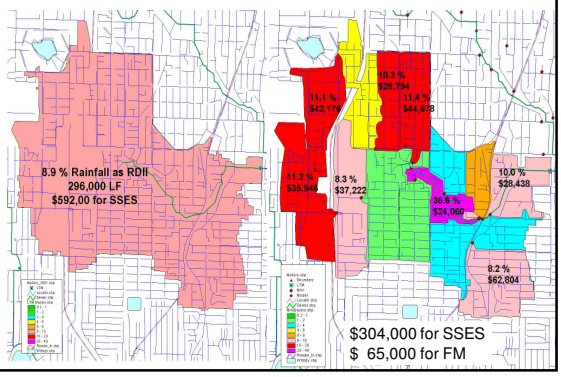



Percentage of Rainfall and
SSES Cost ($ 110,520) in 2
Mini Basins with Excessive I/I.
9.4 %
$44,559
18.9 %
$65,961

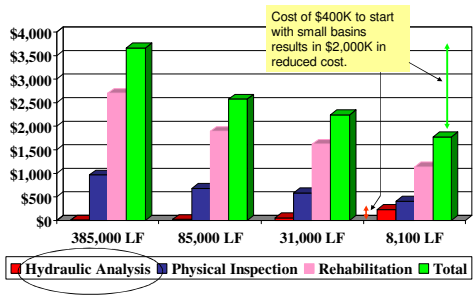

Percentage of Rainfall and
SSES Cost ($ 304,118) in 8
Mini Basins with Excessive I/I.
10.3 %
$28,794
11.1 %
$42,176
11.4 %
$44,678
11.2 %
$35,948
8.3 %
$37,222
10.0 %
$28,438
38.6 %
$24,060
8.2 %
$62,804


Large Basin may justify replace/relief.
Small basin may justify rehabilitation
8.9 % Rainfall as RDII
296,000 LF
$592,00 for SSES
10.3 %
$28,794
11.1 %
$42,176
11.4 %
$44,678
11.2 %
$35,948
8.3 %
$37,222
10.0 %
$28,438
38.6 %
$24,060
8.2 %
$62,804
$304,000 for SSES
$ 65,000 for FM

Cost Savings at $2/LF for SSES

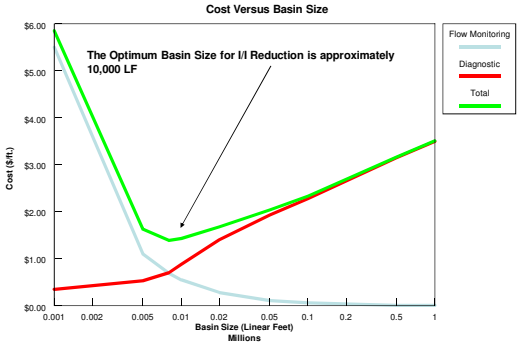


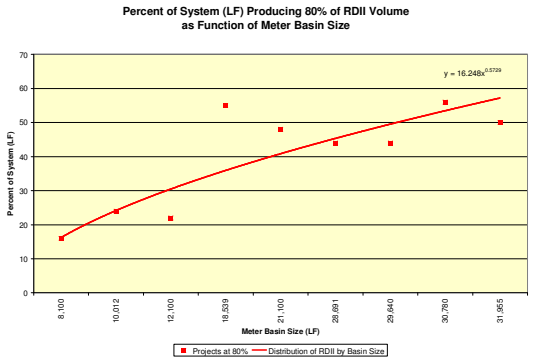
Basin Size has Cost Leverage

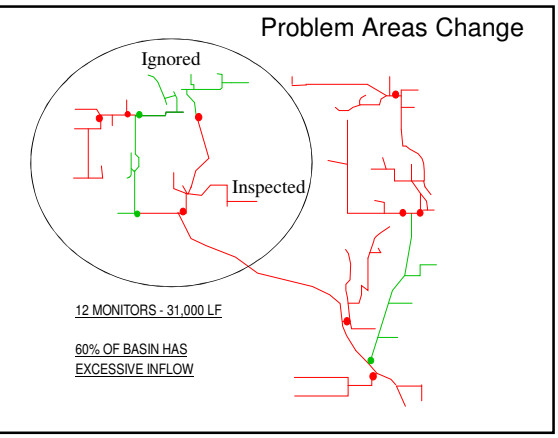


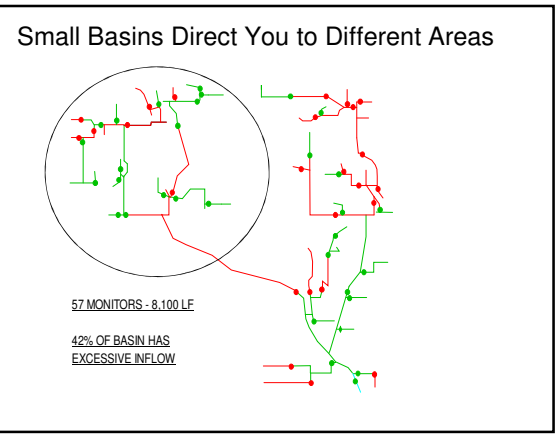
The most common approach to RDII projects is to minimize the first cost, which ultimately increases total cost.

Optimum Basin Size




Percent of System (LF) Producing 80% of RDII Volume
as Function of Meter Basin Size
y = 16.248x^0.5729
Percent of System (LF)
0
10
20
30
40
50
60
70
8,100
10,012
12,100
18,539
21,100
28,691
29,640
30,780
31,955
Meter Basin Size (LF)
Projects at 80%
Distribution of RDII by Basin Size

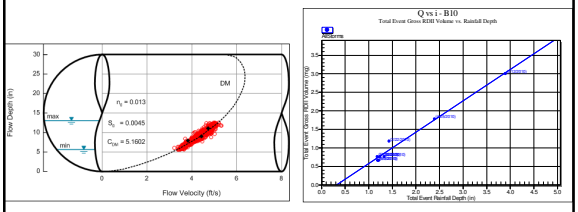

Problem Areas Change
Ignored
Inspected
12 MONITORS - 31,000 LF
60% OF BASIN HAS
EXCESSIVE INFLOW


Small Basins Direct You to Different Areas
57 MONITORS - 8,100 LF
42% OF BASIN HAS
EXCESSIVE INFLOW

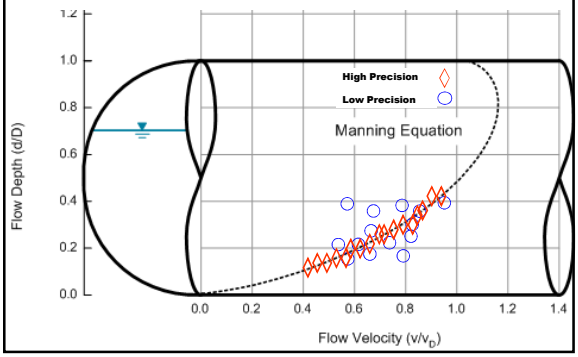
The 10/20 Rule

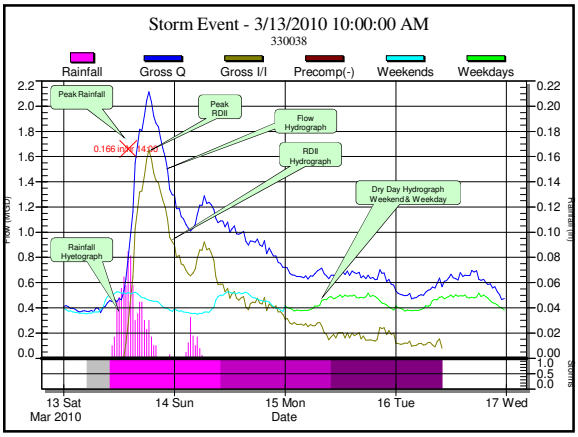
1. Treat sewer system like a tree with leaves, branches and a trunk.
2. Layout meter basins in the 'leaves' with 10,000 LF basins (approximate size of subdivisions)
3. Layout meters to avoid subtractions
4. Make sure downstream meters are far enough apart to create a 'Net' flow of at least 20% of the 'Gross' flow
5. Place meters upstream of modeling 'nodes' or logical restrictions (e.g. siphons) to determine Operation Capacity

Stumbling Block #3
Scattergraphs & Q vs. i Diagrams
KPI's for Flow and Rain Data



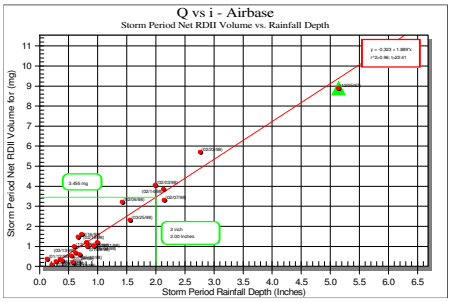
The target performance for a meter is a line.
Low precision meters produce wide scatter.





Q vs. i

- Mother Load of Flow Study
- Should be Linear



Stumbling Block #4
Depth Technology Makes a Difference

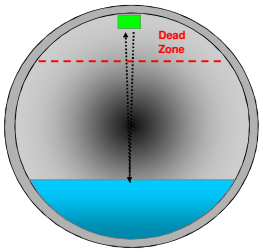
Ultrasonic Depth Always Superior

- **Depth**
- Pressure Sensor
- (Pressure Bubbler)
- Ultrasonic Down-looker
- Ultrasonic Up-looker

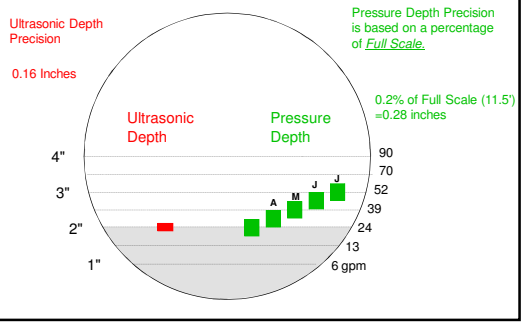
- **Velocity**
- Average Doppler
- Peak Doppler
- Gated Doppler
- Time of Travel
- Faraday
- Surface Radar

Rat's Eye View of a Meter Installation

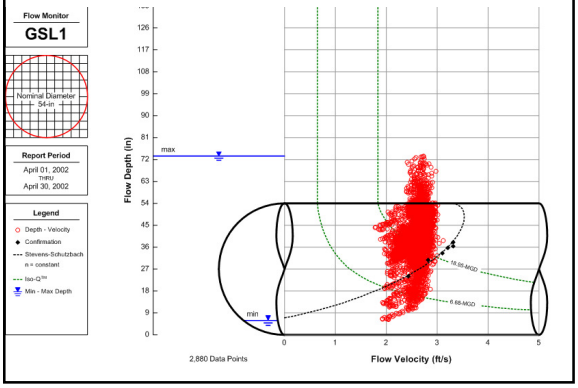
Ultrasonic Down Looking Depth Sensor



Stumbling Block #4 Depth Sensor Technology - "Window of Precision"

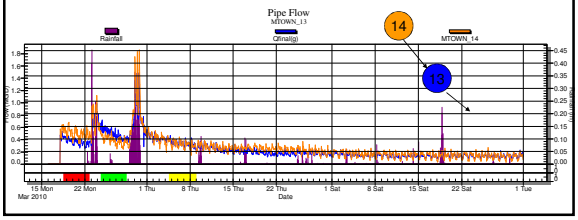


Sensor Drift in Scattergraph View

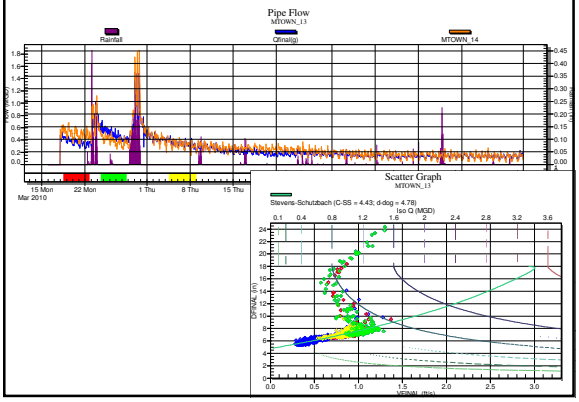


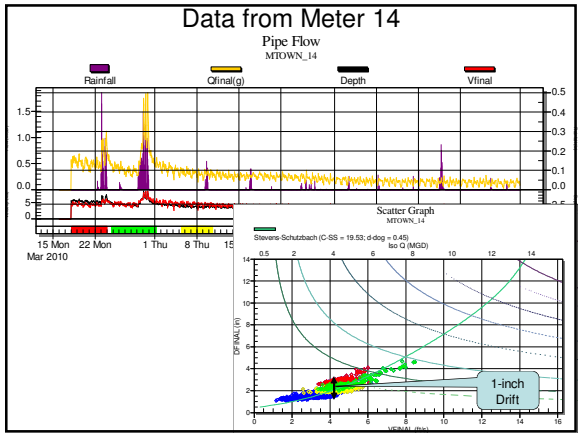
A Sewer Quiz

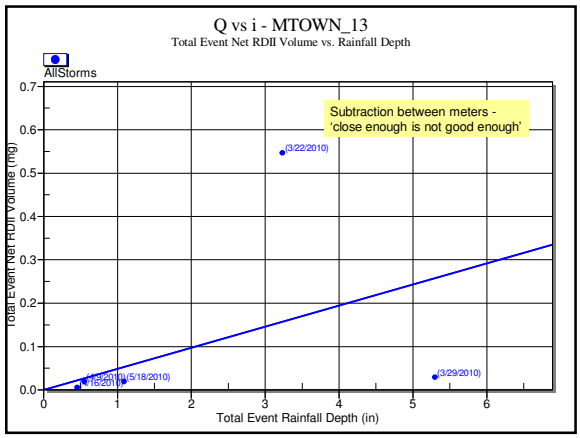
Meter 14 is upstream of Meter 13.
Both meters use pressure sensors for depth.
Notice the meters are in and out of balance.
Which meter is bad and why?



Data from Meter 13







RDII Project Elements to Specify as a Minimum	
RG Strategy	1 every 4 sq. miles
Duration	Minimum of 90 days
QA/QC Touchstones KPIs	Make sure Scattergraphs and Q vs i plots are deliverables.
Metering depth	Ultrasonic Depth technology - pressure backup
Basin Size	10,000 LF Upper end - 20% Net subtraction down
Season	Start in dry - end in wet
RG data	Five-minute data
Tight subtractions	Net Subtraction no less than 20% of Gross flow
RDII Calculation	Capture Coefficient and Gallons/inch/LF (rainfall in the denominator)
Sewer Dynamics	Scattergraph and Q-i will spot restricted sewers and Potential RDII
Control basin	Identify at beginning & Use to evaluate pre- and post metering of rehabilitated basins.
Site Hydraulics	Avoid Silt, Hydraulic Jumps and Dead Dogs

Better Knowledge from Flow Meter Data

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Basic Questions of Collection System Management

1. How much water is coming from upstream (dry and wet) and where is it entering system?
2. What is capacity of downstream pipe?
3. Rehabilitate or replace problem sewer?

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Observations

- Without Flow Metering, symptom = problem.
- With Strategic Flow Metering, the problem(s) can be separated from the symptom.
- Knowledge of pipe's Operational Capacity may change the decision replace or rehabilitate a sewer.
- Longer Term metering provides Key Performance Indicator (KPI).

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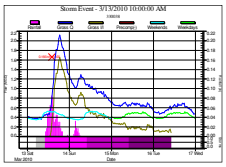
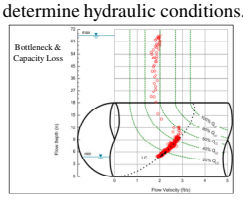
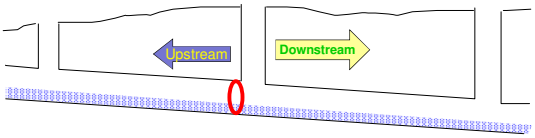
Properly Deployed, a Flow Meter will look both Upstream to measure flow and Downstream to determine hydraulic conditions.







Depth - Velocity Flowmeter

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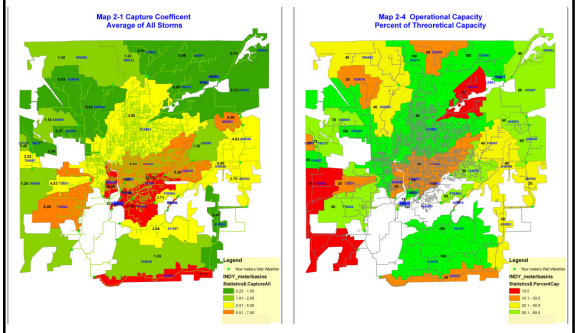
Example of two sets knowledge from single set of meters



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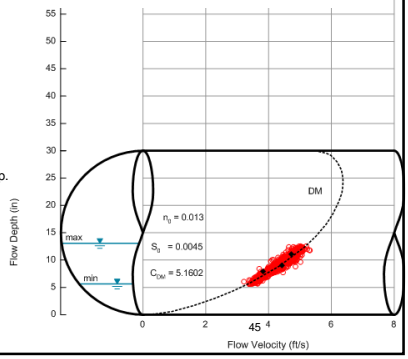
The combination of a Manning Curve, meter data and confirmations reveal a meter's accuracy.

If data do not conform to this pattern:
1.Hydraulics are not normal
2.Meter is inaccurate

This is a 'do not pass go' step.



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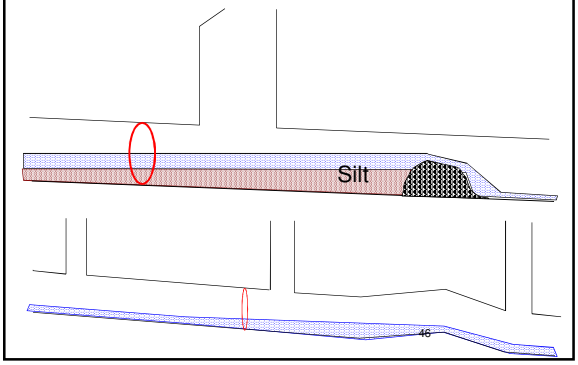
Silt and Obstacles result in backwater at a meter.



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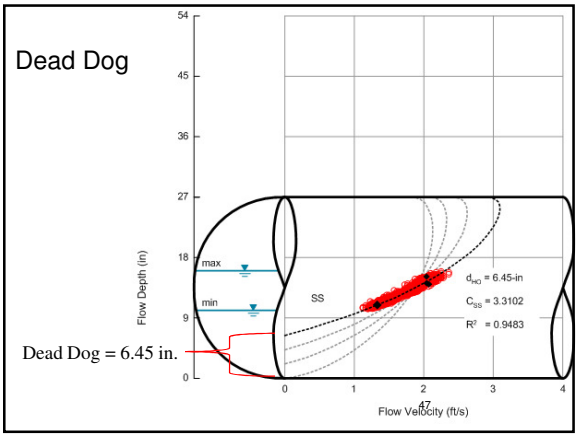
Dead Dog



Dead Dog = 6.45 in.

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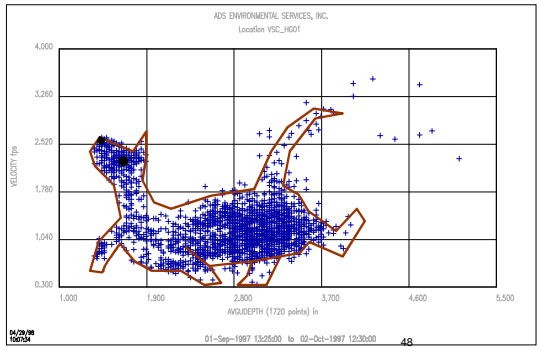
High Technology proves the existence of the Dead Dog in sewers



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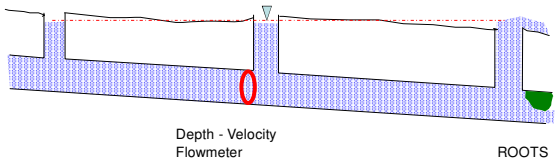
SSO and Bottleneck Downstream of Flowmeter



Depth - Velocity Flowmeter

ROOTS

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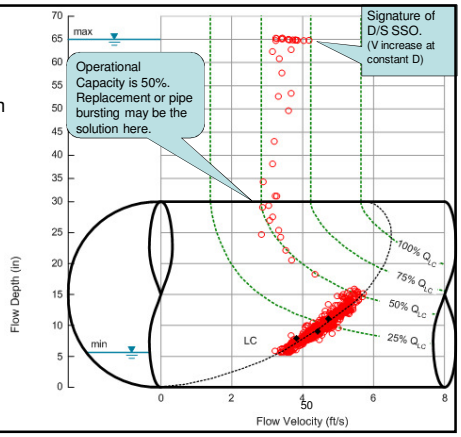
Downstream SSO



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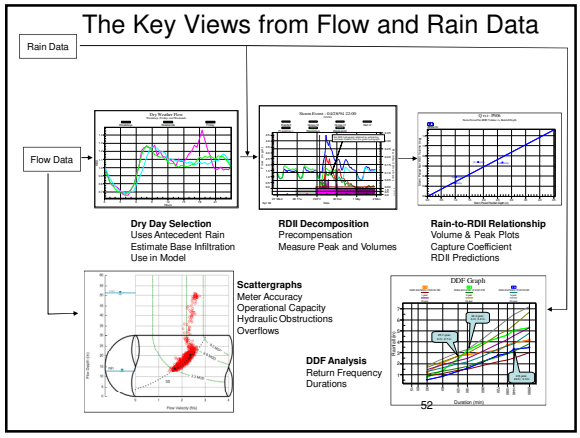
Scattergraph Poster


The Key Views from Flow and Rain Data
Rain Data
Flow Data
Dry Day Selection
Uses Antecedent Rain
Estimate Base Infiltration
Use in Model
RDII Decomposition
Precompensation
Measure Peak and Volumes
Rain-to-RDII Relationship
Volume & Peak Plots
Capture Coefficient
RDII Predictions
Scattergraphs
Meter Accuracy
Operational Capacity
Hydraulic Obstructions
Overflows
DDF Analysis
Return Frequency
Durations
DDF Graph
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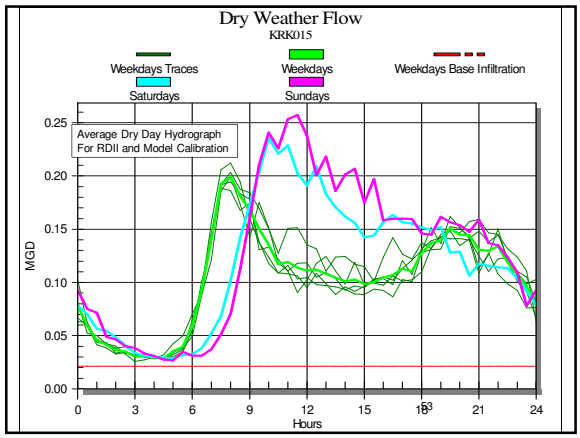
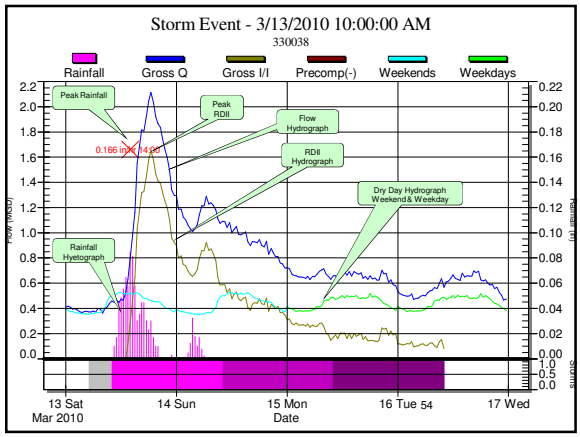
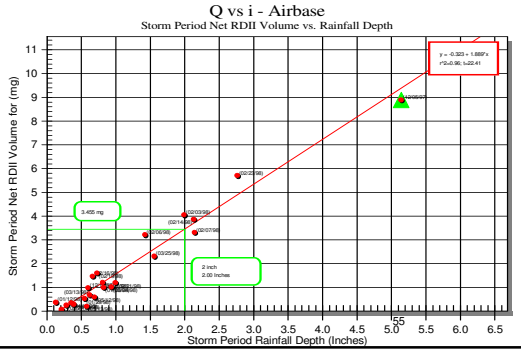

Dry Weather Flow
KRK015
Weekdays Traces
Weekdays
Weekdays Base Infiltration
Saturdays
Sundays
Average Dry Day Hydrograph
For RDII and Model Calibration
MGD
Hours
53


Storm Event - 3/13/2010 10:00:00 AM
330038
Rainfall
Gross Q
Gross I/I
Precomp(-)
Weekends
Weekdays
Peak Rainfall
Peak RDII
Flow Hydrograph
RDII Hydrograph
Dry Day Hydrograph Weekend& Weekday
Rainfall Hyetograph
13 Sat
Mar 2010
14 Sun
15 Mon
16 Tue
17 Wed
Date
54

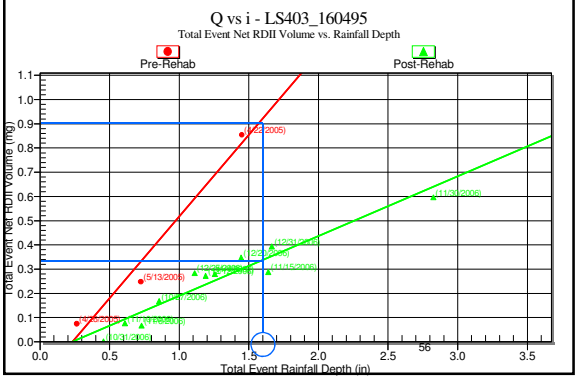
Q vs. i Diagrams

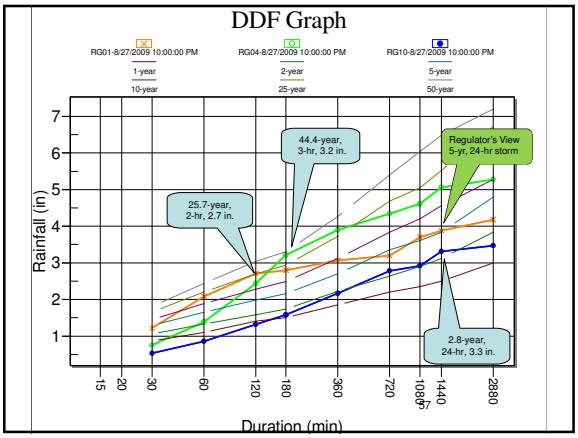
Peak and Volume - Design Storms



Almost everyone in the Sewer Rehab business will eventually ask or be asked;

"What have you accomplished with the money?





Agency Approaches

Agency	Drivers	Satellite Approach	
King County, WA	Capital Cost for new WWTP	Funded all metering to avoid disputes and disparities in conditions. Basin size control	
WSSC	Routine RDII, Modeling	LTM for baseline and performance tracking, temp metering for RDII reduction and model calibration. Basin size control	
Baltimore County	RDII reduction City, CD	Flow to City, RDII reduction, control basin size	
Baltimore City	RDII, SSO reduction, CD	Control basin size	
PSA	CSO Modeling		
ALCOSAN	RDII, CD	Originally let satellite conduct flow metering – 13% was useful. Controlled data in 2nd pass.	
Oakland County, MI	Routine modeling, billing, RDII	Satellites 'own' capacity in trunks, manage peaks.	
San Diego	Billing, modeling, alarming	Billing for 5 satellites and alarming in canyons	
Orange County, CA	Modeling, RDII, Ocean Outfall capacity	Grant Program to fund I/I reduction. Control basin size in second pass.	
Los Angeles	Modeling, RDII	Repeated study after metering technology gave poor results.	
EBMUD	Modeling, CD	Buying or Selling a Property Building or Remodeling in Excess of $100,000 Changing Water Meter Size	

References

For more scattergraph information and to request a poster visit:

http://www.adsenv.com/scattergraphs

For Sliicer.com information visit:

http://www.Sliicer.com

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