Increasing Predictability of Inflow-Infiltration Reduction Outcomes
Some Definitive Guidelines

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Coverage

• Background of the WSAA Project
• Good practice definition
• KPIs and Thresholds
• House laterals
• The Predictive Model
• Takeaways
Who is WSAA

Formed in 1995 as a non-profit organization to support the Australian Urban Water Industry

The Association’s main activities focus on four areas:

• Influencing national and state policies on the provision of urban water services
• Promoting debate on environmentally sustainable development and management of water resources
• Improving industry performance and establishing benchmarks
• Fostering the exchange of information
Recap of WSAA project

Background
- E. Australia experienced a 10-year period of drought due to El Nino
- La Nina shift in 2011 increased rainfall and I/I reduction was back on the agenda
- Evaluation of what was being done in New Zealand, USA, and Singapore

Goals
- Determine current member’s I/I practices
- Research, identify and develop best practices

Results
- Good Practice Guideline
  - Volume 1 – Background and Theory
  - Volume 2 – The “How to”
Experienced based Case Study – Not theoretical

- Australia
  - Sydney Water
  - Goulburn Valley Water
  - Melbourne Water
- New Zealand
  - Auckland (40 catchments)
  - Palmerston North
- Singapore Public Works Bureau
- UK Water
- USA
  - EBMUD, California
Existing guideline documents

- WERF, Reducing Peak Wet Weather Flows through I/I Reduction, 2003
- WEF- Existing Sewer Evaluation and Rehabilitation, MOP FD-6, 3rd Edition, 2009
“It amazes me how people are often more willing to act based on little or no data than to use data that is a challenge to assemble.”

— Robert J. Shiller
Good practice definition
Developing a good process

- Identify key players
- Establish program goals
- Timeline
Good I/I reduction processes

Stage 1
Pre-rehabilitation monitoring and I/I analysis

Stage 2
I/I source detection

Stage 3
Rehabilitation design & implementation

Stage 4
Post rehabilitation FM and I/I analysis

Stage 5
I/I reduction effectiveness assessment
## Summary of **Source Detection** Methods

<table>
<thead>
<tr>
<th>In-sewer Flow Monitoring</th>
<th>ElectroScan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Inspections</td>
<td>Salinity Monitoring</td>
</tr>
<tr>
<td>Smoke Testing</td>
<td>Hydrostatic Isolation Testing</td>
</tr>
<tr>
<td>CCTV</td>
<td>Lateral Surface Flood Testing</td>
</tr>
<tr>
<td>Dye Testing</td>
<td>Ground Assessment (GAP and GIG)</td>
</tr>
</tbody>
</table>
Summary of **Pipe Rehabilitation** Technologies

Table 5.1 Summary of Pipe Rehabilitation Technologies

<table>
<thead>
<tr>
<th>Method</th>
<th>Pipe Parameters</th>
<th>Work Requirements</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ID Diameter Range (mm)**</td>
<td>Max Repair Length</td>
<td>Plugging/by-passing?</td>
</tr>
<tr>
<td>CIP, standard</td>
<td>100-2400</td>
<td>400</td>
<td>Yes</td>
</tr>
<tr>
<td>CIP, Top Hat</td>
<td>100-200</td>
<td>0.5</td>
<td>Yes</td>
</tr>
<tr>
<td>Reinforced gunite</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Spraying, epoxy</td>
<td>80-1000</td>
<td>&lt;100 typ.</td>
<td>Yes</td>
</tr>
<tr>
<td>Robotic repairs</td>
<td>200-1000</td>
<td>10</td>
<td>No</td>
</tr>
</tbody>
</table>

1. Level of Cleaning required: Good / Very Good

2. Level of Cleaning required: General

- Slippining          | 100-2400        | <2000             | No        | Yes          | Yes            | Yes                      | Yes                    | Yes                     | Decrease               | Yes           | Yes                  |
- Close Fit - Fold and form | 80-1000 | <500             | Yes       | No           | No             | Yes                      | Yes                    | No                      | Decrease               | Yes           | Yes                  |
- Close Fit - Deform-reform | 80-1600 | <300             | Yes       | No           | No             | Yes                      | No                     | No                      | Decrease               | Yes           | Yes                  |
- PVC Spiral Wound     | 150-2400        | Vanes with diameter | No        | No           | No             | No/Yes                   | Yes                    | Yes                     | Decrease               | Yes           | Yes                  |
- Spot repair sleeves  | 150-2400        | 300-2000          | Yes       | No           | No             | Yes/Varies               | Local                  | Yes                     | Decrease               | Yes           | Yes                  |
- GRP panels           | Man entry       | No Limit           | Vanes     | Yes          | No             | Yes                      | Yes                    | Yes                     | Decrease               | Yes           | Yes                  |

2. Level of Cleaning required: None / Not Applicable

- Pipe bursting, static | 80-1500        | <250              | Yes       | Yes          | Yes            | Yes                      | Yes                    | Yes                     | Same/increase           | Yes           | Yes                  |
- Pipe bursting, pneumatic | 80-1500 | <250             | Yes       | Yes          | Yes            | Yes                      | Yes                    | Yes                     | Same/increase           | Yes           | Yes                  |
- Pipe bursting, hydraulic | 80-600  | <250             | Yes       | Yes          | Yes            | Yes                      | Yes                    | Yes                     | Same/increase           | Yes           | Yes                  |
- Pipe reaming          | 100-600         | <250              | Yes       | Yes          | Yes            | Yes                      | Yes                    | Yes                     | Same/increase           | Yes           | Yes                  |

- Table entries should be considered indicative of applications but not definitive for all products available in the local market.
- SA Water have expressed some concern over the effectiveness of spiral-wound lining to remove I/I. The authors have not encountered any known problems or issues of this nature.
I/I Reduction effectiveness – R% vs. Rainfall volume

Figure 8.1 Calculating I/I Reduction Effectiveness
Linear Regression (RDI Volume vs. Rainfall Volume) Technique
I/I Reduction effectiveness – **Control vs. Target**

**Figure 8.2 Linear Regression (Control vs. Target) Technique for Calculating I/I Reduction Effectiveness**

- **Prerehabilitation**
  \[ y = 1.20x \]
- **Postrehabilitation**
  \[ y = 0.75x \]

RDII Reduction = 43%
I/I Reduction effectiveness – **Calibrated model**

- Each of the pre and post-rehabilitation scenarios have been developed as the basis for calculating I/I reduction levels.

- The models are run to predict system behavior, overflow volumes and performance over a long time series of rainfall data, typically 10 years, to simulate the performance of the system against a wide range of actual rain events.
KPIs and Thresholds
Definition of I/I KPIs

- Groundwater Infiltration (GWI)
- Sanitary Dry Weather Flows (DWF)
- Rainfall Dependant Inflow and Infiltration (RDII)
I/I Performance **Trigger points**

- **RDII$_1$**: Volume of RDII / Rainfall Volume > 8%
- **GWI$_1$**: GWI / average DWF > 20%
- **GWI$_2$**: average DWF / Population > 66 gallons/person/day
- **GWI$_3$**: average DWF / Water Consumption > 1.2
- **SWI$_1$**: Peak WWF / average DWF > 8
Addressing *house laterals*
Private Lateral I/I background

Quantification of Lateral I/I
- Based on Case Studies – Up to 50% of I/I originating in private laterals
- Based on Removal efforts – Projects that addressed private laterals removed about double the amount of I/I

Ownership Differences
- First Inspection Opening
- Property Boundary
- Junction to Sewer Main

Issues Addressing Private Laterals
- Absence of legal levers
- Political sensitivity
- Remit of local government rather than company or authority
Private Lateral I/I reduction

Research for the best cases
• EBMUD triggers for renewal at property sale
• UK ownership of shared laterals
• Lower Paxton and Susquehanna Townships basin-wide lateral replacement

Develop the business case for rehab with public money?
• The water authority carries out and pays for the repair of the on-property portion of the lateral
• The water authority carries out the repair on behalf of the property owners and charges them for this work by charge, loan or lien
• The property owner carries out the identified repairs and funds it themselves
The Predictive Model
Australia - NZ Predictive model

![Graph showing % RDII volume reduction for different inflow sources and Comprehensive measures.](image-url)
## Predictive model

<table>
<thead>
<tr>
<th>Rehabilitation works</th>
<th>Total % I/I volume reduction</th>
<th>Total % peak wet weather flow reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 - inflow defects only</td>
<td>0-15</td>
<td>0-35</td>
</tr>
<tr>
<td>Level 2 – seal public sewers (plus Level 1 above)</td>
<td>15 - 50</td>
<td>25-40</td>
</tr>
<tr>
<td>Level 3 - seal private sewers (plus Levels 1 &amp; 2 above)</td>
<td>40-80</td>
<td>N/A</td>
</tr>
</tbody>
</table>
RDII reduction predictive model

RDII% Volume reduction = (0.42(1-exp(-9.59.xpublic 3.27)) + 0.57(1-exp(-9.89xprivate 3.2))) \times \frac{(1.36\text{initial})}{(0.12+\text{initial})}

Source – Watercare, NZ
25 additional **US** and **Canada** published Case Studies

- **US**
  - EBMUD, CA
  - King County, WA
  - Milwaukee, WI
  - Houston, TX
  - Saugus, MA
  - LOTT, WA
  - Vallejo, CA
  - Chicago, IL
  - Salem, OR
  - Charlotte, NC
- **Canada**
  - Halton-Toronto
  - Vancouver
**Predictability** - Summary of results

![Graph showing volume reduction data for USA + SE ASIA, Australia, and NZ. The graph includes three levels of work: Level 1: Inflow defects, SW direct connections, manhole repairs; Level 2: Sealing of sewers and includes class 1; Level 3: Repair of laterals and includes class 2.](image-url)
ANZ Predictive model vs US data

% RDII volume reduction

Inflow sources Inflow + mains Comprehensive

Upper bound Lower Bound

King Cty
Houston
Saigus
MMSD
Charlotte
Other

GHD @ WEFTEC 2014
RDI/I reduction predictive model

RDII% Volume reduction = (0.42(1-exp(-9.59xpublic 3.27)) + 0.57(1-exp(-9.89xprivate 3.2))) x ((1.36initial)/(0.12+initial))

Source – Watercare, NZ
Other report features

- Cost effectiveness assessment
- Saline groundwater and seawater infiltration reduction
- Rehabilitation and source detection overview
- Costing database
- KPI calculation macros
- Risks and traps – avoiding failures
Key outcomes

- Calibrated model technique is the comprehensive method
- Half of removable I/I is in laterals
- % Reduction depends on the starting RDII
- 30-40% is the minimal level of rehab
- 85% is maximum level of reduction to anticipate
- Get your lateral program sorted !!!
"You can get in way more trouble with a good idea than a bad idea, because you forget that the good idea has limits."

— Ben Graham
Key takeaways

• Uncertainty of I/I reduction levels is now reduced
• Rehab to reduce I/I is now more reliable
• Internationally proven
• Sound basis for planning
Thank you