IMPLEMENTING WSAA'S WASTEWATER I/I GUIDELINES HERE IN NZ - WHY?, WHAT?, HOW?

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ABSTRACT

With the La Nina weather cycles increasing rainfall along most of eastern Australia and New Zealand in the past 3 years, the reduction of rainfall dependent inflow and infiltration (I/I) as a means of reducing wastewater overflows is now firmly back on the agenda of wastewater system managers on both sides of the Tasman. The Water Services Association of Australia (WSAA) is an industry membership organisation that represents the 25 largest water companies/authorities in Australia and New Zealand. To respond to the evolving market need of its member organisations, WSAA recently engaged GHD, in association with local consulting partner Urban Water Solutions (UWS) to develop a Best Practice Guideline Document on I/I Management.

To the authors' knowledge and understanding, this project effectively represents the definitive worldwide research work into I/I management practices. The resulting Good Practice Guideline Document can now be used by wastewater system managers to more confidently implement I/I reduction programs as a means of better managing wastewater system overflows.

Carried out in two stages of work, the project outputs define both theory and practice of good I/I management. This first stage work considered the processes and outputs of a range of real project case studies to develop the Good Practice Guideline document.

The second stage of the project has more recently been completed and brings forward the outputs of the first stage works into a more detailed and definitive outputs that include not only the background and theory on I/I management but also predictive guidelines on likely I/I reduction outcomes and a range of easily implementable calculation tools. Having consistent approaches and means of quantifying I/I has been proven in the case studies to be a key to the success of I/I reduction programs.

What the WSAA work found was that from the significant number of projects whose outcomes have now been analysed, there is now a robust knowledge base upon which to make far more reliable and informed predictive estimates of I/I reduction levels achieved from different levels of system rehabilitation. The work in New Zealand has evolved to a point where a predictive model now exists of the likely level of I/I reduction that can be achieved from existing levels for different extents of system rehabilitation. This is considered to represent a significant advancement worldwide in the planning of wastewater system improvement and management programmes.

Of greatest value to the wastewater systems industry is that the work gives wastewater planners and managers a far more robust basis upon which to undertake I/I reduction programmes through system rehabilitation with the expectation of certain outcomes for a given financial investment. This paper will therefore be of interest to the wide range of delegates challenged by the issue of infiltration and inflow in the effective management of their wastewater systems.

KEYWORDS

Inflow/Infiltration Reduction, Predictive Model, Rehabilitation, Cost-effectiveness

1 INTRODUCTION AND BACKGROUND

Undertaken in two distinct stages, at its outset, the project had as its objectives to deliver a comparative review and report on the infiltration and inflow management practices within participating Australian Water Utilities with a view to development of Best Practice Guidelines / Methodology document for I/I Management.

The Stage 1 project has been previously reported on and presented at the Water New Zealand conference in 2011 (Carne, 2011). In this project scope, the following were defined and completed –

- Establishment of a common understanding of current I/I performance and management processes across the participating WSAA member organisations;
- Benchmarking these practices with those in use in New Zealand, the USA and any other jurisdictions;
- A definition of how other wastewater system improvements can be integrated with I/I Management Solutions.
- Definition and adoption of a consistent set of I/I key performance indicators;
- A five-step process, which if followed rigorously, will most likely result in reduction outcomes consistent with the most successful programmes completed in these jurisdictions;
- Information on processes associated with saline groundwater or seawater infiltration reduction
- Some broad guidelines about the predictability of I/I reduction levels resulting from certain levels of system rehabilitation

These outputs were based on the successful outcomes observed in a number of actual projects carried out by water agencies in both Australia and New Zealand. These projects were described in the Stage 1 document as Case Studies.

User feedback following initial implementation and use of the Stage 1 outputs within Australian water agencies, identified the desire for further information beyond the scope of the Stage 1 works. Associated topics included the following –

- How I/I reduction programmes can be viewed on a business case basis, with a focus on asset renewals and asset management
- A more detailed review and guideline information on the complex issue of removal of I/I from house laterals
- More detailed information on the predictive information on I/I reduction levels
- Information on how to design and construct new systems to reduce the risk of I/I in the future – preventive measures
- A more detailed consideration of methodologies and effectiveness of I/I source detection and rehabilitation techniques
- A cost database of unit rates to enable initial financial planning of the above
- A suite of calculation tools to permit the standardized calculation of I/I key performance indicators.

As final outputs of the Stage 2 project, the project team produced 2 volumes of the Good Practice Guideline document as follows –

Volume 1 – Background and Theory- aimed at a wide audience from water agency senior executives to group managers , team leaders and practitioners, contained the majority of the information associated with the Stage 1 outputs but with the addition of the sections relating to Business Case and Asset Management perspectives, House Lateral I/I Reduction and Predictive Measures

Volume 2 – the "How-To" document, was aimed more at practitioners and contained detailed descriptions of source detection and rehabilitation methods, unit rate cost estimates thereof and also the calculation processes, including tools and macros to assist in the standardization of the calculation of the suite of I/I key performance indicators.

2 STAGE 2 WORKS – KEY SECTIONS

2.1 HOUSE LATERAL I/I REDUCTION

The WSAA Study Group survey carried out as part of this project indicated the ownership and responsibility of house laterals and hence responsibility for their repair, is many and varied throughout the WSAA membership. Survey responses indicated that the ownership boundary is fairly evenly split between:

- the first inspection opening (I/O)
- the property boundary
- the junction on the main sewer

Most of the more recent projects that have been analysed in detail and also other references (WSAA 2013, Shaw 2012, Carne 2011,2005) acknowledge and document the contributions made to total I/I volumes by house laterals. These sources indicate that up to half of the total volume, comprising both infiltration and direct inflow, is contributed by house lateral sources.

The Hillsborough case study (WSAA 2013) has shown that when comprehensive rehabilitation of house laterals has been carried out, the reduction in RDII compared to adjacent catchments where this has not been done is approximately doubled. This confirms that approximately half of the removable I/I volume comes from the house laterals.

The historical problem with chasing out this RDII is that in all jurisdictions studied, the ownership of the house lateral by the property owner and subsequent responsibility for rectifying the problem has resulted in difficulties in getting laterals repaired. Hence removal of RDII sources arising from faults in the laterals has been problematic. The absence of legal levers, political sensitivities and the responsibility for private drainage frequently falling under the remit of the local government agency, as opposed to the water company or authority, results in difficulties enforcing defect notices and further complicating factors.

The North Shore case study (WSAA2013) is considered to represent the most advanced catchment-wide program aimed at lateral repair in Australasia. This program has worked within the paradigm of the conventional ownership arrangement of private ownership from the property boundary. It has shown the challenges that even with dedicated resources applied to lateral repair, it has taken 2 years to get 75% of identified house lateral defects repaired.

When earthenware and concrete pipes have been used, it is generally recognised in most studies referred to above that a significant source of house lateral I/I is at the actual junction of the lateral with the sewer. The heavy pipes drop vertically over time, shear off the joint and create a major source of entry for infiltration.Tree root intrusion in shallower house laterals is also considered to be a major source of house lateral I/I.

2.1.1 COMPLEXITIES

A number of obvious complexities arise when considering the removal of I/I that enters the system through private laterals:

1. Thinking regarding ownership and responsibility for repair have generally been aligned and so the argument of why a public utility should pay for the repair of a privately owned lateral occurs.
2. A similar argument occurs when one questions why would a private person have to pay for the repair of a lateral it owns when a portion of this might be out in a street or road.
3. Who is responsible for the portion of lateral that connects multiple properties to the public sewer ? – e.g. apartment blocks or strata titled units, particularly in areas where a large portion of tenanted properties exist and owners are non-resident, often in locations well remote from the property, even overseas.

Given all of the above, few agencies have actively pursued large scale lateral repair programs. Research carried out for this project has identified four particular cases where large scale lateral repair programs have been undertaken.

The research carried out in this project identified the EBMUD PSL (WSAA2013) project as the most comprehensive procedural, legal and financial arrangement that has been developed and implemented to address the difficulties related to a system-wide lateral rehabilitation program.

The U.K example (WSAA 2013) case study has addressed the main problem area of the EBMUD program, with the water company assuming ownership of the shared sections of laterals and has also dealt with any inconsistencies with regard to the ownership boundary of the lateral. It does however come with a liability for lateral maintenance and repair which would need to be offset by savings from I/I reduction.

The North Shore CC Rehabilitation Program (WSAA 2013, Shaw 2012) has demonstrated that significant I/I reduction can be achieved through a lateral repair program with dedicated resources however without jurisdictional changes only 75% of defects were rectified within a 2 year period.

It is proposed that if WSAA member agencies wish to seriously address the reduction of I/I coming from private properties, then they consider the implementation of the key aspects of the EBMUD, UK and North Shore CC programs that have been the subject of this investigation,

Key points for consideration are: –

- Funding, resourcing and maintenance of an inflow source detection program for the removal of these defects, including the necessary database management associated with this task is a significant investment in a water agency's human and capital resources.
- A change in the boundary of the lateral ownership where part of the lateral is shared so that the water agency owns the lateral up to the point where it is no longer shared.
- That the ownership boundary in all locations be adopted as the property boundary.
- Legislative change will be required to address these matters and these requirements will vary significantly between Australian states and will be different again in New Zealand.
- Adoption of a multi-criteria trigger point plan for lateral testing and repair (if required) as per EBMUD experience with property sale being at least one of the trigger points with consideration also for major renovations as a trigger.
- As the EBMUD experience highlights, developing policy and protocols for dealing with exemptions and time extensions will be required early in the evolution of such processes.
- In cases where a more targeted program of lateral repair is warranted to reduce I/I in certain concentrated areas, develop a lateral replacement policy informed by an economic business case analysis that considers each and all of the following as options for the funding of the lateral replacement:
    - The water authority carrying out and paying for the repair of the on-property portion of the lateral.
    - The water authority carrying out the repair on the property owners behalf and charging them for this work by one of three methods-
        - a separate charge; *or*
        - a "soft-loan" incentives by the water company-authority to the property owner, reimbursable to the water -authority by separate payment of an on-going levy on their water-wastewater bill or local government rates.
        - where owners are unable/unwilling to pay, place a lien/caveat upon the property for the cost of the works, accruing interest at an agreed rate recoverable upon sale of the property.
    - The property owner carry out the identified repairs and fund it themselves either directly or by the soft-loan mechanism outlined above. Not only does it create an extra burden on ratepayers who may not be adequately skilled to deal with it, this option would require significant monitoring and investment of resources by the water company-authority to ensure compliance. It is hence considered the least-favoured option.

2.2 PREDICTABILITY OF I/I REDUCTION

The Stage 1 outputs proposed the following guidelines relating to predictability of I/I reduction.

Table 1: I/I Reduction Levels for Different Extents of Rehabilitation

Rehabilitation Level	Reduction in RDII (%)	Reduction in Peak Flows (%)
1	0-15	0-25
2	15-50	30-40
3	40-80	No results available

Where rehabilitation works have been categorised into one of the following three classes:

- Level 1 – Removal of all inflow defects identified through a program of house-to-house inspections, smoke testing and maintenance hole inspections;
- Level 2 – Level 1 works in addition to complete sealing of all the public sewers within a catchment; *and*
- Level 3 – Level 2 works in addition to sealing all the private property laterals up to the house.

The former North Shore City Council in New Zealand (now part of Watercare Services Limited) have rehabilitated 34 catchments over the last 10 years. Pre and Post Rehabilitation results have been analysed for 34 of these catchments (Shaw 2012, WSAA 2013).

As a result of this analysis two rehabilitation effectiveness models were developed:

- A model to predict the likely reduction in RDII % (the percentage of the total rainfall falling in the catchment that enters the wastewater sewer); *and*
- A model to predict the likely reduction in peak wet weather flow (L/sec/ha).

During this process it was identified that four variables had the most influence on the reduction in RDII% and PWWF. The four variables were:

- The percentage of the total network rehabilitated
- The amount of the public system rehabilitated
- The amount of the private system that was rehabilitated; *and*
- The initial leakiness of the catchment (measured in RDII%);

An equation that provides an estimate of the leakiness throughout a catchment was also developed, using the leakiness measured at the bottom of the catchment (by a flow gauge) as an input.

The relationship between the most leaky and least leaky areas within a catchment is taken into account within the model; and is also described using the same variables: initial RDII% and the percentage complete.

Based on the sample of catchments analysed, the following predictive model equation has been developed (Watercare, 2012).

RDII% reduction =

$$(0.42(1-\exp(-9.59.x_{public}{}^{3.27}))+0.57(1-\exp(-9.89x_{private}{}^{3.2})))x((1.36\,initial)/(0.12+initial))$$

where

x_{public} is the percentage length of the public sewer that has been rehabilitated

$x_{private}$ is the percentage of private properties that have been repaired

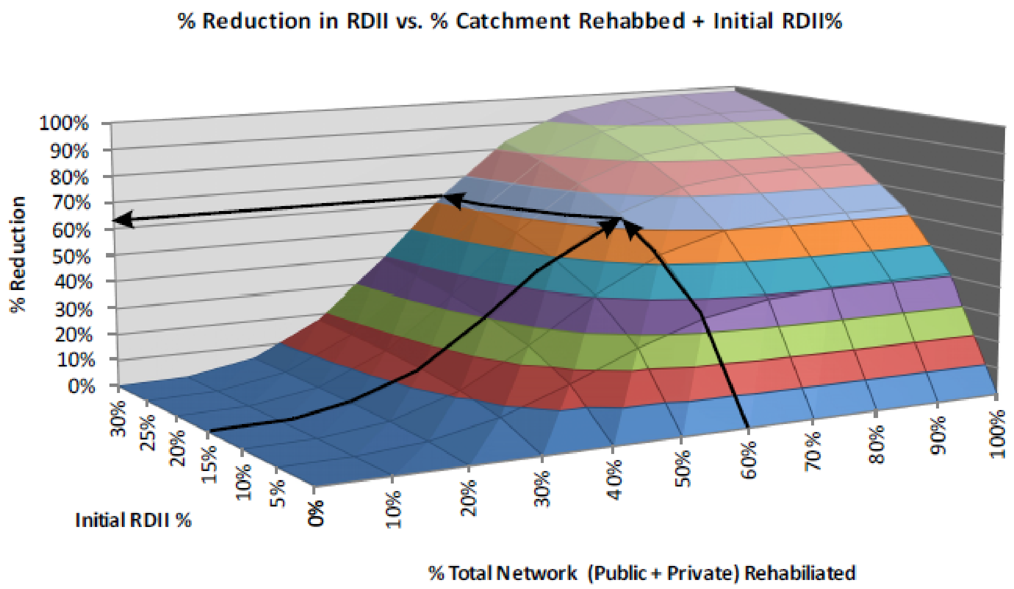
initial is the pre-rehabilitation %RDII of the catchment.

The three dimensional model can be represented graphically by the following Figure 10.1[31]

The model calibration suggests that:

- an exponential increase in the reduction in RDII occurs:
  - until approximately 70% of the public sewer is rehabilitated. Beyond 70% the model calibration suggests that the law of diminishing returns kicks-in with little additional reduction in RDII.
  - as the percentage of private properties increase. When approximately 60% of the private properties had been rehabilitated, the model calibration tapers off quickly, however, the study also found that the maximum number of properties within a catchment with defective drainage is typically 60-70%.
- Up to 45% of the RDII reduction can come from the public network while the remaining 55% can come from the private network.
- The potential to reduce the RDII starts to drop off at an increasing rate when the pre-rehabilitation RDII drops below 10% RDII

Figure 1: 3d Model of I/I Reduction vs Catchment Rehabilitation & Initial RDII%



A similar model was also developed for peak flow rate reduction and this is also discussed and included in the Volume 1 document.

2.3 PREVENTIVE MEASURES

For new sewer systems, it is possible to significantly reduce inflow and infiltration by adopting improved or alternative approaches in the design and construction of pipes, appurtenances and maintenance structures.

Investigations undertaken by Authorities into I/I in new developments have also indicated that a new sewerage system can be highly vulnerable in the period post sewer construction while building works are undertaken. There is also a growing push to require a re-inspection of private house drainage 2-3 years after a new house has been constructed and landscaping is complete.

The following section provides some background on some of the low I/I sewerage construction methods currently being implemented as well as some approaches to mitigate I/I in the early stages of a sewers life and from on-property sources.

Alternate low infiltration specifications have been developed such as Low Infiltration and Leak Tight (used by Sydney Water) and NuSewer (used by Queensland Urban Utilities) systems with the specific aims to:

- Provide a sealed system capable of avoiding root intrusion and stormwater infiltration;
- Eliminate or minimise the need for personnel entry into confined space maintenance holes.

The scope of the Leak Tight specification is limited to property connection sewers and reticulation sewers (DN110 to DN315). However, the principles used may also be applied to the planning, design and construction of branch sewers and trunk sewers (DN400 and larger).

NuSewer was introduced in 2006 by Brisbane City Council (now Queensland Urban Utilities). In response to QUU's initiative, Iplex launched its SewerPlex product range that includes extruded PE100 pipes and associated electro-fusion fittings with a white internal surface to facilitate remote camera inspection.

The following measures are used to prevent infiltration and inflow and are incorporated into the specifications discussed above, such as: -

- Pipe materials
- Maintenance shafts (manholes)
- Property connections
- Acceptance and Validation testing
- Lifecycle maintenance strategy
- Education programs
- Post-construction mitigation measures

2.4 OVERVIEW OF SOURCE DETECTION AND REHABILITATION METHODS

In the Volume 2 document and overview and description of the various I/I source detection methods are given. A summary table shown here as Table 2 is presented.

Similarly, an overview and description of different type of rehabilitation techniques is given. The associated summary table is presented here as Table 3.

Table 2: Comparison of I/I Source Detection Methods

Method	Applications	Advantages	Disadvantages
In-sewer flow monitoring	Used for initial assessment of high flow areas.	Good as an initial and cost effective analytical approach to determining areas with high I/I.	Covers large areas only. Is an indicator only - Does not identify specific defects or connection points.
Visual inspections	Used for the location of likely inflow sources such as downpipes, low gullies, manhole surface defects etc.	Simple. Quick. Can be done by water agency staff.	Significant private property access required.
Smoke testing	More useful for Inflow detection. Its use for identifying infiltration depends on depth of asset, soil type and the water table level.	Quick and simple. Minimises time spent on private properties.	Effectiveness can depend on climatic conditions (clear vs cloudy day) and soil moisture levels when considering laterals. Does not necessarily locate point of connection.
Dye testing	Used to confirm inflow sources identified by smoke testing or cross connections between stormwater and sewerage	Simple. Can be done by water agency staff.	Significant private property access required.

Method	Applications	Advantages	Disadvantages
	system.		
CCTV	Used for location of infiltration sources as well as structural condition assessment in both public and private sewers.	Useful for structural assessment location of infiltration. Locates point of connection.	Difficulty using with high flow. Infiltration sources are less visible in dry soil conditions. Subject significantly to operator skill and consistency in coding defects. Flow diversion, cleaning, root cutting may be required.
ElectroScan	A new technology that can be used to assess the likely leakiness of public and private sewers with non-conductive pipes.	Locates the leak. Can be used in surcharge conditions. Likely to pick up more defects than CCTV.	New technology, few experienced operators Limited track record. Cannot be used for conductive pipes.
Hydrostatic isolation testing	Used to give qualitative indication of likely extent of infiltration and exfiltration in both public and private sewers.	Provides easy indication of the leakiness of pipes- either exfiltration or infiltration potential.	Requires isolation of section of sewer to be tested (i.e. bypass pumping etc. may be required). Does not reliably quantify likely exfiltration or infiltration levels. Doesn't pin point location or nature of defects.
Lateral surface flood testing	Can provide an indication of likely infiltration rates in shallow house laterals.	Gives an indication of likely infiltration rates in private sewers in saturated soil conditions.	Time consuming. Need to isolate the house lateral under test. Difficult to measure flows in laterals.

Table 3: Comparison of Rehabilitation Techniques

Method	Pipe Parameters		Work Requirements					
1. Level of Cleaning required: Good / Very Good								
CIP, standard	100-2400	400	Yes	No	Yes	No	Yes	No
CIP, Top Hat	100-200	0.5	Yes	No	Yes	No	No	No
Reinforced gunite			Yes	No	Yes	No	Yes	No
Spraying, epoxy	80-1000	<100 typ.	Yes	No	Yes	No	No	Varies
Robotic repairs	200-1000	10	No	No	Yes	No	Local	No
2. Level of Cleaning required: General								
Sliplining	100-2400	<2000	No	Yes	No	Yes	Yes	Yes
Close Fit -	80-1000	<500	Yes	No	No	No	Yes	No

Method	Pipe Parameters		Work Requirements					
Fold and form								
Close Fit - Deform-reform	80-1600	<300	Yes	No	No	No	Yes	No
PVC Spiral Wound	150-2400	Varies with diameter	No	No	No	No/Yes	Yes	Yes
Spot repair sleeves	150-2400	300-2000	Yes	No	No	Varies	Local	Yes
GRP panels	Man entry	No Limit	Varies	Yes	No	Yes	Yes	No
2. Level of Cleaning required: None / Not Applicable								
Pipe bursting, static	80-1500	<250	Yes	Yes	No	No	Yes	Yes
Pipe bursting, pneumatic	80-1500	<250	Yes	Yes	No	No	Yes	Yes
Pipe bursting, hydraulic	80-600	<250	Yes	Yes	No	No	Yes	Yes
Pipe reaming	100-600	<250	Yes	Yes	No	No	Yes	Yes

2.5 CALCULATION TOOLS

In this section of the Volume 2 document, a range of methodologies and calculation tools, including Excel macros are provided that enable a standardised calculation of the I/I key performance indicators identified in the Volume 1 document that relate to each of the three components of I/I, being –

- Groundwater infiltration
- Rainfall dependent inflow and infiltration
- Stormwater inflow.

3 CONCLUSIONS

The project has used the outcomes of research and a range of case studies to define what is now regarded as good practice for the Australian and New Zealand water industries and this is now documented in WSAA's Good Practice Guideline document.

Features of this document include:

1. Definition and adoption of a consistent set of I/I key performance indicators.
2. A five-step process, which if followed rigorously, will result in reduction outcomes consistent with the most successful programmes completed across New Zealand, Australia and North America.
3. Advice on expectations of guideline I/I reduction levels achievable if the methodology is followed correctly and a predictive model for these reduction levels.
4. A suite of calculation tools and techniques that will enable consistent calculation and analysis of I/I in wastewater systems and its removal.
5. Discussion of the contentious issues associated with the responsibilities for removal of I/I entering the system through privately-owned house laterals.
6. Advice regarding potential risks and failure points in implementing a successful I/I reduction programme.

Most importantly, based on research carried out as part of this project, it is apparent that much of the findings of this project and content of the WSAA Good Practice Guidelines Document for Wastewater Inflow and Infiltration Management is also relevant for wastewater managers and operators across the USA and Canada.

ACKNOWLEDGEMENTS

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