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World Bank study warns that poor infrastructure in Africa seriously reduces productivity

A study recently undertaken for the World Bank in 24 African countries shows that the poor state of infrastructure in sub-Saharan Africa – its electricity, water, roads, information and communications technologies – reduces national economic growth by two percentage points annually and cuts business productivity by up to 40%.

'Africa's infrastructure: a time for transformation' reveals that Africa has the weakest infrastructure in the world, but that Africans in some countries pay twice as much for basic services as those living elsewhere.

The study argues that well-functioning infrastructure is essential to Africa's economic performance and that improving inefficiencies and reducing waste could bring major improvements to Africans' lives.

The report estimates that $93 billion is needed each year over the next decade, more than twice the amount previously thought. Almost half of this would be spent on addressing the continent's power supply crisis. The new estimate equates to roughly 15% of the continent's gross domestic product (GDP), similar to China's infrastructure investment over the last decade. The study found that existing spending on African infrastructure is much higher than had been thought, at $45 billion a year. Another surprise was that most of this is financed by African taxpayers and consumers. The study also found that there is also considerable wastage – efficiency improvements could potentially expand the available resources by a further $17 billion.

However, even if major efficiencies were found there would still be a funding gap of $31 billion each year, much of it for power and water infrastructure in fragile states. Relative to the size of their economies, the funding gap is daunting for the region's low-income countries (who would need to spend an additional 9% of their GDP) and particularly for the region's fragile states (who would need to spend an additional 25% percent of their GDP),' the World Bank notes. Resource-rich countries such as Nigeria and Zambia face a more manageable funding gap of 4% of GDP. Particularly in light of the global financial crisis, investing in African infrastructure is critical for Africa's future, the report adds. Obiageli Ezekwesili, World Bank vice president for the Africa region, said: 'Modern infrastructure is the backbone of an economy and the lack of it inhibits economic growth.

'This report shows that investing more funds without tackling inefficiencies would be like pouring water into a leaking bucket. Africa can plug those leaks through reforms and policy improvements which will serve as a signal to investors that Africa is ready for business.' ●

California agrees multi-billion dollar water laws

Lawmakers in California have passed a significant $11.1 billion dollar piece of legislation that will comprehensively overhaul the state's ageing water system.

The State Assembly voted in favour of a comprehensive package of four water bills plus a bond to fund them. The plan encompasses new dams, a groundwater clean-up programme, conservation and restoration of the critical Sacramento-San Joaquin Delta, as well as the creation of a stable water supply for cities in the parched south of the state.

The size of the bond jumped from around $9.9 billion in the few days ahead of the vote, as the Assembly added extra water recycling and conservation programmes to the original Senate bill.

There have been arguments over many years about how to upgrade the water system, with the Delta element a particularly sensitive part of the plan. However, three years in which farmers have faced crisis because of low snowpacks led state governor Arnold Schwarzenegger to push hard for an ambitious recovery package, something he had advocated for several years but which had always met with significant resistance. He even threatened a veto of hundreds of unrelated bills earlier this year unless a deal was agreed.

Governor Schwarzenegger called the move 'the greatest package and most comprehensive in the history of California. He said the $11.1 billion would be leveraged against an additional $30 billion to create a $40 billion project. Voters still have to approve the bond sale next year, although supporters of the legislation are keen to point out that the majority of the bonds will not be sold till 2015, when most of the state's debt from previous bond issues will be starting to be paid off.

The funds will also enable repair of the Delta levee network, new water restrictions, the removal of four dams on the Klamath river and a new governing body to oversee the Delta. The law also sketches a plan for a canal to divert waters around the Delta to southern California, but only if extremely high environmental standards are met. This element of the legislation, favoured by governor Schwarzenegger, is likely to meet fierce resistance. ●

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EDITORIAL

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ERC issues paper on the challenges facing the UK water and wastewater sector

The Economic Research Council (ERC) has produced a paper analysing the challenges facing the water and wastewater industry in the UK.

Key points include an observation that trying to produce competition between water companies 'has been a 20 year failure' that seems destined never to produce tangible benefits. ERC says: 'It is time for Ofwat to give up on this and focus on bearing down on excessive investment by the water industry.'

The report adds that a sharp rise in water metering would weaken the case for costly new reservoir investment. It dismisses fixing leaks as only achieving a limited increase in supply, desalination as 'very expensive', and a national water grid as 'financially nonsensical'.

On Ofwat, it says that in the industry review AMP 4 the regulator was too generous in its investment allocation to the water industry, resulting in higher than necessary prices for consumers. 'Unlike Ofgem, who saw sense in not proposing a draft WACC (weighted average cost of capital) when debt markets are so volatile for the next five years, Ofwat is taking a risk with consumers' money by believing it can set the correct rate. ERC suggests Ofwat should set the WACC for three years with a provisional figure for the two years thereafter.'

A future government should make plans to privatise Scottish Water, Glas Cymru, Northern Ireland Water and British Waterways, it adds, although Glas Cymru is in fact a 'company limited by guarantee', a special not-for-profit vehicle created to own, finance and manage the already-privatised Welsh Water.

The report also urges that government should repeal the water-specific mergers legislation and take initiatives 'to encourage UK Water plc to expand its franchise internationally where huge opportunities await.' ●

Spain and IADB announce grants for Latin America watsan problems

The Inter-American Development Bank (IADB) and the Spanish government have announced they will provide $100 million in grants and loans to Bolivia in the first stage of a key partnership to tackle water and sanitation problems in Latin America's poorest communities.

This is one of the first projects jointly funded by IADB and Spanish Cooperation Fund for Water and Sanitation in Latin America and the Caribbean (known as the Spanish Fund), an initiative announced last year by Spanish prime minister José Luis Rodríguez Zapatero.

IADB and the government of Spain signed an agreement in July 2009 to jointly finance and execute projects using a portion of the Spanish Fund's grants. In Bolivia, the fund will contribute $80 million in grants and the IADB another $20 million in ordinary and concessional loans to extend water and sanitation services to around 500,000 people in peri-urban areas of El Alto, La Paz, Cochabamba, Santa Cruz, and Tarija that are currently unserved.

IADB and Spain have also agreed to provide $39 million in grants for water and sanitation projects in Haiti, and are expected to jointly finance projects in Brazil, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Paraguay, Peru, the Dominican Republic and Uruguay between now and mid-2010.

In all, Spain will contribute $407 million in grants to these projects, while IADB will contribute $213 million in grants and loans, and take on the bulk of the project preparation and execution costs. Around four million people in low-income urban and rural communities are expected to benefit directly from these projects. ●

ADB approves sustainable Kyrgyzstan urban service project

The Asian Development Bank (ADB) has approved a $16.5 million loan and a $13.5 million grant for the Issyk-Kul sustainable development project in Kyrgyzstan, which is the first phase in a longer-term initiative by the bank to support environmental management and improve urban service delivery in the oblast, or province.

ADB and the Issyk-Kul government will ensure that the urban services works will increase access to potable water and safe sanitation, including use of proven technologies for treatment and disposal of solid and liquid waste.

The project covers the cities of Balykchy, Cholpon-Ata and Karakol on the northern shores of lake Issyk-Kul, the world's second-largest saline lake. The lake is a Ramsar site of globally-significant biodiversity and is designated as a biosphere reserve by UNESCO.

The lake is a prime tourist attraction in the Issyk-Kul oblast, attracting about a million tourists each year. However, it is polluted partly due to excessive demand on the deteriorating water supply and sanitation infrastructure serving the influx of tourists. Vijay Padmanabhan, an urban development specialist in ADB's Central and West Asia department, said: 'Through the project, the infrastructure and quality of urban services in the region will improve, public health will improve, and the lake's environment will be preserved.'

The project has three parts, the first of which involves the rehabilitation, improvement, and expansion of water supply and sanitation services in the project cities. The second element will focus on improving service delivery and sustaining long-term investments through improved enterprise resource management in cities, and water and sewerage utilities, and the final part will support project management and implementation activities. ●

Change and asset management in wastewater utilities – a UK perspective

Some of the main points we aim to demonstrate in this paper are the following: utilities have to build from legacy where possible through incremental development of systems, processes and people's capabilities; asset management is not a completely new process, rather it is an overall framework in which many legacy/current processes can be aligned to give significantly enhanced outputs; the universal issue of imperfect data can begin to be addressed via explicit uncertainty and Real Options analyses; and people's engagement from across the organisation is crucial. The developments which have taken place over the last two decades are framed from our perspectives of asset management practitioners within utilities, of regulators and of consultancy experience. The chief concern we raise is that the shift from asset failure risk to service failure risk has driven the need to enhance organisational capability, not just through better systems which have been the prime focus to date, but also through the skill sets of people engaged in the asset management discipline. By Adrian Rees, Tim Young and Ian Richardson.

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It is an enduring axiom that the only constant is change. As people who have worked within wastewater utilities in the UK, within their regulator and in providing consultancy services, we certainly endorse this view when reviewing what our sector has seen over the last two decades following privatisation. As is often the case, change can be a result of many things (external pressure, internal innovation), can require short-term pain for long-term gain, and can all seem very obvious when looking back. We outline here the developments that have taken place, and which are currently unfolding, in the UK wastewater (and water) utilities, from the variety of perspectives that we have gained in our experiences.

Currently, risk management practice in wastewater (and water) asset management in the UK is under the banner of the UK Water Industry Research (UKWIR) Capital Maintenance Planning Common Framework ('Common Framework' or CMPCF). This resulted from a truly collaborative effort between utilities and regulators. It provides a common approach across companies, and is based on economics rather than solely cost-effectiveness. However, the Common Framework still stemmed from a crisis, namely that triggered by (the economic regulator) Ofwat's 1999 Final Determination, which reduced companies' capital maintenance estimates, substantially in many cases.

Most papers relating the tale of the rise of risk-based investment planning and asset management point back to that 1999 price review, which prompted the economic regulator Ofwat to issue a letter to water companies' managing directors (MD161, 2000), outlining the steps it saw as essential in developing an economic case for investment. This built in both financial costs to the utility and a monetisation of socio-environmental impacts.

This led directly to the industry collectively formulating the use of risk to service (to customers and the environment), not age and condition of assets per se, as the basis for investment planning and asset management. This was drawn up as the UK Water Industry Research Common Framework (Capital Maintenance Planning: A Common Framework, UKWIR, 2002). This was seen by many, both regulated and regulator, as a chance to determine investment levels for whole programmes of work over a medium-term timeframe, on an economic basis and using risk-based techniques.

In reality, various forms of risk-based approaches had been used in the UK water industry over many years, some pre-dating privatisation in 1989. Previous steps in recognising risks included:

- Formula A recognising consequence of higher loads from intermittent discharges;
- Sewer Rehabilitation Manual criticality (mostly consequence as cost to the business but some elements of disruption and sensitive customers; also defined structural condition grades, effectively as precursors of likelihood of failure);
- Final effluent (FE) consenting on a Monte Carlo analysis basis (recognis-

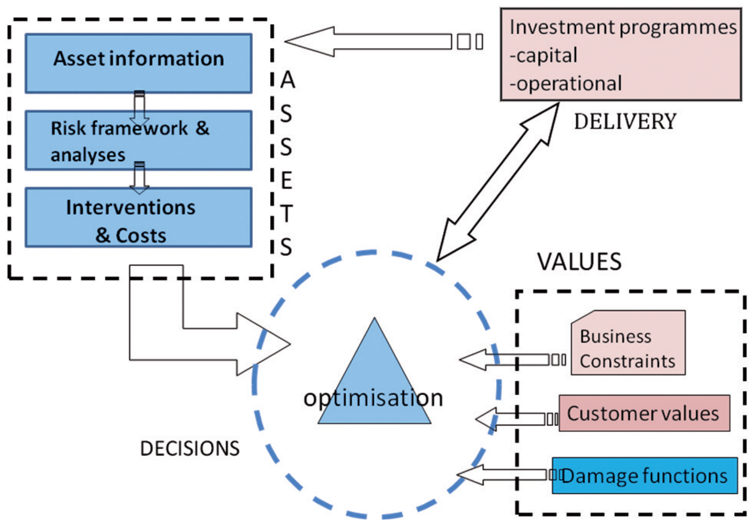

Figure 1
Current risk-based investment planning tools and processes

ing that the probability of a given FE flow/concentration combining with a given river flow/concentration was best expressed as a distribution);

- Urban Pollution Management (UPM) standards – the return period/duration/magnitude criteria in UPM standards basically map onto probability x duration x consequence, being derived from toxicological studies on impacts (with safety factors);
- Sludge quality control moved to a HACCP (Hazard Analysis and Critical Control Points) basis along the same lines as risk controls in the food industry;
- Bathing Water Directive (BWD) standards seem to be moving to a risk basis to include beach management practices and antecedent rainfall (but still have limited links to quantified health impacts – the evidence for cause-effect is ambiguous across the many case studies into bather illness epidemiology, and further attenuated by the seemingly arbitrary factors of safety layered onto the findings of those studies).

In addition, the increasing use (from 1995 onwards) of optioneering as a pre-design phase in project delivery ensured that construction projects were focused on delivering the required outputs at minimum cost. In practice this led to focus on the specific needs raised, rather than increasing longevity of service for the asset base as a whole. This cost effectiveness resulted in targeted expenditure, but did not necessarily give optimal whole life costs for maintaining service. For instance, there are numerous examples from utilities' capital programmes where investment might be well-targeted at compliance with new receiving water quality legislation for a particular sewer overflow, but neglect the maintenance needs of sewers in the upstream catchment, and also have detrimental impacts on energy consumption or flooding protection.

As well as these two near universal gaps across the industry, there was an absence of uncertainty analysis to demonstrate an understanding of how data and information quality might affect the outcomes of investment and whether particular objectives would be achieved by that investment.

Current 'best practice'

The start point for any of the better risk management approaches is in having a set of asset registers which are sufficiently well-populated with attributes such as location, material, age, depth, dimensions, condition etc., all of which help inform risk analyses. Superimposed on these data is information which can help to relate where the asset 'lives' to the likelihood and consequences of its failure (e.g., does it receive aggressive trade effluent, is it adjacent to a sensitive location (river, customer), is it in an area about to undergo new housing development?). A variety of assumptions are generally made about:

- How to translate relative likelihood (as opposed to probability) of failure into a timescale for an intervention;
- What form of intervention is appropriate – for instance: an operational fix such as jetting; capital refurbishment or capital replacement; transfer; or retirement/decommissioning
- How effective the intervention is in mitigating the risk
- What residual level of risk there is following the intervention.

They are often formulated as a rule-based approach to investment planning. For instance, in assigning a timescale to intervene to a relative statement of likelihood of failure, at the simplest level some utilities apply a threshold to a categorical scale of likelihood and any failure with a likelihood above the threshold is seen as a 'must do' investment need, and duly constrained into a programme of work (out to a given planning horizon). As a variation on this, some utilities apply both likelihood of asset failure and service consequences of asset failure; and others have gone a step further in understanding likelihood of asset failure, consequences of asset failure and the likelihood of the asset failure resulting in the service consequence (particularly where there is redundancy, headroom or resilience in the configuration of the asset(s)).

Similarly, rules on which interventions may be applied often derive from an understanding of the root cause of failure, e.g., if poor condition is the driver for an intervention then a simple refurbishment option could be taken, or if the estimated likelihood of failure in combination with its consequence meant that the risk was significant then a like-for-like replacement would be applied. Where lack of capacity (to meet existing required performance, or a new target perhaps driven by legislation) is seen as the underlying cause then upsizing or transfer options would be applied.

In setting a threshold for intervention, a utility is effectively stating a policy, i.e., it will not tolerate asset or service risks above a given likelihood. Similar statements are made to determine what the post-intervention risk position should be, and also the amount by which a given type of intervention will change a risk (i.e., a design standard). Figure 1 shows at a high level the idealised interfaces between systems across a utility.

The running of investment scenarios is often limited by the need to move information from one element of a utility's asset management systems to the next. Workaround systems have been developed by asset management functions because existing legacy systems, many of which were originally for financial or work management purposes, often do not capture the information in the desired format. The downside of this is the proliferation of 'multiple versions of the truth' regarding asset information within a utility, which is further compounded by separate off-line analyses in pockets across the organisation.

Most risk assessments undertaken by UK water companies to date have looked at relative risks (probability, consequence) posed by assets to service, to customers, and to the environment. It is worth emphasising that this shift to risk of loss of service, away from only cost to the business, means that wastewater assets approach parity with the service from clean water assets. Although interruptions to drinking water supply are still the biggest issue for UK customers when consulted, internal flooding of property by foul sewage is close behind, and then most of the rest (such as environmental quality) are related to wastewater.

As things currently stand in risk assessment for investment planning, consequence estimation by asset managers is still qualitative, but curiously is the easier part when looking at the level of individual pipe lengths and plant usage models. This big gap in risk management capability will become even more pronounced due to several regulatory statements made by UK regulators over the last couple of years.

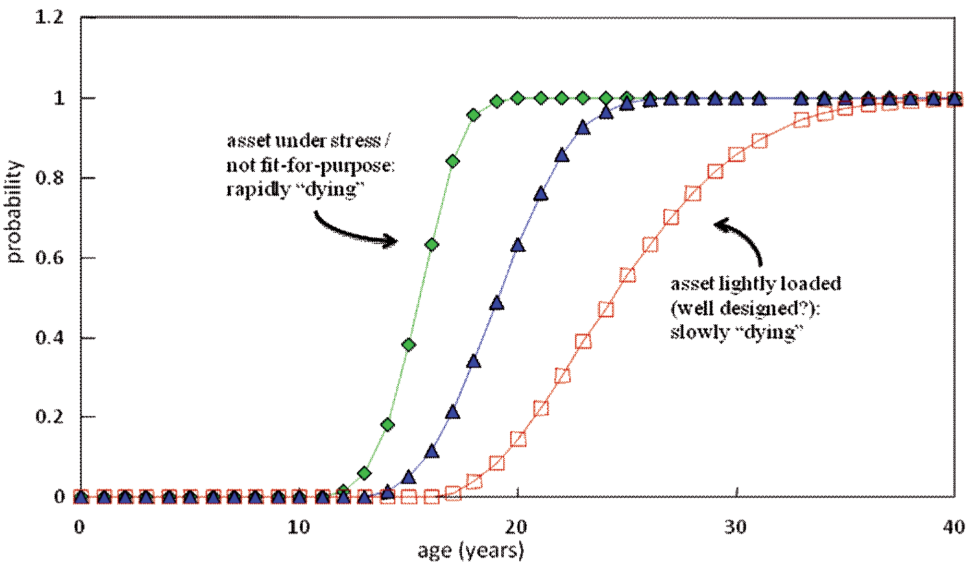

Figure 2
Weibull cumulative probability of failure

State of the art

Probability

The quantified estimation of probability of service loss due to asset failure using deterioration models is still uncertain. However, statistical estimation of probability is quite well developed by some companies through use of techniques such as mortality (Weibull) curves and Markov chains. Some companies can show the way in which an asset that is working hard, or is subject to greater loads, or is not the right piece of kit, will 'die' quicker than one which lives the easy life (Figure 2).

Much of this thinking originally came from the aeronautics, oil/gas and electricity sectors, into the mechanical and electrical (M&E) domain of the water utilities where due to the fast-wearing nature of the assets the relevance was most clear. The methods can also be applied to above ground M&E assets at a low level in the asset hierarchy, such as plant items (e.g., pumps). They have been applied to the slow-degrading below ground civil assets such as sewers and mains, but at best at the level of 'families' of assets (e.g., post-war 450 mm cast iron mains in corrosive soil).

One challenge facing utilities is to adapt such techniques so that they can use the attributes of each asset, pipe length by pipe length, to quantify the probability of asset failure and hence service loss. A small number have already begun this process.

Consequence

The state of the art for estimation of consequence has moved to valuing the service provided by the assets. In essence this is what a non-monopoly service provider does in the market, by conducting customer research. For instance, this type of research reveals why some people are prepared to pay more for (i.e., value more highly) a coffee at a railway station than on the high street.

At present in the UK water industry, this has been done through understanding consumers' willingness-to-pay. Without going into detail, the technique used has been stated preference through choice experiments, where customers are presented with different levels of service with different 'price tags'.

The preferences which emerge from this process establish monetised service consequence and show what the economic level of service should be (i.e., the point at which the marginal cost to supply service begins to be greater than the marginal benefits).

In this way it becomes possible to weigh up literally thousands of potential interventions, say deciding between whether to invest in dealing with multiple chronic low water pressure properties, against small numbers properties experiencing infrequent sewer flooding, against a chronic final effluent failure at a 3000 population equivalent works, against multiple severe transient pollution incidents. In order to do this, UK utilities have generally had to develop five things:

- Some form of Output Performance Measure Framework: these measures allow the alignment of both business drivers and service to customers and the environment. Typically there would be a dozen such measures such as internal flooding of properties from sewers, pollution incidents and final effluent impacts.
- Probability of asset failure: generally these are derived from deterioration models as noted above. The better approaches include estimation of uncertainty.
- Probability of service failure: similarly, the better companies are now moving to a quantified view of the interaction between assets which do not act independently in their effects on delivering output performance. This requires use of reliability modelling which can objectively assess how the configuration of assets affects outputs, e.g., whether in parallel or series, duty or standby. This takes much of the burden away from operational experts in attempting to estimate how likely an asset failure is to result in service failure.
- Value (consequence) of service failure: utilities now quantify these as both financial (private) costs to the organisation and as monetised impacts on customers and the environment (from stated preference studies and from literature on socio-environmental damage functions).
- Costs of intervention: the capital and operating costs of implementing a planned action to resolve the risk of service failure. Generally UK utilities now also have to include the disadvantages of those investments (e.g., the increased carbon emissions from a new high rate treatment process, the embodied carbon associated with new pipe structures).

In general, nearly all water utilities in the UK now undertake a further step, investment optimisation, and feed these pieces of information into some form of optimisation engine, generally using linear programming (although a small number use non-linear) or genetic algorithms.

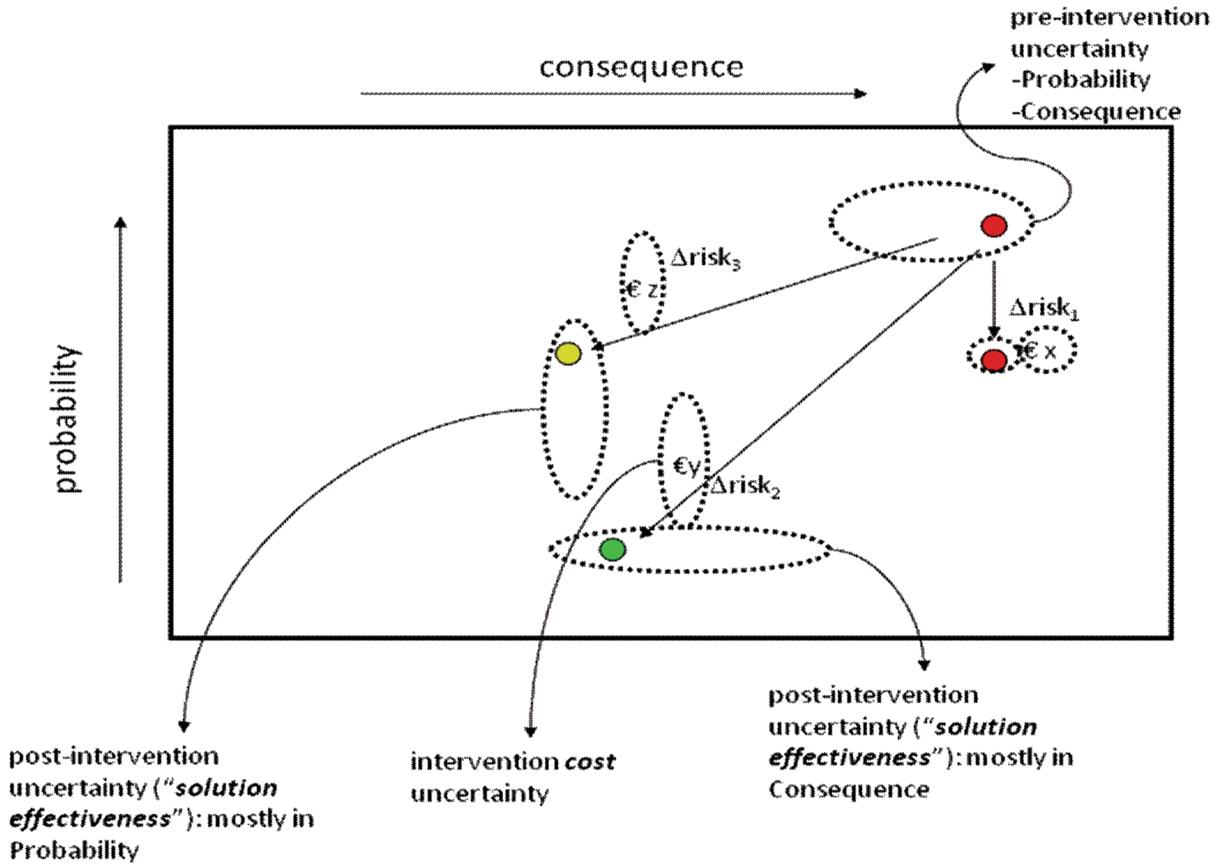

Figure 3
Use of uncertainty in investment planning

Investment optimisation

To some extent, the functionality of optimisation engines is the most straightforward part of UK water utilities' asset management processes, albeit it is highly dependent on information received from sources 'upstream' in the process. The purpose of these tools is to either deliver a specified reward for the least cost, or to deliver the maximum reward within a given budget. Chief among the sources of information feeding optimisation are:

- Risk and cost information
- Business weightings and constraints – utility's senior management
- Customers' valuations and preferences – stated preference choice experiments ('willingness to pay').

However, the complexity of optimisation (c.f. prioritisation) lies in the application of constraints, or targets, to a given snapshot and set of weights. In some sense, once any constraints are applied, the resultant selection of solutions or actions in a portfolio is sub-optimal compared to an entirely unconstrained selection.

Consequently, changing constraints (e.g., levels of service or spend profile) will not simply result in the 'cutoff line' being drawn at a different place in a list of ranked solutions; it can result in significantly different selections of the solutions contained in the portfolio. Consequently, the utility's investment planners have to learn a new discipline of understanding the effects of what may seem small changes to constraints, weights or preferences, and communicate this to the wider business.

The ability to apply constraints within investment scenarios to generate potential portfolios is only limited by the information upstream of the integrated management system. It is possible, for instance, to understand what a portfolio would look like which met compound constraints of <level capex profile> by <operational area> to achieve <minimum flooding performance level of service X> and <minimum treatment compliance service level Y>.

In theory, a utility could use customer valuations segmented from socially disadvantaged groups as the basis for customer valuations if they wanted to explore affordability constraints. If a large proportion of the population served by a utility was metered in its water consumption and effluent, it would be feasible to start to understand the implications of differential levels of service down to high levels of spatial resolution. These are things for the future which should start to be considered now, to inform the industry as a whole, particularly in light of the Water Framework Directive's requirement for a full economic assessment of water.

Uncertainty estimation

In the last couple of years, understanding uncertainty has been coming to the fore of investment planners' thinking. Simply, this is trying to address the questions that senior management put to them, namely: 'With a budget of X, how confident am I that I will deliver this level of service performance?' and 'To be X% confident that I will deliver this level of service performance, how much investment should I make?'

As an example, the application of confidence categories in some utilities' planning approach acknowledges uncertainty in:

- Forecasting of probability and severity
- Estimation of intervention costs
- Effectiveness of interventions
- Deliverability of interventions.

Thus some utilities now not only assess the quality of their risk models and their cost models, they also attempt to take into account the variability that local circumstances can have on the performance of an intervention which has been built to a standard design. In terms of the deliverability of interventions, they are looking at not just individual interventions (i.e., 'Have we built many/none of these before?' 'Do the local conditions make the construction easy/difficult?') But also at the programme level of peaks of activity in particular skill sets or materials, and whether these will impact on the feasibility of resourcing or meeting deadlines.

Uncertainty can be shown as 'noise' around estimates of risk positions (see Figure 3). Each of the bulleted items noted above will have some uncertainty associated with it – the forecasting of the pre- and post-intervention risk position, how effective an intervention is in moving a risk away from its original position, how precise the cost models are for each intervention type, etc.

So, if there were three interventions to address a risk, one intervention might have only a small effectiveness or change in risk (Δrisk1), but be a very well understood option so its end effect is quite certain, as is its cost. Conversely, another option might have a large expected effect on risk (Δrisk2) but with wide uncertainty both around whether it would deal with the consequences, and also its costs. This information can be used by optimisers as both a filter on types of risks and solutions (e.g., only include interventions of a particular level of confidence), or as a data item to feature in the optimisation (i.e., use expected value of benefit rather than a fixed value). At the level of interventions or of programmes of work, there is a need to move to an application of a much-neglected part of the Common Framework, namely the use of real options appraisal (effectively a form of hedging), where uncertainty is explicitly acknowledged in the formulation of investment choices.

For instance, uncertainty over the effects of climate change on performance of wastewater assets, and consequent design requirements, means that some investments may be stranded through risk-averse overdesign, while others are inadequate to meet emergent needs. It is the authors' view that this is likely to be the next stage of development of UK utilities' investment optimisation analyses.

Developing organisational capability – people and business processes

The better implementations of risk-based planning in UK utilities have understood that achieving business change is a tripod approach requiring change across the utility's people, systems and processes if it is to be successful. To some degree, the systems are the least difficult aspects of change. Examples of how moving to a risk-based approach to asset management can drive change are in the areas of new business processes for:

- Risk identification and approval
- Uncertainty banding
- Solution costing and approval
- Portfolio selection and agreement
- Interaction with and management of an ongoing capital programme.

Each of these is worthy of a paper in its own right. For instance, the costing and approval of interventions is an activity that in many utilities with whom and for whom we have worked cuts across multiple teams that historically have been separated in time, i.e., there is a planning function which estimates costs for planning purposes and a capital delivery function which develops costs for solution optioneering and delivery. The delivery and management of an ongoing capital programme often has very few if any feedback loops to the investment planning functions in order to inform forward-looking assessments, e.g., understanding how the forecast costs and benefits of planned interventions may have differed from those which were ultimately delivered.

The people aspects are significant but are often overlooked or underestimated. A truly 'business as usual' approach requires an even closer working relationship. There is a need to move from understanding costing of options and cost-effectiveness to address a single need at a single project level, to seeing how an investment need may be interdependent with others and their associated solutions, in the context of programmes of work trading off different levels of service benefit, investment and operational risks.

In the past, much of this has been possible for experienced individuals to carry out on an ad hoc basis, because they have been working on priorities within separate programmes such as flooding or environmental schemes. Now, in a period of an aging workforce with experience leaving the industry, utilities are looking to maximise value for money for customers by making decisions across all types of investment simultaneously, hence moving to more structured and formal assessments of risk and associated investment requirements. The approach has led to a number of challenging issues arising, such as listed below:

- Is day to day running of deterioration models an operational function, as operations provide the data to update the models, or a strategic planning function?
- A 'business as usual' approach requires data, systems, people and processes to be aligned. Simultaneous change in all four areas is a tremendous challenge. Incremental change reduces risk, but significantly reduces the benefit of the changes until all aspects are in place. It is important that the benefits of change are seen early, to encourage the business on its path.
- Piloting change is difficult when organisations have strict expenditure controls, as the benefits are hard to define at the outset. Hard specifications are difficult to establish in a vacuum when dealing with complex interfaces between business process and data. A compromise has to be drawn between financial efficiency and project effectiveness.

Conclusions

If we were to try to summarise the single biggest shift in thinking that appears to have occurred in the last two decades of asset management in UK wastewater utilities, it would probably be that asset managers now think in terms of dealing with the risks of loss of service as a result of asset failures, rather than the asset failures per se being the driver for interventions.

The implications of this shift have been significant, and not only because it requires better data and information on which to makes decisions. It also requires asset management practitioners to move away from simple rule-based, cost-effective, engineering-led approaches to methods which include practical application of economics, estimation of risk and decision making under uncertainty. Consequently, the people engaged in the discipline of asset management have had to take on a wider skill set than has previously been needed, and work within different business processes to accommodate these changes.

Paradoxically, while many utilities are attempting to provide improved systems to enable such challenges as those listed above to be addressed, these are after all just decision support systems, not decision making systems. These are an attempt to free people's time from the minutiae of analysis to allow them to focus on making better, more transparent decisions. At the end of all this, we do not have a 'computer says "no"' situation: accountability will always remain with an organisation's people. ●

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Integrated strategies for the reduction of infiltration and inflow in sanitary sewer systems

The inflow and infiltration (I/I) of a separated sewer system depends on several factors. The clear water entries into the collection system may result in sewers deterioration with consequences on the reduction of their life cycle. It can also lead to a significant increase in operational costs and efficiency reduction of wastewater treatment. This paper presents a set of technical aspects related to this issue, including the I/I concepts, a brief presentation of applicable detection techniques, a list of I/I causes and of applicable control actions. Here, an integrated asset management strategy is proposed that allows sanitary sewer system managers to have an action plan to achieve a gradual I/I reduction while the benefits of this reduction offset the costs. A methodology for assessing this problem is presented and the different phases necessary to implement a I/I control programme are described. By António Jorge Monteiro and Ana Teresa Silva.

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The main goal of this paper is to propose an integrated methodology for controlling the inflow and infiltration (I/I) problem in sanitary sewer systems, allowing for the assessment of system performance and the support of decision-making in a comprehensive global asset management strategy.

This paper begins with I/I concepts, the presentation of several techniques that may be applied for detection and location of I/I sources, and a list of possible causes and identification of control actions. Finally, a methodology for assessing the problem is presented, describing the various stages proposed to implement an I/I control/reduction programme.

Technical aspects

The inflow and infiltration concepts

The infiltration and rainfall-induced total flow associated with a sanitary sewer system is the difference between the total flow transported to the downstream section of the trunk sewer, and the sum of the wastewater flow produced by the users directly served by the sanitary sewer system.

The clear water introduced in a sanitary sewer system can be divided according to its origin: groundwater infiltration; storm water inflow; and wastewater entries from domestic, industrial and commercial unlicensed users. The detection of wastewater discharges from not licensed users by negligent or intentional action require specific actions that are not covered in this paper. The I/I here addressed corresponds to inputs that may be important in terms of volume entering the system, but that are generally not very significant in terms of pollution load, such as groundwater infiltration and rainfall-induced flows.

The groundwater infiltration flow corresponds to an entry of unwanted groundwater by infiltration along the whole sanitary sewer system, including trunk sewer, sewer pipes, private building laterals, joints, manholes and others. The process of underground infiltration starts when the ground water level reaches the sewer system infrastructures, entering through its defects, and only ends with the lowering of the water table to a level below pipes or manholes. So the infiltration takes place indirectly as a result of long rain events or tidal cycles, which influence groundwater levels. The groundwater infiltration flow is usually characterized by having relatively slow variations and may not be detected for months or even years.

The inflow corresponds to direct entries of rainfall induced flows in the separate sanitary sewer system, in particular by: unwanted connections between storm water laterals or inlets from catch basins and the sanitary sewer system; mixture (partial or total) of stormwater with domestic wastewater in private building networks that are connected to the sanitary sewer system; surface runoff entries through manhole covers; river inflow via backflow in flood situation, particularly by emergency overflow devices/bypass pipes of the separate sewer system, or where the sewer pipes are damaged due to flood occurrence. The rainwater inflow in a sanitary sewer system starts after the beginning of the storm event and finishes shortly after its end. In a combined sewer system, the entry of surface runoff by definition can not be considered an unwanted affluence, because it should be designed considering this contribution. Runoff induced inflow is thus a relevant issue only in separate systems.

Technical inspection and I/I diagnosis

Currently there is a considerable variety of methods to assess the sewer system deterioration level, which can be divided into: tests for anomalies detection; technical inspection; and recently developed multi-sensor integrated systems.

The tests for the detection of possible anomalies are used to identify and locate defects through tests, which include a sound test, smoke and dye test, tracer chemical or physical, and also an isolation test. In terms of technical inspection, there are: visual inspection, physical and geophysical inspection systems. The application of a single method of inspection results often in ambiguities and misinterpretations, leading to the development of integrated multi-sensor systems that apply robots which integrate various inspection systems in order to collect additional data in a single operation. In Duran et al. (2002) is presented the state-of-the-art of sensor technologies for sewer inspection. Shehab and Moselhi (2005) present an automated system that detects and classifies defects in sewer pipes automatically for sewers diagnosis. A simplified decision tool to manage sewers networks and references to decision support models in this subject are presented in Sousa et al. (2007), based in Makar (1999).

Typified causes of I/I

The inflow causes (C) in a sanitary sewer system may be typified as follows:

- Sewer pipes: C01) misconnected rainwater sewer pipes to the sanitary sewer system; C02) misconnected combined or partially-separate sewer pipes to the separate sanitary sewer system; C03) misconnected surface water collection devices to the separate sanitary sewer system; C04) existence of emergency sewer overflow devices.
- Laterals/private building network: C05) misconnected private building rainwater sewer lateral to the separate sanitary sewer system; C06) misconnected private building combined sewer lateral to the separate sanitary sewer system.
- Manholes: C07) damaged cover; C08) ventilated cover; C09) cover with defective close.

The groundwater infiltration flows causes can be typified as follows:

- Sewer pipes: C10) fractures or cracks; C11) collapsed pipes/deflection of the pipe section original form, mostly in sewer mains made of flexible materials; C12) collapsed or broken pipes; C13) surface damage caused by chemical attack (corrosion due to biochemical reactions) or by physical action (abrasion, cavitations, etc.); C14) joint displacements; C15) root intrusion; C16) defective pipe junctions; common in older sewers.
- Laterals/private building network: C17) improper connection of peripheral infiltration drainage systems from basements and low-lying areas; C18) defective pipe junctions or connection to the sewer main.
- Manholes: C19) poor fit between pre-made rings; C20) poor fit between conic cover and the manhole ring; C21) displaced or open pipe joints; C22) fractures, fissures or cracks; C23) surface damage caused by chemical attack or by physical action; C24) defective connection between pipes and manholes.

Typified actions for controlling inflow and infiltration

Here are listed the actions (A) that may be needed to reduce I/I:

- The general actions: A01) perform or complete the cadastral survey of existing sewer system infrastructures; it should also include the collection of historical records and the identification of areas with frequent problems; A02) implementation of a sanitary sewer system operation and maintenance plan.
- For solving the problem of inflow: A03) redirection of the incorrect connections to the sanitary sewer pipe; A04) design and implementation of separate sewer systems; A05) extension of the stormwater collection system to the area in question; A06) use of flow control valves; A07) use of source control systems; A08) use of stormwater in gardens, allowing the reduction of rainfall induced I/I to the sanitary sewers and reducing consumption from public water supply systems for irrigation; A09) construction of storage volumes to regulate surface runoff, reducing discharges in the receiving environment without the necessity of increasing the capacity of the downstream sewer pipe; A10) design and implementation of private separated sanitary sewer network (it may be necessary awareness campaigns and funding schemes); A10b) correction of private building laterals connections; A11) cover replacement of the manhole chamber.
- To solve infiltration problems: A12) replacement of the sewer pipes using the traditional techniques: A13) rehabilitation of the sewer pipe using trenchless technology; A14) manhole replacement; A15) manhole rehabilitation; A16) replacement of lateral connections; A16b) proper re-connection of connections made incorrectly to the surface water sewer pipes.

General methodology for I/I control

General approach

The typical approach to I/I control in sewer systems is to reduce it to acceptable flow values, by rehabilitation or replacement of existing infrastructures, or by correction of misconnections to the sanitary sewer pipes, as described in several reference publications: USEPA (1991), White et al. (1997), Heaney et al. (1999), Wade (2000), 003), ASCE/EPA (2004). The main difficulty is to define the acceptable levels of I/I. The rehabilitation projects may be not justifiable only with the benefits of reducing I/I. Its justification lies in the

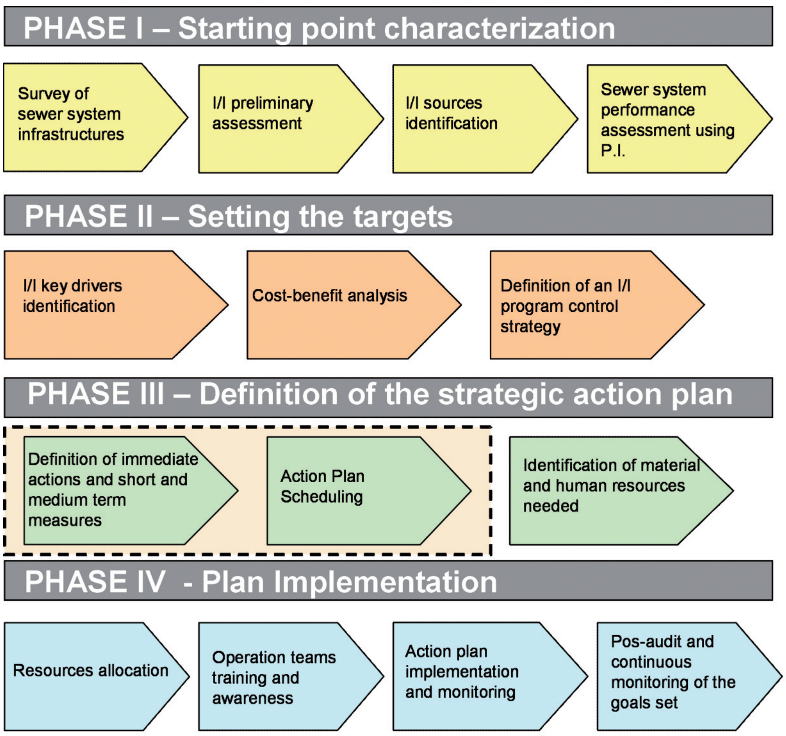

Figure 1 Implementation steps for the inflow and infiltration control programme (ENGIDRO, 2007).

	Action 01	Action 02	Action 03	Action 04	Action 05	Action 06	Action 07	Action 08	Action 09	Action 10	Action 10 b	Action 11	Action 12	Action 13	Action 14	Action 15	Action 16	Action 16 b
INFLOW																		
Sewer pipes																		
Cause 01			X		X		X	X										
Cause 02				X		X			X									
Cause 03			X		X		X	X										
Cause 04			X															
Laterals/ private building network																		
Cause 05			X		X		X	X										
Cause 06			X				X	X		X								
Cause 06 b										X	X							
Manholes																		
Cause 07												X						
Cause 08												X						
Cause 09												X				X		
Cause 09 b				X														
INFILTRATION																		
Sewer pipes																		
Cause 10													X	X				
Cause 11													X	X				
Cause 12													X	X				
Cause 13													X	X				
Cause 14													X	X				
Cause 15													X	X				
Cause 16													X	X				
Cause 16 b																		X
Laterals/ private building network																		
Cause 17			X															
Cause 18														X			X	
Manholes																		
Cause 19															X	X		
Cause 20															X	X		
Cause 21															X	X		
Cause 22															X	X		
Cause 23															X	X		
Cause 24															X	X		
Cause 25															X	X		
Cause 26															X	X		
Cause 27															X	X		

Figure 2
Summary matrix of causes and control actions of inflow and infiltration (ENGIDRO and HIDRA, 2007).

range of benefits that may arise from also reducing operating costs and maintenance, reducing the impact of unwanted discharges in the receiving environment and increasing the infrastructure life period.

It is important to establish an integrated strategy that allows each entity responsible for sewage systems to have an action plan to achieve a gradual reduction of I/I while the benefits of this reduction offset the costs. To make more efficient the investment and optimize the available resources, it is necessary to establish action priorities, defining when and where interventions are needed.

The methodology here proposed (Silva, 2008) is a general approach to the problem, with several steps: it begins with an assessment to find the size of the problem, through the status quo characterization; includes setting the targets; defining the programme of action to I/I control; and implementation of suitable actions and results evaluation. Figure 1 describes the different phases necessary to implement the proposed I/I control programme.

Phase I – starting point characterization

The starting point characterization includes the following main objectives: characterization of the drainage systems; quantify the inflow and infiltration problem; identify the unwanted clear water flow sources; and comparative performance analysis of the different basins studied.

The quantification of the I/I should be done using a set of performance indicators able to quantify the problem and to allow a comparison between different systems. The infiltration performance indicators recommended are those proposed in the APUSS project (Cardoso et al., 2005). To evaluate the inflow problem may be used the performance indicators proposed by Cardoso (2007).

Phase II – setting the targets

After evaluating the I/I problem, it should be established the goals and targets for the inflow and infiltration reduction. At least two scenarios should be examined: a 'business as usual'/status quo scenario and a scenario of reducing inflow and infiltration. These scenarios should be defined based on the study area diagnosis that should identify key areas responsible for rain induced and infiltration flows. Should be evaluated the financial resources needed for the implementation of each scenario.

To define reduction goals and targets the following activities are needed:

- Identification of external factors (social, environmental and physical) and internal factors (technical, human, material and financial) that may affect the targets setting.
- Economic comparative analysis of the investment return of the possible actions and the additional cost of transporting and treating I/I flows in the status quo scenario.
- Definition of monitoring and control methods (material/ human resources needed and related costs) to measure changes in rain induced and infiltration flows, in order to be able to assess the results of the implemented actions and to identify the need for further interventions.

The methodology to support the investment strategy must have a bottom-up approach and try, wherever possible, to analyze the different investment scenarios converting all the benefits, advantages and disadvantages in a single monetary unit (Monteiro et al., 2008). The main goal of this multicriteria approach is that the evaluation can be obtained by the sum of different valuations from each point of view. Faced with an investment scenario, it is necessary to evaluate each scenario by the global net present value (NPV) of benefits or costs, considering all the components of the project (with or without tax optimization). Each scenario should be assessed by separation the cost in two types: i) direct costs; all costs that affect directly the company accountability; ii) external costs; other costs that results from company actions or omissions that originate damages or loss of efficiency for the community (non-productive time because of floods or environmental damage by unwanted sewer discharges). The unitary costs used for the evaluation of the external costs may be dependent on the public opinion pressure.

Phase III – definition of the strategic action plan

Once identification and quantification of I/I has taken place, and established objectives and targets for its reduction formed, the sanitary sewer system manager must develop a strategic action programme. The programme must define a set of actions leading to the reduction of I/I, allocating the necessary resources (human, physical and financial) to implement the actions identified as critical in order to achieve the I/I reduction in the established deadline and in a measurable way.

Figure 2 presents a summary matrix that relates the I/I causes to the applicable control actions. For some causes, there can be more than one applicable action, sometimes being complementary. Some actions may have effects in controlling both infiltration and inflow. Regardless of actions needed to be implemented, it is always essential to begin with a complete survey and registration of existing infrastructure.

Reducing the volume of unauthorized inflowing water to the system requires the adoption of corrective actions that consider the relative importance of its groundwater and rain components. While the reduction of the infiltration flows is achieved through the rehabilitation or replacement of existing infrastructures (pipes and/or manholes) by traditional methods or relining techniques, the inflow reduction implies the correction of misconnections to the sanitary sewer pipes. It is necessary to define the rehabilitation and maintenance techniques more suited to each intervention characteristics based on technical, economic and operational criteria. More information regarding the selection of technologies for sewer rehabilitation and replacement can be consulted in NRCC & FCM (2003b), and regarding illicit discharge detection and elimination in Brown et al. (2004). It is important that the plan considers the possible revision of the goals after evaluating the results of the first actions, in order to allow adjustments or corrections.

Phase IV – plan implementation

The plan implementation cannot be normalized and should be adapted to each utility context. For the training and awareness of the teams involved, a preliminary phase should be promoted, including a pilot programme to test the actions recommended. The plan should establish a hierarchy of actions that allows the achievement of the goals in a consolidated manner. The implementation of the action plan should start with simple actions or actions that will support the ones with greater complexity and higher investment. These actions include solving open questions in the sewer registration, establishment of monitoring points or setting the conditions for the water balance calculation. With the implementation of such actions, usually classified as immediate or preparatory actions, additional information is gathered and can be used to consolidate the action plan, validating or redefining the short and medium term actions. Only after the revision of the action plan to take in account the results of immediate actions implemented should subsequent actions be initiated. Its implementation should start in areas where the gains achieved are more relevant.

Conclusions

The implementation of an I/I control strategy requires constant results evaluation in order to set the best solutions and priorities for investment. The performance indicators can monitor the efficiency and effectiveness of the proposed actions over time and thus correct the action programmes to meet the goals established. Audit mechanisms should be created for effective control of the planned actions and the methodology used. The implementation of the best practices in the design and execution of new drainage systems should be applied in expansion areas thus avoiding the spread of identified mistakes that are usual.

A Portuguese sewer system utility (Águas do Ave) is currently developing studies on this subject using this approach. These studies should be regarded with interest in order to improve the overall approach here proposed. Regardless, the actions needed to be implemented in the short or medium term, it is considered essential to survey and undertake registration of existing infrastructure, and to implement a structured operation and maintenance plan, to be included in the asset management general strategy.

In terms of future research, the establishment of cost functions for the various corrective actions here identified is needed, in order to allow an easier cost-benefit analysis in the choice of the actions to be applied in the I/I control. ●

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A simplified methodology to estimate rainwater contribution to domestic sewers

Modelling domestic separate sewer systems becomes an increased challenge when unwanted inflows (from infiltration or unwanted rain connections) are presented. It is quite different from modelling a combined sewer system, where in general a hydrological model is calibrated to estimate the inflow resulting from all the water generated in the catchment. In some cases, it is important to have a simplified methodology to estimate the inflow runoff, especially in scenarios of lack of resources. Small wastewater utilities frequently face human resources restraints. Separate domestic sewers may therefore be discharging for a long time before corrective actions are provided. In these utilities it is particularly important to have a simplified methodology able to identify the magnitude of the problem. A proposed methodology and its application to two experimental basins located in Portugal are presented in this paper. By Rita Brito, José Saldanha Matos, António Monteiro, Filipa Ferreira and Bruno Machado.

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Over the last 60 years, after the approval of national legislation related to wastewater drainage, most urban drainage systems in Portugal have been designed as separate. Nevertheless, most domestic separate systems face functional problems when it rains, due to the existence of erroneous connections. Left unchecked, widespread illegal connections lead to increasing operational and maintenance costs, and may result in sewer overflows and pollution of the receiving waters.

Despite the large investments that took place in the wastewater sector, particularly in the past two decades, in many situations the performance of these systems is far from satisfactory, mostly due to erroneous connections. Although data on the magnitude of this problem in Portugal is currently unavailable (Machado et al., 2007), its consequences are well known.

These connections need to be properly rerouted. Careful investigation of local conditions is still the most traditional approach to the problem. Crews have to perform visual inspection on every manhole and pipeline, eventually using CCTV inspection. Such fieldwork is laborious, expensive and time consuming.

Modelling tools may contribute to identify the most problematic areas where such fieldwork should be intensified. Managers are interested in predicting the benefit gained by investing in one area instead of the other, with a reduced amount of data. The small wastewater utilities do not benefit from large-scale human resources management and can rarely compromise with long-term field campaigns and complex data editing, validation and interpretation. The main objectives to be achieved with modelling the extraneous flows to sewer systems are the following:

- Identify which catchments are more likely to register sewer overflow during rain events;
- Localise the sub-catchments that mostly contribute to the sewer system with unwanted flows; and
- Quantify the amount of impervious area connected to the sewer pipes.

In this paper, a methodology for addressing this problem and the practical application to two Portuguese case studies is presented. The case studies are very different. The Caparide system consists of a large catchment with almost 14,000 hectares. The Águas do Ave system comprises 12 small pilot catchments, with two to ten ha.

Method – modelling strategy for extraneous flows

Separate sewer hydrology

Urban hydrology could be described as being the study of rainfall runoff in urbanized areas, including the evaluation of how much and how often rainfall is drained by a collection system. In urban hydrology, the mathematical interpretation of these physical processes is rather complex.

Although similar, the response of a sanitary separate sewer or a combined sewer to wet-weather conditions differs. The effect of hydrological processes in a combined sewer system is clearer and better understood.

The three major components of wet-weather wastewater flow into a sanitary sewer system are wastewater flow (WF), permanent groundwater infiltration (GI), and rain dependent inflow and infiltration (RDII), as illustrated in Figure 1.

In the presented methodology, GI and WF are analysed together as dry-weather flow (DWF). One of the main objectives in both case studies was to identify the most problematic areas where fieldwork should be intensified. Being so, it was considered acceptable to include the wet period increase in GI as part of the water volume that enters from unwanted connections.

RDII is the rainfall-derived flow response in a sanitary sewer system. Early in the rain event, surfaces and soils may accumulate some of the rainfall before a response is observed, and, if the event is small enough, there may not be a response at all. Being so, in a combined sewer system, wet weather runoff derives directly from hydrologic conditions – whereas in a separate sewer system, runoff derives partially from hydrological conditions and mostly from unwanted connections.

Methods for RDII quantification

McDermott et al. (1992) described an empirical separate sewer hydrology model and the concept of 'virtual rainfall' was presented. The authors emphasised the impracticality of generalising model parameters for separate sewer systems with erroneous connections, and on the need for further research. Vallabhaneni et al. (2002) and Wright et al. (2001) discussed various practices in simulating RDII using rainfall-runoff tools. A Water Environment Research Foundation (WERF) publication (Bennett et al., 1999) and a conference paper (Schultz et al., 2001) reviewed RDII prediction methods in literature dating back to 1984 (EPA, 2007). The 1999 WERF study identified eight methodologies for RDII quantification. Specifically, the methods should be able to:

- Predict peak flow for individual and multiple storms
- Predict volume for individual and multiple storms
- Predict the hydrograph timing, shape, and recession limb
- Operate on commonly available data

These methods, their application and major constraints, are largely described in EPA (2007).

Percentage of rainfall volume (R-value) method

In the present study, the percentage of rainfall volume (R-value) method was believed to be the one, among the ones presented in EPA (2007), that mostly met the defined objectives, namely in terms of simplicity. This method calculates RDII volume as a fixed percentage of the rainfall amount.

In EPA (2007), authors advise modellers to be careful when extrapolating the R-value to estimate flow volumes for high-intensity, high-volume design storm events, such as a five or ten-year storm. Antecedent moisture conditions significantly affect the RDII response to rainfall events. When attempts are made to extrapolate the calculated R-values for frequent storms, that typically occur in a monitoring period, to an infrequent storm such as a ten-year design storm, even the slightest change in the slope of the regression line can significantly impact the predicted R-value. Additionally, the authors refer that this method is unable to estimate peak flows or hydrograph timing and shape. As in the case of all other RDII methodologies, this method is based on simplified assumptions. Being so, this method is considered insufficient for designing conveyance and storage facilities where hydrograph timing, peak flows, and shape are needed.

According to EPA (2007), the R-value is relatively easy to calculate as long as you have reliable flow monitoring and rainfall data, and can be used as a guide to determine the relative number and size of RDII defects within a particular sanitary sewer system. The RDII process and associated data are very much site-specific. In fact, no single flow prediction method is likely to be universally applicable.

In the present study, estimating flow volumes for high-intensity storm events was not considered a goal. Estimating peak flows and defining the hydrograph timing and shape was not the objective per se, but was considered useful for model calibration and validation, as well as for the tentative approach for the location of critical areas. This method is considered useful to estimate volumes, in order to comply with the project objectives.

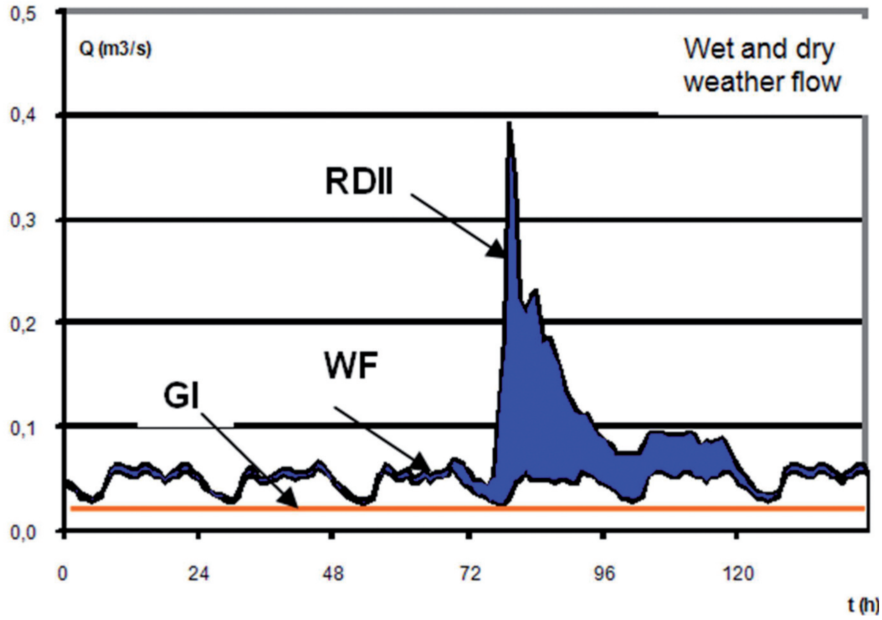


Figure 1 **Components of wet-weather wastewater flow**

Peak flow analysis – rational method

Traditionally, the peak flow after a rain event is estimated by the application of the Rational Method. It represents a global and simplified but widely used approach of the hydrology phenomena in urban catchments.

According to the Rational Method:

$$Q = C\,i\,A \tag{1}$$

Where:
Q: peak flow (m^3/s)
C: runoff coefficient (-)
i: rainfall intensity (m/s)
A: catchment's area (m^2)

Developed methodology for estimating an apparent C coefficient (C')

Dry-weather flow

In order to establish a pattern of dry-weather flow (DWF), Brito (2002) analysed a period of three-year data from 36 flow meters, with diameters varying from 200 mm to 500 mm. The dry-weather patterns were normalised (through division by its average DWF). It was possible to determine that most pipes up to 350 mm (small DN) had a similar pattern and that pipes with a bigger cross section (medium DN) had another. It was also necessary to distinguish weekdays from weekends. Based on this procedure, the DWF patterns presented in Figure 2 were introduced as input data in the present study.

Contributing impervious area, A'

Based on the R-value method and on the Rational Method, the objective of the studies was to quantify the amount of impervious area connected to the sewer pipes.

Catchment	Number of events	C'
Caparide	6	1.1%

Table 1
Obtained C' coefficient for Caparide sewer

Simulation models require the definition of the catchment's impervious area, and assume that all this area is about to contribute to pipe flow. When facing a separate sewer system with unwanted runoff connections, the contributing impervious area is difficult to quantify. Being so, in such systems it may not be useful to accurately determine the real impervious areas. This would mean that the whole amount of net precipitation would drain to the pipes, which is of course not correct.

The part of runoff that derives from the hydrological model could be determined considering that the R-value method calculates RDII volume as a fixed percentage of the rainfall amount.

Based on the R-value method and the Rational Method, it is feasible to adopt an auxiliary parameter, contributing impervious area A', suitable to estimate extraneous rain water flows. A' represents the amount of impervious area connected, a parameter that varies with the rain events.

$$V' = C\,I\,A' \qquad (2)$$

Where:
V': extraneous volume in the sewer system (m^3)
C: coefficient that stands for the characteristics of the catchment (-)
I: rainfall depth (m)
A': contributing impervious area (m^2)

Apparent coefficient, C'
The resemblance of the described method with the Rational Method allows the definition of an apparent coefficient, C', which represents the percentage of net precipitation draining to the separate sewer system, corresponding to the existence of a contributing impervious area A':

$$V' = C'\,I\,A \qquad (3)$$

Where:
C': apparent C coefficient (-)
A: catchment's area (m^2)

Assuming that an impervious area has a C value of 1.0, C' stands for the percentage of impervious area in the catchment actually connected to the system.

The procedure to simulate extraneous flow in the present study was to introduce various values of A' in the model in order to guarantee, for each event, the smallest error possible in the hydrograph. Minimizing errors in hydrograph timing, peak flows, and shape was also a goal.

Results – case studies
Caparide sewer system (Cascais, Portugal)
The Caparide stream line is approximately 5700 m in length and presents 151 manholes. The catchment area is 14,000 ha. The sewer diameter varies from 400 to 700 mm. The sewer was designed as a separate sewer system and receives 28 sewer connections along its path, with diameters varying from 200 to 500 mm. This sewer system has two flow meters installed. The model was applied to all the branches in between.

The Caparide sewer is installed along a stream that discharges near to a beach of high tourist interest. Any discharge from this sewer system becomes an environmental incident with immediate public repercussions.

Modelling in the Caparide sewer study was accomplished with the MOUSE model, from Danish Hydraulic Institute (DHI). Detailed description of this project can be found in Brito (2003).

The normalised DWF patterns presented in Figure 2 were applied to all connections. Rain and flow data from three years monitoring were available. Model calibration and validation was done based on six multiple rain events. Some of this multiple events lasted for more than five days. An average value of 1.1% of C' was obtained. In average, this means that approximately 1.1% of all impervious area is connected to the Caparide sewer. Table 1 summarises this result.

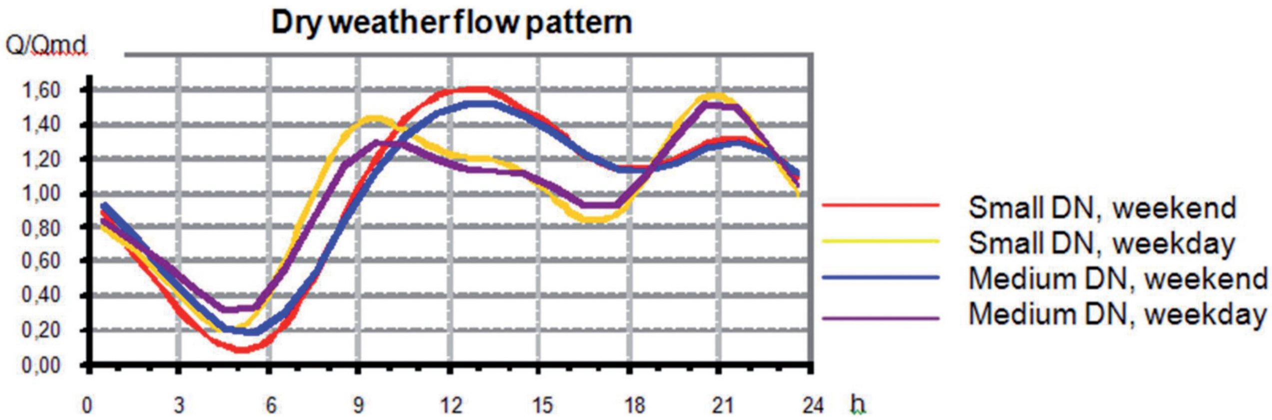
Based on this data, several scenarios with test multiple events were modelled and the capacity of the pipe was studied. Locations more subject to surcharge and discharge were identified. This analysis allowed managers to identify areas in the catchment where greater investments ought to be made in order to reduce the unwanted extraneous flows.

Águas do Ave sewer system (northern Portugal)
Águas do Ave is the company responsible for managing the bulk network of various municipalities in northern Portugal. In a broader project, modelling of separate sewer systems in small catchments was performed. Pilot catchments were selected with areas between two and ten ha and network length of approximately one km. Flow measurement was located in an outlet of the pilot catchments. The pipes diameters are very small, varying from 200 up to 250 mm. In this project, input data was provided by a short-term survey. Detailed description of this project is presented in Machado et al. (2007).

Modelling in this case study was done with SWMM (Storm Water Management Model), developed by the Environmental Protection Agency (EPA). Due to the fact that only a short-term survey was provided, the DWFs were difficult to obtain. Being so, the same methodology applied in Caparide sewer was used, and the flow patterns presented in Figure 2 were applied. Different multiple rain events were studied with variable characteristics.

As in Caparide, in all of these catchments a brief previous inspection

Figure 2
Normalised dry weather flow pattern



was done in every manhole. In some cases, unwanted connections were detected, so modelling was initially performed considering that only these sub-catchments were contributing with rainwater. If runoff generated by these areas was lower than the hydrograph showed, then additional contribution area was considered. Table 2 identifies, for each catchment, the average value of C' for the various events, for each of the 12 pilot catchments in Águas do Ave. In this project, the values of C' varied from 1% to 54%, meaning that 1% to 54% of all impervious area, in each sub-catchment, is connected to the separate sewer systems.

Modelling the whole pipes in each catchment allowed to verify whether and where there was pipe surcharge or sewer overflow. Table 3 presents whether or not (yes:Y or no: N) these situations occurred.

It was also possible to determine the origin of the contributing areas. As previously mentioned, the main purpose was to identify the pilot catchments that mostly needed further investment in order to correct erroneous connections. Whether and where pipe surcharge and sewer discharge occurred was identified. As Tables 2 and 3 present, this characteristic does not always relate to a higher value of the average C' coefficient. Being so, the results of this study revealed that catchment GUI_01 was where further investment should be done, followed by catchment FAF_01 (overflows were only detected in these two catchments). Secondly, fieldwork should be directed to catchments TRF_02 and VNF_01 and finally, to FAF_02 and VIZ_02. In these two last catchments, although pipes surcharge, a low value of C' coefficient occurs, associated with disperse contributions in the whole catchment. Investing in these two catchments is not advisable, since it will require greater effort and resources that may probably produce just minor results.

Conclusions

Reducing extraneous flows in domestic sewers may become an expensive, laborious and time-consuming task if performed the traditional way. Applying a simplified methodology that may be able to quantify and localize the magnitude of the problems, through estimating the percentage of contribution area, may allow for a more adequate planning, focused in an investment versus benefit strategy. Nevertheless, modelling erroneous connection effects represents an additional challenge when it comes to a separate sewer pipe, and modellers face the problem of having to apply empirical methods, derived from actual flow data, to estimate the hydrologic response.

In the present paper, the R-value method was adapted, and the results of simulation were interpreted as an apparent C coefficient (C'), standing for the percentage of impervious area contributing with runoff to the domestic system. A study of dry-weather patterns was also developed in order to provide input data for estimating the dry-weather base flow.

In a large catchment (Caparide), it was possible to identify the most critical areas, as far as surcharge and discharge are concerned. For these areas, the estimated C' coefficient was quantified in order to prioritise investments. An average C' coefficient value of 1.1% was obtained. In a system that consists of several small catchments (Aguas do Ave), the application of the same methodology allowed to identify the catchments with a higher contribution of extraneous flow, and to relate that information with the estimated C' coefficient. Average C' coefficient values between 1% and 54% were obtained, which, along with additional information, allowed prioritising investments in the catchments.

It is important to emphasize that the presented methodology is adequate for predicting volumes of extraneous flows, but should be improved whether the purpose of the study was related to hydrographs shape and peak flows. Moreover, it is important to recommend that short-term surveys should at least, ideally, last for a year, in order to provide reliable extensive data. ●

Table 2 Obtained C' coefficient for Aguas do Ave pilot catchments

Catchment	C'	Catchment	C'
FAF_01	10%	VIZ_01	2%
FAF_02	5%	VIZ_02	1%
GUI_01	56%	VMI_01	2%
GUI_02	7%	VMI_02	14%
TRF_01	10%	VNF_01	12%
TRF_02	23%	VNF_02	14%

Table 3 Hydraulic conditions modelled in Águas do Ave pilot catchments

Catchment	Pipe surcharge	Overflow	Catchment	Pipe surcharge	Overflow
FAF_01	Y	Y	VIZ_01	N	N
FAF_02	Y	N	VIZ_02	Y	N
GUI_01	Y	Y	VMI_01	N	N
GUI_02	N	N	VMI_02	N	N
TRF_01	N	N	VNF_01	Y	N
TRF_02	Y	N	VNF_02	N	N

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Sustainable, real-time wastewater utilities

With increasing populations, stricter regulations, and soaring costs, wastewater utilities around the world feel the increasing pressure of remaining sustainable. With the continued social, economic, and environmental challenges, this paper discusses how real-time and historical data enables wastewater utilities to save and make money, meet stringent environmental discharge regulations and achieve sustainability. From the thousands of wastewater utilities around the world, many are not collecting or fully utilizing the data they are regularly generating. This is due in large part to the challenges of disparate data systems, lack of understanding about advanced data analysis and ever-changing technology environments. Case studies will demonstrate how utilities can leverage real-time information to integrate their operations and disparate systems, as well as provide enterprise visibility in support of real-time decision making at all levels of the organization. With real-time data, wastewater utilities manage assets and increase their lifecycle, defer millions of dollars in capital expenditures, streamline billing systems, optimize operations, reduce energy and chemical consumption, enable capacity planning, meet and monitor environmental compliance, ensure public safety, and achieve corporate sustainability in a secure and auditable manner.
By Gary LS Wong.

Gary LS Wong, Global Water Industry Executive, OSIsoft Inc., USA. Email: gwong@osisoft.com

With increasing populations, stricter regulations, and soaring costs, wastewater utilities around the world feel the increasing pressure of remaining sustainable. With the continued social, economic, and environmental challenges, this paper discusses how real-time and historical data enables wastewater utilities to save and make money, provide safe drinking water, meet stringent environmental discharge regulations and achieve sustainability.

Case studies will demonstrate how utilities can leverage real-time information to integrate their operations and disparate systems, as well as provide enterprise visibility in support of real-time decision making at all levels of the organization.

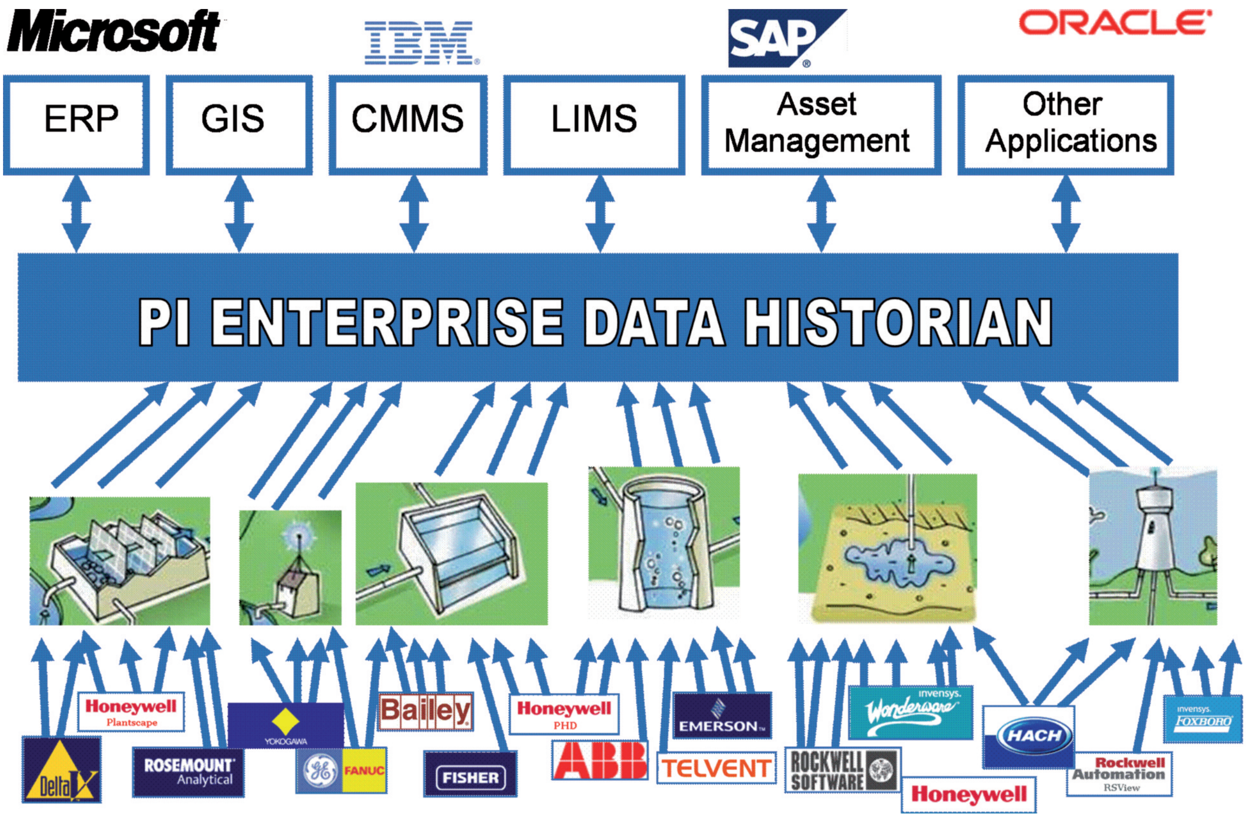
With real-time data, wastewater utilities manage assets and increase their lifecycle, defer millions of dollars in capital expenditures, streamline billing systems, optimize operations, reduce energy and chemical consumption, enable capacity planning, meet and monitor environmental compliance, ensure public safety, and achieve corporate sustainability in a secure and auditable manner.

The industry challenge

From the thousands of wastewater utilities around the world, many are not fully utilizing the data they are regularly collecting. This is due in large part to the challenges of disparate data systems, lack of understanding about advanced data analysis and ever-changing technology environments.

It is difficult to manage an array of operating systems, databases, infrastructure and development environments, particularly when tens of thousands of data points (or more!) are continually generated: in real-time, daily, weekly, etc. The ability to capture, integrate and disseminate data from disparate systems – from sources such as laboratory information management systems (LIMS), Geographic Information System (GIS), Enterprise Resource Planning (ERP) and process control systems – is a critical step in creating visibility into operations throughout the organization.

Additionally, while organizations may be collecting data from thousands of instruments or other data sources, they often do not have a reliable, single data collection platform and intuitive user interface to enable people to turn raw data into actionable information. By replacing non-cohesive data in disparate and obsolete systems with an integrated and automated information platform, wastewater utilities can help users better analyze all the different data that is available to them in a more



consistent and standardized manner.

Figure 1 Tying all data/information together in a common platform

Enterprise data historian: a foundation for achieving the real-time enterprise

Enterprise data historians are a proven technology solution for efficient collection, analysis and dissemination of time-series data – such as water pressures, flows, chlorine levels and amount of energy or chemical consumed. Utilities can reliably and accurately collect process control and automation data by tapping into the potential of data already in place, and making it easily available to any user in the organization through a corporate web portal on any standard desktop.

An example of an enterprise data historian such as the PI System delivers one common interface for all real-time process data access to any control system, and integration of process data to other business applications, e.g., ERP, asset management, LIMS, GIS, Computerized Maintenance Management System (CMMS), etc.

At any given wastewater utility, there are more than a dozen roles which can benefit from consistent information and advanced analysis of real-time or historical data: from operators who use the information to manage water distribution, to engineers and managers who use the data for capacity planning and deciding whether or not building a new $200 million plant is required to treat wastewater.

- Through dashboards, executives have the ability to view the cost per 1000 litres of wastewater treated or the amount of energy consumed in real-time, giving the executive a high-level view of the overall core business effectiveness.
- Even boards of directors use this information to make more informed decisions on multi-million dollar capital expenditure projects.
- Planners use the data to trend and predict flows and safe operating levels of the sewer system to determine when to build new sewer infrastructure. This prevents sewer overflow onto streets and homes, while mitigating legal risk.
- Foremen/supervisors use data to determine the daily operating plan and set points for a treatment facility to meet water demand or wastewater treatment, resulting in efficient service delivery and quality of water/wastewater.
- Quality Assurance/Quality Control analysts, engineers and operators use data to determine the wastewater effluent quality or drinking water quality and what operating conditions may have caused an upset in the treatment facilities. This allows utilities to meet wastewater effluent quality when it is discharged to the river or ocean and thereby avoid million dollar fines or to deliver clean, safe drinking water to residents.
- Instrumentation and automation engineers use data to tune loops, reduce cycling of equipment, and develop and test control strategies for automation, leading to increased operational efficiency, increased asset lifecycles and continuous operations.

By gathering all dynamic data in one repository, monitoring and analyzing data from the perspectives of both operations and engineering, and wastewater utilities can transform this wealth of data into actionable information, directly affecting bottom-line measures.

Case studies: real-time data in action

An enterprise data historian is the first step required for any optimization or analysis to be achieved effectively. Take, for example, the following case studies, which demonstrate a variety of uses for and benefits derived from implementation of an enterprise data historian, specifically: the OSIsoft PI System.

Medium Canadian wastewater utility: reducing energy consumption

About 30% of total costs of water and wastewater operations is attributed to energy consumption. Optimized pumping strategies, cogeneration and consistent real-time monitoring can reduce energy consumption and

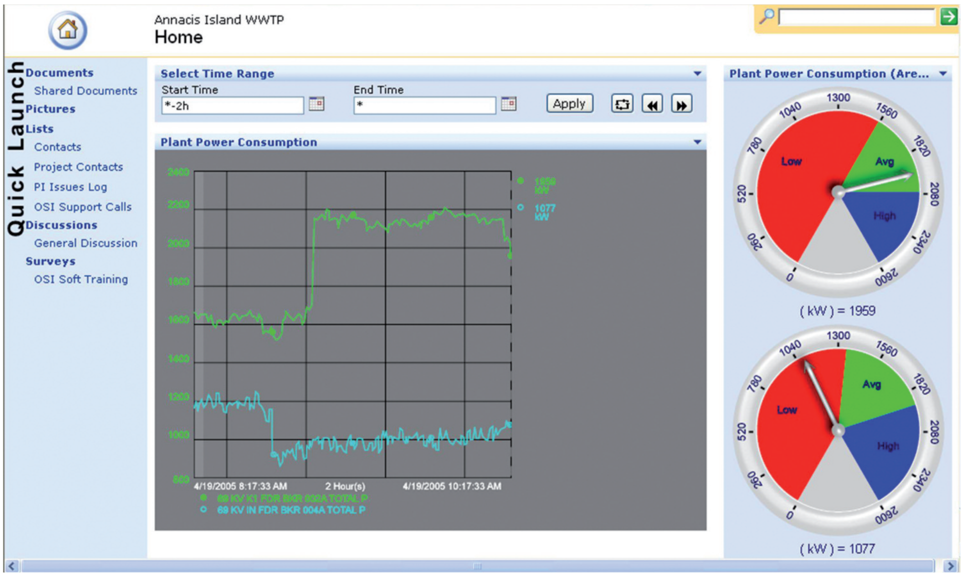


Figure 2
Real-time power consumption optimization reducing cost

costs during peak hours. By assessing electricity usage trends via an enterprise data historian, companies can better manage energy allocation, drawing in electricity during non-peak hours and feeding energy back to the grid during peak demand times.

One medium Canadian wastewater facility saves $1.5 million/year on energy optimization alone by using the real-time and historical data from their historian to increase the use of digester gas and to import/export electricity from the grid based on time of use rates, while running operations to meet wastewater quality standards.

During rainstorms, the PI System is critical in maintaining compliance with regulators, providing the data necessary to prove that the utility is operating within operating permits. For this wastewater utility, the PI System provides all real-time and historical data consistently and efficiently, and integrates seamlessly with reporting and disparate systems already in place, such as ERP, LIMS and asset management. It is also an effective reporting tool, and used in the emergency operations centre for real-time decision making.

As a result of the OSIsoft PI enterprise data historian and energy optimization initiatives, the utility has realized the following benefits:

- Savings of $1.5million/year in energy cost reduction
- Reduced natural gas consumption to zero

Medium Australian wastewater utility: asset management

With a PI enterprise data historian, this Australian utility has been able to effectively manage hundreds of waste-water pumping stations across its region, increasing asset life and reducing maintenance costs.

The utility relies on the enterprise data historian PI System for real-time asset management – standardized key performance indicator forecasting to predict maintenance required. Parameters include real-time and historical analysis of run-time hours, power load on pumps, and start/stops per hour, enabling condition-based and predictive maintenance on waste-water pumping stations.

Conclusions

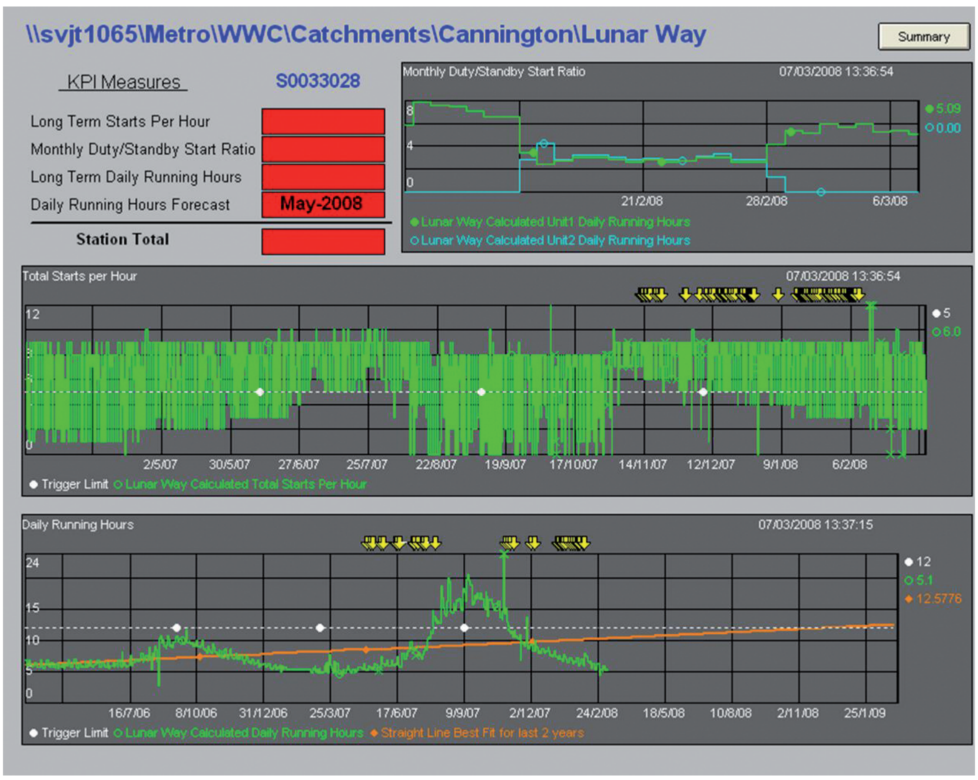
When we consider that the biggest issue in the water industry is sustain-ability, we need to look at how our business operations can be more efficient in order to reduce water usage and conserve supply. For many water and wastewater facilities, the data is there, but:

- Is the data working towards meeting the social, environmental and economic goals of the organization?
- Is the data playing the lead role that it should in water distribution and wastewater collection, water and wastewater treatment, irrigation, desalination, hydrology and metering?

By ensuring that control system data and information is seamlessly delivered and integrated to the corporate IT desktop through data historians, water/wastewater utilities will realize overall efficiency gains throughout the value chain. The value of the data already being collected will increase exponentially, as critical decisions can be made ahead of time or in real-time.

Enterprise data historians turn raw process control data into actionable and consistent information for decision making, and unlike relational databases, specialize in managing time-series process control data and integrate to your relational business data systems. Enterprise data historians are the basis for operations optimization as without the data, utilities are unable to measure, analyze, or act in an efficient and informed manner. Consistent, reliable and actionable data from an enterprise data historian will improve operations and quality, lower costs, and ultimately,be the foundation for the sustainable, real-time enterprise. ●

Figure 3
Real-time asset management dashboard



Trends and challenges in strategic asset management

Managing urban infrastructure assets is a continuous task, starting at the time of construction, so therefore asset management is nothing new for the utilities. Nevertheless, a more comprehensive and well-devised strategic approach has been evolving in recent years, from fundamental concepts to practical implementation. The key concept as summarised by Haskins (2008) understands strategic asset management (SAM) as a set of processes aiming at minimising life-cycle costs of owning, operating and maintaining infrastructure assets, while continuously delivering established levels of service at an acceptable level of risk.

This broad concept includes institutional, programmatic, informational and operational matters, which make progress in SAM dependent upon a variety of circumstances. Current key issues as identified in the SAM workshop at the 2008 IWA World Water Congress were the following:

- Creating an enabling environment for AM on a national level
- The role of standardisation for developing AM concepts
- Support of organisational awareness within the utilities
- Role and importance of models and tools (including IT environment for data gathering)
- Knowledge transfer and training: how best practice is spread

Creating an enabling environment for AM on a national level

Obviously, the management and development of infrastructure on a national level is very much influenced by tradition, experience and the stage of development of the infrastructure. The Portuguese example from the national regulator IRAR (Baptista, 2008) demonstrates that a given AM attitude can be positively influenced by the impact of good governance, regulatory bodies, associations and stakeholder groups. It became obvious that it was not the existence or non-existence of a regulator that matters, but the way a national AM strategy is being developed and implemented. Basic conclusions were that encouraging responsibility for the utilities' own assets is the pre-requirement for a successful AM environment, which can be achieved e.g. by involving the utilities in the process of developing such a strategy. This involvement can be seen in examples in the set-up of the national Portuguese strategy, the joint development of the Common Framework for Infrastructure Management by UKWIR or – as an example for a 'self-regulating' environment in Germany – in the development of AM guidelines in a self-organised process from the industry and facilitated by the German water associations DVGW and DWA. Other important aspects were the need for longer horizons in national planning on the strategic level, typically covering four to six years, combined with a more operational view in a timescale of one to three years. It was considered that national strategic AM plans should include both engineering and financing aspects. In the absence of a regulatory body and without direct competition, the need for market-elements such as benchmarking or a concession market was regarded to be supportive.

The role of standardisation for developing AM concepts

A common base of experience was regarded as helpful, creates standards of good practice, and spreads expertise among the utilities. This is the case of existing guidance documents and manuals on infrastructure management like the International Infrastructure Management Manual 2006 (IIMM, 2006). This is also the case of international or national standards or specifications. Some national standards establish a more detailed and technical level, such as the DVGW Technical Guidelines on construction and maintenance of water supply networks (DVGW W 400 series), which creates standards of good practice and spread expertise among the utilities. Whether existing knowledge can be compressed and generalised into an international standard is still a subject of some debate. In any case, the need for more specific guidance documents regarding the actual state of AM in an individual country can be clearly seen.

Support organisational awareness within the utilities

From the examples of SAM implementations in the US (Haskins, 2008), UK (Parker, 2008) and from World Bank projects (Janssen, 2008), features and models for enabling AM environments within a utility were given. Advanced AM implementation in a company covers strategic and operational levels in comprehensive planning and execution loops, includes business and budget planning, workforce development concepts and company wide risk management.

The aspect of 'getting started' in a utility requires attention, because typically most utilities already have established partial aspects of AM, or are shrinking back from the comprehensive challenge of advanced AM systems. There is a strong need to support the build-up and development of AM, more describing a pathway with priorities in a step-wise approach rather than pushing complex and integrated schemes from the very beginning. This is regarded even more relevant for smaller utilities with limited human resources or utilities in developing countries. A proactive role of IWA and the IWA Specialist Group was encouraged, possibly by providing experience and lessons learned in case reports, arranging peer contacts and coaching opportunities.

Role and importance of models and tools (including IT environment for data gathering)

The fundamental importance of data availability, well-designed data gathering pathways including field data, input in IT systems and data processing were part of Jo Parkers' report from the UK experience (Parker, 2008). During the 2008 IWA World Water Congress, several sessions and workshops were dedicated to the comprehensive and specialised AM models and tools, providing a good overview on the current level of understanding and model development.

Open for discussion is still the question of whether models developed from a given context in one utility could be transferred and applied usefully in another. Further questions might arise on standardisation of tools and models and current needs and gaps.

Knowledge transfer and training: how best practice is spread

The aspect of learning from examples and from best practice is fundamental on all levels of AM, either strategic, tactical or operational. The relevant question for further consideration within the IWA SAM SG is how experience transfer could be organised most effectively, moreover when different stages of infrastructure development are to be considered. The range could be from organising conferences, providing manuals and case-study compilations up to the organisation of thematic exchange groups with peers, staff exchange or knowledge transfer.

Furthermore, the role and the need for involvement of stakeholder groups, from consumer interest groups and non-governmental organisations looking at water service quality needs further attention, particularly exploring the potential leverage effect of the biannual SAM leading edge conferences of IWA. Stakeholder involvement in context with pricing policies and the affordability of water services will set the scene for upcoming debates on the appropriate SAM approach for the individual utility. ●

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Challenges facing management of transferred sewers

The UK Government in April of this year published a draft Flood and Water Management Bill, which may become legislation in 2010.

The Bill aims to improve flood risk management as a response to Sir Michael Pitt's review of the 2007 floods across England, which caused the largest loss of essential services since World War II, and water resources management during drought. It will implement the recommendations made by Sir Pitt and define responsibilities regarding flood risk and drainage systems as well as give water companies in England and Wales new powers to improve control of non-essential domestic uses of water during periods of water shortage.

The changes regarding responsibility for drainage and sewers, says David Bowen, Principal Consultant at Farrer Consulting, an environmental asset management specialist, means that water companies could become responsible for around twice the amount of sewer infrastructure than they currently hold responsibility for as privately owned sewers are passed over to utilities.

'It is not only the quantity of pipe that is unknown but the condition of what exists underground,' he says. 'No official record exists on this, or the building materials used in any instance, nor the state of repair of any of the pipes making forced adoption a step into the darkness for the water companies.'

Issues arise regarding information about the assets, their state of repair, boundaries and responsibilities and excavation and repair work on private property. 'It is easy to see how quickly costs could spiral,' says Bowen, 'but the question is whether the water companies can afford not to undertake such surveys. In order for them to realistically forward-plan it is essential to know exactly what assets are underground and what it is responsible for. A concern is the 'here and now' and how many problems a survey would uncover that urgently needed repair – again resulting in potentially large expense.'

In response to this potential range of issues, Farrer has developed a service for utilities in order to increase their knowledge of underground water infrastructure. By selecting a specific area within a water company's remit and using mapping technology to fill in the missing gaps, Farrer can produce a sample report on what the company can expect to find throughout the area. This will give them a realistic idea of the length of sewer to be adopted, and also the potential cost of maintenance and repair.

'This information can then be used by the water company to strengthen its position, in any way it may need,' concludes Bowen. 'This is an interim solution but nevertheless a step forward in the discovery of all underground water assets.' ●

Based on comment piece by David Bowen. Email: david.bowen@farrerconsulting.com

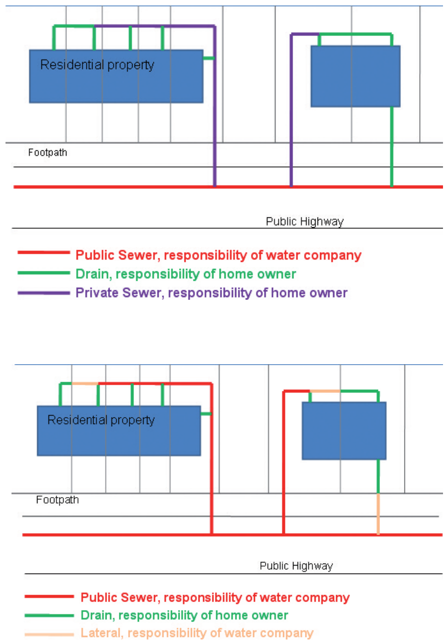

Figure 1
Sewer responsibility before (top) and after (bottom). Source: DEFRA.

AM DIARY

A listing of upcoming asset management-related events and conferences. Send event details to WAMI for inclusion.

27th International Training Program: Utility Regulation and Strategy
11-12 January 2010, PURC, University of Florida, USA
Web: www.cba.ufl.edu/emailer/purc/itp.html

MENA Water Resource World
19-20 January 2010, Dubai
Contact: Ms Reema Patnaik, Water Team, Centre for Management Technology
Tel: +65 6346 9144
Email: reema@cmtsp.com.sg
Web: www.cmtevents.com/?ev=100104&pu=198449

6th Interpipe 2010
31 March-2 April 2010, Beijing, China
Contact: Ms Alissa Ritter
Tel: +49(0)511/90992-20
Email: a.ritter@eitep.de
Web: www.pipechina.com.cn/en/2010.html

Asiawater 2010 - 6th Asiawater Expo and Forum
6-8 April 2010, Kuala Lumpur, Malaysia
Contact: MEREBO Messe Marketing, Germany
Phone: +49 40 3999905 0
Email: contact@merebo.com
Web: www.asiawater.merebo.com

Institute of Water Conference: Global Challenges - Local Solutions
13-14 May 2010, Belfast's Waterfront Hall, Belfast, UK
Web: www.instituteofwater.org.uk

Leading Edge Technologies Conference
2-4 June 2010, Phoenix, USA
Email: let2010@iwahq.org
Web: www.let2010.org

Water Loss 2010
6-9 June 2010, Sao Paolo, Brazil
Email: committee@waterloss2010.com
Web:www.acquacon.com.br/waterloss2010/en

7th International Conference on Sustainable Techniques and Strategies for urban Water Management
28 June-1 July 2010, Lyon, France
Contact: Novatech Secretariat
Tel: +33 (0)4 72438368
Email: novatech@graie.org
Web: www.novatech.graie.org

Singapore International Water Week
28 June-2 July 2010, Singapore
Contact: Samantha Shoo
Tel: +65 6346 4402
Email: waterconvention@siww.com.sg
Web: www.siww.com.sg/water-convention

IWA World Water Congress
19-24 September 2010, Montreal, Canada
Web:www.iwa2010montreal.org

2nd WaterLoss Asia 2010 Conference and Exhibition
14-15 October 2010, Kuala Lumpur, Malaysia
Web: www.waterlossasia.com

6th International Conference on Sewer Processes and Networks
7-10 November 2010, Surfers Paradise, Australia
Web: www.iwahq.org