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Support for Eastern Europe and Central Asia diverted as services decline

Development assistance to the countries of eastern Europe, the Caucasus and central Asia (EECCA) is being diverted to other regions of the world at a time when assets are deteriorating and services are declining as a consequence, a conference on financing in the region has heard.

The OECD conference was held in Yerevan, Armenia in November and brought together economy/finance, water, and environment ministers from the EECCA region along with representatives of OECD countries, international organisations, the private sector and civil society. The conference heard that the overall situation regarding service provision remains 'critical', but that there are positive experiences emerging that potentially be replicated to bring improvements across the region.

Peter Borkey heads the water sector reform programme of the Environmental Action Programme Task Force that OECD supports. He comments: 'An important point that came up is the overly optimistic picture that indicators on the water supply and sanitation Millennium Development Goals are painting – the indicators that the Joint Monitoring Programme of the UN is producing. These figures in fact obscure the fact that there is a very serious situation in the water sector... and that in fact the JMP figures are probably diverting official development assistance away from this region.'

This point is based on the fact that there is extensive infrastructure in the region inherited from Soviet times but that this is deteriorating. 'It's quite a different situation than in Africa where you have very little infrastructure and essentially a challenge which consists of extending infrastructure. Here in the EECCA region you have extensive in infrastructure but it is deteriorating. The challenge is more in terms of maintaining it, and the JMP indicators don't tell you anything about the quality of the water services that are being provided,' says Borkey, adding, 'That these figures are not reliable creates the impression in development ➤ *cont:*

Asset alternative to protect Thames

Ofwat, the economic regulator for the water companies of England and Wales, has published an independent report by consultant Jacobs Babtie that recommends partial solutions to the problem of intermittent storm discharges to the river Thames tideway rather than construction of the proposed £1.7 billion, 35km Thames Tideway interceptor sewer.

The view clashes with that of the Thames Water-commissioned strategic study, begun in 2000 and published earlier this year, that recommended building the major storage and transfer tunnel. This would intercept the main stormwater discharges from the combined sewer overflows along the Tideway.

The Jacobs Babtie review, which began this August following the publication of the strategic study document, calls this report 'extensive and thorough', while noting that significant changes have been made to it between the August edition and a recent amended version.

The review found that sewage-related debris made up just 10% of the litter affecting the Thames, and that it therefore had limited impact on the public. This, it says, makes a major capital investment difficult to justify, something borne out by cost-benefit studies.

The review argues that setting dissolved oxygen levels to avoid fish kills is too high a standard, higher than those needed to maintain a sustainable fish population. Also, it notes, some larger fish may just migrate away from pockets of low dissolved oxygen.

The review also found, from the strategic study data, that most of the required improvements will be made under existing Thames Water AMP 4/AMP 5 schemes.

A review of bacteriological data by eminent specialist Professor David Kay suggested the available data was insufficient to draw conclusions and the review's statistical analysis not in line with WHO guidelines.

The number of recreational water users likely to experience immersion and to be at risk is smaller than the study claims, the review asserts. It considered other partial options including floating treatment systems on the Thames itself. The review favoured the composite solution approach taken for Boston harbour in the US, which replaced a similar single tunnel scheme.

Ultimately, the review took suggestions from all four possible schemes including the favoured single-tunnel approach, creating a new 'Strategy Five'. This would include source control or sustainable urban drainage, separation, storage and real time control within the sewerage system. Other suggestions include storage tunnels and primary treatment of stored stormwater discharges as well as reoxygenating equipment and litter skimmers for the river. This work is costed at between £1.1 billion and £1.6 billion.

● **Lis Stedman**

water
asset management
INTERNATIONAL

EDITORIAL

Editors

Steve Allbee
allbee.steve@epamail.epa.gov

Andrew Foley
at_foley@hotmail.com

Andrew Smith
andrew.smith@yorkshirewater.co.uk

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Papers for consideration should be submitted to the editors or to:

Oisin Sands
Publishing Assistant
osands@iwap.co.uk

PUBLISHING

Associate Publisher
Keith Hayward
khayward@iwap.co.uk

Publisher
Michael Dunn

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IWA Publishing
Alliance House,
12, Caxton Street,
London SW1H 0QS, UK
Tel: +44 (0)20 7654 5500
Fax: +44 (0)20 7654 5555
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Web: www.iwapublishing.com

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Contact
Portland Customer Services
Commerce Way, Colchester,
CO2 8HP, UK
Fax: +44 (0)1206 799 331
Email: sales@portlandpress.com

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Scottish progress on delivery

A report on Scottish Water's performance has found signs of progress in the authority's capital investment and asset maintenance programmes, but notes that there is room for further improvement.

Scottish Water was set up in April 2002 as a 'public corporation of a trading nature'. In this role it is expected to behave as a commercial enterprise, in that it should cover its costs from the charges levied, but it has no shareholders and does not pay dividends in the same way as the privatised companies in England and Wales.

The basic remit on unification was for the new authority to make the Scottish water industry more efficient and competitive, improve value for money as a result of economies of scale, and harmonise charges across the country by no later than 2005/06.

The report, by Scotland's Auditor General, notes that Scottish Water has made some progress in improving the efficiency of its capital investment programme to upgrade and replace its assets. It still faces significant challenges in delivering this programme to 2006 while achieving the efficiency savings demanded by the Water Industry Commission [the industry's economic regulator].' As will happen in England and Wales next year, the single economic regulator has been replaced by a board.

Much of the improvement is attributed to Scottish Water's (and its predecessors') efforts to refurbish service reservoirs and upgrade or replace smaller water treatment works. Improvements in surface waters are due to investment in wastewater treatment works.

The report notes that the authority has responded well to a series of targets set in the auditor's 2001/02 report, having either addressed them or being in the process of addressing them. These required Scottish water to compile a consolidated fixed asset register, carry out a review of its fixed assets, formulate an infrastructure maintenance plan, harmonise non-domestic income systems, review debt management arrangements and control the harmonisation of its financial systems.

Scottish Water's current £1.8 billion ($3.2 billion) capital investment programme has a deadline of April 2006 and it is estimated that £253 million ($450 million) worth of work will remain to be undertaken at that point. Meeting the deadlines of the capital investment programme is essential for future performance and efficiency gains.

Audit Scotland is to undertake a separate study of the issue of achieving the capital programme and will report on this in late 2006.

The report adds that Scottish Water can improve efficiency and performance still further. It notes that while the body has set a sound base for strategic and business planning and performance reporting, it can do better there as well. ● **Lis Stedman**

➤ assistance agencies that water is not an issue in this part of the world. So, I think the implications in terms of development cooperation are in fact quite serious.'

The conference heard that energy costs and unaccounted-for water are two to three times higher in EECCA countries compared to OECD countries. Furthermore, investment is said to be only 10-20% of that required to maintain and renew existing water infrastructure.

The conference highlighted slow progress in reform at the municipal level as being one of the most important obstacles to improved provision of urban water supply and sanitation services. Related to this, there is still much work to be done, for example, in order to facilitate financing of improvements. An issues paper prepared for the conference noted that public budgets will be essential in most countries, particularly for capital costs. Fiscal transfers from central and regional authorities to the local level have an important part to play and such transfers should be designed to provide a predictable stream of revenues and incentives for sound financial management at the local level.

The issues paper describes reform of the relationship between local governments and service providers as being 'critical'. Rather than utilities being departments within local government, the paper points to international experience as having demonstrated that policy and regulation should be separated as functions from service provision. Performance contracts between municipalities and utilities are said to be 'helpful' in clarifying the roles and responsibilities of the two sides. Alongside this, local authorities should set consistent and stable objectives for the water supply and sanitation sector, elaborate realistic finance strategies to achieve these objectives, and to translate these into rolling, medium-term investment programmes, rather than the annual programmes that many municipalities currently follow.

Perhaps the biggest note of optimism arising from the conference is that there is an increasing number of positive experiences on which to draw. Examples include Surgat and Yaroslavl in the Russian Federation and Yerevan in Armenia. The important features of such experiences are that the municipalities have adopted plans with clear objectives and have identified the means for achieving them. In some instances it has even been possible to take on debt to finance improvements, although such cases are 'very much the exception' in terms of what has been achieved. Alongside this, the EAP Task Force now has a considerable range of tools available to support reforms. These tools include a computer tool (Feasible) that allows identification of realistic infrastructure development objectives, a multi-year investment planning tool for municipalities, and a toolkit for benchmarking water utility performance.

This provides grounds for optimism, but Borkey warns of the substantial challenges that exist away from the main cities. 'Another thing that came up quite strongly in the conference was that the medium and small cities, and especially the rural areas, are essentially left aside at this stage. The water quality problems are much bigger than in the large urban areas and at the same time the financial challenges and the financial problems are also much more serious. Also, there are no mechanisms in place at this stage to provide specific assistance to these areas, so that's a big challenge. There is a lot of work that needs to be done, especially in these areas, and clearly capacity constraints at the local level are a very big problem. They are problems in the big cities, but in the small cities it is even worse.' ● **Keith Hayward**

A view of AM across the sectors

● Strategic asset management in the water sector is developing in the broader context of such an approach being used in other sectors. **KEITH HAYWARD** spoke with **DARYL MATHER**, an asset management consultant and author of a new book, about the wider picture of asset management.

Asset management is, according to Daryl Mather, an approach for asset-intensive sectors whose time has come. 'I think we are really seeing a dramatic change in the landscape of asset management. We've got a lot more capability than we used to have in terms of methodology, technology, etc. Not only that, but the area itself is becoming vastly more important. We're at point now – you see it all over the world – where the whole focus on the way capital expenditure is funded has become a lot more difficult.

There is increasing pressure on reducing operating expenditure, and we've got to a situation whereby a lot of the easy benefits have gone – depending on what industry you are talking about. The large savings have been made, so there's really a need to look in other areas, to look at more sophisticated methods of developing, implementing and performing asset management.'

Alongside this Mather notes the developing area of corporate risk management. 'I think that's an area also where we are seeing dramatic shifts in thinking around risk, particularly the risk of safety issues.'

It in this context that Mather has authored a book, 'The maintenance scorecard: creating strategic advantage' which he says 'basically talks about asset management as a whole, in terms of developing the area as one where we can get further economic value from the physical asset base and developing the area of corporate risk management.'

Mather is senior asset management consultant with AMT-SYBEX Ltd and has worked in over 20 countries and in the majority of industrial sectors, including the rail industry in Spain and the water industry in the UK. It is from such a perspective that he can see how the general pressures can be manifested in different sectors. 'Asset management as a corporate discipline is definitely moving forward,' he says. Some examples of drivers for this around the world include the US electricity blackouts in August 2003 driving reliability improvements in electricity in the States, pressures in the mining industry driving down capitalization, and the regulatory framework for water in the UK driving increased efficiencies in capital and operating expenditure. 'Around the world we are seeing a massive drive towards smarter ways of doing things – more sophisticated ways of getting value from the assets,' says Mather.

All of this means progress is being made outside of what were the traditional strongholds. 'Geographically, until now you could really see places like South Africa and Australia being pockets of excellence, and I don't say that merely because I'm an Australian. I think [having] industrial economies coupled with isolated environments meant people had to improvise and [this] really gave a focus to reliability and really getting the most out of things... So, up to recent times you've definitely seen those two countries as being relatively well developed. Now, some of what is going on in the UK is particularly impressive, and I think we are really tending towards a fourth generation thinking in asset management.

> ***Around the world we are seeing a massive drive towards smarter ways of doing things.***

Alongside these country-based experiences, Mather identifies experiences from different sectors that form the approaches he says leading-edge companies are adopting. 'If you look at the way that proactive risk management is managed in the rail industry, it's quite impressive. If you look at the way that risk in general is managed in oil and gas, it is relatively impressive. I would say the airline industry and the medical industries are exceptionally good in terms of performance reliability.' He also cites the condition monitoring practices in the electricity industry, and highlights the benefits demonstrated by the automation and data management in the manufacturing industry in the States which, he says, is 'mainly because it is under such pressure now'.

Such are the pressures and the general awareness of possible solutions that Mather feels there are no great barriers to gaining acceptance of the need to take asset management-based approaches. The challenges lie in implementation. 'The barriers to be quite frank are less than you would think. Knowing that more economic value is needed and better management of risk is required is no surprise at all to asset managers or asset-centric organisations. The challenge for them really, and it's really not a welcome challenge... the challenge is obviously working out how. The barrier, the challenge, is getting people who may not be of an asset management background to understand that there are more sophisticated means of tying this all together.'

Mather's book is obviously intended as a contribution on this front. It it he explains that, currently, most organizations are either working with or planning to work with, large-scale enterprise asset management or enterprise resource planning systems for driving inefficiencies out of their administration functions. Yet many of these systems are yet to realize the full benefits offered by such data capturing and analysing systems. When managed correctly asset data can power decisions such as how and when to extend asset life, determining the return on investment of asset acquisitions or interchanges,

➤ *cont:*

➤ analysing whether risk profiles are being adequately managed, and determining which assets are not being maintained or operated in a manner that supports the minimum whole-of-life cost profiles.

The book explains that such an approach needs to be supported by asset knowledge, which is contained within the experience of the workforce, the manufacturers, and similar equipment users throughout the industry. This presents the problem of knowledge capture. This requires a comprehensive approach that must enable people to contribute their experience, understanding, judgment, and suggestions in a structured and controlled manner. If structured correctly, a knowledge gathering process could become a valuable improvement initiative in itself. Within modern asset management there are a range of initiatives that support this form of knowledge collection. Methods such as reliability-centered maintenance, whole-of-life progression management, problem elimination logic and technical change management processes are all examples of collaborative working practices.

I think without a doubt there is a need for further standardisation.

Mather highlights areas in which there have been particularly useful developments: proactive methods of measuring risk exposure and proactive measures of implementing risk management. He also draws attention to the method in the book of achieving business control of day to day actions though performance indicators and key performance indicators.

On this basis, organisations have much experience to draw upon when taking a strategic approach to asset management. But a problem they face is in knowing just what advice to follow. Is there, then, the potential for standardisation? 'I think without a doubt there is a need for further standardisation,' says Mather. 'Without doubt standardisation is a good thing – good for industry in terms of leading practice and method selection. It also reduces the likelihood of getting it wrong.'

But he does add a note of caution. 'We are talking about a very, very big area here, so one of the dangers that we get into when we start standardising asset management as a discipline is that it can be potentially restrictive. The discipline is evolving rapidly. Not only that but the whole thing may not be suitable for everybody.' Because of this he suggests a better approach is to standardise elements of the discipline, using standards as a means of focusing on potential minimum criteria as component methods within asset management. Here is points to the International Society of Automotive Engineers' Standard JA1011 'Evaluation criteria for reliability-centred maintenance (RCM) processes' as an example. Such an approach would, he says, give 'flexibility while still maintaining that drive towards leading practice and the clarity of vision there'. ●

Daryl Mather is Senior Asset Management Consultant for AMT-SYBEX Ltd. His book, 'The maintenance scorecard: creating strategic advantage', (Industrial Press, ISBN 0831131810) is available at www.industrialpress.com.

New CIS for Alaskan utility

Indus International Inc, a leading Service Delivery Management (SDM) solution provider, have announced the rollout of a new Indus SDM solution at Anchorage Water & Wastewater Utility (AWWU), successfully replacing the utility's antiquated mainframe-based system with a highly accessible and flexible Web-based application for customer service and billing.

Alaska's largest water and wastewater utility, AWWU, has installed the new Indus customer information system (CIS) as part of an aggressive initiative to provide world-class customer service to its 55,000 customers. AWWU recognised the urgent need to install newer, more advanced technology that is less expensive to maintain and more flexible in order to adapt to evolving technology and customer expectations. The new Indus solution met these goals by providing a Web-based platform that provides customer service account representatives with efficient access to diverse customer information. Among other features, it offers and manages 'customer choice' options in deregulated utility areas, enrolling customers and automatically handling provisioning, pricing and contract renewals.

The solution also provides streamlined integration to key third-party systems such as interactive voice recognition and online service options for customers.

'A new era has begun at AWWU,' said John J McAleenan Jr, manager of AWWU's Customer Service Division. 'Indus' comprehensive CIS provides highly advanced billing capabilities, and it goes 'beyond the bill' to help us manage all aspects of customer service, providing all the processes and information we need to quickly respond to our customers' needs.' ●

Black & Veatch announce IT services partnership with EDS

Global engineering, consulting and construction company Black & Veatch have announced a seven-year strategic relationship with EDS, a leading global technology services company. The agreement provides Black & Veatch with expanded global IT capabilities, which will supply the IT foundation needed to help meet the growing international demand for energy, water, information and government services.

'This partnership creates a strategic fit that enhances our ability to meet our clients' needs in a more robust manner, at the same time it provides us with expanded global IT capabilities and further strengthens our ability to focus on our core business,' said Len C. Rodman, Chairman, President and CEO of Black & Veatch.

'EDS' global IT and industry capabilities and proven operational excellence complement our business attributes, provide us with a reliable and cost-effective solution, and enables BV Solutions Group to continue providing technology solutions to its clients.'

EDS will manage the IT infrastructure for Black & Veatch's worldwide enterprise including desktops, servers, communication networks and software applications. EDS Agility Alliance partners will provide their products and ongoing technology development support.

'EDS has committed to go beyond IT in delivering services to Black & Veatch. We will use our experienced industry, technology and business development resources worldwide to help build upon its engineering, procurement and construction processes,' said EDS US Energy Industry Leader Mike O'Hair. 'Like Black & Veatch, we equally value our people, processes and culture, and look forward to welcoming our new team members.'

The new agreement also calls for EDS to manage applications development and maintenance, project support, desktop computers, and provide helpdesk and user support for desktops and networks for more than 7000 employees in approximately 90 locations worldwide. EDS will also be responsible for the related asset management, procurement and third party provider relationships.

As part of the agreement, EDS will acquire selected assets and accounts of BV Solutions Group (BVSG), a subsidiary of Black & Veatch. EDS will continue to support and build upon BVSG services, which deliver IT services to clients throughout the United States.

Approximately 280 Black & Veatch and BVSG professionals will join EDS and complement its growing Utilities Industry Group as well as continue to build a scalable global IT infrastructure at Black & Veatch.

With 150-plus utility clients in 17 countries, EDS works with the energy, water, chemical, oil and gas and telecommunications sectors around the world. For more than 30 years, EDS has helped utility clients improve operations through advanced technology and business processes. ●

Asset management worldwide: the lessons learned

This article tries to find answers to the question asked by asset managers and owners around the world: how can we drive logical, sustainable, cost effective asset management across my organisation to derive the benefits available through advanced asset management techniques? To achieve best value asset service delivery at the lowest sustainable triple bottom line cost for present and future generations of customers and stakeholders.

In 1999, after completing the initial draft of the International infrastructure management manual (IIMM) I was extremely concerned that although Australia and New Zealand were leading the world in this area, the performance in both countries' states, regional areas and across all municipal agencies varied considerably.

GHD's Asset Management Group had helped over 200 organisations to start down the path of AM improvement in both countries and throughout SE Asia. However, what we found was that although many clients were adopting the advanced practices and deriving significant benefits, this performance was not uniform across the entire group and many were deriving less than 40% of the benefits others derived, while many had lost their way altogether. We decided we needed to know why?

Although our approach, processes and tools had improved significantly over the years we were able to complete hindsight assessments that enabled us to compare them with the more modern approaches being undertaken at this time.

This article looks at the steps that have been taken to address these issues and try to make asset management and integral part of all municipal activities.

Roger Byrne
GHD, Australia

At the GHD Asset Management Group, we started by undertaking a survey of many of our clients in order to review: the progress they had made; the benefits they believed they had derived; the issues that had contributed to improved performance in this area; the issues that had detracted from improved performance; items that would help in driving cost effective improvements in asset management.

The results of this survey were a bit of a shock to us, with the key conclusions being:

- many clients who have rated highly on our TEAMQF quality rating (85) had dropped back, losing over 75% of their gains made – to their scores prior to commencing asset management – for example, (50);
- the changes that had been evident five years after they started were now lost and they reported continuous improvement activities were not practised;
- data on asset condition, performance and cost was no longer being maintained and in several organisations the data had been lost or discarded;
- some clients believed they had derived significant benefits from the improvement that had been implemented, while other senior management teams didn't even know what we were talking about;
- clients expressed concern over their ability to decide how to set the best appropriate practice for their organisation and the assets to which it should be applied;
- they felt that the processes being promoted by the industry organisations and consultants like GHD were incapable of being tailored to their specific problems and needs;
- they were unable to effectively monitor the progress they were making (or decline);
- they found the benefits difficult to quantify and although they knew asset management was good it didn't actually save money against existing budgets;
- they were unable to decide what was really important: what to do next; what would represent the best 'bang for their buck';
- they were unable to keep the council and senior management focussed on the program as it went on for too long. Other issues arise and distract the senior management and councillors from what the staff see as core activities – the delivery of community services using infrastructure-rich programmes;
- inadequate budget and application of resources means that most AM improvement programmes never meet their timelines or achieve their original objectives;
- organisations that had purchased all the original AM Manuals

(Australian/ New Zealand and the IIMM) and full sets of GHD AM manuals could not find any of them. It was presumed that departing staff had taken them with them.

Conclusions

The key conclusions reached by our group of clients around the world were:

- the life cycle processes of sound asset management are now becoming a science and are common world wide for similar services;
- the specific best practice techniques applicable to individual asset types are also well known (for instance condition assessment, maintenance, valuation, rehabilitation and so on);
- the data we need and the information systems required to store and manipulate the data are meeting the life cycle asset management needs;
- we had not successfully addressed the organisational and group/individual change management issues that ensure that the processes and practices were bedded into the organisation and set in stone;
- the range of implementation success was significant, ranging from minus 25% to an over 200% increase, thereby resulting in an equivalent range of benefits being achieved;
- the waste of effort and investment in the poor performers was considered significant (a GHD view).

Causes of poor performance

The principal causes to the key problems identified were seen to be:

- no clear ISO-based quality framework existed to enable organisations to fully understand where they are currently and what they need to do to improve;
- organisations allowed most asset management activities to be completed by their consultants and never really took ownership of the results;
- inadequate training was undertaken to raise the awareness and understanding of AM across the whole organisation (all business units) and vertically down through the organisation from its elected members to management and to the actual workforce carrying out the activities, whether contractors or in house staff;
- the way the organisation communicates its messages to all stakeholders, particularly its customers and ratepayers, and the community at large;
- difficulty in quantifying the benefits that have been derived by others and being able to apply them to their organisation, and more importantly convince the elected members that they are real and tangible.

Sustainable AM – a best practice model

The outcomes of this survey resulted in the development of a sustainable best practice model that was the subject of a paper to the Institute of Public Works Engineering Australia (IPWEA) and Ingenium in 2003. The model can be applied to a single business, an industry (municipal councils) or even whole of state or federal jurisdiction. The key findings of that work were that there was:

- a need for a vision of best appropriate practice: this paints a clear picture of what a best appropriate practice organisation looks like, what it does to manage its infrastructure, and how it manages the different service programmes across the council;
- a need to set minimum standards – establish a minimum level of asset management that is necessary to manage the type and value of infrastructure involved: below that the assets are not being managed, and negligence could be involved. Letting assets decline is not a crime, not transparently reporting it is;
- a need to monitor performance against the best appropriate practice model outlined in the vision above and report on this. This needs some form of regulation, whether self-assessment or external validated audits is up for debate, though it is easy to prove that selective external audits improve the quality substantially;
- a need to implement a continuous improvement programme regime. Based on the above assessment, the organisation must continuously improve to meet best appropriate practice. However, it should be realised that the world of advanced asset management is not standing still. It is moving ahead at an incredible rate and all organisations need to improve to just keep pace.

The International Infrastructure Management Manual (IIMM) covers many of these issues, and the New Zealand Audit framework has covered other areas but the missing pieces are requirements, in order to:

- allow organisations to assess themselves against a best practice ISO quality framework;
- establish a methodology that enables each organisation to determine its own best appropriate practice level;
- improve the ability of organisations to estimate the benefits that will be derived by making these improvements;
- enable organisations to tailor their improvement programme to suit themselves, their customers' needs and their asset portfolios and decide:
- how far to go – where to set their best appropriate practice;
- what order to do them in – the priority for their improvements;
- how fast to get there – to match the budget limitations they may have;
- how to achieve clear ownership of the programme by all levels of the organisation and council;
- how to ensure skills transfer to the organisation's staff. We need a better way to train existing staff - particularly new staff - within a good best practice framework;
- how to begin accreditation for staff with asset management responsibilities as well as associated training programmes and education courses with full national (and international) accreditation;
- how to achieve better national and international coordination to ensure that there is no duplication of effort and ensure that best appropriate practices are disseminated to all practitioners as quickly as possible.

What is being done to try and overcome these issues?

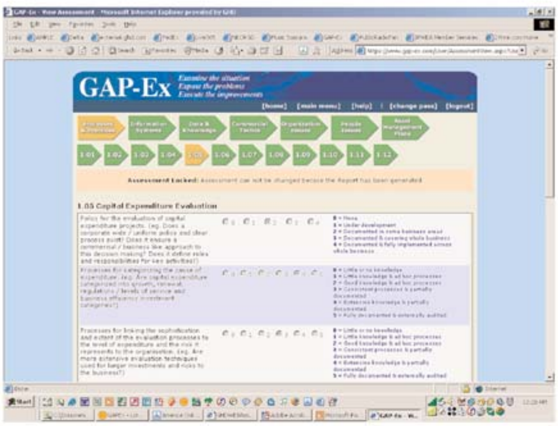
Throughout the world there are developments being undertaken or in development that constitutes a movement towards this model. I list these for your information. They do not include all that is being done, but from my perspective constitute some real great steps.

The MAV study (Victoria)

For the first time anywhere in the world the Municipal Association of Victoria undertook a full input/ process-driven benchmark of all municipalities (98% in reality, as two refused for a year).

This gap analysis process benchmarking doesn't try to assess the quality of service and the cost of service (output benchmarking), which is impossible to normalise. But it looks at the quality with which organisations

Figure 1
The GAP-EX tool, an ISO based quality framework that enables standardised benchmarking.



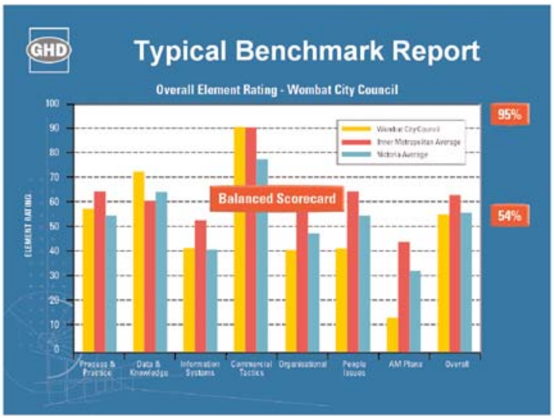


Figure 2
Typical benchmark report from the GHD study tour.

manage their infrastructure service delivery. This approach used the Beta prototype of the Gap Ex tool, which is an ISO-based quality framework now being used across the world. This study enabled us to analyse and verify the actual quality with which these councils were managing their infrastructure asset portfolio.

The MAV then instigated a 'step-by-step' programme to help all councils to drive improvements based on the priorities identified by the gap analysis. This study gave us a baseline for 2001 and will enable us to monitor the gains or losses made over the ensuing four years and monitor the effectiveness of the step-by-step programmes implemented.

Soon data will be available to enable benchmarking to be completed against like organisations from all over the world based on the same quality framework.

Looking at worldwide performance
By this stage in our development GHD had undertaken asset management projects in many parts of the world but had not studied the entire jurisdictions in any logical way. In 2001 we undertook a study tour that collected sufficient data to construct a picture of worldwide practice.

We equated this survey with the best practice picture we had established for sustainability as reported in our paper to the 2003 Ingenium conference on Achieving sustainable infrastructure asset management. The type of results derived are shown in Figure 2.

Getting a broader vision - AMQI website
This Penny Burns-created website represents a wonderful source of data and information on all aspects of asset management from a broad raft of participants. This approach gives users a broader range of experiences than is generally provided by industry-based web sites and Penny's unique way of presenting the information also helps sell the benefits and the desire to adopt these different approaches.

Awareness raising for non-experts
Getting our management and elected members to better understand the benefits of advanced asset management has been achieved by the NAMS.nz group with their Ride of your life video and training programme. Although they have a new version, it doesn't hit the mark like the original one, which we continue to recommend throughout the world.

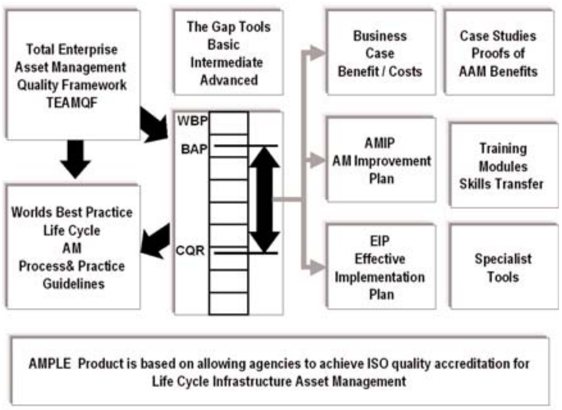
Useful manuals and guidelines
Valuable materials are available in a variety of locations:

- the International infrastructure management manual (IIMM) Australia and New Zealand, which has editions being completed in other jurisdictions.
- AM standards – UK. The Institute for Asset Management has worked with the Standards Association to produce PAS 55. A great guide to the principles of asset management.
- Canadian Department of Infrastructure guides.
- the AMPLE project – web-based learning experience.

This latter project attempts to address all the issues raised in these surveys and the feedback from clients. It is a web based asset management programme learning environment (AMPLE) that includes the following major modules:

- the TEAMQF Quality Framework – TEAM stands for Total Enterprise Asset Management and draws attention to the need for all organisations to work as a single team and cover all assets in their portfolio or system.
- best practice asset management processes covering the entire life cycle, with direct relationship to the TEAM quality framework listed above.
- best practice – practices related to each asset type or group covering all municipal service programmes
- the gap analysis tools – these have three levels that enable users to understand their current quality rating (CQR), and compare and benchmark this with a vast database of similar clients, as well as setting improvement targets for both short term and long term objectives.
- the benefits module, which enables organisations to determine the benefit that will be derived in driving improvement. This has three main parts.
- the asset management improvement planning module, which allows companies to determine the most appropriate improvement programme to deliver the best cost-effective solutions while moving them to becoming a sustainable asset management organisation. It will provide a road map for the journey, but the organisation will control how far, how fast, and how much it spends on it.
- the effective implementation module, which covers all the issues that ensure successful implementations including planning, cultural change and organisational support issues.
- the training or learning environment modules, which enable staff at all levels in the asset management programme to learn using a web based curriculum.

Figure 3
Programmes incorporated in the AMPLE tool.



These programmes can be developed for individual industries and businesses, covering all issues that need to be addressed. This is best shown in Figure 3.

Linking this to education and training

The educational aspects of asset management are not being effectively addressed. Industry associations and other commercial training agencies are undertaking nominal training activities that are driven as much by commercial profits as by educational aspects. We need to not only face the skills needed but also enable ourselves to replace the baby boomers who have held high positions in local government for many years.

We have not considered the key issues of identifying and understanding the skill sets required, developing the necessary curricula, and then driving national training through the normal education systems. Without these, we will never make the changes required. The AM positions, their roles and responsibilities need to be better developed and an educational qualification or accreditation or reward system needs to be developed.

We also need to address the ways in which we train existing staff at all levels. We have an enormous backlog, and a self-driven distance learning arrangement, so the web is the best way to achieve this.

In terms of educating our future

industry leaders we need AM to be tied into the needs of the individual service industries and the key elements required for good succession planning. Figure 4 shows how AM, IT and data will feature in all future municipal management programmes.

The National AM committees

When I began working in AM we had no forum for debating these issues. Australia led the way with the National Asset Management Steering (NAMS) committee formed in 1991/92, which was responsible for completing the initial Australian manual (1993). This was closely followed by the New Zealand equivalent in 1995.

Now we have a network of similar bodies developing across the world. We all face identical challenges – delivering best value (lowest sustainable TBL cost) infrastructure services to our present and future generations of customers. Our problems are identical. The best appropriate life cycle processes are the same for all of us. The best practices for each asset type are the same. We now recognise that the differences that need to be accommodated are:

- the current status of the organisation in terms of its AM management quality (CQR);
- the size, value and condition or performance of its asset portfolios;
- the expectations of its customers and their willingness and ability to pay for the levels of service required;
- the regulatory framework under which each body operates;
- the financial ability of our organisations to undertake this work and drive their AM improvement programmes.

We believe that the latest approaches being developed do enable all these issues to be addressed and applied via a 'one world' model that can be tailored to suit each individual agency within the greater jurisdictions:

- a single agency – such as a water utility;
- a combined agency – such as a municipality that delivers all typical services;
- a state wide approach;
- a federal or national approach.

Overall conclusions

The world of infrastructure asset management is shrinking. The rest of the world is recognising the benefits identified first fully recognised in Australia and New Zealand.

They have identified that sound and sustainable asset management significantly impacts on our communities and national standards and cost of living, and we are learning how to sell this perspective to all stakeholders.

We have moved advanced life cycle asset management from a glorified art form to a pure science. We have begun to better understand our weaknesses and have learned from our failures and have addressed these in the approaches and tools that have been and are being developed.

We have integrated AM into the other key global issues of sustainability, risk management, triple bottom line reporting covering economics, social and environmental. The broader AM community is developing products that will expand our vision and capability of performing advanced asset management in a way we have never dreamed of before.

We just need to collaborate better, work better as one AM world, co-ordinate the research and development so we don't duplicate our efforts, and modify this one-world model to suit our jurisdictions.

Where to from here?

We have led the world in helping to show the benefits of advanced asset management. The rest of the world has resources that will drive the development of these products far faster and far more effectively than we could ever consider. All AM practitioners will benefit from these developments.

Our NAMS efforts need to recognise this, develop a niche where we dominate and make this our contribution, and draw off the best pieces from around the world to apply to our needs. As individual asset managers, we must learn from these lessons and failures, and make sure we deliver sustainable AM improvements to organisations. We must continue to learn and apply those processes and practices that are justified for each organisation.

We must continue to contribute to the pool of knowledge with lessons learned and what has been found to be most successful. We must participate, contribute, and encourage managers, peers and staff. ●

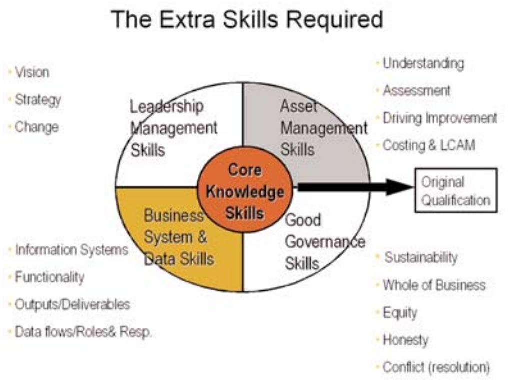


Figure 4
Asset management, IT and data skills required in future municipal management programmes.

Acknowledgements

I would like to acknowledge the role clients, colleagues and other dedicated people in the broader asset management community have played in helpng me get to this point in my career. I would also like to acknowledge the key role those clients and industry association leaders (The NAMS Committees) have played. It has been through our clients' courage and innovation that many of these ideas and approaches have been conceived, developed and taken through to successful outcomes. I and GHD are proud to have partnered these clients in this process and sincerely thank them for their part in this progression.

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NAMS Australia is an initiative of the IPWEA www.ipwea.org.au/nams

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Have asset management models compromised effective asset maintenance?

Different asset management philosophies and models were developed in the 1990s. But the basic approach to their application has been the same in different market sectors. This approach may provide a long-term focus for managing assets. However, it often fails to recognise the crucial relationship between capital investment associated with maintenance on the one hand, and operational maintenance costs on the other.

This paper asks:

- How should maintenance be dealt with as part of an asset management model?
- What is the relationship between operating costs and capital investment that maximises financial benefits whilst optimising asset performance?

Mike Levery
MCL Consultancy Ltd
UK

Outsourcing of maintenance grew significantly in the 1990s. Facilities management and construction companies started to take on asset maintenance contracts. At the same time asset management developed as a philosophy for the client organisations, particularly those managing infrastructure assets. For the first time in many organisations, the subject of maintenance became a board-room topic. The attractiveness of delivering immediate financial benefits through outsourcing maintenance now needed to be matched by an understanding of how assets perform.

Asset Management models help clarify the roles and responsibilities associated with firstly owning, secondly investing in, and thirdly operating and maintaining assets.

A typical hierarchical asset management model is shown in Figure 1. This model sets out the four core roles that have responsibility for the assets, and the relationships between them.

The Asset Owner is responsible for securing the operational expenditure requirements (OPEX) and both capital maintenance and strategic investment requirements (CAPEX) so that the Asset Manager can deliver the long-term performance required by the Asset Owner. Capital maintenance includes large repairs outside the scope of operational expenditure and minor improvement work.

The Asset Manager must set the necessary operational performance criteria so that the Asset Operator has performance objectives and targets within the OPEX allocation. The Asset Manager is also responsible for delivering the necessary CAPEX investment to meet the long term performance objectives.

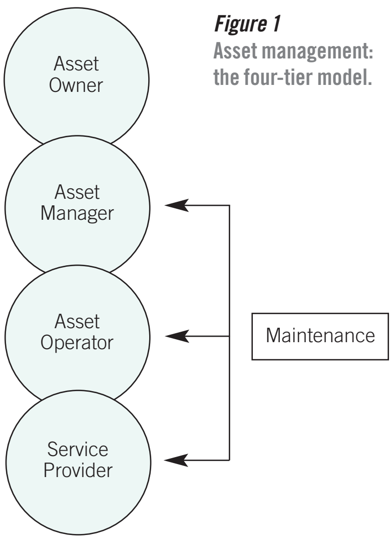


Figure 1
Asset management: the four-tier model.

The Asset Operator must organise his resources to meet the operational performance objectives and targets. These will apply both to the Operator's activities and to work carried out on the assets delivered by Service Providers.

The Service Provider delivers services to the Asset Operator through vehicles such as service level agreements (SLA's) or other forms of contractual arrangements.

Maintenance and Asset Management

When organisations try to fit the maintenance activity into the Asset Management Model, they are usually determining whether it should be performed by the Asset Operator or by a Service Provider. There is a general failure to recognise that the maintenance activity is also a fundamental element of the Asset Manager's responsibility and therefore bridges three of the core elements of the Four-Tier Model, namely: Asset Manager, Asset Operator and Service Provider.

Inevitably the following questions then arise:

- Who is accountable for maintenance? Is it the Asset Manager or the Asset Operator?
- Who should hold the maintenance budget?
- Who should manage Capital Maintenance?

Many organisations fail to grasp these questions. Instead they treat maintenance simply as an OPEX activity delivered as a service to the Asset Operator. The critical part played by Capital Maintenance in improving asset performance throughout the predicted life of the asset is thereby overlooked or ignored.

In some operations it is wholly appropriate that maintenance is a pure service provision. Where the risk for asset performance sits wholly with the Asset Operator, it is the operator's responsibility to determine the maintenance regime. Typically, these arrangements are appropriate where the quality of operation of the asset is crucial to asset performance and longevity. Elsewhere, the assets are effectively passive; there is no direct operational input that affects the performance of assets. Asset performance is wholly dependant on how well the assets are maintained both with operational expenditure and capital maintenance funding.

Take the railways as an example: is the performance of the infrastructure assets down to how well they are operated or how well they are maintained? Most of the railway infrastructure - including the network's bridges and structures, the rail itself including the points, and the signalling systems - is effectively passive. Operational decision-making has little influence on the performance of the assets. How well the network is maintained is the main determinant of performance.

Remodelling Asset Management

The Four-Tier Asset Management Model fails to represent maintenance and presents a picture of the Asset Manager as the custodian of the assets. Those responsible for running the assets are merely depicted as the Asset Operators, usually with ongoing short term operational performance objectives and targets to meet. These operational targets are often in conflict with maintenance needs, and generally give the operator little or no interest in the long term resilience of the assets and their overall performance.

How often, no matter what sector of industry you may work in, do production/operations show an active interest in the long-term benefits of planned preventative maintenance? There still is, in many sectors, an "if it ain't broke don't fix it" mentality borne of a drive to maximise productive output. The Four-Tier Asset Management Model reinforces the thinking of the Asset Operator to continue operation without regard to the consequences of failure, as ownership of maintenance is not their responsibility.

The only way to get the production/operations function to start taking ownership of the long-term performance of the assets is to remove the Asset Manager role and integrate it into the production/operations function. Production/operations then have full responsibility not just for the ongoing performance of the assets but for the whole life performance. No longer should they be judged simply on performance and financial targets associated with OPEX; they must now take a longer term view matching performance criteria with Capital Maintenance investment. This approach ensures that proactive initiatives such as planned preventative maintenance are taken on board by production/operations functions to deliver longer term operational performance and cost benefits.

The asset management model must now be redesigned to reflect this changing role. There is no longer a requirement for a separate role of Asset Operator. In effect, the production/operations function is taking on the role of the Asset Manager and so becomes the custodian of the assets throughout their predicted life. Further, they are responsible for managing all externally delivered activities - usually those related to maintenance - that impact on the assets. Their service provision arrangements must reflect the risk and accountability that the Service Providers impart when working on the assets.

The remainder of the Asset Manager's responsibility; namely the development of existing assets beyond their predicted life, together with new investment, forms a separate function reporting to the Asset Owner. Asset Development and Investment focuses on delivery of capital projects, whether for infrastructure enhancement or renewal, or new build.

The result is the Infrastructure Management Model as shown in Figure 2.

Financial Approach to Maintenance

The financial distinction between OPEX and CAPEX has driven how organisations structure themselves as well as how they present their accounts. Investment is viewed as financing new requirements and not as a vital requirement for cost-effective operation of existing assets. Therefore, although maintenance has a foot in both camps, it is usually placed in the 'OPEX' part of the organisation. The result? – the CAPEX element of maintenance gets neglected. CAPEX, however, however has a major impact on long-term OPEX – a point which tends to be overlooked by financial functions.

...it is no longer appropriate to squeeze the OPEX funds to meet short-term shareholder expectations and expect CAPEX to bail out when there are crisis...

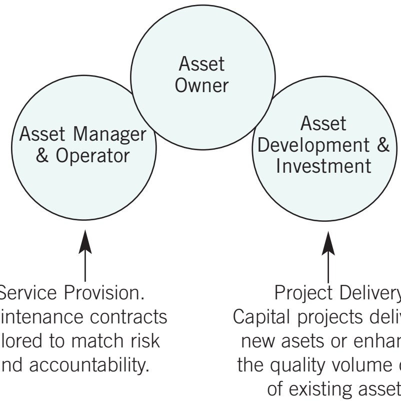


Figure 2 Asset management: the infrastructure management model.

The need to drive down OPEX continuously, to deliver 'efficiencies' causes many organisations to bend their investment rules so as to appear to achieve their OPEX objectives. I have found that in a number of infrastructure organisations a significant and growing proportion of CAPEX is in reality the capitalisation of unpredicted, costly failures. What is really OPEX appears in the accounts as CAPEX. In some market sectors, and particularly in regulated businesses, there is a drive to maximise potential CAPEX in order to create sufficient resources to cope with unpredicted operating failure.

I have worked with a number of organisations which are struggling to deliver their predicted capital programme because of pressures on the CAPEX budget arising from unpredicted failures. It is now clear to me that a much more strategic approach needs to be taken to the financial management of existing assets. It is no longer appropriate to squeeze the OPEX funds to meet short-term shareholder expectations and expect CAPEX to bail out when there are crises.

I propose the following as key features of an improved Infrastructure Management approach:

- Those responsible for managing the assets on a day to day basis should also be responsible for the long term resilience of the assets within their predicted life.
- Appropriate funding must be provided in order that CAPEX is targeted for maintenance investment purposes. Planned and strategic shut down of plant to carry out refurbishment is a CAPEX activity and not routine OPEX.
- CAPEX should be separated out into capital maintenance (CAPMAINT) and strategic

investment (CAPSTRAT), with CAPMAINT being managed and controlled by the production/operations function alongside their OPEX budget. The key components of CAPMAINT and CAPSTRAT are shown in Figure 3.

Further explanation follows using the water industry's water supply and sewerage networks as examples:

CAPMAINT is made up of two key elements:

1) Failure capitalisation involving the repair/replacement of failed assets falling outside the OPEX maintenance criteria. These are generally unpredictable failures requiring significant expenditure that has not been budgeted for. A capital block allocation is made to cover for such eventualities usually based on historical experience. Typical CAPMAINT expenditure would involve repairs to a burst strategic water main or repairing a collapsed trunk sewer. The cost of such repairs would usually be a five figure sum.

2) Minor capital repair/improvement involving repair/replacement of failing assets outside the OPEX maintenance criteria. Planned preventative maintenance is the key source for identifying this form of investment together with the necessary routine refurbishments associated with planned shut down activities. Typical minor capital expenditure would involve replacing a section of water main prone to excessive leakage, or a section of sewer which frequently blocks due to a partial collapse. Again the cost of repairs would be in the order of a five figure sum.

CAPSTRAT is also made up of two key elements:

1) Capital infrastructure involving planned investment to extend existing assets beyond their predicted life. The water industry spends significant sums on rehabilitation of its water supply and sewerage networks. This includes major relining or replacement – for example of trunk water mains, trunk sewers, water supply zones, or sewer catchment networks. Capital infrastructure projects are generally of the order of six figure sums, with some projects running into the millions.

2) Capital enhancement involving new development to achieve quality and/or volume demands. The first ten years of water privatisation saw significant investment in improved water treatment processes to achieve high quality standards in the supply of potable water. Sewage treatment facilities were upgraded where they existed and new facilities built, particularly on coastal outfalls to meet EU bathing water standards. The majority of these schemes were multi-million pound civil and mechanical/electrical projects.

Any planned expenditure of CAPMAINT should demonstrate through cost benefit analysis the impact on the OPEX budget as a result of this investment, with the necessary adjustments to OPEX for future years. In this way reductions in future OPEX are carried out in a structured way rather than being driven by fixed financial objectives. This naturally leads to a focus on asset performance, planned investment to resolve issues and reduced OPEX as an outcome.

The Future

Asset Management has made its first tentative steps into promoting the needs of the assets as the foundations underpinning an organisation's business model, but has made mistakes in applying generic business models in all situations.

There is, in my view, a case for developing a specific business model for infrastructure management organisations whether they be rail, water, gas or electricity. The drivers and principles are similar. There has to be a shift from the OPEX/CAPEX mentality to (OPEX + CAPMAINT)/CAPSTRAT and the development of the Infrastructure Management Business Model which will deliver a much more robust and long-term solution to the operation and maintenance of physical assets.

Can the financial systems cope with such a change? If financial markets can provide investment funding for 'not for profit' mutual organisations then Plcs should be able to determine shareholder returns based on a mixed OPEX and CAPMAINT approach to running their infrastructure assets.

Summary

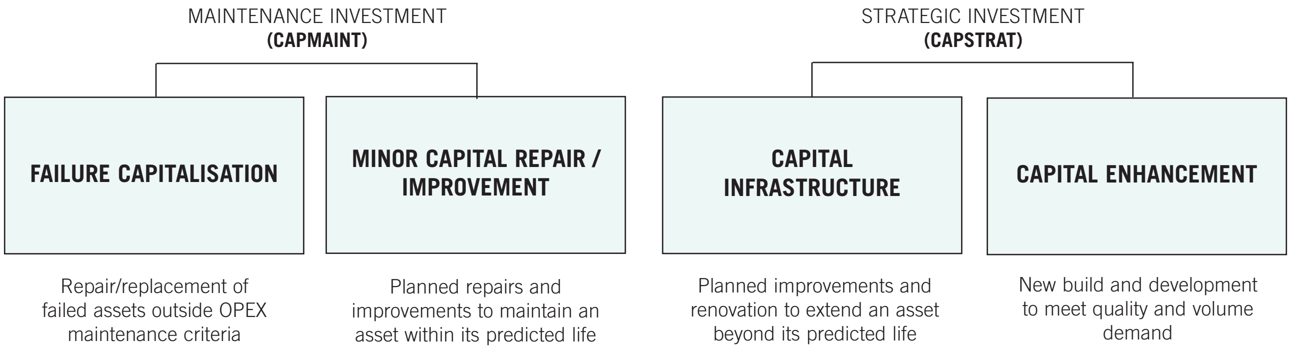
Regulated infrastructure organisations are attempting to apply long term thinking through asset management in a short term environment which continuously drives down operating costs. The maintenance activity is caught in the middle – expected to contribute OPEX benefit whilst achieving improved performance and reliability in the long-term.

Asset Management Models are often applied generically, but for companies managing infrastructure assets an Infrastructure Management Model is required that recognises the importance of the asset operations function in the long term management of infrastructure assets.

Infrastructure Management changes financial management from an OPEX/CAPEX relationship to (OPEX + CAPMAINT)/CAPSTRAT.

Building an infrastructure organisation based on the 'needs of the assets' is the key to ensuring the long term-viability of assets. Genuine reductions in OPEX and capitalised failure costs then become possible and profitable operation is secured for the future. ●

Figure 3
Allocating CAPEX funding.



Water main rehabilitation prioritisation: getting the data together for OWASA

The Orange Water and Sewer Authority (OWASA), in Orange County, North Carolina, is proactively prioritising mains in its 360-mile water system that may need to be replaced or rehabilitated (R&R). This paper describes the first phase of the project to create a dynamic water main R&R prioritisation model: data gap analysis and weighted service level criteria factors.

Baseline data was collected and input into OWASA's geodatabase, and Earth Tech assisted by populating specific fields such as date of installation, water quality concerns, number of breaks/leaks, and hydraulic performance. The final product will be an MS Access/ARCGIS model with detailed documentation.

Kilmeny J Stephens
Earth Tech
USA

OWASA serves the Chapel Hill area of Orange County. Encompassed in this service area are the town of Carrboro, the town of Chapel Hill, the western edge of the city of Durham, the University of North Carolina and the university hospital. The service area has a population of approximately 77,000.

The project approach for this analysis has been developed by Earth Tech, in conjunction with OWASA, and is specifically for OWASA's use with their system. OWASA has identified through master and capital improvement planning several water distribution projects that need to be undertaken over the next 15 years in order to proactively manage its water system and maintain its high level of service.

The water distribution rehabilitation and replacement project list encompasses several million dollars and several budget cycles. Therefore, it is important that OWASA understands the level of re-investment that is required and how to prioritise this. The purpose of the water main replacement and rehabilitation prioritisation project is to:

- provide guidelines on the annual re-investment required for water mains
- provide a dynamic model for the prioritisation of replacement/rehabilitation programme
- coordinate the replacement/rehabilitation programme with the existing capital improvement plan

The first step leading to the successful completion of this project involves analysing the level of data available – a data gap analysis. A certain amount of information is necessary for the analysis to be representative of the whole system. The ideal situation would be for the material, age and diameter of each water main to be known, without any uncertainty, and with such information as the breakage history of the pipe and other useful data.

To determine the prioritisation of replacement or rehabilitation of each pipe, it is necessary to know how critical it is in the system. The service level criteria and weighting factors used to identify system-critical pipes were developed in workshops with key OWASA management personnel. Some of the lessons learned during this project involve version/conversion issues, data transfer, and the level of detail necessary to complete objectives.

Data gap analysis

The data collected falls into the following categories:

- system inventory
- physical condition of water mains
- history of water main repairs
- water quality
- water main location
- water system characteristics
- soil condition
- planned construction activity

Figure 1 North Carolina location map.

Several different sources were reviewed for relevant data to input into the database. A summary of the information obtained and the associated source is provided in Table 1.

System inventory

A thorough and accurate system inventory is critical for completion of this project. The following information sources were used to create this: GIS geodatabase created by ITRE; water system grid sheets (1999 and 2000); as-built drawings (1926 to 2003); interviews with OWASA staff.

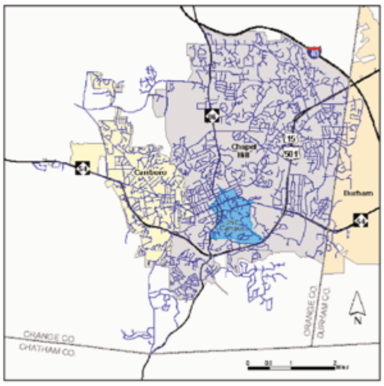


Figure 2 OWASA service area.

Institute for Transport Research and Education (ITRE)

ITRE completed the conversion of the paper version of the OWASA water system to a geodatabase. The conversion was undertaken by digitising the OWASA water system grid sheets, shown in Figure 3, into a geographical information system (GIS). The key attributes in the ITRE GIS database included the age, material, diameter and length of each pipe segment.

The ITRE database contained 17,764 water main segments, to a total length of 581.9km. The water main replacement/rehabilitation prioritisation analysis addresses the core distribution system and does not include water mains less than 100mm in diameter and/or pipe segments less than 8.3m in length, fire hydrant legs or services lines. These water mains were selected using queries in the GIS, both by attributes (for instance *select water lines ? 100mm*), and by location (for instance, *select water lines that intersect hydrants*). Once these segments were removed, 6,193 segments remained, a total of 514.5km (88% of the system, by length), for inclusion in the prioritisation database. Review of the key attribute data associated with these water main segments revealed that approximately 40% were missing the date of installation, and approximately 4% to 18% were missing water main diameter and material of construction, respectively.

Water system grid sheets

OWASA maintains over 150 paper grid sheets that illustrate the water main location, diameter, material of construction and date of installation for the water system, as shown in Figure 3. The grid sheets represent a compilation of historical system knowledge, developer as-built data, and OWASA system improvement data via hand-sketched maps. As the water system is modified, the grid sheets are updated.

Earth Tech created a set of 35 (11x17) sheets to use in completing the gaps in the ITRE data. ITRE data was colour-coded for size and material with the date of installation displayed adjacent to each pipe. Pipes without size, material or date information were highlighted on the plots, and compared to OWASA's year 2000 grid sheets to reduce the number of unknowns. By comparing the year 2000 grid sheets to the geodatabase created by ITRE (1999 version grid sheets) several areas were found that need updating or were incorrectly input.

Using this approach, incomplete data was reduced to less than 25% for date of installation and less than 1% for the diameter and material of construction for the 6,193 water main segments.

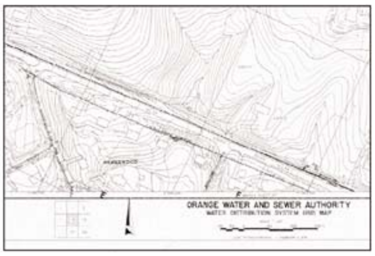


Figure 3
OWASA grid sheet.

Figure 4
Unknown data highlighted.

Staff interviews, as-builts and maps

The data gap was further reduced based on interviews with OWASA staff. Old water system field notebooks and as-built drawings were also reviewed. Additionally, Orange County tax maps and historical town of Chapel Hill insurance maps were reviewed to help in determining the physical parameters of date of installation, material of construction and diameter. Following this effort, the incomplete data was further reduced to 9.1km for date of installation (2%), 1.7km for the diameter (<1%) and 6.27km for the material of construction (1%).

System inventory confidence level

A level of confidence in terms of the accuracy of the data input in a prioritisation project is important. For each category of data, a confidence level was assigned to the data input. A three level system was used, with 1 being the most accurate and 2 or 3 indicating a lower level of confidence. If no confidence level integer exists or the value equals zero, the data was input by a source other than Earth Tech. Criteria for each of these confidence levels is described in Table 2.

Summary of system inventory data

System inventory data relating to material and diameter were not as subjective or incomplete as date of installation. Therefore a confidence level value was not stored in the prioritisation database for these factors. The data stored in the prioritisation database for each system inventory

Table 1
Data description and information source.

Category	Parameter Description	Source
System inventory	water main diameter water main material water main age length of water main segments	ITRE, grid sheets, as-built drawings, tax maps
Physical condition	internal corrosion external corrosion tuberculation	Master plan, OWASA inspections
	theoretical 'C-factor'	WaterCAD
History of Repairs	Location and date of breaks and leaks	Trouble card spreadsheet, HiperPM database, Work order MS Access database
Water quality	location, type (colour, odour) and date of water quality complaints	Trouble card spreadsheet, HiperPM database, Work order MS Access database
Water system characteristics	measured static pressure measured dynamic presssue measured fire flow	Fire flow test reports
	theoretical Headloss per 1000 ft theoretical velocity	WaterCAD
	estimated static pressure	OWASA Topo & USGS Quads
Soil condition	pH resistivity chloride sulfate	Master plan field data
Planned construction activity	street resurfacing streetscape construction sidewalk construction	Town of Chapel Hill and Carrboro
	road construction	NCDOT, Div. 7, Dist. 1 office
	electric utility projects	Duke energy
	natural gas projects	Public Service Company of NC
	telephone and telegraph projects	Bell South, TWC, MCI, level 3

Confidence level	Description
0	Pipe segment or inventory attributes not populated or changed by Earth Tech
1	Highest level of confidence -a direct transfer of data from the grid sheet to the GIS maps or a confident transfer of information from OWASA Stafff to Earth Tech.
2	Direct transfer of one or more inventory attributes from grid sheets. However, an attribute may be missing and several pipes in the area have similar attributes. Installation date based on input from OWASA staff and other research. Accuracy of installation age: +/- 5 years.
3	Other scenarios that do not fit criteria above or the range of possible date of installation are outside of range established in confidence level 2

Table 2
System inventory confidence level descriptions.

category is summarised in Table 3.

Physical condition

The failure of a water main is directly related to its physical condition. Therefore, an indication of the physical condition of the water system is an important input to the prioritisation model. Unfortunately, due to a lack of extensive pipe core sampling data, direct information on the physical condition of OWASA's water distribution system is limited. The following were available information sources of relevant data that could provide indirect information on the physical condition of the water system:

- OWASA master plan and field inspections
- WaterCAD hydraulic model (comprehensive master plan, 1999)
- Pitometer water distribution system study (1992)

OWASA master plan and field inspections

During the preparation of the 1999 master plan 21 sites were selected for field inspection. OWASA staff conducted the field inspections during normal maintenance and repair duties. The field inspection records were input into the prioritisation database as points, and then the data joined to the closest pipe. The data input into the database consisted of an inspection record label (S01 through S21), and a binary value representing the presence or absence of internal corrosion, external corrosion and/or tuberculation.

The exact location for some of the field inspections was indeterminate, and was therefore approximated based upon description of address, pipe size and pipe material. Confidence levels were assigned to the field inspection data as shown in Table 4.

WaterCAD hydraulic model

OWASA provided a hydraulic model of the water system completed as part of the 1999 comprehensive master plan. The model is skeletonised, as shown in Figure 5, and as such only represents a portion of the critical water distribution system mains. The OWASA water system was modelled using WaterCAD software by Haestad Methods.

Earth Tech used the base model configuration to simulate flows and pressures under peak hourly water demand scenario to obtain the theoretical hydraulic condition of the water mains represented in the model.

In order to transfer the information from the WaterCAD hydraulic model to the GIS prioritisation database, an automatic spatial join was attempted, with limited success. A shapefile was created from the exported coordinates of the model pipes and nodes. The schematic nature of the WaterCAD model and close proximity of several parallel and adjacent pipe segments prevented a complete data transfer.

Instead, Earth Tech used the GIS to simultaneously display the two files, and individually selected water mains that represented the hydraulic model and transferred the data to these water mains in the prioritisation database. Pipe labels (as referenced in WaterCAD) and C-factor data were taken from the model, which consisted of 692 unique segments, and input on 541 pipes in the prioritisation database (representing 139 unique values).

The manual method of data transfer was more time consuming, and therefore it was decided to only use data that would be relevant in the analysis portion of the prioritisation model, that is, if the Hazen-Williams C-factor was less than 100, the data was transferred. This explains the relatively small number of values transferred, compared to the complete model. This same process was used to transfer information on headloss, velocity, flows and pressures.

The segments of the water distribution system where C-factor testing had been conducted during Pitometer's 1992 study and during the recently (December 2002) completed UNC-Chapel Hill water and sewer masterplan were input with unique confidence levels. This helps to quickly identify which c-factors within the OWASA system have actually been field verified.

WaterCAD data confidence level

Confidence levels were again assigned to the water pipes, based on the accuracy of the data. See Table 5.

Summary of physical parameter data

Information relating to the physical parameters of the system is available with an even spatial distribution across the water main system, on about 10% of the pipes. Table 6 summarises the confidence level of the physical parameters.

History of water main repairs

OWASA has used the following tools to track the history of water main repairs:

Description	Length of pipe in miles (Number of records)	Percent by length (Percent of records)	Confidence level by length (Confidence level by number of records)			
			0	1	2	3
Total ITRE segments	361.6 (17,764)	100% (100%)	10,558			
Prioritisation GIS Database (subset of ITRE data	319.7 (6193)	88% (35%)	4866	1366	660	35
Known date of installation data	314 (5901)	99% (97%)	67%	22%	10%	1%
Known material data	316 (5988)	98% (95%)	n/a	n/a	n/a	n/a
Known diameter data	318 (6093)	>99% (98%)	n/a	n/a	n/a	n/a

Table 3
System inventory data summary.

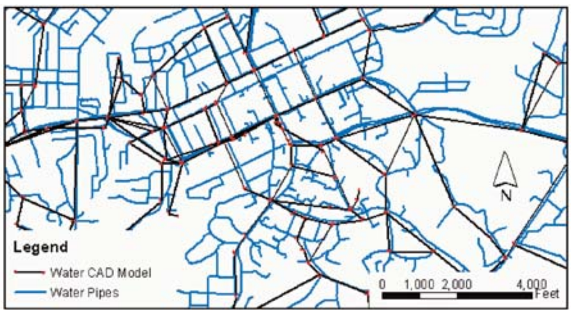


Figure 5
Skeletonised WaterCAD model.

- trouble cards
- HiperPM database
- work order MS Access database

Trouble card spreadsheet
Trouble card reporting was used by OWASA to document water system maintenance and repairs before any computerised system was installed. Several 'banker boxes' of the paper format documentation were input into a spreadsheet by OWASA staff , ranging from 1980 to 1999. The spreadsheet is a summary of OWASA trouble card data as it relates to system repairs.

Numerous categories were used to describe the type of problem. A few of these categories are: contractor, coupling, fitting, hydrant, main, meter, saddle, service and valve. Earth Tech sorted the 1,984 records to eliminate the smaller diameter pipes (less than 100mm) and the repairs that did not relate to the prioritisation analysis.

The data was further reduced by deleting records with duplicate dates, or with identical or similar addresses. The resulting spreadsheet contained 556 break and leak records. The spreadsheet provided by OWASA did not identify the specific details regarding the trouble reported or repair performed.

HiperPM database
HiperPM is a computerised maintenance management software (CMMS) system that was used by OWASA to track maintenance and repair of the water and sewer system from approximately 1997 to 2000. The software utilises a proprietary user interface to a SQL Server database.

OWASA provided a SQL backup file to Earth Tech that contained maintenance data in over 150 separate relational data tables. Earth Tech restored the SQL server database archive, converted it to MS Access, and filtered the information to obtain the data relevant to the prioritisation analysis.

The electronic work order (HiperPM) data was filtered based upon work order task descriptions such as water main repair, water main leak and water quality. The resulting file consisted of 585 records. Each of these 585 HiperPM entries contained a problem description and a work order closeout explanation. Earth Tech reviewed the 585 entries and further reduced the data by removing duplicate records and records unrelated to water main breaks and leak and water quality. The resulting file contained 247 'break/leak' records.

Current work order MS Access database
In 2000, OWASA began utilising a customised MS Access database for tracking system maintenance and repair records. The database file contained over 5,600 records on water and sewer system maintenance. Earth Tech reduced the data through a series of sorting and selective deletions to 66 relevant break/leak records. These records vary in date from July 2000 through May 2002.

Geocoding and confidence levels for history of repairs
Each of the three data sources for the history of repairs contained date, problem and address information. The address of the break/leak was used to create a point representing the incident, using geocoding. The geocoding process matches an address to a physical location along a street, using the street number and name.

The data being geocoded often contained incomplete or unrecognisable addresses that produced unreliable matches. For example, some records listed apartments as the location, so a list of apartment addresses in Chapel Hill and Carrboro was found on the internet, and the actual address typed in for the record to enable a geocoding match. A place name Excel spreadsheet was maintained throughout the project, which listed the street addresses of locations such as apartments, shopping centres, hotels and businesses.

Each of the three sets of data was geocoded separately, and then the three were combined into one file, representing all of the break/leak incidents. Dates in the trouble card spreadsheet ranged from 8/17/1984 to 12/23/1999 and those in the HiperPM database ranged from 7/1/1997 to 6/1/2001, while those in the current work order database ranged from 7/20/2000 to 5/12/2002. There was some duplication of records, resulting from one incident having been present in more than one data source. Duplicates were removed.

Locations of the points were checked visually, and corrected if necessary. This might occur when the street file didn't have numbers for that particular street, and the point was placed arbitrarily half way along it. During the geocoding process a score of 0 to 100 is assigned to the point, dependent on the quality of the match. Matches of less than 80 were looked at individually. Sometimes descriptive information could be used to locate the problem.

If a point was manually corrected, the score was updated to reflect this. Additionally, where more than one water main was located at an address, the work order descriptions were referenced to verify that the point would be closest to the appropriate

Table 4
Field inspection data confidence level descriptions.

Confidence level	Description
1	Confidence that data applied to correct water main: 90 to 100%
2	Confidence that data applied to correct water main: 50 to 90%
3	Confidence that data applied to correct water main: less than 50%

Table 5
WaterCAD data confidence level descriptions.

Confidence level	Description
0	Pipe segment not considered during WaterCAD database population.
1	Pipes, street intersections and nodes match (GIS vs. WaterCAD) without significant uncertainty. Pipe sizes in GIS and WaterCAD match 100%
11	Hazen-Williams 'C-factor' input from Pitometer Associates' measured values.
2	Either of the following apply: a) Pipes, street intersections and model nodes match, and the pipe diameter in WaterCAD and the pipe diameter in GIS do not match. or b) Pipes, street intersections and nodes match reliatively closely and the pipe diameter in GIS do not match.
3	Pipes, street intersections and nodes are significantly different, but correlation to the GIS and model networks makes logical sense and the diameter of the pipes in GIS and WaterCAD data match.

Table 6
Physical parameter data summary.

Information source	Available data	Usable data	Confidence level			
			11	1	2	3
OWASA field inspections	21	20	0	0	20	0
Measured C-factor (1992 and UNCs)	4	4	4	0	0	0
WaterCAD theoretical C-factor	692	139	4	99	29	7

pipe segment. The following confidence levels were assigned to the points, based on the geocoding score:

After the location of the points was verified, the data from them was spatially joined to the pipe segments, and data columns added multiple times, if there were multiple incidents for a particular pipe. The highest number of incidents for an individual pipe was six. See Figure 6 for the distribution and confidence levels of repair data.

Summary of history of repairs data
Data relating to the history of repairs was available for the entire system, with records dating back to 1980. Of these records, 555 contained usable data, of which 72% had the highest confidence level. The data is summarised in Table 8.

Water quality
Water quality concerns were tracked by OWASA using the same tools as for the history of repairs:
- trouble cards
- HiperPM database
- work order MS Access database

Summary of water quality data
Data relating to water quality concerns was available for the entire system, with records dating back to 1980. Of these records, 419 contained usable data, shown in Figure 7. The data is summarised in Table 9.

Water main location
The effect on the community and system in the event of a failure of each water main is an important consideration during the prioritisation of water main replacement and rehabilitation. The service area was evaluated to develop general service location categories, which included:
- university/hospital
- downtown
- major commercial
- NCDOT roads
- other areas

Critical customers were also identified. It is important that water supply to emergency support services and medical facilities is not interrupted, for example. Addresses for critical customers were supplied by OWASA. These were geocoded, and the associated information added to the relevant pipe.

Information source	Available data	Usable data	Confidence level		
			1	2	3
Trouble cards spreadsheet	553	357	68%	24%	8%
HiperPM	471	143	78%	16%	6%
Work order database	65	55	80%	11%	9%

Table 8 History of repairs data.

Information source	Available data	Usable data	Confidence level		
			1	2	3
Trouble cards spreadsheet	363	290	71%	24%	5%
HiperPM	114	79	91%	9%	0%
Work order database	55	50	62%	26%	12%

Table 9 History of repairs data summary.

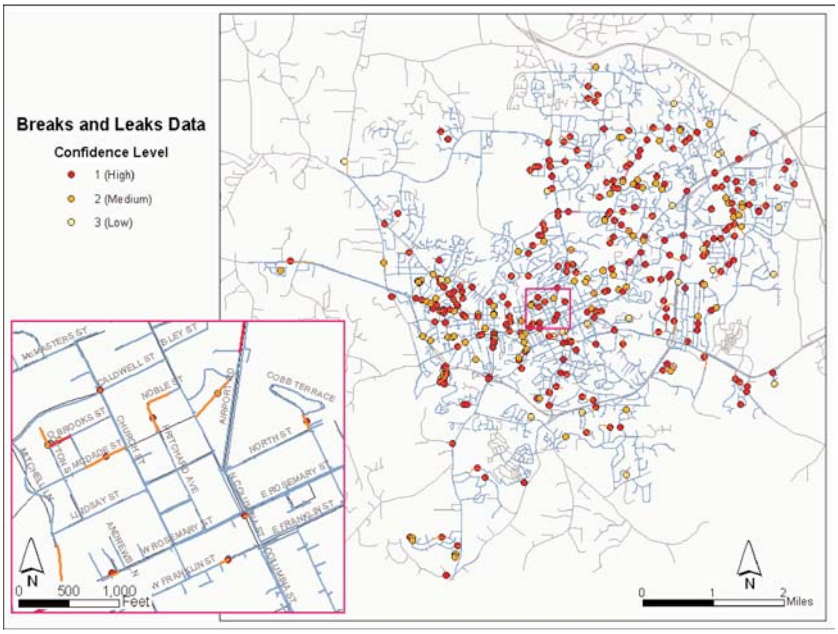


Figure 6 Water main repair data.

Confidence level	Description
1	Geocoding match score higher than 80
2	Geocoding match score 61 to 80
3	Geocoding match score 60 or lower

Table 7 Geocoding confidence level descriptions.

Water system characteristics
One of the most critical criteria is the ability of the water system to provide the flows needed at the required pressure. The following information sources were available for review and input into the prioritisation database:
- fire flow test reports
- Carrboro and Chapel Hill zoning maps
- WaterCAD hydraulic model

Fire flow test reports
The OWASA water system is tested periodically to document the available fire hydrant flow and the associated water system pressures. Fire hydrant test reports are prepared at the time of testing. OWASA provided Earth Tech with copies of fire flow test reports dating from 1984 to 2002. Each report documented the date of test, location, flow measured, and residual pressure and static pressure observed. Duplicate or illegible reports were not considered. In the case of duplicate reports the most recent was used. Earth Tech populated the pipe segments with the following data: static pressure, residual pressure, flows and fire flow sheet number.

Fire flow test reports confidence level criteria
The data provided on the fire flow test reports was assumed to be accurate and values were input as indicated from each test report. Earth Tech established confidence levels to assist with indicating the relative difficulty of locating the data within the water system. Upon receiving the ITRE-completed geodatabase, the fire flow data was transferred and checked for relative accuracy. The confidence level criteria shown in Table 11 were applied during input of fire flow test reports.

Fire flow requirements
Fire flow requirements vary throughout the system and were determined based approximately on the zoning of areas being served. Existing zoning maps were used to determine the required fire flow. Five land use categories, shown in Table 12 with their proposed fire flow requirements, were delimited.

WaterCAD hydraulic model
The OWASA WaterCAD hydraulic model was used to simulate velocity

Table 10 Critical customers data survey.

Information source	Available data	Usable data	Confidence level		
			1	2	3
Critical customers spreadsheet	85	83	44	39	0

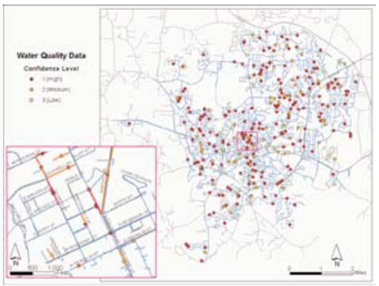


Figure 7 Water quality data.

Table 11 Fire flow test reports confidence level criteria.

Confidence level	Description
1	Streets, pipes and hydrants on paper map matched GIS map 100%, pressure and flow numbers are legible.
2	a) Pipe in GIS is on opposite side of the road from paper map. Everything else matches. b) One hydrant is not on GIS map, all other infomation matches. c) All spatial information matches, but cannot read pressure numbers d) All spatial information matches, two sets of data on sheet - one chosen. e) Location is correct, but cannot tell extent of relevent information along pipe.
3	Pipe location is uncertain, examples include: a) Map is a sketch with no pipes marked. Enough information to get location but no other verifiable information

Table 13 Service level data summary.

Information source	Available data (records)	Usable data (records)	Confidence level		
			1	2	3
Fire flow field reports	688	342	42%	53%	5%
WaterCAD hydraulic model	692	139	71%	21%	8%

and headloss under the peak hour water demand scenario. Water velocity and theoretical pipe head loss (m/300m) as calculated from the model were assigned to the appropriate water main in the prioritization database. Water velocity and head loss per 300m of pipe are used as measures of pipe hydraulic performance and may indicate areas within the water system where level of service may be compromised due to inadequate pipe capacity The hydraulic model consists of 692 unique segments, and input on 541 pipes in the prioritization database (representing 139 unique values). The confidence level criteria detailed in Table 5 were applied to all data transferred from the WaterCAD model.

Summary of service level data

Service level data is representative of the system as a whole, being widely distributed, but less than around 5% of the pipes have data associated with them. Table 13 summarizes the service level data.

The usable data for the WaterCAD model reflects those records that were modeled during peak hourly demands to have velocity greater than 1.5m /sec or headloss greater than or equal to 3m/300m.

Water pressure

The sustained static pressure is a variable that can influence the failure of some water mains. Based on OWASA's experience, pipes in areas of higher pressure are more likely to fail. The OWASA water system has two pressure zones, one operating at a hydraulic grade of 225m and the other at hydraulic grade of 195m. It was originally decided to focus on the pipes with approximately 6.9 bar or greater static pressure as being more likely to fail. To globally locate these pipes an estimate of the location of the 510 elevation contour and 410 elevation contour was needed to

Table 12 Land use categories.

Land use	Required fire flow
Single family residential (SF)	1000
Multiple family residential (MF)	2500
Commercial (COMM)	2500
Office/Institutional (OFF/INST)	2500
Industrial (IND)	3500

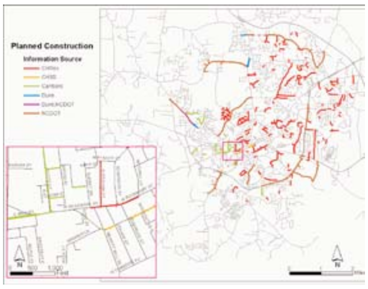


Figure 8 PSI check.

compare against the hydraulic grade of each pressure zone.

Topographic data came from two different sources. The first source was OWASA, which provided planimetric data for most of the service area that included topographic information. These 127 files were combined, and the 115m and 125m elevations extracted. In areas where planimetric data was not available, USGS Quadrangle maps were used to digitise the two required contours.

Following this, OWASA decided to estimate the pressure in more detail. Topographic contours were added every 15m across the entire area. A polygon was digitised, encompassing the whole area. The contour lines were used to make polygons, which were attributed with the elevation ranges. This was used to 'select pipes by location', and add the appropriate psi to each pipe. A quick check was made to verify the psi estimates, by comparing the topography (representing the psi based upon hydraulic grade) to the measured static pressure during fire flow testing, as shown in Figure 8.

Soil condition

Information on the condition of the soil surrounding the water main can help to determine the effect the host environment could have on the external corrosion of the water main. Earth Tech researched several areas looking for soils information. The 1999 OWASA master plan contained soil analysis from eight sites. These points were input as points, attributed with associated laboratory results.

We also undertook research with the National Association of Corrosion Engineers (NACE), the Soil Survey Geographic database and the Ductile Iron Pipe Research Association. However no other data was found that would enable us to determine corrosive soil types in OWASA's service area.

Planned construction activity

To proactively manage OWASA's water system, the rehabilitation programme needed to consider construction activity within the service area. These activities could then be coordinated with OWASA's capital improvement plan and water main R&R activities. The following information sources were reviewed and input into the prioritisation database:

- town of Carrboro
- town of Chapel Hill
- North Carolina Department of Transportation (NCDOT)
- Duke Energy – electric service
- Public Service Company of North Carolina (PSNC) – gas service
- telephone and telegraph companies

The town of Carrboro had street projects listed in its capital budget plans for 2001 to 2006. The town of Chapel Hill has three different programmes with construction that could affect OWASA's rehabilitation/replacement schedules. These are the Streetscape programme, the street improvement programme, and the sidewalk programme. The NCDOT projects ranged in scope from bridge replacement to installation of bicycle lanes, planned between 2002 and 2010.

Details from these programmes were added to the relevant pipes. Descriptions of the locations of the projects were very detailed, so confidence levels were not assigned. Duke Power, PSNC and the telephone and telegraph companies were either planning above ground projects, or were undertaking installations on an 'as-needed' basis, so these were not added to the database.

Service level criteria

The methodology to systematically prioritise the OWASA water main rehabilitation and replacement programme is based on assigning a priority action number (PAN) to each service level criteria and the associated water main within the prioritisation database.

The PAN represents a varying value for specific service level criteria for each individual water main segment. A higher PAN will indicate reduced ability of the water main to meet the required service criteria. The water main segment with the highest PAN has the highest priority for replacement/rehabilitation. The PANs will range from 100 to 0 with 100 being a higher priority for rehabilitation or replacement.

Each service level criteria will be weighted by assigning a weighting factor of 5 to 1, with 5 being the highest. These weighting factors allow OWASA to decide which of the service level criteria should carry more significance during the prioritisation. The service level criteria include:

- water main age
- water main breaks and leaks
- water quality
- water main importance
- hydraulic performance
- water main corrosion
- water main material
- water system pressure
- location of water main
- critical customer impact

Water main age

In general, water mains deteriorate faster during the latter part of their expected service life. For this analysis a pipe is considered to be in its original structural condition up to 50% of its anticipated life span; for this reason the PAN is 0 until the remaining useful life of the pipe is less than 50%. As illustrated in Table 3 the PAN increases with decrease in useful life percentage.

Water main breaks and leaks

Guidelines for the industry-accepted number of breaks per mile include the following:
- 0.25 to 0.3 breaks/mile/year (AWWARF - Distribution system performance Evaluation, 1995)
- 0.15 to 0.2 breaks/mile/year - target level of some utilities

The model converts the number of breaks for each water main segment to breaks/mile/year to calculate the individual PAN. OWASA has established target levels lower than most utilities and therefore considers it prudent to prioritise on a more stringent scale than industry standards. The PAN for breaks and leaks was determined based on the relationship listed in Table 4.

Table 14 Age priority action number (PAN).

Remaining useful life (%)	PAN
0	100
0 - 25	25 - 100
25 - 50	0 - 25
> 50	0

Table 15 Water main breaks and leaks PAN.

Breaks & leaks/mile/year	PAN
< 0.1	0
0.1 - 0.15	50
0.15 - 0.2	80
> 0.2	100

Table 16 Water main importance PAN.

Criteria	PAN
Static system pressure: ≥ 40 psi < 40 psi	 0 100
Fire flows: Available fire flow > Needed fire flow Available fire flow < needed fire flow	 0 100
System critical water main (10-inch diameter and aboove): Yes No	 50 0

Table 17 Hydraulic performance PAN.

Hydraulic criteria	PAN
Headloss: ≥ 10 ft/1000 ft of water main < 10 ft/1000 ft of water main	 20 0
Velocity: ≥ 5 fps < 5 fps	 20 0
Hazen-Williams C-factor: ≥ 100 < 100	 0 20

Water quality

OWASA staff considered that although water quality is a critical service level, there is not sufficient current data to reliably assign a PAN. It was therefore agreed that the prioritisation model will include provision to accommodate water quality information, but for this version a weighting factor of zero will be applied to water quality.

Water main importance

The determination of the water main importance PAN is assigned in accordance with Table 16.

Hydraulic performance

The following guidelines were used to determine the PANs for hydraulic performance. They provide an indication of whether individual water mains are reaching their hydraulic capacity to provide the needed flows.

- a headloss greater than 3m/300m of water main
- a velocity greater than 1.5m/sec
- Hazen-Williams C-factor of less than 100 (C-factor is either determined from field tests or as coded in the hydraulic model.

Table 19 Water system pressure.

Description	Water system pressure			
	≥ 80 psi	≥ 100 psi	≥ 120 psi	≥ 140 psi
Asbestos cement	20	40	80	100
IPS PVC (iron pipe size)	20	40	80	100
Cast iron	20	40	60	80
Galvanised iron pipe	10	40	80	100
Concrete	0	20	60	80
PVC	0	20	40	60
Ductile iron	0	15	25	40

Water main corrosion

Similar to the water quality PAN, OWASA staff considered the water mains' external corrosion to be a critical service level, but accurate data was limited at this time. OWASA crews have begun documenting corrosion or tuberculation during field inspections for work order completion. It was agreed that the prioritisation model will include a provision to accommodate water main corrosion, but for this version a weighting factor of zero will be applied.

Water main material
Similar to water main age, the water main material of construction information has been collected previously during system inventory updates. Each water main segment has been assigned a PAN based on the type of material of construction. OWASA and the water industry as a whole are moving toward replacement of asbestos cement pipes. Additionally, non AWWA C900 class PVC pipe, in OWASA's experience, is more likely to split or rupture than PVC bearing the C900 classification. These pipes will be labelled as iron pipe size (IPS) PVC for PVC pipes installed in 1977 or earlier. Table 18 summarises the proposed PANs relative to differing material of construction.

Table 18 Material priority action number.

Material of construction	PAN
Asbestos cement	100
IPS PVC (iron pipe size)	90
Cast iron	80
Galvanised iron pipe	80
Concrete	80
PVC	60
Ductile iron	40

Table 20 Location of water main PAN.

Location	PAN
University/hospital	100
Downtown	80
Major commercial	80
NCDOT roads	50
Other areas	20

Water system pressure
Higher water system pressure can reduce the life expectancy of water mains. In OWASA's experience, certain pipe materials such as asbestos cement and PVC are more susceptible to this than others. To account for higher water system pressure and the increased risk of failure, a PAN has been applied to water mains that experience pressures ranging from 5.5 bar to over 9.65 bar static pressure.

Table 21 Critical customer PAN.

Customer code	Customer description	PAN
MED	Non-UNC Hospital/medical research/health care	100
NH	Nursing homes	100

Location of water main
Community impacts are addressed in the relative locations of water mains, and are assigned the PANs listed in Table 20.

Critical customer impact
Another important consideration when prioritising water main replacement and rehabilitation is determining the effect on certain critical water services during a water main failure. To help in assigning a critical customer impact PAN to the water main system, the billing classification codes were consolidated and assigned a ranking based on health and safety.

The water mains serving these critical customers, based on classification codes, has been determined and assigned a customer impact PAN. The customer classification with associated PANs is presented in Table 21.

Weighting factors
Once the service level criteria have been established, the level of magnitude (weighting) of each service level criterion must be determined. The assignment of weighting factors is subjective and based on experience and staff knowledge. The prioritisation model allows the weighting factors to be changed for each category of water main. Based on previous discussions with OWASA staff, the weighting factors in Table 22 are currently included in the model.

Table 22 Weighting factors.

Service level criteria	Weighting factor (scale 1 to 5)
Water main age	4
Water main breaks and leaks	5
Water quality	0
Water main importance	3
Hydraulic performance	0
Water main corrosion	0
Water main material	2
Water system pressure	2
Location of water main	2
Critical customer impact	3

Lessons learned

Version/conversion and data transfer
Our data gathering/attribution efforts began before the ITRE geodatabase was available (finished and verified). We had a shapefile of OWASA's water system, which had been produced by OWASA in the course of their work. We decided to proceed with adding attribute data to the shapefile, knowing we would have to transfer the attributes to the geodatabase later.

This was not an ideal situation, but our time constraints dictated this approach. Transferring attributes (such as fire flow data) involved using the unique IDs of the pipes, which were generally consistent. In some areas, new pipes had been added, or the configuration of the pipes in the shapefile had been incorrect. In these cases, the data was transferred manually, rather than automatically.

We received an initial copy of the ITRE geodatabase, which was manually checked against the OWASA grid sheets while determining more complete diameter, age and material data. Inconsistencies in the location of pipes were identified during this procedure, and updates had to be made to the geodatabase. Multiple transfers of datasets should be avoided if possible. When this is necessary, procedures should be in place to verify that the most current data set is being used.

Level of detail
The labour involved in assembling the data for this project was significant. To thoroughly characterise a pipe's need to be replaced or rehabilitated, a certain level of detail is necessary. In order to add data efficiently, certain decisions were made regarding the level of detail. For example, data from the WaterCAD hydraulic model was added only if it would be relevant in the prioritisation analysis, as described in the section on the physical condition of the pipes.

There were some categories of data that were not complete enough to be representative of the whole system. This is obvious from Table 22, weighting factors. The water quality, hydraulic performance and water main corrosion categories are assigned a zero, until more data becomes available.

Conclusion
The water system data, service level criteria and the weighting factors were programmed into MS Access 2000 to automate the calculation of each pipe segment's overall PAN. ARC/GIS was used to provide the background data tables and to display the results of the calculation. The final product is being used to proactively prioritise the rehabilitation and replacement of OWASA's water system using a systematic, reproducible and policy-driven approach. ●

Acknowledgements
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COST-S: a new methodology and tools for sewerage asset management based on whole life costs

This paper discusses the development of a methodology and software tools aimed at assisting management decisions in order to provide acceptable performance at a minimum cost over the whole life of the sewerage system. Whole Life Costing (WLC) approaches have been shown to offer an ideal platform to provide investment and operational management tools that take account of the timing of interventions, system behaviour and performance all within a sensible economic and engineering framework. The need for such a methodology and the requirements for its useful implementation are introduced first. The paper then describes how research collaboration between the UK Water Industry and two UK research centres (Centre for Water Systems at Exeter University and Pennine Water Group at Universities of Sheffield and Bradford), and supported by the UK Engineering and Physical Sciences Research Council grant, resulted in an innovative, practical and auditable methodology with associated tools for better proactive management of ageing and rapidly deteriorating sewerage systems.

Dragan A Savic, Slobodan Djordjevic, Gianluca Dorini
Centre for Water Systems, University of Exeter
UK

Will Shepherd, Adrian Cashman, Adrian J Saul
Pennine Water Group, University of Sheffield
UK

Sewer performance, the maintenance of sewer assets, the flooding of properties by sewage and the costs associated with the provision of an acceptable level of sewerage services are matters of grave concern in the UK as well as in many other countries. Unlike many other infrastructure services the problems associated with their deterioration and the consequences of inadequate maintenance are far from obvious and it is often only when catastrophe strikes that such problems become manifest or visible – even to the service provider.

The case for sewerage service providers to demonstrate that their sewer asset management plans can deliver robust performance that meet regulatory requirements and that investments are sustainable as well as economically, socially and environmentally justifiable has never been stronger. Although significant progress has been made in the integrated assessment of different aspects of water distribution network performance that may be used to decide replacement and management strategies, by contrast sewerage systems performance has not until now received the same attention and is not as well understood in terms of its interrelationship of physical and economic behaviour, modelling, and the impact of different management strategies. An acknowledged priority is the need for funding faster improvement in sewerage services to reduce the risks and consequences of sewer flooding. At the same time service providers must demonstrate that their plans for asset management will deliver the robust performance required to meet regulatory requirements, and that such investments are sustainable as well as economically, socially and environmentally justifiable (WaterVoice, 2003). Furthermore in the future service providers will have to respond to changing public perceptions and expectations (Ofwat, 2003). Hence there is a need to develop tools that take account of system behaviour, performance and regulation within a sensible economic and engineering framework, tools that cane be proven to be intellectually robust (Ofwat, 2000).

Whole Life Costing Approach

Whole Life Costing (WLC) is a tool to assist in assessing the performance of a system, aimed at facilitating choices where there are alternative means of achieving the objectives and where those alternatives differ, not only in their initial costs (CAPEX) and in their subsequent operational costs (OPEX), but also in the relative timing of the potential interventions. These tools have been shown to offer an ideal platform for delivering better investment decision making within a single framework for water distribution system management (Engelhardt et al. 2002, Skipworth et al. 2002). By taking a long-term, holistic approach WLC is able to demonstrate the cost effectiveness of any regime of operation and intervention for a given set of internal and external constraints. Changes in performance, efficiency gains and regulatory goals over time can also be accommodated. The development of a WLC approach to sewer asset management that links system performance, cost and decision making is of particular interest for a number of reasons:

- The need to better understand performance using the available existing data and to model integrated performance such that changes in one aspect of performance can be tracked across all the other aspects.
- Socio-demographic changes across the urban landscape, which hold major implications for the usage, performance and fitness-for-purpose of existing sewer assets, must be included if investment and performance are to be optimised.
- The EU Water Framework Directive with its support for full-cost pricing (operational, capital and environmental) means that more holistic and comprehensive approaches are a necessity rather than a luxury.

However, there are several difficult questions that need resolving before implementing WLC, including:

- How to explicitly assign the costs at the appropriate decision level?
- How to define risk in monetary terms only?
- How to adequately predict the performance of the system over an extended time horizon?
- How to determine social and environmental costs and link them to an analysis of cost drivers.

The collaborative project between the UK Water Industry and two UK research centres (Centre for Water Systems at Exeter University and Pennine Water Group at Universities of Sheffield and Bradford), and funded by the UK Engineering and Physical Sciences Research Council, has answered those questions by developing the methodology and the tool for WLC management of sewer systems – COST-S.

The COST-S Methodology

A key feature of the methodology is how it incorporates the different aspects of system behaviour and performance, their inter-related nature, how they affect each other as well as how changes manifest themselves across the system's performance. The efficient and effective management of urban drainage systems should be based on a number of prerequisites. These include a proper and adequate knowledge of the assets, and an understanding of their system performance, the level of service provided and required, the management intervention options available and their impacts, the costs associated with system performance, failure and interventions and, the consequences of service failure for the service provider, the environment and society.

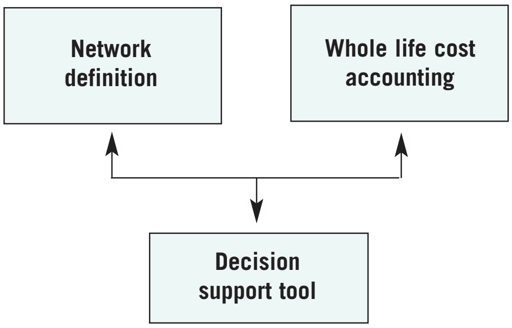


Figure 1
COST-S components.

A key element in the COST-S methodology is the integration of the hydraulic modelling platform with system performance models of collapse, blockage, sedimentation, CSO/storage and interventions as predictive tools. This allows the impact of different scenarios on hydraulic performance and flooding to be evaluated in terms of both performance and cost and couples system hydraulic inadequacy to the cost modelling of flooding impacts.

An important aspect of this work is the development of a specific set of Key Performance Indicators (KPIs) based on indicators that are either currently in use or have been suggested (IWA, 2003). The KPIs are generated by the modelling and that are used to both evaluate performance and act as a mechanism to initiate intervention options. This approach allows the impact of decisions on physical performance and performance indicators, through the hydraulic platform and also the costs associated with performance to be investigated across the whole life of the system in terms of serviceability indicators and capital and operational expenditures. This must implicitly recognises the long lived nature of the assets and the fact that any fair and proper evaluation of performance must allow all the impacts arising from interventions to become manifest such that a proper trade-off between the short- and long-term effects of capital and maintenance strategies can be made. In this respect WLC approaches have been proven to offer an ideal platform for integrating such aspects within a single framework (Cashman et. al., 2004).

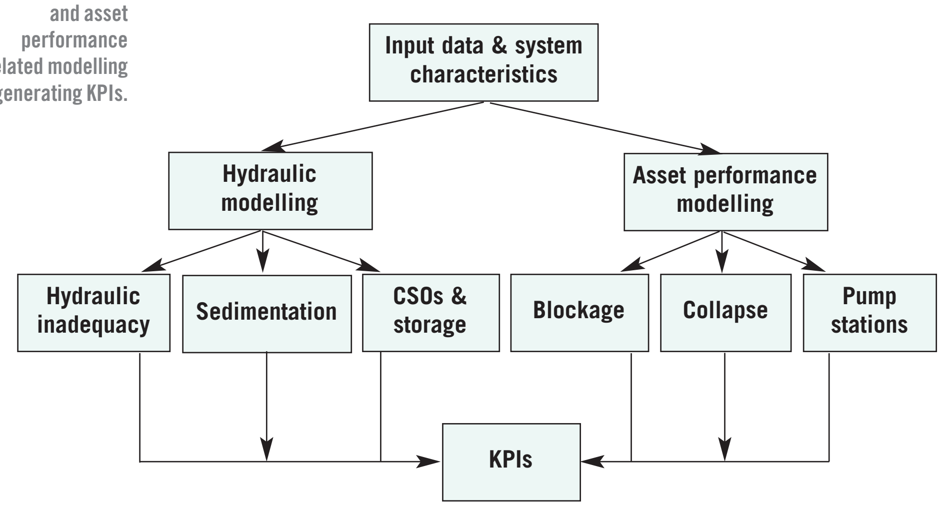
Architecture

The COST-S methodology has three components: network definition which includes modelling, whole life cost accounting, and a decision toolkit (Figure 1). This approach recognises that any urban drainage system comprises a network of assets which should provide an efficient service whilst meeting a variety of performance requirements. The complexity of dealing with these requirements leads to the need for a clear delineation of functions within the WLC framework.

Network definition

Network definition encompasses current and future network configuration and performance and the effect on performance of interventions at any given time horizon. The urban drainage network must be defined in a manner that is compatible with the accounting module over the selected period of analysis, which necessitates that all aspects of performance that have a cost impact should be considered holistically and be capable of being quantified. A distinction is made between hydraulic performance related features and asset performance related modelling. In the first instance

Figure 2
A distinction is made between hydraulic performance related features and asset performance related modelling in generating KPIs.



aspects such as sedimentation, hydraulic adequacy and CSOs are included and through them flooding behaviour whilst under asset performance modelling blockage, collapse and pump station failures are considered. Together these aspects are reflected in the generation of KPIs as indicated in Figure 2.

Performance modelling
Performance modelling involves computing of indicators based on hydraulic modelling and asset modelling.

Hydraulic KPI – wet weather flow Hydraulic modelling is used to assess system performance in terms of Dry Weather Flows (DWF), Wet Weather Flows (WWF) and sedimentation. A major operational concern for urban drainage systems is their performance under WWF and especially the onset of hydraulic incapacity in system and any resultant flooding. This issue is being approached by reference to a series of design events with a range of return periods with the ability to alter the duration of the events. The proposed performance measure for hydraulic incapacity under WWF is based on a modified performance assessment system (Cardoso et al, 2002) expressed either in terms of discharge (Q) or water level (H) (hydraulic head), Figure 3 shows this in terms of water level. The Hydraulic KPI (HKPI) is considered to be satisfactory (100%) for water levels up to a certain value H* below pipe soffit (pipe nearly full) which corresponds to discharges up to Q* (Q* smaller than the full pipe flow), falling to X% at surcharging (full pipe flow), and further falling to 0% when hydraulic head reaches the ground level and flow rate reaches some Qflood (start of flooding). This function represents different levels of performance of an asset under WWF: satisfactory / acceptable / non-acceptable, at a moment in time. The extent of incapacity or flooding is introduced by computing a 1-hour moving average of HKPI, i.e. by averaging over the 'worst' one hour, for a rainfall event – hence, flooding that took place for 15 minutes with a moderate flood volume would still result in some small positive KPI value, whereas only flooding longer than one hour would give zero KPI. For one return period, this is done for a series of design events so that critical storm duration (ie, the one which gives smallest KPI) is used for each pipe. Further aggregation is done by summing up thus obtained KPIs with their probabilities. The described procedure results in a set of KPIs values for every individual pipe, which comprehensively describe system functioning under a wide range of relevant conditions. Values of H*/Q* and X* are dependent on pipe size, category, condition grade and possibly other factors.

Sewage Available to Transport (SATT) – dry weather flow
Dry weather performance is determined by reference to the system's ability to transport dry weather flows, referencing the total available capacity with the required capacity of the system. The derived indicator is akin to determining the available 'headroom' in the system, either at an individual asset level or system level. The SATT score (Figure 4) is calculated as a difference between the available (non-occupied) pipe volume and the total volume, divided by the total volume, based on 24-hour simulation with diurnal variation of dry weather flows

Sedimentation
The flow simulations are also used to determine 'actual' velocities in the system and to reference these against critical or self-cleaning velocities according to the CIRIA Design Manual Report 141 (Ackers et al, 1996). Sedimentation KPI is calculated as a percentage of time (during 24 hour simulation) during which the velocities in a pipe are smaller than self-cleansing velocity. This is then used as an indicator of likelihood of sedimentation problems in the system, with pinpointing the likely locations. Further details of definition of hydraulic based KPIs are described by Djordjevic et al (2005).

Asset Performance modelling
Asset performance modelling aims to describe the performance of assets over the whole life horizon. Currently the Cost-S asset performance models predict blockage, collapse and deterioration. These models are derived from historic data, thus the primary limitation is quantity and quality of data. It is planned to expand asset performance modelling to include other parts of the sewerage system, such as CSOs and Pumping stations.

Deterioration modelling
An important feature of the WLC approach is the ability to make predictions of future performance of the system. Over these longer periods of time, deterioration will become important. The deterioration model has been developed through the analysis of repeat CCTV data, such that the condition of a sewer is known at two fixed points in time. Following previously published work (Micevski et al (2002), Wirahadikusumah et al (2001)), deterioration is applied to the system based on a Markov transition at each timestep. Transition probabilities (pj,k) in Table 1 have been derived from repeat CCTV data.

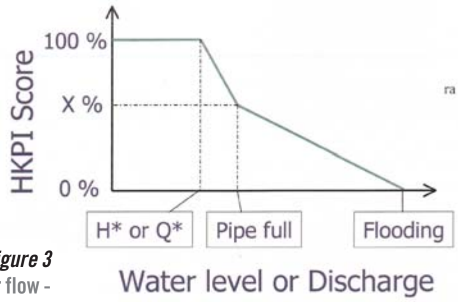


Figure 3 Wet weather flow - hydraulic KPI.

	ICG at t_{i+1}					
ICG at t_i		1	2	3	4	5
	1	p1,1	p1,2	p1,3	p1,4	p1,5
	2	0	p2,2	p2,3	p2,4	p2,5
	3	0	0	p3,3	p3,4	p3,5
	4	0	0	0	p4,4	p4,5
	5	0	0	0	0	p5,5

Table 1 Transition probabilities for internal condition grade (ICG).

Blockage and collapse modelling
Blockage and collapse models have been developed from the analysis of incident records and sewer asset databases. The models have been developed to predict numbers of blockages and collapses within pipe sub-groups over the catchment, rather than actual locations of incidents.

To develop successful models, it was necessary to consider the various factors which affect the risk of blockage and collapse incidents occurring. These include the physical properties of the pipe, including condition and surrounding soil, as well as the properties of the sewage conveyed and location of the pipe. Further discussion on sewer blockage is reported in Shepherd et al (2005). Figure 5 illustrates the blockage model, which predicts the number of blockages per Km of sewer per year in each asset category. The categories are defined by the internal condition grade of the pipe, and the relative velocity (RV) multiplied by the pipe length. The relative velocity is a function of pipe diameter and gradient. It can be seen that blockage risk decreases with increasing RV x

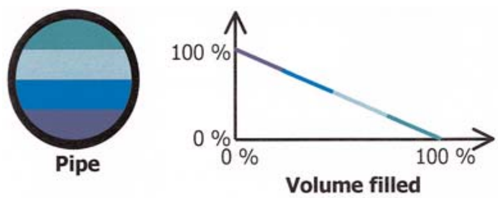


Figure 4 Dry weather flow - SATT.

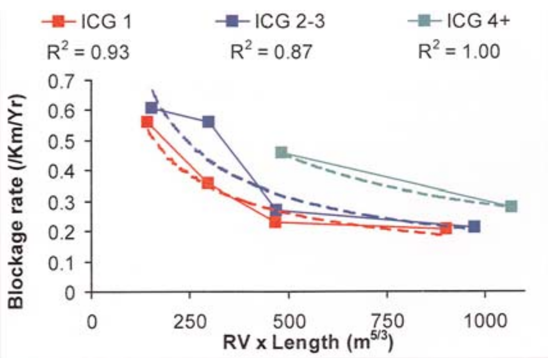


Figure 5
Blockage prediction model.

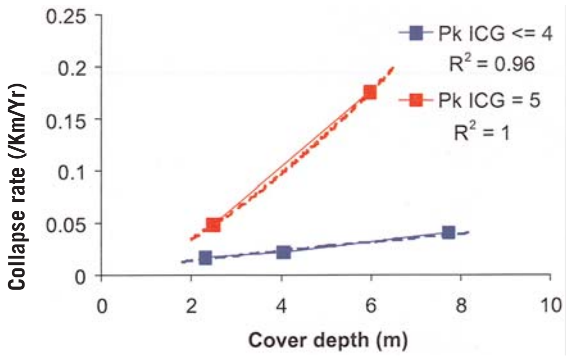


Figure 6
Collapse prediction model.

Length, and increases with ICG.

As collapses are far less frequent than blockages, there is a correspondingly smaller quantity of data from which to build a model. This has led to the collapse model, shown in Figure 6, considering a smaller number of contributory parameters. This model suggests that depth of cover is an important factor, with variation in ICG only becoming significant when sewers are in grade 5 (poorest condition). It might be expected that at very small depths, collapse rates would increase due to live loading becoming significant; this is not shown in the model as the dataset does not include a significant number of pipes with small depths of cover.

The models are based on the available data and the factors which were shown to most significantly affect blockage and collapse risk. It is anticipated that as data quality and availability improves, these models will be improved upon, however they do present a good starting point.

Cost accounting

The accounting module provides a methodology whereby the costs arising from the operation, maintenance and management of a network are identified and coupled with the performance of the network. Cost identification utilises an activity-based costing approach (Innes and Mitchell, 1990) in order to relate activities to their contingent costs rather than simple measures of output. Sewerage networks may be regarded as systems transforming external inputs into outputs that also have unintentional discharges and emissions (flooding) – system losses. The results of which add to the cost of operating the network and in fact represent a significant source of operational expenditure. An objective should therefore be to reduce to a minimum such waste of resources.

However, there is not a simple relationship between a particular cause, such as a blockage, and the actions needed to address it. The approach adopted is that for each particular causal loss, eg, blockage, collapse, equipment failure or hydraulic inadequacy, a probabilistic approach to the range of available responses, impact and consequential costs is adopted in order to determine the range of expected costs associated with a range of incidents. These are based on actual practice and analysis of incident data in order to derive realistic probability-consequence models. Costs are broadly associated with one of three cost categories: planned, unplanned-reactive and, planned-proactive, that reflect the level of activity occurring in the drainage system. The characterisation of the distribution of activities and costs has been based on both analysis of incidents and expenditure and institutional knowledge to provide a methodology for the redistribution of costs that is able to trace consequent costs back through an organisational hierarchy.

Decision support tool

The COST-S decision support tool (DST) represents the integration of the accounting and network definition modules onto a software platform. This consolidates the network data required for physical representation, in order that its performance can be modelled, and cost data as identified by the accounting module. The tool's Graphical User Interface (GUI) has two modules: DST Builder and Policies Explorer. A feature of the approach is the inclusion of performance based cost drivers linked to the KPIs as well as the cost of rule based management intervention strategies that can be adjusted over different time periods. Interventions, whether reactive or pro-active, represent actions that can be undertaken that will have an effect on the performance of the system, eg, structural relining. The performance effects impact on the cost drivers over the period of analysis and the updated values of the cost drivers are picked up by the cost relationships identified in the accounting module. The updated cost values ultimately accrue to the WLC account. Different scenarios and strategies can be investigated through the decision support tool.

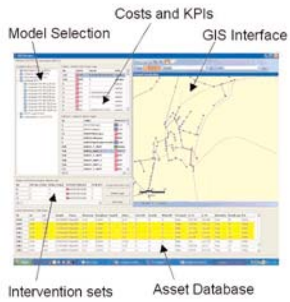


Figure 7
The DST builder.

Figure 8
The policies explorer.

A comprehensive mathematical framework for a generalised modular DST for assets management has been developed and implemented within a software tool. This framework consists on four units:

1. A discrete-time dynamic system unit
2. Space and time aggregation and selection unit
3. Interventions selection unit
4. Multi-criteria decision analysis unit

The purpose of each unit is to embed standard interfaces for certain types of services, eg, modelling, optimisation and multi-criteria decision analysis.

The first unit encompasses all the performance models discussed above. The structure is developed as a discrete-time dynamic system, which evolves through a sequence of stages. At each stage the system is in a particular state and a set of interventions is specified. Based on available information the models then compute the state at the next stage and generate a set of indices that quantifies impact of the interventions taken over the assets (generally in terms of cost or KPIs). The integration of various models is implemented in such a way that allows easy replacement of each of them, for example if one wanted to replace the built-in hydraulic model it would be easy to replace it with another model and produce the same set of KPIs.

The purpose of the second unit is to provide the user with a GIS-based tool for the analysis of simulation results. Such a unit is embedded within the DST builder (Figure 7). The indices (cost or KPIs) can then be viewed, selected and aggregated in space and/or in time.

The third unit allows the selection

of suitable intervention solutions for local problems (eg, selection of pipe replacements and/or relining for improving hydraulic performance, or selection of pipes to be cleaned to reduce cost of repeated blockages) through the DST builder. Selection of assets for a particular intervention is performed through the GUI by the user. Intervention parameters (eg, new pipe diameters for pipe replacement or new storage volumes in providing new storage) are set manually, allowing the user to run the models and select interventions of interest. However, the software is designed so that, such operation can be performed automatically by any optimisation technique, such as genetic algorithms. The selected interventions for each sub-problem are saved as an options set thus allowing further analysis of each of the sets.

The Policies Explorer includes units three and four and allows the user to assess the cost and performance associated with different intervention sets over both a single and multiple stages (Figure 8).

For each stage interventions over a period of time can be selected from the created options sets and then the behaviour of the system simulated and compared with other interventions in terms of costs and KPIs. This allows sequences of decision to be made and compared. Similarly to operations within unit three, this operation is performed manually by the user, but it can be easily automated, by including dynamic-simulation-based optimisation techniques.

Since interventions or intervention sequences are generally compared on the basis of more than one criterion, multi-criteria decision analysis techniques are needed and the software includes a generic interface for a variety of such technique to be plugged-in.

Conclusions

Sewerage service providers need to demonstrate that their sewer asset management plans will deliver robust performance that meet regulatory requirements and that investments are sustainable as well as economically, socially and environmentally justifiable. The development of the COST-S methodologies and tools demonstrates that sewerage systems performance has finally received the same attention as the integrated assessment of different aspects of water distribution network performance that may be used to decide replacement and management strategies. The new tools improves understanding of sewer system interrelationships, of physical and economic behaviour, modelling, and the impact of different management strategies. ●

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Integrating sustainability into asset management programmes

Life cycle cost analyses using whole system design and the ecological footprint

Effective asset management is about ensuring that service levels are met, risks minimised, and costs optimised. A critical aspect of successful asset management is that future, not only current, requirements are anticipated and planned for. In other words, the concept of sustainability is integral to long-term asset management thinking. This paper focuses on the sustainability aspects of asset management, and considers some of the ways in which leading-edge industrial ecology theory and practices can be applied to asset management, in order to achieve goals of sustainable standards of service and maximum efficiency.

Priscilla Bloomfield and Steve McDonald
Carollo Engineers
USA

Asset management programmes are designed to improve decision-making about assets in order to manage both existing and future assets more effectively. Effective asset management ensures that service levels are met; risks, including public health, safety, financial, and environmental, are minimised; and costs optimised.

Sustainability can be defined as meeting '…the needs of the present without compromising the ability of future generations to meet their own needs'.[1] It is based on the recognition that when resources are consumed faster than they are produced or renewed, the resource is depleted and eventually used up. In a sustainable world, society's demand on nature is in balance with nature's capacity to meet that demand.[2] Global and US trends toward more sustainable practices, emerging contaminants of concern and future regulations, rising energy costs and other natural resource limits, climate change, financial considerations, and public pressure are driving the water industry to consider sustainability in their decision-making. Sustainability requires decision-making criteria be expanded to include social and environmental impacts, as well as broader economic impacts; and to consider those impacts over generations, a longer period of time than considered for most decisions made today.

Better decision-making is crucial to achieve both asset management and sustainability goals. One key to making better decisions is having the right information available at the right time to support the decision-making process. Energy efficiency expert Joseph Romm reports that for a typical building, by the time '1% of the project's up-front costs are spent, up to 70% of its life cycle costs may already be committed'.[3] Clearly, there is a need to understand the impacts of alternatives on life cycle costs before any decisions are made.

One analysis method used for asset management that facilitates long-term cost optimisation is the use of life cycle cost analyses (LCCAs). A typical life cycle cost analysis (LCCA) includes evaluating the costs incurred by an asset over its useful life to find the least cost solution. These costs generally include acquisition, installation, operations, maintenance, and disposal costs. However, since the goals of asset management also include meeting level of service (LOS) standards and reducing risk, the solution with the lowest life cycle cost (LCC) is frequently not the optimal solution.

The 'critical' LCCA meets asset management goals by incorporating LOS, condition, criticality, vulnerability, risk, and remaining useful life into the analysis. The goal of a critical LCCA is not merely the least cost solution but the least cost solution that meets the asset management goals, or the 'optimal' cost solution. In order to incorporate LOS goals into the critical LCCA, the existing condition and desired LOS of an asset must be compared to determine if any gap exists. This gap identification provides the basis for determining which assets need to be improved to meet the target LOS and, conversely, which assets can potentially sustain a decrease in their LOS target. Incorporating risk, a combination of criticality and vulnerability, and managing its reduction involves identifying assets that need to have their current risk levels reduced and, conversely, assets that can potentially sustain an increase in risk level. Analysing risk and LOS goals allows priority assets to be identified. The assets with the greatest gap between LOS and condition and those assets with the highest risk are the highest priority.

While critical LCCAs address asset management goals beyond least cost, they do not consider potential costs or benefits to the environment or society. In order to make the critical LCCA as robust as possible, environmental and social costs and benefits should be considered with the economic, LOS, and risk management goals. A more robust critical LCCA may lead to significantly different decisions in an asset management programme.

Sustainability is the concept of managing natural resources in a manner that does not cause harm to the ecosystem and allows it to be as fruitful as possible, while permitting human activity to be productive and long lasting as well. Consider this: 'if everyone in America integrated these…technologies (premium efficiency motors and electronic ballasts) into all existing motor and lighting systems in an optimal way, the nation's $220-billion-a-year electric bill would be cut in half'.[4] And 'only 1% of the energy consumed by today's cars is actually used to move the driver', and through the use of low priced but less efficient transformers, $1 billion is wasted each year.[5]

Additionally, 'every day…US farmers and ranchers draw out 20 billion more gallons of water from the ground than is replaced by rainfall' and only about 5% of the waste Americans produce is recycled.[6] Including sustainability goals such as zero waste, zero toxics, and energy and water efficiency, into an asset management programme can lead to cost savings and innovative solutions.

Sustainability is a simple idea and should not be thought of as a separate or stand-alone discipline, but rather the concepts and goals should infuse all aspects of planning and design activities. There is a variety of sustainability conceptual frameworks, metrics, and design guidelines that can help exist, including The Natural Step, ecological design, industrial ecology, Leadership in Energy and Environmental Design Green Building Rating System (LEED), eco-effectiveness/Sustainable Design Protocol, Natural Capitalism, and the Ecological Footprint, that are designed to integrate sustainability into decision-making.

The Natural Step is a sustainability methodology that focuses on 'building awareness and understanding', conducting a 'Sustainability Analysis', developing 'a strategy and action plan', and supporting 'step by step implementation'.[7] It has four system components:

- 'substances from the Earth's crust must not systematically increase in nature',
- 'substances produced by society must not systematically increase in nature',
- 'the physical basis for the productivity and diversity of nature must not be systematically diminished',
- 'just and efficient use of energy and other resources'[8]

The Natural Step is based on the concept that as demand increases and resources decrease, a funnel is created where productivity will be limited by the walls of the funnel. Many states, counties, cities, and governmental organisations across the US are adopting and implementing this framework. Ecological design principles include:

- 'solutions grow from place'
- 'make nature visible'
- 'design with nature'
- 'ecological accounting informs design'
- 'everyone is a designer'[9]

By understanding the local geography and conditions, designs can complement and cause no harm to the natural environment. Making nature visible allows for a better understanding of the ecosystem and human impacts to it. By designing with nature, natural diversity is sustained and protected, and the ecosystem continues to function as it should, returning all 'waste' back into the natural elements. Understanding the material and energy flow provides the opportunity to develop ecologically sustainable designs.

The goal of industrial ecology is to 'incorporate the cyclical patterns of ecosystems into designs for industrial production processes that will work in unison with natural systems'.[10] The US Department of Energy has outlined six principal elements, including:

- industrial ecosystems
- balancing industrial input and output to the constraints of natural systems
- dematerialisation of industrial output
- improving the efficiency of industrial processes
- development of renewable energy supplies for industrial production
- adoption of new national and international economic development policies

These principles are targeting a closed-loop system among industries to produce no waste, a decrease in the amount of materials and energy consumed, the redesign of industrial processes, and the identification of non-harmful interactions with the ecosystem.

Developed by the US Green Building Council, LEED is a framework for developing high quality, sustainable buildings, whose goals are to develop a common 'green' measurement system, promote whole building design, recognise leadership, and raise awareness.[11] LEED has developed standards for commercial, institutional, and residential buildings, including new construction and renovations. The measurement system awards credits for each 'green' feature under the following categories:

- 'sustainable sites'
- 'water efficiency'
- 'energy and atmosphere'
- 'materials and resources'
- 'indoor environmental quality'
- 'innovation and design process'

Based on the points earned, 'green' buildings are awarded different levels of certification.

Eco-effectiveness is a concept of sustainability where both humans and the environment are productive and regenerative ' within cradle-to-cradle life cycles'.[12] Its formative strategy is that waste equals food and that biological nutrients' return to the organic cycle and 'technical nutrients' recycled in technical processes that allow them to maintain their physical integrity and quality. 'Biological nutrients' are substances that do 'not contain mutagens, carcinogens, heavy metals, endocrine disrupters, persistent toxic substances, or bio-accumulative substances'. 'Technical nutrients' could be provided as a service, rather than a product, where the customer purchases the use of the product and the manufacturer takes back the product at the end of its useful life for recycling, saving the manufacturer from having to purchase additional raw materials. Additional strategies include:

- respecting diversity
- using solar energy
- restoring accountability
- making prices reflect costs
- making conservation profitable
- getting business out of government[13]

A proprietary tool, the McDonough Braungart Index of Sustainability, 'evaluates a product's materials and processes so that redesign for sustainability can take place'.[14]

Natural Capitalism lays out four principles to achieve sustainability. They are:

- Increase natural resource

productivity
- Biologically inspired models
- Solutions based model
- Invest in natural capital[15]

Strategies to increase natural resources productivity include: changing the design perspective to a 'whole-systems' design process; counting all 'multiple' benefits; taking the right steps at the right time and in the correct order; and incorporating new technologies.[16] For example, shifting to biological-inspired production models involves using methods such as closed-loop manufacturing to prevent waste production or in other words, any material that is left over as waste is completely reused in the next production cycle.[17] A solutions-based model is one where a service, rather than a product, is supplied to the customer. For example, a pesticide company would provide crop protection to a farmer rather than sell pesticides, and be responsible for maintaining the absence of pests with the incentive of making greater profit by using fewer chemicals. Investing in natural capital is, simply, '…restoring, sustaining, and expanding…natural habitat and biological resource base'.[18]

The Ecological Footprint (EF) measures many external and difficult to quantify costs to the environment, and thus society as well. The EF measures the bioproductive area required to produce all the resources consumed, and absorb all the wastes produced, by a person, group, or process, expressed in standardised acres and normalised by biological productivity.[19] This metric allows comparison of the relative ecological impacts of differing alternatives, accounting for the life cycle impacts of construction materials, transportation energy, chemicals and energy for operations, and emissions, such as methane and carbon dioxide.[20]

These sustainability frameworks all work towards developing and sustaining a system where the use of resources is restorative and non-harmful, allowing both humans and the ecosystem to thrive. They strive to accomplish this goal by creating little or no damage to natural ecosystems, sustaining natural resources and increasing their productivity, understanding the environmental impacts of different choices, creating little or no waste, and rethinking current design practices. A few of these ideas can specifically be integrated into critical LCCAs that are applicable to the water and wastewater industry.

Based on these frameworks, two potential methods will be discussed for incorporating sustainability principles in a critical LCCA. The first method is to change the way a critical LCCA is developed – by looking not just at one asset but at a whole system design, as outlined by Natural Capitalism. For example, rather than analysing and optimising just one pump, the analysis would include the entire pumping system – pumps, motors, piping, valves, etc. The second technique is to quantify environmental cost, through specific use of the Ecological Footprint, and integrate it into the critical LCCA.

The theory of whole system design contradicts the concept of diminishing returns and is, to a large part, based on expanding returns, the idea that it can actually cost less to save a greater amount of resources than a smaller amount, referred to as 'tunneling through the cost barrier'.[21] For example, building a house with thicker insulation and more efficient windows can eliminate the need for a furnace, as well as its ongoing operations and maintenance costs, such as fuel and electricity, which saves substantially more money than the additional capital cost of the insulation and the windows.[22] Typically, each asset or component of a system is optimised for cost, energy use, and performance in isolation, rather than optimising an entire system as a unit and considering all resulting benefits, which tends to make the entire system less efficient and optimal, and at the same time more expensive. This concept of rethinking design processes can be achieved either when designing new infrastructure, or through rethinking or piggybacking on planned renovations or improvements.[23]

Two specific examples of the benefits of whole systems design applicable to the water and wastewater industry involve reducing friction and changing the order in which equipment layout is developed. In 1997, Interface Corporation, a commercial flooring manufacturer, was building a new factory. Before construction began, Jan Schillham, an Interface engineer, made two changes to the plans. First, he redesigned the pumping system, choosing fatter pipes and smaller pumps, resulting in reducing power requirement from 95 horsepower to 7 horsepower, a 92% power reduction. The fatter pipes create less friction and therefore need less pumping energy, which translates into smaller pumping equipment. The reason this design was originally overlooked was that the higher capital cost of the fatter pipe was compared only to the savings in energy use. When the lower capital cost of the smaller pumping equipment was included in the comparison, it was a less expensive alternative. When Schillham optimised the whole system, the additional capital cost of the fatter pipe was offset by the lower capital cost of the pumping system equipment, making the new design not only less expensive to operate, but also less expensive to build than the original design.[24]

The other change Schillham made was to reverse the order of pipe and equipment layout. He laid out the pipe system as straight as possible in the building before positioning the equipment, resulting in shorter length of pipe and fewer fittings and lower capital costs. Friction was further reduced due to the shorter pipes and fewer bends/fittings, which again resulted in smaller pumping equipment and less pumping energy, and therefore both capital and operating savings. The pipes were faster to install because the lengths were shorter and there were fewer fittings, which reduced labour costs. Finally, the pipes were easier to insulate, which resulted in lower capital and operating costs as well. The new design was less expensive to build and operate than the original, easier to build, used less floor space, was easier to maintain, had fewer parts to fail, was more reliable to operate, and had overall better performance. It should be noted that laying out pipe before placing equipment and whole system evaluation of using fatter pipe and smaller pumps are two steps that can be taken to reduce friction in pipes, and friction is only one of the forces that must be overcome by a pumping system. Similar ideas can be incorporated into R&R decisions as well.[25]

Changing the design framework to consider whole systems can support good decisions about where to spend resources, such as on fatter pipes, to realize multiple benefits. This requires that the ' right steps be taken in the right order'.[26] Downstream changes can create much larger upstream savings,' for example, saving one unit of liquid flow or friction in an exit pipe saves about 10 units of fuel, cost, and pollution at the power station'. Developing critical LCCAs by looking at a whole system rather than just one asset can result in less expensive systems that are more efficient and use fewer materials. By looking at a whole system design, the 'optimal' cost solution is quite often more sustainable, with fewer negative impacts to society and the environment.

By quantifying costs through an EF, a critical LCCA can result in a more robust analysis by including environmental and societal costs. The premise of an EF is that it quantifies the impacts of resource consumption and waste production assimilation for given populations or activities. It covers renewable resources only, as well as the greenhouse gas impacts of burning fossil fuels. It does not address toxicity, biodiversity loss, or depletion of non-renewable resources. The EF is based upon five major assumptions:

- 'it is possible to keep track of most of the resources people consume and the wastes people generate'
- 'most of these resource and waste flows can be converted into biological productive area that is required to maintain these flows'
- 'these different areas can be expressed in the same units (hectares) and … scaled proportionally to their biomass productivity'
- 'these areas stand for mutually exclusive uses, and each standardised acre represents the same amount of biomass productivity, and they can be added
- This area for 'total human demand can be compared with nature's supply of ecological services, since it is also possible to assess the area on the planet that is biologically productive'[27]

These assumptions allow the EF to be put into strict mathematical terms, based on readily available data, by allocating land to biologically productive uses. The three major components are total food and fiber (crop demand, forest products, grass fed animals, and fish), total energy (fuel wood, nuclear, hydro, and CO2 from fossil fuels), and built up land.[28] These categories are added to get an EF value in global acres or acres per year.

While the EF value is not in monetary terms, it can be used to compare different projects or decisions. For example, if a critical LCCA completed for several projects and two have the same life cycle cost, an EF value can be calculated for each alternative and then compared to allow the more sustainable project, with the lower EF value, to be chosen.

The City of Petaluma, CA recently incorporated EF methodology into their decision making process for selection of treatment alternatives for their new water recycling plant. The EF was considered in addition to more traditional evaluation criteria, such as lifecycle costs and reliability, to select a treatment process. The City is environmentally aware and based their final decisions on both cost and sustainability. EF values were calculated for each alternative, and categorized based on materials, chemicals, and energy consumption, for construction and operation, required for each alternative, as shown in Figure 1.[29]

Alternative 5, extended aeration, was chosen because of its lower EF, even though it was the second most expensive alternative.[30] Vegetated treatment wetlands and ultraviolet disinfection were also chosen instead of Dissolved Air Flotation and chlorine disinfection, respectively, based on their sustainability factors, expressed by EF values. It should be noted that the results of this study cannot be extrapolated to other situations, since local factors such as sources of energy, and transport distances for materials, supplies and biosolids disposal affect calculation of the EF.

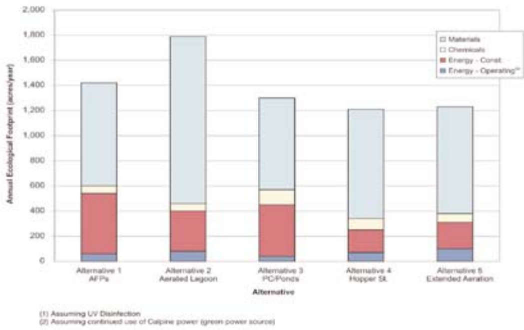

Figure 1
Ecological footprint (EF) for different water treatment alternatives.

King County, WA has used EF analysis in a slightly different way to answer the question 'Does this water reuse project increase overall sustainability?' for decisions regarding the design and construction of their Sammamish Reclaimed Water Production Facility.[31] By directly incorporating both the costs and the benefits into a decision with an EF, King County was able to consider more comprehensive environmental impacts in their decision analysis.

As shown in Figure 2, the EF cost of building a recycled water facility to the EF benefits of increasing water supply locally are roughly equal with the assumption that a typical energy supply of coal, natural gas, and hydroelectric power would be supplied.[32] In this figure, the costs are approximately equal to the benefits, but, if King County is able to obtain 'green' power (ie, small-scale hydro, solar, wind, etc), as expected, the operational energy costs decrease from over 500 to 17 global acres. In this case, the EF benefits greatly outweigh the EF costs, indicating that reuse may be the best alternative from an ecological standpoint.

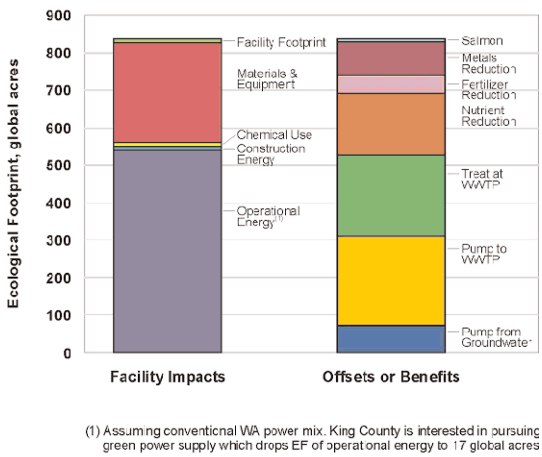

Figure 2
Ecological footprint set against offsets or benefits.

Critical LCCAs that integrate whole system engineering and EF methodologies, can provide more comprehensive information on which to base decisions. Applying the hidden synergies leading to efficiency improvements possible through whole systems design, coupled with the relative ecological impact assessments provided by the EF to asset management programmes can help agencies make better 'optimal' cost decisions that are also more sustainable. The implementation of these decisions can help agencies not only meet LOS goals, reduce risk and costs, but also meet environmental goals to sustain our ecosystems for current and future generations. ●

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Network management choices

● A recent conference in Chile provided a strong focus on asset management. Water Asset Management International takes a look at the papers presented at the event. Report by **LIS STEADMAN**.

Asset management was a prominent topic, either directly or indirectly, of the *Efficient Use and Management of Urban Water Supply* conference in Chile held earlier in 2005. One notable paper on optimal long-term planning model for improving water distribution networks by sub-zoning was presented by Chun-Woo Baek, Seok-Woo Kim, Joong King, Eung-Seok Kim, Moo-Jong Park, Woojin Lee, Jeehyeong Khim and Seung Hong.

In this, the authors noted that water distribution systems in many countries are sufficiently developed, and the main focus of water service is moving from constructing new pipelines to improving the performance of the existing system.

Older systems suffer from increasing demand and decreasing capacity, and improvements in performance can be achieved by replacing, repairing and rehabilitating some of the network – replacing it all would be unrealistic and unnecessary.

In most cases, the order and way in which pipes are replaced or rehabilitated should be chosen to ensure water quality and demand requirements can be maintained through the planning periods. Decisions need to consider economic and hydraulic constraints, about which many studies have been undertaken.

The paper presented at the conference assigned rehabilitation priority to each sub-zone in a network, not to each pipe, allowing the model to be used for capital improvement projects. The practical use of the model was increased by adding a graphical user interface (GUI).

The new algorithm is derived from an artificial process used to search for better harmonies in musical performance processes, such as a jazz trio, hence the name. There are three basic parameters used to find near-global optima. HM (harmony memory) memorises the best sets of harmony; HMCR (harmony memory considering rate) is used to get beyond local optima, and PAR (pitch adjusting rate) is used to improve the solution by searching nearby regions.

The model was developed for pipe network decision-making based on economic analysis and an examination of the system's hydraulic reliability (using KYPIPE). The economic analysis included pipe break history, pipe repairs, rehabilitation and replacement costs and benefits from reduced pumping costs and lower leakage.

The model uses the economic analysis to choose the best improvement plan, maximising cost-benefit while satisfying the hydraulic reliability of the network. The new system has been demonstrated in Daegu, South Korea, with a network consisting of 198 nodes and 260 pipes, divided into eight small zones.

Two plans, with 20-year and eight-year horizons, were tested. In both, rehabilitation was shown to be a suitable choice. The total cost for the 20-year plan was less than for the eight-year plan but in a country with significant inflation, this must be taken into account.

Aguas Andinas

Enrique Cruzat spoke about asset management at Aguas Andinas. In his paper he explained that Spanish utility Agbar took control of Aguas Andinas, the largest water treatment operation in Chile, in September 1999. The corporation produces, distributes, treats and collects water for six million inhabitants of the 600km^2 Santiago basin.

The maintenance sub-management group, created in 2003, was tasked with preparing a maintenance plan that would efficiently create, implement and manage Aguas Andinas' water treatment infrastructure. The plan is working well and should be concluded by the end of 2006.

Successfully implementing the SAP-PM maintenance management system at the company meant, firstly, undertaking a comprehensive stock take and bar coding over 10,000 water treatment system parts, which took from July to October 2003. Second, a robust IT system was integrated with the rest of the corporation, allowing support and management of information on each piece of equipment in the same way that work orders are generated during maintenance.

The corporation also developed a training programme for maintenance staff that will enable, over a two-year period, multi-task workers that understand mechanics, electricity and instrumentation. Staff maintenance is restrictive and prevents speedy fulfilment of work orders.

Setting up SAP-PM also meant applying technology to many processes, or the management system would not have been updated and would have become unreliable. SAP does increase the administrative workload – at present, over 30% of maintenance staff time is taken up with this. To avoid continued loading of the SAP-PM system with data obtained manually by pen and paper in the field, digital data capture is required.

Current maintenance plans at water treatment works and booster plants are not set according to equipment hour-meters but for a fixed amount of time following the last maintenance work. This is far from ideal but the only possible method for the corporation at the moment because of the costs of assigning maintenance staff to obtain data on equipment working hours.

Self-maintenance commits the operator to the equipment and makes them able to spot possible faults first. The time taken for maintenance staff to go from their office to the location of the equipment is inefficient; it is thought having operator-maintainers on site would improve efficiency and empower the operators.

Eighteen months after beginning to implement the programme the corporation already enjoys world-class standards. In future the barriers developed to slow new competition will come not from adapting to market changes and demands but rather from corporations' in-depth knowledge about how things are done.

The Canberra study

A Turner, S White and G Bickford presented a paper on the Canberra least-cost planning case study. This looked at a preliminary least-cost planning assessment carried out for Australia's capital city as part of its 50-year water resources strategy.

Canberra is likely to need another major water supply source before 2020 due to population increases, drought security issues, climate change and catchment regeneration due to major forest fires. However, the local government has indicated that building dams for a further supply must be avoided if possible and has identified demand management targets of 12% and 25% reduction in per capita demand by 2013 and 2023 respectively.

Similar targets have been set for re-use and stormwaters, so a suite of demand management, source substitution and re-use options have been developed to find out whether such targets could be met and to enable comparison of these options against supply options being developed by water service provider ACTEW.

First, a reference case demand for water over the 50-year planning horizon under consideration had to be determined. The timescale of the development of the water resources strategy, released in April 2004, was too short to develop a full end-use model so data on water demand by sector, indoor and outdoor demand, information on current and future proportions of single and multi-residential dwellings, occupancy ratios and the number of non-residential properties were collated and analysed to determine the reference case demand.

Potable water demand is expected to grow from over 63,000ML/year to over 83,000ML/year with the single residential and top 150 non-residential high water users continuing to dominate demand.

To achieve the government targets, a selection of options was considered, grouped under demand management, source substitution, measures for the neighbouring town of Queanbeyan and re-use, and compared against a selection of supply options. The water savings were obtained, where possible, from evaluations of similar programmes.

The results showed that demand management alone could achieve the 2013 demand management target for a cost of AUD45 million ($34M). By 2023, demand management options would be providing a saving of 12,500ML/year, equivalent to a 16.5% reduction in demand rather than the proposed 25% reduction target. To achieve that target a similar programme of source substitution and demand management will have to be applied in Queanbeyan, and reuse options with a higher cost than the suite of demand management options developed will be needed.

The low-cost demand management options will buy time for a more detailed assessment of the situation. Since the assessment, a water efficiency team has been created to begin implementing the programmes developed. These could defer supply augmentation requirements for many years.

Avoided cost analysis

Thomas Chesnutt and Gary Fiske presented a paper on avoided cost analysis in integrated planning for water efficiency: methodology, concepts and theory.

AWWARF and CUWCC sponsored research on water efficiency programmes for integrated water management that addressed the issue of avoided cost analysis, some of which was summarised in this paper.

The concept is relatively new and there is not enough consensus about its relevance and use as yet. Comparing resource options requires a methodology for measuring costs or savings. If demand management or conservation strategies are in the mix of options, as least-cost planning dictates, the concept of avoided cost is very relevant.

Avoided-cost analysis can be used to evaluate the benefits of resource alternatives, leak detection and repair programmes, water purchases and treatment options as well as for complex management issues such as the benefits of regionalisation through partnerships and utility mergers.

Concepts such as fixed and variable costs, assignable and joint costs and data quality and availability are important to understanding the costing methods needed to estimate avoided costs.

It is also important to define marginal costs – the cost of producing – or not producing – another unit of water supply. Calculating marginal costs involves projecting capacity and operating costs, and water demand over a specific time period.

Two important components of marginal costs are the change in operating costs caused by a change in the use of existing capacity (short-run marginal operating costs) and the cost of expanding capacity (long-run marginal capacity cost)

MOC can be calculated by forecasting the annual operating expenses for the first year that a capacity increment is due to become operational then divide that cost estimate by the forecast revenue-producing output for that year. The main advantage of this technique is its low data requirement; its main disadvantage is that it produces an estimate of average, not marginal operating costs, strictly speaking.

A recent study (Bishop and Weber, 1996) used three years of monthly historical cost data to develop statistical estimates of marginal operating costs. This allows comparison of average operating cost methods with methods that control other factors.

Most of the marginal cost capacity (MCC) estimation techniques used are variations of two basic approaches: the avoided cost due to system expansion deferral and the average incremental cost used to estimate a change in capacity requirement. Depending on the method used, other information may be required.

The avoided capital cost calculated directly by this method applies directly to valuing the worth of conservation programmes, which attempt to affect the growth of demand. Variations of the approach have been proposed to produce a seasonal estimate of MCC. Several applications have stressed quantifying future demand and linking changes to the size of the deferrable facilities.

The average incremental cost (AIC) approach to estimating MCC involves annualising the average incremental cost. All of the approaches shed light on issues that have to be addressed in estimating marginal costs, but none is sufficient as a method to be used by utilities given real-world resources and analytical constraints.

Pipe bursts and leakage

A series of papers also examined the important subject of pipe bursts and leakage. Delius Misiunas, Martin Lambert, Angus Simpson and Gustaf Olsson looked at burst detection and location in water distribution networks.

Losses in distribution systems can be divided into two major elements – apparent and real losses. Apparent losses are due to unauthorised consumption and meter inaccuracy; real losses include leakage and overflows.

Although background leakage is often the main contributor to volumetric loss, pipe bursts' overall costs can be significantly larger and include the repair of damaged surrounding infrastructure, flooded properties and customer complaints.

The losses associated with bursts can be reduced by minimising the time of burst detection and location., which can be quite long. Most network monitoring approaches focus on assessing the leakage present in the system, the most common concept being the district metering area (DMA).

A simple mass balance analysis of the flow entering the DMA can allow an estimate of leakage levels. For sudden pipe bursts of medium to large size with potentially dangerous consequences, the proposed technique is based on a combination of continuous monitoring of the pressure at a number of points in the network and hydraulic transient theory.

In a sudden pipe burst, a transient wave is generated and propagates through the network away from the burst point. If the pressure is continuously measured at two or more points in the network, the arrival times of the burst-induced wave at these points can be used to derive its location.

The cumulative sum (CUSUM) change detection test can be used to monitor the measured pressure for a negative burst-induced pressure wave and has been extensively applied for change detection in different time series analysis problems.

A real distribution network was used to verify the proposed method for detection and location. Around 250 houses are connected to it, fed from a fixed-head reservoir. A network model was built containing 108 pipes and 79 nodes to calculate theoretical transient wave travel times and transmission coefficients.

All the bursts were successfully located, including one where the transient wave was detected at only two monitoring stations.

Jae Chan Ahn, Su Won Lee, Gyu Seong Lee and Ja Yong Koo presented a paper on predicting water pipe breaks using neural networks. This examined the relationship between pipe breaks in service pipes and mains and the various factors involved. Historical pipe breaks and water and soil temperatures were modelled using an artificial neural network to propose a new method of predicting pipe breaks to enable efficient management and maintenance of networks.

Seoul city is in the west central area of the Korean peninsula, and has an area of 605km^2 and ten million inhabitants. The potable water system has six intakes along the Han river providing raw water to six treatment works.

The average number of pipe breaks per kilometre was 1.9 in 2002, with 14 per kilometre in galvanised steel pipes and five per km for PVC, with 1.5 per km for cast iron. Causes of breaks were classified, the main one being ageing, mostly in steel and cast iron pipes. Pipes were also classified according to the break position and water and soil temperature.

Neural network models focus on finding repeated, recognisable and predictable patterns between causes and effects from past operation data records. The approach does not require a description of how the processes occur, only knowledge of important factors that govern the process. There is no mathematical algorithm required, the network simply learns from the sample data and generates a black box-type relationship.

The data were randomly separated into two sets on a monthly basis from January

1995 to May 2004, the training set having 91 observations and the verification set 22 observations.

The sensitivity was not good when the pipe breaks rapidly increased or decreased, but the model gave a good performance and will be useful to predict pipe break patterns on a seasonal basis.

Andrea Mangano and Dewi Rogers looked at the leak detection programme in San Pedro Sula, in Honduras, which is subject to water shortages and low pressures. These are caused by the high level of non-revenue water. A detailed study showed that 85% of this was due to leakage.

A mathematical simulation model (EPANET) was applied to the network, which was divided into 15 permanent zones, each supplied by a single pipe. In this way it was possible not just to continuously quantify the leakage levels so that leak location activities are always directed to the worst parts of the network at the most appropriate time, but also to control the pressure so that lower leakage rates occur in future.

The model identified many previously unknown partially-closed valves and was also used to identify the natural hydraulic boundaries of the existing network, which could be closed without affecting the system's current operation. It was also used to design selective reinforcement needed to increase the network's hydraulic capacity.

Another paper, by Jaime Bonilla, Hernando Leal and Juan Carlos Gil looked at the success experienced by the city of Palmira in Colombia in controlling water losses.

Acuaviva operates water services in Palmira, which lies in the south west of Colombia, with the support of French group Safege. It designed a master plan for potable water that divided the city into four district management zones.

The plan also involved drilling new deep wells, installing flowmeters at the outlets of the treatment works, undertaking a pipe replacement programme, implementing leakage control, replacing domestic meters, and installing pressure reducing stations.

These actions reduced the amount of unaccounted-for water from 39% to 26% over six years. This figure placed Acuaviava among the best performers in Colombia. This plan exhausted economic alternatives for improving the level of unaccounted-for water, at least on the technical side.

Further pressure reduction was not thought possible: one problem was that although the pressure at the outlet of the pressure reducing station was mainly constant, it varied at some critical points, making it impossible to reduce the pressure further.

International leakage reduction company Fluidis, which had been working with the best performing utilities in the country, had been testing eequipment and developing procedures to successfully install its CAP-D system, which is based on active pressure control – a concept that involves controlling the amount of water flowing through leaks by reducing the pressures.

Since most domestic dwellings in Colombia have internal storage tanks, only 50% of the consumption of a typical house is affected by supply pressure. In residential zones, the night flows should be almost zero and the flow that there is will be due to leakage.

With this in mind, Acuaviva acquired and installed CAP-D systems for the three existing pressure reducing stations and built a fourth, with the intention of reducing pressure at night and increasing it during the day, ensuring that client service was not disturbed.

The system was commissioned and calibrated in under a week in 2003. The results showed a total reduction of 47 litres/sec at the four stations, from 652 litres/sec before the programme to 605 litres/sec after its implementation.

The project was successful because of the choice of a compact and reliable yet affordable system, which provided its own energy and was protected against the humid, corrosive environment of the site. The system was also easy to program and provided the ability to analyse how the system was performing, with data on inlet and outlet pressures.

The monitored sectors remained within the pressure criteria chosen, even if the operator or other elements caused mistakes. The active pressure control technology has now been successfully implemented in six differing Colombian cities, with similar results. ●

Diary

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

The Adam Smith Institute's 11th Annual Conference: The Future of Utilities
27 & 28th March 2006, London, UK
Building on the success of ten years, this conference has become the industry-leading event in the utilities sector, offering an excellent platform for the senior decision-makers to come together and examine the pertinent issues facing the industry. Confirmed water industry speakers are:
- Jeremy Pelczer, Chief Executive Designate, RWE Thames Water
- Philip Fletcher, Director General, Ofwat
- Katharine Bryan, Chief Executive, Water Service Northern Ireland

Key questions to be addressed at the event include:
- How can utility companies operate successfully in a time of rising prices?
- What role do governments, markets and regulators play in the utility sector?
- How can companies minimise the impact of wholesale price increases on the customer?
- Can adequate efficiencies be gained through effective asset management?
- What is the investment challenge facing utilities?

For more information visit: **www.marketforce.eu.com/utilities**

Water Loss Task Force Visit to Italy
13-21 May 2006, Genoa, Ferrara, Italy
This week-long visit to Italy takes in two main events: on the Monday, delegates will atttend the Workshop for Water Industry Representatives in Genoa, followed by the H20 Fair - Ferrara International Fair, which runs from Wednesday through to Friday. On the Tuesday and Saturday visitors will take in the sights with a boat tour of the scenic coast and a day in Venice. For more information, contact Marco Fantozzi: **marco.fantozzi@email.it**

1st World Congress on Engineering Asset Management (WCEAM)
11-14 July 2006, Queensland, Australia
The objective of WCEAM is to bring together leading academics, industry practitioners and research scientists from around the world to:
- Advance the body of knowledge in engineering asset management
- Strengthen the link between industry, academia and research
- Promote the development and application of research
- Showcase state of the art technology

This will be a refereed congress, with all final papers peer reviewed in full by a panel of international experts. Industry case studies will also be featured. The Congress will also host selected short courses in Asset Management on July 14 2006. Delegates will attend from all parts of the world and will include professionals from many areas of government (including policy makers), academia and industry.

The Congress will consist of keynote presentations, oral submitted presentations and poster submitted presentations. Suggested topics include:
- Strategic asset management
- Risk management in asset management
- Asset data warehousing, data mining and fusion
- Asset condition monitoring and intelligent maintenance
- Intelligent sensors and devices
- Fault diagnosis and prognostics
- Deterioration and preservation models for assets
- Human dimensions in integrated asset management
- Design and life-cycle integrity of physical assets
- Maintenance strategies in asset management
- Asset performance and level of service models
- Information systems and knowledge management

For more information and to apply, visit: **www.wceam.com**

SUDS: PERFORMANCE AND WHOLE LIFE COSTS

In parts of the US, alligators and beavers pose problems when it comes to the maintenance of sustainable drainage systems (SUDS). In the UK maintenance issues may seem more prosaic but flora, fauna, litter and vandalism demand new skills from both design engineers and maintenance teams.

Although SUDS are now generally recognised as being best practice in the design of new drainage, their rapid development has left owners and operators with a need for greater confidence in their use, particularly in terms of their long term costs and performance. A recently completed research project, funded by UKWIR, has reduced some of this uncertainty by providing a comprehensive evaluation of performance issues and a Whole Life Cost tool.

SUDS offer significant benefits over conventional drainage systems. They have the potential to attenuate runoff through storage, reduce total flows and enhance groundwater recharge via infiltration. They also present opportunities for 'natural' treatment processes (such as sedimentation, filtration, adsorption and biological degradation) for urban runoff pollutants. This has the clear benefit of reducing the flood and pollution risks to downstream areas that might otherwise result from development. In addition, the local environment stands to gain as a result of added ecological value and amenity enhancement.

However many of the components of SUDS systems are relatively new to the water industry. This means there is some uncertainty in terms of costs, operational requirements and liabilities. UKWIR (UK Water Industry Research) joined with WERF (Water Environment Research Foundation) to commission a transatlantic research programme drawing upon the experience and expertise of SUDS academics, designers and operators from the both the UK and USA to improve our understanding in this area. The research project, 'Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems', sought specifically to:

- address the lack of data on the operational performance of SUDS;
- quantify, as best as possible, financial and other liabilities and in particular operation and maintenance costs;
- establish an understanding of the long-term performance of SUDS to improve confidence in adopting these systems.

The research was carried out on behalf of UKWIR/WERF by a consortium made up of Black & Veatch, HR Wallingford, Abertay University, the University of Texas and Glenrose Engineering.

The project has pushed forward the boundaries of knowledge in relation to the water quality and Whole Life Costs issues of SUDS. Results have been published in two comprehensive reports and an accompanying CD-based Whole Life Cost tool, which engineers and designers can use when designing SUDS. The Whole Life Cost tool, developed by HR Wallingford, has drawn upon all available data on the construction and operation of various SuDS components and addresses all aspects of both financial as well as non-monetary cost valuation on a whole life costs basis.

The findings of this research, and in particular the new Whole Life Costs tool, will be presented to the water industry at the 'SUDS: Performance and Whole Life Costs' workshop organised by UKWIR. The conference will be held on 29 November at School of Oriental and African Studies (SOAS), University of London. It will also cover the future direction of SUDS research sponsored by UKWIR. ●