Managing the water balance

A holistic approach in the analysis of and turnaround strategies for municipal water supply systems – the perspectives of a financier. **BY KONSTANT BRUINETTE* AND TIAN CLAASSENS****

FOR MANY years, municipal supply systems have been operated inefficiently with little focus on best practice operation and maintenance. In many districts, losses have increased to such an extent that demand is outstripping supply.

Refurbishment of systems is often viewed as a simple process of replacing old pipes with new pipes, but achieving a financially sustainable water supply business is much more complex. The quantum of investment required is often of such magnitude that it lies outside the normal capital expenditure budget range of most municipalities. An obvious solution is for municipalities to secure external finance for these works, but the credit and risk evaluation requirements of financiers go way beyond a simple plan to replace pipes.

Existing methods to prepare projects of this nature are typically one-dimensional and lacking in adequate risk assessment. This paper introduces a new, holistic approach, through which key risks are identified and mitigated with the main purpose to facilitate the granting of finance for these projects.

Current analysis approach

Figure 1 illustrates the Best Practice Water Balance as published by the International Water Association (IWA).

It identifies components that make up the total demand for water at the input of a water supply system. It is useful to formulate simple strategies to enhance the viability of a supply system. A key problem is that most of the subcomponents are not readily quantifiable.

The dilemma a municipality faces is this: how to evaluate a project to reduce the real losses and motivate the required capital investment if the quantum of the real losses is unknown or, at the very least, highly uncertain. Addressing this dilemma is explored further in this article.

In this context, one should differentiate between the identification of the presence of real losses versus the quantification thereof. For example, monitoring of night flows in an area can indicate the presence of new leaks, which can then be fixed. At some point in time, however, the frequency of new leaks, etc., would indicate the need for overall replacement of the distribution/reticulation system. At this point in time, the need to quantify real losses would arise, as it will play a critical role in the capital investment decision.

Best practice in real losses is, internationally, loosely upon agreed at 15%. A uniform figure cannot apply to every system, as the law of diminishing returns applies to the reduction of real losses.

In response to this, the IWA has developed the concept of unavoidable annual real losses (we refer to unavoidable real losses or URL) and a methodology for estimating URL. Based on this development, the real losses in a system can be split into two components: the URL and recoverable real losses (RRL). From a financing perspective, only capital invested to eliminate the RRL can be motivated.

But the problem of achieving a sustainable system goes further than eliminating the RLL. It is the view of the authors that, unfortunately, the focus has been isolated on real losses at the expense of ignoring other critical parameters. For example, when looking at the water balance, the impression may be gained that the component revenue water translates directly into revenue for a municipality. That is not true. The process of converting revenue water to revenue is a risky process.

It is critical that recovery risk be assessed and adequately factored into a project. To achieve this, the water supply system must be designed to minimise this risk and it is clear that the pricing, metering, billing, accounting and collection functions are part of this system. To better understand this risk, the consumer base can be evaluated and the revenue water can be divided into the components shown in Figure 2.

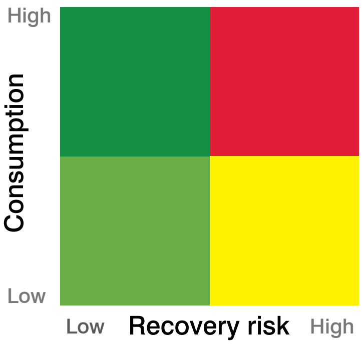
The impact of the four components reflected above on the actual revenue of a municipality will differ significantly. In general, different water supply strategies, systems, service levels and recovery strategies should be applied to all four components, but, in practice, it seldom happens.

It is also clear that capital expenditure that will rely on revenue collected from the

FIGURE 1 Best Practice Water Balance as published by the International Water Association (IWA)

System input volume (corrected for known errors)	Authorised consuption	Billed authorised consumption	Billed metered consumption (including water exported)	Revenue water
			Billed unmetered consumption	
		Unbilled authorised consumption	Unbilled metered consumption	Non-revenue water
			Unbilled unmetered consumption	
	Water losses	Apparant losses	Unauthorised consumption	
			Metering inaccuracies	
		Real losses	Leakage on transmission and/or distribution mains	
			Leakage on overflows at utility storage tanks	
			Leakage on service connections up to point of customer metering	

FIGURE 2 Consumer base analysis



high-recovery-risk components will be more difficult to motivate for finance.

Another critical factor in play revolves around the economic phenomenon of the price elasticity of demand, which dictates that, as the price of a commodity such as water declines, demand/consumption will increase and vice versa. To illustrate the impact of this further, we define the economic cost of water (units R/kℓ) as the cost that fully provides for all system input costs, system operating and maintenance costs, billing and collection costs, cost of capital as well as a charge for risk. A typical price elasticity of demand curve is illustrated in Figure 3.

This figure highlights three key parameters:

- **Zero base system demand:** demand for water that will result in the system if water is priced at the economic cost and there is no other restriction on consumption.
- **Elevated demand:** demand for water that will result in the system if water is priced below the economic cost and there is no other restriction on consumption.
- **Suppressed demand:** demand for water that will result in the system if water is priced above the economic cost or there are other restrictions on consumption.

The difference between elevated demand and zero base system demand is labelled overconsumption. In itself, overconsumption is not necessarily a bad thing. There are two situations, however, where overconsumption is financially debilitating for municipalities and is critical to eliminate:

- when overconsumption occurs in the high recovery risk portion of the consumer base
- when new water resources have to be developed (at great cost) to meet growing demand.

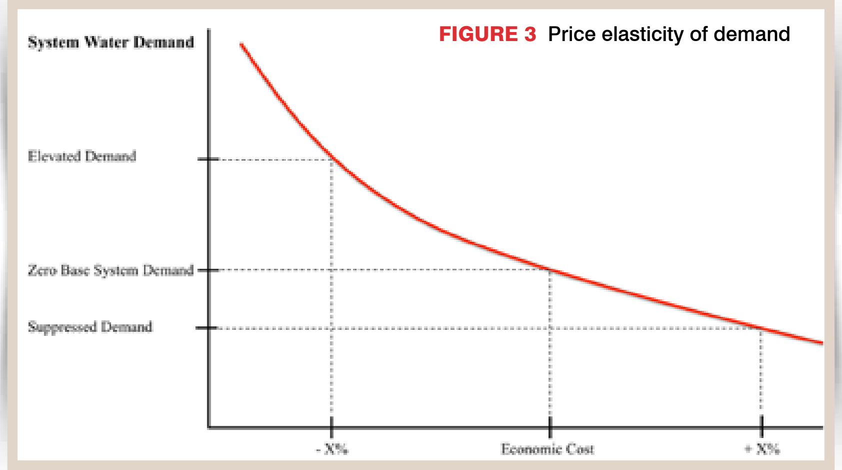
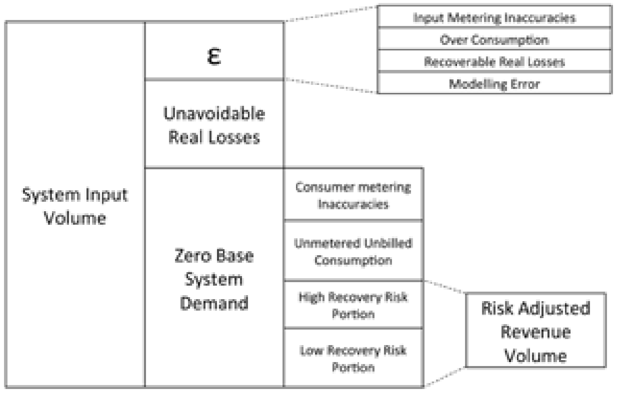


FIGURE 3 Price elasticity of demand

FIGURE 4 Alternative perspective of the water balance



A holistic approach

The discussion leads us to an alternative, more holistic perspective of the water balance, presented in Figure 4.

Zero base system demand is the system demand that will result if water is priced at the economic cost and there is no other restriction on consumption. There are various methods through which this parameter can be estimated. It is important that this remain an estimate and any model used should preferably be based on reliable statistical analysis that will provide quantitative information on the uncertainty in the estimate. This uncertainty represents demand risk – one of the key risks in the water value chain of a municipality and it is critical, from a financing perspective, that this risk be adequately mitigated. Zero base system demand is, thus, a statistical variable with an associated probability distribution as illustrated from an actual case study in Figure 5.

The probability distribution reflected in Figure 5 has a mean of 93.2 Mℓ/day with an 80% certainty that the true demand lies in the range of 78.8 Mℓ/day to 108.5 Mℓ/day. This range is a direct measure of the demand risk of the relevant system, although, in practice, the variance of the distribution would be used for this purpose. In the absence of a complete and accurate measurement system, this distribution represents the best estimate of the true system demand. Given the particular distribution, it is clear that ignoring demand risk in any analysis of the system would be perilous.

URL is estimated as per the guidelines of the IWA. Due to the uncertainties around different parameters that are likely to exist in any system, this parameter should also be a statistical variable with an associated probability distribution.

ε is a difference parameter that is obtained by subtracting the aggregate zero base system demand and the aggregate URL from the aggregate system input volume for a given time period. The parameter ε will also be a statistical variable with an associated probability distribution.

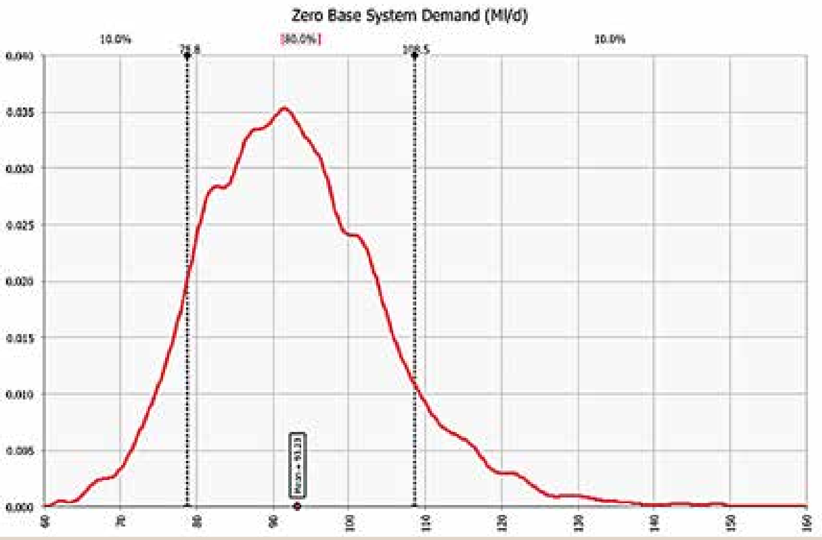
The width of the distribution of ε in Figure 6 indicates just how uncertain this variable is and how risky it would be to base any calculations on a single value.

In the alternative perspective, presented in Figure 4, ε is the aggregate of four different statistical variables:

- input metering inaccuracies
- overconsumption
- recoverable real losses
- modelling error.

If the input metering inaccuracies are eliminated and it is assumed that the modelling error is relatively small, then the probability distribution of the parameter ε represents an upper bound for the probability distribution of the sum of overconsumption and RRL.

FIGURE 5 Example of the probability distribution of zero base system demand



In the absence of extensive metering and other analysis that will allow these two variables to be quantified, they should be treated as inseparable. This implies that the formulation of any water conservation project must aim to address both these parameters, and this highlights the risk of focusing on the elimination of real losses in isolation.

The alternative perspective of the water balance in Figure 4 assists to identify two generic types of projects:

- conservation projects
- demand-side projects.

The capital investment for any conservation project will be motivated through:

- the potential cost savings through a reduction in the system input volume. The probability distribution of the parameter ε represents the risk that this saving will materialise and will enable robust risk analysis of the proposed investment
- the financial benefit that will result if capital expenditure on development of new water resources can be delayed for any length of time due to the reduction in the system input volume.

The capital investment for any demand-side project must be motivated through an appropriate increase in the risk-adjusted revenue volume and the associated increase in revenue to the municipality. It is important to note that the ratio of the risk-adjusted revenue volume/zero base system demand represents the true performance of the municipality from a recovery perspective.

Any turnaround programme to re-establish the sustainability and financial viability of the water business of a municipality must focus on the maximisation of the risk-adjusted revenue volume as a priority – thus, demand-side projects. From this perspective, it is critical to:

1. Understand the geographical distribution of the recovery risk areas.
2. Formulate separate strategies for the supply to and recovery from these consumer population groups.
3. Adjust the overall system design to implement the strategies formulated in 2 above.
4. Maintain the recovery ratio of the municipality above a suitable threshold.

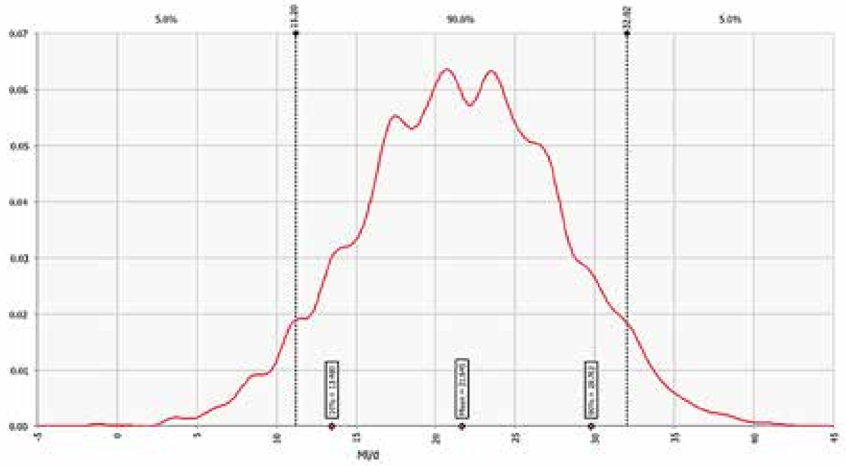
Municipal tariffs

The full cost of the URL must be included in the economic cost. Also, the economic cost should include a cost for carrying risk and the key risks to be included in this regard are demand risk and recovery risk. Determining and setting the appropriate tariff is a key step towards financial turnaround and sustainability of a municipality.

Conclusion

The basis of a holistic approach in the turnaround of municipal water supply systems and

FIGURE 6 Example of a probability distribution of ε



re-establishing sustainability may be summarised as follows:

1. Use of a suitable model to establish the zero base system demand and to quantify demand risk.
2. Use of a suitable model to estimate the URL.
3. Establish the different recovery risk and consumption components and to suitably quantify the risk-adjusted revenue volume.
4. Calculation of the existing recovery ratio of the municipality as a key performance measure.
5. Calculation of the economic cost of water supply.
6. Adopting an appropriate tariff structure to achieve specific strategies (such as eliminating overconsumption, etc.)
7. Identification and formulation of suitable conservation projects on a zone, district or subregional basis through:
    a) Testing for the likely presence of overconsumption and factors contributing towards overconsumption
    b) Estimation of the aggregate of RRL and overconsumption (i.e. ε i)
    c) Redesign of the relevant supply system of elements thereof
    d) Cost/benefit analysis through a suitable risk model.
8. Identification and formulation of suitable demand-side projects on a zone, district or subregional basis through:
    a) Setting an appropriate target for the recovery ratio
    b) Designing a suitable recovery strategy
    c) Redesigning existing distribution and reticulation systems where necessary
    d) Integrating future system requirements
    e) Conducting cost/benefit analysis through a suitable risk model. 3S

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