Performance target based non-revenue water reduction contracts: a new concept successfully implemented in southeast Asia

R. Liemberger
BWS Austria, Hasnerstrasse 7, A-9020 Klagenfurt, Austria (E-mail: roland.liemberger@bws-austria.com)

Abstract Non-revenue water (NRW), the difference between water produced and water sold, has reached unacceptable levels in the majority of water utilities all around the world. Outsourcing of NRW reduction activities is often the only feasible solution. The paper describes the concept of “performance target based non-revenue water reduction contracts” in general and provides detailed information on the world’s largest NRW reduction contract – the Selangor NRW reduction project. The performance target of Phase 1 was to reduce NRW by 18,540 m³/day. The works were completed on time and the target has been over-achieved. Based on this success, Phase 2 of the project has commenced in April 2000 with the aim of reducing NRW across the entire state of Selangor, by 200,000 m³/day over a 9 year period. After the first 15 months of the project, all targets have been substantially over-achieved. The project cost is RM 398 M (equivalent to US$ 105 million) with a pay-back period of 6.7 years. The internal rate of return was calculated to be 33.2% based on the assumption that the value of water equals the average tariff of RM 1.27 (equivalent to US$ 0.33). It can be concluded that performance target based NRW reduction contracts are a feasible model for water utilities around the world.

Keywords Malaysia; non-revenue water reduction; performance target based contracts

Introduction
During the last decade, some significant advances have been made in the understanding and modelling of water loss components. Started by the regulatory pressure in England and Wales on one hand, and general economic considerations on the other, increased attempts were made to define the economic level of leakage for individual systems. Yet, despite some encouraging success stories, the majority of water supply systems all around the world continue to experience high levels of water loss, many of which are almost certainly higher than their economic level. However, it is not only financial consideration which encourage utility managers to reduce water loss – in many parts of the world it becomes increasingly difficult to meet the water demand.

In southeast Asia, the drought caused by the last El-Niño weather phenomenon (1997–98) has once more demonstrated that the water demand of many cities (or even countries) has reached critical levels. The development of new raw water resources is capital intensive, requires long planning and implementation time and has, in many cases, negative environmental impacts. The reduction of physical losses would delay the need for the development of new resources, would reduce energy consumption for water production and distribution and could improve the present supply situation, whilst the reduction of non-physical losses would improve the revenue of the water utilities. All these aspects are of utmost importance for the majority of water utilities in CEEC.

To achieve a sustainable reduction of physical loss, a manpower intensive active leakage control policy has to be implemented by the respective water utility. Most government owned utilities have experienced substantial problems in doing so. In cases where full privatisation (e.g. concessions) is not appropriate or not welcomed by any of the stakeholders, outsourcing of these activities in the form of performance target based
non-revenue water (NRW) reduction contracts is a possible alternative. This concept was developed by Bristol Water Services (BWS) in order to provide a solution to the NRW problem in the Malaysian state of Selangor.

The concept was highly appreciated and a first phase (Phase 1) was awarded to the contractor PABW Sdn Bhd. (a Malaysian JV company of BWS). This was as part of the Selangor State Government’s policy to improve the water supply for the population by reducing the losses caused by leaking pipes and service connections and by increasing revenues by customer meter accuracy improvements.

The purpose of the Phase 1 project was to demonstrate the viability of the proposed methods of NRW reduction, within chosen pilot areas, with a view to the future establishment of a long term statewide project, provided the proposed methods were found to be effective.

The contract term of Phase 1 was 18 months and the project started in September 1998. The scope of works involved all aspects of NRW management activities, including pressure management, active leakage control, replacement of service connections and a customer meter exchange programme. The performance target was to reduce NRW by 18,540 m³/day. The works were completed on time and the target has been over-achieved. Based on this success, Phase 2 of the project commenced on 15 April 2000 with the aim of reducing NRW across the entire state of Selangor, by 200,000 m³/day over a 9 year period.

By the very nature of the work, NRW reduction projects are manpower intensive and require significant project management and organisational skills. Typically, as in Selangor, the implementation of such a project is in many countries beyond the normal resource capabilities of the local water supply and distribution network operator. The size of the contract is best illustrated with the manpower resource schedules which total approximately 750 months of foreign NRW specialists and more than 15,000 months of local Malaysian engineers, technicians and support staff.

Phase 2 is now well into its second year, and the encouraging results (all targets have been over-achieved) suggest that performance based NRW reduction contracts are a feasible model for utilities in other countries.

**Background information and definitions**

**Non-revenue water (NRW) and the IWA water balance**

Although the term non-revenue water is self-explanatory, its definition shall be given, along with IWA standard definitions that are relevant when talking about water loss reduction. Additionally, the new, standardised IWA water balance (Figure 1) demonstrates how NRW fits into this concept.

Definitions of principal components of the IWA water balance are as follows.

- **System input volume** is the annual volume input to that part of the water supply system to which the water balance calculation relates.
- **Authorised consumption** is the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so, for residential, commercial and industrial purposes. It includes water exported.
- **Water losses** is the difference between system input volume and authorised consumption. It consists of apparent losses and real losses.
- **Apparent losses** consists of unauthorised consumption and all types of inaccuracies associated with metering.
- **Real losses** on mains, service reservoirs and service connections, up to the point of customer metering. The annual volume lost through all types of leaks, bursts and overflows depends on their individual frequencies, flow rates and duration.
Non-revenue water (NRW) is the difference between the system input volume and billed authorised consumption. NRW consists of: unbilled authorised consumption (usually a minor component of the water balance); apparent losses; and real losses.

"BABE" – the burst and background estimates concepts
As early as 1994 Alan Lambert started to promote the principles of the “bursts and background estimates” (BABE) concepts on various occasions. At that time, BABE was known only to a few specialists in the UK water industry. Nowadays, BABE concepts are used in countries as different as Brazil and Tajikistan, in cities ranging from Cartagena to Amman to analyse the respective NRW problems.

BABE is a vital tool for feasibility studies to enable a rapid assessment of the NRW situation and to quantify the individual components that combine to result in the massive NRW problem in so many systems. Only by virtue of this assessment, is the Contractor able to accept a performance target based contract.

The BABE analysis helps to quantify the components of real losses, which are considered to consist of:
- background leakage at joints and fittings (leaks with flow rates too low for sonic detection if non-visible);
- reported leaks and bursts – typically high flow rates but short duration;
- unreported leaks and bursts – moderate flow rates with an average duration dependent on the method of active leakage control.

By quantifying the upper and lower level of savings that can be made from a wide range of NRW reduction investment options, BABE is able to assist in the economic analysis to determine the optimum investment level and develop the performance targets. These ensure that an acceptable payback period is guaranteed and are a key element in convincing the respective water authority or government that the project is financially viable.

Performance target based NRW reduction contracts
Performance target based NRW reduction contracts are lump-sum contracts based on a performance target with a clearly stated implementation time. The purpose of this concept is to relate the performance in achieving NRW reduction to the payment received by the contractor.

If the contractor does not achieve the savings agreed then he suffers a penalty that is directly proportional to the value of the water that was not saved. Likewise, if the contractor exceeds the agreed performance target, he may be rewarded with an additional bonus.
directly proportional to the value of the extra water saved. The determination of fair, but still challenging, performance targets is a key issue. The target should be based on a transparent BABE analysis (see above). This gives both the client and the contractor the confidence that the agreed target is both feasible and reasonable. Monitoring of flow and pressure is required in order to measure performance against targets.

This section describes the procedure that would be used if universal customer metering is available. If this is not the case, a less accurate way (minimum night line) has to be used. However, as customer metering is strongly recommended for various reasons (e.g. demand management) it is assumed that customer meters are either available or will be installed in the beginning of the NRW reduction project.

For optimum physical loss reduction, the distribution network will be split into discreet supply zones, consisting of between 500 and 2000 service connections.

After a NRW zone is isolated (prior to starting any NRW reduction activities), an inflow meter has to be installed at the inflow point and a continuous measurement over a period of 7 days has to be performed. The average daily quantity, in cubic metres per day (m³/day), over the 7 day period is calculated and will be used as Inflow \( I_{\text{start}} \) to the zone.

For the same period, all customer meters have to be read and the metered consumption of the zone has to be determined (in cases of billing according to estimated figures, both parties have to agree on a reasonable value which is in accordance with the average per capita consumption of this zone). The total daily average consumption (m³/day), of all metered consumers plus the cases with estimated consumption will be used as Consumption \( C_{\text{start}} \) of the Zone. The NRW level before carrying out reduction activities will then be determined according to the following formula:

\[
\text{NRW}_{\text{start}} = I_{\text{start}} - C_{\text{start}}
\]

After all NRW reduction activities have been carried out, the entire measurement procedure will be repeated as described above such that:

\[
\text{NRW}_{\text{end}} = I_{\text{end}} - C_{\text{end}}
\]

The zone performance achievement (ZPA) will then be calculated as:

\[
\text{ZPA} = \text{NRW}_{\text{start}} - \text{NRW}_{\text{end}}
\]

In southeast Asia (like in many other parts of the world), water supply systems often experience intermittent supply. Since the number of supply hours per day is significantly affecting the level of NRW, this has to be taken into account when measuring the performance achievement of the contractor. As the supply time often varied from day to day, NRW will be calculated in m³/hr when the system is pressurised.

The supply time (S) will be calculated from pressure measurements across the zone taken concurrently with the measurement of inflow to the zone. The total number of hours of supply time for the day (hrs/7 days) monitoring period is then used to determine the average flow rate per hour as follows:

\[
\text{NRW}_{\text{start}} = \frac{(I_{\text{start}} - C_{\text{start}})}{S_{\text{start}}}
\]

where \( C_{\text{start}} \) and \( I_{\text{start}} \) are in units of m³/7 days.

After all NRW reduction activities have been carried out, the entire measurement procedure will be repeated as described above such that:
\[ NRW_{\text{end}} = \left( I_{\text{end}} - C_{\text{end}} \right) / S_{\text{end}} \]

where \( I_{\text{end}} \) and \( C_{\text{end}} \) are in units of \( m^3/\text{day} \).

The zone performance achievement (ZPA) will then be calculated in the same manner as for areas with 24 hours supply and converted from a rate in \( m^3/\text{hr} \) to \( m^3/\text{day} \) using the supply time measured at the end of the NRW reduction as follows:

\[ ZPA = (NRW_{\text{start}} - NRW_{\text{end}}) \times S_{\text{end}} \]

In several countries, illegal connections account for a substantial part of NRW (unauthorised consumption). Wherever illegal connections are found, they will be immediately reported to the client for either disconnection or the installation of a meter. In cases where the client legalises the connection and installs a meter, the average daily metered consumption over a 2 month period will be used to calculate the achieved NRW reduction. In the case of a disconnection, a consumption figure typical for the type of customer involved and will be used to determine the NRW reduction.

The total performance achievement (TPA) will be the sum of the achievement in all the NRW reduction zones and will be determined as follows:

\[ TPA = \sum \left( ZPA_1 : ZPA_x \right) + \text{SIC} \]

where \( x \) is the number of zones established and SIC are the savings from illegal connections (\( m^3/\text{day} \)).

**The Selangor NRW reduction project**

**Phase 1**

As mentioned above, the serious drought in 1997–1998 was the main reason for the Selangor NRW reduction contract. It was the first time in Malaysia that a performance target approach had been used for this kind of work.

Selangor State, including the federal territory of Kuala Lumpur, is home to the majority of the major manufacturing industries of Malaysia. Covering an area of almost 800,000 hectares, Selangor has a population of some 5 million people. This is anticipated to rise to over 8 million by the year 2010 and to 10.3 million by the year 2020. The corresponding water demand, which is at present slightly less than 3 million litres per day (ML/day) is expected to be around 4 ML/day by the year 2010 and rising to more than 5 ML/day by 2020.

At present, water production is just meeting the demand, and several small sources inside the State of Selangor are being developed. Thereafter, additional water will have to be imported from a neighbouring Malaysian State, the conveyor scheme crossing the main mountain range of the country.

Developing these new water sources takes time and, in the meantime, each day millions of litres of water are being lost and wasted within the system, due to a combination of:
- Leakage from cracks and faulty joints from the more than 13,000 km of water pipelines making up the water supply distribution system of Selangor State.
- Leakage and wastage by overflow from reservoirs, tanks, valve chambers and hydrants.
- Leakage from service connections (found to be the largest source of leakage).

On top of all these physical losses, a substantial problem is also the permanent loss in revenue, due to inoperative or inaccurate meters and, sometimes, illegal connections. The amount of NRW within Selangor State was calculated to be about 40% of production.

Whilst not purporting to provide the entire solution to all Selangor’s water supply problems, a project involving the reduction of NRW to a more acceptable level, provides an
effective and comparatively cheap solution to increasing the headroom between supply and demand, which will be particularly relevant to the situation in Selangor over the next decade, when available resources will be stretched to the absolute limit.

The overall performance target of the contract was to reduce non-revenue water by a total volume of 18,450 m³/day of which; (i) physical losses were to be reduced by at least 10,450 m³/day; and (ii) an increase in metered water consumption of at least 6,400 m³/day was to be achieved. The contract value was fixed as a lump sum of RM 17.1 million (US$ 4.5 million) and included planning, leak detection, supply of materials, civil works, construction supervision and all other works and activities to necessary to achieve the target:

A physical loss reduction programme, comprising:
- selection and establishment of NRW reduction zones;
- supply of materials and equipment;
- execution of all leak detection and repair works.

A meter replacement programme, consisting of:
- analysis of historical meter data and selection of meters to be replaced;
- supply and installation of new meters.

The achievements of the physical loss reduction component were monitored and calculated as described above. The achievements of the meter replacement programme were calculated based on average daily consumption prior to and after the meter replacement. Average daily consumption based on actual billing data of a 12 month period preceding meter exchange was compared with average daily metered consumption for the 3 month period following the exchange. The difference will be the increase or decrease in metered consumption. The sum of these values at the end of the meter exchange programme will constitute the total increase in metered consumption achieved by the contractor.

At the end of the contract period, the contractor has over-achieved all targets (Table 1):

### Phase 2

The object of this project is to extend the benefits of the Phase 1 works throughout all the JBAS Districts, including the federal capital of Kuala Lumpur and, furthermore, to demonstrate the long-term benefits of sustainability and continuity of NRW reduction over a 9 year period. Yearly, as well as overall performance, targets have been set. These are:

1. Projected annualised volume saved in million cubic metres (combined savings from reduction in physical losses and increases in meter accuracy) as in Table 2.
2. By the end of the contract, the contractor will meet the overall performance target which is to reduce NRW (i.e. total reduction through reduced physical losses plus improved customer meter accuracy), by a total of 198,900 m³/day.

This loss reduction has to consist of a leakage reduction of at least 97,500 m³/day, (equivalent to supplying at current levels an additional 467,800 persons) and an increase in the accuracy of metering in order to register (at least) an additional 81,450 m³/day.

The contract is a lump-sum contract, with a total amount of RM 391.5 million (US$ 103 million). Present projections indicate that about 15,000 months will be needed to carry out this ambitious project. A small portion of this will be international specialists, who will train and guide the local staff. Thus a maximum transfer of technology is assured.

### Table 1  Selangor phase 1 target achievement

<table>
<thead>
<tr>
<th>Component</th>
<th>Target (m³/day)</th>
<th>Achieved (m³/day)</th>
<th>Ratio of achievement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical loss reduction</td>
<td>10,450</td>
<td>11,429</td>
<td>109</td>
</tr>
<tr>
<td>Meter accuracy improvement</td>
<td>6,400</td>
<td>9,212</td>
<td>144</td>
</tr>
<tr>
<td>Illegal connections</td>
<td></td>
<td>257</td>
<td></td>
</tr>
<tr>
<td>Total NRW reduction</td>
<td>18,540</td>
<td>20,898</td>
<td>113</td>
</tr>
</tbody>
</table>
**Target achievement up to date.** So far, the contractual targets have been substantially over-achieved. Already after 15 month the two year target of 17.46 Mm$^3$ (see Table 2) has been exceeded (see Table 3).

**Economic benefit.** The determination of the proper value of water is always a critical and controversial issue. Like in many places, this figure is unknown in Selangor. It was agreed between the contractor and the respective authorities that the average tariff (at present RM 1.26 per m$^3$ which equals US$ 0.33) will be used as the value of water saved. (This approach certainly has its weaknesses and the computed economic benefits will tend to be on the high side.)

The justification is simple: (i) water saved can be sold to existing or additional customers (as water production is insufficient); and (ii), the meter accuracy improvement directly increases revenues to that amount.

The payback period of the project is 6.7 years, and the internal rate of return is 33.2%.

### Table 2
Phase 2 annualised savings (annualised volume = average daily saving at end of year $\times$ number of calendar days in the year).

<table>
<thead>
<tr>
<th>End of year</th>
<th>Annual performance target (annualised volume of savings accrue) (Mm$^3$)</th>
<th>Cumulative savings (annualised volume of savings accrue) (Mm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.65</td>
<td>2.65</td>
</tr>
<tr>
<td>2</td>
<td>17.46</td>
<td>20.11</td>
</tr>
<tr>
<td>3</td>
<td>32.41</td>
<td>52.52</td>
</tr>
<tr>
<td>4</td>
<td>43.65</td>
<td>96.17</td>
</tr>
<tr>
<td>5</td>
<td>52.88</td>
<td>149.05</td>
</tr>
<tr>
<td>6</td>
<td>60.24</td>
<td>209.29</td>
</tr>
<tr>
<td>7</td>
<td>67.95</td>
<td>277.24</td>
</tr>
<tr>
<td>8</td>
<td>72.17</td>
<td>349.41</td>
</tr>
</tbody>
</table>

### Table 3
Target achievement phase 2

<table>
<thead>
<tr>
<th>Annualised NRW reduction</th>
<th>Target (Mm$^3$)</th>
<th>Achieved (Mm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>after 12 months</td>
<td>2.65</td>
<td>11.94</td>
</tr>
<tr>
<td>after 15 months</td>
<td>6.35</td>
<td>17.75</td>
</tr>
</tbody>
</table>

**Figure 2** Selangor phase 2: internal rate of return
already taking into account additional (and increasing) maintenance costs after the completion of the project. Although this figure is certainly overestimated because of the assumptions made for the value of water, it is without any doubt a strong economic justification for a project which is sustainable, environmentally friendly and will help to increase the Selangor water supply system’s efficiency and improve the supply of JBAS’ customers.

Conclusions
NRW reduction is extremely manpower intensive and thus difficult to manage. Governmentally owned water utilities, which have very limited possibilities to pay performance related salaries to their staff and are limited by all kind of legal restrictions, are mostly not in a position to substantially reduce NRW – even if the necessary know-how is available.

The success of phase 1 and the first 15 months of phase 2 of the Selangor NRW reduction project demonstrate that performance target based NRW reduction contracts are a possible alternative for water utilities in to reduce their non-revenue water level.

The BABE concepts have proved to be an important tool in the entire process, from the initial analysis to the daily needs of the NRW reduction teams.