Performance Based Contract for Non-Revenue Water Reduction – Case Study Bahrain

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Keywords: Non-Revenue Water; Performance-Based Contract; Sustainability

Abstract

A performance based contract (PBC) for Non-Revenue Water (NRW) reduction was executed in the Muharraq Governorate of the Kingdom of Bahrain over a three year period between 2013 and 2016. The contract included a mixture of fixed and performance based payment terms. The fixed element included an audit and assessment of the existing utility NRW management practices, production of a new NRW code of practice and a water balance calculation for the entire country, including breakdown of NRW components.

Water loss management software was implemented and integrated into existing utility corporate systems. The performance element of the contract included the establishment of 35 District Metered Areas (DMAs) within the Muharraq Governorate and the targeted reduction of NRW by 15 percentage points.

The contract was very much a partnership between the contractor and the utility, whereby the contractor undertook the investigative work, while the utility was responsible for executing all the construction type activities that resulted from the contractor's investigations and subsequent recommendations. The entire contract was designed to provide a learn by doing experience for the utility, so that a successful strategy could be replicated in the rest of the country, thus building on and sustaining the benefits of the project.

The project was eventually successfully concluded in about double the time originally planned for. NRW was successfully reduced in the project catchment through a combination of customer meter replacement and monitoring, pressure control and targeted leak detection and repair.

A number of important lessons were learnt that should be applied to future projects. There were a number of issues with the contract design, which arguably placed too much risk upon the contractor. The original project timescale of 18 months proved to be completely unrealistic. A fair and equitable contract model, with appropriate performance metrics, is crucial for ensuring project success.

The data collected following the DMA establishment process enabled the cause of NRW in each DMA, whether real or apparent losses, to be determined and the appropriate action taken. The quick wins for real losses was automated pressure control, while permanent monitoring of large industrial users represented the same for apparent losses.

Knowledge transfer to the utility proved to be arguably more important than actual achievement of contractual NRW related targets. The contractor-utility working relationship proved crucial in overcoming the many challenges and facilitated eventual project success.

Introduction

Context in Bahrain

In the arid Gulf region of the Middle East, potable water is expensive to produce, with the vast majority of it coming from desalination of seawater. The Electricity and Water Authority (EWA) of the Kingdom of Bahrain report that the total production and delivery cost of water, over 90% of which is desalinated, works out at US$ 1.98 per m^3. Until 2016, water bills in the small island nation were heavily subsidised for domestic users. Since then, subsidies have been gradually removed, such that by 1st March 2019, the full production cost of water will be charged for all commercial and expatriate domestic users, and for Bahraini domestic users with more than one home (EWA, 2016). All this means that water in Bahrain has as high an economic value as anywhere in the World and is a powerful driver for ensuring that water losses in the country are minimised.

The Water Distribution Directorate (WDD) of EWA has responsibility for Non-Revenue Water (NRW) management and underwent an organisational review through 2010 and 2011, which identified the need to improve the management and control of NRW. This led to a decision to prepare a Terms of Reference for private sector involvement in management and control of NRW in the country.

Performance Based Contracts for Non-Revenue Water

Performance Based Contracts (PBCs) for NRW reduction are an innovation that has seen increasing use in recent years, a successful example being New Providence, Bahamas (Wyatt, 2018). The concept involves linking payment terms to the service provider with actual achievement of volumetric reductions of NRW (Richkus et al. 2016). This is as opposed to conventional utility projects, which would typically involve payment to a service provider based on a series of inputs such as staff resources, time and equipment. PBCs aim to incentivise the service provider by linking a proportion of the payment to quantifiable outputs or benefits.

The World Bank have instigated a programme to develop good PBC practices for managing NRW (World Bank/PPIAF, 2016). This involves the creation of a series of diagnostic tools, term sheets and standard Terms of Reference for NRW PBCs that could be adapted to a specific country or utility context anywhere in the World. These would factor in issues such as the economic value of water, institutional capacity and commitment of the utility to reducing NRW, the availability of data, intermittency of supply and the interest of the private sector in providing such services.

Proposed contract models for NRW PBCs include a Design, Build, Operate, Maintain (DBOM) type contract, whereby the contractor would be responsible for all physical works required to reduce real (physical) losses. This contract type would involve a significant transfer of both network control and risk to the service provider. A Self-Optimising Contract provides for payment linked to measures such as number of customers on continuous supply, customer revenue or total volume of water supplied.

Cost plus style contracts more closely resemble traditional utility projects, in that the service provider charges for specified inputs, incorporating a profit margin. These can be used in the early stages of the development of NRW PBCs, when the exact utility requirements are still uncertain.

Incentivised Programme Management Contracts are where the service provider provides a team of experts to lead and manage the strategy for NRW reduction on behalf of the utility. Any physical works that result from these efforts would typically be carried out by third party contractors. The contractor would typically be paid management fees for their services, as well as bonus payments for achieved NRW reductions. The level of risk transfer would be relatively low to moderate for both parties, depending respectively on whether the third party contractors were managed directly by the utility or by the contractor on the utility's behalf.

Tender Process for Bahrain NRW Project

The Terms of Reference for the Bahrain NRW project was split into two phases. The first phase consisted of:

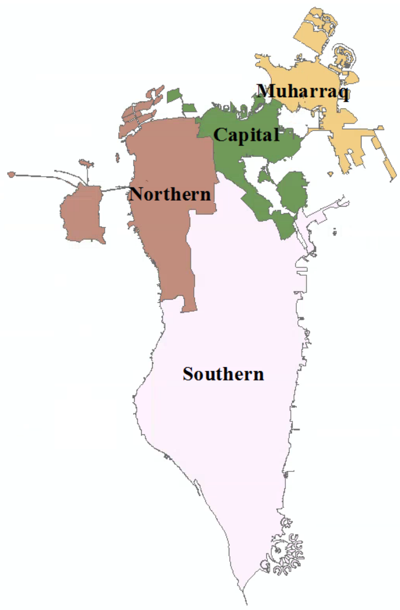
- Audit of the existing practices of the utility in relation to NRW management
- Production of a new Code of Practice and Key Performance Indicators (KPIs) for dealing with NRW
- Top down Water Balance, with NRW breakdown, for the country
- NRW Baseline for agreement of Phase II NRW reduction targets

The second phase consisted of District Metered Area (DMA) establishment and targeted NRW reductions within Muharraq Governorate, one of four Governorates within the country, as shown in Figure 1. Muharraq, with a customer base of over 60,000 at the project outset, was naturally isolated from the other Governorates, being itself an island off the Bahraini mainland, making it suitable for such a PBC.

The main objectives of the PBC were as follows:

- Full District Metered Area (DMA) coverage over project area
- Reduce NRW to below 20%
- Automated Monitoring System for continuous monitoring

Figure 1 Governorates of Bahrain



A total of 35 DMAs were to be established and an automated monitoring system implemented and fully initialized for the PBC catchment. NRW in the PBC catchment was assumed to be at 35% in the Terms of Reference and was to be verified and baselined during Phase I. The performance target was to achieve an NRW level of 20%, or to reduce it by 15 percentage points. The overall NRW project was meant to provide a learn by doing experience to the utility, to ensure a similar achievement by the utility across Bahrain over successive years following successful project completion. The Terms of Reference specified that the utility would be responsible for DMA meter installations. Other than that, it was not prescriptive on who was responsible for any physical works required.

The original timescales in the Terms of Reference were six months and one year for Phases I and II respectively, making a total proposed project execution period of 18 months. The pre-bid meetings took place in January 2012, after which four bids were submitted. Bids underwent a technical and financial evaluation, with 80% weighting towards the technical component. This resulted in a contract award to MWH, now part of Stantec, for US$ 3 million. The payment terms agreed during contract negotiation are summarised in Table 1.

Table 1 Bahrain NRW Contract Payment Terms

Phase I – 6 months	**% of Total Phase I Fee**
Mobilisation	15%
Data Collection	15%
Draft Phase I Report	30%
Approval of Phase I Report	40%
Total	**100%**
Phase II – 12 months	**% of Total Phase II Fee**
12 Base Monthly Payments	34%
Equipment (Procure – Install – Configure)	10%
Automated Monitoring System (Install – Commission)	14%
DMA Establishment (35 DMAs)	29%
NRW Reduction (15 percentage points)	13%
Total	**100%**

The risk of not achieving the most challenging aspect of the contract, reducing NRW by 15 percentage points, was mitigated by the proportion of the total contract sum linked to it, as shown in Table 1. For each percentage of NRW reduction achieved during Phase II, the payment to the contractor would be increased proportionally up to a maximum of 15 percentage point payments. Similarly, a payment would be due to the contractor for each DMA established, up to a maximum of 35 DMAs.

Regarding the NRW performance element of the contract, the contractor was to conduct all necessary investigative field work to identify all sources of NRW, both real and apparent (commercial). All necessary construction activities resulting from these investigations were the responsibility of the utility. This encompassed the following:

- DMA Meter Installation and Chamber Construction
- Customer Meter Installation/Replacement
- Pressure Control Implementation and Optimisation
- Leak Repairs
- Main and Service Pipe Replacement and Extensions
- Rectify Illegal Connections

The utility retained full operational control over the network. The contractor were only authorised to make recommendations. The decision on whether to implement these recommendations rested with the utility. As such, this project most closely resembled the Incentivised Programme Management Contract type described above and was very much a partnership between the contractor and utility. Project success was dependent on a positive working relationship, with each party fulfilling all of their obligations.

Project Execution

Phase I – Bahrain NRW Audit and Muharraq Baseline Study

Phase I commenced in January 2013 with a core contractor team of four specialists. By agreement between the parties, equipment procurement and implementation of the automated monitoring system was brought forward and progressed during Phase I. The automated monitoring system chosen was the Netbase water management software developed by Crowder Consulting, who were subcontracted to MWH/Stantec for the project. The Netbase system was designed to automatically import data from the following existing utility corporate data sources:

- Supervisory Control and Data Acquisition (SCADA)
- Customer Billing System
- Geographic Information System (GIS)

As part of the DMA establishment process, permanent flow and pressure monitoring was created at all newly installed DMA meters, at selected critical pressure monitoring points and at large commercial and industrial customers. This data was transmitted daily via the global system for mobile communication (GSM) and integrated into the Netbase water management software.

The preparation of DMA schematics for the 35 DMAs was also brought forward to Phase I. Following their approval by the utility, a Bill of Quantities for DMA meter procurement was prepared. Though these were originally meant to be procured by the utility, for purposes of expediency it was decided to issue a Variation Order to allow the contractor to procure the electromagnetic DMA meters for issue to the utility, who remained responsible for installation.

The accuracy of each of the metered system inputs within the PBC catchment was verified using temporary insertion flow meters to increase the confidence of the baseline calculation for the planned NRW reductions in Phase II.

The Phase I audit of existing NRW practices culminated in an NRW workshop in July 2013 delivered to all relevant utility departments. This was followed by the submission of the Draft Phase I Final Report in August 2013 as scheduled. The NRW baseline and breakdown for the project catchment was verified and agreed, and is shown in Table 2 below.

Phase II – Muharraq DMA Establishment and NRW Reduction

Phase II commenced with DMA isolation activities in September 2013, with a contractor resource of three field teams and a Project Manager/NRW Specialist. Due to the high quality of the GIS system, and effective cooperation between the contractor and utility on site, this process proceeded as smoothly as could have been hoped for. Some DMA boundaries were adjusted during the site work. There was also some adjustment of the boundaries of the tank supply zones fed from the distribution stations from the initial designs. The Muharraq water network was successfully split into 35 DMAs within six tank supply zones. NRW levels within each of the individual water supply zones were then calculated.

Prior to the procurement of the DMA meters, the utility proceeded with chamber construction into which the meters would be installed. Most DMAs were successfully isolated by the end of February 2014, though approval for the contractor to procure the DMA meters was only obtained from the utility in March 2014. In the absence of the majority of the DMA meters, use was made of existing meters already owned by the utility, along with temporary insertion flow meters. This allowed a total of 14 out of the 35 DMAs to be established early. These 14 DMAs encompassed full DMA coverage within one of the six water supply zones.

Active NRW detection was initially undertaken in these DMAs, prioritising those with high NRW. The topography of the Muharraq catchment was quite flat. It was found that pressure control was appropriate at the inlets to the six water supply zones. There was limited need for pressure control further downstream in the network. During Phase I of the project, it had been identified that four of the six zones had a plunger/needle control valve by which a suitable pressure management regime could be implemented. However, none had been optimised, leading to an unstable operating regime which contributed to increased NRW levels. This was exacerbated when one of the stations had to be shut down for maintenance by the utility Water Transmission Directorate. During the shutdown period the network was supplied by fixed speed pumps instead of via the pressure control valve, causing an erratic supply regime and an immediate increase in NRW in the area. The previous installation and configuration of the Netbase water management software enabled this effect to be observed immediately.

Due to such maintenance and data communication issues, it was only possible to optimise pressure control in the single zone where full DMA coverage had been achieved early. Pressure control was crucial as, prior to its implementation, the zone was prone to leak reoccurrence following any repairs. Automated pressure control in this zone, combined with a sustained effort in field NRW detection and repair resulted in significant savings in NRW in this zone. The majority of sources of NRW detected in the field were concentrated in just two DMAs. Leaking service pipes and faulty customer meters constituted the vast majority of detected sources of NRW.

Due to procurement and delivery lead times, the majority of the electromagnetic DMA meters were installed by the utility, with the contractor overseeing, during August and September 2014, at the end of the original Phase II time period. Due to this delay, the utility granted the contractor an extension of time, with no additional cost, until the end of December 2014.

A number of DMA meter installations were in locations that required a protracted wayleave application process. The last DMA meter installation was thus not completed until December 2014. By the end of the extended Phase II period, all 35 DMAs had been established covering all of the project catchment, but NRW had only been reduced in one zone. NRW in the catchment as a whole had not been impacted in a significant way. It had increased in some other zones, most particularly where the distribution station was shut down for maintenance.

Extended Services

The failure to achieve substantial NRW reductions during Phase II led to a standoff of several months between the contractor and utility. The utility senior management held that the contractor had failed to honour the terms of the contract as NRW had not reduced. The contractor cited the delay in procurement and installation of DMA meters, the lack of pressure control throughout most of the project catchment, negative impacts of actions by the utility in certain zones and the positive experience of NRW reduction in the one zone where the full contractor recommended strategy was implemented.

Eventually, a compromise solution was brokered whereby two contractor staff were seconded into the utility to work directly alongside utility staff over a further seven-month period, starting in October 2015, to achieve further NRW reductions as part of an Extended Services Contract Amendment. Three engineers and three field teams, were provided by the utility to work full time alongside the contractor specialists.

The utility arranged for automated pressure control at a further three water supply zones, making that four out of six with automated pressure control. The establishment of full DMA coverage in Phase II enabled targeted NRW investigations to take place throughout the catchment. This boosted the productivity of the field teams.

The very last DMA to be established during Phase II turned out to have the highest NRW of all 35 Muharraq DMAs. This was due to a large illegal connection, which would likely not have been discovered for a long time without the DMA data. These efforts resulted in significant NRW reductions by the end of the Contract Extension period in May 2016, though the contractual target of 20% was not quite reached just yet.

While pressure control represented the quick win for real loss reduction, logging of the large customers represented the same for apparent losses. Approximately 10 industrial customers were identified for permanent logging. These large customers consumed vast quantities of water, relative to the overall NRW levels. This resulted in the identification of deteriorating customer meters, each of which had a significant impact on NRW. These were combined with improvements in customer metering and billing by the utility throughout the project catchment.

Working closely with the utility enabled the contractor to produce a series of well-targeted Technical Notes aimed at ensuring that the utility were well positioned to build on and sustain the NRW reductions. This led to production of a Code of Practice and Bahrain NRW Reduction Roadmap better suited to the utility context. Working side by side enabled the utility to understand the challenges faced by the contractor in executing the project and meeting the targets.

Project Achievements

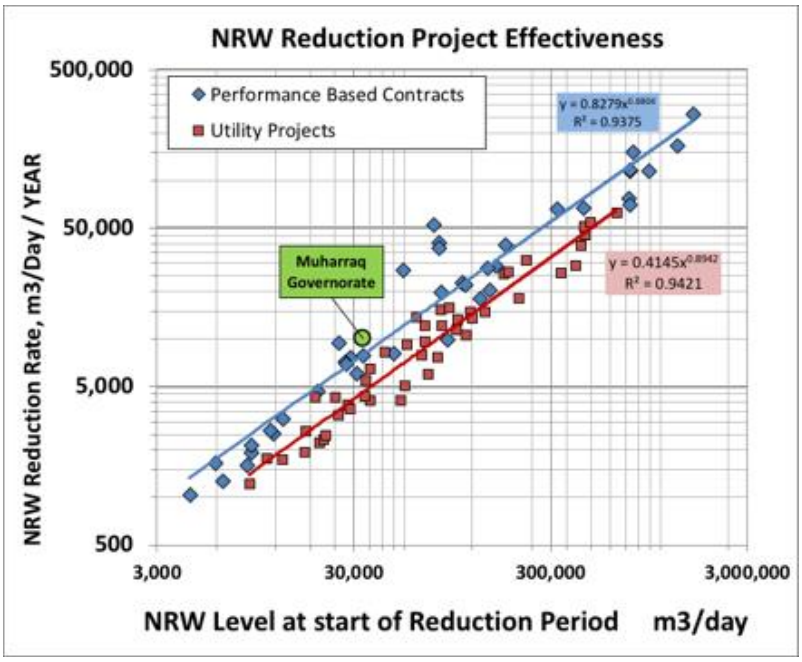
Shortly after the official end of the Extended Service period, the utility implemented automated pressure control at a fifth water supply zone in Muharraq, leaving just one station without automated pressure control. This immediately led to further NRW reductions and ensured the completion of the project to the satisfaction of all parties, surpassing the contractual target. The final project NRW achievements are summarised in Table 2.

Table 2 Muharraq NRW Achievements

	System Input (MLD)	Billed Consumption (MLD)	NRW (MLD)	NRW (litres/ connection/ day)	NRW (%)
Start (Year prior to Project)	93.5	59.9	33.6	861	36.0%
End (Year following Project)	97.0	80.0	17.0	420	17.5%

The total NRW saving was approximately 16.6 million litres per day (MLD), or 441 litres per connection per day, over the three year period of project activities, discounting for time during which little work was carried out. The volumetric NRW reductions achieved are comparable to other PBCs and compare favourably with achievements from conventional utility projects, as illustrated in Figure 2.

Figure 2 Bahrain NRW Reduction Achievements (Wyatt, 2018)



In terms of the financial value of the NRW savings, even though water was heavily subsidised for domestic users during the project time period, as these subsidies are being phased out it is appropriate to consider the reported economic value of water of US$ 1.98 per m^3 when assessing the return on investment. This translates to a financial value of NRW savings of over US$ 32,800 per day or over US$ 12 million per year.

In order to do a full value for money analysis, the total costs expended by the utility on the project would have to be considered along with the US$ 3 million payment to the contractor. Unfortunately, it was not possible to obtain this information with reliable accuracy for inclusion in this document. Nevertheless, there can be little doubt that the decision to procure a PBC has been vindicated.

Since completion of the project, the utility has actively embarked on replicating and building on the success of the NRW PBC to achieve similar results in the rest of Bahrain, using mainly internal resources. One challenge that has been encountered since project completion is the maintenance of the DMA meter installations. The climate in Bahrain is one of the most aggressive in the World. During the summer months, the heat and humidity in the DMA chambers reach very high levels. This has caused deterioration of the permanently installed equipment in some cases. It is important that any such equipment has the maximum level of protection in a climate like Bahrain’s. Despite such challenges, the utility is well placed to sustain and build on the achievements of the project.

Conclusions and Lessons Learnt

The main lessons learned from the Bahrain NRW Project, which are recommended to be applied to future NRW PBCs are as follows:

Realistic Time Period

The original project time period of 18 months was completely unrealistic for the expected achievements. The actual time spent was effectively double this period, about three years in total, with two years spent on DMA establishment and NRW reduction. A more realistic timeframe should have been included in the Terms of Reference. While it didn’t stop bids from being submitted, it resulted in unrealistic expectations. While the risk to the contractor was mitigated in terms of the relatively limited performance element of the contract sum, it still led to a confrontational relationship between the parties at key moments. While thankfully the parties managed to resolve the matter amicably, there was a serious risk of the many benefits being lost, especially if key individuals had not committed to seeing the project through to a successful conclusion.

Fair and Equitable Contract Model

The contract model of the contractor completing the investigative work with the utility being responsible for all construction activities, while retaining full operational control of the network, arguably placed too much risk upon the contractor, especially given the original project timescales.

The delays in procuring and installing DMA meters and in implementing automated pressure control significantly impacted on progress of achievement of NRW reductions, over which the contractor had little control. DMA meter installation was a utility responsibility, yet the contractor was still liable for the NRW reduction targets. This arguably represented a flaw in the contract design that resulted in inappropriate risk transfer.

Project Ownership and Understanding

This project was a joint effort between the contractor and utility Water Distribution Directorate. However, other utility Directorates had a significant influence to bear on whether the project was a success. Due to the utility corporate structure, the other Directorates were often more resembling of external stakeholders than of parties to the contract. A project challenge was to ensure that the other utility Directorates were aligned with the project objectives.

Ensuring understanding of all stakeholders of the nature of the work is a key challenge. During the Phase I and Phase II periods the capital outlay was high as the systems were implemented. These systems formed the basis for eventual successful achievement of NRW reductions. Yet at key moments during the contract, it led some to question the return on investment of this expenditure. There was an unrealistic expectation that NRW savings would be realised immediately following DMA establishment. Only by sustaining the effort to a successful conclusion was the strategy eventually vindicated.

Appropriate Performance Metrics

Using percentages of NRW is definitely not recommended as a performance metric. As is widely recognized among NRW practitioners, it fails to capture the many variables that determine what the volumes of NRW are. Volumetric reduction targets would have been more appropriate.

Independent Oversight

The lack of any independent oversight was a drawback on the project, particularly during the period when the project achievements were in dispute. There exists a strong case for an Independent Engineer to provide an impartial view throughout such a project and to ensure that all disagreements are quickly and amicably resolved. Project success would likely have been achieved much sooner had such an Independent Engineer been in place.

Data Management

The availability of enhanced data monitoring greatly facilitated the NRW PBC. The consequences to NRW of changing the system flow and pressure were able to be observed immediately, communicated effectively with evidence, and corrective action taken. Without the Netbase water management system it would have been far more challenging to monitor project progress and the project ambitions and achievements would likely have had to have been reduced.

DMA Approach reduced both Real and Apparent Losses

It was unknown in advance whether the main source of NRW was real or apparent. Certain DMAs turned out to have more real losses while others had more apparent losses. It was only following the establishment of the 35 DMAs that improved data availability led to the source of NRW in each DMA being identified and the correct NRW reduction strategy taken. Establishing the DMA and quantifying the level of NRW was the first positive step taken before splitting NRW into its real and apparent components. While it is often correctly pointed out that real and apparent losses have different cost curves and require different skill sets, in this case, discussions of whether NRW consisted of mostly real or apparent losses were often fruitless prior to the achievement of full DMA establishment. The contract was targeted with reducing NRW, of whatever type. This successfully incentivized significant reductions in both real and apparent losses across the project catchment.

Knowledge Transfer and Relationship Management

The close working relationship between the contractor and utility throughout the project, but especially during the Extended Services period, and the associated knowledge transfer proved to be crucial in reaching a successful conclusion to the project. While knowledge transfer was envisaged during the original NRW PBC time period, the other contract priorities by necessity took precedence. Even when the project achievements were in dispute, personal relationships between the parties remained warm. It was understood that this represented a challenge that had to be overcome. This avoided the disagreements escalating to a level that would have placed the project achievements in genuine jeopardy.

Knowledge transfer should be a central part of any such project, not just an afterthought as it arguably was here originally. Knowledge transfer is arguably more important than actual achievement of contractual NRW reduction targets as it ensures the utility is well placed to sustain and build on the project achievements. This should be reflected in the contract payment terms. This could consist of separate payment terms specifically aimed at a maintenance period. Payment terms could include a base payment for continued support and knowledge transfer, combined with bonuses and penalties aimed at sustaining low levels of NRW. A payment structure could be agreed in principle at the project outset and negotiated and finalised following a successful NRW reduction achievement to tailor the payment mechanism to the specific project circumstances.

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