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FELDA CHUPING NON-REVENUE WATER MANAGEMENT SYSTEM

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ABSTRACT

Non-Revenue Water (NRW) is a part of water production but bring no revenue to the water authority. NRW control has been given high priority by the Malaysian Government. As NRW cannot be totally avoided, understanding and managing its components is very crucial. Felda Chuping water distribution system is taken as a case in this study. A conceptual model for treated water distribution system that consists of the configuration for water source, water storage, water network, and the supply area has been identified. The seven NRW components identified by International Water Association have been grouped into four different sections in the model. A comprehensive and flexible web based prototype has been developed for Felda Chuping water distribution system that incorporates function for data recording, NRW estimation and report generation. The prototype covers all aspect of water management which enables the water authority to use its output for decision making and planning. The prototype was developed based on two models, a framework and a work procedure for NRW analysis.

Keywords: non-revenue water, water management, water distribution system

1.0 INTRODUCTION

Water lost from the many public water utilities due to poor water distribution network facilities and management, which resulted in a negative impact on the utilities is also known as non-revenue water (NRW). NRW is sometimes categorised as the amount of water put into the supply systems that bring no revenue to the supply authority and sometimes defined as the difference between water produced and water sold. IWA defined NRW as the difference between the System Input Volume and Billed Authorised Consumption (Liemberger, 2001). 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 authorized to do so, for residential, commercial and industrial purposes. Figure 1 shows the IWA standard water balance and terminology where NRW consists of real losses, apparent losses and unbilled authorized consumption.

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption (including water exported)	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	**Unbilled Metered Consumption**	**Non-Revenue Water (NRW)**
			Unbilled Unmetered Consumption	
	Water Losses	**Apparent Losses**	**Unauthorised Consumption**	
			Metering Inaccuracies	
		Real Losses	**Leakage on Transmission and/or Distribution Mains**	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer metering	

FIGURE 1: IWA Standard International Water Balance and Terminology (NRW and its components shaded grey)

In many countries, the water distribution system is organize in a network of pipes made of asbestos cement, PVC, mild steel and others. Pipes are buried underground and lined along the roads and highways. These pipelines are exposed to nature activities and will deteriorate and loose their initial water tightness (Hunaidi *et al.*, 2004). Causes of the deterioration include corrosive environments, soil movement, poor construction standards, fluctuation of water pressure, and excessive traffic loads and vibration. Due to the causes, water lost could occur at different components such as transmission pipes, distribution pipes, service connection pipes, joints, valves, fire hydrants, and storage tanks and reservoirs.

In the 21st century NRW reduction has been one of the hottest water topics among water authority and water institutions around the world (Liemberger and Fanner, 2002). In many countries, NRW control program has shown a major reduction of NRW. Gaza, Palestine (Jme'an and Al-Jamal, 2004) for example manage to reduce NRW from 50% (in 1996) to 30% (in 2000). The same impact is experience by Bangalore, India (Suzuki, 2005) with the reduction of NRW from 48% (in 2003) to 22% (in 2006). The NRW give an economic impact to the consumer and water authority as budgets amounting to millions of dollars have been spent for pipe replacement and water management.

2.0 CASE STUDY

NRW control has been a high priority issue by the Malaysian Federal Government. In the Eighth Malaysia Plan a total of RM640 million was expended to reduce the NRW. The activities involve the replacement of old pipes and old water meters and reduction of water pilferages as well as the rehabilitation and upgrading of water distribution system. In the Ninth Malaysia Plan, the effort to reduce the NRW is to be continued in order to improve the efficiency of water supply. RM 1088.3 millions is budgeted to reduce the NRW from 38% (2007) to 30% (2011) (Economic Planning Unit, 2006).

Perlis, one of the smallest states in Malaysia, has also experienced high level of NRW that are 44% in 2000 and 37% in 2005. The state water supply section is the authority that handles the management of treated water for domestic and non-domestic in Perlis. Felda Chuping is one of the small consumer zones that experienced NRW. Previous research shows that Felda Chuping NRW is around 37.56% in January 2004 (Ku-Mahamud *et al.*, 2004).

The research focus on Felda Chuping as a case study. Felda Chuping is one of the consumer zones that obtained treated water from underground sources and experiences huge water loss as water is conveyed to a supply tank before it reaches the consumer area. NRW percentage for Felda Chuping consumer zone is about 37.56%. In order to reduce the NRW, the water authority will have to identify the source of NRW. Until now, it is a problem for the water authority to identify the source and magnitude of the NRW.

3.0 CONCEPTUAL MODEL OF TREATED WATER DISTRIBUTION SYSTEM

Felda Chuping treated water distribution system can be summarized as consists of water sources, water treatment plant, storage, distribution pipes and service pipes, and consumers meter (consumer area). Based on the collected data and schematic diagram of Felda Chuping water production, a conceptualize model is formalized as shown in Figure 2. This model shows the main components of Felda Chuping water distribution system. As shown in Figure 2, water is pumped from borewells and treated at the pumping house before been stored in supply tank. The transmission is through the distribution mains. After the supply tank, the water is supplied to consumer through service connections.

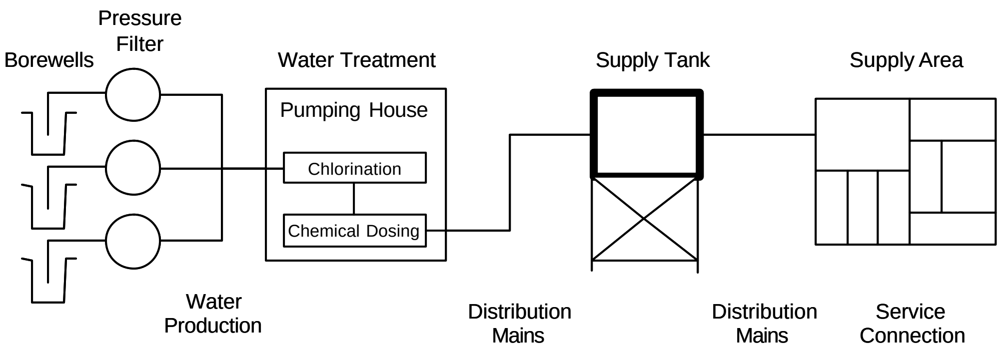


FIGURE 2: Conceptualization of Felda Chuping treated water distribution system

Based on the conceptual model, further analysis has been made and four water loss areas have been identified. Details of the losses are described in Table 1. Figure 3 depicts the framework of NRW classification, both by water loss area and type of NRW. The areas are at the water loss transmission pipe before tank (A1), the tank (A2), transmission pipe after tank (A3), and consumer area (A4). At each area, the possible type of NRW has been identified.

TABLE 1: NRW Code Description

Code	Descriptions
NRW01	Unbilled Metered Consumption
NRW02	Unbilled Unmetered Consumption
NRW03	Unauthorized Consumption
NRW04	Meter Inaccuracies
NRW05	Leakage on Transmission and/or Distribution Mains
NRW06	Leakage and Overflow at Utility's Storage Tank
NRW07	Leakage on Service Connections up to point of Consumer metering

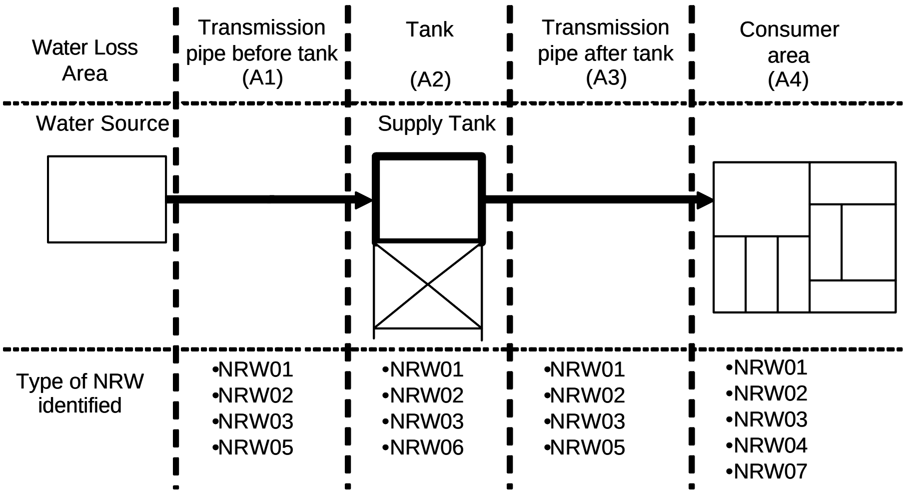


FIGURE 3: Framework of NRW identification and classification

4.0 PROTOTYPE DEVELOPMENT & TESTING

In this study Visual Basic.NET and ASP.NET technology were used to develop the prototype. This technology centers on an integrated development environment which lets programmers create standalone applications, web sites, web applications, and web services that run on any platforms supported by Microsoft's .NET Framework. This solution can give rapid development and easy to update the requirements. In addition, Microsoft SQL Enterprise Manager is used to store and manipulate data.

Figure 4 shows the entities involved in this prototype development. The entities are consumer, meter and billing histories, source input, constant parameter and NRW consumption.

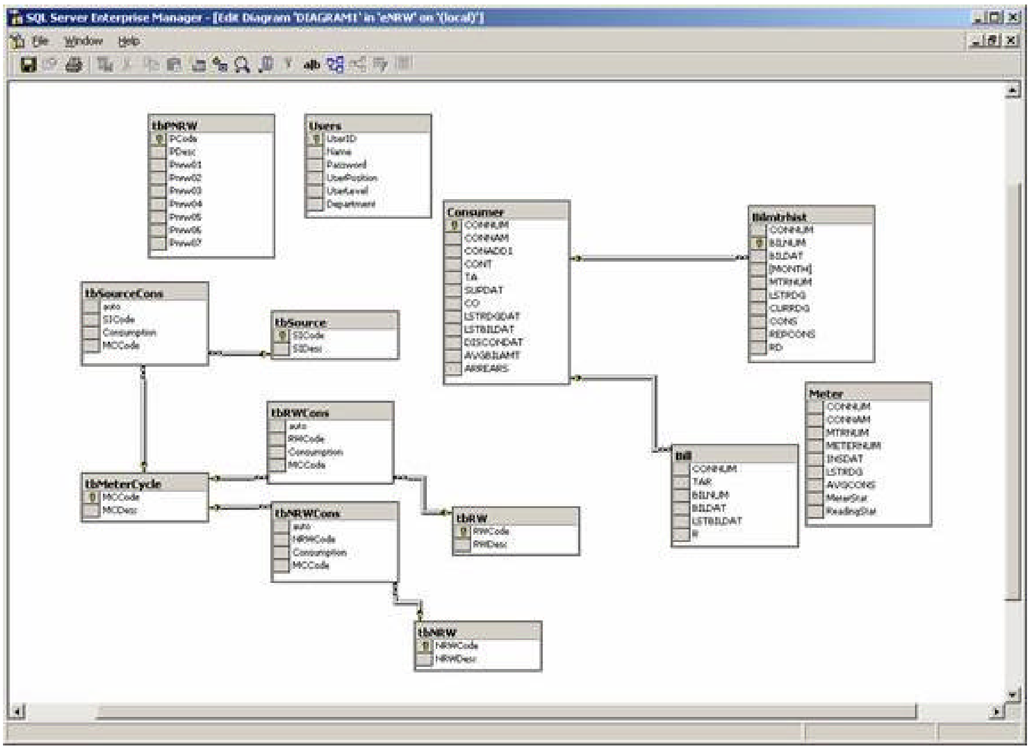


FIGURE 4: Entity Class Diagram for NRW-Felda Chuping Prototype

Prototype system is design and developed based on Web-based application. The prototype main components are client site and server site. The client sites are located at Perlis Water Authority headquarters, Repoh Maintenance Unit, and Rumah Pam Felda Chuping. The computer server using Windows Server 2003 operating system, which support ASP.net technology and VB.net scripts is located at the Perlis Water Authority headquarters in Utan Aji. Access to the prototype is through existing Perlis Water Authority network facility. The prototype employs Microsoft SQL Enterprise Manager database for storing and manipulating the NRW data. FIGURE 5 shows the physical layout of the prototype.

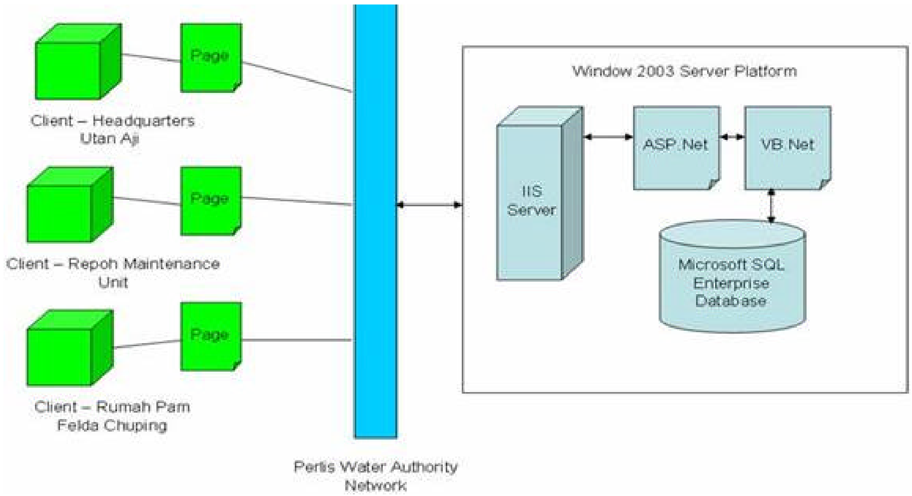


FIGURE 5: Prototype Physical Layout

The prototype menu consists of four main functions which are system parameter, data entry, data manipulation, and report. The system parameter setup can be used to set up of the parameters of Felda Chuping water distribution system. There are six sub-menus available. The functionalities of these sub-menus are shown in Table 2.

TABLE 2: Functionalities of System Parameter

Sub-Menu	Description
Month Cycle Code	Define the month cycle code
System Input Code	Define the system input code
Revenue Water Code	Setup the revenue water code
NRW Code	Setup the NRW code
NRW Parameter	Define NRW constant value
System User	Manage system user account

Data entry sub-menu consists of source input consumption, revenue water consumption, and NRW consumption. The functions of the sub-menus are listed in Table 3.

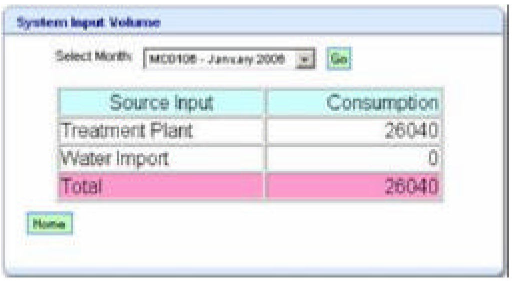
TABLE 3: Data Entry Sub-menu Functionalities

Sub-Menu	Description
Source Input Volume	Input source water consumption
Revenue Water Consumption	Input revenue water consumption
NRW Water Consumption	Input NRW Water consumption

In this study the source input considered are from the treatment plant and import water. Water from treatment plant is the water produced from borewells and pumped to Felda Chuping area, while import water is water obtained from treatment plants or transmission pipe in other NRW zones. These data are recorded monthly. Revenue water is the water that is charged to the consumers in Felda Chuping area. Revenue water is also known as Billed Authorized consumption. The data is obtained from billed metered consumption and billed unmetered consumption on monthly basis in the present Water Billing System.

NRW water consumption data is obtained from the report produced by Repoh Maintenance Unit. This unit is responsible for site inspection, maintenance and repair. NRW data include unbilled metered consumption, unbilled unmetered consumption, unauthorized consumption, metering inaccuracies, leakage on transmission pipe, leakage at utility's storage, and leakage on service connections up to consumers' meters. These data are recorded on monthly basis.

Data manipulation option is for estimating NRW volume and percentage. Estimating NRW volume is based on the defined constant values. Report option on the main menu consists of 19 types of report available for the user to generate. The types are reports on system input, authorized consumption, water losses, billed authorized consumption, unbilled authorized consumption, apparent losses, real losses, billed metered consumption, billed unmetered consumption, unauthorized consumption, metering inaccuracies, leakage on transmission, leakage at utility's storage, leakage on service connections, revenue water, non-revenue water, and consumer information. Figures 6-11 show example of reports that are generate by this prototype. Reporting can include data from a combination of the months.

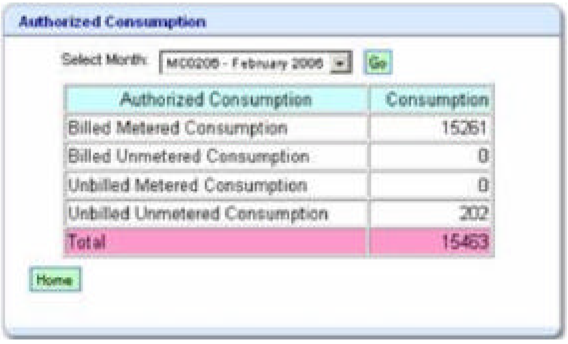

System Input Volume

Select Month: MC0106 - January 2006 Go

Source Input	Consumption
Treatment Plant	26040
Water Import	0
Total	26040

Home

FIGURE 6: Report on Source Input

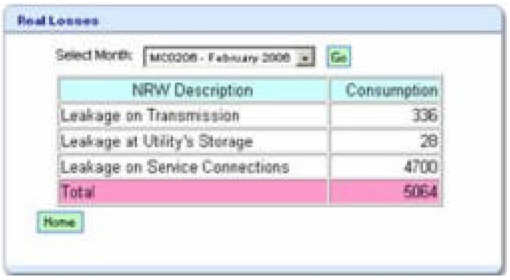

Authorized Consumption

Select Month: MC0206 - February 2006 Go

Authorized Consumption	Consumption
Billed Metered Consumption	15261
Billed Unmetered Consumption	0
Unbilled Metered Consumption	0
Unbilled Unmetered Consumption	202
Total	15463

Home

FIGURE 7: Report on Authorized Consumption

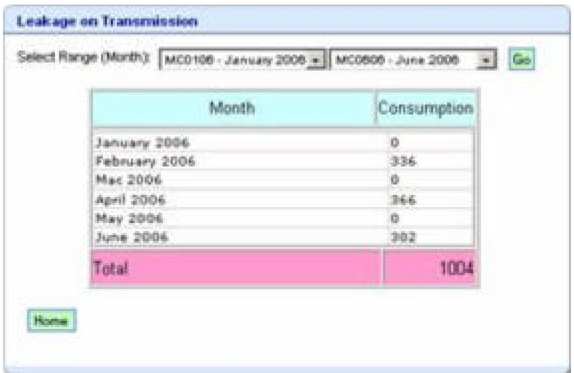

Real Losses

Select Month: MC0206 - February 2006 Go

NRW Description	Consumption
Leakage on Transmission	336
Leakage at Utility's Storage	28
Leakage on Service Connections	4700
Total	5064

Home

FIGURE 8: Report on Real Losses

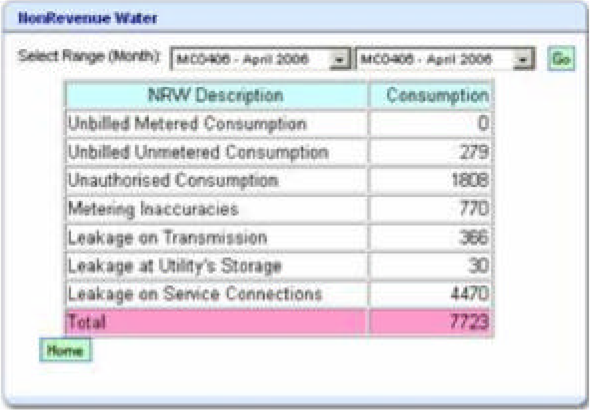

Leakage on Transmission

Select Range (Month): MC0106 - January 2006 MC0606 - June 2006 Go

Month	Consumption
January 2006	0
February 2006	336
Mac 2006	0
April 2006	366
May 2006	0
June 2006	302
Total	1004

Home

FIGURE 9: Report on Transmission Leakage

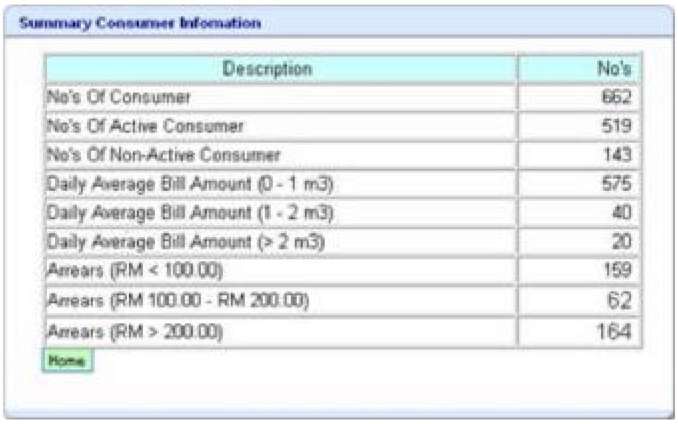

NonRevenue Water

Select Range (Month): MC0406 - April 2006 — MC0406 - April 2006 [Go]

NRW Description	Consumption
Unbilled Metered Consumption	0
Unbilled Unmetered Consumption	279
Unauthorised Consumption	1808
Metering Inaccuracies	770
Leakage on Transmission	366
Leakage at Utility's Storage	30
Leakage on Service Connections	4470
Total	7723

[Home]

FIGURE 10: Report on NRW Consumption


Summary Consumer Information

Description	No's
No's Of Consumer	662
No's Of Active Consumer	519
No's Of Non-Active Consumer	143
Daily Average Bill Amount (0 - 1 m3)	575
Daily Average Bill Amount (1 - 2 m3)	40
Daily Average Bill Amount (> 2 m3)	20
Arrears (RM < 100.00)	159
Arrears (RM 100.00 - RM 200.00)	62
Arrears (RM > 200.00)	164

[Home]

FIGURE 11: Summary Report of Consumer Information

Testing of the prototype includes validations of the main modules of the prototype. Main modules are:

a) source input data,
b) revenue water consumption,
c) comparing the NRW metered consumption and collected NRW component data,
d) monthly NRW component data

The source input is validated using the following formula (as suggested by Distribution Engineer at Perlis Water Work);

$$\text{pumping rate} = \frac{\text{tank width x tank length x tank height x } 6.25}{\text{pumping hour}} \qquad (1)$$

where 6.25 is the fixed parameter for the imperial tank that represent the water cube. The new pumping rate for imperial tank can be obtained for 16 pumping hours test is calculated as below.

$$\text{pumping rate} = \frac{120{,}000 \text{ gallons}}{16 \text{ hours}}$$
$$= 7503 \text{ gallons/hours} \equiv 34.11 m^3/\text{hour}$$

The difference between the adopted pumping rate and the new pumping rate is around 2.54%. This shows that the pumping rate adopted (i.e. 35 m^3/hours) is acceptable. The result also shows that accuracy of the source input volume is 97.46%.

The revenue water is validated based on the estimation of water used per day. As suggested by Bina Runding (1991), average water use per day is around 0.23m^3/day (equivalent to 50 gallons/day). Bina Runding also suggests that the average number of person or consumer in Felda Chuping is 4 persons per active consumer. The formula to calculate the monthly revenue water is as follows:

Revenue Water = (per month)	No. of active consumer x Average usage per active consumer x Average water use x No. of days	(2)

Based on the formula and Felda Chuping consumer information, the monthly revenue water can be estimated as follows:

$$\text{Revenue Water (for February)} = 605 \times 4 \times 0.23 \times 28 = 15585\ m^3$$

When compare the actual and estimate data, the percentage of accuracy of the metered revenue water is about 97.88%.

The NRW volume estimated by the prototype is validated by comparing this volume with the actual data collected on the NRW. The collected NRW volume is based on the difference of source input and revenue water. Result of the comparisons shows that the accuracy of the result produced by the prototype is more than 85%.

5.0 Conclusion

The prototype has been developed using web-based technologies. The prototype is design to model the existing Felda Chuping water system. The design includes the establishment of the related entities, physical and interface design. Based on the constant NRW parameters, the prototype can be used to identify the NRW components and estimate the magnitude of NRW. This leads to the identification of the source or location of the water loss. The prototype has the capability of performing monthly NRW calculation where previously NRW figure can only be obtained on yearly basis. As the prototype covers all aspect of water management, the output produced from the prototype can be used by the water authority for decision making and planning.

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