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# MODELLING THE PERLIS NON-REVENUE WATER

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**ABSTRACT**

Many reasons have been identified as contributing to or causing high level of non-revenue water such as poor organizational structures in the responsible agency, insufficient funds, poor water network implementation and low profile of actions addressing optimization of services including leakage control, inadequate tariff and collection systems. This paper describes a simulation system that was developed to predict the supply and demand of treated water as well as non revenue water source and magnitude for a case study of a public treated water distribution system. The system can also be used in assisting the management of the water department in simulating future development such as demand and new construction of water distribution. In conclusion, the developed system has increased the knowledge of the distribution system and understanding of consumption patterns and non revenue water zones, which has allowed the water authority to optimize its distribution system.

## 1. INTRODUCTION

Water is one of the most common substances of the world and one of the main sources for living. Many organizations such as International Water Management Institute (IWMI), The International Water Association (IWA) and World Water Council (WWC) are set up to organize and monitor global water management. Water loss is one of the major issues in water management. Water loss is caused by natural process such as evaporation, runoff and human or technical errors. [1] discussed the water loss management and techniques based on IWA standard international water balance and terminology which highlights that water loss is a part of non-revenue water (NRW) where water loss consists of real losses and apparent losses. The standard has been applied in many countries such as in Southeast Asia [2], Middle East [3] and South Africa [4].

NRW is categorised as the amount of water put into the supply systems that bring no revenue to the supply authority. NRW consists of real losses, apparent losses and unbilled authorized consumption. Controlling and reducing NRW is one of the issues to consider in sustaining the water resources [5]. NRW control has been given high priority by the Malaysian Federal Government. [1] reported that in 2001 Malaysia is having 36.4% of NRW.

Computerized models have been used as one of the approach in water management. [6] studied the problem of poor water management in Scottsdale City, Arizona which fails to serve its growing number of consumers. A model was designed to react similarly to the actual physical water system with pipes, junctions, reservoirs, wells and booster pumps. It produce reports on parameters used, flow rate, velocity, pressure loss, and demand. [7] discussed the use of interactive simulation modelling approach for pumping in water supply networks. The approach allows the engineer to retain the human supervisory element for control, while using an off-line minicomputer to guide the decision-making.

This study has developed a model for a case of the public treated water distribution of Perlis, Malaysia. Based on the model, a system for the water distribution has been developed. The system can be used to simulate future demand, consumption and the NRW.

## 2. CASE BACKGROUND

The management of treated water in Perlis is handle by the Water Supply Section, which is the state water authority. The existing treated water distribution system consists of distribution pipeline, canal, pumping main, closed valve, reducer, booster station, bore wells, service reservoir, treated plant and storage/supply tank. Clean water is obtained from three main sources i.e MADA canals, Timah Tasoh dam and underground water. Water is treated at the treatment plants before being sent through pipes to storage or supply tanks and later distributed to all consumers (domestic – 86.3%, non domestic – 13.7%) around Perlis. Usually, the treated water is being stored in several tanks before reaching the consumers. However, there is a case where the treated water is directly pumped from the treatment plant to the consumers. A consumer is charged or billed based on the amount of water consumed and is recorded by a meter.

There are nine treatment plants in Perlis. However, only four are being used for water treatment with total output capacity of 109 million litre/day. Perlis has 25 tanks (classified as booster, reservoir, elevated and ground) for storing and supplying treated water to 99% of the rural and urban areas. However, only 12 tanks are being used due to water shortage and low pressure. Different types of pipe are used for delivering water and these vary from type of material used and size. There are 56,615 connections of which 51,632 are domestic connections. Four types of meter are used and some of the meters have been used for more than ten years.

There are four supply zones namely Wang Kelian, Timah Tasoh, Felda Chuping and Arau, which are divided into smaller zones called NRW zones. The zone is categorized as such to facilitate the management of the NRW. Some NRW zones are connected to more than one supply tanks and some supply tanks deliver water to more than one NRW zone. NRW percentage in Perlis, was estimated to be 43.8% in 2000 and a reduced in percentage to 39.2% was observed in 2001. However, the percentage has increased in 2002 to 40% and 41.6% in 2003. The operating costs of the water authority were about 12.3, 12.4, 12.9, and 13.7 millions while the total revenues were about 11.1, 12.8, 12.7, and 12.9 millions for the 2000, 2001, 2002, and 2003 respectively.

## 3. METHODOLOGY

The study begins with the collection of information and data of the treated water distribution system followed by the analysis of the existing water network distribution. Model conceptualisation of the water distribution system layout was then designed. Formula to calculate NRW for each zone is then established. This is followed by the design of the database of the water system. Rational Rose as a tool is used in this phase to produce the use case diagrams for the purpose of identifying the actors and tasks involved in the operation of the water distribution.

System development based on the model is then undertaken. This includes the development of the user interface and the database. For the purpose of validating the developed system, extensive testing with real data has been done to determine its accuracy in producing the correct output. The system is then used to simulate the NRW, water consumption and production.

## 4. SYSTEM CONCEPTUAL MODELLING

Figure 1 below shows the conceptual network modelling which consists of connection between treatment plants and NRW zones.

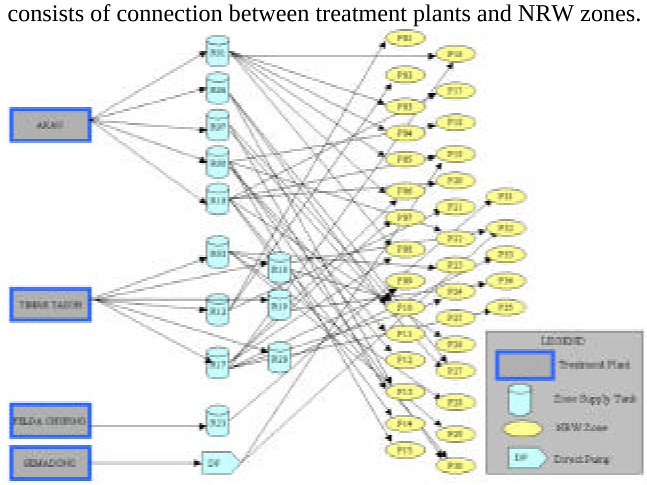

Figure 1. *Network Modeling For Treated Water Distribution System*

Use case diagrams have been developed and five actors have been identified. The actors are the system administrator, NRW Engineer, treatment plant engineer, distribution engineer and consumer engineer. One of the use case diagrams is as depicted in Figure 2. Fifteen use cases/tasks have been identified to represent the functions provided by the NRW system.

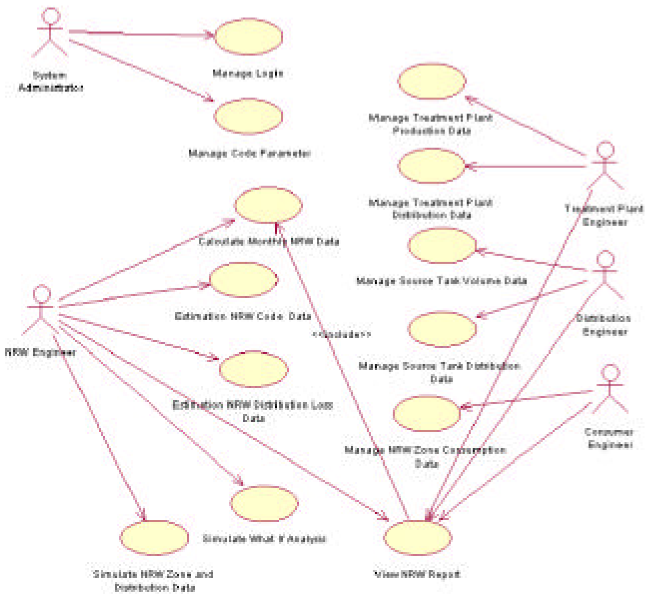


Figure 2. *Use Case Diagram for Perlis NRW System*

Figure 3 shows a class diagram that was created to reflect the classes and relationships that are needed for the set of use cases that have been identified. Data modelling has been performed to show the structure of the organizational data and later used to develop and analyse class diagrams which reflect the relationship among that remain constant in the system over time.

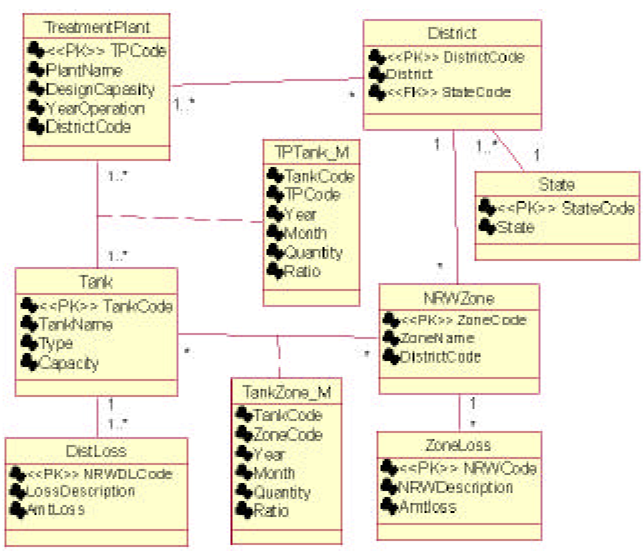


Figure 3. *Conceptual Data Model*

## 5. SYSTEM DEVELOPMENT

Perlis NRW systems is design and develop under on world wide web based application and the architecture consists of two main components: client and server sides. Intranet users accessed the server directly through local area network connection, while Internet users accessed the server through the Internet. The server uses Windows 2003 platform, which support dynamic web pages, embedded with Active Server Page and VB.net scripts. These scripts connect the users with the SQL database, which store the information on water system.

The main user of the system is the Perlis water authority officer. The system is equipped with password, which allows access to certain officers who have right to the data. Figure 4 shows the main interface of the system. The researcher and user did extensive testing on the system, which involve water production data, source tank distribution, zone consumption, NRW details, and monthly NRW summary. System output is compared with the actual published report in this validation process. Results produced showed that the system is error free.

The system workflow can be divided into four categories: code setup, data entry and calculation, data simulation and report. Code setup is use to set and initialize the codes and basic parameters for treatment plant, supply tank, NRW zone, NRW code, distribution loss code, treatment plant distribution, and source tank distribution. These codes and parameters will be used in the data entry and calculation sections. The system can be used to simulate the distribution of NRW, identification of NRW zone, combine NRW and performing the what-if analysis. The users particularly the water authority may view and analyze the system output through a series of reports such as report on source tank mapping, water production, source tank input/output, NRW zone comparison, monthly summary, NRW zone detail, distribution loss details and NRW reduction. Reports may be exported to other report formats such as worksheet. This will enable the reports to be manipulated and represented in other forms such as graph and worksheet view.


Figure 4. *Main Interface*

## 6. SYSTEM SIMULATION

Three what-if models have been developed to simulate the production analysis, consumption analysis, and NRW percentage to find out if certain changes of the data for each analysis will have effects on others. The simulation is based on actual data calculated by the system as in the report generated. System user can do what-if analysis on monthly basis. The system can forecast the impact of water consumption on the water production if NRW is maintained and vice versa.

Simulation of NRW for January 2004 has shown that the highest and lowest NRW for various zones is between 39.91% and 31.28%. These figures were not obtained from previous conventional operation where only the total NRW percentage is obtained.

## 7. CONCLUSION

The system that has been developed for the treated water distribution system has increased the knowledge of the distribution system and understanding of consumption patterns, which has allowed the water authority to optimise distribution systems. The system supports most of the functions performed in the conventional operation. It also utilized database utilities with extended graphic user interface and can assist users, typically water authority in report preparation. The code and scripts embedded in the system can easily be modified and updated. In addition, the system can be used to simulate the water production, the user consumption and the NRW rates. This can help the water authority in forecasting future impact and plans for the water distribution system.

Future work on the system could include a more detail formula for the NRW, a comprehensive database on the type of consumers for each area, the activities along the distribution lines as well as the pressure and type of pipes and age of the meters used in the present system. In addition, artificial intelligence techniques such as neural network, fuzzy logic, and expert system can be utilised to enhance the system capability. These techniques are potentials for forecasting, solving fuzziness where water flow can be measured as low, heavy, and etc instead of the exact figures, and provide expert advice for novice and intermediate users. The user interface of the system can be improved to include animation of the water flowing through the distribution system and has the hypermedia capabilities.

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