A Conceptual Water Demand Prediction Model

Man Djun Lee, Houssein M.A. E. & Shahidul, M.I.

Faculty of Engineering, University Malaysia Sarawak, Malaysia

Abstract: This paper is about model building to evaluate water demand for current and future. This research project has under taken to support water management authority to provide with a water demand evaluation tool for achieving economic and environmental sustainability. The ultimate target of this model is to contribute to water footprint model. The require information we collected from recently published journals and books. We used engineering procedure to develop model for evaluating water demand for current and future. This paper presents information on available water source, water stock, water use, consumptive water and water balance. This study has also successfully generated empirical model to predict water demand. The developed model is useful to provide insight of the water source and demand behaviour of any geographical area. This model is useful tool for water production management and government policy maker. The developed model is not available in published materials; in this aspect it is novel. This work will add new information in the knowledge stock. This study suggests for further work on model building in water for industry and water for public health. This work is designed to address water demand issue in line with economic and environmental aspect.

Keywords: Water Demand, Prediction Model, Conceptual Modelling, Water Footprint

I. INTRODUCTION

Water demand modelling is essential for planning and managing of water resources to ensure sustainable water supply. It is evident that rapid urbanization, economy migration from agriculture to industrialization, and changing lifestyle has contributed to increase the demand of potable water. We notice water users have also contributed to pollute water. Ultimately, all these issues have created water supply constraint (Gizelis and Wooden, 2010). This scenario requires immediate attention to water supply management in an effective manner for achieving balance between water production capacity expansion and water conservations (Westerhoff and Lane, 1996). Therefore, water demand prediction model is essential to tackle global water problem.

Literature suggests that water demand depends on demographic character, and demand size increase with time (Sime, 1998). The fact is the major water demand components are residential, industrial and agricultural activities. Based on this concept, it could be stated that water demand is a function of above components which shown in the following function model:

$$Water\ Demand, D = f(time, residential, industrial, agricultural) \qquad (1)$$

Concept of Water Footprint

The footprint concept has been introduced to gain better insight regarding the reality of water consumption. The water footprint model is an indicator of water use that could provide useful information in addition to the traditional production-sector-based indicators of water use (Hoekstra and Hung, 2002). The water footprint of a country is defined as the total volume of freshwater that is used to produce the goods and services consumed by the people of the country. However, not all goods consumed are produced in that country, therefore water footprint consists of two parts which are domestic water use and outside the country water use (Hoekstra and Chapagain, 2007). The people of the US that have the largest water footprint, with 2480 m^3/year/capita, followed by the people in south European countries such as Greece, Italy and Spain (2300 – 2400 m^3/year/capita). Water footprint is one of the important tools to evaluate water demand in macro level. However, to address current and future water supply demand, we need a model that is useful at micro level. The micro level water footprint is an indicator of water use in a township, village or a manufacturing industry. Therefore, this study is designed to address this issue.

II. CONCEPTUAL MODEL

To achieve sustainable water supply, we must analyse available water sources and water demand. It is reported that, all water source are not recyclable due to character of the water consumption. The conceptual model of water source, water use and balance of available water are presented in Figure 2 (Sánchez-Román et al., 2009).

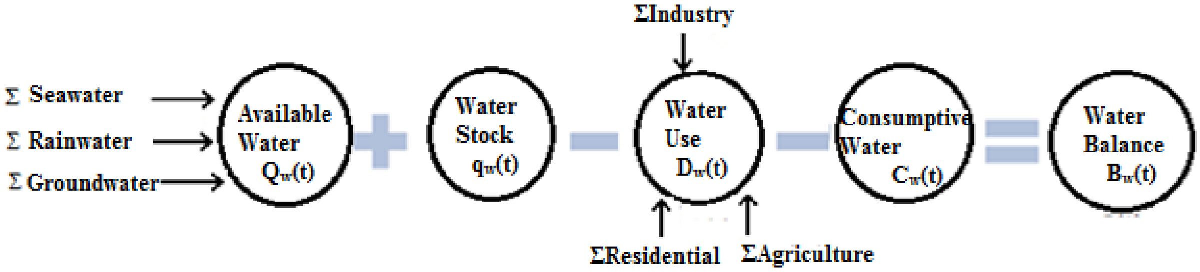

Figure 2: Conceptual model for water balance

Here, the $Q_w(t)$ is available water sources which composed of seawater (96.4%), rainwater (0.001%) and underground water (1.68%). The $q_w(t)$ is the stored water available at Artic, Antarctic and Greenland and estimated total is about 2% (Azrin et al., 2013). The Dw(t) is the water use of three major sectors namely industry, agriculture and residential. The $C_w(t)$ is the consumptive water that are not returning to the recycle chain. The $B_w(t)$ is the available balance water to be used. The mathematical model of the above mentioned concepts are shown in equation (2).

$$B_w(t) = Q_w(t) + q_w(t) - D_w(t) - C_w(t) \tag{2}$$

Where $B_w(t)$ is the water balance for year t (m^3 $year^{-1}$); $Q_w(t)$ is the available water source for year t (m^3 $year^{-1}$); $q_w(t)$ is the water stock; $D_w(t)$ is the total water use (m^3 $year^{-1}$); $C_w(t)$ is the consumptive water use (m^3 $year^{-1}$). The detail structure of water demand model D(t) will be shown in the next section.

III. STRUCTURE OF WATER DEMAND

It is reported that Agricultural activities [A(t)] is highest water consumption sector of economy and accounted for about 70% of total global water consumption. The manufacturing industrial sector [I(t)] is consuming about 15-20% water. For residential or domestic usage of water [R(t)] is about 10-15% (UN-Water, 2015). Therefore, water demand [D(t)] can be expressed in following mathematical form:

$$D(t) = R(t) + I(t) + A(t) \tag{3}$$

Each components of water demand will be explained in the following section.

A) Water Consumption at Residence

Water for residential includes drinking water, public services, and homes. The world average water use per person is estimated to be 52 cubic metres per year (Roberts et. al., 2011). Residential water demand can be calculated from the model below (Agthe et al., 1986; Chicoine et al., 1986; Dandy et al., 1997):

$$R(t) = [r(t) * h(t)] \tag{4}$$

Where, R(t) is the total residential water use in year (t), in million gallons per day; r(t) is the per-household water use in year (t); and h(t) is the number of households served by public supply in year (t).

B) Commercial and Industrial Water Consumption

Industries require tremendous supplies of water. Machinery relies on water for cooling purposes to allow continuous manufacturing process. The mining industry needs water to separate ores from other particles. The electrical power plant also uses water to cool equipment and turbines (Qin et al., 2015). The quantity of industrial water demand in forecast year could be calculated from equation (5):

$$I(t) = N(t) * d(t) \qquad (5)$$

Where, I(t) is gallons per day used in subsector (s) in year (t); N is the number of employees in subsector (s) in year (t), and d(t) is the average daily water-use rate per employee in subsector (s) in year (t).

C) Water Consumption for Agriculture

Agriculture sector is the main user of water including irrigation and livestock. The total volume of water used globally for crop production is 6390 Gm^3/year at field level. Rice has the largest share in the total volume water used for global crop production which is accounted for 1359 Gm^3/year: about 21% of the total volume of water used for crop production at field level (Hoekstra and Chapagain, 2007). The second largest water consumption in wheat field at estimated level of 12%. The agriculture water demand could be calculated by equation (6) (Suttinon and Seigo, 2008; Lupia and Pulighe, 2015):

$$A(t) = W(t) + L(t) \qquad (6)$$

Where W(t) is irrigation water demand can be calculated by equation (7); L(t) is the water use for livestock that is obtainable from Department of Livestock Development.

$$W(t) = \sum_{crop=1}^{n} \left(ET_{crop} - Pe_{crop}\right) * A_{crop} \qquad (7)$$

Where, ET_{crop} is the water requirement in each crop; Pe_{crop} is effective rainfall; A_{crop} is the crop area

D) Water Demand Prediction Model

The water demand prediction model derived from equation (1),(2),(3),(4),(5),(6) and (7) and combination form is shown in equation (8) below:

$$D(t) = [r(t) * h(t)] + [\mathrm{N(t)} * \mathrm{d(t)}] + \left[\sum_{crop=1}^{n} \left(ET_{crop} - Pe_{crop}\right) * A_{crop}\right] + L(t) \qquad (8)$$

Where r(t) is the per-household water use in year (t); and h(t) is the number of households served by public supply in year (t); N is the number of employees in subsector (s) in year (t), and d(t) is the average daily water-use rate per employee in subsector (s) in year (t); ET_{crop} is the water requirement in each crop; Pe_{crop} is effective rainfall; A_{crop} is the crop area; L(t) is the water use for livestock that is obtainable from Department of Livestock Development.

IV. PRACTICAL IMPLICATIONS

The developed empirical water demand and supply models can be implemented in the relevant sectors. To use this model, few information and skills are required, namely, information on available water source, lifestyle of the people, agriculture potentials, industrial growth feature and economic growth trend. Additionally, people with know-how in water management, water handling equipment, planning and scheduling of water supply are essential to use this model. Finally, government policy is essential to apply this model in the water management.

V. CONCLUSION AND RECOMMENDATIONS

The ultimate target of building water demand model is to contribute to water footprint model. This model is useful to provide insight of the water source and demand behaviour of any geographical area.

Water for agriculture, water for industry and water for public health are equally important to economy. Water for agriculture is readily available on the surface and underground, if it is free of arsenic and other toxic heavy metal. Water for industry is directly related to economy but this water is not readily available on the surface and underground. Water for industry basically is the water for machine and water for product processing. However, higher degree of technological input is essential to produce water for machine and product processing. Water for public health is well defined by WHO. To produce water for health sector, we need to follow many protocols that strictly guided by WHO and national health policy. To produce water for public health need of theoretical background on medical science, engineering and environment. In conclusion, the current study suggests for further work on water production modelling for water for industry and water for public health.

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Ethical statement: The authors declare that they have followed ethical responsibilities

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