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Application of Water Evaluation and Planning Model to Assess Future Water Demands of Surat City

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Abstract

Integrated water resources planning models can simulate the water balance and the impact of different water uses on the water balance. Different management schemes can be implemented and compared. WEAP (Water Evaluation and Planning System) is a model particularly strong in the development of IWRM (Integrated Water Resource Management) schemes for a sustainable water use in the region or catchment. In this study, a WEAP model for the water supply system of Surat City, is developed, that can be used to analyze different options for future water supply under growing water demand. Evaluation of WEAP is done for 2011 population census and the water distributed across various Water Distribution Systems are the data of 2011. The final scenarios include High Population Growth Rate as 3.5% and Low Population Growth Rate as 1.5%. Climatic variations by water year method were considered for the prediction of future water demand.
Keyword- IWRM, Population Growth Rate, Sustainable Water Use, WEAP

I. INTRODUCTION

There is a strong positive correlation between water demand and urbanization or population growth. Urban water system should provide safe water for different uses without harming the environment, and increasing demand for sustainable development will deeply effect on all urban infrastructures. Therefore, sustainable management of water supply for various water uses in urbanized cities is extremely important to achieve the sustainable development of these cities.

Yates et al., 2005; Hamlat, Errih & Gui-doum, 2013 suggested that Water resources planning and management was generally an exercise-based on engineering considerations in the past. Nowadays, it increasingly occurs as a part of complex and multi-disciplinary. Loucks, 1995; Laín, 2008 proposed that successful planning and management of water resources requires application of effective integrated water resources management (IWRM) models that can solve the encountering complex problems in these multi-disciplinary investigations. Raskin et al., 1992 studied the water development strategies and water supply- demand analysis for the Aral Sea region. WEAP introduced major advances, including a modern Graphic User Interface and a robust solution algorithm to solve the water allocation problem. Rosenzweig et al., 2004 analyzed the application of WEAP models to major agricultural regions in Argentina, Brazil, China, Hungary, Romania, and the US, by simulating future scenarios about climate change, agricultural yield, population, technology, and economic growth. Van Loon & Droogers, 2006 studied about water evaluation and the planning system in Kitui-Kenya and clearly demonstrated that WEAP is a powerful framework in the evaluating of current and future options of water resources. R. L. Teasley and D. C. McKinney, 2007 considered the Binational Rio Grande/ Bravo Basin, located in North America to evaluate its hydraulic and physical assessment. To evaluate the hydrologic feasibility of possible water management scenarios, a hydrologic planning model was constructed in the Water Evaluation and Planning system, or WEAP. Guilherme Fernandes Marques et al. 2008, presented the application of the decision support tool WEAP to simulate water transfers scenarios in the Sao Francisco River basin (Brazil) and provide local stakeholders with shared vision planning exercise aimed at building consensus on the watershed problems. S. Sandoval-Solis et al. 2008, studied the scarcity of the water resources in the Rio Grande/Bravo basin and highlighted the alternative water management policies or “Scenarios” that have been evaluated to determine their hydrologic feasibility and the individual or joint benefits to water users in the basin. Eusebio Ingol-Blanco and Daene C. McKinney 2009, presented a hydrologic modeling application to assess climate change impacts on the water resources of the Rio Conchos basin, especially for agriculture and domestic water uses, using WEAP. Rajaei, Foroozan et al, 2011, investigated the effects of artificial recharge plans on the aquifer and demand management techniques in Shahrekord, Iran. A WEAP model was generated and was used to simulate aquifer water levels for a thirty-year period applying artificial recharge.

II. STUDY AREA

Surat City is spread over 326 square kilometers and had a population of 4.4 million at the time of Census 2011. It continues to be among India's fastest growing cities in the country, with a decadal growth of 83% during 2001-2011 and with its population having grown ten-fold in the last four decades. Currently, insufficient data and lack of the plan for the future are restricting the management of the water supply system of Surat City and the decision making for future options for various urban issues.

Fig. 1: Map of Surat City
(Source: www.lahistoriaconmapas.com as on January 16th 2016)

A. History of Water Supply

The water needs of Surat are being managed by The Surat Municipal Corporation. The major source of water supply is the perennial river Tapi. The water supply network was commissioned in the year 1898 in Surat. Over the decades, the city has invested in the water supply, and now has a well-managed system. The River Tapi originates from Madhya Pradesh and passes through Surat City via the Ukai Dam, constructed in 1972 in the upstream of Surat City at about 100 Km from Surat with various purposes like irrigation, Hydro-power and partial flood control. The flow in the river, down-stream of Ukai dam and Kakrapar weir is now being controlled by Gujarat Electricity Board/Water Resources Development authorities. There has been a drastic reduction in the river flows and now the river flows mostly as a small stream on the opposite side of the old water works of Surat City due to the reduction in flow. In addition, the silt deposition around the infiltration wells and radial collecting wells, which has been increasing year after year, reduces the percolation of water and well yields, which has affecting the water supply to the Surat City. The Surat Urban Development Authority has faced difficulties in developing proper integrated planning of the region. As a result, a new urban development body, the Surat Metropolitan Region Development Authority, was planned in 2008 for the entire Surat Metropolitan Region.

B. WEAP Model

This section includes the development of WEAP model for SCWSS (Surat City Water Supply System). In order that the water supply in the future is sustainable and adequate in quality and quantity to meet the booming demand, WEAP model will be developed and applied to evaluate the existing SCWSS and expected future scenarios for SCWSS by taking into account the different factors and policies that may affect demand and supply sources.

WEAP is a practical tool for water resources planning which incorporates not only water supply-side and water demand-side issues, but also water quality and ecosystem preservation issues, by its integrated approach to simulate water systems and by its policy orientation. In this study, WEAP model is selected to use as a database tool, a forecasting tool, and a policy analysis tool to analyze about Surat City Water Supply System to forecast for the future options.

Application of the WEAP model generally includes the following steps:

- Setting up the Study Definition, which includes the spatial boundary, the time frame, the system components, and the configuration of the problem.
- Entering data in the Current Accounts, which provides an overview of the actual situation of the system (water demand, supply resources, pollution loads), and can also be viewed as a calibration step in the development of an application.

- Creating Key assumptions in the Current Accounts, if necessary, which represent policies, costs and factors that affect demand, pollution, supply, and hydrology.
- Building Scenarios on the Current Accounts, which can be explored the impacts of alternatives on the future water supply and demand.
- Evaluating Scenarios, regarding with water demand coverage, costs, compatibility with environmental targets, and sensitivity to uncertainty.

III. MODEL DEVELOPMENT

The systematic procedure for the development of the model and the entry data analysis of Surat City Water Supply System was implemented, and then the detail data sets required for the model inputs were studied. The figure in the following section mentions the WEAP model of Surat City Water Supply System. It has four water works and various Water Distribution Systems (WDS).

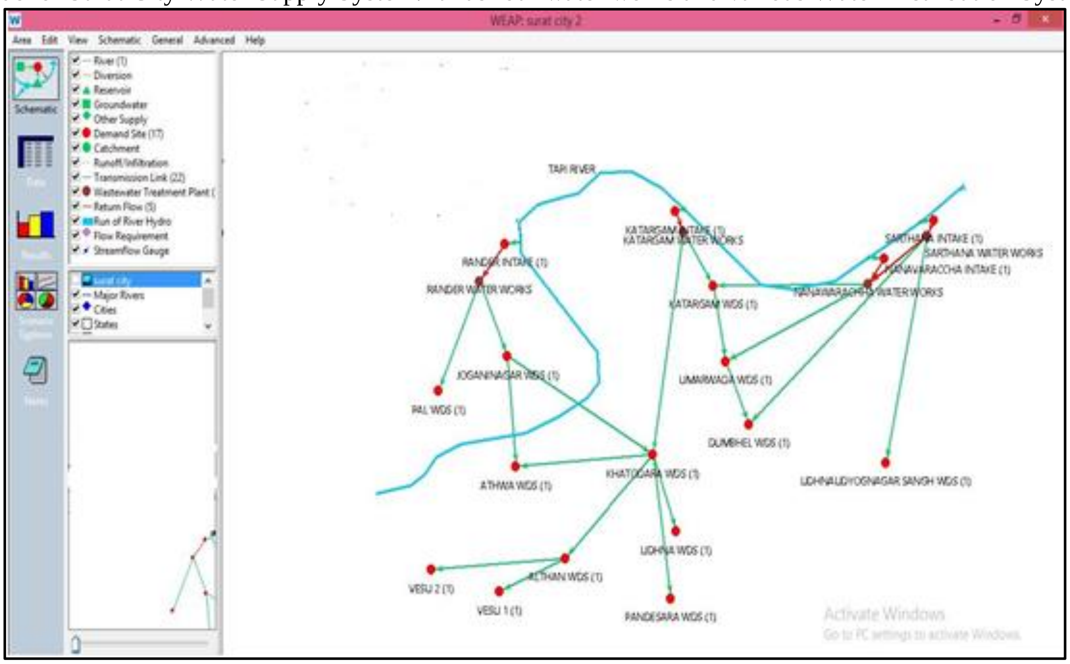

Fig. 2: Simplified Schematic for WEAP model of Surat City Water Supply System

After creating the study area, the study period for the model is needed to define. For this model, the Current Accounts Year is set as 2011 and the Last Year of Scenarios is set as 2041. The Time Steps per year is used as 12 based on a calendar month by starting in January and adding leap days. The Current Accounts Year is chosen to work as the base year of the model, and all system information, such as demand and supply data, on this year is input into the Current Accounts. Monthly data have been entered as the Headflow in cms for Tapi River for the year 2011. This has been shown in the table below.

Month	*Headflow in cms*	*Month*	*Headflow in cms*
January	*36.847*	*July*	*515.00*
February	*1.443*	*August*	*1473.98*
March	*0.000*	*September*	*1165.154*
April	*2.789*	*October*	*2.880*
May	*0.000*	*November*	*0.000*
June	*20.116*	*December*	*0.000*

Table I: Monthly data of Headflow of Tapi River uploaded for 2011

In this study, the demand data is available for individual sites of Surat City, that means the detail data for differ water uses (population).

Demand Site (WDS)	*Population (2011)*	*Demand Site (WDS)*	*Population (2011)*
Pal	*143892*	*Pandesara*	*134019*
Joganinagar	*408760*	*Althan*	*201284*
Athwa	*27224*	*Vesu 1*	*20196*
Khatodara	*107056*	*Vesu 2*	*98743*
Katargam	*705163*	*Dumbhel*	*60891*
Umarwada	*928213*	*Rander*	*29084*
Udhnaudyognagar Sangh	*687413*	*Katargam*	*252010*
Udhna	*453953*	*Nanavaraccha*	*208921*

Table II: Annual Activity level entered for various demand sites

Demand sites in WEAP can be defined according to the following groupings, as major cities or countries, individual user that manages a water withdrawal point, irrigation sites, demands which return to a wastewater treatment plant, water utilities. In this Surat City Water Supply System model, Sarthana, Rander, Nanavarachha and Katargam water works are take into consideration as demand sites together. The gross daily average water supply for the reference year 2011 and the rest of the year have been mentioned in the table below:

Water supply source	*Gross daily average water supply (2011) (MLD)*	*Water supply source*	*Gross daily average water supply (2012-2041) (MLD)*
Rander water works	*43.5*	*Rander water works*	*190*
Katargam water works	*67.5*	*Katargam water works*	*350*
Nanavarachha water works	*33.25*	*Nanavarachha water works*	*50*
Sarthana water works	*56.25*	*Sarthana water works*	*375*

Table III: Gross average daily water supply in the reference year 2011 and the projected years (2012-2041)

IV. SIMULATED SCENARIO

In this study, Reference Scenario were applied to analyze the situation of Surat City Water Supply System without any development of the system except the population growth with normal growth rate 2.5%. *High Population Growth (HPG) scenario*: It analyses the situation with high population growth rate 3.5%. *Low Population Growth (LPG) scenario*: It analyses the situation with low population growth rate 1.5%. The other scenario is for the climatic conditions that are on the basis of water year method that includes five categories of division. They are discussed in table IV.

Inflow relative to normal year	*Reference*
Very dry	*0.7*
Dry	*0.8*
Normal	*1*
Wet	*1.3*
Very wet	*1.45*
**(1.45 means that year has 45%more flow than normal year)*	

Table IV: Reference values for WEAP model influencing he climatic conditions

Scenario was formulated to show the impact of increase in population growth rate (varying demand) and variation in climatic condition (varying supply). Water year method was used to show variation in climate (varying supply) and the model was set up to use this method by creating reference to it for river Inflows. Table V shows the assumed climatic data entered for the scenarios.

Year	*Water year type (Assumed values)*	*YEAR*	*Water year type (Assumed values)*	*Year*	*Water year type (Assumed values)*
2011	*Normal*	*2022*	*Very wet*	*2032*	*Very wet*
2012	*Dry*	*2023*	*Dry*	*2033*	*Dry*
2013	*Very dry*	*2024*	*Very Dry*	*2034*	*Normal*
2014	*Normal*	*2025*	*Very wet*	*2035*	*Normal*
2015	*Wet*	*2026*	*Normal*	*2036*	*Dry*
2016	*Very wet*	*2027*	*Normal*	*2037*	*Wet*
2017	*Wet*	*2028*	*Dry*	*2038*	*Normal*
2018	*Normal*	*2029*	*Wet*	*2039*	*Dry*
2019	*Dry*	*2030*	*Dry*	*2040*	*Normal*
2020	*Very Dry*	*2031*	*Wet*	*2041*	*Very wet*
2021	*Wet*				

Table V: Water year type (Assumption)

V. RESULTS AND VALIDATION

WEAP model is fit to represent the actual situation of Surat City Water Supply System. The present situation of Surat City Water Supply System can be evaluated according to the result of the Current Accounts and Reference Scenario. The calculation by the Surat Municipal Corporation (SMC) for the daily average water supply was 840 MLD for the year 2012 and 900 MLD for the year 2013 as shown the Figure 3. The method used by SMC was Method of Density and Arithmetic Growth Method. With the WEAP model applied as per the census 2011 and the various climatic conditions the calculated average water supply was 855.32 MLD and 885.25 MLD for the years 2012 and 2013 respectively. Thus the validation of the WEAP model could be determined for the future years, i.e. 2016 to 2041.

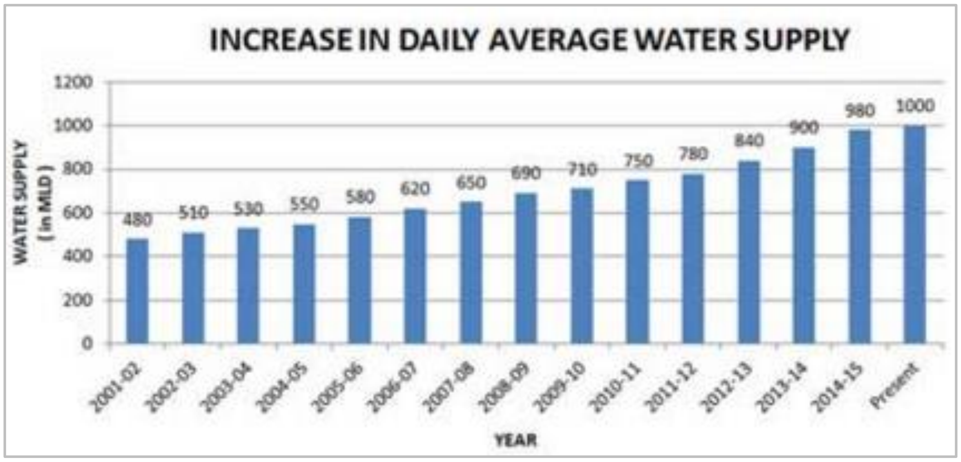

Fig. 3: Graph representing increase in daily average water supply for the years 2001 to 2016 (present)
(Source:http://www.suratmunicipal.gov.in/Departments/HydraulicWaterSupplyAndIncrease as on 20th January 2016)

Surat Municipal Corporation had prepared a long-term Master Plan in the year 1995 for Water Supply Scheme of Surat city in consultation with Tata Consulting Engineers, Mumbai. The Master Plan was prepared to fulfill the water demand for the projected population growth for the horizon year 2021, considering the base year as 1995. Preliminary forecasted figures of water demand up to year 2041 have shown given in the figure 4. The predicted value by the WEAP model for water demand was 2319.52 MLD for the year 2041. As the value forecasted by SMC IS 2367.23 MLD, thus the model is acceptable.

Fig. 4: Preliminary forecasted figures of water demand up to year 2041 by SMC
(Source:http://www.suratmunicipal.gov.in/Departments/HydraulicWaterSupplyMasterPlan as on 20th January 2016)

The water demand for the years 2012-2041 for various regions of Surat have been shown in the Figure 5. Figure 6 predicts the cumulative demand for the years to come for various regions.

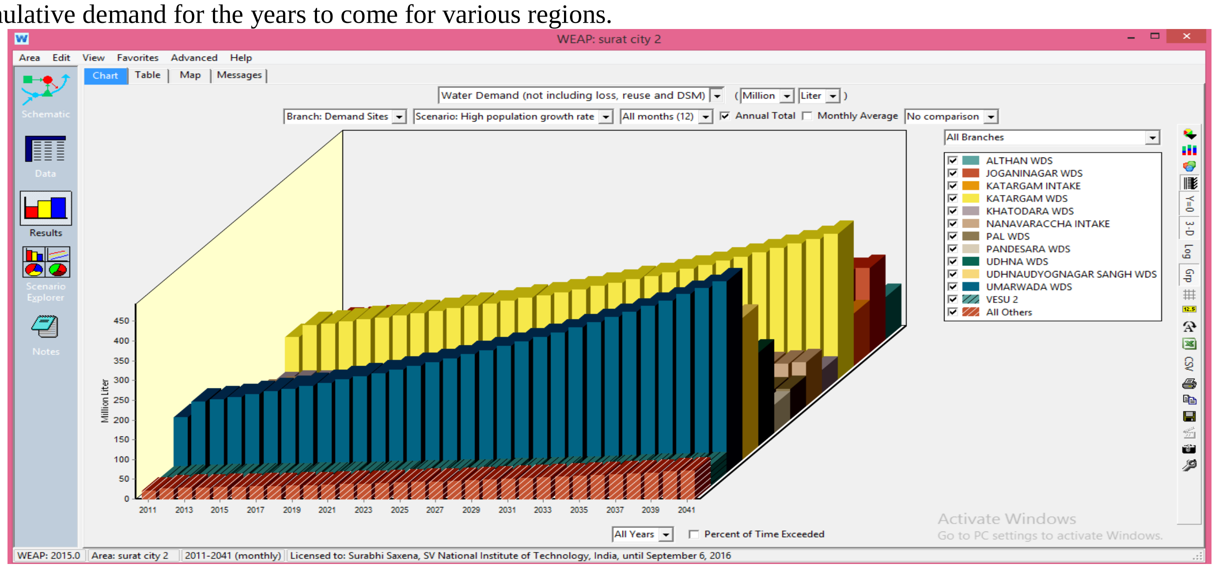

Fig. 5: Water demand prediction for the years 2012-2041 for all demand sites with scenario as “High Population Growth Rate”

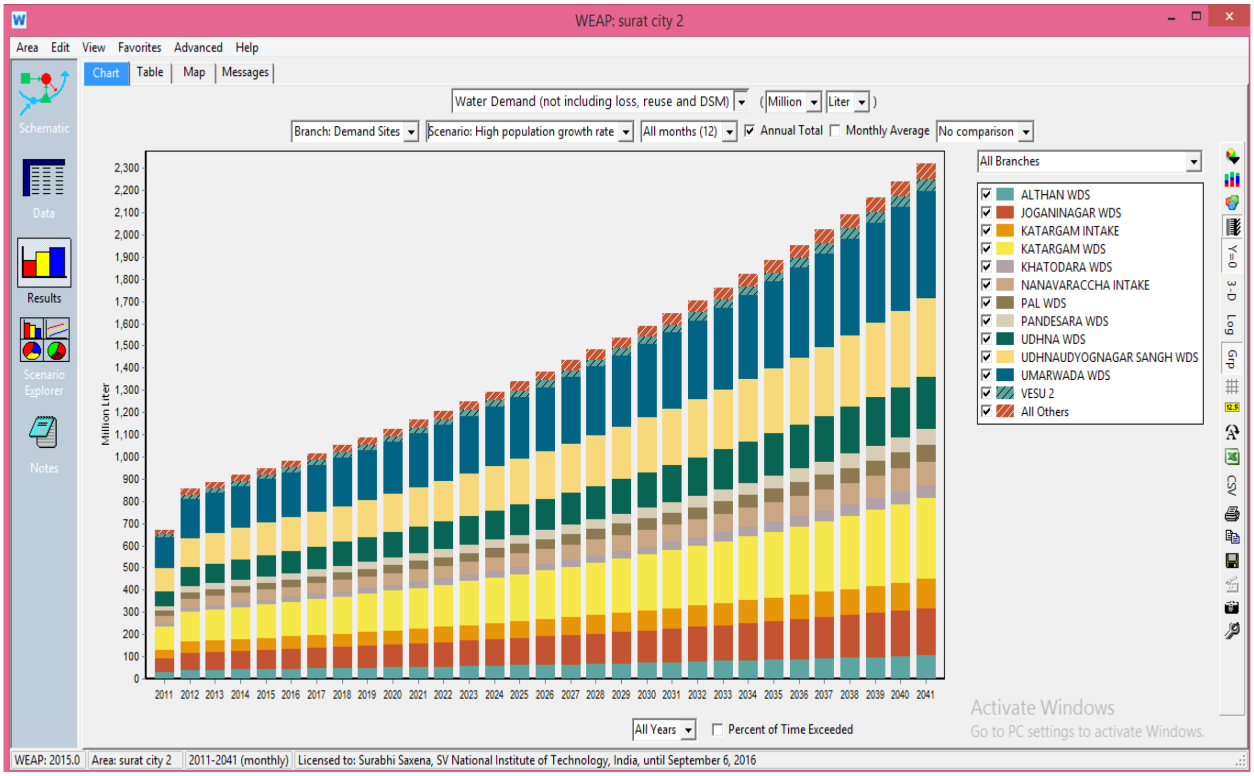

Fig. 5: Cumulative water demand prediction for the years 2012-2041 for all demand sites with scenario as "High Population Growth Rate"

VI. Conclusion

Following are the conclusions drawn from this study:

- The WEAP model was chosen for this study because of its integrated approach to simulating water systems. This study clearly recommended that WEAP is powerful in evaluating the current situation and future options in water supply system.
- WEAP Model was validated by using the demand data of the study area for the year 2012 and 2013 and water demands for 2012 to 2041 was predicted.
- The calculation by the SMC for the daily average water supply was 840 MLD for the year 2012 and 900 MLD for the year 2013. With the WEAP model applied as per the census 2011 and the various climatic conditions the calculated average water supply was 855.32 MLD and 885.25 MLD for the years 2012 and 2013 respectively.
- The deviation of the predicted value and the actual value of the water demand for the year 2012 and 2013 were 15.32 MLD and 44.75 MLD respectively.
- The formulated scenarios for year 2041 with possible future growth of population and change in climatic conditions results in increased water demand.
- The results obtained from the study indicate that the model can perform well to assess future water demand.

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