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"Evaluation of Drinking Water Supply Demand for Peri-Urban Region"

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Abstract –The drinking water supply during pre-monsoon season in India is one of the major problem in peri urban region. Vapi in India is one of the fast developing peri urban region. This research was commenced with the objective to assess drinking water supply scenario for 2041 using the Water Evaluation and Planning (WEAP) model, considering 2014 as the current year for the study region. Data were assembled and analyzed in order to design 2 different scenarios- Actual demand and simulated demand with %Error. The current demand depicts the total water demand of Vapi city in 2014. The simulated demand takes into consideration all the conditions of current demand, but works with the increased demand. The current water demand in Vapi district is 18.22 Million Cubic Meter and is expected to continuously increase. The source of water for this region is Madhuban dam which is situated upstream of study region on Damanganga River.

Keyword-Water Demand;Water Use Rate;WEAP Software;Population; Percentage Error.

I. Introduction

According to National Water Development Agency, Surplus Water of Damanganga Basin is diverted to Bhugad and Khargihill Dam to Pinjal Dam, Vaitarna Basin and after that it is transferred to Greater Mumbai.only one district Vapi, Gujarat of basin downstream is considered for finding future water demand.There is a strong positive correlation between water demand and urbanization or population growth.Therefore, sustainable management of water supply for various water uses in urbanized cities is extremely important to achieve the sustainable development of these cities.

Raskin et al., 1992 studied the water development strategies and water supply- demand analysis for the Aral Sea region. 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. 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.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.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.

WEAP Software is used in 2004 for Volta Basinto model water allocation to akosombo,in 2008 for Blue Nile to simulate current and future water demand, Matthew, in 2011 for Niger River in Zakari to find the future water demand.

II. Study Area

Vapi is a city and municipality in Valsad District in the state of Gujarat. It is situated near the banks of the Damanganga River and is the largest city in the Valsad district and also the largest city after Surat in South Gujarat. (Figure 1)

The Arabian Sea, at the delta of the Damanganga, is about 7 km to the west. The city has tropical weather and enjoys three distinct seasons: winter, summer and monsoon, with rainfall ranging from 100 inches to 120 inches per annum. The Dhobikhadi, Bhilkhadi, Kolak and Damanganga rivers flow through Vapi.

Around 28 km south of the district headquarters in the city of Valsad, it is surrounded by the Union Territories of Daman to the west and Dadra and Nagar Haveli to the east. Economic and industrial growth in recent decades has blurred the physical boundaries, and a small stretch of roughly 21 km of Daman-Vapi-Silvassa has almost become a single urban area.

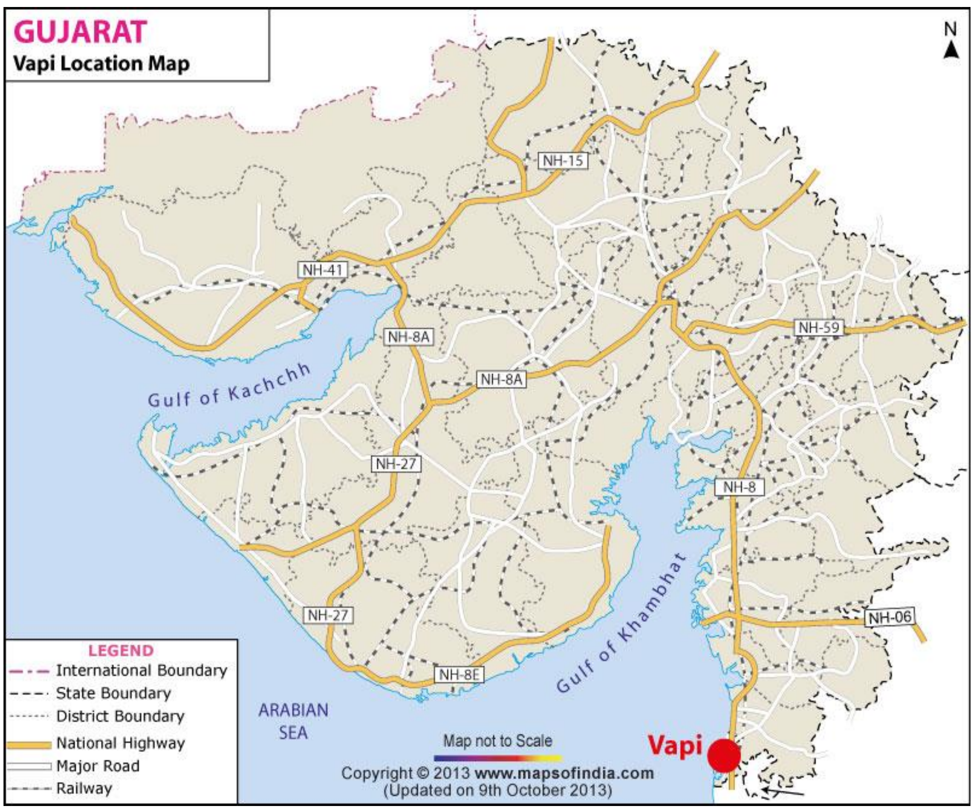

Figure 1. Vapi Map

III. DATA COLLECTION

The population of Vapi city for last three Decades are shown in Table 1.The silent features of Madhuban dam is appended as Table 2.

Table 1. Population Data

Year	Population(Soul)
1991	31533
2001	71406
2011	163630

(City Population)

Table 2.Silent features of Madhuban dam

Location	Village – Madhuban
	Taluka – Dharampur
	District – Valsad
Purpose	Irrigation, Water supply and power generation
River	Damanganga
Mean annual runoff in the catchment	3771.60 Mm^3
Mean annual rainfall	2382 mm
Year of commencement of construction work	1973-74
Year of completion	1998
Area of catchment	1813 Km^2
Maximum Observed Flood	6.16 Cumecs
Yield in Million Cubic Meter	Maximum-5426 MCM
	Average-3150 MCM
2)DAM	
Type	Composite(Masonry and Earthfill)
Bed Rock	Basalt
Maximum height above the lowest point of foundation	58.60 m
Length at the top of the dam	2870 m
Total Volume Content:	
Concrete	0.085 Mm^3
Masonry	0.30 Mm^3
Earthwork	11.46 Mm^3
3) RESERVOIR	
Area at full reservoir level	51.44 km^2
Gross storage capacity	567 Mm^3
Dead Storage capacity	65 Mm^3
Effective storage capacity	502 Mm^3
Area under submergence	a) Forest - 1202 ha
	b) Waste land - 987 ha
	c) Culturable - 2955 ha

III. METHODOLOGY

The methods of population forecasting are arithmetical increase method, geometrical increase method, incremental increase method, decrease rate of growth method, graphical extension method, graphical comparison method, zoningmethod, ratio and correlation method and growth composition analysis method. Arithmeticalincrease method and incremental Increase methods are not suitable for Vapi city due to its limitation. In this research work population has been computed using geometrical increase method.

$$P_n=P\,[1 + (r/100)]^n \quad [1]$$

Where, P_n = Population after n decade, P = Present population, r = Growth factor, n = No. of decade.

Table 2.Input Data for WEAP software

VAPI (Input Data for year 2014)	
Description	**Quantity**
Population(Geometrical Increase Method)(soul)	226954
Water used for drinking (MCM-Per Annum)	18.90
Per capita water demand(LPCD)	220
Scenario for Year 2041:Increased Population	
Population (Forecasted - Geometrical Increase Method)	1965030

(Damanganga Canal Distribution Divn No.3,Balitha (Vapi))

The first step is to set up the study definition (study region), which includes the spatial boundary, the time frame, the system components and the configuration of the problem. The next step is to enter data in to Current Accounts, which provides an overview of the actual situation of the system (water demand, supply resources and pollution loads).This may be viewed as a calibration step in the development of an application. Create key assumptions in the Current Accounts, if necessary, which represent policies, costs and factors that affect demand, pollution, supply, and hydrology.Scenarios are developed on the Current Accounts, which can explore the impacts of alternatives on the future water supply and demand. Scenarios can be evaluated for water demand, coverage, costs, compatibility with environmental targets and sensitivity to uncertainty. Table 2 presents input data used to compute water demand using WEAP software.

V. RESULTS & RESULTANALYSIS

The result analysis is carried out in three steps. In the first step using data of year 2014 model was calibrated. After calibration of model forecasting of water demand has been carried for the year 2041.In the third step it has been checked weather forecasted demand is meet with available resources or not.

A. CALIBRATIONOF MODEL

The calibration of model was carried out using 2014 year data. The actual demand of Vapi city for year 2014 is 18.22 MCM and simulated demand using WEAP software is 18.9 MCM (Figure 2& Table 4). The percentage error between observed and computed demand has been worked out using equation 2.The Table 3 shows the percentage error for water demand actual and simulated of Vapi.

$$\text{Percentage Error} = [(Ys - Y_i) / Y_i] * 100 \qquad [2]$$

Where, Y_s = Simulated demand, Y_i = Actual demand. The percentage error between actual and simulated demand is less than 10%.

Table 3. Actual Demand and Simulated Demand of Vapi

Actual Demand(MCM)	Simulated Demand(MCM)	Error (%)
18.22 MCM	18.9 MCM	3.73%

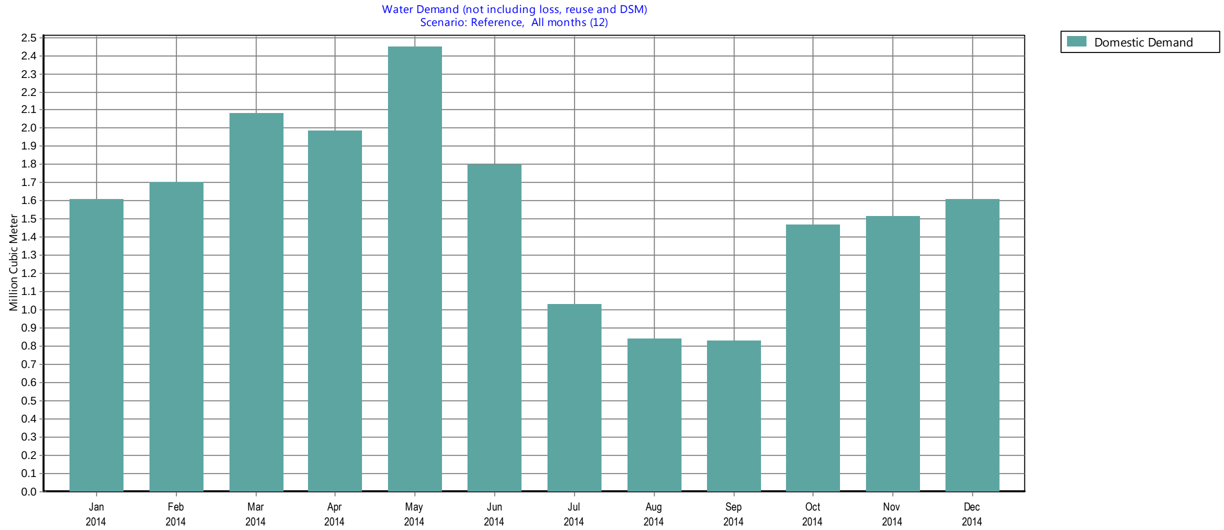

Figure 2. Simulated Water Demand for year 2014

Table 4. Monthly Simulated Demand for year 2014

	Jan-41	Feb-41	Mar-41	Apr-41	May-41	Jun-41	Jul-41	Aug-41	Sep-41	Oct-41	Nov-41	Dec-41	Sum
Domestic Demand	1.68	1.7	2.08	1.98	2.45	1.8	1.03	0.84	0.83	1.47	1.51	1.61	**18.9 MCM**

B. INCREASED POPULATION SCENARIO

The calibrated model for drinking water supply demand of year 2011 has been used to predict increased population scenario for the year 2041.The simulated demand for year 2041 is **161.61 MCM**as shown in Table 5 and simulated monthly demand is as shown in Figure 3.

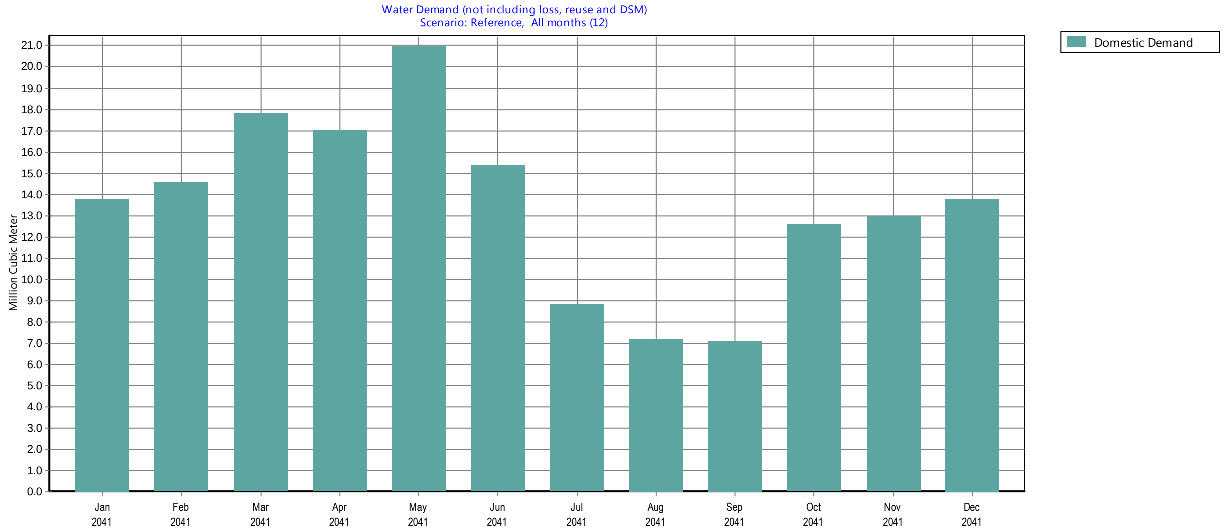

Figure 3. Simulated Demand for year 2041

Table 5. Monthly Simulated Demand for year 2041

	Jan-41	Feb-41	Mar-41	Apr-41	May-41	Jun-41	Jul-41	Aug-41	Sep-41	Oct-41	Nov-41	Dec-41	Sum
Domestic Demand	13.74	14.54	17.78	16.97	20.93	15.35	8.79	7.17	7.11	12.56	12.93	13.74	**161.61 MCM**

When the **dependable flow** is **75%** then the inflow in madhuban dam is **1178.99 MCM**, which is more than demand of vapi district of year 2041.

VI. CONCLUSION

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 using the data ofyear 2014 and water demands for 2041 was predicted. The deviation of the predicted value and the actual value of the water demand for the year 2014 is **3.73%**.The formulated scenarios for year 2041 with possible future growth of population resulted in the increased water demand Of **161.61 MCM**. The results obtained from the study indicate that the model can perform well to assess future water demand. If dependable flow of madhuban dam is 75%, it will meet the future demand of vapi for year 2041.

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