Groundwater for Sustainable Development 7 (2018) 8–19

Contents lists available at ScienceDirect

Groundwater for Sustainable Development

journal homepage: www.elsevier.com/locate/gsd

Research paper

Predicting future water supply-demand gap with a new reservoir, desalination plant and waste water reuse by water evaluation and planning model for Chennai megacity, India

Nabaprabhat Paul, L. Elango*

Department of Geology, Anna University, Anna University, Chennai, India

A R T I C L E I N F O

Keywords:
Chennai
Desalination
Integrated water resources management
Decision support system
WEAP
Predicting future
Sustainable development

A B S T R A C T

The objective of this study is to predict the gap quantitatively in water demand and supply in Chennai megacity of India until the year 2050 considering the scenarios of business as usual and various additions to existing supply system by using a decision support system of known as Water Evaluation and Planning Model. Results obtained from this modelling study of the water resources system of the Chennai mega city indicate that an increase in reliability of water supply by about 30% will be attained by reusing waste water, 19% by using the new reservoir and 10% with the proposed additional desalination plant.

1. Introduction

A robust water management system has always been the key for sustainable life. The emergence of the ancient civilizations on the banks of great rivers indicates the importance of water as a resource for agricultural, industrial, transportation and domestic needs including social, recreational and aesthetic pleasures. With time most of such ancient localizations have flourished into hotspots of rich human population developing into modern day cities and megacities. Due to the high population density, a plethora of water challenges is being faced today in these regions. Each region has its unique problems of water quality and quantity depending on their climatic, geographic, geologic, social and economic conditions. With the advent of climate change and global warming, the rainfall pattern is likely to change all over the world. Modelling studies undertaken up to the year 2050 have predicted that the world's freshwater distribution is on the way towards a paradigm shift (Alcamo et al., 2007). Surface water and groundwater are two main sources of water. Over-exploitation of both, to meet the growing needs, has caused pollution and depletion of the resource globally. Uncontrolled abstraction rate of groundwater has led to depletion of groundwater table. Land subsidence and saltwater intrusion are the current problems in cities of Mexico (Lundqvist et al., 2005), Bangkok (Shin-ichi et al., 2008), Dhaka (Zahid and Ahmed, 2006), Beijing (Xu et al., 2008), Kolkata (Chatterjee et al., 2006), Chennai (Rajaveni et al., 2016) due to over exploitation of ground water. Studies have been undertaken to improve the water resilience of the world by a detailed appraisal of the resources utilizations potential (UN, 1979). The United Nations Development Program's sixth Sustainable Development Goal mandates the availability of clean water as one of the key elements for attaining Sustainable Development (Sustainable Development Goals, 2016). The Mekong river basin and Nile river basin have undertaken Integrated water resource Management and have evolved into more sustainable entities (MRC, 2011–, 2015). Ecological flow (Richter et al., 2003), virtual water, implications of climate change, water rights of indigenous people, water tax and plenty of other factors today are critical in designing a robust water management plan. With the increasing complexity of decision making processes, new tools such as Decision Support Systems (DSS) such as WEAP have emerged. WEAP has been used to predict future scenarios of water availability in various river basins successfully (Mounir et al., 2011) (Haddad et al., 2007) (Hollermann et al., 2010) (Danner, 2006) (Hoff et al., 2007) (Arranz and McCartney, 2007) (Sivan et al., 2007). Chennai which is a fourth largest city in India has suffered a lot of problems in the pursuit to meet the city's growing demand for water but facing periodical droughts and flooding. Even with the various management initiatives, it still suffers a very low liter per capita per day (LPCD) of just 108 of water supply (Roumeau et al., 2015) which is lesser than the WHO prescribed minimum limit of 150 LPCD. The city faces drought as well as floods in the same year. UNDP has already undertaken various studies in fields of availability and quality (UNDP, 1987), seawater intrusion and change; but there is no holistic study of the Chennai region to assess its water demand and its supply. The objective of this study is

* Corresponding author.
E-mail addresses: paul_nabaprabhat@outlook.com (N. Paul), elango@annauniv.edu (L. Elango).

https://doi.org/10.1016/j.gsd.2018.02.005
Received 25 August 2017; Received in revised form 25 February 2018; Accepted 25 February 2018
2352-801X/

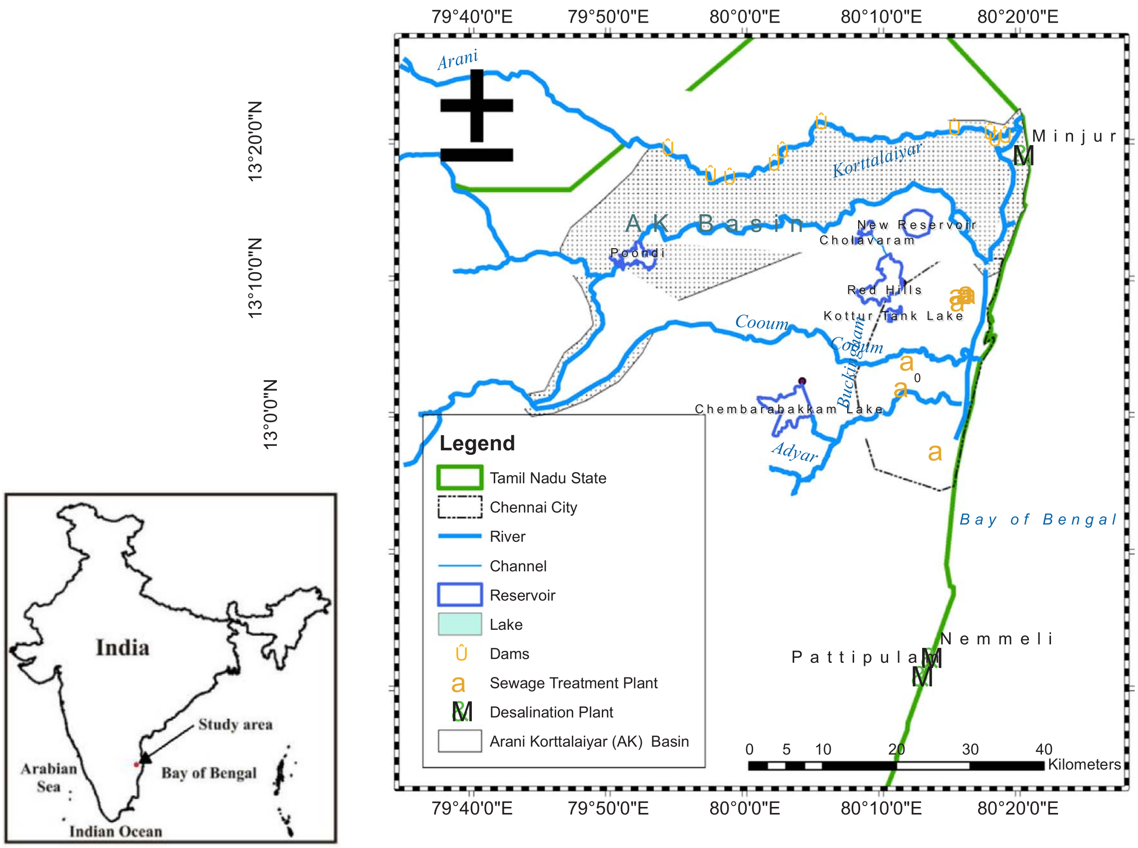

Fig. 1. Location of the Chennai city.

to predict the outcomes of various possible augmentation steps to enhance the availability of water in the Chennai city quantitatively by observing its effect on the unmet demand. Various scenarios have been run in WEAP model to obtain results. The data used are mostly from Chennai Metro water supply, IMD and UNDP Reports of Chennai city.

2. Water resource of Chennai

2.1. Description of study area

The study area comprising of Chennai city and its surroundings is located within the latitudes of 13°0′00″ to 13°10′00″ North and Longitudes 80°08′00″ to 80°20′00″ East. It is situated on the Coromandel coast of Bay of Bengal (Fig. 1) and has the longest beach in Asia, the Marina beach. The last recorded population of Chennai city for the year 2011 was about 47 million (Census, 2011) and presently it is expected to exceed 62 million, hence it is a megacity. It is the largest industrial center in southern India and is also known as the “Detroit of India” (Krishnamurthy and Desouza, 2014) with several automobile factories. It is 37th in the list of largest urban areas of the world with Delhi being 6th and Kolkata 12th (Demographia - World Urban Areas and Population Projections, 2009). Since the year 1961, its population has doubled approximately from 33.6 million to 62.4 million presently, but its decadal growth rate has been falling over time from 22.30% in 1971 to 11.72% in 2001 and 7.8% in the year 2011 (Sekar and Kanchanamala, 2011). Table 1 presents the population, decadal growth rate and areal extent of this megacity. The Arani-Korttalaiyar river Basin (AK Basin), located in north of the city and the Cooum - Adyar river Basin (CA Basin) which is in the central part of the city (Fig. 1), are the two main river basins of the city. The AK Basin has a total catchment area of 5254 km. and the CA basin 1542 sq. Km. (Dhayamalar, 2012). None of these rivers are perennial, but Adyar and Cooum seemingly have become perennial as they carry the entire city's

Table 1
Population, decadal growth rate and areal extent of Chennai city.

Census	Population	Decadal growth rate (%)	Extent/Sq. km.
1961	17,49,000	–	128.83
1971	24,69,449	41.19	128.83
1981	32,76,622	32.69	176.00
1991	38,43,195	17.29	176.00
2001	43,43,645	13.02	176.00
2011	46,81,087	07.80	176.00

sewage which then flows into the sea. The approximate contribution towards city water supply from the surface reservoirs, well fields, desalination plant, Veeranam lake and Krishna River is 51%, 1%, 17%, 19% and 11% respectively. Additional water requirement in future is likely to be met from the new desalination plants, planned new reservoir north west of Chennai and additional water release from Krishna canal (CMDA, 2004; Parimalarenganayaki, 2014).

2.2. Water supply scenario in Chennai

Until the year 1870, the people of Chennai quenched most of their water demands by shallow wells, harnessing water from the aquifers that are replenishable by rainfall (CMWSSB, 2016). Construction of a diversion channel on the Kosathalaiyar river (Korttalaiyar river) in 1872 was the cornerstone of a managed water supply system, designed and supervised by a civil engineer J.W. Madeley (Narain, 2005). The water from the diversion flowed to the Red Hills reservoir from where with the help of a slow gravity filtration method after treatment it was supplied to meet the city's requirements. Since then there has been a multitude of steps have been undertaken to manage the vast amount of water made available by rainfall. The average annual rainfall in Chennai was 1200 mm and it has become 1350 mm after very heavy