Analysis of Water Demand and Forecasting Water Demand for Year 2048 Jabalpur City

Ankit Kumar Nigam[#1], Prof. D.C Rahi[#2]
M.E Environmental Engineering, Civil Engineering Department, Jabalpur Engineering College Jabalpur, RGPV University Bhopal, India[#1], Assistant Professor, Civil Engineering Department, Jabalpur Engineering College, Jabalpur, India[#2]

Abstract

The accuracy of water demand projections depends on the availability of reliable population and water use data as well as an understanding of the distribution of different types of users within the community. Correct prediction of these factors determines the extent to which a network can satisfy critical demand and maintain economic efficiency. Forecasting water demand is inherently challenging, as the factors that most directly affect water demand are difficult to predict. However, effective water resource planning can account for economic, social, environmental, and political impacts on water demand. Though water demand models assume various forms, model developed in this research is for forecasting water demand for a period of at least 25 to 30 years.) Calculation of water demand forecasting for Jabalpur City Water was anchored on economic characteristics of water demand such as, customer behaviors, income levels, level of industrialization, etc. Water forecasts, together with an evaluation of existing supplies, provide valuable triggers in determining when, or if new sources of water must be developed.

Keywords - *Forecasting Water Demand, Population Projection, Water Supply.*

I. INTRODUCTION

Water demand forecasting has become an essential ingredient in effective water resources planning and management. Forecasting the amount of water to be supplied is a very important factor for design and operational demand. To guarantee high reliability for water supplies, an intensive investment to augment flow and operational programme is required. Water demand indicates both current and/or expected water consumption in any given area over specific time period. Forecasting water demand is inherently challenging, as the factors that most directly affect water demand are difficult to predict.
As per Census 2011, Population of Jabalpur is 1206917. At Present, the Municipal Corporation of Jabalpur draws about 269 MLD of water.

II. MATERIALS AND METHODS

The ultimate objective of this research was to come up with a Calculation for water-demand forecasting with population growth estimation.

A. Population Growth Trend

According to 2001 Census, population of Jabalpur is 9,56,107 (With 5,46,561 males & 4,09,546 females), but due to inclusion of 55 villages in the Municipal Corporation Jabalpur, the census population is increased to 12,06,917 in the year 2011. The Decadal increase in population was 2,50,810 with a decadal population growth rate of 26.23% (2001-11), which is higher than that of the previous decade (1991-2001). During the decades 1981-91 and 1991-2001, the population growth rate was moderate to high at about 17.79% & 25.05% respectively, whereas during the period 2001-11 the decadal growth rate of population declined to 10.09% .But during the past (1941-1981) , the population growth rate has been higher around 45% . This Exponential growth of the population may have occurred due to increase in area, as this was the period when Jabalpur municipality became Municipal Corporation.

YEAR	POPULATION	INCREASE/D	GROWTH RATE
1941	140227		
1951	203659	63432	0.4524
1961	295375	91716	0.4503
1971	442481	147106	0.498
1981	649085	206604	0.4669
1991	764586	115501	0.1779
2001	956107	191521	0.2505
2011	1206917	250810	0.2623

The Period 1951-1981 saw a high population growth rate due to high economic growth, which has impacted economic growth rate and population. It can be seen that 2001-2011 has been decade with low rate one of the major reason is slowdown in economic locality.

Population projection as per city development plan (CDP)

Y E A R	2006	2008	2009	2010	2011	2021	2024	2034
POPULATION	10.75	11.24	11.49	11.74	12.00	14.48	15.37	20.33

B. Population within the Project Area

The Assessment of future population of a city is an important parameter to decide the city's development and investment plan. In the context of the Water supply system , population estimation and projection are being carried out with th following objectives:

To obtain a realistic estimate of the total current population in the city and spatial distribution of , the same through empirical methods

Census Year	Population	Increment X	Incremental Increment Y
1941	140227		
1951	203659	63432	
1961	295375	91716	28284
1971	442481	147106	55390
1981	649085	206604	59498
1991	764586	115501	-91103
2001	956107	191521	76020
2011	1206917	250810	59289
Average		152385	31230

To take informed strategic decisions on provision of water supply infrastructure and services for the city as a whole and for a different parts of the city

In taking strategic decisions, to strive for a reasonable balance between the risks of adequacy and viability in the future.

C. Population Projection

Based on Decadal population, the future population has been projected as per different prevalent methods such as arithmetical increase, incremental increase, geometrical increase, graphical etc. Considering higher growth incremental increase method has been adopted for estimating future population as it gives more population than that by other methods.

Geometric Method (P = P (2011)+(1+r)^n)	
Year	Population
2016	1398458
2018	1483331
2033	2307564
2048	3589792

Incremental Increase Method (P = P(2011)+nX+n(n+1)Y))	
Year	Population
2016	1294821
2018	1332169
2033	1652094
2048	2042287

D. Arithmetic Mean Method

Table 2-1 Population Projection by Arithmetic Method

Cencus Year	Population	Increment X
1941	140227	
1951	203659	63432
1961	295375	91716
1971	442481	147106
1981	649085	206604
1991	764586	115501
2011	1206917	250810
Average		152385

Arithmetic Method (P = P (2011)+nX))	
Year	Population
2016	1283110
2018	1313587
2033	1542164
2048	1770742

E. Geometric Mean Method

Table 2-2 Population Projection by Geometric Method

Cencus Year	Population	Increment X	Incremental Increment Y	Rate of Increment (r)
1941	140227			
1951	203659	63432		0.452
1961	295375	91716	28284	0.452
1971	442481	147106	55390	0.498
1981	649085	206604	59498	0.467
1991	764586	115501	91103	0.178
2001	956107	191521	76020	0.250
2011	1206917	250810	59289	0.262
Average		152385	31230	
Geometric mean, r				0.343

F. Incremental Increase Method

Table 2-3 Population Projection by Incremental Method

G. Linear Curve

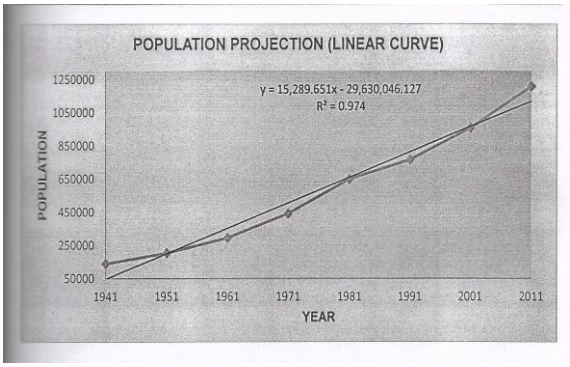

Table 2-4 Population Projection by Linear Curve

Year	2016	2018	2033	2048
Projected Population	1193891	1224470	1453815	1683160

H. Logarithmic Curve

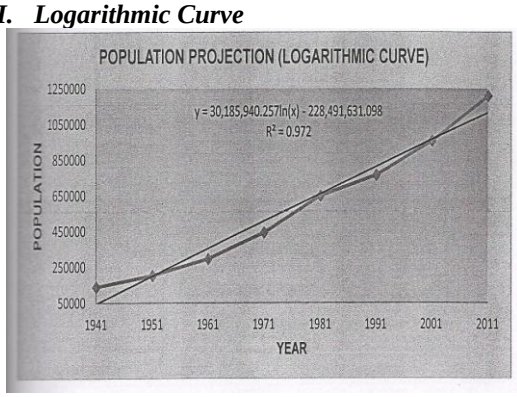

Table 2-5 Population Projection by Logarithmic Curve

Year	2016	2018	2033	2048
Projected Population	1189284	1219215	1442761	1664663

III. FINAL PROJECTION

The Increase in population of a town or an area is affected by many factors such as in-migration of people from rural areas , uplift of socio economy status which bring about exceptional conditions terms of flocking of people for their livelihood, more and more urbanization surrounding the town, growth of commercial activities and building, improvement of infrastructures and industrial development. Industrial growth around this city leads to the rapid growth of Jabalpur area. The Future design population of Jabalpur using different method is given in table below of the above described method, the incremental increase method has been adopted for the water demand assessment and further design purpose .

Table 3-1 Summary of Population Projection

Method		Base Year	Intermediate Year	Final year	Remarks
	2016	2018	2033	2048	
Geometric Method	1398458	1483331	2307564		
Incremental Increase Method	1294821	1332169	1652094	2042287	
Arithmetic Method	1283110	1313587	1542164	1770742	
Linear Curve	1193891	1224470	1453815	1683160	R^2=0.974
Logarithmic Curve	1318771	1368406	1770299	2224478	R^2=0.972

Table 3-2 Population Projection for Water Project

Year	Population
2018	1332169
2033	1652094
2048	2042287

A. Existing Water Supply System in Jabalpur

Municipal Corporation of Jabalpur meets its domestic and commercial water requirements from surface and sub-surface water sources. The Surface sources comprise

- Khandari Reservoir
- Gaur River
- Pariyat Dam
- Phagua Nallah
- Narmada River.

The Surface water from these sources is trated at water treatment plant located at

- Ranjhi
- Bhongadwar
- Lalpur (Phase I & II) and
- Ramnagra.

The Treated water is being supplied to the Jabalpur City through this. The Sub-Surface sources are constituted by about 719 tube wells fitted with power pump constructed since th drought of 1956-66, about 1372 bore-wells fitted with hand pumps . The Sub-surface sources serve as de-centralized local sources catering to small pockets of population within their respective service areas. The water supply system in Jabalpur City has been developed through seven major stages, beginning from 1983 with the Khandari water reservoir on Gaur River.

In Hilly Areas of the Municipal corporation Jabalpur where piped water is presently not accessible, the water is supplied by the 30 numbers of truck and tractor fitted with tanker.

- ❖ Coverage of Water Supply Connections = Existing 55%
- ❖ Per Capita Supply of Water = Existing 147 lpcd*
- ❖ Extent of Non-Revenue Water = Existing 30%
- ❖ Quality of Water Supplied = Existing 89.70%
- ❖ Extent of Metering = Existing 4.59%
- ❖ Efficiency in Collection of Water Charges = Existing 30%
- ❖ Cost Recovery = Existing 50%

B. Water Supply Projects

The water sources for drinking water supply in the Municipal Corporation of Jabalpur are met by five Major Surface water supply projects and a number of local sub-surface sources in the form of tube wells, bore wells fitted with hand pumps and open wells. The Surface water –based projects include:

- Khandari Reservoir and Katiyaghat Gaur River Water Supply Project.
- Pariyat and PhaguaNallah Water Supply Project.
- Narmada River Water Supply Project - Lalpur Water Works (Phase-I).
- Narmada River Water Supply Project - Lalpur Water Works (Phase-II)
- Narmada River Water Supply Project - Ramnagra Water Works.

C. Source of Water

At Present, the Municipal Corporation of Jabalpur draws about 269 MLD of water from the three surface sources and the tube wells. The details given below presents a summary of the quantity of water drawn by MCJ from the various sources (surface & sub-surface).

In Surface Source like Pariyat Dam & Phagua Nallah having 45 MLD Withdrawal Quantity, Khandari Reservoir & Gaur River having 27 MLD Withdrawal Quantity, Narmada River (Lalpur Water Works) – Phase I & II having 97 MLD Withdrawal Quantity, Narmada River (Ramnagra Water Works) having 80 MLD Withdrawal Quantity.

D. Water Treatment Facilities

MCJ has four raw water treatment plants for the treatment of the water drawn from different surface sources. The treatment capacity of the four treatment plants taken together is 298 MLD. This list of treatment plants, their source of water and capacities are presented in the table below-

Table 3-5 Details of Existing WTP

S No.	Location of WTP	Source of Water	Year of Commissioning	Installed Capacity (MLD)	Present Production (MLD)
1.	Bhongadwar	Khandari Reservoir & Gaur River	1976	27.00	27.00
2.	Ranjhi	Pariyat River	1966	54.00	27.00
3.	Lalpur (Phase-I)	Narmada River	1983	42.00	42.00
4.	Lalpur (Phase-II)	Narmada River	2005	55.00	55.00
5.	Ramnagra	Narmada River	2011	120.00	80.00
		TOTAL		298.00	231.00

IV. RESULT AND DISCUSSION

The Objective of a Public protected water supply system is to supply safe and clean water I adequate quantity, conveniently and as economically as possible. Engineering decisions are required to specify the area and population to be served, the design period, the per capita rate of water supply, other water needs in the area, the nature and location of facilities to be provided, the utilization of centralized or multiple points of treatment facilities and point of water supply intake and waste water disposal. Projects have to be identified and prepared in adequate detail in order to enable timely and proper implementation. Optimization may call for planning for a number of phrases relating to plant capacity and the degree of treatment to be provided by determining the capacities for several units, working out capital cost required, interest charges , period of repayment of loan, water tax and water rate. Uncertainties in such studies are many, such as the difficulties in anticipating new technology and changes in the investment pattern, the later being characterized by increasing financing costs.

A. Population

As Per the census 2011, Jabalpur City is having population of 1206917. This includes the population of newly added 55 villages.

Estimation Forecasting of future population for Jabalpur has been made for the Period up to the year 2048 using Various mathematical and graphical methods such as:

I. Arithmetical Increase Method
II. Geometrical Increase Method
III. Incremental Increase Method
IV. Graphical Projection Method

The Population projections by various methods are described in the previous contents of this in details and the summary of projected population for base, intermediate and design year is given in the below table:

Year	2018	2033	2048
Population	1332169	1652094	2042287

1) Source

The biggest advantage of Jabalpur city in context of water supply source is the presence of perennial rivers Narmada and Gaur and a few reservoirs, which provide the city with water throughout the year. Despite proximity to water source and good availability, the coverage is not at par the norms, but citizen are resorting to use of their own bore well.

Presently 6.5mld of water is being withdrawn from the tube wells. Rapid withdrawal of ground water is causing depletion of water table and hence adequate supply of portable water will eventually reduce the consumption of ground water. The following existing

sources of water supply to cater the need of Jabalpur city will be utilized under this proposal:
Pariyat Dam and PhaguaNallah
Khandari Reservoir and Gaur River
Narmada River For Lalpur and Ramnagra water works

2) ***Design Period***

Water Supply projects are normally Designed to meet the requirement over 30 years period after their completion, except in regard to some components, depending on their useful life or the facility for carrying out extension when required and rate of interest so that expenditure far ahead of utility is avoided.
The Forecasting and projects components of Jabalpur Water Supply System may be designed to meet the requirement of the following design periods:-

S No.	Components	Design Periods (Years)
1.	Storage by Dams	50
2.	Infiltration Works	30
3.	Pumping	
	a. Pump House (Civil Works)	30
	b. Electric Motors and Pumps	15
4.	Water Treatment Units	15
5.	Raw Water and Clear Water Conveying Mains	30
6.	Clear Water reservoirs at the haed works, balancing tank, service reservoir (OHT/GSR)	15
7.	Distribution System	30

3) ***Water Demand***

Table 4.1.A Proposed Rate of Supply for Jabalpur City

S No.	Parameter	Supply rate
1.	Domestic and Non-Domestic Demand-Metropolitan and Mega Cities provided with piped water supply where sewerage system is existing/ contemplated.	150lpcd
2.	Fire Demand (KL)	$100\sqrt{P}$ P is population in thousand
3.	UFW	15%
4.	Bulk Supplies To commercial, institutional and industrial establishments- Khamaria Ordinance Factory (Raw Water) Defence Vehicle Factory SAF Battalion Military Engineering Services Central railways Other Bulk Consumers	As Per the Assessment

Based on the Above mentioned assumption and recommended rate of water supply, the present and future requirement of clear water is given in the table below-

Year	2016	2018	2033	2048
Total Clear Water Demand (MLD)	245.51	252.55	312.43	385.37

4) ***Gap Analysis in Water Demand***

Table 4.1.B Gap Analysis in Water Demand

Year	2016	2018	2020	2023	2026	2030	2035	2038	2044	2048
Demand	245.5	252.5	259.7	271.0	282.8	299.4	321.3	335.3	364.6	385.3
GAP(with Existing infra.)	-14.5	18.5	11.3	0.0	-11.8	-28.4	-50.3	-64.3	-93.6	114.3
Production with installed Capacity	231.0	271.0	271.0	271.0	271.0	271.0	271.0	271.0	271.0	271.0
Production with Augmented Capacity	231.0	271.0	271.0	336.0	336.0	336.0	336.0	336.0	336.0	336.0

It is clear from the above table that the existing water treatment facilities will not be sufficient to provide the treated water to the Jabalpur City for the next 30 years. The total Installed capacity of all four water works is 298 MLD which are currently producing 231 MLD treated water. Since the installed capacity of Ramnagra Water works is not fully utilized, its production capacity need to be increased from the base year 2018. Increase in the production of Ramnagra WTP (120MLD) shall cater the water requirement till 2023 only and there after production would be required by

augmentation/construction of new water treatment plant.

B. Construction of New WTP

Presently the Jabalpur city is having infrastructures to produce treated water of 298MLD, which is adequate to cater the water requirement in the future. With the recommended rate of supply as 150LPCD, the city will be required the enhancement in the production of treatment plant after the year 2023.

Table 4.2.A Installed Capacity Vs Utilized Capacity of WTP

Water Works	Unit	Installed Capacity	Production Capacity 2016 2018	
Ramnagra	MLD	120	80	120
Lalpur				
Phase-I	MLD	42	42	42
Phase-II	MLD	55	55	55
Bhongadwar	MLD	27	27	27
Ranjhi	MLD	54	27	27
TOTAL		298	231	271

The clear water demand in the year 2048 is more than 385 MLD against the production with installed capacity of 298 MLD. A New WTP of Capacity 65 MLD is proposed to be constructed in the 2023. The Growth pattern would be required to reassess while finalizing the capacity of new WTP. Since the WTP is designed for 15 years of design speed this would meet the demand up to year 2048.

REFERENCES

[1] K.N Duggal; 2002, Elements of Environmental Engineering.

[2] S. K Garg 2000, Environmental Engineering (Vol-1), Water Supply Engineering.

[3] Dr. B.C Punmia, Dr. Ashok Kumar Jain, Dr. Arun Kumar Jain; 2011, Environmental Engineering -I ,Water Supply Engineering.

[4] Integrated Urban Development in Madhya Pradesh (IUDMP)ADBTA NO.3759-IND,draft final report, volume 2 city reports Bhopal.

[5] Jabalpur city development plan Jawaharlal Nehru national urban renewal mission report 2011.

[6] Surendra, H. J. and Deka, P. C. Effects of Statistical Properties Artificial Intelligence Techniques for Urban Water Consumption Time Series. International Journal of Civil Engineering & Technology, 3(2), 2012, pp. 60–69

[7] Arbues, F., Garcia-Valinas M. A. and Martinez-Espineira, R. Estimation of residential water demand: a state-of-the-art review. The Journal of Socio- Economics, 32, 2003, pp. 81–102.

[8] Espey, M., Espey, J. and Shaw, W. D. Price elasticity of residential demand for water: a meta-analysis. Water Resource Research, 33(6), 1997, pp. 1369–1374.