WATER SUPPLY PROJECTS
AND
WATER DISTRIBUTION SYSTEM
OPERATION & MAINTENANCE

Welcome to Mumbai the Capital of Maharashtra State and financial nerve centre of India.

Introduction

The city of Mumbai was originally a cluster of seven islands inhabited by fishermen. Mumbai was ruled by various Hindu dynasties till 1348 when the Muslims took over. In 1534 Mumbai was handed over to the Portuguese who offered the city as dowry to Charles II of England in May 1664. In 1668, the East India Company took over Mumbai and started developing it as a firm base of their commercial activities. Land reclamation was started.

The residents drew water from wells and tanks which were, before long, inadequate for the growing needs. In the absence of Perennial River, harnessing of surface water was the only feasible solution. Search for a suitable site for impounding the monsoon runs-offs was started in 1845. The sites existed far away from the island city and deep into the main land. Right from beginning the piped water supply, impoundage and long conveyance system bringing water by gravity have remained the unique characteristic of Mumbai's water supply. The population continued to grow rapidly, particularly post Independence in 1947, and necessitated repeated augmentation of water supply.

Mumbai, the capital city of the State of Maharashtra, is also the commercial and financial capital of the country. With a population more than twelve million, it is among the five most populated megacities of the world. The water supply system of Mumbai is unique and complex. The water supply system has grown over the last 150 years and it is amongst the few largest water supply systems o the world.

VEHAR SCHEME

Vehar has the distinction of being first piped water supply scheme of Mumbai, commissioned in 1860. Three earthen dams and stone masonry overflow section were constructed to impound Mithi river water 20 Km. north of Mumbai. The impoundage is named as Vehar Lake. A 1200 mm diameter Cast Iron pipe carried water supply of 32 Million Litres per Day (MLD) to a population of 700 thousand. Supply from this source was increased by raising the height of the dams in 1872, to 68 mld. The Scheme is still in operation.

Presently the Water Treatment Plant of this scheme is being under refurbishment by using latest advances in water treatment technology.

TULSI SCHEME

Major Tullock's treatise on "Water supply to Bombay" published in 1872 documented the various possible future sources of water supply to the city. Debate over the choice of the best source continued for years and in 1885 it was decided to develop Tansa as the next source. Meanwhile, a critical situation of water shortage arose and led to the immediate development of Tulsi Lake, upstream of Vehar Lake, on the river Mithi. The scheme consisted of an earthen dam and a masonry dam and a 600 mm diameter pipe line, to carry 18 MLD of water to the service reservoir at Malabar Hill situated at the southern end of the city. Slow sand filters were also constructed at the service reservoir and subsequently shifted to a site near the Lake. The Scheme is still operational supplying water to elevated localities by gravity.

POWAI SCHEME

While Tansa scheme was under construction, Powai scheme was taken up on a tributary of the Mithi river, as an emergency measure to mitigate the anticipated water famine in 1891. However, due to the inferior water quality from this catchment, the 4 MLD water supply available from this source was later diverted for Industry, dairy and agricultural user. The Scheme is still operational.

TANSA SCHEME

In 1886 it was decided to tap river Tansa situated about 110 km to the north of the city, in the mainland. The potential of Tansa was so large that it satisfied the needs of the city for nearly five decades. This source was developed in four stages. The first stage was completed in 1892. A 2.8 Km Long masonry dam was constructed across river Tansa and the dream of Major Tullock, the British Army Engineer who was the architect of the scheme, was translated into reality.

The impoundage thus created was conveyed to the city by constructing a 42 km long closed masonry aqueduct on the hill ridges and laying a 53 km long 1200 mm diameter Cast Iron pipe line in the valleys. The Elevation of this distant source permitted 77 MLD of water flow from the dam to the city by force of gravity.

The second stage was commissioned in 1915 when an additional pipe line of 1250 mm diameter was laid in the valley to increase the supply by additional 82 MLD.

In the third stage, popularly known as Tansa duplicating works, the height of the dam was raised by three meters to increase the storages and a new conveyance system consisting of two 1800 mm diameter mild steel riveted pipe lines along a much shorter route was created and commissioned in 1925. These pipe lines crossed the Thane Creek over a steel bridge near Kasheli. The bridge later became part of Mumbai-Agra National Highway. The water supply to the city was increased by another 68 MLD.

The fourth and last stage was completed in 1948 when the storage capacity was increased by providing 38 flood gates, each 15.24 M Long

and 1.20 M in height. The dam was strengthened by providing prestressed anchors through the body of the dam. The water supply further increased by 181 MLD, bringing total supply from this source to 410 MLD.
The dam over river Tansa completed 100 years in 1992 and strengthened against seismic forces by constructing counter fort buttresses. The conveyance system from dam to Gundavali (40 Km) is being replaced by one 2750mm diameter MS water main. The old mains laid in the city under this project also currently under process of rehabilitation / replacement.

VAITARNA SCHEME

India got independence in 1947 which also brought about the partition of the country and led to a large scale migration into the city. Mumbai stood poised for unprecedented industrial and commercial growth. The Vaitarna cum Tansa scheme was conceived, planned and executed to meet the increased water demand by a team of Municipal engineers under the able guidance and leadership of the late Mr. N. V. Modak. The impoundage on river Vaitarna was named "Modak Sagar" by the Corporation in the memory of the invaluable services of Mr. Modak.

Salient features of the scheme included construction of a 90 M high and 500 M long concrete dam across river Vaitarna, construction of 7.2 km long (2.9M diameter) Horse shoe tunnel between Vaitarna and Tansa and laying of 2400 mm diameter pipe line from Tansa to the city for a length of 76 km. The dam was the first concrete gravity dam in the country that was constructed using pre-cooled control concrete. A new design of the pipe line providing ring girders and roller support with expansion joints in the above-ground sections achieved significant savings in the use of steel plates. This pipe line, in those days, was the largest and longest pipe line of this type ever laid in the world.

On its completion in 1957, this scheme brought additional 490 MLD of water supply to the city. Modak Sagar, which was situated at higher level than Tansa, facilitated water supply from this source by gravity.

UPPER VAITARNA SCHEME

The Upper Vaitarna Scheme was executed by the Government of Maharashtra as a hydro-electric-cum-water supply scheme. The works, completed in 1972, made available additional 544 MLD of water supply to the city. Upper Vaitarna water, after generation of power, was released into the river course which flowed into Modak Sagar (Lower Vaitarna) and then conveyed to the city. A pipe line of 3000 > 2750 > 2400 mm diameter was laid by the Corporation. Tunnel below creek bed to carry water across the Thane Creek was bored to carry the entire water supply under the creek, in the event of damage to across creek pipeline.

Another tunnel, known as Mulund-Kandivali tunnel, was constructed through the hills of the Borivali National Park for supplying water to the growing needs of suburbs in western part of the city.

During the execution of Lower Vaitarna and Upper Vaitarna Schemes, additional service reservoirs were constructed in different parts of the city for better distribution of water supply.

Upto this time, the unique feature of water supply of Mumbai was that the entirely supply was by gravity and moreover the catchments of Tansa, Lower Vaitarna and Upper Vaitarna dams were naturally so well protected that the water hardly needed any conventional treatment. Only chlorination was done to ensure disinfection of water before distributing to the consumers.

MUMBAI WATER SUPPLY AND SEWERAGE PROJECT (MWSSP)

Despite the water supply schemes mentioned so far, a huge scarcity of water supply started arising towards the end of 1960s. The rate of growth of the population during the decades of 1950s and 1960s was unprecedented. A master plan was, therefore, prepared for integrated development of water supply and sewerage facilities. This project, titled Bombay Water Supply and Sewerage Project, was planned to be implemented in three phases. Each of these three phases envisaged additional water supply of 455 MLD, to be drawn from the Bhatsa river. The Government of Maharashtra had constructed a dam across river Bhatsa and release of water downstream was regulated. The abovementioned project, taken up on 1974-75, involved abstraction of water from a small impoundage created by constructing a weir at village Pise, 48 km. downstream of the Bhatsa dam. The project also envisaged construction of pumping, treatment and conveyance facilities at Pise, Panjrapore and Bhandup. The three stages of the project were commissioned in 1981, 1989 and 1997 respectively. Each of this stage of the project has been financially assisted by the International Development Association and the World Bank.

Stage 1 comprised construction of weir at Pise, a structure to house seven pumps each with Discharging Capacity of 90 MLD and a 2235 mm diameter MS rising main to convey raw water to Panjrapore, where it was clarified. The clarified water was injected into the two Vaitarna mains near village Yewai. The blended water carried through the Vaitarna mains was delivered through an inlet tunnel to Bhandup.

A massive Water Treatment Plant (1910 MLD), with pumping station and Master Balancing Reservoir came up at Bhandup Complex. Bhandup complex was established on the northern edge of the Vehar Lake to provide for a full two stage treatment to 1910 MLD of raw water. Bhandup WTP was the largest treatment plant in Asia at that time. The complex includes plant for pumping the filtered water to a Master Balancing Reservoir (MBR) of 246 ML capacity. The MBR feeds all the service reservoirs in the city and suburbs by gravity. This stage was commissioned in 1981, with total water supply to city 1983 MLD.

Stage II comprised expansion of the pumping station at Pise, construction of pre-chlorination plant at Pise, laying of 2235 mm diameter MS rising main from Pise to Panjrapore, construction of 455 MLD capacity filters at Panjrapore, construction of MBR II of 130 ML capacity at Yewai hills and laying of 48 km long 2345 mm diameter transmission mains. In addition, two tunnels one 3500mm diameter across Thane Creek and another 3000mm diameter between the Race Course and Malabar Hill Reservoir were constructed. This stage was commissioned in 1989, augmenting the city's water supply to a total of 2438 MLD.

The third stage envisages the provision of additional pumps at Pise and Panjrapore, laying of 2235 mm diameter pipe line from Pise to Panjrapore, complete two stage treatment plant at Panjrapore and laying of 31 km of 3000 mm diameter of pipe line between MBR II at Yewai and Bhandup. On commissioning of this stage during 1996-97, the city's total water supply will reach 2890 MLD.

Government of Maharashtra allocated additional 650 MLD water under Mumbai IIIA & IIIB on temporary basis the surplus water available at Bhatsa source, due to unutilized irrigation potential. The weir capacity was increased by erecting inflatable gates, 640 MLD pumping capacity was created at Pise and Panjrapore and additional surplus water was injected into Vaitarna system at Yewai. The total average water supply to city increased to 3350 MLD in 2007.

FUTURE SOURCES

The present trends in growth of population indicate that by the year 2041, the population of Mumbai will be around 16 million and water demand will be around 5400 MLD. To meet this demand, the sources identified are as under:

Source	Yield in MLD	Likely Year of completion
Middle Vaitarna	455	2013
Gargai	440	2016
Pinjal	865	2021
Damanganga	1586	2025

MIDDLE VAITARNA PROJECT

MCGM has taken up the Middle Vaitarna Project, which includes six components viz. RCC (Roller Compact Concrete) Dam, Intake tower at Modak Sagar, 7Km-3500mm diameter tunnel & 40Km-3000mm pipeline and 900 MLD Water Treatment, Pumping Station & 140 ML Master Balancing Reservoir at Bhandup Complex.

The project cost including all major components is 228.5 Billion Rupees. Out of which Govt. of India has vetted 132.95 Billion Rupees aid under JNNURM (Jawaharlal Nehru National Urban renewal Mission)

Three components viz. pipeline, pumping station and Master Balancing Reservoir are completed in all respect.

The Dam & Water Treatment Plant will be completed by end of June 2013 and the work of Intake Tower & tunnel is likely to be completed by December 2013.

The scheme has been partially commissioned and water supply is augmented by 200 MLD bringing total supply of Mumbai to 3550 MLD. On full commissioning of project in December 2013 the supply will be augmented by 455 MLD bringing total city supply to 3800 MLD.

FUTURE WATER SUPPLY PROJECTS

Salient Features of Gragai scheme

Source : Gargai river; tributory of Vaitarna river.
Location : Ogade, Wada Taluka in Thane District.
System : Gargai waters will be conveyed to Modaksagar through proposed 2.5 kms long tunnel, then to City through existing conveyance system after being treated, pumped, stored in proposed Water Treatment Plant, Pumping station & MBR at Bhandup Complex.

Yield	:	440 Mld
Dam Height	:	69.00 mtrs
Dam Length	:	1200.00 mtrs
Catchment Area	:	110 Sq. Km.

Submergence	:	750.00 Hectares
No. of villages under submergence	:	6 villages.
Cost of the project (based on 2010 costs)	:	Rs. 2725 crore
Commencement / Completion	:	August 2015 / August 2019

Salient Features of Pinjal scheme

Source : Pinjal river; tributory of Vaitarna river.
Location : Khidse, Jawhar Taluka in Thane District.
System : The headworks will be constructed by MCGM/GoM. Further MCGM will convey Pinjal waters, along with diverted Damanganga waters, upto Gundovali through proposed 5500mm diameter- 64 kms long tunnel and then further conveyed upto Bhandup complex by ongoing 14Km-5500mm diameter Gundovali-Bhandup tunnel. This water will be treated, pumped, stored in the proposed Treatment Plant, Pumping Station & MBR respectively, in Bhandup Complex.

Yield	:	865 Mld
Dam Height	:	70.00 mtrs
Dam Length	:	750.00 mtrs
Catchment	:	316 Sq.Km.
Submergence	:	2000.00 Hectares
villages under submergence	:	11 villages
Cost of the project (based on 2010 costs)	:	Rs. 8,017 crore
Commencement / Completion	:	April 2016 / March 2022

Damanganga Project

The project envisages construction of two dams viz. Bhugad in Nashik district, and Khargihill in Thane district, interconnecting them through 5000mm diameter -17 kms long tunnel and further, connecting to Pinjal reservoir through 5250mm diameter -26 kms long tunnel. The Pinjal dam will be constructed by MCGM/GoM. Further MCGM will convey Pinjal waters, alongwith 1586 MLD water diverted from Damanganga, through proposed 5500mm diameter -64 kms long tunnel upto Gundovali and further convey upto Bhandup complex, through ongoing Gundovali-Bhandup tunnel, where this water will be treated, pumped, stored in proposed Treatment Plant, Pumping Station & MBR at Bhandup Complex. Total estimated project cost is Rs. 11,519 Cr.

Thus on completion of these projects, the total water supply of city will increase to 6696 MLD. By this time the excess water available from Bhatsa (640 MLD) may have to be surrendered for Irrigation and considering supply to en-route consumers, the supply will meet the demand.

DISTRIBUTION OF WATER SUPPLY OPERATION AND MAINTENANCE

Distribution & Control

The distribution system comprises 27 service reservoirs constructed of Colcrete or Reinforced Concrete at different periods of time. The network of water mains has a total length of about 4000 km and diameters varying from 80 mm to 1800 mm, laid over the last 150 years. There are different types of valves and appurtenances. Because of this varied conglomeration of different units created over a long time period with different materails, the distribution system has become very complex.

The entire water distribution network of Mumbai is divided in to 109 water supply zone fed by 27 service reservoirs. The supply is intermittent and each zone is fed for limited hours as the demand is more than the current supply.

A supervisory Control And Data Acquisition (SCADA) system equipped with V-SAT communication mode is created for continuous monitoring the flow and pressures from source to WTP and MBR to various service reservoirs with Master Control at Bhandup Complex. The master Control Center located at Bhandup Complex regulates the available water supply from different sources and ensures the uniform supply from WTP throughout the year. In addition the MCC also monitors the inputs and outputs at the filtration plants and monitor the flow from the MBR to the service reservoirs to maintain the allocated duty of each service reservoir.

The supply from each reservoir is continuously monitored by the three local control stations located in island city, Eastern suburb and Western suburb. The Controls also record consumer complaints and coordinate the supply during modification and maintenance activities. The Reservoir outlets are installed with Flow monitoring devices with GPRS communication system with local controls. Flow Meters are also being installed in field at entry points of zones. These devices will facilitate measurement of water supply in each ward and each water supply zone.

The water distribution network for each of the zone is analyzed on computer and master plan for laying additional water mains required for the 2021 stage of developments is prepared. During this analysis, it has become evident that there will be a paucity of underground space for laying water mains under roads, busy traffic corridors and as such many underground Tunnels are proposed many of them are constructed, few are in progress and a few under feasibility study.

Rehabilitation / Replacement

The internal tuberculation in water mains and leakages through cracks in pipes and pipe joints often led to complaints regarding reduced pressures and contamination. With intermittent supply, every source of leakage during water supply hours becomes a source of contamination during the non-supply sours. The high sub soil water table, large un-sewered localities and the backflow from consumer service connections passing through water logged unhygienic house gullies (Open space between two adjacent buildings) are main sources of contamination.

The roads in the island cit are narrow and crammed with other utilities. Replacement of the existing mains or laying additional mains under these roads is an arduous task.

In order to combat these problems without interrupting the daily water supply, the technique of cleaning and internal cement mortar-lining of small diameter water mains found to be most suitable and large scale rehabilitation of the old network in island is implementation in the phased manner.

The cleaning removes the internal tuberculation and the mortar-lining provides a smooth internal surface, thereby reducing frictional losses. Besides, the leakages through the pipes or joints are plugged, The consumer service pipes are also replaced, resulting in reduced contamination complaints and improved water pressures.

WATER QUALITY MONITORING

For monitoring the quality of raw and treated water, laboratories equipped with modern equipments have been set up at the treatment plants. These laboratories monitor the physical, chemical and bacteriological parameters continuously.

The drinking water parameters as per Indian Standard IS10500 :1991 and quality of Mumbai treated water are tabulated as under -

QUALITY STANDARDS OF TREATED WATER IN MUMBAI

TESTS	IS 10500 : 1991		Filter water	
	ACCEPTABLE	MAX.PERMISSIBLE	MAXIMUM	MINIMUM
TURBIDITY N.T.U.	5.00	10.00	0.80	7
COLOUR H.U.	5.00	25.00	<5	<5
PH	6.5 - 8.5	6.5 - 8.5	6.85	6.70
TOTAL SOLIDS mg/l	N.P.	N.P.	34.00	20.00
SUSPENDED SOLIDS mg/l	N.P.	N.P.	NIL	NIL
DISSOLVED SOLIDS mg/l	500.00	2000.00	34.00	20.00
CHLORIDES mg/l	250.00	1000.00	10.00	9.00
ALKALINITY mg/l	200.00	600.00	34.00	25.00
TOTAL HARDNESS mg/l	300.00	600.00	50.00	34.00
CALCIUM HARDNESS mg/l	N.P.	N.P.	32.00	19.00
CALCIUM AS Ca^{++} mg/l	75.00	200.00	12.80	7.60
MAGNESIUM AS Mg^{++} mg/l	30.00	100.00	5.72	2.64
IRON AS Fe^{++} mg/l	0.30	1.00	0.04	0.02
MANGANESE AS Mn^{++} mg/l	0.10	0.30	NIL	NIL
ALUMINIUM AS Al^{+++} mg/l	0.03	0.20	0.02	NIL

At present, about 4000 samples per month are collected from various reservoirs and sampling points by Water and Health Department in the distribution system for analysis and monitoring. On receipt of the report about a sample being unfit, the area from which the sample was collected is surveyed for leaks in the system. The detected leak points are rectified and a sample is taken again. The exercise is repeated till the sample is found fit. With the help of the epidemiological section of the Health Department of the Municipal Corporation, the areas reporting larger number of cases of water borne diseases are identified. The water mains are flushed through hydrants / flush points and a booster Chlorine does is injected by mobile chlorinators, till the contamination is controlled and spread of water borne disease is abated.

TARIFF

The water supply to the households of Mumbai is highly subsidized. The tariff structure is such that nearly 42% of total revenue from water charges is generated by non residential consumers (Industries and commercial establishments) who use only 10 % of total water supply
The tariff for water used for domestic purpose is Rs.3 (US $ 0.06) for slums and Rs.4 (US $ 0.08) for planned Housing per KL. The tariff for various commercial and industrial consumers ranges from Rs.16 to 60 (US $ 0.32 to 1.20) per KL. Additional 60% of water charges are recovered against sewerage charges.
The Domestic consumers are charged in telescopic system with single rate upto 150 lpcd, double rate between 150 and 200 lpcd, three times the rate for consumption between 200 and 250 lpcd and four times the rate for consumption above 250 lpcd.
The cost of water production has the advantage of old assets and gravity flow and is currently Rs. 12 per KL. The marginal cost with every additional new source will, however, be much higher.
A computerized billing system has been developed and now functional for almost a decade.

Water Distribution Improvement Programme (WDIP)

The Municipal Corporation of Greater Mumbai (MCGM) has embarked on an ambitious program to improve water distribution system. The programme shall include:

- Survey and Mapping of Water Distribution Network.
- Assessment of Non Revenue Water (NRW).
- NRW reduction.
- Setting up permanent NRW Assessment System.
- Develop Strategy for 24 x 7 Water Supply System.

The salient features of WDIP are:

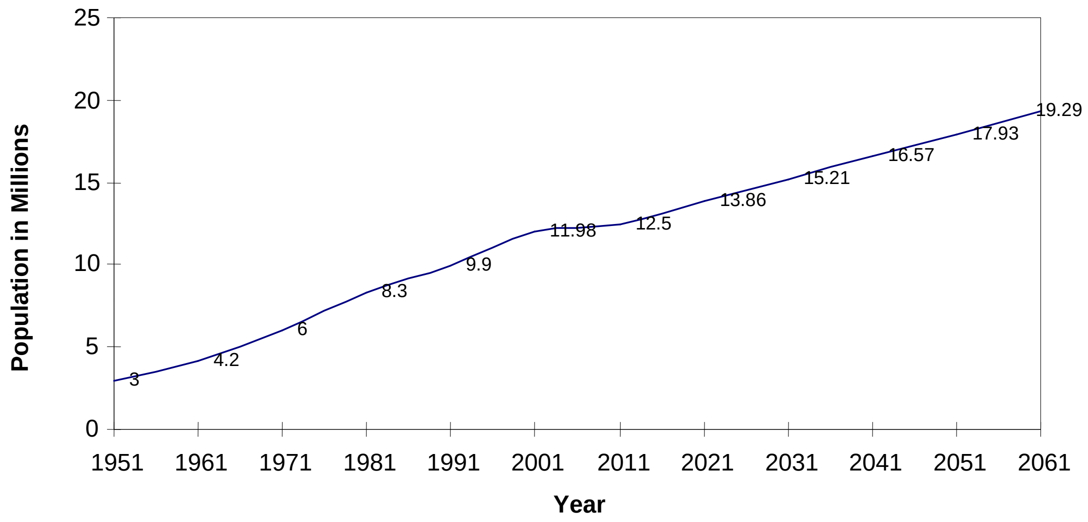
1. Quality improvement (in terms of longer hours of water supply) & Quantity improvement (in terms of equitable water distribution).
2. To abate the Non Revenue Water (NRW) for maximum utilization of available water.
3. Mapping, updating with GPS referencing and GIS formatting of water utility.
4. Design & Modeling of water supply zones to optimize the Capital Expenditure.
5. Creating District Metering Areas (DMAs), measuring Unaccounted For Water (UFW), reducing UFW (Intermittent vis-à-vis 24x7 basis) and finally switching over to longer or preferably 24x7 water supply.

The major components of programme are:

- 100% consumer Metring: AMR enabled Meters or Manually read Mechanical Meters are being installed on 400,000 consumer service connections.
- Installation of Flow & Pressure regulating devices.
- Installation of NRW assessment devices and to develop permanent NRW assessment system.
- To delvelop the leak detection and repair mechanism.
- To develop a system of utility map updating procedures.
- To develop an asset renewal programme.
- To utilize the available resources optimally.
- To develop customer relation and complaint redressal system.

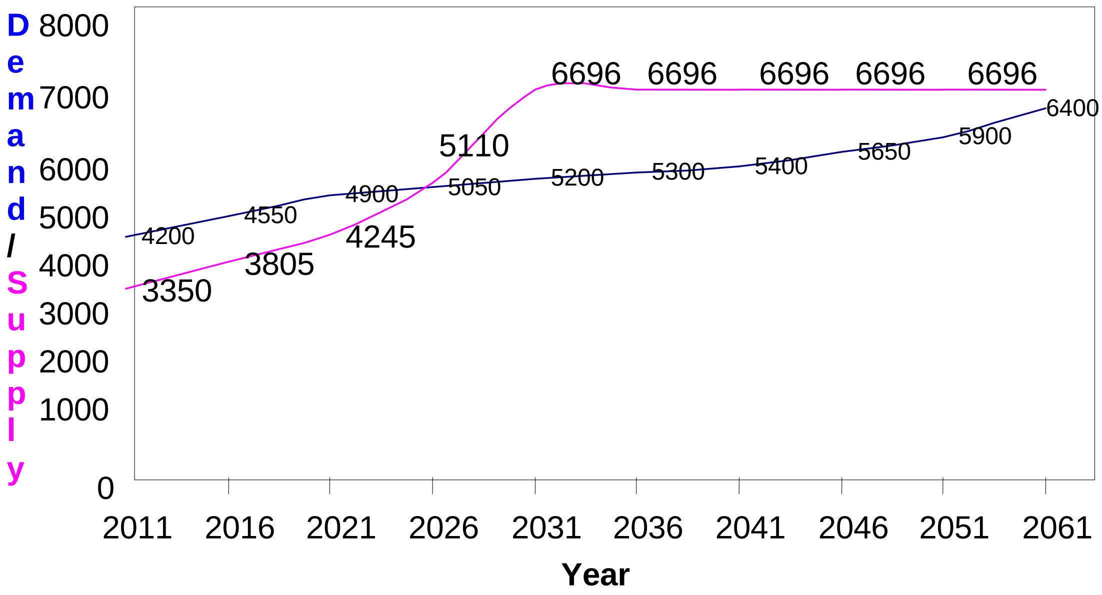
Population Data & Projections

(Upto the year 2051)



Demand Supply equation

Mumbai water Works, made a humble start with distributing 32 MLD of water to a population of 700 thousand in 1860, now treats and distribution 3550 MLD of water to a population of over 12.5 million. It looks forward and prepares itself to handle a daily supply of 6000 MLD by 2041 for a population of 15 million.



BREAK - UP AVAILABLE SURFACE WATER IN THE YEAR 2021

Source	Water supply	
	In MLD	%
Vehar stage - I & II	68	0.11
Tulsi	18	0.26
Tansa scheme stage I to IV	408	5.12
Vaitarna Scheme	490	7.11
Upper Vaitarna	544	7.90
Bhatsai scheme phaseI I, II, III	1365	29.25
*Mumbi III A + IIIB	650	6.60
Middle Vaitarna	455	1.68
Gargai	440	6.39
Pinjal	865	12.56
Damanganga	1586	23.02
TOTAL	6889	100

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- Temporary allocation likely to be withdrawn on development of Irrigation potential