Concept Plan for MUMBAI METROPOLITAN REGION India

Phase 2 - Draft Regional Concept Plan

Sectoral Report 7 - Utility & Infrastructure

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Approvals	Name	Designation	Date
Author	Wong Teck Jee Simon	Vice President	22-09-2010
Author	Lissiana Markun Lauwa	Engineer	22-09-2010
Reviewer	Yin Kam Meng	Senior Vice President	22-09-2010

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Project Background

Mumbai, the economic gateway to South Asia, is gaining increasing recognition as an emerging global city. Recent researches have showed that, in wake of the accelerating pace of urbanization across India, the population in Indian cities would expand by 10% in the next 20 years. By 2032, Mumbai and its metropolitan region are anticipated to become one of the largest urban agglomerations in the world by 2030, with an esitmated population of 36 million. Powered by India's economic reforms and driven by a young skilled population, the Mumbai Metropolitan Region (MMR) will witness a 5-fold increase in GDP in the next 20 years. In light of this, the City's stakeholders envision to *"transform Mumbai into a world class city with a vibrant economy and a globally comparable quality of life for its citizens"*.

However, the present situation does not seem to be aligned with this vision. The Region is currently witnessing an overall decline in the economy as well as living standards, with shorfalls in the business, employment, housing and infrastructure sectors. In a bid to tackle these issues, the Mumbai Metropolitan Regional Development Authority (MMRDA), the apex body for planning and co-ordination of development activities in the Region, has already undertaken several major planning and infrastructure development projects. Since the current Regional Plan (1996-2011) is due to expire and is to be updated soon, MMRDA has taken this opportunity to seek new planning ideas from international consultants on the future development strategy for MMR. They have authorized the Mumbai Transformation Support Unit (MTSU) in the All India Institute of Local Self Government (AIILSG) to facilitate and manage the preparation of a long-term strategic development plan for MMR.

Project Commissioning, Scope and Objective

In November 2009, on behalf of MMRDA, MTSU engaged Surbana International Consultants Pte. Ltd., Singapore, to carry out the concept plan study for MMR. The project officially commenced in March 2010. This Regional Concept Plan, when completed, could serve as a long-term development framework of MMR, which could be incorporated into the new Regional Plan for MMR currently being prepared by the Metropolitan Planning Committee (MPC), with technical assistance from MMRDA.

The project scope comprises three different levels of planning tasks, as shown below:

Planning Area	Size	Scope of Work
a) Mumbai Metropolitan Region	4, 355 sq. km	Regional Concept Plan & 7 Sectoral Studies
b) 3 Urban Areas (locations to be determined)	20 sq. km each	Development Guide Plan
c) 2 Urban Centres (locations to be determined)	4 sq. km each	Urban Design Plan

The Regional Concept Plan accompanied by 7 specific sectoral studies would be developed based on two horizon years: namely, 2032 (medium term) and 2052 (long term). The next 2 levels of planning i.e. Development Guide Plan and Urban Design will attempt to demonstrate how different planning models for urban rejuvenation & redevelopment, as well as for new township development, are used to address the various key urban issues facing MMR.

Project Schedule, Process and Deliverables

The project duration is 66 weeks and consists of several phases, as listed below:

- **Phase 0: Start-up Investigation**
  - This involves the process of data collection, site visits, interviews and desktop research in order to establish a working base before actual project study begins.
- **Phase 1: Planning Strategy and Structure Development**
  - The first phase involves 2 tasks:
  - Socio-economic Analysis
  - This involves analysis of the projected economic and demographic outlooks for MMR for Year 2032 and Year 2052, as well as assessment of the scenarios of dimensions of future growth for MMR.
  - Planning Concept Options
  - This involves recalibration of the vision for MMR as well as setting of long term goals and strategies to realize the vision. Further, three planning concept options would be explored to illustrate different planning structures and focuses for future MMR. A preferred option will be selected for further detailed development in the next phase of the project.
- **Phase 2: Draft Regional Concept Plan**
  - The second phase involves two tasks:
  - Concept Plan for MMR
  - This involves expansion and illustration of the preferred planning concept option into a specific Concept Plan for MMR, defining the overall land use structure and distribution, urban node hierarchy, major transportation and infrastructure systems as well as environmental management strategies.
  - Sectoral Studies
  - To strengthen the planning ideas in the regional concept plan, separate studies for 7 key sectors would be undertaken: namely,
  - Housing
  - Transportation
  - Utilities and Infrastructure
  - Environmental Sustainability
  - Parks and Recreation
  - Heritage and Urban Design
  - Land Use Management

- **Phase 3: Final Regional Concept Plan**

This stage involves the finalization of the Draft Concept Plan and the supporting sectoral studies prepared in Phase 2.

- **Phase 4: Local Planning and Urban Design**

This phase involves micro level planning involving preparation of Development Guide Plans for 3 local areas of 20 sq. km. each and Urban Design Plans for 2 urban centres of 4 sq. km. each to crystallize specific planning proposals.

- **Phase 5: Implementation Strategy**

This stage examines priority investment projects, identification of feasible development models based on the planning proposals, and then recommends possible financing strategies to facilitate realization of the Concept Plan.

- **Phase 6: Final Submission**

The project concludes with a Concept Plan Summary Report which summarizes the proposals, key recommendations and outcomes of each planning phase.

The following report would be prepared during the various phases of the Project:

- Phase 0:
  - Inception Report
- Phase 1:
  - Dimensions of Growth of MMR
  - Vision Report for MMR
- Phase 2 and 3:
  - Regional Concept Plan Report for MMR
  - Sectoral Reports for 7 key sectors in MMR
- Phase 4:
  - DGP Reports for 3 Urban Areas
  - Urban Design Reports for 2 Urban Centres
- Phase 5:
  - Implementation Strategy Report
- Phase 6:
  - Concept Plan Summary Report
  -
  - The planning process adopted for this project is described in Figure 1.

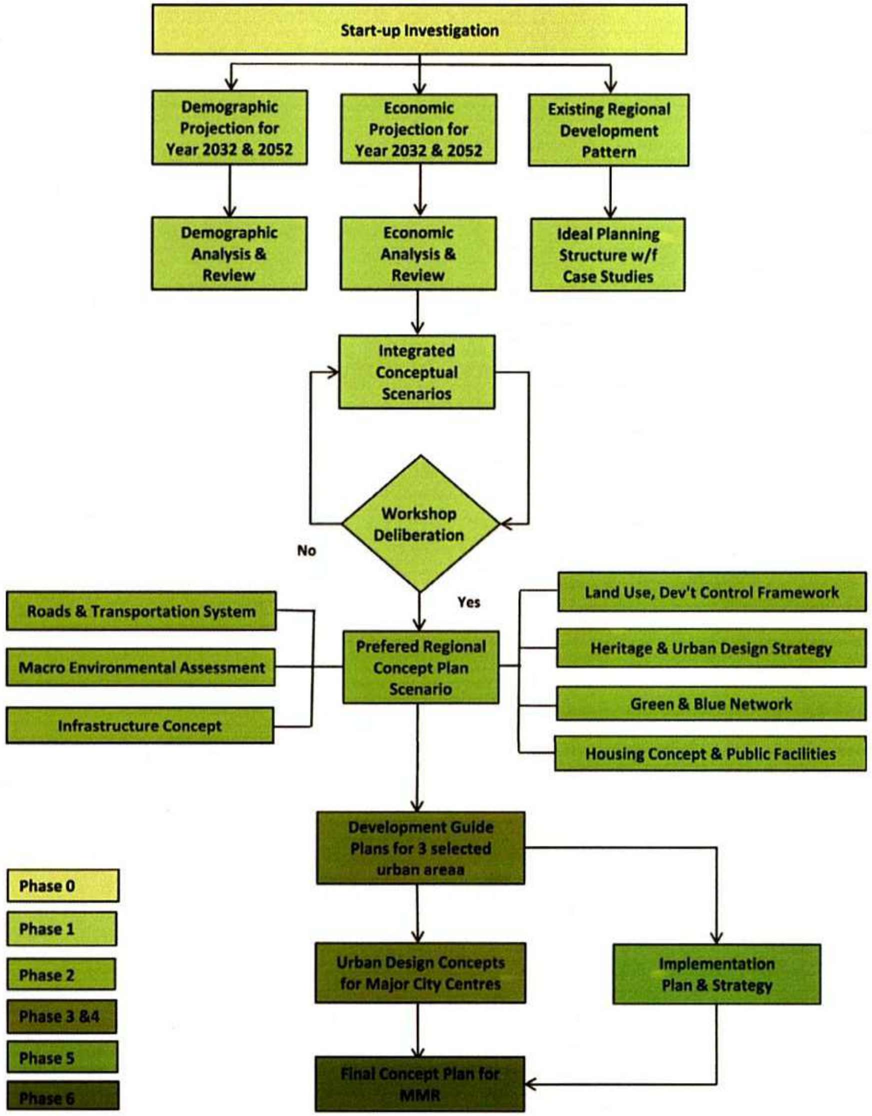

Figure 1: Proposed Planning Process for the Concept Plan for MMR Project
Source: Surbana

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EXECUTIVE SUMMARY

Background and Purpose

The population of the Mumbai Metropolitan Region (MMR) is expected to increase to 44 million in 2052. When that happens, MMR will be one of the largest urban conurbations in the world. Currently, the population growth in MMR has exceeded the growth of the infrastructure facilities. As a result, the cities are experiencing shortage of infrastructure supply and services. To transform MMR into a global city, the provision of 'best in class' infrastructure facilities and services are essential. It is also important to establish a strategic framework to provide sustainable solutions to address the infrastructure challenges in the year 2032 and 2052. This Sectoral Report will analyze the current infrastructure situation in MMR, which includes existing issues, assets, institutional framework and existing supply, current planning initiatives, etc. The findings and recommendations of this sectoral study will be used as the basis for development of future infrastructure facilities and services in MMR.

Existing Context, Assets and Issues

Four major infrastructure components were covered in this Sectoral Report. They are water supply, storm water drainage, sewerage and solid waste. Power supply is not included in this study as it is traditionally planned at the National or State levels, which is beyond the jurisdiction and boundary of MMR.

- Water Supply

Currently, water supply planning in MMR is the responsibility of the municipal corporations. Water is drawn from MMR's extensive network of lakes and rivers. Bhatsa Lake, Vaitarna Lakes, Tansa Lake and Morbe Lake are some of the major water resources in MMR. Various dams, weirs, barrages, water treatment plants and water supply network have been built to supply good quality water to the end users. To augment the water supply system, rainwater harvesting has also been implemented.

Despite all the efforts to develop a reliable water supply infrastructure, it is consistently outpaced by rapidly growing demand for water supply as a result of urbanization and population growth. The situation is aggravated by the deteriorating water supply network as the result of under maintenance of the water supply infrastructure. Significant water loss of about 20 – 40% and water contamination through leakage are the common issues that are faced by the municipalities. Most of the times, piped water supply is only available 2 – 4 hours daily in the urban area and 1 – 2 days weekly in the rural area. The business model of the water providers is not sustainable due to the highly subsidized water tariff.

- Storm Water Drainage

The existing storm water drainage network consists of open drain, box culvert, pumping stations and marine outfall. The old drains are in bad condition and overflow easily during heavy storm event. The drains at the newer urban centres are in better condition and have been designed to receive higher rainfall intensity.

There is no storm water retention pond in MMR due to the high value of the land. The water quality in the drain is bad due to the illegal dumping of garbage and the discharge of raw sewage into the drain. It is worsened by the practice of the slum dwellers to wash and bathe in the public drain.

MMR is hit by localised flooding 2 to 3 times annually during the monsoon season because the current rainfall intensity far exceeds the design capacity of the existing drain. The current physical defence against flooding is by the installation of storm water pumping station and flood gate at selective areas. Upgrading of the existing drain is being carried out at the flood prone areas such as Greater Mumbai.

- Sewerage

Sewerage network are only available in the urban area. The urban areas are divided into several sewerage zones. The sewage is treated at the sewage treatment plant (STP). The sewage is generally treated to an acceptable standard. The quality of the treated effluent is still below the allowable discharge standard set by Maharashtra Pollution Control Board. Stricter requirements are being imposed by the Maharashtra Pollution Control Board in order to reduce the water contamination level at the existing creeks and seas.

Currently, Greater Mumbai, Navi Mumbai and Thane have the most sewerage network coverage in MMR. The older sewer pipes are in poor condition due to under maintenance. Sewer pipes in Navi Mumbai are in a better condition as they are relatively new.

Septic tanks are widely used in areas that are not connected to the sewerage network. The sanitation system in the slum depends on the septic tanks, public toilets and community toilet that were built under the Slum Sanitation Program.

- Solid Waste

In the urban areas, municipal solid waste solid are collected by municipal and private collectors. They are directly disposed at open dumping grounds without any pre-treatment. The waste separation will be done in the dumping ground by the rag pickers. The collected recyclable waste is sold to the recycling facilities. Slums are not eligible to enjoy the private solid waste collection system. As a result, they resort to open space dumping.

The municipal corporations have moved toward implementing sustainable waste management systems. Recycling and waste separation are encouraged at the household. Proper closure of the fully utilized dumping ground has been initialized starting with the scientific closure of Gorai Dumping Ground project.

Construction debris is either recycled or dumped illegally at the open space and dumping ground. Hazardous waste has to be treated by the generator, but it has not been fully complied with at the moment. Biomedical waste from hospitals is sent for treatment at Hazardous Waste Treatment and Disposal Facility at Taloja.

Key Planning Initiatives and Their Implications

Over the years, the municipal corporations have initiated various infrastructure projects so that the people could enjoy higher living standard from the increased efficiency, reliability and availability of the infrastructure system. The past, present and future planning initiatives for infrastructure undertaken in MMR are summarized in the table below.

Infrastructure	Past Planning Initiative	Present and Future Planning Initiative
Water Supply	• Mumbai Water Supply Project; • Privatization of Water Supply Operation & Maintenance System in Navi Mumbai; • Purchase of Morbe Dam by NMMC; • Setting Up of Shahad Temghar Water Authority.	• Commissioning of SCADA System in Thane; • Feasibility Study on Implementation of Water Desalination Plant in Greater Mumbai; • Construction of New Water Reservoir in MMR.
Storm Water Drainage	• Proposal of Brihan Mumbai Storm Water Drainage Project; • Improvement Work on Mithi River; • Construction of Holding Ponds in Navi Mumbai.	• The implementation of Brihan Mumbai Storm Water Drainage Project Phase I and II; • Improvement Work on Mithi River Phase II.
Sewerage	• Implementation of Mumbai Sewage Disposal Project I.	• Implementation of Mumbai Sewage Disposal Project II • Implementation of Slum Sanitation Program.
Solid Waste	• Implementation of Parisar Vikar Scheme; • Construction of biomedical Waste Treatment Facility at Sewree; • Commissioning of Turbhe Sanitary Landfill; • Commissioning of Karghar Debris Recycling Plant	• Implementation of Advance Locality Management System; • Implementation of Slum Adoption Scheme; • Development of Regional Landfill Sites in MMR; • Implementation of Gorai Dumping Ground Closure Project.

Future Demand and Gap Analysis

McKinsey has projected future demand for water supply, sewerage and solid waste in MMR. In line with the conceptual master plan, Year 2032 and 2052 are chosen as the infrastructure planning horizons. Gap analysis was carried out by comparing the current infrastructure capacity against the projected demand. Various strategies were proposed in this study to close the gap.

- **Water Supply**

The projected water demand was selected based on "best in class standard'. Domestic and commercial water demands were considered in the projection of future water demand. The result of the gap analysis indicated a water supply deficit of 5,822 and 9, 758 MLD by 2032 and 2052 respectively. To close the huge water supply gap, water demand reduction and water supply augmentation strategies are proposed. Water demand reduction can be achieved by establishment of active leakage control and metering system in the distribution system and Installation of water saving devices.

To provide the additional water supply, alternative water supply resources are proposed in order to preserve and reduce the over-exploration of surface water. The additional water supply can be obtained from wastewater reclamation, seawater desalination and rainwater harvesting.

- **Sewerage**

Projection of wastewater generation was based on the assumption that 80% of the water demand will be turned into sewage. Similar to water supply, the projection is based on the "best in class standard". The gap analysis results indicated that the deficit in the sewage treatment capacity is 9,077 MLD and 16,026 MLD by 2032 and 2052 respectively.

In view of the high volume of sewage to be treated, centralized STP will be proposed. There should be at least 2 centralized STPs in a district to share the volumetric loading. The new STP will have to comply with MPCB's requirement on the allowable effluent discharge quality into the water bodies. 14% of the treated sewage effluent will be recycled to be used for non-potable use.

- **Solid Waste**

Municipal solid waste and construction waste made up the total projected solid waste generation in MMR. There will be a deficit of disposal capacity of 55,942 Ton/d and 77,528 Ton/d by 2032 and 2052 respectively. It was a huge gap considering that the current disposal capacity in MMR is only 5,450 Ton/d. Sourcing for disposal sites with a total capacity of 10 times the existing disposal site for the next 40 years will be a monumental task. The key to resolve the issue is through waste reduction.

Several methods to reduce the mass and volume of waste generated are incineration and recycling of municipal and construction waste. Through proper planning and implementation, the recommended strategies should be able to bring down the gap to 15,127 Ton/d and 19,975 Ton/d respectively. The composition of the remaining waste to be disposed should consist of unrecyclable construction waste, non - incinerable waste and incinerated ash. The dumping ground will progressively be phased out and replaced by sanitary landfill to protect the environment from contamination.

Development Strategies and Recommendations

Infrastructure goals will be set to emulate the success of other global cities in overcoming the current infrastructure problems and to ensure sustainability of the resources in the future. Proper planning of infrastructure will not only improve the living quality of the MMR residents but also provides a conducive environment to support the transformation of MMR into a global city. The goals will focus on letting the people in the entire MMR to enjoy efficient and reliable infrastructure facilities.

Goals and Recommended Strategies

Infrastructure	2032 Goal	2032 Strategies	2052 Goal	2052 Strategies
Water Supply	To increase water availability from 160 lpcd to 180 lpcd.	•To construct new reservoirs to increase fresh water storage capacity. •To construct seawater desalination plant; •To implement rainwater harvesting; •To implement wastewater recycling.	To provide 100% coverage for continuous piped water supply for entire MMR;	• To expand the existing water supply network to cover the entire MMR.
	To provide 100% coverage of continuous piped water supply in urban area	•To ensure adequate water supply from all secured sources throughout the year; •To expand the existing water supply network to reach the previously unserved area.	To provide additional water supply resource;	•To further increase the number of fresh water reservoirs for storage; •To expand the capacity of the existing seawater desalination plant
	To reduce unaccounted-for-water from about 20-40% to 15-30%	•To perform regular inspection, maintenance and upgrading of •the entire water supply network; •To carry out comprehensive water audit; •To install water saving devices.	To reduce unaccounted-for-water from about 15-30% to 10-15%;	•To phase out the aging water supply network; •To phase out flat rate water tariff system.
Storm Water Drainage	To create flood control system against storm event of up to 50-year return period	•To design major waterway to withstand storm event of up to 50 – year return period; •To upgrade the existing storm water drainage system; •To use Mahim Bay Barrage (if implemented) for flood control.	To create flood control system against storm event of up to 100-year return period	• To design major waterway to withstand storm event of up to 50 – year return period; • To upgrade the existing storm water drainage system.
	To eliminate the practice of discharging raw sewage and untreated industrial effluent into water bodies	•To enforce rules on discharge of raw sewage and industrial waste; •Treat all the Generated Sewage in MMR.	To beautify the waterway	•To clean up the waterway; •To implement public private participation scheme.
Sewerage	To provide 100% sewerage coverage in urban area	•To map areas that require upgrading and expansion of the existing sewerage network •To construct centralized STP within the Integrated Waste Management Zone.	To provide 100% sewerage coverage in MMR	•To provide Sanitation System to the Remaining Unsewered Areas; •To upgrade capacity of the existing centralized STP within the Integrated Waste Management Zone.
	To provide proper sanitation facilities in the rural area.	•To proposed onsite STP; •To participate in Central Rural Sanitation Program.		
	To improve the quality of the treated sewage effluent	•To upgrade the treatment method of the existing STP; •To construct wastewater recycling plant; •To collaborate with the private sector to commercialize the recycled effluent.		
Solid Waste Management	To provide 100% solid waste collection services in urban area	•To privatize solid waste collection services; •To prolong the lifespan of dumping ground and landfill.	To phase out unlined dumping ground	•To inspect and monitor inactive dumping ground; •To scientifically close dumping ground at the end of its lifespan.
	To provide proper solid waste disposal and treatment	•To create Integrated Waste Management Zone (IWMZ); •To recover energy from solid waste; •To construct integrated engineered landfill.	To provide 100% solid waste collection services in entire MMR	•To upgrade the capacity of the existing solid waste management within the IWMZ.

Case Studies and Benchmarking

The infrastructure planning of two global cities: Singapore and Netherland were studied. The key policies, strategies and provision standards of these two cities were benchmarked against MMR infrastructure goals. Singapore is chosen because of its success in providing reliable and good infrastructure to its people, despite the lack of natural resources and land area. Netherland is chosen because it has been successful in strengthening its sea and river defence against flooding.

- **Singapore – Total Water Resource Management System**

Singapore used to depend on imported water from its neighbor, Malaysia as its main water supply source. Singapore has been progressively reducing its dependence on imported water by focusing on alternative water supply. The three alternative water supply sources are recycled water, harvested rainwater and desalinated water. These three components made up 60% of Singapore potable water supply.

To fulfil Singapore's vision to transform the City into a city of garden and water, ABC Water Programme was introduced. The main approach of the program is to transform Singapore's reservoirs and waterways beyond their functional uses.

To create a vibrant water industry in Singapore, Singapore's water supply authority has involved the private sector in its latest water supply projects. The benefit of this competitive public – private participation scheme is to keep the project financially viable and improve the project quality.

Learning Points from Singapore – Water Resource Management Project

Learning Points	Strategies
Use of technology to provide alternative source for water supply	• Seawater desalination; • Wastewater recycling; • Rainwater harvesting.
Development of water resources beyond functional use	• Beautification of the existing waterways, reservoirs or rivers; • Incorporation of the water features into the upcoming commercial and residential development.
Effective public private participation scheme	• Inviting public sector to tender for public water supply project; • Involve local industries to build the water industry; • Knowledge sharing with the private sector.
Public education	• Educate public on good practices to conserve water.

- **Singapore – Solid Waste Management System**

Singapore generates 5.5 million tonne of solid waste annually. Despite the scarcity of land and high waste generation, Singapore is able to plan for an effective and efficient solid waste disposal system by waste minimization and recycling.

Organic waste is incinerated to reduce 80% of the waste volume. The heat generated from the incineration process is recovered to run the energy intensive plant. Recyclable waste is recycled to reduce the need for disposal into the landfill. By implementing these two strategies, only 10% of the generated waste is disposed at the sanitary landfill.

Learning Points from Singapore – Solid Waste Management Project

Learning Points	Strategies
Waste Minimization	• Recovery of valuable resources by recycling; • Volume reduction by processing the waste at the incineration plants; • Fee collection for solid waste disposal at the incineration plant and landfill.
Sanitary Landfill	• Selection of site that is far from the populated area; • Properly designed landfill to create clean and odour free landfill so that it can be used by public for recreational purpose; • Creation of offshore landfill site by land reclamation
Public education	• Setting up of National Recycling Program to collect the recyclable waste from the household directly; • Creation of educational program to increase the public awareness on recycling;
Public private participation scheme	• Invitation to the public sector to tender for setting up the incineration plant; • The use of private contractor to collect all the solid waste generated in Singapore; • Tax incentive scheme for business owner who uses energy saving machines for its business.

- **Netherland - Flood Control System**

Netherland is prone to flooding as one quarter of the country is below sea level. Netherland has been able to strengthen its coastal and river defences by constructing drainage ditches, canal, pumping stations, flood gate, storm surge barrier and dikes. Two of Netherlands flood control system, Delta Work and Zuiderzee Work has been declared as two of the Seven Wonders of the Modern World .

Despite having an extensive flood control system, Netherland still invest in sophisticated inspection and monitoring system on the existing flood control structures to safeguard against the climate change and sea level rise. Design guidelines for the flood control structures are constantly reviewed to reduce the failure risk.

Learning Points from Netherland - Flood Control System

Learning Points	Strategies
Construction of flood control system	• Construction of storm surge barrier; • Construction of flood gates; • Constant upgrading of the existing infrastructure.
Systematic monitoring process	• Setting up of various system to monitor the existing condition of the flood control structure; • Regular review of the design guidelines for the major flood control structure;
Strong funding commitment	• Delta Work cost an estimated $7 billion of which 15% was spent on fundamental research.

CHAPTER 1: INTRODUCTION

The Sectoral Report on Infrastructure for MMR is part of the second phase of the Concept Plan for Mumbai Metropolitan Region project. After completion of the first phase, namely, Dimension of Growth, Visioning and Development Concept Options, in August 2010, phase 2 of the project has commenced which involves the development of the Concept Plan for MMR as well as detailed studies on key sectors affecting the regional development. Together, the Draft Concept Plan Report and the 7 Sectoral Reports mark the culmination of the second phase of the project.

1.1 Background and Purpose

The Sectoral Report on Infrastructure is prepared in conjunction with the Concept Plan for MMR. While the Concept Plan suggests strategies and projects for the physical development of the Region, the Sectoral Report on Infrastructure is a focus study on the state and provision of infrastructure in the Region.

During the first phase of this project, two key studies were undertaken, namely the detailed socio-economic study for MMR, and elaboration of a vision and strategic concept option for guiding the physical development of the Region. The Sectoral Report on Infrastructure takes an in-depth look at the current infrastructure situation in MMR, namely the issues, assets, institutional framework and existing supply, current planning initiatives, etc. In line with the overall vision for MMR, several goals for the infrastructure sector were established during the visioning stage. Based on these goals, as well as the learning points from international case studies and benchmarks, the future infrastructure demand for MMR is projected, and strategies and recommendations to meet this demand in the short, medium and long terms are proposed. The findings and recommendations of these Sectoral studies would offer practical strategies and possible development schemes for the Regional Concept Plan to adopt as part of its overall concept proposal.

1.2 Organization of the Sectoral Report - Infrastructure

In addition to this chapter, the report consists of other following chapters:

Chapter 2: Existing Context, Assets and Issues – This chapter analyzes and identifies the existing assets, issues, key policies and institutional setup in relation to infrastructure planning and implementation in MMR. In this project, four main type of infrastructure will be studied; they are water supply, sewerage, storm water drainage and solid waste management. Power supply is not included in this study as power supply infrastructure such as power generation plants, power grids, electrical substations, etc. are usually planned at the national level or state level. In MMR, power supply projects are undertaken by M.S.E.B Holding Co. Ltd, Maharashtra State Power Generation Co. Ltd, Maharashtra State Transmission Co. Ltd, and Maharashtra State Distribution Co. Ltd.

Chapter 3: Planning Initiatives and Their Implications – This chapter summarizes the key findings of the past, current and future planning initiatives for the infrastructure developments within MMR. The implications of these projects towards the future development of infrastructure in MMR will be analyzed.

Chapter 4: Future Demand and Gap Analysis – This chapter presents demand projection for the infrastructure in the future based on two planning horizons, i.e. 2032 and 2052. The existing infrastructure supply and condition will be analyzed to determine the additional infrastructure required in order to meet the projected future demand.

Chapter 5: Vision for MMR, Infrastructure Goals and Development Strategies – This chapter compares the past visions for infrastructure developments in MMR, recalibrates the vision of MMR towards the planning horizon, and sets the goals for the different infrastructure to support the vision of MMR to be a world class global city. This chapter will also outline specific strategies that are necessary to achieve the proposed infrastructure goals listed in the preceding chapter. Various infrastructure development strategies will be recommended for the 2 planning horizons.

Chapter 6: Case Studies and Benchmarking – This chapter presents the key findings of the infrastructure system in two global cities in the world. These cities will be used as benchmarks for MMR to develop its infrastructure to a higher standard in order to realize its vision to be a global city.

CHAPTER 2: EXISTING CONTEXT, ASSETS AND ISSUES

This chapter presents the existing conditions of the infrastructure systems in terms of planning, operation and management of various major infrastructures in MMR.

2.1 Existing Infrastructure Conditions

2.1.1 Water Supply

Potable water supply is essential to support every thriving society including MMR. The main source of water supply for MMR is surface water from the existing rivers and lakes (refer to Table 2.1 and Figure 2.1). Dams and weirs are constructed at these water bodies to extract the raw water for treatment. Most of the dams are located outside of MMR. Hence, long transmission network is often required to bring the water into the cities.

The raw water is treated at various water treatment plants managed by the water supply agencies and municipal corporations. After treatment, the potable water is transmitted to the respective municipalities and local areas. The water is usually stored at Master Balancing Reservoirs or Elevated Storage Tanks before it is distributed to the end-users through the underground water supply network.

Table 2.1: MMR - List of Major Water Resources

Water Resource	Capacity (MLD)	Location	Supplied Area
Tulsi Lake	18	Within the precinct of Sanjay Gandhi National Park, Mumbai	Greater Mumbai
Vihar Lake	110	Vihar Village on the Mithi River within the precinct of Sanjay Gandhi National Park, Mumbai	Greater Mumbai
Tansa Lake	484	Shahapur, Thane District (100km from Mumbai City)	Greater Mumbai
Upper Vaitarna Lake	1,000	Khodala, Thane District (173 km from Mumbai city)	Greater Mumbai
Lower Vaitarna Lake		Khodala, Thane District (110 km from Mumbai city)	Greater Mumbai
Bhatsa Lake	1,900	Shahapur, Thane District (100km from Mumbai City)	Greater Mumbai
Morbe Lake	450	Karjat Taluka, Raigad District	Navi Mumbai
Ulhas River	620	Originates from Karjat, Western India and flowing westward through Raigad and Thane District	Thane, Mira – Bhayander, Kalyan – Dombivali
Surya River	60	Bapgaon, Thane District	Vasai – Virar

Source: MCGM, Disaster Management by Interlinking Water Works in Mumbai Metropolitan Area

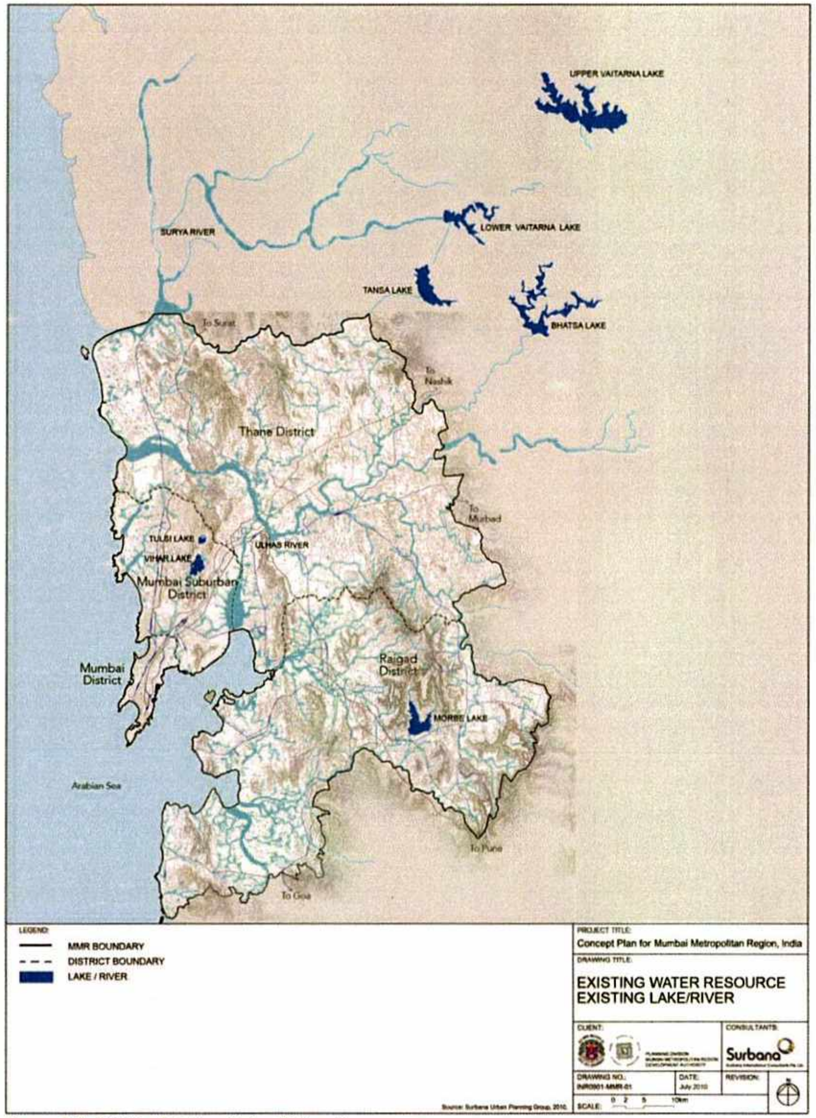

Figure 2.1: MMR – Existing Major Water Resources
Source: Surbana

Most of the urban areas are connected to the respective municipal water supply network. Water supply network at older city such as Mumbai city can be as old as 150 years. Residents receives water supply for approximately 4 – 6 hours per day from the water supply network. At areas where the water supply network is inaccessible, residents depend on wells for water supply.

Registered slums get water from the municipal water supply network. The supply rate is at the range of 25 – 40 lpcd (liter per capita per day) which is significantly lower than the average consumption rate of 90 lpcd to the urban areas. The remaining slums are not connected to the municipal water network. They get water from the communal or public water tap or tap illegally from the municipal supply pipelines.

In general, Greater Mumbai and Navi Mumbai enjoy the highest water supply rate among the other cities in MMR due to their extensive water supply network and numerous dams (refer to Figure 2.2). Navi Mumbai is the only region with a surplus of water supply due to its ownership of Morbe Dam. It also generates revenue by selling the excess water to the neighbouring municipalities.

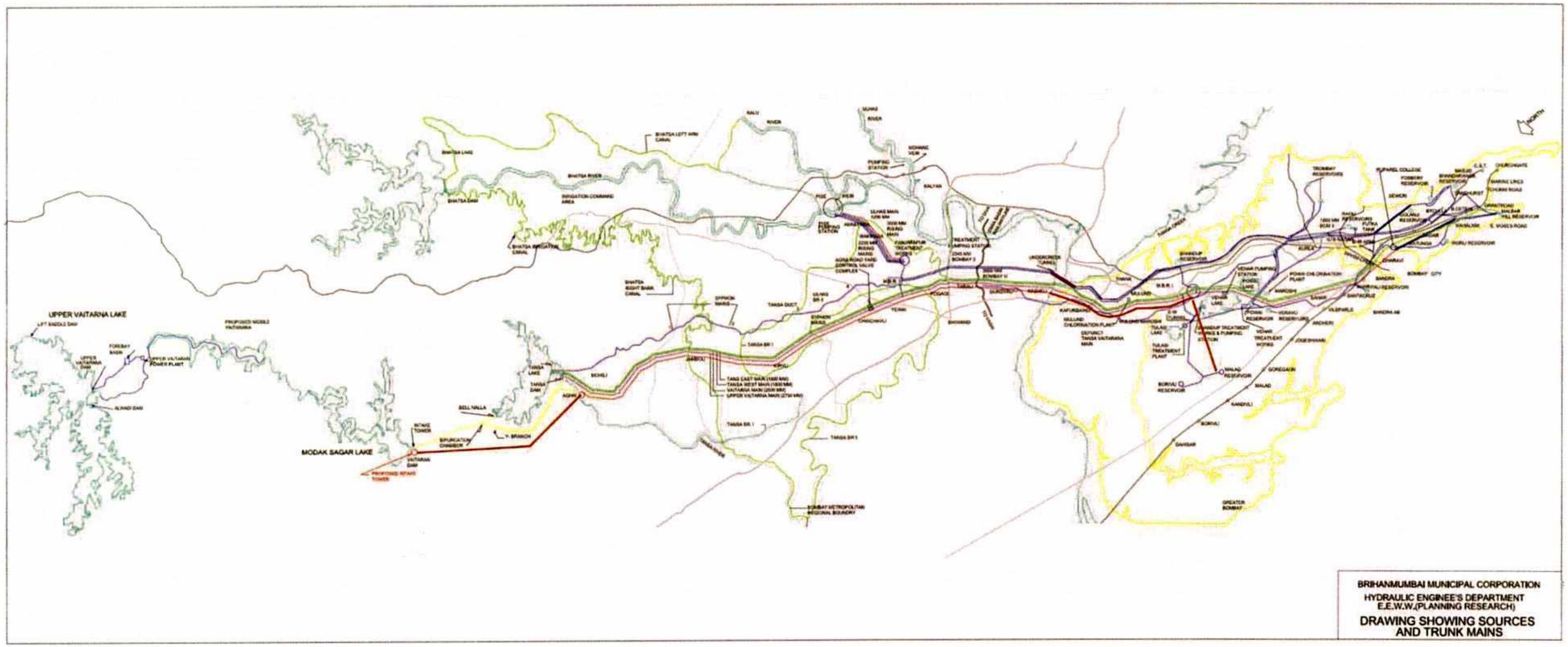

Figure 2.2: Greater Mumbai – Existing Water Resources & Trunk Mains
Source: MCGM

2.1.2 Storm Water Drainage

Drainage facilities in MMR consist of open drains, box culverts, pumping stations and marine outfalls. Greater Mumbai has the oldest and most extensive drainage network within MMR with approximately 3,000 km of network. Most of the existing drainage networks except at Navi Mumbai are old. They are designed based on the rainfall of 25 mm – 64 mm at low tide.

The drainage system flows by gravity with pumping stations installed at strategic locations to speed up the flow during storm event. The runoff is discharged into the Arabian Sea, Mahim Creek, Mahul Creek and Thane Creek.

In low lying areas such as Navi Mumbai, there is a comprehensive storm water management system to control the ingress of the sea water during high tide. The system consists of holding ponds, retaining wall, flap gates and storm water pumping station.

Flood is a natural phenomenon especially during the monsoon season when the rainfall intensity is higher. Sea water level also plays an important part in the flooding at the coastal areas. Greater Mumbai, especially along the coastal area is more prone to flooding due to the combination of high tide and heavy rainfall (refer to Figure 2.4). It has a lot of storm water pumping stations. Pumps are used to discharge the excess water from the city during monsoon season. Areas with storm water pumping station has experienced lesser flooding compared to those without one. Pumping station is usually located near the outfall along the coastal area.

The last major flood in MMR occurred in July 2005. It was caused by 24-hour rainfall figure of 994 mm. Mumbai, Thane and Kalyan were severely hit by the flood which caused at least 700 deaths and massive destruction of the city's infrastructure (refer to Figure 2.3). Till now, MMR is experiencing smaller flooding events 2 to 3 times annually during monsoon season.

Figure 2.3: Greater Mumbai – Major Flood in 2005
Source: Adlandcreative, People Daily

Figure 2.4: Greater Mumbai – Flood Prone Area
Source: Fact Finding Committee on Mumbai Floods

2.1.3 Sewerage

Currently, the sewerage system in MMR consists of sewage collection and treatment at centralized Sewage Treatment Plant (STP), septic tanks and direct discharge into the water bodies.

City areas at Greater Mumbai, Navi Mumbai and Thane are almost fully connected to the sewerage network. Outside these 3 areas, only less than 20% of the population have access to the sewer lines. These cities are divided into various sewerage zones based on the geographical location and topography. Each sewerage zone is usually served by 1 STP or more (refer to Table 2.2 and Figure 2.6). The sewage from each zone is collected and treated at the respective STP.

The common treatment methods are preliminary treatment by aerated lagoon, facultative lagoon with floating aerators and aerobic digestion. Majority of the sewage are treated to an acceptable standard. The treated sewage effluent is discharged into the nearest water bodies such as Arabian Sea, Malad Creek and Thane Creek.

Residents without connection to the public sewer line use septic tanks. Septic tanks are not so suitable for the water deficit MMR as septic tank operation requires high amount of water for flushing. Poorly maintained septic tank may also cause groundwater contamination.

Unregistered slums do not have access to the public sewer. Large proportion of the slum dwellers depends on septic tanks and public toilets for sanitation (refer to Figure 2.5). Registered slums, that participated in Slum Sanitation Program, use and maintain their own community toilets.

Table 2.2: MMR - Capacity of the Existing Sewage Treatment Plant

Sector	No of STP	Present Capacity (MLD)
Greater Mumbai	7	2,530
Navi Mumbai	8	347
Thane	1	54
Ulhasnagar	1	28
Kalyan – Dombivali	2	30
Bhiwandi – Nizampur	1	17

Source: Surbana

Figure 2.5: MMR - Conditions of Existing Public Toilet in Slum
Source: World Bank Urban Notes – Reaching the Poor through Sustainable Partnership

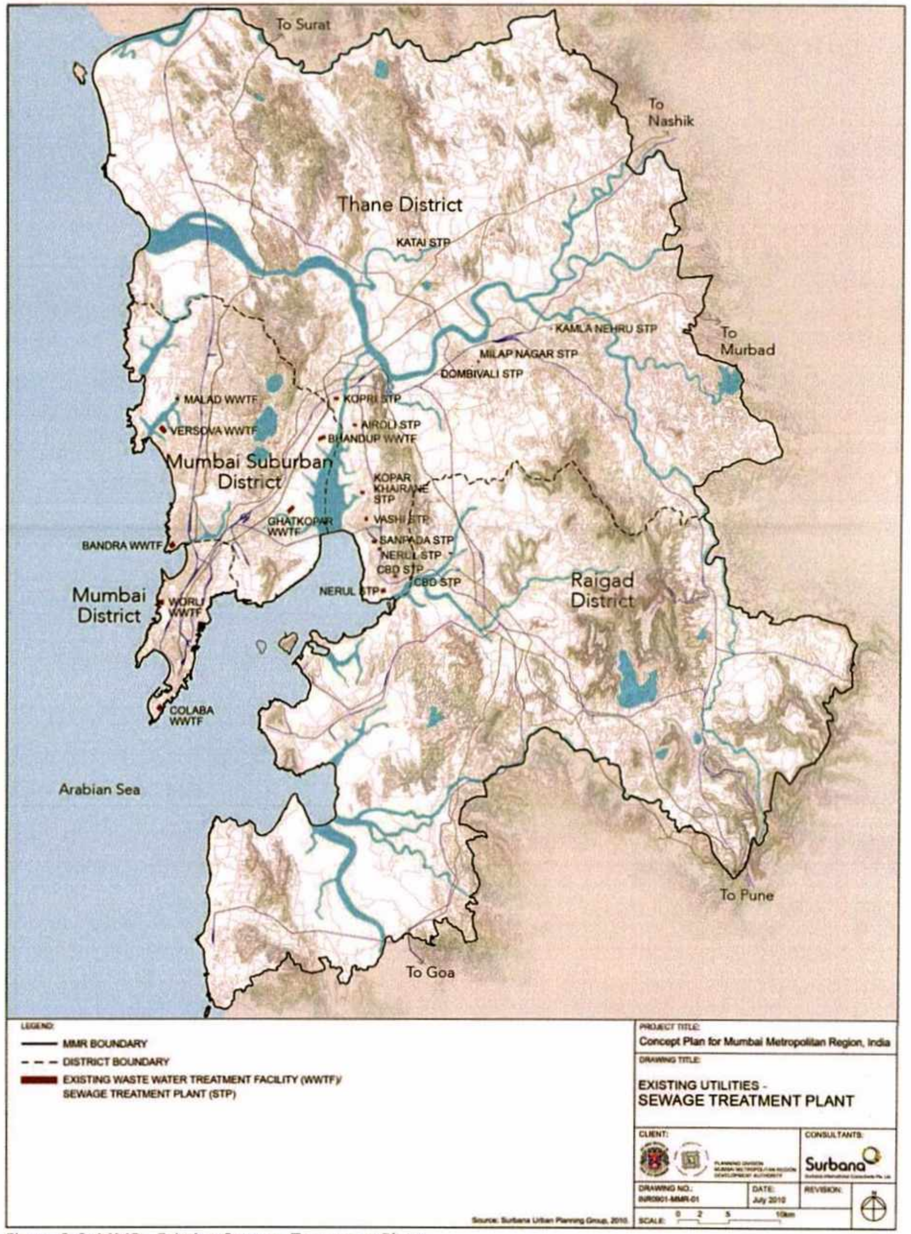

Figure 2.6: MMR - Existing Sewage Treatment Plant
Source: Surbana

2.1.4 Solid Waste Management

MMR generates approximately 10,500 million ton of solid waste per day (MT/d). Average daily solid waste generation per capita is 0.5 kg. The composition of the solid waste consists of mostly municipal waste, construction waste and small percentage of biomedical waste. In general, solid wastes generated within MMR are disposed at open dumping grounds without any pre-treatment or separation. There are 13 authorized dumping grounds in MMR for municipal and industrial waste (refer to Figure 2.7 and Table 2.3). Dumping grounds that had reached their maximum capacity were abandoned without proper closure. In the future, it could cause groundwater contamination and release of toxic gasses from the site. Gorai dumping ground was the first dumping ground in India scientifically closed in 2007 by MCGM.

The waste disposal method from the urban area varies depending on the type of the waste. Municipal waste is collected through community bins and door to door collection and disposed at the dumping grounds by private contractor. Construction debris are usually not allowed to be dumped at the dumping ground as it is bigger in size and reduce the dumping ground capacity rapidly. Hence, the contractors dispose them at abandoned mines or any open space. Biomedical waste from hospitals are either disposed directly at the dumping ground or sent for treatment at the only Hazardous Waste Treatment and Disposal Facility at Taloja.

Slums, except slums registered under the census of slums, are not serviced by the municipal solid waste management system. Slum dwellers usually resort to illegal dumping at open space or the public drain.

Navi Mumbai is the only area with a properly designed landfill sites and debris recycling plant. The mixed garbage is treated with culture for biostabilization to generate electricity. With the help of this technology, Navi Mumbai has been able to reduce the amount of greenhouse gas, especially methane gas, released into the atmosphere thus improving the air quality. NMMC are also earning revenue by selling the generated electricity from the landfill and the construction related products such as bricks and interlocking pavers from the debris recycling plants.

Municipal corporations are encouraging recycling and waste segregation in an effort to reduce the waste generation and disposal quantity. At the household level, the residents are encouraged to separate dry and wet waste. The program has not been entirely successful but the municipal corporations together with the Non Government Organizations (NGO) are actively promoting the importance of waste segregation to the residents. MCGM is imposing fine to individuals who fail to do so. At the dumping ground, rag pickers are coordinated by NGO to retrieve any recyclable items from the waste pile to be sold to informal dealers or recycling plants.

Table 2.3: MMR - Capacity of the Major Dumping ground and Landfill

Sector	Location	Capacity (ton/d)	Remaining Usable Period
Greater Mumbai	Deonar (131 ha)	6,000	4 years
	Mulund (24 ha)	2,500	1 year
Navi Mumbai	Turbhe Landfill (26 ha)	450	60 – 70 years
Thane	-	500	18 – 25 years
Kalyan – Dombivali	Adharwadi	550	-

Source: Surbana

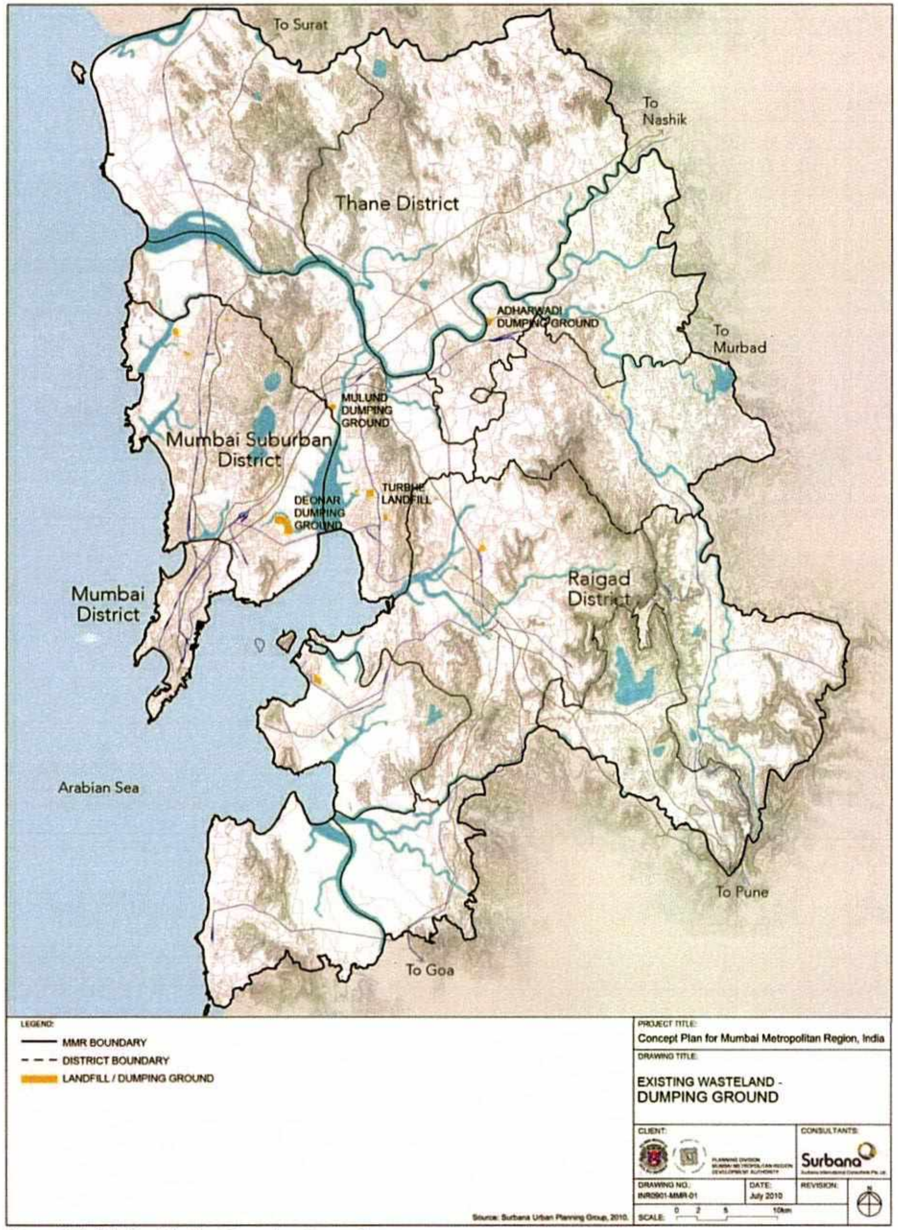

Figure 2.7: MMR - Existing Dumping Ground

Source: Surbana

2.2 Existing Infrastructure Key Issues

2.2.1 Water Supply

- **Deficit of water supply across MMR**

Current water supply rate ranges from 90 lpcd to 180 lpcd. At the slum area, the water supply rate can be as low as 25 lpcd. On average, the water supply rate for Greater Mumbai is 130 lpcd while at the outskirts of MMR, it is generally lesser than 40 lpcd. This is still lower than the average water demand rate of 180 lpcd. With the ever increasing population in MMR, a sustainable solution has to be provided to ensure sufficient water supply to the entire MMR population for the next 30 to 40 years.

- **High water loss through the distribution network**

The water loss in the water supply system ranges from 20% to 40%. There are two factors that contribute to the high loss. First is the lack of maintenance of the aging water pipes. It was mainly caused by lack of funding and difficulty in locating the leakage or pipeline burst. It is worse for densely populated slum areas because the pipes could run in bunch through narrow passages and side gutters. The second factor is water theft due to illegal tapping into the water supply network.

- **Unsustainable business for water supply providers**

Water supply service providers in MMR are making losses because the water tariff is deliberately kept low to ensure affordability. In addition, most of the water supply connections are unmetered. End-users pay very low monthly fixed rate regardless of the amount of water they used. Keeping the water tariff low is beneficial for the end users however it is not sustainable for the service providers as the revenue generated is usually not enough to cover the operation and maintenance cost.

- **Absence of centralized water supply planning agency**

Water supply planning for each area is taken care by its own municipal corporation and council with the support from several water supply agencies such as Maharashtra Industrial Development Corporation (MIDC) and Shahad Temghar Authority (STEM). Each of the agencies are developing water supply to suit their individual requirements without any organized planning. This kind of arrangement is suitable for big municipal corporations with enough resources and funding. However smaller municipal corporations and councils will be struggling to be self-sufficient due to the lack of funding.

- **Dependence of the water supply system on rainfall**

The water supply to the people in MMR is highly dependable on the water level in the dam. When the dam's water level is too low, water supply cut are often enforced especially during dry season. The cut could be as high as 15% of the already low normal supply rate. The most recent water cut was imposed by MCGM and TCM (August 2010) due to the lower than expected water levels in the reservoirs. The water cut for Greater Mumbai residential and commercial users are 10% and 30% respectively while Thane residents are experiencing 10% water cut.

2.2.2 Storm Water Drainage

- **Flooding**

Key reasons for flooding are the combination of one or more of the following: insufficient drainage capacity, tidal variations, mud flats, loss of holding ponds, encroachment on drains, choking due to sewage inflows and garbage dumping. The cause of flooding is different in each sector. In Greater Mumbai where the drainage network is more than 75 years old, the major cause of the occasional flooding was the blocked and under-design drain, choked rivers and tidal level. In Navi Mumbai where the drainage network is relatively new, localised flooding occurs only after extremely heavy rain.

- **Insufficient capacity of the existing drainage network**

Most of the drains were designed to cater to low rainfall intensity. The existing capacity is routinely exceeded during monsoon season in MMR. In July alone every year, the wettest month in MMR, it is common to witness two or more big storm events (above 100mm). Flooding is inevitable as most of the old drains in MMR are only designed to cater to 25 – 40 mm of rainfall. The effective capacity of the drain is also reduced due to the accumulation of garbage dumped into the drain.

- **Lack of storm water retention facility**

Uncontrolled development will reduce storm water retention capacity and increase the flood risk. One of the ways to solve this issue is to have storm water retention facility as a temporary storage for the storm water before it is slowly released into the drainage network. However a number of the allocated holding pond sites in Greater Mumbai and Navi Mumbai had been converted into residential and commercial plots due to the scarcity of land.

- **Poor water quality in the drain and holding ponds**

The poor water quality is caused by the inflow of untreated sewage and garbage and also due to unhygienic activities such washing of clothes, bathing, etc. (refer to Figure 2.8). Not only it produces bad odour, it has also contributed to the increase in the water borne disease for the residents staying next to the drain.

Figure 2.8: MMR – Existing Drain Conditions
Source: Surbana

Sewerage

- **Insufficient sewerage network coverage**

Sewerage network coverage by population In Greater Mumbai, Navi Mumbai, Thane and Bhiwandi are 42%, 100%, 27% and 30% respectively. The coverage is likely to be lower at smaller cities such Ulhasnagar, Kalyan – Dombivali, etc. The sewerage coverage in Greater Mumbai is relatively low despite its 150 years of history in sewerage system development because the sewerage network is only serving the residents in the urban area. Almost 50% of people in Greater Mumbai live in the slums. Slum dwellers are usually not served by the sewerage network and rely on public toilet and septic tank for their sanitation.

- **Aging sewerage network**

Sewer pipes especially in Greater Mumbai are more than 100 years old and in need of major rehabilitation due to the dilapidating conditions. At times, the sewer and water pipe run parallel to each other; any leakages from the sewer pipe may contaminate the drinking water easily. The difficulty in replacing the old pipes could have been caused by huge funding needed to replace them and the lack of proper coordination among the relevant authority.

- **Discharge of untreated sewage into the public drain and water bodies**

At poor neighbourhoods without access to the sewerage network or public toilets, the sewage is discharged directly into the public drain. The mixing of the sewage and storm water in the drain may cause issues such as deteriorating water quality because all the public drains will convey the water into the rivers and the seas, reduction in the drain capacity, bad odour and increase of waterborne disease risk to the people staying next to the drain. The large inflow of the untreated sewage has caused the deteriorating water quality at those water bodies especially Thane Creek. Thane Creek is the most polluted water body because it receives 1,260 MLD of untreated sewage from various sources (refer to Table 2.4 for the water quality parameters of the existing water bodies). High level of N and P found in the Creeks indicates organic pollution from the sewage.

- **Lack of Maintenance of the existing sewerage network and public facilities**

During monsoon season, heavy storm event could overflow the under-maintained sewerage network. The public toilets are in a bad condition as it is free for public use. Lack of maintenance funds and limited water supply make it difficult to maintain the cleanliness of the toilet which put off the public from using them.

Table 2.4: MMR - Water Quality Parameters of Major Creeks During 2007 - 2008

Monitoring Location	DO (mg/l)	BOD (mg/l)	PO4 – P (mmol/l)	NO3 – N (mmol/l)	NO2 – N (mmol/l)	NH4 – N (mmol/l)
Baseline	**3 – 7**	**1 – 3**	**<3**	**<5**	**<3**	**<3**
Thane	0.4 – 4.7	0.5 – 3.9	1.4 – 16.7	2.6 – 75.9	0.9 – 27.2	0.3 – 13.2
Manori	1.7 – 4.7	2.3 – 4.1	5.4 – 33.6	4.2 – 21.0	1.9 – 7.0	4.0 – 88.2
Versova	0.8 – 3.1	1.8 – 2.9	3.2 – 18.2	4.3 – 17.1	1.3 – 4.1	4.4 – 29.2
Mahim	3.3 – 4.7	2.1 – 3.3	2.4 – 9.7	4.6 – 11.7	0.6 – 2.6	3.1 – 28.4

Source: Environment Status of BrihanMumbai, 2008 - 2009

2.2.3 Solid Waste

- **Lack of proper treatment to the solid waste**

Without proper treatment, the untreated organic waste will undergo decomposition and generates leachate over time. The fluid is extremely harmful without proper treatment and may penetrate the soil and contaminate the ground water. Some other common problems generated by the dumping ground are smell, pests breeding on the waste and air pollution. Mitigation measures such as lining of the dumping ground, installation of leachate collection system, tree plantings, proper coverage of the garbage, regular spraying of the garbage piles with chemicals will minimize the problem. However many dumping grounds in MMR are not equipped with proper operation and maintenance system.

Other than the environmental issues, the lack of proper treatment to the solid waste could also pose health hazard to the resident staying near to the dumping ground site. Ideally, dumping grounds have to be located at the city outskirts where there are lesser human population. A buffer zone of no development has to be maintained around the site. However, due to increase in population, land scarcity and lack of land use planning, people may not have a choice but to stay near dumping ground.

- **Difficulty in securing land for new dumping ground.**

The lifespan of dumping ground is usually 30 to 40 years. Most of the dumping grounds in MMR are already nearing their designed lifespan. In the case of Greater Mumbai, the remaining life of Deonar and Mulund dumping ground are 4 and 1 year respectively. New dumping grounds have to be secured immediately to replace the existing dumping grounds. Selection of dumping grounds has to follow stringent requirement to ensure minimum disruption and contamination to the environment such as the groundwater table of the site, the distance of the site from the populated areas and the water bodies, sufficient size for the site to last at least for 25 years, the site topography, etc. Hence only limited areas can be used as dumping grounds. Adding to the problem is the social resistance from the residents due to the problems that the dumping ground may cause such as odour and devaluation of their land.

- **Lack of proper waste management system.**

The current municipal solid waste management system caters to the urban and sub-urban areas only. People who are not served by the system such as slum dwellers dump their waste at open space. Construction debris is disposed illegally at the roadside and open space due to the lack of debris processing facility and restriction to dump at the dumping ground.

2.3 Institutional Setup

2.3.1 Key Agencies and Their Roles

Mumbai Metropolitan Area (MMR) is divided into 7 municipal corporations and 13 municipal councils.

Prior to 2003, MJP was responsible for the planning, design and execution of water supply and sewerage schemes in Maharashtra State. Due to the change in constitution which encourages decentralization of infrastructure sector in MMR, every municipal corporation is now responsible for the infrastructure planning for its own area. All of them will provide their own water supply, sanitation, storm water and solid waste management facilities and services.

Currently, there is no single agency that oversees and coordinates the infrastructure sector in MMR. Every municipal corporation and councils are working on its own. For water supply, there are a few agencies which supply water to specific users such as industrial and rural users. The key players for infrastructure planning in MMR area are shown in Table 2.5.

Plan for future Infr. Planning

Table 2.5: MMR - Key Players for Infrastructure Planning

Agency	Roles
Maharashtra Jeevan Pradikaran (MJP)	Maintain water supply systems at Ambarnath, Badlapur and Vasai – Virar.
Shahad Temghar Authority (STEM)	Maintain the water supply developed by MJP at Thane, Mira - Bhayander, Bhiwandi - Nizampur and adjoining rural areas.
Maharashtra Industrial Development Corporation (MIDC)	Provide water supply to the following area: • Industrial areas at Navi Mumbai, Thane, Kalyan – Dombivali, Ambernath and Badlapur. • Few residential areas at Navi Mumbai, Thane, Kalyan – Dombivali, Ambernath and Ulhasnagar.
City and Industrial Development Corporation of Maharashtra Ltd (CIDCO)	Prevent population influx into Mumbai by providing urban township alternative and basic civic amenities. Navi Mumbai was one of the townships developed by CIDCO in MMR.
Municipal Corporation of Greater Mumbai (MCGM)	Plan, Build and Maintain basic infrastructure facilities at Greater Mumbai.
Navi Mumbai Municipal Corporation (NMMC)	Plan, Build and Maintain basic infrastructure facilities at Navi Mumbai.
Thane Municipal Corporation (TMC)	Plan, Build and Maintain basic infrastructure facilities at Thane.
Mira - Bhayander Municipal Corporation (MBMC)	Plan, Build and Maintain basic infrastructure facilities at Mira – Bhayander.
Ulhasnagar Municipal Corporation (UMC)	Plan, Build and Maintain basic infrastructure facilities at Ulhasnagar.
Kalyan - Dombivali Municipal Corporation (KDMC)	Plan, Build and Maintain basic infrastructure facilities at Kalyan – Dombivali.
Bhiwandi - Nizampur City Municipal Corporation (BNCMC)	Plan, Build and Maintain basic infrastructure facilities at Bhiwandi – Nizampur.

Source: Disaster Management by Interlinking Water Works in Mumbai Metropolitan Area

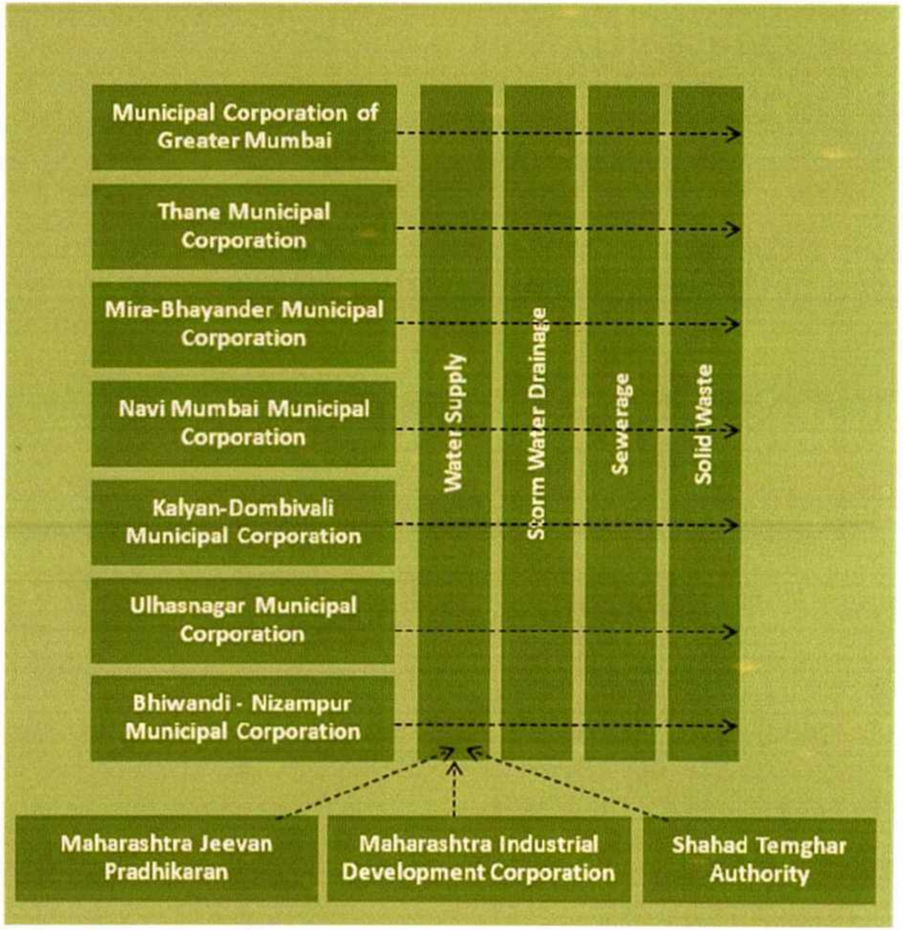

Figure 2.9: MMR - Institutional Set-up
Source: Surbana

2.3.2 Assets

Most of MJP's infrastructure assets in relation to water supply and sanitation facilities were handed over to the respective local municipal corporations after the decentralization in 2003. List of major infrastructure assets owned by the key agencies in MMR are listed in Table 2.6.

Table 2.6: MMR - List of Major Infrastructure Assets Owned by the Key Agencies

Agency	Water Supply Assets	Sewerage Treatment Assets	Solid Waste Management Assets	Storm Water Management Assets
Government of Maharashtra	Reservoir: • Bhatsa.	-	-	-
MJP	Barrage and Water Works: • Badlapur.	-	-	-
STEM	Water Treatment Plant at: • Shahad; • Temghar. Mohane Weir	-	-	-
MIDC	Reservoir: • Barvi; • Ransai; • Murbad; • Savitri; Water Treatment Plant at: • Jambhul;	-	-	-
CIDCO	Reservoir: • Hetawane;	-	Municipal Solid Waste Processing and Disposal Facility: • Village Chal, Taloja	-
MCGM	Reservoir: • Tulsi; • Vihar; • Tansa; • Upper Vaitarna; • Lower Vaitarna. Treatment Plant: • Bhandup; • Panjrapur; • Vihar. Master Balancing Reservoir: • Yewai; • Bhandup.	Waste Water Treatment Facility: • Malad ; • Versova; • Bandra; • Worli; • Colaba; • Ghatkopar; and • Bhandup.	Dumping Ground: • Deonar; • Mulund; • Kanjurmarg. Refuse Transfer Station: • Gorai; • Mahalaxmi; • Kurla.	Storm water network: • 1,990 km of open drain; • 565 km of piped drains • 287 km of major and minor nallah • 180 no of outfall • 151 km of box drains • Pumping station
NMMC	Reservoir: • Morbe Master Balancing Reservoir: • Shil; • Nehru.	Sewage Treatment Plant: • Airoli; • Kopar Khairane; • Vashi; • Sanpada; • Nerul (2 nos); • CBD (2 nos).	Landfill: • Turbhe.	Holding Ponds: • Airoli (2 nos); • Kopar Khairane; • Bonkode; • Vashi (5 nos); • Sanpada; • Nerul (2 nos); • Belapur (2 nos). Retention Pond: • CBD. Pumping Stations: • CBD; • Vashi.
TMC	Water Treatment Plant at: • Temghar.	STP: • Kopri. Sewage Pumping Stations (8 nos).	• Dumping Ground; • Biomethanation Plant; • Biomedical Waste Plant at Kalwa.	-
MBMC	-	-	Dumping Ground.	-
UMC	-	STP: • Kamla Nehru.	Dumping Ground: • Adharwadi.	-
KDMC	-	STP: • Milap Nagar • Dombivali	Dumping Ground.	-
BNCMC	-	STP: • Katai	-	-

Source: Surbana

2.3.3 Issues

Big municipal corporations usually have sufficient resources and funding to build and maintain their infrastructure projects. Smaller municipal corporations such as UMC, KDMC, MBMC, etc. generally take care of their own infrastructure except for water supply. Most of them get their water supply from the neighbouring municipal corporations or agencies such as MCGM, MIDC and CIDCO.

At the moment, there is no central agency to coordinate the infrastructure planning in MMR. Key issues which may arise from this are:

- **No integrated infrastructure plan for the whole MMR**

All of the municipal corporations and councils are planning for infrastructure to suit their requirements without any organized plan of action. The cost to construct water supply reservoir is relatively high and it is usually located at the outskirt area. Quite often, the water reservoir is located 50 to 100 km away from the end – users. Expensive water transmission network has to be laid across two or more sectors to bring the water into the intended supply area. If there is an integrated water supply plan, it could be planned to supply water to various sectors within the transmission pipe vicinity. This way the cost for the water supply resource development could be shared among the respective municipal corporations.

- Lack-of monitoring of the regulations enforcement

There are many regulations which control the infrastructure project's planning and execution. Without a central agency, municipal corporations are free to decide when or how to enforce the regulations. One simple example will be on the effluent discharge standard from Sewage Treatment Plant. MCGM, NMMC and TMC are currently discharging part of their treated sewage effluent sewage into Thane Creek. Each of the municipal corporations will treat the sewage up to different level of quality standard. Hence, it will be very difficult to improve the water quality of Thane Creek to the desired standards without any coordination among all the municipal corporations.

2.4 Key Policies, Regulations and Their Implications

2.4.1 Raw Water Abstraction & Tariff

Central Ground Water Authority (CGWA) is the authority that regulates the extraction and use of ground water. Over the years, extraction of ground water has caused aquifers to dry up in some areas in MMR. To prevent over extraction of ground water, it has issued the following directions for ground water extraction:

- All tube well owners shall register their existing ground water extraction structures (wells, bore wells, tube wells and any other structures regardless of the uses) with CGWA;
- Construction of well to extract ground water from aquifer less than 120m depth is prohibited without approval from CGWA;
- Construction of well with diameter of 100 mm or less for domestic use requires approval from CGWA;
- Ground water extraction is prohibited in some regions where water depletion is critical.

Maharashtra Water Resources Regulatory Authority (MWRRA) is responsible for the allocation, regulation, management and utilization of water resources in Maharashtra. It has established MWRRA Act (2005) as a guideline for water tariff system in Maharashtra and water charges at sub-basin, river-basin and state level. Key points from MWRRA Act are as follows:

- The water tariff shall be derived from the operation and maintenance (O&M) cost;
- The O&M cost shall include the maintenance cost of the water supply system and employee's salary;
- The O&M cost shall be apportioned among agricultural, domestic and industrial users based on the following parameters, affordability, accessibility and quantity of water supply. Different weightage value shall be assigned to each category of user for each of the three parameters.

There is no standard water tariff in MMR despite the MWRRA Act. All municipal corporations and councils are free to set their own tariff schemes because the MWRRA Act does not dictate water tariff at distribution level. Water is priced differently depending on the various users, population density and source of water. Industrial water tariff is set by MIDC as the water supplier for industrial areas.

Water tariff for domestic users is the lowest. However, not all domestic users are metered in MMR. Hence, they are only being charged a flat rate irrespective of consumption volume. In the newly developed areas, metering system is implemented and customers are charged accordingly. The water tariff is higher for the commercial users in order to subsidize the domestic users and recover some of the operation cost.

In general, water tariff in Greater Mumbai and Navi Mumbai are cheaper than the remaining areas because they have their own water supply resources and loss recovery through various taxes. The water tariff outside Greater Mumbai and Navi Mumbai depends on the price of purchased water. Table 2.7 compares the water tariffs among the major municipal corporations in MMR.

Table 2.7: MMR – Comparison of Water Tariffs

	Water Charge (Rs)			
Category	**Greater Mumbai**	**Navi Mumbai**	**Thane**	**Ulhasnagar**
Domestic Stand Post Buildings	 2.50/m³ 3.50/m³	-	-	9/m³
Domestic Consumption <20 m³/month Consumption of 20 -27 m³/month Consumption >27 m³/month	-	 4.75/month 6.00/month 7.00/month	-	-
Domestic Flat Rate Areas <25 m² Areas 25 - 40 m² Areas 40 - 50 m² Areas 50 - 60 m² Areas >60 m²	-	 75/month 82/month 99/month 120/month 125/month	-	40 – 100/month
Domestic Consumption <18 m³/month Consumption 18 - 24 m³/month	-	-	 5.00/m³ 6.00/m³	-
Institution	10.50/m³	14.00/m³		24/m³
Industrial	18.00/m³	-		24/m³
Refineries, Airports	25.00/m³	-		24/m³
Hotels, Race Course	38.00/m³	35.00/m³		24/m³

Source: Bombay Community Public Trust, CIDCO, TMC, Ulhasnagar CDP

2.4.2 Rain Water Harvesting & Groundwater Recharge

With the present shortage of water supply against the ever increasing water demand in MMR, various strategies have been implemented to meet the demand. Other than increasing the water supply resources by building more dams, alternative sources of water supply are also explored such as rainwater harvesting and groundwater recharge.

Annual rainfall in MMR ranges from 1,800 mm to 2,480 mm, with Navi Mumbai having the highest annual rainfall within the region. Almost 70% of the rain falls during the monsoon season (June – September). With such amount of water, rainwater harvesting has been considered to provide additional water supply to the households.

Water Supply & Sanitation Department of Government of Maharashtra issued a Government Resolution in 2002 approving rainwater harvesting as an alternative source to improve water supply. The recommended methods to harvest rainwater are:

- Storage in underground or above ground tanks. Under the new regulations, it is compulsory for new buildings with plot area of at least 1,000 m2 to harvest rainwater;
- Direct or forced recharge of the aquifer through bore wells or dug up wells;
- Recharge of the subsoil water through percolation.

Several rainwater harvesting agencies have been set up to give guidance and consultation with citizen's groups on the rainwater harvesting system. They consist of National Water Harvester's Network (NWHN), Centre for Environmental Science (Delhi), Central Ground Water Authority (Nagpur) and Groundwater Survey and Development Agency (Thane and Pune).

The appropriate rainwater harvesting techniques should be chosen based on the development site conditions. For example, at the coastal area of Greater Mumbai, over extraction of groundwater has caused parts of the area prone to seawater ingression. Hence, more focus is given to pumping rainwater into the soil to prevent the ingression. It is necessary to ensure that the aquifer is recharged with uncontaminated rainwater. Regular maintenance of the rainwater harvesting system is important to ensure that there is no contact with any pollutants such as sewage, solid waste, etc.

MCGM is one of the first municipal corporations which have started to enforce these regulations in Greater Greater Mumbai (refer to

Table 2.8 for the list of actions taken by MCGM). Other municipal corporations have also started rainwater harvesting recently, e.g. Navi Mumbai and Thane by integrating rainwater harvesting into all new projects.

Table 2.8: Greater Mumbai - List of Actions Taken by MCGM to Encourage Rainwater Harvesting

Agency	Actions Taken	Implications
MCGM	• Enforce the regulations on new building development with plot area of 1,000 m2 and above to install a rainwater harvesting system; • Set up rainwater harvesting cell which promotes rainwater harvesting to Mumbai residents by holding competitions, seminars and awareness program; • Set up rainwater harvesting pilot scheme in various buildings • Set up 2 rain centres at Byculla and Borivali to showcase the pilot projects, working model, library of books and documentations, poster, etc. • Protect the existing wells by preparing a list of wells and bore wells in Mumbai and prohibiting it from being filled up	Till June 2009, 900 buildings had been implemented with the rainwater harvesting system.

Source: Water Conservation & Rainwater Harvesting for Brihan Mumbai

2.4.3 Land Acquisition for Storm Retention and Drain Widening

The Land Acquisition Act of 1894 is a legal Act in India which allows the Government of India to acquire any land in the country for public purposes. Procedures for the land acquisition are:

- **Investigation**

When a local authority needs land, an application need to be submitted to the revenue authority. The application has to be accompanied by supporting documents indicating the purposed of the acquisition, the reason why the particular land is chosen and cost provision for the acquisition. Once it is approved the owner will be notified and prohibited from selling or carrying any construction work on the land.

- **Objection and confirmation**

An officer from the revenue authority will be appointed as the collector to carry out the necessary procedures. All parties interested in the land will be invited to voice out any objections towards the land acquisition within 30 days after the notification date. The collector will submit his evaluation on the land acquisition to the authority after hearing all the objections. Once the land is cleared for acquisition, he will mark out and measure the site.

- **Claim and Award**

The collector will then arrange for compensation payment to the rightful land owner. The compensation will be based on the market value of the land as on the date of the issue of the notification. Annual interest of 15% is payable to the land owner if there is a delay in the payment beyond one year from the land handover date.
Delay to the land acquisition process usually happens because compensation offered to the land owners are below the market value. Opposition to the land acquisition could also happen when the relocation of the land owners affected by the land acquisition is not followed up adequately.

For the implementation of BRIMSTOWAD Project in Mumbai, some of the land required for the storm retention and drain widening project do not belong to MCGM. Hence, it poses a challenge to MCGM in improving its storm water management system. Land acquisition process may drag for years if it is met with opposition from the residents. Proper land acquisition committee is required to coordinate and acquire all the affected lands.

2.4.4 Effluent Discharge Standards & Pollution Control

Effluent discharge standard was controlled by Maharashtra Pollution Control Board (MPCB). It is under the control of Environment Department of Government of Maharashtra. It is responsible in planning and implementing various environmental legislations in Maharashtra State, India.

It has produced various regulations to control the water pollution such as Water (Prevention and Control of Pollution) Act and Water (Cess) Act. The comparison of the latest effluent discharge standard into the water bodies and the effluent discharge from the various municipal corporations are shown in Table 2.9.

Table 2.9: MMR - Effluent Standard Discharge from STP

Location	pH	DO (mg/l)	BOD (mg/l)	COD (mg/l)	SS (mg/l)	Nitrates (mg/l)
Standard	**5.5 – 9.0**	**> 4.5**	**< 100**	**< 250**	**< 100**	**10**
Greater Mumbai						
Worli	6.9	-	125	280	60	-
Mulund	6.9	-	186	272	72	-
Ghatkopar	6.8	-	24	64	16	-
Bhandup	7.0	-	130	196	24	-
Colaba	6.9	-	90	368	182	-
Malad	6.7	-	120	292	98	-
Navi Mumbai						
CBD	6.7	-	52	114	24	-
Nerul	7.89	-	18	52	65	-
Vashi	6.95	-	65	116	78	-
Koparkhairane	6.8	-	30	96	58	-
Airoli	7.16	-	65	88	68	-

Source: Maharashtra Pollution Control Board, NMMC Environmental Status Report, Report on Environment Status of Greater Mumbai

From the comparison shown in Table 2.9, effluent discharge quality from Greater Mumbai is still below standard because STPs in Greater Mumbai are designed to treat the wastewater up to the preliminary treatment only. Meanwhile, NMMC's STP has produced effluent within the acceptable standard.

In the future, MCPB has planned to enforce more stringent discharge standards, 20 mg/l BOD and 30 mg/l SS for discharges into creeks and harbours, 100 mg/l BOD and 100 mg/l SS for discharges into the Arabian Sea by 2025. It is important that every municipal corporation strive to comply with the effluent discharge standard to reduce the pollution level in the existing creeks or sea. Most of the municipal corporations has included plan to upgrade the existing STP and build more STP to comply with the effluent discharge standard in their City Development Plan.

2.4.5 Solid Waste Disposal – Hazardous & Non-hazardous

3 main regulations on solid waste disposal are Biomedical Waste (M&H) Rules, Hazardous Waste (M&H) Rules and Municipal Solid Waste Rules (2004). They are enforced by MPCB. MCGM and NMMC have been the most proactive in implementing the new regulations within their jurisdictions. Some of the key points from these rules are summarized in Table 2.10.

Table 2.10: MMR - List of Key Policies for Solid Waste Management and Their Implication

No	Rules	Key Policy	Actions Taken
1.	Municipal Solid Waste Rules (2004)	Implement public awareness program for understanding the importance of waste segregation at source.	MCGM: • Implementation of Advance Locality Management (ALM); • Carry out campaign instructing citizens to separate their waste. NMMC: • Put up informative hoardings at various places; • Appointed advertising agency for public awareness.
		Organize house to house collection of municipal waste from residential, slum and commercial areas	Most of the municipal corporations are implementing the door to door waste collection by engaging private contractor. Slums are not included in the door to door system unless they are registered under the slum census.
		Separation of wet and dry solid waste.	MCGM and NMMC: • Daily collection for wet waste and weekly collection for dry waste; • Waste separation before disposal into the landfill.
		Provision of community waste storage bins	Has been provided partially at the big cities such as Greater Mumbai, Navi Mumbai and Thane.
		Scientific landfill is encouraged as proper method to dispose waste	MCGM: • Propose new scientific landfill site at Kanjurmarg. NMMC: • Construction of sanitary landfill at Turbhe.
2.	Hazardous Waste Rules (2008)	Waste processing facilities to include composting, incineration or energy recovery based on technology approved by MCPB.	NMMC: • MSW are treated at processing facility at Taloja; • Biomedical waste is sent to common biomedical waste facility at Taloja for disposal. • Construction debris are recycled into construction related material
3.	Biomedical Waste Rules (1998)	The bio-medical waste has to be treated separately with treatment facilities like incinerator, autoclave and microwave system.	MCGM: • Biomedical waste is sent to hospital at Sewree for treatment NMMC: • Biomedical waste is sent to common biomedical waste facility at Taloja for disposal.

Source: New Practices of Waste Management – Case of Mumbai, Report of Environmental Status of Navi Mumbai Region

CHAPTER 3: PLANNING INITIATIVES AND THEIR IMPLICATIONS

3.1 Past Planning Initiatives

3.1.1 Water Supply:

- **Mumbai Water Supply Project (1981 – 2006)**

This project was completed in 4 stages. It aimed to improve the existing water supply network and increase water supply to Mumbai City (refer to Table 3.1 for the list of completed work). In total, an additional 1,840 MLD of water supply to was provided for Mumbai City.

Table 3.1: Greater Mumbai - Mumbai Water Supply Project Stage I – IV

Stage	Completion Year	List of Completed Work	Augmented Water Supply (MLD)
I	1981	• Pick up weir across Bhatsa River at Pise; • Treatment plant at Panjrapur and Vihar Lake; • Treated water pumping station; • Laying of new water pipes; • Construction of control valve, intake channel and tunnel.	455
II	1989	• Expansion of treatment plant at Panjrapur and Pise pumping station; • Laying of new water transmission mains; • Construction of service reservoir and tunnel.	455
III	1997	• Expansion of treatment plant at Panjrapur and Pise pumping station; • Laying of new water transmission mains; • Construction of reservoir at Bhandup, Worli, Borivali and Malabar Hills.	475
III A	2006	• Expansion of treatment plant at Panjrapur and Pise pumping station; • Laying of new water transmission mains; • Construction of water tunnels from Bhandup and Vervali reservoir.	455

Source: Mumbai City Development Plan 2005 – 2005

- **Privatization of Water Supply Operation and Maintenance System in Navi Mumbai (2004)**

In order to provide more reliable water supply services to the residents, NMMC had awarded a comprehensive contract for the operation and maintenance of the water supply network in Navi Mumbai to private sectors. The contract was evaluated on a performance basis to encourage better services from the service provider. This move had resulted in better water quality and reduced water leakages.

- **Purchase of Morbe Dam by NMMC (2003)**

Morbe dam was originally built and owned by MJP. MJP supplied 50 MLD of water to NMMC from Morbe Dam. In order to solve the water supply deficit issue in Navi Mumbai, Government of Maharashtra approved NMMC's request to purchase Morbe Dam from MJP in 2003. Morbe Dam will be fully owned by NMMC in 2010 after the payment of the final instalment.

With the purchase of Morbe Dam, NMMC is able to be self sufficient in water supply although it still purchase small amount of water from CIDCO and MIDC as back up. The NMMC are earning additional revenue from the sale of extra water and electricity generated from the Morbe Dam.

- **Setting Up of STEM Authority (2000)**

Shahad Temghar Water Authority (STEM) was formed on 1st April 2000. It is formed by 3 Municipal Corporations to manage their bulk water supply. The 3 municipal corporations are TMC, BNMC and MBMB. STEM is managed by an executive committee consisting of representatives from the 3 Municipal Corporations.

The main responsibility of the agency is to manage the water supply system to Thane, Bhivandi Nizampur, Mira Bhayander and the adjoining 34 villages in the rural area. The water supply system was originally built and maintained by MJP. After the formation of the agency, the system was handed over from MJP to STEM.

The main water supply source for the scheme is Mohane weir at Ulhas river. The raw water is treated at STEM's treatment plant in Shahad and Temghar. In total, STEM supplies approximately 280 MLD water to Thane, Mira Bhayander, Bhiwandi Town and 34 villages in Bhiwandi Taluka.

3.1.2 Storm Water Drainage:

- **Brihan Mumbai Storm Water Drainage Project (BRIMSTOWAD – 1993)**

The project was a response to the major flood event that hit Greater Mumbai in June 1985. The proposal to improve the existing storm water drainage network was prepared and submitted in 1993 by Watson and Hawskley International with their Indian partner Associated Industrial Consultants Ltd.

The report recommended MCGM to implement the following strategies:

- Redesign the existing drains to accommodate the runoff inflow of 50 mm/hr from the existing drain capacity of 25 mm/hr;
- Perform regular desilting of the existing drain;
- Remove obstruction from the drains such as water mains and cables;
- Construct drains in the part of the city where it does not exist;
- Construct storm water pumping stations at Worli, Haji Ali and Cleaveland Bandar.

Only 25% of the recommended works was completed with the total cost of Rs 143 crore. The recommended strategies were not fully implemented until the more recent catastrophic flood in 2005 due to the financial crisis faced by MCGM during that period, institutional hurdles, shifting of utilities and encroachment removal issues.

- **Improvement Work on Mithi River (1993 - 2006)**

Mithi River is important as it divides Mumbai's urban and sub-urban area. It is among the major water courses carrying storm water from the suburbs into the sea. Its flooding will have direct impact on 5 transport corridors in Mumbai.

The improvement work for Mithi River was specifically mentioned in the BRIMSTOWAD report (1993) and Development Action Plan for Environmental Improvement of Mithi River and along its Banks Report by Centre for Environmental Science and Engineering (2006). Both reports recommended dredging of Mithi River to widen and canalize the river and clearing illegal encroachment along the river banks. Upgrading of the drainage network that is feeding into Mithi River needs to be done to increase the conveyance efficiency.

During Mumbai major flood in July 2005, Mithi River flooded Kurla, Chembur and the island city catchment near Mahim. To prevent Mithi River from future flood, MCGM has started to improve the existing conditions of Mithi River based on the recommendations from the Centre for Environmental Science and Engineering report. The work was split into 2 phases. It involved de-silting and widening of the downstream stretch of Mithi River with a total length of 6km. The work was completed in June 2006.

- **Construction of Holding Ponds in Navi Mumbai**

NMMC created storm water holding ponds to prevent flooding. These holding ponds were designed to retain storm water runoff during the monsoon season and most of them dry up during dry season. To utilize the recreational potential of the pond in dry season, NMMC started work to beautify it by providing jogging track, landscape parks, etc. Unfortunately, due to lack of monitoring and maintenance, some of the holding ponds were not functioning well and were converted into office, commercial area and cemetery.

3.1.3 Sewerage:

- **Mumbai Sewage Disposal Project 1 (1995 – 2003)**

The objective of the project was to improve the sanitation system in Greater Mumbai. The US$192 million project was funded by World Bank. Completed works were as follow:

- Construction of marine outfalls at Worli and Bandra;
- Construction of sewage tunnel at Ghatkopar;
- Construction of pumping station at Bandra;
- Construction of aerated lagoons at Bhandup and Ghatkopar;
- Slum Sanitation Program;
- Segregation of sewage from storm water in the public drains.

The project was completed and fully commissioned in December 2003. The outcomes of the project were increase in the sewage treatment capacity, higher service coverage, improvement in the sanitation facilities for slum and cleaner beaches.

3.1.4 Solid Waste Management:

- **Parisar Vikar Scheme (2000 – 2005)**

This scheme was initiated by a Mumbai based NGO, Stree Mukti Sanghatana (SMS). SMS works with women primarily to create awareness of woman rights and issues in the society. In this scheme, the targeted beneficiary is the rag picker group, of which 80% were female. The main objective is to improve the living standard and skills of the rag pickers.

Main strategies for the program involved the following:

- Creating zero waste situation in the cities by introducing the latest and affordable technique of waste treatment and recycling to the rag pickers
- Training the women rag pickers in alternative skills such as vermi-composting, gardening, etc.

The rag pickers collected the already segregated dry and wet waste from the households. The wet waste will be converted into compost for sale in the market. The composting process was done at the scheme's own two biogas plants. The dry waste was sold directly to waste recycling unit.

A monthly charge of Rs 10/household was collected by SMS to fund the scheme. Rag pickers would earn money from the sale of compost and dry waste. The success of this scheme had made MCGM realized the importance of rag pickers in the solid waste management cycle. They received better price for the collected materials, better health and insurance service.

- **Biomedical Waste Treatment Facility at Sewree (2002)**

Greater Mumbai generates 10 metric tonne of biomedical waste per day (MTPD) from both municipal and private medical institutions. As required by Biomedical Waste (M&H) Rules, MCGM developed a biomedical waste treatment facility at GTB Hospital, Sewree in 2002 to treat different type of biomedical waste. The facility had a designed capacity of 10 MTPD. It was equipped with one incinerator, one shredder and two autoclaves. The treated waste from the facility was disposed at Deonar dumping ground.

However the incinerator was closed down in 2003 as its emission quality did not comply with the required standard by Biomedical Waste (M&H) rules. Since then, the incinerable waste was sent to similar biomedical treatment facility owned by TMC at Taloja. The remaining biomedical waste is still being treated at Sewree facility.

- **Commissioning of the First Sanitary Landfill in MMR by NMMC (2005)**

The 65 acres sanitary landfill is located at Turbhe. The development of this Municipal Solid Waste Disposal Facility was done in phases. The first phase of the landfill was commissioned on June 2005.

No untreated waste and unauthorized dumping were allowed in the landfill. Mixed garbage was treated with culture for biostabilization. The end product of the treatment was disposed at the landfill. The operation and maintenance of the landfill was carried out by private contractor. AFM based product was sprayed on the disposed waste to minimize fly and odour nuisance. The facility was equipped with leachate collection tank to prevent groundwater contamination. NMMC is also earning carbon credit through a project to reduce the carbon dioxide emission produced by the garbage.

- **Commissioning of Debris Recycling Plant**

The first ever debris recycling plant was a joint initiative by CIDCO with NGO called Youth for Unity and Voluntary Action (YUVA). The first ever project was launched in 2002 at Karghar, Navi Mumbai. The plant was an answer to providing environmental friendly and cost effective way to recycle the ever increasing construction waste. The plant is able to convert 160 tonnes of debris into 1,300 blocks of bricks, interlocks and paver blocks daily. Figure 3.1 shows the schematic debris recycling method.

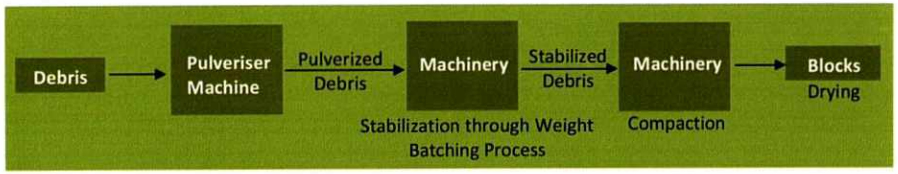

Figure 3.1: Debris Recycling Method.
Source: Surbana, CIDCO Yuva Building Centre

3.2 Present and Future Planning Initiatives

3.2.1 Water Supply:

- **Commissioning of SCADA System to Operate and Maintain Water Supply Network at Thane**

TMC is using Supervisory Control and Data Acquisition (SCADA) system to carry out water audit and maintenance on the existing water supply system. The real time system has helped TMC to improve the reliability and efficiency of the water supply network. Field instruments and sensors installed at various water points in Thane are able to give real time feedback to the operator on various parameters such as water quality, flow, pressure, level, etc. The benefit of this system is that the operator can directly locate any leakage or anomaly on the water supply network and arrange for checking and repair as soon as the problem is identified.

- **Water Desalination Plant**

MCGM is going to conduct a pilot study on water desalination plant to increase its water supply. Feasibility study is being conducted to study the possibility of 100 MLD seawater desalination plant at various locations namely Vasai – Virar, Mira – Bhayander and Mumbai city.

- **Construction of New Dams to Provide Additional Water Supply to MMR**

The list of the approved project for the dams is shown in Table 3.2. The dams will be providing a total of 5,110 MLD to MMR by 2021. A great portion of the water will be supplied to Greater Mumbai as it has the highest projected water demand due to the increasing population.

Table 3.2: MMR - Approved Water Resource Projects

No	Dam	Location	Capacity (MLD)	Progress	Completion Year
1.	Middle Vaitarna	Vaitarna River, at Makhoda, Thane	455	• Dam is to be constructed by MCGM; • Construction is in progress.	2012
2.	Gargai	Gargai River at Igatpuri Taluka, Nasik	440	• Dam is to be constructed by MCGM; • Yield and feasibility study are completed;	2017
3.	Pinjal	Pinjal River	865	• Dam will be constructed by MCGM; • Water treatment, laying of transmission and distribution main will be completed by MCGM; • Yield study is completed; • Feasibility study is underway.	2021
4.	Kalu	Kalu River	1,140	• Multipurpose project by Government of Maharashtra; • Dam is to be constructed by MMRDA; • 590 MLD of the water will be supplied to MCGM; • MCGM will treat the water and lay the water pipe to Greater Mumbai.	2014 (likely to be delayed)
5.	Shai	Shai River	940	• Dam will be constructed by MMRDA; • 800 MLD of the water will be supplied to TMC; • 140 MLD of the water will be supplied to Bhiwandi, Ulhasnagar, Kalyan-Dombivli, Ambernath and Badlapur.	2014 (likely to be delayed)
6.	Poshir	Poshir River	920	• Dam will be constructed by MMRDA; • The dam will supply water to Thane and Raigad District.	2014
7.	Balganga	Balganga River at Pen, Raigad	350	• MMRDA has appointed CIDCO to construct the dam; • Land acquisition is in progress; • The dam will supply water to Thane and Raigad District.	2015

Source: MCGM, TMC

3.2.2 Storm Water Drainage:

- **BRIMSTOWAD Phase I and II (2006 – 2010)**

After Mumbai was hit by the major flooding in July 2005, BRIMSTOWAD project was revived in 2006 to prevent major flooding in the future. Additional study was done to study the relevance of the recommendations in the BRIMSTOWAD report to be implemented in the future due to the change in the topography and rainfall pattern since 1993 to 2006.

The government appointed a fact finding committee led by the Madhav Chitale to study the BRIMSTOWAD report by Watson Hawskley and the cause of the 2005 flood event. The study recommended the implementation of the BRIMSTOWAD project.

The implementation of BRIMSTOWAD project is split into 2 phases. The first phase was started in 2006. It is expected to be completed by end of 2010. The completed works are as follow:

- Widening of Walbhat River, Mhatre Nalla, Saphed Pool Nalla, Mahul Creek and Usha Nagar Nalla;
- Reconstruction of collapsed wall at the eastern suburbs;
- Construction of Nalla at the bed of Dahisar River;
- Improvement work to the existing culvert at the eastern suburbs.

Subsequently the second phase of the work will start from 2011 onwards. It will include the following works:

- Augmentation of various existing drain in the city area;
- Cleaning and improvement of various existing drains in the western suburbs;
- Construction of pumping station at Britania Outfall, Gazdarband and Mahul Outfall;
- Widening of the various existing nalla system in the eastern suburbs.

- **Mithi River Development Phase II (2007 - 2010)**

The second phase of Mithi River development project will involve dredging, deepening and widening of the remaining stretch of Mithi River, construction of retaining walls and service roads and beautification of the river.

The project is expected to be completed by December 2010. After the completion of the project, it is expected to solve the flooding problem within the catchment areas of the Mithi River particularly in the financial centre of Bandra – Kurla Complex.

3.2.3 Sewerage:

- **Mumbai Sewage Disposal Project II (2005 – 2010)**

After the completion of Mumbai Sewage Disposal Project I, MCGM has started on the second stage of the project to cater for the projected increase in sewage generation by 2025 and meet higher sanitation standard in the future. Focus will be given to the improvement of water quality in the coastal regions and creeks, increase in the projected sewage generation, rehabilitation of the existing sewerage network, upgrade of the existing STP and slum sanitation program.

The following outcomes are expected by the end of the project:

- Reduced pollution level in nallas, creeks and Arabian Sea;
- Total removal of sewage from the city's drain, water bodies and beaches;
- More sanitation facilities built for the slum communities;
- Full compliance on the effluent discharge standard as required by Maharashtra Pollution Control Board (MPCB).

- **Slum Sanitation Program (1997 – 2010)**

Slum sanitation program is a demand-driven participative community program to provide sustainable sanitation facilities to the slum community. This program is part of Mumbai Sewage Disposal Project I. The main objective of the program is to build community toilet operated and maintained by the slum dwellers. Most of them usually go to the public toilet which may not be located near their place. Having one community toilet located within their house vicinity will be more convenient and safe especially for women who have stronger concerns for privacy.

Partnership between MCGM and Community Based Organization (CBO) as the slum dwellers representative is very important. MCGM as a service provider provides funding for the construction of the community toilet and the necessary infrastructure such as water and power supply. CBO will act as the representative of the slum dwellers in collecting the maintenance fund and maintaining the cleanliness of the toilet.

Slums are usually densely built hence it is quite a challenge to decide where to construct the toilet. Resistance to the program usually comes from the residents who are not used to the concept of paying to use the toilet. However after seeing the improvement in the hygienic quality, most of them are more than willing to contribute to the maintenance fund.

The program has already built more than 400 community toilets with 350 more under construction. Most of the toilet buildings are also equipped with community hall for the residents to hold any public activity (refer to Figure 3.2).

Figure 3.2: MMR - Community Toilet Block (left), Community Hall on the Second Floor (right)
Source: World Bank Urban Notes – Reaching the Poor through Sustainable Partnership

3.2.4 Solid Waste Management:

- **Advance Locality Management System (1997 – 2010)**

This scheme was initiated by MCGM to get the citizens to participate actively in solving the solid waste management problem. The residents will sit down with MCGM to discuss on solid waste issues and find a solution together. The main objective of this program is to achieve zero garbage by promoting 3R (Reduce, Reuse and Recycle) and waste segregation at source (refer to Figure 3.3).

Each society has to register with MCGM to participate in the program. MCGM provides the necessary support in the technology and coordination while the residents carry out the recommended strategies. A daily fund of Rs 1/apartment is collected for the Maintenance Fund. All expenses for the scheme are going to be incurred from this fund.

Under the scheme, the wet waste is processed by vermi-composting process which can be installed at individual household or community composting facility. Rag pickers are also earning income as they could sell the recyclable dry waste from the residents. As their role is very important in this scheme, MCGM has worked with Non-Governmental Organization (NGO) to provide them with training with better health and insurance services.

This success of this scheme is significant in reducing the burden of primary collection, transportation and disposal of waste which in turn reduce the MCGM's solid waste disposal expense.

Some of the problems that were faced during the early implementation stage of this scheme are the reluctance of the residents to undertake activities which should have been the responsibility of MCGM, unwillingness to contribute to the maintenance fund and the smell that arises from the installation of vermin composting within their living area. However, as the residents felt the benefit of this scheme, they were more willing to participate and contribute in the scheme.

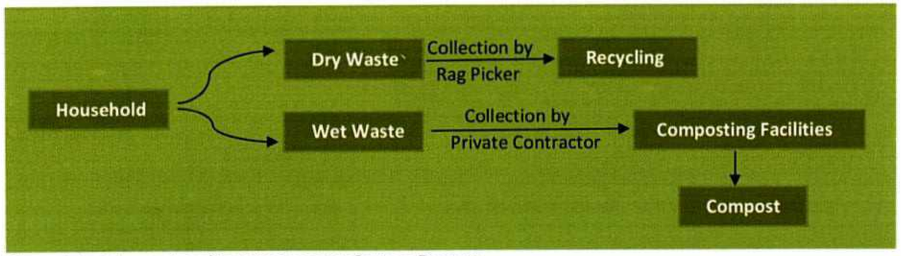

Figure 3.3: Advance Locality Management System Process
Source: Surbana

- **Slum Adoption Scheme (2000 – 2010)**

This scheme was initiated by Community Based Organization (CBO) that has been involved in Solid Waste Management related work in Mumbai since 1999. This scheme aimed to improve the living condition in the slum by involving the slum dwellers to form self sustainable garbage communities.

Waste from the slums was collected door to door through handcarts, auto rickshaws or smaller vehicles due to the narrow pathway of slums. The waste was sent to the dumping ground for final disposal.

The initial funding for the program was provided by MCGM for the first 3 years. The CBO was expected to be self sustainable in managing the solid waste management service at the end of the third year. Every household in the slum paid monthly contribution of Rs 10/household for house to house waste collection and maintenance of the toilet blocks. The money was used to hire workers to do the cleaning job.

The drawback of this scheme is that it only serves the authorized slums in Mumbai. The non-authorized slums did not have any means to deal with the solid waste management issues. As CBO only serves a small section of the slums allocated to them, quite often the total contribution from the slum dwellers was not sufficient to cover the operation cost which resulted in the lower-than-expected cleanliness standard in the slum.

- **Development of Regional Landfill Sites in MMR**

MMRDA is planning to develop landfill sites in MMR. It is proposed to be implemented on Public Private Participation (PPP) basis in 2 phases. For phase I, the following locations have been identified: Bhiwandi (352 Ha), Kalyan (259 Ha) and Taloja (443 Ha). Identified locations for phase II are Ambernath - Ulhasnagar (1225 Ha) and Old Pune - Panvel road (207 Ha). Land acquisition for these sites is in progress.

- **Gorai Dumping Ground Closure Project (1997 – 2010)**

The project was part of Mumbai Solid Waste Management Project to reduce the greenhouse gas emission and prevent contamination from the dumping ground. Gorai dumping ground was to be converted into green landscaped spaces for Mumbai residents in the future. Environmental mitigation measures such as impermeable surface cover and landfill gas recovery system were incorporated as a part of the closure strategy. The landfill gas recovery system will comprise of landfill gas and leachate collection and treatment system, transportation pipeline system, 2 MW thermal power generation plant and flare system.

MCGM is earning carbon credit from its effort to reduce the greenhouse gas emission. Asian Development Bank (ADB) has paid an advance payment of Rs.25 crores to MCGM for the future Carbon Credits to be collected from the Gorai Methane Land Fill project.

CHAPTER 4: FUTURE DEMAND AND GAP ANALYSIS

This chapter presents the demand projection for the infrastructure in the future based on two planning horizons, i.e. 2032 and 2052. The existing infrastructure supply and condition will be analyzed to determine the additional capacities required in order to meet the projected future demand. All the estimated infrastructure demand is derived from the projection done by Mckinsey for "Vision Mumbai" report as requested by Mumbai Transformation Support Unit (MTSU).

4.1 Water Supply

For the future water demand in MMR, McKinsey had projected the demand based on two expected living standards, basic and "best in class" (refer to Table 4.1). The projected demand for "best in class" standard is higher because good quality water is assumed to be easily accessible to the various users. To support MMR vision to be a global city, the water demand based on "best in class" projections are chosen as the target to be achieved by 2032 and 2052.

The estimated water demand (best in class) was compared against the existing and planned water supply capacity to determine the water supply gap. MMR is estimated to receive a total of 9,550 MLD of water supply when all the approved water supply projects are completed in 2021. The numbers include the existing water supply resources that are assumed to be still in operation in the future. The water supply deficit is expected to reach 5,822 and 9,758 MLD by 2032 and 2052 respectively.

To close the huge water supply gap, there are two main strategies that can be implemented. They are water demand reduction and water supply augmentation from damming up of water bodies and alternative water sources.

Water demand reduction is an important strategy. Municipal corporations can keep building new water reservoirs but they will never be sufficient if the water demand is increasing uncontrollably. Reduction in water demand could be achieved by:

- Establishment of active leakage control and metering system in the distribution system. Active leakage control will be able to alert the water service provider of leakage in the water supply system so that immediate repair can be done while metering system will prompt end user to conserve water as they are charged based on their consumption. 10% demand reduction is targeted from these systems. This is comparable to the water saving of 10 – 20% experienced by other major cities that are using the same method.

- Installation of water saving devices. Water saving devices is easily available in the market at an affordable price currently. Some of the water saving devices that can be used is low-flow shower heads, low-flush toilets, pressurized water brooms, etc. They can be used for household and commercial developments. Depending on the efficiency of the water saving devices, the saving from these devices could range from 10 - 30%. For MMR, 10% water saving is targeted.

Water recycling has not been practiced in MMR although it is a common practice in major cities such as Singapore, London, California, etc. with more countries picking up on this alternative water supply source. The reclaimed water is normally used for non-potable uses. More potable water will be available for drinking purpose, since lesser potable water will be used for non-potable uses. MMR's high projected water demand means higher wastewater generation that can potentially be recycled and supplied to the non residential user. It is targeted that by 2032 and 2052, the water recycling component could supply 35 and 40% of the commercial and industrial demand respectively.

Table 4.1: MMR – Projection of Future Demand and Gap Analysis for Water Supply

Year	2032		2052	
Estimated Water Demand (Basic hygiene)	13,140 MLD		15,523 MLD	
Estimated Water Demand ("Best-in-class" standard)	**15,372 MLD**		**19,308 MLD**	
	5,049 MLD (Commercial)	10,323 MLD (Residential)	7,241 MLD (Commercial)	12,068 MLD (Residential)
Existing & Planned Water Supply	9,752 MLD (by 2021)			
Water Supply Deficit	5,620 MLD		5,620 MLD	
Reduction in demand through active leakage control & metering in the supply system	1,537 MLD (10% of overall demand)		1,537 MLD (10% of overall demand)	
Reduction in demand through water-saving device	1,537 MLD (10% of overall demand)		1,537 MLD (10% of overall demand)	
Water recycling for non-potable use	1,515 MLD (30% of commercial demand)		1,515 MLD (30% of commercial demand)	
Rainwater harvesting & gray water reuse	769 MLD (5% of overall demand)		769 MLD (5% of overall demand)	
Additional Water Supply Required	262 MLD (2.7% of existing & planned supply)		262 MLD (2.7% of existing & planned supply)	
Proposed Water Resources (Option 1)	Mahim Bay Barrage (100 MLD) Desalination Plant (165 MLD)		Mahim Bay Barrage (100 MLD) Desalination Plant (165 MLD)	
Proposed Water Resources (Option 2)	Desalination Plant (265 MLD)		Desalination Plant (265 MLD)	

Source: McKinsey, Surbana

Rainwater harvesting has been slowly implemented in MMR in response to the Government Resolution issued by Water Supply & Sanitation Department of Government of Maharashtra in 2002. The resolution approves the use of rainwater harvesting as an alternative source to improve water supply. With the support and enforcement of the regulation by municipal corporations, the rainwater harvested is expected to substitute 5% and 8% of the water demand by 2032 and 2052 respectively.

After deducting the water supply deficit with water saved by the various water reduction strategies, MMR will only require additional 212 MLD and 849 MLD of water supply in 2032 and 2052 (refer to Table 4.1).

Two options are proposed to provide the additional water supply. First option will be the construction of new reservoirs in MMR. New reservoirs can be created at Mahim Bay and Thane Creek which are located offshore unlike the existing inland water reservoirs. The locations are chosen to minimize over exploration of the existing water bodies and land acquisition process that is usually required to dam up the water bodies. Having said that, further detailed study will be required to determine the feasibility of these projects.

The second option will be the provision of additional water supply by seawater desalination in the event that the proposed Mahim Bay Barrage and Thane Creek Reservoir are found not feasible. The abundance of seawater in MMR as is a potential that is yet to be explored in MMR. The biggest water consumer in MMR, namely Greater Mumbai, Navi Mumbai and Thane are located along the coastal line where seawater intake and supply of the treated water will not be a major issue. Coastal cities all over the world with increasing water demand and limited water supply such as Aruba, Perth and Sydney have turned to seawater desalination to augment their water supply.

4.2 Sewerage

Projection for sewage generation in MMR is based on the assumption that 80% of the water demand will be turned into sewage. Similar to water supply, the projection is based on the "best in class" standard.

The estimated sewage generation was compared against the existing and planned sewage treatment plant (STP) capacity to determine the sewage treatment gap. Many of the planned sewage treatment plant projects were part of the upgrading of the existing STPs. The non-upgraded STPs are assumed to be in operation up to 2032. The sewage treatment deficit is expected to reach 9,077 MLD and 16,026 MLD by 2032 and 2052 respectively (refer to Table 4.2).

MMR should move forward to having at least two centralized STP in every district instead of having numerous STPs scattered around as it will be easier to control the operation and maintenance and the quality of the treated sewage effluent of a centralised STP. The centralized STP can be part of the Integrated Waste Management Zone (IWMZ) together with the other waste treatment facilities. Pollution problem, if any, will be contained within the zone so as to control the damage magnitude on the environment and living organism.

Maharasthra Pollution Control Board (MPCB) plans to enforce more stringent requirements on treated sewage effluent discharge quality in a bid to improve the quality of the water bodies. The new STP should be designed to produce effluent quality that is up to the desired standard. Currently, the effluent quality produced by the existing STPs is still below the requirement from MPCB. Therefore by 2052, all the existing STPs should be slowly phased out to make way for the centralized STPs.

A portion of the treated sewage effluent will be further treated to potable water standard to be supplied back to the community for non-potable use. The water recycling plant should be located next to the centralized STP to minimise the cost of laying transmission network.

Table 4.2: MMR – Projection of Future Demand and Gap Analysis for Sewerage

Year	2032	2052
Estimated Sewage Flow (Basic hygiene)	10,143 MLD	12,263 MLD
Estimated Sewage Flow ("Best-in-class" standard)	**12,512 MLD**	**16,026 MLD**
Existing & Planned STP Capacity	3,435 MLD	Decommissioned
Additional STP Capacity Required	9,077 MLD (2.6 x existing & planned capacity)	16,026 MLD (4.7 x existing & planned capacity)
Proposed Number & Capacity of STPs	7 nos. x 1,300 MLD (Total 9,100 MLD)	7 nos. x 2,300 MLD (Upgrade to 16,100 MLD)
Tertiary Treatment for Water Recycling *(For non-potable use)*	1,515 MLD (12% of estimated sewage flow)	2,896 MLD (18% of estimated sewage flow)

Source: McKinsey, Surbana

4.3 Solid Waste

Projection of solid waste generation in MMR was based on two major components, municipal solid waste and construction waste. The projection is based on the "best in class" standard. The daily solid waste generation rate was assumed to be 1.4 kg per person.

The estimated solid waste generation was compared against the existing and planned dumping ground capacity to determine the gap. The existing dumping grounds that are nearing the end of their lifespan are excluded in the analysis. By the year 2052, all the existing dumping ground would have reached the end of their lifespan. The deficit in the dumping ground capacity is 55,492 Ton/d and 77,528 MLD by 2032 and 2052 respectively (refer to Table 4.3)

To address the huge gap in the solid waste management system, two strategies are recommended. They are waste reduction and construction of sanitary landfill.

Waste reduction is essential in bringing down the amount of waste to be treated and disposed into the landfill. The lesser waste generated, the area required for the landfill could be reduced drastically. Based on the type of waste, the amount of waste can be brought down by:

- **Municipal Waste Recycling**

Small scale municipal and construction waste recycling has been adopted by Greater Mumbai and Navi Mumbai. Recycling of municipal waste has a lot of potential because the solid waste generated in MMR has a composition of 20 – 40% of recyclable waste.

- **Construction Waste Recycling**

MMR also generates considerable amount of construction waste. The number is going to increase in the future as a result of the economic and population expansions. Construction waste is generally bigger in size compared to municipal waste. Hence, it is usually not allowed to be disposed at the dumping ground as it will reduce the dumping ground capacity rapidly. The construction waste will be recycled into construction related materials.

- **Incineration**

The organic waste shall be sent to the refuse incineration plant. Incineration will reduce the volume of the waste to less than 20% of its original volume. The incinerated ash produced is harmless and will be sent to the landfill for final disposal.

The previously mentioned waste reduction strategies will be able to reduce 70% – 75% of the waste by weight. The remaining waste will be sent to the sanitary landfill for disposal. The estimated landfill site areas required by 2032 and 2052 are 2,500 and 3,300 ha respectively in total (refer to Table 4.3)

Table 4.3: MMR – Projection of Future Demand and Gap Analysis for Solid Waste

Year	2032	2052
Estimated Solid Waste Generated (Ton/d)	50,618 Ton/d (Municipal)	64,607 Ton/d (Municipal)
	10,774 Ton/d (Construction)	12,921 Ton/d (Construction)
Existing & Planned Landfill Capacity	5,450 Ton/d	Decommissioned
Deficit in the Dumping Ground Capacity	55,942 Ton/d	77,528 Ton/d
Recycling of Municipal Waste	15,185 Ton/d (Municipal – 30%)	16,300 Ton/d (Municipal – 40%)
Recycling of Construction Waste	3,232 Ton/d (Construction – 30%)	5,168 Ton/d (Construction – 40%)
Total Incineration Capacity Required (Assuming 90% incinerable municipal waste)	26,985 Ton/d	43,476 Ton/d
Proposed Number & Capacity of Refuse Incineration Plants	7 nos. x 4,000 Ton/d (Total 28,000 Ton/d)	7 nos. x 6,250 Ton/d (Upgrade to 43,750 Ton/d)
Additional Landfill Capacity Required (Assuming construction waste, 10% non-incinerable municipal waste & 17% incinerated ash)	7,542 + 2,998 + 4,587 = 15,127 Ton/d (Approx. 2,500 ha)	7,753 + 4,381 + 7,391 = 19,975 Ton/d (Approx. 3,300 ha)
Proposed Integrated Waste Management Zone (STP, Incineration Plant and Energy from Waste Facility)	7 nos. x 115 ha	7 nos. x 170 ha
Proposed integrated landfill sites	7 nos. x 360 ha	7 nos. x 475 ha

Source: McKinsey, Surbana

CHAPTER 5: VISION FOR MMR, INFRASTRUCTURE GOALS AND RECOMMENDED STRATEGIES

5.1 Positioning of Future MMR

The overall visions for MMR discussed in the Vision Report submitted earlier are as follows:

2032

Transforming MMR into a "World Class Metropolis" with a vibrant economy, a globally comparable quality of life and a healthy and attractive environment for all its residents

2052

Elevating MMR to be a "Global City" with a unique identity and global recognition as an international business hub, a leading technological innovator, a melting pot of local and cosmopolitan cultures, and a centre of excellence for urban environmental management

To elevate MMR status to a global city, MMR has to undergo major transformation in terms of the economic growth and quality of live. As discussed in Chapter 2, the infrastructure utilities in MMR such as water supply, sanitation, storm water and solid waste are still inadequate as the result of the rapidly increasing population, urbanization and economic development.

MMR has to start setting goals for infrastructure development and emulate the success of other global cities to overcome the current infrastructure problems and to ensure sustainability of the resources in the future. Proper planning of infrastructure will not only improve the living quality of the MMR residents but also provides a conducive environment to attract investment and to support the transformation of MMR into a global city.

5.2 Past Goals for Infrastructure

Several studies were conducted in the past to identify the key issues in the existing infrastructure within MMR and recommend strategies to overcome them. Three vision reports for MMR and Greater Mumbai were reviewed to understand what had been planned for MMR and whether MMR has moved towards achieving those goals.

Vision Mumbai by Bombay First (2003) document focused on Greater Mumbai only. It had identified water supply, sanitation and solid waste management as the key areas of improvement which would lead to better quality of life for the Mumbai citizen. The subsequent Vision Mumbai Report by Bombay First (2009) gave priority to solve the key issues in water supply. The Business Plan for MMR report done by MMRDA and LEA Associates set goals for water supply, storm water drainage, sanitation and solid waste. The comparison of the infrastructure goals from these reports are summarized in Table 5.1.

Table 5.1: MMR - Infrastructure Goals in Various Past Visions

Details	Vision Mumbai, by Bombay First and Mc Kinsey	Vision Mumbai, by Bombay First - Strategy Papers	Business Plan for MMR, by MMRDA and LEA Associates
Publication	Sept 2003	Nov 2009	Aug 2007
Region	Greater Mumbai	Greater Mumbai	MMR
Projection Year	2013	Varies	2032
Water Supply	• To upgrade piped water availability (from 160 lcpd to 250-300); • To increase water tariff from Rs 2.25 - 3.5 to Rs 3.8; • To reduce unaccounted for water to 15-20%; • To corporatize the water department in order to achieve greater efficiency, budget utilization and service quality.	• To reduce the unaccounted for water to below 10%; • To achieve 100% metering of the water supply network; • To focus on long term source development; • To prioritize the following projects: Treatment, distribution enhancement, identification of alternate sources: desalination & waste water recycling; • To increase project readiness through land acquisition; • To establish of tariff setting authority; • To develop separate water supply network to supply recycled wastewater for areas with high non-potable use.	• To provide water supply of 240 lpcd in Greater Mumbai and 200 lpcd in rest of MMR on 24/7 basis.
Storm Water Drainage	-	-	• To prevent loss of life and property and disturbance to traffic due to flooding.
Sanitation	• To increase the ratio of public toilets from 17 million to 100 per million.	-	• To achieve 100% sewerage network coverage in MMR including the slum.
Solid Waste	• To increase solid waste disposed in landfills (from 10% to 30-50%); • To promote waste reduction • To secure new landfill sites.	-	• To achieve 100% daily collection of solid waste; • To use environmentally friendly method for solid waste disposal.

Source: Surbana

5.3 Proposed Goals and Recommended Strategies for Infrastructure

The proposed infrastructure goals for 2032 and 2052 are formulated based on the previous goals recommended by Bombay First and various goals successfully and commonly implemented by other global cities. The main focus is to ensure that every resident in MMR could live in a flood free area with access to the municipal water supply, sanitation, solid waste management system. At the same time, the quality of the infrastructure will be improved progressively to reach the recommended standards as required by the central government's regulations.

The implementation of the infrastructure goals will be carried out progressively and divided into two milestones due to the complexity of the work and massive amount of funding required. The first milestone is by the year 2032, where the focus will be on the coverage improvement and the augmentation of the existing network and system at the urban areas to catch up with the rapid population and economic expansions. By the year 2052, the main focus will be on improving the quality of the infrastructure at the outskirt areas and slums coupled with the introduction of technology not commonly used in MMR such as wastewater reclamation and solid waste incineration. Table 5.2 listed the summary of the proposed infrastructure goals for MMR.

Table 5.2: Proposed Infrastructure Goals

Proposed Goals	2032	2052
Water Supply	• To increase water availability from 160 lpcd to 180 lpcd. • To provide 100% coverage for 24-hour piped water supply in urban area; • To reduce unaccounted-for-water from about 20-40% to 15-30%.	• To provide sufficient water supply for the entire MMR; • To provide 100% coverage for 24-hour piped water supply for entire MMR; • To reduce unaccounted-for-Water from about 15-30% to 10-15%;
Storm Water Drainage	• To create flood control system against storm event of up to 50-year return period in major waterway; • To eliminate the practice of discharging raw sewage and untreated industrial effluent into waterways.	• To create flood control system against storm event of up to 100-year return period in major waterway; • To make use of waterway for recreational & commercial purposes.
Sewerage	• To provide 100% sewerage coverage in urban area; • To provide sufficient septic tanks for sewage treatment in rural area; • To constantly treat the sewage to the required standard by MPCB.	• To provide 100% sewerage coverage in MMR.
Solid Waste	• To provide 100% solid waste collection services in urban area; • To provide proper solid waste disposal method.	• To provide 100% solid waste collection services in entire MMR; • To decommission or rehabilitate all existing unlined landfill sites.

Source: Surbana

5.3.1 Water Supply – 2032 Goals

5.3.1.1 Increase of Water Supply Availability (from 160 lpcd to 180 lpcd)

As the city develops, the living standard is expected to increase and so is the water demand. Based on the Manual on Water Supply prepared by the Central Public Health and Environmental Engineering Organization (CPHEEO) of Ministry of Urban Development India, the water supply norm for communities with population above 100,000 is in the range of 125 lpcd – 200 lpcd. Currently, water supply rate in urban areas has reached 160 lpcd. To keep up with the future development, additional 10% increment in the water supply rate is targeted. By 2032, approximately 180 lpcd has to be made available to the MMR residents.

The water cycle of MMR is shown in Figure 5.1. Out of the three potential water resources, highlighted in red in Figure 5.1, only rainwater has been utilized in MMR at the moment. Seawater and treated wastewater effluent has not been considered in the earlier planning process. It shows that there is a lot of potential in alternative water supply resources.

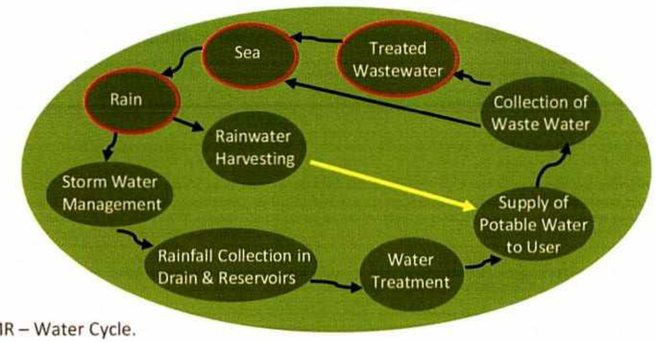

Figure 5.1: MMR – Water Cycle.
Source: Surbana

To increase the water supply availability in MMR, the following strategies are recommended.

- **Construction of More Water Reservoirs**

To increase the water supply in MMR, there is a need to construct more water reservoirs to store the storm water collected during the monsoon period. It is reported that Mumbai has a record rainfall of 3000mm this year. It is estimated that 75,000 million litre of the storm water goes to waste. In view of this, the fresh water supply in MMR can be increased by constructing more water reservoirs at strategic locations to capture the excess storm water during the monsoon period. As land is required to create such reservoir, one of the options worth exploring for MMR is to create an offshore water barrage.

An onshore water barrage can be considered in response to the limited land area that can be converted into fresh water reservoir within MMR. Mahim Bay is a suitable candidate due to its strategic location relative to the city centre of Greater Mumbai and fed by several rivers. Mahim Bay could be damned up by constructing a flood gate (approximately 700m) at the western boundary to separate the fresh water reservoirs from the seawater. The flood gate could be constructed parallel to the existing Bandra Worli Sea Link (refer to **Error! Reference source not found.**).

Through natural flushing process, the seawater within the Mahim Bay Barrage is expected to turn into fresh water in 3 to 5 years. The proposed barrage depth can be set at 5m. This can be achieved by deepening the seabed, if necessary. The 700-ha dam is estimated to yield 100 MLD of water supply.

If the barrage is constructed, Its close proximity to the city centre of Greater Mumbai will create opportunity for waterfront development with residential, hotels and commercial properties surrounding the barrage (refer to **Error! Reference source not found.**). A walkway could be created on the flood gate structure for the public to cross the barrage and enjoy the scenic view of the sea and the city (refer to **Error! Reference source not found.**).Individual rainwater harvesting should be prohibited within the water catchment of Mahim Bay barrage to maximize the inflow of rainwater into the barrage.

Having said that, the feasibility of the barrage will depend on how soon the Mithi River can be free of sewage discharge and how much storm water can be collected in the Mahim Bay barrage during the monsoon season. A detailed feasibility study shall be carried out by the relevant authority if the option is to be pursued later.

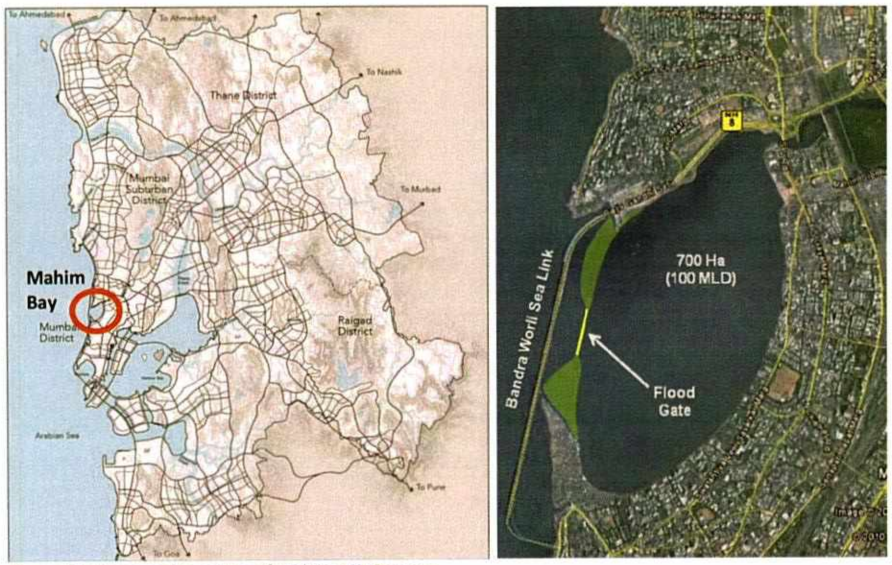

Figure 5.2: Proposed Location of Mahim Bay Barrage

Source: Surbana, Google Earth

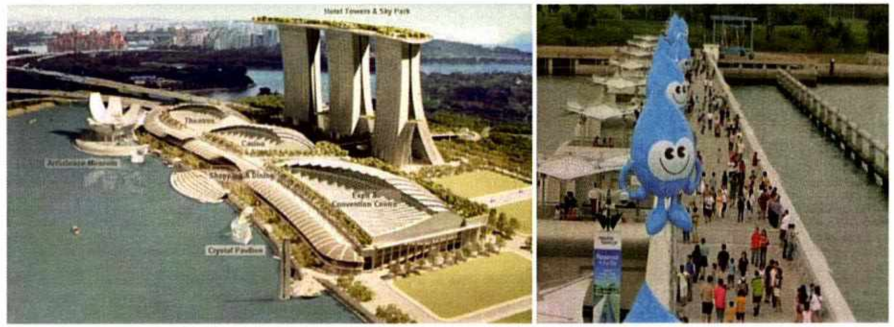

Figure 5.3: Singapore - Marina Bay Sands (left), Walkway on Marina Barrage Flood Gate Structure (right)
Source: Marina Bay Sands, PUB

- **Construction of Seawater Desalination Plant**

There are several factors to be considered in setting up the seawater desalination plant. First is the plant location. It is important to set up the plant near the source and the intended end users to save the cost of constructing long seawater intake and distribution network. Coastal cities such as Greater Mumbai, Navi Mumbai and Thane, Mira - Bhayander and Vasai – Virar are more suitable for the implementation of this technology as they are located at the coastal areas (refer Figure 5.4)

The second factor to consider is the desalination treatment technology. There are various seawater desalination technologies that are available in the market. At this moment, it is still more costly than the conventional surface water treatment technology. To choose the most efficient and cost effective treatment method, several factors such as the seawater quality, the required treated water quality and the membrane cost will be considered. The higher the salt content and the purity of the treated water, the more costly the process will be.

The third factor is the energy sources. Desalination is energy intensive. Continuous power supply is required to keep the plant operational. The energy sustainability could also be achieved by supplementing the municipal power supply with direct employment of renewable energy such as solar power, wind turbines, water turbines, wave or tidal power.

The last factor is the plant capacity. In general, the cost of desalinated water usually decreases when plant capacity increases. The cost saving is due to the fact that operational, labour and maintenance costs can be allocated over a larger capacity. Hence it will be more suitable for urban areas with high water demand. The plant has to be designed to allow for further expansion.

In conclusion, it is recommended that big coastal areas in MMR such as Greater Mumbai, Navi Mumbai and Thane, Mira - Bhayander and Vasai – Virar to start considering this option to augment their water supply. Municipal corporations should start by carrying out feasibility studies for seawater desalination plant in their respective areas. At this moment, MCGM is preparing a feasibility study to set up seawater desalination plant to supply to its residents.

- **Implementation of Rainwater Harvesting**

The state government of India has realized the importance of rainwater harvesting by issuing Government Resolution on rainwater harvesting (refer to Section 2.4.2 on Rain Water Harvesting & Groundwater Recharge). It has immense potential to be used for non potables use such as gardening and cleaning.

In general, MMR receives an annual rainfall of 1,800 mm - 2,500 mm. Based on MMR's geographical area of 4,355 km^2, it will receive 8,780,000 million litres of water or 24,000 million litres a day (MLD). Assuming that 50% of the whole MMR is developed and only 80 per cent rainfall from this developed area can be harvested, it will still amount to 9,600 MLD. In the case of rooftop water harvesting (refer to Figure 5.5), even with the assumption that only half of the area is roofed, MMR can easily harvest approximately 4,800 MLD. This is a significant amount compared to the MMR current total supply of 4,600 MLD.

- **Implementation of Wastewater Recycling**

MMR generates approximately 4,000 MLD of sewage of which less than 75% are treated to different quality depending on the treatment type. Everyday, both the treated and untreated sewage are discharged into the nearby creeks and sea. All the effluent is wasted into the sea without ever being reused.

To set up wastewater recycling plant, several factors have to be considered. First is the selection of the plant location. It has to be located at the low lying area in order to collect the raw sewage by gravity. Sufficient buffer from the populated area has to be provided.

The second factor to consider is the type of membrane and pre-treatment method to be used depending on the sewage composition. One of the systems that will be suitable to be used in MMR is Membrane Bioreactor (MBR) system. It is suitable to be used for wastewater treatment in MMR because it can treat both municipal and industrial area. Another important feature is the small footprint requirement for the plant compared to the conventional water treatment plant which will make it easier to be implemented in the land-scarce MMR.

The last factor is the demand for the recycled water. The quality of the recycled water can be tailored to suit the requirement. Recycled water has been used for groundwater recharge, indirect potable use, cooling purpose in the power generation plant, etc. The higher quality of the recycled water could be used by the semiconductor and pharmaceutical industry. In MMR, the recycled water will be beneficial for groundwater recharge to mitigate the groundwater overexploitation and to increase the water reservoir level during the drought season.

In conclusion, wastewater recycling is beneficial for MMR as it will be able to reduce the dependence of the water supply system on the depleting surface water. It is easy to implement, decentralized or centralized, as most of the membrane system could be installed in modules.

Figure 5.4: Israel - IDE Hadera Seawater Desalination Plant at Hadera Coastal City
Source: IDE Technologies

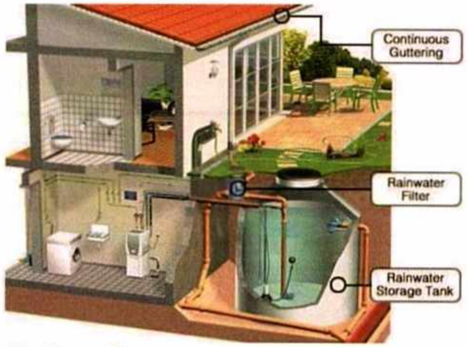

Figure 5.5: Rooftop Harvesting System Diagram
Source: Broken City Lab

Figure 5.6: Sydney - Wollongong Recycled Water Plant
Source: Sydney Water

5.3.1.2 Provision of 100% Coverage of Continuous Piped Water Supply in Urban Area

Having an uninterrupted 24-hour water supply in every household is the prerequisite for a global city. For the water service provider, improved water supply network means lower water losses. To provide 24-hour water supply, a well-managed transmission and distribution system is essential. For the consumer, having water available at the turn of a tap any time of the day or night, means better time management as they will not need to spend several hours daily to collect water. Health risks could be reduced because intermittent supply results in contaminated water from the surroundings getting into the supply network through leaks. For the municipal corporation, continuous water supply will minimize uncontrolled, illegal exploitation of groundwater resources

To achieve 100% coverage of 24 – hour piped water supply in the urban area, the following strategies are recommended.

- **Securing Adequate Water Supply Throughout The Year**

To secure adequate water supply throughout the year, it calls for ample and reliable water sources and adequate capacity for treatment, transmission, and distribution, as well as properly functioning pumps, reservoirs, and networks. How all these facilities are operated and maintained can greatly affect the water supply quality and the required funding in expansion.

Other than maintaining the existing water supply, agency at every municipality has to ensure timely completion of the proposed water supply project. A special committee has to be set up to monitor the progress of the project and perform pilot testing on the water supply quality produced from the project, if applicable. The authority has to be innovative in exploring alternative water supply such as seawater desalination and rainwater harvesting to reduce its dependence on surface water.

- **Expansion of the Existing Water Supply Network to Reach the Previously Un-served Area**

A complete and thorough survey has to be carried out in MMR to generate a comprehensive regional water supply network map. The map can be used to identify and prioritize the areas that require new water supply network and the existing water network that can be expanded to supply water to the particular area. Strong commitment from the municipal authority and the state government is required to fund the expansion of the water supply network due to the massive capital cost of laying the water pipes.

5.3.1.3 Reduction of Unaccounted for Water in MMR (from 20 – 40% to 15 – 30%)

As described in Chapter 2, MMR is currently facing water supply deficit due to the insufficient water resources to match the rapidly growing population. Another factor that is making the situation worse is the unaccounted for water (UfW) loss from the water supply distribution network. The water loss ranges from 20% - 40% which means that only 60% - 80% of the treated water reaches the end users. The actual water loss could be higher because it is difficult to measure unaccounted for water in systems where consumption is not metered.

UfW consists of various components such as leakage from the water pipes, illegal tapping into the water supply network and inaccurate or lack of metering system. High water loss will result in higher operation cost on the water supply providers as they have to supply more water in order to meet the intended water supply rate. The lowest unaccounted for water rate in developed countries such as Japan and Denmark is at the range of 10 – 15% currently. The reduction of the unaccounted for water loss is targeted to be done progressively with the targeted unaccounted for water of 15 – 30% by 2032.

Prior to launching UfW reduction program, cost/benefit analysis should be carried out to ensure that the cost of the reduction program does not exceed the value of the water to be saved or the additional revenue to be collected. Several strategies to reduce UfW are described in the following paragraph.

- **Regular Inspection, Maintenance and Upgrading of the Entire Water Supply Network**

Regular inspection of the existing water supply network should be performed to measure and identify the cause of the water loss. Measurement of the water loss can be done by dividing the city into different pressure zone and isolating even the smaller sectors of the network. The inspector could use venturi type meters or pitometer to perform the testing.

Another monitoring system that will be beneficial for MMR in monitoring the performance of the water supply network is SCADA system. SCADA stands for Supervisory Control and Data Acquisition. It is a centralized computer system that is used for process monitoring and automation. The control room can be located anywhere as long as it is connected to the system's communication network. SCADA system is able to give real time updates on the water flow, leaking, reservoir water level etc. The real time monitoring means that the operator can immediately detect any problem in water network and send the technician to do maintenance or repair.

There are two major losses that can be measured. Physical losses through leaks could occur in any part of the water supply network such as transmission pipes, distribution network, house connections, etc. To evaluate physical losses, the bulk meters have to be working properly. Most of the time, the network is no longer adequate to serve the area with increasing population or the pipes have simply reached the end of their useful life. In this case, pipe replacements should be quickly done. As there are still many areas in MMR without any metering system, water leakage instrument (refer to Figure 5.7) and temporary meters can be used to detect water leakage.

Figure 5.7: Water Leakage Detection Instrument
Source: FSC Leak Detection

The other losses are administrative losses. It is related to the illegal connections to the water network and inaccuracy of the billing due to the faulty meters or wrong reading of the meters. The solution of this problem will be to regularly inspect the water supply network and replace the faulty meters.

MMR could start by installing metering system in all urban area to detect water losses and encourage water conservation. Field testing should be performed on a regular basis. To improve the efficiency of the monitoring system, SCADA system should be implemented in MMR by 2032.

- **Installation of Water Saving Devices**

Using less water doesn't mean living without water. People tend to waste a lot of water if water is easily accessible (one of the goals to be achieved as explained in section 5.3.1.2). Water has to be used wisely. Water conservation can be achieved by simply installing water-saving devices. The most water consuming activities take place in the toilet and kitchen. A lot of water saving devices are designed to reduce the amount of water for bathing, flushing and washing (refer to Figure 5.8).

By 2032, every household and commercial areas in MMR has to use water saving devices in order to reach the targeted 10% water demand reduction through the installation of water saving devices (refer to Table 4.1)

Figure 5.8: Dual Flush Toilet, Low Flow Shower Heads and Kitchen Faucet Aerator
Source: Toto, Waterpik, Shanhe

- **Comprehensive Water Audit**

Water audit can be done on 2 different levels, overall network and household level. On the network level, paper audit of the billing system and the overall water supply network should be done before actually verifying the accuracy of the numbers with field work.

On the household level, the water supply agency could create a program to encourage every household to do its own water audit. The authority could prepare water audit checklist for the household. In general, the home owner should identify all the water-consuming activities in the house, estimate the water flow used for each activity and check the weekly reading to confirm the estimated water usage against the actual consumption. After completing the water audit, he should identify the activities that consume the most water and try to reduce it.

Comprehensive water audits are quite costly, and should not be carried out without strong commitment from the municipal corporations to implement their recommendations. It means that the water supply agency together with the respective municipal corporations must be in agreement to provide the necessary manpower, equipment, and materials for the programs implementation that may last several years.

5.3.2 Water Supply – 2052 Goals

5.3.2.1 Provision of 100% Coverage of Continuous Piped Water Supply in the Entire MMR

After the implementation of the continuous water supply for the urban area in the year 2032, the coverage has to be extended for the remaining areas in MMR for 2052. The areas shall include slums, rural and outlying areas.

- **Expansion of the Existing Water Supply Network to Cover the Entire MMR**

By year 2032, the regional water map that was proposed under section 5.3.1.2 should have been completed. The map should be the basis to expand the water network to reach the non – urban areas. Due to the massive area to be covered in this project, the areas could be grouped based on the urgency to get water supply connection. Strong commitment from the municipal corporation is required to provide the necessary funding, resource and manpower to plan and construct the water supply network.

5.3.2.2 Augmentation of Water Supply Resource

As projected in Table 4.1 under Section 4.1, there will be a huge jump of water demand in 2052. After the water reduction and conservation effort, additional 850 MLD of potable water is still required to meet the water demand in 2052. One of the options which can be explored to produce the additional water supply is by converting the existing Thane Creek into a fresh water reservoir. The viability of this option depends very much on the result of a detailed feasibility study and the success of the cleaning up of Thane Creek. If Thane Creek reservoir project is found to be not feasible, the seawater desalination plant constructed earlier will be upgraded to produce the required water supply. The option of converting the existing Thane Creek is elaborated in details below for reference.

- **Construction of Thane Creek Reservoir**

Subject to further feasibility study, the idea is to convert the existing Thane Creek into a fresh water reservoir. Thane Creek is a suitable site as it can provide the required footprint to produce 610 MLD of water supply. Its proximity to the new city centres in Greater Mumbai and Navi Mumbai will enable Thane Creek reservoir area to be developed beyond its functional use into waterfront development. The proposed Thane Creek Reservoir occupies an area of 6,000 ha. Assuming a 5m depth, the reservoir has the potential to provide approximately 1,000 MLD of water to MMR.

The feasibility of Thane Creek Reservoir will depend very much on the amount of storm water to be captured and the success of Thane Creek cleanup project as mentioned in MMR Sectoral Report for

Environment. When the water quality in the Thane Creek has improved, it will be easier to turn the seawater into fresh water through natural flushing process. From the preliminary discussions with the relevant authority, it was mentioned that there is a backflow of seawater from Vasai Creek into Thane Creek during drought season through Ulhas River. If it is found to be affecting the flushing process, a flow control structure (e.g. flap gates) can be installed at the confluence of the Ulhas River & Thane Creek to prevent seawater backflow into Thane Creek.

After Thane Creek is cleaned up, the seabed shall be dredged to the designed depth (approximately 5m). Two strips of land will be reclaimed on the creek to form the reservoir (refer to Figure 5.9). Residential or commercial properties can be built on the two strips of land. The reservoir will be split into two sections by a water gate.

There is an existing mangroves habitat along the coast line of Thane Creek. As mangroves require seawater for its survival, the two strips of land will be formed approximately 500 m away from the coast line to allow for seawater circulation. Figure 5.9 shows the location and the concept of Thane Creek Reservoir.

The future Thane Creek development could be modelled after Roosevelt Island in New York (refer to Figure 5.10). The Island boasts a selection low end to high end waterfront residential development. The island is connected to New York by a bridge called Queensboro Bridge.

To plan and manage the integration of Thane Creek Reservoir into a mixed use waterfront development, the state government could set up a state owned enterprise. It could form several subsidiaries to focus on three development areas; they are water resource, property and lifestyle. The proposed core business of each of the subsidiaries is shown in Table 5.3.

Table 5.3: Proposed Business Model for Thane Creek Mixed Use Development

Thane Creek Development Holding Co. Ltd				
Subsidiaries	Water Resource	Property		Lifestyle
		Commercial	Residential	
Core Business	• Development and operation of water infrastructure; • Sales of raw water to municipal corporations and water service providers.	• Development of basic infrastructure on reclaimed islands and sales or leases of land parcels; • Development of commercial and residential properties for sale or lease.		• Development and operation of recreational facilities such as holiday resorts, golf club and water theme park.

Source: Surbana

- **Expansion of the Existing Seawater Desalination Plant**

By 2032, there would have been several seawater desalination plants that are operational in MMR if the recommended strategy is implemented. Depending on the land area allocated for the plants, the additional 850 MLD can be shared among these plants. It is preferable to expand the existing operational plant than constructing a new plant due to highly expandable seawater desalination module, complexity in acquiring new site for the plants and the high capital cost.

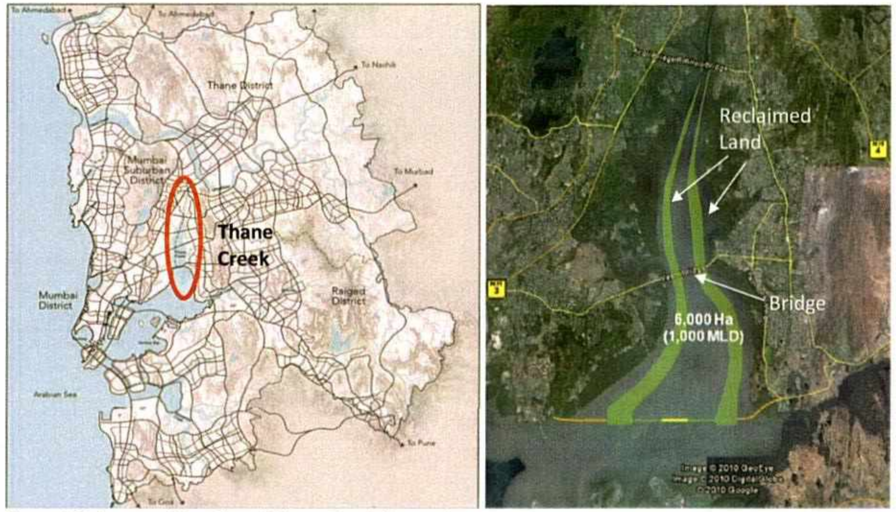

Figure 5.9: Proposed Location of Thane Creek Reservoir
Source: Surbana, Google Earth


Figure 5.10: New York - Roosevelt Island Development
Source: Google Earth

5.3.2.3 Reduction of Unaccounted for Water (from 15 – 30% to 10 – 15%)

By the year 2032, the unaccounted for water (UfW) in MMR would have been lowered to 15 – 30% due to the implementation of one of more of the recommended strategies in section 5.3.1.3. By 2052, the UfW will have to be lowered to 10 – 15%. The figure is comparable to the current UfW of global cities such as Singapore and Tokyo.

- **Phasing Out of the Aging Water Supply Network**

Water mains in MMR water supply network are usually made of cast iron, mild steel and ductile iron. Properly designed ductile iron pipe systems could have a useful lifespan of more than 100 years. The lifespan of cast iron and mild steel are approximately 40 – 50 years. Some of the areas in MMR especially Greater Mumbai has a long history of piped water. The water pipes can be more than 100 years old by the year 2052. Inspection of the water supply network has to be carried out to determine the area with aging and dilapidated water pipes. All of these pipes have to be phased out and replaced with new pipes.

- **Phasing Out of Flat Rate Water Tariff**

It is difficult to measure the administrative water losses from the water network without metering system. Hence it is recommended that by 2052, metering systems have to be installed for every household connection in MMR. It means that the flat rate water tariff system has to be replaced with consumption based water tariff. Flat rate tariff does not promote water conservation as the customers are paying the same amount regardless of their water consumption.

5.3.3 Storm Water Drainage – 2032 Goals

5.3.3.1 Creation of Flood Control System to Withstand Storm Event of Up To 50 - Year Return Period

Flood happens annually in MMR due to the inability of the existing drain to cope with the high rainfall intensity during the monsoon season. It is extremely important to create a flood free city because flooding would damage the existing infrastructure facilities and disrupt the life of the people in MMR. During the major flood in July 2005, the rain water caused overflow of the existing sewage system and contamination of the water supply system, disruption the electricity supply and the collapse of the existing drains. To prevent this from ever happening, the flood control system has to be strengthened. New drains, storm water retention pond, flood gate and storm water pumping station should be added. The system has to be designed properly taking into account of the current rainfall intensity and the sea level rise. By 2032, the flood control system has to be able to tackle storm event up to 50 – year return period.

- **Design of the Major Waterway to Withstand Storm Event of Up to 50 – Year Return Period**

To anticipate the climate change and increase in sea level, MMR has to ensure that its waterway has sufficient capacity to withstand storm event with return period of 50 years. Firstly, there should be a thorough study on the existing capacity of the waterway. The current capacity of the waterway may not be the same as the designed capacity. The reduction in capacity could be caused by soil erosion, siltation, solid waste disposal, inflow of raw sewage and construction on the waterway's flood plain area as a result of land scarcity in the city area.

After the completion of the first study, a detailed topographical survey should be conducted to determine the waterway's drainage catchment area. This is essential to study how much runoff will be flowing into a particular waterway. The survey could also help to identify low lying area in MMR.

New Intensity Duration Frequency Curves for MMR has to be plotted based on the latest rainfall intensity data. The current rainfall pattern in MMR has showed an increasing rainfall intensity compared to 50 years ago. The major flood in July 2005 was caused by a record breaking 942 mm of rain in a 24-hour period on 26 July 2015.

The waterway will be split into major and minor waterway by comparing the size of the catchment area. The existing capacity of the existing major waterway will be checked against the rainfall intensity for 50 – year return period from the IDF curve. If it is found to be insufficient, it has to be redesigned to satisfy the new design guidelines. The most straightforward method to increase the capacity will be to deepen and canalize the waterway.

The widening of the waterway will depend on the ownership of the areas surrounding the waterway. If it belongs to the municipal corporation, the widening project could be done immediately. If it belongs to the individual person, the land has to be purchased under the land acquisition act which will cause some delay to the project.

To minimize the project cost, it is best to reserve the area around the major waterway as flood plain area. The flood plain area shall be planted and free from any development. During heavy storm event, the flood plain area will experience occasional flooding but will be dry most of the time.

- **Upgrading of the Existing Storm Water Drainage System**

The first phase of the upgrading project should be targeted at the existing drain network that are more than 50 years old as these drains are designed based on rainfall intensity of less than 50 mm/hour. The drain can be cleaned up, widened, deepened and canalized due to the existing site conditions and land availability.

The next priority should be given to drain upgrading at the flood prone areas. The completed topographical studies could be compared with the existing land use map and new IDF curve to identify the flood prone areas and type of flood that may hit them (tidal flood, urban flood or river flood).

There should be identification and reserve of open space to be converted into storm water holding ponds. The presence of holding ponds will be beneficial for retention of storm water runoff partially. It will greatly reduce the required capacity of the drainage system and save the construction cost.

The storm water drainage system should at least be designed to carry runoff from storm event with return period of 5 years. By the year 2032, the upgrading of the existing storm water drainage system in the urban area should be completed.

- **Use of Mahim Bay Barrage (if implemented) for Flood Control**

Other than functioning as fresh water reservoir (refer to Section 5.3.1.1), Mahim Bay Barrage, if found to be feasible and implemented, can also double up as flood control facility because the area around the Mahim Bay is prone to tidal and river flooding. The flood gate (refer to Figure 5.11) installed at the western boundary of the reservoir (refer to **Error! Reference source not found.**) is used to not only separate the fresh water and the seawater but also to control the water level in the reservoir. When the sea level increases during heavy storm event, the gate will be closed so that the sea water could not infiltrate into the mainland. When the reservoir level exceeds the design level during high tide, the excess water will be pumped out into the sea.

Figure 5.11: London - Thames Barrier
Source: Wikipedia

5.3.3.2 Prohibition of Raw Sewage and Untreated Industrial Effluent Discharge into the Water Bodies

Discharge of raw sewage and untreated industrial effluent into the water bodies through the drainage network is a common practice in MMR. It has polluted numerous water bodies in MMR. The suspended solids in the sewage and industrial effluent could also clog the drain and reduce the effective drain capacity and cause flooding during heavy storm. By 2032 it is targeted that the water bodies and public drain be free from raw sewage and untreated industrial effluent.

- **Enforcement of The Rules On Discharge of Raw Sewage And Industrial Waste**

There should be no discharge of untreated sewage into the water bodies under the Water (Prevention and Control of Pollution) Act. The act has been closely followed by the municipal corporations. However there was no strict enforcement by the authority of this act. It is recommended that each municipal corporation sets up a special committee to enforce this act and closely monitor the water quality in the waterway and drainage network.

- **Treat All the Generated Sewage in MMR**

The municipal corporations also need to be fully committed to the proposed year 2032 goal for sewerage, which is to collect and treat 100% of the generated sewage in the STPs and septic tanks (refer to Section 5.3.5). If all the generated sewage is treated, there will be no inflow of raw sewage into the waterway and drainage network.

5.3.4 Storm Water Drainage – 2052 Goals

5.3.4.1 Creation of Flood Control System to Withstand Storm Event of Up To 100 - Year Return Period

The climate change and increase in sea level is predicted to continue beyond 2032. Hence the effort to strengthen the flood control system in MMR should not stop in 2032. The waterway and the drainage network should be monitored closely. The design guidelines for waterway should be reviewed continuously. By 2052, the flood control system should be upgraded to tackle storm event up to 100 year return period.

- **Design of the Major Waterway to Withstand Storm Event of Up to 50 – Year Return Period**

The survey on the existing waterway capacity and the topographic level in MMR has to be carried out at least every 10 years to provide the latest information of the flood control system and the drainage catchment area.

The capacity of the existing major waterway shall be compared against the estimated runoff based on 100 – year return period. Improvement work will be done on the waterway with inadequate capacity. By the year 2032, land for drain widening will be more limited due to the economic and population growth. The best option for the major waterway will be deepening of the waterway. However, in the case of waterway with sufficient flood plain area, the flood plain area could be converted into part of the waterway.

- **Upgrading of the Existing Storm Water Drainage System**

After the upgrading of the existing storm water drainage system in the urban area is completed in 2032, the upgrading project will be extended to include existing storm water drainage system in the non - urban areas.

5.3.4.2 Beautification of Waterway

As part of storm water management system, waterways do not have to be dull. The area around the waterway could be converted into public space for jogging, cycling, relaxing, etc or developed as part of the landscaping for residential and commercial area (refer to Figure 5.12). To develop the waterway to go beyond landscaping for public place, the waterway could be incorporated into the regional or local master plan to set a direction for the type of development it aimed to be.

- **Clean Up of the Water Quality**

Clean water is an important factor in the waterway beautification. Clean water will be more attractive to the public. Various water sports can also be proposed to be carried out in the waterway.

A special committee can be set up to plan, coordinate and implement the cleanup program because it is an extensive task with multiple projects to be done at the same time. It includes the identification and elimination of the pollution source and installation of debris trapping and water treatment system. Depending on the water quality, cleaning up of the waterway alone may take several years, e.g. it took 10 years in the case of Singapore River.

- **Implementation of Public Private Participation Scheme**

The private sector could be involved in the various stages of the river clean up system such as the master planning for the waterway, designing of the clean up method, landscaping of the surrounding areas, etc. After the completion of the river cleanup project, the plots around the waterway could be sold to the private sector for further development into waterfront residential or commercial projects.

Figure 5.12: Singapore - Riverside Development along Singapore River
Source: SMC Alsop Architect

5.3.5 Sewerage – 2032 Goals

5.3.5.1 Provision of 100% Sewerage Coverage in Urban Area

Sewerage system is as important as the water supply system and forms an integral part of environmental character of a city. Sewage treatment facilities in MMR have been substantially improved over the years to cater to the ever increasing population. The urban areas are connected to centralized sewage collection network and sewage treatment plant. The sewerage network is acknowledged to be only suited to developed areas which enjoy water supply that are plentiful and reliably delivered to household connections. The connectivity of the urban area in MMR to the sewerage network has been significantly higher as compared to the non – urban areas. Any new sewer lines for the urban area can be easily expanded from the existing sewerage network. In 2032, it is targeted that urban area in MMR area are fully connected to the sewerage network.

- **Mapping of Areas that Require Upgrading and Expansion of the Existing Sewerage Network**

Mapping of the areas that required new sewer lines and improvement work are essential to plan for the sewerage network expansion. There are several steps that have to be carried out to map out the sewerage network.

Firstly, detailed topography survey has to be carried out. The same topography survey that was mentioned in Section 5.3.3.1 could be used. The area is then divided into three types of sewerage zones based on the sewage collection method. First zone is the collective sewerage zone where the developments are dense enough for the sewer to be collected by the sewer lines and treated at a centralized treatment plant. Usually, urban areas will fall under this category. The second zone will be the autonomous sewerage zones, where the developments are scattered, not densely populated or geographically impossible for implementation of centralized sewerage network system. The rural and the outskirt areas are usually grouped under this zone. The last zone is the provisional sewerage zone. Non rural areas that cannot be connected to the existing sewerage network due to its geographical location and the reserve site for the future development usually fall under this category. This map is useful to assess the most suitable sanitation facilities for each area.

After the completion of the study, the entire existing sewerage network within the collective sewerage zones should be divided into smaller sub-catchment for the network detection and inspection. The existing sewerage network map shall be checked against the real condition on the ground. Assessment of condition of the existing sewerage network is helpful in assessing the rehabilitation possibilities and comparing option of rehabilitation versus replacing the old system.

All the new developments in the urban area will be automatically connected to the existing sewerage network. There should be comprehensive planning for the urban areas development in MMR so that the treatment capacity of the existing Sewage Treatment Plant (STP) could be increased progressively to cater for the projected population growth.

By 2032, all the improvement and expansion work in the urban areas of MMR have to be completed.

- **Construction of Centralized STP within the Integrated Waste Management Zone**

The volume of the sewage collection will increase significantly once the whole urban area is connected to the sewerage network. The success of achieving the goal to provide 100% sewerage coverage in urban area is dependent on the ability of the sewerage system to cope with increasing raw sewage to be treated. As illustrated in Table 4.2, there will be a treatment capacity deficit of 9,000 MLD by 2032.

Seven STPs will be proposed in MMR to treat the additional raw sewage. The footprint of the STP has to cater to future expansion. All the STPs will be housed together with the other waste management facilities called Integrated Waste Management Zone (refer to Section 5.3.7.2 for detailed explanation of the zone).

5.3.5.2 Provision of Proper Sanitation Facilities in the Rural Area

Based on the mapping of the sewerage zones, the existing conditions of the rural area are assessed to decide on the most appropriate sewerage system. Most of the time, due to the geographical location or low sewage generation in the rural area, it may not be economically viable to connect the rural area to the city's main sewerage network. In such cases, decentralized sewerage system has to be adopted. Currently, the most typical sanitation facilities in the rural area are latrines. Latrines are created by digging a deep hole in the ground to contain the raw sewage. The sewage is not treated and there is a high chance of groundwater contamination if the pit is not properly lined. The main objective of the sanitation program in rural areas is to propose a cost efficient sewerage system that can properly treat the sewage and minimize contamination of the existing environment.

- **Proposal of Onsite Sewage Treatment System**

Onsite sewerage treatment method such as septic tank and waterless toilet shall be proposed to replace the latrine system (refer to Figure 5.13). The selection of the treatment method is made after assessing the cost – benefit analysis of each of method. Rural areas with limited water supply could consider waterless toilet. Little or no water is required for this toilet. Sewage is collected and digested in the composting pile to produce mature compost. Septic tanks could be proposed for rural areas with decent water supply as septic tank operation require water for flushing.

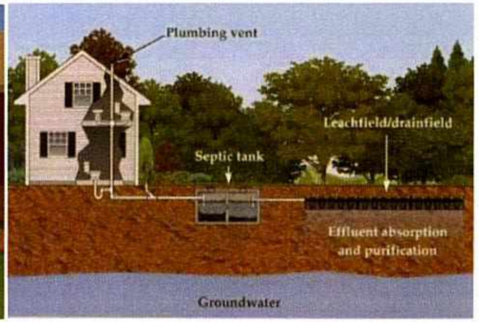

Figure 5.13: Waterless Toilet and Septic Tank
Source: Envirole, The Natural Home -

(i) **Participation in Central Rural Sanitation Program**

Central Rural Sanitation Programme (CRSP) is a program launched by the Central Government of India with the objective of improving the quality of life of the rural people. Demand - driven approach is adopted with by creating awareness of the rural people towards the need for hygienic sanitary facilities to create cleaner environment. The funding comes from Government of India and the State Government.

The program participation level has been low among the rural communities in MMR because the municipal corporations let the Non Governmental Organizations (NGO) to work independently. NGO has an important role in the success of the program as they are responsible for educating the rural people on the importance of rural sanitation, monitoring the project implementation and acting as the middle man between the state government and the rural people. The municipal corporations should work hand in hand with the NGOs by providing the necessary financial, resources and manpower support to increase the participation of the rural communities and success rate of the Central Rural Sanitation Programme.

5.3.5.3 Improvement of Treated Sewage Effluent Quality

Currently, raw sewage, untreated industrial wastewater and treated wastewater effluent are discharged into the creeks and seas daily. The discharged water are of various quality with majority of the effluent exceeds the allowable effluent discharge quality. A series of allowable discharge parameter can be found in the Water Act formulated by Maharashtra Pollution Control Board (MPCB).

A goal to improve the water quality of the existing water bodies and drainage network was set for 2032 (refer to Section 5.3.3.2 and 5.4.4.2). The achievement of this goal depends on the success of the following strategies to improve the effluent discharge quality. All the municipalities in MMR have to fully commit to only discharge effluent that complies with discharge standard set in the Water Act.

- **Upgrade of the Treatment Method of the Existing STP**

The most common treatment method used by the existing STPs in MMR is preliminary treatment followed by the aerated lagoon. This method alone is not sufficient to treat the wastewater up to the standard set by MPCB. Therefore, it is necessary to upgrade the treatment method. Cost – benefit analysis should be carried out to determine feasibility between replacement of the entire treatment system with Membrane Bioreactor system or putting in additional treatment steps such as clarifier, or ultraviolet disinfection, etc. Navi Mumbai has upgraded its existing STPs by adding facultative pond after the aerated lagoon. It has successfully produced higher quality effluent compared to the allowable standards.

Strict enforcement action has to be carried out on the industries that generate high amount of wastewater. The authority could give incentives such as tax reduction scheme to encourage the industries that are able to treat their own wastewater either by upgrading their existing STPs or constructing new STP.

- **Construction of Water Recycling Plant**

With the increase in population and industrial area in MMR, there is a huge amount of wastewater readily available to be recycled. In 2032, MMR is expected to generate 12,512 MLD of wastewater (refer to Table 4.2). Wastewater recycling is similar to the conventional wastewater treatment system, but produces higher effluent quality as it needs to be reused for non potable use as explained in Section 4.3.1 under the alternative water supply source.

In 2032, the goal is to recycle 14% of the wastewater generated in MMR (1,767 MLD) to supply to the commercial and industries for non potable use. It is an achievable target considering that Singapore, Israel and Spain have been able to recycle 30% (486 MLD), 75% (417,000 MLD) and 12% (4,320,000 MLD) within the last 20 years respectively.

- **Collaboration with Private Sector to Commercialise the Recycled Water**

The recycled water is not for direct potable use because the potable water standards, originally developed for natural ground water, may not be appropriate for identifying contaminants in reclaimed water. Pathogens and unknown chemical compounds may be present in reclaimed water. Indirect non-potable use may not be implemented in the short term, as water recycling is still new to MMR. There may be social resistance from the people due to the origin of the recycled water. The most suitable use for the recycled water in the first 5 to 10 years is to sell the recycled water to the industrial and commercial developments for non potable use. There are various uses for recycled water including toilet flushing, gardening, street cleaning, cooling process for power generation plant, etc (refer to Figure 5.14).

There are two ways to encourage the use of recycled water among the private sectors. The authority should put in place new regulation to make it mandatory for private sector to use recycled water for non potable water use. The second is to subsidize the recycle water price as it is usually more expensive than the normal treated water.

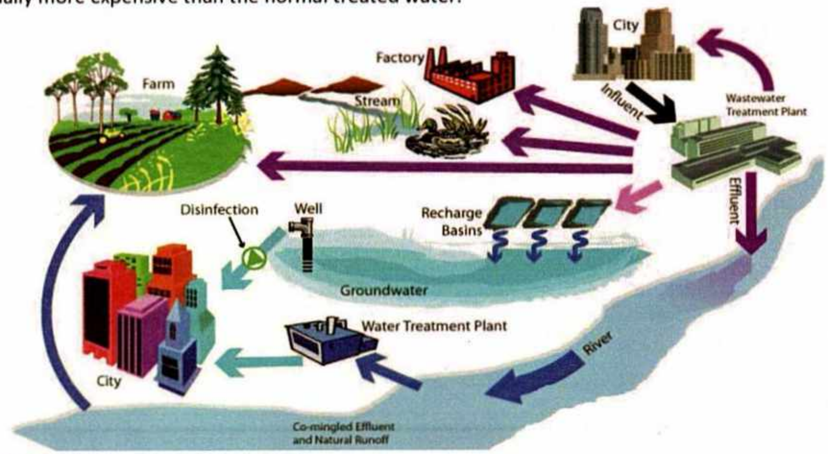

Figure 5.14: Various Use of Recycled Water
Source: California Department of Water Resources

5.3.6 Sewerage – 2052 Goals

5.3.6.1 Provision of 100% Sewerage Coverage in the Entire MMR

By 2032, the people in urban and rural areas should have enjoyed 100% connection to proper sanitation system. Regular inspection and maintenance of the system has to be carried out to ensure the integrity of the sewerage network and facilities. There should be a comprehensive database of the existing sewerage network and sewerage zoning map of MMR upon the completion of the detailed topography and network detection survey.

In 2052, the population and economic growth is expected to increase the sewage generation in MMR by 30%. The sewerage goal in 2052 is to provide 100% sewerage connection to the entire MMR by reaching out to the people in the outskirt areas and to augment the treatment capacity of the existing centralized sewage treatment plant to cater to the increasing sewage generation.

- **Provision of Sanitation System to the Remaining Un-sewered Areas**

After the completion of the upgrading of the sewerage system of the urban and rural areas, the remaining un-sewered outskirt areas that are classified under the provisional sewerage zone should be developed too. To minimize the additional load on the already established sewerage network of the urban area, decentralized approach should be adopted for the outskirt areas. New sewerage network with an onsite STP can be considered.

- **Upgrading of the Capacity of the Existing Centralized STP within Integrated Waste Management Zone**

The sewage generation is estimated to reach 16,062 MLD in 2052 (refer to Table 4.2). The capacity of the existing centralized STP within the designated Integrated Waste Management Zone (IWMZ) shall be upgraded accordingly.

By 2052, all the existing sewage treatment plants outside the IWMZ should have been decommissioned to make way for the transition from decentralized system to centralized sewerage network in the urban area. By having centralized STP to serve a particular area, the authority could reduce the operation and maintenance cost of the treatment plant. Higher plant capacity will bring down the cost. It will also be easier to control the treated effluent quality as all the sewage is going through the same treatment process in the centralised plant.

5.3.7 Solid Waste – 2032 Goals

5.3.7.1 Provision of 100% Solid Waste Management Services in Urban Area

To realize the vision to be a global city, the municipal corporations in MMR has to work together to create a clean and waste free environment. To achieve it, the entire urban area of MMR has to have a comprehensive solid waste management system by 2032.

- **Privatization of Solid Waste Management Services**

Privatization of municipal solid waste (MSW) collection services could improve the overall service quality and reduce cost. The municipalities can be divided into smaller waste collection zones. Each zone can be contracted out to different contractor to establish a competitive market and reduce the risk of having incapable company serving large collection area. The contractor's contract shall be reviewed periodically on a performance basis.

A proper zoning plan that divides the entire area into several sub-regions is important to encourage the privatization of MSW collection. It creates more business opportunities for the contractors. Instead of bidding for the entire area against numerous competitors, contractors now can choose areas to bid for. The zoning plan can prevent the domination of a single company in the market and increase the variety of contractors. Privatization of the solid waste management system is not limited to the collection system, but could also be extended to transportation, disposal, processing, recycling and monitoring of the waste.

The big municipalities such as Greater Mumbai, Thane and Navi Mumbai in MMR have been engaging the service of the private contractor to take care of their solid waste collection system in the urban area. The remaining municipalities should start privatising their solid waste management system progressively.

- **Prolongation of the Lifespan of Dumping Ground and Landfill**

The collected solid waste within MMR will have to be disposed off at a disposal site. All the existing dumping grounds in MMR are only designed with life span of 20 – 40 years with most of them reaching the end of their lifespan soon, especially Deonar and Mulund in Greater Mumbai. Site selection and land acquisition for solid waste disposal site is not an easy task.

While the new disposal site is sourced, it is recommended to implement measures to prolong the lifespan of the existing disposal site to allow for any delay in getting the replacement site. The approach to extend the lifespan of disposal site is by minimizing the amount of solid waste being disposed at the dumping ground.

Waste reduction can be done at different levels. At source, the residents have to make an effort to reduce their individual waste generation by recycling and reusing everything before disposing it. The waste is separated into dry waste and wet waste before it is collected by the contractor. Recycling bin shall be provided at public places and housing estates to collect recyclable items. At the collection level, the contractor has to separate the vehicle used for collection of dry and wet wastes. The vehicles shall be equipped with compactor to reduce the volume of the waste. At the dumping ground, only treated wet waste, inert waste and incineration ash shall be allowed to be disposed at the disposal site

Assuming recycling rate of 30% and successful implementation of the waste reduction program, there should be a 75% reduction of solid waste to be disposed at the disposal site (refer to Table 4.3). This means that the lifespan of the disposal site could be prolonged by 4 times of its designed lifespan.

5.3.7.2 Provision of Proper Solid Waste Disposal and Treatment

Proper disposal and treatment of solid wastes is one of the most important challenges faced by MMR. Currently, municipal solid waste is not treated before disposal in MMR except at Navi Mumbai. Groundwater contamination, toxic gas production, bad odour are several operational problems that could arise from under maintained disposal site. Based on the gap analysis on the solid waste disposal facility in MMR (refer to Table 4.3), there is an urgent need to provide more disposal site with additional capacity of 15,127 tonne/day. The following strategies are recommended to address the issues.

- **Creation of Integrated Waste Management Zone (IWMZ)**

The concept of Integrated Waste Management Zone (IWMZ) is to house all the waste treatment and disposal facilities in the same location. The objective is to integrate waste stream, collection and treatment system into a practical and sustainable system to optimize its environmental benefit, economic value and social acceptability. The main approach of the system is to reduce the amount of waste for final disposal as much as possible based on the fact that by- product generated from one treatment process could be the resource for another treatment process. For example, the toxic landfill gas produced by the landfill is a valuable resource for power generation at the energy-from-waste facility (refer to Figure 5.15 for the complete diagram).

The integrated waste management combines various treatment options including recycling, energy recovery, incineration, etc. The highlight of the system is not on how many high technology waste management options are used but how they are part of an integrated system that is unique to MMR requirements.

Each IWMZ will consist of a sewage treatment plant, a refuse incineration plant and an energy recovery facility. IWMZ are proposed to mainly cater to the urban districts with relatively denser population

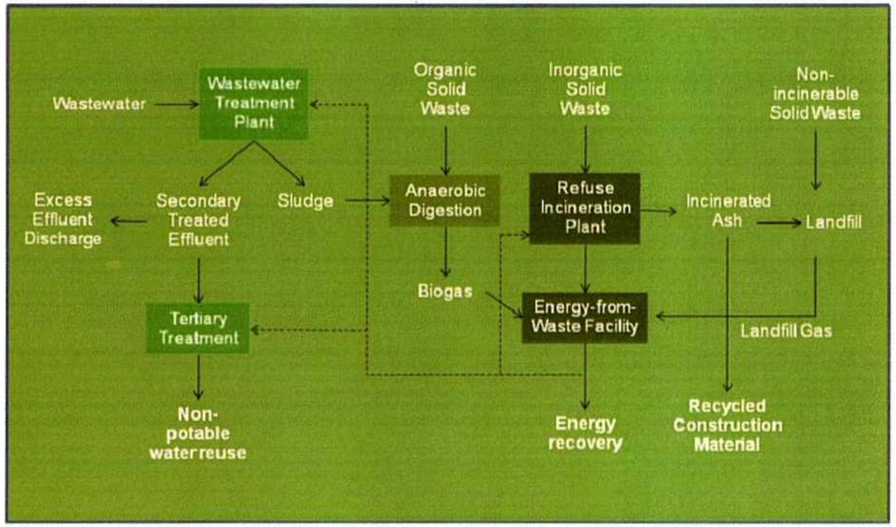

Figure 5.15: Schematic Diagram of Integrated Waste Management Zone
Source: Surbana

Criteria to choose the site for IWMZ are as follows:

- **Low lying area with gentle slope**

  As the zone will house wastewater treatment and reclamation plant, the site has to be located at the lowest area in the sewerage zone so that the sewage could be collected by gravity. Gentle slope is prefered due to the huge footprint of the plants.

- **Proximity to the water bodies**

  The site has to be located near to a major water bodies to discharge the excess treated effluent from the wastewater treatment plant.

- **Accessibility**

  The site has to be accessible by a major road network because there will be daily traffic to transport the solid waste from the city into the refuse incineration plant and from the site to the sanitary landfill for disposal of incinerated ash.

- **Distance from the populated area**

  Due to the presence of various wastes within the IWMZ, the site has to be located far from the populated areas such as residential and commercial areas.

The size of each of the IWMZ is approximately 115 and 170 ha by 2032 and 2052 respectively. It is recommended to acquire land based on the ultimate size requirement which is 170 ha. The excess areas shall be reserved for future expansion (refer to Figure 5.17 for the proposed IWMZ location).

To successfully implement this project, a technical committee with representative from various disciplines such as water supply, sewerage, solid waste and environmental should be set up. It has to set up the framework of the project, conduct feasibility study, source for funding from the central government or the municipal corporations, plan and coordinate the project construction, operation and maintenance. Strong commitment is required from every municipal corporation as this project will require huge allocation of manpower, resources and funding.

- **Energy Recovery from Solid Waste**

Municipal Solid Waste (MSW) contains organic and inorganic matter. By choosing the suitable waste processing technologies, energy can be recovered from the waste. Waste with high organic content is food waste, wood, paper, cardboard, animal waste, etc. The composition of solid waste generated in MMR has been found to contain more than 60% of organic waste; hence it has high potential for implementation energy recovery from waste project.

Other benefits of energy recovery from solid waste are waste reduction (60 – 90%), reduction in demand for landfill hence reduction in the transportation cost of solid waste to the landfill. The main technological for energy recovery is incineration, gasification and biomethanation (refer to Figure 5.16). Preliminary study on the quantity, physical and chemical quality of MMR's municipal solid waste has to be carried out to assess the most suitable recovery technology and the expected energy yield. In the IWMZ, the energy recovered from the waste will be reused for to operate the refuse incineration and wastewater treatment plant.

- **Construction of Integrated Engineered Landfill**

Sanitary land filling of solid waste is a common practice in industrialized countries. However it has barely been initiated in MMR except for the only sanitary landfill owned by NMMC at Thurbe.

For a rapidly growing metropolitan such as MMR, engineered landfills could provide a waste disposal solution that is more environmentally acceptable than open dumping grounds and uncontrolled waste burning. Implementation of controlled landfill can also be linked to public health reasons. Urban residents produce more solid waste per capita than rural residents and large amounts of uncontrolled refuse accumulating in areas of high population density could be the breeding ground for disease.

A sanitary landfill (refer to Figure 5.16) should have the following features:

- Full or partial hydro-geological isolation
- The landfill shall be properly lined to protect the soil and groundwater from the leachate. Onsite leachate collection and treatment system must be provided.
- Formal engineering preparations
- The landfill designs should be developed based on geological and hydro - geological investigations.
- Permanent control of the landfill operation
- Trained staff should be based at the landfill to supervise the site regular operation and maintenance process. He has to ensure that the landfill operates based on the approved waste disposal plan.
- Permanent cover of the waste

The land filled waste should be spread in layers and compacted. After that it has to be covered with earth to contain the smell.

The land area required for the sanitary landfill in MMR is 360 ha and 475 ha by 2032 and 2052 respectively. Due to the massive footprint required for the sanitary landfill, the landfill site will not be part of IWMZ. One sanitary landfill will serve one IWMZ. However it could be split into several smaller landfills if there is a difficulty in the land acquisition process.

Figure 5.16: Chennai Biomethanation Plant and Puente Hills Sanitary Landfill
Source: Chennai Metropolitan Development Authority, Sanitation District of Los Angeles County

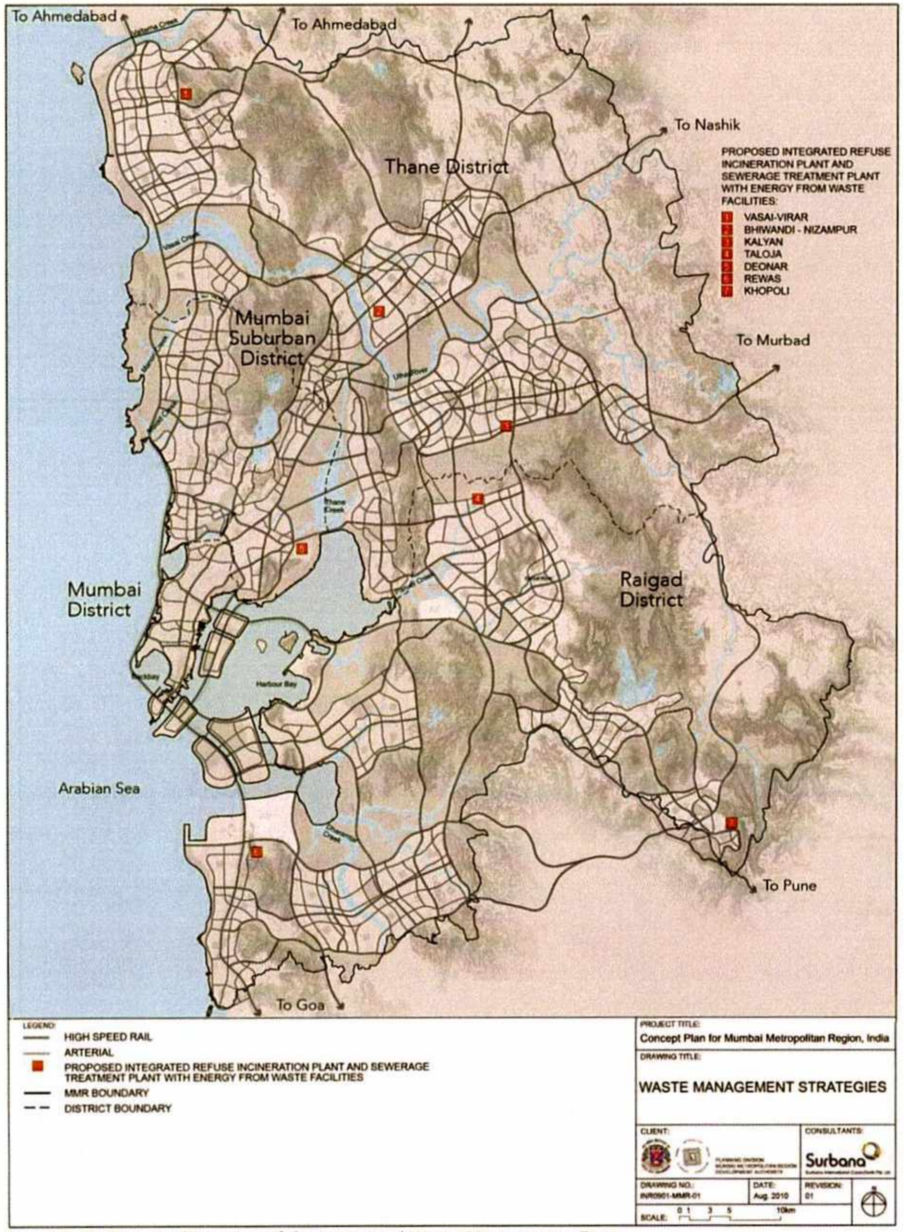

Figure 5.17: Proposed Location of the Integrated Waste Management Zone
Source: Surbana

5.3.8 Solid Waste – 2052 Goals

5.3.8.1 Phasing Out of Unlined Dumping Ground

With the implementation of the Integrated Waste Management Zone, there should be no more open dumping ground in the urban area. By providing proper closure to the dumping grounds, such dumping grounds will be phased out entirely from MMR solid waste management system. After 30 years, the closed dumping ground could be reused for developments such as parks or golf courses.

- **Inspection and Monitoring of Inactive Dumping Ground**

All the dumping grounds in MMR that had ceased operation prior to the closure of Gorai Dumping Site in Greater Mumbai were not scientifically closed. Regular inspection and monitoring of the sites have to be carried out to make sure that there is no water resources contamination from leachate and no explosion hazard from the landfill gas generated by the decaying buried waste.

- **Scientific Closure of Dumping Ground at the End of Its Lifespan**

All the currently operational dumping ground would have reached the end of their lifespan by 2052. These sites have the potential to cause adverse impacts to public health, safety, and the environment from the leachate and landfill gas generation in the long run. A variety of unwanted materials, such as contaminated soils, construction waste could be used to provide a foundation layer for final cover materials to reduce the closure cost. After the dumping ground is properly capped, the dumping ground operator has to maintain and monitor the site for up to 30 years.

5.3.8.2 Provision of 100% Solid Waste Management Services in the Entire MMR

After achieving the goal to provide 100% Solid Waste Management Services coverage for the urban area in MMR, it is targeted to increase the coverage of the solid waste collection management services for non – urban areas. Based on the gap analysis on the solid waste disposal facility in MMR (refer to Table 4.3), there is an urgent need to provide more treatment capacity and landfill sites with additional capacity of 15,127 tonne/day.

- **Upgrading of the Capacity of the Existing Solid Waste Management Facilities within the IWMZ**

The projected solid waste generation in 2052 is 77,528 tonne/d. The effort in recycling and incineration is expected to reduce the amount of waste to be disposed off at the landfill. However, there is still an additional 4,848 tonne of solid waste that has to be disposed off. To this end, each of the landfill area should be expanded from 360 ha to 475 ha. The incineration plant capacity will also need to be increased by 60%.

5.4 The Way Forward

Infrastructure goals and strategies for year 2032 and 2052 have been discussed in details in the previous sections. The 2032 goals focus on providing 100% infrastructure services for the urban areas. The recommended strategies described for 2032 are integrated with plan to augment the existing capacity of the infrastructure system.

The expansion of the existing infrastructure network and systems can be carried out progressively over the next 22 years to achieve the goals set for year 2032 as there are already considerable infrastructure network and coverage in the urban area. A lot of the proposed solutions are new for MMR. This period is the critical phase of assessing the feasibility of all the proposed projects in MMR. Various preliminary and feasibility study of the existing site conditions and the proposed technologies have to be carried out. All the approved infrastructure projects will be given priority to be completed by 2020.

The short term recommendations to be implemented by 2020 are listed in Table 5.4.

Table 5.4: Short Term Recommendations by 2020

Infrastructure	2020
Water Supply	• To replace the leaking water supply pipe; • To set up a centralized water agency to coordinate the water supply planning within MMR; • To complete the construction of the approved water supply projects (Shai Dam, Kalu Dam, Gargai Dam, etc); • To carry out water yield and feasibility study on Thane Creek Reservoir project.
Storm Water Drainage	• To upgrade the existing dilapidated storm water drain; • To implement the improvement works recommended in BRIMSTOWAD such as canalization of the Mithi River and widening of Pohisar, Dahisar and Oshiware River; • To reconstruct and widen the existing nallas ; • To carry out detailed topography survey to map the existing storm water catchment; • To identify all the flood prone areas in MMR; • To carry out water yield and feasibility study on Mahim Bay Barrage Project. • To clean up the river within the catchment area of Mahim Bay and Thane Creek;
Sewerage	• To replace the leaking sewer pipe; • To increase the participation of slum dwellers in the Slum Sanitation Program; • To complete the upgrading of the approved sewerage treatment plants; • To carry out detailed topography survey to map the existing sewerage zones.
Solid Waste Management	• To source for suitable site for Integrated Waste Management Zone; • To rehabilitate the existing dumping ground by lining it with landfill liner; • To prepare the transition process from open dumping ground to landfill to incineration; • To prepare the regulation on the operation of landfill and incineration plant; • To carry out feasibility study on the solid waste characteristic in MMR.

Source: Surbana

CHAPTER 6: CASE STUDIES AND BENCHMARKING

This chapter presents the key findings of the infrastructure system focusing on water management and solid waste management in two global cities in the world: Singapore and Netherland. The policies and strategies adopted by these two cities were elaborated in this chapter to justify the goals set for MMR to develop its future infrastructure system to a higher standard in order to realize its vision to be a global city.

Singapore is chosen because it has successfully provided reliable and good infrastructure to its people, especially a high quality of water supply despite the lack of natural water resources. Its success in the development of NEWater, an ultra pure recycled wastewater, has been a breakthrough in the water recycling industry. Its integrated solid waste management project has also been instrumental in creating the clean environment that can be enjoyed by all the residents.

Netherland is another global city with good infrastructure system. Despite located below the sea level, it has been able to strengthen its sea and river defence against flooding. It has the most extensive flood control system after centuries of experience fighting against flood.

6.1 Singapore – Water Resource Management Project

6.1.1 Background

Public Utilities Board (PUB) is Singapore's national water agency. PUB is responsible for the collection, production, distribution and reclamation of water in Singapore. Four decades ago, Singapore was faced with water shortages, flooding and water pollution problem. PUB had assisted in Singapore transformation into a nation with robust, integrated and sustainable water supply source commonly known as the Four National Taps. Flooding problem has been greatly minimized while drains, rivers and waterways are cleaned up and beautified as part of Singapore's vision to create a city of garden and water through the Active Beautiful Clean (ABC) Water Programme.

6.1.2 Strategies

6.1.2.1 Four National Tap

Singapore relies on 4 National Tap as water sources, they are:

- **Imported Water from Malaysia (40% supply)**

Singapore has been importing water from Malaysia to supply half of the water consumption in Singapore for decades under the two bilateral agreements which are due to expire by 2011 and 2061 respectively. There has been an ongoing dispute between two countries on the price of the supplied water. To safeguard the country's water supply, Singapore has been progressively reducing its dependence on imported water by focusing on alternative water supply.

- **Reclaimed Water (30%)**

NEWater is Singapore's brand name for treated wastewater that is further purified with dual membrane and ultraviolet technology after the conventional water treatment. Water reclamation industry had been introduced in the 1970s but the implementation was deterred by the unreliable technology and high cost. Singapore's commitment to invest in research and technology to close the water loop coupled with the advancement in membrane technology and decreasing membrane prices, NEWater was born in 2003.

NEWater is potable and very pure. The water quality has passed the World Health Organisation requirements. Currently, it is injected back into the reservoirs as indirect potable use and sold to industries that require high grade water. The development of NEWater helped Singapore to close its water loop and improve the sustainability of its water supply system (refer to Figure 6.1)

NEWater is ideal for industry that requires supply of ultra pure water, such as wafer fabrication processes. It is currently sold to wafer fabrication, electronics and power generation industries as well as commercial and institutional complexes. This has freed a big bulk of the potable water for domestic use.

Currently there are 5 NEWater plants in operation to supply 30% of Singapore's total water demand.

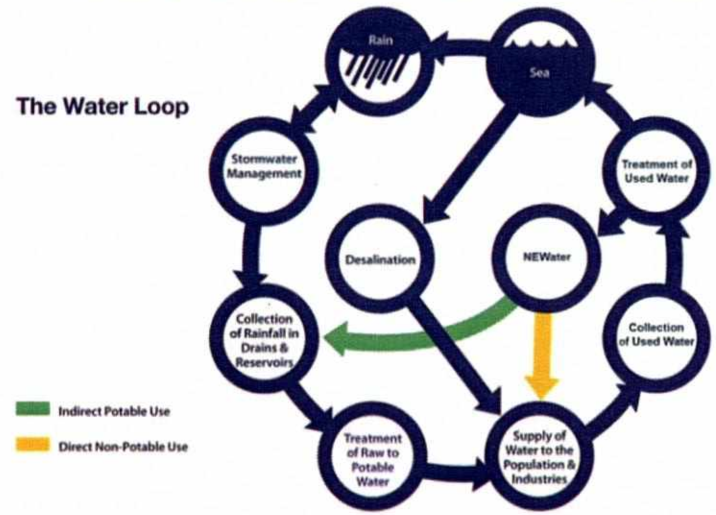

Figure 6.1: Singapore – Closing Water Loop
Source: PUB

- Rainfall (20%)

Singapore is harvesting as much rainfall as possible through a comprehensive network of drains, canals, rivers and storm water collection ponds due to the absence of natural aquifer and lakes. All the storm waters are channelled into its various reservoirs for storage. Currently, Singapore has 19 reservoirs that capture storm water from two thirds of Singapore land area. This makes Singapore one of the few countries in the world that harvests urban storm water on a large scale for its water supply. To maximize the harvested rainwater amount, residents are allowed to harvest rainwater for their domestic use.

- Seawater Desalination (10%)

Singapore has 1 seawater desalination plant with total capacity of 140 MLD. It is one of the largest plant in the world at the moment. The plant is using the same technology adopted in the production of NEWater. The seawater will first go through a pre-treatment process to remove the suspended solids before undergoing reverse osmosis process. The treated water will be mixed with the treated potable water before it is distributed to the end users.

6.1.2.2 ABC Water Programme

ABC Water Programme was introduced by PUB in 2006 to fulfil the Singapore's vision to transform the City into a city of garden and water. It aims to transform Singapore's reservoirs and waterways beyond their functional uses of water storage and conveyance so that people are able to enjoy recreational activities around them. Streams, rivers and lakes will be designed with the following concepts in mind: dynamic, full of live and activities for the public (Active), aesthetically pleasing (Beautiful) with good water quality (Clean).

Numerous projects have been completed at Bedok Reservoir, MacRitchie Reservoir and most recently Marina Barrage, transforming the surrounding areas into vibrant hotspots for the community.

- Marina Barrage

Marina Barrage is the latest addition to Singapore numerous reservoirs. It is a fresh water dam built across the 350-metre wide Marina Channel to keep out seawater. It was launched on 1 November 2008. It is the first reservoir to be located in the city area of Singapore.

The main function of Marina Barrage is to increase Singapore fresh water supply. With the barrage keeping out the seawater, the seawater within the reservoir is expected to turn into fresh water by 2011 through natural flushing. Thereafter, the water in the reservoir will be harvested and treated using advanced membrane technology for consumption. It is designed to meet 10% of Singapore's current water demand.

Marina Barrage is also designed as part of comprehensive flood control scheme to alleviate flooding issue in the low lying areas within its vicinity. Nine crest gates will release excess storm water into the sea during heavy rain and low tide (refer to Figure 6.2). In the case of high tide, seven massive pumps will pump the excess water out into the sea.

As the water level in Marina Barrage is kept at a constant level, it is ideal for all kinds of recreational and water sport activities such as boating, windsurfing, kayaking, etc. Public can visit the grass carpeted green roof and solar park on top of the building, stroll along the Marina Bridge and eight viewing decks overlooking Marina reservoir to enjoy the panoramic cityscape (refer to Figure 6.2).

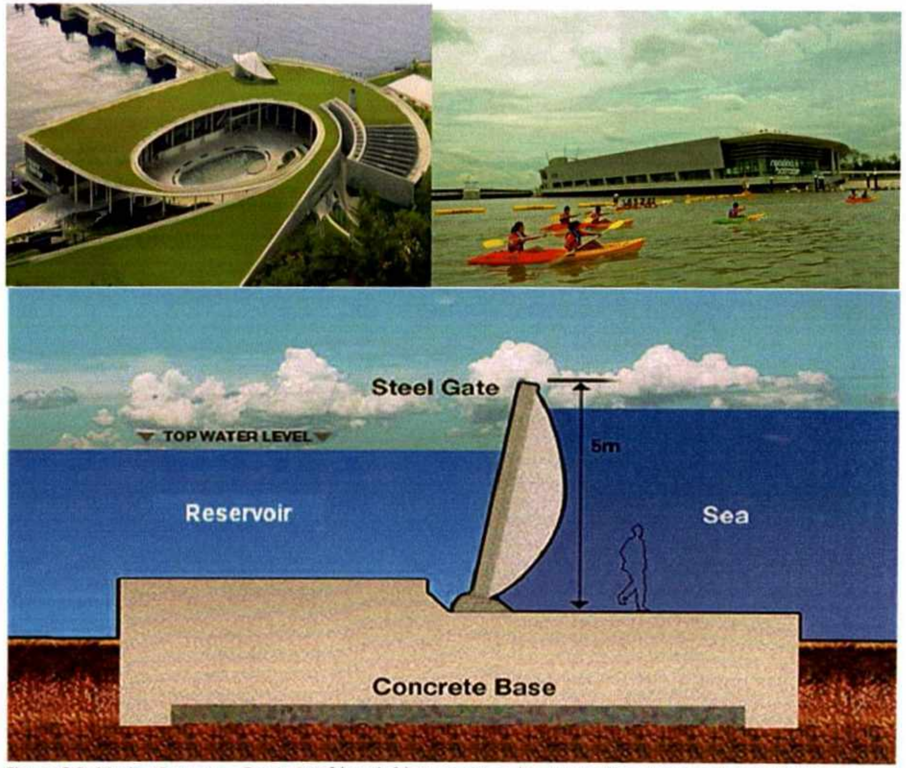

Figure 6.2: Marina Barrage – Green Roof (top left), Recreational Activities (top right) and Crest Gates (bottom)
Source: PUB

6.1.2.3 Public-Private Participation

PUB has initiated 3 water supply projects on under public – private partnership initiative. They are SingSpring Desalination Plant, Keppel Seghers Ulu Pandan NEWater Plant and Sembcorp Changi NEWater Plant (refer to Figure 6.3). Various reasons behind PUB's decision to involve the private sector are:

- **To built vibrant water industry in Singapore.**

Local companies will be able to build their expertise and track record in water industry and compete with the international players in the overseas market

- **To keep the cost affordable.**

In the case of desalination, there are various desalination methods that are currently being used. They are all costly and energy intensive. By calling tender for this project, private sectors were able to select and optimize the technology configuration to offer PUB a competitive price for the desalinated water.

- **To increase the quality of the project.**

The participating company has to comply with PUB's technical specifications. As the contract is evaluated on a performance basis, the quality of the products offered to the public will be of good quality.

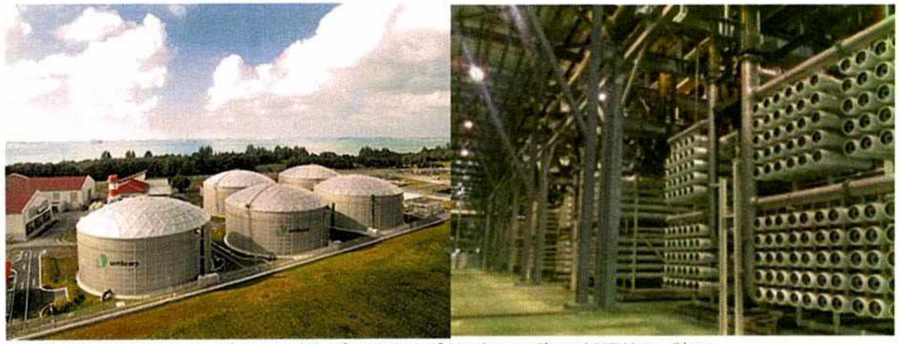

Figure 6.3: The External and Internal Configuration of Sembcorp Changi NEWater Plant
Source: Strait Times, Mena Infrastructure

6.1.3 Learning Points for MMR

The learning points for MMR are summarized in Table 6.1.

Table 6.1: Learning Points for MMR from Singapore Water Management System

Learning Points	Strategies
Use of technology to provide alternative source for water supply	• Seawater desalination; • Wastewater recycling; • Rainwater harvesting.
Development of water resources beyond functional use	• Beautification of the existing waterways, reservoirs or rivers; • Incorporation of the water features into the upcoming commercial and residential development.
Effective public private participation scheme	• Inviting public sector to tender for public water supply project; • Involve local industries to built the water industry; • Knowledge sharing with the private sector.
Public education	• Educate public on good practices to conserve water.

Source: Surbana

6.2 Singapore – Solid Waste Management

6.2.1 Background

The National Environment Agency (NEA) has overall responsibility for the planning, development and management of solid waste disposal facilities and operations in Singapore. This includes the licensing and regulation of solid waste collection and enforcement of illegal dumping. Despite the scarcity of land and the dense population, NEA has been able to plan effective and efficient solid waste disposal system. The overall waste management strategy of NEA is waste minimization and recycling. Singapore generates almost 15,000 tonnes of solid waste daily. Currently, about 54% of the solid waste is recycled with the remaining 43% incinerated and 3% disposed at the landfill directly.

6.2.2 Strategies

6.2.2.1 Waste to Energy Incineration Plant

Wastes that are not recyclable are sent to the waste-to-energy incineration plants. Incineration is the most suitable treatment method for Singapore as it reduces 80 to 90% of the waste volume resulting in lesser ash to be disposed and lesser amount of land required for landfill.

Incineration produces flue gases that can cause air pollution. These gases are treated with lime powder and electrostatic precipitators before they are released into the atmosphere. The plants use no fuel for the incineration. The heat generated by the incineration process at Singapore's four incineration plant is recovered to generate electricity to run the plant while the excess electricity is sold to the power supply provider. The resulting incineration ash is subsequently disposed at Semakau Landfill.

6.2.2.2 Recycling

43% of solid waste generated in Singapore is recycled. Recycling helps to recover valuable resources such as ferrous metal, glass, scrap tyres, timbers etc and minimise the need for waste disposal. Singapore has also launched a National Recycling Programme (NRP) to provide door-to-door collection services for recyclables waste. Since 2007, centralised recycling bins are provided for every 5 blocks of flats in HDB estates to encourage Singaporeans to recycle. NEA has also created educational programmes and campaigns to improve Singaporeans' knowledge of recycling.

6.2.2.3 Sustainable Landfill

Semakau landfill, the only sanitary landfill in Singapore, is located offshore on a reclaimed island (refer to Figure 6.4). Every day, the incinerated ash is transported to the island by a covered barge from Singapore's four of the incineration plants. A disposal fee is charged for disposing waste at the landfill based on full cost recovery to minimize waste and encourage recycling.

The landfill was scientifically designed to ensure that the site is clean, odour free and scenic. The landfill is lined with impermeable membrane to keep the surrounding water from contamination. Regular testing is carried out on the liners to ensure that its integrity. The land filled waste are properly covered with earth and planted with grass. The leachate is collected and treated in the leachate treatment plant onsite.

Currently, the landfill is a home of various birds and marine creature. It is also open for public to do recreational activities such as fishing, bird watching, recreational outing etc. At the end of its lifespan, the landfill will be converted into an eco - park which will be used for recreational and research facilities of renewable and clean technologies.

Figure 6.4: Tuas South Incineration Plant and Semakau Landfill
Source: NEA, Samwoh

6.2.3 Learning Points for MMR

The learning points for MMR are summarized in Table 6.2.

Table 6.2: Learning Points for MMR from Singapore Solid Waste Management System

Learning Points	Strategies
Waste Minimization	• Recovery of valuable resources by recycling; • Volume reduction by processing the waste at the incineration plants; • Fee collection for solid waste disposal at the incineration plant and landfill.
Sanitary Landfill	• Selection of site that is far from the populated area; • Properly designed landfill to create clean and odour free landfill so that it can be used by public for recreational purpose;
Public education	• Setting up of National Recycling Program to collect the recyclable waste from the household directly; • Creation of educational program to increase the public awareness on recycling;
Public private participation scheme	• Invitation to the public sector to tender for setting up the incineration plant; • The use of private contractor to collect all the solid waste generated in Singapore; • Tax incentive scheme for business owner who uses energy saving machines for its business.

Source: Surbana

6.3 Netherland - Flood Control System

6.3.1 Background

Netherland is vulnerable to flooding because of its topography and geographical location. A quarter of the country is below the sea level with the lowest point at 6.76m below sea level. Netherland is also situated in the delta of 3 major rivers in Europe which consist of Rhine, Meuse and Scheldt. These two factors combined with the increasing seawater level could cause flooding in Netherland if they are not handled properly.

Netherland has been strengthening its coastal and river defences by constructing complicated and extensive system. It consists of drainage ditches, canal, pumping stations, flood gate, storm surge barrier and dikes. Some of these structures can be dated back to 11^{th} century. The flood control system is managed by Dutch Water Board. It is responsible for managing the water barriers, the waterways, the water levels, and the water quality in its region.

6.3.2 Strategies

6.3.2.1 Construction of Extensive Flood Control System

One of the most famous flood control system in the works is Delta Works. This project was built between 1950 and 1997 to protect the southwest of Netherland around the Rhine-Meuse-Scheldt delta from the sea. The extensive network consist of dams, sluices, locks, dikes, levies, and storm surge barriers. The aim of the dams, sluices, and storm surge barriers was to reduce the number of dikes that had to be raised by shortening the Dutch coastline. It is declared by American Society of Civil Engineers as one of the seven wonders of the modern world.

The project was finished in 1997 with the completion of the Maeslantkering Storm Surge Barrier in the Nieuwe Waterweg and the Hartelkering Storm Surge Barrier in the Hartel Canal near Spijkenisse.

The Maeslantkering Storm Surge Barrier is one of largest moving structures on Earth (refer to Figure 6.5). It is located between the towns of Hoek van Holland and Maassluis. The storm surge barrier was built to protect Rotterdam harbour and the surrounding towns and agricultural areas from flooding. Originally reinforcement of existing dikes at the harbour was proposed. However due to the complexity and the cost of the work, the storm surge barrier was proposed as an alternative. It is designed to withstand storm event of 1 in every 10,000 years.

The storm surge barrier is controlled by a self-operating computer system which is linked to weather and sea level data. Under normal weather conditions, the two doors are opened providing 360 meter wide of passageway for the ships to pass. The doors will be closed automatically if a storm surge of 3 meters above normal sea level is expected in Rotterdam.

6.3.2.2 Continuous Planning to Anticipate the Effect of Climate Change and Sea Level Rise

The Dutch have been constructing dikes and flood control structures for many centuries to strengthen their sea and river defences. They are constantly coming up with innovative project that are specifically engineered for Netherland's unique condition such as innovative flood surge barriers like the Eastern Scheldt Barrier (refer to Figure 6.6), which has movable components to make sure the unique ecology of this estuary was not damaged by closing it from the sea, the Maeslantkering barrier and the Ramspol barrier.

In order to arm the country with the effect of climate change, various inspection and monitoring system are developed to gather information on the strength of the existing flood control structures on a continuous basis by using remote sensing, satellite information and GIS modelling. Dikes has been rebuilt, heightened and reinforced to safeguard against the rising sea level rise.

Design guidelines for the flood control structures are constantly updated depending on the climate condition. At this moment, in North and South Holland, the most flood prone area in Netherland, the major flood control structures has to be designed to withstand storm with occurrence of up to 1 in 10,000 years.

Figure 6.5: Maeslant Storm Surge Barrier
Source: Official Site of Holland

Figure 6.6: Eastern Scheldt Barrier
Source: Official Site of Holland

6.3.3 Learning Points for MMR

The learning points for MMR are summarized inTable 6.2.

Table 6.3: Learning Points for MMR from Netherland Flood Management System

Learning Points	Strategies
Construction of flood control system	• Construction of storm surge barrier; • Construction of flood gates; • Constant upgrading of the existing infrastructure.
Systematic monitoring process	• Setting up of various system to monitor the existing condition of the flood control structure; • Regular review of the design guidelines for the major flood control structure;
Strong funding commitment	• Delta Work cost an estimated $7 billion of which 15% was spent on fundamental research.

Source: Surbana

BIBLIOGRAPHY

Key Publications

- Central Water and Power Research Station (2006). *1-D Mathematical Model and Desk Studies for Mitigating Floods of Mithi River in Mumbai.* Mumbai Metropolitan Region Development Authority.
- Center for Environmental Science and Engineering Indian Institute of Technology (2006). *Development of Action Plan for Environmental Improvement of Mithi River and Along its Banks.* Center for Environmental Science and Engineering Indian Institute of Technology
- Chitale Committee. Fact Finding Committee on Mumbai Floods (2006). Government of Maharashtra.
- Dr. J. V. Modi et al (2002). *Action Plan for Implementation of MSW Rules 2000 in Maharastra.* All India Institute of Local Self Government
- Maharashtra Jeevan Pradhikaran (2006). *Disaster Management by Interlinking Various Water Works in Mumbai Metropolitan Area.* Government of Maharashtra – Water Supply and Sanitation Department.
- Maharashtra Water Supply and Sanitation Department (2006). *Disaster Management by Interlinking Water Works in Mumbai Metropolitan Area.* Government of Maharashtra – Water Supply and Sanitation Department.
- Municipal Corporation of Greater Mumbai (2009). *Environment Status of Brihan Mumbai 2008 – 2009.* Municipal Corporation of Greater Mumbai.
- Municipal Corporation of Greater Mumbai (2002). *Final Feasibility Report for IIIA Mumbai Water Supply Project - Volume 1 & 2.* Municipal Corporation of Greater Mumbai.
- Thane Municipal Corporation (2005). *City Development Plan.* Thane Municipal Corporation.
- Water and Power Consultancy Services (India) Limited (2007). *Study on Flood Mitigation for Dahisar, Poisar and Oshiware Rivers in North Mumbai.* Mumbai Metropolitan Region Development Authority.

Web Sources

- Appraisal of City Development Plan - Kulgaon Badlapur. Retrieved June 2010, from http://www.niua.org/jnnurm/CDP%20Appraisal_Kulgaon%20-%20Badlapur_NIUA.pdf
- Appraisal of City Development Plan - Mira Bhayander. Retrieved June 2010, from http://www.niua.org/jnnurm/CDP%20Appraisal_Mira%20Bhayandar_NIUA.pdf
- Appraisal of City Development - Navi Mumbai. Retrieved June 2010, from http://www.niua.org/jnnurm/CDP%20Appraisal_NAVI%20MUMBAI_NIUA.pdf
- Appraisal of City Development – Ulhasnagar. Retrieved June 2010, from http://www.niua.org/jnnurm/CDP%20Appraisal_Ulhasnagar_NIUA.pdf
- Conducting a Water Audit. Retrieved June 2010, from http://nalno.com/communications/50-communication-articles/109-conducting-a-water-audit
- Greater Mumbai City Development Plan (2005 to 2025). Retrieved December 2009, from http://www.mcgm.gov.in/irj/portal/anonymous?NavigationTarget=navurl://095e1c7b9486b1423b881dce8b106978
- Guidelines on Central Rural Sanitation Programme (June 2010). Retrieved July 2010, from http://www.indiaenvironmentportal.org.in/files/TSC%20GUIDELINES%20%20June%202010.pdf
- How Waterless Toilet Works. Retrieved June 2010, from http://science.howstuffworks.com/environmental/green-tech/sustainable/waterless-toilet.htm
- Increasing Storm Water Drainage Capacity of Mithi River and Mumbai City Drains. Retrieved December, 2009 from http://emi.pdc.org/soundpractices/Mumbai/SP1-Mumbai-Mithi-river.pdf
- India National Drinking Water Mission. Retrieved December, 2009 from Retrieved June, 2010.
- India Total Sanitation Campaign. Retrieved December, 2009 from http://mahawssd.gov.in/home.html
- Managing Urban Water Supply and Sanitation: Operation and Maintenance. Retrieved June, 2010 from http://www.gdrc.org/uem/water/wb-urbanwater.html
- Mumbai Water Supply – Understanding Our Civic Issues. Retrieved December 2009, from http://www.bcpt.org.in/webadmin/publications/pubimages/watersupply.pdf
- MMRDA to build dams, create water systems. Retrieved May 2010, from http://www.projectsmonitor.com/NEWPROJECTS/mmrda-to-build-dams-create-water-systems
- Municipal Solid Waste (Management and Handling) Rules, 2000. Retrieved December 2009, from http://www.nls.ac.in/CEERA/ceerafeb04/html/documents/Muncipalsoildwaste.htm
- Municipal Solid Waste Management - Model Tender Documents for MSW Management. Retrieved June 2010,from http://mpcb.gov.in/muncipal/modeltender.php
- NMMC – Environmental Status Report (2006 – 2007). Retrieved December 2009, from http://www.nmmconline.com/english/services/data/esr2006_07/summary.pdf
- Navi Mumbai City Development Plan – 2031. Retrieved December 2009, from http://www.nmmconline.com/CDP/cdpMain.php
- Navi Mumbai - Existing Infrastructure. Retrieved December 2009, from http://www.nmmconline.com/CDP/bin/cdpData/Chapter-3.pdf
- Public Private Partnership in Drinking Water Supply of Greater Mumbai. Retrieved December 2009, from http://webcache.googleusercontent.com/search?q=cache:iD1TKVyJr5QJ:www.esocialsciences.com/data/articles/Document1122200890.1991541.doc+m
- Regional Plan for Mumbai Metropolitan Region 1996 – 2011. Retrieved December 2009, from http://www.regionalplan-mmrda.org/
- Sanitation System in Mumbai - Understanding Our Civic Issue. Retrieved December 2009, from http://www.bcpt.org.in/webadmin/publications/pubimages/sanitation.pdf
- Solid Waste and Storm Water Initiatives. Retrieved December 2009, from http://www.mcgm.gov.in/irj/portal/anonymous?NavigationTarget=navurl://460f603d5843609f6e3ee9eae76c67b3
- Solid Waste Management. Retrieved December 2009, from http://www.mcgm.gov.in/irj/portalapps/com.mcgm.ahome_keyprojects/docs/2-7%20Solid%20Waste%20Management.pdf
- Solid Waste Management - Understanding Our Civic Issues. Retrieved December 2009,from http://www.bcpt.org.in/webadmin/publications/pubimages/solidwaste.pdf

- Storm Water Drainage. Retrieved December, 2009 from http://www.mcgm.gov.in/irj/portalapps/com.mcgm.ahome_keyprojects/docs/2-6 Storm Water Drainage.pdf
- The Application of Experience in European Integrated Waste Management to Latin America Conditions. Retrieved August 2010, from http://www.bvsde.paho.org/bvsacd/acodal/ii.pdf
- Urban Notes Thematic Group on Services to the Urban Poor. Retrieved December2009, from http://www.archidev.org/IMG/pdf/The_Slum_Sanitation_Program_in_Mumbai_India.pdf
- Urban Poor Community Participation for Improved Sanitation. Retrieved December2009, from http://www.indiaurbanportal.in/bestpractice/national/BP-Cities/maharashtra/mumbai_urbanpoor.pdf
- Water Conservation and Rainwater Harvesting for Brihanmumbai. Retrieved December 2009, from http://www.mcgm.gov.in/irj/portalapps/com.mcgm.solidwastemanagement/docs/RWH_E1.pdf
- Water Resource Planning and Development. Retrieved December, 2009, from http://www.regionalplan-mmrda.org/N-10.pdf