Republic of India

Chennai Metropolitan Water Supply and Sewerage Board

Republic of India
Preparatory Survey on Chennai Seawater Desalination Plant Project

Final Report

February 2017

Japan International Cooperation Agency (JICA)

Nippon Koei Co., Ltd.
INGÉROSEC Corporation
Nippon Koei India Pvt. Ltd.

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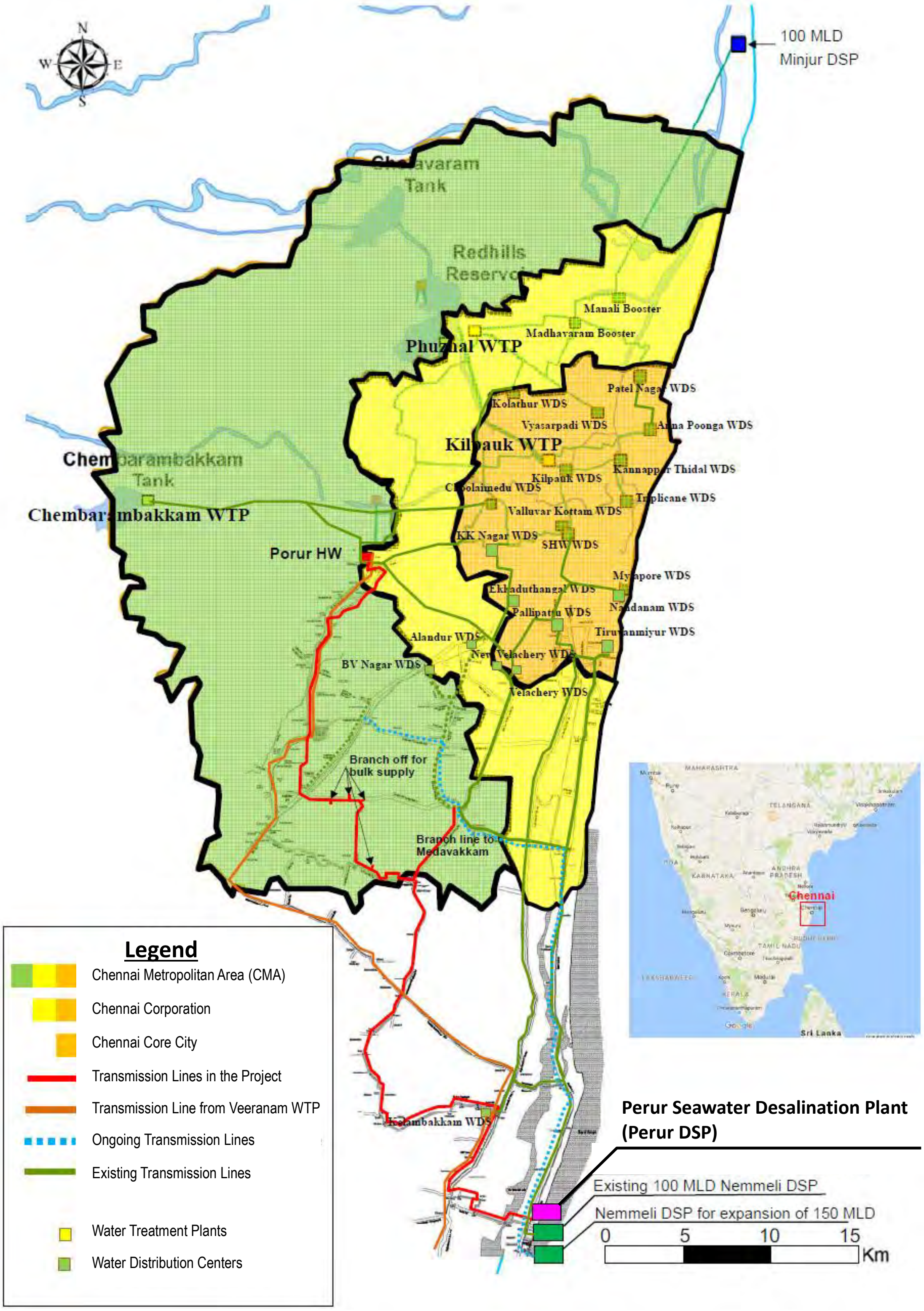
In this Final Report, the following exchange rates have been adopted.

(1) USD 1 = JPY 116.0 (December 2016 monthly average from Bank of Japan data)

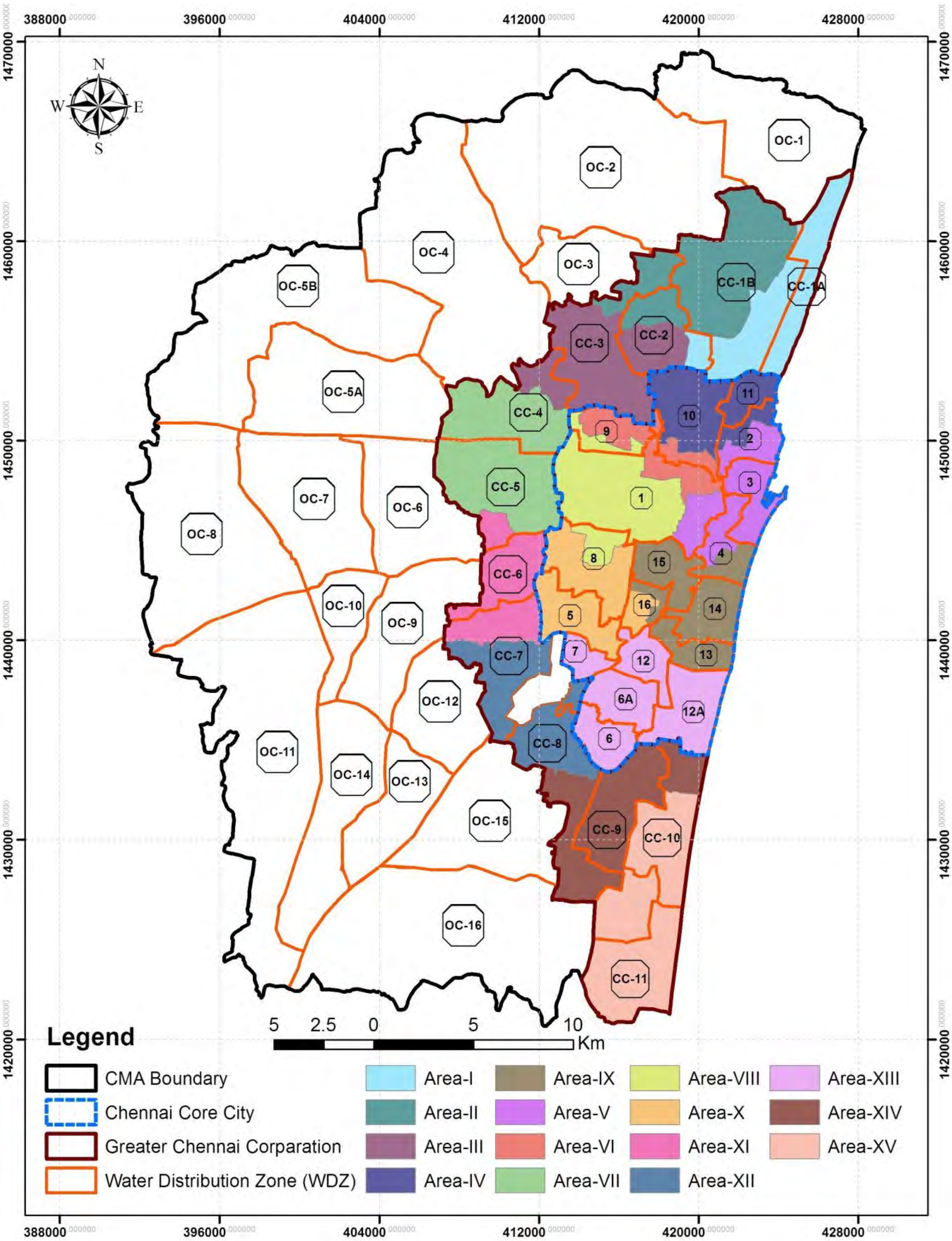
(2) USD 1 = INR 67.9 (December 2016 monthly average from Reserve Bank of India data)

(3) INR 1=JPY 1.71 (calculated by dividing (1) by (2) above)



Study Area-1

(Locations of the Existing and Planned Major Facilities of CMWSSB)



Study Area-2

(Boundaries of Administration Areas and Water Distribution Zones of CMWSSB)

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List of Abbreviations

AA	Administrative approval
AAOD	Annual Average Occurrence Days
AC	Asbestos Cement
ACR	Annual Confidential Report
AE	Assistant Engineer
AEE	Assistant Executive Engineer
AIS	Air-insulated Switchgear
AMIC	Amritsar Kolkata Industrial Corridor
AMR	Automatic Meter Reading
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AMSL	Above the Mean Sea Level
ARV	Annual Rateable Value
ATR	Average Tariff Rate
B/C	Benefit-Cost Ratio
BG	Broad Gauge
BMEC	Bengaluru Mumbai Economic Corridor
BOAT- TARAMANI	Board of Apprenticeship Training - TARAMANI
BOO	Build Own Operate
BOOT	Build Own Operate Transfer
BOQ	Bill of Quantities
BOT	Build Own Transfer
BP	Booster Pump
BR	Brine
BW	Back Wash
BWP	Back Wash Pump
BWT	Back Wash Tank
CAPEX	Capital Expenditure
CB	Circuit Breaker
CBW	Cost associated with Bore Well Water
C&M	Contracts and Monitoring
c/c	Centre to Centre
CBIC	Chennai Bangalore Industrial Corridor
CC	Chennai Corporation
CC	Cement Concrete
CDL	Chart Datum Level
CE (Con)	Chief Engineer (Construction)
CE (O&M)	Chief Engineer (Operation & Maintenance)
CHC	Community Health Centre
CI	Cast Iron
CIP	Cleaning In Place
CMA	Chennai Metropolitan Area
CMCDF	Chennai Mega City Development Fund
CMCDM	Chennai Mega City Development Mission
CMDA	Chennai Metropolitan Development Authority
CMIC	Coimbatore Madurai Industrial Corridor
CMRL	Chennai Metro Rail Limited
CMWSSB	Chennai Metropolitan Water Supply & Sewerage Board
CPCB	Central Pollution Control Board
CPCL	Chennai Petroleum Corporation Ltd
CPHEEO	Central Public Health and Environmental Engineering Organization
CPI	Consumer Price Index
CR	Completion Report
CRR	Cost Reduction Rate

CRZ	Coastal Regulation Zone
CRZC	Coastal Regulation Zone Clearance
CSIC	Coimbatore Salem Industrial Corridor
CT	Current Transfer
CTIC	Chennai Tiruchirappalli Industrial Corridor
CTIIC	Chennai Thoothukudi Industrial Corridor
CVT	Capacitor Voltage Transformer
CWDL	Chennai Water Desalination Ltd
CZMA	Coastal Zone Management Authority
CZMP	Coastal Zone Management Plan
DA	Dearness Allowance
DAE	Deputy Area Engineer
DAF	Dissolved Air Flotation
DBO	Design, Build, Operate
DBOOT	Design, Build, Own, Operation and Transfer
DEA	Directorate of Economic Affairs
DCS	Distributed Control System
DFR	Detailed Final Report
DFR/FR	Draft Final Report/Final Report
DGDPPC	Daily GDP per Capita
DIP	Ductile Iron Pipe
DIPP	Department of Industrial Policy & Promotion
DLP	Defect Liability Period
DMA	District Metering Area
DMF	Dual Media Filter
DMIC	Delhi Mumbai Industrial Corridor
DOE	Department of Environment
DP	Distribution Pipe
DPR	Detailed Project Report
DR	Drain
DS	Disconnector
DSP	Desalination Plant
DST	Department of Science and Technology
EAC	Expert Appraisal Committee
EC	Environmental Clearance
ECR	East Coast Road
ECS	Electronic Clearing System
EE	Executive Engineer
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EL	Earned Leave
EN	Exchange of the Notes
ENVIS	Environmental Information System
EOI	Expression of Interest
EPC	Engineering Procurement Construction
ERD	Energy Recovery Device
ES	Effective Size
ESR	Elevated Service Reservoir
EVT	Economic Value of Time
FCV	Flow Control Valve
FF	Fact Finding
FIDIC	International Federation of Consulting Engineers
FIRR	Financial Internal Rate of Return
FR	Final Report
FRC	Free Residual Chlorine

FS	Financial Sanction
FW	Filtered Water
FWP	Filtered Water Pump
FWT	Filtered Water Tank
GCC	Greater Chennai Corporation
GDP	Gross Domestic Product
GE	Galvanized Iron
GER	Gross Enrollment Ratio
GI	Galvanized Iron
GIS	Geographic Information System
GIS	Gas-insulated Switchger
GO	Government Order
GOI	Government of India
GOJ	Government of Japan
GOTN	Government of Tamil Nadu
GSDP	Gross State Domestic Production
H.W.	Head Works
HDD	horizontal well with directionally drilled collectors
HDPE	High Density Poly Ethylene
HO	Head Offices
HP	Horse Power
HP	High Pressure
HQ	Headquarters
HPP	High Pressure Pump
HR&CE	Hindu Religious and Charitable Endowment
HRM	Human Resource Management
HSC	House Service Connection
HTL	High Tide Line
HVF	Heavy Vehicle Factory
HWL	High Water Level
IA	Impact Assessment Division of MoEF
ICB	International Competitive Bidding
ICF	Integral Coach Factory
ICM	Inventory Control Manager
ICR	Inception Report
IEC	Information Education Communication
IEE	Initial Environmental Examination
IFC	Investor Facilitation Cell
IIP	Index of Industrial Production
IMD	Indian Meteorological Department
IMF	International Monetary Foundation
IR	Impact Rate
IS	Indian Standards
ISO	International Standards Organisation
ISWM	Integrated Solid Waste Management
IT	Information Technology
ITR	Interim Report
IUDM	Integrated Urban Development Mission
IWA	International Water Association
IWV	Incremental Water Volume
JA	Junior Assistant
JCCIC	Japanese Chamber of Commerce and Industry, Chennai
JE	Junior Engineer
JICA	Japan International Cooperation Agency
JNNURM	Jawaharlal Nehru National Urban Renewal Mission

JV	Joint Venture
KDCZMA	Kancheepuram District Coastal Zone Management Authority
KfW	Kreditanstalt für Wiederaufbau (German Reconstruction Finance Corporation)
KICT	Kattupalli International Container Terminal
KL	Kilo litre
km	kilometre
KPS	Kilpauk Water Supply System
KPS	Kilpauk Pump Station
KwH	kilowatt hour
LA	Loan Arrangement
L&T	Larsen & Toubro
LAP	Land Acquisition and Resettlement Action Plan
LMH	Litre per Metersquare per Hour
LML	Low water Level
LP	Low Pressure
LPCD	Litters per Capita per Day
LTL	Low Tide Line
LTSB	L&T Shipbuilding Limited
m	metre
M	Motor
m/hr	metre per hour
M/P	Master Plan
m/s	metre per second
MAWS	Municipal Administration Water Supply
MCF	Micron Cartridge Filter
MCPP	Medical Cost Per Person
MD	Managing Director
MD	Minute of Discussion
MDPE	Medium Density Polyethylene
MED	Multi Effect Distillation
MF	Micro Filtration
MFL	Madras Fertilizers Limited
MG	Metre Gauge
mg/L	milligram per litre
MIS	Management Information System
MLD	Million Litres per Day
mm	millimetre
MOEF	Ministry of Environment, Forest and Climate Change
MOF	Ministry of Finance
MORD	Ministry of Rural Development
MOUD	Ministry of Urban Development
MR	Metered Rate
MS	Mild Steel
MSF	Multistage Flash
MSL	Mean Sea Level
MTIC	Madurai Thoothukudi Industrial Corridor
NB	Number of beneficiaries
NBH	Number of beneficiaries Household
NCEPC	National Committee on Environmental Planning and Coordination
NECP	National Committee on Environmental Planning
NCSCM	National Centre for Sustainable Coastal Management
NCZMA	National Coastal Zone Management Authority
NEERI	National Environmental Engineering Research Institute
NGC	National Green Corps
NGO	Non-Governmental Organization

NH	National Highway
NHAI	National Highways Authority of India
NIC	National Informatics Centre
NLCP	National Lake Conservation Plan
NLDC	National Load Despatch Centre
NOC	No Objection Certificate
NPV	Net Present Value
NRCP	National River Conservation Plan
NRW	Non-Revenue Water
O&M	Operation and Maintenance
OC	Outer Corporation
ODA	Official Development Assistance
OECD	Organization for Economic Co-operation and Development
OHT	Over Head Tank
OPE	Other Payroll Expenses
ORP	Oxidation Reduction potential
P & D	Planning and Design
P&A	Personnel and Administration
PC	Personal Clark
PCB	Pollution Control Board
PCV	Pressure Control Valve
PERT/CPM	Program (or project) evaluation and review technique / Critical Path Method
PF	Pressure Filter
PH	Public Hearing
PHC	Primary Health Centre
PHED	Public Health Engineering Department
PIU	Project Implementation Unit
PLC	Programmable Logic Controller
PM	Purchase Manager
PMC	Project Management Consultant
PN	Nominal Pressure
PO	Purchase Officer
POSOCO	Power System Operation Corporation Limited
PPM	Post Project Monitoring
PPP	Public Private Partnership
PQ	Pre-Qualification
PS	Pump Station
PSC	Pre-Stressed Concrete
PSW	Plant Service Water
PT	Potential Transformer
PVC	Polyvinyl Chloride
PW	Permeate Water
PWD	Public Works Department
PWP	Permeate Water Pump
PWT	Product Water Tank
PX	Pressure Exchange
QA	Quality Assistance
QAW	Quality Assistance Wing
QCBS	Quality cum Cost Based Selection
R&R	Resettlement and Rehabilitation
RBI	Reserve Bank of India
RBP	Recycle Booster Pump
RCR	Revenue Collection Rate
RDF	Refuse Derived Fuel
RFP	Request for Approval

RNDC	Regional Load Dispatch Centre
RO	Reverse Osmosis
RO	Regional Office
RR, R/R	Recovery Ratio
Rs	Rupees (Indian)
RTS	Rapid Transit System
RWC	Rate without Connection
RWH	Rain Water Harvesting
S/S	Substation
S.No	Serial Number
SBS	Sodium Bisulfite
SC	Steering Committee
SCADA	Supervisory Control And Data Acquisition
SCF	Standard Conversion Factor
SE	Superintending Engineer
SEC	Specific Energy Consumption
SEIAA	State Level Environment Impact Assessment Authority
SERC	Structural Engineering Research Centre
SFT	Saved Fetching Time
SHO	Saved Hours Operating Bore Well Water
SIA	Social Impact Assessment
SIM	Social Impact Management
SLD	Saved Lost Days
SLDC	State Load Dispatch Centre
SOE	State of Environment
SPC	Special Purpose Company
SPCB	State Pollution Control Board
SRLDC	Southern Regional Load Despatch Centre
STC	Shah Technical Consultants Pvt. Ltd
STEP	Special team for Economic Partnership
STP	Sewage Treatment Plant
SV	Supplied Volume
SW	Sea Water
SWM	Solid Waste Management
SWP	Sea Water Pump
SWRO	Sea Water Reverse Osmosis
TA	Travel Allowance
TA	Technical Assistant
TANGEDCO	Tamil Nadu Generation and Distribution Corporation Limited
TANTRANSCO	Tamil Nadu Transmission Corporation Limited
TBT	Top Brine Temperature
TCE	Tata Consulting Engineers
TDS	Total Dissolved Solids
TIDCO	Tamilnadu Industrial Development Corporation Ltd
TNDOE	Tamil Nadu Department of Environment
TNEB	Tamil Nadu Electricity Board
TNIPD	Tamil Nadu Infrastructure Policy and Pollution
TNPCB	Tamil Nadu Pollution Control Board
TNSCZMA	Tamil Nadu State Coastal Zone Management Authority
TNSUDP	Tamil Nadu Sustainable Urban Infrastructure Development Project
TNUDP	Tamil Nadu Urban Development Project
TO	Technical Officer
TOR	Terms of Reference
TP	Town Panchayat
TP	Transmission Pipelines

TPL	Tamil Nadu Petro Products Limited
TS	Technical sanction
TSS	Total Suspended Solids
TTRO	Tertiary Treatment Reverse Osmosis
TUFIDCO	Tamil Nadu Urban Finance and Infrastructure Development Corporation Limited
TUIFSL	Tamil Nadu Urban Infrastructure Financial Services Limited
TWAD	Tamil Nadu Water Supply & Drainage Board
UF	Ultra Filtration
UFW	Unaccounted of Water
UGSS	Underground Sewerage Scheme
UGT	Underground Tank
UIDSSMT	Urban Infrastructure Development Scheme for Small and Medium Towns
UIDSST	Urban Infrastructure Development Scheme for Satellite Town
UIG	Urban Infrastructure and Governance
ULB	Urban Local Body
UMI	Upper Middle Income
USD	United States Dollar
UTM	Universal Transverse Mercator
VAT	Value-added Tax
VCIC	Vizag Chennai Industrial Corridor
VFD	Variable Frequency Device
VSD	Variable Speed Drive
WACC	Weighted Average Cost of Capital
WDS	Water Distribution Station
WDZ	Water Distribution Zone
WHO	World Health Organization
WRD	Water Resource Department
WSS	Water Supply System
WSSB	Water Supply & Sanitation Board
WTP	Water Treatment Plant
WTP	Willingness to Pay
WWT	Waste Water Tank

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

The Chennai Metropolitan Area (CMA) is facing chronic water shortage due to the short rainfall and the increasing water demand resulting out of increasing population and growing economy. The surface water from the rivers and reservoirs, as well as the groundwater, has been the major water resources for the CMA. However, the yields from such conventional water resources are not stable because of the frequent droughts.

According to the Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, the estimated water production in 2015 was about 686[1] million liters per day (MLD) against the demand of 933 MLD. In wide areas in Chennai, the service continuity is only three to four hours in a day.

To secure sufficient water supply for the people and businesses, as a countermeasure against the said issue, the State Government of Tamil Nadu (GOTN) decided to construct seawater desalination plants (DSPs) as one of the reliable water resources, which is not subject to drought.

As shown in Table 1.1.1, at present, two DSPs are already operational in the CMA, but the water demand is not yet satisfied. In order to further mitigate the water shortage, GOTN has prepared an expansion plan of the existing Nemmeli DSP by 150 MLD and a construction plan of a DSP with a capacity of 400 MLD at Perur (Perur DSP). Following the state government's direction, the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) prepared the detailed project reports (DPRs) for the projects mentioned above.

In accordance with the results of the DPR, the Government of India (GOI) proposed the construction project of Perur DSP in the list of expected projects for Japanese Official Development Assistance (ODA) loan, known as the Rolling Plan. On receiving the proposal from GOI, the Japan International Cooperation Agency (JICA) has decided to carry out the Preparatory Survey on Chennai Seawater Desalination Plant Project (the Study).

Table 1.1.1 Existing and Planned DSPs in the CMA

No.	Name	Capacity	Status
1	Minjur DSP	100 MLD	Operational since 2010
2	Nemmeli DSP (Existing)	100 MLD	Operational since 2013
3.	Nemmeli DSP (Expansion)	150 MLD	Planned
4.	Perur DSP	400 MLD	Planned

Note: DSP, desalination plant; MLD, million liters per day
Source: JICA Study Team

[1] Total amount of the production by CMWSSB for the Chennai Corporation (596 MLD) and the estimated production from the wells outside the Corporation and within the CMA (90 MLD)

1.2 Objectives, Scope and Target Area of the Study

1.2.1 Objectives

The Study has been carried out to verify the validity and feasibility of implementing the Chennai Seawater Desalination Plant Project, which is to construct the Perur DSP, by Japanese ODA.

1.2.2 Scope

The Study consists of the work items shown in Table 1.2.1.

Table 1.2.1 Scope of the Study

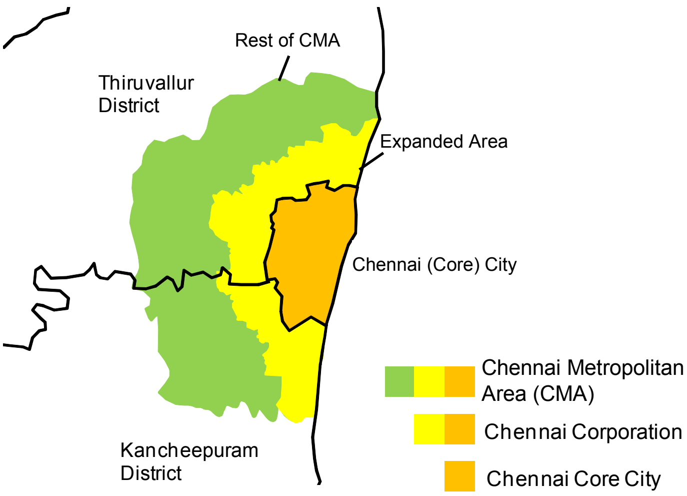
No.	Work Items
1	Preparation of Inception Report
2	Collection and analysis of basic information relevant to the Study
3	Review of the existing DPR
4	Study on necessity and scale of the Project
5	Study on the basic project scope
6	Consideration of O&M implementation structure of the DSP
7	Preparation of Interim Report and discussion with the relevant authorities
8	Preliminary design of the facilities
9	Cost estimation
10	Environmental and social considerations
11	Preparation of project implementation plan
12	Establishment of action plans for organizational improvement
13	Financial and economic analyses
14	Project evaluation and proposals on indicators for measurement of the project effects
15	Identification of risks and plan of the aversion/mitigation measures
16	Preparation of Draft Final Report and discussions with relevant authorities
17	Preparation of Final Report

Source: JICA Study Team

1.2.3 Target Area

The CMA is the target area of the Study. As shown in Figure 1.2.1, the CMA consists of Chennai Corporation, which includes the Chennai District (or Chennai Core City), and part of the districts of Thiruvallur and Kancheepuram.

In the Study, the peripheral areas in the Corporation outside the Core City are called as the "Expanded Area." The areas outside the Corporation and inside the CMA are called as the "Rest of CMA."



Source: JICA Study Team

Figure 1.2.1 Composition of the Target Area of the Study

1.3 Outlines of the Detailed Project Report of the Project

CMWSSB awarded the consultancy services for preparation of the DPR for the construction project of 400 MLD DSP at Perur (DPR for the Perur DSP Project) to M/s AECOM (I) Pvt Ltd, Gurgaon, India in association with GHD Pty Ltd, Australia & Watek, USA.

The scope of the work included designing of the DSP, the treated water transmission mains, the power receiving facilities, preparation of operation and maintenance (O&M) plan, and cost estimation of the project. According to CMWSSB, the contract between CMWSSB and the consultant also includes bid document preparation and bid assistance in procurement of the contractor(s).

The final version of the DPR is dated February 2014. It received approval from the Ministry of Urban Development (MOUD) on 14th January, 2015. The findings and outcomes of the consultancy study presented in the final DPR are summarized in Table 1.3.1.

Table 1.3.1 Summary of the Findings and Outcomes of the Consultancy Study for the DPR

No	Description		Findings
1	Seawater desalination plant	Capacity	• 400 MLD • Reverse osmosis (RO) technology
		Pre-treatment	• Fine screen – Lamella filter - Dissolved Air Floatation (DAF) – Dual Media Filter (DMF)
		RO unit	• 16 duty trains and 1 standby train for 400 MLD production • Recovery rate: 46%
		Post-treatment	• Lime stone and chlorine
2	Power receiving facilities	-	• Power reception by 2 lines of 110 kV from the existing grid via a new external 230/110 kV substation • An internal 110/11 kV substation in the plant
3	Product water main	-	• 60 km of the total length • Diameter: 1.2m or more • Pipe material: Mild Steel
4	Operation and maintenance (O&M) Plan	-	• O&M by the design-build contractor for a period of 10 or 15 years. • Product water main will be included in the O&M by the contractor.
5	Project cost estimation	Capital cost	• Capital cost: INR 41,160 million • The capital cost includes all cost for engineering and construction for the DSP and the product water main
		O&M cost	• Water cost per m^3: Rs 48.97 including O&M and depreciation.

Source: DPR for the Perur DSP Project

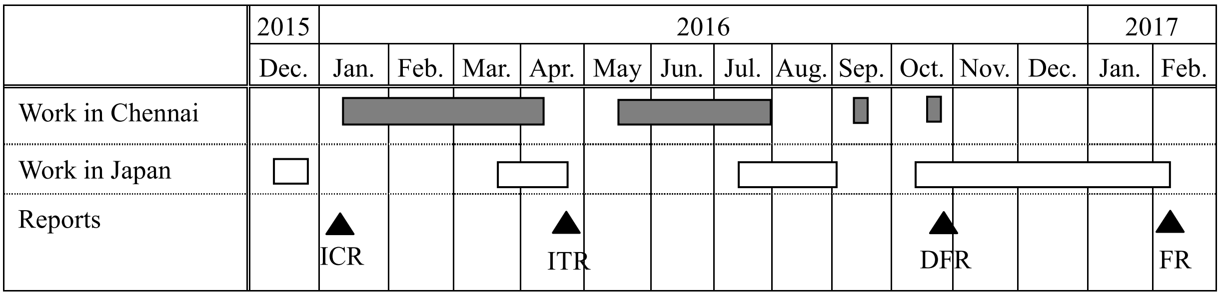
1.4 Schedule of the Study

Figure 1.4.1 shows overall schedule of the Study. The JICA Study Team finished the 1st part of work in Chennai by the middle of April 2016, which included the work items No. 1 to 5 as shown in Table 1.2.1 and the preliminary works for the items No. 6 and 8 to 13. Outcomes from the 1st work in Chennai were compiled as the Interim Report (ITR) in Japan.

The 2nd part of work in Chennai started in the middle of May 2016. In the initial phase of the 2nd work, specifically on 30th May and 13th June, the study team conducted presentations of the ITR to

CMWSSB. Based on the discussions following the presentations and held throughout the 2nd work period between the study team and concerned authorities, especially JICA and CMWSSB, the team carried out preliminary design of the facilities, cost estimation, preparation of project implementation plan and evaluation of the project's validity from environmental, financial and economical aspects, which included all work items from No. 6 to 15 in Table 1.2.1. After discussions among JICA, CMWSSB and the study team on 24th and 25th October 2016 in Chennai, all results of the work items from No.1 to 15 were compiled in the Draft Final Report (DFR) by the end of October 2016.

After the submission of DFR, the study team received opinions and comments on DFR from both the Japanese and Indian authorities concerned. The Final Report (FR) has been prepared as the final product of the Study after reviewing all the opinions and comments.



Legend: ICR: Inception Report, ITR: Interim Report, DFR: Draft Final Report, FR: Final Report
Source: JICA Study Team

Figure 1.4.1 Overall Schedule of the Study

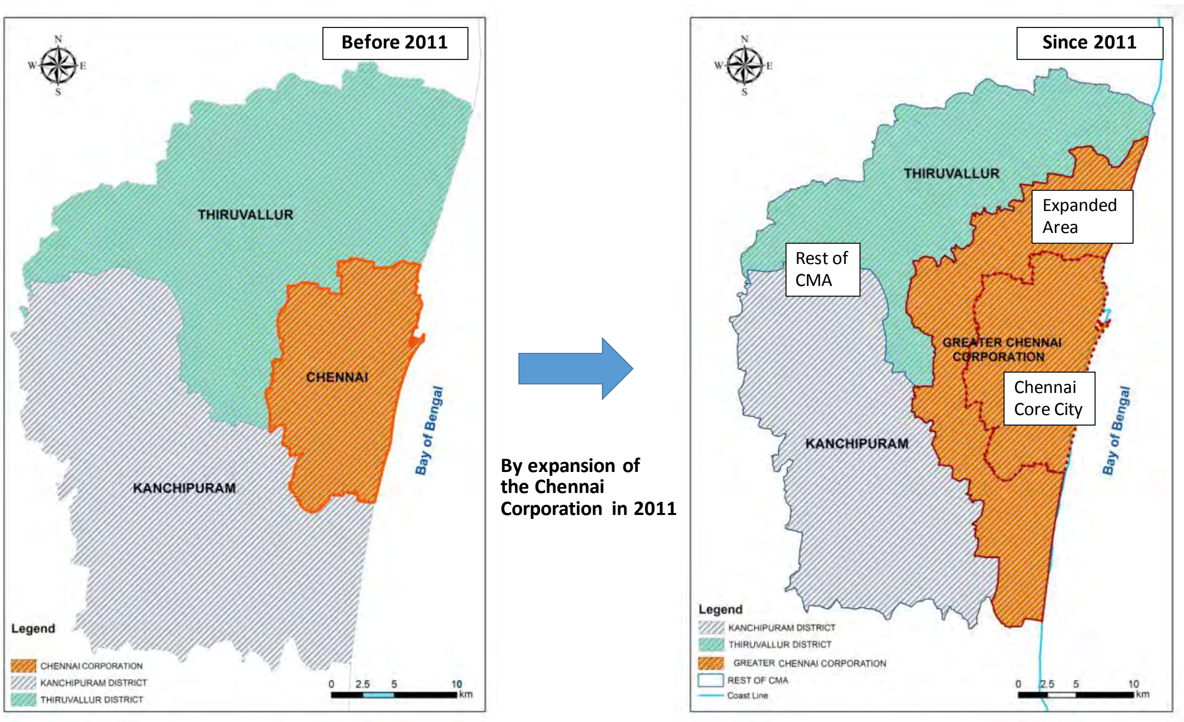
CHAPTER 2 PRESENT SITUATION OF THE STUDY AREA

2.1 Administrative Boundaries and Population

Chennai Corporation, which was established as Madras Corporation in 1688, is the oldest municipal body in India. The boundary of the Corporation was expanded from 176 km^2 to 426 km^2 in 2011 and transformed to the Greater Chennai Corporation (hereinafter, "Chennai Corporation") by integrating 42 Urban Local Bodies (ULBs[1]), comprising 9 municipalities, 8 town panchayats or towns, and 25 village panchayats or villages. After the integration, the old Chennai Corporation area is called as the Chennai Core City and the merged areas are generically called as the Expanded Area. The corporation used to have 158 wards, and in 2011, some of them were merged into 107 wards. The 42 ULBs in the Expanded Area made 93 wards. Accordingly, the current Chennai Corporation has 200 wards, an increase of 42 wards by the expansion in 2011.

The Chennai Core City and the Expanded Area form the Chennai Metropolitan Area (CMA) with the fringe area of the Corporation, the Rest of CMA. The Rest of CMA includes 7 municipalities, 12 towns, and 189 villages.

The population of the Chennai Corporation was 6.4 million in 2011. The population of the Rest of CMA was 2.3 million. The area of CMA is 1189 km^2. Figure 2.1.1 shows the scenario prior to and after the year 2011. Administrative boundaries in CMA and list of wards in the Corporation and ULBs in the Rest of CMA are given in Appendices 2.1 and 2.2 respectively.



Source: JICA Study Team

Figure 2.1.1 Scenario in the Expansion of the Chennai Corporation in 2011

[1] In India, local autonomous bodies are generically called as Urban Local Bodies (ULBs). ULBs include municipalities, town panchayats (or towns) and village panchayats (or villages). Each ULB has a council, whose members are elected.

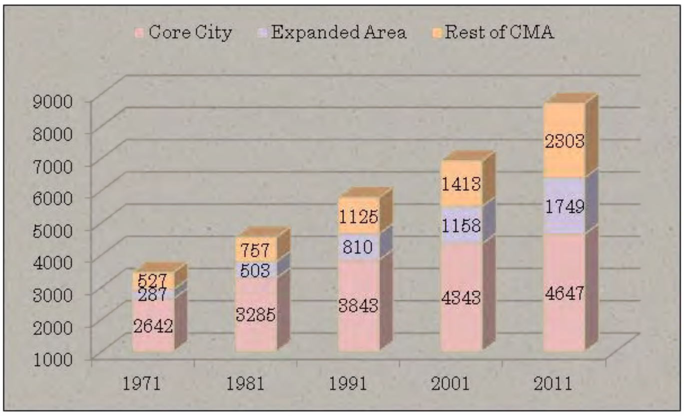
The demographics of the Chennai Core City, Corporation and CMA in the census year 2011 and the historic trend since 1971 based on the past census results are presented in Table 2.1.1. The population growth trend based on the historic census population from the year 1971 to 2011 is shown in the Figure 2.1.2.

The demographic growth indicates that the population growth rate in the Core City is reducing due to stabilization. The growth rate in the Expanded Area has been steady and that in the Rest of CMA is increasing due to rapid urbanization and industrialization in the fringes.

Table 2.1.1 Demographics of Chennai Metropolitan Area (1971 to 2011)

Area	No. of Wards/ULBs		Population in thousands (Annual growth rates in the previous decades)					Area (km^2)
	Before 2011	Since 2011	1971	1981	1991	2001	2011	
1. Chennai Core City	158 wards	107 wards	2,642	3,285	3,843	4,343	4,647	176
			(-)	(2.44%)	(1.70%)	(1.31%)	(0.70%)	
2. Expanded Area	9 m'ties*, 8 towns, 25 villages	93 wards	287	503	810	1,158	1,749	250
			(-)	(7.53%)	(6.11%)	(4.30%)	(5.11%)	
3. Rest of CMA	7 m'ties, 12 towns, 189 villages		527	757	1,125	1,413	2,303	763
			(-)	(4.37%)	(4.87%)	(2.56%)	(6.30%)	
Chennai Corporation (1. + 2.)	158 wards, 9 m'ties, 8 towns, 25 villages	200 wards	2,929	3,788	4,653	5,502	6,396	426
			(-)	(2.94%)	(2.29%)	(1.83%)	(1.63%)	
CMA (1. + 2. +3.)	158 wards, 16 m'ties, 20 towns, 214 villages	200 wards, 17 m'ties, 12 towns, 189 villages	3,457	4,545	5,778	6,915	8,699	1,189
			(-)	(3.15%)	(2.72%)	(1.97%)	(2.58%)	

*: municipalities
Source: Census 2011



Source: JICA study team based on Census 2011 data

Figure 2.1.2 Demographics based on Census (1971 to 2011)

2.2 Social Conditions

India is one of the world's fastest-growing major economies, whose Gross Domestic Product (GDP) growth in 2015 was estimated at 7.6% by the World Bank. Among the country, the Tamil Nadu State is one of the most industrialized and developed states and highly contributes to the country's fast economic growth by attracting investments in various businesses and infrastructures.

The social conditions of the study area that include politics, economy, industry, public health and education are described with relevant statistics in Appendix 2.3.

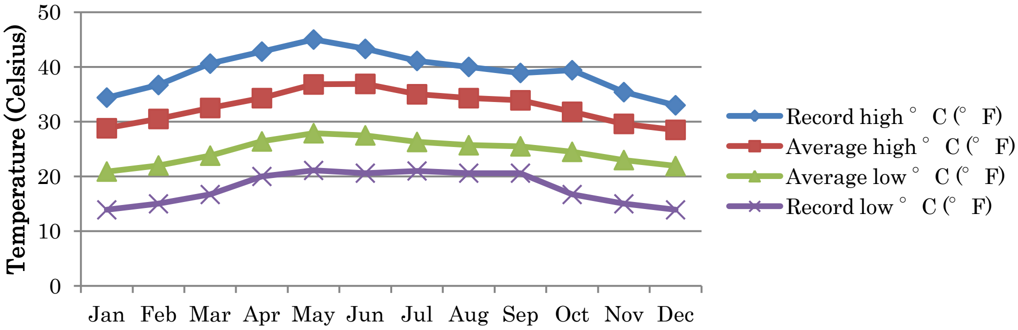
2.3 Natural Conditions

The summary of the natural conditions of the study area is given in this section. The detailed natural conditions including weather, climate and climate change, topography and geology, and flora and fauna are given in Appendix 2.4.

2.3.1 Weather, Climate and Climate Change

Based on the data from the Indian Meteorological Department (IMD), the average and the recorded (maximum and minimum) values are presented in Figure 2.3.1.

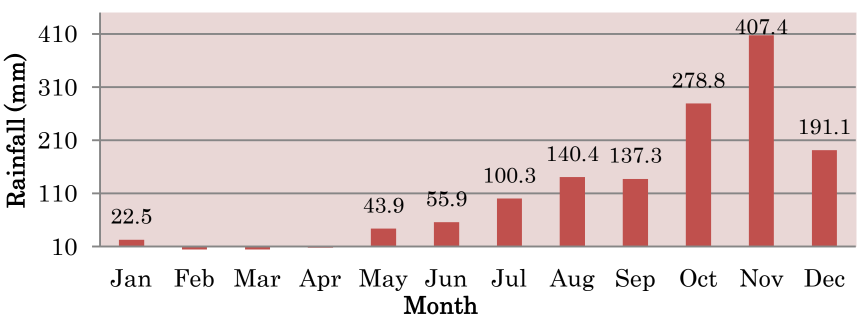
Chennai has a tropical wet and dry climate. The peak summer is usually in late May and early June, and the recorded highest temperature is in the month of May, i.e., about 45 °C. The coolest part of the year is in the month of January, with average low temperature about 20 °C.



Source: Indian Meteorological Department (IMD), as observational data in 1971-2000

Figure 2.3.1 Variation of Temperature for Chennai

Chennai is more dependent on the annual rains of the monsoon season to replenish water reservoirs as there are no major water resources or perennial rivers to serve the city. The average annual rainfall is 1,400 mm, and the average rainfall in a year is 60 days. The city gets most of its seasonal rainfall from the north east monsoon, from middle October to middle December, as shown in Figure 2.3.2. Cyclones often hit the city during the monsoon seasons. From July to September, the rainfall is greater than the other months except for the north east monsoon and this period is defined as south west monsoon.

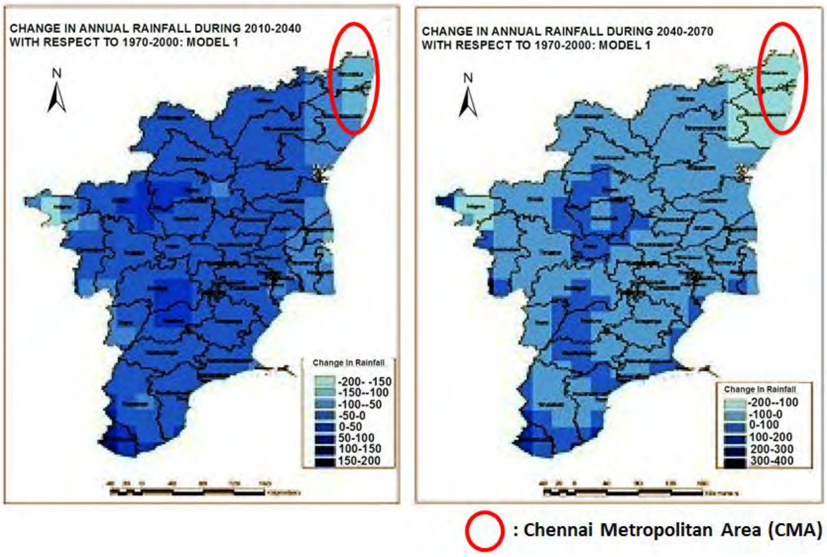


Source: Indian Meteorological Department (IMD), as observational data in 1971-2000

Figure 2.3.2 Average Monthly Rainfall for the Chennai Corporation

As per the Tamil Nadu State Action Plan for Climate Change, CMA will face a decrease by 100 to 150 mm in 2010-2040 compared to that in the 1970-2000 period as shown in Figure 2.3.3. The same projection for 2040-2070 indicates that the rainfall in CMA will also be lower by 100 to 200 mm than that in 1970-2000 and that in this period most other areas in the state will also face a decrease in rainfall by 0 to 100 mm.

From the climate change simulations above, CMA is likely to suffer from a decrease in the rainfall, which will result in lower water availability from the reservoirs whose catchment is in and around Chennai.

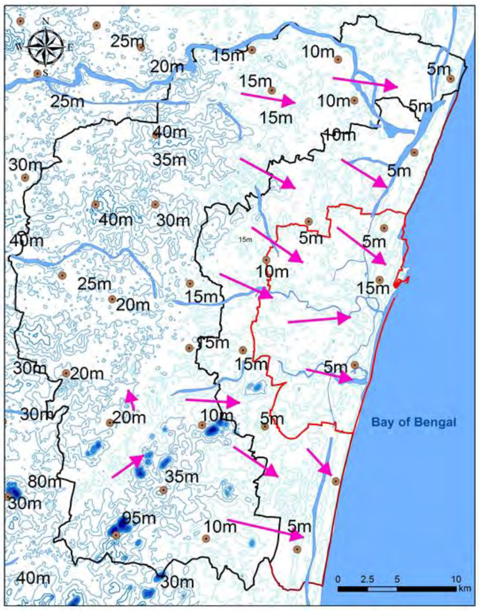


Source: Tamil Nadu State Climate Change Action Plan

Figure 2.3.3 Projection of Rainfall for Tamil Nadu

2.3.2 Topography and Geology

The topography of Chennai is very gentle and varies from 1:5,000 to 1:10,000. It is a low laying area and resembles a pancake. The elevation away from the core city increases up to 7 m above the mean sea level (MSL) as the distance from seashore increases, as many localities are at MSL affecting the drainage system and causing inundation within the city. The general topography of the city is shown in Figure 2.3.4.



Source: JICA Study Team

Figure 2.3.4 Topographical Map of CMA

The Chennai Corporation is classified into three regions based on geology, sandy areas, clayey areas, and hard-rocks areas. The geology of the planned 400 MLD DSP at Perur is located at coastal deposits. The transmission main alignment covers coastal deposits near the plant and charnockite deposits towards northern side. Then it meets with sand and sandy clay near Porur Head

Works, the ending point of the transmission line.

2.3.3 Flora and Fauna

Flora and fauna are found in Guindy National Park, the Theosophical Society, Adyar Estuary, Pallikaranai Marsh, Nanmangalam Reserve Forest, Arignar Anna Zoological Park, and along the southern stretches of the beach in Chennai. However, these national parks are not influenced by the construction works of the Project, including that for the DSP and the transmission lines.

2.4 Infrastructure Development

2.4.1 Transportation

The current development conditions of airports, seaports, roads, railways and bus transportation in the Study Area are described in A2.5.1 of Appendix 2.5.

2.4.2 Power Supply

In Tamil Nadu, the Tamil Nadu Electricity Board Limited (TNEB), under the administrative control of the Energy Department of the Government of Tamil Nadu, and its subsidiary companies conduct the power supply. TNEB is a holding company, whose subsidiary companies are Tamil Nadu Transmission Corporation Limited (TANTRANSCO) and Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO). TANTRANSCO is responsible for power transmission system and substations, and TANGEDCO is responsible for power generation and power distribution system.

Table 2.4.1 shows the peak demand and the available supply in the southern region in India by state and all India in 2015. The peak demand in the Tamil Nadu State in 2015 was 13,580 MW against the available supply of 13,505 MW. Thus, there was a shortage of 75 MW, which was equivalent to 0.6% of the peak demand in the state. The southern region in total and all India also faced power shortage, and the shortages in 2015 were 2.7% and 3.2%, respectively, against the peak demands. Although the power shortage prevails all over India, the percentage of power shortage in the Tamil Nadu State is smaller than the total southern region and all India.

Table 2.4.1 Demand and supply from April, 2015 to November, 2015

State	Peak Demand	Available Supply	Surplus/ Deficit (-)	
	(MW)	(MW)	(MW)	(%)
Andhra Pradesh	7,032	6,913	-119	-1.7
Telangana	6,854	6,849	-5	-0.1
Karnataka	9,463	9,335	-128	-1.4
Kerala	3,762	3,632	-130	-3.5
Tamil Nadu	13,580	13,505	-75	-0.6
Puducherry	368	350	-18	-4.9
Lakshadweep	8	8	0	0
Southern Region	**37,801**	**36,786**	**-1,015**	**-2.7**
All India	**153,366**	**148,463**	**-4,903**	**-3.2**

Source: Executive summary power sector November-15 (Central Electricity Authority)

2.4.3 Sewerage and Sanitation

By the Act 28 of 1978, CMWSSB is responsible for the provision of sewerage services in CMA. The CMWSSB conducts the development and operation and maintenance (O&M) of the sewerage system in the Chennai Corporation including the Core City and the Expanded Area. However, the works in the Rest of CMA are carried out by ULBs.

Table 2.4.2 is a list of Sewage Treatment Plants (STPs) of CMWSSB in the Chennai Corporation as of 2015. The STPs in the table covers the entire Core City and a part of the Expanded Area. As not all the STPs have a flow meter, the operation rates of the STPs are unknown. In the Core City, the sewerage network has covered 98% of the city area, while the coverage in the Expanded Area is unknown.

The total capacity of the STPs is sufficient against the estimated current water consumption (652 MLD) among the water supplied by CMWSSB, but the total consumption including groundwater extracted by private wells may be greater than the STP capacity.

Table 2.4.2 Existing Sewage Treatment Plants of CMWSSB

Location of Treatment Plant	Treatment Capacity (MLD)	Length of sewer network in km	Sewer connections in no	Sewage Pumping Stations in no
Nesapakkam	117			
Kodungaiyur	270			
Koyambedu	214			
Perungudi	151			
Villivakkam	5			
Alandur	12			
Total	769	3,994	778,488	228

Source: Policy Note 2015 – 2016 of Municipal Administration and Water Supply Department of Government of Tamilnadu

In the Expanded Area, which consists of 42 ULBs[2], 16 ULBs are currently constructing new sewerage systems and 22 ULBs have construction plans as shown in Table 2.4.3.

Table 2.4.3 Development Status of Underground Sewerage Schemes in the Expanded Area

Total No. of added areas in the Expanded Area (municipalities, towns and villages)	Works Completed	Works In progress	Works to be taken up	
			DPRs Completed	DPRs under preparation
42	4	16	10	12

Source: Policy Note 2015 – 2016 of Municipal Administration and Water Supply Department of Government of Tamil Nadu.

For the Rest of CMA, the Tamil Nadu State has a plan to expand the coverage of sewerage system to the entire CMA. The "Master Plan for Water supply and Sewerage sections in Chennai Corporation and Rest of CMA" has developed a development plan of sewerage systems to cover the CMA.

Detailed information on the present situations of the sewerage systems is given in A2.5.2 of Appendix 2.5.

[2] Although the ULBs in the Expanded Area were disestablished after the mergence in 2011, sewerage systems are being developed by grouping the Expanded Area by the former administrative boundaries of the ULBs.

2.4.4 Drainage

In Tamil Nadu, storm water drains are built and maintained by the respective corporations and local bodies. For the Chennai Corporation area, the stormwater drains are not under the control of CMWSSB but are under the Greater Chennai Corporation authority. For the Rest of CMA, the respective local bodies like municipalities, town panchayats, and village panchayats construct and maintain the storm water drains.

The recent and planned development of storm water drainage systems are described in A2.5.3 of Appendix 2.5. Detailed descriptions of the disastrous flood event, which hit Chennai in December 2015, are also given in the same appendix.

2.4.5 Solid Waste Management

In Tamil Nadu, about 7,597 t of municipal solid waste is generated daily in 11 Corporations (other than the Chennai Corporation) and 124 municipalities. Besides, 1,967 t of municipal solid waste is being generated daily in 528 town panchayats. In the Chennai Corporation, on the other hand, the generation of municipal solid waste is 5,200 t per day (garbage 4,500 t and building debris 700 t). The current situations of the solid waste management in the state and the corporation are described in A2.5.4 of Appendix 2.5.

CHAPTER 3 PRESENT SITUATIONS OF THE WATER SUPPLY AND SEWERAGE SECTOR IN THE STUDY AREA

3.1 Sector Policies and Institutional Situations

3.1.1 National and State Policies

National Water Policy is formulated by the Ministry of Water Resources of the Government of India to govern the planning and development of water resources and their optimum utilization. The first National Water Policy was adopted in 1987, after which it has been updated in 2002 and later in 2012.

The primary emphasis of National Water Policy 2012 is to treat water as economic good so as to promote its conservation and efficient use. Major features of National Water Policy 2012 are as follows:

- The Centre, the States, Municipal Corporations and the Urban Local Bodies (ULBs) must ensure access to a minimum quantity of potable water for essential health and hygiene to all its citizens, available within easy reach of the household.
- There is a need to remove the large disparity between stipulations for water supply in urban and rural areas.
- Efforts should be made to provide improved water supply in rural areas with proper sewerage facilities. Least water intensive sanitation and sewerage systems with decentralized sewage treatment plants should be incentivized.
- Urban and rural domestic water supply should preferably be from surface water in conjunction with groundwater and rainwater. Where alternate supplies are available, a source with better reliability and quality needs to be assigned to domestic water supply.
- Exchange of sources between uses, giving preference to domestic water supply should be possible. Also, reuse of urban water effluents from kitchens and bathrooms, after primary treatment, in flush toilets should be encouraged, ensuring no human contact.
- Urban domestic water systems need to collect and publish water accounts and water audit reports indicating leakages and pilferages, which should be reduced.
- In urban and industrial areas, rainwater harvesting and desalination, wherever techno-economically feasible, should be encouraged to increase the availability of utilizable water.
- Urban water supply and sewage treatment schemes should be integrated and executed simultaneously. Water supply bills should include sewerage charges.

The government of India recognizes that water supply and sanitation is a state subject to be implemented under the central government's instruction, based on the federal Constitution of India. It also recognizes that the implementation requires the strong involvement of city level institutions and stakeholders. Moreover, although there are the common elements that characterize urban areas of India, there are many factors that are particular to states and cities, such as historical legacy, political situations, economic and social conditions, climate, etc. Therefore, Government of India allows the various states like Tamil Nadu to develop its own state-level strategy to achieve the policy goals set out in the National Water Policy above.

In this regard, the effort to augment the available water volume by seawater desalination technology, which is the objective of the target project of the Study, is a particular strategic approach of the Tamil Nadu State to cater for the huge domestic and business water demand under the water-scarce climate conditions in the state.

Other notable points in the policy target in the National Water Policy are exchanges of sources between uses, utilization of used water and reduction of water loss by leakage. Reallocation of the water from agricultural water to domestic water and water recycle need to be pursued to satisfy the various water demands, although the reallocation will require long term efforts involving multiple sector authorities, politics, and various water users, which is beyond the power of CMWSSB. Also, CMWSSB is requested to make efforts to ensure complete tariff collection, for water saving as well as for financial sustainability of water supply and sewerage services.

3.1.2 Fundamental Laws in the Sector

The following are the important acts and rules applicable to water and sewerage sectors including sea water desalination project:

- The CMWSSB Act, 1978 (Act no 28 of 1978)
- The Chennai Metropolitan Area Groundwater (Regulation) Act, 1987
- The Tamil Nadu Groundwater (Development and Management) Act, 2003 (Act no 3 of 2003)
- The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013
- The Water (Prevention and Control of Pollution) Act, 1974 as amended in 1978 and1988.
- The Tamil Nadu Water (Prevention and Control of Pollution) Rules, 1983
- The Water (Prevention and Control of Pollution) Cess Act, 1977 as amended in 1991.
- The Water (Prevention and Control of Pollution) Cess Rules, 1978. as amended in 1992
- The Environment (Protection) Act, 1986.
- The Environment (Protection) Rules, 1986
- The National Environment Tribunal Act, 1995 (No.27 of 1995)
- The Environmental Impact Assessment Notifications, 2006 (Now notification in force)
- Coastal Regulation Zone Notification, 1994 (www.tnpcb.gov.in/enforcement.asp)

3.1.3 Structure of the Sector in the State and Chennai Metropolitan Area

(1) National level

The Ministry of Urban Development, Government of India, formulates policy guidelines in respect of urban water supply and sanitation sector and provides technical assistance to the states and ULBs.

Central Public Health and Environmental Engineering Organization (CPHEEO) under the ministry is the nodal agency to directly take care of the water supply and sanitation sector.

The central government acts as an intermediary in mobilizing external assistance in the water supply and sanitation sector and routes the assistance via the state plans, by the Ministry of Finance to represent the central government. The central government also provides direct grant assistance to some extent for water supply and sanitation programs in urban areas.

(2) State level

Water supply and sanitation is treated as a state subject as per the federal Constitution of India and; therefore, the states are vested with the constitutional right on the planning, implementation and cost recovery of water supply and sanitation projects. At the local level, the responsibility is entrusted by legislation to the local bodies like boards, municipal corporations, and ULBs.

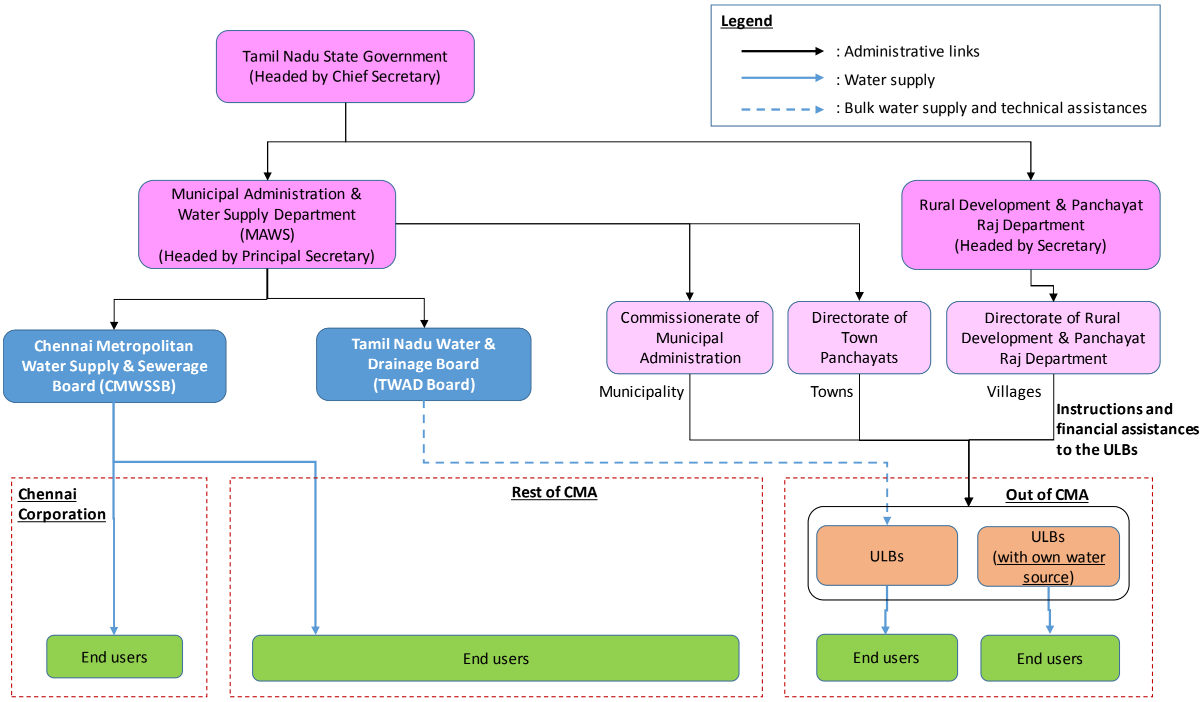
In the Tamil Nadu State, implementation structure of the water supply services should be explained for the ideal case, which is the stipulated structure in relevant laws such as the CMWSSB Act, 1978, and the actual case, which is the current situation practically. Figure 3.1.1 presents the implementation structure in the ideal case and Figure 3.1.2 shows that in the actual case.

In any case, Municipal Administration and Water Supply Department (MAWS) of Government of Tamil Nadu has the overall responsibility of providing water supply and sewerage facilities to the entire Tamil Nadu State except to village panchayats. Water supplies to village panchayats are under responsibilities of Rural Development and Panchayat Raj Department.

According to CMWSSB Act, as shown in Figure 3.1.1, CMWSSB is to provide water supply to all people and businesses in the entire CMA including Chennai Corporation and Rest of CMA. People out of CMA are to be provided by ULBs, some of which receive bulk water supply from TWAD Board and others utilize their own water sources. In addition to the bulk water supply, TWAD Board is to provide technical assistances to ULBs, including project implementation of water supply facilities in the ULBs on behalf of the ULBs, using the state funds. Commisionerate of Municipal Administration, Directorate of Town Panchayats and Directorate of Rural Development and Panchayat Raj Department, as the administrators of the ULBs, will give instructions and finances for water supply projects and O&M in water supply services in the ULBs in their respective mandates.

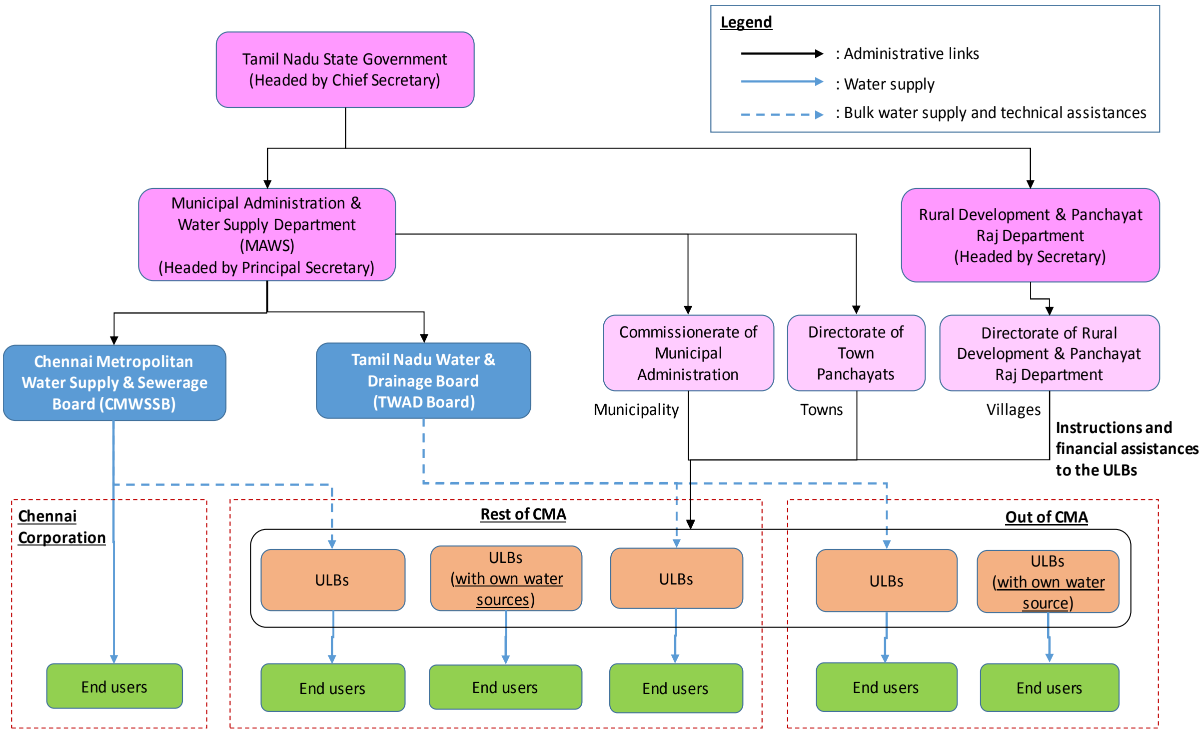
In actual situations, as shown in Figure 3.1.2, direct water supply services of CMWSSB is limited to the Chennai Corporation due to insufficient water volume and human resource availability and also due to respect to autonomy of the ULBs. In the Rest of CMA, respective ULBs are carrying out water supply services using the water distribution networks developed by them. CMWSSB's involvement in the Rest of CMA is only bulk supplies to seven (7) municipalities. The other ULBs are conducting water supply services using their own water sources or receiving bulk supplies from TWAD Board. Whether the bulk suppliers to a ULB in the Rest of CMA will be CMWSSB or TWAD Board is determined by Principal Secretary, who is heading MAWS.

The state government and CMWSS has an intention to shift gradually to the ideal case shown in Figure 3.1.1, but it may not be completed before integration of the Rest of CMA by the Corporation, which is said to be done in near future.



Source: JICA Study Team

Figure 3.1.1 Structure of Water Sector in Tamil Nadu State as Stipulated Conditions



Source: JICA Study Team

Figure 3.1.2 Structure of Water Sector in Tamil Nadu State as Actual Conditions

3.1.4 Jurisdictions of Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

The Corporation of Chennai, established on 29th September 1688, the oldest Municipal Institution in India was also looking after the water supply and sewerage services in the corporation until August 1978, when CMWSSB was formed. CMWSSB is a statutory body formed by CMWSSB Act 28 of 1978, dated 14th June 1978 by the Government of Tamil Nadu. The functions of CMWSSB as mentioned in the Act are summarized below:

- Development, operation, maintenance and regulation of water supply and sewerage system in the CMA
- Prepare / Update long term plans to meet future requirements of water supply and sewerage in the CMA
- Undertake development activities to meet future needs of water supply and sewerage in the CMA
- Operation and Maintenance of the water supply and sewerage services in the CMA
- Other functions related to water supply and sewerage as the Government may entrust to the Board

As described above, the jurisdiction of CMWSSB is the entire CMA. However, practically CMWSSB's service area is limited to the Chennai Corporation in principle and their services in Rest of CMA are only bulk supplies to several municipalities as explained in the previous subsection.

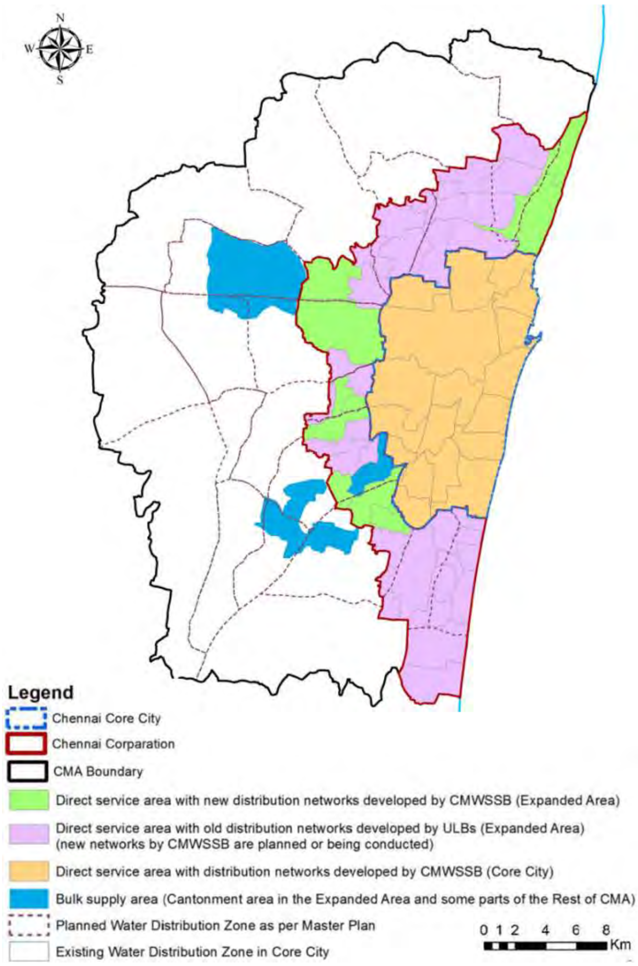
Map of the entire CMA, which is the mandated area of CMWSSB, with administrative boundaries and the list of the corporation, municipalities, towns, and villages were given in Appendices 2.1 and 2.2.

3.2 Present Conditions of the Water Supply and Sewerage Services

3.2.1 Target Area of the Water Supply Services and Zoning by CMWSSB

(1) Service area

Service coverage of CMWSSB is the entire corporation area in principle. Out of the Corporation, there are seven municipalities in Rest of CMA, who are receiving bulk water supply. Figure 3.2.1 presents the overall service coverage of CMWSSB including direct supply and bulk supply. The bulk supply area in the Core City, shown in Figure 3.2.1, is a military base, where the distribution network is owned and operated by the military. In the Expanded Area, CMWSSB is developing water distribution networks to replace the existing ones that were once developed by the ULBs before the mergence.



Source: JICA Study Team

Figure 3.2.1 Present Service Area of CMWSSB

(2) Administration Area and Water Distribution Zones

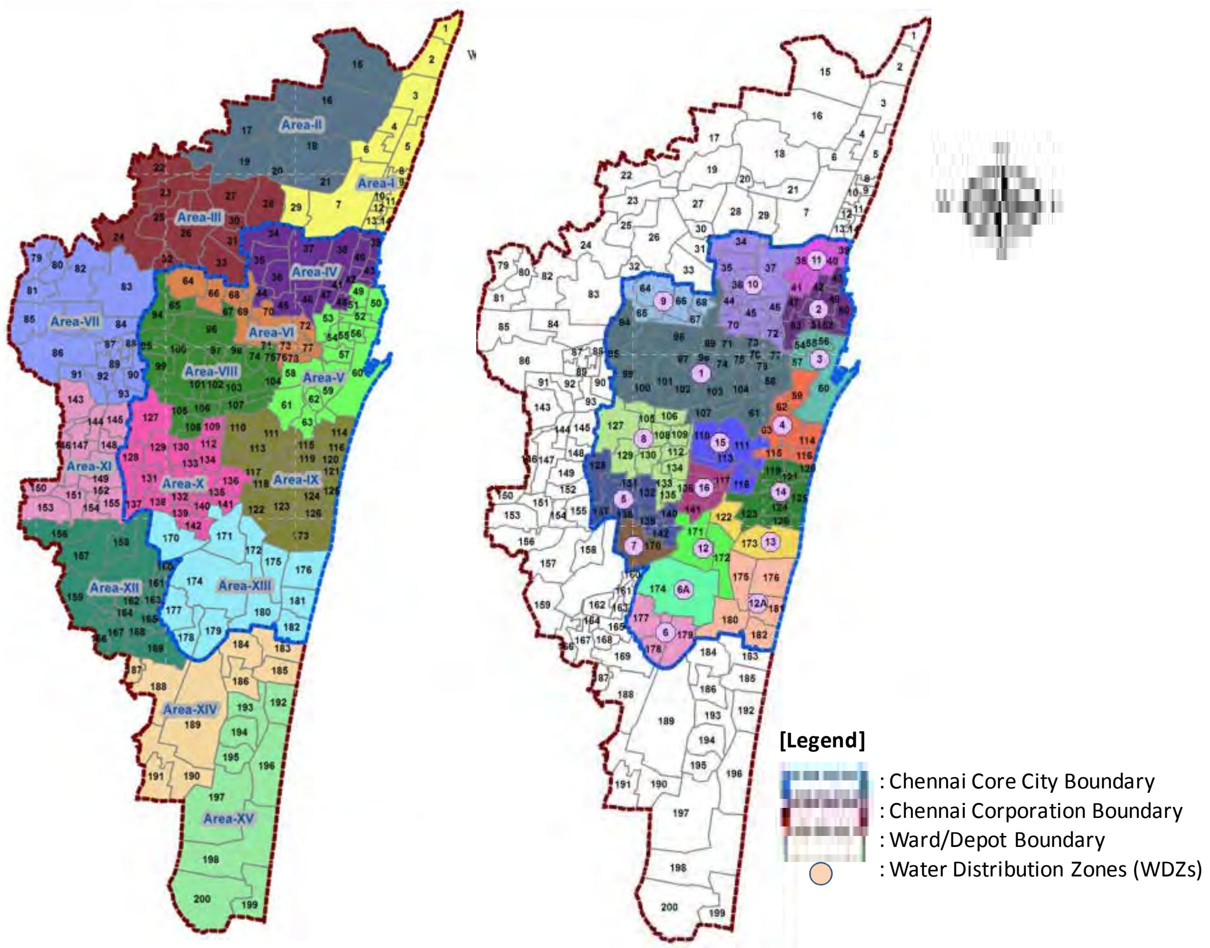
As shown in Figure 3.2.2, CMWSSB divides the Corporation into 15 Administration Areas and further divides into 200 depots which are corresponding to the wards of the same number. Every depot has depot office of CMWSSB and the depots are the minimum units in management of consumer information, asset information and consumer cares.

Separate from the Administration Areas and depots, CMWSSB divides the Chennai Core City into 18 Water Distribution Zones (WDZs) as also shown in Figure 3.2.2.

WDZs are physical segments of water distribution networks, each of which has Water Distribution Station (WDS). In principle a WDZ is supplied from the reservoir and pumping station at the WDS in the zone, while the zones are usually linked by interconnections.

In the Expanded Area and the Rest of CMA, no WDZ has been established yet but has just been proposed by "Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015".

By comparing the maps in Figure 3.2.2, boundaries of the Administration Areas and the WDZs do not match each other. The both boundaries as well as those of depots are overlaid in Appendix 2.1.



Administration Areas
Water Distribution Zones

Source: JICA Study Team

Figure 3.2.2 Administration Areas and Water Distribution Boundaries of CMWSSB

3.2.2 Performances of the Services by Service Indicators

Table 3.2.1 shows the present key indicators of the water supply and sewerage services of CMWSSB. Table 3.2.2 presents the breakdown of the service connections in the Corporation by category. Detailed information on served population, service connection, assesses (equivalent to water and sewerage taxes[1] payers) by area are given in Appendix 3.1. In addition, Appendix 3.2 illustrates unit domestic water consumption as litre per capita per day (lpcd) by ward and ULB. The unit water consumption is estimation by CMWSSB, where CMWSSB estimates domestic water consumption, excluding water loss, and population by street, although the detailed methodology has not been disclosed.

CMWSSB has 673,339 service connections as of July 2016 in the Chennai Corporation but metered ratio of the service connections is only 3.9%. It means most consumers are paying only flat rate

[1] CMWSSB collects water and sewerage taxes from consumers based on their assessed annual value that include annual income for individuals and annual revenue for business entities.

instead of volumetric tariff. Service connection rate is 58 % in the overall Corporation, which means the remaining 42% are receiving water supply from CMWSSB by lorries and stand posts. Connection rate in the Core City, which is 65%, is greater than that in the Expanded Area, which is 41%.

Past values of the indicators are presented in Table 3.2.3. It is noted that the past indicators in the table refer to the Policy Notes of the Municipal Administration and Water Supply Department of the State Government of Tamil Nadu, since 2006-2007 to 2015-2016. The illogical values such as the served population, which is constant from 2009 to 2011, was derived from the Policy Notes. It is also noted that the served population Table 3.2.3 does not match the estimated population by CMWSSB (8.629 million) shown in Table 3.2.1. From the census population of 6.396 million in the Corporation in 2011, the population in the policy note will be closer to the actual served population.

Some notable points on the indicators are raised by JICA Study Team as follows:

- Served population: According to CMWSSB, almost all households and businesses in the Corporation have access to the services of CMWSSB through service connections, lorries and/or stand posts. CMWSSB's estimation and official value published by the state government have a wide gap. By comparing with the total population in the Corporation, CMWSSB's estimation is too high. Probably the greater served population estimated would have been derived from greater presumption by CMWSSB on the members per household.
- Connection rate: The connection rate in the Core City is only 65%. To utilize the water to be supplied from the existing and future water sources, installation of service connection is necessary. In the Expanded Area, although it is lower than the Core City, the connection rate will gradually increase naturally according to development of the water distribution networks by CMWSSB. In estimation of service connection rate, the estimated served population by CMWSSB has been used for consistency with the members per connection (8.5 persons per connection), which was also the estimation of CMWSSB. However, due to the high estimation of the population, the estimated connection rate might have been lower than the actual situation.
- Unit water consumption: National requirement on the unit water consumption in lpcd by Central Public Health and Environmental and Engineering Organization (CPHEEO) Manual is 150 lpcd in any corporation in India. CMWSSB, whose service is currently 101 lpcd, needs to augment the water production to reach the requirement. Among the Corporation area, the lpcds in the Expanded Area tend to be lower than those in the Core City. The uneven distribution of lpcd is expected to be mitigated along with the ongoing expansion of new water distribution networks by CMWSSB.
- Water production capacity and actual production: Various efforts made by the Government of Tamil Nadu and CMWSSB to satisfy the increasing water demand have doubled the production capacity from 2007 to 2013. However, actual production has remained at the same level except for the year 2012. CMWSSB is facing difficulties in satisfying the increasing water demand due to low availability of raw water, derived from frequent drought. Gaps in the potential water

availability, water production capacity and actual water production are presented in Table 3.2.4 for respective water sources, with the reasons for the low production volume.

- Recovery and re-degradation of water production in 2016: The production of CMWSSB was 596 MLD in 2015 but, after the intense rainfall in November and December 2015, it increased to and was maintained at around 830 MLD by September 2016. However, the production has fallen to 636 MLD by December after a sharp degradation of storage volume. (See Subsection 3.3.2 for relevant information and analysis on surface water availability.)
- Production control of CMWSSB in 2016: Figure 3.2.3 illustrates past monthly production by water source since 2014. In 2014 and 2015, the serious drought forced CMWSSB to operate the seawater desalination plants (DSPs) at high operation rate because of the low availability of surface water. After the intense rainfall in November and December 2015, however, water production from surface water recovered and accordingly the operation rate of the Nemmeli DSP was low (30 to 60%). As observed from the constant production, CMWSSB controlled the total production at 830 MLD, although the target LPCD of 150 was not satisfied. More production from the Nemmeli DSP would satisfy more water demand but CMWSSB limited the operation of the DSP. The low metered rate, by which fixed rate is applied to most water users, and the low water tariff does not motivate CMWSSB to operate the DSP at higher rate. (See Subsection 3.6.4 for financial condition of CMWSSB.)
- Operation rate of the seawater desalination plants: As explained above, CMWSSB controls production of the Nemmeli DSP so that the total production of CMWSSB would be their target volume (current target volume is 830 MLD). On the other hand, production of the Minjur DSP is constantly maintained at the high rate of 85 to 100 MLD because the plant is being operated under BOT scheme with take-or-pay rule[2]. In October and November 2016 CMWSSB increase the production in the Nemmeli DPS due to the low availability of surface water but the productions of both the DSPs decreased significantly in the next month. The reasons for the lower productions are influence of high turbidity of the seawater in the Nemmeli DSP and suspension of power supply to both the DSPs caused by Cyclone Wardha. (See Items (2) of Subsections 3.4.3 and 3.4.4 for influence of the high turbidity on the DSPs.)
- Non-Revenue Water (NRW)[3] and water loss: Due to the low metered rate and the flat rate charge to the unmetered customers, the concept of NRW cannot be adopted in Chennai. According to CMWSSB, however, estimated water loss ratio is about 20%, which is not a high value. One of the reasons for the low water loss ratio is the achievement by intensive distribution network rehabilitation project done by The World Bank in 1989-2001 (See Subsection 3.3.11 for more information on the project.)[4]. Short service hours and low pressure may also be the reasons for the low leakage.

2 Take-or-pay contract is a rule, where the company either takes the product from the supplier or pays the supplier a penalty.
3 Volume of water that were produced but not billed, which includes water leak, illegal consumption, metering error, etc.
4 The World Bank Project rehabilitated the distribution network in 11 water distribution zones out of 16 in the core city. Implementation Completion Report, of the project states that the leakage reduced by the project from 40% to 11%.

Table 3.2.1 Present Service Outlines of Water Supply Services by CMWSSB

Item		Outlines	Remarks
Service connections		673,339 nos	Those under the bulk meters are not counted.
Served population		8.63 million*1	In the Corporation
Served population through service connections		4.97 million*2	Estimated based on 8.5 persons per connection, agreed by CMWSSB (See Appendix 3.1)
Service connection rate	Core City	65%*2	See Appendix 3.1. People without service connection are receiving water from CMWSSB by lorries and stand posts.
	Expanded Area	41%*2	
	Corporation	58%*2	
Water consumption	Domestic	604 MLD	Including small-scale business, in 2016 (average)
	Non-domestic	48 MLD	Bulk industries and commercials, in 2015 (average)
	Total	652 MLD	-
Unit domestic water consumption	Core City	101 lpcd	Domestic consumption in litres per capita per day excluding water loss. See Appendix 3.2 for mapping by depot.
	Expanded Area	62 lpcd	
	Corporation	80 lpcd	
	Rest of CMA	30 lpcd*3	Information for 2013. It is reference information because the Rest of CMA is not service area of CMWSSB.
Service hours through the private connections		3 to 4 hours in a day in average	Observation by CMWSSB
Metered rate		3.9%	-
Water production		811 MLD	Average production in 2016 (See Table 3.2.4 for breakdown by water source).
Water loss ratio		20%*2	Estimated based on the consumption and production

*1: Official figure published by the state government is different. (See Table 3.2.3)
*2: Estimation by the JICA Study Team
*3: Estimation by the JICA Study Team based on information from TWAD Board in 2013. (See Table 5.1.4)
Source: CMWSSB except for *2 and *3 above

Table 3.2.2 Number of Service Connections by Category and Metered/Unmetered

Category		Number of private connections as of July 2016			Metered rate
		Unmetered	Metered	Total	
Domestic	Residential	574,893	10,163	585,056	1.74%
	Partly commercial	51,064	8,454	59,518	14.20%
	Subtotal	625,957	18,617	644,574	2.89%
Commercial	Commercial	2,082	6,483	8,565	75.69%
	Water intensive	0	6	6	100.00%
	Non water intensive	18,408	18	18,426	0.10%
	Private hospitals	272	284	556	51.08%
	Private education	255	443	698	63.47%
	Other hospitals	0	3		
	Subtotal	21,017	7,237	28,254	25.61%
Institutional	Governmental hospital	1	57	58	98.28%
	Other institutions	95	313	408	76.72%
	Subtotal	96	370	466	79.40%
Special bulk accounts	Municipal bulk supply*1	0	24	24	100.00%
	AUA*2 commercial	0	21	21	100.00%
	Subtotal	0	45	45	100.00%
Total		647,070	26,269	673,339	3.90%

*1: Among 24 bulk supply connections, nine connections are active at present, 15 connections, which are located in the Expanded Area, are not active after expansion of the direct service area of CMWSSB to the current corporation area. Out of nine active accounts, eight accounts are of seven municipalities and the other is of the military base.
*2: Adjacent-to-Urban-Area
Source: JICA Study Team

Table 3.2.3 Past Performances of the Water Supply and Sewerage Services by CMWSSB

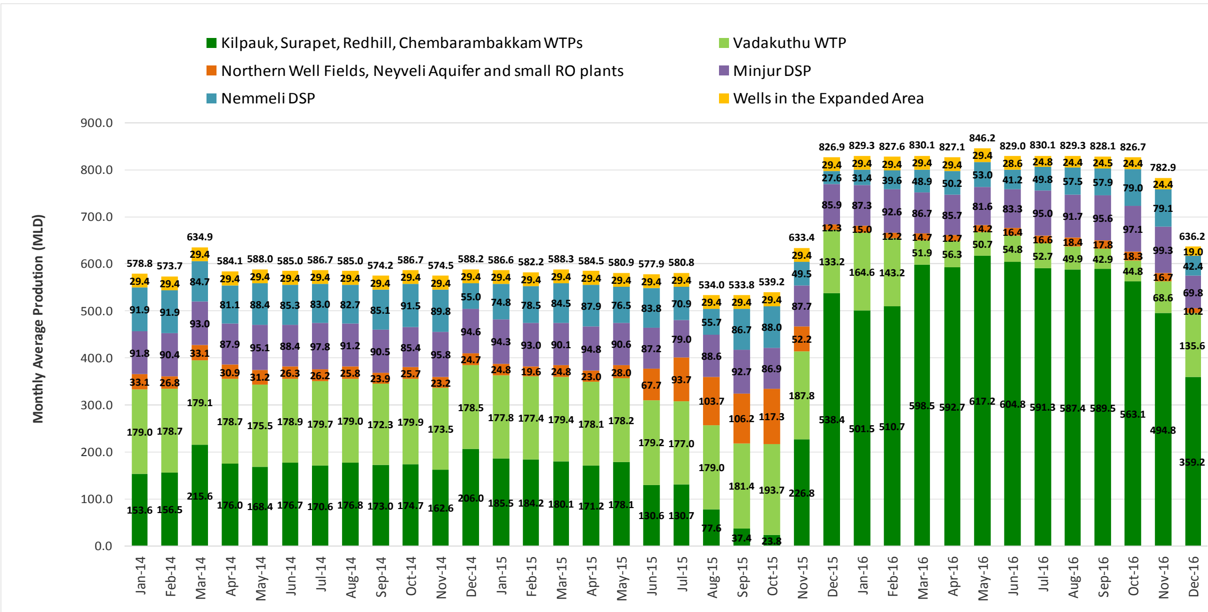
		2007	2008	2009	2010	2011	2012	2013	2014	2015
General Information										
Mandated area (km^2)*1		176	176	176	176	176	426	426	426	426
Population*2	Core City	-	-	-	-	4,647	-	-	-	4,728
	Corporation	-	-	-	-	6,396	-	-	-	7,054
Water Supply Services										
Served population (1,000 persons)*3		5,375	5,400	5,500	5,500	5,500	6,727	6,727	7,068	7,188
Number of connections		435,755	479,850	492,362	497,811	515,076	518,514	622,906	624,631	661,405
Production capacity (MLD)*4		850	1,380	1,380	1,394	1,523	1,523	1,623	1,623	1,623
Potential water availability (MLD)*5		1,410	1,410	1,410	1,510	1,539	1,539	1,639	1,639	1,639
Water production*6		642	657	639	660	797	845	713	587	596
Length of distribution network (km)		2,887	2,924	2,930	2,930	2,930	2,930	5,275	6,518	6,520
Sewerage Services										
Number of sewer connections		515,560	563,094	595,441	598,249	610,318	611,275	735,608	771,168	778,488
Treatment capacity (MLD)*7		486	486	486	486	486	558	558	649	769
Length of sewer network (km)		2,663	2,671	2,677	2,677	2,677	2,677	3,643	3,989	3,994

*1: Expansion of the mandated area took place in 2011 but it was reflected in the Policy Note from 2012.
*2: Populations in 2011 refer to Census 2011 and those in 2015 refer to population forecast in Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015 (M/P)
*3: Served population of CMWSSB is larger than population in its mandated area because CMWSSB provides bulk water supplies to outside its mandated area. Nevertheless the served population estimated by CMWSSB is much greater although CMWSSB does not include the served population under the bulk supplies.
*4: Water production capacity include the capacities from the surface water and seawater, which are indicated in the Tamil Nadu Policy Notes, and the safe yield of the groundwater from the Northern Well Fields (100 MLD) estimated in M/.P
*5: The potential water availability refers to “Potential Yield”of the existing fresh water supply presented in M/P. Breakdown of the figure for 2015 (1,610 MLD) is potential supply capacity of the reservoirs in CMA, allocated for drinking water (Poondi, Cholavaram, Redhill and Chembarambakkam) (200 MLD), authorized allocation from the Krishna River (930 MLD) and Veeranam Reservoir (180 MLD), safe yield from the Northern Aquifer (100 MLD) and the capacity of the seawater desalination plants (100 MLD x 2), and capacity of the existing wells in the Expanded Area (29 MLD).
*6: Water productions are based on operational data provided by CMWSSB.
*7: Actual treated volume is unknown because the flows are not measured at all treatment plants.
Source: Tamil Nadu Policy Note 2006-2007 to 2015-2016 (Municipal Administration and Water Supply Department, the State Government of Tamil Nadu), except *2 and *6 above

Table 3.2.4 Gaps in the Potential Water Availability, Production Capacity and Production

Water resources	Potential water availabilities	Production facilities	Production capacities	Production*		Reasons for the low production
				2015	2016	
Reservoirs in the Tamil Nadu State	200 MLD	Kilpauk WTP Surapet WTP Puzhal WTP Chembarambakkam WTP	1,114 MLD	159 MLD	551 MLD	• Evaporation and seepage from the reservoirs and transmission channels • Low precipitation in drought years • Illegal tapping from the channels mostly by farmers (for the Krishna River water, such tapping exists in Andhra Pradesh State side, too)
Krishna River	930 MLD					
Cauvery River (Veeranam Reservoir)	180 MLD	Vadakuthu WTP	180 MLD	177 MLD	76 MLD	• Low precipitation in drought years • (in 2016) Low availability of the raw water due to desludging work of the reservoir
Seawater	100 MLD	Minjur DSP	100 MLD	88 MLD	89 MLD	• Suspension of power supply • Maintenance work (no stand-by RO unit is equipped)
	100 MLD	Nemmeli DSP	100 MLD	74 MLD	53 MLD	• Suspension of power supply • Deteriorated performance in high turbidity conditions in monsoon seasons
Sub-total			1494 MLD	498 MLD	769 MLD	
Groundwater (or subsurface water)	129 MLD	Northern Well Fields, Wells in the Expanded Area, etc.	129 MLD	98 MLD	42 MLD	Deterioration of the pumps in the Northern Well Fields
Total	1,639 MLD	-	1,623 MLD	596 MLD	811 MLD	

* : Water production in annual average
Source: JICA Study Team



Source: JICA Study Team

Figure 3.2.3 Monthly Water Production of CMWSSB by Water Source

3.2.3 Public Awareness to the Services

(1) Results in a past study by CMWSSB

In the year 2000, CMWSSB entrusted Economic Perspectives Consulting Pvt. Ltd. to conduct Customer Satisfaction Surveys in Chennai City, which is the current Core City, among CMWSSB Assesses and Slum Dwellers. It was a long-run survey from August 2000 to April 2006 that included sending questionnaires to 56,000 households and businesses to inquire about water use condition, satisfaction level, and requirement to the water supply services of CMWSSB. After 2006, no similar survey has been conducted by CMWSSB or other entities. In March 2016, the JICA Study Team received the report of the customer service survey in 2000 to 2006. The major findings of the survey are listed below:

- 89% of the respondents chosen by random sampling in the Core City received water from CMWSSB (Metro Water); 81% of them also had their own sources. The other sources were bored wells or open wells.
- 77% of those who used Metro Water had piped service. It is equivalent to 69% of all the respondents.
- A majority of those who received supply water used the Metro Water for drinking (85%) and cooking (90%). This indicates the high quality of Metro Water. Groundwater from the wells of the respondents was also used for drinking (14%) and cooking (19%).
- Among those who received Metro Water, 80% respondents said that water was adequate in quantity, 80% said that the water was of good quality, 44% said that the pressure was good, and 26% said that the pressure was normal.
- Most of the complaints were related to non supply of water (52%), water contamination (11%), sewer block in the house (27%), sewer block on road (4%), and the rest had complaints such as lack of pressure.

As described above, the satisfaction level of the Metro Water in the early 2000s in the Chennai Core City was generally high in terms of both quantity and water quality.

(2) Result of the Social Baseline Survey by the Study Team

1) Outlines of the Survey

The JICA Study Team has conducted a social baseline survey, which included questionnaire survey to 1,200 households and businesses in CMA on water supply and sanitation conditions. The major items investigated by the survey are the followings:

- Water sources of the people in the sample households and businesses and water use purpose by water source
- Service levels of the water supply and sewerage services by CMWSSB to the connected people to CMWSSB services and satisfaction of the water users to the services

2) Samples of the questionnaire survey

The Social Baseline Survey took 1,244 samples across the Chennai Corporation, the current service area of CMWSSB, and certain areas from the Rest of CMA that will be served by the Project. The surveyed areas in the Rest of CMA are OC-15 and OC-16. (See Subsection 5.2.3 for determination of the influence area of the Project)

Among the 1,244 samples, 903 samples were domestic, 281 samples were partly-commercial and 60 samples were commercial. Partly-commercial is a category for domestic consumers combined with commercial space in the same building. Table 3.2.5 shows the number of the samples.

Table 3.2.5 Composition of the Samples in the Social Baseline Survey

	Sample category			Total
	Domestic	Partly-Commercial	Commercial	
Core City	436	138	48	622
Expanded Area	331	119	12	462
Rest of CMA	136	24	0	160
Total	903	281	60	1,244

Source: JICA Study Team

3) Connection to the CMWSSB's water supply services

Table 3.2.6 presents the connection of domestic samples including partly-commercial category to the water supply services by CMWSSB in the Corporation. Of the total respondents (1,024 samples), 78.4% (803 samples) answered that they received water supply from CMWSSB. However, only 11.6% used water from the tap while 88.1% used a hand pump or sump to extract water from the water distribution network.

The low percentage of the respondents using water tap will be derived from the short and low frequency of water supply services by CMWSSB and low water pressure. The most consumers, who are using hand pumps and sump, once store the supplied water before they use it. Consumers using hand pump are extracting water from the network by their hand pumps connected to the distribution mains. Without the hand pumps, the water will not reach their houses. (See Table 3.3.8 in Subsection 3.3.7 for typical section of the service connections)

Comparing the two areas, more people used taps in the Expanded Area than the Core City. The reason for this difference is unknown.

Table 3.2.6 Connection to the CMWSSB's Water Supply Services

Having Connection and Method of Drawing Water	Core City			Expanded Area			Total for the Corporation		
	No.	%	Valid %	No.	%	Valid %	No.	%	Valid %
Yes, hand pump	256	44.6	50.4	134	29.8	45.4	390	38.1	48.6
Yes, tap	23	4.0	4.5	70	15.6	23.7	93	9.1	11.6
Yes, sump	227	39.5	44.7	90	20.0	30.5	317	31.0	39.5
No	66	11.5	-	155	34.4	-	221	21.6	-
Yes, but no supply	2	0.3	0.4	1	0.2	0.3	3	0.3	0.4
Total	574	100	100	450	100	100	1024	100.0	100.0

Source: JICA Study Team

4) Supply frequency and duration

Table 3.2.7 and Table 3.2.8 present the frequency and duration of water supply by area in the domestic samples that are connected to the CMWSSB's water supply services.

In the overall Corporation, 48.9% responded that they received water supply daily, while 44.0% responded that the water supply is alternate day or more. People in the Core City are enjoying water supply services of higher frequency than those in the Expanded Area but still 31.9% are not receiving daily supply. Service frequency in the Expanded Area is the worse, where only 25.9% are receiving daily supply. The reasons for the less frequency in the Expanded Area will be primarily less capability of the water distribution networks in the area and may be high prioritization given to the Core City by CMWSSB.

Duration of the water supply services is also low level in the Corporation. Only 5% are receiving 24 hour supply and the 88.1% are four hours or less. In the Expanded Area, especially, the service duration is two hours or less at 81.8% of the respondents. In addition to insufficient water volume, as the reasons for the shorter service duration, incapability of the water distribution networks in the Expanded Area is suspected.

Table 3.2.7 Water Supply Service Frequency of CMWSSB

	Core City			Expanded Area			Total for the Corporation		
	No,	%	Valid %	No,	%	Valid %	No.	%	Valid %
Daily	322	63.4	68.1	71	24.1	25.9	393	48.9	52.6
Alternate Day	122	24.0	25.8	136	46.1	49.6	258	32.1	34.5
Twice a week	12	2.4	2.5	29	9.8	10.6	41	5.2	5.5
Erratic	17	3.3	3.6	38	12.9	13.9	55	6.8	7.4
Not disclosed	35	6.9	-	21	7.1	-	56	7.0	-
Total	508	100.0	100.0	295	100.0	100.0	803	100.0	100.0

Source: JICA Study Team

Table 3.2.8 Water Supply Service Duration of CMWSSB

	Core City			Expanded Area			Total for the Corporation		
	No,	%	Valid %	No,	%	Valid %	No.	%	Valid%
24hours	21	4.1	6.0	8	2.7	3.5	29	3.6	5.0
<=12hours	37	7.3	10.6	3	1.0	1.3	40	5.0	6.9
<=4hours	91	17.9	26.1	31	10.5	13.4	122	15.2	21.0
<=2hours	132	26.0	37.8	64	21.7	27.7	196	24.4	33.8
<=60mts	61	12.0	17.5	106	35.9	45.9	167	20.8	28.8
Up to 30 mts	7	1.4	2.0	19	6.4	8.2	26	3.2	4.5
Not disclosed	159	31.3	-	64	21.7	-	223	27.8	-
Total	508	100.0	100.0	295	100.0	100.0	803	100.0	100.0

Source: JICA Study Team

5) Water quantity

Table 3.2.9 presents satisfaction level to water quantity from the CMWSSB's water supply services. 61.8% of the respondents expressed that the water volume was adequate in the Corporation, while 38.2% expressed that the volume was sometimes or always inadequate. Satisfaction to the adequacy is the better in the Core City than that in the Expanded Area, which is the similar trend as the water service frequency and duration.

Compared with the survey result in the survey in the year 2000, the satisfaction level to the water quantity had been deteriorated. The satisfaction rate to the water adequacy was 80% in the survey in 2000.

Table 3.2.9 Adequacy of Water Supply Volume by CMWSSB

	Core City			Expanded Area			Total for the Corporation		
	No,	%	Valid %	No,	%	Valid %	No.	%	Valid
Adequate	327	64.3	68.7	129	43.7	49.2	456	56.8	61.8
Inadequate, sometimes	118	23.2	24.8	69	23.4	26.3	187	23.3	25.3
Inadequate, always	31	6.1	6.5	64	21.7	24.4	95	11.8	12.9
Not disclosed	32	6.3	-	33	11.2	-	65	8.1	-
Total	508	100.0	100.0	295	100.0	100.0	803	100.0	100.0

Source: JICA Study Team

6) Water quality

Table 3.2.10 presents the water quality satisfaction level of households who are connected to CMWSSB's services. In the overall Corporation, 86.0% expressed satisfaction to the water quality and 46.5% answered that the quality is very good or good. On the other hand, dissatisfaction rate in the Corporation was 14.1%. There is little gap in the dissatisfaction rates between the Core City (13.3%) and the Expanded Area (15.6%), whose reasons will be that the Core City and the Expanded Area share the water sources.

The reasons for the dissatisfaction were colors and odors. To the questionnaires on color of the water supplied, approximately 50 % of the water consumers of CMWSSB in the Core City and the Expanded Area responded that the water was sometimes or always yellow or turbid. Similarly, approximately 50% in both areas responded that the water had sometimes or always odor.

From the satisfaction rate of 86.0%, the water quality of CMWSSB is evaluated as good and it is better than the survey result in 2000, where the satisfaction rate was 80%. However, it should be noted that the current percentage of "very good" or "good" is still 46.5%. It is suggested that there would be room for improvement in the water quality.

Table 3.2.10 Water Quality of CMWSSB

	Core City			Expanded Area			Total for the Corporation		
	No,	%	Valid %	No,	%	Valid %	No.	%	Valid %
Very good	41	8.1	8.6	31	10.5	11.7	72	9.0	9.7
Good	175	34.4	36.8	97	32.9	36.6	272	33.9	36.8
Satisfactory	196	38.5	41.2	96	32.5	36.2	292	36.4	39.5
Not satisfactory	26	5.1	5.5	19	6.4	7.2	45	5.6	6.1
Bad	26	5.1	5.5	11	3.7	4.2	37	4.6	5.0
Very bad	11	2.2	2.3	11	3.7	4.2	22	2.7	3.0
Not disclosed	33	6.5	-	30	10.2	-	63	7.8	-
Total	508	100.0	100.0	295	100.0	100.0	803	100.0	100.0

Source: JICA Study Team

7) Water pressure

Table 3.2.11 presents satisfaction level of the households to the water pressure of the water supply by CMWSSB. Satisfaction in the Corporation was 88.0%, while the percentage of “very good” or “goo” was only 45.3% expressed that the pressure was very good or good. There is little gap between the satisfaction level between the Core City and the Expanded Area.

As a whole the satisfaction level to the water pressure is good in the Corporation. As the service frequency is low and the duration is short, however, the current satisfaction of the consumers to the water pressure will not be decisive evidence of the capability of the water distribution networks. The water pressure will be different when the water supply frequency and duration are improved.

Table 3.2.11 Water Pressure of CMWSSB

	Core City			Expanded Area			Total for the Corporation		
	No,	%	Valid %	No,	%	Valid %	No.	%	Valid %
Very good	34	6.7	7.3	24	8.1	9.2	58	7.2	8.0
Good	187	36.8	40.0	85	28.8	32.4	272	33.9	37.3
Satisfactory	194	38.2	41.5	117	39.7	44.7	311	38.7	42.7
Not satisfactory	32	6.3	6.9	19	6.4	7.3	51	6.4	7.0
Bad	18	3.5	3.9	12	4.1	4.6	30	3.7	4.1
Very bad	2	0.4	0.4	5	1.7	1.9	7	0.9	1.0
Not disclosed	41	8.1	-	33	11.2	-	74	9.2	-
Total	508	100.0	100.0	295	100.0	100.0	803	100.0	100.0

Source: JICA Study Team

8) Conclusions

From the survey results above, it was found that only 48.9% in the Corporation received daily water supply and especially the daily supply rate in the Expanded Area was as low as 25.9%. The service duration was four hours or less at 83.6% of the responded in the Core City and, in the Expanded Area, service duration of two hours or less shares 81.8%. Water volume was adequate for 61.8% respondents in the Core City, while it was only 49.2% in the Expanded Area. The result indicates that the service level of CMWSSB had been significantly deteriorated from the year 2000, when the similar survey found that 80% of the water consumers were satisfied to the water volume adequacy.

In conclusion, increasing water demand and the limited production volume by CMWSSB have resulted in lower service level in terms of water service frequency, service duration and water adequacy by CMWSSB. Augmentation of the water production is obviously an urgent issue to satisfy the water consumers. The inferior service level in the Expanded Area to the Core City would be derived from the incapability of the existing water distribution networks, whose improvement by CMWSSB is expected. Satisfaction level to the water quality is not low, but CMWSSB would be required to make efforts to eliminate the dissatisfaction and to raise the perception of “Satisfactory” (currently 39.5%) to “Very good” or “Good” (46.5% totally).

3.3 Present Conditions of the Water Supply Systems and Facilities

3.3.1 Overviews on the Water Supply

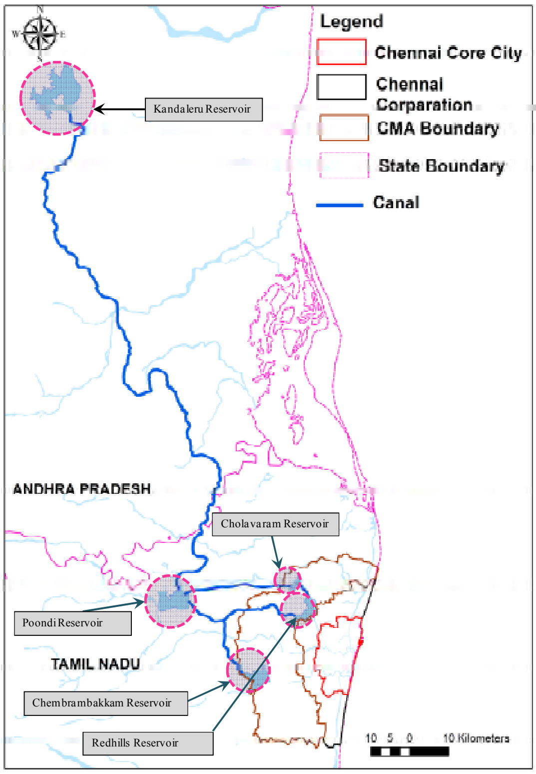
Water supply facilities of the CMA are controlled by CMWSSB and the ULBs. CMWSSB exclusively controls the water supply facilities for the Chennai Corporation Area, while respective ULBs control those for the Rest of CMA.

Control of the surface water resources and operation and maintenance of the water reservoirs are the responsibility of Water Resource Department (WRD), a branch of the Public Works Department (PWD), an agency of the Government of Tamil Nadu State.

The water supply facilities have been created and improved during the development of the City Corporation and the Rest of CMA. Major water supply facilities available at present to CMWSSB and ULBs are presented below.

Source: JICA Study Team

Picture 3.3.1 Poondi Reservoir



Source: JICA Study Team

Figure 3.3.1 Water Reservoirs and Canals

(1) Chennai Corporation Area

For the Chennai Corporation, there are three types of drinking water production facilities including Water Treatment Plant (WTP), Seawater Desalination Plant (DSP), and well to extract ground water. There are five WTPs with a total design capacity of 1,294MLD, two DSPs with a total design capacity of 200MLD and six well field on the Northern Aquifer (180MLD) and that on Southern Coastal Aquifer (10 MLD).

Among the three systems, WTPs are mainly serving the drinking water purpose of the Chennai Corporation, and the DSPs and Southern Costal Aquifer are serving the drinking water and industrial use, and six well fields are mainly serving for the industries in the northern part of the Corporation.

However, the average of the production of the five WTPs in last five years until 2015 has been about 47% of the total design capacity due to inadequate raw water resources, deterioration of water supply facilities and insufficient operation and maintenance. Evaporation and seepage from the reservoirs and canals also contribute to the shortage of the raw water volume. Further, Chembarambakkam treated water transmission main is being expanded to increase the transmission capacity by installing 2,000 mm diameter new parallel pipelines, however, this may not contribute to the increase of water supply volume to the Chennai Corporation especially during the dry season or drought years unless raw water resources are augmented by ensuring adequate receipt of Krishna water from neighbouring Andhra Pradesh State.

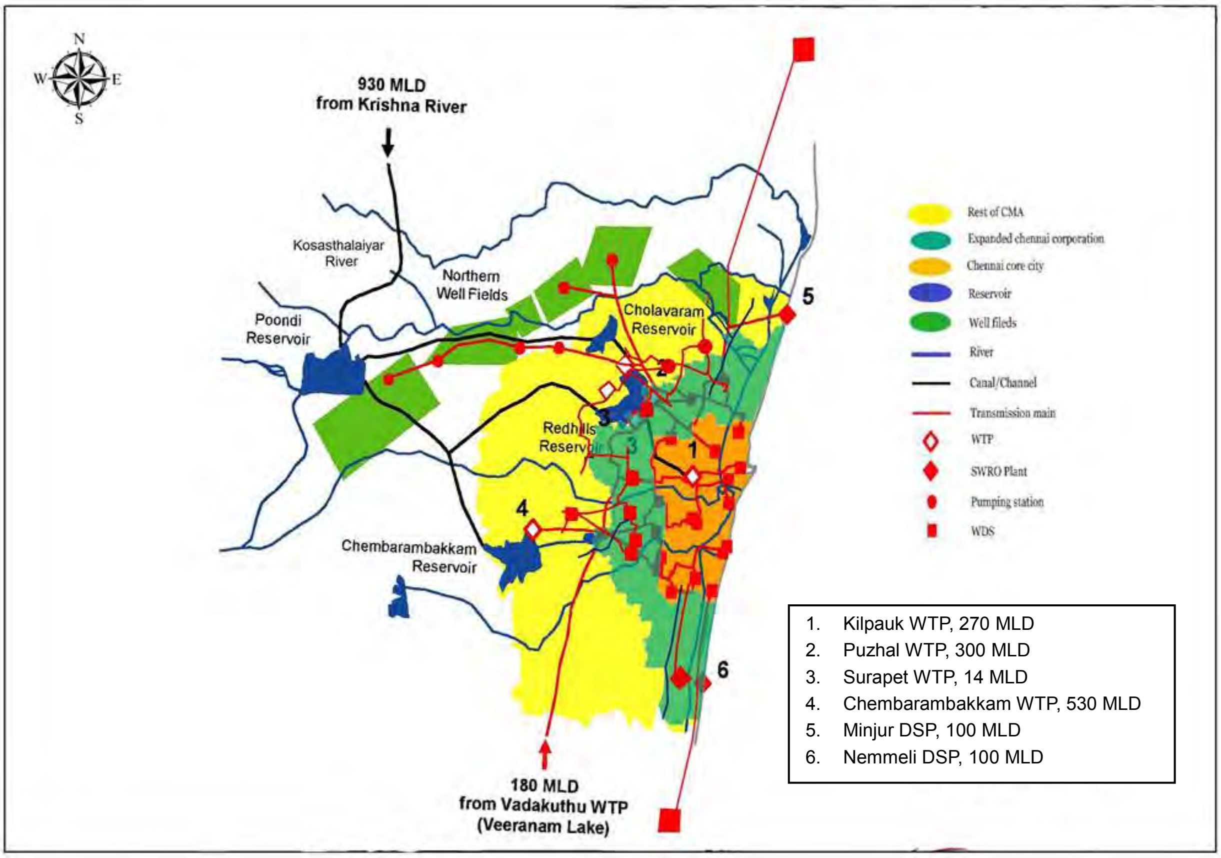
CMWSSB has five raw water sources viz., Poondi, Cholavaram, Redhills (Puzhal), Chembarambakkam and Veeranam reservoirs with a total capacity of 354.58M m^3.The four (4) reservoirs with a combined capacity of 313.1Mm^3 around Chennai Corporation, serve as an exclusive water sources for four (4) WTPs viz Kilpauk WTP, Surapet WTP, Puzhal WTP and Chembarambakkam WTP. Poondi reservoir is connected with three (3) reservoirs viz. Chembarambakkam, Redhills and Cholavaram through linked canals with the total length of 84 km. During the dry season, Poondi reservoir, which receives Krishna water directly from the neighbouring Andhra Pradesh state, is the main water source for Chembarambakkam, Redhills and Cholavaram reservoirs. According to the Inter State water agreement made between Tamil Nadu state and Andhra Pradesh state, Andhra Pradesh state has a responsibility to supply the 930 MLD of raw water from Kandaleru reservoir having the capacity of 1,924 million m^3 to Poondi reservoir. From the statistical data, out of the allocated 930 MLD, the highest volume received by the Poondi reservoir is 678 MLD in the year 2011. Since 2012, the received volumes have been less than 300 MLD except for the year 2014, which was provided with 528 MLD. Reasons for the less amounts than the agreement is due to the drought conditions and unauthorized tapping in the Andhra Pradesh state along the raw water transmission channel.

During the drought years, most of the four (4) reservoirs get dried up and very less sometimes no raw water will be supplied to the WTP, and groundwater well fields including private agricultural wells and SWRO Plant mainly supply water to the customers. Veeranam reservoir situated about 200 km south of Chennai, with a capacity of 41.48 million m^3, used for both drinking and agricultural purposes, serves as the primary water source for Vadakuthu WTP.

The Chennai Core City is divided into 18 Water Distribution Zones (WDZs) having 18 Water Distribution Stations (WDSs), which receive water supply from the various WTPs, DSPs and wells. The produced water from the water sources is transmitted by pumps to the18 WDSs by water transmission mains having a total length of 490 km. Beside the Core City, various underground tanks or reservoirs located in the Expanded Area also receive water by direct tapping from the water transmission mains. Due to the shortage of water, CMWSSB supplies the treated water to each WDS and the Expanded Area based on certain rationing schedule with limited volume.

In the Corporation, there are distribution pipes with a total length of 6,520 km and 673,339 service connections. Due to lack of water pressure at the terminal of the distribution networks, many consumers own hand pumps and underground tank or sump so as to collect the water from the distribution main.

General layout of the existing water supply system of CMWSSB is shown in Figure 3.3.2.



Note: Location of Vadakuthu WTP is given in Appendix 3.5.
Source: JICA Study Team

Figure 3.3.2 General Layout of the Existing Water Supply System of CMWSSB

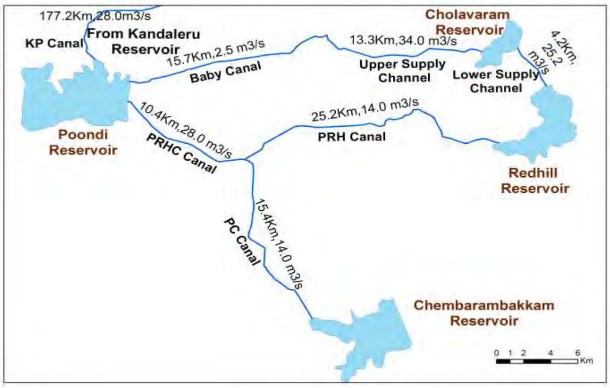
(2) Rest of CMA

All the ULBs in the Rest of CMA have water supply schemes composed of water sources of own wells and water distribution networks, basically provided by ULBs or by the TWAD Board. The per capita water supply rate per day is mostly in the range of 20 to 70 litres according to Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA. The total average has been estimated by the JICA Study Team at 30 lpcd in 2013. (See Table 5.1.4)

3.3.2 Water Resources and Raw Water Transmission

(1) Water resources

CMWSSB has five raw water sources viz., Poondi, Cholavaram, Redhills (Puzhal), Chembarambakkam and Veeranam reservoirs with a total capacity of 354.58 million m^3 and these reservoirs are operated and maintained by PWD. Reservoirs of Poondi, Cholavaram, Redhills (Puzhal) and Chembarambakkam are located in the western part of the Chennai Corporation as shown in Figure 3.3.2, and Veeranam is located about 200 km south of the Chennai Corporation. (See Appendix 3.5 for location of the Veeranam reservoir) Figure 3.3.3 illustrates a raw water transmission network linking the four reservoirs.



Source: JICA Study Team

Figure 3.3.3 Location of 4Four Reservoirs and Raw Water Transmission Canals

General characteristics of the raw water reservoirs are shown in Table 3.3.1. Four water reservoirs out of five reservoirs are used only for drinking water purposes and Veeranam reservoir is used for both drinking and agricultural purposes.

Table 3.3.1 General Characteristics of the Water Reservoirs Used by CMWSSB

	Name of Reservoir	Storage Volume (Million m^3)	Water Spread Area (km^2)	Catchment Area (km^2)	Purpose
1	Poondi	91.49	32.63	1,968.40	Drinking water
2	Cholavaram	24.95	5.18	28.49	Drinking water
3	Redhills (Puzhal)	93.45	20.20	59.57	Drinking water
4	Chembarampakkam	103.21	25.24	354.17	Drinking water
5	Veeranam	41.48	38.65	28.00	Drinking water and irrigation water for 1,800ha
	Total	354.58		2,438.63	

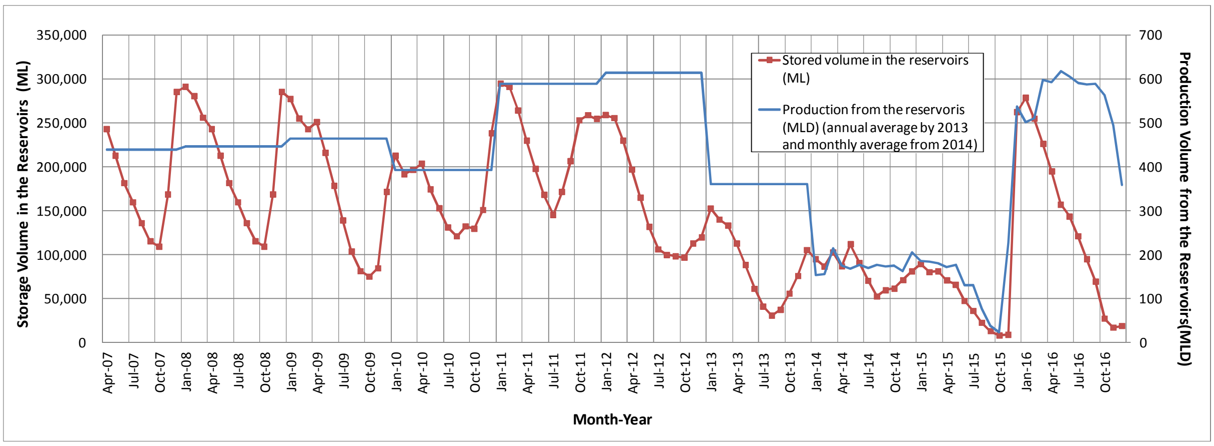
Source: CMWSSB website and Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

In addition to the above water sources, there is one seepage ground water resource in the coal mine site of Neyveli Lignite Corporation located around 5.5 km away from the Vadakuthu WTP (See Appendix 3.5.1 for the location), which supplies the raw water of 40 MLD to the Vadakuthu WTP during the drought year i.e. whenever Veeranam reservoir was not able to supply water to Chennai Corporation.

The four reservoirs of Poondi, Cholavaram, Redhills, and Chembarambakkam are mostly recharged during the northeast monsoon from October to December. Three major rivers viz., Araniyar river, Kosathaliyar river and Cooum river convey the rain water from the catchment areas to the four reservoirs. In addition, raw water transmission system extended from the Kandaleru reservoir draws raw water from the Krishna river. However, the three major rivers in the Tamil Nadu State, which are non-perennial rivers, have only seasonal flows during the rainy season. The south west monsoon during June to August brings lesser rain and helps to improve ground water table in the Chennai Corporation but it does not significantly contribute to the storage in the reservoirs. Veeranam reservoir is recharged by Cauvery river, whose flow depends on the rainfall of the southwest monsoon.

Figure 3.3.4 presents water storage in the four reservoirs and the annual average production from the reservoirs since April 2007, when the water intake arrangements in the Chembarambakkam reservoir were constructed. It is observed that the water storage in the reservoirs have direct link with the production. In every year, water storage recovers in the north east monsoon during October and December. Much storage during the north east monsoon enabled high water production in 2011 and 2012. However, water storage did not recover much in the monsoon in 2012, 2013 and 2014, which has resulted in low production in 2013, 2014 and 2015.

In November and December 2015, the intense rainfall recovered the storage in the reservoirs. After the recovery, CMWSSB has increased the production to about 600 MLD, which is almost the highest level since 2007, and the high production level has been maintained in until August 2016. However, as the storage has dropped sharply, CMWSSB reduced the production from the reservoirs in August 2016. Although CMWSSB expected recovery of the storage in north east monsoon from October, the low precipitation caused further degradation of the water level. In December 2016, as the storage volume fell to the least level since 2007, CMWSSB was forced to reduce the production to 359.2 MLD, which was only 60% of the production by August in the same year. Reportedly the rainfall by Cyclone Wardha, which hit Chennai in 13th December, has recovered the storage somehow but its impact on the water production is limited. CMWSSB will still face severe surface water shortage in 2017 because the monsoon has ended with the extremely low storage volume.



Source: JICA Study Team based on operational data provided by CMWSSB

Figure 3.3.4 Storage Volume of the Four Reservoirs and the Monthly Average Production Volume from the Reservoirs

Regarding the Veeranam reservoir on the other hand, due to direct flow from the Cauvery river, raw water loaded with soil enters the Veeranam reservoir and decreases the water storage volume due to soil settlement. In April 2016, desludging (Picture 3.3.2) was started by the Water Resource Department of the Tamil Nadu State to restore the original storage volume. It was scheduled to complete the desludging in eight months and during this period groundwater extracted from the nearby areas became the raw water source of Vadakuthu WTP. The desludging work was completed by September 2016 and the tank was filled up with water.

All five reservoirs mentioned above are shallow in depth with a range of 4.8 m to 10.7 m and wide water spread area. The Master Plan estimated that the water losses due to evaporation from the reservoirs over 43 %. The estimation was based on the annual water flow to the reservoirs, evaporation rate of 4.5 mm per day[5], and water spread of the reservoirs.

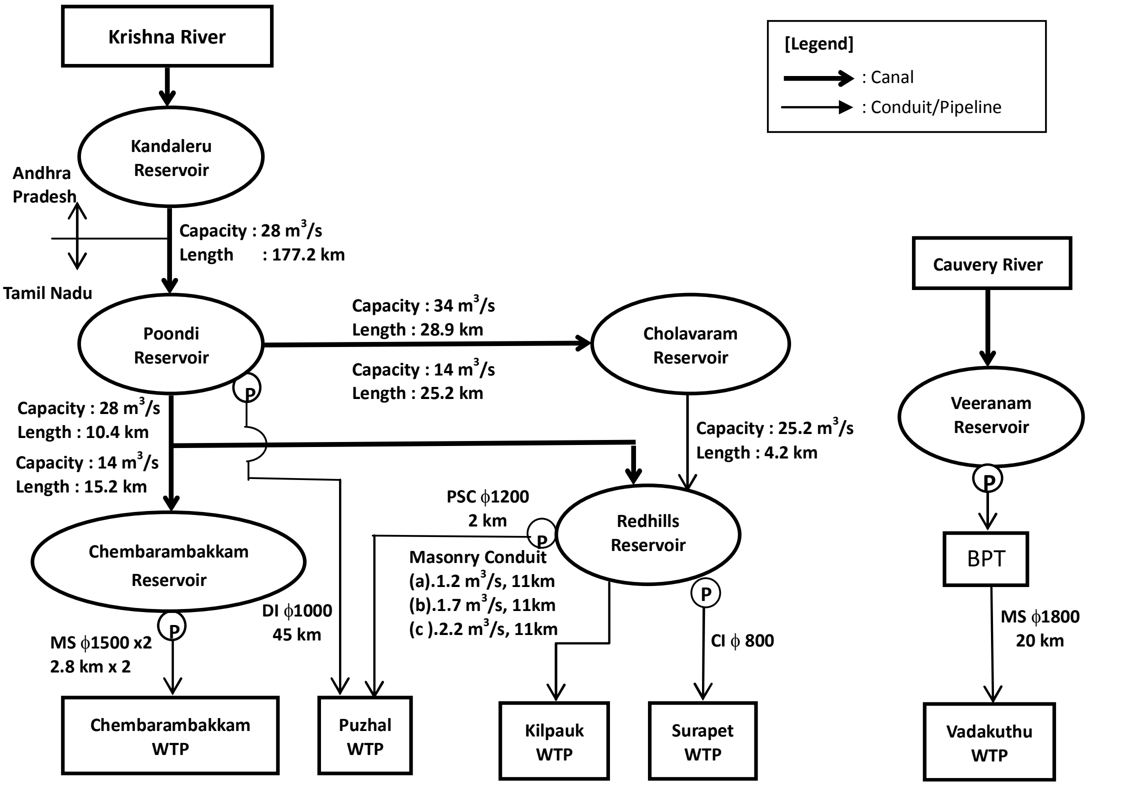
Source: JICA Study Team

Picture 3.3.2 Veeranam Reservoir, Empty for the Desludging Work

(2) Raw water transmission system

The raw water is transmitted by the canals and raw water transmission mains. The purpose of the canals is to convey the raw water to the reservoirs having the arrangement for WTPs, and the purpose of raw water transmission main is to supply the raw water from the intake to the WTPs. However, Veeranam reservoir directly receives the raw water from the Cauvery river. Raw Water Transmission System including the length and capacity information is shown in Figure 3.3.5.

[5] M/P mentions that evaporation rate of the reservoirs in India is generally 2.0 to 2.5 m per year, which is equivalent to 5.48 to 6.85 mm per day.



Note: BPT: Break Pressure Tank, P: Pump(s), PSC: Pre-Stressed Concrete Pipe, MS: Mild Steel Pipe, DI: Ductile Iron Pipe: CI: Cast Iron Pipe

Source: JICA Study Team

Figure 3.3.5 Raw Water Transmission System for the Chennai Corporation

1) Canals

Raw water of the Poondi reservoir is conveyed from Kandaleru reservoir situated in the north in state of Andhra Pradesh through Telugu Ganga canal having a length of 177 km. Poondi reservoir supplies the raw water to the three reservoirs namely Chembarambakkam, Redhills and Cholavaram through canals having a total length of 85 km.

The canals are mainly utilized during the dry season to convey Poondi reservoir water when other reservoirs have less water. According to CMWSSB, one of the main reasons for water losses is evaporation from the canals; therefore CMWSSB has requested WRD to limit the use of canals. Further, it is also observed that the inadequate canal maintenance (Picture 3.3.3), which is responsibility of WRD, is also one of the causes for the water losses.

Source: JICA Study Team

Picture 3.3.3 Damaged Canal Slope

2) Raw water transmission mains

Intake facilities for raw water are located in five reservoirs. Puzhal WTP has two intakes which receive water from Redhills and Poondi reservoirs while the other four WTPs have one intake each. Long transmission main (45 km) was laid from the Poondi to the Puzhal WTP to minimize transmission water loss from the canal. Detailed information of the water transmission mains is given in Appendix 3.5.

Among the water transmission mains, noticeable deterioration of masonry conduits from Redhill Reservoir to Kilpauk WTP is observed. The masonry conduit of 2.2 m^3/s (190 MLD) capacity, built in 1983, is in disuse now due to brick arch failure in many places. Also due to certain difficulties encountered during the operation and maintenance and aging facilities, the other two masonry conduits are also deteriorating thereby affecting both quantity and quality of raw water to Kilpauk WTP.

Operation and maintenance of the raw water transmission mains are done by CMWSSB. CMWSSB has taken up the replacing works of the masonry conduits but they have not been carried out in the entire stretch due to the land acquisition problem.

3.3.3 Water Treatment Plant

The present conditions of the existing water treatment plants (WTPs) are described in the subsection. Details on the existing seawater desalination plants will be given in a separate section, Section 3.4.

(1) General information

Under CMWSSB, five WTPs with a total design capacity of 1,294 MLD are currently operated and act as main water supply facilities to the Chennai Corporation. However, the actual water production has been much less than the designed capacity due to insufficient volume of raw water mainly and facility deterioration and lapse in operation and maintenance partly. According to the operational data of CMWSSB from the year 2011 to 2015, the lowest annual average production of the five WTPs was 460 MLD, and the highest was 703 MLD, which are 36% and 54% of the designed capacity respectively. In 2016, after the intense rainfall in December 2015, the monthly productions from the five WTPs have been maintained at 656 MLD but it is 51% of the design capacity. WTPs are not operated to full capacity even when reservoirs are full due to the regulation of intake volume to conserve water sources to maintain consistent water supply throughout the year including dry season.

General information of the existing WTPs of CMWSSB is shown in Table 3.3.2.

Source: JICA Study Team

Picture 3.3.4 Puzhal (Redhills) WTP

Source: JICA Study Team

Picture 3.3.5 Chembarambakkam WTP

(2) Operation and maintenance (O&M) conditions of the WTP facilities

Operation and maintenance of three WTPs out of five WTPs is done by outsourcing to O&M contracting companies, and rest of the WTPs is managed by CMWSSB.

According to the site investigation, O&M companies, especially for Puzhal WTP and Vadakuthu WTP, need to improve the skill of existing operators and/or assign skilled workers to carry out the proper, efficient and safe O&M, which is evaluated from the observed problems such as insufficient process operation like mud in the filter, direct dosing chlorine gas without measurement, insufficient equipment maintenance and so on. For the backwashing of filters, all of the WTPs have some physical or O&M problems, and it needs to be modified for efficient washing by modifying back washing facilities and improvement of the operator's skill.

Table 3.3.2 General Information of the Existing Water Treatment Plants of CMWSSB

Name of WTP	Kilpauk WTP	Surapet WTP	Puzhal (Redhills) WTP	Chembarambakkam WTP	Vadakuthu WTP
Design capacity	270 MLD (45/135/90 MLD)	14MLD	300MLD	530MLD	180MLD
Production*1 (high/Low)	242MLD (2012) 79MLD (2015)	5MLD (Constant)	162MLD (2012) 108MLD (2015)	222MLD (2011) 102MLD (2014)	177MLD (2014) 70MLD (2011)
Year of construction	1959/1969/1983	1965	1996	2007	1974/2004
Fund	Government	Government	World Bank	French/Government	Government
Treatment Process	Rapid sand filtration	Rapid sand filtration	Rapid sand filtration	Rapid sand filtration	Rapid sand filtration
Main facility	• Catch basin • Raw water pump house • Clarifloculator • Rapid sand filter • Clear water tank • Clear water pump house • Over head tank • Back wash pump • Sludge treatment system (Not in use) • Chemical dosing system (Chlorine, Alum and Lime) • Emergency Gen House	• Raw water pump house • Aeration • Clarifloculator • Rapid sand filter • Clear water tank • Clear water pump house • Back wash pump • Chemical dosing system	• Catch basin • Clarifloculator • Rapid sand filter • Clear water tank • Clear water pump house • Back wash pump • Sludge treatment system (Not in use) • Chemical dosing system • Emergency Gen House	• Aeration chamber • Clarifloculator • Rapid sand filter • Clear water tank • Clear water pump house • Over head tank • Back wash pump • Sludge treatment system • Chemical dosing system • Clear water pump house • Emergency Gen House	• Catch basin • Clarifloculator • Rapid sand filter • Clear water tank • Clear water pump house • Over head tank • Back wash pump • Sludge treatment system • Chemical dosing system Emergency Gen House
Water quality*3	Sometimes or often turbidity is not meeting with the standard*4	No data obtained	Meet with the standard	Meet with the standard	Meet with the standard
Loss in WTP	Less than 5 %	Less than 5 %	Less than 3.4 %	Less than 1 %	Less than 5 %
O&M*4 made by	CMWSSB	CMWSSB	VATECH WABAG (Private)	Degremont (Private)	VATECH WABAG (Private)
TOR of the O&M company	-	-	All O/M activities except major repair and electric cost	All O&M activities except electric cost	All O&M activities except electric cost
Number of O&M Staff	75 to 80	10	121	72	79

*1: Production (High/Low) is the highest and lowest yearly average production for last 5 years.
*2: Indian Drinking Water Standard stipulated in IS 10500-2012 (See Appendix 3.8)
*3: See Subsection 3.3.9 for water quality data provided by CMWSB
*4: O&M: Operation and Maintenance
Source: CMWSSB compiled by JICA Study Team

For monitoring O&M activities and coordinating with the O&M companies, in CMWSSB, Superintending Engineer, Executive Engineers and Assistant Engineers under the Chief Engineer (O&M II) are assigned. (See Figure 9.1.3 for organizational chart of CMWSSB)

Descriptions of the O&M conditions of respective WTPs and their issues are shown in Appendix 3.4.

3.3.4 Wells

In and surrounding the Chennai Corporation, development of the groundwater sources has been done using deep and shallow wells. Groundwater is extracted through wells from three main aquifers viz., Northern Aquifer, Southern Coastal Aquifer and Neyveli Aquifer, besides many shallow wells which were developed and are equipped with hand pumps and motorized pumps for non-drinking purposes.

(1) Northern Aquifer (Northern Well Fields)

In 1963, the area of north and west of the Chennai City was first taken up for an extensive hydro-geological study by United Nations Development Program (UNDP) to assess the potential of development for the groundwater. Based on the recommendation of the study, six well fields in the northern aquifer have been developed with the total designed capacity of 180 MLD. Currently, 34 wells out of 74 wells are operational resulting in lowered pumping capacity of 34 MLD due to deterioration of the well facilities and improper operation and maintenance. Characteristics of the six well fields in Northern Aquifer are shown in Table 3.3.3.

Source: JICA Study Team

Picture 3.3.6 Deterioration of Well Pump in Poondi Wellfield

Table 3.3.3 Characteristics of the Well Fields in the Northern Aquifer

Name of Well Filed	Year of Commissioning	Wells (nos.)	Designed Yield (MLD)	Operational Wells (nos.)	Pumping capacity (MLD)
Tamaraipakkam	1969	30	50	19	18
Panjetty	1969	13	41	0	0
Minzur	1969	8	34	4	2
Poondi	1987	13	27	9	13
Flood Plains	1987	5	14	2	1
Kannigaiper	1987	5	14	0	0
Total		74	180	34	34

Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

When the storage water volume in the surface water reservoirs are poor, CMWSSB purchases bulk water from the private agricultural wells to augment the water supply. The groundwater from the private agricultural wells is conveyed to the WTP, Chennai Corporation, and other consumers.

In 2015, the water volume from the Northern Well Fields was 58 MLD as annual average, of which approximately 40 MLD was purchased from the agricultural wells. In 2016, as the surface water availability is high, the production from the wells has been constantly in the range between 10 and 20 MLD.

(2) Southern Coastal Aquifer

In 1976 a well field was developed in the southern coastal area of the Chennai City to mitigate the severe drought distressing the city. The well produced 10 MLD, but the safe yield is marginal because of its close location to the sea. The current production from the wells is 0.55 MLD in 2016.

(3) Neyveli Aquifer

In July 2003 detailed investigation and assessment were made in the Neyveli Aquifer for the extraction of ground water to meet the Chennai City's water requirement by utilising the Chennai Water Supply Augmentation Project's (Veeranam Project) pumping system, pipeline, and other infrastructures. Accordingly, 45 Borewells were erected with submersible pumps to extract 60 MLD from the Neyveli Aquifer by the Ground Water Wing of Tamilnadu PWD. At the same time, in addition, necessary pipeline for connecting the wells and the underground tank of Vadakuthu WTP was also constructed.

The Neyvil Aquifer is tapped whenever Veeranam reservoir, which is the water resource of the Vadakuthu WTP, does not have sufficient storage. In 2016, as the Veeranam reservoir is under the desludging work, CMWSSB has been extracting 50 to 60 MLD from the Neyveli Aquifer to treat in the Vadakuthu WTP.

(4) Public and private wells for non-drinking purposes

Generally, water for non-drinking purposes is met by shallow tube wells by a series of tube wells within the Corporation and surrounding areas by tapping water from shallow perched water table and semi-permeable aquifer. There are reportedly about 5,700 shallow tube wells (of depth up to 8 m), and 4,240 deep well hand pumps (depth up to 22 m) and the yield from all these wells could be assessed at an average of 50 MLD. In addition, an ordinary dug well constructed to a depth of 8 m to 10 m with small motorised pump sets are available in most of the houses and industries, and they are fairly dependable except in years of drought.

Source: JICA Study Team

Picture 3.3.7 Agricultural Bulk Supply Pipes in Poondi Wellfield

3.3.5 Water Transmission Mains

(1) Existing water transmission mains

The water transmission mains comprise multiple reaches of pipeline and two head works, which are pumping plants in the transmission mains, conveying water from clear water reservoirs at WTPs and DSPs to the underground tanks in 18 Water Distribution Stations (WDSs). The total length of water transmission mains serving the CMWSSB water supply system is about 490 km with pipeline diameter ranging from 228 mm to 2,000 mm.

The water transmission mains are directly operated and maintained by the CMWSSB except Veeranam water transmission main which conveys the treated water from the Vadakuthu WTP to Porur head works (HW) over a total length of 206 km. The transmission line from the Vadakuthu WTP is maintained by an O&M contractor.

Source: JICA Study Team

Picture 3.3.8 K1 Transmission Main (Riveted Steel) Installed in 1914

The layout of the existing water transmission mains, excluding that from the Vadakuthu WTP, is given in Figure 3.3.6. Characteristics of the transmission mains and the layout of the transmission main from Vadakuthu WTP are given in Appendix 3.5.

(1) Notable issues in the water transmission mains

1) Extra tapping from the water transmission mains in the Expanded Area

Initially, the transmission mains were designed as dedicated mains between the respective WTPs and the WDSs located in the Chennai Core City. Subsequently, when the Chennai Corporation was formed by annexing 42 ULBs with the Core City, the tapings from the transmission mains have been provided for supplying the water to these areas, this directly has affected the water volume delivered to the WDS.

2) Leakage in the transmission pipelines

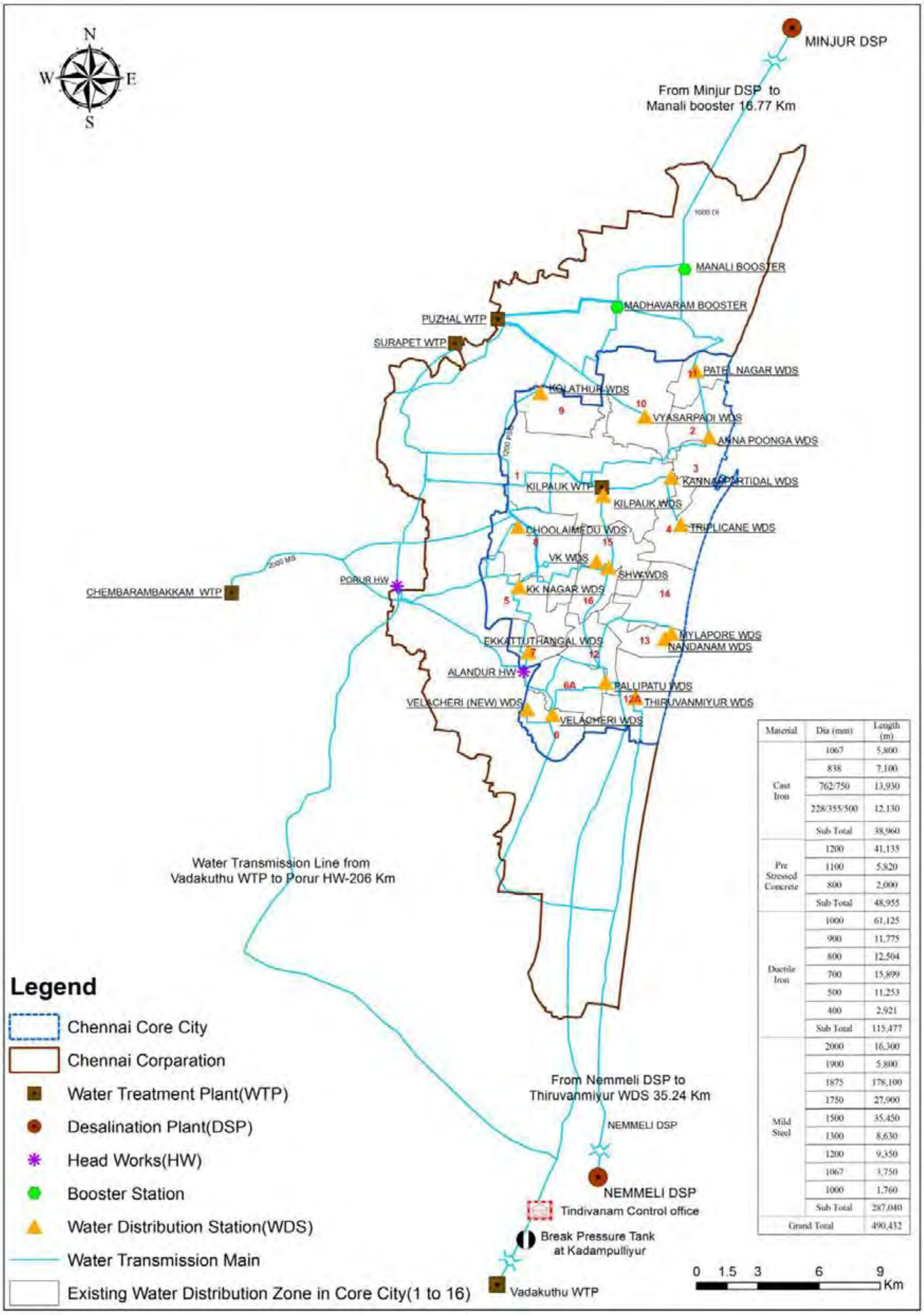
Conditions of the water transmission mains are good according to CMWSSB, except for Pre-Stressed Concrete (PSC) pipelines. Leakages from the transmission mains are mainly occurring in the PSC pipes installed in North Chennai Main, Central Chennai Main (from Puzhal WTP to Vysarpadi and Anna Poonga WDSs), and South Chennai Main (from Puzhal WTP to KK Nagar and Ekkatuthangal WDSs), which are those extended from Puzhal WTP and were constructed in the 1990s. Most of the PSC pipes were laid under the road berm during the construction period however pipes are currently in the road due to the widening of the road, and the heavy traffic has damaged the PSC pipe joints.

Also, it is presumed that the water transmission mains of K1, K2, K3, and K5 are timeworn and it might have some leakages. These mains, which are conveying treated water in Kilpauk WTP, were constructed in 1914 (K1) and 1948 (K2, K3 and K5). (See Appendix 3.5 for the characteristics of the transmission mains of K1, K2, K3 and K5)

3) Monitoring and control of water loss along water transmission mains

Currently, control and monitoring of water loss for the water transmission main is not done by CMWSSB. This is due to the malfunctioning flow meters and no separate responsible section within

CMWSSB. Such section is essential for managing and controlling the water loss from the water transmission main.



Material	Dia (mm)	Length (m)
Cast Iron	1067	5,800
	838	7,100
	762/750	13,930
	228/355/500	12,130
	Sub Total	38,960
Pre Stressed Concrete	1200	41,135
	1100	5,820
	800	2,000
	Sub Total	48,955
Ductile Iron	1000	61,125
	900	11,775
	800	12,504
	700	15,899
	500	11,253
	400	2,921
	Sub Total	115,477
Mild Steel	2000	16,300
	1900	5,800
	1875	178,100
	1750	27,900
	1500	35,450
	1300	8,630
	1200	9,350
	1067	3,750
	1000	1,760
	Sub Total	287,040
Grand Total		490,432

Source: JICA Study Team

Figure 3.3.6 Water Transmission Mains other than that from Vadakuthu WTP

3.3.6 Water Distribution Stations and Water Distribution Networks

(1) General

Table 3.3.4 summarizes development status of the water distribution networks in CMA.

Water distribution systems of CMWSSB cover the overall Chennai Core City. In the Expanded Area, the existing distribution networks as well as the wells were constructed and used to be operated by ULBs, and they were handed over to CMWSSB in 2011. As the existing networks by ULBs are old and not capable of corresponding to future water demand, CMWSSB is expanding their water distribution networks to the Expanded Area gradually. In the areas where CMWSSB has not completed the water distribution networks, the existing wells and networks are supplying water under CMWSSB's operation and maintenance. When CMWSSB completes a new water distribution network, it abandons the existing old wells and the network in the area constructed by the ULB.

In the Rest of CMA, water supply services are being carried out by respective ULBs. Involvement of CMWSSB is only bulk water supply to seven municipalities. For the time being, CMWSSB does not have any plan to develop their water distribution network in the Rest of CMA.

Table 3.3.4 Summary of Development Status of the Water Distribution Networks in CMA

Area	Development status	Future pan
Chennai Core City	• Water distribution networks of CMWSSB covers the entire area. • In most areas, old pipes were replaced by a project funded by the World Bank by 2003.	• Water distribution networks of CMWSSB covers the entire area. • Improvement and rehabilitation will be the major scopes of CMWSSB.
Expanded Area	• ULBs developed the water distribution networks. Existing networks are presumed to have cover most residential areas. • In 2011 the existing networks were handed over to CMWSSB. • Since 2011, CMWSSB is developing distribution networks in the Expanded Area. After the development, the old networks are abandoned because they are old and not capable for future water demand.	• CMWSSB is going to develop the new water distribution networks in the entire Expanded Area. CMWSSB has completed the networks in some areas in the Expanded Areas, and most of the remaining projects are already ongoing. • The existing networks by ULBs will be completely abandoned.
Rest of CMA	• ULBs developed the water distribution networks. Existing networks are presumed to have covered most residential areas. • CMWSSB is doing bulk supply to seven municipalities in the Rest of CMA. • If required by ULB, CMWSSB conducts new water distribution network project on behalf of the ULB using the ULB' fund.	• CMWSSB does not have any plan to develop their water distribution network in the Rest of CMA. • For the time being, CMWSSB's involvement will be the implementation of the network projects on behalf of ULBs and bulk supplies. • When the Rest of CMA is integrated to the Chennai Corporation, CMWSSB will start their direct water supply and development of new water distribution networks.

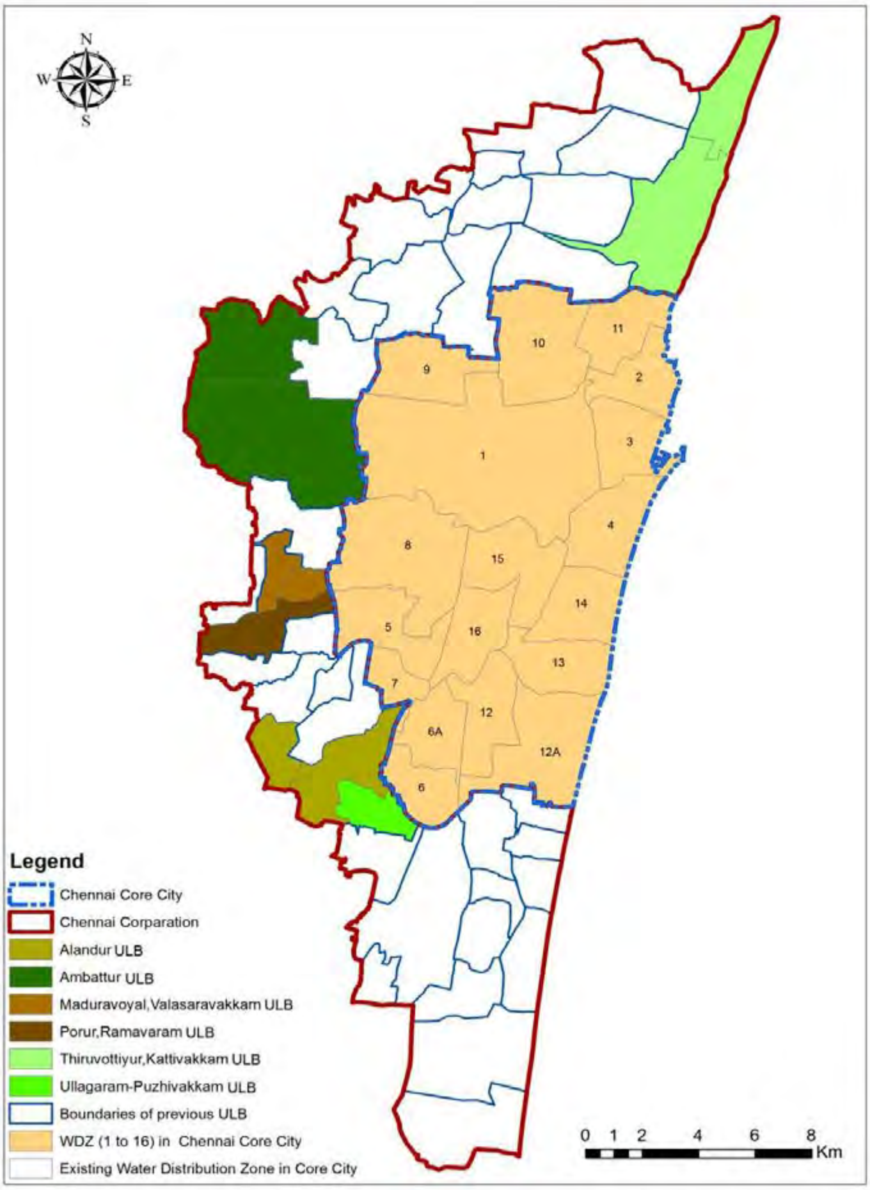
Sources: JICA Study Team

(2) Water Distribution Zones (WDZs) and Water Distribution Stations (WDSs)

The Chennai Core City is divided into 18 Water Distribution Zones (WDZs), each of which has a Water Distribution Station (WDS) as shown in Figure 3.3.7. The WDZ are sometimes called as hydraulic zones but they have not been established as physical hydraulic zones as they are linked by interconnections usually used.

WDSs receive water from the various WTPs and DSPs through water transmission mains and head works of Porur and Alandur. For the Expanded Area, drinking water is tapped from various water transmission mains to supply the four service areas of Ambathur, Alandur, Porur/Ramapuram and Maduravoyal/Valasaravakkam.

Duration of the water supply is 3 to 4 hours per day generally in the Corporation. Water allocation plan in the Corporation of the Production of CMWSSB and the profiles of the 18 WDZs are shown in Table 3.3.5.



Note: In the white areas in the Expanded Area, CMWSSB is conducting water distribution by the existing networks constructed by the ULBs.

Source: JICA Study Team

Figure 3.3.7 Water Distribution Zones in the Chennai Core City and Development Status of the Existing Water Distribution Network in the Expanded Area

Table 3.3.5 Present Water Allocation in the Chennai Corporation and Profiles of the Water Distribution Zones in the Chennai Core City

Zone	Name of WDS	Underground Tank (UGT) (ML)	Elevated Service Reservoir (ESR) (ML)	Water source	Planned Supply Volume*1 (MLD)	Supplied by	Water Level of the Reservoir	
							HWL*3	LWL*3
1	Kilpauk	81.32	15.80	Kilpauk WTP	94	Pump and ESR	+5.56	+0.86
2	Anna Poonga	22.50	2.50	Kilpauk WTP	20	Pump and ESR	+3.372	+0.552
3	Kannaparthidal	16.00	-	Kilpauk WTP	18	Pump	-	-
4	Triplicane	10.00	2.40	Kilpauk WTP	10	Pump and ESR	-	-
5	KK Nagar	14.00	2.40	Chembarambakkam WTP Vadakuthu WTP	28	Pump and ESR	+10.00	+5.00
6	Velachery	6.00	-	Chembarambakkam WTP Vadakuthu WTP	25	Pump	+5.60	+0.80
6A	Velachery (New)	2.00	-	Chembarambakkam WTP Vadakuthu WTP	5	Pump	-	-
7	Ekkauthangal	4.50	-	Chembarambakkam WTP Vadakuthu WTP	5	Pump	+7.00	+3.00
8	Choolaimedu	43.00	-	Chembarambakkam WTP Vadakuthu WTP	35	Pump	+9.00	+6.40
9	Kolathur	20.00	-	Redhills WTP & Minjur DSP	30	Pump	+10.50	+5.00
10	Vysarpadi	22.00	-	Redhills WTP & Minjur DSP	30	Pump	+5.10	+0.00
11	Patel Nagar	14.00	-	Redhills WTP & Minjur DSP	20	Pump	+3.00	-2.10
12	Pallipattu	17.00	0.75	Chembarambakkam WTP Vadakuthu WTP	29	Pump and ESR	+7.00	+0.00
12A	Thiruvanmiyur	3.00	0.75	Nemmeli DSP	5	Pump and ESR	-	-
13	Nandanam	11.00	-	Chembarambakkam WTP Vadakuthu WTP	15	Pump	+3.00	-1.00
14	Mylapore	11.50	-	Chembarambakkam WTP Vadakuthu WTP	25	Pump	+3.00	-1.00
15	Southern Headworks	24.00	4.50	Kilpauk WTP & Redhills WTP & Minjur DSP	55	Pump and ESR	+7.35	+3.70
16	Valluvarkottam	15.00	3.00	Redhills WTP & Minjur DSP	15	Pump and ESR	-	-
Other Areas (Industries, Expanded Areas, bulk supply, tank lorries etc.)		-	-		366	Various		
Total		336.82	32.10	-	830	-	-	-
		368.92*2						

Note: Mentioned water supply volume is effective from November 11, 2015.
*1: Basic water allocation by CMWSSB
*2: Capacity of the reservoirs including UGT and ESR is equivalent to 10.6 hours distribution amount, assuming 830 MLD of the daily distribution.
*3: HWL: High Water Level, L.W.L: Low Water Level
Sources: JICA Study Team

(3) Water distribution networks

At the present, the length of the distribution networks extends to 6,520 km in the entire Chennai Corporation according to Tamil Nadu Policy Note 2015-2016. The present situation of the water distribution networks in the CMA are described below by area; the Core City, the Expanded area and the Rest of CMA:

1) Chennai Core City

A major portion of the water distribution networks in the Core City has been redeveloped based on a Detailed Project Report (DPR) entitled "Detailed Engineering Design of Water Distribution System for Chennai City", September 1998, prepared by Kirloskar Consultants (hereinafter, Kirloskar Report). According to CMWSSB, total pipe length in the water distribution networks in the Core City is 2,381 km. Old distribution pipes together with 205,000 service connections were replaced by a program of leakage reduction, named as the Unaccounted for Water (UFW) Program in Chennai City, funded by the World Bank, which was conducted from 1989 and completed on 2001. Afterward CMWSSB has continued rehabilitation works especially for WDZs 6A and 12A.

Although the current total length in the Core City was informed by CMWSSB as 2,381 km, CMWSSB does not have consolidated database for pipe inventory. Therefore, field data books on April 2003, which was prepared after the World Bank's program, is the only guide to understand the physical characteristics of the existing distribution pipes.

Pipe length of the distribution pipes by age, material and diameter are summarized based on the field data books above in Tables 3.3.6 and 3.3.7 and Figures 3.3.8 and 3.3.9.

According to the data books, the total length of the distribution pipe was 2,303.533 km having the pipe materials of Cast Iron (CI), uPVC (Polyvinyl Chloride), Ductile Iron (DI), Galvanised Iron (GI) and Asbestos Cement (AC)[6]. Most of the pipes are CI, whose share is more than 90% and uPVC has the second highest share of 6.17%. 62.98% of the pipes are less than 30-year old, while 17.18% is already 40 years or more, which would have been deteriorated. The range of diameter is from 40 mm to 750 mm and the pipes of 100 mm and less than 150 mm occupy 85.34%.

Distribution network maps by WDZ are given in Appendix 3.6.

Table 3.3.6 Detail of Distribution Pipes of Age and Material

Age	Pipe Length by Material (m)								
	CI	uPVC	DI	GI	AC	Sub-Total	Share	Accumulation	Unknown
Y < 20 years	865,096	48,238	39,441	8,030	0	960,805	42.41%	42.41%	
20≦Y < 30 years	406,872	58,013	500	0	647	466,032	20.57%	62.98%	
30≦Y < 40 years	419,588	29,678	0	406	0	449,672	19.85%	82.82%	
40≦Y < 50 years	243,908	3,795	751	0	0	248,454	10.97%	93.79%	37,866
50 years or more	140,419	90	0	195	0	140,704	6.21%	100.00%	
Sub-Total	2,075,883	139,814	40,692	8,631	647	2,265,667	42.41%	-	
Share	91.62%	6.17%	1.80%	0.38%	0.03%	100.00%			
Total: 2,303,533									

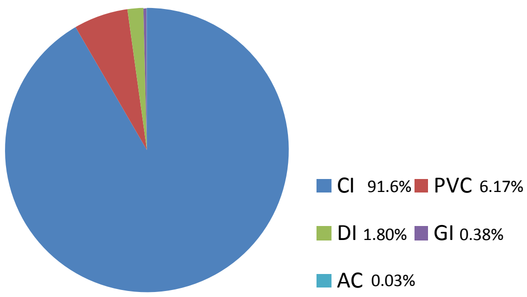
Source: JICA Study Team based on Field Data Books of 2003

[6] According to CMWSSB, all of the AC pipes have been replaced after 2003 and currently none of AC pipe remains.

Table 3.3.7 Details of Distribution Pipes of Diameter

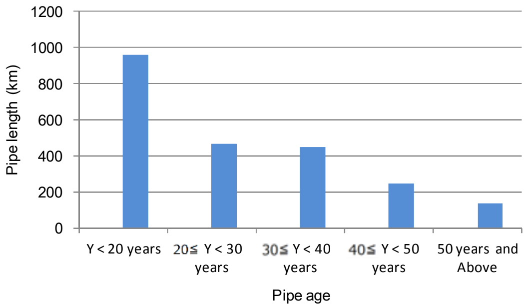
Diameter (mm)	40≤D<100	100≤D<150	150≤D<200	200≤D<300	300≤D<400	400≤D*	Unknown	Total
Length (m)	2,646	1,965,834	206,334	70,158	11,698	5149	41,714	2,303,533
Share	0.11%	85.34%	8.96%	3.05%	0.51%	0.22%	1.81%	100.0%
Accumulation	0.11%	85.45%	94.41%	97.46%	97.97%	98.19%	100.00%	-

*: The largest diameter is 750 mm.
Source: JICA Study Team based on Field Data Books of 2003



Source: JICA Study Team based on Field Data Books of 2003

Figure 3.3.8 Materials of Distribution Pipes



Source: JICA Study Team based on Field Data Books of 2003

Figure 3.3.9 Age of Distribution Pipes

2) Expanded Area

In the Expanded Area, the water distribution networks developed by ULBs have covered most residential areas. Since 2011, CMWSSB is executing the expansion of the distribution networks with its own fund, and has completed the constructions in Ambathur, Alandur Valasaravakkam, Porur, Ramapuram, Maduravoyal Areas. One information from the CMWSSB says that the total pipe length in the Expanded Area is approximately 1,850 km but the evidence is not available.

The new distribution networks by CMWSSB are designed to satisfy 150 lpcd, which is the requirement from the national standard. CMWSSB is going to replace all existing distribution networks in the Expanded Area. Although some of the projects are still waiting for finance, completion of all the projects will not take ten years.

3) Rest of CMA

In the Rest of CMA, pipe length of the existing water distribution networks is not known. Coverage of the networks is also unknown and will vary by ULBs.

(4) Issues in the water distribution network of CMWSSB

According to the site investigation and information of CMWSSB, following technical, management and O&M problems for the water distribution zone and systems are observed;

1) Technical problems

- Pipe Burst and Leakage

According to CMWSSB, pipe burst sometimes occurs along the uPVC pipes, and leakage occurs at the connection points, but in case there is an increase in pressure in future due to better water availability, more leakages and burst at weak points such as old pipes and connections can be expected.

- Deficiency of elevated service reservoirs (ESRs)

According to the Kirloskar Report, ESRs were required to be provided in all the WDSs for stabilizing the pressure in the pipeline, but during implementation of the projects, ESRs have been provided only in eight WDSs and others are supplied by direct pumping to the consumers resulting in unstable water pressure in the pipeline.

- Low water pressure or negative pressure in the network and at the terminal of the pipelines

Due to intermittent water supply, the distribution networks often become empty during the non-supply hours and thereby, when water supply starts, CMWSSB needs to operate one pump in each WDS for priming. Even during priming, required pressure is not built up as consumers in the initial reaches start tapping the water. Also, the water flow is higher than the peak demand in the Kirloskar Report because all the consumers are waiting for the water supply with their taps open and they operate hand pumps to extract the water from the distribution mains.

Due to all these above, water pressure in the networks tend to be low and water does not reach to all consumers. In certain areas, negative pressure in the distribution networks or terminals occurs, which causes contamination.

- Unrealized isolation of the WDZs

The basic concept of the Kirloskar Report was to establish independent hydraulic zone for each WDZ. However, in between the WDZs, isolation of the WDZs have not been conducted and the interconnections are always used. For good management of the water distribution networks, as planned in the Kirloskar Report, isolation of the WDZs to establish hydraulic zones will be necessary.

2) Management and O&M problems

- Difference between Administration Area and WDZ

The operational areas and depots of CMWSSB are aligned geographically to those of the wards, and not spatially to that of the WDZs. Interface issues across areas due to this misalignment always take place, resulting in inefficiency of O&M works and complicating the data management and documentation works.

- Unavailability of map of distribution networks

The updated map of the distribution network showing all required details is not available in CMWSSB. The knowledge of the locations of this underground distribution network lies only at the individual level in the organization and as such, there is a need to build an organizational knowledge-base in this regard to improve the efficiency of operation.

- Restricted maximum power demand

The number of pumps designed to be operated is not operated entirely due to restricted maximum power demand obtained by CMWSSB from the power company. This is one of the reasons for making the low pressure in the distribution networks.

3.3.7 Service Connections and Water Meter

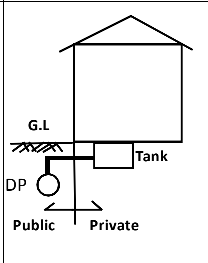
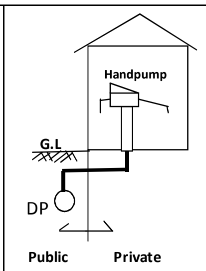
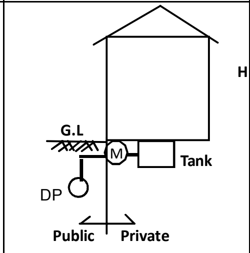
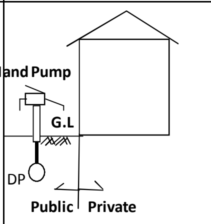
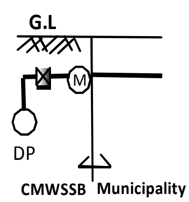
(1) Existing facilities

CMWSSB is having 673,339 service connections including the 647,070 non-metered connections, 26,269 metered connections, and 24 bulk supply connections as of July 2016, and 23,104 public fountains as of December 2015. From the numbers of the total service connections and metered connections, the metered rate is as low as 3.9%.

Service connection is categorised into domestic, non-domestic, which includes commercial and institutional, and bulk supply accounts. Domestic and non-domestic accounts have the metered and non-metered connections, while all the bulk supply accounts are metered. The public fountains are located in the lower income areas with water supplied free of charge.

Service connections for the domestic use can be divided into two major types as connecting with private underground tank or sump and with tap with hand pump. Most domestic consumers receive water by private underground tank directly or through hand pump. Most non-domestic consumers receive water at private underground tanks through the meters. Bulk supply is connected to water supply facility of the municipalities. Typical types of the existing service connections are shown in Table 3.3.8.

Table 3.3.8 Typical Types and General Specifications of the Existing Service Connections in the Service Area of CMWSSB

Item	Non-Metered Connection		Metered Connection	Public Fountains	Bulk Supply
Section					
Type of Connection	Connecting with private tank/sump	Connecting with tap with hand pump	Connecting with private tank/sump	Connection with hand pump	Connecting with municipal pipeline
Major consumers	Domestic	Domestic	Non-Domestic	Low Income Residents	Bulk-supplied municipalities
No. of Connection	647,070		26,269	24,712	24
Diameter (mm)	15 to 20	15 to 20	15 to 50	20	50 to 200
Materials	GI/MDPE	GI/MDPE	GI/MDPE	GI	GI

Note: Data of number of connection is as of July 2016. Public fountain is as of December 2015. GE: Galvanized Iron, MDPE: Medium Density Polyethylene, DP: Distribution Pipe, M: Meter

Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

(2) Issues in the service connections and water meters

The existing water service connections and water meters have some technical and management problems.

At present, water service availability by CMWSSB is only a few hours in a day. Due to the low service level, households are not willing to install water meters and consequently metered connections are only 3.9% of the total connections.

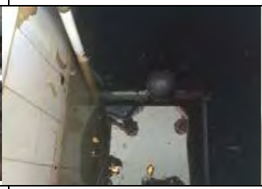
Many people are forced to operate hand pumps to draw the water from the distribution networks to their underground tanks. The intermittent water supply and low or negative water pressure in the distribution networks are causing contaminations of the water in the pipelines and private underground tanks. Water leakages are frequently occurring especially at the joints in the service connections of galvanized iron pipe. The main reasons for the leakages are poor installation skills or low-quality materials used for the connections and damages given by other construction works.

The installation and maintenance of the service connections are the responsibility of the water consumers but the water consumers often fail to maintain the water connections properly. It is one of the reasons for contamination of the treated water. Besides, due to the limited hours of water supply and the fixed water rate adopted by the most water users, the water users always keep taps open, which is leading to wastage of water.

The always-open taps has brought about a vicious circle that is worsening the water supply service frequency and duration. Because the water consumers keep their taps open to receive the water whenever supplied and store the water, the water flows in the distribution networks are always the peak flow during the service hours. As a result, water consumers located to the service point (WDSs) extract the water first but the water does not reach the water consumers far from the WDS. This situation leads more people to the behaviour to keep the taps open and to use hand pumps to extract as much as water whenever available, which further worsens the service frequency and duration.

Table 3.3.9 depicts some typical problems in the water service connections, and water meters in the service area of CMWSSB. More detailed descriptions of the problems are given in Appendix 3.7.

Table 3.3.9 Typical Deficiencies of the Existing Connections

Cover of under-ground Tank	Underground tank	Hand pump	Metered connection	Public fountain
				
Many houses use the underground tank due to low pressure. Stored water is subject to contamination especially during the rainy season.	Water in the underground tank is contaminated. One of the reasons will be back flow from the households to the distribution pipe due to negative pressure in the distribution network.	Many houses are forced to install hand pumps for sucking the water due to low pressure.	Water meter is installed without check valve and stop valve. This might be backflow to the distribution pipe due to negative pressure.	When water pressure in the distribution network increases, overflows sometimes occur because of the absence of stop valve.

Source: JICA Study Team

3.3.8 Monitoring and Control System

At present, a systematic monitoring and control system does not exist in the water supply system of CMWSSB.

For the WTPs, two WTPs viz Chembarambakkam WTP and Vadakuthu WTP out of the five WTPs are equipped with SCADA (Supervisory Control and Data Acquisition) system to perform the data acquisition, system control, monitoring, and reporting, however, Vadakuthu WTP's system is currently not in use due to some repairs. Monitoring of the remaining three WTPs and currently the Vadakuthu WTP are mainly done for raw and treated water quality and treated water volume. Controls of the four WTPs are also done manually such as backwashing, regulation of the flow, injection of the chemicals. Important data such as water production volume, water loss in the WTPs, water loss and pressure in the water transmission mains, and the water level of the reservoir are not systematically acquired.

Source: JICA Study Team

Picture 3.3.9 Monitoring Room

As for raw water transmission and water distribution systems, CMWSSB has established a data acquisition system for the 18 WDSs to transmit the information of flow rate and residual chlorine analysis, and also installed the level sensors with transmitters for Telugu-Ganga Channel, Poondi reservoir, Redhills reservoir and Chembarambakkam reservoir for monitoring the water level, storage volume, inflow, outflow and rainfall to transmit the live information to control room situated at CMWSSB's head office.

It is proposed that all water supply service related facilities, such as the intakes, WTPs, reservoirs, wells, valve pits, pressure reducing chambers, pumping facilities and so on will be brought under automation and will be established with SCADA system. With this, all the facilities can be supervised and remotely controlled in real time.

This scenario will allow for qualitatively and quantitatively optimizing the water supply system. In addition, the combined use of surface water, groundwater and desalinated water can be regulated efficiently, and will help the efficient operation of the water transmission and distribution networks.

3.3.9 Water Quality Management

(1) Water quality management system of CMWSSB

For continuous surveillance, assessment, and monitoring of the drinking water quality to assure protected water supply, the Quality Assurance Wing (QAW) was established in CMWSSB in 1978. The QAW monitors the quality of drinking water supplied in the Chennai Corporation. The QAW division is headed by an executive engineer with support engineers and analysts under the Chief Engineer (O&M I). (See Figure 9.1.2 for organizational chart of CMWSSB) QAW has its own water quality laboratory which is well-equipped analytical laboratory with competent staff and located at Kilpauk.

Functions of the QAW are;

- Investigation, preventive action, sanitary survey and providing necessary assistance to the field staff
- Collecting water samples at various locations like sources, WTP, WDS and distribution network points all over the Chennai Corporation
- Carrying out water quality analysis in the laboratory and submitting the reports to the executive engineers

In addition to the above, CMWSSB separately monitors the quality of the raw and treated water at each WTP's laboratory.

(2) Monitoring of water quality

The scientific personnel in the analytical section have a periodical sampling program as per the WHO (World Health Organisation) norms and the Indian drinking water quality standard, for monitoring water quality at the sources, treatment plants, WDSs and in the distribution networks. The Indian drinking water quality standard is given in Appendix 3.8.

Water samples from the raw water of the reservoirs and treated water of WTP are being collected and analysed for conformity to the physical, chemical, and bacteriological standards once a month by the QAW. While, the laboratory located in each WTP also carries out the water quality test such as turbidity, pH, residual chlorine, residual aluminium, colour, TDS etc. on a daily basis. Samples of the treated water from the WTPs are collected from the test tap for analysis. According to the result of water quality analysis, all of the treated water meets the standard except the turbidity value at Kilpauk WTP, which is probably caused by the raw water contamination from the masonry conduits as mentioned in Item (1) of Subsection 3.3.3. The result of water quality test done by the WTP laboratory is presented in Table 3.3.10.

About 150 water samples are collected on a daily basis to analyse the residual chlorine content and 60 samples for bacteriological analysis. In addition to these samples, 2,500 water samples are collected from various parts of Chennai Corporation and checked for residual chlorine by the field staff from 200 depot offices to ensure the water is safe for drinking. According to the residual chlorine report dated February 12, 2016, is 3 samples out of 105 samples are failed to meet the standard of less than 0.2 mg/l.

Table 3.3.10 Result of Water Quality Test

Test Item	Permissible Range	Kilpauk WTP	Puzhal WTP	Chembarambakkam WTP	Vadakuthu WTP
Turbidity (NTU)	< 5	10	2.8	0.91	3.32
pH	7 to 8.5	7.2	7.7	7.13	7.59
Residual Chlorine		7.2	1.0	2.0	-
Residual Aluminium (mg/l)	< 0.3	0.05	-	0.02	0.06
Color	< 5	-	-	< 5	5
TDS	< 500	340	340	N/A	332

Notes: Kilpauk WTP, Chembarambakkam WTP and Vadakuthu WTP is data of November 2015. Redhill WTP is data of April 2016. "-" means data not obtained.
Sources: CMWSSB

3.3.10 Water Pressure

Water pressure at connections or in water distribution networks is not monitored and controlled by CMWSSB. According to the Report for Study of Reduction in Unaccounted for Water 1991, the pressure of the distribution pipeline is recommended for 10 m head with 6 hours supply duration, and the report said that the recommended value is achieved during the program period. However, current water supply condition has again reduced to 3 to 4 hours water supply. According to O&M wing of CMWSSB, the farthest area from the WDS cannot receive the piped water due to negative pressure.

Low pressure in the distribution pipeline is due to various technical and operational reasons as follows;

- In some areas, water demand will be higher than the design flow of the water distribution networks, which results in low water pressure
- As explained in Item (2) of Subsection 3.3.7, Due to intermitted water supply, the consumers always keep the taps of both public stand posts and service connections in an open condition so as to receive water and thereby prevent the security of sufficient water pressure in the distribution networks.
- In certain cases, the capacity of the pump is not able to meet the current demand.
- Elevated service reservoirs (ESRs) with pumping facilities are missing in some WDZs.

3.3.11 Water Leakage and Losses

Since the year 1989 and until the year 2001, the Unaccounted for Water (UFW) Program in Chennai City was carried out and most of the distribution pipes and 205,000 service connections were replaced by the program. The program was to evaluate and reduce the water losses from the distribution pipes and service connection in five phases under World Bank fund. The project's completion report evaluated that water leakage ratio in the target area of the project was reduced to 11%. Contents of the program by phase and the program's coverage are given in Appendix 3.9.

During the program, CMWSSB established the leak detection and control unit for the programme headed by UFW senior engineer under the Operation and Maintenance Department. However, this was discontinued after completion of the program, and till date no section relating to Non-Revenue Water (NRW)[7] exists.

At present, CMWSSB has no any information concerning the magnitude of the various sources of NRW. According to CMWSSB, water leakage is not much and fairly comparable to elsewhere in India and most of water leakage and losses are due to tampering in the distribution pipes by people, leakage from the service connections and aged uPVC pipes. Beside illegal consumptions hardly exist because consumers pay for the water at a flat rate, while illegal motorized line pump in the consumer's property sometimes exist to suck greater volume of water from the distribution pipes.

In a case of increase in water production by the construction of DSP, water pressure will surely increase, and this will lead to increase in water leakage. Therefore, it is essential to establish a dedicated NRW control unit. In addition, establishment of District Metered Areas (DMAs) is also essential for CMWSSB to enable efficient monitoring and control of NRW.

3.3.12 Asset Information Management

CMWSSB is responsible for maintaining various assets like raw water transmission conduits and pipelines, water treatment plants, treated water transmission mains, water distribution stations, water distribution pipeline network, sewer collection system with sewage pumping stations, sewage treatment plants, etc. with all required facilities. The total value of the fixed assets as per the balance sheet of CMWSSB (2013-14) is INR 54,524 million.

In the present asset management system of CMWSSB, the overall financial value of assets is readily available in the computer database of the Financial Department at the Head Office. However, for individual physical components of the assets, one has to refer to the respective O&M wings like the offices of the 15 administration areas or 200 depot offices. The information is generally not available on computers in a consolidated form but maintained in the form of ledgers only. Details like diameter, age, and the exact location of the pipes are very difficult to obtain.

[7] Recently International Water Association (IWA) recommends to use the term of NRW, instead of UFW, to define the water loss more specifically.

For the past 25 years, the following procedure is being adopted in CMWSSB in asset information collection:

a. After technical sanction of the cost estimate for any construction project made the Engineering wing, which is usually approval of detailed project report (DPR), a copy of the estimate is sent to the Finance wing for allotment of a project code number.
b. For each estimate, a unique 12 digit project code number is allotted, and the same is informed to all the departments. Hence, at the time of contract of any construction work, the contract will have its own project code.
c. All payments like those to the contractors, for road restoration, advertisement charges, etc. made under the contract are computerized and booked under the project code number. In fact, without mentioning and booking under the project code number, no payment could be effected.
d. After completion of all the work allocated under that project code number, a completion report is prepared by the Engineering wing, wherein all assets created are mentioned in a broad manner along with all financial expenditure and sent to Finance wing for reconciliation and approval.
e. Once the completion report is reconciled and approved, the final bill is paid to the contractor and the assets created are brought in the books of CMWSSB. In this way, the overall financial value created under the project is readily available. On the other hand, information on individual physical components is transferred from the Project wing to O&M department by measurement books, which are prepared on a monthly basis by the Project wing for each contract to monitor the progress and authorize the bills of the contractors, such as-built drawings, O&M manuals, etc.

As explained above, there is no procedure to register the physical components of the facilities constructed in the projects in any consolidated format or system. Storage of the documents handed over by the Project wing is dependent on the personnel in charge in the O&M department; as such it is difficult to get information later on. Hence it is suggested that a suitable software system should be created wherein all the required information including both physical and financial aspects could be extracted at any point of time.

3.4 Present Conditions of the Existing Seawater Desalination Plants

3.4.1 General

(1) Capacities and locations

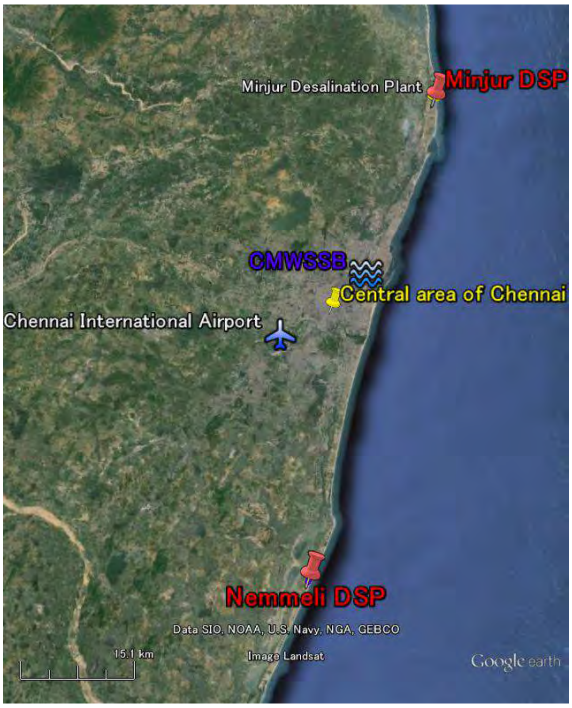
There are two DSPs in CMA to supply water to the households and businesses in Chennai Corporation, as shown in Figure 3.4.1.

Both plants adopt reverse osmosis (RO) technology and the production capacities are 100 MLD.

The Nemmeli DSP, which was inaugurated on February 22, 2013, and has owned by CMWSSB, is located at the southern side of the Chennai city.

The Minjur Plant, which started the operation in July 2010 by a private operator under Design-Build-Own-Operation (DBOOT) scheme, is located at the northern side of the Chennai city.

Table 3.4.1 presents the outlines of the two DSPs in CMA.



Source: JICA Study Team

Figure 3.4.1 Locations of the existing DSPs

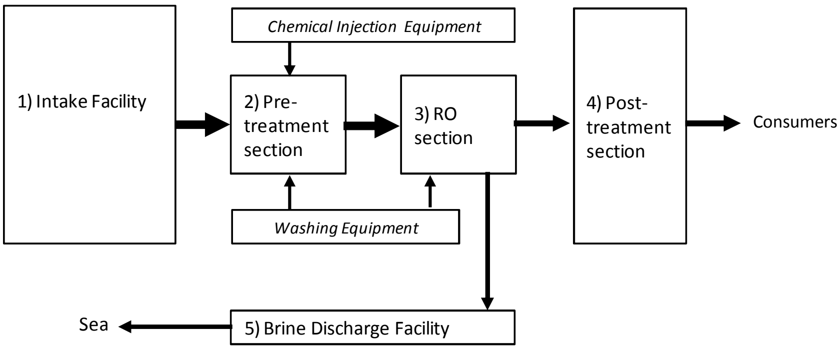
Table 3.4.1 Outlines of the Existing DSPs of CMWSSB

Item		Nemmeli	Minjur
Contractor		VATEC WABAG (India) + IDE Technology (Israel)	Abengoa (Spain) + IVRCL (India)
Contract type		Design-Build-Operate(DBO) (7-year operation)	Design-Build-Own-Operate-Transfer (DBOOT) (25-year operation)
Raw seawater quality	Max. TDS*1 (mg/l)	38,000 (Jan 2015 - Dec 2015)	34,000 (July 2014 - July 2015)
	Temperature (deg. C)	26 - 31 (Jan 2015 - Dec 2015)	26 - 31 (July 2014 - July 2015)
	Max. TSS*2 (mg/l)	400 (Jan 2015 - Dec 2015)	280 (July 2014 - July 2015)
Pre-treatment section		Up-flow filter + Disc filter + Ultra filtration (UF)	Lamella filter + Dual media filter
RO section		One stage RO, Spiral membrane. Micron cartridge filters (MCF) are inserted before the RO units	One stage RO, spiral membrane, Pressure filter and MCF are inserted before the RO units
Recovery ratio		45%	45%
Post-treatment section		CO_2 injection + Limestone filter + Disinfection injection + Caustic soda dosing	CO_2 injection + Lime powder dosing + Disinfection injection

*1: Total Dissolved Solids, which is the indicator for salinity in the seawater
*2: Total Suspended Solids, which is the indicator for cleanliness of the seawater
Source: JICA Study Team by compiling information from CMWSSB

3.4.2 Common Understandings on Seawater Desalination Process by RO Technologies

Seawater Desalination by Reverse Osmosis technology (SWRO) mainly consists of five components and their accessories, excluding the power receiving facility, buildings, warehouses, etc. as shown in Figure 3.4.2. More general information on SWRO is given in Appendix 3.10.



Source: JICA Study Team

Figure 3.4.2 General Configuration of SWRO

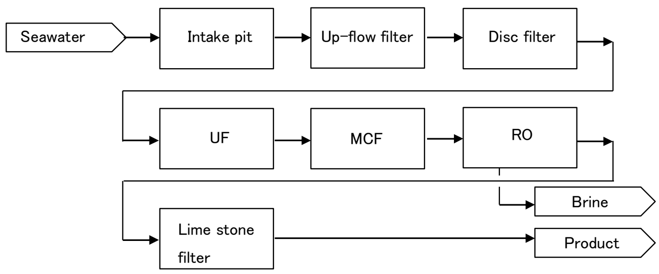
3.4.3 Nemmeli DSP

(1) Treatment process

Treatment process of the Nemmeli DSP is illustrated in Figure 3.4.3. The plant takes seawater from the Bay of Bengal and treats the seawater by RO technology.

The seawater inlet pipe is 1,600 mm in diameter and has a length of about 1,200 m. Sodium hypochlorite is added to the raw seawater at the intake to avoid clogging of the intake pipe by organisms such as clams and seaweeds.

Pre-treatment section comprises of the up-flow filter, disc filter, UF membrane and micron cartridge filter. The designed coagulant, to be injected before UF, is $FeCl_3$. Nevertheless, the chemical is not injected usually as the effluent from the disc filters is better than expected.



Source: CMWSSB compiled by JICA Study Team

Figure 3.4.3 Block flow sheet of Nemmeli DSP

RO units are equipped with micron cartridge filter (MCF) to protect the RO membrane. A total of 12 units of RO are installed in the plant, and it is one stage[8]. The recovery ratio is 45%. In each RO unit, one high-pressure pump, one recycle booster pump, one permeate pump and a unit of energy recovery equipment of pressure exchangers are arranged.

[8]Some SWRO plants have multiple stage RO. It is mostly aimed at removing boron to satisfy the previous WHO guidelines, which were stricter than the present guidelines.

RO permeate is sent to post-treatment section consisting of a CO_2 injection system, limestone filters, a degassing tower and the associated facilities. Treated water from the post-treatment is delivered to the Chennai Corporation. In a case of suspension of the plant operation, product water is sent to two tanks, each of which has a capacity of 14,000 m^3, and to be stored until resumption of the operation.

Brine from RO is discharged to the sea. The plant has brine discharge pumps. Nevertheless, the pumps are not used because it has been found that the 1,200 mm discharge pipe can discharge the brine by gravity flow. The length of the discharge pipe is 500 m.

More detailed descriptions of the treatment process and the list of its major equipment in Nemmeli DSP are given in A3.11.1 of Appendix 3.11.

Source: JICA Study Team

Picture 3.4.1 UF rack in the Nemmeli DSP

Source: JICA Study Team

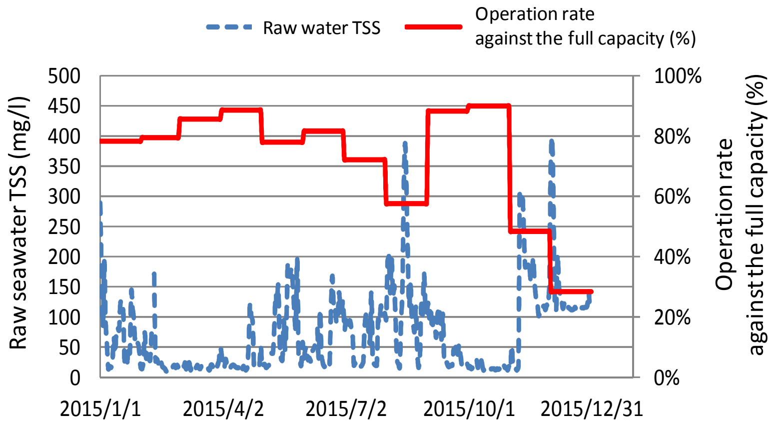
Picture 3.4.2 RO rack in the Nemmeli DSP

(2) Seawater condition and performance of the DSP

During the north east monsoon, from October to December, the raw seawater condition tends to be deteriorated in terms of turbidity. As shown in Figure 3.4.4, the high turbidity forces the plant to reduce the operation rate to as low as 60% for several days as the pre-treatment system performance declines. The operation rate was as low as 50% in November 2015 and 30% in December 2015 but they were not for the technical reason. As shown in Figures 3.2.3 and 3.3.4, because the intense rainfall in the two months recovered the surface water availability, CMWSSB limited the operation of the DSP. (Operation of the Minjur DSP has not been limited because the plant has been operated under BOT scheme.)

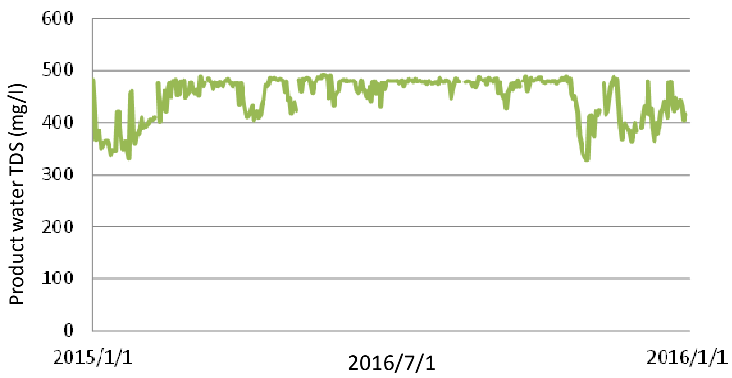
As shown in Figure 3.2.3, deterioration of the monthly operation rate in December 2016, which fell to 42.4%, was significant. It was due to a combined impact of the high turbidity and suspension of the power supply caused by the Cyclone Wardha.

Concerning product water quality, as presented in Figure 3.4.5, the Nemmeli DSP has excellent performance as TDS of the product water is always maintained within the targeted range, which is below 500 mg/l.



TSS: Total Suspended Solids
Source: CMWSSB compiled by JICA Study Team

Figure 3.4.4 Seawater Condition and Operation Rate of the Nemmeli DSP



TDS: Total Dissolved Solids
Source: CMWSSB compiled by JICA Study Team b

Figure 3.4.5 Product Water TDS of the Nemmeli DSP

(3) Evaluation of the plant

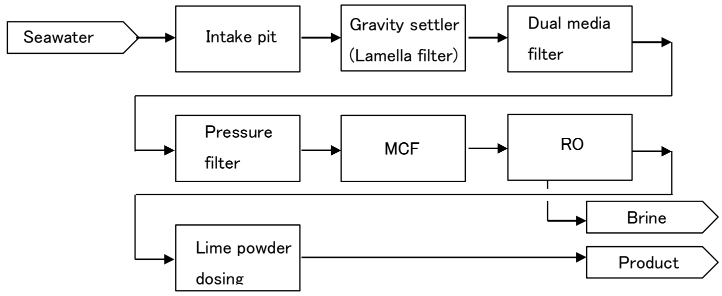
Overall the Nemmeli DSP is operated and maintained with no critical problem by the well-trained operation staff. One regrettable point is the low production rate during the monsoon. The pre-treatment system is recommended to be replaced with stable one, such as lamella filter instead of up-flow-filter, to ensure full-capacity operation even on the high turbidity conditions. The timing of the replacement will be after completion of the planned expansion project by 150 MLD.

3.4.4 Minjur DSP

(1) Treatment process

The treatment process of the Minjur DSP is illustrated in Figure 3.4.6. Similar to the Nemmlei DSP, the Minjur DSP also takes seawater from the Bay of Bengal and treats the seawater by RO technology.

The seawater inlet pipe is 1,600 mm in diameter and has a length of about 640 m. As the plant operator was not allowed by the Pollution Control Board (PCB) to inject the chemical at the intake, sodium hypochlorite is injected only at the on-shore intake pit. Nevertheless, the plant operator told the study team that they were not aware of clogging in the seawater intake pipe. The frequency of the cleaning inside the pipe is about three times a year.



Source: CMWSSB compiled by JICA Study Team

Figure 3.4.6 Block flow sheet of Minjur DSP

Pre-treatment section comprises of the gravity settler (or lamella filter), which is after the flocculation basin, and dual media filter (DMF). Chemicals to be injected in the flocculation basin are H_2SO_4 for pH adjustment, $FeCl_3$, and polyelectrolyte for coagulation.

The RO section is equipped with pressure filter and micron cartridge filter (MCF) to protect RO membrane. The RO unit consists of a high-pressure pump, an energy recovery equipment of pressure exchanges, a recycle booster pump, and RO membranes. Five RO units are installed. The recovery ratio is 45%.

The permeate water from RO is treated by CO_2 and lime powder solution injection for drinking water application and sodium hypochlorite injection for disinfection and sent to the Chennai Corporation.

Brine from RO is discharged to the sea by gravity. No discharge pumps are installed, which is different from the Nemmeli DSP. Brine discharge pipe is 1,600 mm in diameter and 840 m in length.

More detailed descriptions of the treatment process and the list of its main equipment in Minjur DSP are given in A3.11.2 of Appendix 3.11.

Source: JICA Study Team

Picture 3.4.3 Gravity Settler in the Minjur DSP

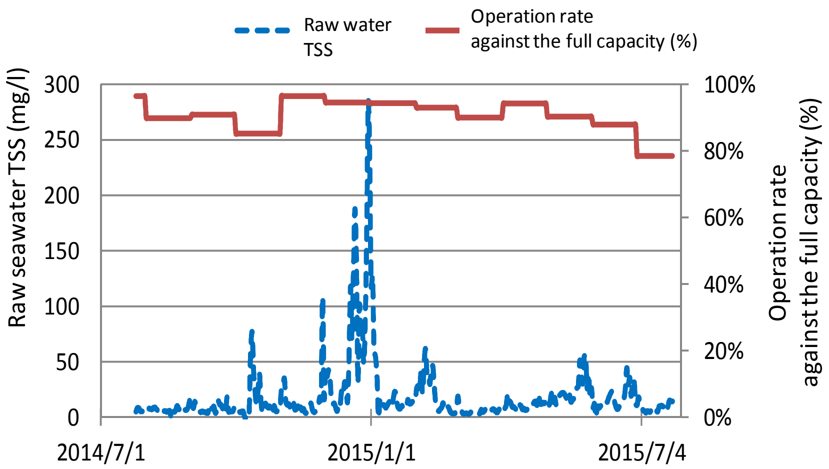
Source: JICA Study Team

Picture 3.4.4 Train in the Minjur DSP

(2) Seawater conditions and performance of the DSP

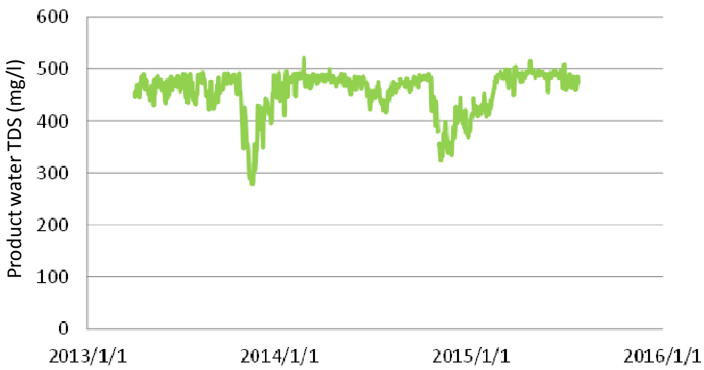
Similar to the case of the Nemmeli DSP, the raw seawater quality at the Minjur DSP is deteriorated in terms of turbidity during the monsoon season, from October to December. However, the Minjur DSP shows no significant production drop as shown in Figure 3.4.7. In December 2016, as shown in Figure 3.2.3, the operation rate of the DSP fell to 69.8% due to suspended power supply caused by Cyclone Wardha but the high turbidity was not the reason for the low operation rate. The existing pre-treatment system is evaluated to be properly functioning against the high turbidity condition.

The Minjur DSP has excellent performance in terms of product water quality as the TDS is always maintained within the required range, which is below 500 mg/l, as illustrated in Figure 3.4.8.



TSS: Total Suspended Solids
Source: CMWSSB compiled by JICA Study Team

Figure 3.4.7 Seawater Condition and Operation Rate of the Minjur DSP



TDS: Total Dissolved Solids
Source: CMWSSB compiled by JICA Study Team

Figure 3.4.8 Product Water TDS of the Minjur DSP

(3) Evaluation of the plant

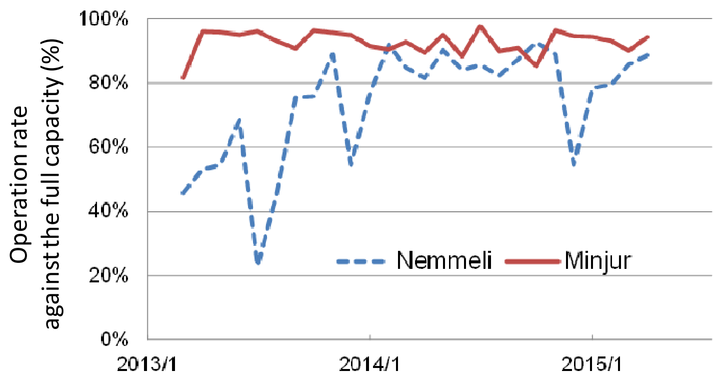
Overall the Minjur DSP is operated and maintained with no critical problem by the well-trained operation staff. It maintains the production volume even in the monsoon season, while the Nemmeli DSP's production deteriorates. One important recommendation is to provide a standby RO unit to keep continuous production of 100 MLD even during membrane cleaning or replacement work.

3.4.5 Notes for Design of the Perur DSP

The raw seawater quality of the new 400 MLD will be almost the same as that of the Nemmeli DSP, as the two seawater intake points will be located close to each other. Therefore, the Nemmeli plant's operation data should be highly taken into account in the design of the Perur DSP. Operation data of the Minjur Plant is also useful for the designing the Perur DSP because the raw water quality is similar to that of the Nemmeli DSP.

As described in the previous sections and Figure 3.4.9, Nemmeli DSP is forced to reduce the operation rate in high turbidity condition, which often occurs in the monsoon seasons. In the severe water-stress condition in CMA, it is expected that the 400 MLD plant will be able to maintain the full capacity operation in the monsoon season. To avoid the adverse influence of the monsoon, the pre-treatment system of the Minjur DSP, which is stably operating in the monsoon season, will be advantageous.

Further, redundancy plan is also important for the Perur DSP. Since the Minjur DSP is not equipped with standby RO unit, its production is often reduced for maintenance works. Installation of standby RO units, with economically acceptable number, for critical equipment needs to be considered in the preliminary design of the Perur DSP in the Study.



Source: CMWSSB compiled by JICA Study Team

Figure 3.4.9 Comparison of Operation Ratios of the Nemmli and Minjur DSPs

3.5 Present Conditions of the Water Recycle System

(1) Supply of the secondary treated sewage to industries

At present, CMWSSB is supplying secondary treated sewage of sewage treatment plant (STP) at Kodungaiyur to three industries as shown in Table 3.5.1. In CMA, majority of industries depend on ground water and private tanker suppliers to meet their water requirements. The treated sewage is considered as an alternative source of water for certain industrial purposes, which do not require high quality of water.

Volume of the secondary treated sewage supplied to the industries were 21.20 MLD in the fiscal year 2012-2013 and CMWSSB collected treated sewage tariff at a rate of INR 11.60 per kilo litters (KL). According to the annual report of CMWSSB, revenue from the treated sewage supply was INR 126.6

million in 2012-2013. Past annual revenues from 2000-2001 to 2012-2013 are given in Figure A3.12.1 in Appendix 3.12.

In the Kodungaiyer STP, there are three (3) units of treatment plants and their total capacity is 270 MLD. Utilization of the secondary treated sewage at the plant is calculated at 8%.

Table 3.5.1 List of Industries Supplied by CMWSSB including Treated Sewage Supply

S.No	Name of Industry	Location	Potable water source	Quantity of water supplied in 2012-2013 (MLD)	
				Potable water	Treated sewage
1.	Integral Coach Factory (ICF)	Perambur	Kilpauk WDS	3.00	-
2.	Heavy Vehicle Factory (HVF)	Avadi	Surapet WTP	4.00	-
3.	Madras Fertilizers Limited (MFL)	Manali	Well Fields & 100 MLD Minjur DSP	3.00	4.26
4.	Southern Railway (Manali)	Manali	Kilpauk WDS	3.50	-
5.	48 Small Industries (Manali)	Manali	Well Fields & Minjur DSP	2.40	-
6.	Tamil Nadu Petro Products Limited (TPL)	Manali		1.00	-
7.	Chennai Petroleum Corporation Ltd (CPCL)	Manali		2.00	14.50
8.	Manali Petro Chemicals-I	Manali		1.00	2.44
9.	Manali Petro Chemicals-II	Manali		1.20	
10.	Sriram Fibers	Manali		0.80	-
11.	Coramandel Fertilizers	Manali		0.40	-
12.	Tamil Nadu Petroleum Limited	Manali		0.40	-
13.	L & T Ship Building	Kattupalli		0.18	-
Total				**22.88**	**21.20**

Source: CMWSSB and Demand Assessment Study Report on the supply of TTRO water to the industrial units located in North Chennai prepared by ITCOT Consultancy and Services

(2) Ongoing projects for water recycle by reverse osmosis technology

For maximum utilization of the limited water resources, CMWSSB is constructing two water recycle plants by using reverse osmosis technology called as Tertiary Treatment Reverse Osmosis (TTRO). As presented in Table 3.5.2, the TTRO plants will be located beside the Koyambedu STP and Kodungaiyur STP for tertiary treatment of the secondary treated sewage from the respective STPs. The capacity of both the plants will be 45 MLD.

Among the two plants, construction of Koyambedu TTRO Plant was awarded to M/s VA TECH WABAG, an Indian plant supplier. Construction of Kodungaiyur TTRO Plant under World Bank funding was awarded to M/s BGR Energy Systems Ltd, an Indian plant supplier. Both the plants are expected to be commissioned by 2018.

The TTRO water will be provided to the industries by pipelines. About 90 km of the pipeline is being planned to be constructed from the Koyambedu TTRO Plant to Sirperambudur and Oragadam, which are located approximately 10 to 15 km away from the southwestern boundary of CMA and where various industries are agglomerated. The pipeline will be funded by JICA through a program for acceleration of industrial infrastructure development called Tamil Nadu Infrastructure Policy and

Promotion (TNIPD), whereas the pipeline from the Kodungaiyur TTRO Plant will be funded by the World Bank.

Locations of the planned TTRO plants and the industries that are to receive the recycled water are given in A3.12.2 in Appendix 3.12. The planned coverage area of the TTRO plants will include the regions outside the CMA.

Table 3.5.2 Planned TTRO Plants by CMWSSB

S.No	Name of TTRO plant	Capacity (MLD)	Fund	Target Areas for supply
1.	Koyambedu	45	TN State Government	Industries in Sriperambudur & Oragadam
2.	Kodungaiyur	45	World Bank	Industries in Manali

Source: CMWSSB

3.6 Financial Conditions of the Stakeholders and Tariff Rate

3.6.1 Present Conditions and Historic Trend of Water Rate

CMWSSB sets tariff for metered and unmetered customers. The metered customers are billed according to their consumption, but unmetered customers pay the flat rates. Out of 673,339 water connections in total, only approximately 3.9% of customers are equipped with the water meters, and the remaining 96.1% customers pay the flat rates.[9] CMWSSB categorizes consumers and tariff rates into Domestic, Commercial, Institutional, and Public Supply. Sewerage tariffs are also included in the water tariffs, but for the metered consumers an extra cost of 25% is added as sewerage charges based on their water usage. Table 3.6.1 summarizes the tariffs for the usage of water and sewerage services.

Since the volume of water provided through pipelines falls short of demand and few areas are also not connected to the piped water supply, CMWSSB has started selling water to consumers by using water lorries at fixed rates given in Table 3.6.2.

[9] Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and rest of CMA

Table 3.6.1 Water and Sewerage Tariff Rates

	Unmetered			Metered				
	Water		Sewerage	Water				Sewerage
				Minimum Charge		+Volumetric *1		
	Flat Rate (INR)	Unit		Minimum Charge (INR)	Unit	Usage (KL)	Rate (INR/KL)	Rate (total)
Domestic								
Residential (i) *2	50.0	/m./d.u.	included	50.0	/m./d.u.	0 - 10	2.5	+25%
						11 - 15	10.0	
						16 - 25	15.0	
						25 -	25.0	
Residential (ii) *3	50.0	/m./flat	included	50.0	/m./flat	0 - 10	2.5	+25%
						11 - 15	10.0	
						16 - 25	15.0	
						25 -	25.0	
Residential (iii) *4								
Non-Water Intensive								
Partly Commercial	150.0	/m./flat	included	150.0	/m./flat	-		included
All Others	400.0	/m./flat		400.0	/m./flat	-		
Water Intensive *5								
Private Hospitals	800.0	/m./flat	included	800.0	/m./flat	-		included
Institutional	300.0	/m./flat		300.0	/m./flat	-		
Private Educational Institution	400.0	/m./flat		400.0	/m./flat	-		
All Others	650.0	/m./flat		650.0	/m./flat	-		
Commercial								
Non-Water Intensive								
Private Hospitals	800.0	/m.	included	800.0	/m.	0 - 500	50.0	+25%
All Others	400.0	/m.		400.0	/m.	0 - 500	35.0	
Water Intensive *6								
Private Hospitals	800.0	/m.	included	800.0	/m.	0 -	80.0	+25%
All Others	650.0	/m.		650.0	/m.	0 -	60.0	
Institutional								
Private Educational Insitution	400.0	/m.	included	400.0	/m.	0 -	40.0	+25%
Government Hospitals	200.0	/m.		200.0	/m.		20.0	
All Others	300.0	/m.		300.0	/m.		30.0	
Public Supply								
Municipal Bulk Supply	50.0	/m.	included	50.0	/m.	0 -	15.0	+25%
							7.0	

Note: m = month, d.u. = dwelling unit

*1: Volumetric Charges will be charged only for the portion exceeding the minimum charge.

*2: Domestic Residential premises (Other than Flats or Block or line of Houses)

*3: Flats or houses in a Block of flats or line of houses respectively used wholly for residential purposes. Total consumption divided by the no. of flats.

*4: Individual flats or Houses in a Block of Flats or line of houses, respectively, used for other than residential purposes.

*5: Water intensive for unmetered means premises used fully or partly as Theatres, Hotels, Boarding Houses, Lodges, Clubs, Private Hospitals, Private Hostels, Kalyanamandapams (Ceremony halls), Clinic with inpatient facility, Swimming baths, Places for keeping animals, Vehicle Service Stations, and Nurseries.

*6: Water intensive for metered commercial means commercial premises using more than 500 KL of water in a month.

*7: Sewerage charges at 25% on water supply charges wherever sewer connections are provided.

Source: CMWSSB

Table 3.6.2 Price of Water Sold by Water Lorries

	Mobile Water Supply			Water Supply at Filling Points		
	Charges (INR) per load of			Charges (INR) per load of		
	6KL	9KL	10KL	1KL	6KL	9KL
Domestics						
Residential	400.0	600.0	670.0	40.0	-	-
Partly Commercial						
Domestic Purpose	400.0	600.0	670.0	-	-	-
Other than Domestic Purpose	510.0	765.0	850.0	-	-	-
Commercial						
Comercial incl. Private Hospital	510.0	765.0	850.0	60.0	-	-
Institutional						
Private Educational Institution incl. Hostels	510.0	765.0	850.0	40.0	-	-
Gov't Offices/Schools Colleges/Hospitals etc.	400.0	600.0	670.0	40.0	-	-
Employees of the CMWSSB						
Employees of the CMWSSB	-	-	-	-	200.0	300.0

Source: CMWSSB

The tariff has not been revised since many years. The last revision for residential (domestic) tariff was made in 1998 and for commercial tariff in 2003. Considering that the wholesale price index in India has increased by 2.5 times since 1998, the real price of water has significantly dropped down for consumers.

In addition to water and sewerage tariffs, CMWSSB collects water and sewerage taxes from consumers based on their assessed annual value that includes the annual income for individuals and annual revenue for business entities. The Chennai Corporation conducts annual value assessment of each household and commercial entity on behalf of CMWSSB, post of which the water tax has been determined as 1.5% per annum and sewerage tax as 5.5% per annum of the annual assessed value. Upon receiving bills from the CMWSSB, consumers have to pay tariffs and taxes to the regional CMWSSB offices or through the designated banks.

3.6.2 Mechanism and Procedure of Water Rate Setting and Improvement Plans of Revenue and Metering

1) Proposed rate setting mechanism and revenue increasing plan

CMWSSB Act ensures the Board has the power "to determine, levy, and collect taxes, rates, fees, charges, surcharges, rents, costs and expenses.[10]" CMWSSB has the policy to set these rates to generate enough revenue to recover annual cash outflow including the O&M cost, employment expenses, administrative expenses, and other charges. Although CMWSSB holds the sole power to adjust the tariffs, the decisions are often political. Since the provision of water is an essential public utility, the CMWSSB runs with large grants from the Tamil Nadu Government. As to be explained in Subsection 3.6.4, CMWSSB's cash outflow has been exceeding its income since the fiscal year 2010-2011. According to the financial officer at CMWSSB, there is an internal discussion to increase the tariff to gain additional revenue of INR 200 crores (2,000 million) per year. Table 3.6.3 summarizes the proposed schemes by CMWSSB. The schemes being discussed are yet to be published

[10] The Chennai Metropolitan Water Supply and Sewerage Act, 1978

or announced, however, CMWSSB has a mind set to achieve the balanced annual cash flow in the near future by strengthening the income side by introducing the proposed schemes.

Table 3.6.3 Proposed Schemes for Revenue Increase

No.	Scheme	INR in Crores
1	Flat Domestic Tariff increase from Rs. 50/- to Rs. 150/- per month	82.00
2	Partially Commercial Tariff increase from Rs. 150/- to Rs. 300/- per month	20.00
3	Metered Tariff Revision	25.00
4	Mobile Water Supply (Tanker Supply) increase by 30%	10.00
5	Municipal Bulk Supply – Outside CMA Limits – Increase from Rs. 26/- per KL to Rs. 35/- per KL	7.00
6	Industrial Supply – Increase from Rs. 60/- to Rs. 75/-	28.00
7	Increase in Sewer Charges from 25% to 40%	8.00
8	Increase on account of category change, additional connections	20.00
	Total	200.00

1 Crore = 10 million
Source: CMWSSB

The detailed revision of the metered tariff (listed as scheme 3 in the Table 3.6.3) is described in the Table. 3.6.4. The proposed water tariff has been enlisted in the terms and conditions of the contract between Tamilnadu Urban Finance and Infrastructure Development Corporation (TUFIDCO) and CMWSSB on the funding of water supply project under Atal Mission for Rejuvenation and Urban Transformation (AMRUT). Accordingly, the increased tariff is likely to be executed only from 2017 onwards, but there is no commitment from CMWSSB on the increased level of tariffs in writing. The Board discussion may only openly commence after the Tamil Nadu Local Body Elections, which was originally scheduled on October 2016, but it was deferred based on orders of Hon'ble High Court of Madras. The election is yet to take place and the dates of election are also not finalised till date.

Table 3.6.4 Proposed Water Tariff by CMWSSB

Consumer Category	**Proposed Water Tariff**	Current Water Tariff
Residential		
0 – 10 KL	**INR 5/- per KL**	INR 2.5/- per KL
11 – 15 KL	**INR 20/- per KL**	INR 10/- per KL
16 – 25 KL	**INR 30/- per KL**	INR 15/- per KL
>25 KL	**INR 50/- per KL**	INR 25/- per KL
Commercial	**INR 70/- per KL**	INR 35/- per KL *1
Industrial	**INR 125/- per KL**	INR 60/- per KL *2

*1: Volumetric charges for Commercial Non-Water Intensive Category.
*2: Volumetric charges for Commercial Water Intensive Category.
Source: CMWSSB

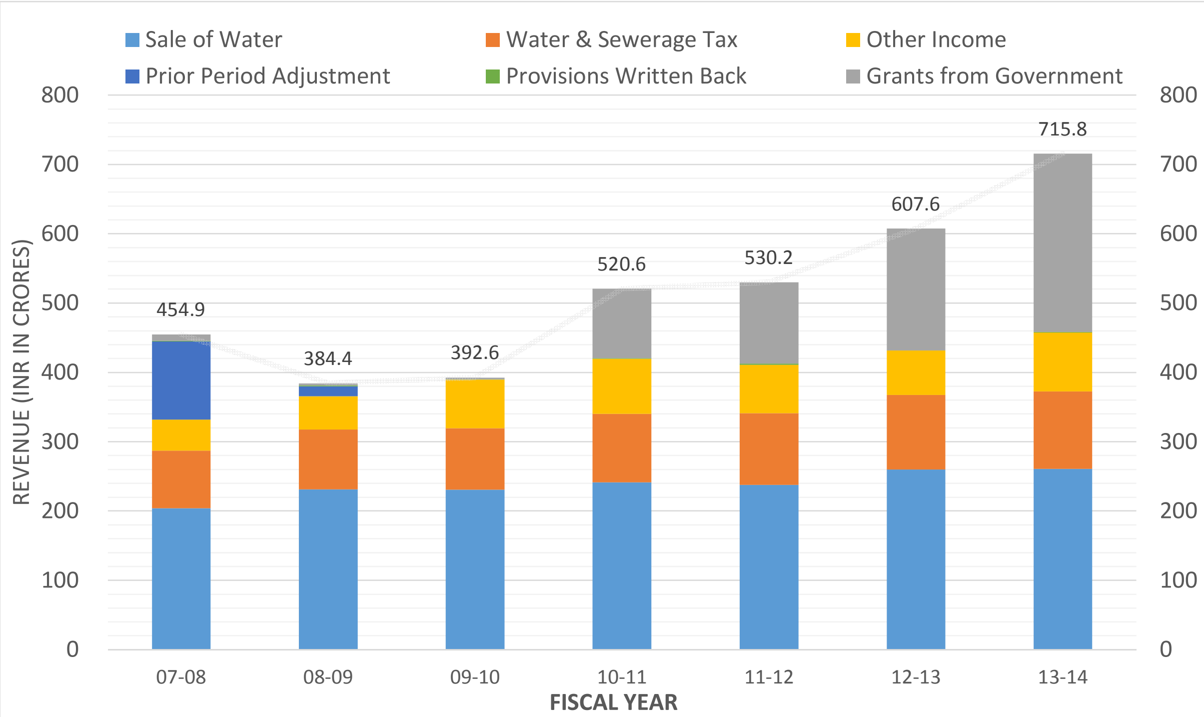
2) Metering plan

CMWSSB currently does not have immediate plans for metering of consumers. CMWSSB lacks requisite staff strength to attend the meter repairing works and to take monthly readings. Under the current metering situation, increase in metered tariff rates will have only limited impact on the revenue.

On the other hand, the increase in the flat tariff rates is more certain to bring a larger impact on the revenue in short-term duration.

3.6.3 Total Revenue Amount of CMWSSB

Main financial sources of CMWSSB are 1) sales of water, 2) tax collections, and 3) grants from governments. Figure 3.6.1 shows the historical trends of revenue break down at CMWSSB, which concludes that a substantial amount of its revenue comes from the sales of water. Since 2010-2011, governmental grants increased drastically to finance the fiscal deficits. The grants were from local governments and other several development funding schemes, such as the Second Chennai Water Supply and Sanitation Project, and the Chennai River Conservation Project. The total revenue of CMWSSB in the fiscal year of 2013-14 was INR 715.8 crores (INR 7,158 million), of which 64% or 458.5 crores (4,585 million) is its source of income.



1 crore = 10 million
Source: CMWSSB

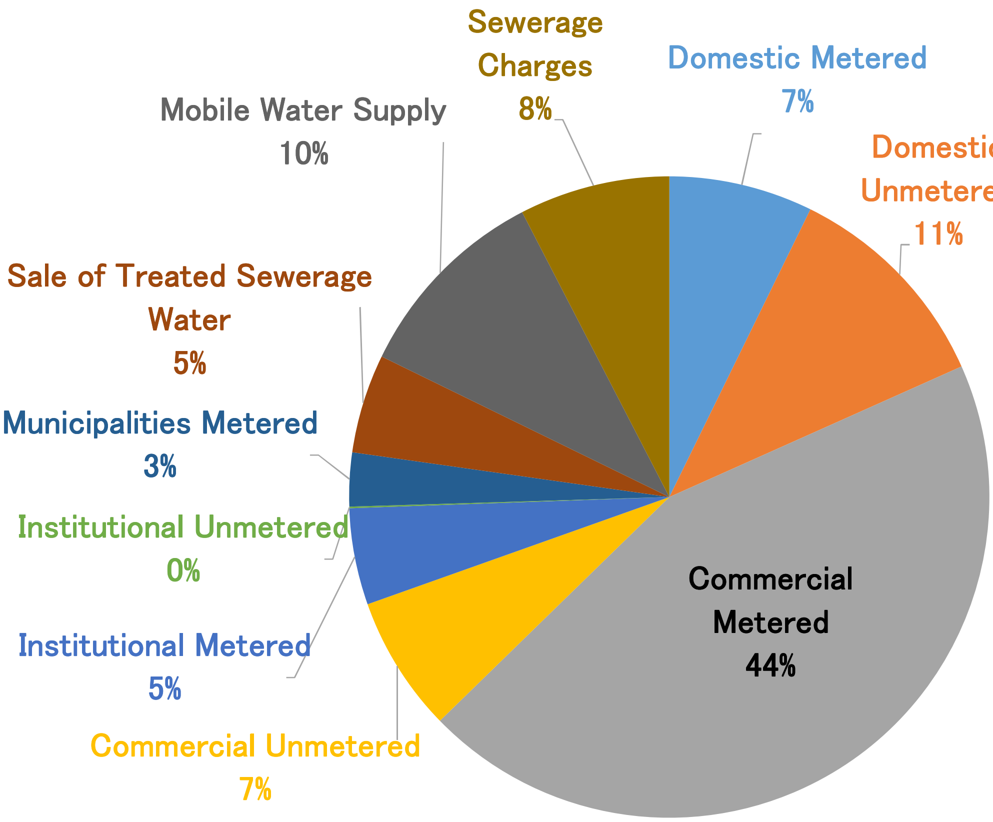
Figure 3.6.1 Trends of CMWSSB Revenues[11]

Despite the significant enlargement of the mandated area in the year 2011, the collected tax amount for water and treated sewage sale remained stable. CMWSSB has not been able to systemize the tariff and tax collections scheme from these enlarged service areas.

The sale of water is supported heavily by other commercial sale sectors. As given in Figure 3.6.2 presenting the breakdown of CMWSSB's revenue, 51.3% of the total revenue from the water sales come from metered and unmetered commercial consumers. Domestic (Residential) metered revenue

[11] Revenue and Expenditure details are retrieved from CMWSSB Annual Reports. 2013-14 is under draft.

accounts for 18.3%, whereas the revenue from the water supply by water lorry called Mobile Water Supply is only 10%, as shown in the figure.



Source: CMWSSB

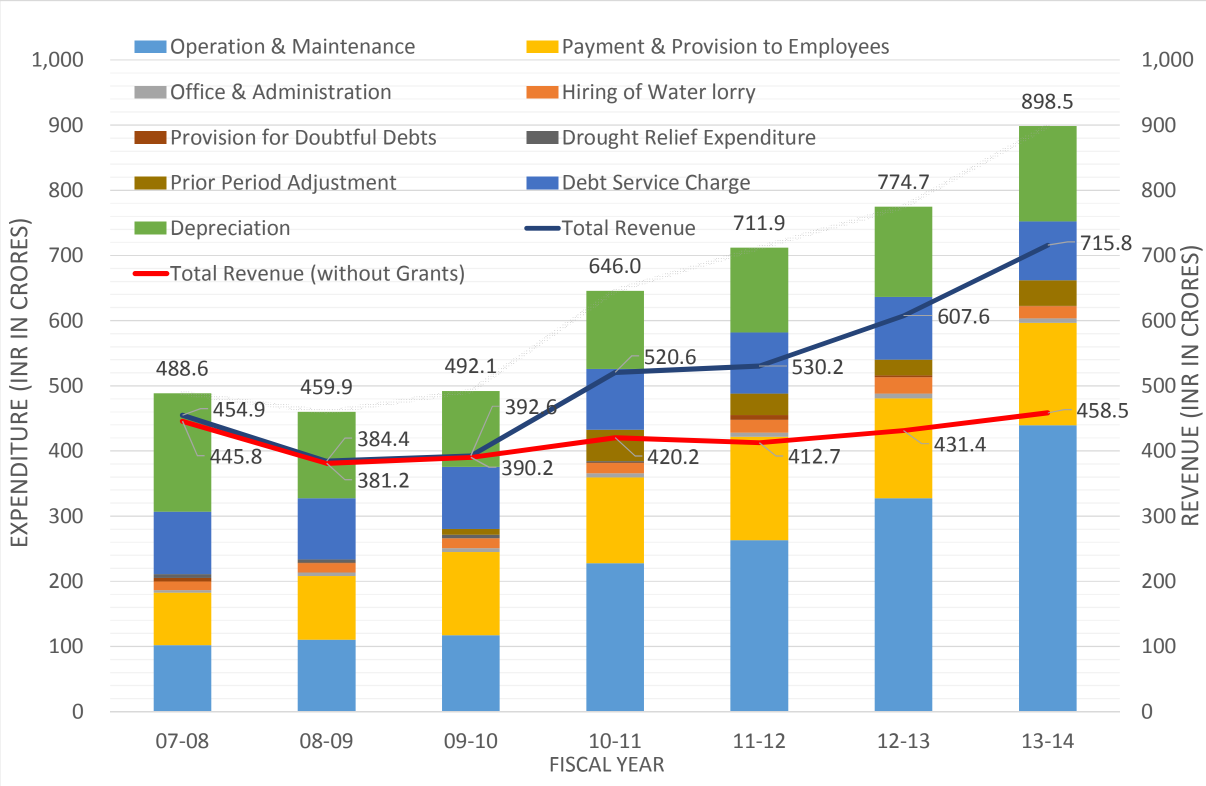
Figure 3.6.2 Paid Amount Share of Consumer Types for Sales of Water & Sewerage Charges (2013-14)

For domestic consumers, installed household meters are rare. In fact, only 3.9% of the total customers are equipped with the water meters and the unmetered customers pay only the flat rates. Therefore at least for unmetered category, increase in the water supply volume by CMWSSB does not result in the revenue growth within the current scheme.

The collection rate for taxes and water charges in the fiscal year 2014-15 is 70.68%. In the fiscal year 2010-11, CMWSSB had 79.58% on record collection rate that decreased by 10% in the last four years. The enlargement of the supply area contributed to the increase in the billed amount. However, the collected amount did not increase as supposed due to the fall in the collection rate.

3.6.4 Financial Conditions of CMWSSB

Main expenditures of CMWSSB are 1) O&M, 2) Payments to employees, 3) Office administration, 4) and Water lorry hire charges. Figure 3.6.3 shows the breakdown of expenditure at CMWSSB. The expenditures including investment depreciation total to INR 898.5 crores (8,985 million) in the fiscal year 2013-14. Without depreciation, the expenditure is INR 752.2 crores (7,522 million).



1 crore = 10 million
Source: CMWSSB

Figure 3.6.3 Trends of CMWSSB Expenditures

As presented in Figure 3.6.3, cash outflow has been exceeding cash inflow in the recent years. Thus, the financial condition of CMWSSB is very weak. The total revenue without government grants has not been able to recover the cash outflow since the fiscal year 2010-11. The O&M cost saw a steep hike in the fiscal year 2010-11, and it continued to rise in the following years. The O&M includes the purchase of desalination water from the Minjur DSP, which came into operation under the DBOOT (Design-Build-Own-Operation-Transfer) scheme. In addition, O&M for water production increased after the Nemmeli DSP came into operation at the end of the fiscal year 2012-13.

Other costs, such as labor cost and office administration, saw slight increase after the expansion of coverage in 2011. At the same time, water lorry hires have been increased to deliver water to the areas without CMWSSB water supply network. Since the fiscal year 2014-15 CMWSSB has not been able to pay the debt service charge.

The new DSPs will impose heavy burden on CMWSSB expenditures. Since CMWSSB's financial policy is expenditure driven, the Board needs to consider adopting the new schemes presented in the Table 3.6.3 as soon as possible to recover the increasing running costs.

Almost all investments to new plants, tanks and pipelines in CMWSSB service area have been made through grants from the Government of India and the Government of Tamil Nadu and contributions from local bodies and some other urban development funds, such as Tamil Nadu Slum Clearance Board and Tamil Nadu Urban Development Fund. Since these investments are given as grants, the revenue generated from selling, of water from existing and new plants are used to cover O&M and other annual cash outflow.

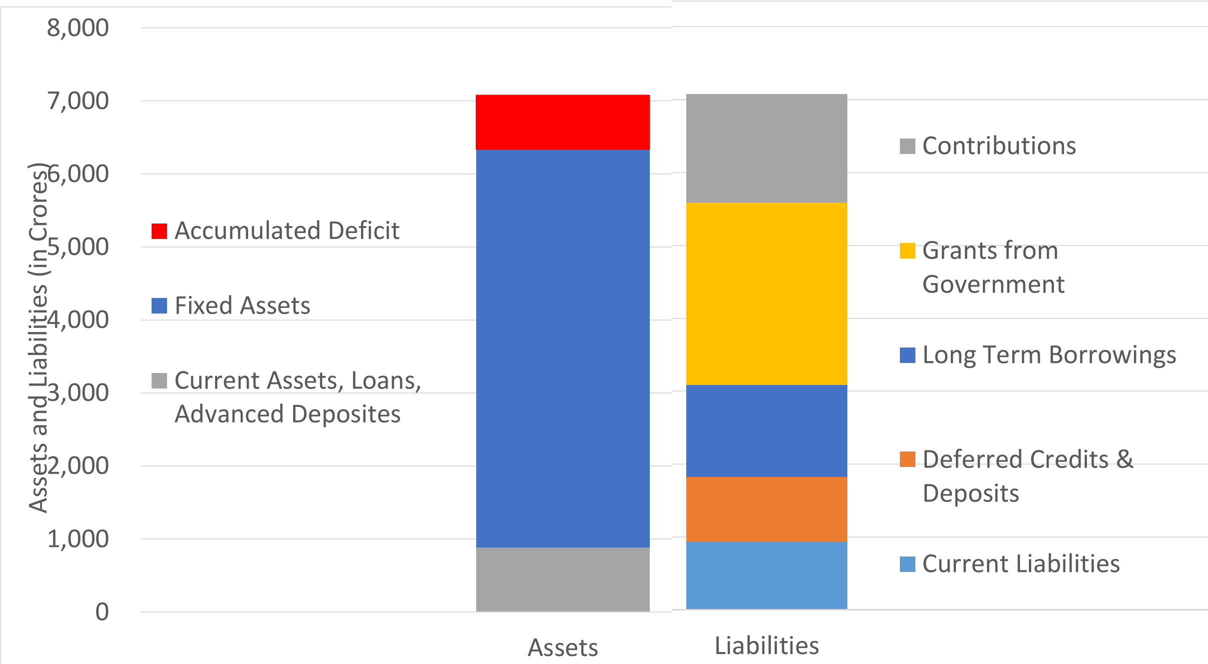
Table 3.6.5 presents the balance sheet of CMWSSB at the end of the fiscal year 2013-14.

Table 3.6.5 Balance Sheet of CMWSSB (2013-14)

Assets	(Crores)	Liabilities	(Crores)
Fixed Assets	**5,452.4**	**Contributions**	**1,483.7**
A. Water Supply at Cost	1,703.6	A. Contribution from Government	488.0
B. Sewerage at Cost	552.2	B. Contribution from Public	634.2
C. General at Cost	24.0	C. Excess of Assess over Liabilities Transferred from C.M.C	15.9
D. Project in Progress	3,053.8	D. Excess of Assess over Liabilities Transferred from P.W.D	5.2
E. Drought / Flood Relief Work	118.8	E. Excess of Assess over Liabilities Transferred from ADIIOC Board	0.1
Current Assets, Loans, Advanced Deposites	**885.5**	F. Excess of Assess over Liabilities Transferred from ULB's	-43.7
A. Inventory	12.0	G. Capital Reserves	274.8
B. Sundry Debtors	187.1	F. Funds	109.2
C. Cash and Bank Balances	328.0	**Grants from Government**	**2,508.0**
D. Loans and Advances	69.5	A. Second Chennai Project	137.4
E. Deposits and Investments	288.8	B. CCRCP	351.6
		C. JNNURM	202.1
		D. Desalination Plant at Nemmeli	719.2
Accumulated Deficit	**741.6**	E. Others	463.4
		F. CMCDM	258.3
		G. ULB Grants	165.7
		H. Devolution Fund	210.3
		Long Term Borrowings	**1,267.7**
		A. Loans from Government	727.5
		B. Bonds	0.0
		C. Loan from Financial Institutions	540.2
		Deferred Credits & Deposits	**885.2**
		A. Deposits from Public	839.8
		B. Sec. Deposits and Retention Money	45.3
		C. Advance for Sale of Lands	0.0
		Current Liabilities	**935.0**
		A. Sundry Creditors	157.2
		B. Interest Accured	580.5
		C. Other Liabilities	197.3
total	**7,079.5**	total	**7,079.5**

1 crore = 10 million
Source: CMWSSB

CMWSSB maintained accumulated surplus until the fiscal year 2008-09, and the balanced budget was recorded in the fiscal year 2009-10. The net deficit has been continuously increasing since fiscal year 2010-11 at INR 210.07 crores (2,100.7 million) to INR 741.0 crores (7,410 million) in 2013-14. Over the trend, the Grants from Government have increased by around 5 times over the last 6 years from INR 552.5 crores (5,525 million) to INR 2,508.0 crores (25,080 million). Most of the capital works over the last 5 years have been executed through funds obtained as Grants from Government. Figure 3.6.4 illustrates the numbers in the Table 3.6.5.



1 Crore = 10 million
Source: CMWSSB

Figure 3.6.4 CMWSSB Balance Sheet (2013-2014)

Current ratio (current asset / current liability x 100) is 94.65, which implies that CMWSSB has low liquidity capacity. Incoming cash flow needs to be strengthened to achieve sustainable financial budget.

3.6.5 Financial Conditions of the State Government

The revenue deficit of the Government of Tamil Nadu (GoTN) for the year 2014-15 is estimated at INR 11,455 crores (114,550 million) with fiscal deficit at 2.90% as illustrated in the Table 3.6.6. The state has registered revenue deficit in the past 3 fiscal years. The deteriorating financial health is expected to continue in the next 2 years also.

Table 3.6.6 Financial Condition of Tamil Nadu State

(INR in Crores)

Fiscal Indicators	**2012-13**	**2013-14**	**2014-15**
State's Own Revenues	80,249	83,061	94,640
Tax Revenues	73,560	73,718	85,773
Non Tax Revenues	6,688	9,343	8,867
Central Transfers	21,529	24,975	38,548
Share in Central Taxes	14,520	15,853	16,824
Grants	7,009	9,122	21,724
Total Revenue Receipts	**101,777**	**108,036**	**133,188**
Current Expenditures	90,571	96,695	120,835
Salaries	29,393	31,863	37,604
Pensions	12,965	14,159	16,706
Non-Wage O&M	8,194	8,999	10,884
Subsidies and Transfers	39,977	41,644	55,611
Other Expenditures	43	30	31
Current Expenditures	20,341	18,795	23,809
Capital Outlay	19,165	17,173	20,341
Net Lending	1,175	1,622	3,468
Total Expenditures	**110,912**	**115,490**	**144,644**
Fiscal Indicators			
Revenue Surplus / (Deficit)	-9,135	-7,454	-11,456
Revenue Surplus / (Deficit) %	-8.98%	-6.90%	-8.60%
Fiscal Surplus / (Deficit)	-19,889	-20,584	-27,346
Fiscal Deficit %	-2.88%	-2.55%	-2.90%
Outstanding Liabilities	147,416	165,459	189,256
GSDP at Current Prices	690,542	808,766	942,225

1 crore = 10 million
Source: Government of Tamil Nadu

The increasing deficit is on account of the general economic slowdown and the various social welfare schemes being undertaken by the GoTN without corresponding increase in tax collections. The borrowings of the GoTN have considerably increased in the last few years and the committed expenditure in the form of interest payments is likely to increase in future. Therefore, improving the tax collections in the coming years is vital for taking up new capital intensive projects. The state also ranks low in non-tax revenue, which has a potential to increase.

Nevertheless, Tamil Nadu is one of the better managed states in India and its financial condition is better than other states in India. The state has till date not defaulted in any of its loan repayments. Besides, after the elections steps have been initiated to close the fiscal deficit gap. The local body elections are due in October 2016 and there is proposal for increase in taxes levied by ULBs after the elections. Thus the financial conditions are expected to be better in the coming years. Taking into consideration the same, the Tamil Nadu Government has the financial capacity to undertake the project.

3.6.6 Public Awareness to the Water Tariff Rate

The Social Baseline Survey in the Study identified willingness to pay for the connection to the water supply services by CMWSSB. Table 3.6.7 shows the result of asking how much money the unmetered domestic consumers are willing to pay at flat rates if they had access to 24-hours water supply from CMWSSB.

Table 3.6.7 Willingness to Pay for 24-Hours Water Supply

Willingness to Pay	Number	Percentage	Valid Percentage
Above INR200	6	1.1	4.6
INR151 to INR200	29	5.4	22.3
INR101 to INR150	33	6.1	25.4
INR51 to INR100	16	3.0	12.3
INR50	46	8.5	35.4
Not disclosed	409	75.9	
Total	539	100.0	100.0

Source: JICA Study Team

Among the people who showed a willingness to pay, 35.4% are willing to pay an amount of INR 50 per month, which is the current tariff rate level. Other 64.6% showed acceptance to increase in the flat rate, and 26.9% are willing to pay more than INR 150 per month that CMWSSB proposed in their internal discussion. The weighted average of above becomes INR 106.9. Even for the 6-hours of supply of water, the weighted average of the willingness to pay is INR 90.275. The willingness to pay tends to be estimated lower than the affordability to pay in case of utility payments such as water; however, the survey results show that the consumers have a general acceptance to the increase in the water tariffs. The survey also identified that 64.0% of the consumers are aware of the CMWSSB's efforts to augment water supply.

3.7 Past, Planned and Ongoing Assistances of Donors on Major Projects

CMWSSB has received financial assistances from other donors. Major projects that have been undertaken in the past are listed below:

- Puzhal WTP Project: World Bank, completed in 1996
- Chembarambakkam WTP Project: French Development Agency, completed in 2007
- Unaccounted for Water (UFW) Program: World Bank, conducted in four phases completed in 1991, 1995, 1999 and 2001 respectively
- Second Chennai Water Supply Project: World Bank, completed in 2003 to improve existing water distribution network

Furthermore, there are several other ongoing or planned major projects to be financed by donors as listed in Table 3.7.1.

Table 3.7.1 Ongoing and Planned Projects Financed by Donors

Project names	Project scope	Donor	Project period	Amount (INR in million)	Status
Pammal Water Supply Scheme	Providing comprehensive Water supply scheme to Pammal Municipality, adjoining Greater Chennai Corporation	World Bank	2013 - 2016	431	Work is in progress
Pallavaram Water Supply Scheme, Package I,II & III	Providing comprehensive Water supply scheme to Pallavaram Municipality, adjoining Greater Chennai Corporation	World Bank	2013 - 2016	999.5	Work is in progress
Madhavaram Water Supply Scheme	Providing comprehensive Water supply scheme to Madhavaram area of Greater Chennai Corporation	JICA	2012 - 2016	550	Work is in progress
150 MLD DSP at Nemmeli with product water main	Constructing of 150 MLD DSP at Nemmeli and transmission main for the Chennai Corporation	KfW	2016 -2020	13,718.6	Tenders invited with bid submission date fixed as 7th March 2017
45 MLD TTRO Plant at Kodungaiyur with product water main	Constructing Tertiary Treatment Reverse Osmosis (TTRO) plant and transmission main to industries	World Bank	2016 -2018	2,550	Work is in progress

Source: CMWSSB

Among the projects mentioned above, 150 MLD DSP, to be financially assisted by KfW, has a direct link with the Perur DSP Project. The 150 MLD DSP will be located beside the Perur DSP and will jointly formulate a wide influence area together with the existing Nemmeli DSP. KfW and the Government of India agreed to a loan agreement of 100 million Euros on 28th June, 2016. The agreed amount will cover 60% of the total project cost for capital investment, and the remaining 40% will be financed by the Government of Tamil Nadu. In July 2016, CMWSSB sent the tender document to KfW for concurrence and to the Government of Tamil Nadu for approval. CMWSSB received the approval and the tenders invited with bid submission date fixed as 7th March 2017.

The contract will be undertaken under the Design-Build-Operate (DBO) scheme, which will include O&M works for 20 years. Procurement will be adopted post pre-qualification (PQ) process, where the bidders will submit three envelops for PQ, technical proposal and financial proposal at the same time.

3.8 Issues to be Solved in the Water Supply Services and System of CMWSSB

Based on assessment of the present situation given in sections 3.3 to 3.6, major issues to be solved in the water supply services and system of CMWSSB are summarized below:

(1) Service level

a. Availability of the surface water resources of CMWSSB is chronically much lower than (in most years less than 50% of) the production capacity of the WTPs due to severe climate conditions and water losses in raw water transmission and reservoirs. Especially the storage volume in the reservoirs of Poondi, Cholavaram, Redhills, and Chembarambakkam, which are the main surface water resources of CMWSSB, in recent years are serious. Against the requirement from Central Public Health and Environmental Engineering Organisation (CPHEEO) of 150 lpcd, the current unit water consumption is only 80 lpcd.

b. One of the reasons for the low production is the limited operation of the Nemmeli DSP. Because of the flat and low rate, CMWSSB has not been motivated to operate the DSP at high operation rate under usual climate condition.

c. Low water production results in an intermittent water supply. According to the Social Baseline Survey in the Study, people who are receiving water every day is only 48.9% in the Chennai Corporation. Service duration for 88.1% of the water consumers are four hours or less.

d. Service connection rate in the Corporation is still 58%. 65% in the Core City and only 41% in the Expended Area have service connections. A large number of people are still depending on stand posts, water tankers of CMWSSB and private supplier, and/or private wells.

(2) Deficiencies in raw water transmission and water production facilities

a. Raw water transmission channels and pipelines are facing deterioration in some sections, which is generating leakage of valuable raw water, and some of the leakages are causing contamination by soil. Among them, damaged embankment of the raw water channels of the Water Resource Department and water transmission lines from Redhills Reservoir to Kilpauk WTP are reported.

b. O&M of the water treatment plants (WTPs) need improvement, especially the filters and the back washing system in the WTPs of Puzhal, Vadakuthu, and Chembarambakkam.

c. The Nemmeli DSP cannot produce the designed amount of water during monsoon due to low performance of the pre-treatment facility on high turbidity condition. Regardless of the water shortage in Chennai, production of the DSP sometimes deteriorated to 60% of the design capacity in 2014 and 2015.

d. Some pumps in the Northern Well Fields are out of order.

(3) Deficiencies in treated water transmission and distribution facilities

a. Treated water transmission mains have deteriorated in some sections. Among them, the pre-stressed concrete pipes from Puzhal WTP are significantly damaged. Water transmission mains of cast iron from Kilpauk WTP, most of which were constructed in 1914 and 1948, are suspected to be leaking.

b. Most existing water distribution pipes of CMWSSB were installed after the 1990s and estimated water loss ratio in the water transmission and distribution networks are not high (21.1%). However, old pipes still remain and the length of the existing pipes, which are 40 years old or more is 389 km.

c. The existing networks do not have monitoring system of water pressure and water losses.

(4) Challenges in management aspects of the water supply services

a. CMWSSB does not have computerized consolidated data based for asset information management. Pipe inventory, which is currently registered in paper-based form, has not been updated since 2003.

b. The metering rate of CMWSSB is only at 3.9%. According to CMWSSB, the low service level makes the water users refuse the meter installation. The extremely low metering ratio prevents CMWSSB from measuring NRW.

c. CMWSSB does not have special unit for NRW management.

d. Intermittent water supply leads people to keep the taps open to receive water any time supplied, which further worsen the water supply frequency, duration and pressure.

e. O&M cost of CMWSSB is increasing especially from 2010-2011 when the mandated area of CMWSSB expanded and Minjur DSP started operation. From 2011-2012, revenue of CMWSSB has not been able to cover O&M cost excluding depreciation. Water rate is too low to achieve cost recovery.

f. The major cause of the insufficient water sales of CMWSSB is the low metering rate, due to which the low flat rate is applied to most water consumers. The prevailing flat rate gives CMWSSB a negative incentive to save water production from the DSPs even in severe drought condition because the high operation cost of the DSPs will worsen the revenue deficit. Introduction of volumetric water rate at sufficient level to recover the operation cost of the DSPs is fundamental for sustainable and sufficient water services.

CHAPTER 4 REVIEW OF THE WATER SUPPLY AND SEWERAGE MASTER PLAN OF CMWSSB

This chapter explains the contents of the "Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA" (hereinafter, M/P)" and provides an assessment on the M/P by the JICA Study Team. Proposed modifications on the M/P by the study team relevant to the rationale and scope of the Project will be given in Chapter 5.

4.1 Introduction

4.1.1 Background, Study Area and Objectives of the Master Plan

Chennai Corporation is suffering from chronic water shortage, and the water service level is inferior to the other major cities such as Delhi, Mumbai or Calcutta. To improve the service to achieve 24 x 7 (24 hours for seven days in a week) water supply with 100% service connections, Shah Technical Consultants Pvt. Ltd. (STC) was engaged in developing comprehensive master plans for the water supply and sewerage systems or the M/P.

Target area of the M/P is the entire Chennai Metropolitan Area (CMA), namely the present Chennai Corporation including Chennai Core City and the Expanded Area and the Rest of CMA. The horizon period of the M/P is the year 2035 as the mid year and the year 2050 as the ultimate year, which is 30 years from the year 2020 as the base year.

After the final draft version submitted in July 2015 and Technical Review Committee on August 2015, the final version was presented in February 2016.

4.1.2 Scope of the Master Plan

M/P is a compilation of the following works and studies:

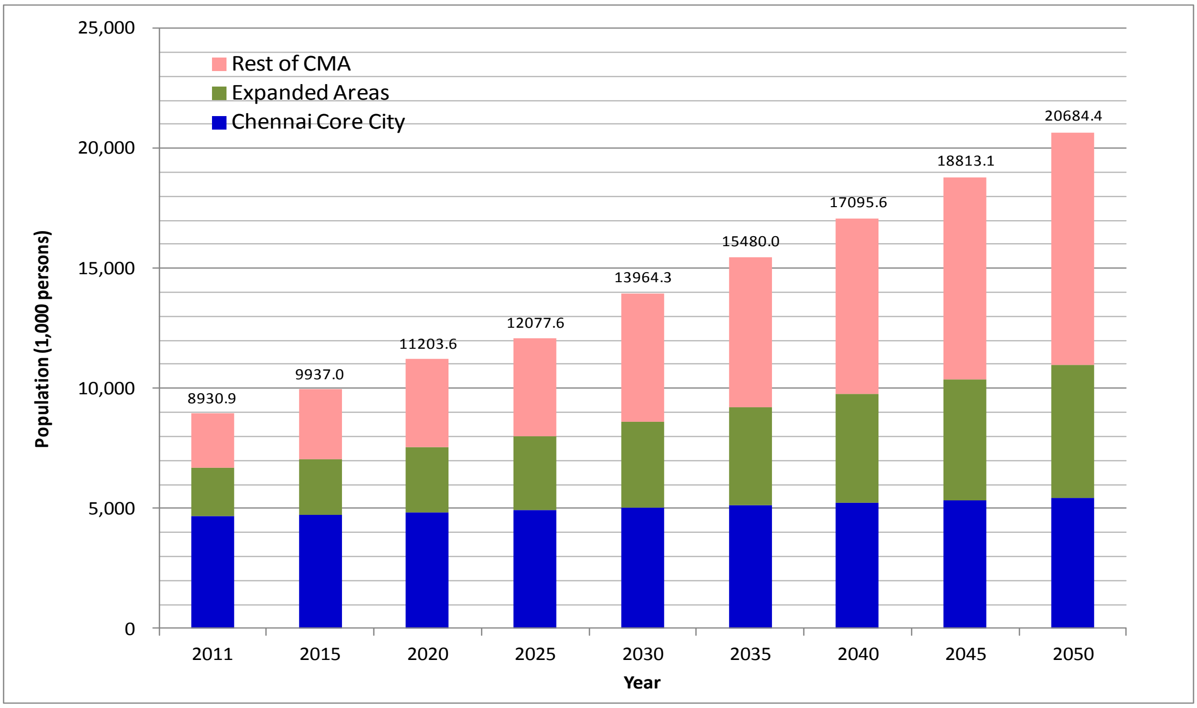
- Review of the previous master plans in respect of water supply and sewerage sector, which are Madras Metropolitan Area-Master Plan for Water & Sewerage in 1978 and Madras Metropolitan Area-Master Plan for Water & Sewerage in 1991
- Forecast of population, water demand, and sewage generation for the years 2020, 2035 and 2050 for the entire CMA
- Assessment of the potentials of the existing water sources to identify the future demand/supply gap to be resolved and preparation of augmentation plan of the water sources
- Preparation of water allocation and water transmission plan from the water sources
- Development of sewerage master plan to reduce pollution of the rivers
- Estimation of the capital and O&M costs of the proposed projects
- Preparation of implementation schedule of the proposed projects

4.2 Population Forecast

4.2.1 Methodologies of the Forecast

M/P evaluated the past population forecast for CMA conducted in "Second Master Plan for Chennai Metropolitan Area, 2026" (hereinafter, "CMDA-MP"), which was prepared by Chennai Metropolitan Development Authority in 2008. CMDA-MP is the latest city planning document for the entire CMA. By comparing the forecast population for 2011 in CMDA-MP with the census results in 2011, M/P concluded that the forecast in CMDA-MP was an overestimation for the corporation and subsequently carried out its own estimate to incorporate the latest population trend found in the census 2011.

Results of the population in the M/P are shown in Figure 4.2.1. Details of the methodology and results of the forecast are given in Appendix 4.1. The forecast population in the M/P expresses general trends that the Chennai Core City will have only little growth potential and that the population growth will happen in the outskirts of the Core City.



Area	Population								
	2011	2015	2020	2025	2030	2035	2040	2045	2050
Rest of CMA	2,264.3 (-)	2,883.2 (6.23%)	3,646.3 (4.81%)	4,104.2 (2.39%)	5,345.6 (5.43%)	6,299.9 (3.34%)	7,337.2 (3.10%)	8,468.8 (2.91%)	9,711.8 (2.78%)
Expanded Area	2,019.6 (-)	2,326.1 (3.60%)	2,727.0 (3.23%)	3,034.9 (2.16%)	3,585.2 (3.39%)	4,042.4 (2.43%)	4,519.2 (2.25%)	5,016.7 (2.11%)	5,535.7 (1.99%)
Chennai Core City	4,647.0 (-)	4,727.7 (0.43%)	4,830.2 (0.43%)	4,938.6 (0.44%)	5,033.4 (0.38%)	5,137.7 (0.41%)	5,239.3 (0.39%)	5,327.6 (0.33%)	5,436.9 (0.41%)
CMA Total	8,930.9 (-)	9,937.0 (2.70%)	11,203.6 (2.43%)	12,077.6 (1.51%)	13,964.3 (2.95%)	15,480.0 (2.08%)	17,095.6 (2.01%)	18,813.1 (1.93%)	20,684.4 (1.91%)

*: Values in the brackets are annual population growth in % from the previous population

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

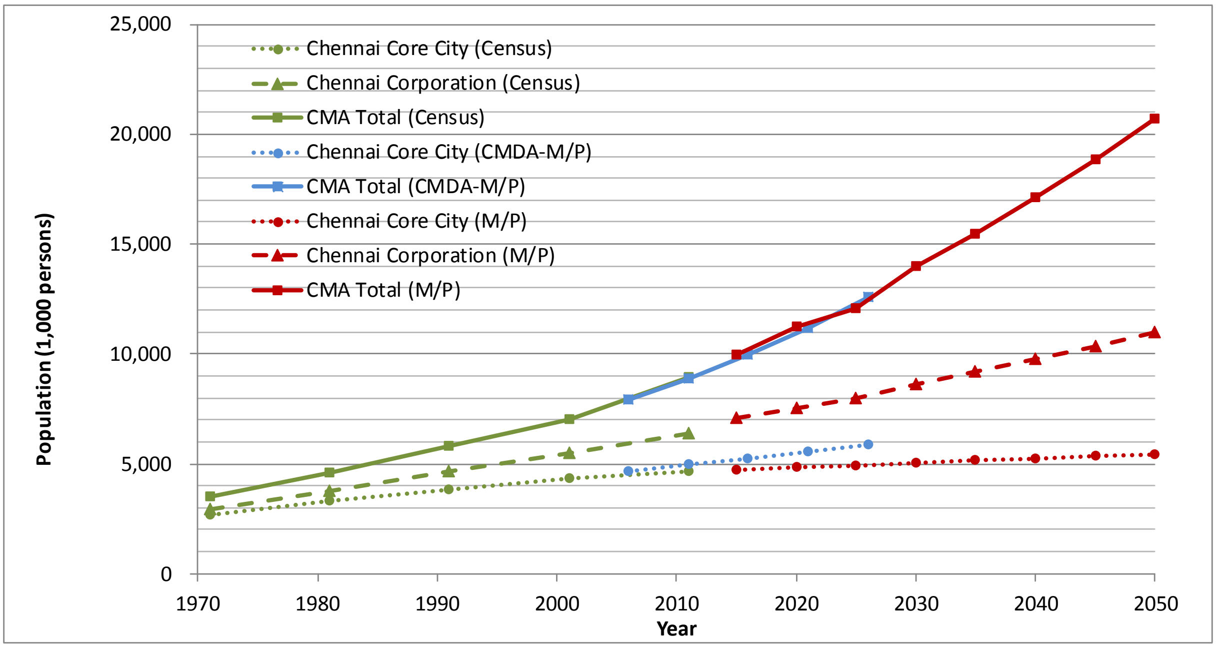
Figure 4.2.1 Population Forecast in the M/P

4.2.2 Assessment of the Forecast

Figure 4.2.2 compares the population forecasts for Chennai Core City and the entire CMA in the M/P with those in CMDA-MP. It also plots past census results for the same areas. CMDA-MP conducted the forecast up to 2026, while the M/P's forecast was up to 2050.

For the entire CMA, the population forecasts in M/P and CMDA-MP are quite similar, and both are in line with the past trend from the census results. From the high growth potential in the outskirts of the core city, the forecast for the entire CMA in M/P is assessed as reasonable. For the core city, on the other hand, the forecast in M/P is lower than in CMDA-MP. Compared with the census results, CMDA-MP's forecast is obviously overestimation and the M/P matches with the past trend.

JICA Study Team assesses that the population forecast in the M/P successfully incorporated the latest trend from the past census results and reflects the growth potential of CMA.



*: Population forecast in CMDA-M/P (prepared in 2008) for the Chennai Corporation is not available because the master plan was made before the expansion of the corporation to the current area.

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

Figure 4.2.2 Comparison of the Populations in the Past Census Results and the Forecasts in CMDA-MP and the M/P

4.3 Water Demand Forecast

4.3.1 Methodologies of the Forecast

Common basic formula for water demand forecast is as follows:

$$Q = (P \times c \times q / 1{,}000 + Vi + Vc) \times A / (1\text{-}e)$$

Where,
- Q : Water demand (m^3/day)
- P : Forecast population (person)
- c : Service coverage (%)
- q : Unit water consumption per person per day (l/person/day)
- Vi : Industrial water demand (m^3/day)
- Vc : Commercial water demand (m^3/day)
- A : Peak factor
- e : Water loss ratio (%)

M/P adopted the basic formula above. Assumptions for the factors in the formula are summarized in Table 4.3.1. Details of the assumptions are given in the following subsections:

Table 4.3.1 Assumptions in the Water Demand Forecast in the M/P

Factors	Assumptions
Population (P)	Results of the population forecast were adopted.
Service coverage (c)	100%
Unit water consumption (q)	Different unit water consumptions were adopted by corporation/municipality/town/village based on CPHEEO manual.
Industrial water demand (Vi)	10% of the domestic water consumption (P x c x q / 1,000) was assumed.
Commercial water demand (Vc)	5% of the domestic water consumption (P x c x q / 1,000) was assumed.
Peak factor (A)	Peak factor was considered at 1.0.
Water loss ratio (e)	5 % in treatment plants and 10% in distribution network

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

4.3.2 Assumptions for the Factors in the Water Demand Forecast

(1) Service coverage

In the Chennai Corporation, a good number of people are receiving water supply from stand posts or lorries without registration or payment. Therefore, exact service ratio of CMWSSB in the corporation is unknown. However, CMWSSB presumes that almost 100% people in the Chennai Corporation are receiving the water supply service of CMWSSB because the groundwater in the corporation is not safe drinking water source concerning water quality. Thus the M/P presumed 100% service coverage because most people would have access to the water from CMWSSB by private connection, stand post, or water lorries.

As for the Rest of CMA, the current water supply services are not covered by CMWSSB but by Tamil Nadu Water Supply and Drainage Board (TWAD Board) or urban local bodies. A good number of people there will be using only their own wells, which means the service coverage of public water will not be 100%. In this regard, M/P's assumption of 100% coverage was not correct. For CMWSSB, besides, water demand in the Rest of CMA is generated only in the areas where it gives water supply. Currently, the service coverage of CMWSSB in the Rest of CMA is only seven municipalities. An assumption of 100% coverage would be an overestimation.

Furthermore, it should be noted that the unit water consumption depends on the water service types. Therefore, service coverage by service connection and other measures such as lorries and stand posts needs to be identified. Otherwise, water demand forecast will assume uniform unit consumptions in wealthy households and those in informal settlers.

(2) Unit water consumption

Central Public Health and Environmental Engineering Organization (CPHEEO) Manual recommends that the water utilities provide people with the water to satisfy the unit water consumptions as presented in Table 4.3.2. CPHEEO Manual describes that the recommended unit consumption includes domestic, commercial, institutional and minor industries and that large consumers need to be counted separately.

Table 4.3.2 Recommended Unit Water Consumption in CPHEEO Manual

Classification	Recommended Daily Maximum Consumption (litter per capita per day: lpcd)
Towns provided with piped water supply but without sewerage system	70
Cities provided with piped water supply where sewerage system is existing/contemplated	135
Metropolitan and mega cities provided with piped water supply where sewerage system is existing/contemplated	150

Note: In urban areas, where water is provided through stand posts, 40 lpcd should be considered.
Source: CPHEEO Manual

Based on the recommendation above, the M/P adopted the unit water consumptions as shown in Table 4.3.3, as the most area of CMA is planned to be covered by the sewerage system. Unit consumptions in towns and villages in the Rest of CMA vary by town/village. The Chennai Corporation is expected to have 150 lpcd as early as 2020, while the unit consumptions in other areas were presumed to increase gradually to the final year of 2050.

Table 4.3.3 Planned Unit Water Consumption in the M/P

Area		Year and unit water consumption (lpcd)			Remarks
		Year 2020	Year 2035	Year 2050	
Chennai Corporation		150	150	150	Complying with the CPHEEO manual
Rest of CMA	Municipalities	135	135	150	Defined as future mega city
	Towns	90/110/135	110/135	135	Expected to be upgraded to cities (municipalities)
	Villages	55/70/92	55/70/110	110/135	

Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

The JICA Study Team has no objection to the ultimate target for 2050 as it is the fundamental policy which CMWSSB holds the right to determine. However, the study team evaluates that the targeted unit consumptions for 2020 will be too ambitious to achieve. More moderate improvement for the coming five to ten years will be realistic. In addition, the JICA Study Team suggests that a certain percentage of people will continue to use lorries or stand posts. For such people, 40 lpcd are the reasonable unit water consumption.

(3) Bulk industrial and commercial and institutional water demand

According to the CPHEEO manual, water demands of large-scale industrial, commercial and institutional entities need to be added to the water demand calculated by the recommended unit water consumption, although the definition of large scale is not clear. The M/P assumed that the bulk industrial water demand would be 10% of the domestic water consumption and the bulk commercial and institutional consumptions would be 5%.

The JICA Study Team received from CMWSSB a list of consumers by category, which contained bulk consumers. According to the list, the total consumption by the bulk consumers was 48 MLD in 2015. The total production in 2015 was 591 MLD and that in 2016 has been 832 MLD. Considering water loss of 20%, the total consumption in the Corporation in 2015 were 473 MLD, while that in 2016 has been 652 MLD as presented in Table 3.2.1. From the productions in 2015 and 2016 and the bulk consumption, the percentages of the bulk consumers are 10.1% to 7.6%.

From the information above, the JICA Study Team deems that the total of 15% for the bulk consumers would be in a reasonable range. Due to the industrialized characteristics of CMA, demarcation of the bulk consumption, where 10% is for industries and 5% is for commercial and institutional entities would be acceptable. However, the percentage for the industrial consumption will not be constant in the entire CMA. Because of the limited potential for further industrial development, in terms of land availability and land price, the percentage in the Corporation will gradually decrease. On the other hand, the Rest of CMA has a large potential of industrial development and various industries have already established and are establishing their factories in the area. Therefore the industrial demand in the Rest of CMA would increase at a high rate similar to the population growth or higher.

Regarding the bulk commercial and institutional demand, as the commercial water demand has a direct link with population, the percentage of 5% can be assumed to be constant in the entire CMA.

(4) Peak factor

Peak factor is usually used to convert daily average consumption to daily maximum consumption. However the CPHEEO Manual does not discuss daily or seasonal fluctuation of water demand.

In general cases of mega cities worldwide, daily or seasonal fluctuations by 10% are usual, while the CPHEEO Manual conceives that the water consumption in India is constant. The concept of the CPHEEO Manual will be that the consumers will have greater potential water demand than 150 lpcd, which means that the infrastructure capacity limits the water consumption. In addition the common practice of the consumers in India to store the supplied water to the private tanks will be another reason for the constant consumption.

Considering the growing economy and the fact that 150 lpcd includes minor commercials and industries, the JICA Study Team deems that the potential water demand in Chennai will be greater than 150 lpcd. Therefore, it will be realistic not to take into account peak factor in water demand forecast.

(5) Water loss

To satisfy the water demand for domestic, industrial and commercial purposes, the M/P took into account the water loss in the water treatment facilities by 5% and the transmission/distribution network by 10% to estimate the total water demand.

Water loss in the network is recommended to be taken into account by CPHEEO Manual. The manual states that Non-Revenue Water (NRW)[1] should be limited to 15%. As shown in Table 4.3.4, NRW is defined as the total of unbilled authorized consumption, apparent losses and real losses. The water loss to be considered in the total water demand calculation is "Real Loss", which are the leakage and overflow in the transmission/distribution network. In this regard, the assumption of water loss by 10%, which will be the targeted 15% NRW ratio after deducting some unbilled authorized consumption and apparent losses, is understandable.

However, the real situation of water loss in the transmission/distribution network will not be 10%. As presented in Table 3.2.1, water loss ratio in the Corporation has been estimated at 21.1% by the JICA Study Team. In addition, the completion report of the water loss reduction program by the World Bank reported that the program reduce the water leakage ratio to 11% but it was more than 15 years ago and the target area was only the Core City. Therefore, the water loss ratio needs amended for more reliable water demand forecast.

Table 4.3.4 Definition of Non-Revenue Water (NRW)

<table>
<tr><td rowspan="9">System Input Volume (Water Produced)</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Billed Volume</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakages and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakages on Service Connections up to point of Customer metering</td></tr>
</table>

Source: International Water Association (IWA)

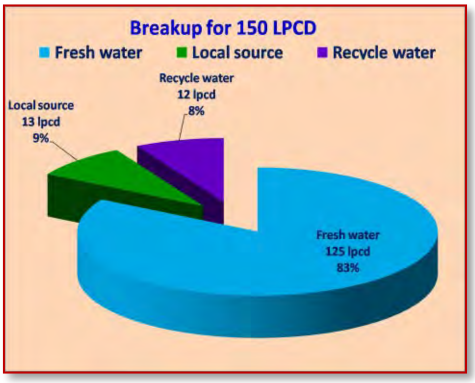
As for the treatment loss, 5% of water loss in treatment plants may occur indeed. However, it is not usually included in water demand forecast because the forecast is the requirement to production

[1]CPHEEO uses "Unaccounted for Water (UFW)" instead of NRW in the manual. Both UFW and NRW signify the water loss. However, recently International Water Association recommends to use NRW because it defines the water loss more exactly.

volume instead of raw water volume. JICA Study Team suggests that the treatment loss be removed from the water demand forecast and it be taken into account in the water (re)source development plan.

4.3.3 Results of the Forecast

Based on the basic formula and the assumptions given in the previous subsection, the M/P computed water demand as shown in Table 4.3.5. The M/P categorized the water demand into "Fresh Water", "Local Domestic Sources", which means private bored wells, and "Recycled Water". Demarcation among the demand categories was calculated based on assumptions on water use for different purposes for each lpcd level, whose example for 150 lpcd case is given Figure 4.3.1.



Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

Figure 4.3.1 Water Demand Demarcation by Water Source Proposed in M/P

Table 4.3.5 Result of Water Demand Forecast in the M/P

Year	Water Demand in MLD			
	Total Demand	Fresh Water	Local Domestic Sources	Recycled Water
2015	1,136	825	240	28
2020	1,721	1,259	251	157
2035	2,522	1,870	314	265
2050	3,746	2,844	397	405

Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

By the categorization of the water demand, the M/P intends to plan the water source augmentation to satisfy the "Fresh Water" demand only. However, JICA Study Team evaluates that the categorization in the M/P will not be valid for the following reasons:

- The recommended unit water consumption by CPHEEO is the requirement to the public water utilities. In principle, CMWSSB should not rely on the private water source.
- The common understanding in CMWSSB on the private bored wells is that people are forced to use the private bored wells because of the insufficient water volume from CMWSSB regardless of not-cheap operation cost and low water quality of the wells. Thus, CMWSSB needs to improve their services to eliminate such unwilling use of the private wells.
- To realize water savings by using recycled water in households, distribution or delivery system must be developed. As the development of such system to households needs huge investment and time, utilization of recycle water should be confined to commercial or industrial use, to which the recycled water will be delivered by water tanker.

JICA Study Team held a discussion with STC, the engaged consultant to prepare the M/P, for several times on the issues above but both the parties did not arrive at an agreement.

4.3.4 Assessment of the Forecast

In the previous subsections of 4.3.2 and 4.3.3, water demand forecast in the M/P was explained, and some suggestions and opinions on the methodologies and assumptions were given by JICA Study Team. Table 4.3.6 summarizes such suggestions and opinions on the forecast in the M/P.

Table 4.3.6 Assessment by the JICA Study Team of the Water Demand Forecast in the M/P

Item	Assessment
Basic formula	• The formula is commonly used one and valid.
Population (P)	• The population forecast in M/P, which successfully incorporated the latest trend from the census 2011, is adopted.
Service coverage (c)	• 100% is assumed in the entire CMA. • 100% will be true in the corporation, but service ratio by service connections and that by lorries or stand posts need to be identified for more accurate water demand forecast. • In the Rest of CMA, the service coverage needs to be in accordance with the service area of the bulk supply by CMWSSB. It is currently much less than 100%.
Unit water consumption (q)	• Ultimate targets comply with CPHEEO manual. • More moderate improvement from the present situations will be more realistic. • Separate lpcd needs to be adopted by the water users by lorries or stand posts.
Bulk industrial water demand (Vi)	• Assumption of 10% against the domestic water demand will be reasonable in the corporation, but the percentage will gradually decrease in the corporation. • Rest of CMA has a high potential of industrial development, where the percentage of the industrial water demand against the domestic demand will be constantly 10% or higher.
Bulk commercial water demand (Vc)	• There is no valid data to examine the assumption but 5% will be in a reasonable range. • Proportional increase in the domestic water demand will be reasonable.
Peak factor (A)	• Peak factor is not counted as the unit consumption is the daily maximum value.
Water loss ratio (e)	• Assumed rate (10%) for the water loss in transmission/distribution network complies with CPHEEO manual. It is valid as a future target but the present situations, which will be higher than 10%, needs to be taken into account. • Treatment loss in treatment facilities is suggested to be removed from the demand forecast.

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

4.4 Water Sources Augmentation Plan

4.4.1 Potentials and Availabilities of the Existing Water Sources

After the water demand forecast, the M/P conducted an assessment of the potentials and availabilities of the existing water sources. Table 4.4.1 presents the assessment results of the existing water sources in the M/P.

"Potential Yield" for the four lakes (200 MLD) is analysis result of the past water levels in the four lakes by M/P but the availability in good years is only 125 MLD from the actual yield in the recent years. "Potential Yield" of Telugu-Ganga or the Krishna River (930 MLD) is the agreed amount with the Andhra Pradesh State as the annual volume to be measured at the boundary of the states, but the actual yield has been much less than the agreement. Water from Veeranam Lake is originally expected to be 180 MLD but the M/P assessed that the availability is only 100 MLD from the past and current performance.

On the availabilities of the existing water sources, which will be the "base flow" in the water source augmentation plan, JICA Study Team raises the following points to be considered:

- The M/P stated that the availabilities of the water sources were determined from the actual yield but actual yields presented in the document are only those in October 2015.
- The existing DSPs are producing 85 to 90 % of their maximum capacities, but it is not taken into account.
- Definition of availability in "good years" is not explained. Also, target climate condition in preparation of the water source augmentation is not discussed. Augmentation plan will be different between the cases where the water demand should be satisfied in good years and drought cases.
- The M/P did not distinguish the raw-water-based volume and treated-water-based volume. Mixing these different characteristics will result in incorrect adoption of treatment loss in the water source augmentation plan

Table 4.4.1 Assessment Results of the Existing Water Sources in the M/P

Water sources		Water Volume in MLD			Volume Base*2
		Potential Yield	Availability in good years	Present availability (October 2015)	
1. Surface water sources					
	a) Four lakes (Poondi, Red Hills, Cholavaram and Chembarambakkam)*1	200	125	75	Raw water
	b) Telugu-Ganga Project (Krishna River)*1	930	400	200	Raw water
	c) Veeranam Lake	180	100	100	Treated water
2. Groundwater					
	d) Northern well field and southern well field	100	25	25	Treated water
	e) Subsurface water in Rest of CMA	32	32	32	Treated water
3. Seawater desalination					
	f) Minjur DSP	100	100	100	Treated water
	g) Nemmeli DSP	100	100	100	Treated water
Total		1,642	882	632	Treated water

*1: Water from Krishna River is combined with the other surface water in the four lakes and processed in the existing water treatment plants.

*2: "Volume Base" is not noted in the M/P but is an additional description by JICA Study Team.

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

4.4.2 Water Source Development Plan

To satisfy the "Fresh Water" demand in CMA, the M/P prepared water sources augmentation plan as shown in Tables 4.4.2 and 4.4.3. Descriptions of the water sources augmentation projects are summarized in Table 4.4.4.

Table 4.4.2 List of the Existing and Future Water Sources in the M/P

Water sources*1		Water Volume in MLD			Volume Base*3	Year of augmentation
		Availability in good years	Augmented Volume	Total availability after augmentation		
1. Surface water sources						
	a) Four lakes (Poondi, Red Hills, Cholavaram and Chembarambakkam)*1	125	75	200	Raw water	2020, 2040, 2045
	b) Telugu-Ganga Project (Krishna River)*2	400	530	930	Raw water	2020, 2025, 2035, 2040, 2045, 2050
	c) Veeranam Lake	100	80	180	Treated water	2025
	1) Mettur Project (new)	-	700	700	Treated water	2030, 2045
2. Groundwater						
	d) Northern well field and southern well field	25	75	100	Treated water	2020, 2025, 2030
	e) Subsurface water in Rest of CMA	32	-	32	Treated water	-
3. Seawater desalination						
	f) Minjur DSP	100	-	100	Treated water	-
	g) Nemmeli DSP	100	150	250	Treated water	2020
	2) Perur DSP (new)	-	400	400	Treated water	2020, 2045, 2050
4.	External sources					
	3) Madurantagam Lake (new)	-	25	25	Raw water	2040
	4) Chengalpathu Lake (new)	-	35	35	Raw water	2035
	5) Abandoned Quarries (new)	-	10	10	Raw water	2020
	6) New surface storage projects (new)	-	20	20	Raw water	2025
	7) Palar Source (new)	-	30	30	Raw water	2030
	8) Neyveli Aquifer (new)	-	25	25	Raw water	2045
	9) By harvesting rain water in off stream lakes (new)	-	30	30	Raw water	2040, 2045
Total		882	2,185	3,067	-	-

*1: Serial codes for the water sources by alphabets, which stand for the existing ones, correspond to those in Table 4.4.1. The codes by numbers stand for the future sources.

*2: Water from Krishna river is combined with the other surface water in the four lakes and treated in the existing water treatment plants.

*3: "Volume Base" is not noted in M/P but is an additional description by JICA Study Team.

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

Table 4.4.3 Future Water Demand and Supply Balance in the M/P

SUPPLY MANAGEMENT TO MEET OUT FUTURE FRESH WATER DEMAND-ENTIRE C M A

Quantity in MLD

Year	Fresh Water Demand	Normal Supply: Surface	Normal Supply: DSP	Normal Supply: Total	Cumulative Qty. of Sources Developed	Total Sources available	Balance	Capacity of Sources to be Developed: DSP: Nemmeli	DSP: Perur	Surface/Ground Sources: Telugu Ganga	Veeranam Sub Surface	By Harvesting Rain Water in Off Stream Lakes	New Mettur Project	OWN Sources Local 4 Lake Sources (Internal)	External Sources (Maduranthagam/Chengal pattu/Abanded Quarries/New surface storage projects/Palar source/Neyveli Aquifer)	Northern well fields	Total
							Total Augmented up to 2050	**150**	**400**	**530**	**80**	**30**	**700**	**75**	**145**	**75**	**2185**
1.	2.	3.	4.	5. (3+4)	6. col.16+ value above	7. (5+6)	8. (7-2)	9.	10.	11.	12.	13.	14.	15.	16.	17.	18. Add. Col.9 to 17
2015	**825**	682	200	882	0	882	57	-	-	-	-	-	-	-			0
2020	**1259**	682	200	882	425	1307	48	**150**	**100**	**100***				**40**	**10**	**25**	425
2025	**1341**	682	200	882	650	1532	191			**100***	**80**				**20**	**25**	225
2030	**1718**	682	200	882	1055	1937	219						**350**		**30**	**25**	405
2035	**1870**	682	200	882	1190	2072	202			**100**					**35**		135
2040	**2041**	682	200	882	1355	2237	196			**100**		**15**		**25**	**25**		165
2045	**2577**	682	200	882	1920	2802	225		**100**	**65**		**15**	**350**	**10**	**25**		565
2050	**2844**	682	200	882	2185	3067	223		**200**	**65**							265
							TOTAL	**150**	**400**	**530**	**80**	**30**	**700**	**75**	**145**	**75**	**2185**
*If supply is not obtainable from DSP, the supply will be augmented from Telugu Ganga vice versa											Total including existing sources						**3067**
Simultaneously action to be taken for implementation of Mettur Scheme											Balance available over ultimate demand of 2844						**223**

Note: The detailed description of the component work to be taken up during the various years is furnished in the main report.

Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

Table 4.4.4 Descriptions of the Planned Water Source Augmentation Projects in the M/P

Water sources	Descriptions of the planned projects
1. Surface water sources	
a) Four lakes (Poondi, Red Hills, Cholavaram, and Chembarambakkam)*	Improvement of the existing lakes by de-silting, debris removal, the heightening of bunds, etc.
b) Telugu-Ganga Project (Krishna river)*	Construction of new reservoirs, rehabilitation of the water channels, etc.
c) Veeranam Lake	Construction of infiltration wells to take water from the Cauvery river to recover the original capacity
1) Mettur Project (new)	Construction of new intake at an existing reservoir, WTP and a transmission main of 300 km to the Corporation
2. Groundwater	
d) Northern well field and southern well field	No project suggested in M/P, but the augmentation is expected
e) Subsurface water in Rest of CMA	-
3. Seawater desalination	
f) Minjur DSP	-
g) Nemmeli DSP	Expansion of the capacity by 150 MLD
2) Perur DSP (new)	Construction of new DSP of 400 MLD
4. External sources	
3) Madurantagam Lake (new)	Conversion of 25 MLD of agricultural water into domestic water, which is expected due to the reducing irrigated land by urbanization, at the lake 50 km southwest from Nemmeli
4) Chengalpathu Lake (new)	Utilization of 35MLD in the lake 30 km west from Nemmeli, although it is severely polluted by wastewater at present (Currently the water right belongs to agriculture sector)
5) Abandoned Quarries (new)	Utilization of harvested rainwater in abandoned quarries distributed in the corporation. (They are not "external".)
6) New surface storage projects (new)	Construction of new reservoirs to store rain water in the corporation. In 1992, a master plan for storm water drainage proposed eight reservoirs. Some of them are planned in the Core City, while some others are planned at more than 250 km from the city.
7) Palar Source (new)	Construction of a new dam to enable efficient recharge to the groundwater from the Palar River, which runs about 30 km southwest from Nemmeli. Even the construction site has not yet been identified.
8) Neyveli Aquifer (new)	Utilization of groundwater at Neyveli, which is located about 200 km southwest from Nemmeli.
9) By harvesting rainwater in off stream lakes (new)	No description on specific project in the M/P

*: Water from Krishna River is combined with the other surface water in the four lakes and treated in the existing water treatment plants.

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

4.4.3 Assessment of the Water Sources Augmentation Plan

JICA Study Team views that the basic approach of the M/P for the development of the water sources augmentation plan, which tried to balance the increasing water demand and water source availability by gradual augmentation of the water sources, was valid. Nevertheless, it raises the following points to be more discussed:

- As also mentioned in Subsection 4.4.2, reasons for the evaluated availabilities of the existing water sources were not clear.
- Target climate condition in preparation of the water source augmentation was not discussed, as also pointed out in Subsection 4.4.2.
- Yield from the raw-water-based sources was overestimated. For example, 930 MLD from the Krishna River is raw water volume, but the M/P expected all 930 MLD will be available as treated water. Even if 930 MLD is available from the Krishna River, the treated water will be half because of evaporation and water leak from the reservoirs and channels. New water storage projects in the "external sources" have the same problem.
- Efficiencies of the planned (and the existing) DSPs were not taken into account. They cannot be operated at their full capacities through a year.
- Proposed projects for "external sources" included those which would not be technically, financially or socially feasible. New storage projects in the Corporation will have no space for them. Long-distance transmission for more than 200 km for only about 20 MLD will not be financially feasible. Also, the Mettur project is reported to have conflict with the local farmers.
- Specific project scope to augment the water availability from the Northern Well Fields and rainwater harvesting were not explained.
- Separate from the water sources augmentation plan, the M/P proposed water recycle projects, whose total production will be 405 MLD, for industrial uses. However, such projects were not taken into account in the water source augmentation plan.
- Project implementation schedule was not consistent with CMWSSB's present intension. DPR of the Perur DSP Project, which is the target of the Study, has planned to construct the entire 400 MLD plant in a single phase. Expansion of the Nemmeli DSP, which will be conducted with financial assistance from KfW, will be commenced within this year.

Taking into account the above discussion points, improved water sources augmentation plan proposed by JICA Study Team will be presented in Chapter 5 to conclude the necessity and scale of the Perur DSP Project.

4.5 Water Transmission and Distribution Plans

4.5.1 Plan of Water Transmission System

(1) Proposed system

The M/P proposed to divide the entire CMA area into seven major water supply systems based on the source of their water supply as shown in Table 4.5.1 and Figure 4.5.1. The water supply systems were planned to have dedicated transmission mains from their water sources. In addition, the M/P proposed a main ring concept, whose tentative alignment is also shown in the Figure 4.5.1. Planned length, diameters, and materials of the transmission lines for the respective water supply systems are given in A4.2.1 in Appendix 4.2.

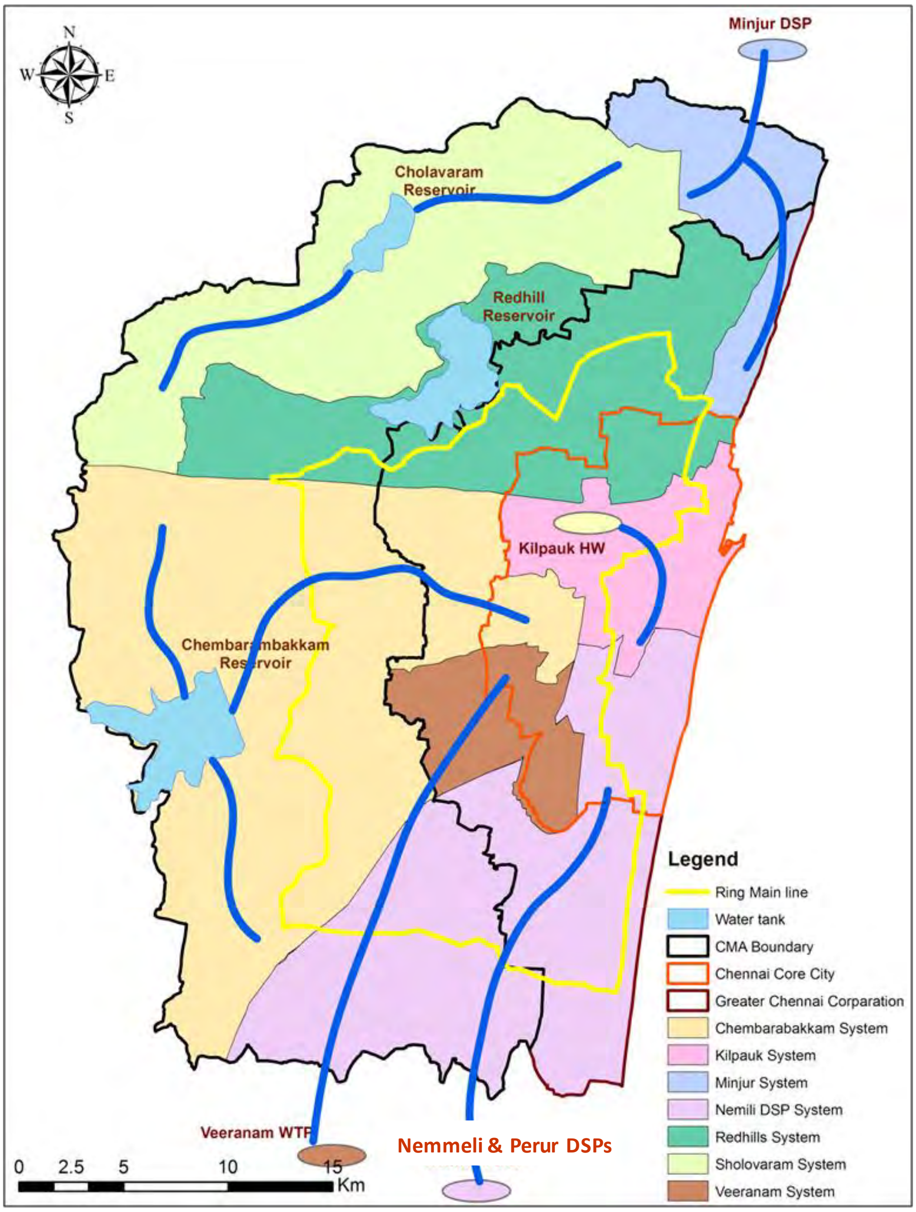
The main ring concept was expected to function as interconnection among different water sources, during emergency operations or failure of any one of the water supply systems. However, the M/P did not consider the feasibility of the ring main, especially regarding the constructability to be limited by the space for laying the new pipeline. Also, the M/P did not analyze the possibility of interconnecting the existing transmission mains assigning them a new functionality other than their current function.

Figure 4.5.2 shows the plan of the transmission main in the Nemmeli water supply system, where the Perur DSP was intended to belong. In the M/P, water from the Perur DSP would be conveyed in the limited influence area of the Nemmeli and Perur DSPs by four transmission mains. This concept was different from the plan in the Detailed Project Report (DPR) of the Perur DSP Project, where the water from the Perur DSP would be transmitted to a much wider area through the Porur Water Distribution Station (See Section 5.2 for the plan in the DPR). Therefore, to finally determine the project scope of the Project, water allocation and transmission plan of the Perur DSP needs to be studied and concluded in the Study.

Table 4.5.1 Summary of the Water Supply Systems proposed in the M/P

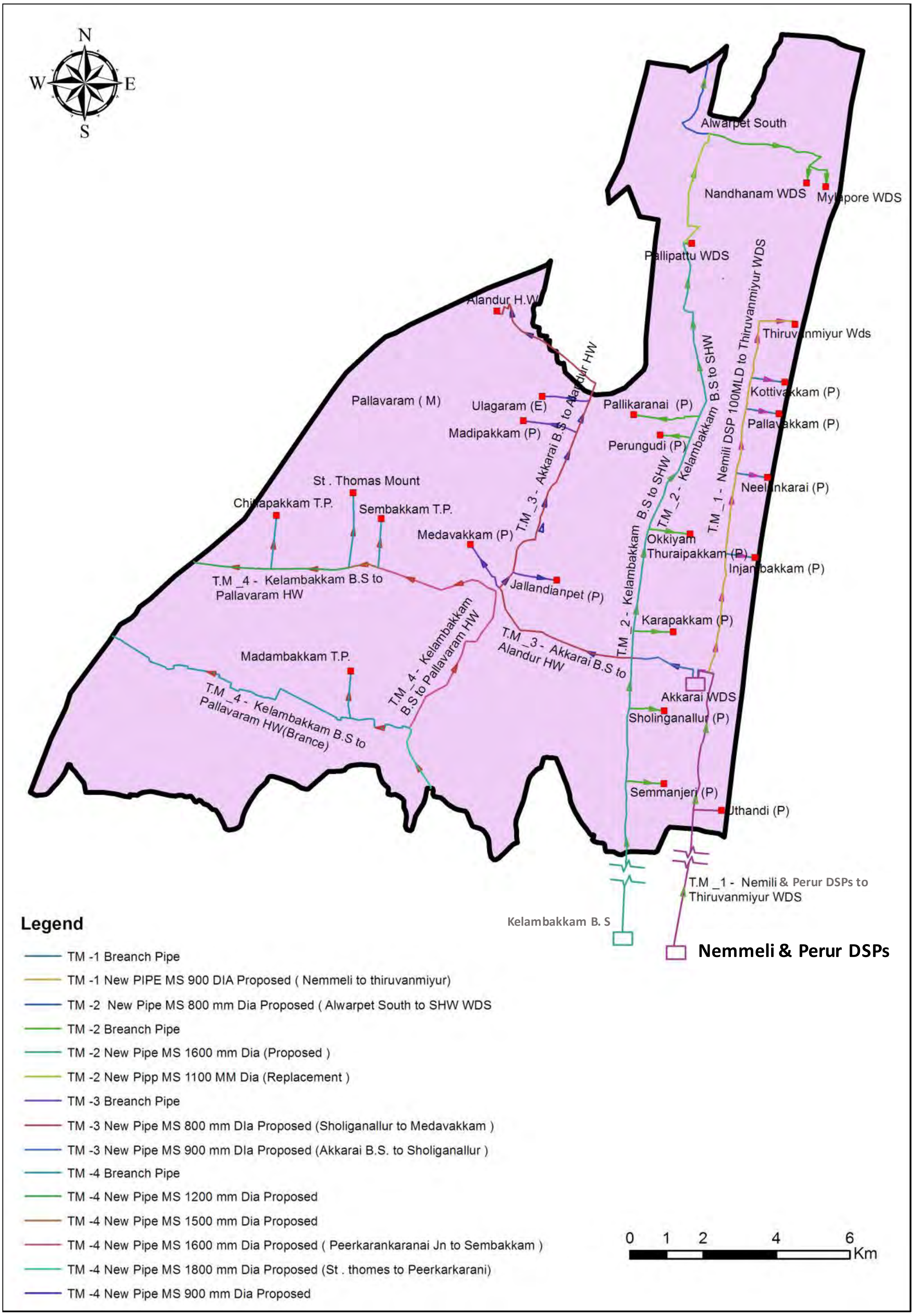
No.	Name of the water supply system	Water source	Water Distribution Zones to be Covered
1.	Redhills Water supply system	Redhills (Puzhal) WTP	Zones-9, 10, 11, CC1 to 13, CC2, CC3, OC4, OC3, OC5A
2.	Kilpauk water supply system	Kilpauk WTP	Zones 1, 2, 3, 4, 15
3.	Cholavaram water supply system	Sholavaram WTP	OC2, OC4, OC5, OC3
4.	Chembarambakkam water supply system	Chembarambakkam WTP	Zone-8, CC5, CC6, OC6, OC7, OC8, OC9, OC10, OC11, OC12, OC13, OC1
5.	Veeranam water supply system	Veeranam WTP (Porur sump)	Zones-5, 6, 6A, 7, CC7
6.	Minjur water supply system	Minjur DSP	CC1-A, OC-1
7.	Nemmeli water supply system	Nemmeli& Perur DSPs	Zones-12, 12A, 13, 14, 16, CC8, CC9, CC10, CC11, OC15, OC16

Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015



Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

Figure 4.5.1 Plan of the Water Supply Systems by Water Source in the M/P



*: Kelambakkam Booster Station (B.S) will be connected with Nemmeli and Perur DSPs by transmission main.

Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

Figure 4.5.2 Plan of Transmission Main for the Nemmeli Water Supply System in the M/P

(2) Evaluations by the JICA Study Team

Division of the CMA by water source is a valid idea. A separate system for each water source will realize the easy operation of the WTPs and DSPs as well as the transmission systems. However, the JICA Study Team raises the following points to be considered for more practical transmission plan to mitigate the critical water shortage conditions in CMA:

- Fixed separate zones by water sources will function well only when the all water sources have sufficient production to satisfy their respective zones. However, CMA is at a stage to augment the water sources step by step to meet the water demand as the entire CMA instead of by zone. Water resources of CMA are not abundant to secure sufficient water production in each zone. Therefore, the influence areas of the respective water sources need to change according to the progress of water sources development and increase in the water demand. More flexible water transmission system is necessary for the efficient satisfaction of the water demand.
- It is supposed that the M/P expected the ring main to realize flexible transmission system, but it did not present required capacity to function sufficiently. Further, the M/P does not consider the feasibility of such ring main especially in terms of constructability. Practically, in addition, it will not be hydraulically realistic that one ring main will accomplish the flexible system to satisfy the entire CMA. Transmission mains, instead of the ring main, will need to be planned to respond to the required flexibility.
- Under the flexible transmission system, water sources of each zone will change according to the fluctuation in the water demand and supply balance. A water source may provide its produced water to only one zone in a certain year but in later years it may provide the water to another zone to fill a negative gap anticipated in the zone. Considerations on the short-term, middle-term and long-term water balances are necessary to design water transmission system in CMA.

4.5.2 Plan of Water Distribution Zones in the CMA

(1) Water distribution zones

The M/P planned water distribution zoning in the water supply systems to ensure the equalization of supply of water throughout CMA. Division of the entire CMA into distribution zones was planned keeping in view the existing natural conditions and physical conditions such as national highways, railway lines, major roads, rivers and canals, etc. to form the boundaries of the zones. The division was also planned so that a distribution zone does not have the difference in the elevation more than 15 to 25 m. The M/P planned that the adjacent zones would be interconnected to provide water supply in case of emergency and the valves between the zones will usually be kept closed during normal operations.

Figure 4.5.3 shows the planned water distribution zones in CMA. Configurations of the water distribution systems in respective water supply systems are given in A4.2.2 in Appendix 4.2.

Water distribution zones in the Core City were proposed to be maintained as the current system. For the Expanded Area, the M/P newly proposed 11 WDZs from CC-1 to CC-11 (Prefix “CC” infers to Chennai Corporation). Beyond the corporation limits, the Rest of CMA was proposed to be divided into 16 WDZs from OC-1 to OC-16 (Prefix “OC” infers to Outside Corporation).

(2) Water Distribution Stations (WDSs)

The M/P proposed WDSs based on the WDZ plan explained above. Configurations of the water distribution systems, wherein the M/P proposed to consider the Elevated Service Reservoirs (ESR) to be constructed in all water distribution zones and the distribution systems need to be catered through the proposed zonal ESRs. The M/P recommended constructing the ESRs for a capacity to meet the ultimate water demand.

In the Core City, the M/P specified that some of the existing WDSs (Kilpauk, Triplicane, Mylapore, Valluvarkottam, and Southern head works) are already over-saturated with the higher population densities requiring greater water supply. Therefore, the M/P proposed to upgrade the pump capacities in such WDSs to cater for the future water demand. In the Expanded Area, new WDSs for the respective WDZs were expected in the M/P.

For the Rest of CMA, the M/P proposed to introduce local booster pumping stations. As the WDZs are very broad in the Rest of CMA, such local booster pumping stations will be necessary to ensure sufficient water volume and pressure to the end users.

(3) Water distribution network

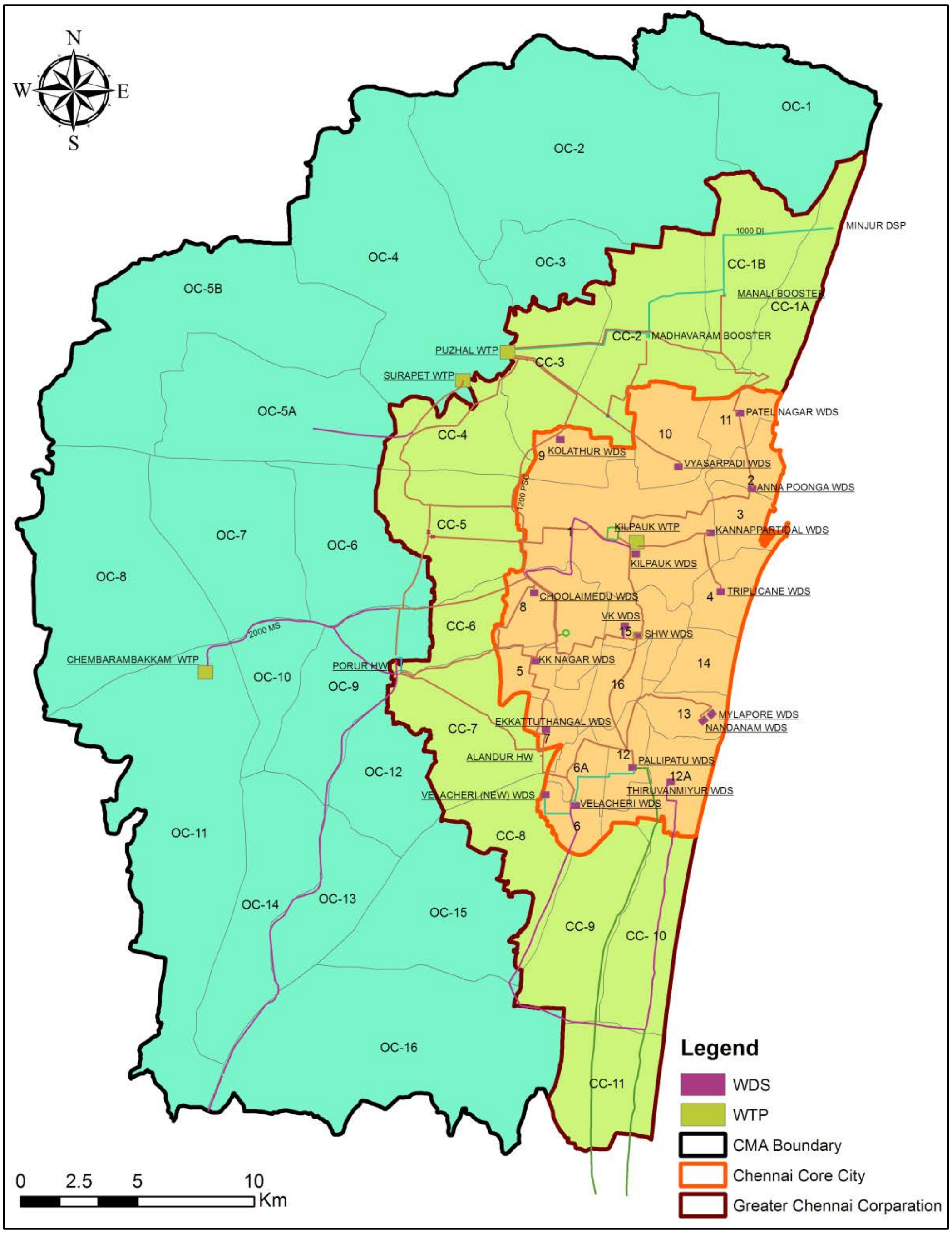
In the main text of the M/P, no specific plan in rehabilitation or expansion of water distribution network was mentioned because such plans would be prepared in planning stage of each project. However, the capital investment plan in the M/P listed the following programs for the water distribution networks in CMA:

- Chennai Core City: Optimization of distribution mains including replacement/rehabilitation of the existing length of mains (Diameter of pipes ranging from 150 mm to 400 mm for 558,266 m by 2020 and 980,994 m in 2020-2030)
- Expanded Area: Optimization of distribution mains including replacement/rehabilitation of the current length of mains (Diameter of pipes ranging from 150 mm to 350 mm for 681,107 m by 2020 and 733,632 m in 2020-2030)
- Expanded Area: Installation of distribution mains (Diameter of pipes ranging from 150 mm to 350 mm for 4,850,000 m in 2020-2030.)

Additionally, the M/P recommended raising the service connection pipes to 1m above the ground level, to facilitate detection of illegal connections or tampering in the connections.

(4) Evaluations by the JICA Study Team

The JICA Study Team evaluates the concept to set up water distribution zones and WDSs will be valid to control the service level in respective zones in terms of water volume and water pressure. It will also be useful for water loss management. However, the limitation in land availability for WDSs and ESRs may prevent the proposed system from being completely realized.



WDS: Water Distribution Stations, WTP: Water Treatment Plants

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

Figure 4.5.3 Plan for Water Supply Distribution Zones in the M/P

4.6 Sewerage System Development and Water Recycling Plans

4.6.1 Sewerage System Development Plan

The M/P targeted to cover 100% of Chennai Corporation area by sewerage system by 2035. To achieve the target, as shown in Table 4.6.1, the M/P proposed to develop additional STPs of the total capacity of 1,715.5 MLD based on the sewage generation projection and the existing STP capacity. The presumed sewage generation volume was 85% of water supplied, out of which 80% is direct sewage contribution and 5% is infiltration.

More specific information on the sewerage development plan in the M/P is given in Appendix 4.3.

Table 4.6.1 Summary of Planned Capacities of STPs

S.No	Area	Total planned capacity of STPs (MLD)			Total Capacity (MLD)
		2020	2035	2050	
1	Near Existing STP Locations	430.0	300.0	387.5	1,117.5
2	New Locations	161.5	170.5	266.0	598.0
-	Total	591.5	470.5	653.5	1,715.5

Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

4.6.2 Water Recycling Plan

The M/P proposed to utilize secondary treated recycled sewage for (i) Industrial usage (ii) Domestic usage for non-potable purpose (iii) Commercial usage for the non-potable purpose. M/P suggested to reduce the fresh water requirement by utilizing the recycled water from treated sewage from existing STPs. M/P considered, a contribution of 12 Litters per capita per day (LPCD) from recycled water to supply 150 LPCD to the corporation area.

From its water demand projection, the M/P proposed to meet the recycled water requirement of 405 MLD by 2050, however, the M/P did not clearly specify the transition plan of meeting the recycled water requirement in 2020 and 2035. Also, the M/P did not indicate the way to develop a dual pipe system in the water distribution, as it would be necessary for the commercial and industrial entities. Also, the M/P did not consider the current development plan for Tertiary Treatment Reverse Osmosis (TTRO) Plants being developed by CMWSSB, 45 MLD TTRO plants at Koyambedu and Kodungaiyur respectively.

4.7 Overall Investment Plan

Based on its all technical proposals, the M/P estimated the capital expenditure (CAPEX) necessary to carry out the water supply and sewerage projects separately. Estimated CAPEX in the M/P is summarized in Table 4.7.1. The breakdowns of the investments are given in Appendices A4.4.

Table 4.7.1 Estimated CAPEX in the M/P

Sector	Capital Expenditure (in million Rs. except "Total in million USD")				
	Total amount (By 2050)	Phase I (By 2020)	Phase II (2020-2030)	Phase III (2030-2040)	Phase IV (2040-2050)
Water Supply	222,784.18	19,243.52	144,379.80	57,508.78	1,652.00
Sanitation and Sewerage	100,524.86	6,576.92	38,562.42	50,491.23	5,189.29
Total	323,309.04	25,820.44	182,942.22	108,000.01	6,841.29
Total in million USD	4,854.49	387.69	2,746.88	1,621.62	102.72

* USD1 = INR 66.6
Source: Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

CHAPTER 5 STUDY ON NECESSITY, SCALE AND SCOPE OF THE PROJECT

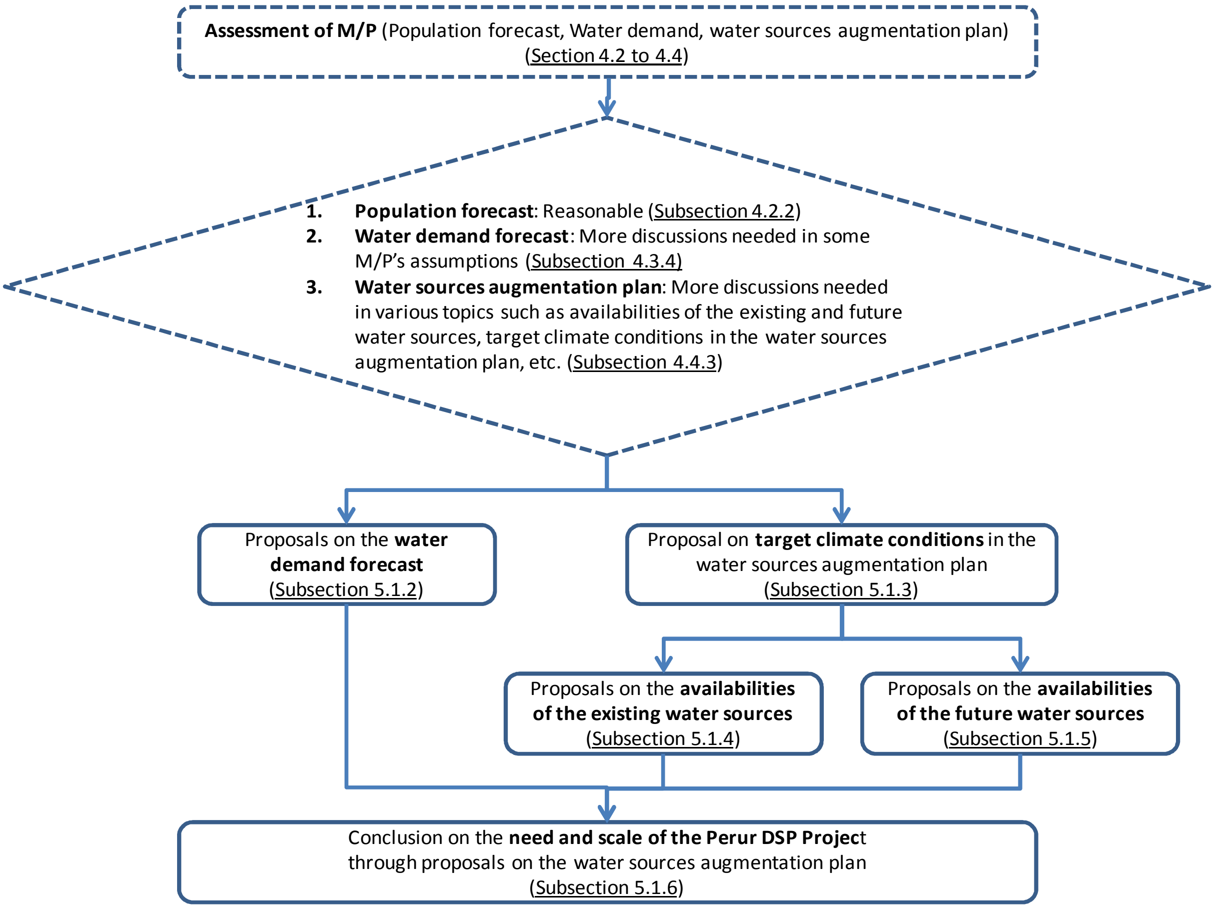
5.1 Necessity and Scale of the Project

5.1.1 Methodologies to Conclude the Necessity and Scale of the Project

(1) Introduction

In Sections 4.2 to 4.4, the JICA Study Team analyzed the population forecast and water demand forecast as well as water sources augmentation plan prepared by Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015 (the M/P). Through the analysis, the study team raised several points to be considered to achieve a more practical water sources augmentation plan.

Following the studies above, to conclude the necessity and scale of Perur Seawater Desalination Plant (DSP) Project, Section 5.1 proposes a modified water source augmentation plan by JICA Study Team. Workflow for the conclusion is presented in Figure 5.1.1. The target year of the study is the year 2050 and the study covers the entire CMA, in compliance with the M/P. Inclusion of the entire CMA is on a presumption that the Rest of CMA will be integrated in the Corporation in the near future.



Source: JICA Study Team

Figure 5.1.1 Work Flow in Examination of the Necessity and Scale of the Project

It is noted that the objective of the modification of the water sources augmentation plan is for the planning of the Perur DSP, which is expected to mitigate the urgent water crisis as the most reliable water source among the planned ones. The entire water sources augmentation plan modified is a suggestion to the M/P, based on which CMWSSB will consider how to finalize the long-term water sources augmentation plan.

5.1.2 Proposals on the Water Demand Forecast

(1) Proposed modifications on the water demand forecast

From the assessment on the water demand forecast, the JICA Study Team proposes the following amendments to the water demand forecast in the M/P:

Table 5.1.1 Amendment by JICA Study Team on the Water Demand Forecast in the M/P

Item	Amendment
Basic formula	• No amendment (The formula in the M/Pwas valid)
Population (P)	• No amendment (The population forecast in the M/P was valid)
Service coverage (c)	• Gradual increase from the current coverage has been taken into account. (The M/P assumed 100% coverage from 2015) • Separate service coverage by service connection and lorries/stand posts has been introduced. (The M/P assumed 100% connection rate from 2015.)
Unit water consumption (q)	• More moderate improvement from the present situations than M/P has been proposed. • Unit water consumption for the consumers by lorries and stand posts has been introduced separately from those by service connections. (The M/P applied the same unit consumption to all kind domestic consumers)
Bulk industrial water demand (Vi)	• In the Corporation, the bulk industrial demand has been set as 10% of the domestic demand in 2015, and it will be constant until 2050. (The M/P assumed that the bulk industrial demand in the Corporation would increase along with the domestic demand) In the Rest of CMA, due to the high potential of industrialization, the percentage of the industrial water demand against the domestic demand has been set as 20%.
Bulk commercial water demand (Vc)	• No amendment (The assumption in the M/P was reasonable)
Peak factor (A)	• No amendment (Peak factor was not counted in the M/P)
Water loss ratio (e)	• Estimated current water loss ratios by area have been applied and gradual improvement has been taken into account. (The M/P assumed 10% but it will be far from the actual situation) • Treatment loss in treatment facilities has been removed from the water demand forecast. (The M/P added 5% to the water demand to compensate the treatment loss)

Source: JICA Study Team based on Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

1) Basic formula for the water demand forecast

JICA Study Team also adopts the basic formula used in M/P.

2) Population

Population forecast in M/P is used in the proposal of JICA Study Team.

3) Service coverage

JICA Study Team proposes the service coverage as shown in Table 5.1.2. In the corporation, service coverage and the service connection rates in the Core City and the Expanded Area have been identified based on information from CMWSSB given Appendix 3.1.

In the Rest of CMA, all seven municipalities are already receiving bulk supply from CMWSSB; hence the municipalities have already been included in service coverage of the CMWSSB. There is no information on the coverage and service connection rates but they have been presumed at 60 % of the Expanded Area. For the towns and villages, coverage by CMWSS will take place after integration of the Rest of CMA into the Chennai Corporation. In the Study, the integration has been presumed to take place in 2025.

Table 5.1.2 Proposed Service Coverage by JICA Study Team

Area		Year and service coverage (%)								Remarks
		Present	2020	2025	2030	2035	2040	2045	2050	
Chennai Corporation										
	Core City	100% (65%)	100% (80%)	100% (95%)	100% (95%)	100% (95%)	100% (95%)	100% (95%)	100% (95%)	Gradual increase of service connection rate up to 95% in 10 years.
	Expanded Area	100% (45%)	100% (60%)	100% (75%)	100% (80%)	100% (90%)	100% (90%)	100% (90%)	100% (90%)	Completion of distribution network will be before 2020 but 10 years may need to improve the connection rate to 90%.
Rest of CMA										
	Municipalities	60% (25%)	80% (45%)	100% (60%)	100% (75%)	100% (90%)	100% (90%)	100% (90%)	100% (90%)	Integration of the Rest of CMA into the Chennai Corporation is presumed by 2025. The connection rate will improve to 90% in 20 years.
	Towns	0% (0%)	0% (0%)	100% (25%)	100% (50%)	100% (70%)	100% (80%)	100% (90%)	100% (90%)	
	Villages	0% (0%)	0% (0%)	100% (25%)	100% (50%)	100% (70%)	100% (80%)	100% (90%)	100% (90%)	

( ): Connection rate by service connection. The remaining consumers receive water supply by lorries and stand posts.
Source: JICA Study Team

4) Unit water consumption

Regarding unit water consumption, the JICA Study Team has considered more moderate improvement than the expected improvement in the M/P. Considering the current wide shortage of water resources, steady improvement needs to be planned with the realistic improvement. The proposed lpcd for CMA has been proposed as shown in Table 5.1.3. Considerations made in the proposals on the lpcd target are listed below the table;

Table 5.1.3 Proposed LPCD by the JICA Study Team

Area	Year and unit water consumption in lpcd								Remarks
	Present	2020	2025	2030	2035	2040	2045	2050	
Chennai Corporation									
Core city	120	135	150	150	150	150	150	150	150 lpcd by 2025
		(150)							
Municipalities	80	100	135	150	150	150	150	150	150 lpcd by 2035
		(150)							
Towns	40	70	100	135	150	150	150	150	150 lpcd by 2035
		(150)							
Villages	40	70	100	135	150	150	150	150	
		(150)							
Rest of CMA									
Municipalities	60	70	90	100	110	135	135	150	150 lpcd by 2050
		(135)						(150)	
Towns	40	40	40	70	90	100	110	135	More moderate improvement than the municipalities
		(90/110/135)			(110/135)			(135)	
Villages	40	40	40	70	90	100	110	135	
		(55/70/92)			(55/70/110)			(110/135)	
Water users by lorries or stand posts in the entire CMA									
All CMA	40	40							Based on CPHEEO

*: Figures in ( ) are the lpcds expected in Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015.

Source: JICA Study Team

- The present lpcd in the Corporation has been set based on the current lpcd estimated by CMWSSB, which was given in Table 3.2.1 (101 lpcd in the Core City and 62 lpcd in the Expanded Area). As the current lpcd is combined figure of the consumers who have service connections and who do not have service connections (40 lpcd), lpcd figures of the connected consumers by area have been estimated so that the combined lpcd with not-connected consumers will match the current lpcds as a result of the water demand forecast.
- In the Rest of CMA, the JICA Study Team has utilized information from TWAD Board, which was provided during a study by JICA, named as Chennai Bengaluru Industrial Corridor Infrastructure Master Plan (CBIC M/P) in 2014. It is noted that the current lpcd in the municipalities would have been increased by the bulk supply from CMWSSB after the data from TWAD Board.
- The entire corporation needs to achieve 150 lpcd. Achievement of 150 lpcd in the core city will be the immediate target by 2025. 150 lpcd in the municipalities/towns/villages in the corporation will be later than the corporation but will be realized by 2035, the middle term of the M/P.
- Ultimate target for the municipalities in the Rest of CMA will be 150 lpcd assuming the Rest of CMA will be integrated into the corporation. In the water demand forecast the integration is presumed to take place in 2025. LPCDs for the towns and villages will be 135 lpcd by 2050,

after which 150 lpcd will be realized.

- Improvement in the municipalities in the Rest of CMA can take place before integration into the corporation through bulk supply. On the other hand, improvement in towns and villages will take place after the integration.

Table 5.1.4 Estimated Present Unit Water Consumption in the Rest of CMA

Area		Estimated Production in 2016 (MLD)[*1]	Estimated consumption[*2] (MLD)	Population in Census 2011 (1,000 persons)	Estimated unit consumption (lpcd)	Adopted current unit consumption (lpcd)
Rest of CMA	Municipalities	46	32.2	980	33	60[*3]
	Towns	30	21	395	53	40
	Villages	14	14	889	16	
	Total	90	67.2	2,264	30	-

*1: Data provided by TWAD Board to the study team of Chennai Bengaluru Industrial Corridor Infrastructure Master Plan (CBIC M/P) by JICA in 2014. These figures are presumed to be pumping capacity instead of actual production.
*2: Estimated consumption for the municipalities and villages are 70% of the production, presuming 30% of water loss. For the villages, no water loss is presumed because the water supply would not be piped supply in most areas.
*3: In the municipalities, greater lpcd than the estimated consumption is adopted because the recent bulk supply from CMWSSB would have increased the lpcd.
Source: JICA Study Team based on the information whose sources are described above.

5) Bulk industrial water demand

The present bulk industrial water consumption will be equivalent to about 10% of the domestic water consumption. The M/P presumed that "10%" will be constant in the entire CMA up to 2050. JICA Study Team views that the industrial water demand in the Chennai Corporation will be constant in volume at the amount in 2015, because of the already saturated land use. Regarding the Rest of CMA, on the other hand, 20% has been adopted because the area is recently accepting various large-scale industries in recent years. As presented in Appendix 3.12, CMWSS is going to supply potable water and recycled water by TTRO to the industries outside the CMA boundary. The high percentage of the industrial water demand set in the Study takes into account such an expansion plan of CMWSSB's service to the growing industries in and outside the CMA.

In addition to the bulk industrial water demand to be computed by the specific percentages against the domestic water demand, the Study has presumed a specific water demand in an industrial township, called "OneHub Chennai". OneHub Chennai, which is located outside the CMA and at about 10 km southwest from the Nemmeli DSP, concluded a contract on water supply services of 36 MLD. The 586 ha industrial township is a combined development area of industrial spaces, business park, residential spaces, amenity and welfare facilities and has started the commercial operation since 2012. As the contracted water supply is not only for the industrial but also for domestic and commercial purposes, the water demand in OneHub Chennai needs to be satisfied by freshwater instead of TTRO. As the water supply to the industrial township will be conducted by a dedicated transmission line from the Nemmeli DSPs and/or Perur DSP, no water loss has been taken into account in the Study on the specific water demand of 36 MLD.

6) Bulk commercial water demand

As planned in the M/P, JICA Study Team also presumes that the commercial water consumption will be equivalent to 5% of the domestic water demand.

7) Peak factor

Peak factor is not considered because the water consumption in Chennai will be constant, which complies with suggestion by CPHEEO Manual.

8) Water loss

The M/P presumed 15% of water loss, of which 5% is that in water treatment process and the remaining 10% is that in the water transmission/distribution system.

The JICA Study Team proposes that water loss in the treatment process be not considered in the water demand forecast because the forecast is the requirement to the production volume.

As for the water loss in the transmission/distribution system, the assumption in the M/P was merely the target value required by CPHEEO Manual, but the water demand should consider the present conditions and future improvement plan. Although the extremely low rate of the metering prevents any estimation of the current water loss level, the present water loss rate in the Corporation has been estimated at 21.1%, as presented in Table 3.2.1, the assumed 10% in the M/P is suspected to be inconsistent with the actual conditions.

According to CMWSSB, old pipes in the core city have been mostly or entirely replaced in the 1990s under the Unaccounted for Water (UFW) Water Program in Chennai Core City, funded by the World Bank. In fact, the share of older pipes more than 30 years is about 10% in the Core City. (See Subsections 3.3.6 and 3.3.7 for the World Bank program and the present water loss conditions) In the Study, the present water loss rate in the Core City is presumed at 20%, which is based on the Implementation Completion Report of the UFW Program in the Chennai Core City (Report No. 29333) in 2001. The report described that the project, which covered 11 out of 16 WDZs at that time, improved the water leakage ratio to 11% in most areas by the project. The assumption of 20% takes into account the project's incomplete coverage in the Core City and some increase in the water loss after the project.

In the Expanded Area and the Rest of CMA, there are old water distribution networks, whose water loss is presumed at 30%. The old networks in the Expanded Area will be eliminated in five years as CMWSSB is carrying out replacement of all old distribution networks.

In the Rest of CMA, improvement of the water loss will be slower than the Expanded Area. The ongoing water distribution network construction in municipalities, by state or central government funds, will gradually reduce the water loss. Further, if the area is merged to the Corporation, CMWSSB will construct new water distribution networks, which will also lower the water loss ratio.

Table 5.1.5 shows proposals on the water loss ratios by the JICA Study Team for water demand forecast. The ultimate water loss ratio is 10% in the entire CMA. 10% is the expected physical loss ratio when the NRW ratio achieves 15% in compliance with CPHEEO Manual.

Table 5.1.5 Proposed Water Loss Ratio by the JICA Study Team

Area		Year and water loss (%)								Remarks
		Present	2020	2025	2030	2035	2040	2045	2050	
Chennai Corporation										
	Core city	20%	15%	10%	10%	10%	10%	10%	10%	Prioritized rehabilitation in 10 years
	Municipalities	30%	10%	10%	10%	10%	10%	10%	10%	Gradual improvement in the course of development of new water distribution network by CMWSSB
	Towns	30%	10%	10%	10%	10%	10%	10%	10%	
	Villages	30%	10%	10%	10%	10%	10%	10%	10%	New development
Rest of CMA										
	Municipalities, Towns, Villages	30%	30%	25%	20%	15%	10%	10%	10%	After integration of the Rest of CMA into the corporation, new distribution network to be constructed by CMWSSB will lower the water loss.

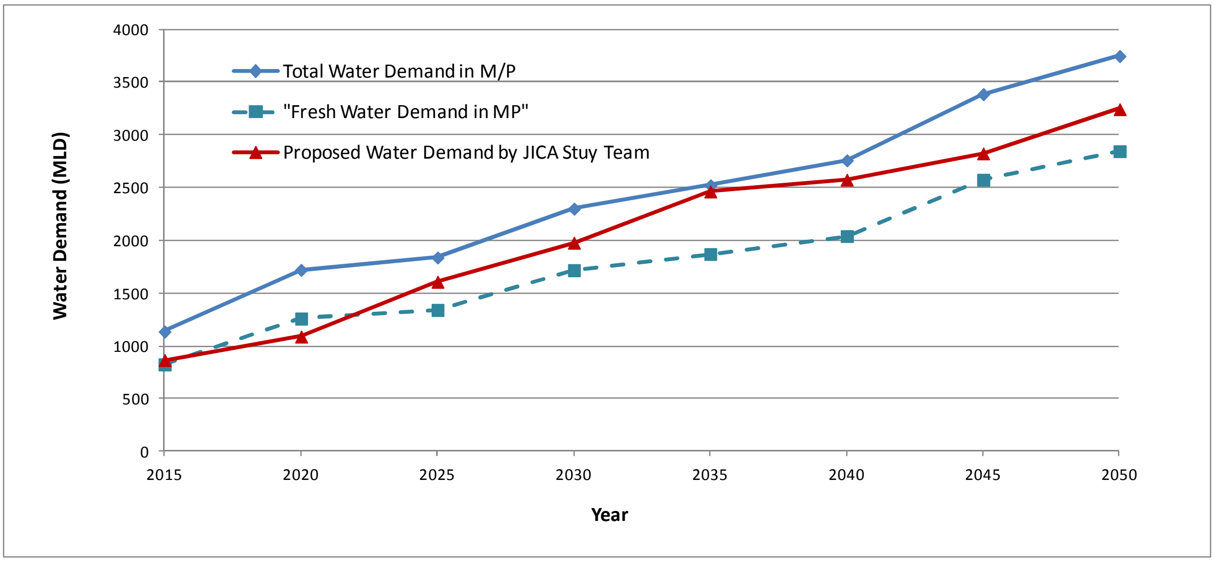
Note: The assumption in the M/P was 10% in all areas from the present situation until the year 2050.
Source: JICA Study Team

(2) Water demand forecast by JICA Study Team

Based on the proposed modifications on the assumptions, water demand forecast by JICA Study Team is presented in Figure 5.1.2 with a comparison with the forecast in the M/P. Also, Figure 5.1.3 shows the area wise water demand forecast. The detailed results are presented in Appendix 5.1.

Water demand forecast by JICA Study Team does not break the water demand into "Fresh Water Demand", "Water Demand for Private Sources" and "Water Demand for Recycled Water" as all water demand needs to be satisfied by public water utility (utilities) and utilization of recycled water will be considered in the water sources augmentation plan.

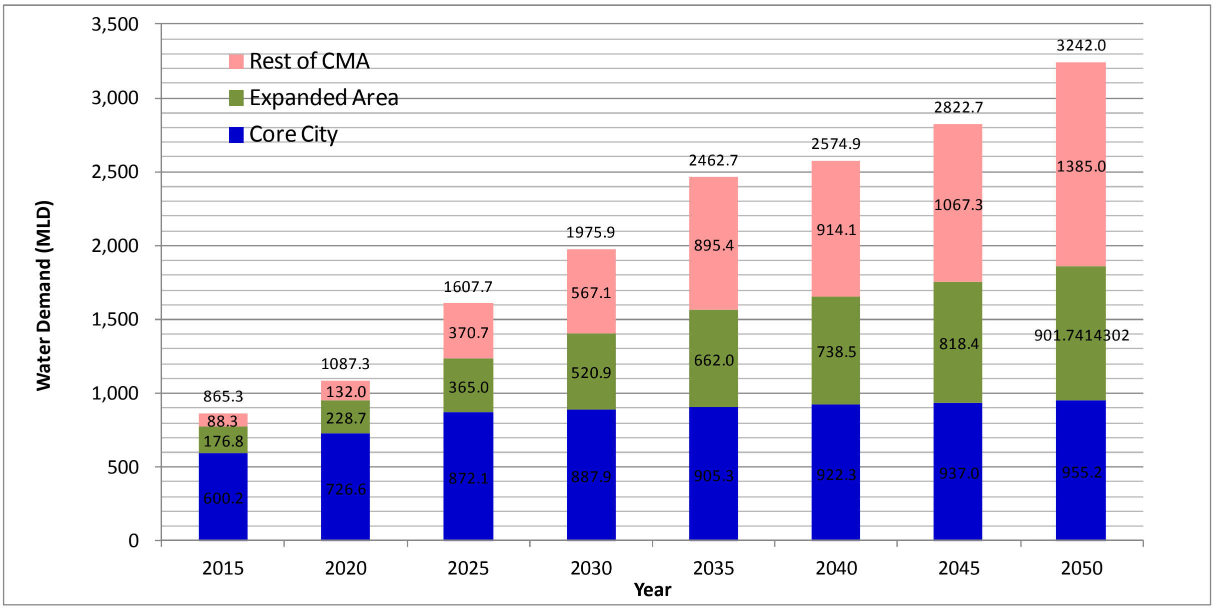
Due to the introduction of more realistic service coverage, unit water consumption, service rate of lorries/stand posts and the constant bulk industrial water demand in the corporation, proposed water demand is lower than the total water demand in the M/P.



		2015	2020	2025	2030	2035	2040	2045	2050
M/P	Total Water Demand	1,136	1,721	1,837	2,300	2,522	2,759	3,385	3,746
	"Fresh Water Demand"	825	1,259	1,341	1,717	1,870	2,041	2,575	2,844
The Study	Proposed Total Water Demand	865	1,087	1,608	1,976	2,463	2,575	2,823	3,242

Source: JICA Study Team and Master Plan for Water Supply and Sewerage Sectors in Chennai Corporation and Rest of CMA, 2015

Figure 5.1.2 Water Demand Forecast Proposed by the JICA Study Team and Comparison with the M/P



Source: JICA Study Team

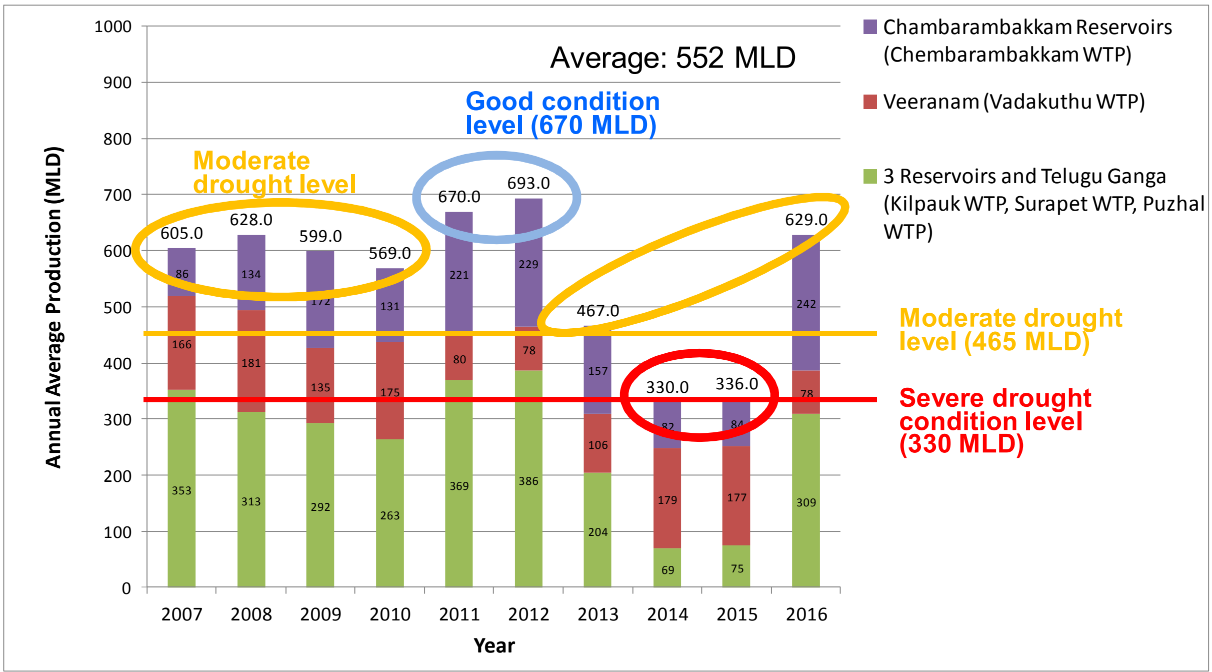
Figure 5.1.3 Area-Wise Water Demand Forecast Proposed by the JICA Study Team

5.1.3 Proposals on the Target Climate Conditions in the Water Sources Augmentation Plan

Figure 5.1.4 presents water production for the Chennai Corporation in recent 10 years from the surface water. Production from the surface water has been affected by climate conditions. In preparation of water sources augmentation plan, the vulnerability of the existing and future water sources to the climate conditions should be taken into account. Necessary volume of additional water sources to satisfy the future water demand will be dependent on the climate conditions or surface water availability presumed.

In the Study, JICA Study Team proposes to define three different climate conditions in terms water availability as shown below;

- Severe drought condition: Water availability is better than the level whose frequency about twice in 10 years
- Moderate drought condition: Water availability is better than the severe drought situation but not as good as the good conditions
- Good conditions: Water availability is as good as the level whose frequency is about twice in 10 years



Source: JICA Study Team based on production data of CMWSSB

Figure 5.1.4 Historical Water Production of CMWSSB in Recent 10 Years and Proposed Grouping of the Years based on Definition of the Climate Conditions

In preparation of the water sources augmentation plan, JICA Study Team proposes that the plan will be prepared so that the target unit water consumption would be achieved in the moderate drought condition. To avoid over-investment, maintenance of the target lpcd will not be pursued in the severe drought condition, but some reduction in the service level will be accepted.

5.1.4 Proposals on the Availabilities of the Water Sources

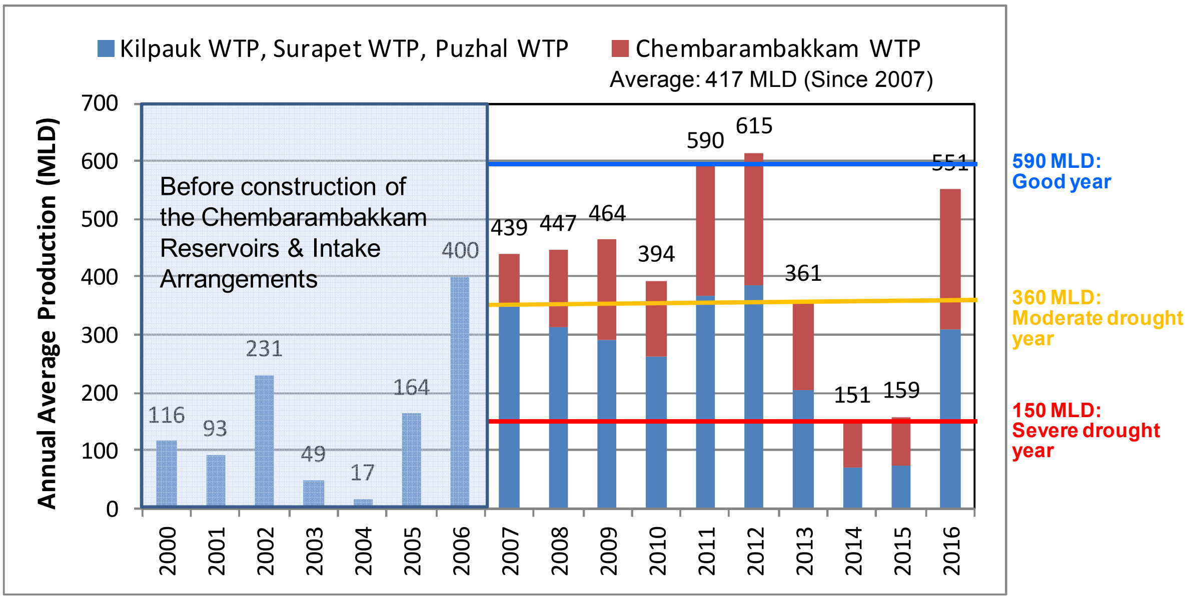
(1) The four reservoirs and the Telugu Ganga Project (Krishna River)

The existing WTPs in Chennai Corporation shares raw water resources. The Kilpauk, Redhills, and Surapet WTPs share the rain water stored in three traditional water resources and the surface water from the Krishna River. The Chembarambakkam WTP also treats the water from the Krishna River in addition to the rainwater flowing from its basins area. As the raw water from the different water resources is combined in the reservoirs before being treated, water availability from these water sources is analyzed jointly. Indeed the raw water from the Krishna river is measured at the border between the two states of Tamil Nadu and Andhra Pradesh. However, independent analysis on the actual production of the water from the Krishna river is impossible because of the uncountable evaporation in the reservoirs and leakage from the water channels for raw water transmission.

Figure 5.1.5 presents past productions from the WTPs using water from the four reservoirs and the Krishna River. From the production since 2007, when the Chembarambakkam Reservoir's intake arrangements and WTP were completed, JICA Study Team proposes 360 MLD as the available water volume in the moderate drought year.

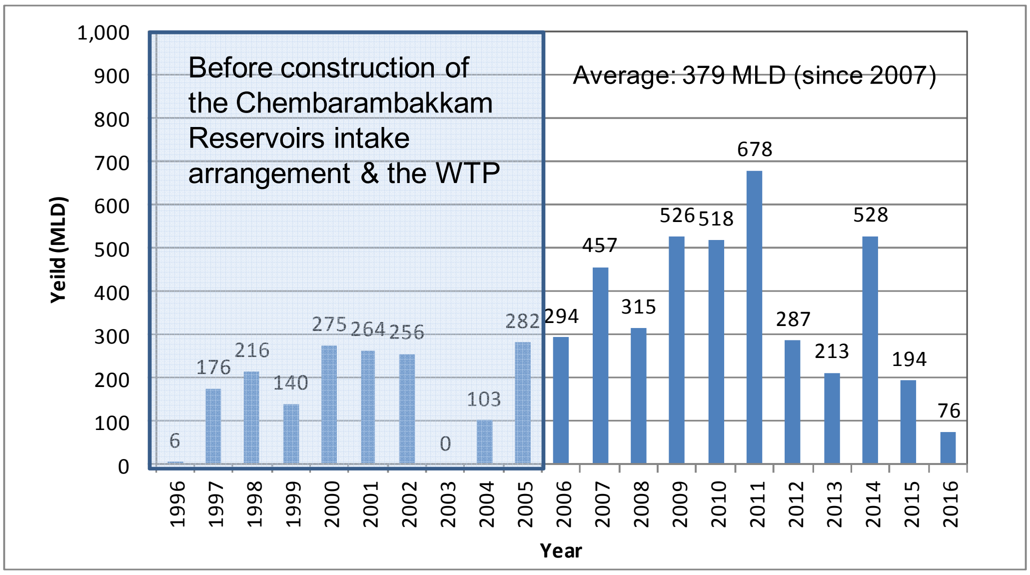
According to M/P, water loss by evaporation in the four reservoirs is 40%. M/P also mentions that a past study reports that annual evaporation from the three traditional sources was 75 million m^3 or 208 MLD. From the surface areas of the reservoirs, the said evaporation is equivalent to 7.5 mm per day. Presuming the same evaporation rate to the Chembarambakkam Reservoir, total water loss from the four lakes will amount to 300 MLD. Compared with the production value in Figure 5.1.5, the water loss is about 40% of the total raw water in a good year and 45% in the moderate drought year. The impact of the evaporation on the water availability is huge.

Figure 5.1.6 presents the raw water volume from the Krishna River since completion of the Telugu Ganga Project. Authorized yield to CMWSSB is 930 MLD, while the maximum yield has been 678 MLD. The average yield since delivery of the Chembarambakkam reservoir is 379 MLD. Reasons for the fewer amounts than the authorized amount are, in addition to the climate conditions, vagaries of water release of the Andhra Pradesh state and interceptions from the water channel in the neighboring state's section. Table 5.1.6 is an approximate estimation of water balance in the stored rainwater in the four reservoirs and the surface water from the Krishna river. Water balance between the rainwater and the river water is approximately 40% and 60% respectively. From these percentages, water production from the rainwater and the Krishna river in moderate drought case (360 MLD) can be separated into 144 MLD from the rain water and 216 MLD from the Krishna river.



Source: JICA Study Team based on production data from CMWSSB

Figure 5.1.5 Analysis of the Water Availability by Production Volume of the Four Reservoirs and the Krishna River



Source: JICA Study Team based on production data from CMWSSB

Figure 5.1.6 Analysis of the Raw Water Availability from the Krishna River

Table 5.1.6 Estimated Balance of the Raw Water and Production from the Four Reservoirs and Krishna River based on Average Level since 2007

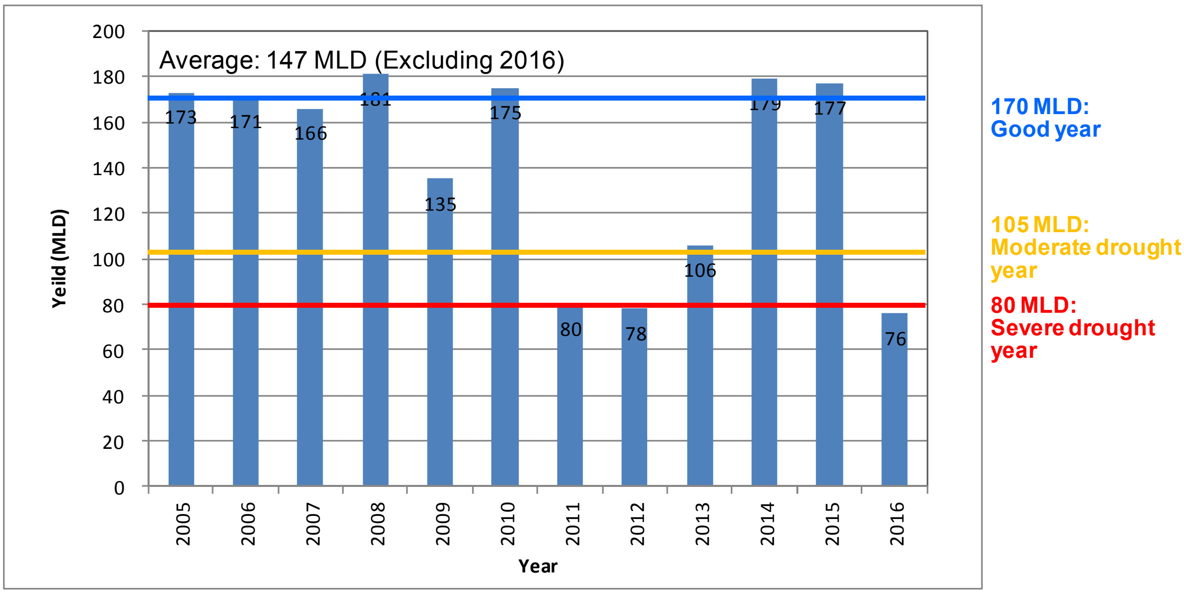
Raw Water Volume	Raw Water	Water loss by evaporation	Production
Rainwater stored in the four reservoirs	338 MLD*1	300 MLD*3	417 MLD*2
Krishna River (Telugu Ganga Project)	379 MLD*2		
Total	717 MLD		

*1: Estimated volume
*2: Actual average volume since 2007 to 2016
*3: Estimated volume based on the evaporation rate at 7.5 mm/day and the total surface area of the reservoirs
Source: JICA Study Team based on the information from CMWSSB

(2) Veeranam WTP

Figure 5.1.7 presents past production of the Veeranam WTP since 2005 when the WTP commenced the operation. The WTP is treating surface water from the Cauvery river. In six years since 2005, the WTP has produced more than 170 MLD, which is very close to180 MLD, the design capacity of the WTP. On the other hand, the water production in 2011, 2012 and 2013 are much less than 170 MLD due to low flow in the Cauvery river, derived from drought in the river's basin. The low production in 2016 has been due to the desludging work of the Veeranam Lake.

The JICA Study Team proposes 105 MLD as the available amount from the Veeranam WTP on the moderate drought condition.



*: The production in 2016 is not taken into account due to the due to the desludging work of the Veeranam Lake in the year.
Source: JICA Study Team based on production data from CMWSSB

Figure 5.1.7 Analysis of the Water Availability of the Veeranam WTP (Cauvery River)

(3) Groundwater

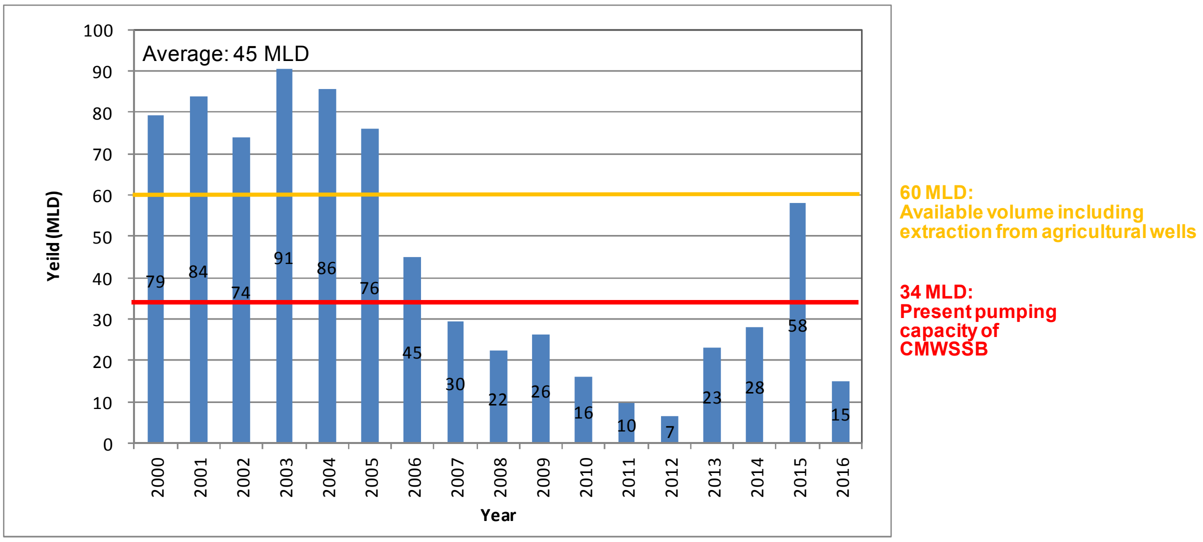
1) Northern Well Fields (or Northern Aquifer)

Figure 5.1.8 presents past production of the Northern Well Fields. Groundwater from the wells is supplied to the Chennai Corporation and some industries in and around the well fields. The safe yield of the wells was assessed as 180 MLD, but the maximum production since 2000 is 91 MLD.

Periodic monitoring data indicates that the water table in the Northern Well Field is recovering but, as explained in Subsection 3.3.4, only 34 wells out of 74 are operational due to significant deterioration of the equipment. In 2015, CMWSSB extracted 59 MLD of groundwater from the Northern Well Fields, including temporary use of agricultural wells with payment to the well owners. According to CMWSSB, more groundwater can be purchased if CMWSSB requests. In 2006 to 2012, CMWSSB exploited only 7 to 45 MLD from the aquifer. The low exploitation was not due to low groundwater availability but due to the steady water demand and supply after completion of Veeranam WTP (in 2005), Chembarambakkam WTP (in 2007) and Minjur DSP (in 2010).

Different from the surface water, availability of groundwater is not directly linked with the short-term climate conditions but with the long-term recharge. From the actual yield until 2005, when Veeranam WTP started the operation and that in 2015, JICA Study Team presumes 100 MLD as the safe yield from the Northern Well Fields as also suggested in M/P. In the Minjur Well Fields, which is located at the most coastal side in the Northern Well Fields, seawater intrusion has been observed already. Therefore, 180 MLD will not be the safe yield anymore.

To improve the water service level in CMA, CMWSSB will need to utilize the Northern Well Fields as much as possible. It is recommended that CMWSSB will recover the pumping capacity to enable them to exploit groundwater by their own equipment.



Source: JICA Study Team based on production data from CMWSSB

Figure 5.1.8 Analysis of the Water Availability of the Northern Well Fields

2) Southern Coastal Well Field (or Southern Coastal Aquifer)

A well field located in the southern coastal area was developed in 1976 to mitigate the severe drought. The wells produced 10 MLD, but the safe yield will be marginal because of its very close location to the sea.

3) Neyveli Well Field (or Neyveli Aquifer)

Neyveli Well Field, which has a pumping capacity to produce 60 MLD, is used to supplement fresh water to Veeranam reservoir when the raw water volume for the Veeranam WTP is not sufficient. Therefore, the production from the well field is counted as a part of the Veeranam WTP.

4) Bored wells in the Expanded Area

Before the integration into the Chennai Corporation, the bored wells operated by ULBs or TWAD Board were the major water sources for the people in the present Expanded Area. Currently, CMWSSB is expanding the coverage of their water distribution network, and the water source in the new coverage areas of CMWSSB are shifting from the local bored wells to the water sources operated by CMWSSB. As the water quality of the groundwater in the Expanded Area tend to be poor, CMWSSB abandons the existing wells when the areas are connected with the CMWSSB's water transmission system. As shown in Table 4.4.1 in Chapter 4, therefore, the M/P did not take into account production from the bored wells in the Expanded Area.

As the productions from the wells are not measured generally, no statistic data to prove the actual water consumption has been available yet in the Study. Only one relevant information available is Figure 3-11 in the M/P, which indicates 29 MLD productions from the wells in the Expanded Area. According to the expansion of the CMWSSB's network, the production will be reducing.

Observing the present situations, the JICA Study Team presumes no production from the wells in the Expanded Area. CMWSSB may continue to utilize some of the wells of good water quality, but productions from such wells will be marginal.

5) Bored wells in Rest of CMA

The M/P presumed 32 MLD as the safe yield from the bored wells in the Rest of CMA. As presented in Table 5.1.2, on the other hand, water production from the bored wells in Rest of CMA is estimated by JICA Study Team at 90 MLD based on information from TWAD Board. Because the Rest of CMA has much wider area than the Expanded Area, it is reasonable that the wells in the Rest of CMA can produce more water than those in the Expanded Area. In addition, inland areas in the Rest of CMA are free of seawater intrusion, which is affecting the Northern Well Fields.

In the Study, it is presumed that the safe yield from the bored wells in the Rest of CMA at 90 MLD. JICA Study Team will continue to collect information on groundwater potential in the area.

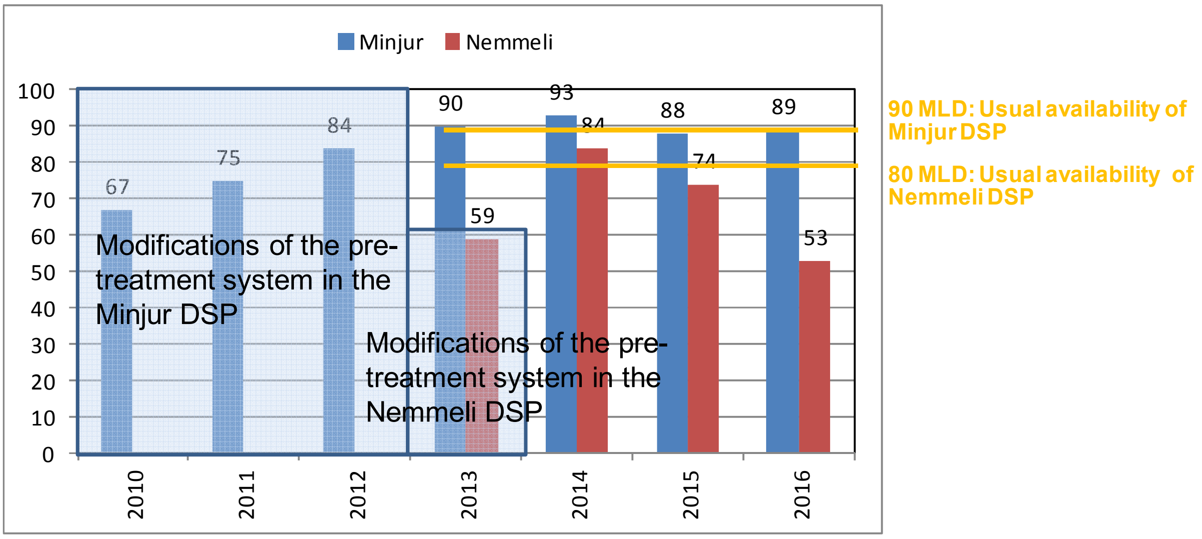
(4) Seawater desalination plants

Figure 5.1.9 presents the past productions of the existing DSPs from the year of their completions. The existing plants have the capacity of 100 MLD respectively.

In the initial years, the Minjur DSP faced operational difficulties against the high turbidity conditions, which caused a significant reduction in the production amount in monsoon seasons. The private operator of the plant conducted modifications in the pre-treatment system and since then the annual average production has been almost stable at 90 MLD. The less production than the production capacity by 10% is due to the suspension of the power supply and critical maintenance works of the plant.

The Nemmeli DSP also spent the first year for modification and adjustment of the process. In the second and the third years (the years of 2014 and 2015), the water production was approximately 80 MLD. In addition to the suspension in the power supply and maintenance work, the high turbidity in the monsoon seasons deteriorates the operation rate. The significantly low production in 2016 was mostly due to the high availability of the surface water. To satisfy the CMWSSB's target supply volume, which is not equivalent to the actual water demand but only the current target volume set by CMWSSB), CMWSSB did not need to operate the Nemmeli DSP at higher rate. It should be noted however that the low production in December 2016 was not derived from such a production control by CMWSSB but from high turbidity problem of the raw seawater and suspension of the power supply caused by damage on the water supply system of TNEB by the cyclone Wardha.

As a result of the analysis on the past production and the efficiencies of the plants, water availability of Minjur DSP and Nemmeli DSP are assessed as 90 MLD and 80 MLD respectively. Because productions of the DSPs are not subject to rainfall, the availabilities of the DSPs are adopted to any climate condition.



Source: JICA Study Team based on production data from CMWSSB

Figure 5.1.9 Analysis of the Water Availability of the Existing Seawater Desalination Plants

5.1.5 Proposals on the Availabilities of the Future Water Sources

(1) Proposals by the JICA Study Team

Table 5.1.7 summarizes the proposals on the availability of the existing and future water sources by JICA Study Team. The explanations for the proposals are given in the following items:

Table 5.1.7 List of the Existing and Future Water Sources Proposed in the Study

Water sources		Water Volume in MLD					
		M/P			Proposals by JICA Study Team in Moderate Drought Condition		
		Availability in good years	Augmented Volume	Total availability after augmentation	Availability in moderate drought year	Augmented Volume	Total availability after augmentation
1. Surface water sources							
	a) Four reservoirs (Poondi, Red Hills, Cholavaram and Chembarambakkam)	125	75	200	144	56	200
	b) Telugu-Ganga Project (Krishna River)	400	530	930	216	150	366
	c) Veeranam Lake (Cauvery River)	100	80	180	105	75	180
	1) Mettur Project	-	700	700	-	350	350
2. Groundwater							
	d) Northern well field and southern well field	25	75	100	60	40	100
	-) Subsurface water in the Expanded Area	-	-	-	-	-	-
	e) Subsurface water in Rest of CMA	32	-	32	90	-	90
3. Seawater desalination							
	f) Minjur DSP	100	-	100	90	-	90
	g) Nemmeli DSP	100	150	250	80	143*+10	233
	2) Perur DSP	-	400	400	-	380*	380
4.	External sources						
	3) Madurantangan Lake	-	25	25	-	15	15
	4) Chengalpathu Lake	-	35	35	-	21	21
	5) Abandoned Quarries	-	10	10	-	-	-
	6) New surface storage projects	-	20	20	-	-	-
	7) Palar Source	-	30	30	-	18	18
	8) Neyveli Aquifer	-	25	25	-	-	-
	9) By harvesting rain water in off stream lakes	-	30	30	-	30	30
4.	Others						
	At several sewage treatment plants	-	-	-	-	270	270
	Additional DSPs	-	-	-	-	950	950
Total		882	2,185	3,067	785	2,508	3,293

*: Expected production volume assuming 95% availability
Source: JICA Study Team

(2) Augmentation of the existing water sources

1) Four reservoirs

The M/P mentioned that a past study concluded safe yield of the reservoirs would be 200 MLD. Based on the estimated production of 144 MLD from the stored rainwater, the JICA Study Team presumes that 56 MLD will be possible by the planned works in the M/P, which includes improvement of the reservoirs and raw water transmission channels and catchment management.

2) Krishna river (Telugu Ganga Project)

The less amount from the Krishna river than the agreed amount of 930 MLD has natural and social reasons. M/P expects to achieve 930 MLD by improving the storage capacity of the reservoirs to prevent overflow from the reservoirs.

CMWSSB is implementing a project to construct a new reservoir to enhance the storage capacity of the raw water from the Krishna river. The project is planned to be completed by 2017. The new reservoir is expected to bring about additional 100 MLD as raw water, which will produce about 60 MLD. Further increase in the production will be 90 MLD, but it will not be realized in several years. Additional reservoirs may be able to enhance the water availability, but such projects have land acquisition issues.

As a conclusion, there is no sufficient information to presume to what extend the expected volume will be recovered. In the Study, CMWSSB's efforts to construct new facilities and to negotiate with the neighboring state will achieve the water availability of 930 MLD in good years. It will be about 250 MLD of the additional amount from the past maximum amount of 678 MLD. Assuming 40% of water loss by evaporation, the additional amount is equivalent to a production of 150 MLD.

3) Veeranam (Cauvery river)

The capacity of Veeranam WTP is 180 MLD, while the availability in moderate drought condition is 105 MLD. To supplement the smaller yield from the Veeranam reservoir in the drought condition, CMWSB has the plan to construct infiltration wells near the Cauvery river, which is the water resource of the Veeranam reservoir. This project is expected to achieve a constant yield of 180 MLD even in the moderate drought condition.

As the infiltration wells project does not have any issue of water right, quick implementation of the project seems to be possible. When CMWSSB announced the bid for the project in 2004, however, the project received strong oppositions from the local farmers. The case was brought to the Hon'ble High Court of Madras, and the judgement supported CMWSSB, but the State Government of Tamil Nadu decided to cancel the bid in consideration of the sentiment of the local people.

Although the above difficult situations exist, CMWSSB will need to communicate with the local communities to foster acceptance to the project for stable utilization of the allocated water right from the Cauvery river. In the Study, JICA Study Team expects that the project will be completed by 2021.

4) Northern Well Fields

Against the estimated safe yield of 100 MLD, the capacity of the operational tube wells in the Northern Well Fields is 34 MLD. Although CMWSSB could provide 93 MLD from the well fields by purchasing groundwater from the agricultural wells in the same area, CMWSBB will need to drill new wells or replace deteriorated equipment to be capable to extract 100 MLD independently. Because there will be no obstacle to prevent the implementation, the Study presumes that the recovery will be made by 2018.

5) Nemmeli Seawater Desalination Plant

Nemmeli DSP will be expanded by 150 MLD with financial assistance from KfW. Considering the possible reduction in the production of power supply suspension and critical maintenance works, 95% availability is presumed for the expanded section. Hence, additional production to be taken into account in the water sources augmentation plan is 143 MLD. CMWSSB and KfW plan to announce the contractor procurement in May or June 2017. Commercial operation of the plant will not be later than 2020.

In addition to the planned expansion, JICA Study Team proposes an improvement work in the existing 100 MLD unit. It is intended to improve the plant's performance in the high turbidity condition and to achieve the availability of 90 MLD. This work is physically possible whenever but needs to be done when the water source has excess amount against the water demand.

(3) New water sources

1) Mettur Project

According to M/P, the project will extract additional 700 MLD from the Mettur reservoir, whose water resources is Cauvery river. The Mettur reservoir is an existing reservoir sourced from the Cauvery river, for irrigation and power generation. The project will construct a water intake from the reservoir, water treatment plant and water transmission line to Chennai. The length of the transmission line will be about 300 km. As the DPR is being prepared, detailed information has not been disclosed to the study team.

From the interviews with the officials in charge of the project, however, the project will need a long time because of the huge construction volume and some social issues including land acquisition and resettlement. CMWSSB has already been given a right to use 700 MLD of water by Water Resources Department of Government of Tamil Nadu but the project is likely to face strong oppositions from the farmers as the water flow from the Cauvery river is chronically low even for irrigation purpose due to enormous water use in the Karnataka State. Therefore, even if the project is implemented, stable water extraction at 700 MLD will be hardly expected.

In the Study, it is expected that the project completion will take more than 10 years, and the production will be 350 MLD, a half of the planned amount. Because CMWSSB has received only about 300 MLD from Krishna river, out of 930 MLD allocated to CMWSSB, even the assumption of 50% will be slightly optimistic.

2) Perur DSP

Perur DSP, which is the target of the Study, is planned to have a capacity of 400 MLD. Considering the power supply suspension and critical maintenance works, availability of the DSP will be at 95%. Assuming procurement of the supervising consultant, contractor and design/construction period, the commercial operation will start in 2022.

3) External sources

M/P proposed seven new water sources as "external sources". In the water sources augmentation plan, JICA Study Team assesses these projects as below;

- Madurantagam Lake: Close location to the core city will make the project feasible financially. An early arrangement of the conversion of the agricultural water into potable water is expected but may need 10 years to complete for the procedures to conversion, preparation and approval of DPR, tender and construction. Expected production will be 15 MLD from 25 MLD raw water.
- Chengalpattu Lake: Closer location to the core city than Madurantagam Lake is advantageous but the polluted raw water may influence technical viability and result in high cost. Preferably, the project will be implemented after installation of wastewater treatment system in the area, although the project delivery will need more than 10 years in that case. Expected production will be 21 MLD from 35 MLD raw water.
- Abandoned Quarries: Technical and financial feasibilities cannot be evaluated from the available information. Nevertheless, the water sources augmentation will not be taken into account in the Study, as the expected water volume is as low as 10 MLD as raw water.
- New surface storage projects: Eight small-scale reservoirs to be scattered in different locations will be inefficient in cost. Reservoirs proposed in the core city will face land acquisition problem and those proposed more than 250 km away from the city will not be financially feasible.
- Palar Source: Close location to the city is advantageous. Expected production will be 18 MLD from 30 MLD raw water. As the site of the dam is yet to be identified, the project will need a long time.
- Neyveli Aquifer: 12 MLD wells are existing, but they are for Veeranam WTP. M/P expects an additional 25 MLD for CMA. However, the wells are not connected to any transmission line at present, and safe yield is unknown. The project will not be taken into account in the water sources augmentation plan
- By harvesting rainwater in off stream lakes: M/P expects 30 MLD, but there is no evidence to prove the expected impact. Nevertheless, JICA Study Team considers 30 MLD (but for far future) because such efforts to harvest rainwater to recover the groundwater in CMA will be necessary.

4) Tertiary Reverse Osmosis (TTRO): Water recycle for industries

CMWSSB is conducting construction of TTRO plants of each 45 MLD at Koyambedu and Kodungaiyur Sewage Treatment Plants. The TTRO plants will provide water to industries, to which the recycled water will be delivered by transmission main dedicated for the recycled water. As explained in Section 3.5, the Koyambedu TTRO is funded by the state government and the

Kodungaiyur TTRO is funded by the World Bank. Both projects are ongoing and the plants are expected to start the operation from 2018.

The M/P proposed 10 TTRO projects, whose total capacity will be 405 MLD but they were not taken into account in the water sources augmentation plan. JICA Study Team recommends to count the TTRO's production in the water sources augmentation plan as long as the production is within the industrial water demand. Subsequently, the requirement of TTRO by 2050 will be 270 MLD from the bulk industrial water demand.

5) Additional DSPs

When the water demand cannot be satisfied by the existing and planned water source development projects, additional seawater desalination will be the most promised option to fill the gap.

5.1.6 Examination of the Project's Necessity and Scale

Based on the potentials of the existing and future water sources, water sources augmentation plan is proposed by the JICA Study Team as shown in Table 5.1.8. List of the projects is shown in Table 5.1.9. Considerations done in the proposals are as below:

- The projects free from the water right can be implemented in early years. Except the ongoing project for Krishna river, improvement of the four reservoirs, infiltration wells at Cauvery river and recovery of the Northern Well Fields are expected to be implemented early.
- Recovery of water from the Krishna river will need long procedures because it includes inter-state issues
- Mettur Project will need more than 10 years because of its huge construction volume and social issues
- Improvement of the pre-treatment process in Nemmeli DSP will be carried out in 2025. At that time, CMWSSB will have excess production capacity because of the giant Perur DSP. Besides, it will be the timing of replacement of equipments which were installed in 2010.
- Operation of the Perur DSP will start from 2023 at earliest taking into account the necessary procedures and duration of the design, construction and commissioning.

From the projected balance between the water demand and water source availability presented in Table 5.1.9, the total production of CMWSSB will underrun the water demand in 2022. This result indicates high urgency of development of additional water source. To satisfy the water demand, construction of the Perur DSP by 2023 with a capacity of 400 MLD, which will enable 380 MLD in annual average, will be necessary.

Table 5.1.8 List of the Projects Proposed in the Water Sources Augmentation Plan by the JICA Study Team

Water sources[*1]		Capacity	Completion Year	Remarks
1. Surface water sources				
	a) Four lakes (Poondi, Red Hills, Cholavaram and Chembarambakkam)	56 (28 + 28)	2020, 2025	
	b) Telugu-Ganga Project (Krishna River)	150 (60 + 45 + 45)	2017, 2026, 2031	
	c) Veeranam Lake (Cauvery River)	75	2021	
	1) Mettur Project (new)	350 (175 + 175)	2029, 2033	
2. Groundwater				
	d) Northern well field and southern well field	40	2018	
3. Seawater desalination				
	g) Nemmeli DSP	153 (143+10[*2])	2020, 2025	Plant capacity in 2020: 150 MLD
	2) Perur DSP (new)	380	2023	Plant capacity: 400 MLD
4.	External sources			
	3) Madurantangan Lake	15	2026	
	4) Chengalpathu Lake	21	2031	
	7) Palar Source	18	2036	
	9) By harvesting rain water in off stream lakes	30 (15 + 15)	2040, 2045	
4.	Others			
	Tertiary Treatment Reverse Osmosis (TTRO) projects	270 (90 + 45 + 45 +45 + 45)	2018, 2025, 2032, 2041, 2048)	
	Additional DSPs	950 (190 + 240 + 330 + 190)	2027, 2035, 2043, 2048)	
Total		2,508	-	

*1: Serial codes of a), b), c), d), g), 1) to 4), 7) and 9) correspond to those in Table 4.4.2. The codes by alphabets stand for the existing sources and those by numbers stand for the future sources.
*2: Improvement of the existing pre-treatment process
Source: JICA Study Team

Table 5.1.9 Water Source Augmentation Plan Proposed in the Study

Year	Water Demand (MLD)	Water Supply in Moderate Drought Condition (MLD)																										Balance
		Existing Water Sources				Additional Water Sources												Total Water Sources										
						Surface Water						Seawater Desalination			Ground water	TTRO									TTRO		
		Surface water	Grounwater	Seawater Desalination	Existing Water Sources	Own Surface Sources in the Corporation	Telugu-Ganga	Veeranam Sub Surface	Havesting Raing Water	Mettur Scheme from Cauvery River	External water sources	Nemmeli	Perur	Additional SWRO	North well fields	TTRO	Total	Surface water total	Groundwater			Seawater Desaination			TTRO	Total	
2015	865	465	150	170	785												0	465	150	80	90	0	0	170	0	785	-80
2016	910	465	150	170	785												0	465	150	80	90	0	0	170	0	785	-125
2017	954	465	150	170	785		60										60	525	150	80	90	0	0	170	0	845	-109
2018	999	465	150	170	785										40	90	130	525	190	80	90	0	0	170	65	950	-49
2019	1,043	465	150	170	785												0	525	190	80	90	0	0	170	66	951	-92
2020	1,087	465	150	170	785	28						143					171	553	190	223	90	0	0	313	67	1,123	36
2021	1,191	465	150	170	785			75									75	628	190	223	90	0	0	313	73	1,204	13
2022	1,295	465	150	170	785												0	628	190	223	90	0	0	313	80	1,211	-85
2023	1,400	465	150	170	785								**380**				380	628	190	223	90	380	0	693	86	1,597	197
2024	1,504	465	150	170	785												0	628	190	223	90	380	0	693	90	1,601	97
2025	1,608	465	150	170	785	28						10				45	83	656	190	233	90	380	0	703	98	1,647	39
2026	1,681	465	150	170	785		45				15						60	716	190	233	90	380	0	703	104	1,713	31
2027	1,755	465	150	170	785									190			190	716	190	233	90	380	190	893	109	1,908	153
2028	1,829	465	150	170	785												0	716	190	233	90	380	190	893	115	1,914	85
2029	1,902	465	150	170	785					175							175	891	190	233	90	380	190	893	121	2,095	192
2030	1,976	465	150	170	785												0	891	190	233	90	380	190	893	126	2,100	124
2031	2,073	465	150	170	785		45				21						66	957	190	233	90	380	190	893	135	2,175	102
2032	2,171	465	150	170	785											45	45	957	190	233	90	380	190	893	146	2,186	15
2033	2,268	465	150	170	785					175							175	1,132	190	233	90	380	190	893	155	2,370	102
2034	2,365	465	150	170	785												0	1,132	190	233	90	380	190	893	165	2,380	15
2035	2,463	465	150	170	785									240			240	1,132	190	233	90	380	430	1,133	175	2,630	167
2036	2,485	465	150	170	785						18						18	1,150	190	233	90	380	430	1,133	177	2,650	164
2037	2,508	465	150	170	785												0	1,150	190	233	90	380	430	1,133	178	2,651	143
2038	2,530	465	150	170	785												0	1,150	190	233	90	380	430	1,133	179	2,652	122
2039	2,552	465	150	170	785												0	1,150	190	233	90	380	430	1,133	180	2,653	100
2040	2,575	465	150	170	785				15								15	1,165	190	233	90	380	430	1,133	180	2,668	93
2041	2,624	465	150	170	785											45	45	1,165	190	233	90	380	430	1,133	187	2,675	51
2042	2,674	465	150	170	785												0	1,165	190	233	90	380	430	1,133	192	2,680	6
2043	2,724	465	150	170	785									330			330	1,165	190	233	90	380	760	1,463	196	3,014	291
2044	2,773	465	150	170	785												0	1,165	190	233	90	380	760	1,463	201	3,019	246
2045	2,823	465	150	170	785				15								15	1,180	190	233	90	380	760	1,463	205	3,038	216
2046	2,907	465	150	170	785												0	1,180	190	233	90	380	760	1,463	215	3,048	141
2047	2,990	465	150	170	785												0	1,180	190	233	90	380	760	1,463	224	3,057	66
2048	3,074	465	150	170	785									190		45	235	1,180	190	233	90	380	950	1,653	233	3,256	182
2049	3,158	465	150	170	785												0	1,180	190	233	90	380	950	1,653	242	3,265	107
2050	3,242	465	150	170	785												0	1,180	190	233	90	380	950	1,653	252	3,275	33

Source: JICA Study Team

5.1.7 Projection of the Water Production at the Perur DSP

(1) Objectives of the projection

In the previous subsections, the necessity scale of the Project was studied so that CMWSSB would be able to satisfy the water demand in CMA even on the moderate drought conditions. In this subsection, production of the Perur DSP in other ordinarily possible conditions will be projected. The projection will be useful to validate the scale of the Project by confirming that the operational rate will not be extremely in usual conditions. In addition, the projected production volume will be used for input conditions in the financial and economical analysis to be presented in Chapter 12.

(2) Conditions of the projection

1) Projection cases

As presented in Table 5.1.10, the projection will be conducted for four cases, which are different in climate condition or surface water availability. The water demand and the different climate conditions take into account the fluctuation of the surface water availability that have been different year by year.

Table 5.1.10 Projection Cases for the Water Production of the Perur DSP

Case	Climate conditions	Remarks
Case 1	Average	Basic condition in the production projection.
Case 2	Good	The most optimistic condition regarding surface water availability. The production of the DSPs will be the lowest.
Case 3	Moderate drought	The condition adopted in the study on the Project's needs.
Case 4	Severe drought	The most pessimistic condition regarding surface water availability. The production of the DSPs will be the highest but the water demand will not be met.

Source: JICA Study Team

2) Methodologies and assumptions

Methodologies and assumptions in the water production projections are as follows:

a. Water demand

- The projected water demand, which was concluded in Subsection 5.1.2, are applied.

b. Allocation of water productions by water source

- Water production of the DSPs will be calculated by deducting the available water volume of the other water sources such as surface water (under the different climate condition cases), subsurface water, recycled water of TTROs from the water demand.

c. Water production from surface water

- From Figure 5.1.4, availability of the surface water in average condition is presumed as 115% (= 552 MLD / 465 MLD) of that in moderate drought condition.
- From the same figure, availability of the surface water in good condition is presumed as 140% (= 670 MLD / 465 MLD) of that in moderate drought condition.
- From the same figure, availability of the surface water in severe drought condition is presumed

as 70% (= 330 MLD / 465 MLD) of that in moderate drought condition.

d. Water production from the wells and TTRO

- In good and average surface water availability cases, Cases 1 and 2, production from the wells is constantly at 150 MLD, which is the current maximum production from the Northern Well Fields and the wells in the Rest of CMA. In moderate and severe drought cases, Cases 3 and 4, the production is expected to increase to 190 MLD since 2018, which is the planned maximum availability in the water source augmentation plan. Because CMWSSB is not sure that 100 MLD can safely extracted constantly, the maximum extraction is presumed only in drought years.
- Production from the TTRO is the greater amount between the total TTRO capacity and bulk industry water demand.

e. Allocation of production among the seawater desalination plants

- The operation rate of the Perur DSP as percentage of the production volume against the available production, 380MLD for the Perur DSP, will always be the same as those of the other DSPs except for the Minjur DSP.
- Production of the Minjur DSP is presumed to be constant at 90 MLD, the average availability of the DSP through a year, because the DSP is operated under DBOOT contract, where CMWSSB is stipulated to purchase full amount of the DSP's production until 2035. Since 2036, all the DPSs will be operated at the same operation rate.

(3) Main projections: Cases 1 (Average surface water availability conditions)

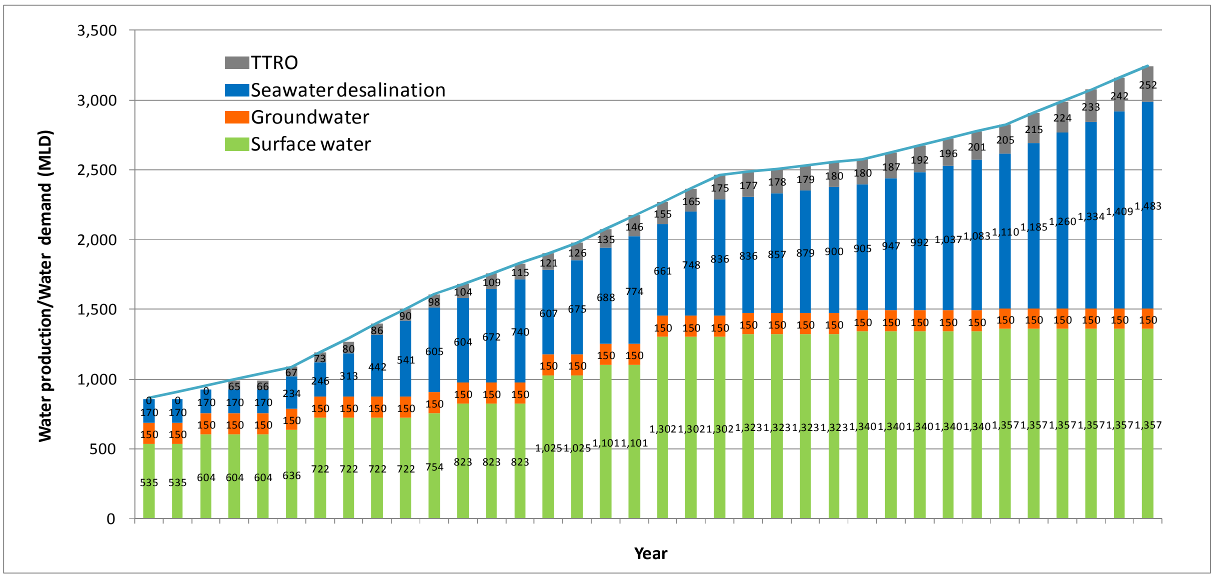
Projection result of the production of the water sources in average surface water availability condition in average demand case and peak demand case are presented in Table 5.1.11 and Figure 5.1.10.

The projected production of the Perur DSP in 2023, the initial year of the operation, will be 222 MLD as annual average, which is equivalent to an operation rate of 55% against the full capacity of the plant, 400MLD. Since the next year the operation rate will be approximately 60 to 85% until the year 2050. Details of the production projection are given in Appendix 5.2.

Table 5.1.11 Projection Result of the Production of the Perur DSP (Case 1)

Year	Average Water Demand (MLD)	Water production (MLD)							Balance (MLD)
		Surface water	Ground water	Seawater desalination	Perur DSP		Recycled water	Total	
					Production	Operation rate*			
2015	865	535	150	170	-	-	0	855	-11
2016	910	535	150	170	-	-	0	855	-55
2017	954	604	150	170	-	-	0	924	-30
2018	999	604	150	170	-	-	65	989	-10
2019	1,043	604	150	170	-	-	66	990	-53
2020	1,087	636	150	234	-	-	67	1,087	0
2021	1,191	722	150	246	-	-	73	1,191	0
2022	1,295	722	150	313	-	-	80	1,265	-31
2023	1,400	722	150	442	**222**	**55%**	86	1,400	0
2024	1,504	722	150	541	**284**	**71%**	90	1,504	0
2025	1,608	754	150	605	**325**	**81%**	98	1,608	0
2026	1,681	823	150	604	**318**	**80%**	104	1,681	0
2027	1,755	823	150	672	**271**	**68%**	109	1,755	0
2028	1,829	823	150	740	**303**	**76%**	115	1,829	0
2029	1,902	1,025	150	607	**241**	**60%**	121	1,902	0
2030	1,976	1,025	150	675	**273**	**68%**	126	1,976	0
2031	2,073	1,101	150	688	**279**	**70%**	135	2,073	0
2032	2,171	1,101	150	774	**320**	**80%**	146	2,171	0
2033	2,268	1,302	150	661	**266**	**67%**	155	2,268	0
2034	2,365	1,302	150	748	**307**	**77%**	165	2,365	0
2035	2,463	1,302	150	836	**265**	**66%**	175	2,463	0
2036	2,485	1,323	150	836	**266**	**66%**	177	2,485	0
2037	2,508	1,323	150	857	**273**	**68%**	178	2,508	0
2038	2,530	1,323	150	879	**281**	**70%**	179	2,530	0
2039	2,552	1,323	150	900	**288**	**72%**	180	2,552	0
2040	2,575	1,340	150	905	**290**	**73%**	180	2,575	0
2041	2,624	1,340	150	947	**305**	**76%**	187	2,624	0
2042	2,674	1,340	150	992	**321**	**80%**	192	2,674	0
2043	2,724	1,340	150	1,037	**254**	**64%**	196	2,724	0
2044	2,773	1,340	150	1,083	**267**	**67%**	201	2,773	0
2045	2,823	1,357	150	1,110	**274**	**69%**	205	2,823	0
2046	2,907	1,357	150	1,185	**294**	**74%**	215	2,907	0
2047	2,990	1,357	150	1,260	**314**	**79%**	224	2,990	0
2048	3,074	1,357	150	1,334	**293**	**73%**	233	3,074	0
2049	3,158	1,357	150	1,409	**310**	**78%**	242	3,158	0
2050	3,242	1,357	150	1,483	**328**	**82%**	252	3,242	0

*: Operation rate against the full capacity (400 MLD)
Source: JICA Study Team



Source: JICA Study Team based on production data from CMWSSB

Figure 5.1.10 Water Production Projection by Water Source (Case 1)

(4) Other cases

By the projections for the other cases, operation rates of the Perur DSP on different conditions in surface water availability and water demand are summarized in Table 5.1.12. Details of the projection results are given in Appendix 5.2.

From the results, on good surface water availability condition (Cases 2), the operation rate of the Perur DSP will be mostly 40 to 65% excluding the initial operation year of 2023. If the water rate is raised to the cost recovery level, CMWSSB may produce more from the DSP to meet extra water demand beyond 150 lpcd. This situation may occur once or twice in ten years according to the recent climate trend.

On the moderate drought condition (Cases 3), the operation rate of the DSP will be 70 to 95% also excluding the initial year. On the severe drought condition (Cases 4), the DSP will be operated continuously at its full capacity but the water demand will not be satisfied. From the recent climate trend, the severe drought may occur once or twice in ten years.

Table 5.1.12 Summary of the Operation Rate Projection Results of the Perur DSP

Case	Case 1	Case 2	Case 3	Case 4
Surface water availability	**Average**	**Good**	**Moderate drought**	**Severe drought**
2023	55%	31%	64%	94%
2024	71%	46%	80%	95%
2025	81%	55%	90%	95%
2026	80%	52%	90%	95%
2027	68%	47%	76%	95%
2028	76%	55%	84%	95%
2029	60%	34%	71%	95%
2030	68%	42%	79%	95%
2031	70%	42%	82%	95%
2032	80%	52%	92%	95%
2033	67%	33%	82%	95%
2034	77%	44%	92%	95%
2035	66%	41%	78%	95%
2036	66%	41%	78%	95%
2037	68%	43%	80%	95%
2038	70%	44%	82%	95%
2039	72%	46%	84%	95%
2040	73%	46%	85%	95%
2041	76%	50%	88%	95%
2042	80%	54%	92%	95%
2043	64%	44%	73%	95%
2044	67%	47%	76%	95%
2045	69%	49%	78%	95%
2046	74%	54%	83%	95%
2047	79%	59%	88%	95%
2048	73%	56%	81%	95%
2049	78%	60%	86%	95%
2050	82%	65%	90%	95%

Source: JICA Study Team

(5) Conclusion

The operation rate of the Perur DSP highly depends on climate condition or availability of the surface water resources. In the average availability condition presumed in the Study, the operation rate will be

60 to 85%. If the surface water availability is good, the operation rate may be 40 to 65%, while in severe drought year the water demand will not be met even with continuous full operation of the DSP.

The low operation rate in good availability condition may discount the project's necessity but for CMA, owning a reliable water source not subject to drought condition is highly useful to maintain the people's daily lives and economic activities. To further increase the possibility of high utilization of the Perur DSP, introduction of appropriate water rate at the cost recovery level is necessary. Such a water rate level will encourage CMWSSB to satisfy the water demand by operating the DSP at high operation rate and, on good surface water demand condition, to produce more than the expected water demand to meet extra water demand beyond 150 LPCD, if any.

5.2 Water Allocation Plan from the Perur DSP

5.2.1 Plan in the Master Plan

As explained in the Subsection 4.5.1 of Chapter 4, the M/P proposed the entire CMA to be divided into seven water supply systems by water source as below;

- Kilpauk (KPS) Water Supply System
- Veeranam (Porur) Water Supply System
- Chembarambakkam Water Supply System
- Redhills Water Supply System
- Sholavaram Water Supply System
- Minjur DSP Water Supply System
- Nemmeli DSP Water Supply System.

In the M/P, the Perur DSP will belong to "Nemmeli DSP Water Supply System", of which water production facilities are the following plants:

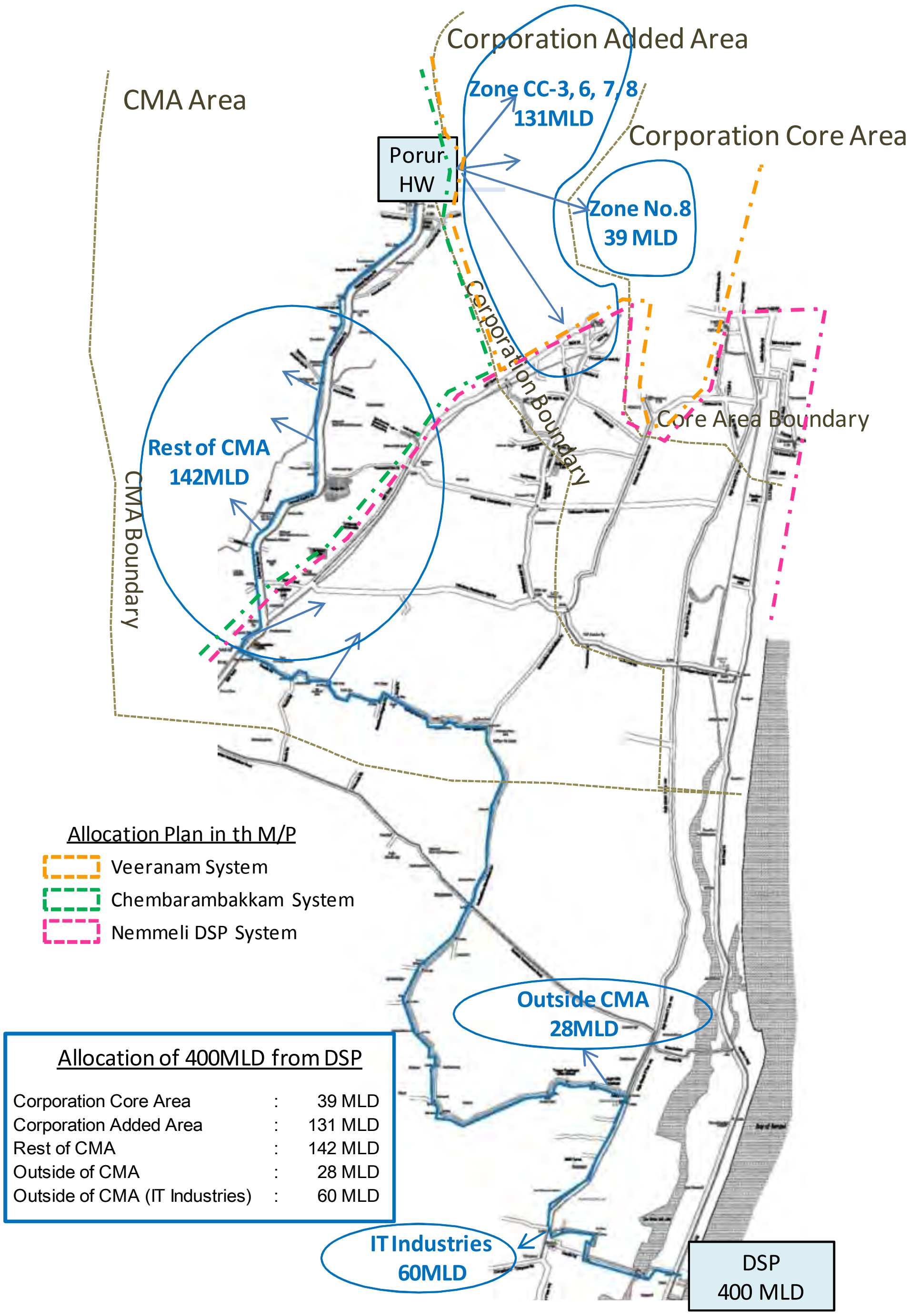
- Existing 100 MLD DSP at Nemmeli
- 150 MLD DSP at Nemmeli (to be constructed with financial assistance from KfW)
- 400 MLD DSP at Perur (to be constructed in the Project, target of the Study)

5.2.2 Plan in the DPR

Figure 5.2.1 shows the water allocation plan, and pipeline route prepared in the DPR. JICA Study Team observes the following problems in the water distribution as follows:

- The allocation plan was worked out based on the water demand in 2017, which is obviously too short timeframe
- Planned destinations are partly overlapped with other water sources such as Chembarambakkam Water Supply System and Veeranam (Porur) Water Supply System in the M/P. The water allocation and water transmission plans in the DPR and the M/P did not match each other.

- Perur DSP is intended to deliver the water outside of CMA, whose reason cannot be found in the DPR. Besides, "IT Industries" to be supplied by the DSP are not clearly defined.
- More than half of 400 MLD is to be supplied to the area which is outside of the Chennai Corporation, the current service area of CMWSSB. From the fact that CMWSSB is still facing challenges in service improvement in the corporation, high priority given to Rest of CMA by the DPR is not deemed to be valid.



Source: JICA Study Team based on the DPR

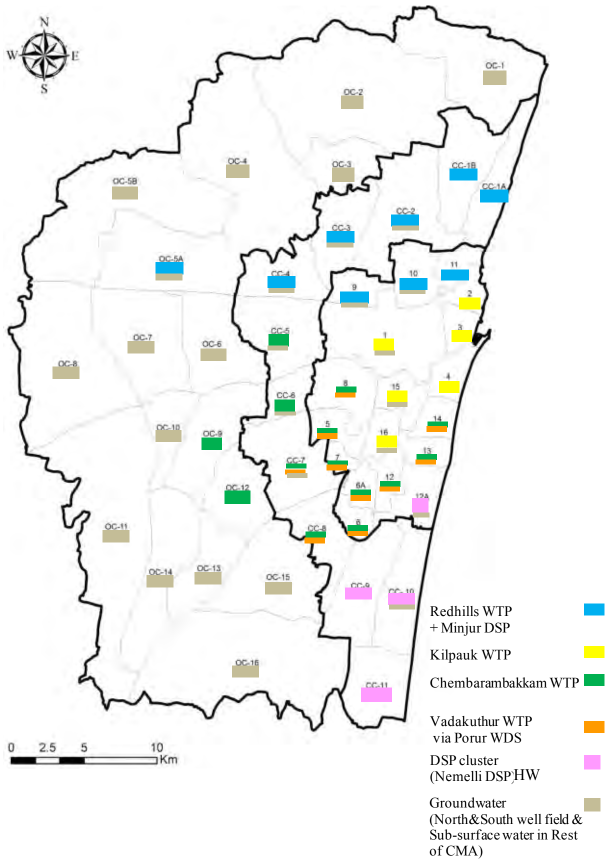
Figure 5.2.1 Water Allocation Plan and Pipeline Route in the DPR

5.2.3 Proposed Water Allocation Plan in the Study

As described in the previous subsections, the DPR proposed a water allocation plan from the Perur DSP but the plan has discrepancies with the water supply system plan in the M/P. Nevertheless, as the DPR does not present valid reasons for its water allocations, JICA needs to develop a new water supply allocation taking into account the water supply system plan in the M/P, as follows:

(1) Present situations of the water allocation

Figure 5.2.2 shows the current water distribution (demarcation of water supply zones by WTPs) in the entire CMA.



Source: JICA Study Team

Figure 5.2.2 Present Water Allocation in the CMA

As shown in the figure, each area of CMA is being supplied from the WTPs as follows:

- Northern part of Corporation Area (core + expanded area) and Industrial area in Rest of CMA:	Redhills WTP and Minjur DSP
- Central part of core area (core):	Kilpauk WTP
- Southern and eastern parts of Corporation Area (core + expanded area) and Industrial area in Rest of CMA:	Chembarambakkam WTP and Vadakuthur WTP via Porur HW
- Zone 12A of core area and south part of expanded area:	Nemelli DSP
- Other Area	Groundwater/Sub-surface water in the Rest of CMA

From the WTPs, the treated water is being transmitted to WDSs. WDSs are distributing the received water to the consumers in their own water distribution zones through the water distribution networks. It should be noted that ground water of north-west well field and east coast well field is also being transmitted to the corporation area through the same transmission pipelines as the water from the WTPs. Ground water from the other wells is being supplied to the local areas around the wells.

(2) Basic planning conditions for water allocation

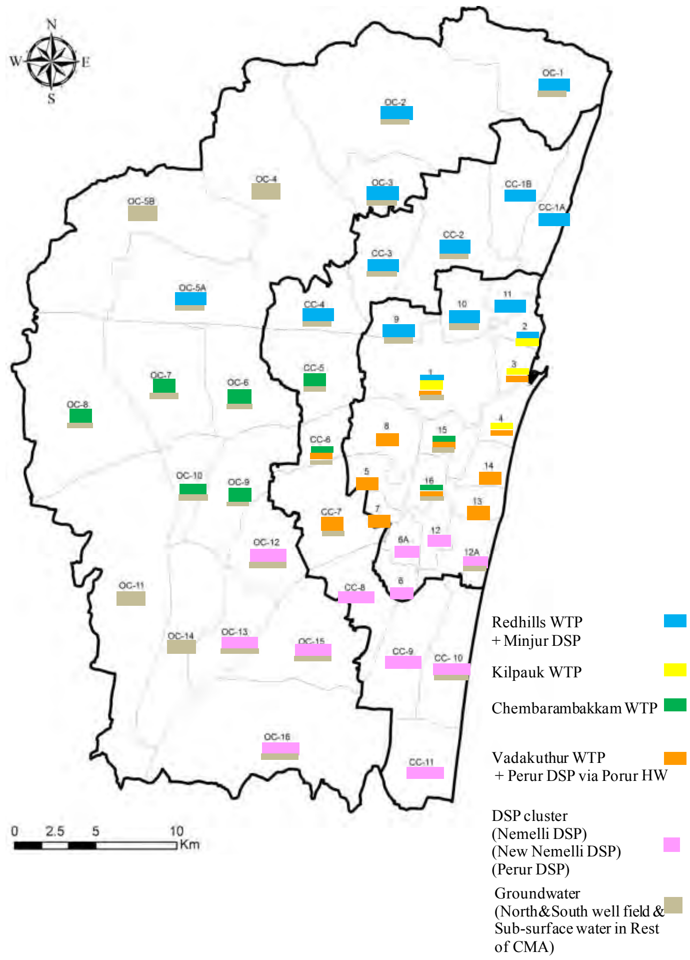
The water allocation plan in the Study was worked out on the following conditions:

- Water Demand: Water demand of each water supply zone for the year 2025, 2035, and 2050 projected in Subsection 5.1.2 and Appendix 5.1, which are consistent with the short-, middle- and long-term target years in the M/P
- Available water: Available water volume of each source as examined and proposed in Table 5.1.7 in subsection 5.1.5 and Table 5.1.9 in subsection 5.1.6.

(3) Water allocation plan in 2025

1) Water Allocation in the entire CMA

The total water demand in the CMA will be 1,608 MLD in 2025. The water allocation plan was worked out considering the geographical distribution of water demand and water availability (location of WTP and transmission pipeline network). Figure 5.2.3 shows the proposed water allocation in 2025. The detail water allocation table is presented in Appendix 5.3.



Source: JICA Study Team

Figure 5.2.3 Water Allocation in 2025

The water of Vadakuthur WTP, which is located at approximately 200 km south of Chennai, is being sent to Porur HW located in zone CC-7 and thereafter sent to WDSs in the Corporation area via the existing transmission pipeline network. It should be noted that Porur HW is an advantageous destination of the water from the Perur DSP also. From Porur HW, the water can be sent to the WDSs in the core area through the existing transmission pipeline network. Sufficient vacant land is available to construct additional reservoirs and pump station in the premise of Porur HW. The WDSs in the Core City are located in high-density area. Additional land for the reservoirs and pumping stations are difficult to be secured.

The figure shows:

- Southern part of the core city area, expanded area and rest of CMA will be supplied from the DSP cluster (Nemelli DSP, New Nemelli DSP and Perur DSP)
- Zone 8, 5, 7, 13, 14 and CC-7, where Chembarambakkam WTP is currently supplying water, will be supplied from Perur DSP as well as Vadakuthur WTP via Porur HW.
- Zone No.1, where high water demand is projected (200 MLD), will be supplied from several water sources via existing transmission pipeline network.
- Chembarambakkam WTP will provide water mainly to the western part of CMA.

2) Water allocation from the Perur DSP

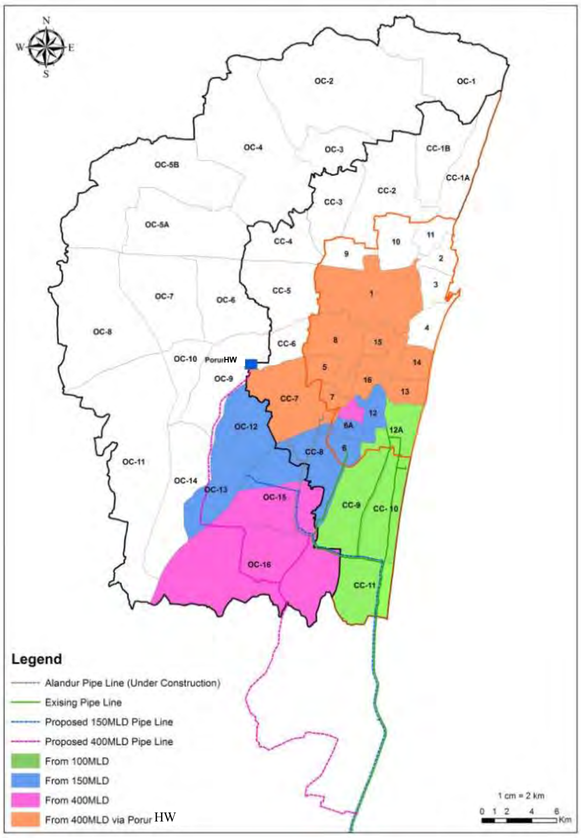
Demarcation of water supply zone by DSPs (Nemelli DSP, New Nemelli DSP, and Perur DSP) was worked out, considering the present and planned water supply zone of Nemelli DSP and additional Nemelli DSP, as well as the water supply capacity of each DSP and water demand in each supply zone. The demarcation is also presented in Appendix 5.3. Figure 5.2.4 shows the planned influence area of the DSPs in 2025.

The proposed water allocation amount of Perur DSP is presented in Table 5.2.1.

Table 5.2.1 Water Allocation of Perur DSP in 2025

Transmission route	Directly from through the transmission line extended from the Perur DSP	From Porur HW after the transmission line extended from the Perur DSP
Supply zone No. and supply amount	6: 24.5 MLD OC15: 10.0 MLD OC16: 26.3 MLD	1: 19.5 MLD 5: 66.7 MLD 7: 6.6 MLD 8: 13.3 MLD 13: 20.8 MLD 14: 41.9 MLD 15: 16.1 MLD 16: 15.6 MLD CC7: 42.0 MLD
Total supply	60.8 MLD	242.5 MLD

Source: JICA Study Team



Source: JICA Study Team

Figure 5.2.4 Influence Area of the DSPs in 2025

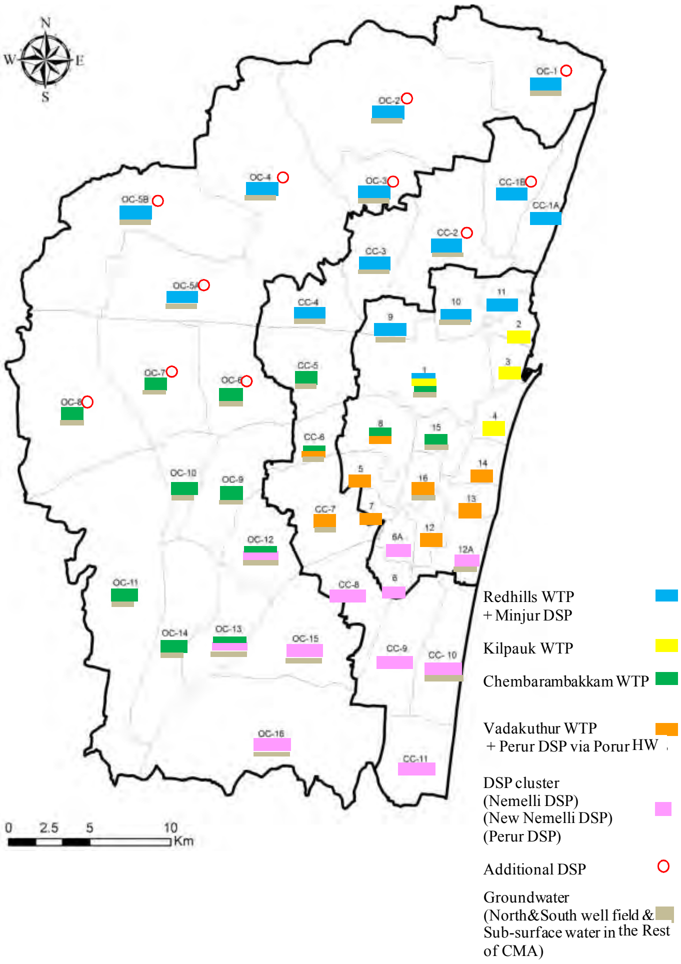
(4) Water allocation plan in 2035

1) Water Allocation in the entire CMA

The total water demand in the CMA will be 2,462 MLD in 2035. The available water volume for the entire CMA in the moderate drought conditions will be increased from 1,647 MLD in 2025 to 2,630 MLD in 2035. The water allocation plan was worked out considering the geographical distribution of water demand and available water (location of WTP and transmission pipeline network). Figure 5.2.5 shows the proposed water allocation in 2035. The detail water allocation table is presented in Appendix 5.3.

By 2035, available resources for the surface water treatment plants of Chembarambakkam WTP and Kilpauk WTP will be increased. Consequently, Chembarambakkam WTP will supply water to zone No.1 & 8 again.

In addition, by 2035, additional DSP plants will need to be constructed to meet the increasing water demand



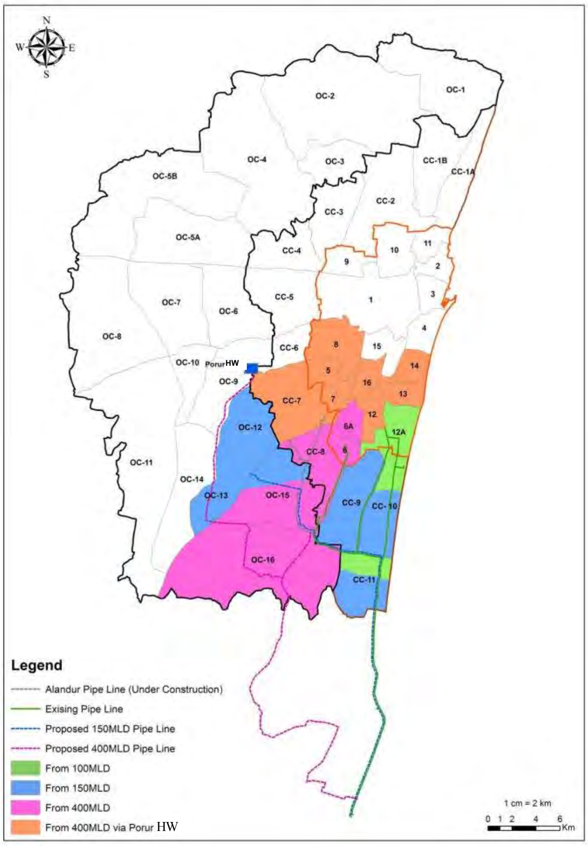
Source: JICA Study Team

Figure 5.2.5 Water Allocation in 2035

2) Water allocation from the Perur DSP

As the water demand in the southern area (Zones OC-15 and OC-16) will increase, coverage of the Perur DSP via Porur HW will shrink accordingly.

Demarcation among the DSPs (Nemelli DSP, New Nemelli DSP, and Perur DSP) will be slightly changed according to the changing balance of the water demand in the southern area (CC-8, 9, 10, 11 and OC-12, 13, 15, 16). Figure 5.2.6 shows the planned influence area of the DSPs in 2035. The proposed water allocation from the Perur DSP is presented in Table 5.2.2.



Source: JICA Study Team

Figure 5.2.6 Influence Area of DSPs in 2035

Table 5.2.2 Water Allocation of Perur DSP in 2035

Transmission route	Directly from through the transmission line extended from the Perur DSP	From Porur HW after the transmission line extended from the Perur DSP
Supply zone No. and supply amount	6: 35.2 MLD 6A: 5.6 MLD CC8: 31.2 MLD OC15: 95.6 MLD OC16: 73.0 MLD	5: 18.7 MLD 7: 1.0 MLD 8: 25.0 MLD 12: 20.1 MLD 13: 15.0 MLD 14: 25.0 MLD 16: 25.0 MLD CC7: 9.6 MLD
Total supply	240.6 MLD	139.4 MLD

Source: JICA Study Team

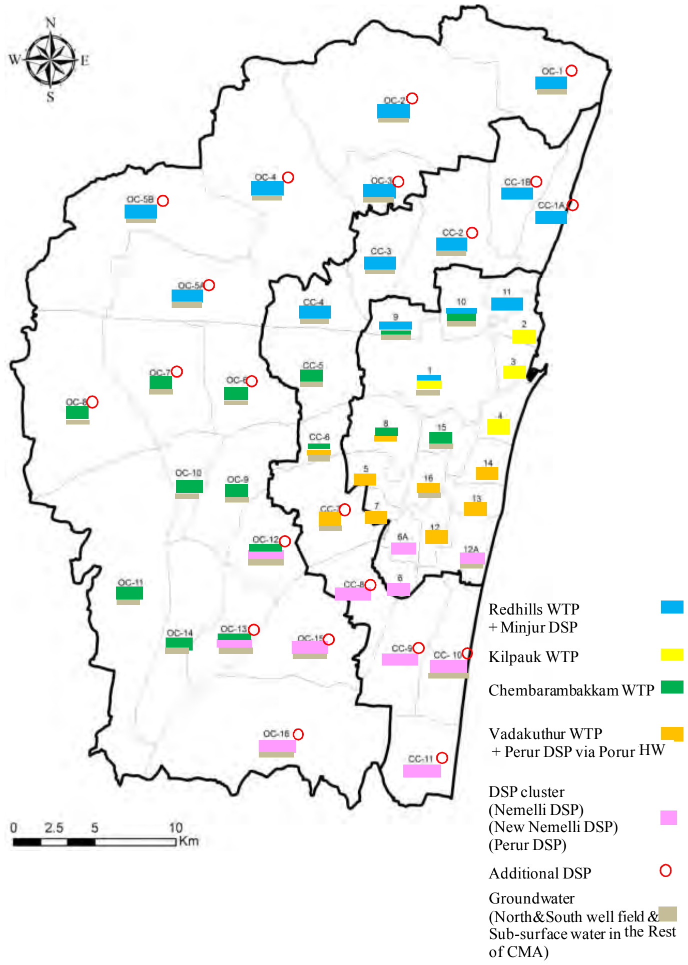
(5) Water allocation plan in 2050

1) Water Allocation in the entire CMA

The total water demand in the CMA will be 3,242 MLD in 2050. The available water volume for the entire CMA in the moderate drought conditions will be increased from 2,630 MLD in 2035 to 3,275 MLD in 2050. The water allocation plan was worked out considering the geographical distribution of water demand and available water (location of WTP and transmission pipeline network). Figure 5.2.7 shows the proposed water allocation in 2050. The detailed water allocation table is presented in Appendix 5.3. Water allocation pattern of 2050 will be almost same as that for 2035. However, more additional DSPs will need to be constructed to meet the increased water demand.

2) Water allocation from the Perur DSP

The planned water allocation from the Perur DSP is also almost the same as of that for 2035, as presented in Table 5.2.3.



Source: JICA Study Team

Figure 5.2.7 Water Allocation in 2050

Table 5.2.3 Water Allocation of Perur DSP in 2050

Transmission route	Directly from through the transmission line extended from the Perur DSP	From Porur HW after the transmission line extended from the Perur DSP
Supply zone No. and supply amount	6: 35.2 MLD 6A: 5.6 MLD CC8: 31.2 MLD OC15: 94.9 MLD OC16: 73.0 MLD	5: 13.7 MLD 7: 6.7 MLD 8: 25.0 MLD 12: 20.1 MLD 13: 15.0 MLD 14: 25.0 MLD 16: 25.0 MLD CC7: 9.6 MLD
Total supply	239.9 MLD	140.1 MLD

Source: JICA Study Team

5.3 Basic Plan of the Perur DSP

5.3.1 Location of the Plant

(1) Area requirement

The plant space needs to accommodate 400 MLD (400,000 m^3/d) desalination plant, seawater receiving pit, product water tank, electric power receiving equipment, warehouse for chemicals and necessary materials for operation, general administration building and parking space, and so forth. Table 5.3.1 presents existing DSPs with capacities of 200 MLD or more in the world and those in Chennai. DSPs to be constructed by Japanese ODA are listed in the table.

From the unit plant space in m^2 per m^3/d, the general land requirement for large-scale DSPs is set at 0.3 – 1.0 m^2/(m^3/d). Therefore, the minimum land requirement for the Perur DSP is calculated at 120,000 m^2 (12.0 ha), and desirably 400,000 m^2 (40 ha) is required.

Table 5.3.1 Land Area of Large Scaled DSPs

Project Name/Location	Country	Plant Status	Plant Capacity (m^3/d)	Plant Space (m^2)	Unit Plant Space $m^2/(m^3/d)$
Nemmeli, Chennai	India	O	250,000*	124,000	0.50
Minjur, Chennai	India	O	100,000	85,000	0.85
El Hamma, Alger	Algeria	O	200,000	51,300	0.26
Mostaganem	Algeria	O	200,000	80,000	0.40
Skikda	Algeria	O	100,000	60,000	0.60
Magtaa	Algeria	O	500,000	200,000	0.40
Port Stanvac	Australia	O	274,000	180,000	0.66
Wonthaggi	Australia	O	444,000	250,000	0.57
Ashkelon	Israel	O	330,000	70,000	0.21
Hadera	Israel	O	368,000	150,000	0.41
Fukuoka	Japan	O	50,000	46,000	0.92
Mamelles	Senegal	P	100,000	39,000	0.39
El Prat del Llobregat	Spain	O	200,000	70,000	0.35
Torrevieja	Spain	O	240,000	70,000	0.29
Sfax	Tunisia	P	200,000	200,000	1.00

* After expansion by 150 MLD
Note: Plant Status: O: under operation, P: Planned
Source: JICA Study Team

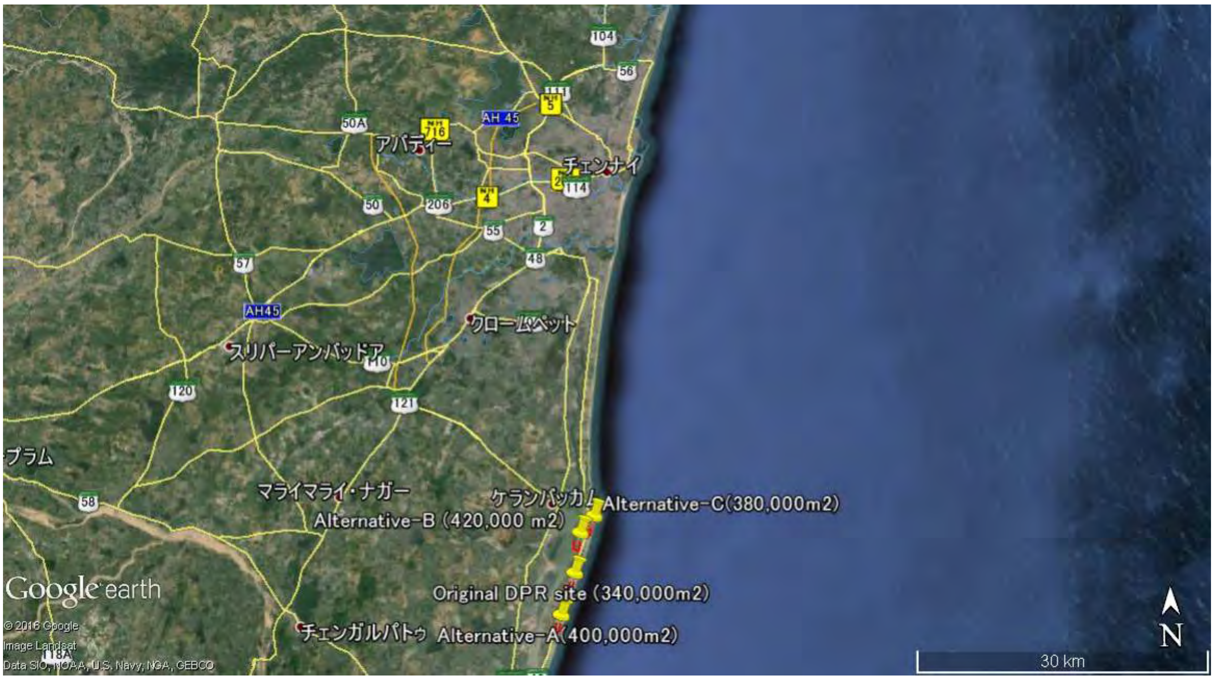
(2) Candidate sites

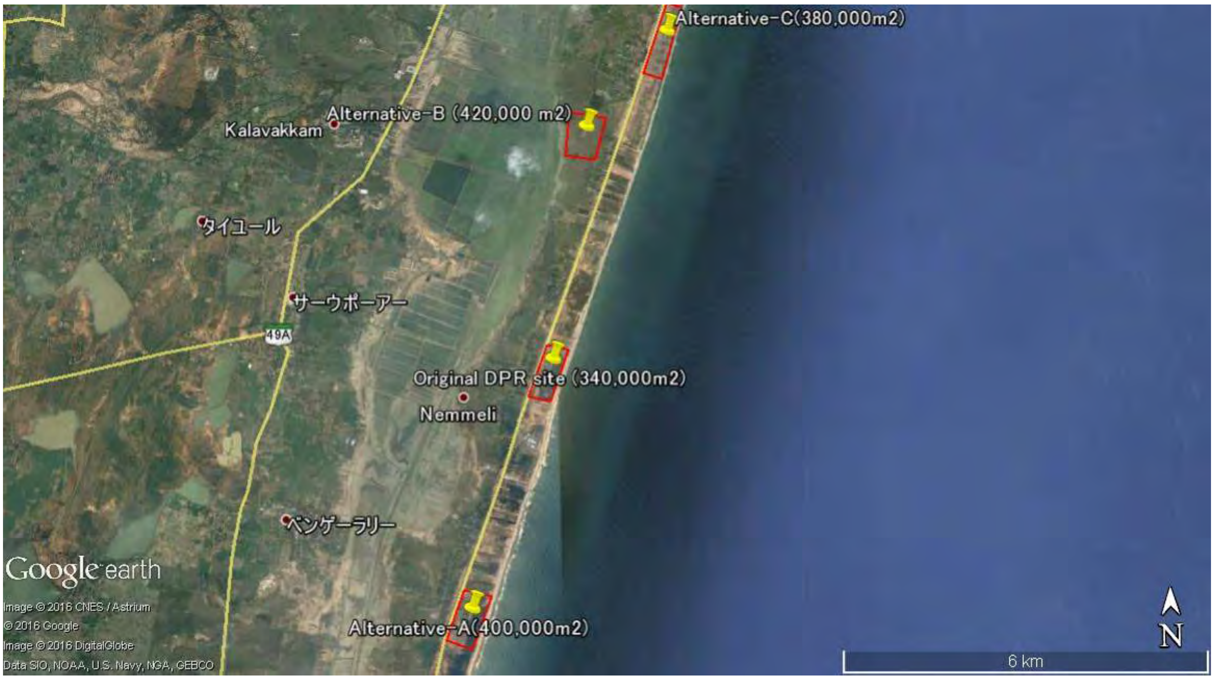
Based on the site reconnaissance and interviews with CMWSSB, JICA Study Team identified three alternative sites other than the original DPR site as shown below and in Figure 5.3.1.

Coastal lands which are closer to the city center will be good alternatives, if available, in terms of efficiency in water transmission. JICA Study Team found there is a vacant land of approximately 35 ha located 8 km north from Alternative C. There are some other vacant lands, which can accommodate the 400 MLD plant, but they are being utilized as beach and are not available to the Project. Locations of the vacant lands, which have not been considered as candidate site, are given in Appendix 5.4.

Among the candidate sites, Alternative A and C, as well as the original DPR site, are owned by a religious and charitable group, M/s Arulmigu Alavandar Nayakkar Trust, which rented the site for the Nemmeli DSP. Alternative B is a private land but currently used for agriculture.

Original DPR site (340,000 m^2)	: Approx. 1km north of existing DSP at Nemmeli
Alternative A (400,000 m^2)	: Approx. 4 km southwest of Original DPR site
Alternative B (420,000 m^2)	: Approx. 3.8 km northeast of Original DPR site 800 m inland from sea shore
Alternative C (380,000 m^2)	: Approx. 5.8 km northeast of Original DPR site





Source: JICA Study Team

Figure 5.3.1 Candidate Sites for the 400 MLD DSP

(3) Selection of the site

1) Evaluation points in the selection

Selection of the best site among the four alternative sites is conducted based on the following criteria:

- Availability of stable and good quality seawater
- Possibility of land acquisition
- Access to the existing power source
- Ground elevation and surface condition (Necessity of large-scale land development for flood

prevention or tree trimming)

- Environmental and social impacts (Necessity of special considerations on social and environment impact by brine discharge on ecosystem, marine activities, etc.)
- Distance to demand centre or main distribution centre
- Other relevant factors (Land shape for layout plan, interaction with other DSPs, etc.)

2) Evaluation of the alternatives

JICA Study Team conducted comparative study on the alternative plant sites as shown in Table 5.3.2. From the land availability and efficiencies in O&M, where collaboration with other DSPs are expected, the original site proposed in the DPR is evaluated as the best site.

Table 5.3.2 Evaluation of the Candidate Sites

Evaluation criteria		Original DPR site	Alternative Sites		
			A	B	C
i)	Availability of stable and good quality seawater	No different conditions are presumed.			
		Good	Good	Good	Good
Be	Possibility of land acquisition	Owned by a trust but agreed on the construction	Same owner as the DPR site	Private land. Moreover intake/discharge lines will be 800 m longer than others, and occupy a land owned by a trust.	Same owner as the DPR site
		Good	Good	Fair	Good
iii)	Access to the existing power source	No different conditions are presumed.			
		Good	Good	Good	Good
iv)	Ground elevation (G.L: ground level above mean sea level)	Half of the lands are covered by plants (need for trimming) but the G.L is about +3.5 to 7.0 m.	Same conditions as the DPR site	It has less plants but the G.L is only 3.0 to 5.0 m	It has less plants but the G.L is only 3.0 m
		34 ha (400 m x 850 m)	40 ha (500 m x 800 m)	42 ha (600 m x 700 m) Around 800m from seaside	38 ha (1,250 m x 300 m)
		Good	Good	Fair	Fair
iv)	Environment impact (Brine discharge, Impact on ecosystem)	No special conditions are presumed.			
		Good	Good	Good	Good
v)	Distance to demand centre or main distribution centre	Farther than Alternative B and C but closer than Alternative A	Farthest from the city	Closest to the city	
		Good	Fair	Excellent	Excellent
vi)	Other factors	O&M can be efficiently done by sharing various resources with the other DSPs nearby.	No special conditions are presumed.	Intake pipe under the trust land may bring about maintenance problem.	Slender shape of the land will give limitation in the layout plan
		Excellent	Good	Fair	Fair
Overall Evaluation		No critical disadvantage and collaboration with other DSPs expected	Farthest from the water supply area	Competitive but occupation of the trust land is problematic	Inferior to the other options in terms of land shape
		Selected	Not selected	Not selected	Not selected

Source: JICA Study Team

5.3.2 Desalination Technologies to be Adopted

The commercial desalination technologies are mainly divided into two technologies as follows.

(1) Reverse Osmosis (RO) Technology

The RO technology is based on membranes which allow fresh water to pass through while ions, the basic elements of salt, are retained. In consequence, the feed water is divided into one stream of pure water (permeate) and one stream containing the rejected ions, called concentrate or brine, which is returned to the sea. The typical recovery ratio, i.e. the permeate flow related to the seawater flow fed into the RO section, is typically 40% to 45%, depending mainly on the sea water salinity and temperature.

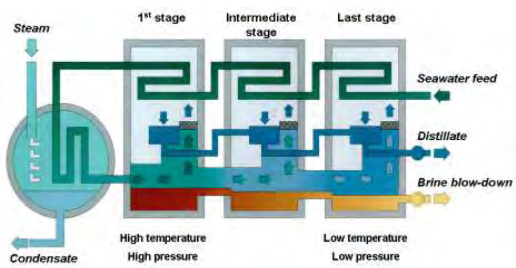
The RO technology requires less energy than other desalination technologies. Therefore, it is more popular in non-oil producing countries since it consumes less energy. Among the membrane processes, the seawater desalination by RO (SWRO) is predominant.

(2) Thermal Technology

1) Multistage flash process

In the multistage flash (MSF) process, the saline water is desalinated by means of evaporation and subsequent condensation. Typically, the heat required for this thermal process is sourced from steam that is extracted from the water-steam cycle of a power plant.

The working principle of an MSF process is shown in Figure 5.3.2. The seawater flow enters the MSF unit at the last, cold stage and flows through the tubular heat exchangers (pre-heater) of all stages into the brine heater. Here, external heat (steam) is used to heat the seawater up to the top brine temperature (TBT). In this condition, the seawater is released to flow back through the flashing compartments of the consecutive stages. The flow pattern, as well as the gradually decreasing pressure in this multi stage arrangement, causes the seawater to boil instantaneously and vigorously (in other words, to flash) upon entering each stage. The vapour generated passes through demisters which condenses on the outside of the pre-heaters, thus transferring the latent heat to the colder seawater. The condensate is collected in distillate trays and withdrawn from the last stage.



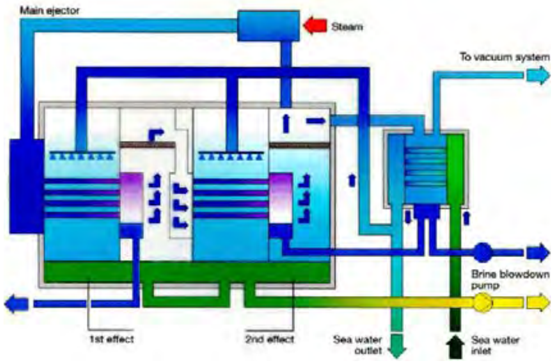
Source: Fichtner

Figure 5.3.2 Working Principle of an MSF Unit (Once through mode)

2) Multiple Effect Distillation Technology

In Multi Effect Distillation (MED) process, the saline water is desalinated by means of evaporation and subsequent condensation as well as MSF process. Typically, the heat required for this thermal process is sourced from externally generated steam.

Basically, the steam produced from seawater in one effect, is used in the subsequent effect for the evaporation of seawater. This procedure is repeated from effect to effect with progressively decreasing temperature and pressure due to temperature differences required for the heat transfer as well as further process and equipment imperfections (like e.g. boiling point elevation due to salinity, pressure drop losses, insulation losses).



Source: Fichtner

Figure 5.3.3 Working Principle of an MED-TVC Unit Technology

(3) Comparison of desalination process

1) Energy Requirements

Table 5.3.3 shows the energy requirements for each process. The table clearly shows that the advantage of the SWRO is less energy consumption at only 10% compared to other processes. The "recovery ratio of RO" means "the percentage of desalinated water against intake volume"

Table 5.3.3 Required Energy for Seawater Desalination by Process

Process	Necessary Power (kWh/m^3)	Necessary calories (kcal/m^3)
RO	3.5	3,010
MSF/MED-TVC	62.9	54,000

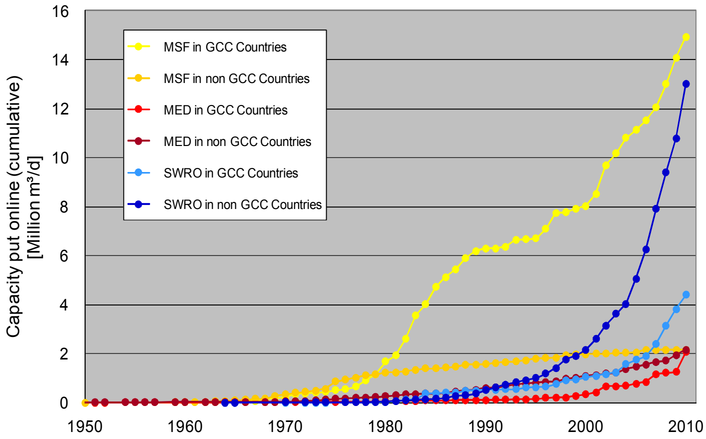
Source: p. 355, Suido Kogaku, Kenji Fujita, et al, 2006

2) Installation of desalination plants throughout the world

At first, the market development shall be discussed on the basis of Figure 5.3.4 showing the cumulative capacity of the main desalination technologies put online and Figure 5.3.5 illustrating the present day online desalination capacity, classified into plant size classes and desalination technologies. In both figures, separate sets of data are shown for the countries of the Cooperation Council for the Arab States of the Gulf (GCC)[1] and Non-GCC countries. Furthermore, both figures refer to desalination plants fed solely by seawater. The data has been generated from the 2010 inventory of desalination plants (GWI: 23rd Inventory 2010, Excel File containing the updated desalination plant inventory, received on Oct. 26th, 2010).

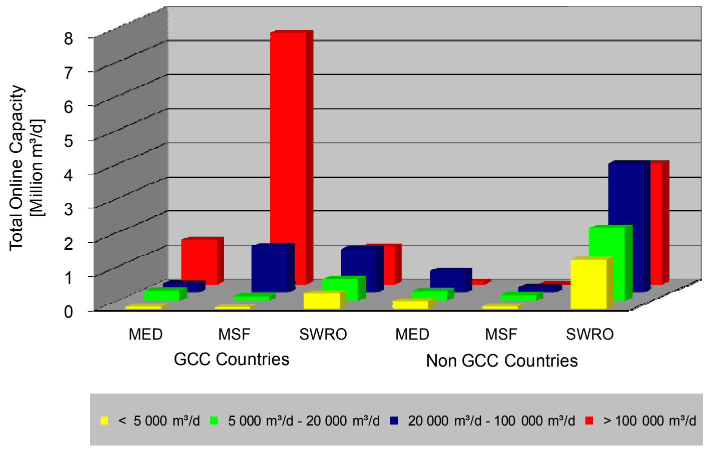
[1] The GCC Countries are: United Arab Emirates, The Kingdom of Bahrain, The Kingdom Of Saudi Arabia, The Sultanate of Oman, Qatar and Kuwait

The figures demonstrate that the past development in the non-GCC countries was different, almost antipodal, to that one in the GCC countries:



Source: Fichtner

Figure 5.3.4 Cumulative Capacity of the Main Desalination Technologies put Online in and Outside the GCC Countries



Source: DesalData

Figure 5.3.5 Online Desalination Plants sorted by Technology and Daily capacity

- In the GCC countries, the MSF technology is by far the dominating desalination technology. This applies to the absolute cumulative capacity as well as for its growth rate. Additionally, the majority (over 80%) of the cumulative MSF capacity is contributed by plants with more than 100,000 m³/d.
- Irrespective of the MSF dominance, both the technologies have gained remarkable momentum in the GCC states: The cumulative SWRO capacity has quintupled from 2000 to 2010; the cumulative MED capacity has sextupled in the same period.
- In the non-GCC countries, the SWRO is playing the same role as the MSF in the GCC countries: it is the dominant technology, representing the largest cumulative capacity and is growing at a rate even higher than the MSF in the GCC countries. Nevertheless, the distribution of the plant sizes is much more balanced compared to MSF plants in the GCC countries; almost one-third of the total online capacity is contributed by plants up to 20,000 m³/d, another third by plants between 20,000 m³/d and 100,000 m³/d, and the last third by plants larger than 100,000 m³/d.
- Contrary to the GCC countries, the MSF is of subordinate importance in the non GCC countries. Since the mid 1990s, there was hardly any increase in the cumulative capacity; the growth in the entire present decade is going to amount to less than 10%.
- The cumulative capacity of the MED technology in the non-GCC countries developed at a comparable constant pace and is found to have (nearly) doubled in the present as well as in the

last decade.

The trends in the above figures are apparently derived from the operation cost. In the GCC countries, where the electricity price is extremely low, MSF and MED can be competitive in the total cost of the capital and running costs, while in non-GCC RO membrane process is by far cost-effective.

3) Selection of desalination process

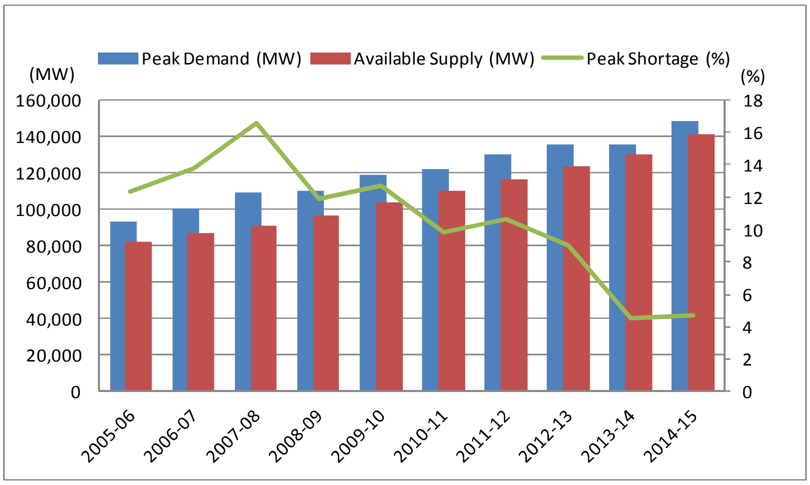
From the recent market trend, the advantage of SWRO in India is evident. The huge capacity of the Perur DSP makes the advantage clearer. Besides, CMWSSB has accumulated experiences in SWRO technologies by the existing two DSPs. As a conclusion, SWRO is the best technology to be adopted in the Perur DSP.

5.3.3 Study on Necessity of Dedicated Power Plant for the Project

The power demand of Perur DSP was estimated at 85 MW in the DPR for the DSP, which is not negligible to Tamil Nadu Electricity Board (TNEB). Thus, if TNEB does not have sufficient power supply capacity, construction of a dedicated power plant can be an option for Perur DSP to secure sufficient power. However, the power plant for Perur DSP would not be required mainly because of the enormous capacities of the expected additional power supply projects and the reliable national grid system of India with interconnections for backup. This subsection explains the detailed reasons for not setting up a power plant.

(1) Current situation of power demands and power supply

As described in Subsection 2.4.2, all India including the Tamil Nadu State faces power shortage. However, this situation has been gradually mitigated in recent years. Figure 5.3.6 presents the historical trend of demand and supply of India for ten years. As shown in the figure, the increasing peak demand has not been satisfied regardless of the augmentation of the power supply capacity, but the percentage of the peak shortage has been steadily decreased. The peak shortage once reached 16.6 % in 2007-08 but since then it has been dropped to 4.7 % in 2014-15.



Source: Annual Report 2014-15 (Ministry of Power) and Load Generation Balance Report 2015-16 (Ministry of Power)

Figure 5.3.6 Demand and Supply of India for Recent 10 years

(2) Demand forecast and power supply plan in the Tamil Nadu State

1) Demand forecast in the Tamil Nadu State

Table 5.3.4 shows the present peak demand and available supply and future peak demand in the Tamil Nadu State. The peak demand and available supply, as of 2012-13, are actual values referred to Vision Tamil Nadu (Vision 2023), which was prepared to set infrastructure development plan until 2023 and was published by the Government of Tamil Nadu. The peak demands in 2021-22 and 2026-27 are predicted data in a planning document of the Central Electricity Authority, one of the governmental institutions in the power sector. According to the projection, peak demand in the Tamil Nadu State will be 29,975 MW in 2021-22 and 43,044 MW in 2026-27 respectively.

Table 5.3.4 Demand forecast in Tamil Nadu until 2027

Year	2012-13*1	2021-22*2	2026-27*2
Peak Demand (MW) ( ): Available supply	12,736 (11,053)	29,975	43,044

*1: Vision Tamil Nadu 2023 (Vision 2023) (Government of Tamil Nadu, February 2014)
*2: 18th report of electric power survey of India (Central Electricity Authority, 2011)
Source: As described above

2) Power supply plan in the Tamil Nadu State

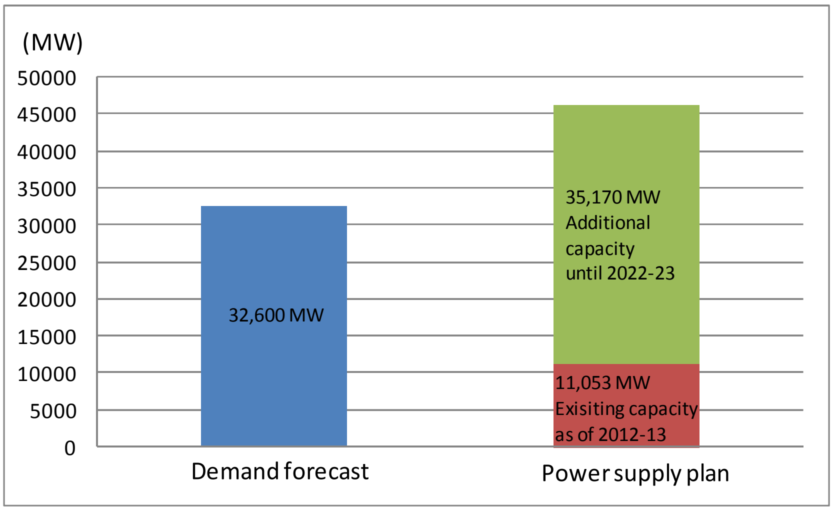
Table 5.3.5 is a list of proposed projects in Vision 2023 to expand power generation capacity. Vision 2023 plans to set additional 35,170 MW including renewable. Thus, as shown in Figure 5.3.7, the available supply including renewable by 2023 would be 46,223 MW based on the existing capacity of 11,053 MW as of 2012-13 and the additional capacity of 35,170 MW.

On the other hand, demand forecast in 2022-23 shown in the figure is calculated at 32,600 MW from the demand forecast for 2021-22 and 2026-27. Therefore, achievement of 65 % of the planned additional capacity will satisfy the forecast demand for 2022-23. 2022 is the expected completion year of the Perur DSP.

Table 5.3.5 Proposed projects in the Tamil Nadu State

No.	Name of the Project	Capacity	Investment	Time Frame
1	North Chennai Thermal Power Project Stage -III	800 MW	Rs. 48 Billion	2017
2	North Chennai Thermal Power Project Stage - IV	1600MW	Rs. 111.55 Billion	2017
3	Ennore Thermal Power Station Expansion	660 MW	Rs. 31.35 Billion	2016
4	Tuticorin Thermal Power Project	800 MW	Rs. 48 Billion	2017
5	Uppur (Thiruvadanai) Thermal Power Project	1600MW	Rs. 96 Billion	2016
6	Udangudi Super Critical Power Project	1600MW	Rs. 90.83 Billion	2017
7	Udangudi Expansion	800 MW	Rs. 48 Billion	2018
8	Ennore Thermal Power Station Replacement	660 MW	Rs. 36 Billion	2018
9	Cheyyur Ultra Mega Power Project	4000 MW (Tamil Nadu share 1600 MW)	Rs. 192 Billion	2020
10	New project - Thermal Power Project - Location to be identified	800MW	Rs. 48 Billion	2017
11	New project - Thermal Power Project - Location to be identified	800MW	Rs. 48 Billion	2017
12	Chattisgarh - MTMTEL	2000 MW (Tamil Nadu share 1000 MW)	Rs. 48 Billion	2017
13	Jayamkondan Lignite Power Project	1500 MW	Rs. 60 Billion	2020
14	Private Sector Power Generation projects	2000 MW	Rs. 100 Billion	2020
15	R-LNG based Gas Turbine Power Plant	1000 MW	Rs. 40 Billion	2017
16	Kundah Pumped Storage Hydro Electric Project	500 MW	Rs. 15 Billion	2017
17	Sillahalla Pumped Storage Hydro Electric Project	2000 MW	Rs. 69.14 Billion	---
18	Velimalai Pumped Storage Hydro Electric Project	200 MW	Rs.12 Billion	---
19	Kolimalai Hydro-electric project	20 MW	Rs. 2.58 Billion	2017
20	Periyar Vaigai Small hydroelectric projects	30 MW	Rs. 2.4 Billion	2018
21	Solar Power Generation Programme	5000 MW	Rs. 500 Billion	2020
22	Offshore Wind Power Generation Programme	200 MW	Rs. 25 Billion	2020
23	Onshore Wind Power Generation Programme	10,000 MW	Rs. 600 Billion	2020
TOTAL		38,570 MW (Tami Nadu share 35,170 MW)	Rs. 2,271.85 Billion	

Source: Vision Tamil Nadu 2023 (Government of Tamil Nadu, February 2014)



Source: JICA Study Team

Figure 5.3.7 Power supply plan as of 2022-23 in the Tamil Nadu State

(3) Demand forecast and power supply plan in India

1) Demand forecast in India

Table 5.3.6 shows demand forecast in India until 2022 referred to a report of the Ministry of Power. The peak demand and the available supply as of 2011-12 are actual values. According to the forecast, peak demand in India will be 197,686 MW in 2016-17 and 289,667 MW in 2021-22. The peak demand in 2021-22 will be more than twice the peak demand in 2011-12.

Table 5.3.6 Demand Forecast in India until 2022

Year	2011-12	2016-17	2021-22
Peak Demand (MW) ( ): Available supply	130,006 (116,191)	197,686	289,667

Source: Report of the working group on power for twelfth (2012-17) (Ministry of Power, 2012)

2) Power supply plan in India

Table 5.3.7 is the generation plan for 2016-17 and 2021-22 in all India. Total additional capacity including renewables and imports until 2016-17 will be 95,485 MW and that of capacity for 2017-18 to 2021-22 will be 123,900 MW. Import of 1,200 MW is expected from Bhutan. Thus, total additional capacity for 2012-13 to 2021-22 is 219,385 MW.

From the additional capacity above and the available supply of 116,191 MW as of 2011-2012, the total available supply for 2021-22 will be 335,576 MW, while the demand forecast for the same years is 289,667 MW. Therefore, the power supply plan in India is evaluated to have been properly planned to satisfy the power demand. Even if the achieved additional capacity is only 80 % of the plan, the total amount of capacity will satisfy the peak demand in 2021-22.

According to the plan of the Ministry of Power, there will be no power shortage in the country as a whole even in 2016-17, although power demand and supply balance limited to some states will be negative. In such a situation, interconnections between the states will be able to satisfy the power demand in the entire India.

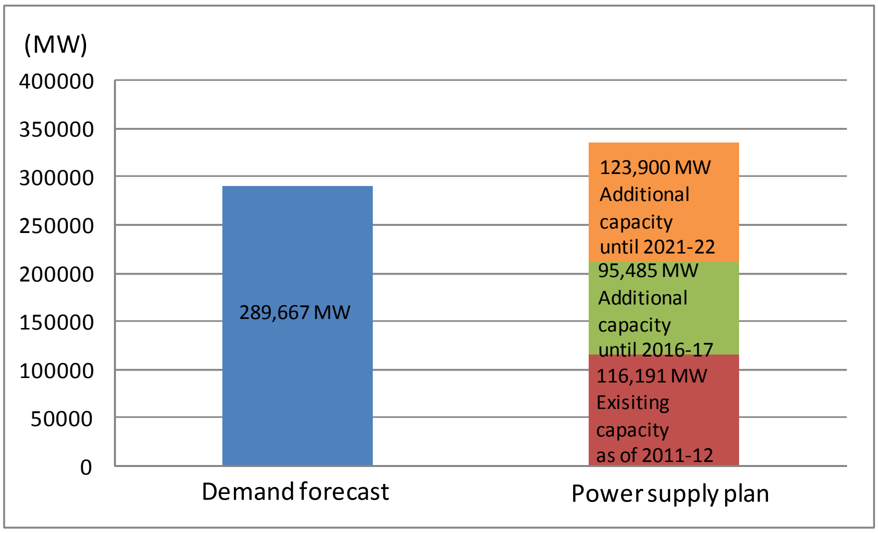
In India, the Power System Operation Corporation Ltd. (POSOCO) is responsible for supervision and coordination of the national grid. The POSOCO has a National Load Despatch Centre (NLDC), five Regional Load Despatch Centres (RLDCs) and 33 State Load Despatch Centres (SLDCs). The NLDC is assigned to supervise the RLDCs, to monitor grid security of the national grid and so on. The RLDCs are assigned to control the inter-state transmission systems, to be responsible for optimum scheduling of electricity within the region and so on. The SLDCs are assigned to keep accounts of the quality of electricity transmitted through the State grid, to be responsible for optimum scheduling of electricity within a State and so on.

In case that the Tamil Nadu State faces power shortage, the SLDC Chennai in the Tamil Nadu State will approach the Southern Regional Load Despatch Centre (SRLDC) as one of the RLDCs located in Bangalore, the Karnataka State, and the SRLDC will arrange power supply through the southern regional grid. In addition, in case of power shortage in the southern region, the NLDC will try to arrange additional power supply through the national grid.

Table 5.3.7 Power Generation Plan in India

Type of Capacity	2016-17	2021-22
	Capacity addition planned (MW)	
Thermal	63,781	63,400
Hydro	9,204	12,000
Nuclear	2,800	18,000
Total	75,785	93,400
Renewables	18,500	30,500
Wind	11,000	11,000
Small hydro	1,600	1,500
Biomass	2,100	2,000
Solar	3,800	16,000
Imports	1,200	---
Total with Renewables and imports	95,485	123,900

Source: Report of the working group on power for twelfth (2012-17) (Ministry of Power, 2012)



Source: JICA Study Team

Figure 5.3.8 Power supply plan as of 2021-22 in India

(4) Assessment of the reliability of the proposed power generation projects in India

The description above mentioned that if the additional capacity in India achieves 80 % of the intended capacity, the total power supply capacity will satisfy the national peak demand in 2021-22. Table 5.3.8 shows the expected additional capacity and actual achievement by power supply capacity from 2007 to 2012 in India. From this table, the Indian power sector has achieved 76 % of the planned project by additional capacity during the years. According to the result of this table, achievement of 80 % expected is considered to be realistic value. It is evaluated that sufficient power supply capacity to Perur DSP will be secured.

Table 5.3.8 Planned and Achieved Additional Capacity of Power Generation in India for 2007 to 2012

Year	Target (MVA)	Actual (MVA)
2007-08	12,039	9,263
2008-09	7,530	3,454
2009-10	14,507	9,585
2010-11	20,359	12,161
2011-12	17,601	20,502
Total	72,036	54,964
Total added capacity against target		76 %

Source: Power scenario at a glance (Central Electricity Authority, 2012)

(5) Conclusion on necessity of new power plant

Analysis on the future power demand and supply balance in this subsection is summarized as below;

- In the Tamil Nadu State, as explained in Subsection 2.4.2, the current shortage of the power supply against the peak demand is only 0.6%. It is much better than the shortage in the entire

India (3.2%). The current gap between the power demand and supply is subtle in the state.

- In the Vision 2023 by the Tamil Nadu State, the state plans to construct power plants with sufficient capacity against the power demand in the state. Achievement of only 65% of the planned additional capacity will satisfy the power demand in the state in 2022-23.
- At the national level, the government has the plan to overcome power shortage by constructing a new plant of sufficient capacity and import one from abroad. Achievement of only 80 % of the original plan for the additional supply capacity will satisfy the power demand in the country in 2021-22.
- Even if the Tamil Nadu State faces power shortage, the southern regional grid or the national grid will function as a backup to maintain the sufficient power supply.

From the above analysis, the power supply by TNEB is evaluated to be robust. Therefore, the power plant for the Perur DSP is not required.

5.4 Basic Plan of the Transmission System

5.4.1 Basic Concept of the Transmission System

(1) Schematic of the transmission system

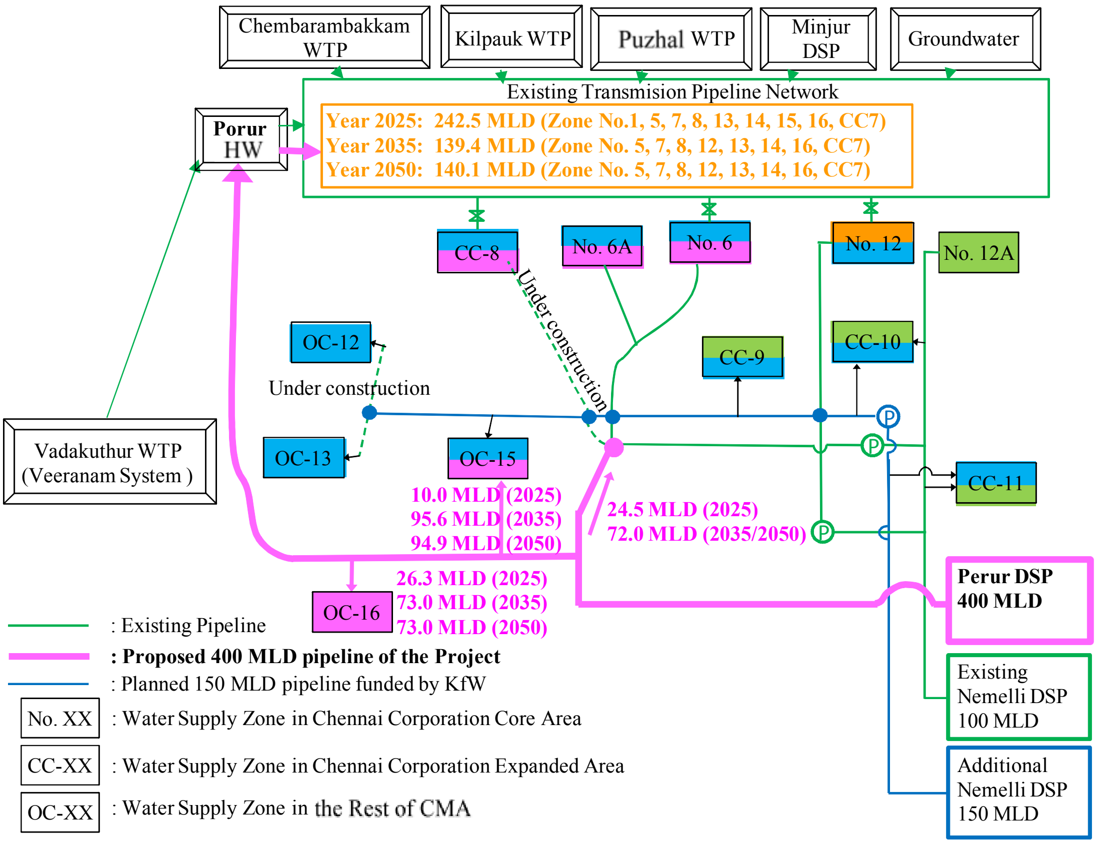
Based on the water allocation plan described in Subsection 5.2.3, the product water from the Perur DSPs will be transmitted mainly to the southern part of CMA, as well as the core area via Porur HW. Table 5.4.1 shows the proposed water supply zone from the DSPs.

Table 5.4.1 Water Supply Zones to be supplied from the DSPs

DSP	Transmission Route	Water Distribution Zone	
		2025	2035/2050
Nemelli DSP (100MLD)	Existing transmission line	12A, CC9, CC10, CC11	12A, CC10, CC11
Additional Nemelli DSP (150MLD)	New transmission line by the additional Nemmeli DSP Project and existing transmission line	6, 6A, 12, CC8, CC9, OC12, OC13, OC15	CC9, CC10, CC11, OC12, OC13, C15
Proposed Perur DSP (400MLD)	New transmission line by the Project and existing transmission line	6, OC15, OC16	6, 6A, CC8, OC15, OC16
	New transmission line by the Project to Porur HW, thereafter existing transmission line	1, 5, 7, 8, 13, 14, 15, 16, CC7,	5, 7, 8, 12, 13, 14, 16, CC7

Source: JICA Study Team

The required function of the transmission system is to deliver the product water to the above water supply zones. Figure 5.4.1 shows the schematic diagram of the transmission system of the DSPs.



Source: JICA Study Team

Figure 5.4.1 Schematic of Water Transmission System from the DSPs

As shown in Figure 5.4.1, the proposed 400 MLD transmission pipeline starts from the Perur DSP and ends at Porur HW. On the way to Porur HW, water from the Perur DSP will be partly diverted to the following zones:

- Zone No.6&No.6A via existing D800 pipeline
- Zone CC-8 via planned D800 pipeline (under construction)
- Zone OC-15 and OC-16 via bulk supply point

The remaining water will be sent to the underground reservoir (UGT) to be constructed in the premises of Porur HW. Then it will be sent to the existing WDS of zone No.1, No.5, No.7, No.8, No.12, No.13, No.14, No.15, No.16, and CC-7 via the existing transmission pipeline network.

(2) Target year in the plan of the transmission system

In the Project, the transmission system will be planned to cater for the water demand up to the year 2035. After 2035, additional transmission system(s) will be necessary to satisfy the water demand in the influence area of the Perur DSP. The additional system(s) will be provided when other water sources such as additional DSP are constructed.

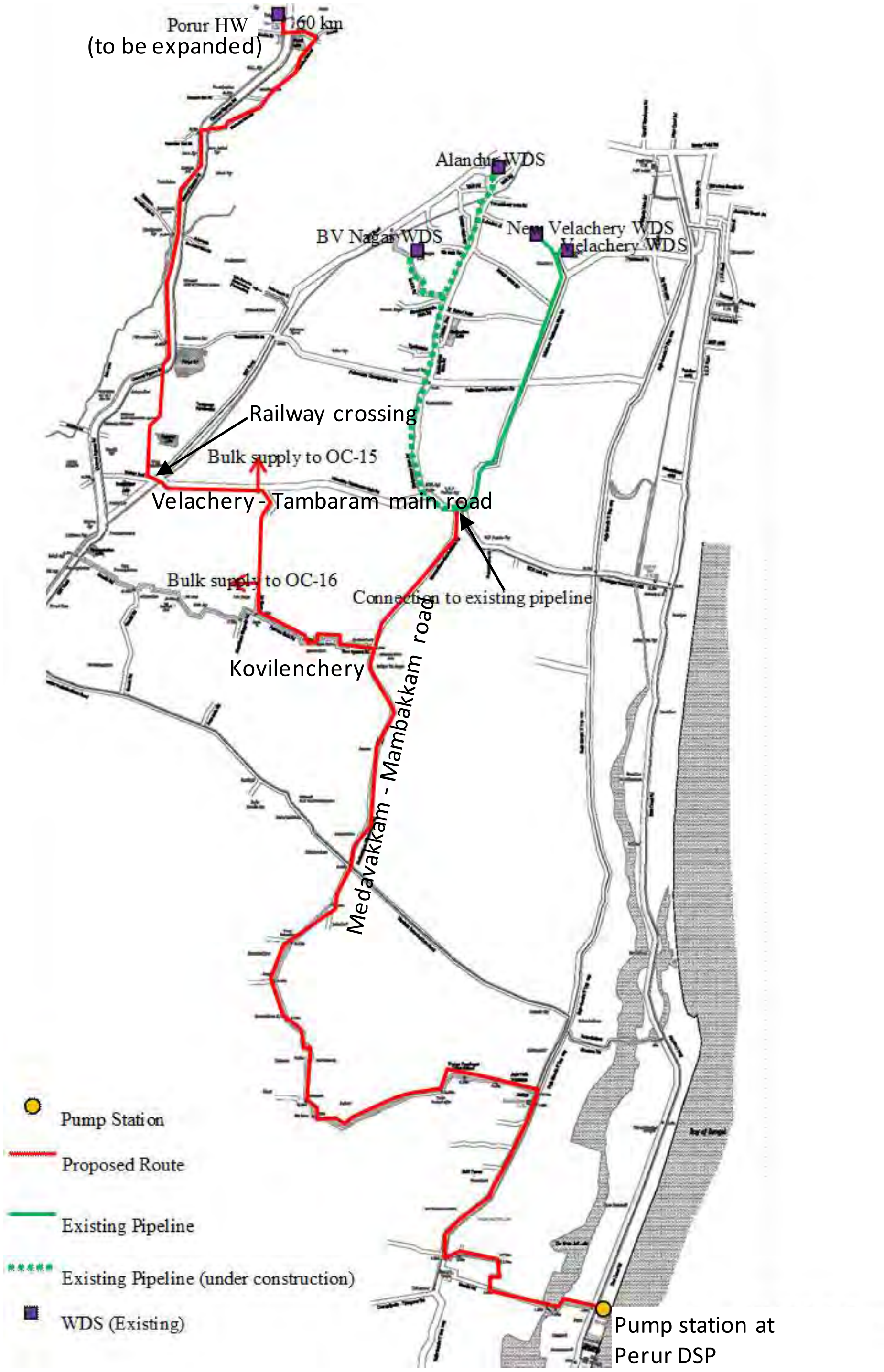
5.4.2 Proposed Plan of Transmission

(1) From Perur DSP to Porur HW

To realize the above basic concept, a new transmission pipeline will be constructed from Perur DSP to Porur HW. On the way, at Kovilanchery, which is approximately 30 km from Perur DSP, a branch line will be constructed that will extend along Medavakkam - Mambakkam road up to the junction of Velachery - Tambaram main road, where the extended pipeline is connected to the existing transmission pipeline, to send water to Zone No.6 & No.6A (Velachery WDS and New Velachery WDS) and Zone CC-8 (Alandur WDS and BV Nagar WDS).

On the way before crossing the railway, tapping points for bulk supply to Zones OC-15 and OC-16 will be constructed. A chamber with a tee, valves and a flow meter will be constructed as an accessory of the transmission line. The diverted water will flow into the reservoirs in the bulk supply areas. The remaining amount of the water will be transmitted to Porur HW.

Figure 5.4.2 shows the outline of transmission facility from Perur DSP to Porur HW.



Source: JICA Study Team

Figure 5.4.2 Outline of the Transmission Facility (Perur DSP to Porur HW)

(2) Porur HW to WDSs in the corporation area

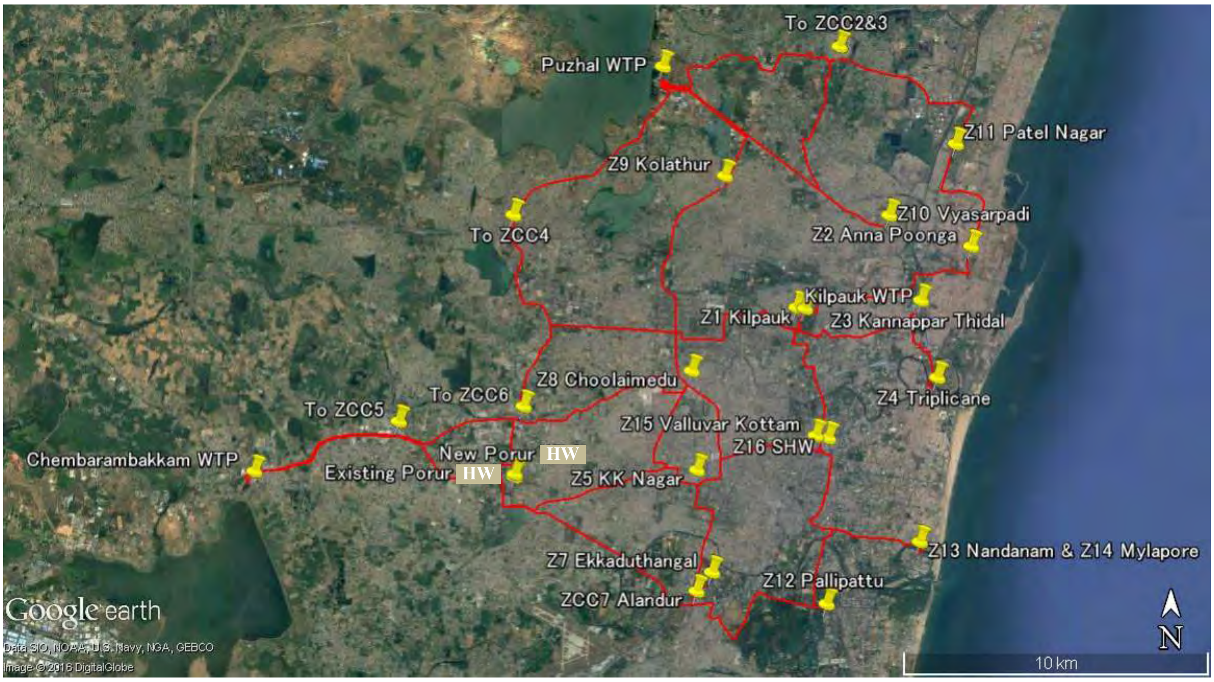
1) General configuration of the transmission system

From Porur HW, as described in Subsection 5.2.3, the water will be sent to the WDSs in the Core City area through the existing transmission network. In the premises of Porur HW, which is currently receiving the water from Vadakuthu WTP, additional reservoirs and a pump station will be constructed in the Project to cater for the additional water from the Perur DSP. The HW has sufficient vacant land already secured by CMWSSB.

Between 2004 and 2007, CMWSSB implemented augmentation of the transmission network, and the current characteristics as shown in Appendix 3.5. The existing WDSs are interconnected by the transmission lines as shown in Figure 3.3.6.

2) Hydraulic modeling for analysis on the capacity of the existing transmission network

To study the necessary water transmission scope in the Project, the capacity of the existing transmission network needs to be examined to determine whether it is capable of delivering the additional water from the Perur DSP to the WDSs. For the examination, a hydraulic analysis by a common hydraulic modeling and design software, EPANET, was performed on the entire transmission network in the corporation area. The network model as shown in Figure 5.4.3 was made by the JICA Study Team by combining the information from the CMWSSB's inventory data on the existing pipelines and WDSs and information presented in the M/P. The water inflows at WTPs and outflow at the WDSs were determined in accordance with the water allocation plan in subsection 5.2.3. The pump head at WTPs were determined based on the information presented in the M/P. The pump head at new Porur HW was assumed to be same as of existing Porur HW, i.e. 25m.



Source: JICA Study Team

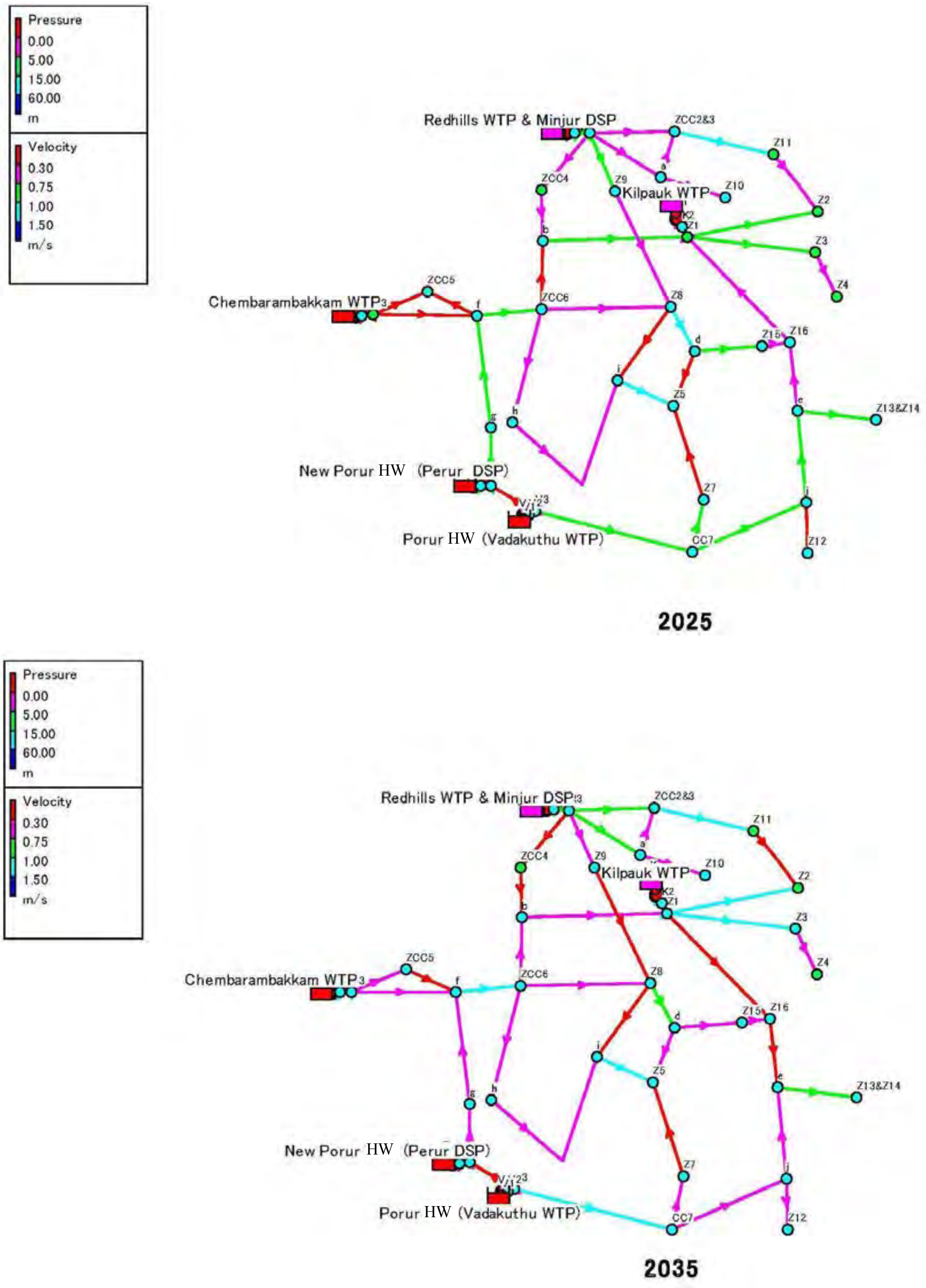
Figure 5.4.3 Network Model of the Existing Transmission Network in the Chennai Corporation Area

3) Capacity of the existing transmission system

Figure 5.4.4 shows the results of the hydraulic analysis on the water demand conditions for the year 2025 and 2035. The input and output data can be confirmed in Appendix 5.5.

As shown in Figure 5.4.4, the water pressures at all WDSs, which are modelled as the nodes, are more than 5 m above ground level, and the pressures at the most WDSs are more than 10 m above ground level in both the 2025 and 2035 conditions. The HWL of UGT of WDS is below GL+1.5 m. So, it can be said that the existing transmission network has sufficient transmission capacity for 2025 and 2035 demands in the corporation area.

As a conclusion, the existing transmission network from the Porur HW will have sufficient capacity to deliver the production from the DSP to the WDSs in the Corporation. Except for the additional reservoirs and a pumping station at Porur, no scope is necessary in the Project on the existing transmission system in the Corporation.



Source: JICA Study Team

Figure 5.4.4 Transmission Network Analysis Results

5.5 Study on the Distribution Components in the Project

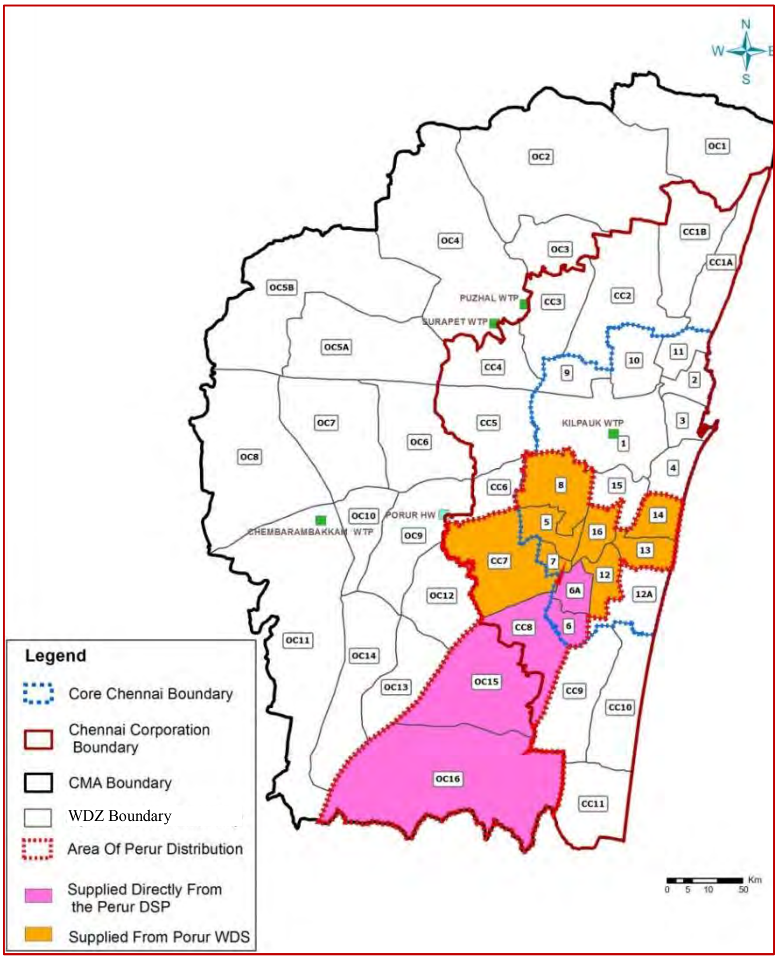
5.5.1 Development Status of the Water Supply Schemes in the Distribution Area of Perur DSP

(1) General

As described in Subsection 3.3.6, the Chennai Core City is divided into 18 water distribution zones (WDZs). Each WDZ has a water distribution station (WDS), which has reservoir and pumps to distribute the water to the WDZ. At present, the interconnections among the WDZs are usually used. Therefore, the WDSs are not physically independent from each other.

Regarding the other areas, as explained in Subsection 4.5.2, M/P has recommended the development of 11 WDZs in the Expanded Area and 16 WDZs in the Rest of CMA but the WDZs have not been established.

Figure 5.5.1 shows the existing and planned WDZs in the M/P. It also presents the influence area of the Perur DSP, referring to Section 5.2. The influence area will cover Zones No. 5, 6, 6A, 7, 8, 12, 13, 14, and 16 in the Core City; CC-7 and CC-8 in the Expanded Area of the Corporation; and OC-15 and OC-16 in the Rest of CMA.



Source: JICA Study Team

Figure 5.5.1 Influence Area of the Perur DSP

(2) Chennai Core City

Table 5.5.1 shows the existing WDZs in the Core City, and the colors indicate the zones to be influenced by the Perur DSP. All 18 WDZs have the existing water supply networks that cover the respective zones in the Core City.

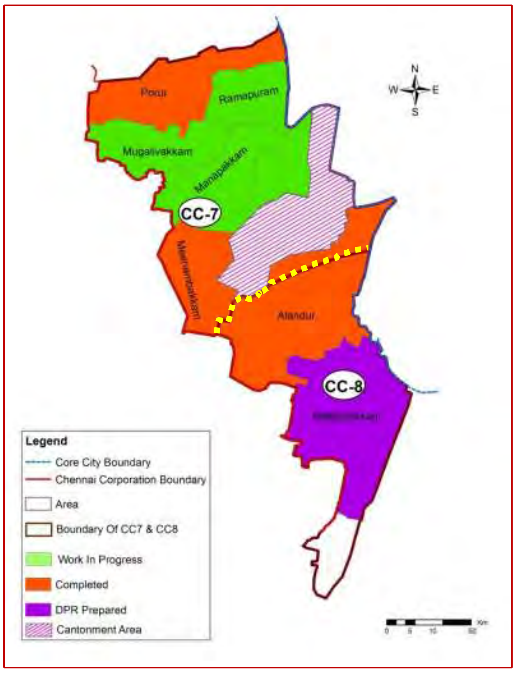
Table 5.5.1 List of WDZ in the Core City Regarding Influence by the Perur DSP

Zone No.	Head Works Location	Zone No.	Head Works Location
1	Kilpauk Pump Station (KPS)	9	Kolathur
2	Anna Poonga	10	Vyasarpadi
3	Kannappar Thidal	11	Patel Nagar
4	Triplicane	12A	Thiruvanmiyur
5	KK Nagar (Old & New)	12	Pallipattu
6	Velachery	13	Mylapore
6A	Velachery-New	14	Nandanam
7	Ekkaduthangal	15	Southern Head Words
8	Choolaimedu	16	Valluvar Kottam

: To be supplied directly from the Perur DSP through the product water transmission main
: To be supplied from the Perur DSP through the Porur HW

Source: JICA Study Team

(3) Expanded Area



*: Cantonment Area is a bulk supply area, whose water distribution network is owned by the army.
Source: JICA Study Team

Figure 5.5.2 Development Status of Water Distribution Networks by CMWSSB in CC-7 and CC-8

The development status of the water distribution networks in the Zones CC7 and CC8, which consist of nine (9) ULBs as presented in Table 5.5.2, and the status of the progress of water distribution networks in these ULBs are presented in Figure 5.5.2. It is noted that a part of Alandur Municipality is covered in both Zones CC7 and CC8.

Before the merger of the ULBs in the Corporation in 2011, ULBs used to construct and operate the water distribution networks in respective areas. After the merger, CMWSSB started to expand their water distribution networks to these areas and has completed the networks in four (4) ULBs (Porur, Meenambakkam, Alandur, and Ullagaram-Puzhudhivakkam) out of nine (9) ULBs. After construction of the new networks by CMWSSB, existing networks developed by the ULBs have been abandoned. Further, CMWSSB is implementing development of the water distribution networks in four (4) other ULBs. The new network construction has not commenced only in one (1) ULB, but it is planned to be constructed by CMWSSB with the "Chennai Mega City Development Fund". Therefore, all ULBs in CC7 and CC8 will have new distribution networks developed by the CMWSSB before the completion of the Perur DSP.

All projects by CMWSSB for water distribution networks in the Expanded Area have been planned after the expansion of the Corporation was determined. The JICA Study Team reviewed the DPRs of these projects and confirmed that the distribution networks were designed to achieve 150 LPCD.

Table 5.5.2 Development Status of Water Distribution Networks by CMWSSB in CC-7 & CC-8

Name of the Area	ULB category	Distribution Status	Distribution Main Length (km)	Fund used for
Zone :CC7: to be supplied by the Perur DSP through the Porur HW				
Porur	Town Panchayat	Completed	48.55	JNNURM*1
Ramapuram	Village Panchayat	Under construction (by 2018)	59.16	TUFIDCO*2
Manapakkam	Village Panchayat	Under construction (by 2018)	24.20	TUFIDCO*2
Nandambakkam	Town Panchayat	Under construction (by 2018)	9.21	TUFIDCO*2
Meenambakkam	Town Panchayat	Completed	1.81	CMCDF*3
Mugalivakkam	Village Panchayat	Under construction (by 2018)	63.85	TUFIDCO*2
Alandur (part)	Municipality	Completed	71.52	JNNURM*1
Zone :CC8: to be supplied from the Perur DSP through the product water transmission main				
Alandur (part)	Municipality	Completed	72.90	JNNURM*1
Ullagaram-Puzhudhivakkam	Municipality	Completed	77.89	JNNURM*1
Madippakkam	Village Panchayat	DPR completed	88.80	CMCDF*3

*1: JNNRUM : Jawaharlal Nehru National Urban Renewal Mission, Govt. of India Fund
*2: TUFIDCO : Tamil Nadu Urban Finance and Infrastructure Corporation, TN State Govt. fund
*3: CMCDF : Chennai Mega City Development Fund, TN State Govt. fund
Source : JICA Study Team based on DPRs and Status of construction works from CMWSSB

(4) Rest of CMA

The water supply services in the Rest of CMA are being conducted and managed by respective ULBs. At present, CMWSSB provides bulk water supply to seven (7) municipalities in the Rest of CMA. In the influence area of the Perur DSP (OC-15 and OC-16), only Pallavaram Municipality is included as bulk water supply receiver. CMWSSB is not involved in the operation of the distribution networks in the bulk supply municipalities.

The list of ULBs covered in OC-15 and OC-16 is shown in Table 5.5.3; it comprises two (2) municipalities, four (4) town Panchayats, and two (2) Panchayat unions[2]. Except in Pallavaram Municipality, the primary water source of all other ULBs is groundwater.

[2] Panchayat Union is a group of village panchayats.

Table 5.5.3 List of ULBs in OC-15 and OC-16

Zone: OC-15			Zone: OC-16		
Name of ULB	Type of ULB	Population in Census 2011 (in thousand)	Name of ULB	Type of ULB	Population in Census 2011 (in thousand)
Chitlapakkam	Town Panchayat	38.0	Madambakkam	Town Panchayat	31.7
Sembakkam	Town Panchayat	45.4	Agaramthen	St. Thomas Mount Panchayat Union	4.2
Koilambakkam	St.Thomas Mount Panchayat Union	27.4	Arasankalani		1.1
Kulathur		6.3	Kasbapuram		2.6
Medavakkam		29.7	Kovilancheri		1.3
Moovarasampettai		9.7	Maduraipakkam		1.0
Nanmangalam		18.6	Meppedu		0.0
Perundavakkam		0.0	Mulacheri		0.1
Tirusulam		14.1	Ottiyambakkam		2.1
Pallavaram-Part	Municipality	(215.4)	Perumbakkam		24.6
Tambaram-Part	Municipality	(174.8)	Sithalapakkam		13.5
			Thiruvancheri		3.4
			Vengaivasal		13.7
Total population			Vengapakkam		2.8
			Kolapakkam	Kattankulathur Panchayat Union	8.0
OC-15		579.4	Nedungundram		14.4
			Vandalur		16.9
OC-16		175.2	Puthur		2.7
			Kilambakkam		5.2
Total		754.6	Peerkankaranai-Part	Town Panchayat	25.9
			Tambaram-Part	Municipality	(174.8)

Source: JICA Study Team (Population is from Census 2011)

CMWSSB develops distribution networks on behalf of the ULBs as deposit work if they receive request of ULBs. In such cases, CMWSSB will just construct the water distribution networks with ULB funds and handover to the ULBs.

The current development status of water distribution networks in the municipalities in OC-15 and OC-16 is presented in Table 5.5.4. At present, CMWSSB is constructing water distribution network in Pallavaram municipality. The distribution network after construction (expected to be completed by 2017) will be handed over to the municipality. Along with the network construction, CMWSSB has a plan to meet the water demand in the municipality by installing a new pipeline of 1,200 mm MS pipe with a length of 21.9 km from Poonamalle to Tambaram, with a capital cost of INR 689.3 million using “Infrastructure and Amenity Fund” (I&A fund). This project will augment water transmission capacity from Chembarambakkam WTP to the municipality and was completed during December 2016 but yet to be commissioned due to the present low surface water storage volume.

Tambaram, which is the other municipality covered in OC-15 & OC-16 in the Rest of CMA, has existing water supply distribution network. Water supply improvement scheme was undertaken by the ULB in the year 2008 for a total cost of INR 322.0 million using JnNURM[*2], Government of India funds. The improvements included construction of storage facilities, pumping stations and pipelines.

In the other ULBs, the existing distribution networks are being managed by ULBs, but there is no comprehensive database to identify the coverages, capacities, ages, etc.

Table 5.5.4 Development Status of Water Distribution Networks in the Rest of CMA

Name of the Area	ULB category	Development Status	Distribution Main Length (kM)	Fund
Zone :OC-15 & OC-16				
Pallavaram - Package-1	Municipality	Under Construction (2017) (The municipality is receiving bulk supply from CMWSSB)	81.17	TNUDP-III*1
Pallavaram - Package-2			94.21	
Pallavaram - Package-2			40.21	
Tambaram	Municipality	Existing distribution network and water supply improvements have been carried out in 2007.	-	JnNURM*2, GoI fund
Others	Towns, Villages	ULBs would have developed distribution networks but information on the ages, capacities materials are not available.	-	-

*1: TNUDP-III – Tamil Nadu Urban Development Project (Assisted by World Bank)
*2: JnNURM : Jawaharlal Nehru National Urban Renewal Mission
Source: JICA Study Team based on interview to CMWSSB

5.5.2 Analysis of Capacity of the Existing Water Distribution Networks and the Storage Capacities

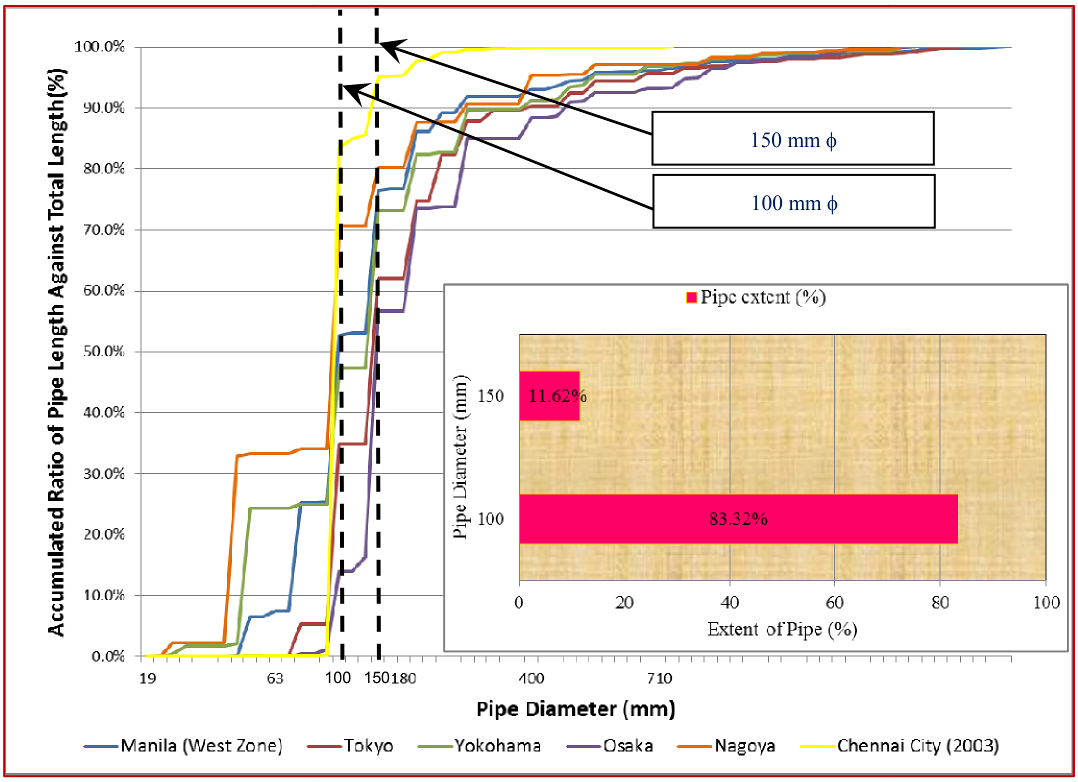
(1) Adequacy of the water distribution networks in the Core City

1) Overall analysis by pipe diameter

The water distribution networks in the Core City were designed by Kirloskar consultants in a Detailed Project Report (DPR) entitled “Detailed Engineering Design of Water Distribution System for Chennai City”, September 1998 (hereinafter, Kirloskar Report). Kirloskar Report was prepared for the target year 2021 to provide a comprehensive design for a project of new distribution stations and networks along with improvements to the existing water supply system in the Chennai Core City (hereinafter, II Chennai Project).

According to CMWSSB, the water distribution networks in the Core City have been upgraded mainly in the II Chennai Project based on the Kirloskar Report. Based on the existing pipe diameter data from the field data books of 2003, as shown in Figure 5.5.3, where the accumulated ratio of pipe length against total length (%) by the pipe diameter has been plotted, there is little pipe (3.04 km, equivalent to 0.13% if the total pipe length) having a diameter smaller than 100 mm in the Core City. Considering that the minimum diameter in the Kirloskar Report was 100 mm, the diameter distribution from the field data books supports the CMWSSB’s explanation that the existing networks have been developed according to the Kirloskar Report.

Figure 5.5.3 also shows the same figures for the existing distribution network data of Manila (west zone), Tokyo, Yokohama, Osaka, and Nagoya for reference. The water distribution networks in the Chennai Core City highly depend on 100 mm pipes than the other mega cities, and on the other hand the shares of 150 mm and 200 mm diameter pipes are extremely lower. Compliance of the minimum diameter of 100 mm is evaluated as high grade compared to the other cities, but the high dependence on 100 mm implies some deficiency in the hydraulic capability of the water distribution networks in the Core City.



Source: JICA Study Team based on field data books of 2003, Annual Reports of Water Works Bureaus of Tokyo, Yokohama City and Nagoya City, Preparatory Survey on Water Supply and Sewerage Development in the West Zone of Metro Manila (2010)

Figure 5.5.3 Pipe Diameter Distribution in the Chennai Core City and Comparison with Other Mega Cities

2) Hydraulic analysis by WDZ

The total water demand forecasted in the Kirloskar Report for the year 2021 was 942 MLD for the Core City while the water demand by the JICA Study Team for 2035 is 904 MLD. On a simple comparison of the water demands, the existing water distribution networks may have adequate capacity to cater to the water demand in the Study for 2035, which is the middle term target year of the M/P. However, the water distribution networks in the respective WDZs may not have sufficient carrying capacities for the water demands for 2035 in the Study. To examine the hydraulic capacities of the existing water distribution networks, the JICA Study Team has conducted a preliminary hydraulic assessment of the networks for the 18 WDZs in the Core City.

As a result of the assessment, the residual pressure at the farthest points from the WDSs in the Zones-5, 8,10,12 and 16 are expected to be lower than 10 m by the year 2035. Furthermore, Zone-13 will be the additional area of low pressure for the water demand in 2050 (See Subsection 6.7.1 for the conditions and results of the hydraulic assessment). Minimum residual pressure as per the CPHEEO Manual is "7m" at the taps, but it is suggsted to design the distribution networks to ensure 10 m at the critical points to achieve the "7 m" at the taps.

3) Necessity of hydraulic reinforcement of the existing water distribution networks in the Core City

From the hydraulic analyses, the JICA Study Team deems that the reinforcement of the existing water distribution networks will be necessary in the WDZs, where the existing networks do not meet the water demand in 2035. Hence it is proposed that the installation of supplementary distribution pipes or replacement of the existing pipes to larger diameter pipes will be included in the Project. Estimated length of the supplementary or new pipes for the reinforcement is 101 km, whose quantification will be explained in Item (1) of Subsection 6.7.1.

(2) Storage capacity

1) Analysis on the adequacy of the storage capacity

The total storage capacity for the 18 WDZs in the Core City is 368.92 million liters (ML); among which, 336.82 ML is catered through Underground Tanks (UGT), and 32.10 ML is catered through Elevated Service Reservoir (ESR).

According to the CPHEEO Manual, the storage volume of a reservoir needs to be calculated by water balance analysis for the respective WDZ to ensure sufficient buffering function of the reservoir, while the manual also suggests that the storage volume will be ideally "1/3rd of one day water requirement", which is equivalent to eight hours volume of the daily supply. From the practices of other water supply projects, the JICA Study Team considers that the six hours volume will be the usual minimum requirement for buffering function and agrees that the eight hours volume suggested by the CPHEEO Manual will be a safe value.

In Table 5.5.5, the current storage has been examined for the projected water demands in the years 2035 and 2050. The analysis shows that Zones-3, 5, 6, 10, 12A and 14 do not have sufficient storage volume, which are calculated as eight hours volume of water demand. Especially, Zones-6 and 12A have only 4.1 hours and 3.4 hours volume even against the water demand for 2035, which indicates urgent need to enhance the storage capacities to achieve uninterrupted supply.

Furthermore, the JICA Study Team points out that that only some WDZs have ESRs and that the storage capacity in the existing ESRs will not be sufficient. Generally, to ensure stable water supply, one hour volume for hourly peak demand is necessary in ESRs. Presuming the hourly peak factor at 2.0 and the water demand in 2015 at 905.30 MLD, total storage requirement in ESRs will be 75.4 ML, while existing storage volume is only 32.10 ML. In addition, the most DMAs do not have SER.

Although both Kirloskar Report and the M/P recommended ESRs, ESRs have been constructed only in limited WDZs in the Core City. The Core City has faced frequent power cut especially in summer season (February to May) and usual period of the power cuts are one to two hours. Construction of

ESRs will improve continuity of water supply under such a power supply condition. Furthermore, because of the current custom of water users in Chennai, where many users keep the water tap open, the water flow in the distribution networks usually exceeds the design flow. The ESRs will contribute to improving the stability of water pressure in the water distribution networks.

Actually all the WDSs are equipped with diesel generator to cater to 100% power requirement for the distribution pumps. However, ESRs will be useful to realize more stable water pressure, to correspond to the excess water flow, and to save the fuel for the generator.

Table 5.5.5 Examination of the Existing Storage Capacity in the Core City by WDZ

WDZ		Existing Storage (ML)			Water demand		Storage rate against the water demand	
		Total	UGT	ESR	2035	2050	2035	2050
		ML	ML	ML	MLD	MLD	Hours	Hours
1	Kilpauk	97.12	81.32	15.80	208.5	220.1	11.2	10.6
2	Annapoonga	25.00	22.50	2.50	58.2	61.3	10.3	9.8
3	**Kannappar Tidal**	**16.00**	**16.00**		**55.7**	**57.6**	**6.9**	**6.7**
4	Triplicane	12.40	10.00	2.40	36.2	36.2	8.2	8.2
5	**K.K.Nagar**	**16.40**	**14.00**	**2.40**	**68.7**	**73.6**	**5.7**	**5.3**
6	**Velachery**	**6.00**	**6.00**		**35.2**	**38.4**	**4.1**	**3.8**
6A	Velachery New	2.00	2.00		5.6	6.0	8.6	8.0
7	Ekkadu Thangal	4.50	4.50		6.7	7.3	16.1	14.8
8	Choolai Medu	43.00	43.00		105.0	111.0	9.8	9.3
9	Kolathur	20.00	20.00		37.4	40.1	12.8	12.0
10	**Vyasarpadi**	**22.00**	**22.00**		**72.5**	**75.3**	**7.3**	**7.0**
11	Patel Nagar	14.00	14.00		37.6	40.3	8.9	8.3
12	Pallipattu	17.80	17.00	0.75	20.1	21.9	21.3	19.5
12A	**Thiruvanmiyur**	**3.80**	**3.00**	**0.75**	**26.8**	**29.3**	**3.4**	**3.1**
13	Nandanam	11.00	11.00		21.3	23.1	12.4	11.4
14	**Mylapur**	**11.50**	**11.50**		**43.8**	**45.5**	**6.3**	**6.1**
15	Valluvar Kottam	18.00	24.00	4.50	32.8	34.5	21.1	20.1
16	Southern Head Works	28.50	15.00	3.00	33.2	33.7	13.2	12.4
Total		368.92	336.82	32.10	905.30	955.20	9.8	9.3

Bold characters indicate that the WDZ does not satisfy eight hours storage volume.
Source: JICA Study Team

2) Necessity of hydraulic reinforcement of the existing water distribution networks in the Core City

From the analysis above, the JICA Study Team deems that there is a necessity to enhance the storage capacities in the Core City especially in Zone-6 and Zone-12A. In addition, reinforcement of ESRs will also be necessary for the ESRs to serve the peak hour demand. Hence the JICA Study Team proposes that additional UGTs and ESRs will be included in the Project.

The estimated quantities of additional storage in the Project are 4.33 ML for UGT and 49.32 ML for ESRs. The quantification of the necessary additional storage will be explained in Item (2) of Subsection 6.7.1.

5.5.3 Study on Needs for Improvement of the Existing Water Supply System in the Core City

(1) Replacement of old pipes in the Core City

1) Current situation of the old pipes and planned replacement by CMWSSB

As most of the pipes in the Core City have been installed after the 1990s, the existing distribution networks will not have serious deterioration, but there are still some old pipes. According to the field data books of 2003, which is the only guide for the latest information on pipe age and material of the water distribution pipes in the Core City, the JICA Study Team analyzed candidate old pipes to be replaced as shown in Table 5.5.6. As shown in the table, a total of 943.39 km in the Core City has been identified as the candidate for the replacement. (See Table 3.3.6 for breakdown of the existing pipes)

On the other hand, CMWSSB has carried out replacement of the old pipes in their daily maintenance works and projects using other funds after 2003. From the asset information stored in the Financial Department of CMWSSB, the total replacement work after 2003 has been 258 km. In addition, CMWSSB has a plan to carry out further replacement works using Infrastructures and Amenity Fund (I&A Fund) for 310 km in the Core City.

Table 5.5.6 Identified Candidate Old Pipes for Replacement in the Chennai Core City based on Field Data Books of 2003

Pipe material	Criteria for replacement	Reasons	Quantity
Cast Iron Pipe (CI)	Age ≥ 30 years	Reaching 40-year old at the time of the Project's completion	803.92 km
Polyvinyl Chloride Pipe (PVC)	Age ≥ 20 years	Most leakages are caused in PVC pipes, according to CMWSSB.	91.58 km
Ductile Iron Pipe (DI)	Age ≥ 40 years	DI is generally reliable material, but the life is 40 to 50 years.	0.75 km
Galvanized Iron Pipe (GI)	All pipes	20 years may be too early for serious deterioration but the GI tends to be corroded before 40 years.	8.63 km
Asbestos Cement Pipe (AC)	All pipes	AC tends to cause a water leak from early years.	0.65 km
Unknown	All pipes	Unknown pipes will be old pipes.	37.87 km
Total	-	-	943.39 km

Source: JICA Study Team based on Field Data Books of 2003

2) Necessary replacement of the old pipes in the Core City

With respect to the current situation of the existing old pipes and the planned replacement works by CMWSSB, the remaining 375 km out of 943.39 km will be left to be replaced, as presented in Table 5.5.6.

Due to the severe water availability in Chennai, where dependence on expensive seawater desalination is being expanded, the maximum utilization of the limited water source is a fundamental issue. Replacement of old pipes will save the water loss in the water distribution networks and is more cost efficient than the introduction and operation of seawater desalination. Therefore, the JICA Study Team deems that the complete elimination of the old pipes in Table 5.5.7 needs to be implemented urgently, and it is proposed that the replacement of the existing pipes for 375 km will be included in the Project. Quantification of the replacement by WDZ will be presented in Item (3) of Subsection 6.7.1.

Table 5.5.7 Proposed Length of Old Pipes Replacement in the Core City in the Project

Item	Quantity (km)	Fund
1. Old pipe to be replaced based on the field data books 2003	943 km	-
2. Replacement under regular O&M works by CMWSSB	258 km	(i) World Bank fund (ii) Chennai Mega City Project (iii) JnNURM[*1], GoI fund
3. Existing old pipes (1.-2.)	685 km	
4. Replacement in a planned project	310 km	I&A fund[*2]
Balance (Length to be included in the Project) (3.-4.)	**375 km**	Replacement requirement after the O&M works and I&A fund project

*1: I& A fund -Infrastructure & Amenities fund, collected through Chennai Metropolitan Development Authority (CMDA) from new developments within Chennai Metropolitan Area (CMA),
*2: JnNURM : Jawaharlal Nehru National Urban Renewal Mission,
Source: JICA Study Team based on Field Data Books of 2003 and interview with CMWSSB

(2) Installation of new water distribution pipes in uncovered streets in the Core City

In the Core City, there are still certain streets that are uncovered by water distribution networks. The calculation of the difference between the total lengths of the streets and the existing water distribution pipes, i.e., streets of 258.27 km, which is equivalent to 10.0% of the total street length, is not covered by the water distribution networks.

To expand the service connection rate and to improve the service level, it is proposed that additional water distribution pipes of 258 km will be included in the Project to cover all streets in the Core City. The area-wise quantification of the additional pipes will be presented in Item (4) of Subsection 6.7.1.

(3) Establishment of Hydraulic Zones and District Metered Areas (DMAs) in the Core City

For better control and monitoring of water supply in the Core City and network management, it will be necessary to establish the planned hydraulic zones (Zones-1 to 16) in the field. Establishment of the hydraulic zones is to physically separate the water distribution networks for each WDZ, by which the WDSs will formulate the hydraulic zones. In addition, District Metered Areas (DMAs) will be necessary within each hydraulic zone for water audit. This will ensure the minimization of water losses within each DMA and result in the overall reduction of NRW.

The concept of the hydraulic zone and DMA was proposed in the M/P. The JICA Study Team agrees to the concept and proposes that the establishment work of the hydraulic zones and DMAs will be included in the Project. Estimated number of DMAs is 58. Plan of the DMAs and the quantification of the valves and bulk meters required to establish the DMAs will be presented in Subsection 6.7.2.

(4) Relevant study to the DMA establishment to be conducted by KfW

In continuation to the funding of 150 MLD DSP, KfW is providing a grant aid for technical assistance to CMWSSB in the improvement of water distribution zones in the Core City. The technical assistance includes the demand-supply management program within each WDZ.

Based on the discussions with CMWSSB officials, it is noted that the Demand Management Study has been initiated by KfW in July 2016, and the team is expected to carry out the study initially in the identified pilot area. The pilot area selected in the Phase-I is Zone-12A (Thiruvanmayur Water Distribution Zone). CMWSSB officials have informed that the study targets (i) 24 × 7 water supply (ii) Non-Revenue Water improvements (iii) Infrastructure improvements within WDZ. The officials have informed that the study will be carried for 6 months in the selected pilot area, and a report on the improvements in the distribution zone is expected to be submitted to CMWSSB by January 2017. Also, CMWSSB officials stated that KfW does not intend to expand the assistance in the demand management to provision of funds to capital investment.

JICA Study Team suggests that the outcomes of the Demand Management Study would be utilized in detailed planning and design of the Project.

5.5.4 Development of New Water Distribution Networks in the Rest of CMA

In the influence area of the the Perur DSP in the Rest of CMA, OC- 15 and OC-16, only two municipalities (Pallavaram & Tambaram) have the existing distribution networks with capacities to serve 135 LPCD, although some areas still need improvements because the target service level in the municipalities is 150 LPCD in future.

In most of the towns and villages, new distribution networks are necessary to be constructed to enjoy the water from the Perur DSP. The existing networks in the towns and villages will have capacities only for lower service levels, and it is suspected that they are deteriorated and their coverage is not sufficient. Hence, it will be necessary to improve and develop new distribution networks to serve 135 LPCD in those ULBs.

At present, CMWSSB's water supply services are basically confined to the Chennai Corporation. Sometimes, CMWSSB conducts construction of water distribution networks on behalf of the ULBs but such works are deposit work. Therefore, the inclusion of water distribution network scopes in OC-15 and OC-16 in the Project will face an institutional issue. However, the Project has been planned and designed in the Study on the condition that the service area of CMWSSB will be expanded to the entire CMA in the near future. Hence, the JICA Study Team carries out the quantification of the water distribution network scopes in OC-15 and OC-16 as a part of the Project, which will be presented in Subsection 6.7.3. (The estimated quantities of the development of water distribution networks in OC-15 and OC-16 are 1,212 km in pipe length, 146.20 ML in storage.)

5.5.5 Improvements to Service Connections and Metering in the Corporation and the Rest of CMA

(1) Service connections and water meters in the Corporation

At present, CMWSSB has only limited metered connections. Out of 673,339 of the total service connection, only 26,269 has water meters, which means the metering rate is only 3.9% in the Chennai Corporation as of July 2016. It means that still 647,070 connections require the installation of water meters for volumetric metering, which is at a planning stage now by CMWSSB. (See Appendix 3.1 for details of the present conditions of the service connections and metering)

Table 6.7.7 presents analysis of service connections and water meters. In addition to the low metering rate, the JICA Study Team points out that the uneven figures of Assesses/Service Connection. In the Core City, there are 1.22 to 1.55 assesses are using one service connection, while in the Expanded Area 1.73 to 7.26 assesses are sharing one service connection. To enable appropriate volumetric tariff, CMWSSB will need to make efforts to install service connections so that the water bills would be delivered to each water consumer. In addition, similar to most cases in developing countries, the existing old service connections, where galvanized iron is mostly used for the service connection pipes, are suspected to be leaking.

Table 5.5.8 Summary of Assesses, Service Connections in Corporation

Area	Total Number of assesses	Service Connections (SCs)			Metered Rate	Assesses/ SC
		Metered	Un-Metered	Total		
Area-I	44,472	112	6,814	6,926	1.6%	6.42
Area-II	23,356	33	7,166	7,199	0.5%	3.24
Area-III	52,361	283	6,313	6,596	4.3%	7.94
Area-IV	75,284	1,708	57,157	58,865	2.9%	1.28
Area-V	69,902	9,572	35,390	44,962	21.3%	1.55
Area-VI	83,635	1,767	66,491	68,258	2.6%	1.23
Area-VII	97,245	1,727	22,917	24,644	7.0%	3.95
Area-VIII	108,800	2,152	81,603	83,755	2.6%	1.30
Area-IX	114,435	4,159	89,803	93,962	4.4%	1.22
Area-X	140,404	1,455	107,832	109,287	1.3%	1.28
Area-XI	90,921	755	25,642	26,397	2.9%	3.44
Area-XII	65,467	386	37,428	37,814	1.0%	1.73
Area-XIII	119,844	1,805	83,970	85,775	2.1%	1.40
Area-XIV	79,629	78	10,890	10,968	0.7%	7.26
Area-XV	51,869	277	7,654	7,931	3.5%	6.54
Core City	712,304	22,618	522,246	544,864	4.2%	1.31
Expanded Area	505,320	3,651	124,824	673,339	2.8%	3.93
Total	**1,217,624**	**26,269**	**647,070**	**673,339**	**3.9%**	**1.81**

Core City   Expanded Area

Source: JICA Study Team based on information provided by CMWSSB

(2) Service connections and water meters in the Rest of CMA (OC-15 and OC-16)

The Rest of CMA has a limited number of service connections, which are being managed by the ULBs. To achieve the targeted service levels, which are 150 LPCD in the municipalities and 135 LPCD in the towns and villages, it is necessary to install new service connections along with meters in OC-15 and OC-16. A complete 100% coverage through metering will be necessary for the introduction of volumetric water rate, water audit, and NRW monitoring. The quantification of meters for OC-15 and OC-16 will be presented in Subsection 6.7.3.

(3) Ongoing and planned improvements and initiatives

Under Atal Mission for Rejuvenation and Urban Transformation (AMRUT), where MOUD has agreed to fund the KfW 150 MLD desalination plant project, MOUD and KfW requested CMWSSB to install water meters to all service connection to realize volumetric tariff by 2020. Based on the discussions in the mission, CMWSSB is currently planning to install metering for all service connections first and try to recover the same from the consumers later in the tariff by adopting volumetric billing, although the fund for the installations is not yet determined.

Also, in the Smart Cities Mission, AMRUT, the Ministry of Urban Development (MOUD), Government of India has selected T-Nagar in Zone-16, Area-X, in the Core City. Under this mission, GoI has allotted INR 0.1 billion for the year 2015-16, out of which GoI will provide 60%, and 40% is to be contributed by the State Government. The World Bank is willing to provide a grant aid for conducting NRW study in the three depots in T-Nagar as a pilot technical assistance cooperation.

Installation of water meters to all service connections is still at planning stage in CMWSSB. For commercial consumers, CMWSSB has a plan to install 33,041 water meters to commercial consumers. The water meters planned are electric ones, which correspond to Automatic Meter Reading (AMR) system.

(4) Proposed improvements to the service connections and metering

Expansion of service connections to more water users and introduction of volumetric tariff with water meters are essential for CMWSSB to ensure sustainability of the water supply services. The exercise is necessary also for the Project’s financial viabilities because the high operation cost of the Perur DSP must be recovered by the water tariff.

In considerations of the necessity discussed above, the JICA Study Team suggests that the Project will cover the installation of service connections and water meters in the Corporation and OC-15 and OC-16. In the Corporation, estimated quantities are 185,496 connections with water meters and 614,029 water meters in existing service connections. Quantities in OC-15 and OC-16 are 193,710 service connections and water meters. The quantifications will be explained in Subsections 6.7.2 and 6.7.3 respectively for the Corporation and the Rest of CMA.

Although CMWSS was requested by MOUD and KfW to realize 100% metering by the year 2020, funding source for the meter installation is not yet determined. If other funds are determined to be utilized before the Project, the quantities will be reduced accordingly. Also, it is noted that the outcomes of the above studies will make suggestions on the necessary improvements in reinforcing distribution system in Core City, which may also affect the scope and quantities.

5.5.6 Scope of Water Distribution System for the Project

From the analyses of the existing and future water supply distribution systems in the Chennai Corporation and the influence area of the Perur DSP outside the Corporation, the water distribution components included in the Project are concluded in Table 5.5.9. The summary of the scopes is explained below by area;

(1) Core City

Referring to Subsection 5.5.3, it is noted that there is a need to replace 346 km of the existing old pipes in the Core City. To the JICA Study Team, CMWSSB expressed its expectation that the old pipe replacement will be included in the Project.

In addition, the JICA Study Team proposes inclusion of the reinforcement of the existing networks and the storage volume, as analyzed in Subsection 5.5.2. Also, the JICA Study Team proposes the new distribution pipes for uncovered streets would be necessary for 238.9 km and the establishment of hydraulic zones and DMAs, as explained in items (2) and (3) of Subsection 5.5.3, respectively. For these components, CMWSSB stated that they cannot make a decision to request JICA to include these components to the Project. However, they acknowledged the necessity to implement these components in the near future and are positive that the inclusion would be recommended by the JICA Study Team.

(2) Expanded Area

As shown in Subsection 5.5.1, the entire CC 7 and CC 8 will have new distribution networks before the completion of the Project. As the networks will be new and have been designed for 150 LPCD, there is no need for strengthening or rehabilitation of the distribution networks in these zones. Hence, it is envisaged that no components on the water distribution network in the Expanded Area would be included in the Project, except for improvement of service connections including water meter installation.

(3) Rest of CMA

Keeping in view of the increased service levels in the future, the JICA Study Team considers that OC-15 and OC-16 will need construction of distribution networks along with the storage facilities. Furthermore, installation of service connections as well as water meters will be necessary for good management of the water distribution networks.

Excluding bulk supplies to municipalities, water supply services in the Rest of CMA are currently under the control of the ULCs. CMWSSB has an intension to expand their direct services to the entire CMA in the future as planned in the M/P but currently they are expanding their water distribution network to the Expanded Area. In the Study, development of the water distribution network in OC-15 and OC-16 are regarded as future project to be conducted by CMWSSB or GOTN. It is not included in the Project.

Table 5.5.9 Possible Scopes to be included in the Project for Water Distribution Network

Area	Influence Area of the Project	Supply Plan	Current Status	Plan under the Project	Remarks
Core City	WDZs No. 5, 6, 6A, 7, 8, 12, 13, 14, 16	From the direct tap from the transmission main or via Porur HW	Existing	➢ Reinforcement of the existing water distribution pipes (101 km) ➢ Reinforcement of storage volume in the reservoirs and ESRs (4.33 ML for UGT and 49.32 ML for ESRs) ➢ Improvement of the existing network: Replacement of old pipes (375 km) ➢ Extension of distribution pipes in uncovered streets (258 km) ➢ Establishment of hydraulic zones and DMAs for all WDZs (58 DMAs) ➢ Installation of new service connections with water meters (185,496). ➢ Installation of water meters in existing service connections (614,029)	Quantifications will be given in Section 6.7.
Expanded Area	CC-7, CC-8	Transmission main from the Perur DSP or via the Porur WDS	Existing or under construction except for one ULB with completed DPR	➢ Improvement in service connections and installation of water meters are necessary but they will be conducted by CMWSSB.	No work is required to achieve 150 LPCD.
Rest of CMA	OC-15, OC-16	Bulk water supply tapped from the transmission main from the Perur DSP	Low coverage of network and existing distribution with lower service level	➢ It is proposed that the new distribution networks (1,212.10 km and 146.20 ML storage) with improvements in Service Connections and establishment of meters (193,710) need to be developed in the towns and villages.	Whether the network development will be included in the JICA loan needs discussion between JICA and the Indian side.

Source: JICA Study Team

5.6 Proposed Project Scope

Based on the studies described in the Sections 5.1 to 5.5, JICA Study Team proposes the project scope as presented in Table 5.6.1. Detailed scopes of the respective items will be designed in Chapter 6.

Table 5.6.1 Proposed Project Scope of the Perur Seawater Desalination Plant Project

Component	Item	Project Scope	
		Proposed Scope in the Study	Original Plan in the DPR
Seawater Desalination Plant	Capacity	400 MLD	400 MLD
	Location	Perur	Perur
	Technology	Reverse Osmosis	Reverse Osmosis
	Project completion	By November 2022	By July 2018 (from November 2015)
Product Water Transmission System	Destination of the transmission main	• Main line to the Porur HW • Branch-line from Kovilenchery to an existing pipeline at Medavakkam • Tapping points for OC-15 & 16 in the Rest of CMA	• Main line to Porur HW • Several tapping points in the main line for the Expanded Area, Rest of CMA and outside of CMA
	Length and diameter of the main*1	• Diameter: 1,000 mm to 2,200 mm • Length: 65 km	• Diameter: 1,600 mm to 2,000 mm • Length: 60 km
	Underground reservoir and transmission pumping station	• 1 pumping station at the Perur DSP*2 • 1 pumping station and 1 reservoir at the Porur HW	• 1 pumping station at the Perur DSP*2 • 1 reservoir at the Porur HW (no pumps)
Distribution Network	Improvement of the existing distribution networks in the Core City*2*3	• Hydraulic reinforcement of the existing networks (101 km) • Reinforcement of the storage volume (4.33 ML for UGT and 49.32 ML for ESRs) • Replacement of the old pipes in the Core City (375 km) • Supplementary pipes to the uncovered streets (258 km) • Establishment of DMAs (58 nos) • Installation of new service connections with water meters (185,496) • Installation of water meters in existing service connections (614,029)	Not included
	New distribution network in OC-15 and OC-16*3	• Development of water distribution networks (1,212 km pipes and 146.20 ML storage) • Installation of service connections and water meters (193,710 nos)	Not included

*1: Design of the transmission main will be given in Section 6.6.
*2: Water storage for the desalinated water is included in the DSP.
*3: See Section 6.7 for the quantification.
Source: JICA Study Team

CHAPTER 6 PRELIMINARY DESIGN FOR THE PROJECT

6.1 Review of the Design in the Detailed Project Report

6.1.1 Seawater Desalination Plant

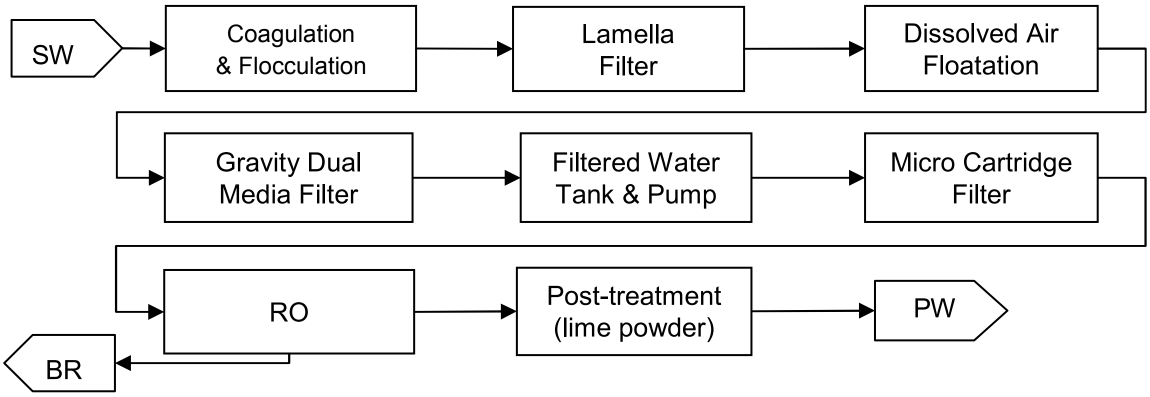
(1) Design outlines

Table 6.1.1 summarizes the design highlights of the Perur DSP in the DPR, as well as the specifications of the existing DSPs for reference. The proposed block flow of the Perur DSP in the DPR is presented in Figure 6.1.1.

Table 6.1.1 Design Highlights of the Perur DSP in the DPR

DSPs		Nemmeli DSP	Minjur DSP	Perur DSP in DPR
Capacity		100 MLD	100 MLD	400 MLD
Recovery ratio		45%	45%	46%
Intake	Intake system and type	Deep water intake system Velocity cap type	Deep water intake system Velocity cap type	Deep water intake system Velocity cap type
	Intake pipe	HDPE pipe, 1,600 mm × 1,200m × 1 line	HDPE pipe, 1,600mm dia. × 636m × 1 line	HDPE pipe, 2,500 mm × approximately 1,000 m × 2 lines
	NaOCl injection	At the intake head	At the intake pit at plant site (not at the intake head)	At the intake head
Pre-treatment	Main process	Up-flow filter + Disc filter + Ultra filtration (UF) + Micron Cartridge Filter	Lamella filter + Dual media filter + Pressure filet + Micron Cartridge Filter	Lamella filter, Dissolved Air Floatation (DAF) Settler) + Gravity Media Filter (DMF) + Micron Cartridge Filter
	Final process	Cartridge filter	Cartridge filter	Cartridge filter
RO	Unit size and number	8,333m^3/d × 12 units	20,000m^3/d × 4 units	25,000m^3/d × (16 units + 1 unit stand-by)
	Membrane type	Spiral	Spiral	Spiral
Post treatment		CO_2 injection + Lime stone filer + Disinfection injection + Caustic soda dosing	CO_2 injection + Lime powder dosing + Disinfection injection	CO_2 injection + Lime powder dosing + Disinfection injection
Brine discharge	Discharge system and type	Deep water discharge system Port riser type	Deep water discharge system	Deep water discharge system
	Discharge pipe	HDPE pipe 1,200 mm ×500 m × 1 line	HDPE pipe 1,600 mm × 836 m × 1 line	HDPE pipe 2,500 mm × 700 m × 1 line
	Water depth at the discharge head	8 m	Not clarified	8 m

Source: JICA Study Team based on DPR for the Perur DSP Project and information on the existing DSPs from CMWSSB



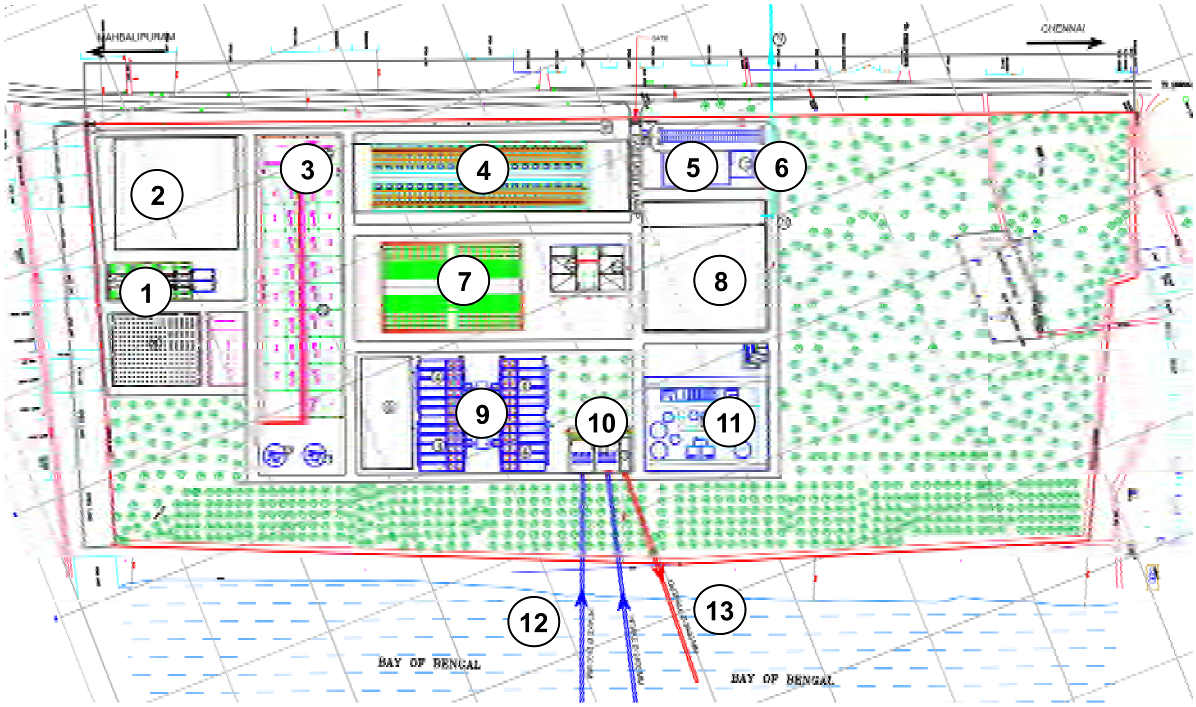
Note: SW: Seawater, PW: Product water (to the water consumers), BR: Brine (to the sea)

Source: JICA Study Team based on the DPR for the Perur DSP Project

Figure 6.1.1 Block Flow Diagram of the Perur DSP in the DPR

(2) Layout plan

Figure 6.1.2 presents the layout plan of the Perur DSP in the DPR. In the proposed site, there is a burial ground in the northern part. DPR prepared the layout plan to avoid the construction of any structures around the burial ground.



1	Chemical storage	8	Product water tank
2	Electrical substation	9	Lamella filter
3	RO building	10	Seawater intake pit
4	Dual media filter	11	Lime dosing system
5	Maintenance shop	12	Intake pipe
6	Administration building	13	Discharge pipe
7	Dissolved air filtration		

Source: JICA Study Team based on the DPR for the Perur DSP Project

Figure 6.1.2 Layout plan of the Perur DSP in the DPR

(3) Suggestions of the JICA Study Team on the design in the DPR

1) Seawater intake facility

DPR plans the intake point assuming the same length of the seawater intake pipe. The validity of the proposed plan, including the pipe length, pipe diameter, and type of intake facility, will be examined in the Study through hydraulic calculation, brine diffusion simulation and alternative studies on the discharge method. In addition, the JICA Study Team raises the following points to be considered in the preliminary design:

- The intake pipeline may need manholes for maintenance in a certain interval whereas the drawing attached to the DPR shows no manholes.
- DPR states in clause 6.4 that seawater pumps shall be 6W + 1S. This statement is inconsistent with the P&I diagram (DWG. No. CMW/SWRO/P&ID/01) which shows 4W + 2S.

2) Pre-treatment section

The DPR adapts a treatment process similar to the Minjur DSP as it has been proved to function even in high turbidity conditions in the monsoon season. Necessity of DAF needs to be studied in the Study.

3) RO section

The recovery ratio in the DPR, which is 46%, is slightly higher than the common practices in other SWROs worldwide. Usually, the recovery ratio is determined at 40 to 45% as a result of the study on the cost analysis including those for construction and operation. The JICA Study Team will study on the validity of the recovery ratio in the preliminary design.

One of the important factors in the determination of the recovery ratio is salinity in TDS, temperature, ion component of the raw seawater quality. During the Study, it was found there was a gap between the TDS values measured at the expected intake point and the design conditions in the DPR. The setting of raw seawater quality will need confirmation in the Study.

4) Post-treatment section

DPR adopts lime powder for post-treatment, which is the same as the Minjur DSP while the Nemmeli DSP adopts limestone. Among the advantages and disadvantages of the two alternatives, the notable disadvantage of lime powder is the possible leakage of powder during handling/charging, which may cause unhealthy conditions for the working staff for long-term work. The post-treatment system will be studied in the preliminary design by a comparative study including considerations on environmental impact.

5) Brine discharge facility

The noticeable points to be studied in the Study, on the brine discharge facilities are listed bellow;

- The brine diffusion simulation in DPR was implemented with limited oceanographic data. The validity of the simulation needs to be verified.

- The discharge point is planned to be located at the shore side from the intake point. The possibility of the recirculation of the brine needs to be confirmed.
- HDPE pipes of 2,400 mm in diameter are planned for the discharge pipe, but such large diameter pipes need to be imported. Moreover, consideration of other alternatives for using smaller diameter pipes, manufactured in India, needs to be carried out.

6.1.2 Water Transmission System

The principal features of the transmission facility are presented in Table 6.1.2. The route of the transmission line is presented in Figure 5.2.1 in Chapter 5.

Table 6.1.2 Principal Features of the Transmission Facilities in the DPR

Facility	Feature	Remarks
I. Pump station at the Perur DSP		
Pump facility	• Pump type: Centrifugal pump, Variable speed drive • Capacity: (Q=2800 m^3/hr; H=60 m) × 8 (6W + 2S)	-
Clear water reservoir	• V= 35,000 m^3	2 hours of 400 MLD
Pipeline		
Pipe laying	• MS* pipe ID2000 (t=17.5 mm) L=42 km • MS* pipe ID1600 (t=14.2 mm) L=18 km	-
Civil work	• Excavation: 542,283 m^3 • D2000 Pipe jacking (under East C Road) • D1600 Pipe jacking (under railway) • Pipe bridge: 4,000 m in total • Pipe pedestal for salt pan crossing: 3800m • Road restoration: 155,000 m^2	-
Valves	• Butterfly valve • D2000: 1 no., D1600: 1 no., D100-D800: 24 nos. • Gate Valves D800: 14 nos.	-
II. Porur HW		-
Receiving tank	• V= 14,200 m^3	2 hours of 170 MLD

*: MS: Mild Steel
Source: DPR for the Perur DSP Project compiled by the JICA Study Team

As per the review of the design drawings and site investigation, the following major issues were observed in the DPR:

- The longitudinal profile of the pipeline does not consider the existing crossing structures such as drainage culvert. Thus the pipe laying depth in the DPR is shallower than the actual required depth. Accordingly, necessary earth work cost is underestimated.
- The cost for temporary facility/work such as earth retaining wall and dewatering has not been properly estimated. For some sections, the estimated unit cost of INR 432 /m is obviously insufficient considering the excavation depth, ground conditions, high groundwater level, as well as high urbanization of more than half of the entire stretch of the transmission line.
- The construction plan for railway crossing is inadequate. The pipe jacking method, planned in the DPR, would be impossible for this section. Only shield tunneling method would be possible.

- The plan of transmission pipeline after branch-off is not mentioned. Delivery points with the existing or future transmission/distribution are not taken into account in the design.
- Comparative study on the necessity of relay pumping station in the transmission line is not carried out.
- Site conditions have been changed due to the construction of new roads, development of residential areas, construction of other utilities in the roads, etc. Latest conditions need to be incorporated into the design. Latest site conditions along the transmission line are described in Subsection 6.2.2 in Chapter 6.

The issues pointed out above will be taken into account in the design of the transmission system in the Study, which will be presented in Section 6.6.

6.2 Site Conditions

6.2.1 Site Conditions of the New DSP at Perur

(1) General description

The proposed construction site of the new DSP is located at Perur, 40 km south from the Chennai city center. It is a rectangular-shaped land having a width of 400 m and length of 850 m with a total area of approximately 34 ha. It is situated along the coastal side of the East Coast Road (ECR), which is the primary access road. Its ground elevation is chart datum + 3.0 to 7.5 m. ECR is approximately CD + 11.0 m AMSL. It should be noted that two graveyards have been identified inside the proposed DSP site.

Source: JICA Study Team

Picture 6.2.1 General site view from East Coast Road

(2) Geotechnical conditions

According to the geotechnical report attached to the DPR, major soil layers and their approximate depths of the proposed DSP site at Perur are as follows (See Appendix 6.1 for the details):

- Greyish silty fine sand: from −0.0 to −10.0 m (SPT N value = 10 to 64)
- Brownish silty stiff clay: from −10.0 to −13.0 / −15.0 m (SPT N value = 7 to 9)
- Soft disintegrated rock: from −13.0 / −15.0 m to −19.0 m (SPT N value ≧ 100)

- Hard granite rock: from −17.0 to −23.0 m
- (SPT: Standard Penetration Test)

(3) Seawater depth and its sediment layers

Table 6.2.1 shows the variation of water depth from the surface to the seabed at the proposed DSP site based on the bathymetric survey results presented in the DPR. Sedimentary layers of silty sand were identified between −0.0 and −8.0 m below the seabed. It should be noted that as per the bathymetry survey results presented in the DPR, buried rocks have been found near the shore that are spread in different direction and depth.

Table 6.2.1 Seawater Depth at Perur

Depth (m)	Distance from the shore (m)
5	340
6	440
7	520
8	660
9	835
10	1,040
11	1,360
12	1,890
13	2,160
14	2,480
15	2,720

Source: DPR for the Perur DSP Project

(4) Seawater quality

1) Water quality survey report in the DPR

During the DPR, a seawater quality survey was conducted between July and August 2013 at the surface and bottom layers of 750; 1,000; and 1,250 m from the seashore. Table 6.2.2 shows the survey results.

Table 6.2.2 Average Seawater Quality Data Surveyed in the DPR

Layer	pH	TDS	Turbidity	TSS	FRC	Temp	T. Hardness	Chloride	T.Alkalinity	Iron	Boron	Sulphate
		ppm	NTU	ppm	ppm	℃	ppm	ppm	ppm	ppm	ppm	ppm
Surface Layer	8.20	35,100	15.4	48.7	0.2	28.4	6,137	18,302	111.7	0.01	3.25	2,758
Bottom Layer	8.21	35,200	25.6	73.3	0.2	27.9	6,038	18,502	116.0	0.01	3.17	2,878

TDS: Total Dissolved Solids, TSS: Total Suspended Solids, FRC: Free Residual Chlorine
Source: DPR for the Perur DSP Project

According to the survey results, the seawater TSS value at the proposed DSP site are lower than the values recorded by the seawater quality survey in the study (See Appendix 6.2). This may be because the survey was conducted during pre-monsoon season and there was no or less influence by the flushed soils by the storm water.

2) Seawater quality survey in the study

JICA Study Team also conducted seawater quality survey in February 2016. During the survey, the samples collected at the candidate points for the intake by the Perur DSP were tested in an Indian laboratory. Table 6.2.3 shows the results the test. Appendix 6.2 provides detail of the sampling points including their location.

Table 6.2.3 Results of the Seawater Quality Test by Indian Laboratory.

Sampling Point	Layer	E. Conductivity	TDS	Turbidity	TSS	Cl^-	Fe	B	Mn	Cu	Ca^{2+}	Mg^{2+}	Na^+	SO_4^{2-}	HCO_3^-	Si	SiO_2	SiO_3	DO
		mS/cm	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
P9 Intake Point (1)	Surface Layer (-1.0 m)	50,290	40,309	0.10	143	21,440	0.120	3.10	0.006	0.06	1,178	4,052	12,603	536.0	6,124.4	0.09	0.20	0.54	5.00
	Intake Level (-5.0 m)	50,830	40,856	0.10	123	21,440	0.130	2.80	0.006	0.06	786	2,622	14,533	475.0	4,593.0	0.09	0.21	0.56	4.70
P10 Intake Point (2)	Surface Layer (-1.0 m)	51,400	41,489	0.10	189	23,993	0.059	2.90	0.005	0.07	393	2,622	13,503	478.0	4,593.0	0.11	0.24	0.65	4.50
	Intake Level (-5.0 m)	50,400	40,048	0.10	116	23,482	0.090	3.20	0.001	0.02	393	3,098	12,603	472.5	4,593.0	0.25	0.11	0.67	4.80

DO: Dissolved Oxygen

Source: DPR for the Perur DSP Project

3) Seawater quality test by Japanese laboratory

Total dissolved solids (TDS) and Boron (B) are the most important parameters in designing the plant for reverse osmosis (RO); therefore, the samples tested by the Indian laboratory were also tested by a Japanese laboratory. According to the results (Table 6.2.4), Japanese laboratory reported lower values than the Indian laboratory especially TDS value. This difference might be because the Indian laboratory contains suspended solids even after the filtration process during the test performed.

Table 6.2.4 Results of the Seawater Quality Test by Japanese Laboratory

Sampling point	TDS	Boron
	mg/l	mg/l
P9: Intake Point (1) Intake Level (−5 m)	37,300	4.1
P10: Intake Point (2) Intake Level (−5 m)	38,100	4.3

Source: JICA Study Team

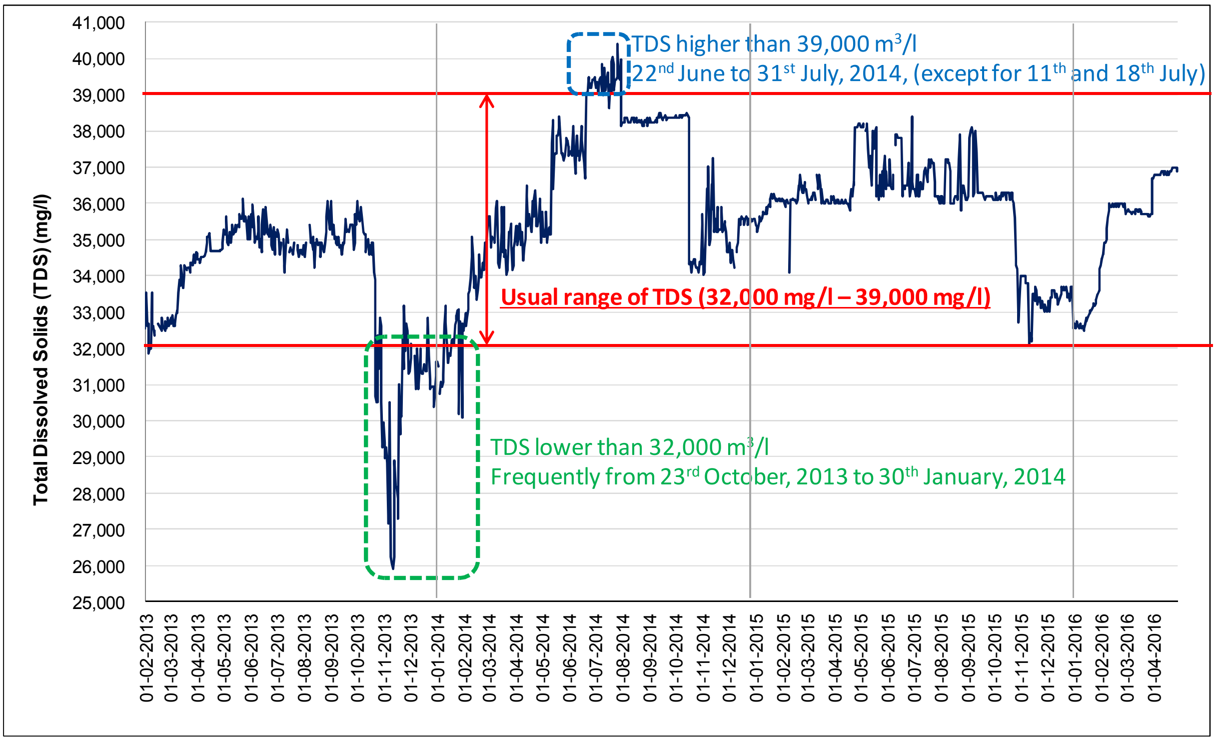
4) Design criteria for the Nemmeli DSP

In addition to the above, "Bid Documents for Construction of 100 MLD Seawater Reverse Osmosis Desalination Plant at Nemmeli, February 2009" adopted value of TDS in the range of 33,000–41,900 mg/l (average: 40,100 mg/l). The TDS value adopted by the bid document is slightly high compared with the actual operational record of the Nemmeli DSP.

5) Operational record of the Nemmeli DSP

Figure 6.2.1 illustrates the TDS values recorded at the existing Nemmeli DSP from February 2013 to April 2016. The range of TDS has been 25,900–40,390 mg/l but usually it is in the range of 32,000-39,000 mg/l. Chennai receives most of its seasonal rainfall (about 60%) during the monsoon period (between October and December). The TDS value tends to be low by dilution effect by the storm water during and post-monsoon periods.

In June to July, 2014, the TDS exceeded 39,000 mg/l, while it frequently dropped to lower than 32,000 mg/l from October 2013 until January 2014. In design of seawater desalination process, maximum level of TDS is one of the key water quality conditions. The extraordinarily high TDS, observed in June and July in 2014 is presumed to have been caused by the extremely low precipitation in the year.



Source: CMWSSB

Figure 6.2.1 TDS Values in the Raw Seawater of the Nemmeli DSP

6) Evaluation of the seawater quality data from various sources

In sum, the TDS values from various resources are shown in following Table 6.2.5. Considering the TDS values of various sources and the usual range of TDS recorded in the Nemmeli DSP, design condition of the TDS for the Perur DSP has been agreed between CMWSSB and the JICA Study team to be from 32,000 to 39,000 mg/l. Design conditions for other parameters, such as boron and temperature, are defined in Section 6.3.1.

Table 6.2.5 TDS Values of Various Sources

Unit: mg/l

Source		TDS (Minimum)	TDS (Maximum)
1	Seawater quality survey result in the DPR	32,000	38,000
2	Seawater quality survey in the Study (1) (Data: Indian Laboratory)	40,048	41,489
3	Seawater quality test by Japanese laboratory (Data: Japanese Laboratory)	37,300	38,100
4	Design criteria for the Nemmeli DSP (Data: Bid documents, February 2009)	33,000	41,900
5	Operational record of the Nemmeli DSP (Data: January 2014–April 2016)	25,900	40,390

Source: JICA Study Team

6.2.2 Site Conditions of the Transmission mains

(1) General description

The total length of the transmission main proposed by the JICA Study Team is approximately 60 km, starting from the new DSP at Perur to Porur HW. Figure 6.2.2 illustrates alignments of the product water transmission main proposed in the Study by JICA Study team and in the DPR.

(2) Site conditions

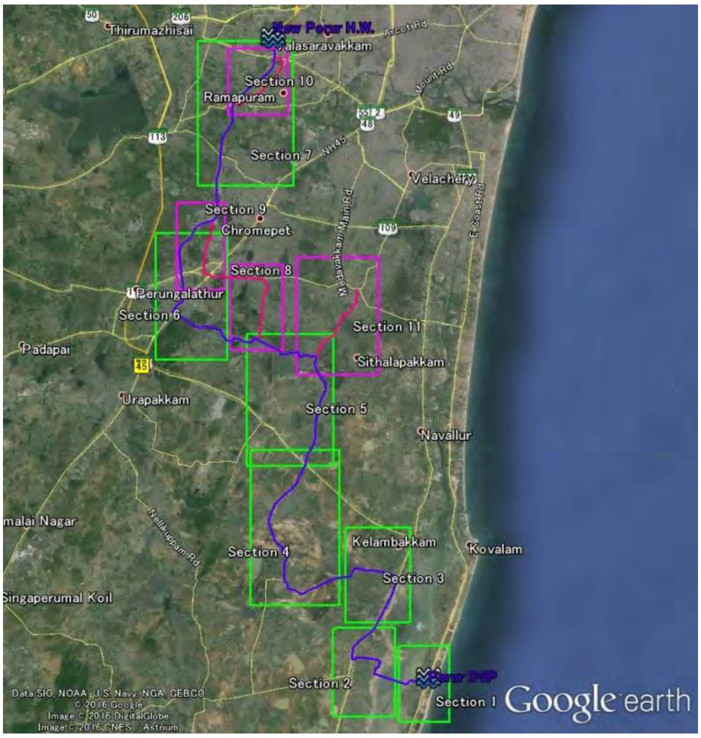
Most part of the transmission main will be installed under the existing roads.

The proposed route has several crossings, for which careful designs are required, such as backwater, railway, river, and lake.

Site conditions including soil conditions along the transmission main are detailed in Table 6.2.6.

(3) Geotechnical conditions

Figure 6.2.3 shows the geological map that covers the project area.

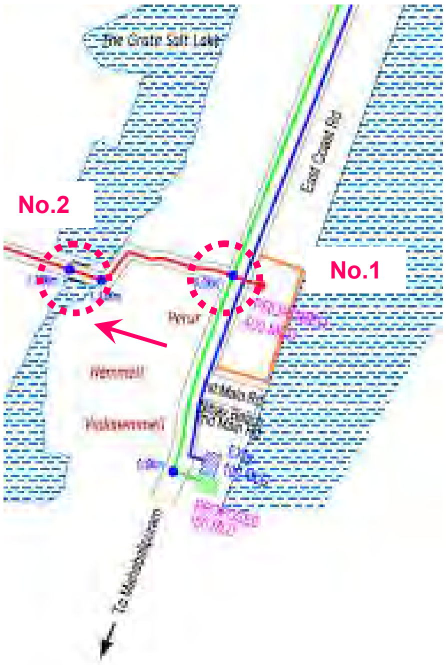


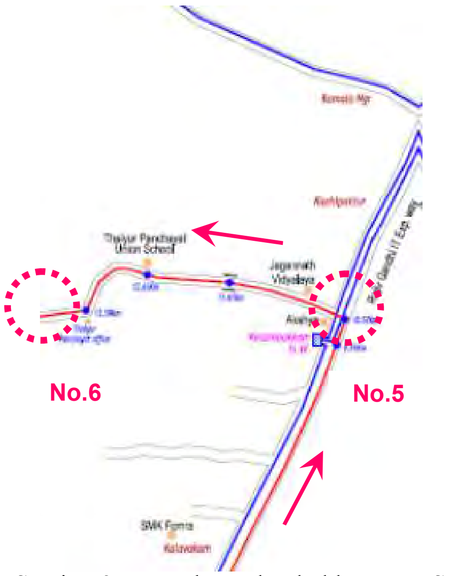
Pipeline routes proposed by the DPR
Pipeline routes proposed by JICA Study Team

Source: JICA Study Team

Figure 6.2.2 Alignment of the Product Water Transmission Main

Table 6.2.6 Site Conditions and Soil Conditions of the Transmission Mains

Section	General view	Remarks
 Section 1: From the Perur DSP	 No.1: Intersection to ECR  No.2: Bridge over backwater	【Site Condition】 • Proposed pipeline crosses the East Coast Road (ECR) and goes to rural road (approximately 4.0 m wide) in Perur village. • Existing pipeline from the Nemmeli DSP (φ1,000 mm) has been installed on the coastal side shoulder of the ECR. • After passing through Perur village, the pipeline traverses the wetland (approximately 1,700 m long) where a private company uses the land as saline. 【Soil Condition】 • The soil consists primarily of fluvial and marine sand along the coastal line and inland backwater/canal.
 Section 2: To the Rajiv Gandhi Exp. Way	 No.3: Exposed rock on the route  No.4: Gandhi Exp. (49A)	【Site Condition】 • After passing through backwater, the proposed pipeline traverses Thiruporur village. • Then, the pipeline goes north along the Rajiv Gandhi Express Way (R49A) where existing pipeline (φ1,500 mm) from the Veeranam WTP has been installed. Some encroachments were found inside the RoW. 【Soil Condition】 • The route enters charnokite (a kind of granite rock) area from Thiruporur village (Photo: No.3).



Section 3: Near the Kelambakkam WDS


No.5: Intersection to Gandhi Exp.

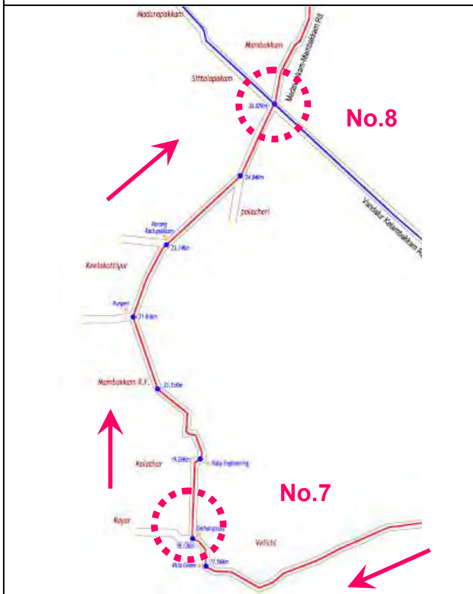

No.6: Road beside wetland

【Site Condition】

- After existing CMWSSB's Kelambakkam pumping station, the pipeline traverses towards west crossing small rivers and wetlands along rural road (approximately 4.0 m wide).

【Soil Condition】

- The route traverses along the edge of charnokite area.
- Construction work in this area may encounter difficulties due to hard granite rock even at the shallow depth from ground level.



Section 4: Medavakkam Rd.


No.7: Medavakkam Rd.

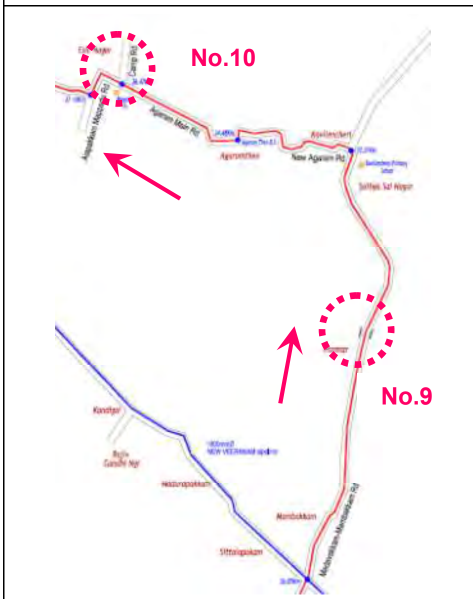

No. 8: Intersection to Vandalur Rd.

【Site Condition】

- After Velichi village, the proposed pipeline turns north along the Medavakkam Rd. and traverses towards the Vandalur–Kelambakkam Rd. (R121).
- Traffic volume at the intersection of the Vandalur–Kelambakkam Rd. where the existing pipeline (φ1,500 mm) from the Veeranam WTP is installed is relatively high (Photo: No.8).

【Soil Condition】

- The route traverses entirely through the charnokite area.



Section 5: New Agaram Rd.–Camp Rd.


No.9: Bridge over river

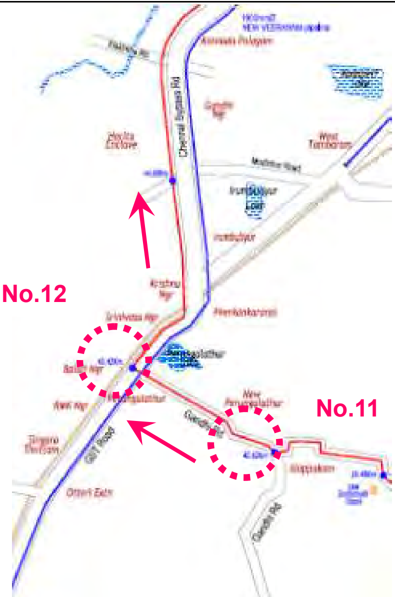
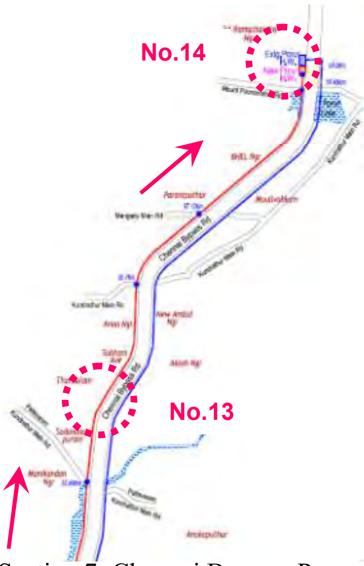
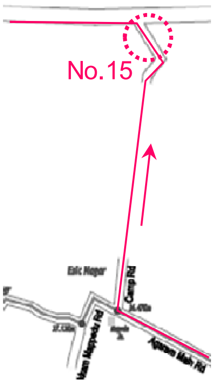

No.10: Camp Rd.

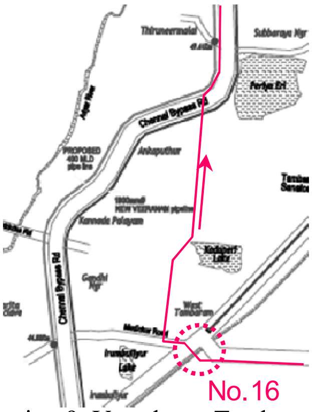
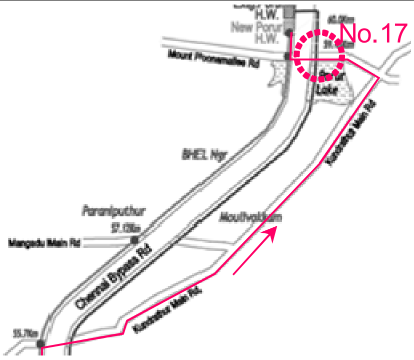
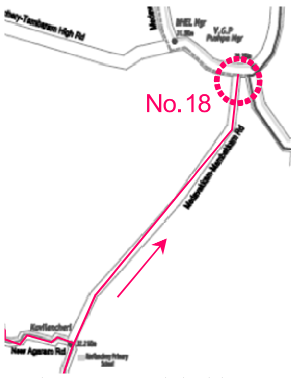
【Site Condition】

- The pipeline crosses a river (bridge is approximately 120 m long).
- The pipeline traverses through residential areas where it passes through the section between Medavakkam and Camp Rd. where a lot of houses are built on both sides of the road.

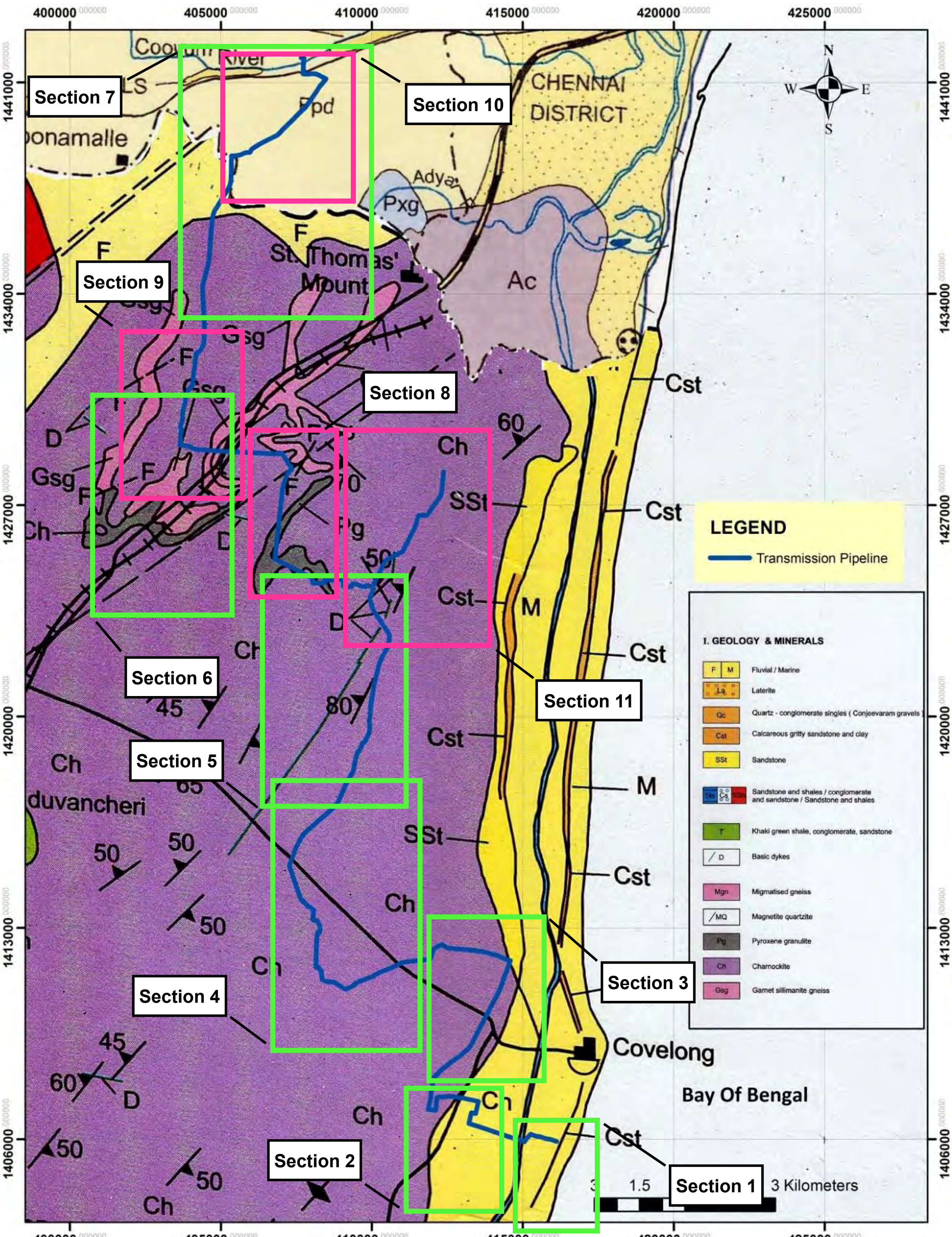
【Soil Condition】

- The route traverses entirely in the charnokite area. Construction work may encounter some difficulties due to rocks.

 Section 6: Camp Rd.–GST Rd.	 No.11: Gandhi Rd.  No.12: Intersection to GTS Rd.	【Site Condition】 • The pipeline traverses beside Air force base and then merges with the Chennai Bypass Rd. • In this route, some three-dimensional crossings will occur between the proposed pipeline and Railway, existing pipeline (φ1,500 mm) from the Veeranam WTP and national highway (NH45). 【Soil Condition】 • The route traverses entirely in the charnokite area. Construction work may encounter some difficulties due to rocks.
 Section 7: Chennai Bypass–Porur	 No.13 : Chennai Bypass Rd.  No.14: Site for new Porur HW	【Site Condition】 • Most part of the pipeline may be buried along the service road for the Chennai Bypass. • In this route, the pipeline crosses the Adyar River, Porur Lake, and the Trunk Rd. (R55). • Land for new Porur HW (approximately 4.3 ha) has already been reserved by CMWSSB. 【Soil Condition】 • After the route crossing the Adyar River, soil condition changes to fluvial sand and clay.
 Section 8: Camp Rd.–Veracherry –Tambaram Rd.	 No.15: End of Camp Rd.	【Site Condition】 • The width of Camp Rd. is generally wide. But the junction with Verachery–Tambaram Rd is congested with traffic. 【Soil Condition】 • The route traverses entirely in the charnokite area. Construction work may encounter some difficulties due to rocks.

 Section 9: Veracherry–Tambaram Rd.–Chennai Bypass	 No.16: Near the Tambaram railway station where a trenchless pipeline work is proposed	【Site Condition】 • The pipeline crosses the railway and GST road. The space for vertical shaft for pipe jacking is available at both sides of railway. 【Soil Condition】 • The route traverses primarily in the charnokite area partly including hard rock area near the Tambaram railway station. Construction work may encounter difficulties due to the hard rocks.
 Section 10: Chennai Bypass–Trunk Rd.	 No.17: Crossing under the Chennai Bypass Rd.	【Site Condition】 • Pipeline route runs along Trunk Rd. where Porur Lake is located, consequently the water table is high. 【Soil Condition】 • The soil consists primarily of fluvial sand and clay of the Adyar River basin.
 Section 11: Medabakkam Rd.	 No.18: Connection point to the existing pipeline installed along the Medabakkam Rd.	【Site Condition】 • The pipeline will be connected to existing pipeline at the junction of Medabakkam and Veracherry–Tambaram Rd. Construction work may encounter heavy traffic. 【Soil Condition】 • The route traverses entirely in the charnokite area. Construction work may encounter some difficulties due to rocks.

Source: JICA Study Team



Pipeline routes proposed by the DPR
Pipeline routes proposed by JICA Study Team

Source: JICA Study Team

Figure 6.2.3 Geological Map along the Transmission Main Routes

6.2.3 Site Conditions of the Trenchless Pipe Construction at Crossing of Railway and GST Road

(1) General description

The pipeline crosses the railway and GST road. The space for vertical shaft for pipe jacking is available at both sides of the railway.

Figure 6.2.4 shows proposed pipeline route and boring locations at the proposed Trenchless pipe construction site (P-A1: 404,153.00 m E, 1,428,837.00 m N, 34.327 m AMSL) near the Tambaram railway station.

Source: JICA Study Team

Figure 6.2.4 Site Location of the Trenchless Pipe construction at Tambaram

(2) Site conditions

According to Figure 6.2.3, the site is located in the charnokite area partly including hard rock (garnet sillimanite gneiss) area near the Tambaram railway station. Thus, the geotechnical investigation was conducted.

(3) Geotechnical conditions

According to the results of geotechnical investigation, the soil consisted of filling soil until −1 m followed by traces of clay up to −3 m from the ground level. Below −3 m, the soil consists of weathered igneous rock up to −8 m and hard massive rock laid after −8 m.

Detailed results of the geotechnical survey at the location in the Study are given in Appendix 6.3.

6.2.4 Site Conditions of the Pumping Station at Porur HW

(1) General description

In this project, construction of new reservoir and pumping station is proposed at a site just beside the existing Porur HW located at 15 km south-east from the Chennai city center. Figure 6.2.5 shows the site location of the new reservoir and pumping station.

Source: JICA Study Team

Figure 6.2.5 Site Location of the New Reservoir and Pumping Station at Porur

(2) Site conditions

Land for the additional WDS at Porur has already been reserved by CMWSSB at south of the existing WDS along service road of the Chennai Bypass. The land, whose total area is approximately 5.0 ha, is almost vacant, and there is enough space for constructing new reservoir and pumping station.

Source: JICA Study Team

Picture 6.2.3 General Site View from West to East

(3) Geotechnical conditions

As per the geological map (Figure 6.2.3), the soil primarily consists of sand, clay, and gravel. The water table is encountered at −3 m from the ground level. Detailed results of the geotechnical survey at Porur in the Study are given in Appendix 6.3.

6.3 Design of the Desalination Plant

As validated in Section 5.3, the Perur DSP will be constructed at the proposed site shown in the DPR. The adopted desalination technology in this project will be RO. JICA Study Team previously visited the existing DSPs of CMWSSB and has analyzed their operational data that they received (described in Section 3.4). In addition to this, they reviewed the design in the DPR as described in Subsection 6.1.1. Based on the aforementioned information, JICA Study Team prepared a key design condition of the Perur DSP as follows:

6.3.1 Design Conditions

(1) Design requirement and basic specification

Basic requirements and specifications of the DSP are as follows:

- Product water quality should be less than 500 mg/l in TDS (see the following items)
- Recovery ratio should be 46% (See section 6.3.4)
- Product water quantity should be 400 million liters per day (MLD) or 400,000 m^3/day

(2) Feed seawater conditions

In February 2016, JICA Study Team implemented seawater sampling at the candidate intake points near Perur and performed laboratory tests on the samples. Parallel to this, actual operation data at Nemmeli and Minjur DSPs were collected and compared with the results of samples tested. According to their comparative analysis, the raw seawater quality in the operation data of the Nemmeli DSP was reliable and useful for the determination of the raw seawater conditions, especially the range of salinity and temperature considering seasonal change.

The feed sea water conditions, comparing with DPR data, was discussed with CMWSSB, and agreed as per the ”Spec of Feed Seawater” in Table 6.3.1. Especially, TDS range was discussed and concluded by referring long term data.

(3) Product water quality

Table 6.3.1 shows required product water quality at the Nemmeli and Minjur, DPR, together with Indian drinking water standard and WHO (World health Organization) standard. Because that both Nemmeli and Minjur follow to Indian standard, and this plant will be constructed in India, this project will also comply with the Indian standard.

With regard to Boron concentration, WHO accepts 2.4 mg/l, but Indian Standard does not follow to this International standard. CMWSSB has already decided to follow Indian Standard “Permissible” range. Therefore this project will also follow to this standard, 1.0mg/l.

Table 6.3.1 Feed seawater condition and design condition

Items	as	unit	Feed Seawater						
			Nemmeli		Minjur		DPR		JICA FS
			Range (year 2015)	Design	Range (2010.8–2014.11)	Range (2014.12–2015.4)	Range	Design	Spec of Feed Seawater
Conductivity (EC)	25℃	μS/cm	45,000? – 55,000?		60,000 – 83,000	73,000 – 82,000		??	–
Total Dissolved Solids (TDS)	180℃	mg/l	32,000 – 38,500	35,200	36,000 – 50,000	47,000 – 53,000	32,000 – 38,000	35,200	32,000 – 39,000
TDS conversion foumula from EC.			= EC x 0.70		= EC x 0.60	= EC x 0.65			ECx0.7 is OK
pH		–	8.05 – 8.2	8.2	??		7.7 – 8.5	8.2	
Temperature		℃	26 – 31	27.9	25 – 31		25 – 32	27.9	25 – 31
Calcium	Ca	mg/l						467	467
Magnesium	Mg	mg/l						1,258	1,258
Sodium	Na	mg/l						10,789	10,789
Potasium	K	mg/l						391	391
Ammonium	NH3							0.2	0.2
Bicarbonate	HCO3	mg/l						126.3	126.3
Chloride	Cl	mg/l						19,247	19,247
Sulphate	SO4	mg/l						2,878	2,878
Nitrate	NO3	mg/l						4	4
Fluoride	F	mg/l						1.63	1.63
Silica	SiO2	mg/l						1.38	1.38
Boron	B	mg/l		3.17	3.7 – 4.0			3.17	3.6
Total Suspended Solids	105℃	mg/l		<75			50 – 200	75	–
Turbidity	NTU	mg/l		<10			10 – 125	<10	–
			Note: Analysis data of JICA FS follows to DPR analysis data at 35,200mg/l in TDS.						

DPR: Detailed Project Report, WHO: World Health Organization, JICA FS: the Study
Source: JICA Study Team

Table 6.3.2 Requirement to Product Water Quality

Item	unit	Product water						
		Nemmeli	Minjur	DPR	India Drinking water standard (IS 10500 : 2012)		WHO	JICA FS
		Interview on 16.2.2016	Interview on 19.2.2016		Acceptable	Permissible		Spec of Product water
Total Dissolved Solids (TDS)	mg/l	500	500	500	500	2000	1,000	500
pH	–			6.5 – 8.5	6.5 – 8.5	–		
Chloride	mg/l	–	250	250	250	1000	250	250
Boron	mg/l	1 (actual 0.2–0.8)	1 (actual 0.8–1.0)	1	0.5	1	2.4	1

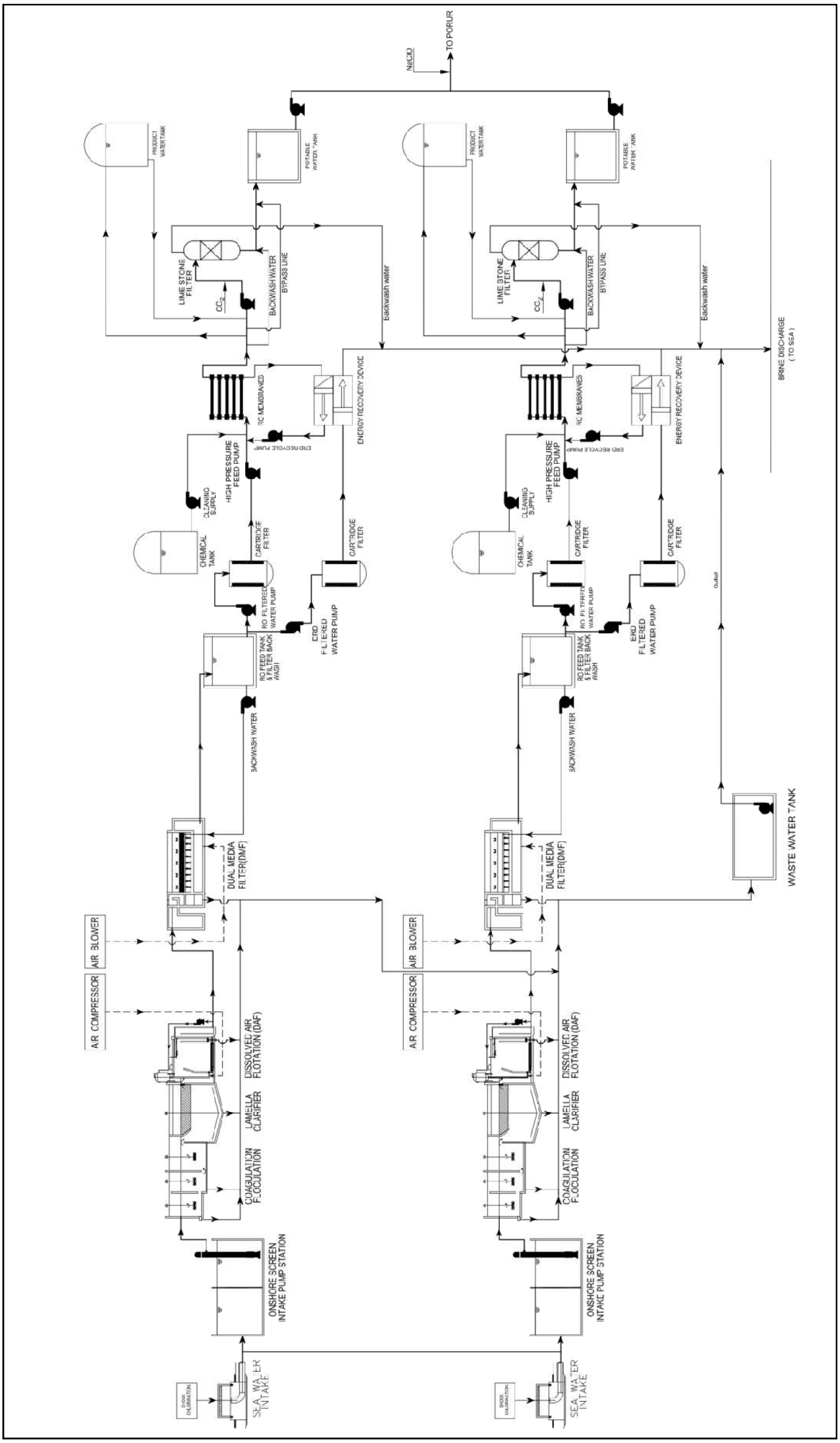
DPR: Detailed Project Report, WHO: World Health Organization, JICA FS: the Study
See Appendix 3.8 for the Indian Drinking Water Standard.
Source: JICA Study Team

6.3.2 Process Flow

(1) Seawater desalination process

Figure 6.3.1 shows the major process of the Perur seawater desalination plant with an RO membrane. This plant consists of Seawater Intake pit - Pre-treatment (Lamella filter / DAF /DMF) – RO with energy recovery – Product and Brine discharge.

The outlines of each component are given below, and the detailed description is provided the next section onwards.



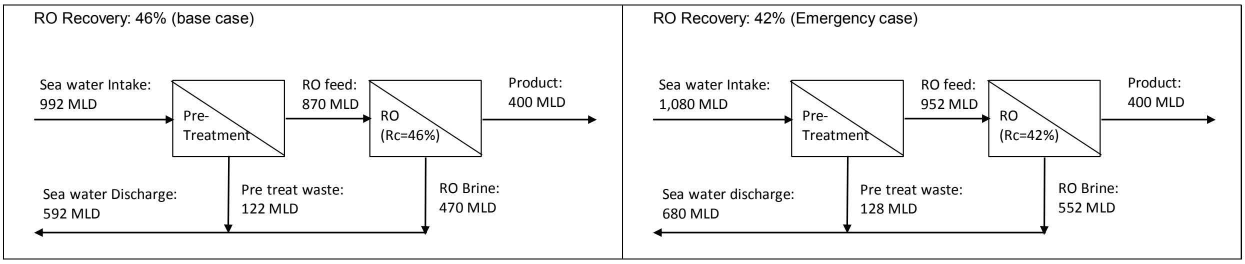
Source: JICA Study Team

Figure 6.3.1 Flow Diagram of the Seawater Desalination System in the Perur DSP

(2) Overview of water balance

To avoid the complete shutdown in any unexpected trouble or planned maintenance case, the desalination system of the DSP is divided into two independent lines, each of which has 200 MLD. The number of RO unit is 17 including one stand-by, and each unit will have a capacity of 25,000m^3/d. This unit size was decided by considering closely maximum size in which there is a track record in the world with small influence of plant shut down. In this case, 16 units are necessary for 400MLD production. If any shutdown by unexpected trouble, remained 15 units, 93.75% of 16 units, can still produce the water. The basic recovery ratio of the RO units will be 46%, which will be explained in Subsection 6.3.4, and it will be vary between 46% and 42% as per the operational conditions.

Water balances in the desalination process are presented in Figure 6.3.2 for different recovery ratios at 46% and 42%.



Source: JICA Study Team

Figure 6.3.2 Water Balances of the Perur DSP in Different Recovery Ratio Cases

(3) Outlines of each process

1) Pre-treatment

To treat suspended solid in raw seawater, a pretreatment system is necessary to feed clean water to RO membranes. There are several methods of filtration such as dual media filter (DMF), dissolved air floatation (DAF), membrane filtration (MF and/or UF), and so on.

In the past, as explained in Subsection 3.4.5, the pre-treatment system of the Nemmeli DSP, which consisted of Up-flow filter + Disc filter + UF + Micron cartridge filter, faces a deterioration in the performance when cyclones attacked Chennai. On the other hand, the pre-treatment system at the Minjur DSP, which consisted of Lamella filter, DMF, Pressure filter and Micron filter, has not faced such deterioration in recent years.

In the Perur DSP, the pre-treatment system will follow the system at the Minjur DSP with an addition of DAF. Basically, from the experience in Cyclone season, Minjur system proves better result than Nemmeli, but sea water quality in Nemmeli site is worse than Minjur, so, adding more filtration system to Minjur system was studied, and concluded that DAF, which is popular filtration process in membrane system, and effective to remove right weight or smaller size of particle, will be added.

Consequently, the pre-treatment system of the Perur DSP will consist of Lamella filter, DAF, and DMF.

2) RO membrane

Filtered water from the pretreatment system is fed to the RO system using the filtered water pump. Micron cartridge filter and static mixer are arranged before high-pressure pump (HPP) or energy recovery device (ERD). Each RO unit will have one set of HPP and ERD. ERD, to reduce the electrical consumption, will be isobaric type as its efficiency is the highest among all the proven types of ERD, which are Pelton turbine, Francis turbine or Turbo charger.

3) Chemical injection

For seawater intake, sodium hypochlorite (NaClO) is dosed to prevent entering of marine life into the system. Ferric chloride ($FeCl^3$) and polyelectrolyte will be dosed after sulfuric acid dosing for better coagulation in the pretreatment system and scale control in the RO system. Sodium bisulfite (SBS) is dosed into the RO membrane feed water to neutralize free chlorine, which is harmful to the polyamide RO membrane. In post-treatment, carbon dioxide (CO_2) is used together with limestone for remineralization, and caustic soda (NaOH) and chlorine (Cl_2) are dosed into the final product water prior to its delivery to the water consumers. Table 6.3.3 summarizes chemicals to be used in the Perur DSP. In addition to the chemicals in the table, some chemicals such as citric acid and ammonia are used for RO membrane cleaning.

Table 6.3.3 List of Chemicals to be used in Daily Operation

No	Chemical	Used at:	Purpose
1	Sodium hypochlorite (shock dosing)	Seawater offshore head	Disinfection to prevent marine growth
2	Sodium oxide (continuous dosing)	-ditto-	-ditto-
3	Sulfuric acid	Seawater to lamella filter	For better coagulation in pretreatment section and prevention of scale formation in the reverse osmosis section
4	Ferric chloride	-ditto-	Coagulant in pretreatment section
5	Polyelectrolyte	-ditto-	-ditto-
6	Sodium bisulfite (shock)	Filtered water	For membrane protection from chlorine attack
7	Sodium bisulfite (continuous)	-ditto-	-ditto-
8	Carbon dioxide	Permeate water	Remineralization
9	Lime stone	-ditto-	-ditto-
10	Sodium hydroxide	-ditto-	Langelier index to be positive
11	Chlorine	-ditto-	Disinfection of the drinking water

Source: JICA Study Team

4) Post-treatment

Permeate from RO trains is treated in the limestone system at which limestone is used instead of lime powder for handling easiness prior to the delivery to the water consumers. The water quality will be adjusted by NaOH to maintain positive Langelier Saturation Index. Chlorine is dosed for disinfection.

5) Product water storage

The product water storage facility is installed in order to save water for on-site use, emergency use during a power failure or malfunction of the plant, and for the smooth operation of transmission pumps. Total tank capacity will be 36,000 m^3 (9,000 m^3 × 4 tanks), which is equivalent to the production for 2-hour operation.

6) Product water transmission pumps

The product water transmission pumps will be installed in the DSP. It will transport the desalinated water from the DSP to the water consumers through the product water transmission mains, water distribution stations, and water distribution networks.

7) Brine effluent discharge facilities

Brine header from the RO trains is connected to the discharge pit, which will also receive effluent from the wastewater tanks. The discharge pit will also receive neutralized wastewater such as chemical area spillage and membrane cleaning waste. The above-mentioned effluents from the DSP will be discharged from the discharge pit to the sea by gravity flow through discharge pipes, which have diffusers at pipe terminals.

(4) Hydraulic section of the DSP

The water level of each major unit is reviewed and confirmed as per Appendix.

6.3.3 Layout Plan

(1) Layout of the facilities in the DSP

CMWSSB has agreed with Hindu Religious and Charitable Endowment (HR&CE) on its use of a land at Perur with an area of approximately 87 acre (34 ha) (Figure 6.3.3). The land includes two burial grounds, located at about 1 km north from Nemmeli DSP. As explained in Subsection 5.3.1, JICA Study Team has concluded that the plant site would be the best location among the possible alternatives sites.

By a requirement from CMWSSB, the DSP is allowed to occupy only about 50 acre (20 ha) to enable CMWSSB for any use of the vacant space in the premises. Consequently, the plant layout will be prepared so that the area of DSP will be within about 20 ha.

DSP: desalination plant
Source: JICA Study Team

Figure 6.3.3 Proposed Site for the Perur Desalination Plant

(2) Plant facilities

As per Table 6.3.4, the Perur DSP requires space not only for the main process units but also for auxiliary facilities such as seawater receiving unit, product water tank, product water transmission pumps to the city, power receiving facility including substation, warehouse for chemical/filter/membrane, administration building, parking space, and so on. The space required for the main process units will follow the result Section 6.3.5. The space required for the auxiliary facilities were estimated by similar desalination facilities.

Table 6.3.4 Required Facilities in the Perur DSP

	Process / facility	Estimated size (in meter)	unit	Key Function
Main	Intake pit	30 x 70	1	Receiving seawater by gravity, and transfer to Lamella filter
	Lamella Filter	100 x 60	2	Removal of suspended solid by sedimentation with inclined plate.
	DAF	130 x 40	2	Removal of suspended solid by upflow stream
	DMF	200 x 30	2	Removal of suspended solid by dual media filter
	Filtrate tank	25 x 100	1	Storage of pre-treated sea water
	RO building	260 x 40	2	Cartridge filiter, high-pressure pump, RO membrane block and energy recovery device are included.
	Post treatment	80 x 100	1	Mainly preparation of lime stone
	Potable water tank	60 x 40	1	Underground pit for adjusting pH, hardness, etc. disinfectant is injected.
	Product water tank	30 m dia (9,000 m^3)	4	Emergency storage tank for product water
	Transmission pump room	20 x 40	1	Transmission of product water to the reservoirs near Chennai city
	Brine discharge	30 x 30	1	Waste water from pre-treatment and concentrated seawater from RO building is stored/discharged to sea
Auxiliary	Power receiving	80 x 80	1	Power receiving, transforming voltage, substation
	Chemical tank	30 x 60	1	Chemicals arrangement for pre-treatment
	Chemical tank	20 x 90	1	Chemicals arrangement for RO building
	Waste treatment	40 x 80	1	Especially sludge treatment
	Workshop	50 x 40	1	Workshop for the site
	Warehouse	80 x 40	1	Warehouse for plant operation
	Administration building	60 x 40	1	Administration office, Laboratory
	Firefighting	20x 40	1	Fire fighting
	Gate house	20 x 20	1	Gate keeper
	Parking	50 x 40	1	Car parking space

Source: JICA Study team

(3) Basic policies in the layout plan

In the layout plan for the DSP, the following policies were considered:

a. No facility will be built in the existing area where cemeteries are situated. Following an agreement done in the stakeholder meeting held by CMWSSB, the access road to the north-western cemetery from the seaside on the eastern part of the cemetery should be maintained. For this reason, land will be used from southern end.

b. About 50 m space will be kept at the western side, which faces toward ECR (Eastern Coast Road), to prevent any damage to the basic foundation slope of ECR.

c. Seawater intake/discharge points will be located at the northern part. This will prevent the discharged brine released from one DSP affecting the raw seawater taken by the other DSP.

d. Required electricity will be supplied from existing power grid, which runs more from southern area from Perur. Therefore, power receiving/substation will be located at the southern end of the proposed site.

e. Transmission pipeline is planned to be laid along the road starting from the 700-m point from south edge of the proposed site, after under crossing ECR. Therefore, product water tanks will be located close to the planned direction of the pipeline.

f. Processing units will be allocated in simple water stream line, that is, seawater receiving → pretreatment → desalination by RO membrane → posttreatment → product water tank → transmission pump.

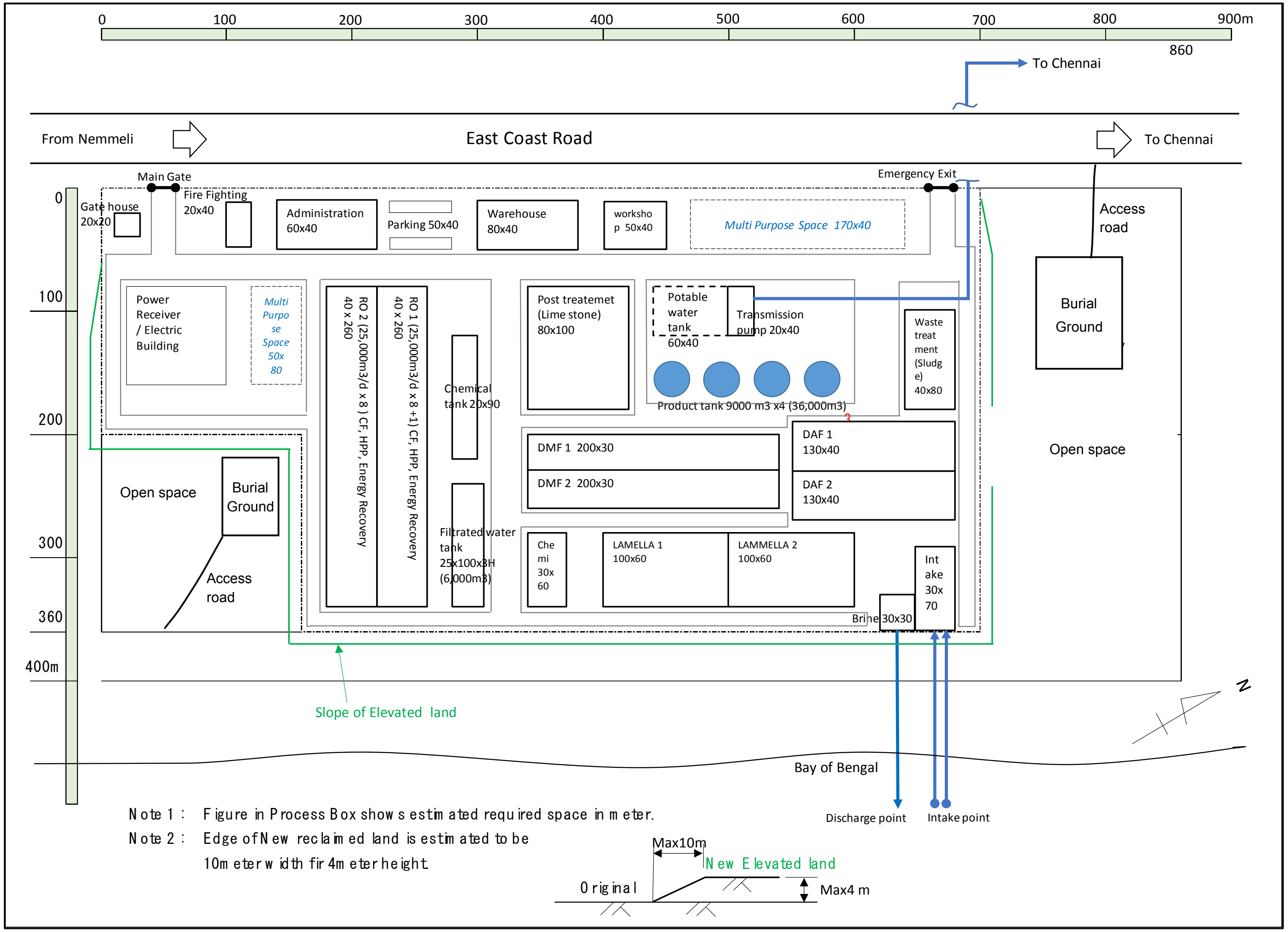
g. Storage facility of necessary chemicals for process and cleaning will be allocated at near place for pretreatment and RO facilities.

h. Warehouse will be located in the same area as administration building for managing stock situation.

i. Ground elevation of the proposed site will be CD +6.5 m in principle (See Subsection 6.3.14 for land development plan). As the current ground elevation in the proposed site is 3–8 m, earth filling by 3.5 m at maximum will be necessary, for which slopes around the plant site boundary will be developed.

(4) Layout of the DSP

In accordance with the basic policies above, layout of the Perur DSP has been prepared as shown in Figure 6.3.4. Consequently, the DSP will occupy 56 acre (22.6 ha). Although it is slightly greater than 50 acre, CMWSSB admitted that it is within permissive level. Detailed layout of the DSP is given in Appendix 6.4.



DMF: dual membrane filter, DAF: dissolved air floatation.
Source: JICA Study Team

Figure 6.3.4 Layout of the Perur Seawater Desalination Plant

6.3.4 Recovery Ratio

(1) Recovery ratio

One of the important factors in design of DSP is “recovery ratio,” which means the ratio of product water quantity against the feed water quantity. The rejected seawater, called as brine, will be returned to the sea, but this water contains some sea water from other treatment processes such as back washing water from pre-treatment process. This means necessary seawater taken for the DSP will be bigger than the feed water to the RO system. In this subsection, recovery ratio is defined as the ratio of the RO product water quantity against the RO feed seawater.

In general, for saving the construction cost of intake and pretreatment system, higher recovery is preferred. However, at the same time, higher recovery ratio creates higher concentration of rejected seawater, which means osmotic pressure becomes higher and subsequently, higher feed pressure with higher energy becomes necessary. In addition, the product water quality tends to be worse due to higher concentration of feed water. Thus, increasing of recovery has both merits and demerits.

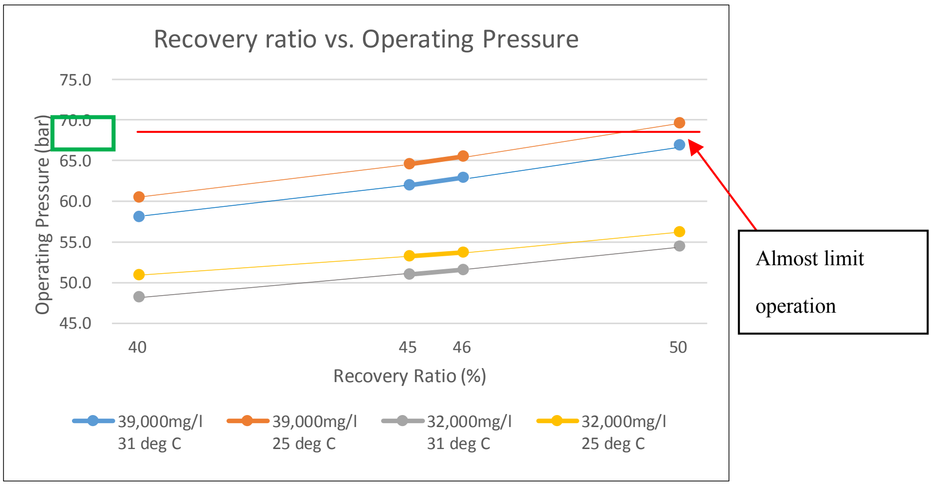
In design of DSPs, the most suitable recovery ratio is determined from several viewpoints including stable operation of the system and equipment and projected power consumption according to the raw seawater and required product water qualities as follows:

(2) Study of operation pressure

Figure 6.3.5 shows expected operating pressure by changing the recovery ratio and feed water condition for different seawater TDS and temperature. This simulation was based on the necessary numbers of RO membrane, total area satisfying the flux of 13.5 $l/m^2/h$, which is widely adopted value by major RO membrane suppliers and plant supplied for the RO membrane flux after the pre-treatment system of the selected type in the Study and was also agreed between CMWSSB and the Study Team. The recovery ratio simulated range is from 40% for the lowest popular recovery ratio in the worldwide seawater DSP to 45% for the actual ratio at the Nemmeli and Minjur DSPs to 46% as per the suggestion in DPR, and to 50% only for study.

As per Figure 6.4.5, required operating pressure at 50% recovery with the lowest temperature and the highest TDS will be almost 70 bar. At present, the worldwide commercial seawater desalination RO membrane element and pressure vessel is designed with maximum operating pressure of 70 bar. In case of 46%, operation pressure is 65 bar, which is acceptable.

To make the operating pressure within the permissible level of the equipment that are commercially produced, the maximum recovery will be 46% or slightly more.



Source: JICA Study Team

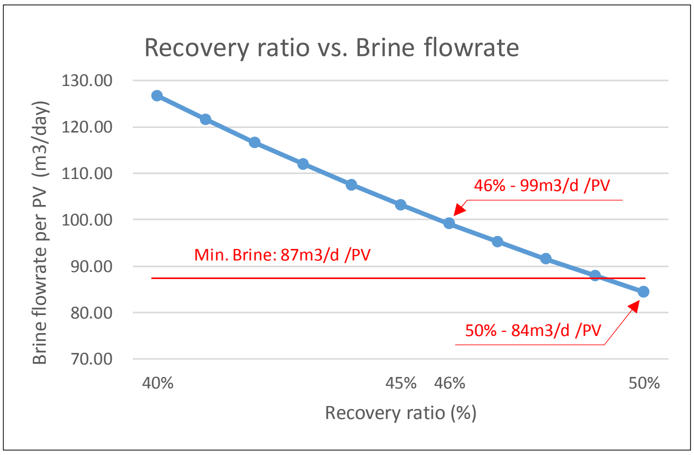
Figure 6.3.5 Relationship between Operating pressure and Recovery ratio (Flux:13.5l/m^2/h)

(3) Study of brine flow rate

A change in the recovery ratio influences brine's flow rate at the RO membrane surface. The brine, which is rejected seawater by RO membrane element, is fed to the next downstream RO membrane element, and flows out as "rejected water" from the RO unit and finally is discharged into the sea. This brine water flow contributes to the cleaning of membrane surface during operation. This is the reason for RO plant being operated for several months continuously without the need for cleaning.

From these viewpoints, minimum flow speed will be advised by the RO membrane supplier. Flow speed will be converted to minimum brine flow rate, and currently a flow rate of 60 l/min (about 87 m^3/d) is recommended.

As per Figure 6.3.6, the higher recovery ratio will result in the lower brine water flow. To maintain the recommended operational condition of RO membrane, 49% will be the maximum recovery ratio.



Source: JICA Study Team

Figure 6.3.6 Relationship between Brine flow rate and Recovery Ratio

(4) Energy consumption

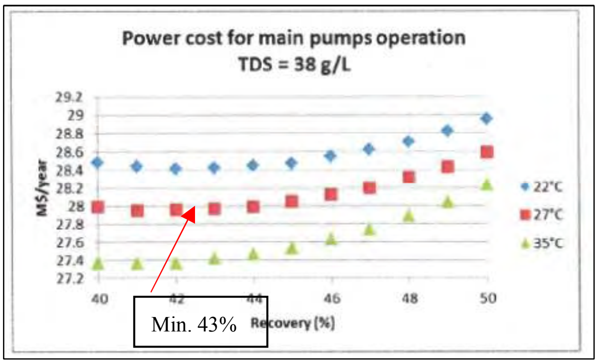
In this preliminary design stage, detailed specification of each process unit will not be determined. Therefore, actual operation cost, most of which will be incurred by energy consumption, cannot be precisely calculated. In this study, a past similar simulation implemented in another project will be utilized to project the best recovery ratio in the project, in terms of energy consumption. The simulation conditions of the referred similar project are as follows:

- Product water quantity: 281,000 m^3/d
- Feed seawater condition: 38,000–42,000 mg/l, 22–35 deg C

Operation cost, including depreciation and chiefly energy for intake unit, pumps in pretreatment unit, RO high pressure pump, and other related pumps will be calculated by changing recovery ratio. We will refer to temperature of 27 °C in Figure 6.3.7 and Figure 6.3.8, because the design conditions of this project is between 25 and 31 °C and 32,000–39,000 mg/l (estimated average is about 35,000 mg/l).

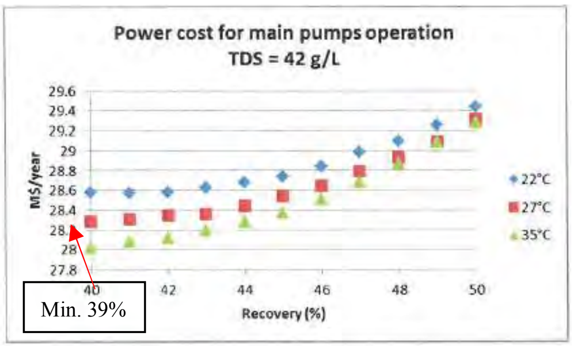
Figure 6.3.7 shows that with 38,000 mg/l TDS seawater, 43% recovery seems to be the lowest energy consumption. Figure 6.3.8 shows that with 42,000 mg/l TDS seawater, less than 40%, seemingly 39%, recovery is the lowest energy consumption.

Figure 6.3.7 and Figure 6.3.8 show that 4% (43–39%) improvement can be achieved by decreasing 4,000 mg/l (42,000–38,000 mg/l). JICA FS project estimated 3% higher than Figure 6.3.7 by decreasing 3,000 mg/l (38,000–35,000 mg/l); therefore, 46% is estimated to be the best.



Source : JICA Study Team

Figure 6.3.7 Operation Cost versus Recovery Rate (38 g/l)



Source : JICA Study Team

Figure 6.3.8 Operation Cost versus Recovery Rate (42 g/l)

(5) Conclusion

As per the discussion given above, 46% recovery has been concluded to be the best recovery ratio for the Perur DSP. This 46% recovery has about 10% margin from the limitation of operating pressure and brine flow rate. At this recovery ratio, the DSP will not face difficulties in satisfying the required product water quality defined in Subsection 6.3.1.

6.3.5 Seawater Intake

(1) Configuration

Seawater intake pit will receive and transfer the seawater to the pre-treatment section. Seawater intake pit will have two chambers separated by a partition wall at the center. The water production capacity of each of the chamber will be 200 MLD. Whenever required, either one of the two chambers can be maintained, cleaned, or repaired while the other chamber is in operation.

The facilities in the seawater intake pit will be as follows:

- Stop logs for major equipment including intake pipes' entrance
- Trash rack (1+1)
- 4 sets of travelling screens (2 sets in each chamber) with stop logs for maintenance
- 6 sets of seawater pumps (3 = 2+1 sets in each chamber)
- Two screen wash pumps (1+1)

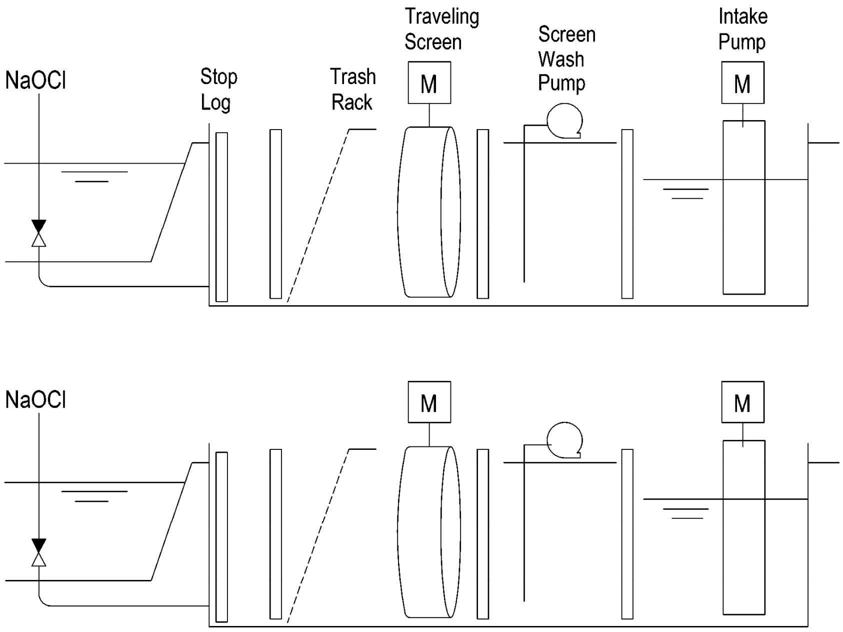
Seawater flow will be controlled according to the set value given by the operator according to the plant operation requirement. Travelling screen will be equipped with timer for cyclic washing. The washing system will run whenever differential pressure across the screen exceeds a set value.

When one of the seawater intake pumps will be started, seawater for screen washing will be fed by the pump by a wash water pipe branched from the discharge line of the intake pump. Therefore, the screen wash pump will be used only for start-up when no seawater is running.

Seawater pumps discharge the seawater to the subsequent lamella filter in the pretreatment section.

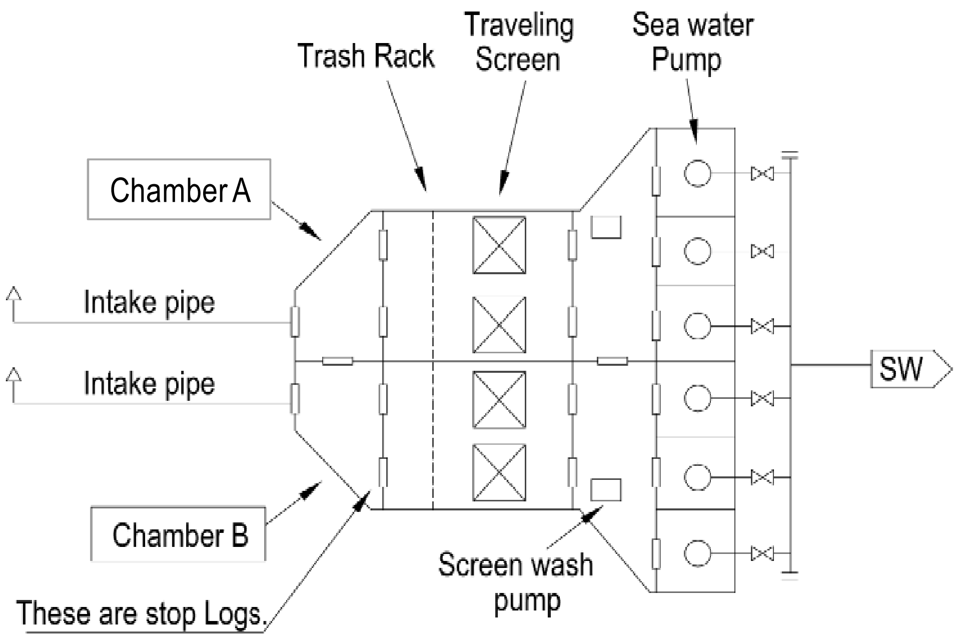
(2) Arrangement

Typical arrangement of the seawater intake is shown below.



NaOCl: sodium hypochlorite
Source: JICA Study Team

Figure 6.3.9 Seawater Intake Arrangement (Section)



Source: JICA Study Team

Figure 6.3.10 Seawater Intake Arrangement (Plan)

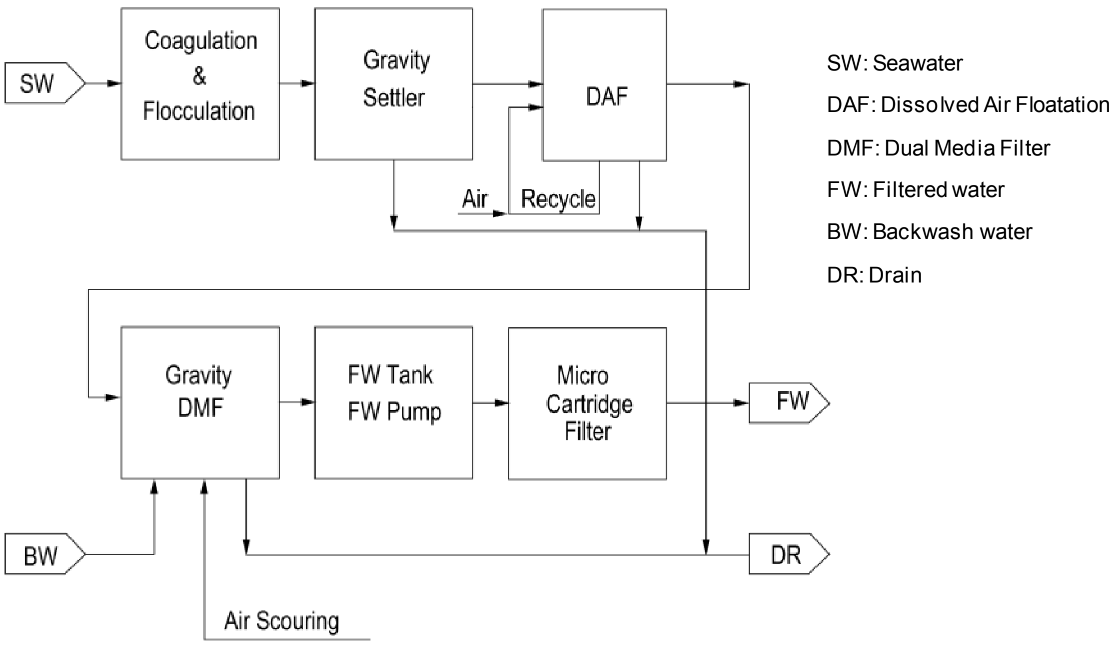
6.3.6 Pre-Treatment Section

(1) Configuration

Seawater from intake pump will be filtered to remove suspended solids thereby preventing the RO membrane from clogging. One set of pretreatment system will be provided for 400 MLD. In case of 200 MLD operation, half of the facilities will be in service and remaining half will be isolated by isolation gates provided at each cell for maintenance of the equipment or cleaning of cells.

Figure 6.3.11 presents block flow of the pretreatment section. The pre-treatment section consists of the following:

- Coagulation 8 cells and Flocculation Basin: 96 cells
- Gravity Settler (Lamella Filter): 24 cells
- Dissolved Air Floatation (DAF): 32 cells
- Dual Media Filter (DMF): 40 cells
- Filtered water storage tanks combined with DMF backwash tanks: 2 cells



Source: JICA Study Team

Figure 6.3.11 Pre-Treatment Block Flow

(2) Coagulation and flocculation chambers

Seawater will be pumped into the coagulation chamber followed by flocculation chambers after mixing with sulfuric acid (H_2SO_4) (for better coagulation and scale control in RO membrane) and ferric chloride ($FeCl_3$) (for coagulation) to remove suspended solids in raw seawater through the following filters.

(3) Gravity settlers (lamella filters)

In the lamella filters, seawater will flow upward between lamella plates. As these plates will be declined, suspended solids will meet the plate during upward flow. When the particles reach the plate surface, they lose upward force and particles move toward downward direction on the surface of the plate. Lamella filters are expected to remove 90–95% of the suspended solids from the raw seawater.

The collected turbid materials will be drained from the filter to wastewater tank periodically.

(4) DAF

The effluent from the lamella filters flows into the DAF. This is a high rate process using microbubbles that cause the coagulated and flocculated particles to float onto the surface of the clarification basin.

If the raw seawater condition is not very bad, recycling and microbubbling processes will be held in standby mode. In this operational mode, the seawater will pass the DAF without treatment. Operation of the microbubbling floatation will be determined according to the conditions of the downstream DMF.

(5) DMF

Effluent from DAF flows into DMF, which is gravity type and contains anthracite and sand in each bed.

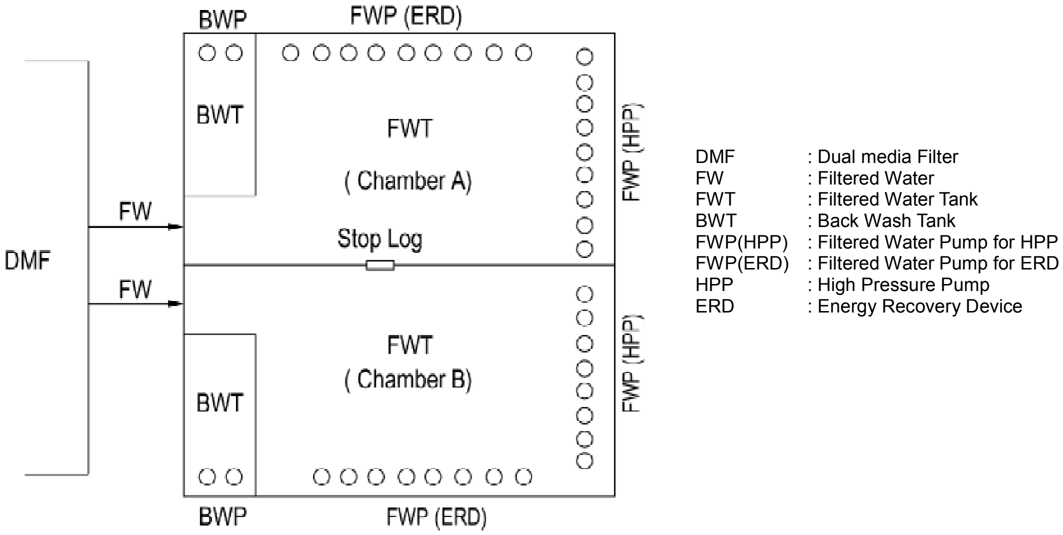
To maintain appropriate function, backwashing system of DMF will be designed to enable "24-h mode," where backwashing of all 40 cells will be completed in 24 h. In 24-h mode operation, which will take place during severe raw water quality condition, backwashing of two cells needs to be performed simultaneously to ensure sufficient backwash duration maintained for each cell. If the seawater condition will be better, longer backwashing interval mode, such as 36-h or 48-h modes, can be selected. The following are the procedural steps in case of 24-h mode in backwashing: (1) drain step, 5 min; (2) air scouring step, 5 min; (3) venting step, 2 min; (4) backwashing step, 13 min; (5) rinsing step, 47 min, totaling to 72 min for 1 cell.

Because the backwash requirement of two cells may come at the same time, 4 numbers of backwash pumps and air scouring blowers will be provided (each 2 (1+1) × 2 = 4). Backwashing water is the filtered water to be taken at the filtered water storage tank.

(6) Filtered water storage tank

Figure 6.3.12 shows layout of the filtered water storage tank. The tank will be divided by a partition wall into two sections, each of which will be capable to operate at 200 MLD production. Chamber A will have feed pumps for nine (9) RO trains and chamber B will have those for 8 RO trains. On the partition wall, a stop log will be provided, which will be opened during usual operation. The stop log will be closed after reducing the plant load to a production capacity of 200 MLD if maintenance work is required.

Each section of the storage tank will have overflow to backwash tank. Seawater flow rate to the pre-treatment system will be controlled to ensure sufficient recharge of the backwash tank to enable the selected backwash cycle mode. Excess filtered water will overflow from the backwash tank.



Source: JICA Study Team

Figure 6.3.12 Filtered Water Tank Arrangement

6.3.7 RO Section

(1) Configuration

RO section is the heart of the plant to produce pure water.

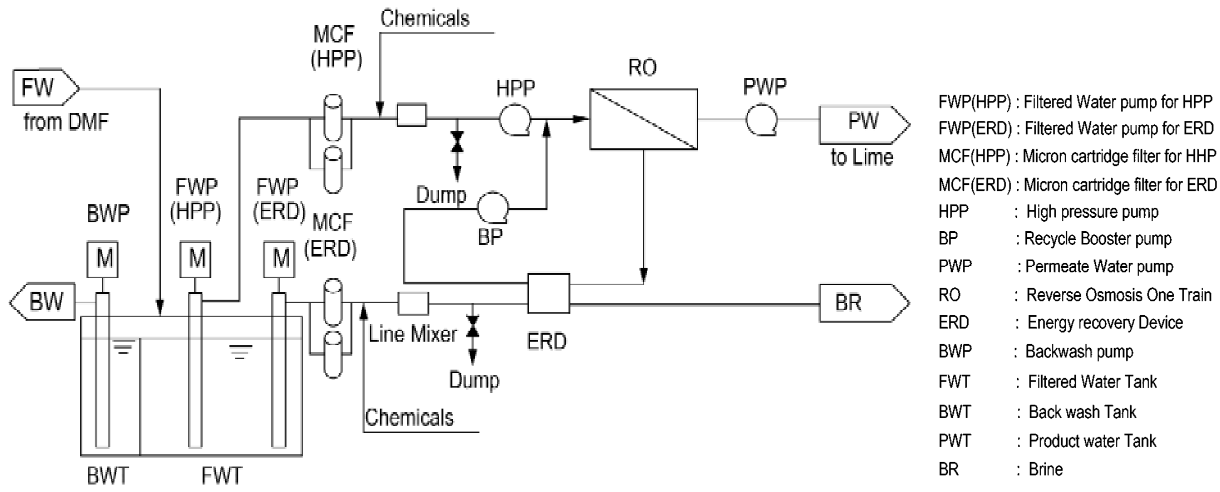
From the filtered water storage tank, the filtered water will be sent to the RO section by filtered water pumps via micron cartridge filter (MCF).

(2) Main components of an RO train

RO train is a single-stage and single-pass design. The main components of an RO train are as follows:

- One filtered water pump for high pressure pump (FWP (HPP))
- One filtered water pump for energy recovery device (FWP (ERD))
- Micron cartridge filter with standby for HPP feed line (MCF (HPP))
- Micron cartridge filter with standby for ERD feed line (MCF (ERD))
- One recycle booster pump (BP)
- One set of energy recovery device (ERD)
- One permeate pump (PWP)

Variable frequency devices (VFDs) will be provided on the FWP (HPP), FWP (ERD), BP, and PWP motors. A total of 17 trains including 1 standby train will be designed for a production of 400 MLD. The standby unit will be necessary to maintain a production of 400 MLD even during periodical chemical cleaning, membrane replacement, or routine mechanical/electrical/instrument maintenance work.



Source: JICA Study Team

Figure 6.3.13 Schematic of a Reverse Osmosis Train

(3) Description of each train

1) FWP (ERD)

FWP (ERD) will be started through dump line provided at downstream of the MCF (ERD) and the line mixer. Required chemical (sodium bisulfite (SBS)) will be dosed to neutralize chlorine. When the feed water quality reaches the permissible range, dump line will be closed and the filtered water will be introduced into the RO train by running recycle BP together with ERD. Flow rate will be adjusted by the VFD installed on FWP (ERD) and BP motors.

2) FWP (HPP)

When BP is started, FWP (HPP) also needs to be started through the dump line provided at downstream of the MCF (ERD). SBS will be dosed. When the feed water quality comes to the permissible range for the operation, dump line will be closed and the HPP will be started. Operating condition will be adjusted by the VFD installed on the FWP (HP). No VFD will be provided to HPP but throttling control valve (PCV) will be provided at the pump discharge for start-up and shutdown operation. PCV will be used to adjust RO feed pressure when the seawater condition goes out of design range due to unexpected heavy rains, which may result in lower TDS condition.

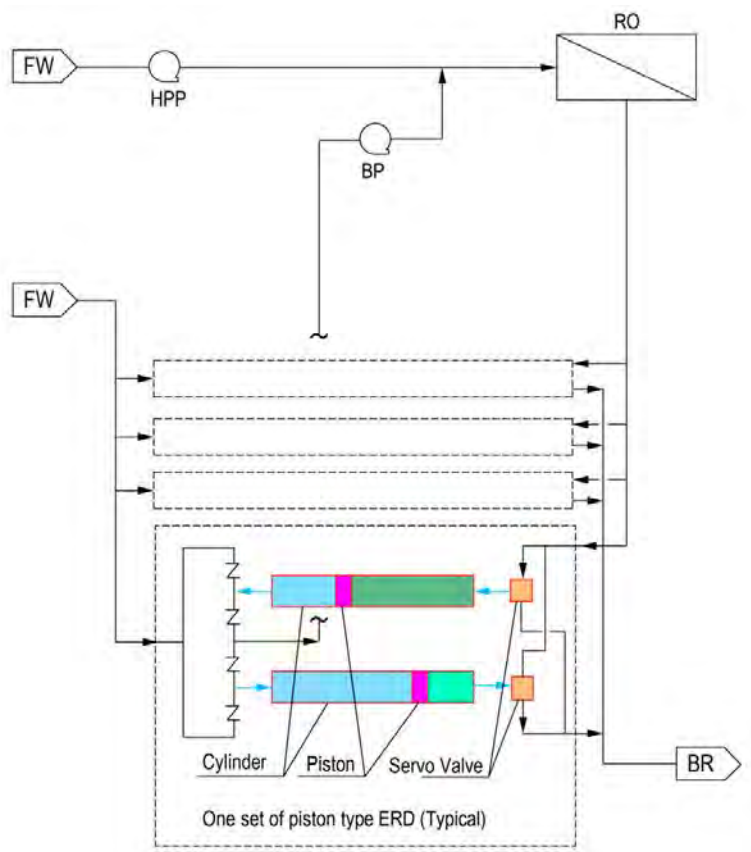
3) MCF

A 5-μ pore size polypropylene wound element will be used. To detect fouling condition, deferential pressure will be installed and a standby unit will be installed for element replacement work.

4) ERD

As the energy recovery efficiency is higher than the Pelton turbine, Francis turbine or turbo charger, the isobaric type will be used in the Project. There are two kinds of isobaric ERD: rotary type and piston type. Although the area to arrange piston-type isobaric ERD requires more space than rotary-type, the piston-type will be used for the Perur project considering less noise and less brine mixing rate than rotary-type.

Figure 6.3.14 illustrates the piston-type ERD system. In this system, two cylinders comprise one set; therefore, several sets will be arranged in one RO train. The high pressure brine from RO membrane comes into a cylinder that displaces low-pressure filtered water. The displaced filtered water traverses into the BP and will be fed to the RO membrane together with HPP outlet flow. After pressurizing the filtered water in the piston cylinder, the brine will be displaced out by the low-pressure filtered water from the cylinder. Each cylinder will have its own servo valve to changeover the brine inlet and outlet of its own cylinder. The servo valve operation will be automatically controlled together with FWP (HPP), FWP (ERD), and BP. The control system will manage RO train operation automatically when the desired production is given by the operator.



ERD: energy recovery device, BR: brine, FW: filtered water, HPP: high pressure pump.
Source: JICA Study Team

Figure 6.3.14 Schematic of Piston-Type Energy Recovery Device

5) PWP

Permeate water from RO trains will be delivered by PWP to post-treatment section. Details of the posttreatment system are described herein after.

(4) RO membrane

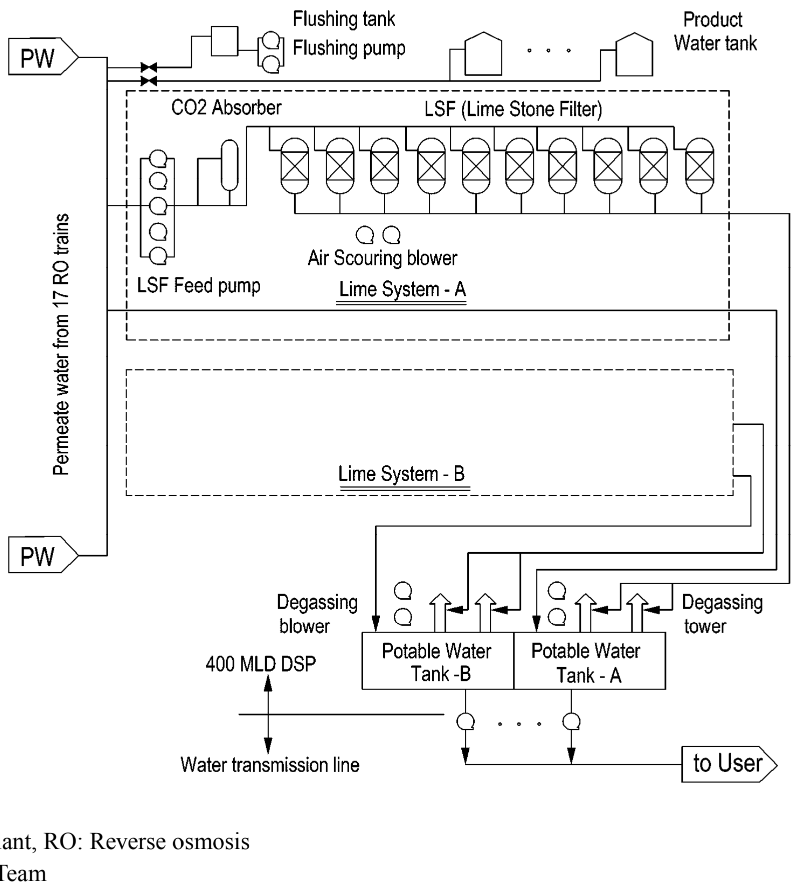
Please refer to Subsection 6.3.1 regarding RO membrane design.

6.3.8 Post-Treatment Section

(1) Configuration

Post-treatment of permeate should meet the statutory product water quality requirements. Post-treatment will consist of remineralization/stabilization and disinfection of water.

Lime stone filters will be used for remineralization and chlorine injection will be used for disinfection, as shown in following flow sheet. The system will be divided into two sections, each meeting the production capacity of 200 MLD.



DSP: Desalination Plant, RO: Reverse osmosis
Source: JICA Study Team

Figure 6.3.15 Schematic of Post-Treatment Section

(2) System description

Approximately 30% of the permeate from RO section will be pumped into the lime stone system after CO_2 absorption, whereas the remaining 70% will be directly sent to the potable water tank.

Consequently, the RO permeate and the mineralized water will be blended together at a rate of 70 and 30%, respectively, in the potable water tank.

In the posttreatment, the CO_2 absorption and lime stone filtration will make the water rich in calcium that can be explained by the following chemical reaction: $CO_2 + H_2O + CaCO_3 = Ca(HCO_3)_2$. The design calcium concentration should reach 40 mg/l. Excess CO_2 gas will be discharged by degassing tower to minimize the consumption of pH adjustment chemical, that is, sodium hydroxide (NaOH). The pH adjustment will result in positive Langelier Index, which will mitigate water pipe corrosion. Finally, chlorine will be added to disinfect the water prior to delivery to the users.

Four product water tanks, each with a capacity of 9,000 m^3, will be provided to store permeate water. When the DSP cannot pump the produced water to the transmission network in case of any failure or unexpected maintenance work in the produced water transmission pumping station or the transmission line, the permeate will be led to the product water tanks, instead of flowing to the posttreatment system. This will prevent any wastage of permeate. As the total capacity is 36,000 m^3, the tanks can store the full production water for 2 h while total capacity of the potable water tanks will be 2,800 m^3, which is equivalent to 10-min production.

6.3.9 Wastewater Treatment

(1) Configuration

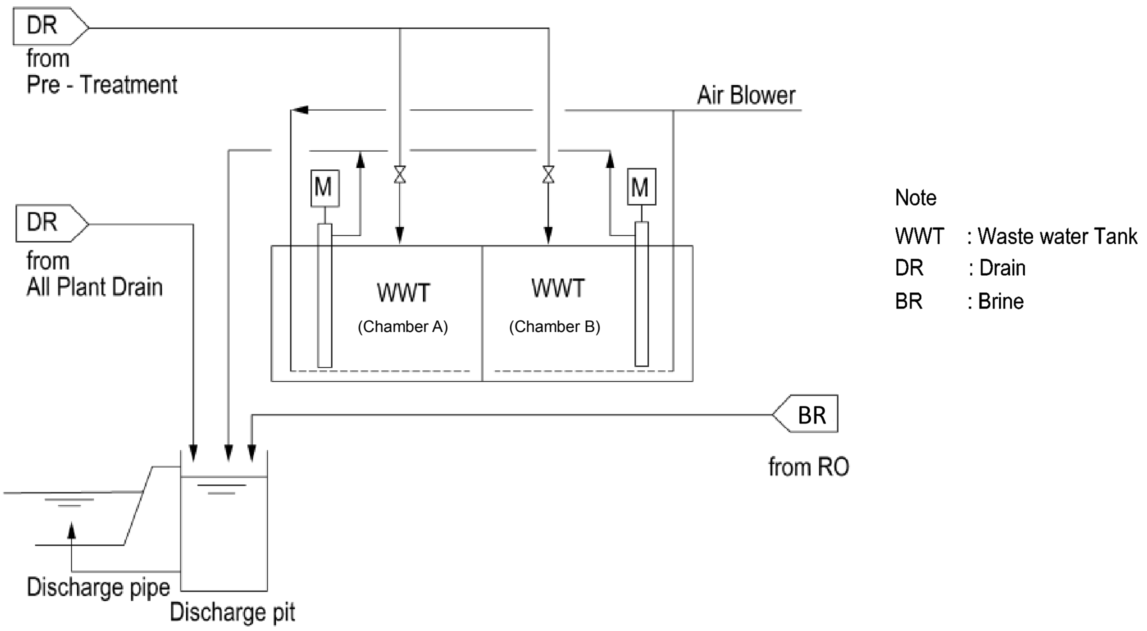
Major wastewater from the DSP is the brine flow from the RO trains. It will be discharged into the sea together with the wastewater from the pretreatment and post-treatment sections through brine discharge pipe. All other plant drains such as chemical yard spillage drain, RO membrane cleaning waste, and laboratory waste will be neutralized prior to being mixed with the brine and being discharged into the sea. Sanitary waste will be treated biologically prior to being discharged through the brine discharge pipes. Storm water will be collected by the drain system in the DSP site and will be discharged to the seaside.

(2) Pretreatment drain

Wastewater tanks will collect and treat drains from pretreatment system, which will consist of lamella filter drain, DAF scraping sludge, and DMF backwash waste. Two wastewater tanks will be provided. Each tank will have 100% capacity against the designed wastewater flow so that cleaning works of the wastewater tanks can be done along with the full load operation. Air blower will agitate the sludge in the tank prior to pumping out of the wastewater and sludge.

(3) RO brine

Brine from all the RO trains will be discharged into the sea via discharge pit together with wastewater tank discharge as shown in flow sheet.



RO: Reverse Osmosis
Source: JICA Study Team

Figure 6.3.16 Schematic of the Wastewater Treatment and Discharge

6.3.10 Chemical Storage

The chemicals to be used in the Perur DSP were listed in Table 6.3.3. The chemicals will be stored in tanks, for each of which at least two tanks will be provided. These storage tanks will be capable of storing chemicals required for two weeks at full load operation. One tank will be used for operation, and the second tank will be on standby, resulting in release of week chemical charges into the empty tank.

6.3.11 Instrumentation, Monitoring, and Control System

(1) Basic concept

The entire plant will be designed for automatic operation to minimize the requirement for manual intervention. Flow rates of main streams, seawater to the pre-treatment section, RO trains' feed water, permeate product water, and so on will be controlled as per the flow rates and will be continuously monitored by the flow meters.

Water quality of the raw seawater and filtered water after passing through the pre-treatment section will be analyzed by laboratory sampling so that the suitable dosing rate of the chemicals is obtained. Water quality (pH and oxidation–reduction potential (ORP)) to RO trains will be monitored and an alarm will annunciate if the values are out of range. The potable water quality going to users will be monitored and chemicals (NaOH and chlorine) will be dosed automatically. Table 6.3.4 lists the summary of the monitoring plan.

Table 6.3.5 Monitoring Plan of the Water Quality

No.	Seawater	Raw seawater	Filtered water	Potable water
1	Silt Density Index	✓	✓	
2	pH	✓	✓	✓
3	Total Dissolved Solids	✓	✓	✓
4	Temperature	✓	✓	✓
5	Electrical conductivity	✓	✓	✓
6	Turbidity	✓	✓	✓
7	Residual chlorine	✓	✓	✓
8	Boron content	✓		✓
9	Langelier index			✓
10	Oxidation–reduction potential		✓	
11	Alkalinity			✓

Source: JICA Study Team

(2) Seawater intake and pretreatment section

Travelling screens at the seawater intake pit will run periodically set on timers, usually once per shift of operation. In addition, it will run when differential pressure across the screen exceeds a certain set value. If differential pressure still increases even after washing, higher rotation speed will be applied.

Seawater flow rate to coagulation and flocculation chambers will be measured and controlled as per the set value given by the operator. In case when running pump trips, standby pump will be automatically started.

Relative dosages of H_2SO_4, $FeCl_3$, and polyelectrolyte will be automatically controlled as per the given dosing ratio.

DMF backwashing regeneration mode can be selected from 24-h mode, 36-h mode, or free mode, which is no backwashing unless operator sets washing mode.

Any pump has alarm warning at low level and trip protection at low–low level.

(3) RO section

RO train can be controlled either by membrane inlet pressure control or permeate water production control at selected recovery ratio. Depending on seawater condition (TDS), operator will select the control mode.

To protect the RO membrane, high pressure is provided for alarm and high–high pressure is provided to trip HPP. For feed water quality, if ORP value exceeds certain set point, that RO train is tripped for membrane protection from chlorine attack.

Chemical dosing will be controlled by stroke control of the dosing pump according to the dosing rate and filtered water flow rate.

If the permeate water quality becomes out of limit, alarm will annunciate and this water needs to be dumped.

(4) Post-treatment section

Flow split, 30% of permeate to lime stone system and 70% bypass, will be controlled automatically. And depending on the total flow of the permeate, number of lime stone filters to be in service will be selected automatically.

Lime stone filter will have level sensor to detect the low level of lime stone layer so as to be changed over to the standby filter for recharging.

Backwashing of the lime stone filter will be performed automatically.

(5) Wastewater tank

When the backwash wastewater flows into the wastewater tank, it will be stored and discharged at a certain flow rate to empty the tank until next batch of backwash waste arrives so that the wastewater discharging impact can be moderately even.

(6) Instrumentation List

Including the instrumentations described above, instrumentation list in the entire Perur DSP is given in Appendix 6.5.

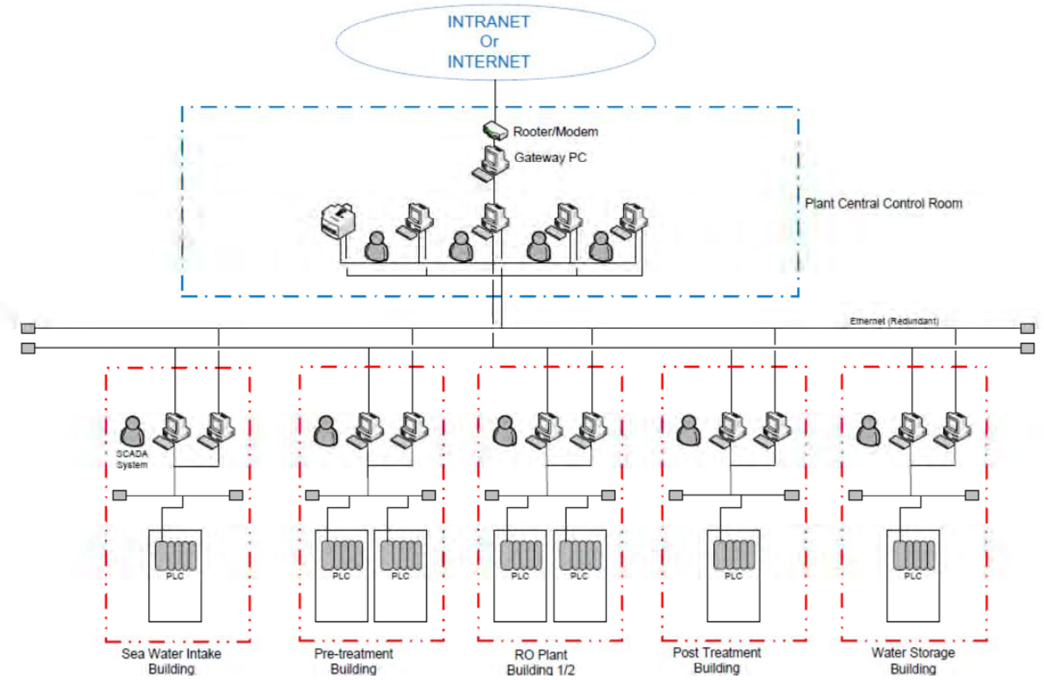
(7) Monitoring and control system

By installing Distributed Control System (DCS), a control center at an administration building, the staff can monitor and operate the main facilities. In addition, the center can conduct the following operations, such as i) data management of the operational conditions like flow rate and other parameters, and ii) preparation of daily or monthly reports.

The outline of DCS is as follows:

- Four sets of Programmable Logic Controller (PLC) will be installed at each electricity room for collecting local information.
- The data collected by the PLC will be transferred to a server of DCS through a LAN connected through optical cables.
- The data stored in a server will be referred to remote control at each facility through the graphic presentation or graph on the monitor called DCS client.
- DCS client will be able to control three facilities simultaneously through three large screens.
- UPS will be installed for printers used for data preparation against any possible power failures.

The overall configuration of the monitoring and control system is illustrated in Figure 6.3.17.



Source: JICA Study Team

Figure 6.3.17 Overall Configuration of the Operation System

6.3.12 Load List and Specific Power Consumption of the Plant

(1) Load list and power requirement

Table 6.3.5 shows load list of the Perur DSP based on the design in the study. According to the list, the total power requirement of the 400 MLD DSP is projected at 73.9 MW, which can be rounded up to 80 MW.

Table 6.3.6 Load List and Specific Power Consumption List

I	**SEAWATER INTAKE**		**1,080**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
		SEAWATER INTAKE	1	set	**89,067.55**	**3,726.10**
II	**CHEMICAL DOSING SYSTEM**		**1,077**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
		CHEMICAL DOSING SYSTEM	1	set	**12,395.72**	**572.39**
III	**PRETREATMENT SYSTEM**		**1,077**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
		PRETREATMENT SYSTEM	1	set	**90,803.89**	**4,340.48**
IV	**REVERSE OSMOSIS PLANT**		**869.6**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
		REVERSE OSMOSIS PLANT	1	sets	**1,194,841.01**	**51,409.10**
V	**POSTTREATMENT**		**400**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
		POST TREATMENT	1	set	**40,704.49**	**1,964.04**
VI	**WATER STORAGE AND PRODUCT WATER TRANSMISSION**		**400**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
		Water Storage and Transfer	1	set	**100,874.08**	**4,211.52**
VII	**SEAWATER OUTFALL**		**680.0**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
		Seawater Outfall	1	set	**112.20**	**4.68**
VIII	**FACILITY POWER**		**400.0**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
		Facility Power	1	set	**22,440.00**	**935.00**
IX	**MARGIN**		**400.0**	**MLD**		
	No.	Position name	Number	Units	Electricity Consumed kW/d	Electricity Usage kW
	1	Margin	1	set	**46,537.17**	**6,716.33**
	Total				1,597,776.11	73,879.64

400.00	MLD
3,994.44	kW/MLD
3.99	kW/m³

In case excluding "VI Water Storage and Product Water Transmission"

400.00	MLD
3,742.26	kW/MLD
3.74	kW/m³

MLD: million liters per day.
Source: JICA Study Team

(2) Comparisons with DPR

In general, power consumption at a seawater DSP of RO technology is approximately 4.0 kW/1 m^3 of production water; however, it varies by raw seawater quality, designed system, products used in the plant, and so on.

Table 6.3.6 presents power consumption per m^3 based on the design in the Study, excluding the product water transmission and marginal power consumptions listed in the table above as "MARGIN"[1], compared with that in the DPR. The projected power consumption in the study and DPR are mostly the same and slightly more efficient than the general value of 4.0 kW/m^3.

Compared with the DPR, the power consumption in the Study is slightly higher. In addition to the security level in selection of motor sizes of the major equipment, increase in the water flow from the intake to pre-treatment, which has been resulted out of revision in the back wash water volume of the pre-treatment system to ensure complete purge, and change of the post-treatment system from lime power to lime filter would be major causes.

Table 6.3.7 Specific Power Demand Projected by the Study and Comparison with the DPR

Item		DPR	JICA Study Team
1	Intake	0.243 kW/m^3	0.223 kW/m^3
2	Pre-treatment	0.203 kW/m^3	0.258 kW/m^3
3	Reverse Osmosis	2.918 kW/m^3	2.987 kW/m^3
4	Post-treatment	0.025 kW/m^3	0.102 kW/m^3
5	Ancillary	0.05 kW/m^3	0.056 kW/m^3
	Total for Plant	**3.439 kW/m^3**	**3.626 kW/m^3**

* To be used as reference
Source: JICA Study Team

6.3.13 Major Equipment and Material for Desalination

Under the conditions described from 6.3.5 to 6.3.10, the required major equipment list and material for Desalination. Abridged edition of list is shown below. Detailed equipment list and material in the entire Perur DSP is given in Appendix 6.6.

[1] The power consumption for "Margin" takes into account temporary hike in power consumption that can be incurred in variation of the water flow or maintenance work. It was not taken into account in the DPR.

Table 6.3.8 Major Equipment and Material List (abridged edition)

Ⅰ SEA WATER INTAKE 1,080 MLD

No.	Equipment name	Capacity(need)	Units	Capacity(select)	Units	Head(m)	Input(kW)	Number: Duty	Number: Standby	Number: Total	Model	Specification	Material/Other
1	Intake terminal	1,080	MLD	22,500	m^3/hr	-	-	2		2			
2	Intake Pump	1,080	MLD	11,250	m^3/hr	25	1000	4	2	6	Virtical Turbin Pump		GFRPP
3	Shock Dosing Pump (NaClO)	3.8	m3/d	1,900.0	L/hr	30	3.7	2	1	3	Chemical Pump	Dose rate:10mg/l	Ti

Ⅱ CHEMICAL DOSING SYSTEM 1,077 MLD

No.	Equipment name	Capacity(need)	Units	Capacity(select)	Units	Head(m)	Input(kW)	Number: Duty	Number: Standby	Number: Total	Model	Specification	Material/Other
1	Dosing Tank (H_2SO_4)	292.7	m^3	100	m^3	-	-	3		3		14days each,Concentration:98%	FRP
2	Dosing Pump (H_2SO_4)	20,905	L/d	217.8	L/hr	30	0.4	4	4	8	Chemical Pump	Dose rate:35mg/l	SUS316
3	Dosing Tank ($FeCl_3$)	922.70	m^3	100	m^3	-	-	10		10		14days,Concentration:40%	FRP
4	Dosing Pump ($FeCl_3$)(For Lamella)	47,072	L/d	82.0	L/hr	30	0.4	24	12	36	Chemical Pump	Dose rate:Max25mg/l,Concentration:40%	SUS316
5	Dosing Pump ($FeCl_3$)(For DAF)	18,829	L/d	25.0	L/hr	30	0.4	32	16	48	Chemical Pump	Dose rate:Max10mg/l,Concentration:40%	SUS316
6	Dosing System (Polymer)(For Lamella)	269,250	L/d	468	L/hr	30	11	24	12	36		Dose rate:0.1-0.5mg/l,Concentration:0.2%	SUS316
7	Dosing System (Polymer)(For DAF)	161,550	L/d	210	L/hr	30	7.5	32	16	48		Dose rate:0.1-0.3mg/l,Concentration:0.2%	SUS316

Ⅲ PRETREATMENT SYSTEM 1,077 MLD

No.	Equipment name	Capacity(need)	Units	Capacity(select)	Units	Head(m)	Input(kW)	Number: Duty	Number: Standby	Number: Total	Model	Specification	Material/Other
1	Lamella Clarifier(Gravity settler)	1,077	MLD	1,870	m^3/hr			24		24		Area required/unit:1,514.17m2,18m×7.8m×24	Concreat+epoxy coating
2	DAF	1,058	MLD	502.5	m^3	-	-	32		32		Area:100.5m^2,Loading:15.0m/hr	Concreat+epoxy coating
3	Dual Media Gravity Filters	1,051	MLD	136.9	m^2	-	-	40		40		Verocity:8m/hr, Filler:Sand-Anthracite,16.2m×9.0m×6.0m	Concreat+epoxy coating
4	Backwash Pump	6,000	m^3/hr	100.0	m^3/min	8	190	1	1	2	Centrifuge Pump	40m/h,10min	Super Duplex

Ⅳ REVERSE OSMOSIS PLANT 869.6 MLD

No.	Equipment name	Capacity(need)	Units	Capacity(select)	Units	Head(m)	Input(kW)	Number: Duty	Number: Standby	Number: Total	Model	Specification	Material/Other
1	Filtered seawater Storage Tank	6,039	m^3	3,000	m^3	-	-	2		2		10min	
2	RO Filtered Water Pump	400	MLD	1,042	m^3/hr	150	620	16	1	17	Centrifuge Pump	Inverter Motor	Super Duplex
3	ERD Filtered Water Pump	470	MLD	1,223	m^3/hr	50	230	16	1	17	Centrifuge Pump	Inverter Motor	Super Duplex
4	ERD Recycle Booster Pump	470	MLD	1,223	m^3/hr	50	230	16	1	17	Centrifuge Pump	Inverter Motor	Super Duplex
5	RO High Pressure Pump	400	MLD	1,042	m^3/hr	560	2,150	16	1	17	HPP	Fixed Motor	
6	Seawater Reverse Osmosis(SWRO)	25	MLD/train	13.5	l/m2/h	-	-	16	1	17	8 inch spiral	Flax:13.5l/m2/h,2,128membranes(133membranes/train)	
7	Energy Recovery System(ERD) In case of DeROs	474	MLD	29.625	MLD	-	-	16	1	17		1uits/system	Piston type
8	Permeat Water Pump	25,008	m^3/d	1,042	m^3/hr	25	100	16	1	17	Centrifuge Pump		SUS316

Ⅴ POST TREATMENT 400 MLD

No.	Equipment name	Capacity(need)	Units	Capacity(select)	Units	Head(m)	Input(kW)	Number: Duty	Number: Standby	Number: Total	Model	Specification	Material/Other
1	Lime Stone Filter Feed Pump	120,000	m^3/d	625	m^3/hr	25	60	8	2	10	Centrifuge Pump		SUS316
2	Lime Stone Filter	120,000	m^3/day	5,000	m^3/hr	-		16	4	20		LV=25m/hr, φ 4.4m(15.2m2)×4.9mH (4.3m)	SUS316
3	Degassing Air Blower	4,188	m^3/hr	69.8	m^3/min	228mmAq	5.5	2	2	4	Rotary twin		FC250
4	Degassing Tower	1,360	m^3/hr	80	m^3			4		4		φ 3.7m(10.7m2)×7.5mH,Air:1,094m3/hr,Water:2,094m3/hr	SUS316
5	Carbon Dioxide absorber	750	m^3/hr	750	m^3/hr	-	-	2		2		Number of Vessels:10	
6	Recorbonation Tower Feed Pump	2,100	m^3/hr	2,100	m^3/hr	20	160	6	2	8	Centrifuge Pump		SUS316

Ⅵ Water Storage and Transfer 400 MLD

No.	Equipment name	Capacity(need)	Units	Capacity(select)	Units	Head(m)	Input(kW)	Number: Duty	Number: Standby	Number: Total	Model	Specification	Material/Other
1	Potable Water Tank	3,000	m^3	1,500		-	-	2		2		10min	Concreat+epoxy coating
2	Product Water Tank	36,000	m^3	9,000	m^3			4		4		2hr	CS+epoxy coating
3	Potable Water Delivery Pump	400	MLD	4,167	m^3/hr	77.8	1200	4	2	6	Centrifuge Pump		SUS316

Ⅶ SeaWater Outfall 680.0 MLD

No.	Equipment name	Capacity(need)	Units	Capacity(select)	Units	Head(m)	Input(kW)	Number: Duty	Number: Standby	Number: Total	Model	Specification	Material/Other
1	Discharge Tower	680	MLD					1		1			

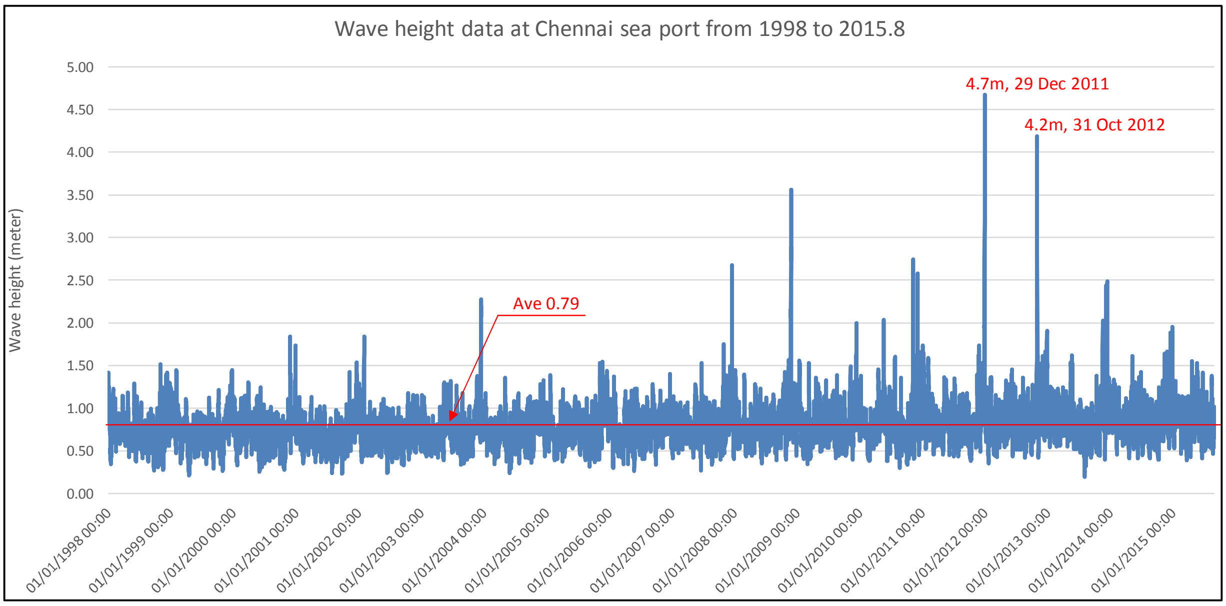
Source: JICA Study Team

6.3.14 Land Development Plan and Foundation of Civil Structure and Building

(1) Land development

1) Long-term data on sea level

The ground level of any plant on seaside needs to be determined so that the plant will not be damaged by waves. At Perur, the wave height is not monitored, but the data at Chennai seaport from the year 1998 to 2015 has been recorded by NIOT (National Institute of Ocean Technology) as shown in Figure 6.3.18. This is wave data that has been recorded at the closest point from the project site.



Source: National Institute of Ocean Technology

Figure 6.3.18Long-Term Wave Level near the Perur DSP Site (at Chennai Sea Port)

According to the figure 6.3.18, the normal wave height is CD +0.2 m to +1.4 m, but sometimes much higher wave heights have been recorded. The maximum height ever is +4.7 m AMSL recorded on 29th December, 2011, followed by CD +4.2 m recoded on 31st October, 2012.

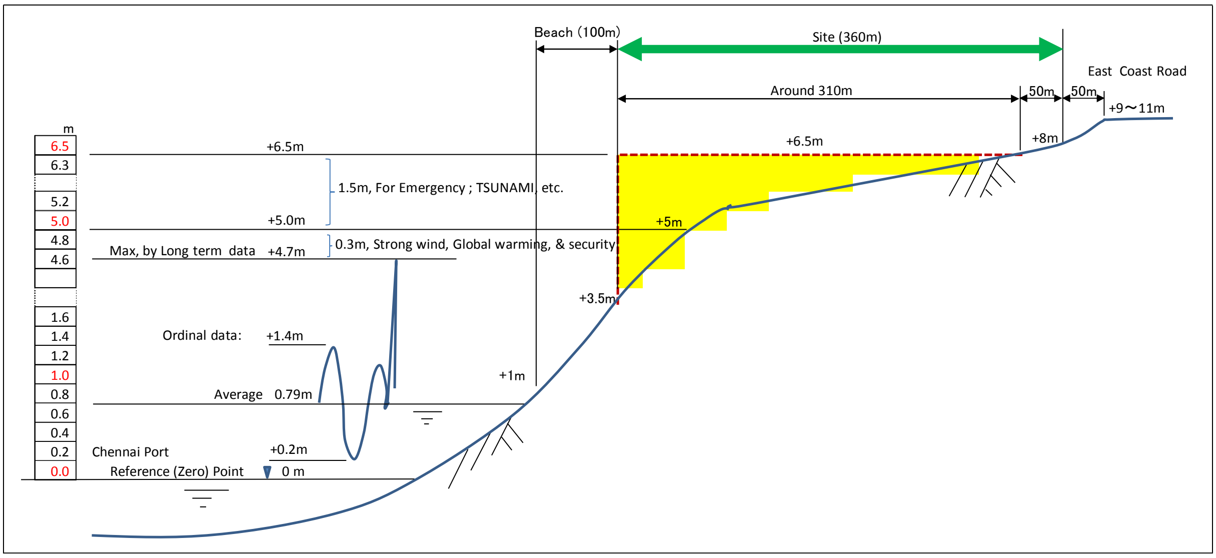
In the disastrous earthquake on 26th December, 2004, called Sumatra-Andaman Earthquake, it was reported that a TSUNAMI hit the project site. However, the recorded wave height in the figure at the date was only one meter, which can be attributed to the topographical condition of the sea port.

2) Wave height level and land height

Based on the highest wave level of CD +4.7, the JICA Study Team presumes the safety wave level eluding the TSUNAMI event at CD +5.0. Additional 0.3 meter to the recorded wave level includes possible influence by strong winds and some margin for sea surface elevation that may be caused by future global warming.

In the determination of the ground elevation of the Perur DSP, the JICA Study Team proposes an additional 1.5 m to the safety level for possible wave height by TSUNAMI. Finally, the ground elevation will be CD +6.5 m. According to the resident in the neighbour village of the site, wave height of the TSUNAMI in 2004 was recorded to be around 5,5m. 6.5m AMSL is also explained that 1 m is added to this height as safety margin.

The recorded wave levels and the determined ground elevation are illustrated in Figure 6.3.19.



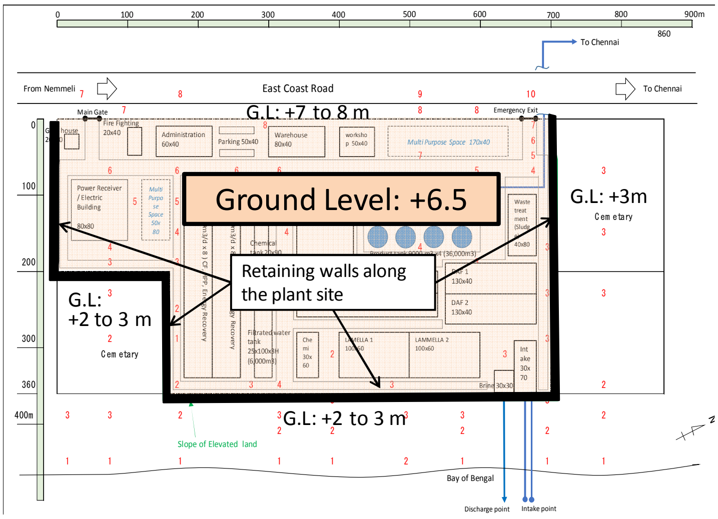
Source: JICA Study Team

Figure 6.3.19 Recorded Wave Levels and the Planned Ground Elevation of the Perur DSP

3) Land development plan

Figure 6.3.20 shows the plan of land development. Since the height of existing project site is CD + 2 to 3 m, earth filling by 4 m will be necessary at maximum to realize the ground elevation of CD +6.5 m.

The border of this newly constructed land and other areas will be retaining wall of reinforced concrete. Embankment is another alternative but the sea wave may scour the foundation of the slope. The retaining wall with pile foundation will be more stable.



Source: JICA Study Team

Figure 6.3.20 Land Development Plan of the Perur DSP

(2) Foundation of the Structure and Building

In the DSP site, several treatment units for desalination and auxiliary buildings and structures will be constructed. In the Study, maximum unit loads of such buildings and structures have been presumed referring similar projects. The surface soil layer in the plant site will be filled soils, which will be capable to bear the unit load not less than 10 kN/m^2 by direct foundation. For the buildings and structures with the unit loads greater than 10 kN/m^2, pile foundation will be necessary.

Table 6.3.9 presents the unit loads, foundation types and pile specifications of the buildings and structures in the Perur DSP. The presumed pipe diameter in the Study is 400 mm, which is the most common diameter of cast-in-place reinforced concrete pile in Chennai. Pipe lengths have been planned so that the piles will be supported by Grayish Weathered Rock layer, with N values of more than 100, which was observed at the depth of 16.5 m from the present ground surface level. (See Appendix 6.1 for the geotechnical survey data) The intervals of the piles have been planned for the respective structures and buildings based on the unit loads, pile diameter and the bearing capacity of the supporting layer.

Table 6.3.9 Unit Loads and Foundation Plan of the Structures and Buildings in the Perur DSP

Major Structure / Building	Unit load (kN/m^2)	Foundation Type	Pile specifications		
			Diameter	Length	Intervals
Intake pit	100	Pile	400 mm	17.0 m	1.9 m
Brine discharge pit	50	Pile	400 mm	15.0 m	2.7 m
Lamella Filter	80	Pile	400 mm	21.0 m	2.2 m
DAF	70	Pile	400 mm	22.0 m	2.3 m
DMF	90	Pile	400 mm	20.0 m	2.0 m
Filtrated water tank	46	Pile	400 mm	23.0 m	2.9 m
RO building (HPP)	12	Pile	400 mm	24.5 m	5.6 m
RO building (RO unit)	30	Pile	400 mm	24.5 m	3.5 m
Chemical tank house	50	Pile	400 mm	24.5 m	2.7 m
Post treatment	100	Pile	400 mm	22.0 m	1.9 m
Product water tank	150	Pile	400 mm	18.0 m	1.6 m
Potable water tank	40	Pile	400 mm	18.0 m	3.1 m
Transmission pump house	150	Pile	400 mm	18.0 m	1.6 m
Waste treatment	45	Pile	400 mm	18.0 m	2.9 m
Power receiving	10	Direct	-		-
Administration building	10	Direct	-	-	-
Gate house	3	Direct	-	-	-
Workshop	10	Direct	-	-	-
Warehouse	5	Direct	-	-	-

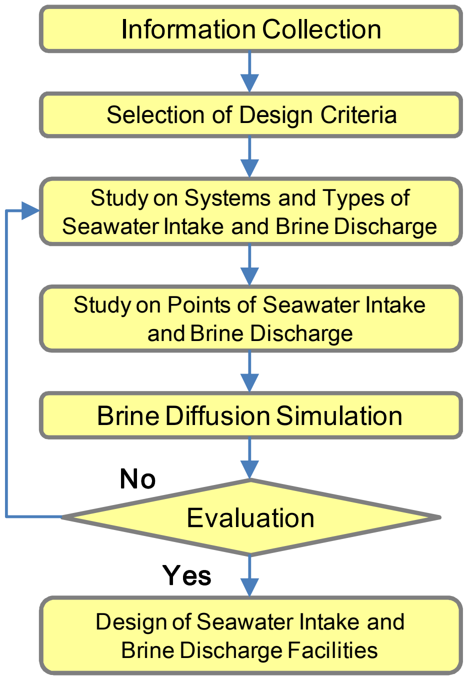
Source: JICA Study Team

6.4 Design of the Seawater Intake and Brine Discharge Facilities

In this section, designs of the seawater intake facility consisting of seawater intake heads, pipes and pit, and brine discharge facility consisting of brine discharge heads, pipes and pit are carried out.

6.4.1 General Procedure for the Design of Seawater Intake and Brine Discharge Facilities

For design of the seawater intake and brine discharge facilities, the systems, types and points of seawater intake and brine discharge are selected based on the procedure as shown in Figure 6.4.1. According to basic information such as the existing oceanographic data and information about usage situations of the beach and sea, studies on systems, types and points are carried out for provisional selection. Thereafter, on the basis of systems, types and points provisionally selected as input data, the brine diffusion simulation is implemented in order to examine the technical and environmental validities. If the validities are verified by the simulation, the systems, types and locations of the intake and discharge facilities will then be finalized. However, if the simulation identifies some deficiencies, the types and locations of seawater intake and brine discharge will be reconsidered and then the same analysis will be again carried out to examine the modified design.



Source: JICA Study Team

Figure 6.4.1 Procedure for the Design of Seawater Intake and Brine Discharge Facilities.

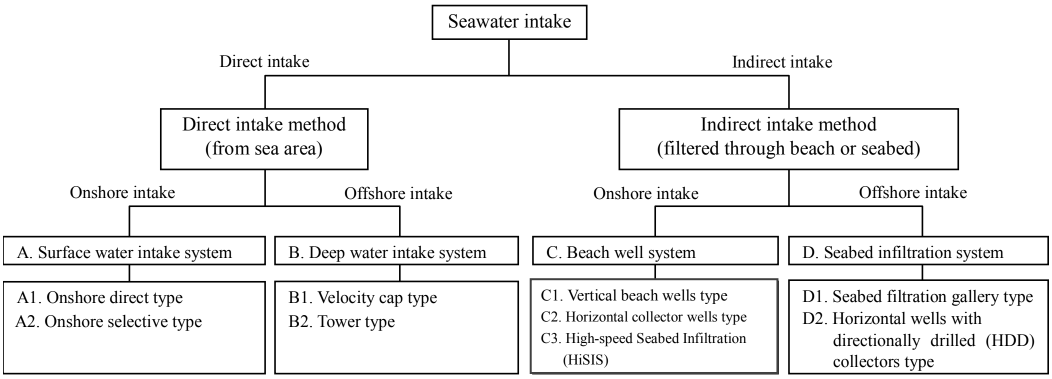
6.4.2 Study on the Systems and Types of Seawater Intake and Brine Discharge

(1) Seawater intake

The category of the seawater intake adopted for DSPs are mainly classified as the direct intake method and the indirect intake method, and each of these methods are further divided into two systems as shown in Figure 6.4.2. The conceptual diagrams of systems and types of direct and indirect intake methods are indicated in Appendix 6.7.

The direct intake method directly draws seawater at the shoreline or via a pipeline from above the seabed at a marine area, and this method is commonly employed for large-scaled plants. This method requires a pre-treatment facility prior to the desalination process in order to remove marine organisms and small particles in the raw seawater.

On the other hand, the indirect intake method obtains the seawater though wells and/or buried collecting pipes beneath the beach or seabed through natural or replaced soil, and normally has limited capacity in terms of water volume to intake. Furthermore, if the soil under the beach or seabed has low permeability, very wide areas will be necessary to intake required volume of seawater. The indirect intake method in contrast to the direct intake method does not often require a pre-treatment facility because of filtration effects in soil.



Source: JICA Study Team

Figure 6.4.2 Classification of Seawater Intake

According to examples of other projects, beach well intake system method is applied to small-scaled plants because large footprint is required for installation of wells, drawing seawater indirectly. One notable case of beach well intake is Sur desalination plant in Oman with a capacity of 80 MLD. The beach wells for the Sur desalination plant are scattered across a wide vacant area of land of about 5 ha in the coastal area.

The seabed filtration intake also occupies a wide area for collection pipes in the seabed. For example, collection pipes of the seabed gallery filtration type applied to Mamizu Pia in Fukuoka prefecture of Japan with capacity of 50 MLD occupy a wide area of approximately 2.9 ha. In addition, the necessary flow rate may not be maintained due to the decrease in water permeability caused by the filtration sand clogging. The horizontal well with directionally drilled collectors (HDD) type has disadvantages similar to the seabed gallery filtration type. Records of adoption of this type of intake are quite limited.

In view of the above said explanation, as for the intake system to be applied to the Perur DSP, beach well intake and seabed filtration intake have been both excluded from the possible options because of the following reasons:

- Enough area for beach well intake cannot be secured in the beach due to large production capacity of the Perur DSP.
- The seabed filtration intake occupies a wide area for the collection pipes, which will result in expensive construction cost and/or serious environmental impact due to the large production capacity of the Perur DSP.

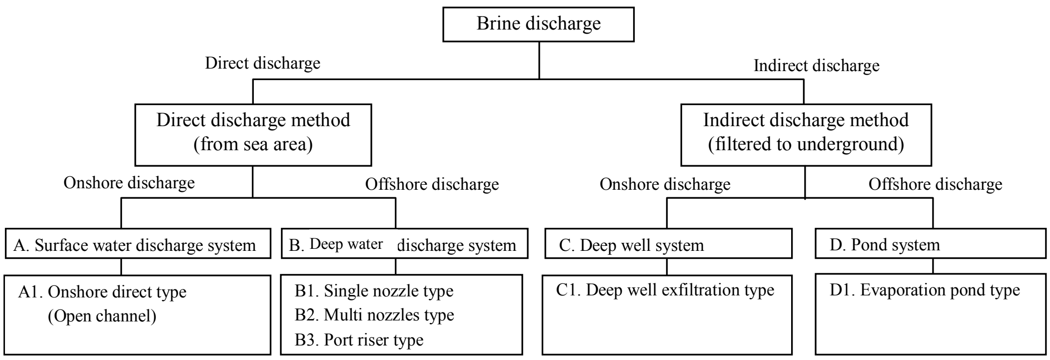
Based on the results of the comparison of advantages and disadvantages of various intake types under the surface water and deep water intake systems (refer to Appendix 6.8), velocity cap type of the deep water intake system has been recommended as the best option for the following reasons:

- The surface water intake system cannot selectively withdraw seawater according to the seawater conditions. Both types of this system, namely Onshore direct type and Onshore selective type, are not suitable for the Perur DSP because dirty seawater is conveyed to the intake facility and water quality is unstable during Monsoon season.

- In case the water depth at the shore is shallow, the surface water intake system requires dredging work, and construction cost will be expensive. Therefore, both types of this system are not suitable in terms of the topographic features of the construction site. The tower type under the deep water intake system has basically the similar characteristics with the velocity cap type. However, tower type is vulnerable to the waves. Therefore, application of the tower type is not recommended because the construction area is exposed to high waves of the Bay of Bengal.

(2) Brine discharge

The category of the brine discharge adopted for seawater desalination plants are mainly classified as the direct discharge method and the indirect discharge method, and each of these methods are further divided into two systems similar to intake systems. The four systems are shown in Figure 6.4.3. The conceptual diagrams of systems and types of direct and indirect discharge systems are indicated in Appendix 6.9.



Source: JICA Study Team

Figure 6.4.3 Classification of the Discharge System

The direct discharge method is the most common type for brine discharge and can be applied for any flow rate. However, this system may have worse impact on marine environment because of low dilution effect. Therefore, brine dilution effect needs to be simulated to examine the environmental impact of the brine.

On the other hand, the indirect discharge method normally has limitation in the discharge volume of the brine derived from permeability of soils and available land area for the discharge system as compared to the direct discharge system. This system has no impact on marine organisms by discharged brine; however, it may have a big impact on aquifers.

As for the selection of brine discharge system for the Perur DSP, the deep well discharge system and the pond discharge system have been excluded from the options because these systems are applied to small-scaled plants only due to the required wide area at beach and impact on the environment.

According to the records in other projects, major discharge system for medium to large-sized plants, with a capacity of 50 MLD or more, adopt the surface water discharge system or the deep water discharge system.

From the discussions aforementioned, possible options for the brine discharge system for the Perur DSP are the surface water discharge and the deep water discharge systems. The brine discharge types under these possible systems have been compared (refer to Appendix 6.10). The most recommended discharge type is the multi-nozzle type, one of the types under deep water discharge system, for the following reasons:

- Near the construction area, several fishes and organisms are protected. Onshore direct type is not suitable because this type has serious impact on the marine environment. Additionally, the construction cost is expensive due to topographic features of the shore.
- The construction cost for all types of the deep water discharge system are almost same, nevertheless, the multi-nozzle type has big advantages with respect to the diffusion efficiency and the facility size.

6.4.3 Study on Points of Seawater Intake and Brine Discharge

(1) Requirements in determination of points of the seawater intake and brine discharge

The points of seawater intake and brine discharge are decided in accordance with the requirements as mentioned below:

- Intake point
  - ✓ The seawater shall be selectively withdrawn in middle layer in order to prevent the inflow of turbid water, discharged brine at the bottom layer or driftwood on surface layer.
  - ✓ The intake structure shall not affect the operations of sailing ships and fishing boats.
- Discharge point
  - ✓ Recirculation of brine to the seawater intake facility should not be avoided.
  - ✓ The brine should not affect valuable marine organisms.

(2) Concern about the recirculation of the Brine from other DSPs

The Perur DSP will be constructed besides the existing Nemmeli DSP. In addition, the Nemmeli DSP will be expanded, for which new brine discharge facility will be constructed at the south side of the discharge facility of the existing DSP. Completion of the additional Nemmeli DSP will be earlier than that of the Perur DSP.

The discharge volume of the brine from the Perur DSP is much bigger than the others, and the possibility of recirculation of the brine to the seawater intake of the existing and additional Nemmeli DSPs, resulting in higher requirement of energy consumption in the desalination process, are to be studied.

Consequently, the situation of the brine diffusion in all development status of the DSPs has been confirmed based on the water quality survey results and brine diffusion simulation as follows:

(3) Study on current diffusion situation of the brine from the existing Nemmeli DSP

First of all, the current diffusion situation of the brine from the Nemmeli DSP was evaluated in accordance with the results of the seawater water quality survey as mentioned in Subsection 6.2.1. According to the results, the brine from the discharge dead flows to offing side along the sea bottom; however, the recirculation of the brine to the intake head was not found. Moreover, the water quality analysis data from the operation of the Nemmeli DSP does not show the evidence. The detailed explanations of the study are shown in Appendix 6.11.

(4) Study on future diffusion situations of the brine in each phase by brine diffusion simulation

1) Simulation cases of the brine diffusion

According to the construction plans of DSPs aforesaid, the brine diffusion simulations have been implemented. In the simulations, three cases, a) Static condition, b) northeast monsoon and c) southwest monsoon, have been studied shown in Table 6.4.1

Table 6.4.1 Simulation Cases for the Brine Diffusion Simulation

Phase	Case
1st phase (Existing Nemmeli DSP only)	a) Static condition: Tidal current 7cm/s b) Northeast monsoon: Tidal current 7cm/s + Northeastward residual current 14cm/s c) Southwest monsoon: Tidal current 7cm/s + Southwestward residual current 14cm/s
2nd phase (After expansion of the existing Nemmeli)	
3rd phase (After the construction of the Perur DSP)	

Source: JICA Study Team

2) Model and conditions of the simulation

In order to simulate the situation of the brine diffusion, Gravity Jet Model for Near-field and Joseph-Sendner's Equation for Far-field have been applied respectively based on the parameters shown in Table 6.4.2. The detailed explanation on the methodology is mentioned in Appendix 6.12.

Due to the lack of data about tidal current at sea bottom, the reliability of the results becomes relatively low. Therefore, it is recommended to carry out the simulation again after the observation of the tidal current at sea bottom. According to the DPR, the salinity of the ambient seawater is set as 38 g/l.

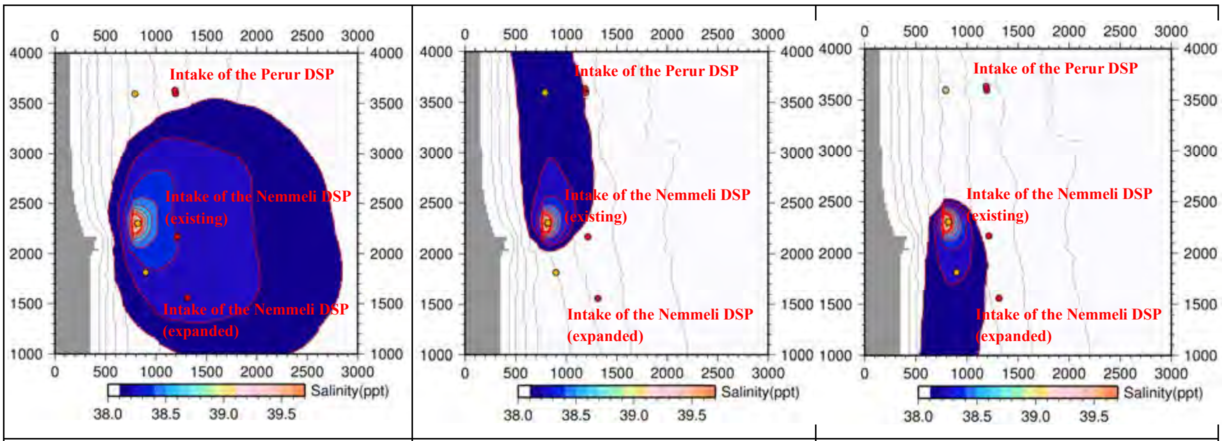
Table 6.4.2 Applied Parameters for the Brine Diffusion Simulation

Category	Parameter
Seawater	Salinity
	Temperature
Brine	Volume
	Salinity
	Temperature
	Density
Discharge facility	Specifications of discharge head
Marine Environment	Bathymetry
	Tide (water surface only)
	Current

Source: JICA Study Team

3) 1st phase (Current situation)

The results of the simulation in 1st phase, showing maximum salinity at each location, are shown in Figure 6.4.4. The results show that the brine from the existing Nemmeli DSP is diffused to the location of intake heads of the expanded Nemmeli DSP to be constructed; however, the possibility of the recirculation of the brine is low because the brine is diluted and its salinity is almost the same as ambient seawater. Further, the maximum values of the salinity are detected at sea bottom due to the heavy weight of the brine. Therefore, the raw seawater of the expanded Nemmeli DSP, whose intake will be located at the middle layer, will not be affected by the existing Nemmeli DSP.



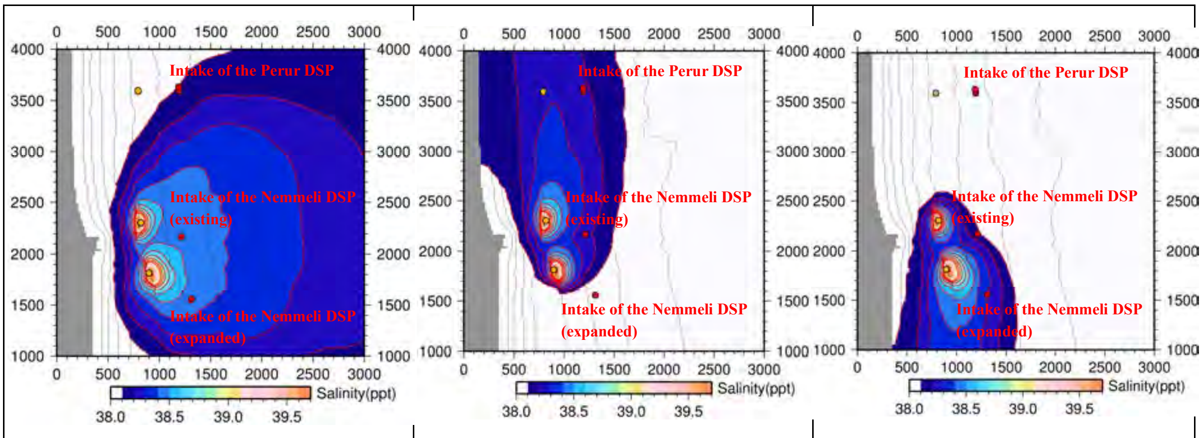
a) Static condition	b) Northeast monsoon	c) Southwest monsoon

Source: JICA Study Team

Figure 6.4.4 The Situation of the Brine Diffusion in 1st phase

4) 2nd phase (after expansion of the Nemmeli DSP)

The results of the simulation on the 2nd phase are shown in Figure 6.4.5. In typical condition, the salinity values around two intake heads of the Nemmeli DSPs will be increased to 38.4 g/l due to the diffusion of the brines. As the breadth of the increase in the salinity is greater than the 1st phase, salinity at middle layer may be increased. Therefore, the recirculation of the brine to the intake heads of existing and expanded Nemmeli DSPs may occur, on which further investigation based on more information on the sea current condition is to be implemented.



a) Static condition	b) Northeast monsoon	c) Southwest monsoon

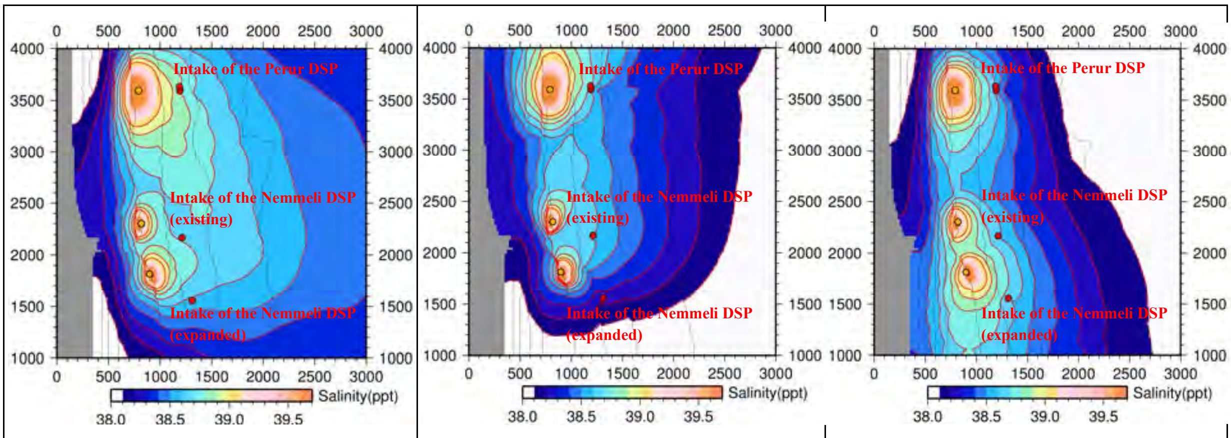
Source: JICA Study Team

Figure 6.4.5 The Situation of the Brine Diffusion in the 2nd Phase

5) 3rd phase (after construction of the Perur DSP)

The results of the simulation in the 3rd phase are shown in Figure 6.4.6. The locations of intake head and discharge head of the Perur DSP have been set in the simulation according to the plan in the DPR.

Due to the huge volume of the brine to be discharged from the Perur DSP, the impact on the salinity of the seawater is significantly greater than the previous two phases. The brine, with a higher salinity by 0.6 to 0.8 mg/l than ambient seawater, is diffused to the intake heads of all the DSPs. Therefore, the recirculation of the brine seems to be inevitable, and countermeasures or mitigation measure to avoid hike in the operation cost needs to be considered.



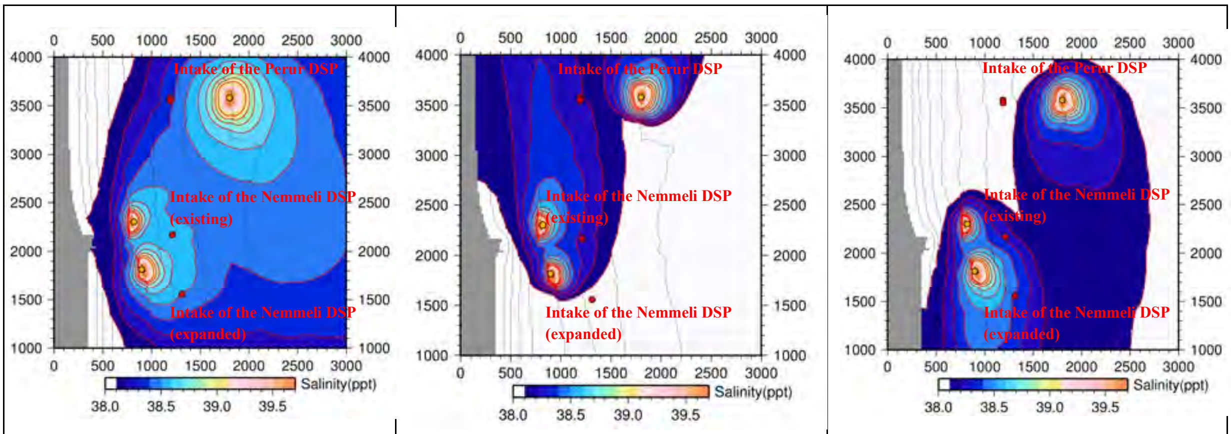
a) Static condition	b) Northeast monsoon	c) Southwest monsoon

Source: JICA Study Team

Figure 6.4.6 The Situation of the Brine Diffusion in the 3rd Phase (at the Discharging Point Proposed in the DPR)

(5) Study on the location of brine discharge head of Perur DSP

As mentioned aforesaid, the brine from the discharge head of the Perur DSP at the location proposed in the DPR may cause recirculation of the brine at all the DSPs. In order to avoid or mitigate the impact on the raw seawater salinity, the JICA Study Team proposes to set the location of the discharge head at 12 m of water depth located at 500 m far from the intake head at the offing side, and the results of the simulation are shown in Figure 6.4.7. As shown in the figure, the impact of the brine is drastically mitigated compared with the location proposed in the DPR.



a) Static condition	b) Northeast monsoon	c) Southwest monsoon

Source: JICA Study Team

Figure 6.4.7 The Situation of the Brine Diffusion in the 3rd Phase (at the Discharging Point Proposed by the JICA Study Team)

6.4.4 Design of Seawater Intake and Brine Discharge Facilities

(1) Design conditions

The design conditions of the seawater intake and brine discharge facilities are shown in Table 6.4.3.

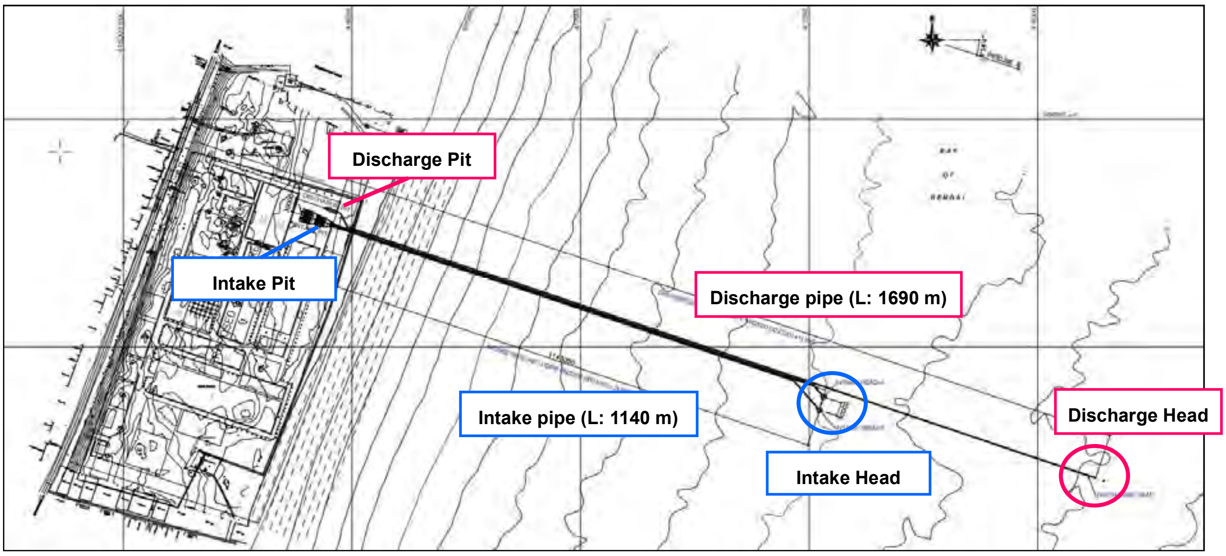
Table 6.4.3 Design Conditions of Seawater Intake and Brine Discharge Facilities

Parameter	Value	Remarks
1. Flow volume		
Inflow volume	1,080 MLD	Product volume: 400 MLD, Recovery ratio of pre-treatment: 42 %, Recovery ratio of RO membrane: 46 %
Discharge volume	680 MLD	= Inflow rate (1,080) – product volume (400 MLD)
2. Tidal level (data of the Ennore port 60 km far from Perur construction site over one year [2015 – 2016])		
High Water Level (HWL)	CD + 1.57 m	Recorded in August, 2015
Mean Sea Level (MSL)	CD + 0.76 m	
Low Water Level (LWL)	CD + 0.04 m	Recorded in July and August, 2015
Chart Datum (CD)	CD ±0.00 m	

Source: JICA Study Team

(2) General layout

The general layout of seawater intake and brine discharge facilities is shown in Figure 6.4.8.



Source: JICA Study Team

Figure 6.4.8 General Layout of the Seawater Intake Facility

(3) Seawater intake facility

1) Basic specifications

The specifications of seawater intake facility are shown in Table 6.6.4.

Table 6.4.4 Specifications of the Seawater Intake Facility

Item	Specification
1. Intake Head	
Intake Type	Velocity cap
Size of the seawater intake head	D: 12 m × H: 9.6 m
Diameter of the velocity cap	ϕ 5.0 m
Height of the intake point	3.0 m from the sea bottom
Material	Carbon steel with epoxy coating
Spacing of the screen bars	0.3 m
2. Intake Pipe	
Number of lines	2 lines
Diameter	DN: 2,300 mm (ID 2,100 mm, SDR22)
Length	1,140m (from intake head to intake pit)
Material	High Density Polyethylene (HDPE)
3. Intake Pit	
Type and number of transmission pump	Vertical mixed flow pump x 6 sets (4 sets for operation, 2sets for stand-by)
Type and number of 1st screen	Bar screen with a mobile trash rake x 4 sets
Type and number of 2nd screen	Traveling band screen (Double flow 2in-1out type) x 4sets
Type and number of screen back wash pump	Centrifuge pump x 4 sets
Material and number of stop log	Carbon steel with epoxy coating, 20 sets

Source: JICA Study Team

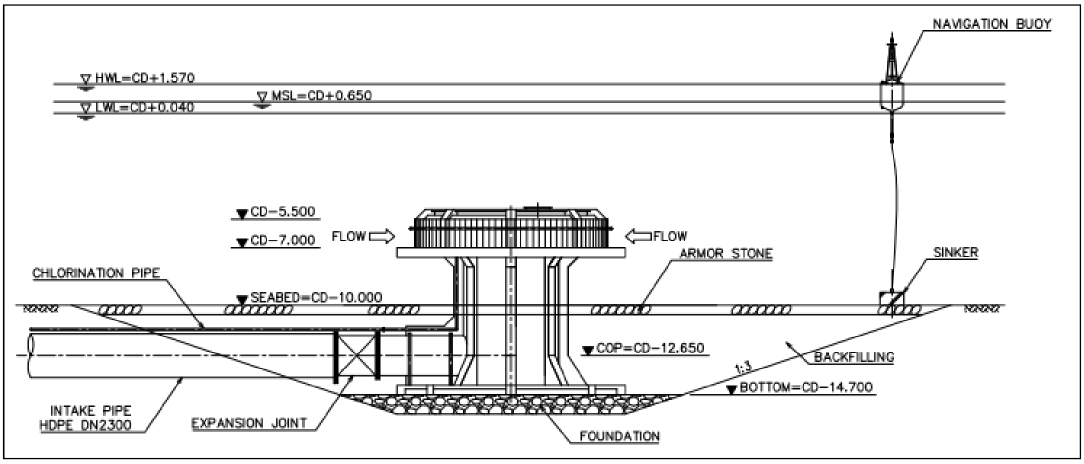
2) Design of intake head

a. Locations

In accordance with requirements mentioned in Subsection 6.4.3, the intake head will be constructed at the water depth of CD -10 m.

b. Layout plan

The layout of the intake head is shown in Figure 6.4.9.



Source: JICA Study Team

Figure 6.4.9 Design of Seawater Intake Head

3) Design of seawater intake pipes

a. Number and material of the pipes

According to the production capacity of the Perur DSP, the diameter of intake and discharge pipes will be large. In the DPR, intake and discharge pipes were designed as two lines of 2,400 mm for the intake and one line of 2,400 mm for the discharge. All lines would be high density polyethylene pipe (HDPE). However, HDPE pipes of such large diameter are not manufactured in India, because of which these products need to be imported.

In view point of cost efficiency, dividing the intake or discharge functions into more lines to avoid import of the pipes will be a possible option. Moreover, a comparative study on different pipe materials will be necessary as it was not done in the DPR.

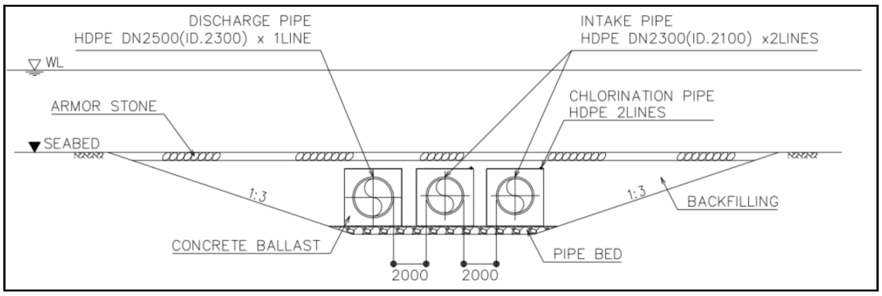
Therefore, alternative studies on the options by number of lines (or pipe diameter) and materials for water intake and brine discharge pipes have been carried out. Options for the pipe materials are HDPE and Steel, which are commonly used for similar purposes.

According to the result of the comparative study on possible alternatives (refer to Appendix 6.13), two HDPE lines are finally recommended for the intake due to the following reasons:

- The three lines of 1,600 mm exceed acceptable head loss.
- The total cost, including the material and construction works, in the case of two HDPE lines will be the lowest.
- HDPE pipe does not need lining for corrosion control, which means HDPE has the lower risk of corrosion than Steel Pipe.
- The two-line cases are more advantageous in terms of frequency of the maintenance than the three-line cases.

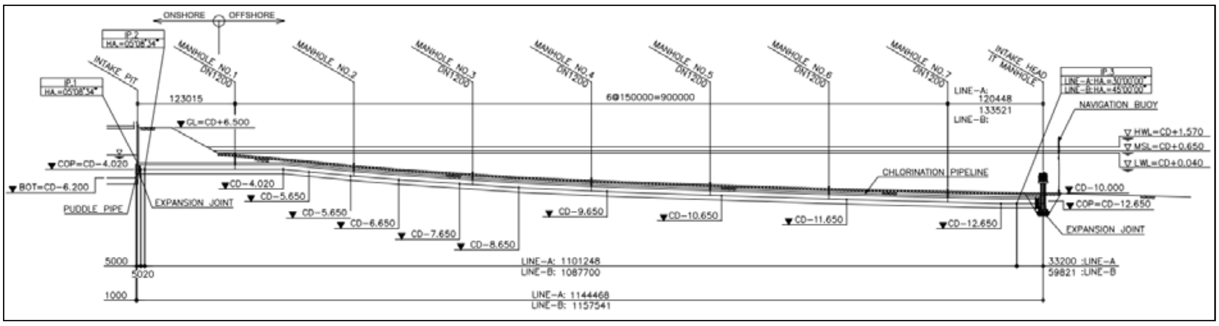
b. Layout

According to the location of the seawater intake head, the length of seawater intake pipe will be approximately 1,140 m. The layout of the intake pipe is shown in Figure 6.4.10 and 6.4.11.



Source: JICA Study Team

Figure 6.4.10 Design of Intake Pipes at Offshore (Cross Section)



Source: JICA Study Team

Figure 6.4.11 Design of Intake Pipes (Longitudinal Section)

4) Design of seawater intake pit

Design of the seawater intake pit is presented in Subsection 6.3.5. Surging analysis on the intake pit based on the design flow rate is given in Appendix 6.14

(4) Brine discharge facilities

1) Basic specifications

The specifications of brine discharge facility are shown in Table 6.4.5.

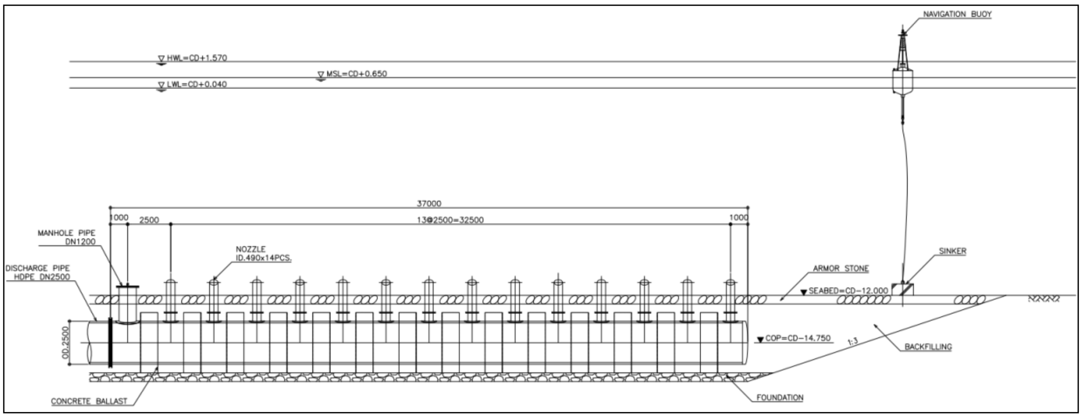
Table 6.4.5 Specifications of the Brine Discharge Facility

Item	Specification
1. Discharge Head	
Type: of discharge head	Port raiser type
Length of the brine discharge head:	47 m
Number and diameter of nozzles:	14 nozzles, φ0.49 m
Elevation angle of the nozzles	50°
2. Discharge Pipe	
Number of lines	1 lines
Diameter	DN: 2,500 mm (ID 2,300 mm, SDR22)
Length	1,690m (from Brine discharge pit to Brine discharge head)
Material	High Density Polyethylene (HDPE)
3. Discharge Pit	
Size	L: 25 m × 6 m
Wall height	1 m from G.L.

Source: JICA Study Team

2) Brine discharge head

In accordance with results and considerations of the brine diffusion simulation implemented in Subsection 6.4.4, the discharge head will be constructed at the water depth of 12m.



Source: JICA Study Team

Figure 6.4.12 Design of Brine Discharge Head

3) Brine discharge pipes

a. Number and material of the pipes

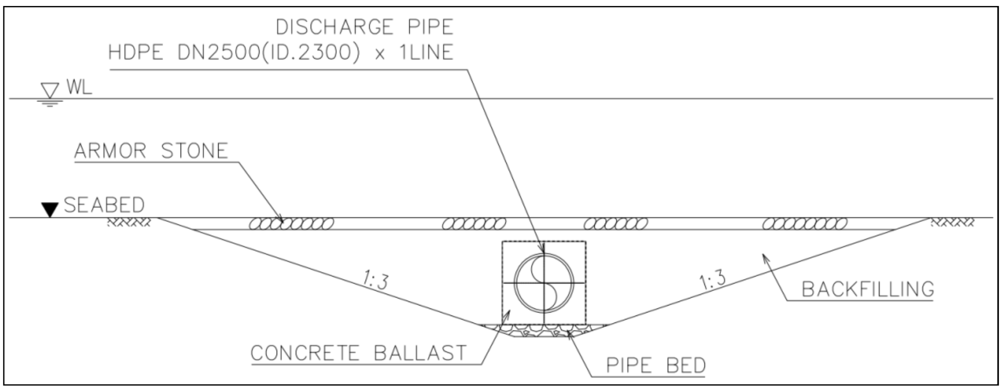
In addition to the selection of the seawater intake pipe, the numbers and material of the brine discharge pipe are also selected.

According to the result of the study (refer to Appendix 6.15), alternative with one HDPE line is recommended for the brine discharge due to the following reasons:

- The total of material and construction cost is the lowest among the other alternatives.
- HDPE pipe does not need lining for corrosion control.
- HDPE pipe requires shorter period for the pipe production work and the offshore work compared to that for the steel pipe.

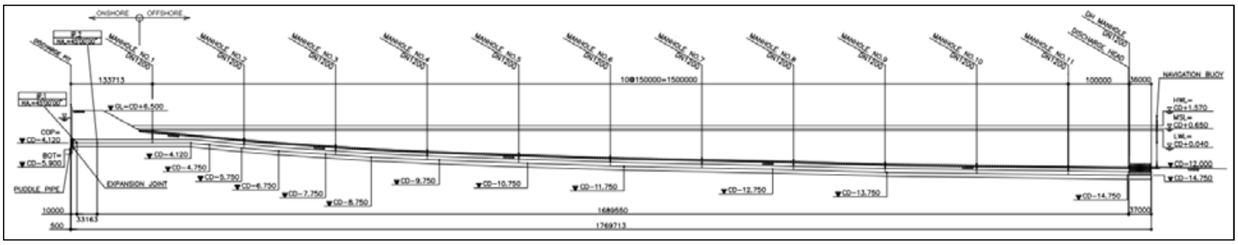
b. Layout

According to the location of the brine discharge head, the length of brine discharge pipe will be approximately 1,690 m. The layout of the brine discharge pipe is shown below:



Source: JICA Study Team

Figure 6.4.13 Design of Brine Discharge Pipes at Onshore and Offshore (Cross Section)



Source: JICA Study Team

Figure 6.4.14 Design of Brine Discharge Pipes (Longitudinal Section)

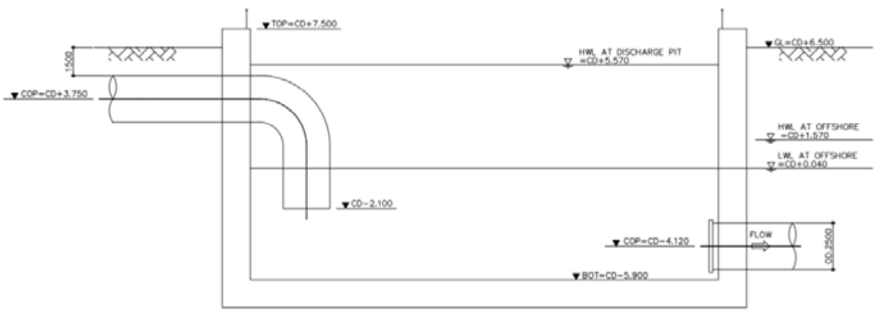
4) Brine discharge pit

a. Location

According to the layout plan mentioned, the discharge pit will be constructed at north part of the Perur DSP, adjoining the seawater intake pit.

b. Layout

The layout of the brine discharge pit is as below.



Source: JICA Study Team

Figure 6.4.15 Design of Brine Discharge Pit

6.5 Design of the Power Transmission and Receiving Facilities

6.5.1 Existing Situation and Existing Plan of Power Receiving System

(1) Existing situation of power receiving system

Figure 6.5.1 shows the existing power transmission line and substation (S/S) for the Nemmeli DSP. 110/11 kV Substation (S/S) in the Nemmeli DSP receives 110 kV transmission line of two circuits. Appendix 6.16 explains the details of the existing situation.

Source: JICA Study Team

Figure 6.5.1 Present Situation of Transmission Lines for the Nemmeli DSP

(2) Original and revised power receiving plans of the DSPs including the Perur DSP

In 2013, CMWSSB requested Tamil Nadu Electricity Board (TNEB) to provide an uninterrupted power supply of 110 MVA to the Perur DSP and an additional 150 MLD to the Nemmeli DSP. Corresponding to the request, the TNEB proposed a power transmission plan, where two independent cables would provide power to a new 230/110 kV S/S to be constructed between the Nemmeli and Perur DSPs.

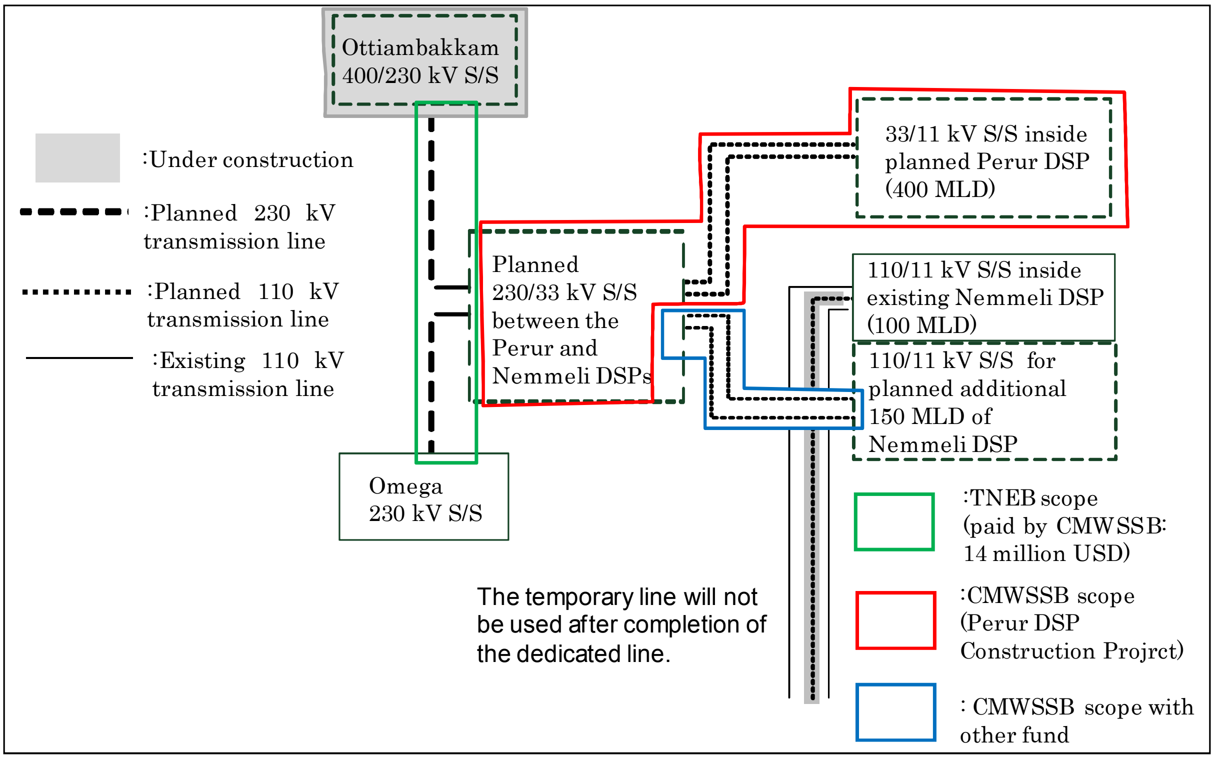
However, in 2015, CMWSSB intended to revise the power receiving plan to integrate the power receiving system of the existing Nemmeli DSP with that of the additional 150 MLD of the Nemmeli and Perur DSPs. CMWSSB requested TNEB to change the construction plan but has not yet received any reply. Detailed information on the original and revised power receiving plan mentioned above are described in Appendix 6.16.

(3) Roles of CMWSSB and TNEB in development of the planned power receiving system intended for the DPR

The DPR was based on the original power receiving plan. It intended that TNEB would carry out the construction of the two transmission lines of 230 kV and the 230/110 kV S/S. It also intended that the installation of two transmission lines of 110 kV from 230/110 kV S/S to the Perur DSP would be conducted by the TNEB. The DPR estimated the cost of these TNEB works to be Rs. 800 million, which will be paid by the CMWSSB. However, in the interview of TNEB by JICA Study Team, it turned out that TNEB did not to intend to conduct the construction of the 230/110 kV S/S and the power cables from the S/S. TNEB presumed that it would construct only the 230 kV transmission lines, and the 800 million rupees estimate in the DPR-based on the quotation of TNEB included the construction of only these two cables. Furthermore, according to TNEB, due to price escalation, the upward cost revision was carried out for the two power lines, which is now Rs. 960 million.

6.5.2 Determination of the Power Receiving Plan of the Perur DSP

The JICA Study Team conducted a comparative study on the power receiving plan of the original and revised plans explained above along with an additional alternative. As a result of the comparison, the original power receiving plan was the most recommended option. Figure 6.5.2 illustrates the original recommended plan. The comparison of the alternatives by the Study Team is given in Appendix 6.17.



Source: JICA Study Team

Figure 6.5.2 Recommended Power Receiving Plan (Original Plan)

6.5.3 Assessment of the Reliability of the Power Supply Network of TNEB

(1) Possible frequency of power failure:

In order to examine the stability of the power supply to the Perur DSP, the actual condition of the existing Nemmeli DSP was analyzed. According to the operational record of the DSP from May 2015 to April 2016, the frequency and durations of power failures have been summarized in Table 6.5.1. Based on this table, the total time of power failures in the Nemmeli DSP has been recorded as 117.3 hours per year, which is equivalent to 4.9 days per year. Hence, the rate of power failure per year is 1.3% or power availability is 98.7%.

Currently, the existing DSP relies on the non-dedicated lines while the Perur DSP is intended to receive power from two lines including one dedicated line. Moreover, the new grid to Perur DSP is considered more reliable than the current grid of the existing Nemmeli DSP because the new grid is a

230 kV system compared to the 110 kV system. Therefore, the power availability at the Perur DSP will be greater than 99%. It is evaluated as highly reliable power supply network.

Table 6.5.1 Frequency and Durations of Power Failures at the Existing Nemmeli DSP

Event	Number of power failure events (a)	Duration (b)	Average duration of power failure (b) / (a)
(1) Planned shutdown by TNEB	16	46.1 hours	2.9 hours
(2) Power failure of TNEB and Nemmeli DSP	20	71.2 hours	3.6 hours
Total (1) + (2)	36	117.3 hours (c)	3.3 hours
Rate per year (c)/(24 x 365)	-----	1.3%	-----

Source: JICA Study Team based on Operational Record of the Nemmeli DSP from May 2015 to April 2016

(2) Power supply capacity of TNEB

In 2013, the CMWSSB requested TNEB to supply 110 MVA, which consisted of 80 MVA for the Perur DSP and 30 MVA for the additional 150 MLD of Nemmeli DSP, and TNEB accepted to satisfy the power demand. However, currently, the capacity is assumed to be 118 MVA, which consists of 85 MVA for the Perur DSP and 33 MVA for the additional 150 MLD of Nemmeli DSP. Besides this, the power consumption of the Perur DSP has been estimated as 1,600 MWh per day as presented in Appendix 6.6. Thus, the CMWSSB and JICA Study Team again confirmed the possibility of supply to TNEB. TNEB agreed to the demands of CMWSSB and JICA Study Team for supplying 150 MVA power from the TNEB grid.

It is noted that the power demand and supply gap in India are likely to be positive, as discussed in Subsection 5.3.3. Based on these circumstances, it has been evaluated that TNEB has sufficient potential to provide the required power to the Perur DSP from their power sources or the backup system using the national grid covering the entire country.

6.5.4 Plan for Power Receiving and Distribution Systems in the Perur DSP

(1) Overview of power receiving plan

The voltage class of the distribution in the Perur DSP is 11 kV. It is planned that the Perur DSP will receive the power at 110/11 kV S/S in the DSP through the new 230/110 kV S/S to receive power from TNEB. While the transmission lines to the 230 kV S/S will be designed and constructed by TNEB, the substations and the transmission lines between the S/Ss are to be planned and constructed by CMWSSB.

The JICA Study Team proposed to modify the step-down plan of the power voltage from the original 230/110 kV and 110/11 kV to 230/33 kV and 33/11 kV as shown in Figure 6.5.3. The modified point is to install the 33 kV equipment instead of the 110 kV equipment. The application of the 33 kV equipment will reduce the cost and require a smaller footprint than the 110 kV equipment. In general, the 33 kV equipment is installed inside a building, but the 110 kV equipment is normally installed outside a building. It is better for equipment to be installed inside to protect them from salt erosion.

As illustrated in Figure 6.5.3, the 230/33 kV S/S is planned in a vacant land between the existing Nemmeli and the Perur DSPs. The planned site is 8.33 acres (3.3 ha), of which 3.42 acres has already been leased to CMWSSB by the same owner of the planned DSP site and the lease of the remaining 4.91 acres are will be contracted between the same owner and CMWSSB. The 33/11 kV S/S will be constructed in the premises of the Perur DSP.

Source: JICA Study Team

Figure 6.5.3 Power Receiving System for the Perur DSP

(2) Single line diagram of 230/33 kV and 33/11 kV substations

Appendix 6.18 shows the single line diagram of 230/33 kV and 33/11 kV substations. Main equipments of the substations are shown in Table 6.5.2.

TNEB will execute the construction of two 230 kV transmission lines and the 230 kV equipment as shown in Appendix 6.18. 230 kV transmission lines will come from two different S/Ss, but metering point by TNEB will be at one location, i.e., at 230/33 kV S/S. The configuration of the 230/33 kV S/S is two banks. In future, the additional 150 MLD of the Nemmeli DSP has been planned to connect to this substation.

The 33/11 kV S/S will receive two 33 kV transmission lines from the 230/33 kV S/S and the configuration of the S/S is four banks. 11 kV feeders are distributed to five electric rooms in Perur DSP and each feeder has spare feeder

Table 6.5.2 Main Equipments of the 230/33 kV and 33/11 kV Substations

Equipment	Description
230/33 kV main transformer	To change voltage from 230 kV to 33 kV without changing frequency
33/11 kV main transformer	To change voltage from 33 kV to 11 kV without changing frequency
Circuit breaker (CB)	To protect electrical circuit from overcurrent or short circuit
Disconnector (DS)	To open electrical circuit when maintenance or repair is needed
Current transformer (CT)	To measure electrical current for protection and metering
Capacitor voltage transformer (CVT) and potential transformer (PT)	To measure voltage for protection and metering
Lightning arrester (LA)	To protect electrical equipment from lightning damages
Capacitor bank	To improve power factor and reduce network losses

Source: JICA Study Team

(3) Transmission lines between 230/33 kV S/S and 33/11 kV S/S

As shown in Figure 6.5.3, the two circuits of 33 kV transmission lines are planned between the 230/33 kV S/S and 33/11 kV S/S. The transmission lines are assumed to be direct buried system and two circuits. The lengths of the underground cables are about 800 m for each circuit that requires a space of 2 m in width.

6.5.5 Design of the Substations in the Perur DSP

(1) Layout of 230/33 kV and 33/11 kV substations

Appendix 6.18 shows the layout of the 230/33 kV and the 33/11 kV substations. The 230 kV switchgear is an air-insulated switchgear (AIS) and shall be installed outside. The 33 kV and the 11 kV switchgears are AIS and cubicle type, respectively, and shall be installed inside the building. The transformers shall be installed outside.

(2) Countermeasures against salt corrosion:

An insulator is used to keep insulation between a conductor and the support. The bushing is an insulation device to connect a conductor safely to a transformer or a circuit breaker. If the insulator and the bushing suffer due to salt corrosion, the strength of the insulation reduces. Accordingly, the insulator and the bushing need to be protected from the salt corrosion. The 33 kV and the 11 kV switchgears are planned to be installed in the buildings so that the countermeasures for the equipment are sufficient.

The 230 kV switchgear is planned to be installed outside, but there is a way to apply gas-insulated switchgear (GIS) type for the 230 kV switchgear and install it inside the building. However, the land for the 230/33 kV substation has huge space, although downsizing is the main advantage of installing GIS. Besides, GIS is more expensive than AIS. Thus, for this project, applying GIS is not an effective plan, and AIS is applied to the 230 kV switchgear. Therefore, anti-fog type insulators shall be used for insulation of 230 kV and bushings enhanced insulators shall be used for the 230 kV switchgear. Besides, insulators and bushings should be cleaned before and after cyclones.

(3) Power supply to secondary substations:

Seawater desalination plants have many power loading points with a small capacity such as a pre-treatment one. For supplying the power to these points, a control center will be installed. For supplying a large amount of power, an individual power control panel has to be installed at intake facilities, RO facilities, post-treatment facilities, and transmission pump facilities. For all facilities, the on-site control panels are to be installed beside the equipment.

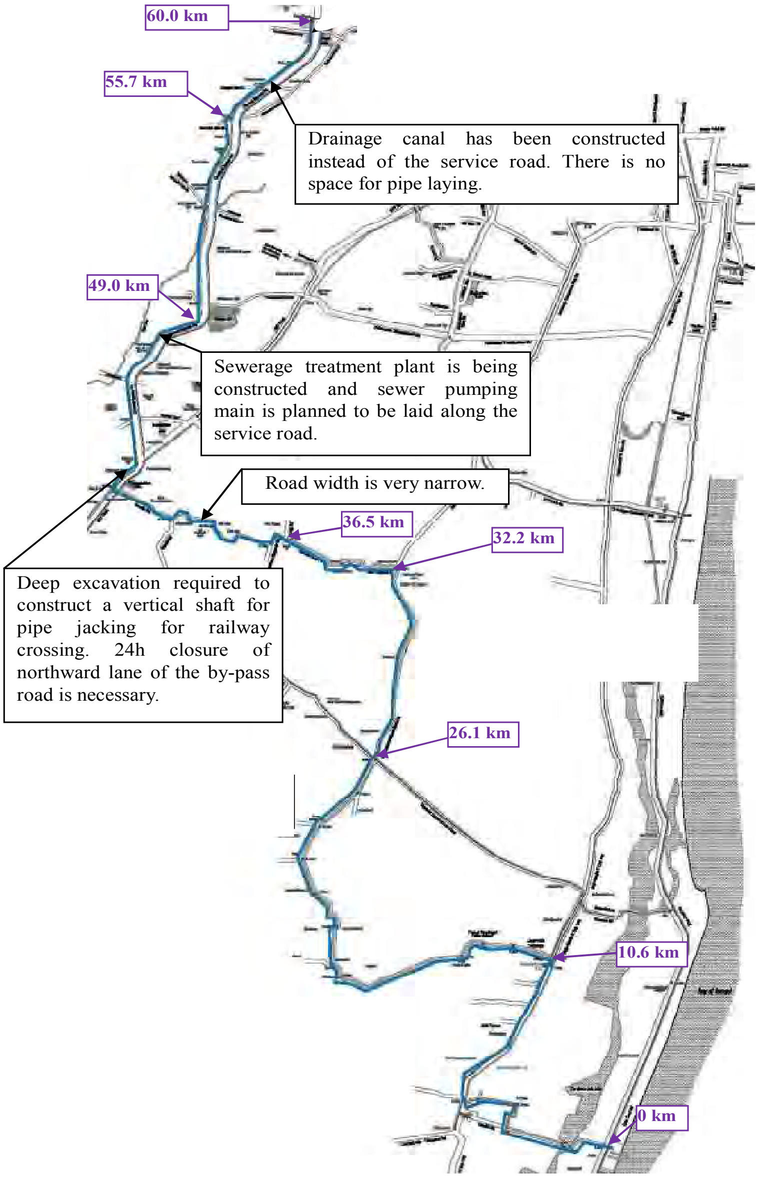
The operational system is controlled automatically from the control center. However, all facilities will be designed for manual operation as well as by installing a manual control panel. In addition, the remote control for main loading facilities, such as intake and transmission pumps, is designed from a central monitoring center.

6.6 Design of Water Transmission System

As described in subsection 5.4.2, the proposed water transmission system of the Project consists of 1) a product water transmission pump station at Perur DSP, 2) a transmission line from Perur DSP to Porur HW that includes a branch line from Kovilenchery, and 3) a new reservoir that receives water from Peuru DSP and a new pump facility that sends the water to the WDSs in the corporation area through the existing transmission pipelines.

6.6.1 Route Selection of Transmission Main from Perur DSP to Porur HW

As shown in Figure 6.6.1, several difficulties were identified on the route presented in the DPR.



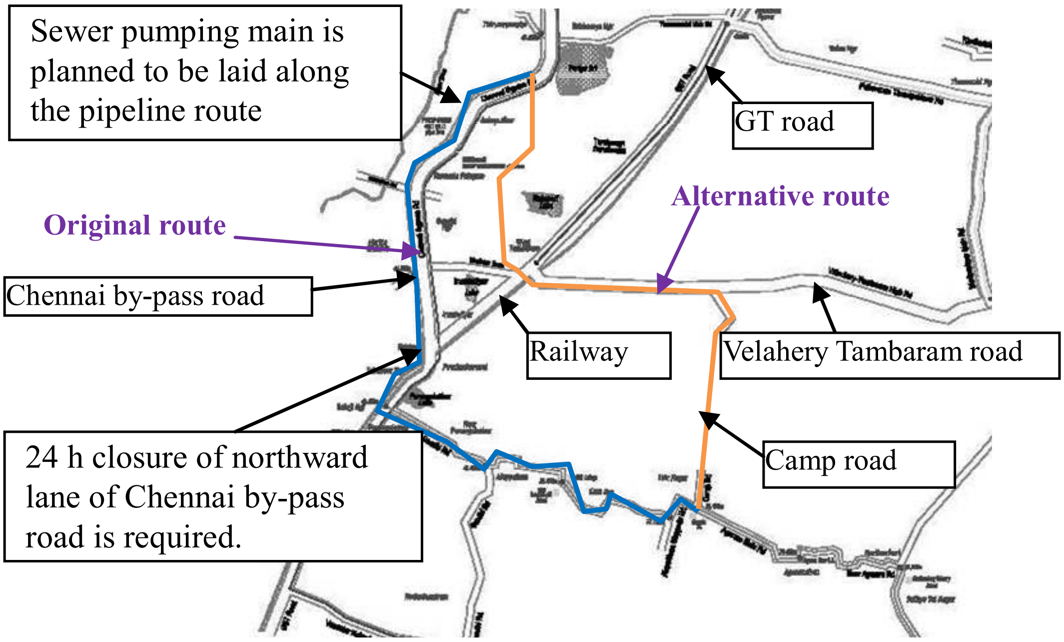
Source: JICA Study Team

Figure 6.6.1 Difficulties in the Route of the Transmission Main in the DPR

Thus, alternative routes were investigated so as to avoid the above-mentioned problems:

(1) From 36.5 km to 49.0 km

As shown in Figure 6.6.2, the alternative route along the Camp road and Velachery Tambaram road was considered. As per the comparison shown in Table 6.6.1, an alternative route was selected since the railway crossing in the original route was judged to be unrealistic. Moreover, a sewer pumping main was found to be under construction along the original route.



Source: JICA Study Team

Figure 6.6.2 Alternative Route (32.2 km to 49.0 km)

Table 6.6.1 Comparison of the Route between Chainage 32.2 km and 49.0 km

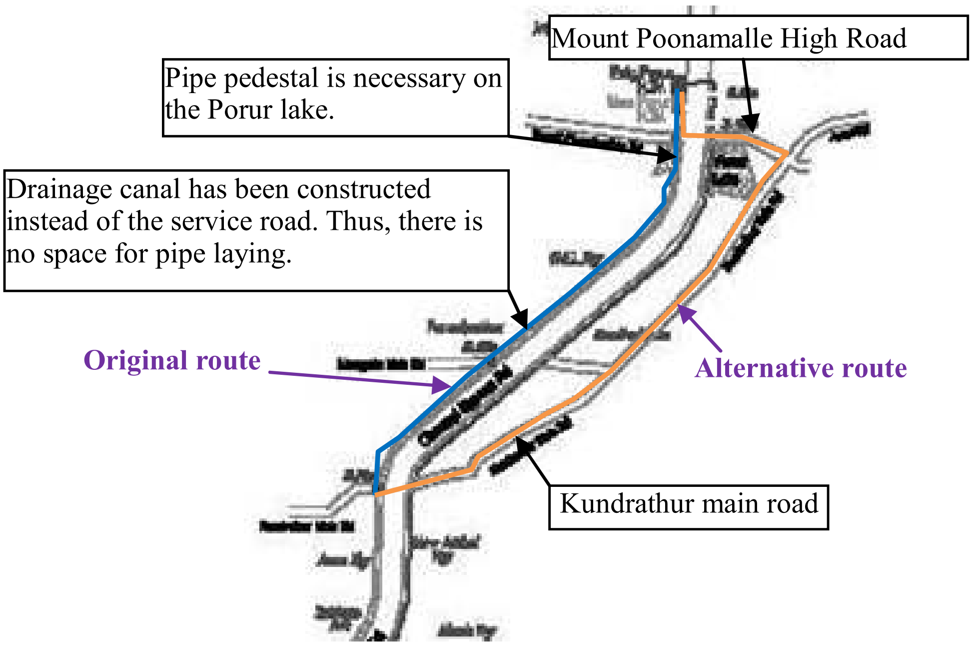
	Original Route	**Alternative Route**
Site condition	• In order to avoid 24 h closure of the northward lane of Chennai by-pass road, which is unacceptable, a shield tunnel of 1,400 m length must be constructed for the railway crossing. (Original DPR planned to apply pipe jacking method) • Sewer pumping main is planned to be constructed along the pipeline alignment.	• Pipe jacking of 100 m length is necessary for the railway crossing. • There are many piers of the flyover of IT road.
Cost	• Involves huge cost for construction of 1,400 m shield tunnel.	• Pipe jacking of 100 m length is necessary.
	Very Bad	Fair
Constructability	• Very low efficiency of shield tunneling work, since the work can be done only during night time (4 hours/day).	• Generally, high efficiency is expected except for the crossing of railway and GT road.
	Bad	Good
Conclusion	**Not Selected**	**Selected**

Source: JICA Study Team

(2) From 55.7 km to 60.0 km

As shown in Figure 6.6.3, the alternative route along the Kundrathur main road was considered. This alternative route was selected based on the comparison of routes in Table 6.6.2.

Deep excavation across Mount Poonamalle High Road where D2000 and D1200 are laid is necessary for both the original and alternative routes.



Source: JICA Study Team

Figure 6.6.3 Alternative Route (55.7 km to 60.0 km)

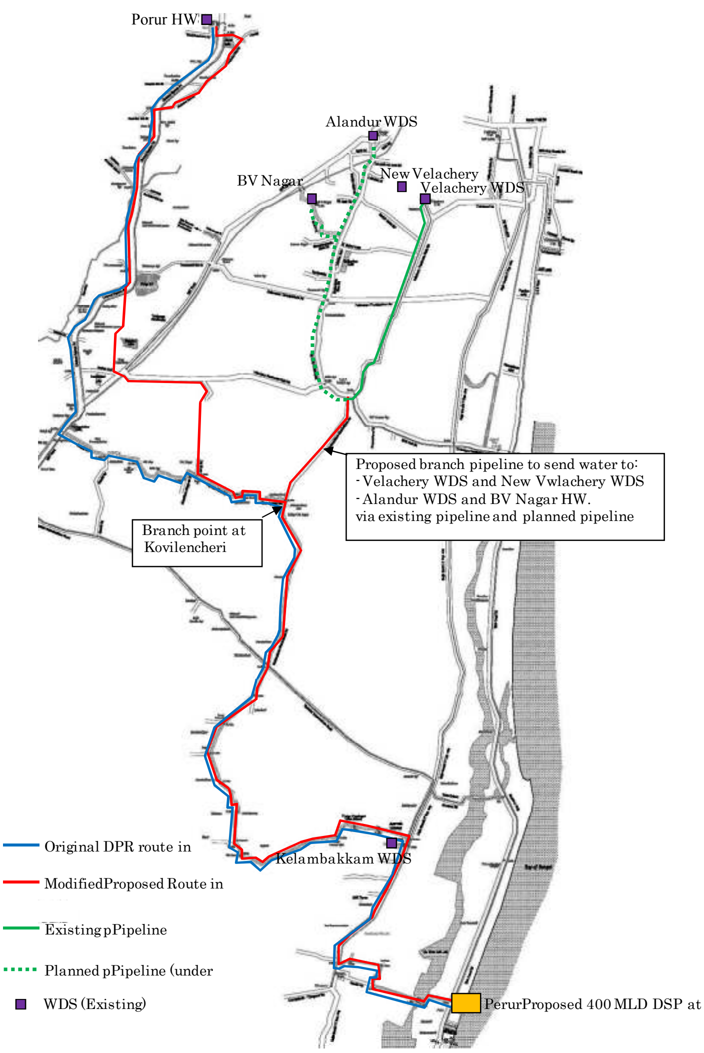
Table 6.6.2 Comparison of the Route between Chainage 55.7 km and 60.0 km

	Original Route	**Alternative Route**
Site condition	• Drainage canal has been constructed instead of the service road. Thus, there is no space for pipe laying. The shield tunnel of 1600 m length can be the only solution. • The pipeline pedestal must be constructed on the Porur lake section.	• Pipeline route is along Kudrathur main road and Mount Poonamalle High Road under which many underground utilities were laid.
Cost	• Involves huge cost for shield tunneling and pipe pedestal on the Porur lake.	• Deep excavation across Mount Poonamalle High Road is necessary. This work can be done only during night time (4 hours/day)
	Very Bad	Fair
Constructability	• Access to the vertical shaft for the shield tunnel is difficult since it is a swampy area.	• Work efficiency is expected to be low since the route is along the congested road.
	Bad	Fair
Conclusion	**Not Selected**	**Selected**

Source: JICA Study Team

(3) Proposed Pipeline Route

Figure 6.6.4 shows the pipeline route after modifications in the Study. As described in Section 5.4.2, the pipeline is proposed to be branched off at Kovilenchery and extended along Medavakkam – Manbakkam Road to the junction of Velachery – Tambaram Road.

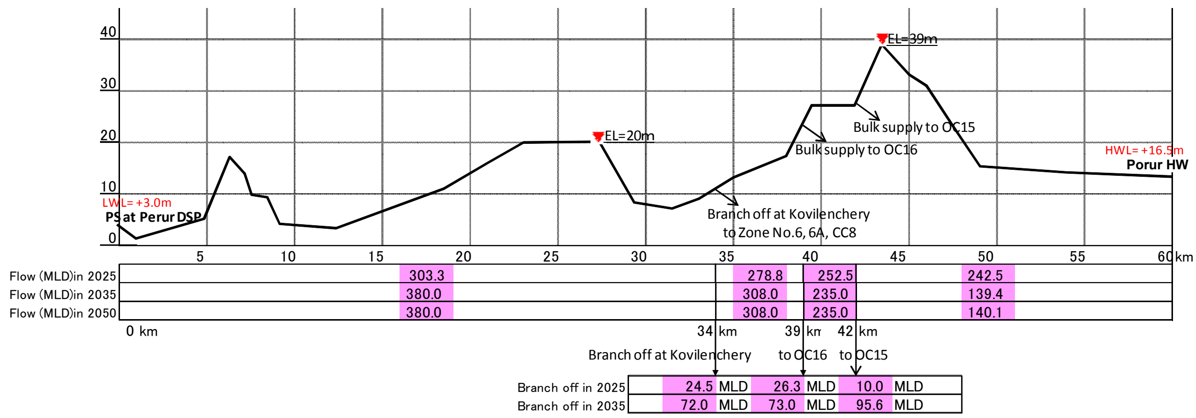


Source: JICA Study Team

Figure 6.6.4 Proposed Pipeline Route (from DSP to Porur HW)

6.6.2 Selection of Pumping Plan and Pipe Diameter

Figure 6.6.5 shows the longitudinal section and flow diagram of the transmission main from Perur DSP to Porur HW .



Source: JICA Study Team

Figure 6.6.5 Longitudinal Section and Schematic Diagram of the Transmission Main

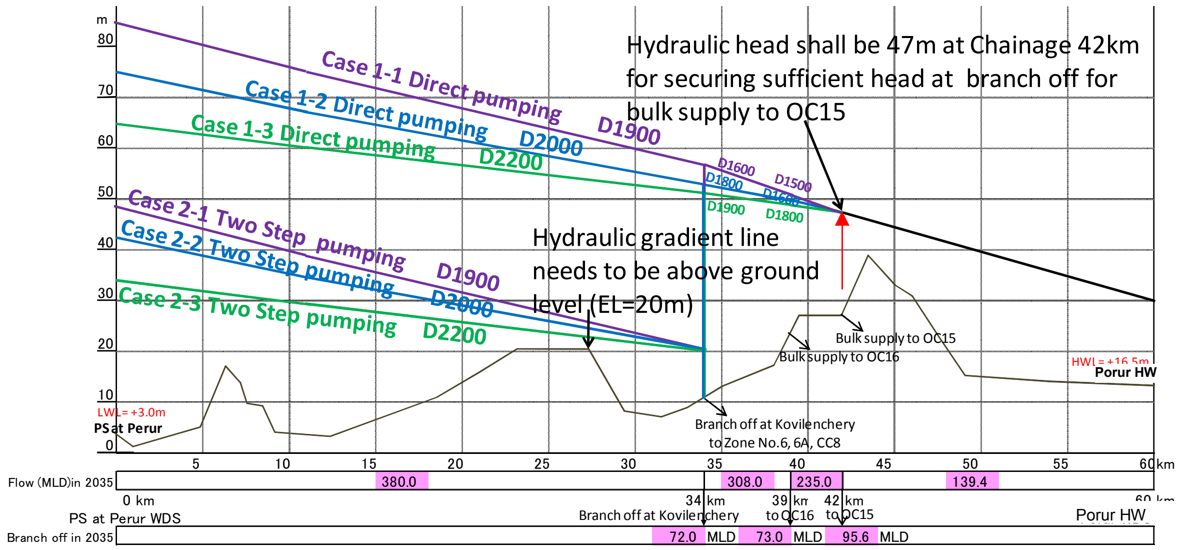
In general, the use of pipes with a larger diameter increases the pipeline cost and reduces the pump head, which will save the operation cost. Therefore, the pipe diameter and pump head for the transmission line need to be selected based on the total cost of the construction and O&M. To determine the pump head and the diameter, alternative studies were conducted for the cases as shown in Table 6.6.3. As the pipeline is quite long (approximately 60 km length), the alternatives included cases to install a relay pumping station in the pipeline.

Table 6.6.3 Alternative Cases for Pumping Plan and Pipe Diameter

Case	Pipe Diameter	Pump Head	
Case-1: Direct Pumping Pump station at Perur DSP only			
Case 1-1	D1900 – D1500	Pump head of PS at DSP: 90 m	
Case 1-2	D2000 – D1600	Pump head of PS at DSP: 78 m	
Case 1-3	D2200 – D1800	Pump head of PS at DSP: 67 m	
Case-2: Two-step pumping Pump station at Perur DSP and Booster pump station at Kovilenchery branch point			
Case 2-1	D1900 – D1500	Pump head of PS at DSP: 52 m	Pump head of Booster PS: 51 m
Case 2-2	D2000 – D1600	Pump head of PS at DSP: 45 m	Pump head of Booster PS: 47 m
Case 2-3	D2200 – D1800	Pump head of PS at DSP: 35 m	Pump head of Booster PS: 44 m

Source: JICA Study Team

Figure 6.6.6 shows the hydraulic grade line of each case.



Source: JICA Study Team

Figure 6.6.6 Hydraulic Grade Line of Alternative Cases

In Cases 1-1 to 1-3, the pump head at the Perur DSP is determined so that the hydraulic head passes the hill at 40 to 45 km from the DSP. On the other hand, in Cases 2-1 to 2-3, the pump head at the DSP will be lower and the relay pump, which is presumed at 34 km, the branch point at Kovilenchary, will boost the pressure to pass the hill.

The comparison of the total cost of the alternative cases including O&M cost for 30 years is shown in Table 6.6.4. The breakdown of cost comparison is presented in Appendix 6.19. Generally, direct pumping plan (Cases 1-1 to 1-3) tends to be more costly in terms of construction cost than the two-step pumping plan due to the higher water pressure in the transmission main, which requires higher specification of the mild steel pipe in terms of thickness. On the other hand, the O&M cost of the direct pumping plan is lower because of the lower power consumption in pumping and lower maintenance cost of the pump facilities.

Table 6.6.4 Comparison of Lifecycle Cost of the Alternatives

Unit: INR million

	Case 1-1	Case 1-2	Case 1-3	Case 2-1	Case 2-2	Case 2-3
Construction Cost	3,051	3,342	4,076	3,207 (Land cost for Booster PS is not included)	3,256 (Land cost for Booster PS is not included)	3,770 (Land cost for Booster PS is not included)
O&M cost (NPV of 30 years)	3,501	3,119	2,825	3,671	3,327	2,963
Total Cost	6,552	6,461	6,901	6,878	6,583	6,733

Note: Cost basis were derived from Cost Estimate in DPR (2013)
Source: JICA Study Team

To finally select the pumping plan and the pipe diameter, the most economical plans among the direct pumping plan and the two-step pumping plan, which are Cases 1-2 and 2-2, were compared as shown in Table 6.6.5.

Table 6.6.5 Comparison of Direct Pumping and Two Step Pumping

Item	Case 1-2 Direct Pumping System Pipe diameter: D2000 – D1600 Pump head of PS at DSP: 78 m	Case 2-2 Two-Step Pumping System Pipe diameter: D2000 – D1600 Pump head of PS at DSP: 45 m Pump head of Booster PS: 47 m
Pump Station		
Operation control	Operation control is simple since there is only one pump station.	Close corporation between two pump stations is necessary. So, operation control becomes complicated.
Maintenance	Less maintenance point	More maintenance points
Land acquisition	No land acquisition	Land acquisition for Booster PS is necessary (Approx. 70 m x 70 m)
Pipeline		
Safety of pipeline	Effect of water hammer and risk of water leakage is higher than Case 2-2.	Effect of water hammer and risk of water leakage can be reduced compared to Case 1-2.
Life Cycle Cost (Case 1-2 = 100)	100	102 (Land cost is not included)
Overall evaluation	Case 1-2 is more advantageous than case 2-2 in easiness of O&M and lifecycle cost. The effect of water hammer and risk of water leakage can be reduced by design consideration and strict construction supervision.	

Source: JICA Study Team

As a result of the comparison described in Table 6.6.4, "Case-1-2: Pipe diameter: D2000 – D1600, Pump head of PS at DSP: 78 m" was recommended for easy O&M and lower lifecycle cost. Thus, the pumping plan and pipe diameters of the transmission main was determined as presented in Table 6.6.6.

Table 6.6.6 Principal Feature of Transmission Facility from DSP to Porur HW

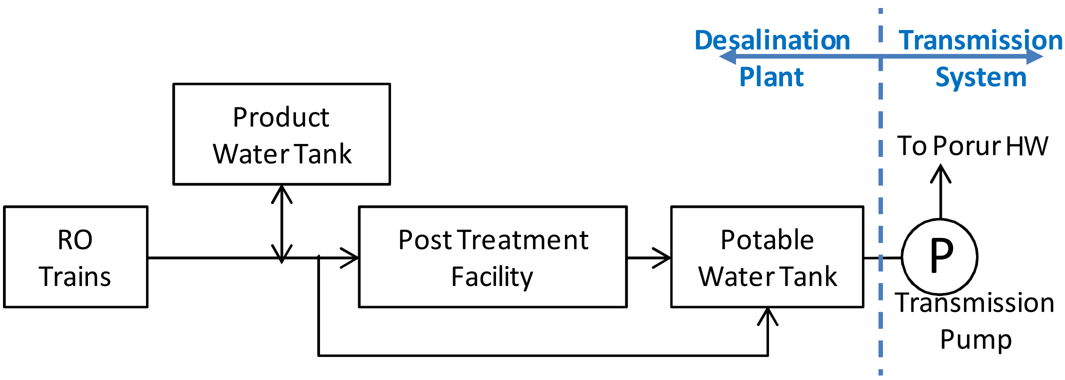
Facility	Feature
Pumping plan	To pump up the product water of the Perur DSP by a pumping station Q= 400 MLD (4.63 m3/sec), H= approx. 80 m
Pipeline	Chainage 0 km - 34 km D2000 L= 34 km
	Chainage 34 km – 41 km D1800 L= 7 km
	Chainage 41 km – 48 km D1600 L= 7 km
	Chainage 48 km – 60 km D1600 L= 12 km *1)
	Branch line from Kovilenchery to existing pipeline D1000 L=5 km *2)

Note 1): The pipe diameter from Chainage 48 km was determined considering the projected flow in 2025 (242.5 MLD) so that the flow velocity is less than 1.5 m/sec.
Note 2): The pipe diameter of branch line was determined considering the projected flow in 2035/2050 (72 MLD) so that the flow velocity is less than 1.3 m/sec.
Source: JICA Study Team

6.6.3 Design of Pump Station at Perur DSP

(1) Interface between DSP and transmission system

As described in Subsection 6.3.8, the final product water from the post treatment facility is sent to the potable water tank with a total capacity of 2,800 m^3 (1,400 m^3 × 2). Then, the product water is pumped to Porur HW by the transmission system to be constructed by the Project. The interface of the DSP and the transmission system are illustrated in Figure 6.6.7.



Source: JICA Study Team

Figure 6.6.7 Interface between the DSP and the Transmission System

(2) Total pump head

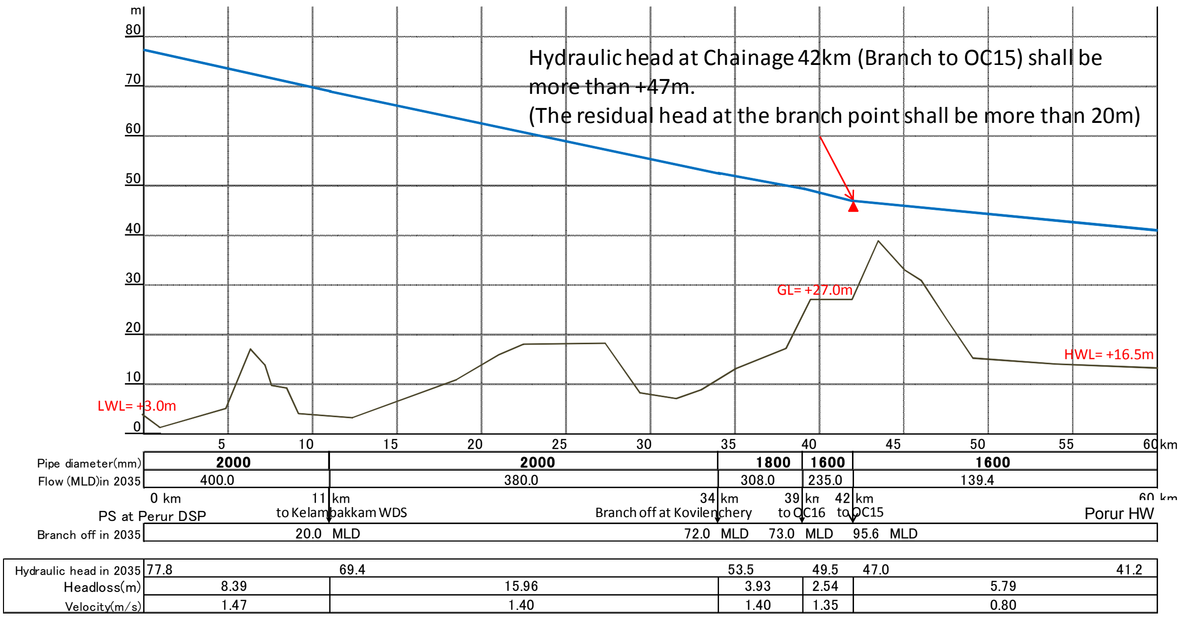
The total pump head is calculated at 77.8 m as shown in Table 6.6.7. Figure 6.6.8 illustrates the schematic diagram and the profile of the transmission main.

It is noted that the transmission system is designed based on the maximum water production capacity of the Perur DSP, i.e., 400 MLD, instead of the presumed amount from the DSP, i.e., 380 MLD. The average annual production is 380 MLD, considering the unavailable duration of the plant caused by maintenance work, unexpected failure or power supply suspension. However, to utilize the maximum capacity of the DSP, the transmission system needs to be designed so as to be able to transmit 400 MLD.

Table 6.6.7 Basic Conditions of Pump Head Calculation

Item	Condition
Total pump capacity	400 MLD (4.63 m^3/sec = 277.8 m^3/min)
Gross pump head	・ Critical point to determine the pump head: Branch to OC-15 (Chainage 42.0 km, Ground level: +27.0 m), residual head: 20 m to enable water delivery to bulk supply users' storages ・ Necessary dynamic head at Chainage 42.0 km: 47.0 m (= 27.0 m + 20.0 m) ・ LWL of the potable water tank: + 3.0 m Thus, gross head = 44.0 m (= 47.0 m - 3.0 m)
Head loss in the pipeline	30.8 m (obtained by formula of Hazen – Williams, C = 130)
Head loss at pump station	3.0 m (assumed)
Total pump head: 77.8 m (= 44.0 m + 30.8 m + 3.0 m)	

Source: JICA Study Team



Source: JICA Study Team

Figure 6.6.8 Schematic Diagram and Hydraulic Grade Line of the Transmission Main

(3) Design of the product water transmission pumps

1) Basic specification of the product water transmission pumps

The basic specifications of the pump facility are presented in Table 6.6.8.

Table 6.6.8 Basic Specifications of the Product Water Pumps at the Perur DSP

Number of pumps	4: Duty 2: Stand-by
Pump type	Double suction horizontal centrifugal pump
Pump discharge	69.4 m^3/min × 4 duty = 277.6 m^3/min in total
Total pump head	77.8 m
Motor output	1,200 kW

Source: JICA Study Team

2) Number of Pumps

The DSP, including the potable water tank, is divided into two segments corresponding to 200 MLD production. Accordingly, the pump system shall consist of two parallel systems to take advantage of the “dual line” concept of the DSP. For each system, multiple pumps shall be installed to enable variable flow rate by changing the number of operating pumps and avoid too large investment on the stand-by pump. One stand-by pump should be installed for each system; thus, the number of stand-by pumps will be two. Installation of two stand-by pumps is stipulated in the CPHEEO Manual.

Thus, the JICA Study Team compared the following two options and selected Case-1: 4 duty + 2 stand-by, in viewpoint of the construction cost including the equipment of pump house:

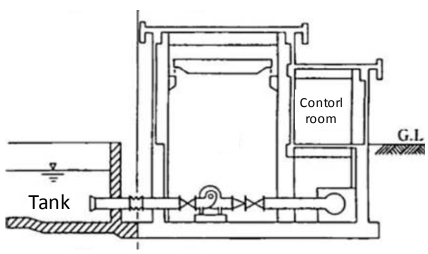
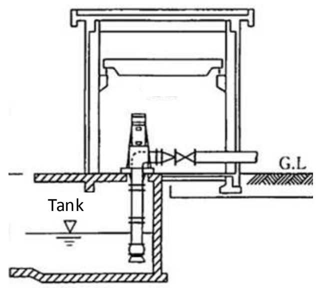
Case-1: (2 duty + 1 stand-by) × 2 systems = 4 duty + 2 stand-by

Case-2: (3 duty + 1 stand-by) × 2 systems = 6 duty + 2 stand-by

3) Pump type

The applicable pump type in the presumed pumping conditions (Q = 69.4 m^3/min, Total head = 77.8 m) are a) Double suction horizontal centrifugal pump and b) Vertical shaft mixed flow pump. The comparison shown in Table 6.6.9 showed that the double suction horizontal centrifugal pump was selected in view of the pump performance and easiness of maintenance.

Table 6.6.9 Comparison of Pump Type for the Product Water Pumps at the Perur DSP

	Double suction horizontal centrifugal pump	Vertical shaft mixed flow pump
Sectional plan		
Main performance of pump Pump Efficiency NPSH* Durability	Good (84.5%) High Good	Fair (82.0%) Slightly lower Inferior to centrifugal pump
Pump house Necessary area Height	Large Lower than vertical mixed flow pump	Less than centrifugal pump High building is necessary
Maintenance	Simple and easy because the main body is easily removed and repaired.	Complicated and difficult because the motor needs to be shifted to repair the main body.
Cost	100	101
Total Evaluation	Advantageous in pump performance and easiness of maintenance (**Selected**)	Inferior in pump performance and easiness of maintenance

NPSH: Net positive suction head
Source: JICA Study Team

(4) Flow control facility

The required production to the DSP at the initial years, i.e. just after the completion of the Project, will not be high, and it will gradually increase year by year. The water demand will have seasonal fluctuations. In addition, the necessary amount to be sent to each destination of the transmission system will need to be controlled according to the water balance in the storage tanks in the water transmission and distribution networks. Therefore, the water flow in the transmission main needs to be controlled both at the product water pumping station and at the branch-off points as follows:

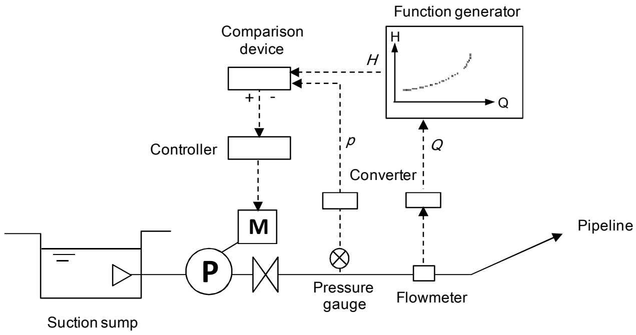
1) Flow control at pump station

i) Control method of pump discharge

Generally, there are three methods for controlling pump discharge: a) Control by the number of operating pumps, b) Control by operation of the flow control valve at discharge pipe from the pumps, and c) Control by pump motor speed. Among these, the control by operation of the flow control valve is not economical since it generates energy loss to limit the water flow. Thus, the combination of control by number of operating pumps and control by pump motor speed is the recommended method for flow control. For controlling pump motor speed, an inverter shall be equipped.

ii) Protocol of the flow control system

Figure 6.6.9 illustrates the concept of the flow control protocol. As shown in the figure, water flow and pressure at the outlet of the pumps are measured in the system. The computing system calculates the theoretical pump head corresponding to the planned water flow. Then the pump discharge pressure is controlled so that the adjusted water flow becomes the planned value.



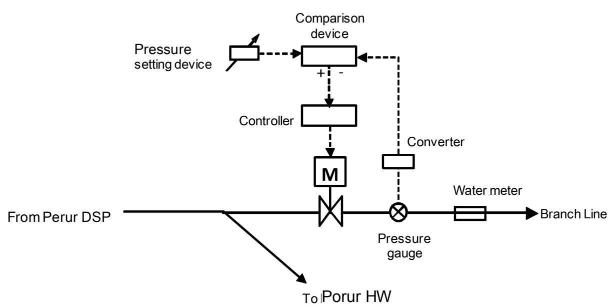
Source: JICA Study Team

Figure 6.6.9 Flow Control System at Pump Station

2) Flow control at branch-off

At the branch-off point, motorized butterfly valve and a pressure gauge will be equipped as shown in Figure 6.6.10. The pressure at the branch point will be adjusted by operating the butterfly valve so that the water flow in the branch line will be equal to the planned value.

A water meter is also installed at the branch for recording the water sales to the bulk water supply receivers.



Source: JICA Study Team

Figure 6.6.10 Flow Control System at Brach-Off Point

(5) Pump house

The area of the pump house will be 54 m × 15 m, and the height will be GL + 10 m at the top and GL - 6.6 m at the bottom. The depth of support layer at the construction site is GL – 12 m to 14 m. Thus, the foundation pile up to GL-14m will be provided for the foundation work of the pump house.

6.6.4 Design of Transmission Mains

(1) Pipe material and wall thickness

1) Pipe material

Conceivable pipe materials for large diameter pressure pipeline are: 1) mild steel pipe (MS pipe), 2) ductile iron pipe (DIP), and 3) high-density polyethylene (HDPE) pipe. The major advantages and disadvantages of these pipe materials are shown in Table 6.6.10.

Due to the resistance to the high pressure, the MS pipe and DIP are more applicable than the HDPE pipe. Between the MS and DIP pipes, the MS pipe is selected due to its wide availability in the Indian market. It is noted that the DPR also selected the MS pipe.

Table 6.6.10 Advantages and Disadvantages of the Pipe Material

Pipe Material	Advantages	Disadvantages
Mild Steel Pipe (MS pipe) (**Selected in the Project**)	• High strength, toughness, shock resistance, and durability • Complete integration by welding joint to avoid separation • Available in Indian market for large diameters of 2,000 mm or 1,800 mm	• Special skills are necessary for high-quality welding of the joints • Prone to corrosion in case surface coating is damaged during construction works or O&M works
Ductile iron pipe (DIP)	• High strength, toughness, shock resistance, and durability • High workability of installation	• Heavy weight • Protection of pipe fittings is necessary • Risk of separation at pipe joint by thrust force • Maximum diameter available in the Indian Market is up to 1,200 mm
High-density polyethylene pipe (HDPE pipe)	• High corrosion resistance • Complete integration by fusion joint to avoid separation • Roughness of inner side does not change by time	• Low strength compared with metal material • Weak to heat and UV • Special tools are necessary for fusion joint • It is difficult to make fusion joint in wet condition • Maximum diameter available in the Indian market is up to 1,600 mm

Source: JICA Study Team

2) Pipe wall thickness

Taking into account the working pressure in the pipes and possible water hammer in the transmission lines, the pipe wall thickness is selected as shown in Table 6.6.11, where the standard thicknesses from the Indian Standard (IS 3589) are selected for respective pipe diameter. The thicknesses fall between

Class A and Class B of STW41 in JIS G 3443. The maximum allowable water pressure, including water hammer, is 3.0 MPa and 2.5 MPa for Class A and Class B, respectively.

Table 6.6.11 Standard Pipe Wall Thickness and Selected Thickness

Nominal Diameter (mm)	IS 3589 Standard Thickness (mm)	STW41 in JIS G3443			Selected in DPR (mm)	**Selected in the Study (mm)**
		Class	Thickness (mm)	Maximum allowable pressure including water hammer (MPa)		
1600	14.2 16.0	B A	12.0 15.0	2.5 3.0	14.2	**14.2**
1800	14.2 16.0 17.5	B A	13.0 16.0	2.5 3.0	16.0	**16.0**
2000	16.0 17.5 20.0	B A	15.0 18.0	2.5 3.0	17.5	**17.5**

Source: JICA Study Team

(2) Ancillary facilities

Ancillary facilities shall be provided at the locations as shown in Table 6.6.12.

Table 6.6.12 Provision of Ancillary Facilities

Facility	Location
Air valve facility	a) High tip end of the vertical alignment b) Just after/before the stop-valve on the down-grade / up-grade line c) At least one place in every one km
Drain facility	Low tip end and near a river / drain channel
Branch-off facility (a tee, valves, water meter, and pressure gauge)	・Chainage 11.1 km: Branch off at Kelambakkam WDS/ Interconnection to Veeranam Pipeline *1) ・Chainage 33.5 km: Branch off at Kovilenchery to Medavakkam ・Chainage 36.4 km: Bulk supply to Madabakkam ・Chainage 41.2 km: Bulk supply to Sembakkam ・Chainage 41.7 km: Bulk supply to Chitlapakkam ・Chainage 42.9 km: Bulk supply to East Tambaram ・Chainage 44.8 km: Bulk supply to West Tambaram
Stop valve facility	a) Just downstream of the branch-off facility b) Before and after the special section (Pipe jacking and pipe bridge)

1): Not included in the water allocation plan.
Source: JICA Study Team

(3) Temporary earth retaining for pipe laying

Based on the ground condition survey results by hand auger boring along the pipeline route, it was found, for most of the pipeline route, the trench for pipe laying can be maintained without installation of retaining wall (steel sheet pile). Thus, for such sections, only simple timbering by the poling board or light sheet pile for safety purpose shall be provided in compliance with the standard practice of CMWSSB.

However, for the section between Chainage 52 km (after crossing Adyar river) and Chainage 54.5 km (before crossing Chennai By-pass road), temporary earth retaining wall by steel sheet pile and H-beam strut will be necessary due to soft soil condition at the sites.

(4) Special sections

1) Highway / Railway crossing by pipe jacking method

For crossing points of highway and railway, as shown in Table 6.6.13, the trenchless pipe jacking shall be applied.

Table 6.6.13 Construction Sites for Pipe Jacking Method in the Product Water Main

Chainage	Crossing facility	Diameter (mm)	Length (m)	Reason for applying trenchless method
00k 010m – 00k 090m	ECR road	2,000	80	Earth covering is 7 m at maximum.
44k 110m – 44k 175m	Railway	1,600	65	To obtain approval from railway company
44k 175m – 44k 250m	NH-45	1,600	75	To obtain approval from national highway authority
47k 714m – 47k 794m	Chennai By-pass	1,600	80	
54k 552m – 54k 632m	Chennai By-pass	1,600	80	

Source: JICA Study Team

a) 00k 010m – 00k 090m

This section is crossing ECR road. To cross ECR road, RC pipe with internal diameter of 3,000 mm will be installed by the cutting edge pipe jacking method. The earth covering is planned to be 2.5 m – 7.0 m. D2000 steel pipe will be installed inside the RC pipe after the pipe jacking. The driving vertical shaft will be constructed in the DSP site and the receiving vertical shaft will be constructed in the road. Temporary road decking will be installed on the receiving vertical shaft for enabling daytime traffic, if the road authority requires to secure two way traffic. Land acquisition is not required for the vertical shafts.

b) 44k 110m – 44k 175m (crossing railway) and 44k 175m – 44k 250m (crossing national highway No.45)

To cross the railway and NH-45 road, RC pipe with an internal diameter of 2,600 mm will be installed by the cutting edge pipe jacking method. The earth covering is planned to be 5 m and total excavation depth will be less than 8 m. According to the geotechnical survey results, the soil consists of filled soil until -1 m from the surface and it is followed by clay layers up to -3 m from the surface. Below -3 m, the soil consists of weathered igneous rock up to -8 m. It was judged the excavation up to GL-8m could be possible.

D1600 steel pipe will be installed inside the RC pipe. The driving vertical shaft for pipe jacking will be constructed within a vacant land owned by the railway authority beside the railway and it will not hider the road traffics. The receiving shafts will be constructed in the roads. Temporary road decking will be installed on the receiving vertical shaft, if the road authority requires two way traffic. Land acquisition is not necessary for the vertical driving and receiving shafts.

c) 47k 714m – 47k 794m and 54k 552m – 54k 632m

These sections are crossing Chennai by-pass road. To obtain approval from national highway authority, the trenchless method was planned to be applied. RC pipe with an internal diameter of 2,600 mm will be installed by the cutting edge pipe jacking method. The earth covering is planned to be 2.5 m - 3.0 m. D1600 steel pipe will be installed inside the RC pipe. The driving and receiving vertical shafts for pipe jacking will be constructed in the road areas. Temporary road decking will be installed on these vertical shafts for enabling daytime traffic, if the road authority requires two way traffic. Land acquisition is not necessary for the vertical shafts.

2) Salt Pan crossing

From Chainage 1.0 km to 2.7 km, the pipeline will be aligned in the salt pan area. Along this section, the D2000 pipe will be installed above the ground on the pipe pedestal made of concrete pier and I-beam (2 × I-588 × 300) girders with a span of 10 m.

3) Crossing Adyar river

At the crossing of the Adyar river at Chainage 51.6 km to 51.8 km, the D1600 pipe will be installed on the pipe bridge by concrete pier with a height of 10 m and I-beam (2 × I-588 × 300) girders with a span of 15 m.

6.6.5 Design of Expansion of the Porur HW

(1) General

Porur HW was constructed as a part of Veeranam Project in 2004. 180 MLD of the treated water from Vadakuthu WTP is sent to Porur HW via the transmission line with a length of approximately 200 km. From Porur HW, the water is sent to other WDSs in the corporation area via the existing transmission lines.

In the premises of Porur HW, a new reservoir and a pump station will be constructed adjacent to the existing reservoir and pump station. The product water from Perur DSP will be sent to these new facilities and then sent to the WDSs in the corporation area via the existing transmission line, which will be shared with the existing water sources. The design water flow to and from the new reservoir and the pumping station is 240 MLD based on the water allocation plan for 2025. According to the water allocation plan for 2035, the water flow will be reduced after 2025.

(2) Reservoir

1) Capacity and number of tanks

As the role of the Porur HW is transmission instead of distribution, the buffering function for hourly peak demand is not required to the reservoir at the WDS. For the same reason, the capacity of the existing reservoir (Veeranam system) is only one hour amount of the daily supply (180 MLD). In the Project, the storage capacity of the new reservoir is also designed as one hour amount of the daily supply amount of 240 MLD, i.e. 10,000 m^3. The reservoir will have two segments separated by a retaining wall.

2) Water level and reservoir type

Water level of the reservoir is shown in Table 6.6.14.

Table 6.6.14 Elevation of the Reservoir of Porur HW

Item	Elevation	Remarks
High Water Level (HWL)	+ 16.9 m	LWL + Effective depth of 4.0 m
Low Water Level (LWL)	+ 12.9 m	Same as the existing reservoir
Planned Ground Level (GL)	+15.0 m	Nearly equal to the original ground level

Source: JICA Study Team

The semi-underground reservoir type is used, same as that of the existing reservoir. The effective depth of the new reservoir is planned as 4.0 m while that of the existing reservoir is 2.9 m. Reasons for the deeper structure are the followings:

- Sufficient residual head of the transmission line is available
- To save the land area for the reservoir

3) Shape and foundation

The area of the reservoir will be approximately 80 m × 35 m, and the height will be GL + 3.05 m at the top and GL - 3.0 m at the bottom. The depth of the support layer at the construction site is around GL – 20 m. Thus, the foundation pile up to GL – 23 m will be provided for the foundation work.

(3) Transmission pumps

1) Basic specifications

Basic specifications of the pump facility are presented in Table 6.6.15.

Table 6.6.15 Basic Specifications of the Pump Facility for Expansion of the Porur HW

Total discharge	240 MLD (166.7 m^3/min)
Number of pumps	4: Duty, 2: Stand-by
Pump type	Double suction horizontal centrifugal pump
Pump discharge	41.7 m^3/min × 4 duty = 166.8 m^3/min in total
Total pump head	25.0 m
Motor output	235 kW

Source: JICA Study Team

As described in subsection 5.4.2, the total pump head shall be 25.0 m as same as the existing pump station. The selection of the number of pumps and pump type is described below.

2) Number of pumps

As in the existing facility, the reservoir will be of two tanks for easy maintenance. Accordingly, the pump system shall consist of two systems. As described in Subsection 6.6.3, the number of pumps shall be "(2 duty + 1 stand-by) × 2 system = 4 duty + 2 stand-by".

3) Pump type

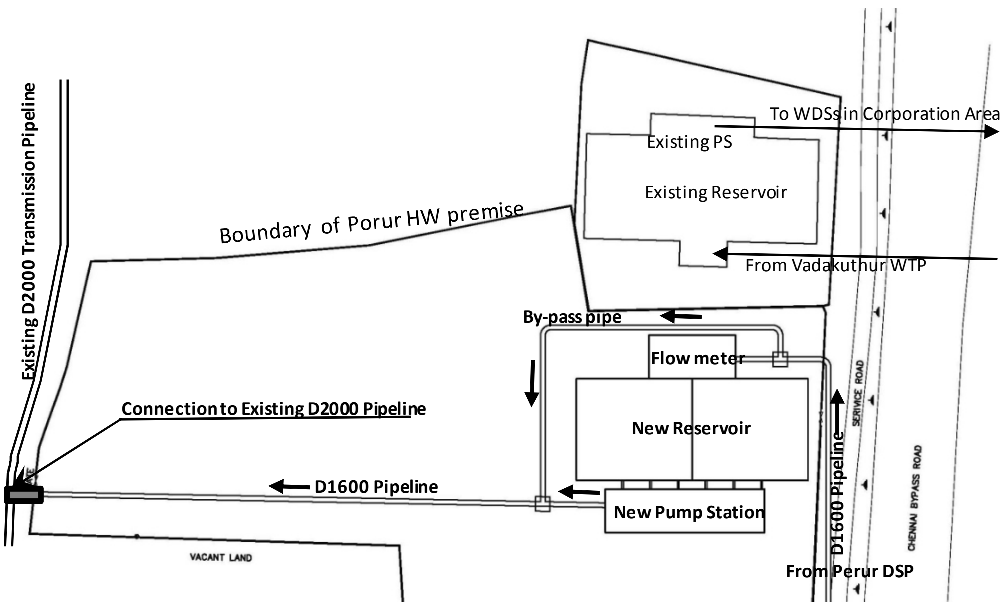
The applicable pump types for the pumping condition (Q = 41.7 m^3/min, Total head = 25 m) are a) Double suction horizontal centrifugal pump and b) Vertical shaft mixed flow pump. As described in Subsection 6.6.3, the double suction horizontal centrifugal pump was selected in view of pump performance and easy maintenance.

(4) Pump house

The area of the pump house will be approximately 45 m × 15 m, and the height will be GL+10 m at the top and GL-5.6 m at the bottom. The depth of the support layer at the construction site is around GL – 20 m. Thus, the foundation pile up to GL – 23 m will be provided for the foundation work of the pump house.

(5) Facility layout plan

Figure 6.6.11 shows the layout plan of Porur HW. A new reservoir and pump station will be constructed adjacent to the existing facility. The outlet pipeline from the pump station will be connected to the existing D2000 transmission pipeline, which is laid beside the Porur HW premise.



Source: JICA Study Team

Figure 6.6.11 Layout Plan of Expansion of Porur HW

(6) Utilization of the residual pressure

It is noted the residual head of the transmission pipeline at Porur HW after 2035 will rise up to around 20 m, as shown in Figure 6.6.8. To utilize this residual head, following measure can be envisaged:

- Using by-pass pipe when sufficient residual head is available (The by-pass pipe of the HW has been designed in the Study.)
- Installation of micro hydroelectric power equipment
- Raise the water level of the new reservoir in the Porur HW, by which the pump head can be saved. The current water level of the reservoir has been proposed at the same level with the existing reservoir so that the reservoirs can be interconnected.

Final selection of the measure to utilize the residual pressure will be made in the detailed design stage or operation phase of the facilities.

6.7 Design of the Water Distribution Network

For the design of the water distribution network for the project, it is envisaged to carry out 1) reinforcement of the existing distribution networks in the Core City, 2) improvement of the water distribution system in the Corporation, and 3) development of the water distribution networks in OC-15 and OC-16.

6.7.1 Reinforcement of the Existing Water Distribution Network in the Core City

(1) Reinforcement of hydraulic capability of the existing water distribution networks in the core city

1) Existing hydraulic conditions in design conditions

A major portion of the rehabilitation in the core city has been carried out during II Chennai project based on the hydraulic design carried out by Kirloskar Consultants. The hydraulic design parameters considered in the design reports are presented in Table 6.7.1

Table 6.7.1 Hydraulic Design Parameters for Distribution in II Chennai Project

Hydraulic Design Parameter	Considered Value	CPHEEO Standard
Design Period	30 years (2021)	
Peak Flow Rate	20 lit/capita/hour	12.5 lit/capita/hour (using 150 LPCD and 2.0 as peak factor)
Minimum Residual Head ➢ Pipes Covered by Network ➢ At Ferrule of SC*	 10 m 7 m	 7m (min) for single storey building,
Hazen-Williams Coefficient (C) ➢ For new pipes/Existing pipes with CM** lined. ➢ For existing pipes without CM lining	 110 80	 140 for DI with lining
Head Grade Level (HGL) at Source	20 m	
Hydraulic Analysis	Using Loop-4 Software	
Pipe Material ➢ Up to 1000 mm ϕ ➢ Above 1000 mm ϕ	 DI pipe (K-9) factory CM lined. MS pipe in situ CM lined	
Minimum pipe size	100 mm diameter	100 mm ϕ (<50,000 population) 150 mm ϕ (>50,000 population),

* SC: Service Connection;
** CM: Cement Mortar
Source: Report on detailed Engineering Design of Water Distribution System for Chennai City by Kirloskar

2) Assessment of the hydraulic capability of the existing networks in the core city

As a whole, as explained in Item (1) of Subsection 5.5.2, the existing water distribution network was designed to cater to sufficient water volume compared with the demand in the Study for 2035. However, to examine the capability of the water distribution networks hydraulically, the JICA Study Team conducted hydraulic assessment of the existing networks by WDZ.

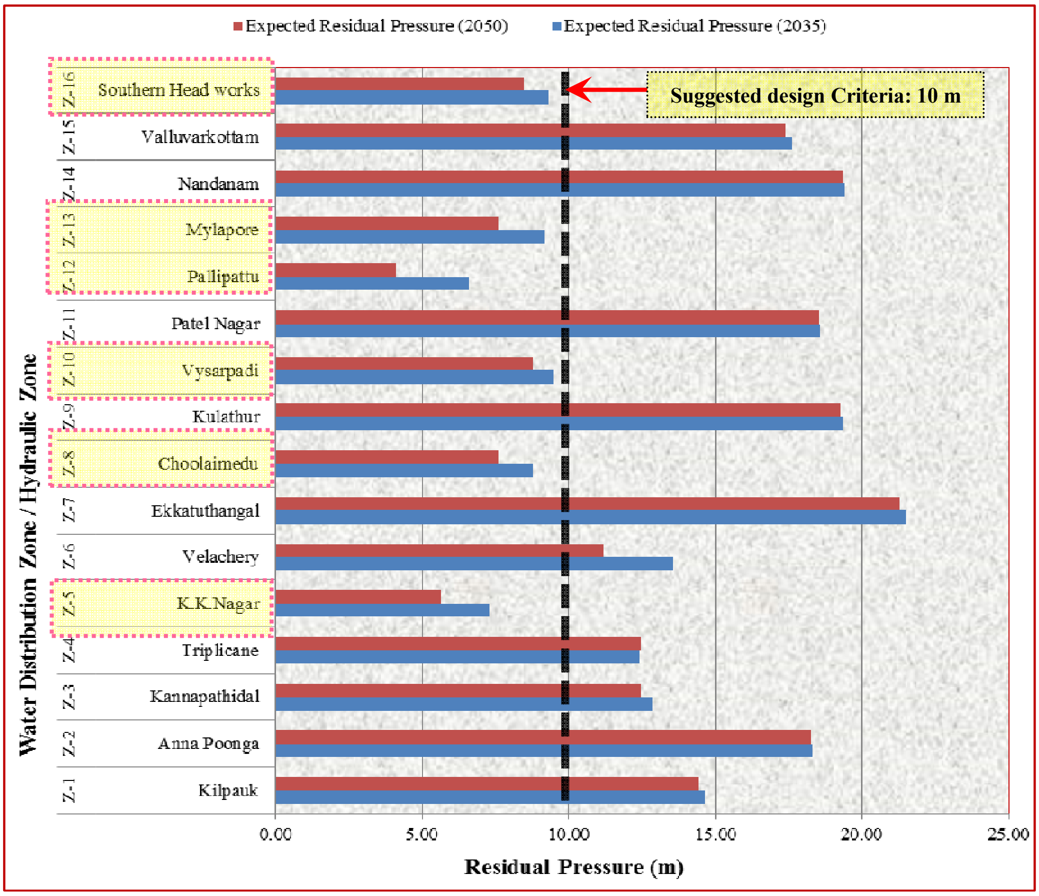
In the assessment, referring Table 6.7.1, the Hydraulic Grade Level at WDS location has been considered as 20 m during the design, the required residual pressure in the water distribution networks at critical points in the WDZs are 10 m, which will be sufficient to meet the pressure requirement for receiving water at a two- storey building.

Regarding the critical points, it is noted that the ground elevation difference in the Chennai Core City is varying from 0.25 m to 10 m, indicating a flat terrain, and that generally each WDZ has an elevation difference ranging from 1m to 2 m. Therefore, the critical point within a WDZ will be the farthest point from the supply points or the WDS and the residual pressure at the critical point will be mostly decided based on the friction losses in the distribution pipes.

Residual pressures at the farthest points in the WDZs have been calculated by Hazen-Wlliams formula with 150 LPCD and the population densities, pipe lengths to the farthest points, ground elevation of the farthest points for years 2035 and 2050. “C” value has been presumed at 100. which is usual value for used pipes.

The outcome of the anlysis is presented in Figure 6.7.1. Calculation sheets of the analysis are given in Appendix 6.20. The residual pressure at the farthest points in the Zones-5, 8,10,12 and 16 are expected to be lower than 10 m in the year 2035. Zone-13 will be the additional area to the list for the water demand in 2050. Minimum residual pressure as per the CPHEEO Manual is “7m” at the taps, but it is suggsted to design the distribution networks to ensure 10 m at the critical points to achieve the “7 m” at the taps.

Currently, the existing WDZs are interconnected to overcome the negative residual pressures at the farthest points. The interconnection is helping and will help the adjacent networks but in future, as the water demand increases, incapability of the respective distribution network may be critical issue, as asessed above.



Source: JICA Study Team

Figure 6.7.1 Preliminary Analysis Results on Minimum Residual Pressures by WDZ for 2035 and 2050

3) Proposals on the reinforcement of the water distribution networks

Referring to the analysis presented in Subsection 5.5.2, it is noted that the improvements within the Core City will be necessary, as the distribution networks designed and executed as per Kirloskar Report will not be capable in some zones to cater to the water demand for 2035. It is proposed that the Project will include detailed hyraulic analysis on the existing water distribution networks and reinforcement of the network by installing supplementary pipes or repalcement of the existing pipes to large diameter.

Quantity for additipnal pipes for reinforcement of the water distribution networks is presented in Table 6.7.2. Estimated length of the additional pipes for reinforcemnet is 100.58 km, which is rounded to 101 km. Diameters of the existing pipes are from 100 mm to 600 mm. In the Study, these pipes have been presumed to be replaced in the Project to 150 mm to 700 mm. Pipe material will be ductile cast iron (DCI), which is the standard material of CMWSSB.

Table 6.7.2 Quantity of Additional Pipes for Hydraulic Reinforcement of the Existing Water Distribution Networks in the Core City

WDZ	Distribution main length from WDSs to their farthest point (km) [1]	Distribution pipes located in the farthest point (low-pressure area) (km) [2]	Project Scope (km)		
			100% for [1]	50% for [2]	**Total**
5	7.11	16.78	7.11	8.39	**15.50**
8	5.90	41.70	5.90	20.85	**26.75**
10	2.85	30.21	2.85	15.11	**17.96**
12	2.29	6.51	2.29	3.26	**5.55**
13	4.05	20.87	4.05	10.44	**14.48**
16	9.55	21.59	9.55	10.80	**20.34**
Total	**31.75**	**137.66**	31.75	68.83	**100.58 => 101 km**

Source: JICA Study Team

(2) Reinforcement of the storage capacity

1) Requirement of Storage Capacities in Core city

The JICA Study Team analyzed the storage capacities of Under Ground Tank (UGT) and Elevated Service Reservoir (ESR) with water demand forecasted for 2035 and 2050 as shown in Table 6.7.3.

The total storage requirement in 2035 is calculated as 6 hours volume as a middle-term target and the requirement for 2050 is calculated as eight hours volume as a long-term target for the Core City. Eight hours capacity complies with the ideal condition stipulated in the CPHEEO Manual. Six hours capacity for 2035 is the minimum requirement suggested by the JICA Study Team so that the buffering function of the ESRs mostly works.

Among the target storages for 2035 and 2050, 2 hours volumes are allocated to ESRs. The allocation to ESRs is determined so that the ESR will serve 1 hour peak demand presuming hourly peak factor of 2.0.

The total storage requirement for UGTs is 1.47 ML for 2035 and 12.33 ML for 2050. The storage requirement of ESRs is 45.34 ML for 2035 and 49.32 ML for 2050. Detailed calculation sheet for the storage requirement and deficiencies of the existing UGTs and ESRs are given in Appendix 6.21.

Table 6.7.3 Required Storage Capacities for UGT & ESR in Core city (2035 and 2050)

WDZ	Name of WDZ	Existing Storage Capacity (ML)		Water Demand (MLD)		Deficiency in the storage volume* (ML)			
						2035		2050	
		UGT	ESR	2035	2050	UGT	ESR	UGT	ESR
1	Kilpauk	81.32	15.80	208.5	220.1	-	1.58	-	**2.54**
2	Annapoonga	22.50	2.50	58.2	61.3	-	2.35	-	**2.61**
3	Kannappar Tidal	**16.00**		55.7	57.6	-	4.64	-	**4.80**
4	Triplicane	10.00	2.40	36.2	36.2	-	0.62	-	**0.62**
5	K.K.Nagar	**14.00**	**2.40**	68.7	73.6	-	3.33	4.40	**3.73**
6	Velachery	**6.00**		35.2	38.4	-	2.93	3.60	**3.20**
6A	Velachery New	2.00		5.6	6.0	-	0.47	-	**0.50**
7	Ekkadu Thangal	4.50		6.7	7.3	-	0.56	-	**0.61**
8	Choolai Medu	43.00		105.0	111.0	-	8.75	-	**9.25**
9	Kolathur	20.00		37.4	40.1	-	3.12	-	**3.34**
10	Vyasarpadi	**22.00**		72.5	75.3	-	6.04	-	**6.28**
11	Patel Nagar	14.00		37.6	40.3	-	3.13	-	**3.36**
12	Pallipattu	17.00	0.75	20.1	21.9	-	0.93	-	**1.08**
12A	Thiruvanmiyur	**3.00**	**0.75**	26.8	29.3	1.47	1.48	**4.33**	**1.69**
13	Nandanam	11.00		21.3	23.1	-	1.78	-	**1.93**
14	Mylapur	**11.50**		43.8	45.5	-	3.65	-	**3.79**
15	Southern Head Works	24.00	4.50	32.8	34.5	-	0.00	-	-
16	Valluvar Kottam	15.00	3.00	33.2	33.7	-	0.00	-	-
	Total	336.82	32.10	905.30	955.20	1.47	45.34	12.33	49.32
	Project Scope							**4.33**	**49.32**

* Values in bold font are the additional storages to be included in the Project
Source: JICA Study Team

2) Quantification of the necessary storage tanks in the Project

Table 6.7.3 shows that there is a necessity for construction of new UGTs in some WDZs and ESRs in most of the WDZs. The JICA Study Team proposes that additional UGT and reservoirs will be included in the Project for the WDZs, where the storage capacities are not sufficient for the water demand for 2035. The additional capacities are proposed to be determined by the water demand for 2050. Subsequently, the additional capacities in the Project will be 4.33 ML for a UGT in Zone 12A and a total of 49.32 ML for ESRs in Zones 1 to 14.

Also, booster pumping stations at these ESR locations will be installed to pump the water from the existing or the new UGTs to ESR with a staging height of 20 m at least and a pump head of 30 m. The discharge rate of the pumps needs to be considered as 1-hour peak discharge with 100% standby arrangement with at least 2 working pumps.

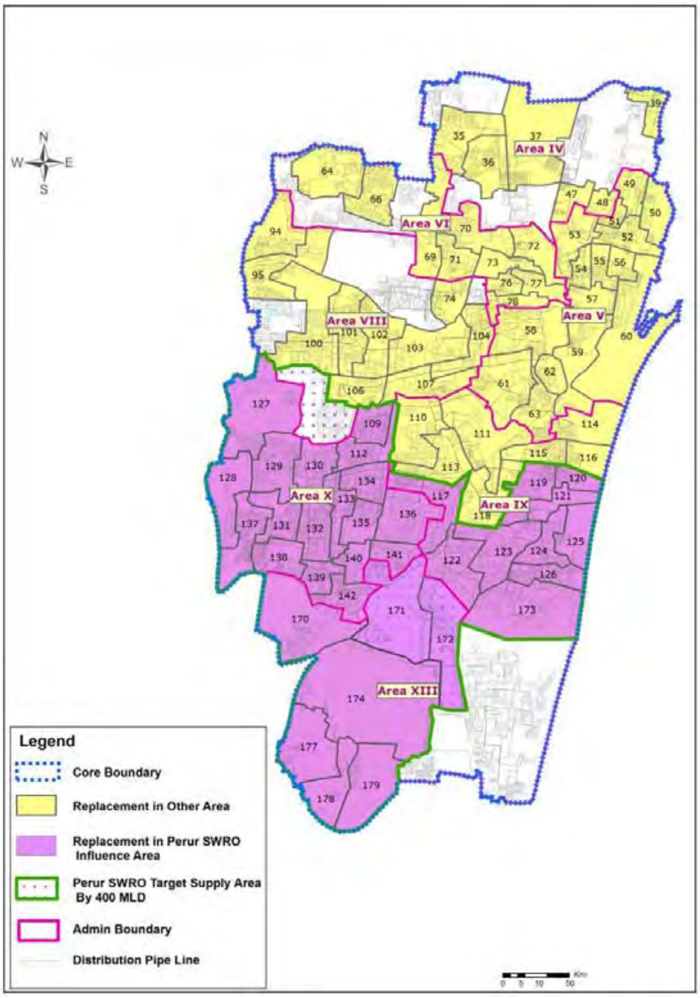
(3) Replacement of the old pipes in the Core City

As explained in Subsection 5.5.3, there will be a need for replacement of 375 km of the existing old water distribution pipe in the Core City. Table 6.7.4 presents the area-wise length of the proposed pipe replacement. The depots or wards, where the replacement works will be necessary, are illustrated in Figure 6.7.2. Diameters of the pipes after the replacement have been presumed to be the same as the existing ones. Pipe material will be DCI.

Table 6.7.4 Summary of the Proposed Replacement of Pipes in the Core City

Area	Length of old pipes to be replaced in the Project (km)	Perur DSP influence area	Other core city
Area-IV	38		124
Area-V	29		
Area-VI	32		
Area-VIII	25		
Area-IX	10	251	
Area-X	180		
Area-XIII	61		
Total	**375**	**251**	**124**

Source: JICA Study Team



Source: JICA Study Team based on Field Data Book of 2003 and interviews with CMWSSB

Figure 6.7.2 Target Areas of the Old Pipe Replacement in the Project

(4) Installation of new water distribution pipes in un-covered streets in Core city

In the Core City, some streets are not yet covered by water distribution networks. By comparing the lengths of the street and water distribution pipe by administration area, the coverage has been estimated as 90% and the gap is 258 km, as shown in Table 6.7.5.

The gap indicates that there is a need for new pipe installation for 258.27 km in the distribution network to achieve 100% coverage in the Core City. Table 6.7.5 presents the area-wise demand for additional water distribution pipes. The JICA Study Team proposes that the supplementary pipes of 258 km to the uncovered streets be included in the Project. Presumed diameters of the new distribution pipes are 100 mm for 75% and 150 mm for the remaining 25% as the pipes to be installed in the un-covered streets will not be main lines in the distribution networks. Pipe material will be DCI.

Table 6.7.5 Requirement of Supplementary Pipes in Uncovered Streets in the Core City

Area	Street Length (km)	Existing pipe Length (km)	Present Coverage (%)	Pipes to be laid in uncovered streets (km)
Area-IV	337.81	244.89	72%	92.92
Area-V	260.62	244.11	94%	16.51
Area-VI	259.76	227.06	87%	32.70
Area-VIII	417.40	391.95	94%	25.45
Area-IX	356.79	342.77	96%	14.02
Area-X	464.93	451.04	97%	13.89
Area-XIII	368.27	305.49	83%	62.78
Other Areas	96.22	96.22	100%	-
Total	**2,561.80**	**2,303.53**	**90%**	**258.27**

Source: JICA Study Team

6.7.2 Improvement of the Water Distribution System in the Corporation

At present, there are no WDZs and DMAs established in the field. The following improvements are suggested.

(1) Development of GIS base map and Database

It is noted that there is no updated and reliable comprehensive distribution database at present, and it will be necessary to prepare a comprehensive distribution network map for the entire corporation depicting the current status of the existing pipe network. Asset mapping will be included in the database development, which will facilitate the maintaining of the record of water infrastructure assets transferred from ULBs to CMWSSB in the rest of CMA in future.

(2) Establishment of hydraulic zones and district metered areas (DMAs) in the Core City

1) Basic concept

The basic Influence area of each WDS is a WDZ. WDZs are not physically independent at present, and the interconnections between the WDZs are usually used. M/P proposed to establish hydraulic zones, whose boundaries will be WDZs. The primary objective of the hydraulic zones is to obtain better control over the water distribution network within the zone. The establishment of WDZs is to physically divide the network at the boundary of WDZs and usually does not use the interconnections.

Also, each zone is required to be further divided into sub-zones or DMAs. DMAs will be equipped with flow and pressure monitoring devices, isolation valves, and bulk meters at their entrances. This will ensure water audit within each DMA and assessment of Non-Revenue Water (NRW) with a combination of water meters to be installed. Based on the assessment on NRW, the action plan is to be prepared to bring it to the acceptable limits as per the standards suggested by CPHEEO (15%).

2) Layout plan of DMAs and work quantities for the establishment

The JICA Study Team has prepared a layout plan of the DMAs and quantified the necessary major equipment for the DMA establishment as presented in Table 6.7.6. The layout plan of the DMAs is given in Appendix 6.22.

As shown in Table 6.7.6, the number of DMAs planned in the Core City is 58. Further each DMA will be divided to two sub-DMAs (116 nos). For the DMA establishment, 174 bulk meters along with 290 isolation valves will be necessary, assuming that two isolation valves will be required for one Sub-DMA and one Isolation valve will be necessary of one DMA in the distribution network. Bulk meters are provided for each DMA and Sub-DMA for a better control and monitoring of flow location. The criteria presumed for the assessment of DMAs and Sub-DMAs is based on the length of distribution pipe and number of service connections to be served by each DMA. Number of the DMA has been planned so that one DMA will have approximately 40 km of water distribution pipes and 9,000-10,000 service connections. Sub-DMA will cover 20km of distribution pipes and 4,500-5,000 Service connections.

Not only in the Core City, but the Expanded Area will also need DMAs by the time the new distribution networks in the area are fully functional. However, quantification for the DMA establishment works for the Expanded Area is not conducted in the Study because the Core City has more significance and urgency.

Table 6.7.6 DMA and Sub-DMA Plan in the Core City

Zone	Name of WDZ or Hydraulic Zone	No. of DMAs	No of Sub-DMAs	Total Isolation Valves	Total Number of Bulk Meters
1	Kilpauk	8	16	40	24
2	Annapoonga	4	8	20	12
3	Kannappar Tidal	3	6	15	9
4	Triplicane	3	6	15	9
5	K.K.Nagar	5	10	25	15
6	Velachery	2	4	10	6
6A	Velachery New	1	2	5	3
7	Ekkadu Thangal	1	2	5	3
8	Choolai Medu	5	10	25	15
9	Kolathur	2	4	10	6
10	Vyasarpadi	6	12	30	18
11	Patel Nagar	2	4	10	6
12	Pallipattu	2	4	10	6
12A	Thiruvanmiyur	4	8	20	12
13	Nandanam	2	4	10	6
14	Mylapur	3	6	15	9
15	Valluvar Kottam	2	4	10	6
16	Southern Head Works	3	6	15	9
	Total	**58**	**116**	**290**	**174**

Source: JICA Study Tea

(3) Service connections and metering improvements

As explained in Section 5.5, installation of service connections and water meters are proposed in the Project. At present, there are 647,070 unmetered service connections in the Corporation. CMWSSB has a plan to install 33,041 electric water meters corresponding to Automatic Meter Reading (AMR) system with a capital cost of INR 4.5 million that will be sourced from public sector banking agency in the state, but no fund has been determined for installation of water meters to realize 100% metering which is still at a planning stage. In addition, multiple water consumers are sharing one service connections in the Corporation and especially in the Expanded Area, number of service connection per assessee is 3.93.

In consideration with the current situations of service connection and metering above, quantification of the connection metering scope in the Project has been conducted as shown in Tables 6.7.7. Assumptions in the quantifications are as follows:

- Quantification is to be conducted by targeting requirement for the year 2020, when the installation of service connections and water meters in the Project will commence after detailed design.
- Target number of water meters presumes 100% metering in the Corporation
- Target number of service connections in the Corporation is calculated from number of assesses by administration area and target value of Assesses/Service Connection. The target value of Assesses/Service Connection is set as 2.0 but, in the areas where the current values are less than 2.0, the target values are the same as the current values. The target value of 2.0 presumes that more water users, currently sharing service connections with others, will have their own service connections gradually. It is necessary in introduction of volumetric water tariff to more water users in a fair way.
- New commercial service connections and water meters that are planned to be installed by CMWSSB shortly are not counted in required quantity in the Project.
- Calculation of the target numbers of service connections and water meters for 2020 takes into account population growth in the Core City and the Expanded Area between 2015 and 2020 based on the population forecast.
- Quantity of new service connections with water meters are calculated by deducting the number of the existing service connections from the total number of the service connections required by 2020
- Quantity of water meters in existing service connections is calculated by deducting the number of the existing water meters and planned new water meters to be installed by CMWSSB soon from the number of the total service connections required by 2020

As a result of the quantification, the Project will conduct installation of new service connections with water meters at 185,496 locations and installation of water meters in existing service connections at 614,029 locations, in order to achieve 100% metering. Material of the service connections is middle density polyethylene (MDPE) pipe, which are recently used for new connections in the Corporation. Water meters are mechanical type.

Table 6.7.7 Quantification of Service Connections and Water Meters in the Project

Admin' Area	Existing Assesses and Connections in 2016					Total Requirement of Water Connections			Planned Installation of Water Meters by CMWSSB	Quantities in the Project	
	Total Assesses	Meter	Flat	Total	Assesses /Connection	Target Assesses/Connection	Target Number of Service Connection as of 2016	Target Number of Service Connection for 2020*		New Service Connections with Water Meters	Water Meters in Existing Connections
-	1	2	-	3	4=1/3	5	6=1/5	7*	8	9=7-3	10=7-2-8-9
I	44,472	112	6,814	6,926	6.42	2.00	22,236	26,067	31	19,141	6,783
II	23,356	33	7,166	7,199	3.24	2.00	11,678	13,690		6,491	7,166
III	52,361	283	6,313	6,596	7.94	2.00	26,181	30,691		24,095	6,313
IV	75,284	1,708	57,157	58,865	1.28	1.28	58,865	60,142	1,919	1,277	55,238
V	69,902	9,572	35,390	44,962	1.55	1.55	44,962	45,938	12,750	976	22,640
VI	83,635	1,767	66,491	68,258	1.23	1.23	68,258	69,739	501	1,481	65,990
VII	97,245	1,727	22,917	24,644	3.95	2.00	48,623	57,000	307	32,356	22,610
VIII	108,800	2,152	81,603	83,755	1.30	1.30	83,755	85,572	4,099	1,817	77,504
IX	114,435	4,159	89,803	93,962	1.22	1.22	93,962	96,001	3,650	2,039	86,153
X	140,404	1,455	107,832	109,287	1.28	1.28	109,287	111,659	4,208	2,372	103,624
XI	90,921	755	25,642	26,397	3.44	2.00	45,461	53,293	72	26,896	25,570
XII	65,467	386	37,428	37,814	1.73	1.73	37,814	44,329	50	6,515	37,378
XIII	119,844	1,805	83,970	85,775	1.40	1.40	85,775	87,636	2,467	1,861	81,503
XIV	79,629	78	10,890	10,968	7.26	2.00	39,815	46,675	42	35,707	10,848
XV	51,869	277	7,654	7,931	6.54	2.00	25,935	30,403	2,945	22,472	4,709
Core City	712,304	22,618	522,246	544,864	1.31	1.31	544,864	556,687	29,594	11,823	492,652
Expanded Area	505,320	3,651	124,824	128,475	3.93	2.00	257,741	302,148	3,447	173,673	121,377
Corporation	1,217,624	26,269	647,070	673,339	1.81	1.81	802,605	858,835	33,041	185,496	614,029
Core City Share	58.5%	86.1%	80.7%	80.9%	-	-	67.9%	64.8%	89.6%	6.4%	80.2%

: Core City
: Expanded Area

*1: Population growths between 2015 and 2020 for the Core City has been taken into account in calculation of the target number of service connections for 2020. Population growth in the five years are: Core City: 2.17%, Expanded Area: 17.23%

*2: The planned installation of water meters by CMWSSB is presumed to include renewal of the existing

*3: Involvement of the Project is percentage of pipe length to be installed in the Project against the existing pipe length.

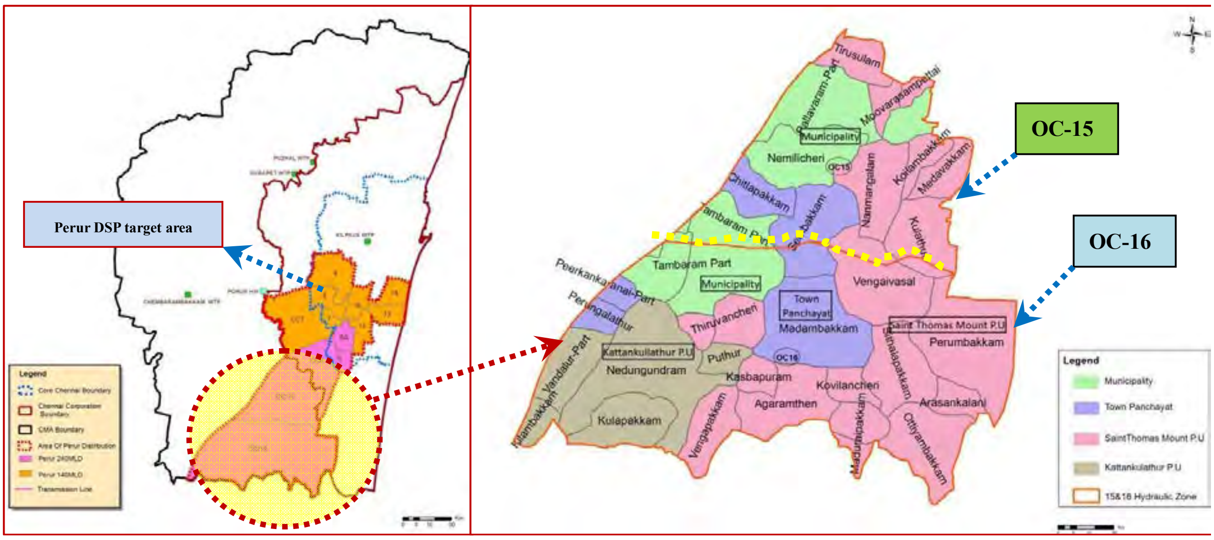
Source : JICA Study Team

6.7.3 Development of Water Distribution Network in Rest of CMA (OC-15 and OC-16)

As described in Item (3) in Subsection 5.5.6, development of water distribution network in Rest of CMA is not included in the Project but is a future project to be implemented by CMWSSB or GOTN. This subsection provides preliminary development plan for facilitation of the future implementation of the project.

(1) Conditions and assumptions in the planning and quantification

The Perur DSP targets to supply the WDZs OC-15 and OC-16 in the Rest of CMA as shown in Figure 6.7.3.



Source: JICA Study Team

Figure 6.7.3 Distribution Area in Rest of CMA (OC-15 and OC-16)

Preliminary assessment of the water distribution and transmission networks and the storage has been conducted for OC-15 and OC-16, considering the existing water distribution network will not be utilized except for Tambaram and Pallavaram municipalities. The reason for discarding the existing system in towns and villages is due to its design service level, presumed as lower than 135 LPCD, which is the target service level in towns and villages in the Rest of CMA.

As for Tambaram and Pallavaram municipalities, it is assumed that 65% of this networks will be utilized, and 35% of the distribution networks will require upgrade or renewal. These two municipalities were formed much earlier; the Tambaram municipality was formed in 1964, whereas the Pallavaram municipality was formed in 1970. Therefore, the existing pipes in these municipalities might have been deteriorated to some extent. However, they have received funds directly from the Government of India under JNNURM and Tamil Nadu State Government for the development of basic infrastructure facilities including water supply. For example, the recent water distribution development works for Pallavaram Municipality under TNUDP-III project, as specified in Subsection 5.5.1 (4). Although the target service level in TNUDP-III is 135 LPCD to suffice the current requirement from CPHEEO, instead of 150 LPCD, the existing pipes will be utilized to achieve 150 LPCD in the area.

The required storage has been estimated in the same manner as the case for the Chennai Core City, where the total storage is 8-hour volume of the water demand and, among the eight hours, 2-hour volume is to be stored in ESRs.

For the distribution pipes, street lengths in the ULBs have been used to estimate the required pipe lengths. The requirement of water storage has been calculated based on water demand for 2035 and

2050. As for metering, the quantities are estimated based on the assumption of 100% metering, population forecast for 2025, and the average number of water users per one service connection (8.5).

(2) Planning and quantification

Table 6.7.8 summarizes the required quantities for improvement and development of the water distribution networks in OC-15 and OC-16. The requirement for the distribution and transmission pipes is about 1,212 km, and the total storage required is 146.20 ML. The detailed breakdown for the quantities is given in Appendix 6.23.

At present, the construction of these infrastructures is under the responsibility of the respective ULBs, instead of CMWSSB. Therefore, they are expected to be developed by the respective ULBs in principle so that they would be able to receive the benefit of higher service level by 2021, when the Perur DSP is operational.

Table 6.7.8 Preliminary Assessment of Work Quantities for Improvement and Development of the Water Distribution Networks in OC-15 and OC-16

Sl.No	Zone	Length of Pipeline (km)			Total Storage Capacity Required (ML)			Meter Requirement
		Distribution	Transmission	Total	UGT	ESR	Total	(2025)
1	OC-15	438.14	87.63	525.77	59.80	29.90	89.70	104,590
2	OC-16	571.94	114.39	686.33	37.67	18.83	56.50	89,120
Total		**1,010.08**	**202.02**	**1,212.10 => 1,212 km**	**97.47**	**48.73**	**146.20**	**193,710**

Source: JICA Study Team

6.7.4 Summary of the Water Distribution Scopes of the Project

(1) Summary of the scopes

As a summary of Section 6.7, the necessary water distribution components that can be included in the scope of the project are presented in Table 6.7.9. As for the components for OC-15 and OC-16, they are to be implemented by the respective ULBs instead of CMWSSB under the present institutional situations. The inclusion of these components will need internal discussions and coordination in the State Government of Tamil Nadu.

Table 6.7.9 Summary of Water Distribution Components in and Relevant to the Project

Items	Quantity	Material	Remarks
A. Chennai Core City: Improvement of the existing water distribution networks (in the Project)			
1. Reinforcement of the existing water distribution networks	101 km (D150-700 mm)	DCI*	WDZ 5, 8, 10, 12, 13, 16
2. Reinforcement of storage capacity by UGT	1 location (4.33 ML)	RCC*-M30 grade	WDZ 12A
3. Reinforcement of storage capacity by ESRs	16 locations (49.32 ML)	RCC-M30 grade*	WDZ 1, 2, 3, 4, 5, 6, 6A, 7, 8, 9, 10, 11, 12, 12A 13, 14
4. Replacement of existing pipes	375 km (D100-450 mm)	DCI*	Area-IV, V, VI, VIII, IX, X, XIII
5. Installation of supplementary pipes	258 km (D100-150 mm)	DCI*	Area-IV, V, VI, VIII, IX, X, XIII
6. Installation of new service connections with water meters	185,496 Nos	MDPE*	All areas in the Corporation
7. Installation of water meters in existing service connections	614,029 Nos	-	All areas in the Corporation
8. Setup of DMAs	58 Nos.	-	290 isolation valves and 174 bulk meters are necessary
B. OC-15 and OC-16 in Rest of CMA: Development of the water transmission and distribution system (in future project)			
1. Transmission Pipe	202 km.	DCI*	-
2. Distribution Pipe	1,010 km	DCI*	-
3. Storage capacity (ML)	146.20 ML	RCC-M30 grade*	-
4. Replacement of Service Connections including water meters	193,710	-	-

* : DCI (Ductile Cast Iron), RCC (Reinforced Cement Concrete Grade M30), MDPE (Middle Density Polyethylene)
Source : JICA Study Team

(2) Suggestions to TOR of Project Management Consultant (PMC) for detailed design

In order to enable the detailed design of the above water distribution components, CMWSSB should provide the PMC with inventory data, maps and drawings to identify the locations of pipes to be replaced and prepare hydraulic models to design the reinforcement work of the existing water distribution networks.

The detailed design by PMC includes (i) mapping of the existing distribution network on the GIS Base map, (ii) field verification and confirmation of the location of existing pipes on the base map, (iii) validation of the collected information, (iv) household data along the streets based on nature of houses (commercial /residential/industrial) will be collected for service connection details, (v) creating the hydraulic network model using design engines like “Water Gems” latest version compatible to GIS, (vi) plan of the WDZs and DMAs, (vii) design of the water distribution networks including reinforcement and new development for respective WDZs, and viii) preparation of detailed design drawings, Bill of Quantities (BOQ), and technical specifications.

For the work items (i) and (iv), the software for the asset information management system, which can integrate the inventory data, GIS and hydraulic modelling, need to be procured. Using the software, CMWSSB will develop an integrated asset information system and through on-the-job training (OJT) with PMC in the design works above. In addition, the CMWSSB staff will be trained so that they will be able to maintain the system. TOR of the PMC, including the plan of OJT, is given in Appendix 11.1.

6.8 Summary of the Project Scope

As a conclusion of the preliminary designs in the chapter, principal features of the Perur DSP, the product water transmission system from the Perur DPS and water distribution components relevant to the DPS are summarized in Table 6.8.1 to 6.8.3 below:

Table 6.8.1 Principal Features of the Perur DSP

Item	Principal Feature
1. General Information	
(1) Production capacity	400 MLD
(2) Treatment process	Pre-treatment by Coagulation and Flocculation, Lamella Filter, Dissolved Air Floatation (DAF), Dual Media Filter (DMF), and Micron Cartridge Filter, followed by Reverse Osmosis Membrane (RO) and Lime Stone Filter
(3) Maximum intake volume	1,080 MLD (In case of operation at 42% recovery rate)
(4) Maximum brine discharge volume	680 MLD (In case of operation at 42% recovery rate)
(5) Site area	34 ha, of which 22.6 ha will be occupied by the DSP
(6) Planned ground level	CD + 6.5 m
(7) Specific power consumption	3.74 kW/m^3 excluding product water transmission pump
2. Seawater Intake	
(1) Seawater intake head	Velocity cap (ϕ 5.0 m), D12 m x H9.6 m,
(2) Seawater intake pipe	DN*1 2,300 mm (ID*2 2,100 mm) x 1,140 m x 2 lines, HDPE*3
(3) Seawater intake pump	11,250 m^3/hr x 25 mH x 6 units including 2 stand-by, 1,000 kW
3. Pre-Treatment	
(1) Coagulation and Flocculation Basin	Coagulation 8 cells and Flocculation 96 cells
(2) Lamella Filter	1,870 m^3/hr x 24 cells
(3) Dissolved Air Floatation	502.5 m^3 x 32 cells, 15.0 m/h
(3) Dual Media Filter	136.9 m^3 x 40 cells, Sand and Anthracite
(4) Filtered water storage tanks/DMF backwash tanks	1,500 m^3 x 2 cells (3,000 m^3)
4. RO Section	
(1) Number of units	17 trains including 1 stand-by (25 MLD / unit)
(2) Recovery ratio	46%
(3) Filtered water storage tanks/DMF backwash tanks	2 cells
(4) Filtered water pump to RO	1,042 m^3/hr x 150 mH x 17 units including 1 stand-by, 620 kW
(5) RO high pressure pump	1,042 m^3/hr x 560 mH x 17 units including 1 stand-by, 2150 kW
(6) Membrane	8 inch spiral, 13.5 l/m^2/h
(7) Energy Recovery Device	29.625 MLD x 17 units including 1 stand-by, Piston type
(8) Product water tank	9,000 m^3 x 4 cells (36,000 m^3)
5. Post-Treatment Section	
(1) Lime stone filter	5,000 m^3/h x 20 units including 4 stand-by
(2) Potable water tank	1,500 m^3 x 2 cells (3,000 m^3)
6. Brine Discharge	
(1) Brine discharge head	Port raiser type (φ0.49 m x 14 nozzles)
(2) Brine discharge pipe	DN 2,500 mm (ID 2,300 mm) x 1,690 m x 1 lines, HDPE
7. Power Receiving Facilities	
(1) Substations (S/Ss)	230/33 kV substation and 33/11 kV substation
(2) Power transmission line	Power line between the substations (900 m)
(3) External power transmission lines	230 kV line from Ottiambakkam S/S to the 230/33 kV S/S 230 kV line from Omega S/S to the 230/33 kV S/S
(4) Monitoring and control system	Distributed Control System (DCS)

*1: DN: Diameter Nominal, *2: ID: Internal Diameter, *3: HDPE: High Density Polyethylene
Source: JICA Study Team

Table 6.8.2 Principal Feature of Product Water Transmission System from the Perur DSP

Item	Principal Feature
Pump Station at the Perur DSP	
Pump facility	
Number of pumps	6 units including 2 stand-by
Pump type	Double suction horizontal centrifugal pump
Pump Capacity	69.4 m^3/min × 4 duty = 277.6 m^3/min in total H= 77.8m
Motor output (per one pump)	1,200 kW
Flow control system	Pump motor speed controller connected with pressure gauge and flow meter
Pump house	Area: 54 m x 15m, Height: Top = GL+10 m, Bottom = GL-6.6 m
Product Water Main	
Pipeline	0 km - 34 km : MS pipe D2000, 34 km - 41 km : MS pipe D1800 41 km - 60 km : MS pipe D1600, Branch line (L=5km): DCI D1000
Ancillary facilities	Air valve: 70 nos., Drain facility: 42 nos., Stop valve: 30 nos. Branch off facility: 7 nos.
Special section	Highway/railway crossing (pipe jacking): 5 nos. (Total 380 m) Salt pan crossing: L = 1,700 m, Crossing of Adyar river: L = 200 m
Expansion of the Porur HW	
Reservoir	
Capacity	5,000 m^3 x 2 = 10,000 m^3 in total, HWL = + 16.9m LWL = 12.9 m
Reservoir type and shape	Semi-underground type Area: 80 m x 35 m, Height: Top = GL+3.0m, Bottom = GL-3.0 m
Pump facility	
Number of pumps	6 units including 2 Stand-by
Pump type	Double suction horizontal centrifugal pump
Pump Capacity	41.7 m^3/min × 4 duty = 166.8 m^3/min in total H= 25.0 m
Motor output (per one pump)	235 kW
Pump house	Area: 45 m x 15 m, Height: Top = GL+10 m, Bottom = GL-5.6 m
Connection to existing pipeline	MS pipe D1600, L= 365 m (including by-pass pipeline)

Source: JICA Study Team

Table 6.8.3 Principal Feature of the Water Distribution Components in the Project

Item	Principal Feature
Improvement of the Existing Water Distribution Networks in the Chennai Core City	
(1) Hydraulic reinforcement of the existing distribution networks	6 Water Distribution Zones (WDZ 5, 8, 10, 12, 13, 16) 101 km, DCI Pipes, Diameter: 150 to 700 mm
(2) Storage reinforcement	
Underground tank (UGT)	1 location (WDZ 12A), V=4.33 ML,
Elevated Service Reservoir (ESR)	16 locations (WDZ 1, 2, 3, 4, 5, 6, 6A, 7, 8, 9, 10, 11, 12, 12A, 13, 14), Total V=49.32 ML
(3) Replacement of the old pipes	7 Administration Areas (Area-IV, V, VI, VIII, IX, X, XIII) 375 km, DCI Pipes, Diameter 100 to 450 mm
(4) Provision of supplementary pipes in the uncovered streets	7 Administration Areas (Area-IV, V, VI, VIII, IX, X, XIII) 258 km, DCI Pipes, Diameter 100 to 150 mm
(5) Establishment of DMAs	
Number of DMAs	DMA: 58 nos, Sub-DMA: 116 nos
Equipment	Isolation valves: 290 nos, Bulk meters: 174 nos
(6) Service connections and water meters	7 Administration Areas (Area-IV, V, VI, VIII, IX, X, XIII)
Service connections with water meters	185,496 nos
Water meters	614,029 nos

Source: JICA Study Team

CHAPTER 7 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

7.1 Objectives of the Considerations and General Requirement of the JICA Guidelines

(1) Objectives of the considerations

With regard to environmental and social considerations, any project to be financed by JICA loan is required to comply with the JICA Guidelines for Environmental and Social Considerations (April, 2010) (hereinafter referred to as "the JICA Guidelines") in addition to any existing laws and regulations in the site country. The environmental and social considerations in the Study are to examine if the Project complies or will comply with all the Japanese and Indian requirements. Furthermore, if any deficiency is found, the JICA Study Team will support executing agency of the Project in compliance with the entire requirement of the JICA Guidelines by proposing relevant actions to be taken by the executing agency.

(2) General requirement of the JICA Guidelines

1) Project Category by the JICA Guidelines

Requirement of the JICA Guidelines are dependent on "project categorization" of the Project, which is stipulated in the JICA Guidelines as shown in Table 7.1.1. Currently, the Chennai Seawater Desalination Project (the Project) has been classified as "Category B" by JICA. However, if the project is likely to have any significant adverse impacts on the environment and society in the Study, the Project may be recategorized as "Category A".

Table 7.1.1 Project Category in the JICA Guidelines.

Category	Description
A	Proposed projects are classified as "Category A" if they are likely to have significant adverse impacts on the environment and society. Projects with complicated or unprecedented impacts that are difficult to assess, or projects with a wide range of impacts or irreversible impacts, are also classified as "Category A". These impacts may affect an area broader than the sites or facilities subject to physical construction. "Category A", in principle, includes projects in sensitive sectors, projects that have characteristics that are liable to cause adverse environmental impacts, and projects located in or near sensitive areas.
B	Proposed projects are classified as "Category B" if their potential adverse impacts on the environment and society are less adverse than those of "Category A" projects. Generally, they are site-specific; few if any are irreversible; and in most cases, normal mitigation measures can be designed more readily.
C	Proposed projects are classified as "Category C" if they are likely to have minimal or little adverse impact on the environment and society.

Source: JICA Guidelines for Environmental and Social Considerations (April 2010)

2) Required study for "Category B" project

For a project classified in "Category B", an "Initial Environmental Examination (IEE) level study" is required according to the JICA Guidelines as shown in Table 7.1.2.

Table 7.1.2 IEE defined by the JICA Guidelines

Item	Definition
IEE	"Initial Environmental Examination (IEE) level study" is a study that includes an analysis of alternative plans, a prediction and assessment of environmental impacts, and a preparation of mitigation measures, and monitoring plans based on easily available information including existing data and simple field surveys.

Source: JICA Guidelines for Environmental and Social Considerations (April 2010)

7.2 Environmental and Social Conditions Relevant to the Project

To have a basic understanding on the present environmental and social conditions in and around the proposed project sites, JICA Study Team reviewed the Detailed Project Report (DPR) (2014), the EIA Report (2014) and other relevant documents as well as conducted site reconnaissances. Table 7.2.1 shows a list of the environmental and social conditions reviewed in the Study.

Table 7.2.1 Reviewed Items for the Environmental and Social Conditions

Category	Items Reviewed	
Pollution	(1) Air Pollution	(5) Noise
	(2) Water Pollution	(6) Subsidence
	(3) Waste	(7) Offensive Odor
	(4) Soil Characteristic	-
Natural Conditions	(1) Climate	(5) Ecosystem
	(2) Geology	(6) Marine Environment
	(3) Earthquake & Tsunami Disaster	(7) Hydrology
	(4) Protected Areas	(8) Flora and Fauna
Social Conditions	(1) Demographic Situation and Community	(3) Archaeological Cultural site
	(2) Land Use	-

Source: JICA Study Team

According to the reviews, the environmental and social conditions can be summarized as shown in Appendix 7.1.

7.3 Environmental Management System in India

7.3.1 Legal Framework

(1) Relevant policy and strategy on environment

1) The Constitution of India (1974)

Articles in the Constitution of India stipulating environmental protection are shown in Table 7.3.1.

Table 7.3.1 Articles Stipulating Environmental Protection in the Constitution of India

Part	Article	Prescription	Note
IV: Directive Principles of State Policy	48A	The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country.	Inserted in the 42 amendment to the Constitution Act in 1976.
IVA: Fundamental Duties	51A	(g) to protect and improve the natural environment including forests, lakes, rivers, and wildlife and to have compassion for living creatures.	Inserted in the 42 amendment to the Constitution Act in 1976.

Source: The Constitution of India as of modified up to December 2007, Ministry of Law and Justice, Government of India

2) Higher legislative framework on environment management

Policies, strategies and action plans as higher legislative framework on environment protection prepared by the Government of India (GOI) are summarized in Table 7.3.2.

Table 7.3.2 Policy, Strategy and Action Plan on Environment

Particular	Year	Brief Description
National Forest Policy	1988	The policy's principal aim is to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium which is vital for sustenance of all life forms including human, animal, and plant.
National Wildlife Action Plan	1983	The plan is a road map to conserve wildlife of the country.
Policy Statement on the Abatement of Pollution	1992	The policy is to integrate environmental considerations into decision making at all levels.
National Conservation Strategy and Policy Statement on the Environment and Development	1992	The strategy and policy provides the basis for the integration of environmental considerations in the policies of various sectors. Outlines government's goals and projects for achieving sustainable lifestyles and proper management and conservation of resources.
National Biodiversity Action Plan	2002	The plan is a principal instrument for implementing the Convention at the national level.
National Wildlife Action Plan	2002	The plan is to strengthen and to enhance the protected area network based on scientific management. Identification of endangered species of flora and fauna and their effective conservation is a priority area under the strategy.
National Wildlife Conservation Strategy	2002	The strategy provides various provisions on wildlife and forests protection in India.
National Environmental Policy	2006	The policy objectives are: Conservation of Critical Environmental Resources, Intra-generational Equity: Livelihood Security for the Poor, Inter-generational Equity, Integration of Environmental Concerns in Economic and Social Development, Efficiency in Environmental Resource Use, Enhancement of Resources for Environmental Conservation.

Source: Ministry of Environment, Forest and Climate Change (MOEF), Handbook on National Environmental Legislation and Institutions in India (2002), World Resource Institution (http://projects.wri.org/sd-pams-database/india/national-conservation-strategy-and-policy-statement-environment-and-developme), Press Information Centre, Government of India

(2) Relevant legislation on environment

Table 7.3.3 shows a list of relevant legislation (Act, Law and Notification) on environment protection and pollution control enacted by GOI.

Table 7.3.3 Legislation on Environmental Protection and Pollution Control

Act and Law	Year
Indian Fisheries Act	1897
Indian Boiler Act	1923
Indian Forest Act / Amendment	1927/1984
Provision in State Acts on Town and Country Planning; Factories Act/Amendment	1948/1987
Industries (Development and Regulation) Act and Amendment	1957/1987
Mines and Minerals (Regulation and Development) Act	1957
Ancient Monuments and Archaeological Sites and Remains Act	1958
River Boards Act	1956
Insecticide Act	1968
Merchant Shipping Act	1958
Urban Land (Ceiling and Regulation) Act	1976
Water (Prevention and Control of Pollution) Act, Rules / Amendments	1974/1975/ 1988
Wildlife (Protection) Act	1972
Forest (Conservation) Act	1980
Air (Prevention and Control of Pollution) Act, Rules/Amendments	1981/1982/ 1983/1987
Oil Fields (Regulation and Development) Act	1948
Model Regional and Town Planning and Development law	1985
Coal Mines (Conservation and Development) Amendment Act	1985
Environment (Protection) Act	1986
Motor Vehicles Act	1988
Coastal Regulation Zone Notification	1991
Public Liability Insurance Act /Amendment	1991/1992
National Environment Tribunal Act	1995
National Environment Appellate Authority Act	1997
National Biodiversity Act	2002

Source: MOEF, Handbook on National Environmental Legislation and Institutions in India (2002)

(3) International treaty on environment

GOI ratified and signed a number of international conventions/treaties/protocols in the field of environment of which a list is attached in Appendix 7.2.

7.3.2 Institutional Framework on Environmental Management in India

Institutional frameworks on environmental management in India consist of a lot of departments/organizations in both the National level and the State level.

- At the National level, the National Committee on Environmental Planning (NCEP) is the principal advisory body relating to environment protection and improvement of GOI. In addition, the Ministry of Environment, Forest and Climate Change (MOEF) is a nodal administrative agency responsible for activities related to environment and forestry as well as climate change and also acts as an advisory body for the Central Pollution Control Board (CPCB).
- At the State level, each state has a Department of Environment (DOE) which acts as a nodal institution for the environment management of the state and also acts as an advisory committee for each State Pollution Control Board (SPCB).

Thus environmental protection and management in India are governed by those committee, departments boards and other relevant offices, as well as coastal zone management authorities for environment managements for the coastal areas at the both levels as summarized below.

(1) National Committee on Environmental Planning (NCEP)

The National Committee on Environmental Planning and Coordination (NCEPC) was constituted in 1972 under the Department of Science and Technology (DST) of India with the following purposes:

- Promoting research related to environmental problems and establishing facilities for undertaking such research wherever necessary.
- To advise and recommend the Central Government for the improvement of environment.

NCEPC was renamed as the “National Committee on Environmental Planning (NCEP) in 1981 with the same purposes and is entrusted with the task of planning and coordinating national environmental policies.

(2) Ministry of Environment, Forest and Climate Change (MOEF)

The Department of Environment (DOE) in GOI was established in 1980 which was reformed to MOEF in 1985 as the nodal agency in the administrative structure of GOI for planning, promotion, co-ordination and overseeing the implementation of India's environmental and forestry policies and programmes.

(3) Central Pollution Control Board (CPCB)

The Central Pollution Control Board (CPCB), an autonomous statutory organization, was initially constituted as "The Central Board for Prevention and Control of Pollution" in September 1974 under the Water (Prevention and Control of Pollution) Act of 1974. In 1981, the board was renamed as CPCB and entrusted with the powers and functions under the Air (Prevention and Control of Pollution) Act of 1981. The following summarizes roles and functions of CPCB which serves as a field formation and provides technical services to the MOEF of the provisions of the Environment (Protection) Act of 1986:

- Principal functions of the CPCB, as outlined in the Water Act and the Air Act are to promote cleanliness of streams and wells in different areas of the States by prevention, control and abatement of water pollution, and to improve the quality of air as well as to prevent, control or abate air pollution in the country.
- Even though CPCB has no direct role in the environmental clearance (EC) process, CPCB acts as a research organization which contributes to MOEF, State Pollution Control Boards (SPCBs) and other stakeholders of environmental clearance process by collecting, analyzing, and disseminating information pertaining to pollution prevention and abatement.
- It is a common practice that technical staff and experts of CPCB are designated in the expert committee constituted by the Impact Assessment Division (IA) of MOEF.
- Member secretary of CPCB or his representative, in particular, is appointed in all sector specific committees

(4) Regional Offices (ROs) of MOEF

MOEF has set up ten regional offices (ROs) with the Headquarters (HQ) at New Delhi having the following roles and functions:

- ROs monitor and implement stipulations under Forest (Conservation) Act (1980), and provisions for environmental clearance, whereas, the HQ at Delhi coordinates with all ROs.
- Post Project Monitoring (PPM) of the cleared projects, in particular, is the major responsibility of these offices.
- Project authorities are required to submit monitoring reports to these ROs every 6 months, detailing progress of implementation of the conditions, detailed while granting EC to the projects.
- These offices are directed to follow up pollution control measures adopted by industries and in this concern; they are allowed to take up site visits.
- If any violation of environmental standards is noticed, ROs inform HQ to take necessary actions.

(5) National Coastal Zone Management Authority (NCZMA)

MOEF has constituted a fourteen-member National Coastal Zone Management Authority (NCZMA) with its headquarters in New Delhi having following functions and roles:

- Protecting and improving the quality of the coastal environment and preventing, abating and controlling environmental pollution in the coastal area
- It provides technical assistance and guidance to the concerned State and Union territory authorities, and other institutions and organizations.
- It examines and accords its approval to area specific management plans, integrated coastal zone management plans and modifications submitted by the State Coastal Zone Management Authorities and Union territory Coastal Zone Management Authorities.
- Deals with all environmental issues relating to coastal regulation zone which may be referred by the Central Government
- Places information regarding the agenda and minutes of its meetings in the public domain and create provision for displaying status of proposals received from the States and Union territories online.

(6) State Department of Environment (DOE)

Environmental matters of any State ranging from the execution to formulation of guidelines have been entrusted to each State Department of Environment (DOE). A cabinet minister heads these departments. In order to carry out its functions, many State Governments have set up their frameworks to accomplish Environmental Clearance (EC) at state levels within each State DOE.

In Tamil Nadu State, the Tamil Nadu Department of Environment (TN-DOE) was created in 1995, which deals with environmental management of Tamil Nadu State. TN-DOE is the nodal agency for planning, promoting, coordinating and overseeing the implementation of all the aspects of environment other than those dealt with Tamil Nadu Pollution Control Board (TNPCB). The objectives of TN-DOE are described in its website as follows:

- Implementation of National River Conservation Plan (NRCP) for the abatement of pollution in Cauvery, Vaigai, Tamiraparani rivers and Chennai City waterways.
- Implementation of National Lake Conservation Plan (NLCP) for the abatement of pollution in the selected lakes.
- To carry out various Environmental awareness programmes for school students, through National Green Corps (NGC) and Eco-Clubs.
- To enforce the provisions of the Coastal Regulation Zone (CRZ) Notification.
- To provide web-based environmental information through Environmental Information System (ENVIS) on State of Environment and related issues of Tamil Nadu.
- Preparation of State of Environment (SOE) Report, SoE Atlas SoE Video and Photo Catalogue of Tamil Nadu.

(7) State Pollution Control Board (SPCB)

A State Pollution Control Board (SPCB) works under each State DOE and each SPCB has a different structure with regard to project appraisals as summarized in Table 7.3.4.

Table 7.3.4 Different Structure of SPCB on Project Appraisal

State	Expert Appraisal Committee (EAC)	No Objection Certificate (NOC)
Andhra Pradesh	EAC under the SPCB	EAC appraises the report submitted by project proponent before issuing NOC.
Maharastra, Gujarat, West Bengal, and Karnataka	EAC under each State DOE	EAC issues NOC
Tamil Nadu and Other States	-	Member secretary or chairman of each SPCB issues NOC

Source: MOEF

- SPCBs issue a No Objection Certificate (NOC) to establish a project requiring a Prior Environmental Clearance (EC) from either Central (MOEF) or State Government, or a CRZ Clearance from Central (MOEF).
- After issuance of a clearance (EC or CRZ), the proponent shall apply NOC for SPCB which will be issued in about 60 days from the application
- IA at MOEF has conferred the responsibility of "public hearings" in EC processes to SPCBs of which minutes of the meetings (M/Ms) and major findings are to be furnished to IA within 30 days.
- In case of non-compliance of industries, the MOEF may direct SPCBs to look into the matter and undertake desired measures.
- Sometimes SPCBs instruct project proponents to submit rapid EIA on one season data, considering the size and type of industry.

In Tamil Nadu State, the Tamil Nadu Pollution Control Board (TNPCB) was established in 1982 with the following objectives:

- To control, prevent and abate pollution of streams, wells, land and atmosphere in the State.
- To protect the environment from any degradation by effective monitoring.
- To implement pollution control legislations.

7.3.3 Environmental Clearance System

In India, there are two clearance systems on environment regulated by MOEF which are summarized as follows:

- Prior Environmental Clearance (EC) stipulated in the Revised Environmental Impact Assessment (EIA) Notification (S.O. 1533 (E), 14th September 2006) of MOEF.
- Coastal Regulation Zone Clearance (CRZC) stipulated in the CRZ Notification (No. S.O. 19 (E), 6th January 2011).

Based on the provisions stipulated in the notifications, environmental clearances required for the Project composed of Seawater Desalination Plant (DSP) and Transmission Pipelines (TPs) are summarized in Table 7.3.5. Thus, only CRZ clearance is required for the Project.

Table 7.3.5 Environmental Clearances required for the Project

Clearance	DSP located in CRZ	DSP located out of CRZ	TPs installed in CRZ	TPs installed out of CRZ
EC	Not Required*	Not Required*	Not Required*	Not Required*
CRZ	**Required**	**Required****	**Required**	Not Required

*: Water supply projects are not listed in the Schedule (project list requiring prior EC) in the Revised EIA Notification
**: Intake/outfall pipelines are to be constructed in CRZ as necessary facilities of DSP
Source: JICA Study Team

1) Prior Environmental Clearance (EC)

Reviews of Prior EC systems and procedures including Administrative Framework, State Level Environment Impact Assessment Authority (SEIAA), Categorization of Projects and Activities, General Condition (GC) and EIA flowcharts stipulated in the EIA Notification are summarized in Appendix 7.3.

2) Coastal Regulation Zone Clearance (CRZC)

According to the CRZ Notification of MOEF (2011), CRZ are classified into four zones (CRZ I-IV) where a clearance is permitted only for the project and activity specified in the CRZ Notification. Areas of CRZ are summarized as follows:

i. The land between the High Tide Line (HTL) to 500 m on the landward side along the sea front.
ii. Land associated with tidal influenced water bodies such as tidal creeks.
iii. The land area falling between the hazard line as defined by the Ministry of Environment, Forest and Climate Change (MOEF) and 500 m from HTL on the landward side.
iv. The land area between the HTL and the Low Tide Line (LTL), which is referred to as the intertidal zone.
v. The water and the bed area between the LTL to the territorial water limit, 12 nautical miles offshore.

Central Government has prohibited certain activities within the CRZ, and has declared certain activities permissible with clearance from the MOEF. Desalination plants are permissible activities with permission from the MOEF, refer Section 4 (ii) (h) of the Coastal Regulation Zone Notification.

CRZ-I, II, III and IV areas are defined in the notification. CRZ zones III and IV are relevant at Perur:

- ✓ CRZ-III: Are areas that are relatively undisturbed.
- ✓ CRZ-IV: Is the water area from the Low Tide Line to twelve nautical miles on the seaward side.

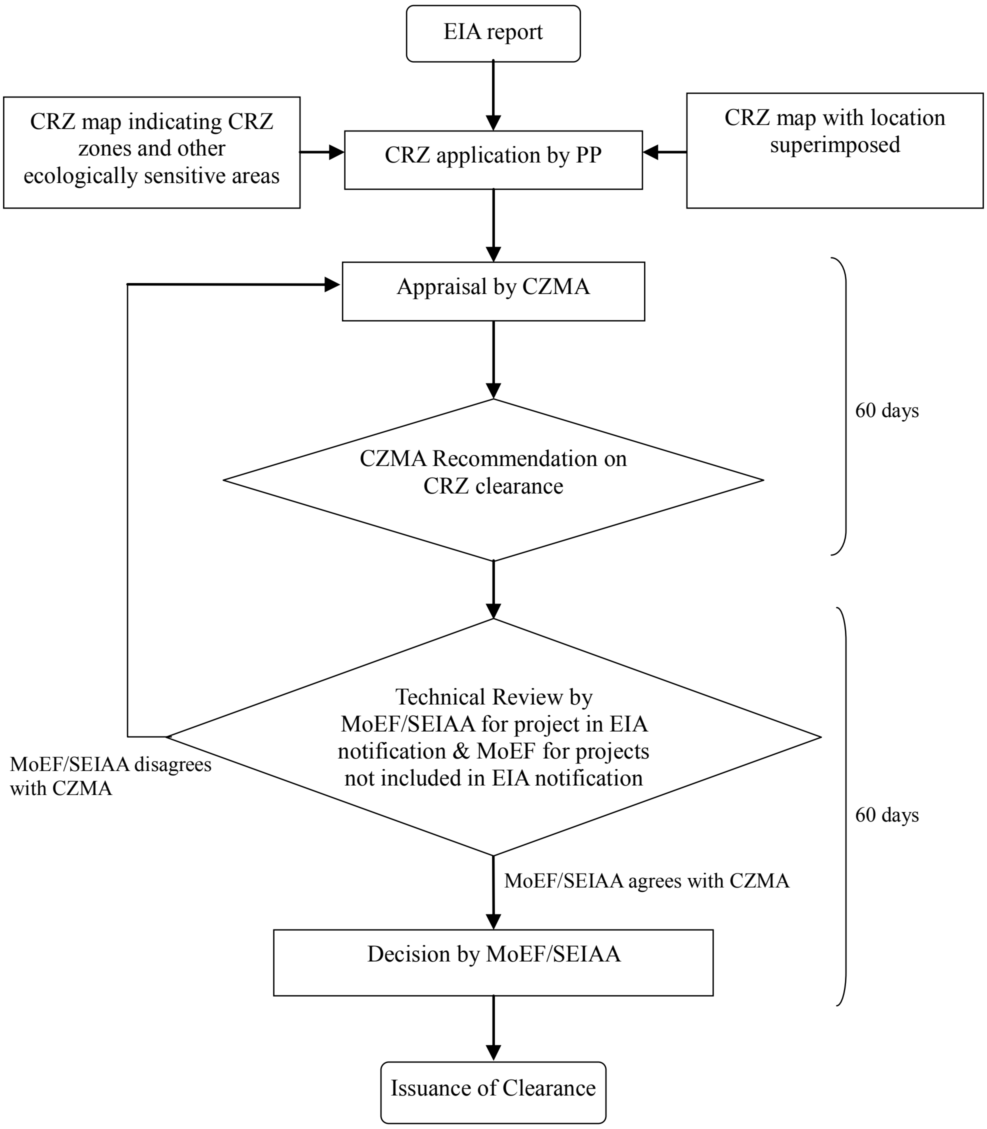
Within CRZ-III there are two designated zones, a “No Development Zone” and the “200 m to 500 m zone”. Within both these zones, “Foreshore activities for desalination plants and associated facilities” are permitted activities, refer Section III, CRZ-III, A (iii) (h), and CRZ-III, B (v). In CRZ-IV areas, the activities impugning on the sea and tidal influenced water bodies are regulated. The construction of intake and outfall conduits, and intake and outfall structures, are regulated in this area.

(Source: DPR for the Perur DSP Project, 2014)

The processes for the clearance for projects in the CRZ are summarized as follows:

- CRZ clearance process involves both central and state level authorities.
- Coastal Zone Management Authority (CZMA) examines the clearance application in accordance with the approved Coastal Zone Management Plan (CZMP) and in compliance with CRZ notification and recommends it to the regulatory authority.
- MOEF or SEIAA functions as a regulatory authority for the project attracting EIA notification 2006 whereas MOEF functions as a regulatory authority for the project not covered in EIA notification, 2006 but attracting Para 4(ii) of the CRZ Notification 2011.
- MOEF or SEIAA considers projects for clearance based on the recommendation from the concerned CZMA.

Figure 7.3.1 illustrates the CRZ Clearance (CRZC) process. The proposed project site in Perur is subject to CRZC process due to the project location of CRZ III, CRZ I (inter tidal zone), and CRZ IV (sea water area).



CRZ: Coastal Regulation Zone
CZMA: Coastal Zone Management Authority
SEIAA: State Level Environment Impact Assessment Authority
SPCB: State Pollution Control Board

Note: Appendix 7.3 for explanation on SEIAA.
Source: CRZ Notification No. S.O. 19 (E), 6th January 2011 MOEF

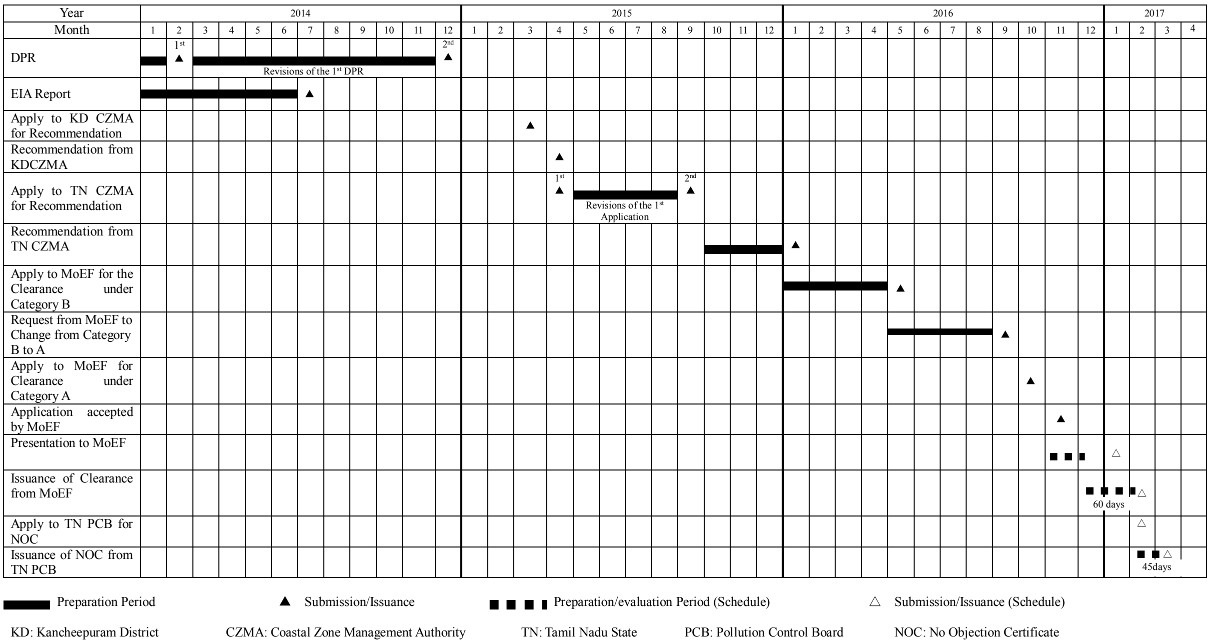
Figure 7.3.1 CRZ Clearance Process

7.3.4 Progress for Obtaining CRZ Clearance

As specified in the previous section 7.3.3, CMWSSB shall obtain a CRZ clearance from MOEF and an NOC (No Objection Certificate) from the TNPCB.

(1) Progress and Schedule

Figure 7.3.2 shows progress and possible schedule of actions taken by CMWSSB for obtaining CRZ clearance and the NOC as of 20th January 2017.



Source: JICA Study Team

Figure 7.3.2 Schedule of CRZ Clearance and NOC (as of 20th January 2017)

In the processes of the CRZ Clearance procedures for the DSP Project (Refer to Figure 7.3.2), the Kancheepuram District Coastal Zone Management Authority (KDCZMA) and the Tamil Nadu State Coastal Zone Management Authority (TNSCZMA) have issued recommendations to TNSCZMA and MOEF respectively as shown below.

1) Recommendation from KDCZMA

At the KDCZMA meeting held on 9th April 2015, the following recommendations for the Proposed Construction of 400 MLD DSP at Perur were issued from KDCZMA to the TNSCZMA.

1. To provide stability to the marine outfall system even during cyclonic conditions, appropriate anchor shall be provided.
2. The pipelines both intake and outlet shall not cause any hindrance to the movement of the local communities including the fisherman.
3. A continuous and comprehensive post-project marine quality monitoring programme shall be taken up. This shall include monitoring of water quality and biological characteristics.
4. It shall be ensured that there is no displacement of people, housing or fishing activity as a result of the project.
5. The marine biodiversity shall be monitored and the report submitted twice in a year to the Ministry of Environment and Forest/ Tamil Nadu Pollution Control Board.
6. Due to desalination process the concentration of toxic trace metals may increase. Hence, periodical monitoring shall be carried out to assess the concentration of toxic trace metals in the reject water.
7. The temperature of the effluent shall also be within the permissible limit. A moored data buoy shall

be maintained in the vicinity of the effluent discharge to continuously monitor the changes in the selected physiochemical parameters (such as salinity, temperature, DO, current etc.). Periodical monitoring of these parameters during the construction and commencement of the plant becomes essentials to undertake corrective measures if needed.

8. The high salinity reject water may be periodically monitored for the physiochemical and toxic trace metal contents through appropriate standard procedures.
9. The sludge shall be disposed in a secured landfill as per Pollution Control Board guidelines.
10. No sand dunes shall be disturbed.
11. The pipelines shall not diturb the movement of fishing vessels or fishermen.
12. Markers shall be installed at every 30m along the pipeline route to indicate the position of the line.
13. The construction of any structures within the CRZ area shall not exceed the height of 9 metres.
14. No Ground water shall be extracted within the CRZ area.

2) Recommendation from the TNSCZMA

At the 87th meeting of the TNSCZMA held on the 14th January 2016, the following recommendation for the Proposed Construction of 400 MLD sea water reverse osmosis desalination plant at Perur was issued from the authority, which is a necessary document for applying to MOEF for a CRZ Clearance.

- The Authority resolved to recommend the proposal to the Ministry of Environment, Forests and Climate Change, GOI subject to the following specific conditions:

a. The proposed activities should not cause coastal erosion and alter the beach configuration.
b. Untreated chemical waste generated due to membrane protection activity and the sewage generated should not be discharged into the sea.
c. The project activity should not affect the coastal ecosystem including marine flora and fauna.
d. It may be ensured that mercury concentration is not present in the end product.
e. The proponent should ensure that the saline water shall not gain access into ground while conveying or processing the sea water.
f. Marine water quality should be monitored at the outfall area every quarter and results sent to Tamil Nadu State Coastal Zone Management Authority.
g. A system shall be evolved for a close and continuous monitoring during the construction and post-construction phases through reputed institutions such as National Centre for Sustainable Coastal Management (NCSCM), Anna University, Chennai/NIOT, Chennai / IIT Chennai. Periodical report shall be furnished to the Tamil Nadu State Coastal Zone Management Authority on the site conditions every year so as to take mitigation measures on the event of any adverse impacts on the coast.
h. The impact on the corals, marine organisms, Turtle nesting etc., due to the above constructions, in long run, should be evaluated and monitored through experts, in which, ecologists should be included.

i. The activities such as intake pipeline and outfall line and intake arrangement in sea and the pipeline should not cause hindrance to fishing activities and to boat movement.
j. Marking the intake and outfall pipelines adequately such that fishing vessels and fishermen are made aware of its presence.
k. No blasting or drilling activities in CRZ is permissible.
l. The proponent should not prevent public from easy access to the beach.
m. The proponent shall implement the Green Belt as envisaged in EIA report.

(2) Further Actions to be taken by CMWSSB

The following actions have been and are to be taken by CMWSSB after the CRZ Clearance application submitted to MOEF on April 2016:

- A presentation about the Project for the CRZ clearance at MOEF: According to CMWSSB, on16th January 2017, the presentation was made at the MoEF by a local consultant officially assigned by CMWSSB .
  - According to the CRZ notification, the duration for the issuance will be 60 days (working days) after the presentation. In this regard, MoEF has informed CMWSSB that MoEF will communicate the minutes to CMWSSB by 15th February 2017.
- Apply to TNPCB for issuance of NOC: 31st March 2017 (prediction).
  - According to TNPCB the duration for the issuance will be about 45 days (working days), therefore, after receiving the minutes on CRZ from MoEF, CMWSSB will apply to TNPCB for NOC, which is expected by 31st March 2017..
- Countermeasures against the recommendations from both CMZAs shall be prepared by CMWSSB.
- Recommendations and supplementary conditions from MOEF may be issued at the issuance of the CRZ clearance which shall be considered by CMWSSB.

7.3.5 Gap between CRZ Clearance Systems and the JICA Guidelines

Table 7.3.6 summarizes consistency between CRZ Clearance and the JICA Guidelines. As JICA loan is expected, the Project shall satisfy the JICA Guidelines as well as CRZ Clearance. The table include actions to be taken to fill the gaps between the two different systems.

Table 7.3.6 Gap between CRZ Clearance and the JICA Guidelines

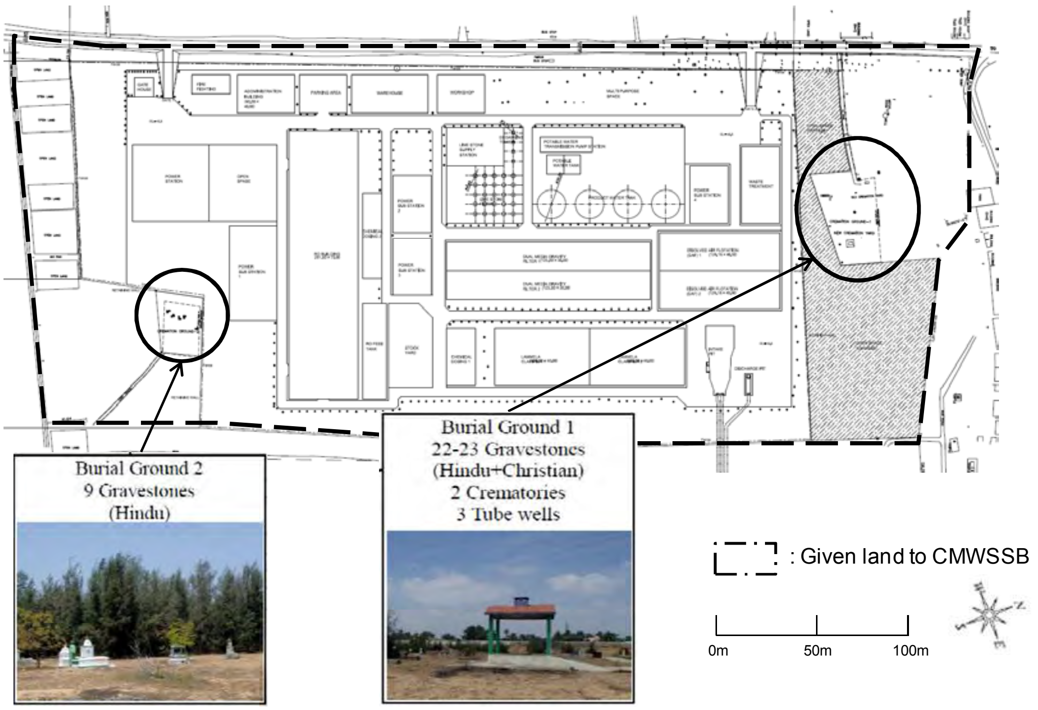
Item	CRZ Clearance	JICA Guidelines	Gap evaluation (✓) and actions to be taken to fill the gap (➢)
EIA & Environmental Permit	• Required by CRZ Notification. • Areas subject to CRZ clearance are within 500 m from HTL. • EIA is one of necessary documents for CRZ Clearance. • The CRZ clearance procedure for the Project has been initiated in accordance with recommendations from CZM Authorities. • Other than the CRZ clearance, an NOC is required from the State Pollution Control Board.	• EIA report is basically required to be prepared by the recipient country government or project implementing agency. • EIA report is a requirement especially for the JICA Guidelines' Category A' projects. • Environmental permissions of the recipient country are required in accordance with recipient country's laws and regulations.	✓ Basically there is no gap. ✓ EIA for DSP was prepared in July 2014. ➢ JICA Study Team will monitor progress of issuances of CRZ clearance and NOC and assist CMWSSB in the process.
Project Categorization	• All projects in CRZ are required CRZ Clearance (no such categorizations of "A" or "B" in the CRZ notification). • DSP in CRZ is not subject to the revised EIA Notification.	• DSP and the transmission system have been categorized as "B" by JICA in accordance with the JICA Guidelines. (See Section 7.1.1). • The JICA categorization is subject to modification based on this JICA Study's assessments of the impacts on environment and social if there are any lager modifications and amendments to DSP.	✓ Basically there is no gap. ➢ JICA Study Team conducts an IEE level study to examine possible impacts on environment and social in accordance with the JICA Guidelines.
Explanation to Local Stakeholders	• Basically not required in the CRZ process. Therefore, so far such explanation has not been held at the time of the EIA study. • However, the CRZ Notification specifies that "MOEF may under a specific or general order specify projects which require prior public hearing of project affected people.	• Required. • Discloser of EIA report is a requirement for Category A (JICA Guidelines) projects and where necessary base for the Category B (JICA Guidelines) projects.	✓ There is a gap with regard to the explanation of Local stakeholders. ➢ Based on discussions between CMWSSB and JICA Study Team, stakeholders' meetings for villages around Perur are planned and held by the CMWSSB initiative.
Review of Environmental & Social Conditions	• Required.	• Required.	✓ No gap is found. ✓ However, environmental and social conditions around the routes for transmission pipelines installed out of CRZ areas have not been implemented. ➢ In accordance with the JICA guidelines, JICA Study Team conducts an IEE level study.
Environmental Management & Monitoring	• A post clearance monitoring is required. • The monitoring report on the stipulated terms and conditions shall be submitted half-yearly (June and December).	• Required. • In accordance with environmental and social impacts Environmental Management & Monitoring Plans and those frameworks are regaled by referring to relevant authorities' regulation and rules of the recipient countries.	✓ Basically there is no gap. ✓ However, monitoring frameworks of CMWSSB is not proposed and planed in EIA report. ➢ JICA Study Team proposes CMWSSB to establish Project Implementation Unit (PIU) which will have functions for Environmental Management and Monitoring systems.

Source: JICA Study Team

7.4 Land Acquisition and Resettlement

In India, land acquisition and resettlement is regulated by "Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act (Act 2013) governed by the Ministry of Rural Development (MORD) (See Appendix 7.4 for details). However, the Project does not require land acquisitions and resettlements as follows:

- DSP is planned to be constructed in a land (no settlements and households) under control of CRZ.
- The land in Perur for the project is planned to be leased for 30 years from the land owner (M/s Arulmigu Alavandar Nayakkar Trust (a religious and charitable group) maintained by the Hindu Religion and Charitable Endowments (HR&CE) Department of the Government of Tamil Nadu (GOTN)) to CMWSSB.
- In the DSP site in Perur, there are two burial grounds but the plant layout has been arranged so that no facility would be constructed in the burial grounds shown in Figure 7.4.1. (See Subsection 6.3.4 for the plant layout).
- An electrical substation is planned to be constructed at a vacant land of 3.37 ha (facing ECR west as well as across a road adjacent to the Nemmeli DSP south) of which 1.38 ha already leased by CMWSBB and 1.99 ha is planned to be leased from the land owner of the Trust.
- High-voltage electrical power lines from the substation to the Perur DSP site of which total length is approximately 400 m are planned to be installed under the east side of ROW of ECR.
- Transmission pipelines are planned to be constructed under the existing roads.



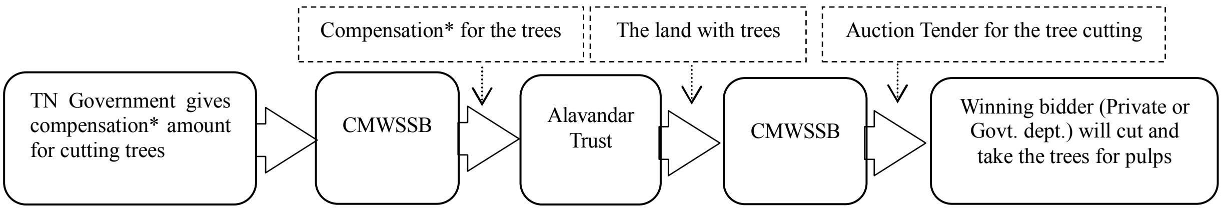
Base Map: Annexure 2 Topography, DPR February 2014
Source: JICA Study Team

Figure 7.4.1 Two Burial Grounds in the Proposed DSP Construction Site

With regard to *"Casuarina"* trees planted in the desalination plant site by the Forest Department of GOTN, the following countermeasures were decided and ordered by GOTN as the Governmental Order of G.O (Ms) No. 157 issued on 29th April 2016.

- *Causarina* plantation of 9 years old have been planted by the Forest Department on the sharing basis agreement of 30% for the Forest Department and 70% for the Trust (Land Owner of the Perur site).
- CMWSSB has to contact the Forest Department or TNPL (Tamil Nadu Newsprint and Papers Limited) to determine the value of the *Casuarina* trees.
- Compensation amount for the loss of the *Casuarina* plantation in the rented land should be paid as a single installment by the CMWSSB to the Trust.

With regard to those trees to be logged and disposed before construction of the DSP, there is no concrete plan on the logged tree disposal management at present. However, according to CMWSSB, those trees of *Causarina* are generally used as pulp woods in India so that the logged *Causarina* trees have commercial values. For this reason, CMWSSB has expressed an idea on the tree cutting as shown in Figure 7.4.2.



*: Compensation amount should be calculated according to the market rate fixed by Forest department/TNPL

Figure 7.4.2 Possible Tree Cutting Management Flow (Draft)

- In accordance with the idea shown in Figure 7.4.2, there will be no generations of waste from the logged trees utilized as pulp woods of which residuals will be disposed by a pulp factory.
- However, exhaust gases and noises will be generated from necessary cutting equipment and transport trucks before the construction stage of DSP in Perur.

7.5 Examination on Environmental and Social Impact

7.5.1 Project Components

The project consists mainly of a DSP and product water transmission systems as summarized in Table 7.5.1 and shown in Figure 7.5.1.

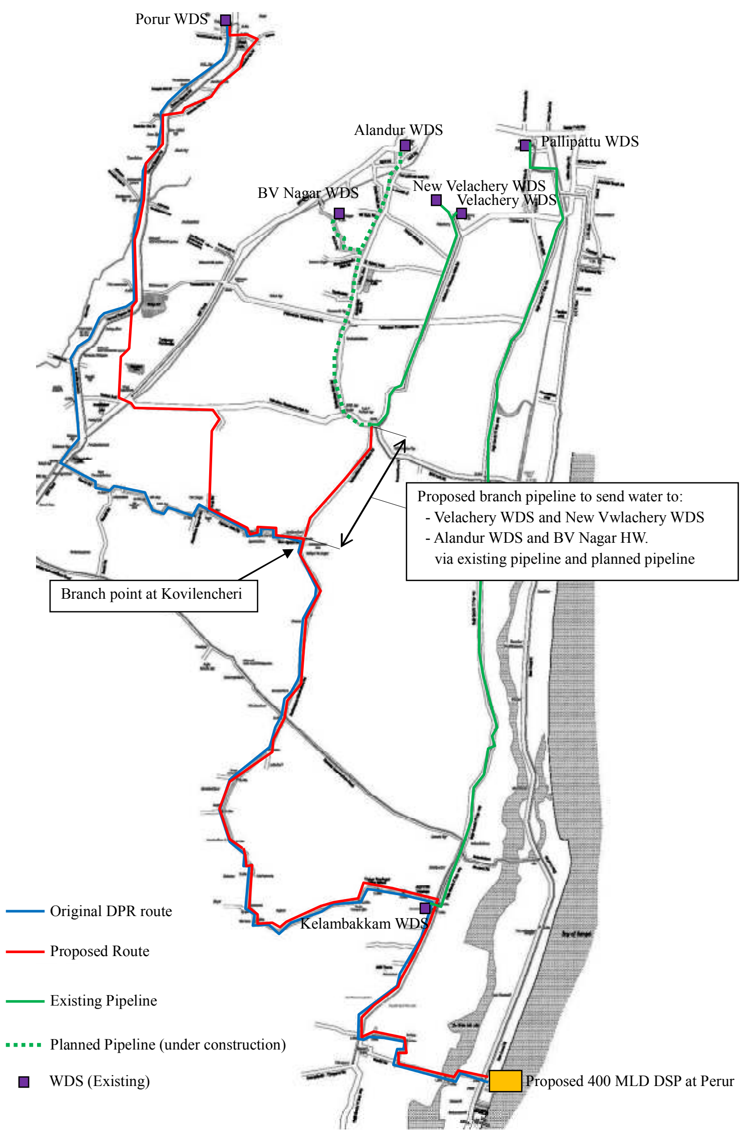
Table 7.5.1 Project Components

Component	Item	Project Scope
Seawater Desalination Plant	Capacity	400 MLD
	Location	Perur
Product Water Transmission System*	Destination of the transmission main	• Main line to the Porur WDS • Branch-line from Kovilenchery to an existing pipeline at Medavakkam • Tapping points for OC-15 & 16 in the Rest of CMA
	Length and diameter of the main	• Diameter: 1,000 mm to 2,200 mm • Length: 65 km
	Underground reservoir and transmission pumping station	• 1 pumping station at the Perur DSP • 1 pumping station and 1 reservoir at the Porur HW
Distribution Network	Improvement of the existing distribution networks in the Core City	• Hydraulic reinforcement of the existing networks (101 km) • Reinforcement of the storage volume (4.33 ML for UGT and 49.32 ML for ESRs) • Supplementary pipes to the uncovered streets (258 km) • Pipe materials: Ductile Iron or High Density Polyethylene Pipe

* The transmission pipelines are proposed to be constructed under the existing roads
Source: JICA Study Team

With regard to the distribution pipelines, those pipelines will be installed in accordance with the "Indian Standard Code of Practice for use and Laying of Ductile Iron Pipes". In addition, those pipe diameters will be smaller than the transmission pipes. By considering those circumstances, impacts caused by the installation of the distribution pipes are considered marginal. Therefore, examination of the impacts of the distribution pipes is excluded from the discussions below.

However, due to the fact that open cut methods will be applied to the installations of distribution pipelines, it can be recognized that environmental and social considerations for distribution pipelines are to be the same as the transmission pipelines which are discussed below.



Source: JICA Study Team

Figure 7.5.1 Project Components

7.5.2 Project Alternative Studies

(1) Perur DSP

Several alternatives were discussed in the course of the design stage of the Perur DSP considering environmental, social, technical and financial differences. It has been recognized that those differences will be dependent mainly on circumstances of the project site in Perur, due to the nature of project components (provided that relevant principal facilities to be constructed by the project are the same) as summarized in Table 7.5.1. Therefore, selected four candidate sites were compared as shown in Table 7.5.2.

Table 7.5.2 Comparison of the Project Sites Alternatives for the Perur DSP

Site Option		Option 1	Option 2	Option 3	Option 4
Alternative		Original DPR Site	A	B	C
Village		Perur	Pattipulam	Thiruvidanthai	Thiruvidanthai
GPS Position (Site Center)	Latitude	12° 42.828'N	12° 40.363'N	12° 45.160'N	12° 45.764'N
	Longitude	80° 13.725'E	80° 12.839'E	80° 14.124'E	80° 14.814'E
Photograph					
Physical Environment	Land to be acquired (m^2)	340,000	400,000	420,000	380,000
	Type of Land	Flat Land	Flat & Vacant Land	Flat & Farmland	Flat Land
	CRZ Area	Yes	Yes	No	Yes
	Location (km)	Approx. 1 km north of Nemmeli DSP.	Approx. 4 km southwest of DPR site (Perur).	Approx. 3.8 km northeast of DPR site and 800m inland from seashore.	Approx. 5.8 km northeast of DPR site.
Social Environment	Resettlement	No	No	No	No
	Owner	Religious and Charitable Trust.	Religious and Charitable Trust. However, there is litigation on the land ownership.	Private.	Government of Tamil Nadu.
	Social Facility	· Two (2) Crematories · Three (3) tube wells. · 22-23 gravestones (northern edge) · 9 gravestones (southern edge).	No (next to the southern border of the site, there is one Crematory)	No	· Three (3) Crematories. · Two (2) dug wells. · Two (2) pumping stations. · Several power poles. · Two (2) gravestones.
	Surrounding Communities	· Nemmeli Village in the north and the south. · Several households in the south.	· Several households in the north. · Pattipullam Village in 0.8 km north.	· Several households in the north east). · Soukya Homestays (rental villas) in the north.	· GT Barefoot Bay (housing complex) in the south. · Thiruvidanthai in the west. · Baasp beach house in the north.
	Distance from nearest arterial road (km)	0 · East of ECR	0 · East of ECR	0.3 · West of ECR	0 · East of ECR
	Water Supply Services	No	No	No	No (Village water supply system for the surrounding village)
	Drainage Systems	No	No	No	No
Total Cost*	DSP facility	Cheapest (Land acquire cost is the cheapest due to the least area among others).	Slightly lower than Option 3 (Land to be acquired is slightly lower than Option 3).	Highest (due to private land acquisition and longer intake/outfall pipelines from/to the seashore.	Slightly higher than Option 1 (Land to be acquired is slightly larger than Option 1).
	Transmission pipelines	Almost same with other options (Total length of the pipelines is approximately 70 km).	Almost same with other options (Total length of the pipelines is approximately 70 km).	Almost same with other options (Total length of the pipelines is approximately 70 km).	Almost same with other options (Total length of the pipelines is approximately 70 km).

* Given that construction cost for DSP is constant for each option
Source: JICA Study Team

- ✓ Option 1 (Original DPR Site) is a flat and basically vacant land in CRZ where resettlement does not generate, but there are two burial lands in the northern and southern edges of the area (DPR has planned the DSP layout to exclude two burial lands).
- ✓ The owner of Option 1 site is a religious and charitable trust maintained by HR&CE Department of GOTN.
- ✓ Option 2 (Alternative A) is a flat and vacant land in CRZ where resettlement does not generate.
- ✓ The owner of Option 2 site is a religious and charitable trust maintained by HR&CE Department of GOTN, however there is an appeal pending in the Madras High Court regarding the ownership of the site.
- ✓ Option 3 (Alternative B) is a flat and farmland where resettlement does not generate.
- ✓ The owner of Option 3 Site is a private person.
- ✓ Option 4 (Alternative C) is a flat land in CRZ where resettlement does not generate, but there are two dug wells (located in about 800 m each other in the central portion of the site) constructed by a rural development scheme of GOTN and three crematories (located in about 400m distance each other in the central portion of the site) and two grave stones (constructed around one crematory in the south).
- ✓ The owner of Option 4 site is GOTN.

Based on the above comparisons, Option 1 (Original DPR site) has been selected as the most suitable site for the project taking into account no possibility of resettlement, less negative social impacts as well as fewer costs in association with less land area to be acquired.

(2) Transmission pipelines

As inevasible facilities of DSP, transmission pipelines are planned to be installed under the existing roads from Perur DSP to Porur HW as summarized in Section 7.5.1. For selections of the roads, several alternative routes have been compared by evaluating “Site Condition”, “Cost” and “Constructability” as discussed in Subsection 6.6.1.

As for environmental and social conditions around the transmission pipeline routes are summarized in Appendix 7.5.

7.5.3 Study on Without-Project (Zero Option)

Consequences for selection of zero option for the Project are considered as follows.

- ✓ The land of Option 1, (the land owner of the Religious and Charitable Trust maintained by the HR&CE Department of GOTN has agreed to lend the land to CMWSSB), will not be used.
- ✓ Impacts on natural and social environment caused by the construction and operation of the Project will not occur at all (due to the without projects).

✓ CMWSSB will study and find other projects on water supply including transmission pipelines, necessary DSP sites and pipeline routes to satisfy the water shortage in Chennai for which more budgets will be further required.

Considering minor environmental and social impacts (discussed below) caused by the project and financial constraints of CMWSSB, it is evaluated that the selection of Zero Option (without-project) is not realistic.

7.5.4 Scoping and TOR for Environmental and Social Considerations

(1) Scoping Results

The definition of "Scoping" in the environmental and social considerations study according to the JICA Guidelines is "scoping means choosing alternatives for analysis, a range of significant and potentially significant impacts, and study methods". Table 7.5.3 shows the scoping result for the proposed project.

Table 7.5.3 Scoping Results

Category/	No.	Environmental Item	Rating Con.	Rating Ope.	Reasons
Pollution Control	1	Air Quality	B-	C	Construction Phase: Worsening of surrounding ambient air caused by exhaust gases and dusts emitted from operation of heavy vehicles, equipment and trucks is predicted during construction of DSP and installation transmission pipelines. Operation Phase: There is no possibility of generation of air pollutants which have negative impacts on ambient air caused by the operation of DSP and the transmission pipelines. However, liquefied gas of Chlorine is planned to be used in the DSP operation as required for disinfection of the product water and for shock chlorination
	2	Water Quality	C	C	Construction Phase: Water pollution caused by construction work and installation work, operation of heavy vehicles, equipment and trucks, and waste water of workers and labors is predicted. Operation Phase: There is possibility of groundwater pollution caused by discharge of waste water from sanitation and kitchen facilities of DSP. In addition, there is possibility of seawater pollution caused by discharge of brine from DSP.
	3	Wastes	B-	C	Construction Phase: Generation of construction waste soil, demolition waste and debris are expected. Operation Phase: Generation of domestic waste from DSP is expected.
	4	Soil Contamination	C	C	Construction Phase: There is possibility of soil contamination due to oil spills from relevant construction vehicles and equipment, and transport trucks. Operation phase: There is possibility of soil pollution caused by discharge of waste water from sanitation and kitchen facilities of DSP.
	5	Noise and Vibration	C	C	Construction Phase: Generation of noise caused by construction vehicles and heavy equipment is expected. Operation Phase: Pumping facility of DSP will discharge noise
	6	Subsidence	D	D	Construction Phase: Construction work and installation work which causes subsidence is not predicted. Operation Phase: Ground water is not used for operation of the DSP and Transmission pipelines at all.
	7	Odor	D	D	Construction work and installation work as well as operation of DSP and Transmission pipelines which causes bad odor are not expected.
Natural Environment	8	Protected Areas	D	D	Protected area and national parks are not existed in and around the DSP site, and transmission pipelines are constructed under the existing roads.
	9	Ecosystem	C	C	Rare and protected species and habitats of flora and fauna have not been identified in and around the project site so far. In order to make sure impacts on ecosystem, reviews of flora and fauna are required especially for marine ecosystem including habitat of sea turtles.
	10	Hydrology	C	D	Construction Phase: There is no river stream and river at all in the DSP construction site. Therefore, not impact on hydrology in the DSP construction site is expected. On the other hand, transmission pipelines are planned to be installed under the existing roads by which several rivers can get across. Therefore, there may be some impacts on such rivers during the construction phase. Operation Phase: No impact on hydrology is expected by the operation of DSP and the transmission lines.

Category/ No.		Environmental Item	Rating		Reasons
			Con.	Ope.	
	11	Topography and Geology	D	D	Large scale excavation and earth fill are not expected due to construction of the DSP facilities and installation of transmission pipelines of 2m diameter. On the other hand, some erosion issues on the coast near the Nemmeli DSP were pointed out by the surrounding villagers. However, construction methods for the Perur DSP are planned to be different ones of underground installations of pipelines which will not cause seacoast erosions
Social Environment	12	Land Acquisition /Resettlement	B-	D	Site for the DSP basically is a vacant in Perur which will be leased from a Religious and Charitable Trust maintained by HR&CE Department of GOTN. In addition, transmission pipelines are planned to be installed under the existing roads. No resettlement is predicted. With regard to "Casuarina" trees planted in the Perur site by the TN Forest Department, the following countermeasures were decided and ordered by GOTN as the Governmental Order of G.O (Ms) No. 157 issued on 29th April 2016. ・ Causarina plantation of 9 years old have been planted by the Forest Department on the sharing basis agreement of 30% for the Forest Department and 70% for the Trust (Land Owner of the Perur site). ・ CMWSSB has to contact the Forest Department or TNPL (Tamil Nadu Newsprint and Papers Limited) to determine the value of the Casuarina trees. ・ Compensation amount for the loss of the Casuarina plantation in the rented land should be paid as a single installment by the CMWSSB to the Trust.
	13	Impoverished Peoples Ethnic Minorities and Indigenous Peoples	D	D	Impoverished (absolute deprivation) people and Project Affected Persons are not identified in the project site. As well ethnic minorities and indigenous peoples are not identified in and around the project site.
	14	Living and Livelihood	B+/-	C	<u>Construction Phase</u>: A temporary employment of the surrounding villagers is expected for the construction work and installation work. There may be negative social impacts on the surroundings of the existing roads (negative impacts on traffic and commercial activities) caused by installation of the transmission pipelines. <u>Operation Phase</u>: An employment (security guards, gardeners and others) of the surrounding villagers is expected in the Operation Phase. Layout of the DSP facilities is planned to exclude two (2) burial lands including gravestones, crematories, three (3) tube wells. However, social impacts on those lands and relevant facilities are necessary to be considered.
	15	Land use and Regional Resources	D	D	<u>Construction Phase</u>: There is no possibility of negative impact on surrounding land use and regional resources caused by the DSP construction and the Pipeline installations <u>Operation Phase</u>: There is no possibility of negative impact on surrounding land use and regional resources caused by the DSP and the Pipeline operations.
	16	Water Right/Use of Water	D	D	<u>Construction Phase</u>: There is no irrigation channel and surface stream at all in the DSP site in Perur, however, the contractors may use groundwater in the site for the construction purposes. As for as construction water concerned, necessary water of 0.5MLD for the DSP construction is planned to be procured from a nearby source as specified in the application form of CRZ clearance. <u>Operation Phase</u>: No impact on groundwater in the site at all.
	17	Social Infrastructures and Services	B-	D	<u>Construction Phase</u>: Negative impacts on surrounding road traffic congestion by increase in the number of heavy vehicles, equipment and transport trucks are temporally predicted during construction period. <u>Operation Phase</u>: No impact on social infrastructure and services is predicted in the operation phase.
	18	Heritage	D	D	Local archeological, historical, cultural, and religious heritages are not existed in the project site of Perur and existing roads for the transmission pipelines.
	19	Social Capital and Social Organization such as decision making bodies	D	D	Any impacts on social capital and social organization are not expected by the project.
	20	Damage and Benefit	D	D	The project is construction and operation of DSP facilities by which such inequality of damage and benefit is not predicted around the project site.
	21	Landscape	D	D	Any negative impacts on the surrounding landscape are not expected by the construction of DSP facilities with the following reasons. ・ Four (4) water reservoir tanks (each 9000m^3 capacity with about 15m height) are planned to be constructed in the project site ・ The site has a vast area of about 340,000 m^2. ・ East side of the site faces the seacoast in Perur. ・ West side of the site faces the East Coast Road (ECR) constructed on the embankment of several meter height ・ Surrounding villagers do not immediately face the project site ・ Construction of buffer zone in the site is proposed in the EIA report
	22	Gender Issue	D	D	Any impacts on gender are not expected by the project.
	23	Rights of the Child	D	D	Any impacts on rights of the child are not expected by the project.

Category/ No.		Environmental Item	Rating		Reasons
			Con.	Ope.	
	24	Risk of infectious diseases such as HIV/AIDS	B-	C	Construction Phase: Temporary influxes of migrant labors increase the risks of STD such as HIV/AIDS during the construction period.
					Operation Phase: Project is a construction of DSP facilities. However, such risks are unknown in the operation phase.
	25	Working Conditions/Work Safety	C	C	Construction Phase: Deterioration of occupational safety and working condition associated with the construction work is anticipated if not properly managed.
					Operation Phase: There will be general educational related activities for DSP staff during the operation phase. Therefore, it is considered that the working conditions for the staff will be moderate.
Others	26	Accidents	C	C	Construction Phase: Accidents associated with construction work is predicted.
					Operation Phase: Accidents associated with operation work is predicted.
	27	Transboundary or Global Issues	D	D	This project is construction and operation of DSP facilities using RO technology and transmission pipelines by which such impacts on transboundary or global issues such as climate change practically are not predicted during construction and operation phases
A+/-	: Significant positive/negative impact is expected.				
B+/-	: Positive/negative impact is expected to some extent.				
C+/-	: Extent of positive/negative impact is unknown. (A further examination is needed, and the impact could be clarified as the study progresses)				
D	: No impact is expected.				

Note: Con.: Construction Phase, Ope.: Operation Phase
Source: JICA Study Team

(2) TOR for Environmental and Social Considerations Study

In accordance with the Scoping Results shown in Table 7.5.3, a Terms of Reference (TOR) prepared for the environmental and social consideration study for the project, to be conducted in the Study, is shown in Table 7.5.4.

Table 7.5.4 TOR for Environmental and Social Considerations Study

Environmental Item	Study Item	Study Method
Alternatives	i. Environmental conditions of alternative sites. ii. Social conditions of alternative sites. iii. Infrastructures around alternative sites. iv. Total cost.	i. –iv. Site reconnaissance, literature reviews and interviews around each site and meetings with relevant officials and stakeholders. Based on these studies, meetings and proposed project components, the most suitable project site is comprehensively evaluated.
Air Pollution	i. Present traffic volume. ii. Air quality in and around the site. iii. Impact during construction and installation.	i. Review of existing data of DPR, EIA reports and others. ii. Review of existing data of DPR, EIA reports, and others as well as site reconnaissance. iii. Based on the above studies, simple calculation of necessary numbers of construction vehicles and equipment, and trucks to be used for the construction and installation is evaluated.
Water Pollution	i. Water quality in and around the site. ii. Impacts during construction and operation phases.	i. Review of existing data of DPR, EIA reports and others and site reconnaissance. ii. Based on the reviews and reconnaissance as well as construction methods, the impacts during construction and operation are evaluated.
Wastes	i. Construction solid waste management. ii. Domestic solid waste management.	i. Interviews with relevant official entities. ii. Interviews with relevant official entities.
Soil Contamination	i. Construction method to be applied. ii. Construction vehicle and equipment to be used.	i. Site reconnaissance and construction plans. ii. Site reconnaissance and construction plans.
Noise and Vibration	i. Construction method to be applied. ii. Construction vehicle and equipment to be used. iii. Pump facility of DSP.	i. Site reconnaissance and construction plans. ii. Site reconnaissance and construction plans. iii. Site reconnaissance and construction plans.
Ecosystem	i. Present condition of flora and fauna in the project site and surrounding marine environment.	i. Review of existing data, field reconnaissance and review of DPR/EIA.
Hydrology	i. River crossing points in the transmission pipeline routes. ii. Construction method and period in such points.	i. Site reconnaissance. ii. Construction plans.
Living and Livelihood	i. Project policy. ii. Impacts on Livelihood.	i. Discussion with relevant official entities. ii. Prediction of impacts on livelihood.
Social Infrastructures and Services	i. Present traffic volume. ii. Construction vehicle and equipment to be used.	i. Review of existing data and construction plan. ii. Site reconnaissance and construction plan.
Risk of infectious diseases such as HIV/AIDS	i. Heath situation in the project area and India. ii. Health education activities.	i. Review of relevant documents. ii. Review of relevant laws and regulations.
Working Conditions/Work Safety	i. Occupational safety systems. ii. Relevant to law and regulation.	i. Review of relevant laws and regulations. ii. Review of DPR/EIA and relevant documents.
Accidents	i. Present traffic volume.	i. Review of existing data and interviews.
Stakeholders Meetings	i. Opinions of stakeholders in and around the project site.	ii. Meetings/interviews with the following stakeholders to be initiated by CMWSSB: - Communities and village heads and/or people living in the surrounding areas of DSP and transmission pipelines.

Source: JICA Study Team

7.5.5 Results of Environmental and Social Considerations Study

(1) Air Pollution

1) Construction Phase

During the construction phases of the Perur DSP and the Transmission Pipelines, heavy vehicles and equipment, and trucks to be used in the project site will generate exhaust gases. The followings summarize total construction periods of DSP and the pipelines.

- The phase for the Perur DSP is scheduled to be total 42 months (3.5 years).
- The phase for the Transmission Pipelines, is scheduled to be total 48 months (4years).

Table 7.5.5 Heavy Vehicle/Equipment Input for 42-month Construction Work (DSP)

Heavy Vehicle and Equipment	Inputs (a) Total Number	(b) Number/day for 42 months (7days/week) =(a)/(365/12*42)	(c) Number/day for 42 months (5 days/week) =(a)/(365/12*42) *7/5
Dump Truck (20m^3)	30,000	23.48	32.88
Other Truck	6,800	5.32	7.45
Rig Machine	360	0.28	0.39
Earth Mover	6,800	5.32	7.45
Hydraulic Mobile Crane	3,400	2.66	3.73
Ready Mix Concrete Loader	4,400	3.44	4.82

Note: Total construction period is 42 months (1,278days = 365 days /12 months ×42months)
Source: JICA Study Team

Table 7.5.6 Heavy Vehicle/Equipment Input for 48-month Installation Work (T. Pipelines)

Heavy Vehicle and Equipment	Inputs (a) Total Number	(b) Number/day for 48 months (7days/week) =(a)/365/12*48	(c) Daily work/km for 48 months (Total 70km) =(b)/70	(d) 5days work/week/km for 48 months (Total 70km) =(b)/70 ×7/5
Heavy Equipment	20,000	13.70	0.20	0.27
Dump Truck	40,000	27.40	0.39	0.55

Note: Total construction period is 48 months (1,460 days = 365 days /12 months ×48 months)
Source: JICA Study Team

In accordance with Table 7.5.5 and 7.5.6, it is understood that the inputs of heavy vehicles and other equipment will be limited for 42-month construction for DSP and 48-month installation for the pipelines as discussed below.

- It can be calculated that total numbers of dump trucks are approximately 24 -33 trucks/day for the 42 months for DSP and are approximately 0.4 - 0.6 trucks/day/km for the 48-month for the pipelines.
- It can be calculated that total numbers of other trucks and heavy equipment to be operated for 42-months for DSP are approximately 6-8 (other trucks and earth movers) and several numbers of equipment per day, and for 48-month installation period for the Pipelines are approximately 0.2 - 0.3 equipment/day/km.

With regard to the construction and the installation phases, due to the fact that the project site in Perur is an open and flat land and the pipelines are installed under the existing roads, it is considered that exhaust gases from those trucks and equipment are easily diffused into surrounding environment.

However, in dry season, dust of dried sandy soil in the Perur site can easily be stirred up by such trucks and equipment operation on site.

2) Operation Phase

According to DPR (2014), liquefied gas of Chlorine is planned to be used in DSP operation as required for disinfection of the product water and for shock chlorination as follows.

- Chlorine will be supplied as liquefied gas in 900 kg drums.
- The system will be configured as a vacuum gas draw system with vacuum valves connected directly to the chlorine drums.

Table 7.5.7 summarizes possible incidents of chlorine leakage and release in DSP and recommendations against such incidents noted in DPR.

Table 7.5.7 Recommendations against Possible Incidents of Chlorine Leakage and Release

Causes	Recommendations
Leakage during unloading of chlorine drums from transport truck	• Unloading of chlorine drums will occur within the chlorine building thereby reducing the risk of chlorine leak outside the building.
Release of Chlorine due to leakage in the Storage tank	• Cylinders containing chlorine should be in upright position. • They should be secured from falling over. Full and empty cylinders should not be stored together. • Containers should be stored on their sides. They should not be stacked or racked more than one high. • All safety measures as per IS 4263 (the latest edition Code of Safety for Chlorine) and IS 10553 (Part 1*) 1983 (Requirements of Chlorination equipment for its safe operations).

* Part 1; General Guidelines for Chlorination plants including handling, storage and safety of chlorine cylinders and drums
Source: DPR, 2014

(2) Water Pollution

1) Construction Phase

Construction workers and laborers will generate human waste which will be discharged as waste water. Total construction workers and laborers are estimated to a total of 255,500 persons for the 42-month construction work (DSP) as well as 200,000 persons per day for 48-month installation work (Pipelines), by which daily average numbers of such workers and laborers are summarized as shown in Table 7.5.8.

Table 7.5.8 Workers and Labors necessary for the Construction and Installation Work

Period	Labor Force	Persons
Construction Work (DSP)	Total construction workers and Labors for 42 months	255,500
	Daily Average Numbers of Workers/Labors (7 working days/ per week basis)	200
	Daily Average Numbers of Workers/Labors (5 working days/ per week basis)	280
Installation Work (Pipelines)	Total construction workers and Labors for 48 months	200,000
	Daily Average Numbers of Workers/Labors (7 working days/ per week basis)	137
	Daily Average Numbers of Workers/Labors (5 working days/ per week basis)	192
	Daily Average Numbers of Workers/Labors/km (7 working days/ per week/ per 1 km basis)	2
	Daily Average Numbers of Workers/Labors/km (5 working days/ pre week/ per 1 km basis)	3

Source: JICA Study Team

- It can be considered that a daily average of such workers and labors to be mobilized will be approximately 200-280 (persons/day) for the construction work (DSP) and approximately 2-3 (persons/day/km) for the installation work (Pipelines) of the total length about 70 km.
- The daily amount of human waste from the workers and labors can be considered about 200-280 (L/day) for the construction work (DSP) and 2-3 (L/day/km) for the installation work (pipelines) as average on the basis that excretion amount unit of one L /person/day (for 8 working hours) is applied.
- To those human wastes in construction works in India, "Act and Rule on Working Condition and Work Safety in India" are applied (See Table 7.5.20) by which necessary sanitation facilities are to be set up in the construction sites.
- In general, leaching pit and/or septic tank methods are applied as temporary sanitation facilities.
- For leaching pit method such as simple pit latrines, WHO (World Health Organization) recommends that those latrines shall be an established minimum safe distance of at least 30 m from the nearest water source like wells as well as at least 2 m from the groundwater table (in wet season) for prevent possible ground water contamination from the latrines. (Source: Simple

pit latrines, WHO, http://www.who.int/water_sanitation_health/hygiene/emergencies/fs3_4.pdf)

- On the other hand, in the case of septage from the septic tanks are disposed to any sewage system, the septage shall meet the Standards for Discharge of Sewages of the Water (Prevention and control of pollution) act, 1974 India.
- With regard to water usage for DSP construction, CMWSSB stated in the Form 1 of the CRZ Clearance application that 0.5MLD from the nearby source for construction purpose including construction labors.

2) Operation Phase

Based on the DPR (February 2014), wastewater managements of DSP are summarized in Table 7.5.9. Plan of the waste-water management is described in Section 6.3.9 in Chapter 6.

Table 7.5.9 WasteWater Management of DSP

Waste Water	Description
Screenings	・ Screenings are planned to be flushed from the screens into wire baskets. ・ The wash water from the screens are planned to be returned upstream of the screens.
Pre-Treatment Waste Water	・ Waste Water will be generated in the pre-treatment system by the following treatment units: - Lamella settlers – settled sludge. - DAF (Dissolved Air Flotation) float. - Filter backwash from gravity dual media filters. ・ All the discharges are planned to be directed to the ocean via the outfall.
Membrane CIP Wastewater	・ The membrane CIP (Cleaning-in-Place) wastewater after neutralization is planned to be directed to the ocean via the outfall. ・ A neutralization tank is planned to be provided in the design.
Domestic Waste Water	・ Domestic sewage waste is planned to be treated independently from all other liquid wastes. ・ A dedicated sewage treatment package plant is planned to be used to treat this waste to a standard suitable for re-use for irrigation or similar purposes. ・ An STP is proposed to be constructed within the plant premises.

Source: DPR, February 2014

With regard to the transmission pipelines, no waste water is discharged by the pipeline operations at all.

(3) Wastes

1) Construction Phase

Considering the nature of construction of buildings and facilities of DSP as well as installation of the transmission pipelines, it can be predicted that debris and wastes which are generated during the construction work and the installation work will not be hazardous wastes such as toxic chemical substances and radioactive waste but rather be general “construction wastes and soils” which are generally collected, transported and treated by all contractors’ management for the construction and the installation.

In addition, soil (sand) generated from the intake and outfall pipelines installation are planned to be backfilled as well as surplus ones are planned to be used as earth fill for the DSP site.

2) Operation Phase

Based on the DPR (February 2014), solid waste management during the DSP operation are summarized in Table 7.5.10.

Table 7.5.10 Solid Waste Management of DSP

Solid Waste	Description
Screenings	・ Screenings are planned to be disposed of to a municipal landfill.
Limewater Clarifier Waste	・ The waste from the limewater clarifier is planned to be dewatered and trucked from the site as a solid. ・ The total provision for the same has been made in the potablization area.
Spent Membranes	・ Spent membranes are planned to be disposed of to a credited inert landfill. ・ Those membranes need to be rinsed with fresh water (or permeate) prior to disposal.

Source: DPR, February 2014

It is considered that wastes generated from the staff and laborers of DSP will be called as "domestic solid waste. Table 7.5.11 shows the data on staff and labours for DSP operation and domestic solid waste generation from DSP.

Table 7.5.11 Domestic Solid Waste of DSP

Category	3 (shift)/day	Operation 7days/week	Waste Unit (in 2011) (kg/person/day)	Total Waste/week (kg/week)
Staff	80	560	0.571*	319.76
Labour	100	700	0.571*	399.70
Total	180	1,260	0.571*	719.46

*Data of the Kanchipuram District (Source: Sustainable Solid Waste Management in India by Ranjith Kharvel Annepu Department of Earth and Environmental Engineering Fu Foundation School of Engineering and Applied Science Columbia University, New York, Jan 10, 2012)
Source: JICA Study Team

- As shown in Table 7.5.11, a total of 0.72 ton/week of domestic solid waste generation can be predicted in the DSP operation phase.
- According to the Nemmeli DSP, the domestic solid waste in the operation phase is disposed of by a local solid waste management/service contractor on weekly basis.

(4) Soil Contamination

1) Construction Phase

Soil contamination caused by oil and fuel spills from dump trucks, other trucks and heavy equipment can be predicted during the construction work (DSP) and the installation work (Pipelines). However, it is considered that those spills are temporal troubles which can be managed by daily visual inspection, stopping lane and load and unload position management, and can be avoided by the use of dump trucks, other trucks and heavy vehicles and equipment maintained properly and periodically.

- For the management of oil spills, the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules 2008 India shall be referred.

2) Operation Phase

Soil contamination caused by domestic wastewater from the DSP is predicted during the operation phase. In this regard, as summarized in Table 7.5.9, the waste water from DSP is planned to be treated with a waste water treatment facility which is planned to be installed.

(5) Noise and Vibration

1) Construction Phase

During the construction work, heavy vehicles and equipment, and a truck as well as electrical drills to be used will generate noise with the following circumstances.

- As noted in Item (1) of Subsection 7.5.5 it can be considered that 24 - 33 dump trucks/day in gross, 6 - 8 other trucks and earth movers and several number of equipment/day/in gross are operated for the 42-month construction work (DSP), and 0.4 - 0.6 dump truck/day/km and 0.2 - 0.3 heavy equipment/day/km in gross are operated for the 48-month installation work (Pipelines).
- Noise standards for automobiles, domestic appliances and construction equipment's have been notified in Part 'E', Schedule-VI of Environment(Protection)Rules,1986, as amended on 19th May,1993, as given in Table 7.5.12.

Table 7.5.12 Noise Standards for Automobiles, Domestic Appliances & Construction Equipment

Category		Noise limit in dB(A)
Vehicle	(a)Motorcycle, scooters and three wheelers.	80
	(b)Passenger Cars	82
	(c)Passenger or commercial vehicles up to 4 MT	85
	(d)Passenger or commercial vehicles above 4 MT and up to 12 MT	89
	(e)Passenger or commercial vehicles exceeding 12 MT	91
Domestic Appliances/ Construction Equipment	(a)Window air conditioners of 1 ton to 1.5 ton	68
	(b)Air Coolers	60
	(c)Refrigerators	46
	(d)Diesel Generator for domestic purposes	85 - 90
	(e)Compactors(rollers), Front loaders, Concrete mixers, Cranes(movable), Vibrators and Saws	75

Source: Part 'E', Schedule-VI of Environment(Protection)Rules,1986, as amended on 19th May,1993, http://envfor.nic.in/citizen/specinfo/noise.html

- Table 7.5.13 shows the permissible exposure noise level in case of continuous noise levels regulated in the Building and Other Construction Workers' (Regulation of Employment and Conditions of Service) Central Rules, 1998.
- Therefore, in cases where well maintained such vehicles and equipment for the construction and installation are used by the contractor(s), the permissible exposure noise level in case of continuous noise levels can be satisfied in 8-hour work per day for the construction.

Table 7.5.13 Permissible Exposure in Case of Continuous Noise

Total time of exposure (continuous or a number of short-term exposures) per day (in hours)	Sound pressure level (in dB (A))
(1)	**(2)**
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
¾	107
½	110
¼	115

Notes: - (1) No exposure in excess of 115 dB A is to be permitted. (2) For any period of exposure falling in between any figure and the next higher or lower figure as indicated in column (1), the permissible sound pressure level is to be determined by extrapolation of a proportionate basis.

Source: SCHEDULE VI, the Building and Other Construction Workers' (Regulation of Employment and Conditions of Service) Central Rules, 1998

- In addition, due to the fact that the DSP project site is an open and flat land as well as the pipelines are installed under the existing roads, it is considered that noises generated from several number of those trucks and equipment to be used during the construction phase are diffused into surrounding ambient environment.

- Generally, noise at construction site can be regarded as a simple sound source whereby noise level will decrease by 6 dB as distance doubles because such noise is inversely proportional to the square of the distance.

As far as vibration concerned, piling for the foundation of DSP is the only activity which discharge vibration to surrounding environment in the construction phases of DSP. An "Earth Auger" is planned to be utilized as necessary construction equipment for the piling of which vibration level is evaluated below.

- Vibration level discharged by the operation of "Earth Augers" is in a range from approximately 50 dB* to 62 dB* at the position of 7 m.
- Therefore, the vibration of "Earth Augers" have a smaller range compared to Vibrohammers (4kW and over: approx.70-92dB) *, Hydraulic pile hammers (8-8.5t: approx.85-92dB) * and Diesel pile hammers (4t and over: approx.70-92 dB) * at the position of 7m.

(*Source: The Ministry of the Environment, the Government of Japan, https://www.env.go.jp/air/sindo/const_guide/full.pdf)

2) Operation Phase

According to DPR (February 2014) and the JICA Study Team, Table 7.5.14 summarizes leading facilities which generate operation noises in the DSP.

Table 7.5.14 Noise Generating Facility in the Perur DSP

Facility	Noise Generation (dB(A))	Installation
Pump Station	85	Interior Installation
In-house power generation (DSP)	105	Interior Installation
In-house power generation (Sub-station)	105	Interior Installation
RO Pumping	60-90*	Interior Installation

*: Facility with less noise generation specification is planned to be procured in the Project.

Regarding the DSP, the facilities are planned to be installed inside of relevant buildings to be constructed on the premises of DSP. Due to the fact that the DSP site is an open and flat land, it is considered that noises generated from such facilities are diffused into surrounding ambient environment. In addition, noise at DSP is generally regarded as a simple sound source whereby noise level will decrease by 6 dB as distance doubles because such noise is inversely proportional to the square of the distance. Therefore, it is considered that noise levels in outside of those buildings can be reduced to the national noise standard of 75 dB (day)/ 70 dB (night) in industrial area (Noise Pollution (Regulation and Control) Rules 2000) in the surrounding environment.

Regarding the transmission pipelines, no noise is discharged by the pipeline operations at all.

(6) Ecosystem

1) Impact by Intake and Outfall

The EIA report (2014) summarizes possible impacts on marine environment caused by the construction and operation of intake and out fall pipelines including attached facilities and discharge brine as well as mitigation measures against such impacts as shown in Table 7.5.15 in which technical proposals in the JICA Study are incorporated for making a comparison.

Table 7.5.15 Impact on Marine, Mitigation and Proposal on Intake/Outfall Facilities

EIA Report				Technical Proposal in the Study (See Subsections 6.4.2 & 6.4.3)
Activity	Impact	Duration of Impact	Mitigation	
Trenching for Intake and Outfall pipelines	Trenching will disturb the sea bed resulting in loss of seagrass beds and associated benthic communities	Temporary	Use of good engineering tools like cutter suction dredger for trenching to be used	Trenching for intake and outfall pipelines is proposed ・ Silt fences (Pollution Control Equipment) are utilized for controlling turbid water during the construction of trenches for the pipelines. ・ The construction periods are considered for 100 days (dredging) and for 70 days (back-filling).
	Increased turbidity affecting the photosynthetic process of the water column	Temporary	Controlled method of dredging with the latest technology which will limit the plume generation	
	Suspended Particles will affect the filter feeders and adult fish will migrate from the site of impact	Temporary	To minimize the spread of suspended particles, silt screens may be deployed.	
Seawater Intake head	Entrapment of fishes and other organisms.	Continuous	Installation of bars with < 10cm opening, subsequently screens with 3mm opening, region covered for 50m radius with nylon mesh having 1cm opening to avoid entry of fishes and fish larvae. The entry should be only sideways with a limiting velocity of < 15 cm/s.	Deep Water Intake having velocity cap and screen is proposed. ・ The intake velocity is limited to 0.15 m/s ・ The bar screen of 0.3 m width is installed
	Entrainment of smaller organisms such as fish larvae.			
Outfall Diffuser	Increased salinity	Continuous	Faster dilution of moderately high salinity levels to ambient levels.	Port riser type is proposed because its brine diffusion efficiency is the best among all types of Outfall Diffuser
	Chlorine concentration	Continuous	Chorine concentration to be maintained below 0.2 ppm	・ Chlorine (Cl_2) dosing rate to intake sea water is designed to be 1 ppm maximum. ・ Residual Cl_2 concentration will be approximately 0.5ppm at the outlet of pretreatment system by consuming Cl_2 in the intake and pretreatment processes. ・ Discharge Cl_2 concentration will be 0.15 ppm = (210*0.5+470*0)/680. (Pretreatment discharge water = 210 MLD, RO Brine = 470MLD, Total = 680MLD) ・ To protect the RO membrane from chlorine attack, Sodium Bisulfite (SBS) is injected for removing Cl_2 at the inlet of the RO membrane. Accordingly, the brine has no chlorine as calculated in above equation. ・ Usually injected amount of SBS in the RO feed water shall be sufficient enough for safety reason. ・ So, the brine contains an excess SBS which can reduce the discharge Cl_2 concentration in the discharge. During normal operation, the Cl_2 concentration of the discharge from DSP can be maintained less than 0.2 ppm.

Source: EIA report 82014) and JICA Study Team

With regard to chorine concentration in the table, the EIA report (2014) explains as follows.

- The residual chlorine present in the return water will affect the animal community living in the area.
- Prolonged exposure of aquatic organism to chlorine at concentration as low as 0.01 mg/L (or even less to especially sensitive species) can be toxic.

The relationship on the explanation of "Chlorine" in Table 7.5.15 and the EIA report noted above can be considered as follows.

- "The General Standards for Discharge of Environmental Pollutants Part -A: Effluents" of the Environment (Protection) Rules, 1986 stipulates that "Total residual chlorine (mg/l) Max. discharged to marine coastal areas is 1.0 mg/l.
- As summarized in Table 7.5.15, "the Cl_2 concentration of the discharge from the Perur DSP will be maintained less than 0.2 ppm" which is regarded as 0.2 mg/l in water..
- Therefore, the maximum concentration value discharged from Perur DSP will be 0.2 mg/l which is 20% of the General Standards of 1.0 mg/l.

In addition, impacts on the marine ecosystem by brine can be explained as follows.

- Rare and endanger species, and corals have not been identified in the adjacent waters around Perur (See Appendix 7.1).
- Based on "Study on current diffusion situation of the brine from the existing Nemmeli DSP (See 6.4.3 of Chapter 6)", prediction on the salinity concentration is a range from 38 ppt to 40 ppt (Max.) against 35 ppt at the present value.
- The increasing rate of the salinity can be calculated about 5% (or 105%) as the maximum of which areas are to be limited around the outfall.
- According to a scientific research paper[1], impact on marine organism caused by response to changes in the concentration of sea salinity is "salinity resistance (osmotic adjustment)" which is reported as follows.
  - Maximum vital possible seawater salinity concentration for invertebrate organisms: 120%
  - Vertebrate animals maintain the salinity from 1/3 to 1/4 of seawater salinity; Namely the maximum of sweater salinity of 133% can be maintained).
- Generally, fish species take action of avoidance behavior in high salinity concentrations under the sea.

With regard to seabed bottom sedimentation during construction, the following are proposed as specified in Table 7.5.15, therefore, no significant impacts on the bottom sedimentation is predicted during the limited construction periods.

- Silt fences (Pollution Control Equipment) are planned to be utilized for controlling turbid water
- The construction periods considered for 100 days (dredging) and for 70 days (back-filling).

In addition, no special substances or a large amount of sludge will not be discharged from the DSP. Therefore, no bottom sedimentation is not predicted during operation phase.

[1] Technical Proposal for Seawater - Mainly, the Treatment of the Wastewater Derived from RO Process- Ikuro TOGO, Bulletin of the Society of Sea Water Science, Japan 69, 84 - 89 (2015)

2) Sea Turtles

According to relevant publications and documents on sea turtles, 5 different species (Olive Ridley *"Lepidochelys olivacea"*, Green *"Cheloniamydas"*, Leatherback *"Dermochelys coriacea"*, Hawksbill *"Eretmochelys imbricate"* and, Loggerhead *"Caretta caretta"*) of sea turtles have been identified in seawater body in India (Bay of Bengal and Arabian Sea). Of these, Olive Ridley has been observed around seawater body in the Tamil Nadu State (See Figure 7.5.2).

By GOI and IUCN (International Union for Conservation of Nature and Natural Resources), the Oliver Ridley turtles have been designated as follows:

- Wildlife Protection Act, 1972 of India has designated Olive Ridley as Schedule 1, by which hunting is prohibited.
- IUCN Red List has designated Olive Ridley as Vulnerable (VU) (likely to become endangered unless the circumstances threatening its survival and reproduction improve)

Source: Sea Turtles of India, 2011, Madras Crocodile Bank Trust

Figure 7.5.2 Sea Turtle Distribution in India

Source: Sea Turtles of India, 2011, Madras Crocodile Bank Trust

Figure 7.5.3 Migratory Route of Olive Ridley

Based on relevant documents[2], reports[2] and web site information[2], including interviews with an expert[3] on sea turtles at the Madras Crocodile Bank Trust as well as an officer[4] of the Nemmeli DSP, the nesting and egg-laying activities of Olive Ridley around Perur DSP project site can be summarized as follows.

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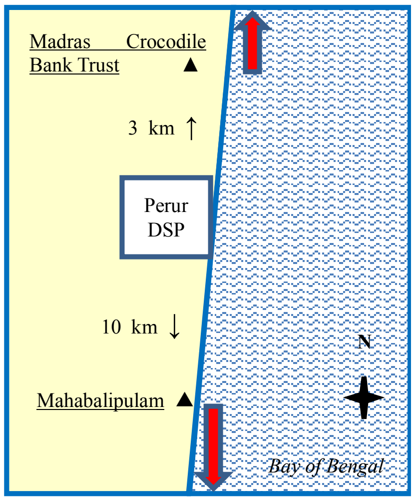
[2] Documents, reports and web site information on sea turtles reviewed are as follows
- SEA TURTLE CONSERVATION, BEACH MANAGEMENTAND HATCHERY ROGRAMMES, A GOI-UNDP PROJECT MANUAL 2003 Centre for Herpetology / Madras Crocodile Bank Trust, Tamil Nadu.
- SEA TURTLE CONSERVATION RESEARCH AND MANAGEMENT TECHNIQUES, A GOI-UNDP PROJECT MANUAL 2003 Centre for Herpetology/Madras Crocodile Bank Trust, Tamil Nadu
- Impact of Casuarina Plantations on Olive Ridley Turtle Nesting along the Northern Tamil Nadu Coast, India 2009 Swapnil A. Chaudhar i, K.V. Devi Prasad and Kar tik Shanker
- Sea Turtles of India, A Comprehensive Field Guide to Research, Monitoring and Conservation Dakshin Foundation, Bangalore & Madras Crocodile Bank Trust, Mamallapuram 2011
- TREE FOUNDATION HATCHLINGS DATA – March 2008 Tree Foundation
- Annexure 1 Turtle nesting conservation plan around the Project area, 2015 CMWSSB
- Olive ridley sea turtle, Wikipedia, https://en.wikipedia.org/wiki/Olive_ridley_sea_turtle (Original Source; Ernst, Carl H.; Barbour, Roger W.; Lovich, Jeffrey E. (1994). Turtles of the United States and Canada. Washington [u.a.]: Smithsonian Inst. Press. ISBN 1560983469)

[3] Mr. Nikhil Whitaker, Head Curator of Madras Crocodile Bank Trust, Tamil Nadu

[4] Mr. K.Syed Amir Basha,CTO & Head Nemmeli Operationsr

- It can be considered that seashore around Perur is a migratory route of the Olive Ridley sea turtle (Refer Figure 7.5.3).
- Most observations are typically within 15 km of mainland shores in protected, relatively shallow marine waters (22 - 55 m deep) and Olive Ridleys are occasionally found in open waters. (Source: Olive ridley sea turtle, Wikipedia)[2]
- In the Perur DSP project, however, the intake pipe is planned to be installed in a distance of 1,140m at the sea depth of 10m and the outfall pipe is planned to be installed in a distance of 1,760m at the sea depth of 12m.
- Based on above recognitions, therefore, the surrounding area of intake and outfall pipes are considered out of the sea turtle migratory route.



Source: JICA Study Team

Figure 7.5.4 Possible Nesting Area of Sea Turtles

- According to the reviews of relevant documents[2] and reports[2], nesting and egg-laying activities of Olive Ridley have mostly been observed in northern part from the Madras Crocodile Bank Trust located at approximately 3 km north of the Perur DSP site, and southern part from Mahabalipuram located at approximately 10 km of the Perur DSP site. (See Figure 7.5.4)
- It can be considered that such nesting and egg-laying activities on seashore around Perur have been discouraged due to impacts caused by developments and human activities (habitats, Fishery, especially lighting in the night) in the area (Source: Head Curator of Madras Crocodile Bank Trust)[3].
- To a question about sea turtle nesting conversation in and around the Perur DSP site as one of the requests placed from TNSCZMA before the 86th TNSCZMA meeting held on 30th Sept. 2015, CMWSSB officially replied similar explanations noted above to the CZMA dated on 26th Oct. 2015. (See Appendix 7.6).

(7) Hydrology

Table 7.5.16 summarizes hydrological situations around the transmission pipeline routes.

Table 7.5.16 Hydrological Situations around Transmission Pipelines

Hydrological Point	Main pipeline route	Branch pipeline route	Installation Methods
Culverts* (total number)	153 (places).	6 (places)	Open-cut method will be applied for the installations.
River crossing points	Buckingham canal (Ch. 1450-1500 and 12750-12800).	-	The pipeline will be installed along a bridge road over the canal.
	Adyar River (Ch. 51600-51850).	-	The pipeline will be installed along a bridge road over the river.
Lakes/Ponds (Either side of the transmission pipeline route)	Two Lakes (Ch. 48200-48550, 59150-59600).	Ch.0-(0-9)	The pipelines will be installed under existing roads along the lakes.
	Five Ponds (Ch. 4650-4750, 5500-5600, 28350-28450, 33450-33600 and 34250-34450).	-	The pipelines will be installed under existing roads along the ponds.

* See Appendix 7.5, Ch.: Chainage; Distance from Origin (DSP for the Main, Branching point around Ch. 33500 for the Branch)
Source: JICA Study Team

With regard to DSP in Perur, there is no surface stream water on the site at all. By Regarding the transmission pipelines, only minor impacts are predicted only at the culvert crossing points during the installation period. However, during the operation phase, there will be no impact at any section of the pipelines.

(8) Living and Livelihood

1) Work Opportunity

Work opportunities of nearby villagers are expected in construction and operation phases by considering the following points.

- About 2,000 people will be deployed during peak construction phase and about 400 personnel will be employed either directly or indirectly during the operation phase which was filled out by CMWSSB in the Form 1 of the application for CRZ Clearance.
- As an example, local people are employed as gardeners and security guards in the Nemmeli DSP at present.

2) Fishery

The EIA report (2014) summarizes possible impacts on fishery caused by construction and operation of intake and out fall pipelines as well as mitigation measures against such impacts as shown in Table 7.5.17. Technical proposals of JICA Study Team are also incorporated in the table. (See Table 7.5.15 for salinity impacts on marine environment)

If any impact on fishery business is observed during construction or operation of intake and discharge facilities, CMWSSB needs to compensate the loss in the fishery business caused the DSP.

Table 7.5.17 Impact on Fishery, Mitigation and Proposal on Intake/Outfall Facilities

EIA Report				Technical Proposal in the Study (See Subsections 6.4.2 & 6.4.3)
Activity	Impact	Duration of Impact	Mitigation	
Trenching for intake and outfall pipelines	Suspended particles will affect the filter feeders and adult fish will migrate from the site of impact	Temporary	To minimize the spread of suspended particles, silt screens may be deployed	Trenching for intake and outfall pipelines is proposed
	Boat movements and fishing activity will be restricted	Temporary	Complete the operation within shortest duration	
Laying of submarine pipelines	Boat movement and fishing activity will be restricted	Temporary	Laying operation may be done in shortest duration within a week	Laying of submarine pipelines
			Barricading the water along the shoreline has to be avoided	
			Install proper marker lights indicating if any obstructions.	
Seawater intake head	Entrapment of fishes and other organisms	Continuous	Installation of trash bars with < 10 cm opening subsequently screens with 3 mm opening, region covered for 50 m radius with nylon mesh having 1 cm opening to avoid entry of fishes and fish larvae. The entry should be only sideways with the limiting velocity of < 15 cm/s.	Deep Water Intake having velocity cap and screen is proposed. ・ The intake velocity is limited to 0.15 m/s ・ The bar screen of 0.3 m width is installed
	Entrainment of smaller organisms such as fish larvae			

Source: EIA report (2014) and JICA Study Team

3) Burial Ground

As explained in the Section 7.4, two locations of burial grounds have been visually identified in the land for the Perur DSP as summarized in Table 7.5.18. At the stakeholder meetings held on 8th July 2016 and 18th August 2016, all participants from surrounding two villages confirmed that there is no such a location in the Perur site other than those two locations.

Table 7.5.18 Burial Grounds in Land for the Perur DSP

Burial Ground	No.1	No.2
Location in DSP Site (GPS Position)	Northwest Area (12° 43.005'N, 80° 13.764'E)	Southeast Area (12° 42.630'N, 80° 13.670'E)
Cluster (Number)	3*	1*
Area (Acre)	1.32**	0.53**
Grave Stone/Marker	22-23 Stones/Markers***	9 Stones***
Religion	Hindu*** and Christianity***	Hindu***
Crematory	2 (New and Old ones) ***	No***
Tube well	3***	No***
Access road	Paved (from ECR to new Crematory)	Not paved (from the Southeast edge to the Grounds)
Photograph	 Grave Stones  New Grave Stone  Access Road  Tube Well	 Grave Stones  Old Grave Stone  Access Road  Damaged Grave Stone

*: Based on a location map prepared by the Revenue Department, GOTN attached in EIA report (2014).
**: Based on a location map prepared by the Revenue Department, GOTN attached in EIA report (2014). However, boundary of each burial ground is not clear.
***: Visual identification
Source: JICA Study Team

- Those grave stones/markers are for Hindu and Christian people.
- Permission on utilization of the areas as burial grounds from the landowner of the religious and charitable trust have not been issued at all (As a result of interviews with the landowner and CMWSSB, it can be evaluated that the owner has given silent approval to use some parts of the land as burial grounds to the surrounding communities).
- Traditionally, vacant lands along the coast have been used as burial grounds by surrounding villagers without any permission from the land owners and the government. (It can be considered that such circumstances of utilization of vacant lands as burial grounds are regarded as a kind of so called "Customary Law" in the social context).
- Therefore, the land owner and relevant official entities including GOTN do not have any definite data and information on the Burial Grounds.
- Meanwhile, there was a similar issue on an existing crematory facility located in the proposed site for the Nemmeli DSP which has been solved as a social consideration by excluding the crematory area from the land layout of the Nemmeli DSP.

- In this regard, those burial grounds in Perur DSP project site are planned to be excluded from the site (as a matter of fact, the layout for Perur DSP in DPR has excluded the two burial grounds from the project site in Perur).

4) Missing Persons by Tsunami Disaster of Sumatra Earthquake

A total of 4 persons has been officially recorded as missing due to the Tsunami disaster caused by the Sumatra Earthquake on 26th December 2004 as summarized in Table 7.5.19. By considering the fact that distances to those missing persons' residences were located in more than 10 km positions from the Perur DSP site at the time of the Tsunami disaster, it can be supposed that there are no possibilities of such missing had been occurred on the premises of DSP site in Perur.

Table 7.5.19 Missing Persons Details of Kanchipuram District due to Tsunami

Name	Age	Sex	Place of Residence	Distance from Perur DSP Site
Selvan. Akarsh	3	M	S/o Vipul Nayar. No.12 Wadders Road, Kilpauk, Chennai-10	Approximately 40km north
Akshit	9	M	S/o Vipul Nayar. No.12 Wadders Road, Kilpauk, Chennai-10	Approximately 40km north
Sangunni Nayar	50	M	C/o V. Nagammal W/o Veeraraghavan Annal Gandhi Street Mahabalipuram	Approximately 10km south
P. Babu	56	M	S/o V. Perumal Reddiar, No.04, Sadras East, D.A.E. Township, Kalpakkam- 603 102	Approximately 20km south

Source: National Information Center, GOI*, JICA Study Team (calculation of the distances)
*(http://www.kanchi.tn.nic.in/Tsunami%20Web%20Project/Missing%20person%20details/missing%20details.htm)

(9) Social Infrastructures and Services

1) Traffic around Perur DSP site

As summarized in Table 7.5.5, 24 - 33 dump trucks/day in gross and 6 - 8 other trucks/day in gross for the 42-month construction period of the Perur DSP. Therefore, it is considered that the traffic congestion of ECR by increase in the numbers of the dump trucks and other trucks is minor and limited for the 42-month construction phase.

With regard to operation phase of the Perur DSP, no impact on the traffic is predicted due to general operation of water supply facility of DSP.

2) Traffic and commercial activities along the Pipelines Routes

Transmission pipelines are basically planned to be installed under the existing roads by the open-cut construction methods. Table 7.5.20 summarizes some significant locations of the installation routes such as areas for utilization of pipe jacking methods, deep excavation, congested traffic and commercial activities. Therefore, some minor impacts on traffic and commercial actives on the surroundings of such areas can be predicted for the installation period only.

As far as possible impacts on the commercial areas caused by the transmission pipeline installations are concerned, the following points have been recognized in the joint site survey by the study team and CMWSSB.

- Widths of those roads facing the commercial areas are relatively wide.
- Therefore, it can be considered that impacts on the commercial areas during installation are small.

- According to CMWSSB, generally for the installation of such pipelines under the existing roads, explanatory meetings in each area and neighborhood are held in advance to explain construction and installation schedules and so on.
- General countermeasures against impacts on the commercial areas to be taken by CMWSSB are that one lane road constructions and construction in the night.

Table 7.5.20 Significant Points on the Transmission Pipeline Routes

Item	Main pipeline route	Branch pipeline route
Pipe Jacking Meted	Ch. 20-80, 44110-44250, 47750-47850, 54600-54700	-
Deep Excavation for crossing Veeranam pipeline	Ch. 11700-11900, 26750-27100, 59550-59650	-
Congested area	Ch. 5700-8600, 39450-45200, 55800-59150	Ch..3-(3-9) and Ch..4-(0-9.5)
Commercial area	Ch. 50-150, 4250-4300, 5500-5600, 7000-7100, 9000-9400, 29250-29400, 34250-34450, 37950-38050, 38650-38850, 39350-41000, 42050-43150, 43900-44050, 45000-45100, 53050-53150, 58800-59150	Ch.1-(2-5)

See Appendix 7.5 for details. Ch.: Chainage; Distance from Origin (DSP for the Main, Branching point around Ch. 33500 for the Branch)
Source: JICA Study Team

(10) Risk of infectious diseases such as HIV/AIDS

It is supposed that migrant workers and laborers with specific skills possibly will be mobilized by contractors for the construction of the Perur DSP and the transmission pipelines. Accordingly, risks of HIV and AIDS for the workers and laborers are considered during the 42-month construction work. In the Tamil Nadu State, AIDS is one of the 21 notifiable diseases declared by the Director of Public Health and Preventive Medicine, the Health and Family Welfare Department of GOTN. Table 7.5.21 shows HIV and AIDS estimates in the Tamil Nadu State in 2011.

Table 7.5.21 HIV Estimate in Tamil Nadu State (2011)

Item		Lower Bound	Estimate	Upper Bound
Estimated Number of People Living with HIV/AIDS (PLHIV)	Total	110,563	132,590	161,038
	Children (<15 yr)	5,143	6,504	8,205
	Adults (15-49 yr)	94,315	113,911	138,535
	Elderly (>49 yr)	11,105	12,175	14,298
	Male	-	91,705	-
	Female	-	40,885	-
Estimated Adult (15-49 yr) HIV Prevalence (%)	Total	0.23	0.28	0.34
	Male	-	0.39	-
	Female	-	0.18	-

Source: State HIV Epidemic Fact Sheets, July 2014, Department of AIDS Control, Ministry of Health and Family Welfare

- A probable number of persons who are HIV positive can be calculated based on 0.28% (Table 7.5.21) among those of the 255,500 construction workers and labours who are planned to be mobilized for the construction work (See Table 7.5.8).
- Namely it is predicted that total 715.4 persons will be HIV positive during the 42-month construction period.
- As regards such risks during the installation work of the pipelines 200,000 persons per day are planned to be allocated for the 48-month installation period (See Table7.5.8).
- Therefore, it can be calculated based on the 0.28% that 560 persons will be HIV positive for the installation labours and workers for the 48-month installation period.

(11) Working Conditions/Work Safety

Considering the nature of general construction work and methods which will be applied for the construction of the DSP, it is believed that working conditions will have nothing special such as using toxic chemical substances and methods required for high-rise buildings. Therefore, work conditions and safety can be managed in compliance with relevant act and rule of GOI as summarized in Table 7.5.22.

Table 7.5.22 Act and Rule on Working Condition and Work Safety in India

Statute	Principal Part/Chapter		Particular Provision
The Building and Other Construction Workers' (Regulation of Employment and Conditions of Service) Act, 1996.	Chapter VI: Hours of Work, Welfare Measures and Other Conditions of Service of Building Workers.		32. Drinking water. 33. Latrines and urinals. 36. First aid.
	Chapter VII: Safety and Health Measures.		40. Power of appropriate Government to make rules for the safety and health of building workers.
The Building and Other Construction Workers' (Regulation of Employment and Conditions of Service) Central Rules, 1998.	Part III: Safety and Health.	Chapter IV: General Provisions.	34. Excessive noise, vibration, etc. 35. Fire protection. 36. Emergency action plans. 37. Fencing of motors, etc. 39. Health and safety policy. 40. Dangerous and harmful environment. 41. Overhead Protection. 42. Slipping, tripping, cutting, drowning and falling hazards. 45. Eye Protection. 46. Head protection and other protective apparel. 47. Electrical hazards. 54. Use of safety helmets and shoes.
		Chapter XVI: Catch Platform and Hoardings, Chutes, Safety Belts, and Nets.	178. Safety belt and its use.

Source: JICA Study Team (tabulated based on the Act and Rules)

In addition, the Bureau of Indian Standards published "Safety colors and safety signs - Code of Practice (First Revisions) on December 2005, as summarized below:

- The standard prescribes safety identification and design principles for safety signs to be used in workplaces and in public areas for the purpose of accident prevention, fire protection, health hazard information and emergency evacuation.
- The standard is applicable to workplaces, all locations and all sectors where safety-related questions may be posed.

(Source: Safety colours and safety signs - Code of Practice (First Revisions), Dec 2005, BIS)

(12) Accidents

Numbers of trucks used for construction are limited as discussed in (1) of the section 7.5.5. Namely several thousands of trucks are not required for the construction. Therefore, rapid increases in the number of trucks in ECR are not considered during the construction phase.

(13) Stakeholders Meetings

1) Stakeholder Meeting 1 (Nemmelikuppam Village)

A stakeholder meeting for the construction project of DSP in Perur was held on 8th July 2016 by the initiative of CMWSSB. According to the Minutes of Meeting (See Appendix 7.7), the following points were explained and discussed at the meeting.

- Purpose of the meeting and Details of the project of DSP in Perur.
- Necessity of 400 MLD of the Perur DSP and 150 MLD of the expansion of the Nemmeli DSP in addition to the present 100 MLD.
- Local Public Opinions and Suggestions for the DSP in Perur.

Table 7.5.23 summarizes the meeting details including participant opinions and countermeasures by CMWSSB as discussed in the meeting. As a result, basically, the local public welcomed the proposed project and agreed to extend their cooperation for the successful completion of the Project.

Table 7.5.23 Stakeholder Meeting 1

<table>
<tr><td colspan="2">Date: 8th July, 2016</td><td>Time: 11:45-12:30</td><td colspan="2">Venue: Community hall, Perur</td></tr>
<tr><td rowspan="6">1. Participants (Appendix 7.8)</td><td>Organization</td><td colspan="2">Name/Title</td><td>Total</td></tr>
<tr><td>CMWSSB</td><td colspan="2">- Sathyamurthi/Chief Engineer (O&M)-II
- Ravichandran/Superintending Engineer (Desal)
- Gnanasekaran/Executive Engineer (Desal)
- Charumathi/Assistant Engineer (Desal)</td><td>4</td></tr>
<tr><td>Trust</td><td colspan="2">- Sivalogam/Manager, (Arulmigu Alavandar Nayakkar Trust: Land Owner)</td><td>1</td></tr>
<tr><td>Local Official</td><td colspan="2">- Parimala/Block development officer(Thiruporur)
- Rajendran/Village administrative officer
- President Nemmeli Village Panchayat</td><td>3</td></tr>
<tr><td>JICA Study Team</td><td colspan="2">- Thenila/Local Assistant (Environmental & Social Considerations)</td><td>1</td></tr>
<tr><td>Local People</td><td colspan="2">- Nemmelikuppam village</td><td>29</td></tr>
<tr><td rowspan="4">2. Main Discussion Points</td><td colspan="2">Opinions from the Village people</td><td colspan="2">Countermeasures by CMWSSB</td></tr>
<tr><td colspan="2">・ Shore erosion caused damage to their houses during execution of the 100 MLD desalination plant in Nemmeli.
・ Hence they requested to provide dykes for a length of 300m approx. for protection before commencement of construction work for the new project.</td><td colspan="2">・ Superintending Engineer (SE) accepted their demand and will be consulting with the implementation team of the project to provide necessary protection.</td></tr>
<tr><td colspan="2">・ Boats and fishing nets are likely to get damaged during dredging for laying of intake pipeline.</td><td colspan="2">・ It will be taken into consideration during execution of the project.</td></tr>
<tr><td colspan="2">・ Public insisted to allocate full stretch of land along East/West encompassing the burial ground which would also allow other commuters to enter burial ground from western end.
・ In addition, public also requested to restore the damaged concrete platform of the temple caused due to soil erosion by waves during the construction of the 100MLD desalination plant in Nemmeli.</td><td colspan="2">・ SE informed that land belongs to Alavandar Trust and has been allotted for this project on “Long term lease basis” by the Government.
・ Hence, this is to be decided in consultation with Alavandar Trust, GoTN and local Revenue department officials.</td></tr>
<tr><td rowspan="2">3. Photograph</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Participants from CMWSSB and the Trust</td><td colspan="2">Participants from the Village</td></tr>
</table>

Source: JICA Study Team and the Meeting Minutes

2) Stakeholder Meeting 2 (Sulerikadukuppam Village)

The 2nd stakeholder meeting for the construction project of the DSP in Perur was held on 18th August 2016 by the initiative of CMWSSB. According to the Minutes of Meeting (See Appendix 7.9), the following points were explained and discussed at the meeting.

- Purpose of the meeting and details of the project of DSP in Perur
- Necessity of 400 MLD of the Perur DSP and 150 MLD of the expansion of the Nemeli DSP in addition to the present 100 MLD.
- Local Public Opinions and Suggestions for the DSP in Perur

Table 7.5.24 summarizes the meeting details including participant opinions and countermeasures by CMWSSB as discussed in the meeting. As a result, basically, the local public welcomed the proposed project and agreed to extend their cooperation for the successful completion of project.

Table 7.5.24 Stakeholder Meeting 2

<table>
<tr><td colspan="2">Date: 18th August 2016</td><td>Time: 11:00-12:00</td><td colspan="2">Venue: Meeting Room in the Nemmeli DSP</td></tr>
<tr><td rowspan="6">1.Participants (Appendix 7.10)</td><td>Organization</td><td colspan="2">Name/Title</td><td>Total</td></tr>
<tr><td>CMWSSB</td><td colspan="2">- Ravichandran/Superintending Engineer (Desal), - Gnanasekaran/Executive Engineer (Desal)</td><td>2</td></tr>
<tr><td>Trust</td><td colspan="2">- Pakkirisami-Clerk (Arulmigu Alavandar Nayakkar Trust: Land Owner)</td><td>1</td></tr>
<tr><td>Local Official</td><td colspan="2">- President, Nemmeli Village Panchayat</td><td>1</td></tr>
<tr><td>JICA Study Team</td><td colspan="2">- Thenila-Local Assistant (Environmental & Social Considerations)</td><td>1</td></tr>
<tr><td>Local People</td><td colspan="2">- Sulerikadukuppam Village</td><td>15</td></tr>
<tr><td rowspan="7">2. Main Discussion Points</td><td colspan="2">Opinions from the Village people</td><td colspan="2">Countermeasures by CMWSSB</td></tr>
<tr><td colspan="2">Due to the implementation of two new desalination plants, their livelihood may get affected and requested to provide permanent employment opportunities per person per family.</td><td colspan="2">SE (Desal) assured that suitable action will be taken to place this issue before the Government through CMWSSB.</td></tr>
<tr><td colspan="2">A relief amount of Rs.300 / day totaling to Rs.9000/ month has to be given to all the members of the Fisherman Cooperative Society of Soolerikattu Kuppam. Further, the villagers had also requested that the Education Fee (school as well as college levels) for the students belonging to their community has to be borne by the Govt.</td><td colspan="2">SE (Desal) assured that suitable action will be taken to place this issue before the Government through CMWSS Board.</td></tr>
<tr><td colspan="2">Protection given for the shore erosion which caused damage to their houses during execution of existing 100 MLD DSP was not of sufficient relief and requested to provide sufficient protection before commencement of construction works for the new projects.</td><td colspan="2">SE (Desal) accepted their demand of providing necessary protective system to the seashore of the village which will be provided in consultation with implementation team of the project.</td></tr>
<tr><td colspan="2">There are chances of further shore erosion in their village due to the implementation of the new plants, which may result in vacating this area completely. Hence, they have requested to provide alternative arrangements for their settlement by Government at free of cost.</td><td colspan="2">SE (Desal) assured that suitable action will be taken to place this issue before the Government through CMWSS Board.</td></tr>
<tr><td colspan="2">The local public requested to consider providing necessary protection in the form of dyke during pipe laying work to avoid further soil erosion at shore near their village.</td><td colspan="2">SE (Desal) informed that the intake / outfall pipeline will be laid below the sea bed by conventional dredging method during non-season time which usually exists for a period of three to four months.</td></tr>
<tr><td colspan="2">It was also informed by local that there are 4 burial grounds existing in this site for an extent of 1.85 acres. Out of which 3 clustered burial grounds located on the north side are accessible from the east & west side and 1 burial ground located on the south side is accessible from south east side. It was also confirmed that there are no other burial grounds than the existing four burial grounds</td><td colspan="2">EE (Desal) informed that CMWSSB would construct a compound wall around the plant leaving the existing burial grounds with suitable pathway for the burial grounds.</td></tr>
<tr><td rowspan="2">3. Photograph</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Participants from CMWSSB</td><td colspan="2">Participants from the Village and Trust</td></tr>
</table>

Source: JICA Study Team and the Meeting Minutes

7.5.6 Impact Examination on Environment and Social

Based on the results of environmental and social consideration study, impacts caused by the project on environment and social are examined as summarized in Table 7.5.25.

Table 7.5.25 Environmental and Social Impact Examination

Category/ No.		Assessment Item	Rating at the Scoping		Impact Assessment by the Study		Reasons
			Con.	Ope.	Con.	Ope.	
Pollution Control	1	Air Quality	B-	C	B-	D	Construction Phase: Dump trucks, other trucks and heavy equipment are to be used for the DSP construction for 42 months and for the pipeline installations for 48 months. ・ Ambient air quality in the construction site will be worsened from exhaust gases from those vehicles if the vehicles are not be well maintained. ・ Soil dust is easily diffused by such trucks and equipment operation during dry season. Operation Phase: Liquefied gas of Chlorine is planned to be used in the DSP operation as follows: ・ Chlorine will be supplied as liquefied gas in 900 kg drums. ・ The system will be configured as a vacuum gas draw system with vacuum valves connected directly to the chlorine drums. ・ Safety measures as per IS 4263 and IS 10553 (Part 1) 1983 are applied.
	2	Water Quality	C	C	B-	B-	Construction Phase: With respect to human waste generated in construction works, "Act and Rule on Working Condition and Work Safety in India" are applied by which necessary sanitation facilities are to be set up with the responsibility of each contractor under the supervision of CMWSSB in the project sites. As for the construction of intake/outfall pipes, turbid water is emerged by dredging and back-filling of trench method. Operation Phase: Waste water from the DSP is planned to be managed as follows: ・ Screenings: wash water is to be returned to screens' upstream ・ Pre-treatment system: All discharges from systems are directed to sea via the outfall. ・ Membrane CIP: After neutralization, the CIP wastewater is directed to sea via the outfall. ・ Domestic wastewater: A STP is constructed in the DSP.
	3	Wastes	B-	C	B-	D	Construction Phase: Construction waste and debris will be managed by each contractor's responsibility under the supervision of CMWSSB. According to CMWSSB, trees planted in the Perur site will be cut before starting the construction of DSP and may be utilized as pulp trees. Operation Phase: Solid waste and sludge of STP generated from the facilities will be collected and disposed of by a waste management service provider, which is to be contracted by the DSP operator.
	4	Soil Contamination	C	C	B-	D	Construction Phase: Oil spills from Dump trucks, other trucks and heavy equipment are predicted. Operation Phase: Waste water from DSP are planned to be managed (see the column of 2 Water Quality)
	5	Noise and Vibration	C	C	B-	D	Construction Phase: Dump trucks, other trucks and heavy equipment are to be used for the DSP construction for 42 months and for the pipeline installations for 48 months. ・ Noise level will worsen in the construction site if those vehicles not be well maintained. ・ As far as vibration is concerned, an "Earth Auger" is planned to be utilized for DSP piling of which vibration level is relatively small. Operation Phase: Noise will be discharged from Pump station, power generations and RO pumping in DSP which will be constructed in robust buildings.
	6	Subsidence	D	D	N/A	N/A	Ground water of DSP site and pipeline routes of the existing roads will not be used for construction/installation and operations. Necessary water of 0.5MLD for the DSP construction is planned to be procured from a nearby source.
	7	Odor	D	D	N/A	N/A	Construction work and methods as well as project operation which cause bad odor are not envisaged.
al Environme	8	Protected Areas	D	D	N/A	N/A	National parks, natural reservoirs and ported areas do not exist in and around the project sites.

Category/ No.		Assessment Item	Rating at the Scoping		Impact Assessment by the Study		Reasons
			Con.	Ope.	Con.	Ope.	
	9	Ecosystem	C	C	C	C	Marine environment and projects are summarized as follows: - Endangered and rare species/ecosystem to be protected and corals do not exist in and around the project sites. - Intake and outfall pipelines are planned to be buried with a trenching method and back filled with native bottom layer sands. - Nesting and egg laying activities of the sea turtles have not been observed around the Perur coast.
	10	Hydrology	C	D	D	N/A	Construction work and methods as well as project operation which may damage hydrology are not envisaged.
	11	Topography and Geology	D	D	N/A	N/A	Construction work and methods as well as project operation which may damage Topography and Geology are not envisaged.
Social Environment	12	Land Acquisition/ /Resettlement	B-	D	B-	N/A	· Necessary lands for DSP in Perur are planned to be leased for 30 years from the land owner of religious and charitable trust maintained by HR&CE Dept. of TN Gov. The Transmission pipelines are planned to be installed under the existing roads. · Trees planted in the DSP site are to be cut without any land acquisition before the DSP construction which are planned to be compensated by CMWSSB.
	13	Impoverished Peoples, Ethnic Minorities and Indigenous Peoples	D	D	N/A	N/A	Ethnic minorities and indigenous peoples do not exist in and around the project areas.
	14	Living and Livelihood	B+/-	C	B+/-	B+	Construction Phase: Minor and limited impacts on fishing activities around Perur seashore caused by installations of intake and outfall pipelines and associated devices are predicted which can though be managed by contractors under the supervision of CMWSSB. On the other hand, at the stakeholder's meeting held on 8th July 2016, the local public welcomed the proposed project and in general, agreed to extend their cooperation for the successful completion of project. As far as possible impacts on the commercial areas caused by the transmission pipeline installations concerned, the following points have been recognized. · Widths of those roads facing the commercial areas are relatively wide. · Therefore, it can be considered that impacts on the commercial areas during installation are small. · According to CMWSSB, for the installation of such pipelines under the existing roads, generally explanatory meetings in each area and neighborhood are planned to be held to explain construction and installation schedules and so on in advance. · General countermeasures against impacts on the commercial areas to be taken by CMWSSB are that one lane road constructions and construction in the night. As positive impact on living and livelihood, there will be possible employment of local people as construction workers and laborers. Operation Phase: As explained in the ecosystem (See Category No. 9.) intake head and outfall diffuser are planned to avoid negative impacts on marine ecosystems. As positive impact on living and livelihood, there will be possible employment of local people as gardeners and security guards at the DSP.
	15	Land use and Regional Resources	D	D	N/A	N/A	There is no possibility of negative impact on surrounding land use and regional resources caused by the DSP and the Pipeline constructions and operations.
	16	Water Right/Use of Water	D	D	N/A	N/A	Construction Phase: Necessary water of 0.5MLD for the DSP construction is planned to be procured from a nearby source. Operation Phase: There are no water right and surface water and utilization of ground water in the DSP site.
	17	Social Infrastructures and Services	B-	D	B-	N/A	· Minor impact on traffic of ECR is considered by increase of the numbers of dump and other trucks for the DSP construction. · Minor impacts on traffic and commercial activities are considered for the installation of transmission pipes.
	18	Heritage	D	D	N/A	N/A	No heritages are identified in the project site.
	19	Social Capital and Social Organization such as decision making bodies	D	D	N/A	N/A	No such social capital and organization is present which will be damaged by the construction and operation of the project.

Category/ No.		Assessment Item	Rating at the Scoping		Impact Assessment by the Study		Reasons
			Con.	Ope.	Con.	Ope.	
	20	Damage and Benefit	D	D	N/A	N/A	No damage and benefit is envisaged by the construction and operation of the project.
	21	Landscape	D	D	N/A	N/A	Project is a construction and operation of DSP facilities.
	22	Gender Issue	D	D	N/A	N/A	Project is a construction and operation of DSP facilities.
	23	Rights of the Child	D	D	N/A	N/A	Project is a construction and operation of DSP facilities.
	24	Risk of infectious diseases such as HIV/AIDS	B-	C	B-	D	Construction Phase: In the Tamil Nadu State, AIDS is declared as one of the 21 notifiable diseases. Appropriate education and instruction to workers and laborers as well as to surrounding villagers on health and sanitation, possibility of outbreak of such diseases especially STD such as HIV/AIDS are required to be implemented by each contractor under the supervision of CMWSSB. Operation Phase: Keeping in view the nature of DSP, it is not predicted that there will be any outbreak of HIV/AIDS by the operation.
	25	Working Conditions/ Work Safety	C	C	B-	D	Construction Phase: Relevant laws and regulations on worker safety for construction work are "Act and Rule on Working Condition and Work Safety in India" which shall be followed by each contractor's responsibility under the supervision of CMWSSB. Operation Phase: There is no construction work in the operation of the project.
Others	26	Accidents	C	C	C	D	Construction Phase: Safety education on traffic accidents, which might be caused by construction trucks and equipment to the drivers and surrounding peoples, are required to be carried out by each contractor under the supervision of CMWSSB. Operation Phase: Education on operational accidents and safety to the staff, and laborers are required to be carried out by a DSP operator as a general requirement for such a facility.
	27	Transboundary or Global Issues	D	D	N/A	N/A	Project is a construction and operation of DSP using RO technologies.
A+/-	: Significant positive/negative impact is expected.						
B+/-	: Positive/negative impact is expected to some extent.						
C+/-	: Extent of positive/negative impact is unknown. (A further examination is needed, and the impact could be clarified as the study progresses)						
D	: No impact is expected.						

Note: Con.: Construction Phase, Ope.: Operation Phase
Source: JICA Study Team

7.5.7 Countermeasures and EMP (Draft)

Considering the environmental and social impact assessment as summarized in Table7.5.25, Table 7.5.26 shows countermeasures and a draft Environmental Management Plan (EMP) for the project.

Table 7.5.26 Countermeasures (Proposed EMP)

Phase	No.	Impacts	Proposed EMP	Implementing Organization	Responsible Organization	Cost and Others
Construction	1	Air Quality*	・ Periodic inspection of exhaust gases of dump trucks, other trucks and heavy equipment to be used. ・ Water spraying for heavy vehicles, equipment and trucks operation on- site in dry season.	Contractor(s)	Supervised by CMWSSB	Visual inspection. Water for the spraying is procured by contractor(s) from outside.
	2	Water Quality	・ Construction and management of on-site toilets for workers and laborers. ・ Utilization of silt screens/fences for the construction of intake/outfall pipelines.	Contractor(s)	Supervised by CMWSSB	Construction water is procured by contractor(s) from out side
	3	Wastes	・ Surplus soil management by back-filling. ・ Construction waste and debris management. ・ Industrial waste management by the use of relevant industrial waste collection and treatment companies. ・ Periodical de-sludge activities for toilets in construction sites by the use of public services or by the service providers. ・ Waste oil (from hydraulic systems and etc.) collection and treatment by waste collection companies.	Contractor(s)	Supervised by CMWSSB	Managed and treated by contractor(s).
	4	Soil Contamination	・ Periodical inspection of such trucks and equipment. ・ Stopping lane and load and unload position management. ・ Spilled oil and fuel management as waste ・ For the management of oil spills, the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules 2008 India shall be referred.	Contractor(s)	Supervised by CMWSSB	Visual inspection.
	5	Noise and Vibration*	・ Periodical inspection of silencers of dump trucks, other trucks and heavy equipment.	Contractor(s)	Supervised by CMWSSB	Visual inspection (common sensation) by contractor(s).
	9	Ecosystem	・ Intake and outfall 【Trenching for Intake/Outfall pipelines】 - Utilization of Silt screens/fences 【Intake head】 - Installation of Deep Water Intake, cap and screen (bar screen of 0.3m width) 【Outfall Diffuser】 - Installation of Port riser type of outfall diffuser (the best brine diffusion efficiency) ・ Environmental education on marine ecosystem as well as habitat of sea turtles to workers, laborers, and surrounding villagers. ・ Preparation of reports of Sea turtle sightings in and around the seashore in Perur to relevant official entities and NGOs. ・ Avoidance of installations of intake/outfall pipelines during the sea turtles during egg laying seasons.	Contractor(s)	Supervised by CMWSSB	Periodic meetings and preparation of relevant notices and warning boards. Setting up sea turtle sightings reporting system
			・ Actions to be taken in cases where sea turtles are observed in and around the seashore in Perur. - Temporary suspension of the constructions for DSP. - Announcement of the existence of sea turtles to contractor(s), construction workers/laborers and surrounding communities. - Contact to relevant NGOs and official entities handling sea turtle conservations and monitoring for getting necessary instructions.	Contractor(s)	Supervised by CMWSSB	Report from CMWSSB to relevant official entities and NGOs which handle protection of seat turtles

Phase	No.	Impacts	Proposed EMP	Implementing Organization	Responsible Organization	Cost and Others
	12	Land Acquisition/ /Resettlement	・ Preparation of an action plan (cutting Schedules, coordination with the Forest Department and/or, TN-Newsprint and Papers, Total value of the trees, Budget allocations, compensation to the landowner, auction systems and management of tree cutting for pulps, waste management, construction vehicle and equipment managements and others) for the cutting of trees in the Perur DSP site.	CMWSSB	CMWSSB	Action Plan for tree cutting
	14	Living and Livelihood	・ <u>Intake/outfall construction management for possible impacts on Fishery:</u> Construction and installation management for intake and outfall pipelines and associated devices to prevent any negative impacts on fishery activities as follows. 【Trenching for intake/out fall pipelines】 - Utilization of silt fences/screens. - Shortest trench construction period. 【Laying of submarine pipelines】 - Shortest laying operation. - Avoidance of barricading the water along the shoreline. - Installation of proper marker lights indicating if any obstructions. 【Sea Water intake head】 - Velocity Cap (<0.15 m/d) - Bar Screen (0.3 m width)	Contractor(s)	Supervised by CMWSSB	Periodic meetings with surrounding communities and grievance redress mechanisms.
			・ Transmission pipelines installation management for possible impact on Living and Livelihood. - If spaces of paddy and/or agricultural lands are required to be used for the following purposes. ➢ transmission pipelines installation/construction works. ➢ utilization as traffic diversions. - Preparation of CMWSSB's compensation plan for utilizations of the such spaces even though for short periods.	CMWSSB	CMWSSB	Meeting with relevant owners of spaces and preparation of CMWSSB's compensation plan
	17	Social Infrastructure and Services	・ Traffic congestion management for construction dumps trucks and vehicles (time restrictions to avoid rash hours and days of surrounding roads of DSP and Transmission pipelines) ・ Setting up of diversion routes (where necessary) and construction time managements especially for commercial areas for the installation of transmission pipelines. ・ Meetings with surrounding communities (where necessary).	Contractor(s)	Supervised by CMWSSB	Meetings with surrounding communities and grievance redress mechanisms.
	24	Risk of infectious diseases such as HIV/AIDS	・ Health and Sanitation education, particularly focusing on infectious diseases including STD to workers, laborers and surrounding villagers.	Contractor(s)	Supervised by CMWSSB	Implemented by contractor(s).
	25	Working Conditions/ Work Safety	・ Preparation of work safety rules and basic personal protective equipment (PPE) such as gloves, helmets, safety shoes and working uniforms based on the relevant rule and act in India.	Contractor(s)	Supervised by CMWSSB	Provided by contractor(s).

Phase	No.	Impacts	Proposed EMP	Implementing Organization	Responsible Organization	Cost and Others
	26	Accidents	・ Compliance with national and local traffic rules. ・ Traffic safety education to the heavy vehicles, equipment and trucks' drivers, and surrounding villagers. ・ Preparation of relevant warning boards and notices based on relevant guidelines in India.	Contractor(s)	Supervised by CMWSSB	Implemented by contractor(s)
Operation	2	Water Quality	・ Periodical maintenance of Screens, Membrane CIP systems of DSP operation, and Sewerage Treatment Plant (STP) based on relevant O/M manuals and instructions of such facilities.	DSP Operator	CMWSSB	Optional Inspection
	9	Ecosystem	・ Cl_2 from DSP shall be maintained less than 0.2ppm at diffuser of outfall. ・ Implementation of environmental education on marine ecosystem as well as habitat of sea turtles to workers and laborers in DSP, and surrounding villagers. ・ Preparation of reports of Sea turtle sightings in and around the seashore in Perur to relevant official entities and NGOs.	DSP Operator	CMWSSB	Periodic meetings and preparation of relevant notices and warning boards. Setting up sea turtle sightings reporting system.

Note: With regard to countermeasures for air quality and noise caused by the use of trucks and equipment for tree cutting activities before the construction phase, same countermeasures specified in the Air pollution are applied to those trucks and equipment for the tree cutting.
Source: JICA Study Team

7.5.8 Monitoring Plan

(1) Monitoring Plan in JICA Study

Table 7.5.27 shows a monitoring plan for the draft EMP which is required to be done by responsible organizations specified in the table in both construction and operation phases. A draft monitoring sheet (in which monitoring sheets for "Monitoring Activities requested by CZMAs (See Table 7.5.28)" and "Marine Environmental Monitoring Proposed in EIA Report" (See Table 7.5.29) are included) is attached in Appendix 7.11. Those environmental monitoring plans shown in Table 7.5.27, Table 7.5.28 and Table 7.5.29 are bundled together in one table in the sequences of per-construction, construction and operation phases as attached in Appendix 7.12.

Table 7.5.27 Monitoring Plan (Draft)

Phase	Environmental Item	Monitoring Item	Location	Frequency	Responsible Organization
Construction	Air Pollution*	・ Visual inspection of discharge conditions of exhaust gases (such as black smoke) of dump trucks, other trucks and heavy equipment and maintenance of the inspection logbook.	Construction site	Daily	Contractors
		・ Visual inspection on soil dust diffusions in dry season for water spraying.	Construction site	Daily (Dry Season only)	Contractors
	Water Quality	・ Visual inspection of back (sewage) water leakage (overflow), bad odour, emergence of vector flies and de-sludge activities) for the on-site toilets	Construction site	Once/month	Contractors
		・ Visual inspection on turbid water in the sea during installations of intake/outfall pipelines	Intake/outfall installation sea areas	Daily for the installation period	Contractors
	Wastes	・ Waste composition, quantity, transportation and treatment methods	Construction site	Once/month	Contractors
	Soil Contamination	・ Visual inspection of leakage conditions of oil and fuel leakages (from Engine, hydraulic power units and fuel tanks) of dump trucks, other trucks and heavy equipment	Construction site	Daily	Contractors
	Noise and Vibration*	・ Visual inspection (common sensation) of silencer conditions of dump trucks, other trucks and heavy equipment	Construction site	Daily	Contractors

Phase	Environmental Item	Monitoring Item	Location	Frequency	Responsible Organization
	Ecosystem	・ Visual inspection on turbid water in the sea during installations of intake/outfall pipelines	Intake/outfall installation sea areas	Daily for the installation period	Contractors
		・ Implementation environmental education on marine ecosystem and sea turtles.	Construction site and surrounding communities	Twice/ year	Contractors/ CMWSSB
		・ Information on Sea turtle sightings in and around the seashore in Perur	Construction site	In the event of Sightings	Contractors/ CMWSSB
		・ Actions on sea turtle sighting (construction suspensions periods, records of the announcements and relevant entities contacted) taken by CMWSSB	Construction site and surrounding communities	In the event of Sightings	CMWSSB
	Land Acquisition/ /Resettlement	・ Implementation of tree cutting action plan (Per-Construction Stage)	Construction site	Once/week	Contractors/ CMWSSB
	Living and Livelihood	・ Visual inspection on turbid water in the sea during installations of intake/outfall pipelines ・ Pipelines installation schedules ・ Installation (Construction) Management	Intake/outfall installation sea areas	Daily for the installation period	Contractors
	Social Infrastructure and Services	・ Implementation of construction vehicle management plans ・ Implementation of commercial area road traffic controls (diversion routes, time restriction) for the instauration of transmission pipelines	Construction site	Daily	Contractors
		・ Implementation of meetings with communities	Construction site and surrounding communities	Where necessary	CMWSSB/ Contractors
	Risk of infectious diseases such as HIV/AIDS	・ Implementation of Health and Sanitation education on STD.	Construction site and surrounding communities	Once/ year	CMWSSB/ Contractors
	Working Conditions/ Work Safety	・ Visual inspection on utilization of PPE by workers/labors	Construction site	Daily	CMWSSB/ Contractors
	Accidents	・ Implementation of Traffic safety education	Construction site and surrounding communities	Once/ year	CMWSSB/ Contractors
Operation	Water Quality	・ Water quality of "Raw seawater and Potable water in DSP as specified in Table 6.3.5,	DSP	Daily	DSP Operator
		・ Concentration of Brine	Sea water at the nearest beach	Daily	DSP Operator
		・ Visual inspection of back (sewage) water leakage (overflow), bad odour, emergence of vector flies of Sewerage Treatment Plant (STP)	DSP	Once/month	DSP Operator
		・ Operational Inspection in accordance with instructions on the STP as suggested by the STP construction contractor.	DSP	As per instructions of the STP contractor	DSP Operator
	Ecosystem	・ Implementation of Meetings on environmental education.	DSP and surrounding communities	Once/ year	DSP Operator /CMWSSB
		・ Information on Sea turtle sightings in and around the seashore in Perur	DSP and surrounding communities	In the event of Sightings	DSP Operator /CMWSSB
		・ Actions (Records of the announcements and relevant entities contacted) taken by CMWSSB	DSP and surrounding communities	In the event of Sightings	CMWSSB

Note: With regard to monitoring for air quality and noise caused by the use of trucks and equipment for tree cutting activities before the construction phase, same monitoring items specified in the Air pollution are applied to those trucks and equipment for the tree cutting.
Source: JICA Study Team

(2) Environmental Monitoring requested by CZMAs

CRZ Notification stipulates the post clearance monitoring which is required to be submitted half yearly compliance reports in respect of the stipulated terms and conditions of the clearance to regulatory authorities. In this regard, in the official CRZ clearance process for the DSP in Perur, KDCZMA and TNSCZMA have made recommendations (See Section 7.3.4) in which several monitoring activities have been included as summarized in Table 7.5.28.

Table 7.5.28 Monitoring Activities requested by CZMAs

CZMA	Monitoring Activity	Frequency	Submitted to
Kancheepuram District (KDCZMA)	Post-project marine quality including water quality and biological characteristics.	Continuous	Not specified
	Marine biodiversity	Twice in a year	MOEF/TNPCB
	Concentration of toxic trace metals in the reject water	Periodical	Not specified
	A moored data buoy shall be maintained in the vicinity of the effluent discharge to continuously monitor the changes in the selected physiochemical parameters (salinity, temperature, DO, current etc.).	Periodical during the construction and operation phases	Not specified
	The high salinity reject water may be periodically monitored for the physiochemical and toxic trace metal contents through appropriate standard procedures.	Periodical	Not specified
Tamil Nadu State (TNSCZMA)	Marine water at the outfall area	Every Quarter	TNSCZMA
	Periodical report on the site conditions so as to take mitigation measures on the event of any adverse impacts on the coast	Every Year	TNSCZMA
	Impact on the corals*, marine organisms, Turtle nesting etc. should be evaluated and monitored through experts (ecologists).	Not specified	Not specified

*: Corals have not been observed around Perur seashore and offshore (See Appendix 7.1)
Source: JICA Study Team based on recommendations from KDCZMA and TNSCZMA

(3) Marine Environmental Monitoring proposed in EIA (2014)

In the EIA report (2014), marine environmental monitoring activities of Seawater & Sediment Quality, Marine Benthic Fauna, and Intake Seawater outfall have been proposed as shown in Table 7.5.29.

Table 7.5.29 Marine Environmental Monitoring Proposed in EIA Report

Monitoring	Purpose	Parameter	Frequency
Seawater & Sediment Quality	To monitor impacts on seawater and sediment quality	Measurements of levels of nutrients and heavy metals in water and sediment samples collected from sides at risk of pollution	Each season: April (Fair Weather), July (SW monsoon) and November (NE monsoon)
Marine Benthic Fauna	To determine the composition and distribution of major groups of fauna	Benthic fauna composition in the water outfall region	Each season as indicated above
Intake	To determine the incidence of entrapment and mortality of marine fauna	Screens on pump stations and effectiveness of management measure	Each season as indicated above
	To determine the impact of entrainment within and external ponds/storage sump/well to assess the loss of fishery	Record abundance of fauna within the pond/storage sump/well	Each season as indicated above
Seawater outfall	To determine the effect of increased temp/salinity on the plankton	Monitor abundance and distribution of both phytoplankton and zooplankton near the outfall	Each season as indicated above
		Monitor abundance and distribution of benthic animal communities near the outfall	Each season as indicated above

Source: EIA Report (2014)

The EIA report has proposed that the results of monitoring shown above can be reported to the relevant authority annually or as required which could include MOEF, State Department of Environment, State Department of Fishery, and State Pollution Control Board.

(4) Possible Monitoring Request from MOEF

MOEF may request any environmental monitoring activities as supplementary conditions in the issuance of CZR clearance for the Perur DSP by referring those recommendations from the CZMAs.

In accordance with those environmental monitoring plans, the following points can be recognized.

- The environmental in and around the Perur DSP can be appropriately conserved and protected in a mutually complementary manner based on those monitoring plans from the JICA Study Team, CZMAs and EIA report as well as may be requested from MOEF.

- Those are the requirements to be conducted by CMWSSB to manage the surrounding environment.

7.5.9 Monitoring System of CMWSSB

At the present there is no environmental division or section in CMWSSB. However, it can be considered that the following circumstances of CMWSSB and the project are effectively functioned as the environmental monitoring system for the project. Namely those functions below can be utilized for organizing the monitoring system in CMWSSB.

- CMWSSB operates the Grievance redressal mechanisms and E-governance.
- The JICA Study has proposed a PIU for the project in which an environmental expert is to be deployed (See Table 9.3.5 in Chapter 9). After the Project, the environmental expert will continue the monitoring work of the social and environmental impacts by the Project.
- An analytical laboratory is planned to be set up in the Perur DSP.

Implementation mechanism of environmental monitoring is presented in Appendix 7.13 for construction and operation phases.

7.6 Environmental Checklist (Draft Final)

The draft final version of the Environmental Checklist (No. 14. Water Supply) of the JICA Guidelines was developed which is attached in Appendix 7.14.

7.7 Recommendations

7.7.1 Construction Phase

(1) DSP

- As per the request from the surrounding people at the stakeholders meeting, enough space for a pathway from ECR to the beach along the burial ground located in the north-east portion of the project site in Perur shall be kept and provided.
- Border lines between the DSP site and each burial ground shall be decided based on the discussions among the stakeholders (CMWSSB, the Trust, HR&CE Dept. and local people).
- In cases where sea turtles are observed in and around the seashore in Perur, the following actions shall be taken by CMWSSB:
  - ✓ Temporary suspension of the constructions for DSP.
  - ✓ Announcement of the existence of sea turtles to contractor(s), construction workers/laborers and surrounding communities.

- ✓ Contact to relevant NGOs and official entities handling sea turtle conservations and monitoring for getting necessary instructions.

(2) Transmission Pipelines

- In cases where any spaces of paddy and/or agricultural lands along the existing roads are required to be used for the transmission pipelines installation/construction works or for utilization as traffic diversions, it is necessary for the utilizations to appropriately be compensated by CMWSSB even though for short periods.
- Time restrictions on installation/construction of the pipelines shall be considered in accordance with social circumstances around the existing roads such as residential areas, commercial activities, traffic congestions, municipal waste collection services and existence of public facilities (such as schools and hospitals) as well as in agreement to relevant laws and regulations.

7.7.2 Operation Phase

In cases where sea turtles are observed in and around the seashore in Perur, the following actions shall be taken by DSP operators and CMWSSB:

- ✓ Announcement of the existence of sea turtles to DSP workers/laborers and surrounding communities.
- ✓ Contact to relevant NGOs and official entities handling sea turtle conservations and monitoring for getting necessary instructions.
- ✓ The environmental expert in PIU shall continue the monitoring work of the social and environmental impacts by the Project in the operation phase.

7.7.3 Complaints and Opinions

Grievance redress mechanisms for the construction and operation shall be set up in cooperation with the existing “CMWSSB Grievance redressal mechanisms and E-governance” and PIU which is proposed by the JICA Study Team.

CHAPTER 8 OPERATION AND MAINTENANCE PLAN FOR THE SEAWATER DESALINATION PLANT

8.1 Objectives of the Study

In this chapter, the implementation plan of the operation and maintenance (O&M) of the Perur DSP has been studied. Security of reliable O&M is one of the key evaluation conditions by JICA to examine the validity of its loan to the Project.

The study begins with an analysis of the implementation structure of the O&M of the existing DSPs and the water treatment plants (WTPs). The analysis includes understanding the roles of CMWSSB and the third parties involved in the O&M and identifying the key issues if any. The best option for the O&M structure for the Perur DSP will be proposed based on the analysis results. If the O&M is outsourced, necessary conditions to be included in the contract or requirement to the plant operator will be proposed through the incorporation of the lessons learned from the existing DSPs.

8.2 Implementation Structure of O&M of Other DSPs and WTPs

8.2.1 Seawater Desalination Plants

Table 8.2.1 summarizes the implementation structure of the existing DSPs as well as the additional units of 150 MLD to be constructed at Nemmeli with financial assistance from KfW.

The existing DSPs adopt different contract types. The Minjur DSP, using the public-private-partnership (PPP) scheme of DBOOT, is owned and operated by a private company. The bulk supply agreement is included in the contract between the CMWSSB and the private operator. The current price is Rs 48.66 per m^3.

On the other hand, the Nemmeli DSP is owned by CMWSSB, and the private operator conducts the O&M under the supervision of CMWSSB with Design-Build-Operation (DBO) contract. According to the contract document, the payment from CMWSSB to the plant operator consists of fixed and variable portions. The energy and chemical costs fall under the variable portion, and the amount that needs to be paid to the contractor is determined based on the actual production volume of water. Any other cost items are included in the fixed portion. From the interviews with CMWSSB, site visits and some O&M data received, the JICA Study Team found no critical problem in the O&M of the Nemmeli DSP, under the DBO contract.

The project of the 150 MLD units at Nemmeli, which is in the bidding stage, adopts DBO contract. The O&M period in the DBO contract will be 20 years, which is much longer than that for the existing units.

Table 8.2.1 Implementation Structures of Other DSPs of CMWSSB

Plant	Minjur DSP	Nemmeli DSP	
		Existing units	Expanding units
Capacity	100 MLD	100 MLD	150 MLD
Operational status	Operational since 25 July 2010	Operational since 22 February 2013	Bidding stage (bid submission date is 7th March 2017)
Finance	Private	Govt of India Grant (State budget)	KfW and State budget
Plant owner	Private	CMWSSB	CMWSSB
Contract type	Design-Build-Own-Operate -Transfer (DBOOT)	Design-Build-Operate (DBO)	Design-Build-Operate (DBO)
Contractor/Operator	Chennai Water Desalination (CWDL)*1*2	VA TTECH WABAG in consortium with IDE Technology	-
Contract period	25 years since 2010	O&M for 7 years	O&M for 20 years

*1: Special purpose company (SPC) held by IVRCL Infrastructure & Projects Ltd. (India) and Befesa Agua (Spain)
*2: EPC contractor of CWDL was a consortium of IVRCL (India) and Abengoa Water (Spain)
Source: JICA Study Team

8.2.2 Water Treatment Plants

CMWSSB entrusted O&M works of WTPs of Puzhal, Chembarambakkam, and Veeranam to private operators. O&M works of the Surapet and Kilpauk WTPs are being conducted directly by CMWSSB, and it is difficult to attract private operators because of its deteriorated condition. The O&M of WTPs, as well as DSPs, is being outsourced by CMWSSB.

From the site visit, as explained in Subsection 3.3.3, Surapet and Kilpauk WTPs, which are under direct O&M by CMWSSB, are not well maintained. It is evaluated that the O&M teams for these WTP would not be able to carry out the O&M of the new DSPs.

8.3 Possible Implementation Structure of the O&M of the Perur DSP

The Project is expected to be financed by the loan from JICA. Hence, any scheme to utilize private finance, such as DBOOT adopted in the Minjur DSP, is not considered. Therefore, the possible O&M structures for the Project are the three options shown in Table 8.3.1. Option A is a direct implementation of O&M works by CMWSSB while Options B and C are outsourcing of the O&M works. Option C is a DBO contract and Option B is an O&M contract, where the O&M contractor will be separately procured from the EPC.

Similar to the cases of the other DSPs, except for the DBOOT case in Minjur DSP, and most of the WTPs, CMWSSB intends to adopt the DBO contract. By including O&M works in the contract, CMWSSB expects that EPC works of the contractor can be more conscientious. In addition, during the O&M period, timely countermeasure and adjustments to any problem can be done by the contractor.

JICA Study Team admits the advantages of the DBO contract that has been mentioned above. DBO contract will be adopted in the Project.

Table 8.3.1 Possible Implementation Structure of O&M of the Perur DSP

	Option	Description	Characteristics	Applicability to the Project
A	Direct implementation	• CMWSSB will carry out the daily O&M works of the DSP. • Some works will be outsourced*.	• CMWSSB needs to employ all necessary operators.	• Low, because currently, CMWSSB does not have enough human resources for O&M works.
B	O&M contract	• CMWSSB will outsource the O&M works to the private operator, who will conduct O&M works under the supervision of CMWSSB. • There are wide options in the roles to be given to the private operator.	• Private operator's roles are determined by the plant owner based on financial viability and their available human resources. • Contract period is sometimes one year when the private operator's service is a provision of labor forces only. • The wider is the role of the plant operator, the longer is the contract period, which is a basic trend.	• High but CMWSSB prefers DBO contract.
C	Design-Build-Operation (DBO) contract	• CMWSSB will outsource the O&M to the EPC contractor under the same contract. • All daily O&M works are conducted by the private operator.	• As all of the O&M works will be entrusted to the private operator, the involvement of CMWSSB in the daily O&M will be very limited. • CMWSSB's daily work will be to order the production. • Contract period tends to be longer for O&M contract. It is at least 3 years and sometimes 30 years for utmost utilization of O&M know-how of the private operator. • Due to the consequent O&M period under the same contract, the contractor's EPC works can be more conscientious and responsible, which is advantageous to CMWSSB.	• High and CMWSSB intends to adopt. • Contract period needs to be studied. • Lessons learned from the ongoing DBO contract need to be studied.

* Possible daily works that can be outsourced are cleaning works, vehicle services, security services, etc.
Source: JICA Study Team

8.4 Terms of Reference of the O&M Work and Contract Conditions

8.4.1 Duration of the O&M Period

There is a wide variety in the duration of O&M period under the DBO contract, some of which adopted for five years and others for 30 years.

Only to utilize the advantage of DBO contract in which the contractor will be more responsible for EPC, initial 10 or 15 years will be sufficient, which is in accordance with the lives of the mechanical and electrical equipment. If the plant owner has an intention to take over the O&M works only after verifying the appropriate functionality of the plant, a shorter period than 10 years, during which initial troubles that may arise in DSPs will be solved, can be adopted.

Nevertheless, the major opinion of CMWSSB is to set the duration for 20 years as the additional Nemmeli DSP of 150 MLD applies. As CMWSSB has no plan to take over the O&M works due to its limited human resources, they need to keep the plant operator as long as possible. On the other hand, the longer O&M period gives the contractor risks of unforeseen troubles in the plant. In bidding documents of most DSP projects worldwide, a requirement for the plant's life is 20 or 25 years.

In the Study, O&M period under the DBO contract of the Perur DSP is proposed at 20 years as presumed by CMWSSB. Alternatively, the JICA Study Team suggests setting the expiration year to coincide with that of the other DSP plants nearby so that the O&M of multiple plants will be integrated into one contract to save the cost and ease the supervision by CMWSSB. The existing 100 MLD plant's contract will expire by the year 2020, and the proposed additional 150 MLD Nemmeli DSP will expire by the year 2040 or 2041 (assuming the construction contract will be completed by 2020 or 2021). The extended period for the existing plant has not been discussed in CMWSSB. Assuming the completion of the construction work of Perur DSP and starting of the O&M work by the year 2022, if the extended period is set at ten years for the existing 100 MLD Nemmeli plant, which is up to the year 2030, eight years of O&M for the proposed 400 MLD plant at Perur will be worth consideration, so that CMWSSB can call for a single O&M contract for both the 100 MLD and 400 MLD, for a further period of 7 or 8 years.

8.4.2 Scope of the Contractor

(1) General scope

Scope of the contractor during the O&M period will be as follows:

a. O&M of the following facilities in the DSP:

- Offshore seawater intake facilities including intake pipeline and onshore pumping station,
- Onshore water conditioning system,
- Pre-treatment system,
- Desalination system by reverse osmosis (RO membrane process),
- Chemical cleaning system,
- Interplant pipelines,
- Chemical storage facilities and dosing systems,
- Post-treatment system including limestone storage and re-charging system,
- Potable water storage excluding transmission pumping station,
- Waste water tank and brine discharge system including pipeline,
- Fire fighting facilities including fire water storage tanks and fire pump house including fire, hydrant network system, potable fire extinguishers and safety equipments,
- Instrumentation, monitoring and control system,
- Electrical power receiving and distribution systems,
- Material handling facilities,
- Repair shop,
- Other non-plant buildings facilities like gate complex cum time office, vehicle parking shed,

amenity building, administrative building, viewing gallery cum guest house including furniture, computers, etc.,

- Boundary wall, inside roads of the plant and green belt,
- Any other facility provided but not mentioned herein, and
- Including all facilities created during the construction contract.

b. Control, regulation and operation of the entire DSP.

c. Preventive and breakdown maintenance of all installations and equipments.

d. Management of the plant in administrative and financial operations connected to the plant management.

e. Training of the O&M staff of CMWSSB.

The scope of work mostly follows the DBO contract, as JICA Study Team views that the scope in the DBO contract covers all works to be conducted by the contractor.

(2) Suggestion to the training of O&M of CMWSSB staff

The JICA Study Team admits the benefits of training the O&M staffs but points out that the purpose and contents need to be clarified in the bid document. As CMWSSB is not going to take over the O&M works, the presumed training course given by the contractor will be only lectures on general topics in O&M of the DSP and short on-the-job (OJT) sessions in the plant. Similar to the case of the existing Nemmeli DSP, general knowledge transfer will be sufficient for the CMWSSB O&M staff in order to supervise the contractor.

However, there is an opinion in CMWSSB that in future they might consider to carry out the O&M by themselves. Furthermore, the JICA Study Team also points out that there is no guarantee that the bid for the extension of the O&M contract, after the DBO contract, will be successful. To be ready for such cases, CMWSSB can request the DBO contractor to carry out the training to develop O&M skill of CMWSSB staffs. The training programs for the cases are suggested as follows:

- General training : 95 mandays (19 persons × 5 days)
- Training for plant operators : 360 mandays (12 persons × 1 month)
- Training for electrical maintenance staff : 60 mandays (2 persons × 1 month)
- Training for instrumentation, control and automation staff : 60 mandays (2 persons × 1 month)
- Training for mechanical maintenance staff : 120 mandays (2 persons × 2 months)
- Training for managerial staff : 180 mandays (1 person × 6 months)

It is noted that the personnel mentioned above are not sufficient to carry out the entire O&M works. The trained personnel are expected to train the other operational staffs to develop a capable O&M team. The necessary number of the O&M team will be approximately 80 persons.

8.4.3 Contract Conditions

(1) Cost items in the contract: Removal of the power cost from the DBO contract

CMWSSB will pay the fixed and variable fees to the contractor. The fixed fee will always be at a constant amount (as quoted by the contractor for that year) while the variable fee will be calculated based on the actual water production. The proposed cost items to be included in the DBO contract are presented in Table 8.4.1.

Table 8.4.1 Cost Items to be Included in the DBO Contract for the Perur DSP

Category	Cost item for	Remarks
Fixed Fee	- Spares, tool and tackles - Administration and management including running of laboratory, workshop, comprehensive O&M, preventive maintenance and cost of lubricants - Consumables and revision and updating of O&M manual	Power cost will not be included in the contract.
Variable Fee	Chemicals	

Source: JICA Study Team

In the DBO contract for the existing Nemmeli DSP, the power cost is included as a variable cost. However, it is proposed that the power cost will be separated from the contract. In the DBO contract, profit of the contractor is generated from the fixed fee portion. Nature of the variable fee consists of only compensation to the contractor for the direct cost. The power cost shares more than 60% of the total O&M cost. By including the power cost in the DBO contract, the contractor is imposed on taxes against the high income, whose major contribution is power cost. Such a high tax on the non-profitable item will only result in the unreasonable increase in the O&M contract price to CMWSSB.

In addition, power tariff is subject to frequent revisions. The tariff revisions will require price adjustment of the DBO contract. Removal of the power cost from the payment item will simplify the procedures, after which CMWSSB will receive the bill from the TNEB and proceed with the payment.

(2) Price adjustment

Price adjustment based on the consumer price index (CPI) will be adapted to all the cost items in the DBO contract. In the existing DBO contract, price adjustment in the O&M work is applicable only to power cost but not to other cost items such as labor cost, chemicals, consumables, etc. However, all these cost items are also subject to price escalation and are beyond the control of the contractor. Application of price adjustment to all the cost items in the contract will be reasonable and will attract more bidders. Besides, due to the price escalation clause, the O&M contract will prevent bidders from quoting abnormal O&M rates as they need not guess price escalation percentage for the next 8 to 20 years of the O&M period.

(3) Penalty to the contractor

Penalties to the contractor will be imposed when it does not satisfy the O&M performances in terms of quality and quantity of water produced, compliance of employment of key personnel, power consumption, and chemical consumption.

The existing DBO contract for the Nemmeli DSP stipulates the following penalties to the contractor:

- For the quality and quantity of water produced: If the contractor cannot produce sufficient quantity of water at required volume to CMWSSB, Rs. 100 per m^3 will be charged.
- For the noncompliance of employment of key personnel: If the contractor does not recruit/depute key personnel identified in the contract, a certain amount will be charged according to the positions of the unrecruited/undeputed personnel. For example, a delay of deployment of general manager will result in a penalty of Rs. 60,000 per month.
- For consumption of excess power as against the specified power consumption agreed: If the power consumption per m^3 is more than the specific power consumption agreed in the contract, a penalty of the same amount as the power cost for the excess consumption will be charged to the contractor.

The penalty needs to function as the deterrent against the intentional lower bid price than the actual possible price as the attempt to win the bid. As shown in Table 8.4.2, there is much difference in the amount of penalties in the case of failures in quantity and power consumption. To ensure fair competition in the bid, penalty on power consumption may need to be more severe than the ongoing DBO contract so that the possible magnitude of the penalty would make the bidders hesitate to do any intentional tampering of the bid price.

Table 8.4.2 Simulation of Penalty Amount in the Existing DBO Contract (100 MLD)

Penalty incident	Penalty policy	Annual penalty amount in case of incompliance by 10%	Percentage against the EPC amount*2
For the quantity of water	Rs. $100/m^3$ for the shortfall	100 MLD × 10% × Rs. $100/m^3$ × 365 = Rs. 365,000,000	5.48%
For consumption of power	Excess power cost caused	100 MLD × 4.0 kWh/m^3 × 10% × Rs. 6.20 / kWh × 365 = Rs. 90,520,000*1	1.36%

*1: Current power tariff is INR 6.20/kWh.
*2: 4.0 kWh/m^3 is a typical specific power consumption in DSPs. EPC amount: USD100 million = INR6.66 billion
Source: JICA Study Team

The penalty on excess chemical consumption is not adopted in the existing DBO contract for the Nemmeli DSP. However, this sanction will be necessary to prevent the dishonest bid. Some bidders may attempt to win the bid by pretending lower chemical consumption than actual possible value. As the chemical consumption is dependent on the raw water quality, the allowable consumption will be calculated by the contractor’s proposal in the bid and the actual turbidity of the raw seawater.

Finally, it is noted that the contractor should be exempted from any penalty when the external operational conditions are beyond the presumption stipulated in the contract, which is generally called as force majeure. Natural disasters, extreme deterioration of the raw sea water, power failure in the external grid, and wars or conflicts are the representative events of force majeure.

CHAPTER 9 ORGANIZATIONAL AND INSTITUTIONAL ANALYSIS AND DEVELOPMENT PLAN

9.1 Present Organizational Situations of CMWSSB

9.1.1 CMWSSB Mandate

Water Supply and Sewerage functions in Government of Tamil Nadu (GOTN) are overseen by the department of Municipal Administration and Water Supply (MAWS). The department executes its functions through local bodies (Corporation, Municipalities and Town Panchayats) and through line agencies (Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) and Tamil Nadu Water Supply & Drainage Board (TWAD)).

Obligations towards Citizens of Chennai Metropolitan Area (CMA) by CMWSSB, as set out under 'The CMWSS Act, 1978' (TAMIL NADU ACT 28 OF 1978 and as Amended up to 30th November 1998) are summarised below:

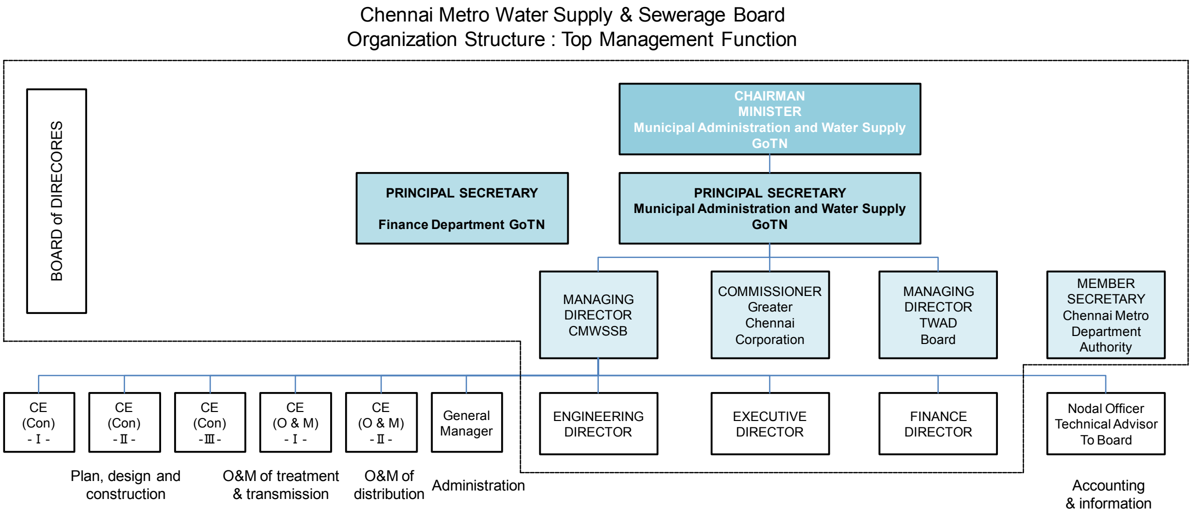
- Promoting or securing planned development, efficient operation, maintenance and regulation of water supply and sewerage system in the Chennai Metropolitan Area (CMA).
- Preparing long term plans to meet the future requirements of water supply and sewerage in CMA, based on the estimates of demand, surveys on availability and usage of water and other relevant matters and periodically reviewing, revising and bringing up-to-date such plans.
- Undertaking development activities with a view to meet the future requirements of water supply and sewerage in the CMA.
- Operating and maintaining the water supply and sewerage services in the CMA to the best advantage of the inhabitants of that area.
- Functions related to water supply and sewerage as the Government may, by notification, entrust to the Board provided that such entrustment shall be with the Board's concurrence, if it does not relate to anything be done in respect to the CMA.

Pursuant to G.O. Ms. No.97, MAWS (Election) Department dated 19.7.2011, coverage of the CMA has been extended; consequently the area under the O&M of CMWSSB has expanded from 174 km^2 previously to 426 km^2, to include 15 Areas Offices, consisting of 200 Depot Offices. As per 'Policy Note (2015-2016)', CMWSSB has established 661,405 water connections and 778,488 sewer connections in CMA.

9.1.2 Organizational Structure

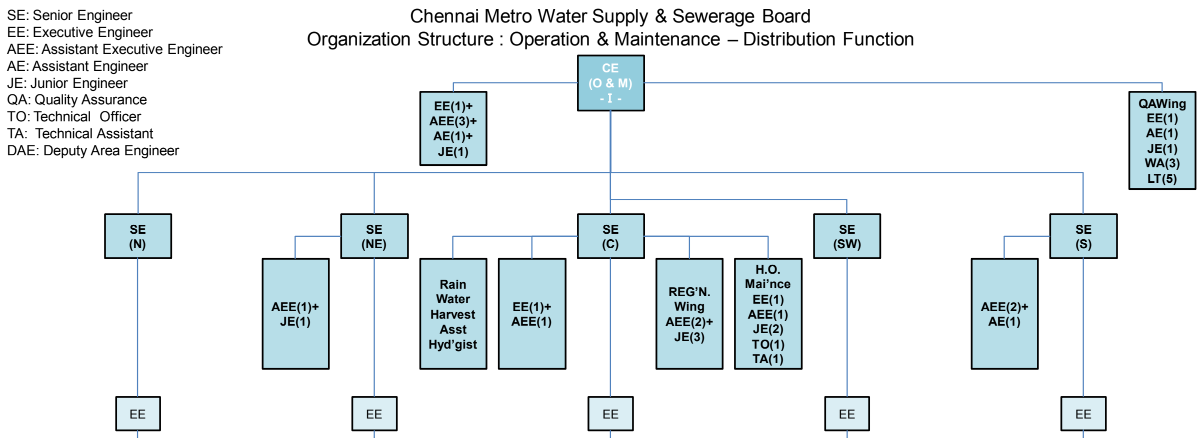
CMWSSB, under the Managing Director, is governed by the Board of Directors. He is amply supported by a sanctioned staff strength of 7,347 employees; of these 748 staff are from the engineering discipline. However, currently, the organization is operating with 42.3% overall staff strength and 68.9% of its engineering team strength. (Refer to Appendix 9.1, Figure A9.1.1 and Table A9.1.1 for Organizational Structure and CMWSSB STAFF STRENGTH).

Board of Directors, and senior functionaries, who constitute the top management, who provide strategic direction, in line with the objectives / functions of CMWSSB, are shown in Figure 9.1.1. The dotted line encompasses CMWSSB Board of Directors. Figures 9.1.2 and 9.1.3 present organizational charts under the Chief Engineer (CE) (O&M) I and II, which are the key areas in the O&M of the water supply system.



Source: JICA Study Team

Figure 9.1.1 Top Management at CMWSSB



Area	The number of DAE/ AE･JE	Responsible Depot
1	4 / 16	1-14
2	3 / 6	15-21
3	4 / 8	22-33

Area	The number of DAE/ AE･JE	Responsible Depot
4	4 / 21	34-48
5	4 / 22	49-63
6	5 / 21	64-78

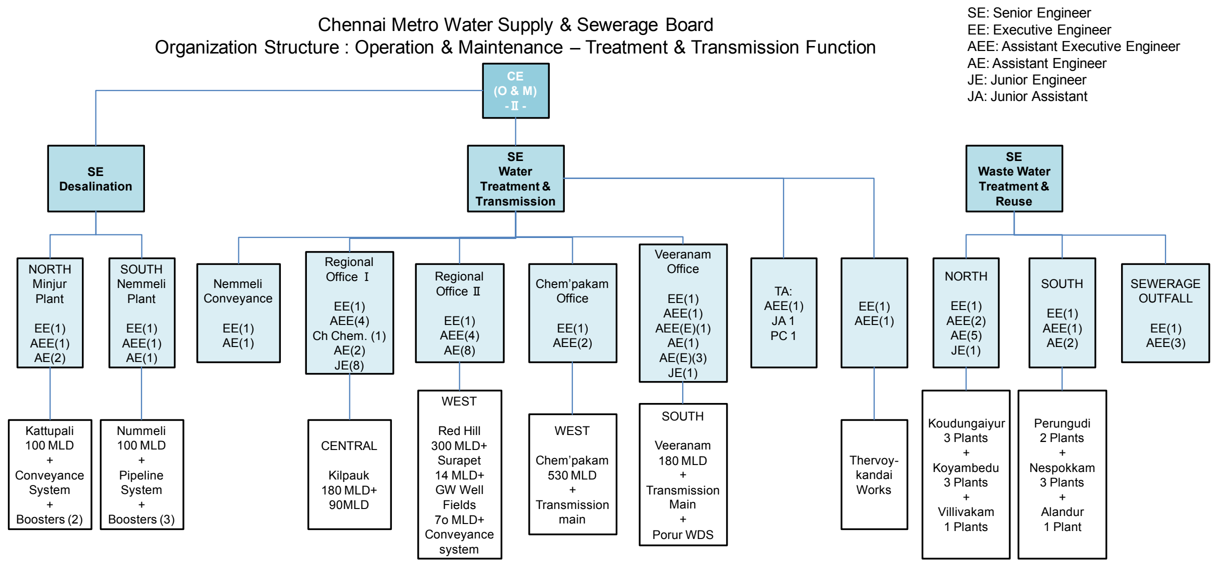
Area	The number of DAE/ AE･JE	Responsible Depot
7	4 / 20	79-93
8	5 / 23	94-108
9	3 / 27	109-126

Area	The number of DAE/ AE･JE	Responsible Depot
10	4 / 23	127-142
11	4 / 13	143-155
12	3 / 10	156-167

Area	The number of DAE/ AE･JE	Responsible Depot
13	5 / 25	170-182
14	3 / 7	168-169 183-191
15	3 / 6	192-200

Source: JICA Study Team

Figure 9.1.2 Organizational Chart for O&M of the Water Distribution Systems



Source: JICA Study Team

Figure 9.1.3 Organization Chart for O&M of the Water Treatment and Transmission Systems

9.1.3 Functional Structure of CMWSSB

Board of Directors are ably supported by line functions who undertake core operational and support services at CMWSSB. Falling under the following heads, brief details of the mandate assigned to each of these departments are provided in Table 9.1.1.

Table 9.1.1 Responsible Tasks Of The Departments In CMWSSB

Area	Headed by:	Responsible tasks
Operation & Maintenance – Water distribution systems	Chief Engineer (O&M – I)	• Managing the distribution of water and collection of sewerage across CMA, • Maintaining various assets linked with water and sewer distribution networks; mobile Water Supply, • Maintaining the quality of water, ensuring it is fit for human consumption as mandated by CMWSS Act.; through its Quality Assurance wing, with its laboratory located at Kilpauk, collect samples, check for residual chlorine levels, carry out bacteriological analyses, monitors hospital for possible cases arising out of contaminated water, • Providing water supply and sewerage connections for new customers, • Grievance redressal, the complaint resolution is undertaken by engineers working out of the Area and Depot Offices, supported by the 24x7 Complaint Redressal Cell at HO, • Facilitating revenue collection at Depot, Area and Head Offices; collections are collated and reconciled at the Area Offices under the supervision of the Area Engineer, • Ensuring adherence to Rain Water Harvesting (RWH) scheme by customers, making periodic field visits to monitor Ground Water parameters, and • Maintaining the estate and other general fixed assets worth Rs. 781.2 million.
Operation & Maintenance – Water treatment and transmission systems	Chief Engineer (O&M – II)	• Maintaining various assets like transmission conduits, filtration plants, water treatment plants, distribution mains, hydrants, boosters and pumping stations, water and sewer distribution networks etc. The total value of fixed assets with respect to water supply was Rs. 29501.7 million for Water and Rs. 12201 million for Sewerage in FY 14-15, and • Overseeing maintenance of contracts for the contractors of the Desalination WTP's and of STP's. Most of the STPs and their respective laboratories are also outsourced which check the bacteriological parameters of the treated effluent before it is let into the rivers.

Construction, Planning & Design (Refer to Table A9.1.2 for Organizational Structure)	Project monitoring teams	• Developing WS & UGSS schemes, involving prioritization of the projects, preparation of DPR and planning of funding for the respective projects, • Planned development of assets to facilitate water supply and sewerage in the 426 sq. km area; involves construction of Water Treatment Plants (WTPs), Desalination plants, Transmission lines, Water Distribution Stations (WDSs), Water Supply Systems (Distribution Network, Water Mains, OHTs, UGTs), Underground Sewer Systems (Sewer Lines, Pumping Stations) and Sewage Treatment Plants (STPs), • Monitoring of project execution by the contractor, in terms of the facilitating all clearances and inspection of project completion (M-book verification), and • Additionally, CE (Con I) oversees the Planning & Design function where the team is responsible for developing DPRs for all types of new assets – WTP, Desalination, STP and other transmission network / distribution network, relaying works, vetting of the designs submitted by the contractor.
Contracts, Materials and Project Monitoring (Refer to Table A9.1.3 for Organizational Structure)	Engineering Director	• All purchases, inventory control, disposal etc. attended to by Materials Department and all contracts are settled by C&M Wing. Schedule of Rates is analyzed and published by the C&M Wing, • Preparing release and award tenders to external contractors; different types of contracts, e.g. DBOOT, Turnkey, and PMC etc., • Preparing tender documents, using standard templates available in CMWSSB, releasing to the public via media, facilitating pre-bid process, selecting via QCBS or L1 system, awarding contract to the successful bidder and issuing Work Order to qualified Contractor, and • Carrying out negotiations and facilitate signing of contract with the successful bidder. The project is then shifted to one of the three Construction Teams (based on geography) for monitoring.
Training (Refer to Table A9.1.4 for Organizational Structure)	Engineering Director	• Making the training calendar, delivery of training to employees of CMWSSB and workers; monitoring preparation of training content; interacting with external / in – house faculty for training delivery, • Acting as a nodal point to facilitate field visits of children from schools / colleges, • Conducting departmental promotion exams for employees, • Performing the library function which houses a collection of 2900 books covering disciplines of Engineering, Technology, Management, Training, Finance and Computers. Also available are operational manuals, specifications and BIS codes, and • Maintaining all guest houses / accommodations for experts and participants.
Personnel and Administration (Refer to Table A9.1.5 for Organizational Structure)	General Manager (on deputation from Revenue Department, GOTN)	• Executing all human resource management tasks from recruitment to retirement, • General administration, recruitment, processing promotions, staff increments, staff leave, adoption of GOTN Government Orders, legal issues, vigilance/disciplinary issues, receipt and distribution of all correspondence, documentation of Board activities, facilitating welfare measures, processing advance payments, health insurance/medical reimbursements, retirement benefits, etc., and • General Manager is also the Secretary to the Board for conducting 'Statutory' meetings.
Finance and Accounts (Refer to Table A9.1.6 for Organizational Structure)	Finance Director	• Finance & accounts, internal audit as well as billing and revenue collection, • Internal book keeping and for identifying sources of finance for the activities of CMWSSB, • Capital and revenue budget preparation, managing funds of the organization, capital expenditure, management of loans / interest payment of loans, • Carrying out regular accounting (books of accounts), processing bills (store / contractor), processing claims, asset related accounting, payment disbursal (Employees / Staff on Deputation /Pensioners / Contractors / Suppliers), payroll (ECS and Non ECS payments, DA revisions, EL encashment, medical bills / advance claims / tours / OPE / TA Bonus payments),

		• Carrying out Pre Audit, Post Audit, Propriety Audit, Stock Audit, Power Audit, Estd. Audit, Financial Transaction Audit, Special Audit (Sewer / Water Applications), • Providing consumer card on establishing new connection, generate bills for metered consumers and flat rate consumers, and generate receipts, • undertaking the overall reconciliation of all payments received, all outstanding receivables are identified from time to time and arrears list generated, • Developing policies / strategies to improve efficiency of revenue operations; collection of arrears involves, raising 'cut off' notices, establishing 'revenue recovery notices', door to door visits; visits along with the engineering team for disconnections, • Attending meetings with Management Committee, Investment Committee and other external agencies, and • Computation/ preparation of statements relating to Statutory Audit, Income Tax, Sales Tax, Service Tax.
Information Technology (Refer to Table A9.1.7 for Organizational Structure)	IT Manager	• Providing IT services to the line departments in the HO and the field offices - for managing the hardware, network and software being used, and provide end user support, • Network maintenance, the internet and intranet connectivity between all Depot Offices, Area Offices and Head Office, • Developing and maintaining mail IDs for all employees; interacting with external agency for ensuring regularity and consistency of network; maintaining CMWSSB's website and update regularly, • Management and maintenance of various databases- consumer database, employee database, stores / inventory etc., • Overseeing the typical server operations that are used, to include servers for Email, Website, File & Print and Operating System, • Troubleshooting hardware / software problems of employees at Head Office and Area Offices, and • New Programming: Any other specific programming requirement that involves minimal customization of existing modules.

Source: JICA Study Team

9.1.4 Decision Making Process

Decisions are taken based on the merits of the issues, relative priorities and availability of funds, in accordance with the documented laid down procedures / defined criteria and rules. The procedures followed in the decision making process, including channels of supervision and accountability, are followed as per prevailing delegation of powers of CMWSSB (updated from time to time).

For initiation of work to be taken up for execution there are three main stages of decision making process as follows:

- Administrative approval (A/A): The formal acceptance of the proposal, to execute a work, by competent authority is termed Administrative Approval of the work. A/A would be awarded by Board of Directors CMWSSB or Government of Tamil Nadu, based on the value of the Project
- Technical sanction (TS): After receipt of A/A, detailed estimates are required to be prepared for TS. TS to the estimate is a guarantee that the proposal is technically sound and that the estimate is accurately prepared and are based on adequate data and appropriate specifications. This entails preparation of Detailed Project Report (DPR) based on adequate data, appropriate specifications, and current schedule of rates. It's then put up for suitable funding (e.g. World Bank, JICA, KFW, GoI, GOTN funds). After receipt of initial agreement from the funding agency TS of the Project is awarded by the Engineering Director / Chief Engineer of

CMWSSB, based on the value of project.

- Financial sanction (FS): FS is accorded to indicate that funds for the project/work have been provided, and liability can be incurred. An order of appropriation or re-appropriation of funds shall operate as sanction to incur expenditure. The funds are provided either in the budget or by supplementary demands or through re-appropriation.

No work would commence or any liability thereon incurred until an A/A has been obtained, DPR is approved with funding, properly prepared detailed estimate has been technically sanctioned and FS has been accorded.

In respect of administrative approval, the process is initiated by the subject dealing members and passes through Assistant Executive Engineer, Executive Engineer, Superintending Engineer, Chief Engineer, Engineering Director, Finance Director, Managing Director and then to Board of Directors.

The process of examination of technical issues is initiated by the subject dealing members and passes through Assistant Engineer, Assistant Executive Engineer, Executive Engineer, Superintending Engineer, Chief Engineer, and finally culminating with the Engineering Director.

During implementation of projects/works till closure, decisions primarily pertain to adherence of financial and administrative decisions approved at the A/A, FS stage respectively along with monitoring the works with respect to specifications laid down and agreed during the TS stage. Variables during the course of implementation are natural and are dealt through decision making process carried out at the review meetings at various levels. Various review meetings, headed by different members of CMWSSB are summed up in Appendix A9.2, Table A9.2.1.

9.1.5 CMWSSB Procurement Process

CMWSSB follows a prescribed procurement process as stipulated by The Tamil Nadu Transparency in Tender Act, (1998) and The Tamil Nadu Transparency in Tenders Rules, (2000). All projects with external funding do not come under the purview of this act / rules. For externally funded projects, the procedure and documents prescribed by the funding agency are utilised; JICA's Standard Bidding Documents and procedure for ODA loans stipulated from 2012 to 2015 will be followed for JICA funded project. Presently, the time-range for any procurement process to be completed is 290-320 days; since JICA's concurrence would be needed after three stages, an additional time of 75 days can be added to this time-range. Procurement procedure follows the sequence presented in Appendix A9.3, Table A9.3.1.

9.1.6 Billing Process at CMWSSB

Under the 74th Constitutional Amendment of GoI and per CMWSS Act, 1978 the Board is allowed to levy and collect charges for the water supply & sewerage services rendered to the citizens of Chennai Metropolitan Area (CMA). For these services, citizens have to pay.

(1) Water & Sewerage tax

This is an integral part, constituting 33.33% of the Property Tax, as assessed by Greater Chennai Corporation (GCC). This one-time assessment in based on Annual Rateable Value (ARV) of the property which is a combination of four factors, viz. Floor Area, Quality of construction, Location of the property in the city and age of the property. The value of Property Tax varies each time the owner modifies his property. CMWSSB has to mandate to collect this tax directly from its customers. The bi-annual amount of Water tax is 3.5% of ARV.

(2) Water & Sewerage charge

As on date, the water charge and sewerage charge per dwelling is Rs. 25 each, totalling to Rs 50.00 per month or based on periodic readings where meters have been installed in such dwellings. Further, all Commercial and Industrial establishments have metered water supply.

Water & Sewerage charge have been detailed out as public information on CMWSSB website. Water & Sewerage tax and Water & Sewerage charges are reviewed by the Board each year but have remained unchanged for the past two decades, other than the addition of Surcharge in the year 2003.

Bills are generated by CMWSSB bi-annually in end of month of June and December, payable by September 30 and March 31 respectively. Property records are updated bi-annually based on inputs from GCC. All citizens who are enrolled with GCC as property tax payers have to pay water and sewerage charge, even if the water supply or sewerage networks have yet to reach their locations. Unpaid bills attract an addition amount in the form of interest on the billed amount.

Customers have the option of making payment by cash or cheque, at: Depot Offices, Area Offices, collection counter at H.O, any branch of the 10 empanelled Banks, through internet, or at counters set up by CMWSSB during specially organized collection drives. During these specially organized collection drives, all SE's (O&M) are given the responsibility for their respective zones. The EE's are assigned targets and they move door-to-door to make these collections. Daily collection is reviewed and monitored by the MD.

Finance and Accounts department is vested with the responsibility of 'Billing and Collection' functions, in addition to their routine accounts functions. There is no dedicated section for undertaking the "Commercial" function at CMWSSB. Water charges and taxes contribute 65% to the total revenue of CMWSSB; this has to be further increased with improved metering, billing and collections. Efficiency of collection of demands is around the 80% and arrear collection efficiencies is about 30%. From the financial data available for the years 2011-12, 2012-13 and 2013-14, there is a negative growth in revenue income from sale of water, from 9 % to 1%; whereas growth in revenue income from water and sewerage tax stagnates at 4 %. This negative trend can be attributed to the following key problem areas in the billing and collection process.

(3) Billing of Industrial / Commercial Customers

Bills of Industrial customers have to be generated on a monthly basis, based on the meter reading (where customers are metered). However, meter reading is not carried out and an average rate is charged; this is mainly due to shortage and age of manpower engaged.

(4) Collections (before due date)

Less than 10% of all collections are through the online option. There is scope for tie-up with other organizations for common collection centres e.g. COC, Department of Post, but these initiatives are yet to be exercised.

(5) Arrear collections

Arrear collections are made through arrear collection drives conducted locally from the depot offices. These drives have limited success owing to shortage of manpower.

Water being an essential commodity, there are several cases of public interest litigations that discourage CMWSSB staff from enforcing ‘connection cut-off’ measures to collect arrear. Erratic water supply by CMWSSB also contributes to public objection to enforcement of ‘connection cut-off’.

(6) Need for specific teams to handle grievances

Grievances with respect to billing and collection, requests for name changes, annual value changes, etc. are currently handled at the Area Office level, efficient handling of such grievances, is yet another area for improvement.

Several complaints arise in the billing and collection process and these are handled by SAOs. Many complaints get escalated to courts of law, especially in the case of water and sewerage taxes. It is necessary to differentiate the SAO’s responsibility from handling ‘commercial’, grievance redressal and accounting; there have to be specific teams to handle each task. Of the existing legal cases faced by CMWSSB pending in the courts of law, 50% are billing and collection related. This causes indefinite delays in payments and hence loss of revenue.

(7) Low level of focus on ‘commercial’ activities (meter reading, and arrear collection)

Owing to manpower shortage and in some cases inaccessibility of meters, meter readings are not taken regularly. The demands are raised using past averages of metered readings. Further, commercial activities and revenue accounting are undertaken by the same team, leading to a situation where by ‘checks and balancing’ is lacking.

9.1.7 Personnel Systems

(1) Recruitment

Emerging staffing requirements at CMWSSB are periodically sent to Employment Exchange, GOTN. Only those candidates, engineers or general functionaries, registered with Employment Exchange, GOTN, are eligible. Among the engineers, entry is at Assistant Engineer level, for those who hold a degree in different engineering disciplines; among general functionaries entry is at Junior Assistant, or Steno Typist level. Candidates included in the list received from Employment Exchange, GOTN, have to appear for an objective-type written exam prepared by ANNA UNIVERSITY, GOTN.

Those who clear the written exam, have to appear for an interview before the recruitment committee comprising members/representative of the Board of Directors, GM, P & A Department Staff, and Senior Engineers (CE/SE). List of selected candidates is prepared as per guidelines prescribed in CMWSSB's GENERAL SERVICE REGULATIONS Section 14. -Reservation of appointment

Appointment letters are mailed to selected candidates. No recruitment is carried out for staff at higher levels other than those mentioned above. However, Senior engineers can be brought in on deputation from other GOTN, Engineering Departments; Senior Administrators are mostly on deputation to CMWSSB, from other GOTN, Departments.

(2) Induction

All new candidates undergo a two-week Induction programme carried out by CMWSSB Training Centre. Induction programme for Engineers includes topics from fields of Engineering, Administration and Finance; the programme is structured to include theory sessions and visits to WTP, STP and construction sites. Induction programme for general functionaries focuses only on Administration and Finance. All candidates continue to be on probation for a period of two years. Their respective candidature is deemed confirmed only on the basis of 'Satisfactory Performance' report furnished by the concerned Superintending Engineer/ Head of Department.

(3) Promotion

Under normal circumstances promotions are carried out over a five year cycle in each employee's service life. Among engineers, for Assistant Engineers to be promoted to Assistant Executive Engineer level, the incumbent has to clear six 'Service Level Departmental Test', conducted by the Training Centre, on the subjects' viz. CMWSSB Act 1978, CMWSSB Office Manual, CMWSSB Service Regulations, Material Management, and Accounting Manual (Lower). For non-technical staff there are five tests on, 'Accounting manual of the board', 'Budgeting, Billing and Collection', 'Elements of Auditing', 'Business Organization and Management', and 'Elements of Book Keeping'.

An elaborate promotion procedure for every level is in place at CMWSSB and is well defined in the document titled SPECIAL REGULATION 1982 (AS AMENDED ON UPTO 29.02.2008)

Based on the availability of vacancies, a 'panel of candidates' is prepared and approval sought from the Board of Directors. Recruitment and Appointments wing of CMWSSB's P&A Department, facilitates the promotion process. All promotions are based on comments in the 'Annual Confidential Report' (ACR) –these include self appraisal, plus comments of the Scrutinizing Officer and Reporting Officer. One or two adverse remarks over a period of five years are generally overlooked; however three such remarks puts a halt on the incumbent's promotion.

The above process is applicable to promotions from AE upto EE level. For promotions from SE to CE to Engineering Director level, special approval is sought from Pr. Secretary, MAWS Department

GOTN. The G.O. is signed by the concerned Minister.

(4) Retirement

P&A Department, facilitates the retirement process for all staff attaining 58 years of age (except for Office Assistants, where the retirement age is 60 years). Last day of the month of completing 58 years is the last working day for the employee.

Approval is sought from the Board of Directors for all retiring employees from AE to SE level; for retiring employees above SE to Engineering Director level, special approval is sought from Pr. Secretary, Municipal Administration & Water Supply Department GOTN.

As a special case, extension can be granted for the service of an extraordinary employee to be extended; however, such an extension has never been sought nor requested.

(5) Staff benefits

On retiring from service, each staff member enjoys financial benefits in the form of pension, gratuity, and Employee Provident Fund; the total amount is remitted to her/his account on last working day of service. (no pension will be available to staff who joined CMWSSB after 2006). Every retiring staff member receives a memento and a gift at a send-off function presided over by the MD of CMWSSB.

Employment is provided to ward's of employees, on compassionate grounds, who expire during their term of service.

Pongal Festival gift/bonus, an annual monetary gift of Rs. 2000/- is given to all staff of CMWSSB, with the exception of the lowest level of employees i.e. Office Assistants, drivers, guards, labour etc. who are given an amount equivalent to 8.33% of their basic pay; all pensioners receive a sum of Rs. 1000/-.

Each employee can request for a salary advance in the form of loan to meet the expenses of marriage, buying a car, building a house, purchase a computer, attaining higher education. Festival advances are also available which are deduced from the salary in 10 equal installments.

Free medical services are available to all employees and their family members under the health service scheme. Expenses incurred due to special medical conditions are reimbursed by taking approval of the Board. All employees can avail the Leave Travel Allowance, once in every 4 year cycle, whereby based on the basic pay, expenses incurred during leave is reimbursed.

Cellular phone, with a specified call limit is provided to each employee (except to the labour). CMWSSB owns a limited number of Lower Income Group houses, which are allocated to a select few, and are charged a nominal amount as rent.

Every employee completing 20 years to service at CMWSSB, is presented with a Certificate of Service, along with a memento, and a GOTN Savings Certificate worth Rs. 2000/-.

(6) Disciplinary process

Complainant could be the General Public or staff member of CMWSSB; with complain coming to light, an Enquiry Officer is appointed, enquiry conducted and he submits his report to the General

Manager. Detailed disciplinary process is elaborated in Chapter VI of GENERAL SERVICE REGULATIONS (1978). Based on the verdict the necessary action is taken.

While the process is underway, the persons 'Promotion' process is withheld till clearance of the case. The process has an impact on the 'Retirement benefits' of the person against whom the complaint has been filed.

9.1.8 Human Resources Development and Staff Training

Training centre was established in 1982 in collaboration with National Water Council of UK (with ODA financial assistance) with the objective to enhance staff capacity to meet present and future challenges in their present and future jobs along with boosting staff efficiency and self confidence.

Governing council approve training related policies. The council has MD as the Chairperson, Executive Directors is the Vice Chairman, along with Finance Director, Engineering Director and Director (Training) as members. Director (Training) is the Secretary to the Council. MD conducts monthly review meeting to assess past work, future requirements and issues pertaining to the Training Centre.

Training Centre conducts in-house training programmes for CMWSSB staff along with CPHEEO sponsored training. Each year, an average 1000 staff undergo training at the centre. Training conducted at the Centre is categorized under six heads as below;

- Operation and Maintenance
- Water Quality
- Sewerage disposal
- Human Resource Development
- Project Management
- Financial Management

It's worth noting that the overall pattern has not undergone any major change since its conception in 1982. Though, modifications are introduced annually after due approved by the council. No study tours have been conducted by the Training Centre since 1993 due to Governments austerity measures.

CPHEEO sponsored training have courses titled:

- Sewerage Work Supervision (10 days),
- Corrosion control (5 days),
- Care and use of chlorinators (5 days),
- Filter Operations (7 Days), and
- Laying of water mains and sewer mains (5 Days).

Faculty are drawn from ANNA University, Scientists of SERC, NEERI, Board of Apprenticeship Training TARAMANI, along with retired Engineers from CMWSSB and TWAD Board.

Special training are conducted for the staff of various Municipalities in Tamil Nadu and special practical field training programme to the field workers emphasising the safe operational procedure of the machineries while working in the sewer system.

Other functions facilitated by Training Centre staff include i) conducting interviews of new entrants/candidates who have successfully cleared their written exams, ii) conducting Induction Programmes for new entrants, and iii) conducting Departmental Exams for staff promotions.

Facilities at the centre include three lecture halls which can accommodate 30 participants, conference room to accommodate 75 persons, hostel accommodation for 14 participants, a library and Administration building. Training expenses during FY 2015-16 totalled Rs. 190,000/- and Rs. 290,000/- has been budgeted for FY 2016-17; Centre's till date maintenance cost is Rs. 440,000/- and Rs. 190,000/- has been budgeted for FY 2016-17. There is no Library budget, hence no new books, publications or journals can be procured.

9.1.9 Utilization of External Resources - Outsourcing

The following functions/tasks are outsourced by CMWSSB:

- All geophysical/geotechnical investigation and topographical survey works
- Design of special works like desalination plant
- Operation and Maintenance of all WTP's and STP's as part of DBO contracts; except Kilpauk WTP
- Operation and Maintenance of all Sewerage Pumping stations; initially for seven to 10 years with contract revision every three years
- Two out of three old STP's, both at Koddangaiour and Koyambedu are outsourced; O&M at the remaining one at each location is managed by CMWSSB staff
- All construction works
- Creating an archive of Consumer Data is outsources to Tata consultancy Services (private IT firm)
- Hiring of water supply tankers
- All vehicles used by CMWSSB staff, (except MD, select CE's, and Area Engineers), are outsourced on annual rate contract

NB: Individual experts cannot be hired. Special skills/advisory requirements can be obtained in the form of consultancy contracts.

9.1.10 Operation and Maintenance of Water Supply Facilities

(1) Operation and Maintenance Structure of CMWSSB

The O&M activity in CMWSSB is currently split across two teams. The first team under a Chief Engineer O&M-I is responsible for managing the distribution of water and collection of sewage across the 15 areas and 200 depots of the Chennai Corporation. The second team under a Chief Engineer CE

O&M-II is responsible for water treatment facilities and water transmission, and sewage treatment and transmission of treated effluent for disposal and reuse.

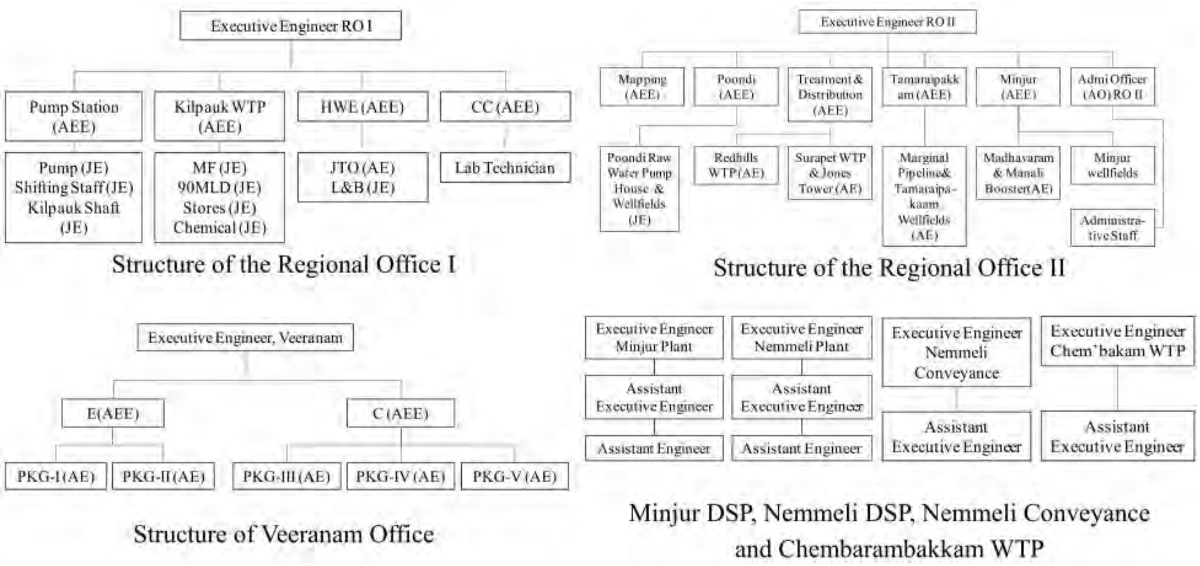
The Chief Engineer O&M-I is assisted by five (5) Superintending Engineers (SEs) in turn assisted by fifteen (15) Executive Engineers (EEs) also called Area Engineers. For water treatment facilities and water transmission, the Chief Engineer O&M-II is assisted by two (2) SEs as SE for Desalination facilities and Water Treatment and Transmission in turn assisted by seven (7) EEs as 2 EEs for Desalination facilities, 5 EEs for water treatment and transmission. Name of the office, Facilities under their control and Responsibility of the EEs are given in Table 9.1.2.

Table 9.1.2 Name of the Office, Facilities under Their Control and Responsibility of the EE

Name of Office	Facilities under their control	Responsibility
Desal Minjur	- Minjur SWRO Plant 100 MLD - Minjur Product water transmission system - 2 booster pumping stations	- Monitoring and coordinating of Minjur SWRO Plant O&M contracting agency's activity according to the contract - Full responsibility for operation and maintenance of Minjur Product water transmission system and 2 booster pumping stations
Desal Nemmeli	- Nemmeli SWRO Plant 100 MLD	- Monitoring and coordinating of Nemmeli SWRO Plant O&M contracting agency's activity according to the contract
Nemmeli Conveyance	- Nemmeli Product water transmission system - 3 booster pumping stations	- Full responsibility for operation and maintenance of Nemmeli transmission system and 3 booster pumping stations
Regional Office I	- Kilpauk WTP 270MLD	- Full responsibility for operation and maintenance of Kilpauk WTP
Regional Office II	- Surapet WTP 14 MLD - Groundwater wellfields 70MLD - Conveyance system - Redhills WTP 300MLD	- Full responsibility for operation and maintenance of Surapet WTP and groundwater wellfields - Monitoring and coordinating of Redhills O&M contracting agency's activity according to the contract
Chembarambakkam WTP	- Chembarambakkam WTP 530MLD - Transmission system	- Monitoring and coordinating of Chembarambakkam WTP O&M contracting agency's activity according to the contract - Transmission system
EE (Veeranam)	- Vadakuthu WTP 180MLD - Transmission System - Porur head works	- Monitoring and coordinating of Vadakuthu WTP and related transmission facilities O&M contracting agency's activity according to the contract
EEs for Area 1 to 15	- All Water Distribution Stations (WDS) & Transmission mains located in the Greater Chennai Corporation - 200 Depots - Distribution networks - Services connections	- Monitoring for WDSS O&M contracting company. - Full responsibility for operation and maintenance of transmission mains, distribution networks and service connections in the Greater Chennai Corporation. - Installation of new service connections.

Source: JICA Study Team

The Organization Structure of O&M and SWRO Plant under Executive Engineers are shown in Figure 9.1.4.



Notes: Assistant Executive Engineer (AEE), Junior Engineer (JE), Head Works Engineer (HWE), Chief Chemist (CC), Mechanical Filter (MF), Assistant Engineer (AE), Junior Telecom Office (JTO), Land and Building (L&B), Personal Clerk (PC),
Source: CMWSSB compiled by JICA Study Team

Figure 9.1.4 (Clockwise) Organization Structure of O&M of WTP and SWRO Plant under Executive Engineer

(2) Issues related to O&M activities

1) Inadequate staff recruitment

According to the sanctioned strength of Regional Office as of March1, 2016, number of posts is 304 and posts filled up are 120 and posts vacant are 184. Posts of higher level engineers such as Executive Engineers, Assistant Executive Engineers have been filled up, however Junior Engineers, Electrical Operators, Electricians and so on who actually work directly at the sites have become vacant due to retirement/promotion. There is always a shortage of lower level staff due to inadequate staff recruitment and insufficient staff allocation made by CMWSSB.

2) Staff training and staff skill

In CMWSSB, there is a training centre for giving training to technical and non technical staff of CMWSSB such as Assistant Executive Engineer, Assistant Engineer, Junior Engineer, filed worker and so on. The technical and management courses relating to the O& M of water supply system are being conducted in the following modules:

<u>Technical courses:</u>

- O&M module including concepts & principles involved in rerouting for major works and trenchless technology, record maintenance, O&M of desalination plants, safety practices in handling equipment.

- Water quality module including water quality assurance & monitoring, management of monsoon/drought.

Management courses:

Project Management module including materials management, contracts management, work management system, integrated project management, procurement & quality testing, selection of mechanical & electrical equipment for water supply system.

Staff skill:

Previously training in detailed operation and maintenance practices such as O&M of filter back wash, installation of the distribution and service pipe, repairing method of the water supply facilities were given. However, currently such training have been stopped because CMWSSB has changed the policy to outsourcing of operation and maintenance functions. This is one of the reasons for reduction in O&M capability among the lower level staff.

3) O&M contracting company

Many of the contracted O&M companies for Water Distribution Station do not have required knowledge of the equipment and their operational details. The company engages persons for operation of facilities having required qualifications but without adequate training in fields such as pumping station. This is causing improper operation and maintenance.

As mentioned in Subsection 3.3.3, contracting O&M companies for WTP are also in the same situation as above except at Chembarambakkam WTP, there is better O&M for Chembarambakkam WTP because the same company that designed and constructed the WTP is in charge of operation and maintenance so they know the system. Since construction skilled staff has been assigned for the purpose. However the seven year O&M period for which the construction company had taken responsibility has ended and it is not certain whether the same company will be able to get the O&M contract for the next five years in the open tendering process of CMWSSB. The strict criteria of the pre-qualification for the O&M contract are essential for procurement of outsourcing O&M company.

9.1.11 Communications with Citizens

As part of its communication strategy, CMWSSB utilizes a variety of means to reach out to its customers. These include

(1) CMWSSB Website

CMWSSB utilizes the facilities extended by National Informatics Centre (NIC), Tamil Nadu State centre under its e-governance project.

(2) Citizen's Charter

With the objective of maximum outreach to all the residents of Greater Chennai city and to make its functions transparent, accountable plus accessible, CMWSSB has followed a Citizen's Charter since 1998. The current version is the third revision since 2003. The same is available on the organizations web site

(3) Annual Industrial Fair

CMWSSB participates in this 90 day event, organized by GOTN Tourism Development Corporation, every January to March.

(4) Publication

1) Annual report

Technical section compiled in-house by Executive Engineer (Contracts & Monitoring) and the Financial section is provided by the Chartered Accountant of CMWSSB

2) Pamphlets/ Handbills

To promote themes like Conservation of Water, Good Sanitation Practices, Rainwater Harvesting through special drives.

3) Special Project Booklets

Contents include project details and CMWSSB activities

4) Annual Training Calendar

Contents include list of In-house training details and CPHEEO sponsored training details

(5) Media usage

CMWSSB promote themes like Conservation of Water, Good Sanitation Practices, Rainwater Harvesting through special drives using Newspaper, Radio and TV announcements/advertisements. Media is made use of to reach out to the citizens during situations like drought conditions, floods or social health outbreaks.

(6) Grievance redressal process at CMWSSB

The water supply and sewerage network of CMWSSB extends over 426 km2, being managed out of 15 Area Offices, which in-turn oversee the operations of 200 Depot Offices. Complaint resolution is undertaken by CMWSSB’s Area and Depot engineers, wherein the complaints received can be classified under following heads, viz.

- No water supply / Defective water supply
- Contaminated water / Water pollution
- House sewer blocked
- Sewer overflow

- Sewer main blocked
- Delay in installing new connection
- Dial for water: Tanker supply

For grievance redressal, CMWSSB maintains multiple channels of logging the complaint, the complete redressal process is illustrated as a series of actions in the matrix in Table 9.1.3 below

Table 9.1.3 Grievance Redressal Process

STEP	ACTIONS
1	Customer can communicate the grievance to CMWSSB by following means: a) Online: Log into the CMWSSB website and register complaint. b) Calling 45674567: Call 24x7 Central complaint cell. c) Calling Depot Engineer/Area Engineer: Call corresponding Engineer's mobile number. d) Meeting Depot Engineer/Area Engineer: Log complaint directly at respective Engineer's office. e) Open house meetings: Customer file complaint during weekly open house meeting at Depot Office or at the meeting held every 2nd Saturday (10.00 AM - 14.00 PM) at Area Offices.
2	• If the complaint has been filed through methods a) and b) above, the complaint is logged onto the Oracle system by the Head Office Complaint Cell. • If the complaint has been filed through methods c), d) and e), the complaint is received directly by the Depot Engineer and entered in the log book.
3	Those complaints received by the Head Office Complaint Cell, are logged onto the system at the Head Office and communicated to the corresponding Area Engineer.
4	Area Engineer forwards the complaint received from the Head Office Complaint Cell to their corresponding Depot Engineer.
5	Depot Engineer, on receipt of the complaint, allocates his labor workforce to attend to the corresponding complaint. The labor workforce uses the required method to resolve the complaint. Once the complaint has been resolved, the labor workforce reports back to the Depot Engineer.
6	Once the labor workforce confirms closure of the complaint to the Depot Engineer, the complaint is closed on the oracle system by the Depot Engineer. He then forwards these closed complaints to Area Engineer, who forwards it to the Head Office Complaint Cell for logging.
Notes	• Area Engineer conducts Depot inspection visits during weekly open house meeting and carries out site visit to locations of unresolved complaints along with corresponding AEE & AE. • Each SE is allocated one Area and he participates as observers in the open house meeting held at Area Offices • Area Office prepares Action Taken Report for previous month and submits to Head Office. • Instant attention is paid to "Special action complaints" got from C.M. Cell or Office of Mayor GCC

Source: JICA Study Team

(7) Key Challenges

On an average, 150 complaints are received each day and this figure doubles during the monsoon months. Of these, 99% of the complaints are received by Area/Depot offices located in the Chennai Core City. The upkeep of such an extensive network can be challenging. Some of these challenges, needing attention, have been segregated with respect to 'Front end' and 'Back end' operations and are enumerated below

1) Front end

Improving customer's perception of water supply and sewerage management, simplifying the customer interface processes, reducing delays and improving efficiency and introducing public participation in monitoring mechanism to ensure that grievances reported are addressed within defined timelines, as per the Citizens' Charter are three such areas of concern

2) Back end

These challenges include, introducing convergence and logging of all complaints into one system, which are received through the multiple interfaces; complaints are received by Head Office Grievances cell, or communicated through the MD's /Executive Director's/ Chairman's office, or directly to Area engineer / Depot engineer. Revamping the system for better monitoring of the efficiency and quality of resolution is yet another necessary change; difficulty is that the person responsible for the activity is possibly the same person logging and reporting on closure. Only 33% of the complaints received directly through call to the Area/Depot Engineers are logged on the online system. There is a need for introducing modification in the system to draw focus on 'repeat complaints' or similar complaints, current system captures the number of pending complaints only. Grievances relating to 'Billing and Collection', 'reported graft/corrupt practice' need further study.

9.1.12 Business Plan of CMWSSB

Currently, CMWSSB uses "Master Plan for Water Supply and Wastewater Management for Chennai Metropolitan Area" as its basic document for planning its future actions. CMWSSB does not have any Business Plan document to share at this point in time. It will be JICA Study Team's endeavour to provide CMWSSB officials with the guidelines to prepare a Business Plan which will reflect the aspirations during the next twenty years i.e. up to 2035 to support scaling up of improved water supply and sewerage services for the city of Chennai.

The plan will set out baseline for the performance of CMWSSB, using service level benchmarks, its priorities and aims for the future. Business Plan will be a guide to implementation of projects and reforms to be undertaken by CMWSSB. In addition, the Business Plan would provide a basis for additional resource mobilization to enhance the credit worthiness of CMWSSB. The 'Business Plan' will answer the questions, "Where is CMWSSB now?", "Where does CMWSSB want to be?" and "How is CMWSSB going to get there?".

Where is CMWSSB now?: CMWSSB is responsible for the administration and operation of Chennai city's water production, treatment, distribution, and wastewater collection and treatment including regulatory compliances. The current situation will be exemplified by the values of the key financial indicators.

Where does CMWSSB want to be?: CMWSSB's approach will be to address both the vertical chains of reform in policy, accountability, technical capacity and resource allocation as well as the horizontal framework of coordination, learning and cooperation so that people of Chennai receive timely and adequate resources and capacity development support to implement programs that are aligned with priorities to ensure access to safe water and sanitation.

9.2 Organizational Evaluation and Recommendations

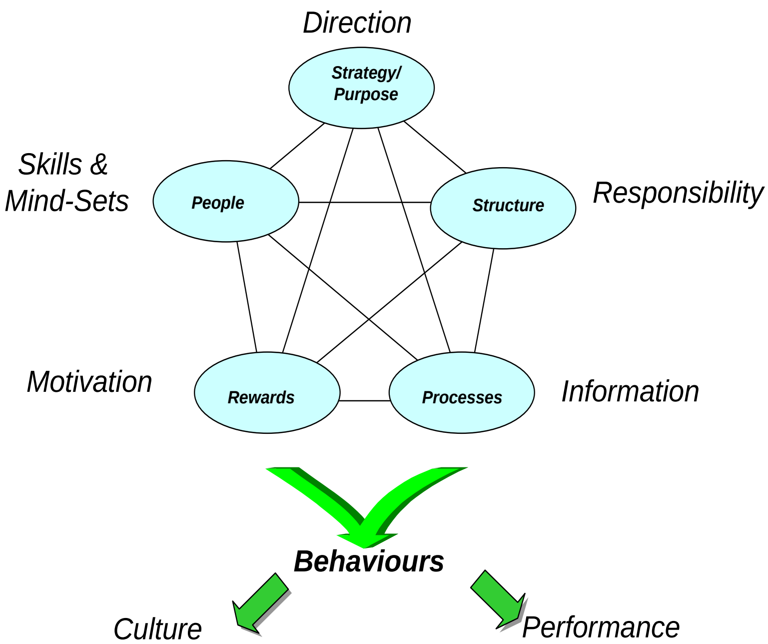
9.2.1 CMWSSB Organizational Strengths

Observations and deliberations have helped culling out the following strengths which exist in the organization.

- CMWSSB enjoys significant attention and support from Government and financial institutions
- City's cosmopolitan culture is a motivating factor for CMWSSB to act professionally
- CMWSSB has technically qualified staff, with prior experience in seawater desalination projects
- Rich experience in building large infrastructure projects on PPP format.
- Enormous scope for development
- Most labour is on contract - low overheads and less labour related problems
- CMWSSB has a strong updated database
- CMWSSB has spacious office accommodation
- Willingness of the Board to carry out reforms

9.2.2 CMWSSB - Organizational Areas for Improvement

The basic model that is to be followed in the organizational strengthening of CMWSSB is an adaptation of J. R. Galbraith's "Star Framework" as presented in Figure 9.2.1 below:



Source: Adapted from Galbraith

Figure 9.2.1 J. R. Galbraith's "Star Framework"

During this first study phase, interaction and observations have resulted in a collection of organizational challenges / issues faced by CMWSSB management and staff, and these “areas for improvement” which have been enumerated below:

(1) Strategic Issues

Strategy point towards the activities are most necessary, however the following strategic aspects have been found to be missing or require attention at CMWSSB

- Lack of clarity on mandate (e.g., Engineers handle legal issues; perform commercial /collection task, involved in Loan / Grant arrangement with limited involvement of staff from the Finance Department).
- Systematic mechanism to plan, monitor, review and regulate is missing with respect to Business Plan, Tariff Setting and NRW reduction
- Deficiencies exist in effective human resource management policy, poor manpower planning over the past years is impacting work output; career path development is missing which has lead to stagnation at various levels. Performance management is limited to filling of the ACR, no performance targets are set or reviewed per quarter; transfer policy is not linked with workload, cause is always attributed to shortage of staff

(2) Structural Issues

Structure determines the placement of area of specialization and authority in the organization. The following functional specialization departments /units are missing at CMWSSB

- Cost control unit,
- Asset management unit,
- Commercial unit,
- HRM and Knowledge management unit;

(3) Processes and System Issues:

Processes are central to the effective functioning of an organization. These processes need to be supported by dual or multidimensional information systems. Those which have been found to be deficient at CMWSSB are bulleted below

- Modern IT tools, yet to be included in the processes and systems are
  - MS Office, Prima Vera software are not available for Project Management; contractors submit PERT/CPM hardcopies, no online monitoring carried out.
  - Computerized Asset management system,
  - GIS mapping of distribution network, remote sensing
  - Usage of SCADA is yet to be applied to its full potential.
- Customer care – computerized logging of complaints is limited to the HO, Depot level

continues to follow traditional logging method.

- Procedures are time consuming and require simplification to remove the bottlenecks e.g. clearing of contractors' bills by Accounts and Audit departments.
- Project Contract period continue to be based on financial value rather than on site condition linked Project Management principles.
- Irrespective of variable/difficult site conditions, 'expenditure incurred' is the only 'success indicator' considered;
- Benchmarks / performance indicators set at the national level are accepted without giving consideration to local elements and further, process to measure achievement is not institutionalized;
- Lack of delegation/decentralization of authority delays decision making; updation of delegation of powers (Rs 7.5 million limit) has not be occurred since the last 15 years, all technical sanction of estimates, based on current schedule of rates, reach the Engineering Directors desk for clearance.
- Quality Audit is not exercised at CMWSSB;
- Poor access to data and information, improved documentation needed;
- Formal coordination mechanism with stakeholders needs to be evolved (feedback mechanism); last customer / social survey was carried out in 2006, Bi-Annual social survey is another area for improvement.

(4) People - HRM Issues

Human resource is the talent required by the strategy and structure of the organization, generating the skills and mind-sets necessary to implement the chosen direction. Gaps that have been identified at CMWSSB are stated below

- Work load analysis required to match geographical spread, manpower and other resources (vehicles) - rightsizing of all units for "adequate" and "appropriate" human resources is needed; deficiency in mobility of staff is more pronounced at remotely located projects as well as for O & M works.
- Feeling of 'demotivation'/'missing ownership' exists among CMWSSB staff due to lack of time bound promotions;
- Need exist to enhance competence by building capacity on emerging factors like, environmental management, IT skills, PPP issues, social issues including - community mobilization, IEC, gender, R&R;
- CMWSSB Training policy document needs to be drafted; TNA based objective oriented training is needed; exposure visits for updating technical skills as well as for learning new skills such as contract management, construction management, and overall project management.

(5) Cultural issues

Behavioral attributes and customers' perception about an organization matter a great deal. The following statement is reflective of CMWSSB culture - "Reactive organizational culture, majority time spent in crisis management"

9.2.3 Recommendations on the Organizational Development

It is to be ensured that organizational redesign is not going to be just about changing the structure; instead all the five elements need to be aligned and consistent. Several organisational issues have been identified above, based on feedback gathered during interactions with stakeholders, which currently hamper the performance of CMWSSB staff.

These need to be addressed and forming five Task Forces (one per category), with the mandate and authority to resolving them, could be one such mechanism of doing so. If not addressed, these issues will continue to hamper progress and never allow an 'evolutionary environment' to exist in CMWSSB.

Since the project's overall objective is to maximize sustainable water services and improved service level for citizens' of Chennai, key strategic, structural and HRM issues with respect to Business Planning, Asset management, HRD, Tariff Setting and NRW reduction have been dealt in Section 9.4 'Organizational Strengthening Plan'.

9.3 Project Implementation - Procedures and Decision Making Process

9.3.1 Relevant Authorities Involved

The list of relevant authorities involved with Seawater Desalination Plant Project, PERUR and their respective roles, including the estimated processing time for their respective actions, have been presented in Table 9.3.1 to 9.3.3 below

Table 9.3.1 Roles of Agencies in Government of Tamil Nadu

Agency	Role	Estimated Processing/Action time
Chennai Metropolitan Water Supply and Sewerage Board, GOTN	• Project Executing Agency	Full term of Project
Municipal Administration and Water Supply Department, GOTN	• Issue Government Order (GO) granting Administrative and Financial approval for the project. • Borrower of Yen Loan will be Municipal Administration and Water Supply Department, GOTN	3 – 6 months
Department of Finance, GOTN	• Grant 'Financial approval' for the project. • Sanction Annual Budget, route finances during the project construction phase • Annually monitor, audit and report expenditure to GOTN.	Full term of Project
Tamil Nadu Urban Infrastructure Financial Services Limited (TUIFSL), GOTN	• Got 3rd Party Technical Review/ proof checking of DPR documents done by Tata Consulting Engineers (TCE) • Only if GOTN decides to use their services, may be made the Nodal Agency for routing project finances and carry out Project physical and financial progress review. • Processing the Loan Agreements	6 months Full term of Project 3 months
Tamil Nadu Generation And Distribution Corporation Ltd, GOTN	• In principle, 'Approval' sanctioned, estimate for laying of main supply cable (Rs. 80 Crores – part of DPR) communicated to CMWSSB; work to commence only after deposit of estimated amount.	1 – 2 Years Plant Life cycle

	• Provide electricity for the Desalination Plant, Product water main pump; periodic Billing and collection of electricity charges • Grant approval and shift Electric poles and cables on the Trunk Main Route - as and when requested	3 months/section
District Collector - Kanjivaram	• Grant 'District level' Coastal Regulatory Zone clearance	Completed
Environment & Forests Department, GOTN	• Grant 'State level' Coastal Regulatory Zone clearance; • Grant approval for cutting of trees on Trunk main route - as and when requested	Completed 1 month/section
Tamil Nadu State Pollution Control Board, GOTN	• Provide clearance and grant • Consent to Build Seawater Desalination Plant (beginning of Project Implementation) • Consent to Operate Seawater Desalination Plant (beginning of commissioning) • Conduct statutory/periodic water sampling and tests	3 months 3 months Plant Life cycle
Highways and Minor Ports Department, GOTN	• Grant approval for cutting of State Highway and Road for laying of Trunk main: part-by-part/section. • Prepare budget estimate for repair of road and collect charges from CMWSSB : part-by-part/section	3 months/section
Department of Municipalities, GOTN	• Grant permission to cut open the roads and their restoration in areas under their jurisdiction	1 month/section
Department of Town Panchayat, GOTN	• Grant permission to cut open the roads and their restoration in areas under their jurisdiction	1 month/section
Tamil Nadu Road Development Corporation, GOTN	• Grant approval for cutting of road falling under their jurisdiction for laying part of Trunk main. • Prepare budget estimate for repair of road and collect charges from CMWSSB	3 months/section
Public Works Department, GOTN	• Grant approval for construction and laying of Trunk main across water bodies (rivers, streams, lakes).	3 months/crossing
Chennai City Police Commissioner (Traffic)	• Grant 'In principle' approval for 'Traffic Management Plan' for constructing and laying of Trunk main through city streets • Position Traffic Controllers on Trunk main route to marshal vehicular traffic: part-by-part/section	1 month 3 months/section
Department of Telecommunication, GOTN	• Grant approval for shifting of optic fibre telephone cables; as & when required	1 month
Tamil Nadu Water Supply And Drainage (TWAD) Board, GOTN	• Calculate and publish 'Schedule of Rates' annually used in preparation of Detailed Estimates ; Used for item rates other than those used by CMWSSB for works in areas outside City Limits.	As needed, Full term of Project
District Collector	• Grant exemption on excise, duties, other levies on imported goods/machinery	3 months
Department of Inspectorate of Factories, GOTN	• Grant 'Licence to Operate' for the desalination plant.	3 months
Tamil Nadu Industrial Explosives Limited, GOTN	• Grant approval for purchase and use of explosive (gelatine) to blast rocks for laying part of Trunk main	2 months

Source: JICA Study Team

Table 9.3.2 Roles of Agencies in Government of India

Agency	Role	Estimated Processing/Action time
Ministry of Urban Development – CPHEEO, GoI	• Grant Technical Approval to the project on behalf of GoI who acts as the guarantor	-
Ministry of Finance - DEA, GoI	• Grant Financial Approval to the project on behalf of GoI	-
Ministry of Environment and Forest GoI	• Grant 'National level' Coastal Regulatory Zone clearance	Awaited 6 months
Ministry of Road Transport & Highways - NHAI, GoI	• Grant approval for cutting of road falling under their jurisdiction for laying part of Trunk main; part-by-part/location	3-4 months/section
Ministry of Railways - Southern Railways, GoI	• Grant approval for laying/constructing part of Trunk main under the rail line; part-by-part/location	6 months

Source: JICA Study Team

Table 9.3.3 Roles of Agencies in Japan

Agency	Role	Estimated Processing/Action time
JICA Tokyo Government of JAPAN	• Conduct Preparatory Study • Conduct Fact-Finding Mission/s • Conduct appraisal Mission • Sign Yen loan agreement • Monitor Physical and financial progress bi-annually	6-7 months 1 – 2 Times (1wk) 1 Time By Dec 2016 Full term of Project
JICA -India, Government of JAPAN	• Facilitate signing of Tripartite agreement between GOTN-GoI-JICA • Monitor Physical and financial progress bi-annually	Full term of Project

Source: JICA Study Team

Step-by-step process involved in the approval of externally funded project (say JICA) by the various authorities, who are directly involved, is available in Appendix 9.4, Table A9.4.1.

9.3.2 Project Implementation Challenges

Anticipated issues and related difficulties that the project implementers from CMWSSB may face have been compiled in the matrix in Table 9.3.4.

Table 9.3.4 Project Implementation Challenges

Concern	Issue	Challenges & Strengths
Delay caused by deficient planning	Time gap/lag between DPR preparation and implementation	• DPR prepared in 2013 is being reviewed in 2016, for implementation in 2017 (cause: lack of funding)
	Outdated cost estimates	• Revision of estimates based on '2015 -16-Schedule of Rates' becomes essential, actual time-lag becomes 5 years • Possibility of changes in DPR are high, necessitating going back to CPHEEO (MoUD, GoI); resultant, more time lag
Deficiencies of Project Implementation Institution (PIU)	Institutional set up of PIU	• Historically, in case of large value projects, CMWSSB-lead-PIU's are effective due to review pressure by Chief Minister's Office. (Example: Veeranam WTP project, DPR preparation to commissioning was completed in 27 months) • Implementation issues are mostly associated with Sewerage projects or Water Distribution projects in Core City of Chennai.
	Setting up of PIU	• Will require CMWSSB "Top Management's" personalized intervention • CMWSSB MD carries out Physical & Financial Review of all projects every month
	Inadequate staff allocation	• Current Engineering Staff (CE to JE) operational strength at CMWSSB stands at 68.85 % of their sanctioned strength. • However, for special category projects, staff positions are filled by appropriate staff • Also, CMWSSB Engineering Staff are eager to work on Water Supply projects as compared to Sewerage Projects.
	Staff budget allocation	• Staffing budget has never been deficient in CMWSSB history
	Inadequate staff capacity	• Maximum value project handled by CMWSSB till date is Rs 1000 Crores • CMWSSB rich in experience with respect to project planning & monitoring • Desalination technology already being utilized at two plants under CMWSSB • However, customized training will be essential.
	Contractual disputes	• Contractor selection will be critical • Poor performance may not be a problem with contractors working on projects valued at Rs. 100 Crores and above. For smaller value projects or

		sub-projects (Rs. 25-30 Crores), financial capability of the contractor is the key cause for poor project performance.
	Payment to contractors – affecting cash flow	• CMWSSB carries a reputation of being a good paymaster where contractor payments are cleared periodically and on time.
Land acquisition	Non-availability of adequate land	• NOT an issue at Desalination Plant site, Government land already available. • Cause for serious concern when Trunk Main passes: • parallel to 0.7 km stretch of agriculture land • opposite Temple at Thiruporur • with only '6 meter wide' service road along Chennai Bypass for 16 km stretch • NO ALTERNATIVE ROUTE for city traffic. Major traffic issues will appear at commercial centers at Vandalur crossing, Kelambakkam Road, and Camp Road area. • Land was acquired for laying of Trunk Mains from Veeranam WTP and Chembarambakkam WTP, therefore till date there have been no issues even with respect to operation and maintenance works on the said transmission pipelines.
Delay in Procurement (Construction Works and Consultancy Services)	Ineffective procurement planning	• CMWSSB has a 'Contracts and Project Monitoring Department' headed by the Engineering Director. • Most repetitive cause for delay is attributed to receipt of quotes exceeding Project 'cost estimates' by 20 %, which necessitates retendering.
	Prior experience and capacity to manage large scale procurement (ICB)	• Nemmeli SWRO plant (100 MLD), Kattupali SWRO plant (100 MLD), Veeranam WTP (180 MLD) and Chembarambakkam WTP (530MLD) projects were all ICB procurements. • The projects were valued at: Nemmeli SWRO plant – Rs 980 Crores, Veeranam WTP – Rs 780 Crores and Chembarambakkam WTP – Rs 250 Crores
	Lack of awareness and capacity on JICA procurement procedures/ guidelines	• Will require training of all personnel associated with the project • However, at CMWSSB, all procurement documentation and procedures follow FIDIC guidelines
Construction delay caused by Late Government Permissions	Delays in approvals from State agencies	• Project Steering Committee will have to play a key role • Approvals from Southern Railways for laying of Trunk Main on National Highway at PERUNGALATHUR Railway station and along KRISHA NAGAR R.O.B. will be a major challenge at the time of implementation. • Approvals from NHAI for crossing NH 45, and work on '6 meter wide' service road along Chennai Bypass for 16 km stretch too will be a major challenge • Getting approvals from Heads of State Agencies associated with the project work (e.g. Highways, Telephone, Electricity, Police, Pollution Control Board, PWD etc) is probably not an issue; however getting these State Agency staff to implement is the real challenge. • Charges by State Agencies for restoration works are exorbitant, leading to increased project cost. • Average time required in obtaining approvals from associated State Agencies is 3 months.
Miscellaneous factors/ unforeseeable circumstances	Elections - change of government	• Elections in the State of Tamil Nadu May 2016; however, the project will be co-terminus with the term of who-so-ever forms the government for next five years. • Signing of the loan agreement will be with 'who-so-ever' forms the government. • Water scarcity and public pressure on the government will continue to put implementation of this project high on the GOTN's priority list.
	Monsoon rains	• North East monsoon (October 15 to December 15) will hamper work progress related with laying of Trunk Main.

		• Ground water level rises to two meters below the ground during and after the North East monsoon till the month of February. Dewatering is a challenge. • South West monsoon (June 01 to August 31) has been 20-30% of its average volume over the past three years, thus it's expected that it will not have too drastic an impact on work progress
	Crossing Water bodies	• Approval needs to be sought from the Public Works department for construction work at/across the various water-bodies. • Construction of Trunk Main will be challenging (especially during and after monsoon) when crossing: • Great Salt Lake (Buckingham canal) • Canal adjacent to THAIYUR PANCHAYAT SCHOOL • ADYAR River (150 mtrs) • PORUR Lake (350 mtrs)
	Law and Order	• If experience of implementing Nemmeli SWRO project is an indicator, Law & Order is not an issue. • Additionally, Water Supply projects don't attract resistance, like sewerage projects
	Holy Days/ Holidays	• Work progress is impacted during 2nd week of January and 2nd/3rd week of October.

Source: JICA Study Team

9.3.3 Recommended arrangements for Project implementation

To manage the project efficiently, a well defined management structure has to be in place well before the first activity can begin. This management structure will comprise of a Steering Committee (SC) and a Project Implementation Unit (PIU).

(1) Project Steering Committee (SC)

The committee will be formed to facilitate, monitor and guide the performance of PIU. The objectives served by this committee will be to:

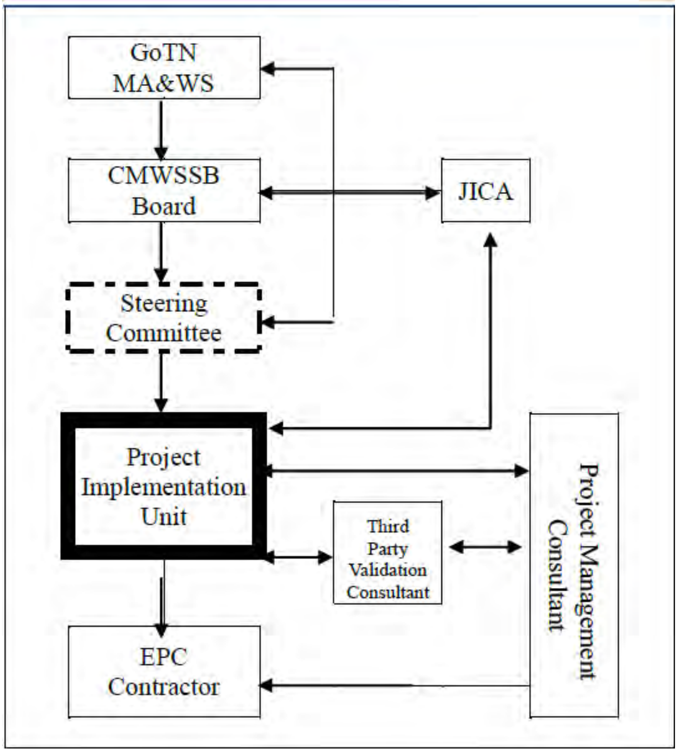
- proactively promote inter-departmental coordination
- provide overall strategic guidance
- review project performance
- decide on major issues, such as funding, manpower resource
- remove implementation bottlenecks,
- resolve land related disputes,
- award permission for special procurement,
- carry out policy reforms, where needed, etc.

Steering Committee will come into existence coinciding with the signing of the Yen Loan Agreement with JICA. Committee members will meet every three months for the total duration of the project. Steering Committee structure will comprise of the following members

- Principal Secretary to Government, Dept. of MA&WS
- Senior Representative of Dept. of Finance
- Managing Director, CMWSSB
- Engineering Director, CMWSSB

- Finance Director, CMWSSB
- Project Director (PIU), as member secretary

All coordination issues will be presented by Project Director (CE- PIU) at the monthly *'Inter-Departmental Coordination meeting'* held under the chairmanship of Managing Director, CMWSSB. All issues requiring escalation to the higher level will be taken up by Managing Director, CMWSSB at the *'High Level Meeting'* under the chairmanship of Chief Secretary, GOTN, as and when needed.



Source JICA Study Team

Figure 9.3.1 Project Implementation Management Structure

(2) Project Implementation Unit (PIU)

CMWSSB has to ensure that the PIU is in place with immediate effect or at least coinciding with the signing of the project 'Yen Loan' agreement. The key aims and objectives of the PIU will be to

- Ensure that SWRO Plant, water transmission and transformation facility, distribution facility are constructed as per design parameters
- Mitigate the risk of construction delay caused by late permissions from State and Central government. Take lead in coordinating with the authorities and utilities for implementation of necessary actions, instead of leaving this responsibility to the contractors.
- Manage the loans, and coordinate with funding agencies and government departments.
- Engage design and supervision consultant for the purpose of planning, and execution of the projects.
- Facilitate arrangements with the agencies for execution of the project on BOO (Build, Own,

Operate), BOT (Build, Own, Transfer) or BOOT (Build, Own, Operate. Transfer) type, as may be the case.

- Execute the project, managing the day-to-day activities.
- Monitor progress of projects under execution, receive implementation reports and issue such directions as may be necessary for securing satisfactory implementation and execution of the projects.
- Monitor and release funds to all such executing agencies who would be engaged for implementing or executing the projects.
- Hire, lease, rent land and property in pursuance of its main and ancillary aims & objectives.
- Engage the services of experts, as and when needed, for advice on specific issues that may arise during the execution of the projects.
- Initiate and implement structural and institutional changes in CMWSSB.

9.3.4 PIU Structure, Tasks and Responsibilities

Project Implementation Unit (PIU) team will comprise of following members as shown in the Table 9.3.5 below

Table 9.3.5 Project Implementation Unit Team

S.No.	Position	Numbers (approx.)	Remarks
1	Project Director	1	Equivalent to Executive Director, experience 25 yrs min
2	Project Manager	1	Equiv. to Superintending Engineer, exp. 20 yrs min
3	Finance Manager	1	Equiv. to Deputy Controller of Finance, exp. 20 yrs min
4	Deputy Project Manager (DSP)	1	Equiv. to Executive Engineer - Civil, exp. 15 yrs min
5	Deputy Project Manager (DSP)	1	Equiv. to Executive Engineer - Elect, exp-15 yrs min
6	Deputy Project Manager (Transmission)	1	Equiv. to Executive Engineer - Civil, exp. 15 yrs min
7	Senior Field Engineers (FE) (DSP & Transmission line)	3	Equiv. to Assistant Executive Engineer-Civil, exp. 8 yrs min
8	Senior Field Engineers (FE) (DSP)	1	Equiv. to Assistant Executive Engineer-Elect, exp. 8 yrs min
9	Field Engineers (FE) (DSP)	2	Equiv. to Assistant Engineer/Jr Engineer-Civil exp. 8 yrs min
10	Field Engineers (FE-Elec.) (DSP)	1	Equiv. to Assistant Engineer/JE-Electrical, exp. 8 yrs min
11	Field Engineers (FE-Env.) (DSP)	1	Equiv. to Assistant Engineer/JE-Environment, exp. 8 yrs min
12	Field Engineers (FE-Inst.) (DSP)	1	Equiv. to Assistant Engineer/JE-Instrumentation, exp. 8 yrs min
13	Field Engineers (FE) (Transmission)	5	Equiv. to Assistant Engineer/JE - Civil exp. 8 yrs min (1per 15 km)
	Subtotal	20	

Support Team

14	Management Info System Officer	1	IT Officer, experience 12 yrs min
15	Accounts Officers	1	experience 15 yrs min
16	Assistant Accounts Officer	1	experience 8 yrs min
17	Personal Assistant/ Computer Operators	3	Graduate in Computer sciences, exp-10 yrs
18	Field Worker/ Office Assistants	5	
	Subtotal	11	

JICA Study Team

PIU Project Director, along with three/four support Engineers should be in position at the earliest, coinciding with JICA's appraisal mission. Other PIU functionaries can be positioned to coincide with the signing of the 'Yen Loan agreement'. The number of staff shown is an optimum number; however these can vary depending on the situation during the life of the project. It has to be ensured that each staff member in the PIU should continue on the project, preferably for the whole term; however, if that is not possible, then at-least for a minimum of three years. It is suggested that should any staff be hired on contractual basis, their services have to be co-terminus with the project.

The general tasks of the team will include, but not limited to, the following:

a. Manage day-to-day implementation of contracts and project activities;
b. Coordinate planning, control, and management of the work of a multidisciplinary team;
c. Preempt, plan and take proactive action in coordinating with State and Central government agencies to get construction permission, relocation/protection of the existing infrastructures or communication with local people before the commencement of works.
d. Develop implementation schedules and resource requirements;
e. Monitor progress, evaluate results, and identify and resolve constraints;
f. Provide long-term input to the development of project methodologies;
g. Identify appropriate technologies and the need for standardization of equipment and materials;
h. Participate in carrying out detail investigation and engineering surveys (geotechnical, topographical, etc), wherever necessary;
i. Participate in and understand designing of Desalination Water Treatment;
j. Ensure ‘Third Party design review’
k. Present designs to all stakeholders (including local government and communities), addressing the concerns where necessary;
l. Participate in developing bidding documents, including bill of quantities and specifications following JICA guidelines and assist in evaluation of bids;
m. Update costs, economic and financial information (including rates of return), when needed;
n. Prepare and update implementation schedule and resource requirements (preferably in Microsoft Project Management software);
o. Supervise all construction activities under the Desalination Water Treatment Project, day-to-day construction management; including liaison with the other teams under the project from all donor financed projects;
p. Define quality control mechanisms and parameters for all components;
q. Develop and implement a quality assurance program for all works, securing compliance with design/standards
r. Develop a coordinating mechanism with the government and the contractor/NGO and prepare public communication products
s. Coordinate collection of ‘environment data’, prepare and submit reports as per JICA guidelines;
t. Develop O&M manuals for future maintenance;
u. Establish a contract tracking systems, including implementation schedules and milestones achievable;
v. Verify project contractors’ bills and facilitate their payments
w. Issue contracts completion certificates, settlement of contractor’s claims;
x. Present progress during project review missions;
y. Facilitate preparation of training programmes for effective implementation and O&M; including training module preparation, training planning and conducting the same through consultant’s staff

and other service delivery institutions.

Though the above list includes most of the tasks to be performed by the team, it is suggested that each team member should be provided with his individual job description. Specific tasks for each team member have to be linked with specific targets derived out of the ‘Project activity’ bar chart. These targets should then feed into the Microsoft Project Management software (MS Project) for regular monitoring.

Timely completion of each milestone should result in the team being rewarded with a monetary incentive and a citation; the incentive amount per milestone should be decided by the Project Steering Committee.

9.3.5 Decision Making in Project Phases

Different decisions are required to be taken during the four phases of the project, i.e. Planning phase, Pre-Implementation phase, Procurement phase and Implementation phase. To be able to better understand the activities in each phase, the type of decisions required to be taken and the decision makers who have/are to take these decisions, Table A9.4.2 provides these details in Appendix 9.4. Roles of the PIU and Steering Committee in decision making are amply demonstrated in the said matrix.

9.4 Organizational Strengthening Plan

A number of activities have been proposed under organizational strengthening plan after deliberation, discussions and arriving at a consensus with the CMWSSB team. These major activities, their expected outcomes have been detailed out and are provided in the plan is presented in Table A9.5.13A and Table A9.5.13B.

9.4.1 Autonomous Business Operations

Policies for regulation, funds allocation and accountability mechanisms need to be re-evolved. CMWSSB has to take the initiative of revising the policies (to the extent possible), defining/clarifying roles, allocating budgets, adopting cost-effective approaches. Designing a strategic planning process for promotion and advocacy of the policy and legislative reforms that incorporate a shared vision linked to project objectives and support the development of the ‘long term, medium term and annual strategic operational plan’.

For effective water supply and sewerage management in future, the challenges identified would have to be addressed through organizational improvements, to include:

(1) Policy Change

Develop, draft, get Board consensus/approval and implement cost-recovery policies (Tariff revision policy, policy on 100% metering, incentive for metering, etc.);

(2) New Units and Redefined Mandate

Strategize and frame policy to redefine mandate of existing departments and evolve new units to undertake new responsibilities; Modify/shift responsibilities from one department to another where appropriate; examples of these new units are, Cost control unit, Asset management unit, Commercial unit, HRM and Knowledge management unit, to name a few

(3) Revised Administrative and Financial Powers

Review and revise existing administrative and financial powers at CE, SE & EE levels; change the "Management Control" of the organization for effective decentralized decision making at the Area Office level itself.

(4) Human Resource Development Policy

Develop, draft, get Board consensus/approval and implement policy for sustained capacity building as a continuous process.

Change in policy, carrying out tariff revision, and incentivizing metering may be the only way for CMWSSB's sustenance.

9.4.2 Business Planning

For CMWSSB, where the existing functioning is to undergo major changes, a '5 & 20 years' business plan is a basic need. CMWSSB Business Plan will reflect the operational scenario during the next twenty years i.e. up to 2035 to support scaling up of water supply and sewerage services for the city of Chennai.

Business Plan details provided in Appendix 9.5, A9.5.1 answers the questions, "Where is CMWSSB now?" and "Where does CMWSSB want to be?" in the form of 'Service Level Indicators' and 'Key Financial Indicators'. Answer to the question "How is CMWSSB going to get there?" is provided in the subsequent sections where activities like asset management, water tariff revision and collection system, improved customer services, non-revenue water (NRW) management, and improved human resources management have been described. Each will contribute towards achieving the targets set in the Business Plan and assist in meeting the overall objective of organizational strengthening.

9.4.3 Water and Sewerage Tariff Revision and Collection System

To ensure the efficient and sustainable delivery of water and wastewater services, water pricing should be based not only on the financial costs involved in producing and delivering services but also on economic, environmental and pro-poor principles. Without the balance of these factors, tariff is not going to be reflective of all costs, leading to rates set below the level of cost recovery and without consideration of a rate of return on capital. This often leads to a serious lack of preventive maintenance and requires significant subsidies for both investment and operation.

Hence, the solutions lie in

- Establishing a transparent structured mechanism for fixing the (cost-based) tariff
- Increasing the number of metered water connections
- Carrying out systematic revenue collection

Appendix 9.5, A9.5.2 provides further details on the possible mechanisms to be adopted by CMWSSB towards improving water and sewerage tariff revision and collection system.

9.4.4 Developing a Reliable Asset Management System

Asset management system would cover CMWSSB facilities for water supply, sewerage, drainage networks, pumping, storage, and treatment. A definitive need was found for better maintenance of the estate and fleet; while the need for Asset Management is clearly felt, it is equally important to have appropriate management information on asset condition, infrastructure costs, their performance, and the consolidated requirements for repairs and maintenance, as well as appropriate maintenance standards.

Developing and operating such an asset management system is proposed and is further detailed out in Appendix 9.5, A9.5.3.

9.4.5 Web based Management Information System (MIS)

At CMWSSB access and availability of authentic data is a key area for improvement. Once the asset management system is in place access to the same shall be facilitated by introducing a web based Management Information System (MIS) that provides the managers with the tools for organizing, evaluating and running their units effectively and efficiently and giving information that they need to make timely decisions. It has several components like the hardware, the software, the database or data resources or information, the procedures or data support systems and the people, and is distinct from other information systems in that it basically aims at decision making that include physical, financial and human resource management, resource planning, project management, performance management, customer relationship management, procurement etc. apart from data retrieval. Most water and wastewater utilities across the world have an MIS department alongside departments of accounting, finance, management or marketing. An action plan is proposed in Appendix 9.5, A9.5.4.

9.4.6 Improved Non-Revenue Water (NRW) Management

Technical problems, management issues and O&M issues have been elaborated in Sections 3.3.6, 3.3.7 and 3.3.11. Though CMWSSB has assessed their un-accounted water percentage /NRW to be 30%, this figure needs to be substantiated and monitored through a systematic NRW management system. It is essential for CMWSSB to redefine O&M functions, whereby management of NRW is a major task. A Non-Revenue Water (NRW) management plan is further detailed out and proposed in Appendix 9.5, A9.5.5.

9.4.7 Improved Customer Services

Customer service system has to be linked to the MIS so that periodic reports get generated automatically for providing important information to management. An implementable plan is proposed in Appendix 9.5, A9.5.6. Key thrust has to be on the need for strengthening the Area Office; improved supervision has to make the Officials at Area and Depot Offices more accountable to the citizens, by making the Area Engineer as an Area Manager and making him accountable for Technical and Commercial matters of his respective Area.

9.4.8 Improved HR Management and HR Development

a) The key HRM management initiatives, towards organizational strengthening of CMWSSB are developing internal capabilities of the O&M team for monitoring the present and future desalination infrastructure, a business linked, an objective 'Performance Management System', introducing revised and new function like commercial, quality assurance, water conservation, risk management, dedicated PR, Branding, Marketing and IT enable all F&A and HRM processes, to name a few. Each of the above listed initiatives has been defined in Appendix 9.5, A9.5.7 along with the human resources development plan ('b' below).

b) As part of HR Development initiatives under the project, actions like HRD Policy document, developing self sustaining "Centre of Excellence" essential towards HR Development and capacity building are outlined in the Appendix 9.5, A9.5.7. Capacity building efforts would be needed to upgrade the skills of the PIU team selected to manage the projects. These training initiatives would also be extended to CMWSSB staff. The list of training programmes and estimated number of participants is detailed out in Table A9.5.6. "Training Titles" presents an indicative list and other courses/training titles can be added as per the training needs of the team. These training have been grouped under the headings, Management Training, Technical Training, Customized workshops and Study Tours. Each of these training topics has been translated into 'Training profile sheets' and each 'Training Profile sheet' is a plan in itself for their respective training delivery. The cost (indicative approximation) mentioned in each profile sheet, is based on calculations available in the appendix. The overall cost estimate of the capacity building initiative amounts to INR 1,54,85,400/-, details are presented in Appendix 9.5, Table A9.5.12. The cost of conducting training pertaining to the new customised software and those related to the desalination plant, has to be build into the vendors' cost of supply of plant, equipment or software.

9.4.9 Organizational Strengthening Action Plan and Schedule

Each of the activity groups proposed above under the organizational strengthening plan will comprise a series of actions and sub actions. Every action has to be initiated and successfully concluded within a stipulated timeframe. Discussions with CMWSSB officials has resulted in timelines as defined in the matrix attached as Table A9.5.13.

A team of consultant will have to be engaged by CMWSSB to complement internal capabilities. The terms of reference of this consultancy team will include, but not limited to, the following:

- Preparing an Action Plan for achieving goals and service level targets projected in business plan; Evolving performance targets along with key monitoring indicators and phase-wise service improvement plan

- Facilitating positioning of new organizational structure with clearly defined roles and responsibilities of each functional group and post.
- Providing specific recommendations for improving the financial management system and cost reduction strategies
- Developing revenue improvement plan including strategies for improvement of coverage, collection efficiencies and tariff structure; work out a capital investment plan for improving service delivery.
- Evolving IT plan with details of functions that have to be computerized and their implementation.
- Strategizing improving customer orientation

The consultant team will be expected to provide handholding support for implementation of plans and strategies developed above.

CHAPTER 10 PROJECT COST ESTIMATION

10.1 Project Cost

10.1.1 Basic Conditions and Composition of Project Cost

(1) Conditions of cost estimation

The conditions for the project cost estimation are shown in Table 10.1.1.

Table 10.1.1 Conditions of the Cost Estimation

Item	Condition	
Construction cost		
1) Base year	January, 2017	
2) Exchange rate	1 USD = 116.0 JPY 1 INR = 1.71 JPY	1 USD = 67.9 INR
3) Price escalation	FC: 1.6%	LC: 3.7%
4) Physical contingency	Construction: 5%	Consultant: 5%
Administration Cost and Service Tax		
1) Rate of Tax	VAT: 15.0 % Work Contract Tax: 5.50%	Import tax: 0.0%
2) Rate of interest during construction	Construction: 1.4%	Consulting service: 0.01%
3) Front end fee	0.2% of the loan amount	

Source: JICA Study Team (based on FY 2016-17Appraisal Parameters for Japanese ODA Loan for India)

(2) Composition of the project cost

The project cost is comprised of the items indicated in Table 10.1.2.

Table 10.1.2 Composition of the Project Cost

Items
(A) Eligible portion for JICA loan
i) Procurement and construction cost (JICA loan portion)
ii) Consulting service cost
(B) Non-eligible portion for JICA loan
i) Procurement and construction cost (Local fund portion)
ii) Land acquisition
iii) Administration cost
iv) Work Contract Tax and VAT
v) Import tax
(C) Interest during the Construction (Eligibility to be discussed)
(D) Front End Fee (Non-eligible portion for JICA loan)

Source: JICA Study Team

10.1.2 Methodologies of the Project Cost Estimation

(1) Construction cost

Table 10.1.3 shows the basis and methodologies for each construction item.

Table 10.1.3 Basis and Methodologies of Cost Estimation for Each Construction Item

Item	Base Data	Methodologies
CP 1 Construction of the seawater desalination plant		
1a. Seawater intake and brine discharge facilities 1b. Seawater desalination facility 1c. Power receiving substation 1d. SCADA system 1e. Power distribution	- Quotation from DSP supplier in India based on the equipment list - Quotation from a marine civil contractor in Japan	- To multiple unit prices quoted by estimated quantities
1f Power transmission line constructed by TNEB	- Interview information with TNEB	-
1g. Land development for the plant sites	- CMWSSB Schedule of Rate (2015-2016)	- To multiply unit prices per area by estimated land area of Perur DSP - To multiply unit prices by estimated quantities
CP 2 Construction of Pumping stations and reservoirs		
2a Perur Pumping station 2b Porur Head Works 2c New Porur Reservoir	Civil work - Schedule of Rate (CMWSS Board, 2015-2016) E&M work - Market rate in Japan	Civil work - To multiply unit prices per area by estimated quantity E&M work - To multiply 60% of unit prices per area by number of equipment
CP-3 Installation of Product water transmission mains		
CP3-1 Section-1 CP 3-2 Section-2 CP3-3 Section-3 CP 3-4 Section-4	- CMWSSB Schedule of Rate (2015-2016) - TWAD Schedule of Rate (2015-2016) - TELANGANA Schedule of Rate (2015-2016) - DELHI Schedule of Rate 2014 (in the order of priority)	- To multiply unit prices per area by estimated quantity
CP 4 Improvement of the existing water distribution networks	- Schedule of Rate (CMWSS Board, 2015-2016)	- To multiply unit prices per area by estimated quantity

Source: JICA Study Team

(2) Other costs

Table 10.1.4 shows the methodologies for other cost items. The land acquisition cost will be considered as O&M cost because the land of the Perur DSP will be leased.

Table 10.1.4 Methodologies for Estimation of the Other Costs

Cost Item	Methodology
Consulting services cost	Based on the manning schedule for the consulting service
Land acquisition cost	To be considered as O&M cost because of the lease contract
Administration cost	1.0 % of (construction cost of eligible and non eligible portions + consulting service cost)

Source: JICA Study Team

10.1.3 Calculation of the Construction Cost of the Project

The construction cost of the project is shown in Table 10.1.5.

Table 10.1.5 Construction Cost of the Project

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10.1.4 Calculation of the Project Cost

Based on the construction cost and other costs, the project cost is estimated as shown in Table 10.1.6. Budgetary estimate at the feasibility study level will need higher amount than the DPR to avoid cost overrun in the bid stage. (See Subsection for comparison with other DSP projects)

Table 10.1.6 Project Cost

Nondisclosure

10.2 Validation of the Estimated Project Cost

10.2.1 Comparison with the Project Cost Proposed in the DPR

In the DPR, the project cost was estimated as shown in Appendix 10.1. The noticeable differences between the costs by the JICA Study Team and the DPR are listed below;

- The JICA Study Team has changed the post treatment process from lime powder to lime stone filter based on the request from CMWSSB for better working condition to prevent health problem.
- The JICA Study Team enlarged the JICA Study Team enlarged the pre-treatment facilities to secure sufficient backwash water volume.
- The JICA Study Team supplemented the cost for the embankment work for the site development of the Perur DSP.
- The JICA Study Team referred latest version of rate of schedule and recent quotation from plant makers, where price escalation and recent market trend were reflected. According to Global Desalination Market 2015 (published by Global Water Intelligence), the 2013 and 2014, when the DPR was prepared, were the most sluggish years to the desalination market. Since 2015, the improving market situation is raising the prices like the situation observed until 2009, when the global economic crisis hit the market.
- The JICA Study Team added construction of one pumping station in Porur WDS in order to ensure the delivery of the product water to the Water Distribution Stations distributed in the Corporation.
- The JICA Study Team added installation of a branch transmission line of 1,000 mm in diameter and 5.0 km in length to provide the product water to the Corporation more efficiently.
- Based on hydraulic analysis on the product water main, the pump head at the pumping station in Perur DS has been increased by 30%.
- The number of the sites of pipe jacking method has been increased in the product water main construction. The increase is necessary due to the recent urban development along the route of the transmission mains occurring after the DPR.
- In order to install the transmission main of 2,000 mm diameter, deep excavation of about 4 m is required. Therefore, the cost of adequate sheet piling has been added.

Appendix 10.2 presents comparison of the project costs in the DPR and DFR.

10.2.2 Comparison with Other DSP Projects

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10.3 Operation and Maintenance Cost

10.3.1 Basic Conditions and Methodologies

The operation and maintenance (hereinafter "O&M") cost is composed of the following costs shown in Table 10.3.1 The methodologies for the estimation of each item are also indicated in the table.

Table 10.3.1 Methodologies for Estimation of the O&M Cost

Cost Item	Methodology
1. Electric cost (basic charge)	Contract capacity (kW) multiplied by the TNEB basic monthly charge (INR/kW)
2. Electric cost (meter rate charge)	Daily electricity consumption (kWh) multiplied by the TNEB meter rate (INR /kWh)
3. Personnel cost	Assumed number of the personnel x monthly salary (INR/month)
4. Maintenance cost	Annual maintenance cost is assumed to be approx. 1.65% of construction cost of the seawater treatment plant excluding land development cost.
5. Replacement cost	1) RO membrane Annual replacement cost is assumed to be 14% of the initial cost of the RO membrane cost 2) Cartridge filter Initial cost is multiplied by the number of annual replacement.
6. Chemical cost	Annual consumption (t/year) is multiplied by the unit cost (INR) for each chemical

Source: JICA Study Team

10.3.2 Operation and Maintenance Cost

Nondisclosure

Table 10.3.2 O&M Cost of the Perur DSP

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10.3.3 Production Cost

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CHAPTER 11 PROJECT IMPLEMENTATION PLAN

11.1 Financial Plan

11.1.1 Standard Conditions of the Japanese Official development Assistance Loan

The Project is expected to be funded by Japanese Official Development Assistance (ODA) loan in Japanese Yen currency.

Conditions of the Japanese ODA loan are dependent on the income level of the borrowing country. At present, the United Nation defines the Republic of India as Low Income Country. The standard conditions of the Japanese ODA loan for the Low-Income Countries are shown in Table 11.1.1. The conditions to be applied to the Project will be finally fixed by the decision of the Government of Japan (GOJ) based on the discussions between GOJ and the Government of India (GOI).

The cost of the Project is divided by eligible cost items, which can be covered by the ODA loan, and non-eligible items, as shown in Table 11.1.2. The cost for the non-eligible items needs to be covered by other sources such as CMWSSB's own and state government's budgets. The value of the items to be covered by the ODA loan will also be determined by GOJ after the discussions between the two governments.

Table 11.1.1 Terms and Conditions of Japanese ODA Loan for Low-Income Countries

Standard/Option	Interest	Repayment period	Grace period
(1) Standard conditions			
1) Fixed interest			
Standard	1.40%	30 years	10 years
Option 1	0.80%	20 years	6 years
Option 2	0.70%	15 years	5 years
2) Variable interest			
Standard	Yen LIBOR+10bp	30 years	10 years
Option 1	Yen LIBOR bp	20 years	6 years
Option 2	Yen LIBOR -5bp	15 years	5 years
(2) STEP*	0.10%	40 years	10 years

*: Special Terms for Economic Partnership (See Subsection 11.1.2 for the details.)
Source : JICA

Table 11.1.2 Usual Eligibility of the Cost Items for the Japanese ODA Loan

Eligible Portion (can be covered by the loan)	Non- Eligible Portion (cannot be covered by the loan)
• Construction cost including price escalation and physical contingency • Consulting service cost including price escalation • Dispute board cost • Interest during the construction	• Land acquisition cost • Administration cost (e.g. cost of SONES for the project implementation) • Value-added tax (VAT) and import tax • Front end fee

Source: JICA Study Team

The borrower of the loan will be GOI, represented by the Ministry of Finance. The State Government of Tamil Nadu (GOTN) will shoulder the repayment obligation of the loan. Whether CMWSSB should repay a part of the credit will be determined through discussions in the state. As the revenue of the CMWSSB is not even at the level of O&M cost recovery, the total repayment will be shouldered by GOTN.

The construction and overall project costs, as well as the loan amount estimated, were presented in Section 10.1.

11.1.2 Special Terms for Economic Partnership (STEP)

(1) Conditions of the scheme

The GOJ introduced an ODA scheme called Special Term for Economic Partnership (STEP), which is expected to raise the visibility of Japan's ODA to the citizens in the recipient countries and Japan through utilizing technologies and know-how of Japanese firms. The possible beneficiary countries of STEP are Low-Income Countries and Middle-Income Countries, to which tied aids can be extended under Organization for Economic Co-operation and development (OECD) rules.

In a project to which STEP is applied, procurement of the contractor and equipment needs to comply with a special condition to utilize Japanese technologies and know-how, while the loan conditions will be very advantageous to the borrower as below;

- Interest rate and repayment period: 0.10% of interest rate, 40 years of repayment period and 10 years of grace period
- Procurement conditions: Prime contractors are tied to Japanese firms. Joint Ventures (JVs) with recipient countries are admitted on condition that the Japanese firm is the leading firm. Sub-contractors are open to all countries.
- Country of origin of goods and services to be procured under STEP: Not less than 30% of the total amount of contract(s) under the project, excluding the consulting services, must be accounted for by either (a) goods from Japan and services provided by Japanese firms, or (b) goods from Japan only, according to the nature of the project. In case of the Water Supply System Development Project in Santiago Island, a similar STEP project of seawater desalination of 40 MLD, option (b) is adopted among the two choices above.

Adoption of STEP is to be determined through the discussions between JICA and Indian sides, including GOI, GOTN and project executing agency, and the final decision is to be made by GOJ.

(2) Ongoing seawater desalination project by STEP

In 24th December, 2013, JICA signed a Japanese ODA loan agreement with the Government of the Republic of Cape Verde to provide a loan of up to JPY 15.292 billion for assistance for the Water Supply Development Project in Santiago Island, which is located at approximately 680 km west from Dakar, the capital of Republic of Senegal in the West Africa. The project includes two plants of 20 MLD (total capacity is 40 MLD) by RO technology.

Consulting service of the project commenced in February 2016, and the project is carrying out the tender for the EPC contractor. Reportedly six groups led by Japanese firms submitted applications to the pre-qualification (PQ).

11.2 Procurement Plan

11.2.1 Contract package

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Table 11.2.1 Contract Packages of the Perur DSP Construction Project

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Figure 11.3.1 Construction Schedule of the Perur DSP

11.3.3 Construction Plan for CP 2

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Figure 11.3.2 Construction Schedule for CP 2

11.3.4 Construction Plan for CP 3

Nondisclosure

Table 11.3.2 Calculation of Period Required for the Completion of CP 3

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Figure 11.3.3 Construction Schedule for CP 3

11.3.5 Construction Plan for CP 4

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Figure 11.3.4 Construction Schedule for CP 4

11.3.6 Construction Plan for CP 5

Nondisclosure

Figure 11.3.5 Construction Schedule for CP 5

11.3.7 Procurement of the Major Equipment and Materials

Nondisclosure

Table 11.3.3 Manufactures of the Main Equipments for the RO Process

Nondisclosure

Table 11.3.4 Country for Procurement of the Construction Materials

Nondisclosure

11.4 Implementation Schedule

11.4.1 Overall Schedule of the Project

Nondisclosure

Figure 11.4.1 Overall Implementation Schedule of the Project

Table 11.4.1 Breakdown of the Project Implementation Procedures

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Table 11.4.2 Project Implementation Schedule

Nondisclosure

Source: JICA Study Team

Figure 11.4.2 Overall Implementation Schedule of the Project in Usual Procedure

11.4.2 Implementation Procedures of the Project

Implementation procedures included in the Project in the basic implementation plan are explained as below;

(1) Preparatory Survey (the Study)

The Study began in January 2016 and will be completed by February 2017 by submission of the Final Report (FR). Comments on the draft final report (DFR) from the relevant authorities in the Japanese and Indian sides have been incorporated in FR.

(2) Funding arrangement

The findings and results of the Study will be reviewed and appraised by JICA and the GOJ regarding its validity as a yen loan project.

In parallel with the appraisal in the Japanese side, CMWSSB will revise the DPR, which was once approved by MOUD in 2014, based on the results of DFR. After the approval of the revised DPR by MOUD, GOI will issue an official request for ODA to JICA on the Project.

After MOUD's re-approval, based on the appraisal results, the GOJ is expected to send "pledge" to the GOI, which will notice the decision to provide the loan to the Project and the terms and conditions of the loan. Subsequently, the two governments will hold final discussions, after which exchange of the notes (EN) and conclusion of the loan agreement (LA) will be done. Temporarily the Study presumes that the pledge will be sent in August 2017 and LA will be signed in September 2017.

(3) Procurement of the Consultant (Project Management Consultant: PMC)

CMWSSB will procure a consulting firm for the Project based on the JICA Procurement Guideline. The procurement process can officially begin after the GOJ pledges the yen loan to GOI. CMWSSB will prepare the draft Request for Approval (RfP) in advance but can send it to JICA for concurrence only after the pledge.

After the pledge, the procurement procedure will take eight (8) months for JICA concurrence on RfP (0.5 month), Expression of Interest (EOI) (1 month), the bid (1.5 months), bid evaluation (2.5 months), negotiation and contract (2 months) and JICA concurrence to the signed contract (0.5 month). In the project schedule, nine (9) months are taken into account by adding one (1) month for preparation of the draft RfP by CMWSSB before the pledge. Review period by JICA on the evaluation results and the signed contract are usually 15 days in principle for each concurrence.

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11.5 Implementation Structure

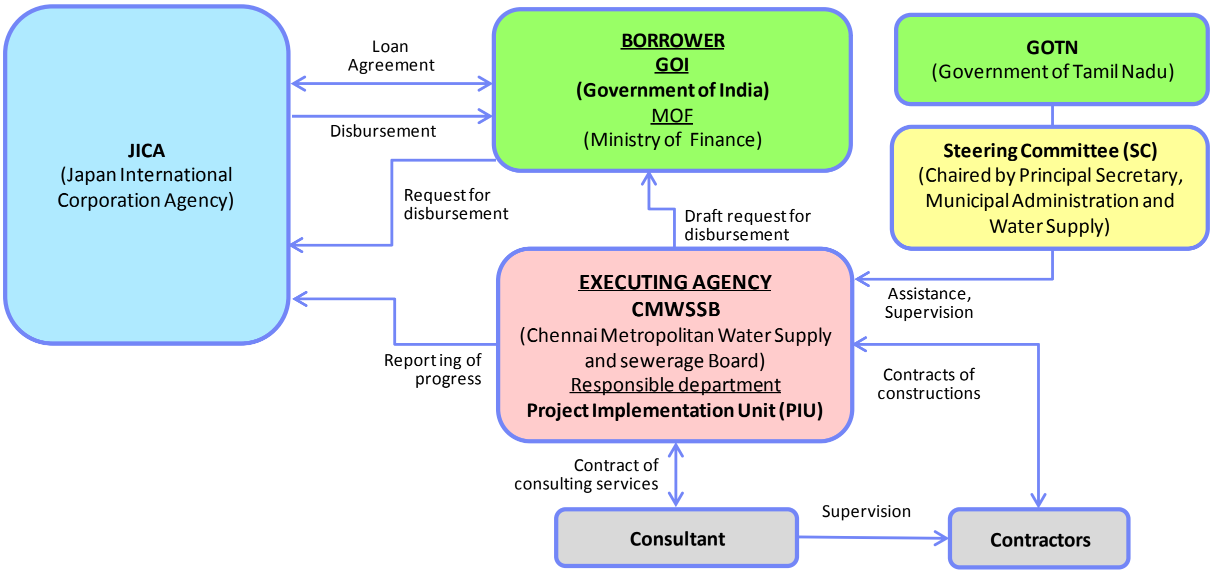
Figure 11.5.1 illustrates the implementation structure of the Project.

The executing agency of the Project is the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB). CMWSSB will execute the Project using yen loan from JICA, for the items that will be agreed to be covered by the loan between JICA and GOI, and the state government's or their own fund for the other items. The direct borrower of the yen loan will be GOI, which will be represented by the Ministry of Finance (MOF).

During the implementation of the Project, based on the documents to be prepared by CMWSSB, MOF will claim to JICA the amounts of the expenditures for the covered items and receive reimbursement. The GOTN, the shareholder of CMWSSB, will supervise the project implementation of CMWSSB. The Steering Committee (SC), which will be headed by the Principle Secretary in charge of water supply sector, will conduct the supervision on behalf of GOTN. The supervision will include monitoring, assistances, especially in coordination with relevant authorities, and advice to CMWSSB, if any.

CMWSSB, as the executing agency, will employ a consultancy company who will carry out designs, tender assistances, and construction supervision during the Project. CMWSSB needs to report the progress of the Project to JICA and also it will prepare the request for disbursement which will be sent to JICA via the MOF, the borrower of the loan. Within CMWSSB, the Project Implementation Unit (PIU) will be established to dedicate itself on the implementation of the Project.

Proposal for the establishment of PIU and SC, as well as their functions and members, are described in Subsection 9.5.1.



* For CP 1, the contract will include O&M works after the construction.
Source: JICA Study Team

Figure 11.5.1 Implementation Structure of the Project

11.6 Proposal on Terms of Reference of the Consulting Services

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CHAPTER 12 ECONOMIC AND FINANCIAL ANALYSES

This chapter will evaluate the viability of the Project from the viewpoints of economic and financial aspects. The financial cost of the Project is weighed against the incremental revenue of the Project's Executing Agency to obtain the financial viability. Then, the economic benefits to the society are evaluated against the economic cost of the Project to capture the economic viability. Finally, the recommendation on the future tariff setting is presented to ensure the economic and financial benefits of the Project.

12.1 Conditions and Methodologies for Financial and Economic Analyses

The analyses will adopt the following conditions and assumptions.

(1) Exchange rates

The same exchange rate is adopted from Chapter 10 Project Cost Estimation.

(2) Evaluation period

The evaluation period is 30 years including the periods for consulting services and construction. The starting year of the evaluation period is 2018, and the ending year of the evaluation is 2047.

(3) Life period

The life period of the civil structures and architectural buildings is estimated at 50 years and that of the mechanical and electrical equipment is set at 20 years. The life period means the actual usage period of the structure and buildings and equipment utilized in the Project. The period length could be different from the amortization period for accounting purposes.

(4) Inflation

The influence of inflation is not considered in the calculation of both cost and revenue. The analyses are conducted using "real prices".

(5) Weighted Average Cost of Capital (for Financial Analysis)

Weighted Average Cost of Capital (WACC) is used as the discount rate for the financial analysis. The WACC is calculated as a weighted average of the costs of capitals by the amounts from the respective financial sources. Table 12.1.1 presents the calculation of WACC of the Project.

Table 12.1.1 Fund Source and WACC of the Project

	Percentage*	Fund Source	Cost of Capital
Eligible Portion of ODA loan	83%	ODA Loan	0.7%**
Self-financing by CMWSSB	17%	Self-financing	6.8%***
Total	100%		1.74% (WACC)

* Share is estimated based on the cost estimation of the eligible portion and non-eligible portion of ODA loan.
** The condition of the ODA loan transfer is not fixed.
*** Central Bank of India 91days T-bill Rate (as of end of July 2016)
Source: JICA Study Team

(6) Discount rate (for Economic Analysis)

The economic analysis will use the discount rate at 10%. This is a commonly used figure for evaluating development projects funded by multinational donors.

(7) Conversion factor (for Economic Analysis)

For the economic analysis, the standard conversion factor (SCF) of 0.9 will be applied to all domestic procurement portion of the cost to factor out the distortions in the domestic market prices such as tariffs, taxes, and subsidies. The standard conversion factor will not apply to the financial cost for capturing the actual financial burden.

(8) With-Project Case and Without-Project Case

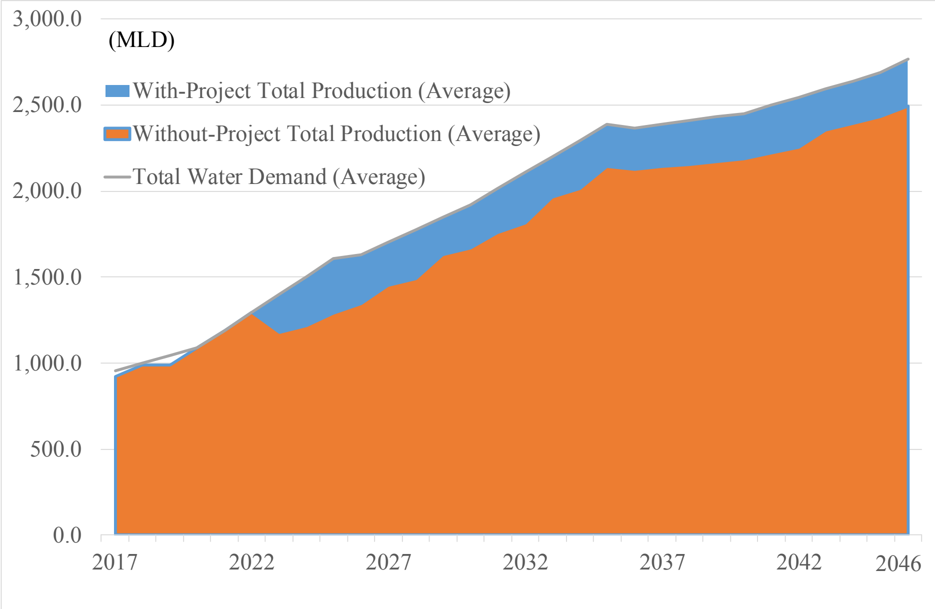
For the analysis, the impacts of the project should be compared between With-Project Case and Without-Project Case in the project area. The basic assumptions in both cases are summarized in Table 12.1.2.

Table 12.1.2 Conditions of With-Project and Without-Project

Case	Condition
With-Project	• The Perur DSP, with a capacity of 400,000 m^3/day, starts operation from the year 2023. • All other projects in the water source augmentation plan proposed by the JICA Study Team (Table 5.1.9 in Chapter 5) become available to users as they planned. • The proposed LPCD (Table 5.1.3) are achieved. • Water loss ratio in the Core City will be reduced to the target level (Table 5.1.5), as a combined effect with the CMWSSB's own network rehabilitation program.
Without-Project	• The water source augmentation plan proposed by the JICA Study Team (Table 5.1.9) except for the Perur DSP becomes available to users as they planned. • The proposed LPCD (Table 5.1.3) are unachieved (Reduced by the proportion of Perur water volume) • Water loss ratio will be reduced by the CMWSSB's own network rehabilitation program but afterward it will be gradually worsened due to deterioration of the remained old pipes.

Source: JICA Study Team

The Figure 12.1.1 shows the differences in the future water supply volume at the with-project case against the without-project case. The cost and benefit associated with the difference of these cases (captured in blue surface) will be accounted into the analysis. The total water volume is reduced by 8 – 10% depending on the year without the operation of the Perur DSP.

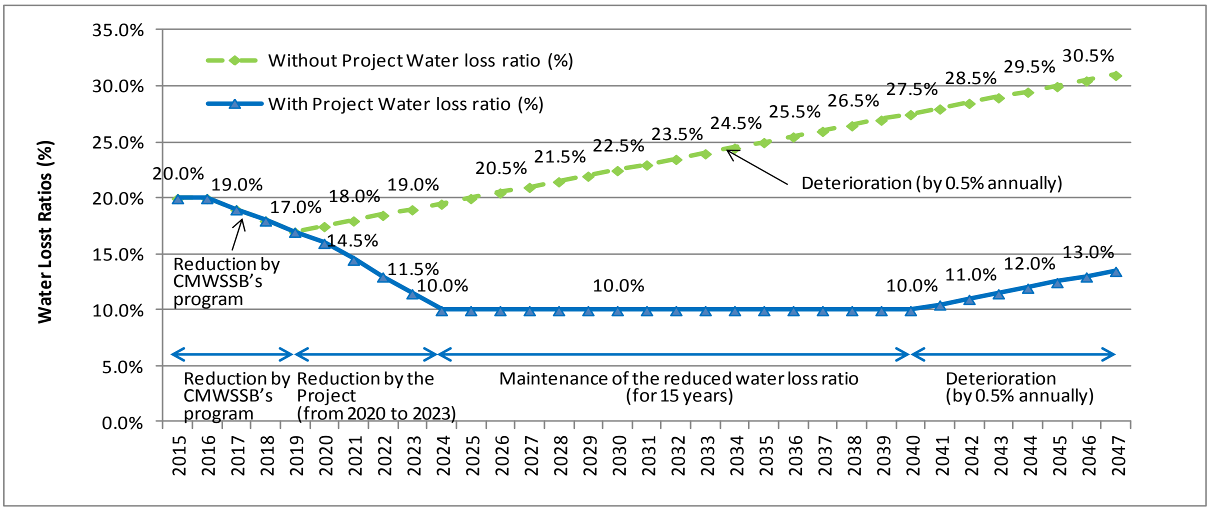


Source: JICA Study Team

Figure 12.1.1 Water Supply Volume in With-Project and Without-Project Cases

From above condition, financial analysis will strictly capture the benefit associated with the augmented volume of water usage of existing consumers. In this case, for domestic case, the number of beneficiaries is all households in Chennai Corporation Area with water connection where Perur water is expected to be distributed. They are all impacted with small magnitudes of water augmentation to each. However, to simplify the economic benefit of the water augmentation in Chennai, the economic analysis will assume that produced water in the Perur DSP will be provided to new consumers, which is identified by dividing the Perur DSP's water production volume divided by proposed household lpcd as well as commercial and industrial water demand. This is to limit the "number of beneficiaries" associated with the project and capture the genuine impacts to society at large.

Figure 12.1.2 presents water loss ratios in the with-project and without-project cases. The planned program by CMWSSB to replace old pipes are presumed to be completed by 2019 in both the cases. Afterward, in the with-project case, the water distribution scope in the Project (CP 4), which will start the construction in 2020 and will be completed by the end of 2023, will realize the target ratio of 10.0% in 2024. The water loss ratio is presumed to be increased at an annual rate of 0.5% since 2040, which is about 15 years after completion of CP 4. In the without-project case, on the other hand, the water loss ratio will be increased since 2020, which is about 20 years after the network rehabilitation project by the World Bank, due to deterioration of the old pipes that have not been replaced in the CMWSSB's program at the same rate as the with-project case.



Source: JICA Study Team

Figure 12.1.2 Water Loss Ratios in With-Project and Without-Project Cases

12.2 Financial Analysis

The financial analysis will assess the financial viability of the Project. The financial cost and benefit for the Project's Executing Agency, CMWSSB, will be assessed and weighed against each other to evaluate how much financial benefit or burden the Project generates on CMWSSB.

12.2.1 Outline of the Financial Analysis

The Table 12.2.1 shows the financial cost and revenue associated with the Project.

Table 12.2.1 Revenue and Cost Items considered in the Financial Analysis

Financial Cost	Financial Revenue
1) Investment Cost • Initial construction cost • Residual value at the end of the evaluation period 2) O&M Cost • Operation and Maintenance (O&M) cost • Future replacement cost for equipment in the plant	• Incremental revenue derived from the additional water production by the Project (difference in payment to CMWSSB between receiving with-project lpcd and without-project lpcd.)

Source: JICA Study Team

12.2.2 Financial Cost

The financial cost covers two categories; 1) investment cost and 2) O&M cost.

(1) Investment Cost

1) Initial Investment Cost

Initial Investment cost will reflect the result of Cost Estimation in Chapter 10.

2) Residual Values

The life period of the civil structure and architectural buildings are assumed to be 50 years. Since the project life evaluation period ends in 30 years, its residual values are added as the revenue (negative cost) in the final evaluation year.

(2) Operation and Maintenance (O&M) Cost

1) Annual O&M Cost

O&M cost will reflect the result of the cost estimation in Chapter 10. The O&M cost is calculated by the forecast production volume and its fixed/variable cost in each year. The O&M cost in the analysis presumes the operation rate of the Perur DSP at 75% because the projected operation rate of the DSP was 60 to 85% in average availability condition of the surface water. (See Table 5.1.11)

2) Replacement Cost

The life period of the mechanical and electrical equipment portion are assumed to be 20 years. 40% of the mechanical & electrical equipment is added to the cashflow as the replacement cost after 20 years of commencement of the operation.

The Figure 12.2.1 presents the financial cost pattern of the Project.

Nondisclosure

Figure 12.2.1 Total Financial Cost Schedule

12.2.3 Incremental Revenue by the Project

The financial revenue captures the additional revenue generated by the implementation of the Project. The augmented water supply volume will incur the incremental revenue to CMWSSB. However, the increase in water supply to non-metered consumers does not expand the financial benefits of the CMWSSB. Only the increase in the volumetric tariff collection from the metered consumers is reflected in the calculations as financial revenue.

Additional Revenue = SV x RCR x MR x ATR

Table 12.2.2 Figures Used for Calculating the Incremental Revenue

Items for calculation	Data source, assumption
SV: Supplied Volume	- Increased Sold Water Volume (Appendix A12.1.7) - For the purpose of the analysis, it presumes that CMWSSB provides priority contracts to industrial usage of water (over commercial usage) after fulfilling the residential demand.
RCR: Revenue Collection Rate	Since SV already accounts for the water loss rate, RCR would reflect CMWSSB's revenue collection rate in the tariff collection operation. - Residential: 80% (2023) – 95% (2047) - Commercial: 85% (2023) – 95% (2047) - Industrial: 90% (2023) – 95% (2047)
MR: Metered Rate	Alternative 1) Maintain the Metered Rate of 2016 until the end - Residential: 1.74% - Commercial: 25.6% - Industrial: 100% Alternative 2) 100% metering are achieved by the commencement of Perur Plan - Residential: 100% - Commercial: 100% - Industrial: 100%
ATR: Average Tariff Rate	- Residential: INR. 25/kl (over the usage of 25KL or more per month) - Commercial: INR 35/kl - Industrial: INR 60/kl

Source: JICA Study Team

12.2.4 Analysis Results

Table 12.2.3 summarizes the results of the financial analysis using the Alternative 1. The analysis is separated to financial benefit against the total cost and O&M cost only. The indicators used to show the results are Financial Internal Rate of Return (FIRR), Benefit-Cost Ration (B/C) and Net Present Value (NPV) of the Project.

Table 12.2.3 Results of the Financial Analysis (Alternative 1)

Cost Scenario	FIRR	B/C	NPV (Million JPY)
Total Cost	Not Applicable	0.26	-181,364
O&M Cost Only	Not Applicable	0.35	-116,498

Source: JICA Study Team

The FIRR is not calculable in this case since the cash flow shows negative values in all years. From looking at the B/C and NPV, the Project shows high negative values when the analysis follows the current metering condition.

Table 12.2.4 summarizes the results of the financial analysis using the Alternative 2.

Table 12.2.4 Results of the Financial Analysis (Alternative 2)

Cost Scenario	FIRR	B/C	NPV (Million JPY)
Total Cost	Not Applicable	0.47	-130,801
O&M Cost Only	Not Applicable	0.65	-63,425

Source: JICA Study Team

The 100% metering has improved the financial test. Again, the FIRR is not calculable in this case. The B/C has improved further to 0.65 in O&M cost only case of the alternative 2 and the NPV has reduced to -63.4 billion JPY.

In either alternative, the financial feasibility could not have been achieved. Thus, 100% metering is not the only solution to achieving the financial stability of CMWSSB. The impact of tariff revision is analyzed in the next section.

12.2.5 Sensitivity Analysis

(1) Fluctuations in Cost and Benefit

The results of the sensitivity analysis are listed in the Appendix 12.4. When current metering situation is applied (Alternative 1) against all cost (Investment + O&M), 50% cost reduction or 50% benefit escalation is not enough for FIRR to surpass the WACC (Appendix A12.4.1). For O&M cost only against Alternative 1, 50% cost reduction plus 50% benefit escalation would result in FIRR of 3.2% (Appendix A12.4.2), which is higher than the WACC of 1.74%. When 100% metering is achieved by 2023 (Alternative 2) against all cost (Investment + O&M), then at least 45% cost reduction plus 30% benefit escalation is needed to be financially feasible (Appendix A12.4.3). However, O&M cost is only managed through “self-financing”. Therefore, FIRR needs to surpass the self-financing cost of 6.8%. In that case, at least 30% cost reduction plus 15% benefit escalation are required to be financially viable (Appendix A12.4.4).

(2) Applying the New Tariff Schedule

As presented in Table 3.7.4, CMWSSB currently considers to increase the metering tariff schedule. Table 12.2.5 and Table 12.2.6 show the result of the financial analysis using the new tariff schedule.

Table 12.2.5 Results of the Financial Sensitivity Analysis (Alternative 1 – New Tariff)

Cost Scenario	FIRR	B/C	NPV (Million JPY)
Total Cost	-9.3%	0.54	-112,509
O&M Cost Only	Not Applicable	0.74	-47,643

Source: JICA Study Team

Table 12.2.6 Results of the Financial Sensitivity Analysis (Alternative 2 – New Tariff)

Cost Scenario	FIRR	B/C	NPV (Million JPY)
Total Cost	-0.6%	0.97	-8,542
O&M Cost Only	Not Applicable	1.33	58,835

Source: JICA Study Team

The new tariff schedule is an increase in the volumetric charges, therefore the impact is small in the alternative 1 (same metering condition as of 2016). Meanwhile, the impact on Alternative 2 (100% metering by 2023) is very large. The FIRR against the O&M is not calculable, but the NPV of Benefit is 33% larger than the NPV of Cost. The Project is valued more than JPY 58 Billion in the NPV.

From the above analysis, the metering as well as implementation of new tariff is strongly recommended in the timely manner to achieve the financial viability of the Perur DSP. If all measurements are successfully imposed, then the Project brings large financial benefit to the organization.

(1) Fluctuations in Water Volume

The production water volume of Perur Plant predicted in this study has not reached the maximum operation capacity. Water production volume at the Perur DSP could vary depending on fluctuated water demand and surface water availability. The Table 12.2.7 summarizes the changes in results with different Perur water production volume, keeping the total supplied volume unchanged. The 100% metered condition is applied for the purpose of capturing the benefit in the augmented volume.

Table 12.2.7 Sensitivity Analysis in Water Volume Fluctuations (Alternative 2 – Current Tariff)

Production Volume	Cost Scenario	FIRR	B/C	NPV (Million JPY)
-20%	Total Cost	-12.3%	0.48	-111,498
	O&M Cost Only	Not Applicable	0.70	-44,122
+20%	Total Cost	Not Applicable	0.47	-150,104
	O&M Cost Only	Not Applicable	0.61	-82,728

Source: JICA Study Team

Since O&M cost per KL of producing SWRO water is higher than the average revenue of sold water per KL, the FIRR reduces as production volume increases. This would mean that the more CMWSSB produces Perur water, the more financial burden is incurred to the organization.

The Table 12.2.8 analyses the differences in results with fluctuations in Perur water supply volume with the new tariff scheme.

Table 12.2.8 Sensitivity Analysis in Water Volume Fluctuations (Alternative 2 – New Tariff)

Production Volume	Cost Scenario	FIRR	B/C	NPV (Million JPY)
-20%	O&M Cost Only	Not Applicable	1.43	62,917
+20%	O&M Cost Only	Not Applicable	1.26	54,753

Source: JICA Study Team

At the new tariff scheme, the average revenue of sold water per KL is set very close to the O&M cost per KL. Therefore, the fluctuations in the water volume does not impose large fluctuations on the analysis results.

12.3 Economic Analysis

The economic analysis will assess the economic viability of the Project. The economic cost and benefits to all relevant stakeholders will be assessed and weighed against each other to evaluate the economic benefit or burden generated by the Project.

12.3.1 Outline of the Economic Analysis

The Table 12.3.1 shows the economic cost and revenue associated with the Project.

Table 12.3.1 Revenue and Cost Items considered in the Economic Analysis

Economic Cost	Economic Revenue
1) Investment Cost • Initial construction cost • Residual value at the end of the evaluation period 2) O&M Cost • Operation and Maintenance (O&M) cost • Future replacement cost for equipment in the plant	(1) Benefit from the incremental water usage by the project (2) Benefit from cost reduction in bore well operations (3) Benefit from the reductions in medical costs (4) Benefit from the reductions in water fetching time of household members

Source: JICA Study Team

12.3.2 Economic Cost

The items listed in the economic cost are the same as that in the financial cost; however, the local currency portion of the cost will be adjusted to economic cost using the SCF. Furthermore, the economic analysis only cares about the total economic cost of the society; the analysis will not be conducted by cost category, which is different from the financial analysis. The summary of the economic cost is presented in the Appendix Figure A12.5.1.

12.3.3 Economic Benefit

The economic benefit has 4 separate categories, each explained in detail below. Also, as explained earlier, the economic revenue will be captured with the presumption that the augmented water volume incurs new water consumers for the simplicity of the calculations.

(1) Benefit from the incremental water usage by the Project

The construction and operation of the Perur DSP will provide additional water to the consumers within the service area of the CMWSSB. The incremental water volume (IWV) will contribute towards the improvements of the economic well-being of the society at large. The economic value of incremental water use is calculated by multiplying the increased water volume and the WTP (willingness to pay) of the users.

"Benefit of Incremental Water Usage" = IWV x WTP, where IWV = Increment Water Volume and WTP = Willingness to Pay.

Table 12.3.2 Figures Used for Calculating the Benefit of Incremental Water Usage

Items for calculation	Data source, assumption
IWV: Increased Sold Water Volume	- Increased Sold Water Volume (Appendix A12.1.7) - Number of Beneficial Service Connection (Appendix A12.1.2)
WTP: Willingness to Pay	Retrieved through the Social Survey conducted in this Project - Residential: INR 106.9 / service connection / month - Commercial: INR 400 / service connection / month - Industrial: INR 400 / service connection / month*1

*1: Industrial WTP was unable to be calculated from the Survey results. For the analysis, the industrial WTP is set at the same rate as the commercial sector to estimate in the safe side since water supply is usually valued higher in industrial sector than commercial sector.

Source: JICA Study Team

(2) Benefit from cost reduction in bore well operations

The 24-hour supply from the Perur DSP will free household from operating and maintaining bore well machineries at home. The reduction in the maintenance cost associated with the O&M of bore well facilities are captured as economic benefit in the analysis.

"Benefit of Cost Reduction in Bore Well Operations" = (NB x CBW x IR) + (NB x SHO x IR x EVT), where NB = Number of Beneficiaries, CBW = Cost associated with Bore Well Water, IR = Impact Rate, SHO = Saved Hours Operating Bore Well Water and EVT = Economic Value of Time

Table 12.3.3 Figures Used for Calculating the Benefit of Cost Reduction in Bore Well Operations

Items for calculation	Data source, assumption
NB: Number of Beneficiaries	- NB = Number of Service Connections (Appendix. A12.1.2)
CBW: Cost Associated with Bore Well Water	The O&M cost of the Machinery is retrieved through the Social Survey conducted in this Project - Residential: INR 1,076 / service connection / annum - Commercial: INR 1,250 / service connection / annum - Industrial: INR 1,250 / service connection / annum*1
SHO: Saved Hours Operating Bore Well Water	The hours associated with retrieving the bore well water is retrieved through the Social Survey - Residential: 0.62 hours/day - Commercial: 0.19 hours/day - Industrial: 0.19 hours/day *1 - Total: 0.98 hours/day
IR: Impact Rate	50%: Assumed by JICA study team following to manual
EVT: Economic Value of Time	- EVT considers 20% of GRDP per capita - Factoring 5/7 days a week and 7/24 hours a week ≒ 20% - GRDP per Capita of Chennai (Appendix A12.1.8 derived from 2015 figure from the Ministry of Statistics and Programme Implementation and growth estimation in the "The World in 2050" report by PWC[1])

*1: Industrial figures employ the same values as commercial sector.
Source: JICA Study Team

(3) Benefit from the reductions in medical costs

There are many diseases associated with water. They are called water-borne and water-washed diseases that are caused by the deficiency in the quantity and quality of water. Currently, CMWSSB fails to supply enough water to fulfill the demands of the households, and many households alternate to the usage of private bore-well water to satisfy the demand. The private bore-well water is not treated properly and therefore, causes water-borne diseases. The financial costs and loss of working hours associated with these diseases are expected to reduce as CMWSSB provides more volume of quality water.

Many studies have shown that increase in the quantity and quality of the water reduces its risk of infected with water-borne and water-washed diseases. An analysis presented in WHO proves that the augmentation in water volume and quality improvement together resulted in 17% reduction of medical

[1] Price Waterhouse Copers (PWC) "The World in 2050 - Will the shift in global economic power continue?" (2015)

morbidity from those diseases.[2] UNESCO World Water Report also supports that the augmentation of water would reduce the burden of the infectious diarrheas by some 17%.[3] Furthermore, the Report states that the universal piped, well-regulated water supply and full sanitation would lead to even 70% reduction in medical burden. The calculation would apply 17%.

The economic benefit of reduction of medical cost is calculated based on the following formula:

"Benefit of Reduction of Medical Cost" = (NB × MCPP × CRR) + (NB × SLD x EVT × CRR), where NB = Number of Beneficiaries, MCPP = Medical Cost per Household (Service Connection), CRR = Cost Reduction Rate, SLD = Saved Lost Days and EVT = Economic Value of Time

Table 12.3.4 Figures Used for Calculating the Benefit from the Reduction in Medical Cost

Items for calculation	Data source, assumption
NB: Number of Beneficiaries	- NB = Number of Service Connections (Appendix. A12.1.2)
MCPP: Medical Cost per Household (Service Connection)	MCPP is retrieved from Social Survey - INR 724.25
CRR: Cost Reduction Rate	- 17%
SLD: Saved Lost Days	Number of sick leaves from work associated with the disease - 6.4 days (from social survey)
EVT: Economic Value of Time	Same as EVT in the Table 12.3.3

Source: JICA Study Team

(4) Benefit from the reductions in water fetching time of household members

Currently, some households fetch water from water tank lorries or private water tanks for collective users. The increase in the water supply from the Perur DSP will allow households to enjoy water from the pipeline connected to each household. Thus, the reductions in water fetching time will contribute towards the economic benefit of the society. The benefit is calculated based on the following formula:

"Benefit of Time Saving for Fetching Water" = NB x SFT x IR x EVT, where NB = Number of Beneficiaries, SFT = Saved Fetching Time (per year), IR = Impact Rate, EVT = Economic Value of Time

The NBH and RWC as well as the SFT will be estimated by the result of household interview surveys. The EVT will be calculated from available statistical data in Chennai and surrounding areas.

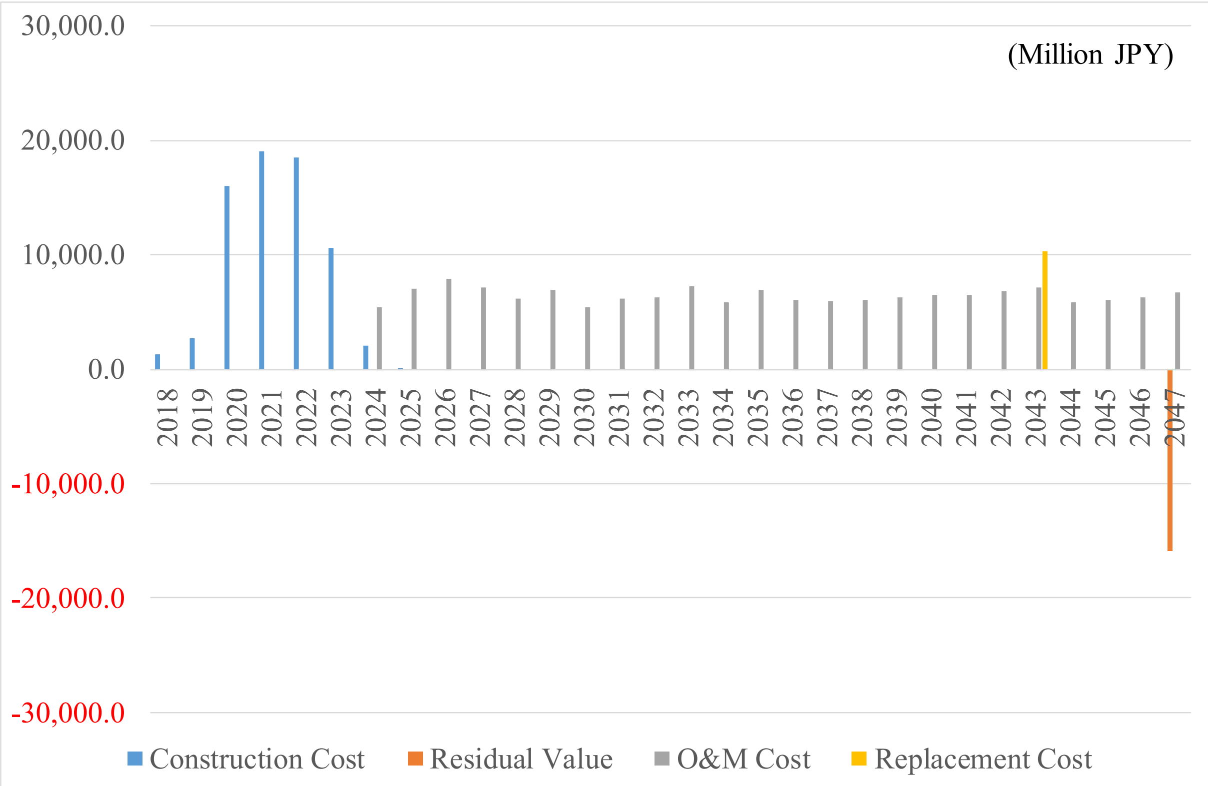
[2] S.A. Esrey et al. "Effects of improved water supply and sanitation on ascariasis, diarrhea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma" Bulletin of the World Health Organization, 69 (5): 609-621 (1991)
[3] UNESCO World Water Assessment Program, "The United Nations World Water Development Report" (2003)

Table 12.3.5 Figures Used for Calculating the Benefit from the Reduction in water fetching time of household members

Items for calculation	Data source, assumption
NB: Number of Beneficiaries	- NB = Number of Service Connections (Appendix. A12.1.2)
SFT: Saved Fetching Time	SFT is retrieved from Social Survey - 4.8 Hours / annum
IR: Impact Rate	50%: Assumed by JICA study team following to manual
EVT: Economic Value of Time	Same as EVT in the Table 12.3.3

Source: JICA Study Team

The Figure 12.3.1 presents the added total economic benefit of the Project.



Source: JICA Study Team

Figure 12.3.1 Summary of the Economic Benefit

From the figure, it shows that the most of the economic benefit is accounted in the cost reduction in the use of bore well water. This is because people spend very many hours operating the bore well to retrieve current source of water. There are much loss in EVT with this activity. The EVT increases as economy grows, so the benefit associated with the EVT are likely to grow as time passes.

12.3.4 Analysis Results

The table 12.3.6 presents the results of the economic analysis. The indicators used to show the results are Economic Internal Rate of Return (EIRR), Benefit-Cost Ration (B/C) and Net Present Value (NPV) of the Project.

Table 12.3.6 Results of the Economic Analysis

EIRR	B/C	NPV
22.5%	3.18	436,588

Source: JICA Study Team

The results show that the project is economically viable at EIRR of 22.5%. The NPV of the benefit became more than 3 times higher than the NPV of the cost. As concluded in the Section 12.3.3, much of the economic benefit came from saving the loss in EVT. Although the Project is financially infeasible, the Project is expected to produce great deal of economic meaning to the society by saving EVT.

12.3.5 Sensitivity Analysis

(1) Fluctuations in Total Cost and Benefit

The Table 12.3.7 summarizes the results of the sensitivity analysis when fluctuations in total economic cost and benefit.

Table 12.3.7 Economic Sensitivity Analysis (Fluctuations in Cost and Benefit)

		Benefit								
		-20%			0%			+20%		
		EIRR	B/C	NPV	EIRR	B/C	NPV	EIRR	B/C	NPV
Cost	+20%	13.4%	2.12	269,302	18.2%	2.65	396,604	22.5%	3.18	523,905
	0%	17.2%	2.55	309,286	22.5%	3.18	436,588	27.3%	3.82	563,890
	-20%	22.5%	3.18	349,270	28.5%	3.98	476,572	34.1%	4.78	603,874

Source: JICA Study Team

The sensitivity analysis shows that the result is slightly sensitive to cost fluctuation than benefit fluctuation. The EIRR is maintained over 10% even the project observes 20% in cost increase and 20% in benefit reduction.

(2) Fluctuations in Water Production Volume

The Table 12.3.8 summarizes the possible fluctuations in the water production volume in the same method as the financial sensitivity analysis.

Table 12.3.8 Economic Sensitivity Analysis (Fluctuations in Water Production Volume)

Production Volume	ERR	B/C	NPV (Million JPY)
-20%	20.2%	3.25	385,803
+20%	24.7%	3.14	487,373

Source: JICA Study Team

The increase in the water volume imposed positive impacts to each economic indicator. This implies that the economic benefit per KL of water exceeds the economic cost per KL of water. The more water Perur Plant produces, the more economic benefit is incurred to the society at large.

12.3.6 Qualitative Economic Benefit

The above results only capture the quantified economic benefits. However, the economic viability of the Project needs to consider both quantitative and qualitative economic benefits. There are multiple economic benefits that are not well captured in quantified equations. The qualitative economic benefits of the Project include welfare improvement of the poor, increase in economic opportunities, and some others that are listed below.

(1) Welfare Improvement of the Poor

The above quantitative analysis captured the welfare improvement of the entire population connected to CMWSSB services using the average GDP per capita. In a sense, the welfare improvement of the poor is included in the quantified calculation. However, economic benefits only arise when economic opportunity costs are barred due to lack of services supplied by this new project. Therefore, the welfare improvement of the poor without significant economic opportunity cost is limited on the equation. Nonetheless, access to water to the poor may incur greater benefit than the number exhibits. Also, augmentation of the piped water supply often creates trickle-down impacts to water markets in the entire region by creating competition to prices and quality of other water sources. Indirectly, the poor are able to access more of quality water for a cheaper price. Improvements in sanitary condition and cost-saving for water purchase may cause greater economic opportunities for the poor.

(2) Increase of Economic Opportunities

The quantified benefits from less water-stops capture the loss in economic activities based on the estimated regional GDP growth. The water supply volume and quality are one of the important decision-making factors when choosing the business location. Due to the increased water supply and fewer water-stops, more factories may choose to locate in Chennai. The increase water quality can also widen the range of industrial sectors since some industries require refined water quality for production. The future total regional GDP may enlarge with the implementation of the project. The magnitude is uncertain; therefore, this factor is discussed qualitatively.

(3) Peak Management

The augmentation of the piped water supply will decline the extraction of the groundwater, ensuring the groundwater supply reliability in the future. In the case of severe drought conditions, the water extraction volume can be increased with the mix of piped water and groundwater. The benefit is discussed qualitatively due to the uncertainty in the added water supply reliability provided by the avoided groundwater pumping.

(4) Wastewater Quality Improvement

When the quantity and quality of the piped water are increased and less bore well water is used, the quality of water flowing to the wastewater plants is improved. Then, the cost of wastewater treatment becomes less, and the life-period of wastewater plants may become longer. The city of Chennai often encounters flooding incidents; in such cases, sanitary impacts may be mitigated with better quality wastewater. The magnitude of quality improvement of the wastewater is uncertain; therefore, this factor is discussed qualitatively.

12.4 Consideration on the Water Tariff of CMWSSB

12.4.1 Possible Impact of the Project on the Water Tariff

The investment portion of the cost is covered by the Tamil Nadu State finance. Ordinarily, CMWSSB financial policy aims to balance the annual revenue to annual O&M costs of administration and water production. The cost of water production for CMWSSB will increase when the Perur DSP comes into operation. Of course, the total cost, as well as the marginal cost of one unit of water, increases since the cost of production through seawater desalination is more expensive than traditional sources of water. The financial analysis has proven that the impact on CMWSSB's revenue from the new DSP operation is limited given the fact that many users only pay the flat rate tariff in the current condition. Without the meter installments, an increase in the volumetric water tariff will not fully reflect incremental revenue. Furthermore, the result of the financial analysis showed that the 100% metering is still not enough to cover the O&M cost of the DSP operation. CMWSSB must consider both 100% metering scheme and new tariff installment as soon as possible.

12.4.2 Tentative Conclusions and Recommendations for Financial Sustainability of CMWSSB

The financial analysis in this Project only considers incremental cost and revenue from the Perur DSP. Analyzing CMWSSB’s financial condition as a whole, JICA Study Team recommends the following policies. The Project is economically meaningful to the society as proved in the economic analysis, therefore the CMWSSB should consider imposing these policies to achieve the future financial sustainability.

- Short-term: Revision of flat rate and volumetric tariff

Considering only 3.90% of users having meters (as of July 2016), the installation of meters will take time. Meanwhile, the flat rate tariff for non-metered users should be raised to increase the revenue. The flat rate payments are stable revenues for the CMWSSB. The M/P proposes the flat rate to be very low; however, the flat rate should be maintained high enough even after the installment of meters so that the CMWSSB has a solid and stable base of financial revenue. The constant share of income would be available to CMWSSB even if Chennai faces water deficiency seasons. Thus, the revision of flat rate tariff is recommended in the short term.

As mentioned in Section 3.6.2, CMWSSB has started considering the revision of volumetric tariffs. Its idea is to double the per KL tariff. The increase in tariff is not easy since it involves political decisions. Hence, the changes to flat rate and volumetric tariffs should be done at the same time. Although the increase in the volumetric charge does not create much impact of residential water usage due to lack of meters, commercial and industrial usage will impact the CMWSSB revenue. The changes in the volumetric tariff may lead to incentives for CMWSSB to fasten the metering program.

- Middle-term: Inducement of water meters

The financial analysis has proved that improvement in metering condition would drastically improve the revenue impact to CMWSSB. The inducement of water meters is recommended in the MP, however, there is no roadmap towards achieving the 100% metering. Under the current tariff scheme, there is no incentive for users to install meters. The cost of meter installation is charged to users, and the metered users have to pay more than the unmetered users. Many customers of CMWSSB are unmetered, and they consider marginal cost of water to be very low since they pay flat rates. Also, the average cost of water diminishes as the water consumption volume increases. These users tend to show hesitation towards the introduction of volumetric charges. Thus, the tariff table needs to reflect natural incentive for users to install water meters. One way is to make the differences in flat charge portions between metered and unmetered customers. CMWSSB should also consider subsidies for meter installment to obtain sustainable future revenue.

- Long-term: Regulations for private bore-well water

Currently, many users mix the use of CMWSSB water and the water from the private bore-wells. The O&M costs for bore well water are only electricity and maintenance of the pump, and they are shared by multiple users in many cases. The attractiveness of CMWSSB water over bore well water is its water quality. However, for some household uses, such as toilet and cleaning water, the quality of bore well water satisfies the needs. When the consumers already have free access to the ground water, consumers will hesitate to consume a large volume of treated CMWSSB water under volumetric charging schemes. In the long-term, after achieving 24 × 7 water supply services, CMWSSB should propose regulations on private bore-well water so that consumers have limited access to untreated water.

CHAPTER 13 PROJECT EVALUATION AND PROPOSALS ON INDICATORS FOR MEASUREMENT OF PROJEFT EFFECTS

13.1 Evaluation of Viability of the Project

Project evaluation includes i) technical, ii) environmental and social, iii) financial and economic and iv) organizational and institutional viewpoints as follows:

(1) Technical evaluation

The necessity of the Project to construct the seawater desalination plant (DSP) at Perur was confirmed through analysis of water demand and supply gap. After analysis of the gap, it was inferred that the planned capacity of 400 million liters per day (MLD) together with all other existing and planned water sources, would be sufficient to satisfy the increasing water demand without over-investment. Potable water to be produced at the DSP will satisfy the Indian standard of drinking water. The power requirement of the DSP will be as huge as 80 MW, but the Tamil Nadu Electricity Board (TNEB) is confident that they will provide sufficient power uninterruptedly by two independent power lines, one of which is dedicated to the DSP.

The produced water at the Perur DSP will be delivered to the water users of CMWSSB through the new transmission system to be constructed by the Project and the existing transmission and distribution systems.

The JICA Study Team examined the capacity of the existing transmission and distribution networks in the core city, a part of which is the influence area of the Perur DSP. The examination found that the hydraulic capacity of the distribution networks and storage capacity of the reservoirs are not sufficient in some zones, even for the water demand for 2035. In addition, there are old pipes whose conditions have deteriorated over the time. Therefore, it was proposed that augmentation of the existing distribution pipes and reservoirs, as well as replacement of old pipes, should be included in the Project. It will contribute to the maximum utilization of valuable desalinated water.

In the DSP's influence area in the Expanded Area, new distribution networks will be soon completed by CMWSSB. In the influence area in Rest of CMA, bulk supply are planned to be provided by CMWSSB to the municipality areas. So far the towns and villages do not have any plan to receive water supply from CMWSSB. However, after the Chennai Corporation integrates the entire CMA area, which is said to happen shortly, CMWSSB will strengthen the existing distribution network or develop new networks to enable sufficient water supply to meet the water demand.

As explained above, the Project will include all components to ensure its contribution in satisfying the water demand in its influence area. It plans to achieve its goal by delivering high-quality water to the water users using the existing and new water transmission and distribution networks. From the projection of the water production volume, the operation rate of the Perur DSP will be 60 to 85% in normal climate years but will be operated at its full capacity in moderate drought years. The development of water distribution network in some towns and villages may take more time, which may prevent the achievement of the planned water allocation. However, even if the expansion of the CMWSSB's service area is delayed, the product water from Perur will be utilized in other surrounding areas.

(2) Environmental and social evaluation

The JICA Study Team evaluated the potential impact of the Project on the environment and social aspects during the implementation of the Project and operation of the facilities to be constructed by the Project.

The construction and operation of seawater intake and brine discharge facilities are sometimes referred as a risk to the marine ecosystem. However, the study has planned the marine facilities have so that such negative impacts can be avoided. As for sea turtles, Olive Ridley, which are reported to live along the east coast in and around Chennai, no nesting or egging activities have been observed in the seashore around the project site at Perur.

Land acquisition and resettlement is not required for the plant site due to Government of Tamil Nadu's decision of the land lease from the land owner (a religious and charitable trust maintained by the HR&CE Department of the Government) to CMWSSB for 30 years. In addition, all pipelines to be installed in the Project will be laid in the existing roads, which means no land acquisition and resettlement are necessary.

As part of the social consideration in the Project, stakeholders meetings have been held by the CMWSSB initiative. In the meetings, negative opinions and objections to the project were not presented from the surrounding villagers of the project site in Perur.

As for CRZ clearance, CMWSSB has officially applied for the issuance to MOEF after getting recommendations of CZMAs (District and State levels). According to the CRZ notification, the CRZ clearance for the Project will be issued in due course. After the issuance of the clearance, CMWSSB shall apply to the State Pollution Control Board (SPCB) for getting an NOC (No objection Certificate), but there seems to be no potential obstacle in obtaining the NOC.

As a whole, no significant impact on the environment and social aspect has been predicted in the Study for the construction and operation of the Perur DSP and the transmission lines in the Project.

(3) Financial and economic evaluation

Nondisclosure

Financial Internal Rate of Return (FIRR) of the Project, calculated based on the incremental sold water volume was incalculable. Since the Project does not generate new consumers of the CMWSSB water other than natural population growth, the current low percentage of meter installation limits the impact of the Perur DSP on CMWSSB revenue. CMWSSB does not have a capacity to repay the cost burden on the construction cost. The only scenario of achieving the financial feasibility against the O&M cost of the DSP is when the 100% metering and draft tariff revision are both achieved by the commencement of the Perur DSP. As for the repayment of the JICA loan, nevertheless, the state government will pay back JICA because CMWSSB is not capable of repayment. The same scheme has been adopted by the other ongoing seawater desalination projects funded by KfW.

The economic analysis proved the economic viability of the Project with the EIRR value of 22.5% exceeding the viable benchmark value of 10%. The B/C became 3.18 where the NPV of the economic benefit exceeds NPV of economic cost by more than 3 times. The reduced cost in operation and maintenance of the bore well water generated the highest economic benefit. To seize the positive economic benefit to the society, CMWSSSB needs to impose necessary fiscal policy amendment to its revenue structure.

(4) Organizational and institutional evaluation

The JICA Study Team has observed several organizational deficiencies in CMWSSB and institutional challenges that CMWSSB will face in the implementation of the Project. CMWSSB has to take the initiative of revising its policies and adopting self-governing systems capable of self-management to overcome the deficiencies and challenges.

One of the critical issues is the management style practiced at CMWSSB, where each technical decision needs the approval of Engineering Director or for that matter; all decisions require the Managing director’s consent to be converted into action. Having become accustomed to such a practice, the project implementation will require CMWSSB’s top management’s personalized intervention along with review pressure from as far up as the Chief Minister’s Office.

Alternatively, a special delegation of powers to the dedicated Project Implementation Unit (PIU) needs to be exercised. For the PIU, the appointment of an experienced director, who has strong leadership has to be given special authorization for decision-making at his level itself. Successful implementation will require taking the lead in coordinating with the authorities and utilities for implementation of necessary actions, instead of leaving this responsibility to the contractors to mitigate the risk of construction delay caused by late permissions from State and Central government. Getting approvals of State Agencies associated with the project work (e.g. Highways, Telephone, Electricity, Police, Pollution Control Board, PWD, etc.) is probably not an issue; however getting these State Agency staff to implement in sync with project timelines is the real challenge.

Adding to this aspect is the fact that most of the senior staffs are fast approaching retirement, with very few replacement options available. This will soon result in depletion of the organizational experience and knowledge bank. Appropriate replacement arrangement for retiring senior staff, who are involved in the Project, are needed for seamless efficiency in the implementation of the Project.

Customized training for PIU staff will be essential; training of all personnel associated with the project on two key aspects i.e. JICA procurement procedures/ guidelines and project management practice is required. Though CMWSSB has executed many projects in the past but the maximum value project handled by CMWSSB till date is INR 10,000 million, this being one-fourth of the Project value.

Since the project's overall objective is to maximize sustainable water services and improved service level for citizens' of Chennai, key strategic, structural and issues with respect to organizational strengthening have to be dealt with, with a sense of urgency and seriousness that it deserves. A team of consultant will be needed by CMWSSB to complement internal capabilities for its organizational strengthening.

Reactive organizational culture, with the majority of the time spent in crisis management, will have to be replaced with a proactive approach. A major strength that goes in favor of CMWSSB is the willingness of the Board to carry out reforms. The fundamental challenge is not to fix the pipes, but rather to 'fixing the institution that fixes the pipes'.

13.2 Proposals on Indicators for Operation and Effects of the Project

To evaluate the operation and effects of the Project, indicators to be monitored after the project implementation are proposed as presented in Table 13.2.1. The indicators include not only those to measure the direct benefit and operational conditions of the Project but those to measure the performance of the overall water supply services of CMWSSB after the Project.

(1) Indicators for the overall operation of CMWSSB after the Project

Indicators for the overall operation of CMWSSB will be general indicators to measure the scale of water supply services by CMWSSB, targeting the entire service area of CMWSSB. Currently the service areas the Chennai Corporation area and some bulk supply areas in the Rest of CMA, but they will expand as bulk supply areas of CMWSSB will be added. If the corporation integrates the entire CMA, the target area will be further expanded to the whole of CMA accordingly.

Because these indicators are highly subject to the service area expansion matter, which is an external condition of CMWSSB or the Project, they are not regarded as those for direct effects of the Project.

(2) Indicators for direct benefits of the Project

Direct benefits of the Project will be service level improvement concerning service connection rate, water volume expressed as litter per capita per day (lpcd), service availability and satisfaction to water quality and water pressure, to which the Project will contribute. The target area of these indicators will be the Chennai Corporation, the present direct service area of CMWSSB. As there is a wide gap in the service level between the Core City and the Expanded Area, these indicators will be measured for the respective areas. For the service availability and satisfactions to the water quality and pressure, CMWSSB will need to conduct customer satisfaction survey to measure the Project's effect.

The Rest of CMA is not the target area of the indicators for direct benefit because CMWSSB is currently not responsible for the service level in the Rest of CMA and there is no timeframe for the expansion of the direct service to the area. In addition, there is no reliable data to set the current values for these indicators.

(3) Indicators for operation of the Project

Indicators for the operation of the Project are those to measure if the facilities constructed by the Project are utilized and functioning as expected in the planning stage. The utilization and function are measured by the annual average production and availability of the DSP.

Table 13.2.1 Indicators for Measurement of Project Effects

No.	Indicator	Target area[*1]	Unit	Present value 2015	Target value 2027[*2]	Remarks (Source of the target values)
(1) The overall operation of CMWSSB after the Project						
1-1	Served population of CMWSSB	CC	Persons	7.19 million[*3]	8.23 million	Water demand forecast in Appendix 5.1
1-2		CMA[*4]	Persons		12.97 million	
2	Served population rate	CMA[*4]	%	72.4	100	
3	Production capacity of CMWSSB	CMA[*4]	MLD	1,623	2,173	Existing + Additional Nemmeli + Perur DSPs
4	Annual average production of CMWSSB	CMA[*4]	MLD	596	1,755	Table 5.1.11
5	Water supply per capita	CMA[*4]	LPCD	82.9[*5]	135.3	1,755 MLD / 12.976 million persons
6	Billed volume of CMWSSB	CMA[*4]	m^3/y	652[*6]	1,354	Domestic and non-domestic water demand in Appendix 5.1
(2) Direct beneficial effects of the Project						
7-1	Service connection rate against the total population	CCC	%	65	95	Table 5.1.2
7-2		EA	%	46	75	Table 5.1.2
8-1	Domestic lpcd based on actual consumption and served population through service connection	CCC	LPCD	120	150	Table 5.1.3
8-2		EA	LPCD	80 in municipalities	135	Table 5.1.3
9-3			LPCD	40 in towns and villages	100	Table 5.1.3
9-1	Coverage of daily water supply	CCC	%	68.1[*7]	100	Table 3.2.7
9-2		EA	%	25.9.[*7]	100	Table 3.2.7
10	Satisfaction to water quality (Very good or good)	CC	%	46.5[*7]	70	Table 3.2.10
11	Satisfaction to water pressure (Very good or good)	CC	%	45.3[*7]	80	Table 3.2.11
12	Metered rate of the service connections	CC	%	3.9	100	-
13	Water Loss Ratio	CCC	%	20[*8]	10[*7]	Table 5.1.5
(3) Operation of the Project						
14	Annual average production of Perur DSP	-	MLD	-	303	Moderate drought case in Table 5.1.12
15	Availability of the Perur DSP[*10]	-	%	-	95	-

*1: CCC: Chennai Core City, EA: Expanded Area, CC: Chennai Corporation, CMA: Chennai Metropolitan Area
*2: Evaluation year is 2-year after the completion of the Project. Completion of CP 4 is planned at 2023
*3: Percentage of the served population (7.19 million) against the total population of CMA in 2015 (9.937 million)
*4: The entire service area of CMWSSB in CMA
*5: Water production (596 MLD) converted into per capita volume by the served population (7.19 million)
*5: The present consumption presented in Table 3.2.1.
*6: Based on the results of the Social Baseline Survey in the Study (See Subsection 3.2.3.)
*7: The estimated present water loss ratio (See Table 3.2.1)
*8: Excluding commercial loss, due to that the present value will not include that.
*9: Percentage of the days or hours when the DSP is available during a year.
Source: JICA Study Team

13.3 Potential Risks in the Project Implementation and their Mitigation Measures

From all descriptions or explanations on the Project in the previous chapters, the JICA Study Team identifies some risks that may prevent the implementation of the Project or deteriorate the beneficial effects of the Project. Mitigation measures against such risks are proposed in Table 13.3.1. Detailed descriptions of the risks and mitigation measures in the format of Risk Management Framework by JICA are given in Appendix 13.1.

Overall, if the countermeasures are implemented successfully, there will be no critical risk of the high probability that may prevent serious delay of the Project or deteriorate the Project's beneficial effects. The most key mitigation measures for the Project's implementation is the establishment of PIU with sufficient power in decision makings and SC to assist PIU. For the Project's beneficial impacts, improvement in metering ratio and introduction of a volumetric tariff to recover the operation cost will be the key.

Table 13.3.1 Risk Assessment to In-Time Delivery and Assurance of the Project's Beneficial Effects of the Project

Potential project risks	Assessment	Probability* / Impact	Mitigation measures
1. Stakeholder Risk			
(Description of risk) Delay in the Project implementation due to **conflicts with the land users of the project site**	- If happens, conflict with the stakeholders may lead to the halt of project, but its probability is low. - CMWSSB has already secured the land and is communicating the land users. - The transmission line will be installed on public roads in principle, for which no conflict will be generated.	Low / High	- Layout of the DSP have been planned to avoid any impact on the burial grounds. Stakeholder meeting by CMWSS was already held at Perur. - A monitoring plan and grievance redressal mechanism have been proposed in the Study.
2. Executing Agency Risk			
2.1. Capacity Risk (Description of risk) Delay in the Project implementation due to **incapability of the project executing agency**	- CMWSSB has experiences of DSP projects but no JICA loan project. - Current decision-making procedure and frequent personnel changes in critical positions will probably affect the implementation efficiency.	Low (high) / Middle	- A dedicated unit for the Project, PIU, has been proposed in the Study and CMWSSB has committed the establishment. - JICA will provide key PIU members with seminars on implementation procedures and rules in JICA loan projects before the Project.
2.2. (1) Governance Risk-1 (Description of risk) Delay in the Project implementation due to **complicated procedures required to conduct the project or unsuccessful coordination with other authorities/utilities**	- The Project will need various external procedures and coordination with other authorities/utilities. - CMWSSB is not powerful enough to complete them smoothly and timely in some of the procedures and coordination.	Low (Middle) / Middle	- Steering Committee (SC) for the Project has been proposed in the Study and CMWSSB committed requesting the state government to formulate the committee. - The committee will assist CMWSSB in any procedures or coordination with the external authorities/utilities.
2.2. (2) Governance Risk-2 (Description of risk) Delay in the Project implementation due to **incompletion of the environmental procedure for the Project**	- Documents for CRZ clearance on the Project has already been transferred from CZMA to MOEF in May 2016. - Probably the clearance notification will be given before the commencement of the construction, but there is no evidence that MoEF has started the evaluation.	Low / Middle	- At present CMWSSB is waiting for contact from MOEF. - CMWSSB will need to ask MOEF the current status of the assessment to MOEF to detect any problem or error if any.
2.3. Fraud & Corruption Risk (Description of risk) **Corruptions in the procurement procedures of the PMC or the contractor**	- CMWSSB is not deemed to be corrupted. - If happens and being exposed, however, the Project may not proceed.	Low / High	- All procurement processes will be conducted strictly complying with JICA's guidelines.
3. Project Risk			
3.1. (1) Design Risk-1 (Description of risk) Delay in the Project due to **technical or financial capability of the contractors**	- A good number of water supply projects in India are facing similar problems due to local contractors' incapability. - In the Project, contract packages for the transmission lines have	Middle / Middle	- Construction of the transmission lines has been divided into four (4) contract packages so that the size of the contract will be within local contractors' capabilities. - In the bidding processes, financial

	such possibilities.		and technical qualifications will be appropriately examined. The bid evaluation will take into account the technical proposals and examine feasibilities of the financial proposals carefully by the bidders.
3.1. (2) Design Risk-2 (Description of risk) Lower project' beneficial effects than expected due to **lower water demand derived from external causes**	- As production requirement to DSPs depends on climate conditions, production of the Perur DSP will possibly be lower than expected. - However, it is definite that the Project will contribute to the satisfaction of the people's water demand even if the production is lower. - Water distribution in the corporation will be completed soon by CMWSSB, but that in Rest of CMA will take time.	Middle / Low	- Sensitivity analysis for the lower production case has been conducted in the Study. - Water demand projection took into account graduate expansion of the water distribution network in Rest of CMA.
3.2. Program & Donor Risk (Description of risk) Lower project's beneficial effects than expected due to **low operation rate for CMWSSB's financial reasons**	- Similar situation exists in the existing Nemmeli DSP. - Improvement of the metering rate and introduction of the volumetric tariff at a financially viable level are the urgent issue.	Middle (High) / High	- CMWSSB has already carried out the financial simulation to know the sustainable tariff level and prepared meter installation and tariff improvement plans. - CMWSSB should achieve internal and external consensus on these plans.
3.3. (1) Delivery Quality Risk-1 (Description of risk) Lower project's beneficial effects due to **frequent failure in quantity or quality of the DSP or the transmission line derived from insufficient O&M skill or management**	- Possibility of O&M failure is not high because it owns an existing DSP under the similar contract to the Project and another similar project will be commenced soon.	Low / Middle	- The Project will adopt DBO contract, where the O&M works will be conducted by the plant provider. - The contract will require the contractor to train CMWSSB staff to obtain general knowledge to enable O&M supervision.
3.3. (2) Delivery Quality Risk-2 (Description of risk) Lower project's beneficial effects due to **severe damage to the facilities by natural disaster**	- If the plant is severely damaged, people may face water shortage for a long time. - Recovery or reconstruction of the plant will need huge investment.	Low / High	- The ground level of the site has been determined at a higher level than the water level at the 2004 Tsunami.

Probability in (　) is that if the proposed mitigation measure is not taken or successful.

Source: JICA Study Team