CHAPTER 4

FIELD SURVEYS AND ON-GOING STUDIES AND PROJECTS

4 FIELD SURVEYS AND ON-GOING STUDIES AND PROJECTS

4.1 WATER QUALITY ANALYSIS

4.1.1 Water Quality Management

(1) Role of Laboratories

a) General

The Central Laboratory Unit of KW&SB was established in COD Hills Water Treatment Plant. The Laboratory Unit is set up under Chief Engineer of the Bulk Transmission Division. The Chief Chemist is head of the Central Laboratory Unit and responsible for water quality testing of not only water treatment plants but also sewage treatment plants. Each water treatment plant has a small testing facility which can examine at least required water quality parameters. At least one lab technician is allocated at each testing room and attempts a daily analysis of raw water and filtered water. In the case of sewage treatment plants, testing laboratory is available only in TP-1 (The first sewage treatment plant in Karachi) within its premise. Consequently, regular water quality test in both TP-2 and TP-3 have not been performed daily. The laboratory attached to the treatment plant also checks out daily behaviour for common sewage parameters such as Total Suspended Solids (TSS), Chemical Oxygen Demand (COD_{Cr}) and Biochemical Oxygen Demand (BOD).

b) Activities of the Central Laboratory Unit

Major activities of the Central Laboratory Unit are as follows;

- Water quality monitoring for distribution network,
- Bacteriological Examination,
- Management of water quality data, and
- Submission of monthly progress report to the Managing Director

The most important task of the Laboratory is collecting samples once a week from representative pumping houses in each township to monitor residual chlorines and coliform count of water to distribute. The Laboratory has basic equipment for bacteriological/ microbiological examination. Most Probable Number (MPN) method is adopted for coliform counts of raw water and post chlorinated filtered water. If any coliform is detected, a result is reported to the Chief Engineer who is in charge of relevant Distribution Zone.

Collected data from each water filter plant are compiled and tabularised in a way easy to understand. The monthly progress report of Laboratory Unit prepared by the Chief Chemist is submitted to the Managing Director. The report includes descriptions for quantity & quality of raw water, disinfection by chlorination, chemical & bacteriological examination and recommendations.

c) Current Situations of Laboratory Unit

There is strong evidence that some functional problems of the Laboratory Unit are obviously present. Visual observation shows the following issues.

- No computerised data processing system causes no data maintenance
- Obsolescence of analytical instrument and outdated reagents/chemicals
- Lack of capacity/skills/experience of laboratory technicians

The Laboratory Unit has a great deal of past water quality data. However, the data have been brought down only “Hard Copies” in the old log books and many pieces of paper. No one gets a handle on those data without computerised data management. During the Basic Study, the Study Team expected that the Chief Chemist had past water quality data for the period between 2001 and 2005. Appropriate data were collected and compiled as the electric data. Tables of past data are shown in **Appendix A41.1**. Past data are evaluated in **Section 4.1.3**.

Analytical instrument for both physico-chemical and bacteriological parameters apparently have been gone out of date. Moreover, due to improper maintenance including no calibration, plenty of instruments have been broken down and abandoned in a corner of the laboratory. A lot of reagents, testing chemicals and standard materials that were likely donated by international agencies are left to stand in the chemical cabinet.

In the background of this situation, previous water quality data do not seem reliable, that is, tested data are nothing but just accumulated. There is no feedback system when abnormal value is obtained among the samples. In order to maintain parallel and independent check on city water supply qualities, assistance from Pakistan Council for Scientific and Industrial Research (hereinafter “PCSIR”) and Karachi University is taken periodically to collaborate and examine the quality of water from plants and different pumping houses of distribution system.

(2) Water Quality Issues of Karachi City and Sindh Province

a) Water Supply

According to Pakistan Social and Living Standards Measurement Survey 2004-5, 84 percent of people in Pakistan have access to improved drinking water; it was 53% in late 1980s. The available water is not sufficient and the quality of water is poor due to pollution from chemicals, including heavy metals, nitrate, fluoride and bacteriological contamination. Because of unsafe and insufficient water supply and low sanitation coverage, as well as people’s poor hygiene habits, around 60 percent of children suffer from diarrhea that is fatal if not treated in time.

A recently conducted ‘Pilot Water Quality Monitoring Program’, prepared by the Environmental Protection Agency Sindh for the Provincial Coordination Cell of the National Drainage Program, concluded that the water analyzed for the Indus River, major wetlands, drains and canals was found contaminated with industrial and municipal waste discharges and had been rendered unfit for human consumption as per the relevant water quality standards. All the industrial effluents from the Kotri Industrial Area are being pumped into the K. B. Feeder and the presence of heavy metals in the Kinjhar Lake can be attributed to Kotri Industrial Area discharges.

Concerns have also been raised by various quarters about contamination in drinking water supply in the distribution network and possible linkages with water borne diseases in the city. The seriousness of the issue can be rated from the fact that in the year 2002, the *Provincial Ombudsman Sindh*, Justice Haziqul Khairi in response to a growing number of reports received from all over the Sindh province about the supply of contaminated drinking water, instituted a study for investigating the claims of the public and assessing the causes of contamination. Regarding the quality of surface water supplied to the consumers, the *Study Report* concluded that about 75% of the water supplied to Karachi is chlorinated. Shortfall in the availability of water for drinking constrains the distribution to intermittent supply that is one of the main causes of water pollution.

The water that leaks through the distribution mains and smaller pipes, particularly the ones that were laid long time before and in the Third Phase of the Bulk Water Supply scheme for Karachi, creates an underground pool during the supply hours. This serves as a nursery to the micro-organisms, including fecal coliform released by the leaky sewers crisscrossing the water supply pipes. Sewage might enter into the distribution system due to vacuum created during idle hours. This is the reason for the gradual depletion of free-active chlorine in the treated water as it proceeds from the filter plant to the distribution network and in its onward journey to the households. The findings of the analysis of the water samples suggest that the water even though treated gets contaminated in the distribution network and on its way to the consumers. This finding suggests that the water as received by the residents is not safe for drinking.

Assessment of ground water quality in the aforementioned *Ombudsman Study Report* indicated that ground water has been over exploited in Sindh and the drying of traditional wells in the vegetable and fruit growing areas in the suburbs of Karachi has occurred. Although water quality has not been tested yet, groundwater pollution by nitrates, pesticides, heavy metals and hydrocarbons discharged into the environment is not negligible. The salinity of groundwater in Southern Sindh, particularly in the coastal areas has increased since over pumping has induced seawater to flow in, causing what is known as seawater intrusion.

The fact, also acknowledged by KW&SB, that 150 mgd (681,900 m^3/day) of water supplied to the consumers is chlorinated and bypasses the KW&SB filter plants is an important indicator of the need of addressing this issue on a priority basis. The *Ombudsman Study Report* says that the water drawn from about 95% of the wells in the city of Karachi is contaminated with sewage bacteria and also contains total dissolved solids beyond permissible limits. The *Ombudsman Study Report* also documents that 90% of the survey sample tests conducted by PCSIR indicate that the water is unfit for drinking purposes referring to the guidelines set by the World Health Organization (WHO).

There is no regulatory body in the city assigned to keep an independent check on KW&SB's activities. However, other studies have also indicated seriously high levels of contamination in the drinking water supply. Surveys conducted by even civic agencies in the past have indicated the presence of E-coli bacteria in drinking water. These pathogenic bacteria are found in domestic sewage, that clearly shows that sewage is getting mixed up with drinking water. KW&SB refutes these claims and attributes water contamination if any to poor maintenance of storage tanks by end users.

b) Sewerage/Sanitation

About 60-70% of the water supplied to Karachi City is said to return as sewage. A total quantity of 315 mgd (1,432,000 m^3/d) of domestic and toxic industrial wastewater is generated in the city. There are three sewage treatment plants in Karachi. The total design capacity of these treatment plants is 151 mgd (686,000 m^3/d). The untreated sewage is disposed of into the sea through nallahs and rivers including the Lyari and Malir Rivers. The total length of sewers is approximately 3,290 km and ranges from 8 inches (200 mm) to 84 inches (2,130 mm) diameter of trunk sewers, secondary sewers and laterals.

Domestic sewage is a major source of pollution. National Conservation Strategy (NCS) states that almost 40% of deaths are related to water borne diseases. The situation is further aggravated by the addition of untreated wastewater from small-scale industries.

Karachi's untreated wastewater including domestic sewage and industrial wastewater is discharged into the Lyari and Malir rivers, which finally flow into the Arabian Sea. This wastewater has begun to pose a negative influence on the marine environment, as the channel water is contaminated not only with bacteria but also with toxic chemicals. Water pollution also extends a savage threat to wildlife. Animals drink water out of polluted water bodies, ailing lagoons, rivers and streams. This sickens the animals and some may even die. Survival of small invertebrates, micro fauna and flora is also threatened.

The Malir River drains into the Arabian Sea via the Korangi Creek/Ghizri Creek. Korangi Creek forms part of the Indus Delta that harbours the fifth largest single arid region mangrove forest in the world. The mangroves play an important role in the swampy eco-systems of the Indus Delta. They accumulate silt, accrete shoreline, preventing erosion of the coastline, beaches and flooding. Their most important function is to provide food, shelter and to serve as nursery grounds for a variety of the larvae and juveniles of marine organisms. They increase primary productivity of the coastal waters. The mangroves support a rich invertebrate fauna dominated by crustaceans and provide food rich habitat to a large number of juveniles, of fish and shrimps. The Korangi and adjoining creeks also support a well established fishing industry. As such the discharges of the polluted city waste is an issue of concern.

The Lyari River flows into the Arabian Sea via the Lyari Estuary/Manora Channel. This discharge also finds its way into the harbor area. The affected area harbors mangrove forestation. Tests conducted in the harbor area have indicated Dissolved Oxygen (DO) and BOD to be at critical levels. The wastewater discharged into the harbour carries on human pathogens and the concentrations of these on the sediments increase the risk of uptake into shell fish and other benthic organisms and hence into the food chain.

In Karachi, drinking water supply lines and open sewage drains in the streets are laid side by side. As a result, water is frequently contaminated when pipes are corroded and/or when pipe joints are inappropriate.

Industrial wastewater contains toxic chemicals in many cases. It is alarming that most industries have been started without proper planning and wastewater treatment plants. They just dispose of untreated toxic wastewater into nearby drains, canals or rivers. There is no doubt that untreated wastewater contributes to major pollution loads into their water bodies in Karachi city.

(3) Water Quality Standard in Pakistan

a) Drinking Water Quality Standards

The basic purpose of making guidelines or standards is to provide safe drinking water to all the citizens. The WHO has provided guidelines for drinking water, which are advisory in nature, and are based on longstanding scientific research and epidemiological findings. The values of various water quality parameters recommended by WHO are the general guidelines. Therefore, different countries have established their own water quality standards to meet their national priorities taking into account their economic, technical, social, cultural, and political requirements. The Pakistan Council for Research in Water Resource (PCRWR) and Pakistan Standard Institution (PSI) have already drafted Drinking Water Quality Standards at National Level. However, the enforcement of these standards is still pending and not approved yet. This matter needs to be addressed on top priority basis.

At present, KW&SB does not have its own water quality standards for drinking water. WHO guidelines for drinking water are adopted as desired value of water treatment processes. In this Study, the WHO Guidelines for drinking water is decided to adopt as targeted Standards tentatively. The latest WHO guidelines which were published in 2005 as the first addendum to the third edition are shown in **Table 41.1.1**:

Table 41.1.1 WHO Guidelines for Drinking Water Quality (2005)

A. Bacterial Quantities

Source/Organisms	Guideline Value
a. All water intended for drinking (E. Coli or thermo tolerant Coliform Bacteria)	Must not be detectable in any 100 ml sample
b. Treated water entering the distribution system (E. Coli or thermo tolerant coliform and total coliform bacteria	Must not be detectable in any 100 ml sample
c. Treated water in the distribution system (E. coli or thermo tolerant coliform and total coliform bacteria)	Must not be detectable in any 100 ml sample In the case of large supplies, where sufficient numbers of samples are examined, must not be present in 95% of samples taken throughout any 12 months period.

B. Chemicals of Health Significance

Inorganic	mg/l	Inorganic	mg/l	Inorganic	mg/l
Antimony	0.005	Copper	2.000	Molybdenum	0.070
Arsenic	0.010	Cyanide	0.070	Nickel	0.020
Barium	0.700	Fluoride	1.500	Nitrate (NO_3)	50
Boron	0.300	Lead	0.010	Nitrite (NO_2)	3.000
Cadmium	0.003	Manganese	0.500	Selenium	0.010
Chromium	0.050	Mercury	0.001		

C. Other Parameters

Inorganic	mg/l	Inorganic	mg/l	Inorganic	mg/l
Colour	15 TCU	1,2 dichlorobenzene	1 – 10	Hardness, pH, DO	-
Taste, Odour	---	1.4-dichlorobenzene	0.3 – 30	Hydrogen sulfide	0.05
Turbidity	5NTU	Dichlorobenzene	1.500	Iron	0.3
Toluene	24 – 170	Synthetic detergents	---	Manganese	01
Xylenes	20 – 1800	Aluminum	0.2	Sodium	200
Ethyl-benzene	2.4 – 2600	Ammonia	1.5	Sulfate	250
Styrene	4 - 2600	Chloride	250	TDS	1000
Monochlorobenzene	10 - 120	Copper	1	Zinc	3

D. Disinfectants and Disinfectant by-Products

Name	Value (mg/l)	Name	Value (mg/l)
Chlorine chlorophenol	600 – 1000	2,4,6-trichlorophenol	2 – 300
2,4-dichlorophenol	0.3 - 40	2-chlorophenol	0.1 - 10

b) National Environmental Quality Standards

The National Environmental Quality Standards for Municipal and Liquid Industrial Effluents has been established and gone through modifications since 1993 as Statutory Notification by the Ministry of Environment, Local Government and Rural Development, Pakistan. The Standards are shown in **Table 41.1.2**.

According to the Standards, BOD into inland waters is regulated not greater than 80 mg/l. Therefore, BOD value of the treated effluent discharged from sewage treatment plant is required below this limit.

Table 41.1.2 National Environmental Quality Standards for Municipal and Liquid Industrial Effluents*

S. No.	Parameter	Into Inland Waters	Into Sewage Treatment	Units
1	Temperature or Temp. increase	≤ 3	≤ 3	°C
2	pH	6 – 9	6 – 9	
3	BOD	80	250	mg/l
4	COD_{Cr}	150	400	mg/l
5	TSS (Total Suspended Solids)	200	400	mg/l
6	TDS (Total Dissolved Solids)	3500	3500	mg/l
7	Oil and Grease	10	10	mg/l
8	Phenolic Compounds (as Phenol)	0.1	0.3	mg/l
9	Chloride (as Cl^-)	1000	1000	mg/l
10	Fluoride (as F^-)	10	10	mg/l
11	Cyanide (as CN^-) total	1.0	1.0	mg/l
12	An-ionic detergents (as MBAS)	20	20	mg/l
13	Sulphate (SO_4^-)	600	1000	mg/l
14	Sulphide (S_2^-)	1.0	1.0	mg/l
15	Ammonia (NH_3)	40	40	mg/l
16	Pesticides	0.15	0.15	mg/l
17	Cadmium	0.1	0.1	mg/l
18	Chromium (trivalent and hexavalent)	1.0	1.0	mg/l
19	Copper	1.0	1.0	mg/l
20	Lead	0.5	0.5	mg/l
21	Mercury	0.01	0.01	mg/l
22	Selenium	0.5	0.5	mg/l
23	Nickel	1.0	1.0	mg/l
24	Silver	1.0	1.0	mg/l
25	Total toxic metals	2.0	2.0	mg/l
26	Zinc	5.0	5.0	mg/l
27	Arsenic	1.0	1.0	mg/l
28	Barium	1.5	1.5	mg/l
29	Iron	8.0	8.0	mg/l
30	Manganese	1.5	1.5	mg/l
31	Boron	6.0	6.0	mg/l
32	Chlorine	1.0	1.0	mg/l

* Statutory Notification, SRO-549(1)/2000, dated August 10, 2000, Ministry of Environment, Local Government and Rural Development, Government of Pakistan.

4.1.2 Evaluation of Water Quality

(1) Terms of Reference for Water Quality Testing

a) Analysed Parameters for Each Sampling Point

Total number of 40 samples of water 2 samples of raw water, 7 samples of treated water (post chlorinated), 18 samples of distributed water, 9 samples of river and drainage water and 4 samples of domestic and commercial wastewater, from 40 different locations, were to be collected in the dry and wet seasons separately and analysed for the physico-chemical and microbiological parameters which were determined by the Study Team. **Table 41.2.1** shows required parameters to analyse.

Table 41.2.1 Chemical and Microbiological Parameters for Testing Water and Wastewater Samples

Raw Water	**Treated Water** Post Chlorination filtered water	**Distribution Water**	**Raw Sewage and Treated Water**	**Domestic and Commercial Wastewater**
02 samples	07 samples	18 samples	09 samples	04 samples
pH	pH	pH	pH	pH
Turbidity	Turbidity	Turbidity		
COD_{Cr}			COD_{Cr}	COD_{Cr}
TDS	TDS	TDS		
Ammonia Nitrogen	Ammonia Nitrogen	Ammonia Nitrogen		
Cadmium	Cadmium	Cadmium		
Total Chromium	Total Chromium	Total Chromium		
Copper	Copper	Copper		
Lead (Pb)	Lead (Pb)	Lead (Pb)		
Mercury	Mercury	Mercury		
Selenium	Selenium	Selenium		
Silver (Ag)	Silver (Ag)	Silver (Ag)		
Zinc (Zn)	Zinc (Zn)	Zinc (Zn)		
Arsenic	Arsenic	Arsenic		
Alkalinity	Alkalinity	Alkalinity		
Elect. Cond.	Elect. Cond.	Elect. Cond.		
Iron (Fe)	Iron (Fe)	Iron (Fe)		
Manganese	Manganese	Manganese		
Boron (B)	Boron (B)	Boron (B)		
Fluorine (F)	Fluorine (F)	Fluorine (F)		
Nitrate	Nitrate	Nitrate		
Nitrite	Nitrite	Nitrite		
Calcium	Calcium	Calcium		
Magnesium	Magnesium	Magnesium		
Sodium	Sodium	Sodium		
Potassium	Potassium	Potassium		
Sulphate ion	Sulphate ion	Sulphate ion		
Chloride ion	Chloride ion	Chloride ion		
	Chlorine	Chlorine		
Coliform	Coliform	Coliform	Coliform	
Faecal Coliform	Faecal Coliform	Faecal Coliform		
Plate Count Bacteria	Plate Count Bacteria	Plate Count Bacteria		
			Ambient Temp.	Ambient Temp.
			Water Temp.	Water Temp.
			BOD	BOD
			Suspended Solids	Suspended Solids
			Total Nitrogen	Total Nitrogen
			Total Phosphorus	Total Phosphorus

b) Methodology

Sampling of water and wastewater was carried out by standard techniques. Samples for the dry season from the identified locations were collected by the sample collection team. The Study Team directly employed the services of water quality technicians from the Laboratory Complex of PCSIR.

Samples of water and wastewater for chemical analysis were carefully collected in plastic containers, samples for BOD were collected in glass bottles and samples for microbiological analysis were collected in sealed sterilized glass bottles and kept in the ice box during transportation and in refrigerator in the laboratory till these were analyzed.

According to the sampling schedule in the dry season, 40 samples of water and wastewater from the identified locations were collected from May 25 to June 14, 2006, in the presence of Mr.

Shahbaz Iqbal, Senior Chemist, KW&SB, who was nominated the Chief Chemist of KW&SB. In the wet season, 40 samples from the same locations were collected from July 29 to August 13, 2006, as per detail given in **Table 41.2.2**. The sampling locations are located in the satellite image maps shown in the respective Sections of this Chapter. The collected samples were analysed for the desired physico-chemical and microbiological parameters by standard analytical methods shown in **Table 41.2.3**.

Table 41.2.2 Details of Sampling IDs with Locations and Date of Sampling

S. No.	Sample ID	Sample Location	Date of Sampling	
			Dry Season	Wet Season
1	RW-1	Before Gujju Headworks, Kinjhar System	25-06-2006	03-0806
2	RW-2	Before Hub Pumping Station, Hub-Karachi main Canal	10-06-2006	08-08-06
3	TW-1	Post Chlorined filtered water, Gharo WTP	08-06-2006	03-08-06
4	TW-2	Post Chlorined filtered water, COD WTP	25-06-2006	03-0806
5	TW-3	Post Chlorined filtered water, Pipri WTP (old)	08-06-2006	03-0806
6	TW-4	Post Chlorined filtered water, Pipri WTP (New, Phase-1	08-06-2006	03-0806
7	TW-5	Post Chlorined filtered water, NEK, WTP (old)	03-06-2006	03-0806
8	TW-6	Post Chlorined filtered water, New NEK WTP	03-06-2006	08-08-06
9	TW-7	Post Chlorined filtered water, Hub WTP	10-06-2006	08-08-06
10	DW-1	Landhi Town, No. 26, Babar Market Pumping Station	02-06-2006	29-07-06
11	DW-2	Korangi Town, No. 6, Korangi 5 ½ Pumping Station	25-06-2006	29-07-06
12	DW-3	Malir Town, No. 15, Saudabad Pumping Station	25-06-2006	29-07-06
13	DW-4	Bin Qasim # 28, Cattle Colony # 1 pumping Station	08-06-2006	29-07-06
14	DW-5	Shah Faisal Town No. 3, Pumping Station # 4	25-06-2006	29-07-06
15	DW-6	Gulshan Town, No. 35, NIPA Pumping Station	03-06-2006	29-07-06
16	DW-7	Jamshed Town, No. 46, Gulistan Club Pumping Station	14-06-2006	09-08-06
17	DW-8	Lyari Town, No. 88, Lea Market Pumping Station	14-06-2006	10-08-06
18	DW-9	Liaqatabad Town, No. 100, Board Office PS	03-06-2006	08-08-06
19	DW-10	Saddar Town # 54 Frere Pumping Station	14-06-2006	05-08-06
20	DW-11	Kemari Town # 89 Gulbai Pumping Station	14-06-2006	11-08-06
21	DW-12	Orangi Town # 122, 4/10A, Banaras Chowk P Station	10-06-2006	08-08-06
22	DW-13	Baldia Town Pumping Station 3 ½	14-06-2006	12-08-06
23	DW-14	SITE Town, No. 131 Qasba Pumping Station	10-06-2006	09-08-06
24	DW-15	Gadap Town Surjani Pumping Station	14-06-2006	08-08-06
25	DW-16	North Karachi Town, No. 95, Khawaja Ajmair Nagri PS	10-06-2006	08-08-06
26	DW-17	Gulberg Town No. 99, Azizabzd Pumping Station	15-06-2006	13-08-06
27	DW-18	North Nazimabad Town, No. 107, B/S No. 2 PS	10-06-2006	08-08-06
28	TP-1a	Inlet Chamber TP1	31-05-2006	05-08-06
29	TP-1b	Outlet Chamber, TP1	31-05-2006	05-08-06
30	TP-1c	Suitable point from Lyari River	31-05-2006	05-08-06
31	TP-2a	Inlet Chamber, TP2	25-06-2006	03-0806
32	TP-2b	Outlet Chamber, TP2	25-06-2006	03-0806
33	TP-2c	Suitable point from Malir River	25-06-2006	03-0806
34	TP-3a	Inlet Chamber, TP3	31-05-2006	12-08-06
35	TP-3b	Outlet Chamber, TP-3	31-05-2006	12-08-06
36	TP-3c	Near the sea front	31-05-2006	12-08-06
37	RWW-1	Orangi Area, Orangi Town	10-06-2006	08-08-06
38	RWW-2	Malir Area, Malir Colony Drain	25-06-2006	29-07-06
39	CWW-1	Saddar Area, Pitcher Drain	14-06-2006	10-08-06
40	CWW-2	Zamzama Area, Nahar-e-Khayyam Drain	14-06-2006	05-08-06

The testing team comprised 1 supervisor, 6 chemical analysis technicians and 3 microbiological technicians.

The physico-chemical analysis of water and wastewater was conducted, applying modern established standard procedures as adopted by American Public Health Association (APHA).

Table 41.2.3 Description of Analytical Methods for Testing Physico-Chemical Parameters

S No.	Parameter	Description of Analytical Methods
1	pH	pH was measured immediately after receiving the sample in the laboratory using Digital Ion Analyzer/pH Meter (Orion–710). Standard buffers are used to calibrate the pH Meter.
2	Sodium (Na) & Potassium (K)	Levels of Sodium and Potassium were estimated on Flame Photometer (Corning 410) after appropriate dilutions of the samples. The standards of sodium and potassium were prepared by using 1000 mg/l standards (Merck); the traceability of the standard is traceable to NIST.
3	Calcium (Ca) and Magnesium (Mg)	Calcium and Magnesium were determined by complexmetric titration using standard EDTA as titrant. Erio-chrom Black T was used as indicator for titration of both i.e. Ca and Mg, while Meuroxide was used to titrate Ca alone. Mg was estimated by difference in the two readings.
4	Chloride (Cl^-)	Chloride was determined by argentometric titration, using standard $AgNO_3$ as titrant. Potassium chromate was used as indicator. The standard and indicator used were of A.R grade chemicals. The titrant was standardized with NaCl.
5	Sulphate (SO_4^{2-})	Sulphate was precipitated with $BaCl_2$ as $BaSO_4$, filtered through Whattman 42 filter paper, washed with distilled water and ignited at open flam to be weighed as $BaSO_4$. The sulphate was calculated by stichiometric ratios.
6	Bi-Carbonate and Alkalinity	These parameters were determined by titration with HCl (standardized) bromocresol green was used as indicator. Alkalinity was determined by calculation and reported as $CaCO_3$.
7	Nitrite (N-NO_2)	The nitrite present in water sample was diazotized with sulphanilic acid and coupled with N-1-Napthyl ethylene diamine dihydrochloride. The absorbance of the resultant azo-dye was measured at 525 nm.
8	TDS	TDS was estimated gravimetrically by evaporating a known volume of sample.
9	Turbidity	Turbidity was measured using HACH-2100 Turbidity Meter. The standards used were also from HACH Company.
10	Free Chlorine (Cl_2)	The free chlorine was measured volumetrically using DPD as indicator and Ferrous sulfate as titrant.
11	Fluoride (F^-)	Levels of fluoride were determined through Fluoride Ion Selective Electrode and a Digital Ion Analyzer (Orion 701). The graph is further checked for its accuracy by using standard fluoride solutions 1 and 10 ppm (mg/l).
12	Nitrate (N-NO_3)	Nitrate contents were measured as NO_3-N through Nitrate Ion Selective Electrode and Digital Ion Analyzer (Orion 710).
13	COD_{Cr}	The Chemical Oxygen Demand was determined titrimetrically after refluxing the samples with potassium dichromate.
14	Lead (Pb) and Cadmium (Cd)	Lead and Cadmium were analyzed by Hitachi Z-8000 Atomic Absorption Spectrophotometer, equipped with Graphite Furnace. Commercially available prepared standard (1000 mg/l) was used for the preparation of working standards. The standard itself is traceable to NIST.
15	Iron (Fe), Zinc (Zn), Copper (Cu), Total Chromium (Cr), Silver (Ag) and Manganese (Mn)	Iron, Zinc, Copper, Silver, Chromium and Manganese were also analyzed by Hitachi Z-5000 Atomic Absorption Spectrophotometric technique with air acetylene flame. Prepared standard (1000 mg/l) was used from Merck for the preparation of standards. The standards are traceable to NIST.
16	Arsenic (As) and Selenium (Se)	Arsenic and selenium were analyzed by using Hitachi Z-5000 Absorption Spectrophotometric equipped with Hydride Formation System. The standard used for the preparation of working standard is traceable to NIST.
17	Mercury (Hg)	Cold Vapor technique was employed for the estimation of Mercury by using Hitachi-Z-5000 Atomic Absorption Spectrophotometric. The Mercury standard used is traceable to NIST.

18	Boron (B)	Boron was estimated calorimetrically after developing color with crucumine reagent. The red colour developed was measured at 540nm by using UV-VIS Spectrophotometer.
19	Total Suspended Solids (TSS)	TSS was calculated gravimetrically.
20	Total Phosphorus (PO_4^{3-})	Total phosphate was estimated calorimetrically after the formation of phosphomolybdate complex, measured at 880 nm.
21	Conductivity	Electric Conductivity was measured by using HACH Conductivity/TDS Meter.
22	Ammonia ($N\text{-}NH_3$)	Ammonia was estimated calorimetrically.
23	Biochemical Oxygen Demand (BOD_5)	Estimation of BOD_5 was carried out by BOD Trak method. The whole procedure involves five days.

For the determination of Total Coliform and Fecal Coliform organisms, Multiple Tube Method [ISO-9308-2(1990)] was used. Measured volume of the water to be tested was added to sets of tubes containing single and double strength isolation media. After 24 hours incubation at 37^{o}C for Total Coliform and 44^{o}C for Fecal Coliform, the tubes were examined for acid and gas production. Positive reactions in tubes were subcultured into confirmatory media, i.e., *Brilliant Green Lactose Bile (BGLB) broth* for Total Coliform and *EC broth* for Fecal Coliform. The numbers of positive tubes were counted and the MPN was determined from table of statistical probability. Total aerobic bacteria count of each sample was cultivated by spread plate count method, by following Standard Method for the Examination of Water and Wastewater, 20th edition (1998), APHA.

(2) Raw Water

Sampling points of raw water samples (Sample ID is RW-1 and RW-2) were selected for different water systems, i.e. Indus River Water (Kinjhar) System and Hub Water System. **Figure 41.2.1** and **Figure 41.2.2** show the locations of raw water sampling points. RW-1 is located in just before Gujju Headworks, Kinjhar System and RW-2 is located before Hub Pumping Station, Hub-Karachi Main Canal.

The test results of two (2) samples of raw water which are collected both in the dry season and in the wet season are given in **Table 41.2.4**. In the dry season, data show that concentration of heavy metals such as Copper, Iron, Manganese and some anions like Chloride, Sulphate and Ammonium of RW-2 are higher than those of RW-1. Electric conductivity of RW-2 is also higher than that of RW-1.

Therefore, the pooled water of Hub Dam makes slow progress in salinisation.

Figure 41.2.1 Location of Sampling Points No.1

Figure 41.2.2 Location of Sampling Points No.2

Table 41.2.4 Results of 2 samples of Raw Water

S. No.	Parameters	Dry Season		Wet Season		Units
		RW-1	RW-2	RW-1	RW-2	
1	pH	8.20	8.40	8.11	8.29	
2	Turbidity	0.19	0.23	0.55	3.5	NTU
3	COD_{Cr}	42	31	ND	ND	mg/l
4	TDS	292	452	254	280	mg/l
5	Ammonia Nitrogen	0.096	0.326	ND	ND	mg/l
6	Cadmium	0.25	0.19	0.94	0.49	μg/l
7	Total Chromium	ND	ND	2.12	12.1	μg/l
8	Copper	2.75	24.75	5.96	16.12	μg/l
9	Lead (Pb)	2.39	2.62	5.1	2.23	μg/l
10	Mercury	ND	ND	ND	ND	μg/l
11	Selenium	ND	ND	ND	ND	μg/l
12	Silver (Ag)	0.27	ND	5.13	4.95	μg/l
13	Zinc (Zn)	0.011	0.042	0.028	0.031	mg/l
14	Arsenic	6.630	3.192	ND	ND	μg/l
15	Alkalinity	107	112	96	91	mg/l
16	Elect. Cond.	412	696	348	433	μS/cm
17	Iron (Fe)	0.11	0.26	0.165	0.406	mg/l
18	Manganese	7.40	14.12	10.81	17.15	μg/l
19	Boron (B)	ND	8.24	5.85	28.58	μg/l
20	Fluorine (F)	0.058	0.057	0.049	0.042	mg/l
21	Nitrate	15.93	15.93	1.12	3.56	mg/l
22	Nitrite	6	30	6	26	μg/l
23	Calcium	30	47	31	33	mg/l
24	Magnesium	15	18	11	11	mg/l
25	Sodium	35	75	26.5	30	mg/l
26	Potassium	6.4	7.6	6.4	6.7	mg/l
27	Sulphate ion	61	111	48	57	mg/l
28	Chloride ion	40	100	30	38	mg/l
29	Coliform	93	240	1100	1100	count/dl
30	Faecal Coliform	43	150	1100	1100	count/dl
31	Plate Count Bacteria	2.3×10^4	8.4×10^4	4.8×10^4	4.2×10^4	cfu/ml

(3) Filtered Water

7 samples of filtered water with post chlorination were taken from each existing Water Filter Plant. TW-1 is called “Gharo Water Treatment Plant” and located about 60 km west of the centre of Karachi City. TW-1 turns out to the representative sample because here is the first point of Kinjhar System. Location of TW-1 is shown in **Figure 41.2.3**. TW-2 is the location of COD Water Treatment Plant and shown in **Figure 41.2.4**. TW-3 and TW-4 are sampling from the old Pipri Water Treatment Plant and the new Pipri Water Treatment Plant. The Plants are located nearby each other in suburbs of Karachi. Those locations are shown in **Figure 41.2.5**. TW-5 and TW-6 are also from the old/new NEK Water Treatment Plants. TW-7 is Hub Water Treatment Plant which shows different raw water characteristics, because raw waters of Hub Water System and Kinjhar Water System (K-III Project) are blended before intake of the treatment plant. **Figure 41.2.2** shows locations of TW-5, 6 and 7.

Results of 7 samples of Treated Water (Post Chlorinated) collected from water treatment plant in the dry and wet seasons are shown in **Table 41.2.5** and **Table 41.2.6**, respectively.

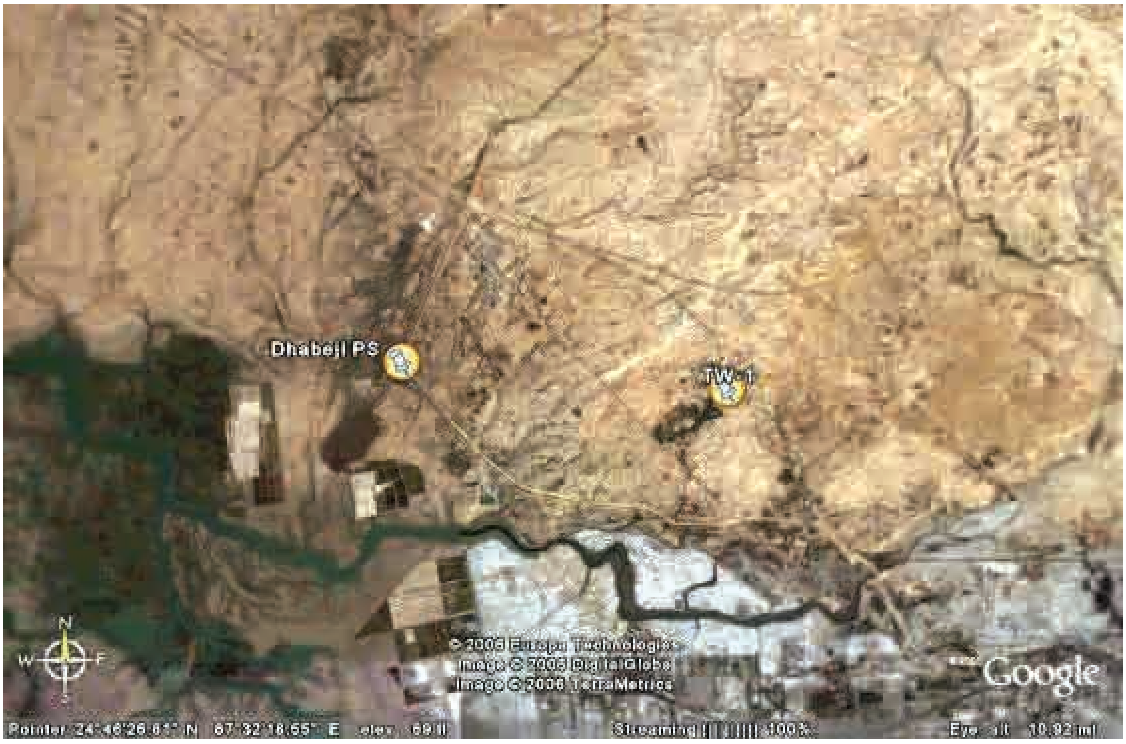

Figure 41.2.3　Location of Sampling Points No.3

Figure 41.2.4　Location of Sampling Points No.4

Figure 41.2.5 Location of Sampling Points No.5

Table 41.2.5 Results of 7 Samples of Treated Water (Post Chlorinated) collected in the Dry Season

S. No.	Parameters	TW-1	TW-2	TW-3	TW-4	TW-5	TW-6	TW-7	Units
1	pH	8.0	7.8	7.7	7.9	7.9	7.9	8.4	
2	Turbidity	0.91	0.34	0.77	0.90	0.24	0.24	0.22	NTU
3	TDS	304	284	278	276	278	276	534	mg/l
4	Ammonia Nitrogen	0.401	ND	0.433	0.290	0.263	0.328	0.470	mg/l
5	Cadmium	0.095	0.304	0.058	0.335	0.913	0.413	0.304	µg/l
6	Total Chromium	ND	ND	ND	ND	ND	ND	ND	µg/l
7	Copper	31.5	10.5	9.5	3.8	5.3	6.0	10.8	µg/l
8	Lead (Pb)	2.09	1.84	1.45	1.29	1.44	1.15	1.54	µg/l
9	Mercury	ND	ND	ND	ND	0.33	ND	ND	µg/l
10	Selenium	ND	ND	ND	ND	ND	ND	ND	µg/l
11	Silver (Ag)	2.97	ND	1.90	ND	0.27	0.80	1.90	µg/l
12	Zinc (Zn)	0.045	0.014	0.015	0.132	0.012	0.318	0.096	mg/l
13	Arsenic	1.474	0.818	ND	0.410	0.736	ND	ND	µg/l
14	Alkalinity	102	102	97	97	97	92	107	mg/l
15	Electrical Conductivity	445	400	416	415	404	410	786	µS/cm
16	Iron (Fe)	0.17	0.19	0.14	0.15	0.04	0.11	0.26	mg/l
17	Manganese	11.40	7.12	7.85	7.60	2.40	5.27	9.57	µg/l
18	Boron (B)	14.80	9.96	ND	ND	ND	ND	2.24	µg/l
19	Fluorine (F)	0.058	0.052	0.052	0.057	0.047	0.051	0.042	mg/l
20	Nitrate	14.81	15.15	20.06	21.28	22.17	20.99	21.48	mg/l
21	Nitrite	2.50	3.75	8.75	6.25	2.50	3.75	5.00	µg/l
22	Calcium	34	32	32	31	31	31	53	mg/l
23	Magnesium	17	13	14	14	12	13	19	mg/l
24	Sodium	40	37	37	34	35	35	88	mg/l
25	Potassium	6.4	6.3	6.4	6.4	6.4	6.4	7.7	mg/l
26	Sulphate ion	61	66	58	60	64	62	131	mg/l
27	Chloride ion	52	42	47	47	44	48	118	mg/l
28	Chlorine	0.06	0.03	0.45	0.05	0.03	0.04	ND	mg/l
29	Coliform	< 3	< 3	< 3	11	< 3	< 3	7l	count/dl
30	Faecal Coliform	< 3	< 3	< 3	< 3	< 3	< 3	< 3	count/dl
31	Plate Count Bacteria	100	62	120	280	90	25	450	cfu/ml

Table 41.2.6 Results of 7 Samples of Treated Water (Post Chlorination) collected in the Wet Season

S. No.	Parameters	TW-1	TW-2	TW-3	TW-4	TW-5	TW-6	TW-7	Units
1	pH	7.85	8.05	7.86	8.09	8.15	8.05	8.09	
2	Turbidity	0.53	0.57	1.30	1.40	0.66	2.20	2.00	NTU
3	TDS	306	268	276	260	262	252	318	mg/l
4	Ammonia Nitrogen	0.038	ND	ND	ND	ND	ND	ND	mg/l
5	Cadmium	0.60	0.66	0.54	0.54	0.55	1.06	0.66	µg/l
6	Total Chromium	ND	ND	ND	ND	ND	2.83	ND	µg/l
7	Copper	27.3	5.2	9.2	5.0	2.2	18.3	3.5	µg/l
8	Lead (Pb)	ND	ND	1.92	1.82	ND	2.15	2.17	µg/l
9	Mercury	ND	ND	ND	ND	ND	ND	ND	µg/l
10	Selenium	ND	ND	ND	ND	ND	ND	ND	µg/l
11	Silver (Ag)	7.68	4.18	2.14	8.79	16.18	18.69	6.47	µg/l
12	Zinc (Zn)	0.016	0.020	0.060	0.022	0.018	0.024	0.021	mg/l
13	Arsenic	ND	ND	ND	ND	ND	ND	ND	µg/l
14	Alkalinity	106	96	91	91	91	86	72	mg/l
15	Electrical Conductivity	478	360	363	357	358	353	515	µS/cm
16	Iron (Fe)	0.10	0.20	0.13	0.14	0.06	0.40	0.11	mg/l

17	Manganese	10.13	8.12	16.57	8.12	6.87	18.29	5.98	μg/l
18	Boron (B)	24.56	31.42	26.08	3.62	ND	1.70	8.74	μg/l
19	Fluorine (F)	0.056	0.057	0.059	0.052	0.048	0.052	0.049	mg/l
20	Nitrate	6.18	1.94	2.91	2.69	2.91	2.63	9.97	mg/l
21	Nitrite	14.00	7.23	30.00	5.00	2.00	6.00	22.00	μg/l
22	Calcium	40	32	32	31	31	31	42	mg/l
23	Magnesium	13	11	11	11	11	11	14	mg/l
24	Sodium	37.5	30	27	27	25	25	35	mg/l
25	Potassium	7.4	6.6	6.6	6.6	6.6	6.6	7.1	mg/l
26	Sulphate ion	52	54	49	52	52	56	72	mg/l
27	Chloride ion	61	33	36	35	33	33	64	mg/l
28	Chlorine	ND	ND	0.80	0.06	0.32	0.13	0.16	mg/l
29	Coliform	< 3	< 3	< 3	4	< 3	< 3	4	count/dl
30	Faecal Coliform	< 3	< 3	< 3	< 3	< 3	< 3	< 3	count/dl
31	Plate Count Bacteria	270	60	80	170	250	40	120	cfu/ml

(4) Water in Distribution System

Sampling in distribution system is very important for water supply system to check whether the operation and maintenance is done appropriately. 18 sampling points were selected from each township in 3 different water supply Zones. These locations are shown in **Figure 41.2.6**. Results of eighteen (18) samples of Distribution Water are shown in **Table 41.2.7** (dry season) and **Table 41.2.8** (wet season).

Figure 41.2.6 Location of Sampling Point No.6

Table 41.2.7 Results of 18 Samples of Distribution Water collected in the Dry Season

S.No.	Parameters	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	Unit
1	pH	8.1	7.7	7.7	8.2	7.8	7.8	8.2	8.2	8.1	8.3	8.3	8.2	8.2	8.2	8.2	8.4	8.3	8.1	-
2	Turbidity	0.4	0.2	0.5	0.6	0.5	0.5	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.2	NTU
3	TDS	278	276	268	290	298	276	288	292	340	274	286	496	320	470	282	430	300	298	mg/l
4	Amm. Nitrogen	0.458	0.341	0.396	0.320	0.280	0.189	0.515	0.354	0.506	0.373	0.380	0.300	0.300	0.831	0.366	0.488	0.319	0.424	mg/l
5	Cadmium	0.244	0.134	0.210	0.155	0.181	0.194	0.065	0.176	0.190	0.248	0.229	0.251	0.202	0.245	0.276	0.408	0.263	0.482	µg/l
6	Total Chromium	ND	ND	4.10	ND	1.65	ND	ND	ND	ND	ND	0.42	ND	ND	ND	ND	ND	ND	0.82	µg/l
7	Copper	4.50	5.75	11.50	9.50	12.00	3.55	3.00	8.75	2.25	7.25	11.75	6.50	7.50	12.00	8.25	10.00	3.75	9.00	µg/l
8	Lead (Pb)	1.89	2.80	1.95	2.07	2.87	2.43	2.79	2,56	2.48	2.06	2.99	3.05	3.36	1.10	1.32	1.32	1.34	1.67	µg/l
9	Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	µg/l
10	Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	µg/l
11	Silver (Ag)	ND	9.17	2.42	6.22	4.32	2.70	12.70	13.50	12.27	17.00	ND	ND	ND	25.92	2.97	7.55	0.27	ND	µg/l
12	Zinc (Zn)	0.617	0.018	0.199	0.193	0.618	0.024	0.018	0.323	0.035	0.603	0.838	0.026	0.179	1.473	0.057	0.905	1.051	0.586	mg/l
13	Arsenic	0.736	0.820	0.654	3.520	1.720	0.492	1.720	1.146	ND	0.900	4.500	ND	1.474	ND	2.046	0.656	0.656	4.500	µg/l
14	Alkalinity	102	102	97	102	107	97	101	102	102	102	102	107	108	108	108	112	101	102	mg/l
15	Elect. Cond.	404	403	403	413	422	406	415	418	493	417	403	764	462	742	410	608	414	420	µS/cm
16	Iron (Fe)	0.10	0.17	0.14	0.14	0.25	0.09	0.64	0.18	0.12	0.23	0.28	0.24	0.20	0.32	0.31	0.24	0.14	0.24	mg/l
17	Manganese	4.50	7.00	5.20	11.60	11.00	4.50	22.85	10.40	5.30	9.42	8.15	9.15	7.87	13.60	25.00	13.27	6.27	33.50	µg/l
18	Boron (B)	9.80	ND	4.72	7.68	9.68	ND	ND	12.60	6.32	9.40	3.72	2.20	5.96	15.10	ND	5.80	5.44	8.44	µg/l
19	Fluorine (F)	0.059	0.041	0.043	0.052	0.055	0.057	0.053	0.055	0.046	0.051	0.064	0.046	0.05	0.051	0.049	0.062	0.061	0.063	mg/l
20	Nitrate	21.58	20.99	19.79	20.07	20.25	15.64	19.70	19.18	19.89	19.35	19.01	20.71	21.58	22.07	21.97	34.25	20.71	21.58	mg/l
21	Nitrite	3	8	8	5	4	4	3	6	4	3	6	4	4	6	6	13	1	3	µg/l
22	Calcium	31	32	32	33	32	30	33	33	34	33	31	51	35	50	30	42	28	33	mg/l
23	Magnesium	12	10	12	13	13	14	13	14	16	13	13	19	15	20	15	18	17	14	mg/l
24	Sodium	35	35	35	37	37	35	35	35	45	35	35	35	75	65	36	62	35	35	mg/l
25	Potassium	6.4	6.4	6.4	6.4	6.5	6.4	6.7	6.7	6.7	6.7	6.6	7.8	7.8	7.4	6.3	7.0	6.4	6.6	mg/l
26	Sulphate ion	51	58	54	58	59	59	58	58	77	54	47	107	57	92	51	92	65	60	mg/l
27	Chloride ion	41	40	41	43	47	43	41	45	58	44	42	113	51	108	41	82	43	45	mg/l
28	Chlorine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	ND	ND	ND	ND	0.06	mg/l
29	Coliform	23	< 3	< 3	< 3	< 3	< 3	< 3	240	< 3	< 3	< 3	< 3	< 3	< 3	<3	< 3	< 3	< 3	Count/dl
30	Fecal Coliform	23	< 3	< 3	< 3	< 3	< 3	< 3	23	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	Count/dl
31	Plate Count Bacteria	1500	290	540	200	5×10^3	50	220	1.2×10^4	2200	150	360	160	180	5200	120	49	2500	2500	cfu/ml

Table 41.2.8 Results of 18 Samples of Distribution Water collected in the Wet Season

S.No.	Parameters	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	Unit
1	pH	7.63	8.23	8.28	8.15	8.15	8.01	8.01	8.24	8.32	8.25	8.17	8.18	8.31	8.16	8.28	8.18	8.16	7.88	-
2	Turbidity	0.6	0.5	1.1	0.4	0.4	1.0	1.7	1.9	1.9	1.0	0.5	2.3	0.5	4.5	1.4	1.7	1.4	1.4	NTU
3	TDS	282	260	256	262	268	260	278	272	354	302	240	356	270	314	270	376	246	270	mg/l
4	Amm. Nitrogen	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.31	ND	ND	0.09	ND	ND	mg/l
5	Cadmium	0.79	0.42	0.75	0.98	0.43	0.47	0.34	0.35	0.33	0.94	0.58	0.62	0.68	0.45	1.16	0.77	0.71	0.25	µg/l
6	Total Chromium	ND	2.15	ND	5.15	1.92	2.15	3.18	ND	3.12	ND	ND	ND	ND	ND	ND	ND	ND	267	µg/l
7	Copper	12.63	11.52	10.25	22.06	8.04	12.83	8.69	5.26	15.40	99.00	4.37	10.71	19.60	8.00	9.82	7.25	7.68	6.25	µg/l
8	Lead (Pb)	4.75	3.14	4.85	6.57	3.94	3.12	3.74	2.32	3.84	4.40	2.15	2.13	ND	ND	ND	53.30	ND	1.82	µg/l
9	Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	µg/l
10	Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	µg/l
11	Silver (Ag)	2.73	6.47	3.94	5.76	4.24	ND	5.26	7.16	10.81	ND	ND	15.62	2.28	15.00	3.84	14.21	2.83	3.14	µg/l
12	Zinc (Zn)	0.004	0.036	0.027	0.068	0.016	0.033	0.019	0.012	0.039	0.046	0.016	0.020	0.021	0.027	0.118	0.038	0.076	0.729	mg/l
13	Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	µg/l
14	Alkalinity	96	96	96	96	96	96	96	101	87	86	91	86	91	77	117	101	91	96	mg/l
15	Elect. Cond.	403	358	357	366	376	364	404	392	519	445	337	505	386	498	378	527	340	383	µS/cm
16	Iron (Fe)	0.25	0.26	0.18	0.35	0.21	0.21	0.31	0.07	0.27	0.14	0.13	0.18	0.52	0.14	0.43	0.18	0.11	0.27	mg/l
17	Manganese	19.48	8.14	9.87	13.8	11.12	8.68	15.18	6.47	11.23	12.01	9.21	8.79	11.16	9.12	3.23	16.57	8.69	13.28	µg/l
18	Boron (B)	21.80	15.49	22.08	3.04	22.56	25.56	2.72	16.96	18.04	ND	4.72	ND	27.80	28.68	28.69	ND	25.80	28.10	µg/l
19	Fluorine (F)	0.049	0.033	0.030	0.047	0.049	0.048	0.044	0.045	0.039	0.044	0.054	0.038	0.040	0.042	0.039	0.054	0.058	0.059	mg/l
20	Nitrate	2.82	0.89	1.06	1.40	9.97	1.51	2.15	2.03	5.31	4.93	2.04	6.34	2.17	6.18	3.56	7.56	2.41	4.24	mg/l
21	Nitrite	9	2	9	2	8	2	6	7	10	5	7	18	80	20	6	10	18	5	µg/l
22	Calcium	33	32	33	32	31	34	32	20	42	25	20	43	30	38	30	40	30	32	mg/l
23	Magnesium	13	10	11	11	12	10	11	11	14	14	11	11	12	12	12	16	11	11	mg/l
24	Sodium	32	29	21.5	30	30.5	30	29	29	45	32	26	37	25	35	27	45	26	26	mg/l
25	Potassium	6.8	6.5	6.6	6.6	6.6	6.4	8.5	6.5	7.0	7.5	6.2	6.9	6.6	6.7	6.9	8.3	6.4	6.6	mg/l
26	Sulphate ion	57	54	55	53	55	47	54	47	86	59	52	72	50	76	50	77	51	44	mg/l
27	Chloride ion	45	32	32	35	36	39	23	32	65	51	28	60	31	48	33	64	30	38	mg/l
28	Chlorine	0.53	ND	0.02	ND	ND	0.18	ND	0.11	0.11	ND	ND	0.16	ND	0.13	ND	ND	0.06	0.13	mg/l
29	Coliform	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	Count/dl
30	Fecal Coliform	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	Count/dl
31	Plate Count Bacteria	2.9×10^4	5.2×10^3	450	2.5×10^3	3.2×10^3	160	100	1000	1.2×10^4	890	850	1100	200	1.7×10^4	2800	60	1500	150	cfu/ml

(5) Raw Sewage and Treated Water

In Karachi, there are three Sewage Treatment Plants that are called TP1, TP-2 and TP-3. Trickling Filter Process is applied in the TP-1 and TP-2. The newest treatment plant, TP-3, applies Stabilisation Pond System.

Water quality analysis of sewage was undertaken to assess the treatment efficiency at the existing TP1, TP2 and TP3 by investigating the receiving water quality in the river and sea. In order to identify the sampling point easily, Sample ID was determined as follows;

- ID-"A" means that the sample is "raw sewage" taken from inlet chamber or adequate point.
- ID-"B" means that the sample is "treated effluent" taken from outlet before discharging.
- ID-"C" means that the sample is "discharged water" taken from meeting point of the mainstream of the large river or sea area.

Comparison between ID-"A" and ID-"B" can assess the treatment efficiency of each TP. Removal rate of TSS and BOD may be simple indicators of functional evaluation for TP.

TP1-C is located 400m downstream of confluence of Lyari River and drainage canal from TP1. TP2-C is located in the mainstream of Malir River near the bridge of Korangi By-pass road. TP3-C is located in the seafront of Lyari River close to the mangrove forest.

Figure 41.2.4 indicates all sampling points of raw sewage and treated effluent. Results of samples of each TP collected in the dry and wet seasons are shown in **Table 41.2.9** and **Table 41.2.10**, respectively.

Table 41.2.9 Results of Samples Collected from each STP in the Dry Season

S. No.	Parameters	TP-1			TP-2			TP-3			Units
		A	B	C	A	B	C	A	B	C	
1	pH	7.4	7.4	7.1	7.7	7.5	7.1	7.8	7.9	8.0	-
2	COD_{Cr}	521	521	5937	325	406	198	2500	937	937	mg/l
3	Coliform	2.8×10^7	1.4×10^7	2.4×10^8	1.1×10^6	7×10^4	1.1×10^6	2.3×10^6	3×10^4	1.1×10^3	count/dl
4	Ambient Temp.	38	38	39	32	32	33	35	36	35	^oC
5	Water Temp.	35	35	38	31	31	32	35	37	36	^oC
6	BOD	278	150	1228	144	100	123	188	78	64	mg/l
7	TSS	104	16	176	44	60	36	24	34	52	mg/l
8	Total Nitrogen	292	252	847	221	355	371	243	279	291	mg/l
9	Total Phosphorus	2.17	1.84	0.27	1.67	2.15	1.70	1.66	1.91	1.83	mg/l

Table 41.2.10 Results of Samples Collected from each STP in the Wet Season

S. No.	Parameters	TP-1			TP-2			TP-3			Units
		A	B	C	A	B	C	A	B	C	
1	pH	7.39	7.09	7.22	7.71	6.80	6.84	7.65	7.50	7.12	-
2	COD_{Cr}	161	290	855	145	169	97	177	121	87	mg/l
3	Coliform	2.8×10^6	2.1×10^6	4.3×10^5	4.6×10^6	2.1×10^6	4.0×10^6	4.3×10^4	3.4×10^4	4.0×10^4	count/dl
4	Ambient Temp.	29	29	29	27	28	28	31	30	30	^oC
5	Water Temp.	30	30	31	29	29	29	33	32	29	^oC
6	BOD_5	69	192	549	94	55	85	118	34	128	mg/l
7	TSS	48	72	100	44	48	32	32	38	76	mg/l
8	Total Nitrogen	135	184	839	150	124	115	172	153	78	mg/l
9	Total Phosphorus	2.02	2.45	2.88	1.17	1.17	1.06	2.25	2.64	2.35	mg/l

Figure 41.2.7 Location of Sampling Points of TP-1

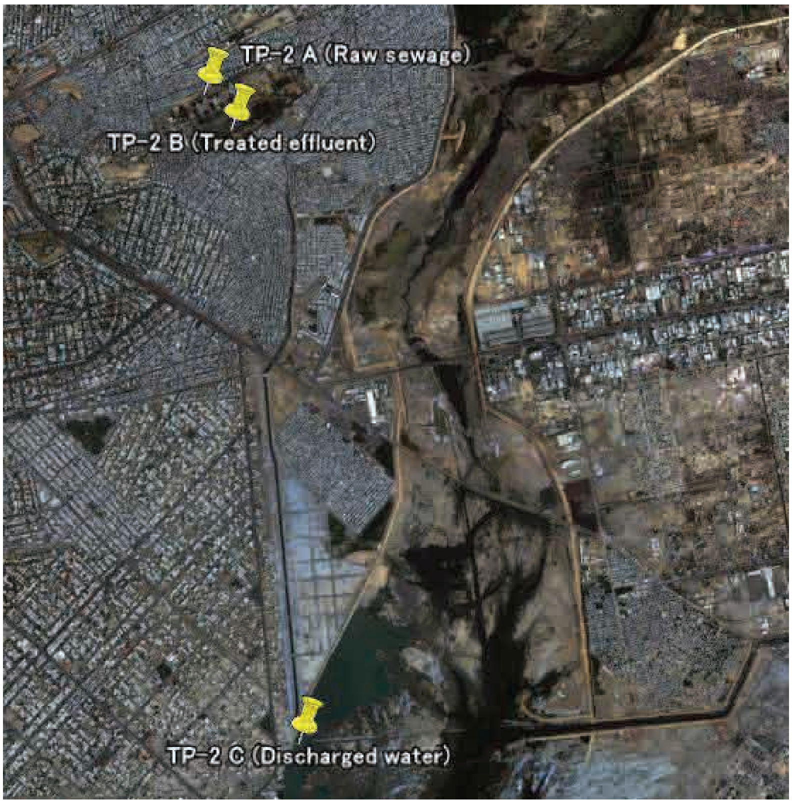

Figure 41.2.8 Location of Sampling Points of TP-2

Figure 41.2.9 Location of Sampling Points of TP-3

(6) Domestic & Commercial Wastewaters

Samples of domestic & commercial wastewater have been collected from the drain/nallah streaming with untreated sewage or wastewater in the representative township. Analysed parameters were same as sewage treatment plant evaluation. RWW-1 (Natural nallah, Orangi Town, in **Figure 41.2.2**) is located in the northern part of Karachi and RWW-2 (Malir Colony Drain, Malir Town, in **Figure 41.2.5**) is located near the International Airport in the east of Karachi. Both sampling points are located in ordinary residential areas which are not sewered. Two other points were selected for commercial areas. CWW-1 is from Pitcher Drain in Saddar Town and CWW-2 is from Nahar-e-Khayyam Drain which flows into Ganda Nallah in Clifton area (both in **Figure 41.2.4**).

Test results of samples collected from domestic & commercial wastewater in the dry and wet seasons are shown in **Table 41.2.11**.

Table 41.2.11 Results of Samples Collected from Domestic & Commercial Wastewater

S.No.	Parameters	RWW-1		RWW-2		CWW-1		CWW-2		Units
		Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	
1	pH	7.3	8.0	8.0	7.0	7.1	7.1	7.0	7.0	
2	COD_{Cr}	73	63	488	268	167	81	385	161	mg/l
3	Ambient Tem.	36	34	32	29	32	31	32	33	^{o}C
4	Water temp.	34	30	31	31	31	30	33	31	^{o}C
5	BOD	100	37	304	231	103	58	194	79	mg/l
6	Suspended Solids	56	14	52	146	32	22	32	34	mg/l
7	Total Nitrogen	414	13	1,746	389	91	236	1,092	224	mg/l
8	Total Phosphorus	0.68	0.46	2.46	4.24	1.44	2.11	1.80	2.43	mg/l

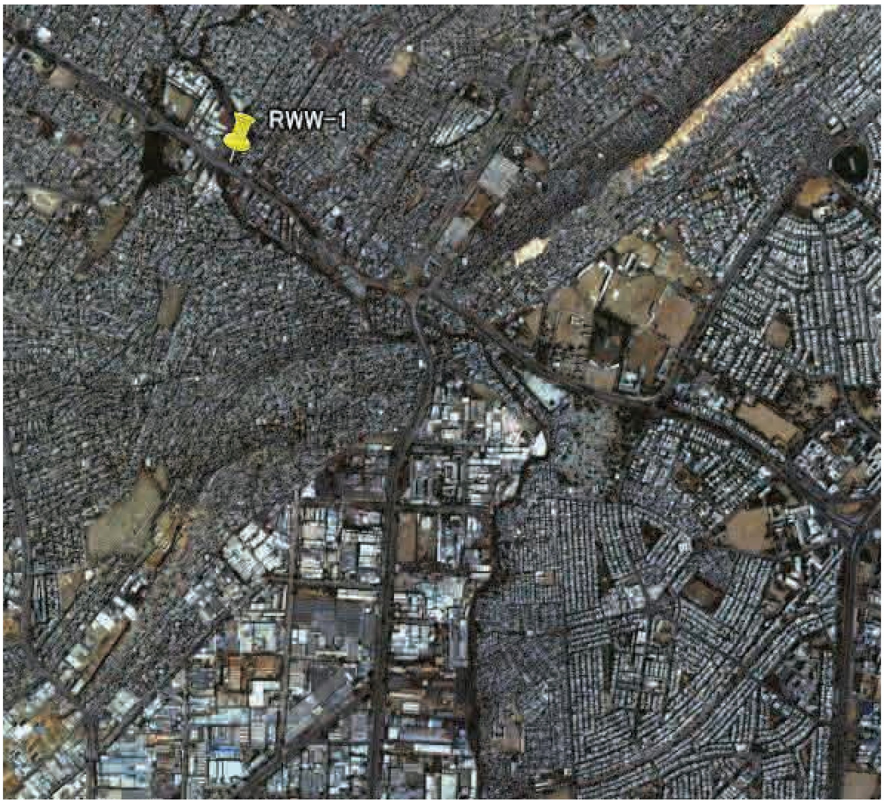

Figure 41.2.10 Location of Sampling Point RWW-1

Figure 41.2.11 Location of Sampling Point RWW-2

Figure 41.2.12 Location of Sampling Point CWW-1

Figure 41.2.13 Location of Sampling Point CWW-2

4.1.3 Results and Discussions

In total, 40 samples of water and wastewater (including 2 samples of raw water, 7 samples of treated (post chlorinated) water, 18 samples of distribution water, 9 samples of raw sewage and treated water river and 4 samples of commercial and domestic wastewater) are analysed for various chemical and microbiological parameters specified by the Study Team in cooperation with Central Laboratory Unit of KW&SB.

According to Scope of Work for the Study, total 31 physico-chemical and microbiological parameters must be examined during the Basic Study Phase. The survey on laboratory capability in Karachi showed that Hexavalent Chromium and Gallium could not be analysed regardless of the reliability of external laboratories. Alkalinity which is a parameter for dosage control of alkaline chemical for coagulation process and Electrical Conductivity (EC) which can simply give an indication of water contamination were substituted for those two parameters.

Total Chromium was analysed as a substitute for Hexavalent Chromium (Cr^{6+}). The metal chrome (the Cr elemental substances) itself is harmless and very stable chemically. However, being oxidized, when it becomes the ions of trivalent and hexavalent, it may reach the level where it has significant virulence for human health. Since the chrome present in the nature is tervalent in most cases, toxicity is not much high in comparison with hexavalent one. If Total Chromium concentration is much less than the WHO's Standards, abundance of hexavalent Chromium is at undetectable order.

Gallium does not exist in free form in the nature, nor do any high-gallium minerals exist to serve as a primary source of extraction of the element or its compounds. While not considered toxic, the data about gallium is inconclusive. Some sources suggest that it may cause dermatitis from prolonged exposure; other tests have not caused a positive effect. It is, however, not found in the chemicals of drinking water standards. An important application is in the compound Gallium Arsenide, used as a semiconductor, most notably in Blue Light-Emitting Diodes (LEDs). Therefore, if it hadn't been for semiconductor industry in the upstream of Indus River, pollution caused by Gallium has never taken place in Karachi's water supply. Reasons for these circumstances, it was concluded that Gallium analysis is not included in the water quality examination.

(1) Water Supply Samples

Table 41.1.1 shown in **Section 4.1.1(3)** gives the limits for drinking water for human consumption, recommended by the WHO. The results show that in 7 samples of treated water (post chlorination) and 18 samples of distribution water, collected in the dry season, the concentrations of analysed chemical parameters have been found within the permissible limits recommended for drinking water for human consumption by the WHO. In some of the samples from the distribution system (Sample ID: DW), iron contents are higher than the recommended limit of 0.3 mg/l. The higher concentration of iron may be attributed to the rusting of aged pipes. The concentration of NO_3-N is found to be comparatively higher in all the samples in the dry season than in the wet season. However, all the samples could meet the limit of standards (less than 50 mg/l). Most water sources are from the surface water which originated from the Indus River. Therefore, concentrations of other heavy metals in water samples are distinctly low.

Although concentration of residual chlorine is either ND (not detected) or very low, both coliform and Faecal Coliform tests have shown good results. Content of residual chlorine is recommended in the range between 0.20 to 0.50 mg/l by KW&SB. Before distributed water reaches the faucet at each house, residual chlorine has been consumed against germs. In general, cross connections may back siphonage of polluted water from leaking point. Moreover, due to intermittent water supply, many customers use their own suction pumps. This is also one of typical causes for water contamination.

Microbiological quality of the collected samples was evaluated by determining the Total Aerobic General Bacteria, Total Coliform and Faecal Coliform counts. In dry season samples of raw water RW-1 and RW-2 showed relatively high Total Aerobic Bacteria, Coliform and Faecal Coliform count. According to WHO Guidelines (Guidelines for Drinking-Water Quality, First Addendum to Third Edition), water for human consumption should not contain any pathogenic bacteria. A zero (or less than 3) Total Coliform, zero (or less than 3) Faecal Coliform and 100 cfu/ml (cfu: colony forming unit) total aerobic bacteria count are appropriate standards for drinking water. Two samples out of seven treated water (TW-4 and TW-7) contain a little high total coliform count, but they have zero or less than 3 Faecal Coliform count. Two samples (DW-1 and DW-8) out of eighteen distributed waters in the dry season contain Total Coliform and Faecal Coliform count. Presence of Faecal Coliform in these samples provides definite evidence of faecal contamination. In the dry season, all of the treated and distribution water samples except TW-1, TW-2, TW-5, TW-6, DW-6 and DW-16 contain high Total Aerobic Bacteria count exceeding the upper limit of 100 cfu/ml.

The raw water samples 'RW-1' and 'RW-2' collected in the wet season shows high level of total aerobic, Total Coliform and Faecal Coliform. In the treated (post chlorination) water the level of Total Aerobic General Bacteria count exceeds the upper limit of 100 cfu/ml in TW-1, TW-4, TW-5 and TW-7, and in the distribution water the level of Total Aerobic General Bacteria Count exceeds the same upper limit in all the samples, except DW-7 and DW-16. As far as the level of Total Coliform is concerned, with the exception of TW-4 and TW-7, it is within the permissible limit of not greater than 3 count/ml in the treated water as well as distribution water. Regarding Total Faecal Count, it is within the permissible limit of not greater than 3 count/ml.

Even if the General Bacteria is detected, there is no direct relation with the pathogenic bacteria. When large number of General Bacteria is detected, however, there is the doubt where the tap water is polluted by the pathogens. In addition, it is judged that chlorine disinfection has not functioned sufficiently with water treatment process or distribution network system.

(2) Sewage, Domestic & Commercial Wastewater Samples

Table 41.1.2 shown in **Section 4.1 (3)** gives the limits for municipal and liquid industrial effluent as per National Environmental Quality Standard (NEQS) of Pakistan. Water quality of sewage was analysed to assess the treatment efficiency of the 3 existing Sewage Treatment Plants. The water quality test results for the 3 sewage treatment plants are mentioned above in **Table 41.2.9** and **Table 41.2.10**. Raw sewage, treated effluent and discharged effluent qualities were analysed for pH, COD_{Cr}, Coliform, Temperature, BOD, Suspended Solids, Total Nitrogen and Total Phosphorus.

The raw sewage and treated effluent qualities were worse in the dry season than in the wet season as expected. Some BOD reduction at TPs was observed during the dry season. In regard to other parameters, most of obtained data did not meet the effluent standards. In addition, some data were judged as abnormal, for example, quality of treated effluent was worse than that of raw sewage. It is difficult to explain what caused such results. In early August 2006 when sampling and water quality test were done for the wet season, TP-1 and TP-2 had not been operated for the past one month or so.

The water quality test results for domestic & commercial wastewater samples are shown in **Table 41.2.11**. The samples for domestic & commercial wastewaters were taken from the artificial drain and natural nallah which were considered representing the whole Karachi city.

Along with the test result of raw sewage and treated effluent, the samples for domestic & commercial wastewaters were also worse for COD_{Cr} and BOD in the dry season than in the wet season as expected. Due to dilution of organic pollutant with rain water, BOD in the wet season meets the Standards except RWW-2.

(3) Past Data Evaluation

The past 5 year water quality data for water supply and sewerage facilities of KW&SB had been transformed to the electric data. Those tables are shown in **Appendix A41.1**. Obtained data are as follows;

- Average Data of Chemical Analysis of Raw & Filtered Water, COD Hills Filter Plant (2001-2005)
- Average Total Coliform count per 100 ml (MPN Method), Bacteriological Analysis Report, of Raw & Filtered Water, COD Hills Filter Plant, (2001-June, 2006)
- Average Data of Chemical Analysis of Raw & Filtered Water, Gharo Filter Plant (2001-2005)
- Average Data of Total Chemical Analysis of Raw & Filtered Water, Pipri Filter Plant (2001-2005)
- Average Data of Chemical Analysis of Raw & Filtered Water, NEK (Old) Filter Plant (2001-2005)
- Average Data of Chemical Analysis of Raw & Filtered Water, NEK (K-II) Filter Plant (2001-2005)
- Average Data of Chemical Analysis of Raw & Filtered Water, Hub Filter Plant (2001-2005)
- Monthly Bacteriological (Total Coliform count/100ml, MPN Method) and Chemical Analysis Data from Pump Houses of Distribution System (2001-June, 2006)
- Average Data of Chemical Analysis of Sewage & Treated Effluent, Sewage Treatment Plant No.1 (2001 to 2005)

Analysed parameters were not the same in all the laboratories, because equipped instrument varies by laboratory. The best equipped laboratory is in the COD Hills Water Treatment Plant which is home to the Central Laboratory Unit. The Central Laboratory Unit is responsible for the analysis of distributed water samples from specified pump houses located in each township. Once every two weeks, those samples are collected and analysed by the laboratory technicians. Under the present situation, microbiological parameters can be tested in the Central Laboratory Unit only.

Collected past data shows that water qualities were generally “acceptable” throughout the year not only water supply samples but also sewage ones. Apart from pumping and feeding troubles, there is no water quality accident according to the data in the past 5 years. Especially, water quality data from TP-1 indicates that sewage treatment was fully functional to reduce BOD and TSS properly.

4.2 WATER AWARENESS SURVEY

4.2.1 Objectives and Survey Design

(1) Objectives

The people in Karachi have diverse social and economical backgrounds because many people have immigrated to Karachi from other provinces of Pakistan and surrounding countries such as India, Bangladesh and Afghanistan. This diversity significantly affects the usage of water supply and sewerage. For example, the people living in Katchi Abadis, who usually belong to low income group or lower middle income group, are using less water comparing to high income group such as the residents living in Clifton.

Recently, CDGK and Bureau of Statistics, Government of Sindh conducted few socio-economic questionnaire surveys that included some questions on water supply and sewerage. However, the results from their socio-economic reports are not sufficient to support decisions in the formulation of Water Supply and Sewerage Master Plan.

The relevant results tabulated in Socio Economic Survey Report-2005 V-1.0, Karachi Master Plan-2002, CDGK are presented in figures in **Appendix A42.1**. Its results show town-wise water supply and sewerage situation as well as household economic situation to some extent. These results are very important to understand the differences among the 18 towns. However, these results do not disclose the differences in water supply and sewerage conditions in diverse types of settlements such as Katchi Abadis, middle income group and high income group.

Karachi Human Rural Settlement Survey Report-2003, Bureau of Statistics, Government of Sindh also disclosed availability and quality of different types of water supply in rural settlements of Karachi. However, its results related to water supply and drainage are quite limited as shown in figures in **Appendix A42.2**.

Water Awareness Survey conducted in this Study consists of three types of questionnaire surveys (one main survey and two supplementary surveys) as listed below with their designed sample numbers.

1) Water Supply and Sewerage Usage Survey (1,000 samples)
2) Existing STPs Environmental and Social Impact Survey (100 samples)
3) Nala (River) Awareness Survey (100 samples)

The main purpose of Water Awareness Survey is to fully understand the existing water supply and sewerage situation, consumer complaints and demands, and acceptability of water meter and willingness to pay (WtP) for improved water supply and sewerage system in different types of settlements in Karachi. For this purpose, Water Supply and Sewerage Usage Survey is conducted. The results of this usage survey will be systematically used in the consideration of a range of aspects including, area prioritization for improvement, feasibility of meter installation, facility planning, O&M planning, economic analysis, tariff design, and awareness enhancement for the formulation of effective Master Plan. This survey was especially designed to clarify the differences between the poor and the more affluent, and the differences within the poor.

Existing STPs Environmental and Social Impact Survey is a supplementary survey to explore the residents' perception on the potential environmental and social impacts caused by the existing sewerage treatment plants (STPs). The results from this survey will be used mainly for environmental and social considerations and will also be referred in Initial Environmental Evaluation (IEE)/Environmental Impact Assessment (EIA).

The existing sewerage system is built on natural rivers/drainages locally called "Nala". In many places, Nalas are used as a substitute for secondary and trunk sewers. Considering financial constrains of Karachi and utilization of existing system, it is unavoidable to use a number of small Nalas as part of the sewerage system continuously in the future. Because Nalas in Karachi are facing many problems such as encroachment and clogging by garbage, Nala Awareness Survey is designed to capture the perception and demands of local people regarding the improvement of Nalas. The results of this survey will be used in the formulation of Sewerage Master Plan to improve Nalas as part of the sewerage system of Karachi in accordance with the desires of the local people.

(2) Survey Design of Water Supply and Sewerage Usage Survey

a. Main Questions

The questionnaire used for Water Supply and Sewerage Usage Survey (see **Appendixes A42.3 and A42.4**) consists of a large range of aspects (more than 200 questions) regarding water supply and sewerage situation and related perceptions of different types of residents, as listed below.

GENERAL

1) Household General Information
2) Household Economic Situation

WATER SUPPLY

1) Various Water Sources and Their Costs
2) Household Water Supply Equipment
3) Complaints and Demands on Public Water Supply
4) Water Conservancy
5) Acceptability of Water meter
6) Willingness to Pay for Improved Services

SEWERAGE

1) Environmental Awareness
2) Sewerage/Sanitation Options
3) Complaints and Demands on Sewerage
4) Willingness to Pay for New Sewerage Connection

OTHERS

1) Public Health
2) Storm Water Drainage
3) Garbage Disposal

There are many questions which are designed particularly to consider the water supply problems of Karachi. Currently, the people in Karachi are not familiar to the necessity of 24 hour water supply and the demand on 24 hour water supply is not well developed. To analyze this aspect, their WtP for different types of future water supply services (good pressure, 8 hour water supply, 24 hour water supply) are asked in separate questions.

Considering sustainable development of water supply in Karachi in the context of its limited financial and water resources, it is necessary to install water meter to each household in order to improve the cost recovery of waterworks and also to encourage water conservancy. Since most of the households are currently not familiar with water meter, enhancing awareness of the importance of water meter is critical for the sustainable development of water supply system. Therefore, in the interviews with the respondents, the advantages of water meter are well explained before asking them whether they support the installation of water meter. To the respondents who answered "Don't support the installation of water meter", their reasons for not supporting it and the conditions on which they will support were asked. The results from these questions will be used to evaluate the feasibility of water meter installation in Karachi.

b. Sampling Design

The survey was conducted in 56 sampling areas of different types of settlements in Karachi. **Table 42.1.1** shows the allocation of 1,000 samples to each type of sampling areas. **Figure 42.1.1** shows the locations of the selected sampling areas of different types.

Table 42.1.1 Sample Number Allocation of Water Supply and Sewerage Usage Survey

Type of Sampling Area	Katchi Abadis	Low&Lower Middle Income Group in Planned Areas	Upper Middle Income Group	High Income Group	Residents in Commercial Area	Bulk Consumers Area	Rural Settlement	Total
Number of Sampling Areas	30	5	4	3	4	3	7	56
Total Sample Number of Each Type of Sampling Area	600	80	64	48	64	48	112	1016

One the main objectives of Water Supply and Sewerage Usage Survey is to understand related problems in Katchi Abadis where about half of the population in Karachi live. To achieve this objective, 600 samples (60% of the total designed samples) are allocated to various types of 30 notified Katchi Abadis over the built-up area of Karachi. From all the sampling areas, household samples were taken randomly using 0.6m high-resolution satellite imagery.

In the analysis of the survey results, the average values for whole Karachi was also estimated using the percentage of each residential type shown in **Table 42.1.2**. This Table also gives post-defined income level criteria for each residential type used in the survey.

Table 42.1.2 Income Range and Population Percentage of Each Residential Type

<table>
<tr><th colspan="2">Residential Type</th><th>Average Monthly Household Income Range Appeared in Water Supply and Sewerage Usage Survey (Post-defined Income Level Criteria)</th><th colspan="2">Corresponding Monthly Household Income Range and Percentage of Each Income Group in Karachi from Socio Economic Survey of Karachi Master Plan-2020</th></tr>
<tr><td rowspan="3">Low&Lower Middle Income Groups</td><td>Katchi Abadi</td><td>Rs. 6,077 – Rs. 13,588</td><td rowspan="3">Rs. 0 – Rs 15,000</td><td>45%*1</td></tr>
<tr><td>Rural Settlement</td><td>Rs. 4,861 – Rs. 12,722</td><td>5%*1</td></tr>
<tr><td>Planned Area</td><td>Rs. 7,079 – Rs. 12,639</td><td>31%</td></tr>
<tr><td colspan="2">Upper Middle Income Group</td><td>Rs. 17,075 – Rs. 30,947</td><td>Rs. 15,001 – 35,000</td><td>17%</td></tr>
<tr><td colspan="2">High Income Group</td><td>Rs. 41,385 – Rs. 109,286</td><td>Rs. 35,001 & Above</td><td>2%</td></tr>
<tr><td colspan="4">Total</td><td>100%</td></tr>
</table>

Note: *1 These percentages are assumed for the calculation of the other percentages.

Figure 42.1.1 Sampling Areas of Water Supply and Sewerage Usage Survey

(3) Survey Design of Existing STPs Environmental and Social Impact Survey

a. Main Questions

The questionnaire used for Existing STPs Environmental and Social Impact Survey (see **Appendixes A42.5** and **A42.6**) consists of about 70 questions regarding existing and potential environmental and social impacts of the three STPs which are under operation in Karachi. The results will be used for environmental and social consideration process of the Study. Main aspects covered in this survey are listed below.

1) Awareness of KW&SB's Work
2) Social Influences of the STP and Effluent Discharge
3) Environmental Influences of the STP and Effluent Discharge

b. Sampling Design

Table 42.1.3 shows the allocation of total 100 samples to each STP. **Figure 42.1.2** shows the sampling areas of the survey. The survey was conducted in residential areas located around the three existing sewerage treatment plants. To find out the geographical extent of environmental and social impact, the sampling areas were set at different directions and at different distances from the STP. Because STP-2 is totally surrounded by residential areas, more than half of the 100 samples are allocated around STP-2. Larger numbers of samples are set down the wind up to about 2km from the centre of smell (primary waste water treatment facilities). Moreover, to find out the influence of discharged effluent from the STPs, samples are also taken around the Nalas where effluent from the STPs discharge into.

Table 42.1.3 Sample Number Allocation of Existing STPs Environmental and Social Impact Survey

Existing Sewage Treatment Plant	STP-1	STP-2	STP-3	Total
Number of Sampling Areas	7	20	4	31
Total Sample taken around Each STP	29	17	54	100

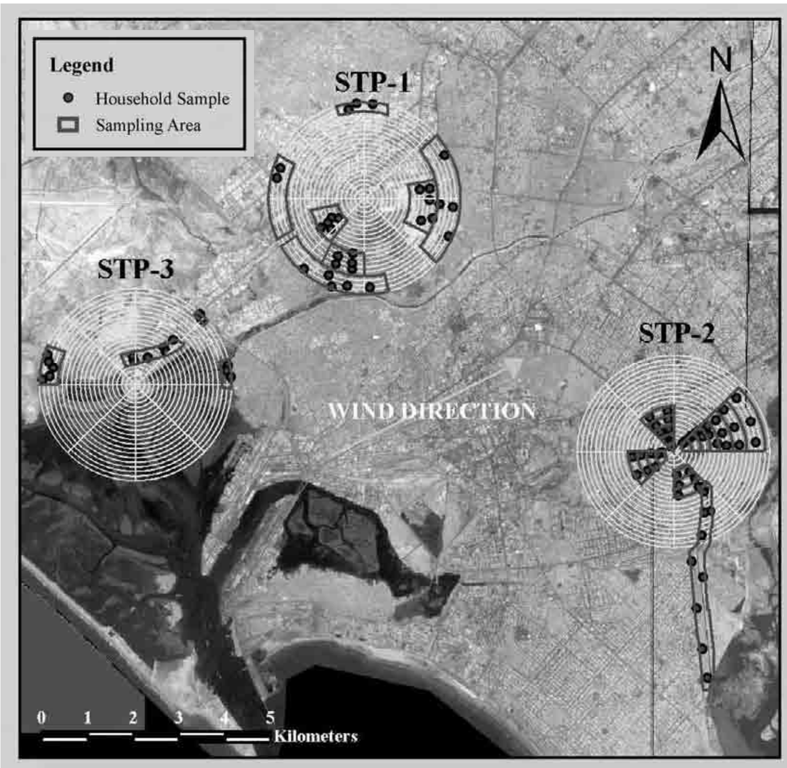

Figure 42.1.2 Sampling Areas of Existing STPs Environmental and Social Impact Survey

(4) Survey Design of Nala Awareness Survey

a. Main Questions

The questionnaire used for Nala Awareness Survey (see **Appendixes A42.7** and **A42.8**) consists of about 110 questions regarding the improvement of small Nalas in communities and large Nalas. This survey is a complementary survey for the sewerage-related part of Water Supply and Sewerage Usage Survey. In the development of questionnaire, the JICA Study Team had discussion with OPP-RTI. Main aspects covered in this survey are as listed below.

1) Construction and Repair Work of Nalas
2) Blockage and Encroachment
3) Flood
4) Pollution and Accident

The results of this survey will be used for the formulation of sewerage master plan which integrates existing Nalas as part of sewerage system while improving water quality of some Nalas. The improvement of Nala includes many social aspects such as demolishment of illegal encroachments along Nalas. Therefore, the questions are designed to clarify the perceptions of the households around different types of Nalas on related social aspects.

b. Sampling Design

In this survey, three types of sampling areas were set in residential areas around Nalas, which are Small Nala Sampling Areas, Large Nala Sampling Areas, and Developed Nala Sampling Areas where Nalas are partly covered or widened (Welfare Colony, Manzoor Colony and North Nazimabard). **Table 42.1.4** shows the allocation of samples to each type of sampling areas. **Figure 42.1.3** shows the sampling areas. Some sampled households belong to high income group. However, about majority of the sampled households belong to Katchi Abadis. Many of them are even encroachers along Nalas.

Table 42.1.4 Sample Number Allocation of Nala Awareness Survey

Sampling Area	Small Nala Sampling Areas	Large Nala Sampling Areas	Developed Nala Sampling Areas	Total
Number of Sampling Areas	5	5	3	13
Total Sample taken around Each STP	40	40	24	104

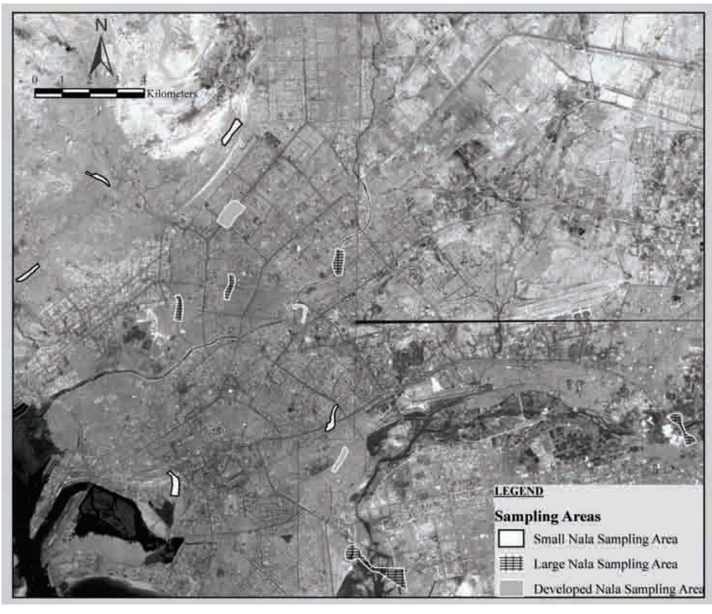

Figure 42.1.3 Sampling Areas of Nala Awareness Survey

4.2.2 Survey Results

(1) Water Supply and Sewerage Usage Survey

Photographs of the observed water supply and sewerage conditions in different types of areas are shown in **Appendix A42.9**. The results of the survey are tabulated and discussed in detail in **Appendixes A42.10** to **A42.12**. The following is the summary of the results.

a. Area Prioritization for the Improvement of Water Supply and Sewerage

1) <u>Water Supply Improvement and Willingness to Pay</u>

1. Small Katchi Abadis (less than 30 acres) have high water line connection rate of more than 60% (90% on average) while large Katchi Abadis (more than 200 acres) have low water line connection rate of less than 60% (28% on average).Water line connection rate is also significantly low in villages and among the residents in commercial areas.
2. In large Katchi Abadis, water line connection rate is much lower than its sewerage connection rate. Main reason of this low water line connection rate seems to be the distance from main streets of planned areas where water distribution mains are installed. In large Katchi Abadis, the willingness to have water line connection is 100% among the un-connected households.
3. The water line connection rates of Low&Lower Income Group in planned areas and Upper Middle Income Group are around 90 %. However among their remaining households of 10%, willingness to have individual water line connection is only about 60% and 30%, respectively. This means many households unconnected to water line in planned areas are already satisfied with their alternative water sources.
4. The water charges that they are paying for line water connection is less than 1% of their average monthly income in most of the residential types. However, the estimated average total expenditure for water including water tankers is around 2.5% of their average income level in most of the residential types.
5. In large Katchi Abadis, where water line connection rate is significantly low, average total expenditure for water is about 9% of their income. In High Income Group and Bulk Consumers such as DHA, where people buy much bottled water for drinking purpose, the total monthly expenditure for water is quite high as well.
6. The average WtP for new water line connection is higher than the average WtP for improved water supply services in Katchi Abadis, Low&Lower Middle Income Group of planned areas, and villages. However, it is other way around in Upper Middle Income Group and High Income Group.
7. In large Katchi Abadis, where people are buying expensive water from Tanker, etc., the average monthly WtP for new water line connection is high, which is around 7% of their average income level. They have strong demand on the expansion of water lines by KW&SB.
8. The WtP for better water supply services is higher in higher income group in general. In large Katchi Abadis, the average WtP for the improvement into 24-hour water supply is significantly high, which is close to 5% of their average monthly income.
9. In conclusion, water distribution network should be expanded in large Katchi Abadis, where connection rate is low but the WtP for new line connection and 24-hour water supply service is significantly high. In Upper Middle Income Group and High Income Group, where WtP for better water supply services are significantly high, the rehabilitation of existing water supply system is more important and sustainable.

2) <u>Sewerage Improvement and Willingness to Pay</u>

1. The sewerage connection rate (percentage of the households connected to sewers locally called “Gutter” and “Gutter line”) is higher than water supply connection rate in general in Karachi except for rural areas, which is estimated at 89% on average. In Upper Middle and High Income Group, the sewerage connection rates have already reached almost 100%.

2. The current level of sewerage charges is only around 0.2% of their household income level.
3. The WtP for new sewerage connection to improve household life is only around 1% of their income in Katchi Abadis and Low&Lower Middle Income Group in planned areas.
4. The WtPs for new sewerage connection to improve both their household life and environment in Karachi are hardly higher than the WtP only for household life improvement. Especially, the households in low and lower middle income groups are not putting their importance on the environment.
5. Considering their high expenditure for water related disease in comparison of their income level, there seems to be potential of higher WtP for sewerage in those areas where sewerage conditions are not desirable. Therefore, it is quite important to raise the awareness on sewerage in Karachi to have the people accept the higher sewerage charges that is necessary for sustainable sewerage improvement in the future.

3) Social Conditions of Different Residential Types

Social characteristics of each residential type are also analyzed below to support proper area prioritization in the social context of Karachi as well as its economical context examined above.

1. About 80% of the respondents in Katchi Abadis and villages were males while this ratio is about 65% in planned urban areas. This suggests higher unemployment ratio, higher labour availability and lower social advance among females in Katchi Abadis and villages.
2. On average 1.7 families belong to one household and 9.2 persons including 2.4 children (blow 10 years old) live in one household in Karachi. These ratios do not differ dramatically among different residential types and income groups.
3. In Katchi Abadis where many immigrants live, only 29% of the households had lived in other urban areas of Karachi before coming to current places. 36%, 8% and 21% of them have come from rural area of Karachi, Interior Sindh and other provinces such as Punjab, respectively
4. Average plot size of household ranges from 90 to 600 square yards mainly depending on their income level. Larger Katchi Abadis usually have larger average plot size.
5. Although the survey was conducted in notified Katchi Abadis, 45% of the households in those Katchi Abadis are built on unleased plots.

b. Current Water Supply Conditions

1) Usage of Different Water Sources and Water Consumption

Table 42.2.1 shows the percentages of the households using different water sources for different purposes.

1. The percentage of the households actually using individual or shared water line connections are 80% in total in Karachi, which is slightly lower than the percentage of the households having water line connections.
2. This table also shows that the percentages of the households using water tankers and wells/bores are both 18%. More than 20% of the households in Katchi Abadis are using water tankers. 28% of Low&Lower Middle Income Group in planned areas are using wells or bore, although about half of this 28% do not use the ground water for drinking purpose because ground water is brackish in many areas.
3. In High Income Group, 30% of the households use bottled water for drinking purpose.
4. 6% and 4% of the households in Karachi use water carrying persons and public water storage tanks.
5. The table also shows that the average number of different types of water sources in use is 1.4 sources in Karachi. In Katchi Abadis, they use individual line connections and water tankers mainly.

Table 42.2.1 Percentage of the Households Using Different Sources

Area Category	Individual Water line Connection (%)			Shared Water Line Connection (%)			Bottled Water (%)			Water Tanker (%)		
	Drinking	Other Usages	All Usages	Drinking	Other Usages	All Usages	Drinking	Other Usages	All Usages	Drinking	Other Usages	All Usages
Katchi Abadis	66	69	68	8	7	9	3	1	4	22	21	23
Low & Lower Middle Income Group in Planned Areas	73	65	76	4	6	7	14	1	14	8	8	12
Upper Middle Income Group	81	85	89	2	2	4	15	0	15	2	6	6
High Income Group	71	96	96	3	0	3	30	0	30	7	13	15
Residents in Commercial Areas	46	55	56	27	29	33	31	0	31	4	5	5
Bulk Consumers	68	86	86	0	0	0	19	0	19	18	33	33
Rural Settlements	24	28	28	6	6	7	1	1	2	46	39	47
Estimated Average in Karachi	69	69	73	6	6	7	9	1	9	15	15	18

Area Category	Water Carrying Person (%)			Public Storage Tanks (%)			Well/Bore (%)			Other Water Sources such as Lake (%)			Average Number of Different Water Sources in Use		
	Drinking	Other Usages	All Usages	Drinking	Other Usages	All Usages	Drinking	Other Usages	All Usages	Drinking	Other Usages	All Usages	Drinking	Other Usages	All Usages
Katchi Abadis	3	4	4	3	3	4	9	13	14	0	1	1	1.1	1.2	1.3
Low & Lower Middle Income Group in Planned Areas	7	2	8	1	1	2	14	28	28	1	1	1	1.2	1.1	1.5
Upper Middle Income Group	2	4	5	2	0	2	2	13	13	0	0	0	1.1	1.1	1.3
High Income Group	0	0	0	0	0	0	1	5	5	0	0	0	1.1	1.1	1.5
Residents in Commercial Areas	3	3	6	3	3	4	10	23	25	0	0	0	1.2	1.2	1.6
Bulk Consumers	0	0	0	5	4	5	0	2	2	0	0	0	1.1	1.2	1.5
Rural Settlements	8	7	8	20	16	21	11	15	15	10	11	11	1.3	1.2	1.4
Estimated Average in Karachi	4	3	6	3	3	4	9	18	18	1	1	1	1.2	1.2	1.4

6. In large Katchi Abadis, where line water connection rate is low, the total percentage of households not having enough water for more than bathing is 33% while those of High Income Group and Bulk Consumers are only 10% and 4% respectively.
7. 26% of drinking water is bottled water in High Income Group while that is only 2% in Katchi Abadis.
8. The consumption of line water in large Katchi Abadis and villages are only 3% and 24% of the total water consumption for non-drinking proposes. However, this rate is 59% and 91% in Katchi Abadis and High Income Group, respectively. In large Katchi Abadis, water tanker supplies 70% of their water.
9. In large Katchi Abadis, households are spending Rs. 670 per month for water tankers while spending only Rs. 12 per month for individual water line connection. High Income Group also pay significant cost for water tankers, which is Rs. 327 per month on

average. They are also paying Rs. 305 and Rs 1,025 monthly for line water and bottled water, respectively.

10. Average income level of notified Katchi Abadis and Low&Lower Income Group in planned areas are almost the same. However, water supply conditions are quite different between them. The percentages of households not having water line connection are 24% and 8% in Katchi Abadis and Low&Lower Middle Income Group, respectively.
11. 75% of the households without water line connection in Katchi Abadis claimed that their reasons of not having water line connection is the lack of public water supply line coverage in their areas, while only 17% of the households claimed so in Low&Lower Middle Income Group in planned areas.
12. Shared water line connection is not common in Karachi, although the percentage of having shared connection is 35% among the sampled households of Residents in Commercial Areas.
13. In Karachi, about 80% of water tankers are private tanker while only 20% belong to Ranger. Water usage of water carrying person and public water storage are both only few percent of total water consumption even in Katchi Abadis.
14. The usage of well/bore is about 15% of total domestic water consumption. Among those wells and bores, about 80% is bore. Average depth of well/bore structure, and depth of water table in wet season and dry season are 18.8m, 9.5m and 7.1m, respectively.
15. The average daily per capita water consumption in Katchi Abadis is significantly influenced by their area size (ranging from 13 gpcd in large Katchi Abadis to 30 gpcd in small ones) because large Katchi Abadis have more difficulty to gain enough water.
16. Outside Katchi Abadis, Bulk Consumers use water the most (59 gpcd) while villages use water the least (17 gpcd). In general, higher income group use more water.
17. It is more difficult to gain water from June to August in Karachi.

2) <u>Conditions of Water Supply-related Facilities and Equipment at Home</u>

1. 45% of installed service pipes are estimated to be made of GI in Karachi. In lower income groups, the percentage of polymeric material such as PVC are higher, which are about 25% in Katchi Abadis and Low&Lower Middle Income Group in planned areas and about 70% in villages.
2. Water meters are installed only in some areas of Bulk Consumers. Those meters are read monthly.
3. In Karachi, water suction pumps are also often used as booster pumps to send water to the overhead tanks of households. 67% of the households in Karachi are using water suction pumps. In Bulk Consumers areas where water meter is partly installed, the usage of water suction pump is relatively low comparing to other urban areas.
4. About 70% and 80% of the households using water line connection have receiving tanks and overhead tanks, respectively, in Karachi.

3) <u>Current Service Level of Line Water Connection</u>

Table 42.2.2 shows the percentages of the water line users who have complain on at least one aspect of each water supply service quality category (water quantity, water quality and public relations) or of all the categories. In the survey, water quality consists of two aspects: water supply hours, water pressure). Water quality consists of four aspects: safety, colour, taste, smell. Public relations consists of five aspects: complaint handling, promptness or repair work, billing and payment services, information notice of KW&SB work, trust on KW&SB officials.

1. In Karachi, 93% of the households have any complain on piped water supply services. In Katchi Abadis, 96% of the households have any complain. The people in Karachi have more complain on public relations of KW&SB (88%) than on received water quantity (61%) and water quality (64%).
2. On the other hand, only 44% of the residents in bulk water supply areas have complain. In bulk supply areas, 89% of the households are satisfied with water quality. It suggests

that there is no significant contamination within their water distribution system. Considering the other areas are using the same water sources for line water, it is important to improve water quality in other areas by removing cross connections and suction pumps drawing dirty water into water lines.

Table 42.2.2 Percentages of Having Complain on Each Service Quality Categories

Categories	Water Quantity	Water Quality	Public Relation	All Service Categories
Katchi Abadis	64%	70%	91%	96%
Low & Lower Middle Income Group in Planned Area	74%	60%	89%	92%
Upper Middle Income Group	39%	60%	81%	92%
High Income Group	35%	59%	75%	85%
Residents in Commercial Area	44%	53%	76%	85%
Bulk Consumers	20%	11%	38%	44%
Estimated Average in Karachi	61%	64%	88%	93%

3. In general, higher income group are more satisfied with current water supply services. For example, 50% of the water line users in Katchi Abadis are not satisfied with hours of water supply while this percentage is only 25% in High Income Group. The satisfaction level among Bulk Consumers is quite high. 83% of them are satisfied with current water supply hours.
4. In general, the water line users have similar satisfaction levels with water quantity, with water quality, and with billing and information notice of KW&SB work. More than 60% of the water line users in Karachi are not satisfied with those aspects.
5. They are especially not satisfied with KW&SB's complain handling and promptness of repair work. 75% of the users in Karachi are not satisfied with those aspects. 70% of them also do not trust on KW&SB officials in Karachi. In large Katchi Abadis, their mistrust on KW&SB is almost 100%.
6. Currently less than 50% of the water line users in Karachi are receiving water daily. More than 30% of them are receiving water two to four days a week. About 10% of them are receiving water only weekly and another 10% claim that water never comes. The situation is more serious in low and lower middle income groups, especially in large Katchi Abadis. The water supply hours per day or each time of water supply is 4.8 hours on average in Karachi, while that of large Katchi Abadis is only 0.7 hour.
7. More than 40% of the users say that water supply frequency and hours are not enough. They are asking for additional water supply of 7.8 hours for summer and 5.3 hours for winter on average in Karachi.

c. Improvement of Revenue Collection

1) <u>Current Billing and Collection</u>

1. Only 66% of water line users are registered in KW&SB in Katchi Abadis, while more than 90% of the users are registered in planned urban areas. In rural areas, only 12% of the users are registered.
2. In Katchi Abadis, only about 40% of the users are receiving water bills although almost all the users receiving water bill pay water charges. Therefore, current low revenue collection rate from Katchi Abadis has its root in KW&SB's billing system.
3. Among Low&Lower Middle Income Group in planned areas, 80% of the users receive water bills and 60% of the users pay water charges. In Upper Middle and High Income Groups, about 90% of the users receive water bills and also pay water charges. Most of Bulk Consumers pay water charges, while most of villagers do not receive water bills and do not pay water charges.

2) Expensiveness of Water Charges

1. More than 60% of the users not paying water charges in Karachi said that they do not pay because water bill is not coming. Even in Katchi Abadis, only 4% of the users not paying answered that it is because they do not have enough money.
2. In Karachi, about half of the line water users think current water supply charges are fair, low or very low, while only 20% and 15% of the users think it is high and very high respectively. We consider these results as a positive sign of potential acceptability of tariff increase required for future water supply improvement.
3. Comparing current water charges with their income level, it is obvious that water charges are not high in Karachi. Therefore, most of the users thinking it is high or very high are expected to understand its lowness after conducting awareness enhancement.

3) Perception on Current Water Tariff Structure and Billing

1. In Karachi, only about 30% of the line water users know that water bill is collected based on household plot size. In Katchi Abadis, only 24% knows it.
2. Monthly billing is more preferred than billing of every six months.
3. The percentage of the users having bank account is about 35% in Karachi, which seems enough to initiate the automatic bill collection using bank accounts.

4) Installation of Water meter and Removal of Suction Pump

The field surveyors explained to the households about the advantages of water meter installation accompanied with the necessary removal of suction pumps that improperly rotate water meter by sucking air when water supply is intermitted.

1. Even before the surveyors' explanation to them, 86% of the water line users in Karachi already know that water suction pumps causes contamination of line water by sucking dirty water into water pipes. After the explanation, almost 80% of the users understand the positive impacts of water meter installation and the removal of suction pumps.
2. 86% of the users in Karachi agreed to support water meter installation. Even in Katchi Abadis, the ratio of supporting water meter is 84%.
3. 80% of the users supporting water meter also answered that KW&SB should put heavy fine to the households using suction pumps continuously to encourage the installation of water mater and the removal of suction pumps.
4. About 75% of the users supporting water meter prefer to pay extra price as part of water charges for the cost of water meter installation instead of paying it at the time of installation at once.
5. Regarding the reasons why about 15% of the users are not supporting water meter, 24% and 34% of their reasons are because of not knowing water meter and because of not able to trust water meter, respectively in Karachi.

d. Organizations for the Maintenance of Water Supply Facilities

1) Permission of Water Line Connection

1. In Katchi Abadis and rural areas, only about 30% and 50% of the households, respectively, know that KW&SB is in charge of public water supply and sewerage services, while this ratio is about 90% in High Income Group.
2. Only about half of line water connections are permitted by KW&SB. 36% of the households having water line connections neither have permission nor know about permission of their connection in Karachi. Interestingly, 10% of the connections are permitted by UC Nazim in Katchi Abadis, while 23% and 15% of the connections are permitted by Town Nazim and UC Nazim respectively in villages.
3.

2) Maintenance and Leakage

1. The water line users think only about 35% of water supply lines are maintained by KW&SB in Karachi. They also think about 15% and 20% of water lines in their areas

are maintained mainly by UCs and household themselves respectively in Karachi. In Katchi Abadis their dependence on UCs is relatively high in terms of the maintenance, while dependence on KW&SB is high in planned urban areas.

2. In Karachi, only 17% of the water line users answered that they would inform KW&SB when they find water leakage outside their houses, while 29% and 41% of the users respectively answered that they would inform UCs and would try to fix it at their cost.

e. Current Sewerage/Sanitation Conditions

1) <u>Satisfaction with Current Sanitation Options</u>

1. In Karachi, most of the toilets/latrines with/without sewerage connection are private toilets/latrines expect for those in villages where about 20% of them are common toilets.
2. Although the sewerage connection rate in Karachi is about 90%, about half of the households are not fully satisfied with their current sanitation conditions.
3. The percentage of the households being satisfied with their sanitation is lowest in large Katchi Abadis and highest in High Income Group and Bulk Consumers.

2) <u>Open Defecation</u>

1. Few percent of the households in Karachi still practice open defecation, mostly in rural areas where 44% of the households practice it, although most of them know that open defecation often cause diseases.
2. In rural areas, about 60% of the households practicing open defecation because they could not afford toilet/latrine while the remaining 40% did not recognize the necessity of toilet/latrine or simply preferred open defecation.

3) <u>Toilet/Latrine without Connection to Gutter or Gutter Line</u>

1. Close to 10% of the households in Karachi use toilets/latrines that are not connected to sewers. In rural areas, 40% of the households still use toilets/latrines without sewerage connection.
2. Majority of those toilets in Katchi Abadis and rural areas are simple pit latrines.
3. 78% of the households using toilets/latrines without connection to sewerage think the effluent from their toilets/latrines pollute the surrounding environment or ground water.
4. In Katchi Abadis, about 20% of the households using toilets without sewerage connection dispose their home wastewater (from kitchen, bathing, etc.) to street surface.

4) <u>Physical Arrangements of Sewerage Connection</u>

1. The most of the toilets/latrines connected to sewerage system have WC style toilet seat (Indian Style). In low and lower middle income groups, most of the households use hand flushing, while majority of the households in High Income Group use tank flushing.
2. 86% and 12% of the sewerage connections in Karachi are connected to gutter lines and closed gutters respectively. Only about 1% of them are connected to open gutters.
3. About 10% of the sewerage connections in Karachi are recognized by the people as being directly connected to the sewers constructed by communities. This ratio is especially high in the large Katchi Abadis in which streets are well organized.

5) <u>Organizations involved in Providing Sewerage Connection and Maintenance</u>

1. In Katchi Abadis, only 22% of sewerage connections have been provided by KW&SB, while UCs and the households themselves respectively provide 27% and 26% of the connections. However, in most of the planned urban areas except for Bulk Consumers, about half of their sewerage connections have been provided by KW&SB.
2. Regarding maintenance of sewer lines, communities/CBOs or households themselves maintain majority of sewers in urban areas. The percentages of areas where their sewers are maintained by communities/CBOs in large Katchi Abadis and High Income Group are

relatively low among those urban areas, which are both about 25%.

3. Only in 8% of Katchi Abadi areas, sewers are mainly maintained by KW&SB, while in about 25% of the planned urban areas sewers are maintained by KW&SB. In village, about 40% of sewers are maintained by UCs.

6) <u>Awareness on Sewerage, Complains and Requests</u>

1. Even in Katchi Abadis, 80% of the sewerage users think that the sewerage form their households should be properly treated at sewage treatment plants although it costs them eventually.
2. Currently only 22% of the households using sewerage in Katchi Abadis knows that people are paying sewerage charge at 25% of water charges. This ratio is higher in High Income Group, which is 65%. On the other hand, almost no one knows it in villages.
3. Although the sewerage connection rate in Karachi is already about 90%, about 70% of the sewerage users have complains on current sewerage conditions. Majority of complains are clogging and overflow from sewers. They also complains on mosquitoes, flies and smell caused by mal-maintenance of sewers.
4. 54% of the sewerage users in Karachi have specific requests to CDGK or KW&SB on sewage disposal. However, only 9 % of the users in Karachi have actually reported their complains about sewerage to CDGK or KW&SB while 22% and 44% of the users have complained to Town Offices and UCs.

f. Storm Water and Solid Waste

1) <u>Storm Water Drainage</u>

1. Most of the areas in Karachi are not served by drainage system.
2. 37% and 17% of the households in Karachi experienced flood below the floorboard and over the floorboard, respectively, at their current dwelling.

2) <u>Solid Waste Management</u>

1. 53% of the households in Karachi do not have any garbage collection facilities in their localities. This ratio reaches 62% in Katchi Abadis. Therefore, 34% and 45% of the households throw out their garbage into Galis in Karachi and Katchi Abadis, respectively.
2. Only 7% of the households in large Katchi Abadis knows that people are paying conservancy at 10% of water charges for CDGK’s garbage collection and disposal. This ratio is 56% in High Income Group.
3. 47% of the households in Karachi are not satisfied with current garbage collection services at all.

g. Public Awareness Enhancement

1) <u>Water Save</u>

1. 90% of the households in Karachi know about the water shortage in Karachi.
2. 98% of the households in Karachi already save water when they use public water supply services. However, 86% of them also think that government’s effort to promote water save in Karachi is far too little or not enough.
3. About 85% of the households saving water answered that they save water because water is limited resource while only about 15% of them save water because water charges is expensive. The introduction of water meter-based water bill seems necessary to enhance the effectiveness of their water save.

2) <u>Environmental Awareness</u>

1. 85% and 13% of the households in Karachi think that water pollution in Karachi is very serious and serious, respectively. 61% of them think the water pollution in Karachi is mainly caused by garbage, while only 18% and 15% of them respectively think its main cause is domestic wastewater and commercial/industrial wastewater/solid waste.

2. Although 48% of them think that the most polluted environment in Karachi are rivers and channels, 37% of the household still think their residential areas is the most polluted. These results suggest that the discharge of domestic wastewater from living environment may still have many problems although sewerage connection rate is quite high in Karachi.

3) <u>Hygiene Enhancement</u>

1. Because only about one forth of the households in Karachi currently uses domestic water treatment, which is mainly boiling, it is important for KW&SB to improve the water quality of line water.
2. Usage of soap after using toilet and before taking food are 96% and 92% respectively in Karachi. However, cross-connections between water lines and sewer lines often cause serious epidemic of water bone diseases in Karachi.

(2) Existing STPs Environmental and Social Impact Survey

The results of Existing STPs Environmental and Social Impact Survey are tabulated in **Appendix A42.13**. The results are fully discussed in **Appendix A42.14**. Some of the important results are spatially analyzed and presented on satellite imageries in this Appendix. The following is the summary of the results.

a. Awareness on KW&SB's Work

1. Almost all the sampled households think that the pollution of water environment in Karachi is very serious and that sewerage is important to improve water environment as well as living environment.
2. Almost all the sampled households already have sewerage connection to gutter lines, but about 80% of those sewerage users have complains on the sewerage system in Karachi, mainly about clogging and overflow.
3. The most of the households around the STPs think that collected sewage should be treated properly at the STPs and are willing to pay for it.
4. 85% of the households around the STPs know that KW&SB is in charge of sewerage services. However, more than two third of their complains on sewerage are reported to the UCs and less than one third of their complains go to KW&SB.

b. Social Considerations

1. About 95% of the households around the STPs think that their STPs contribute to the improvement of life and environment in Karachi. Moreover, 70% of the households feel pride that their areas contribute to environmental protection with their STP. However, many of the households, which are adjacent to STP-2 and along the Nala used as its discharge point, are not proud of their contribution with STP-2.
2. Former land usages of the STP sites are agricultural land, forest, vacant plot, grave yard, salt industry and drying beds of fish. Some households are aware that there were some conflicts in removing fisherman illegally occupying the land regarding STP-3 and also in locating STP-2 site over the boundary of grave yard. Some claimed that some graves are still inside the STP-2 site.
3. About 10% of the households think the STPs had changed the social and commercial value of the surround lands. Some households pointed out the positive value of the current reuse of effluent from STP-1 for park maintenance and agriculture and a possible increase of land value due to STP-3. However, some households around STP-2 pointed out the decrease of land value due to the influences of the STP including its bad smell.
4. Although 40% of the households neither understand nor accept the reasons why the STPs was constructed there, only about 10% of the households feel unfairness regarding that their area have the STP.

c. **Environmental Considerations**

1. 8% of the sampled households around the STPs have noticed any environmental impact of the STPs. Some of them answered that greenery has been increased in their areas because of the reuse of wastewater. Some of them are also aware that sludge from the STPs is partly used for agriculture.
2. However, some of them answered that their STPs are causing pollution and mosquito problems. About 20% of the households around the STPs also think the landscape became less beautiful due to the STPs.
3. 35% of the households around STP-2 also think the odour from the STP is a problem. The households located close to the north boundary of STP-2 are significantly affected by the smell. However, because the most of the households seriously affected are within 100m distance from the boundary of the STP, the intensity and travel distance of the smell from the STPs seem to be limited.
4. In the future, smelly facilities of STP should be located at the far side of adjacent residential areas if it is not avoidable to construct STP close to residential areas. It is also important to adopt wastewater treatment technologies that do not cause strong smell. If possible, new STPs should be constructed at least 100m away from residential areas.

(3) Nala Awareness Survey

Photographs of the observed Nala conditions in differently types of sampling areas are shown in **Appendix A42.15**. The results of Nala Awareness Survey are tabulated in **Appendix A42.16** and discussed in detail in **Appendix A42.17**. In this result tabulation, samples from small Nala sampling areas and large Nala sampling areas are re-categorized into small Nala samples (less than 10 feet in width), medium Nala samples (11 to 40 feet in width) and large Nala samples (more than 40 feet in width). The following is the summary of the results.

1. About 20% of the Nalas in Karachi has been expanded in width usually demolishing the encroaching households along Nalas.
2. About 30% and 45% of the households both around small and medium Nalas think that their Nalas should respectively be widened and deepened.
3. More than 69% of the small and medium Nalas are Katcha Nalas. Most of the households think that those Nalas should be Pakka.
4. The most of Nalas in Karachi do not have any rainwater flow most of the time because rain season lasts for only about one month in Karachi. However, unexpectedly, about 70% of the respondents selected that Nalas should not be used for sewage disposal but only for rainwater drainage to improve natural environment.
5. About 90% and 60% of the households living around Nalas have complains about the present conditions of their Nalas and are not satisfied at all, respectively. Most of the households complain of pollution, danger, bad smell, and breeding of mosquitoes and flies in Nalas. About half of the households complain of blockage and overflow.
6. About 40% of the households around Nalas expect CDGK to coordinate and fund the improvement of Nalas in their community. KW&SB, Town Nazim, UC Nazim, Sindh Government and international agencies were also expected by some parts of the households to take these responsibilities.
7. 76% of small Nalas and 56% of medium Nalas are blocked or narrowed. Around 60% and 20% of the main reasons of the blockage and narrowed flow are respectively garbage and encroachment. About 60% of the Nalas in Karachi have encroachment of houses and shops along them.
8. Most of the households living around Nalas think mainly CDGK and Sindh Government should take actions to stop those encroachments for the improvement of living environment.
9. Only 66% of small Nalas, 39% of medium Nalas and 17% of large Nalas have ever cleaned up. Those Nalas were cleaned up few times in the last 10 years on average.

However, majority of these clean up was done only in emergency.

10. Small Nalas are mainly cleaned up by UCs, while medium and large Nalas are mainly cleaned up by CDGK (KMC/KDA).
11. About 80% of Nalas overflows in rainy season (July to August) and the water enters into 35% of the households around Nalas. Flooding is more serious around small Nalas.
12. The damage due to flood have cost households more than Rs. 60,000 in total per household in the last 10 years, which is expensive considering their average monthly household income is less than Rs 18,000 on average.
13. 55% of the households around small Nalas answered their Nalas are significantly polluted. This ratio is higher than 39% for medium Nalas and 33% for large Nalas. About 60% and 40% of the households both around small and medium Nalas answered respectively that garbage and domestic wastewater is main cause of the pollution.
14. 86% of the households around small Nalas think that their Nalas pollute drinking water. Around small Nalas, average WtP for the water quality improvement of their Nalas is more than Rs. 2,000, which is much higher than those of medium and large Nalas.
15. About 40% of the households around Nalas have ever noticed any accidents regarding their Nalas. Majority of the accidents are the falls of people and children into Nalas.
16. Almost all the sampled households answered that they support the construction of trunk sewers along large Nalas/Nadis in Karachi.
17. Most of them also support the ideas of building river front amenity once the water quality of those Nalas/Nadis improve and of taking strict action against encroachment on the riverfront.

4.3 LEAKAGE AND NRW SURVEY

4.3.1 Objectives

(1) General

The aim of this survey is to provide information which will assist with the overall determination of Non-Revenue Water (NRW) which is comprised of several components as shown in the following **Table 43.1.1**.

Table 43.1.1 Definition of Non-Revenue Water

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption (including water exported)	Revenue Water
			Billed Un metered Consumption	
		Unbilled Authorised Consumption	**Unbilled Metered Consumption**	**Non-revenue Water (NRW)**
			Unbilled Un metered Consumption	
	Water Losses	**Apparent Losses**	**Unauthorised Consumption**	
			Metering Inaccuracies	
		Real Losses (UFW)	**Leakage on Transmission and/or Distribution Mains**	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer metering	

Source: IWA "Best Practice" Water Balance and Terminology

It was known before the surveys commenced that system pressures are not high and domestic consumers are not metered, meaning that conventional methods of measuring minimum night flows to determine the amount of leakage occurring within the distribution blocks were not possible.

Nonetheless, it was agreed that the surveys would provide valuable information for a better understanding of several of the components of Non-Revenue Water shown in the above table and of the water use habits under the prevailing poor supply conditions.

(2) Objective

The overall objective of the Leakage Survey is to determine the extent of the losses (and non-revenue water) in the tertiary distribution system and household water systems, within the constraints of un-metered connections, intermittent and limited daily supplies, and low pressure.

This study is closely related to the formulation of a Non-Revenue Water Reduction Plan. All the data and information obtained from this study will be used to assist with the estimation of the cost, time and manpower required for the implementation of the Non-Revenue Water Reduction Plan.

Past reports completed in 1996 by Mott MacDonald indicated that losses in the tertiary distribution system amounted to 40% of the total system losses. The present state of the distribution system needs to be updated to determine the current situation and to assist with the estimation of losses if the tertiary distribution system were to be pressurized 24 hours per day.
Detailed objectives are to determine major sources of leakage and losses from:

- Distribution system pipes and joints
- Service connections
- Household systems including pumps, underground and overhead tanks

And, major reasons for non-revenue water other than physical losses from:

- Receipt of bills
- Payment of bills
- Illegal/unauthorized/non-registered connections

The survey is also intended to provide information on the extent of direct pumping from distribution mains which affects supply systems, and possible sources of contamination which is known to be a problem.

4.3.2 Implementation of Surveys

The methodology for the carrying out of the leakage surveys was as follows:

- Selection of Survey Areas
- Mapping
- Household Surveys
- Household Water Systems and Source of Supply
- Receipt and Payment of Bills
- Determination of Household Consumption
- Flow and Pressure Measurement
- Leakage Detection

(1) Selection of Survey Sites

The criteria adopted was to select two small distribution blocks each with a total of 200-300 services connections in conjunction with relevant personnel of KW&SB. Selection of these sites was done in consideration of the following factors:

- Areas to be reasonably representative of large parts of Karachi
- One area to be intermittent flow, the other a 24 hour supply
- Least disruption to surrounding areas

- Ease of isolation of the survey areas, and measurement of inflow
- Suitability for night work

From initial examinations the areas selected fitted the above criteria with the category of the residential properties being mainly plots between 61 and 120 yd^2. This category forms over 40% of all residential types (excluding flats) and about 50% of the total residential retail billing (the terminology used for un-metered supplies).

The areas selected were:

• Gadap Town Sector 5, Block B, (Surjani)	3 hour supply every 4 days
• Landhi town J-1 Area (UC 12)	24 hours supply

(2) Mapping

Maps of the selected areas were readily available from the JICA's GIS system and were marked up with the distribution network system for checking on site and selection of the locations for flow and pressure measurement.

(3) Household Surveys

The first task was to draw up a draft questionnaire relevant to the Karachi water supply system to be completed for all the households in the survey areas. Interviews of candidates for the collection of household information were then conducted and a team of four (two male, two female) were selected based on their past experience of conducting similar household surveys.

A training session was held before the surveys commenced to brief the surveyors on the reasons for inclusion of the various questions together with an explanation of the technical aspects of the leakage survey. Following a day of trial surveys discussions were held with the survey teams and the questionnaire was modified to suit the on-site conditions. The questions were chosen to collect information on:

• Housing;	No. and plot size, owned or rented, number of occupants
• Source of Water;	KW&SB, Tanker, shallow well, combination
• Billing Details;	Consumer No., Receiving a bill, paying or not paying
• Storage Tanks;	Dimensions of underground and overhead tanks
• Pumping System;	From distribution pipe, to tanks, combination
• Availability of Supply:	No. of supply hours and days received, water quality
• Other matters	Filter used for drinking water. Any other relevant information

(4) Household Water Systems and Source of Supply

Many houses are equipped with a ground level water storage tank, a small electric pump, usually 0.5 hp, and an overhead tank. Most pumps are connected such that they can pump direct from the distribution main when pressures are too low to fill the ground tank, and for onward pumping from the ground to overhead tank. Direct pumping from the distribution system is illegal but tolerated by KW&SB because it is often the only means possible of obtaining a supply.

Source of supply is generally from KW&SB sometimes supplemented by a shallow well or tanker supplies and occasionally the sole source of supply is a shallow well or water tanker.

(5) Receipt and Payment of Bills

All householders were asked if they received a bill from KW&SB and if so did they pay it. Many householders in Gadap Town who claimed to pay were able to produce the KW&SB new monthly bill with evidence that the bill had been paid.

(6) Determination of Household Consumption

As stated previously there are no domestic meters and alternative methods had to be used to measure consumption.

In Gadap Town fifteen houses were selected and levels for both underground and overhead tanks were measured over a number of days to calculate consumption. Four of these houses were fitted temporarily with domestic water meters to measure inflow when the supply was on. In Landhi Town it was only possible to carry out an interview survey to determine water use habits and estimate household consumption.

(7) Flow and Pressure Measurements

The equipments used for the surveys included:

- Mechanical Listening Rods
- Leak Detector
- Metal Pipe Locator
- Metal Detector
- Pressure Recorder
- Ultrasonic Flow Meters

a) Gadap Town, Sector 5, Block B, (Surjani)

An ultrasonic flow meter was attached to the 12 in (300 mm) AC supply pipeline and when the survey area was isolated the total recorded flow over the 3 hour period from 2.30 to 5.30 am was 658 m^3. The pressure was about 2.5 m head (not accurate on a 0-100 m range recorder) with a high velocity of 1.4 m/s.

b) Landhi Town J-1 Area (UC 12)

The 4 in (100 mm) diameter feeder main was located and an ultrasonic flow meter installed in a temporary chamber. After isolating the block, the maximum recorded flow was about 4 m^3/h and it was suspected that a second feeder main may exist. A flow meter was therefore fitted to a 6 in (150 mm) diameter CI pipe which may also have been a feeder but this recorded a variable flow direction, sometimes a reverse flow of about 9 m^3/h.

A pressure reading on the 15 in (375 mm) diameter trunk main showed a head of less than 2 m whilst the pressure in the distribution system was recorded as zero and sometimes negative.

(8) Leak Detection

In Gadap Town the area was checked by KW&SB staff for visible leakage and five wet areas were located.

In Landhi Town there was no visible leakage since the pressure in the distribution system was either zero or negative.

4.3.3 Survey Results

(1) Gadap Town

a) Distribution System and Water Supply

As stated previously the supply to the survey area is intermittent at 3 hours every 4 days. In response to the questionnaire, the residents gave varying hours of supply of between 1 and 8 hours with an average of 2.7 hours per 4 days more or less confirming the KW&SB schedule.

This area is fed from a 33 in diameter PRCC trunk main through an 12 in (300 mm) diameter AC main reducing to 8 in (200 mm) diameter and into a distribution system comprising of 3 in

(75 mm) and 4 in (100 mm) diameter AC mains.

b) Household Survey

The survey area is in the lower half of the lower middle income group with houses generally on 84 yd^2 plots. The KW&SB tariff system for residential property is based on plot size and all but one of the houses fell inside the category 61-120 yd^2 (one house was 124 yd^2). There was one small shop and one school with 450 pupils. The residents were generally cooperative with only 5 households refusing to take part at all in the survey. Empty services were excluded from the population calculation. The average occupancy rate was 7 persons per household with a minimum of 1 and a maximum of 20. Details of the households are given in the following **Table 43.3.1**.

Table 43.3.1 Survey of Households

Residential Houses			Population for Water Consumption		
Total Units	Not Surveyed	Empty	Measured	Calculated	Total
Excluding 1 School & 1 Shop	No Cooperation 5 Locked 17 Other 3		Maximum 20 Minimum 1 Average 7	25 houses at average number. per household	Estimated population
269	25	11	1693	188	1881

c) Household Water Systems and Source of Supply

As previously stated due to the intermittent supply system households rely on storage for daily water use and pumping is necessary to reach the overhead tanks. The results of the survey are detailed in the following **Table 43.3.2**.

Table 43.3.2 Household Water Systems

No. of Houses	No. of Responses	Houses with underground tank	Houses with overhead tank	Capacity of underground tank m^3	Capacity of overhead tank m^3	Houses with a pump	Pumps connected to distribution
269	228	212	217	Max. 14.4 Min. 0.5 Ave. 4.3	Max. 4.0 Min. 0.3 Ave. 1.7	228	166
	85%	93%	95%			100%	73%

It was observed that tanks are generally half full when the water supply is turned on. Water tanks are an integral part of house construction generally constructed with rendered brickwork and not necessarily water tight. The ground tanks are flush with ground level with a raised portion (about 50 mm) for the cover which is also not water tight. The tanks are easily contaminated particularly during monsoon conditions when inundation occurs.

The connections to the distribution mains do not have a stop tap and the tanks are not equipped with float valves and were observed to overflow during water supply times. Ground tanks are generally located close to the wash/toilet building and observation of the tank water quality raised questions of contamination.

The pumps, purchased by the house occupiers, are generally 0.5 hp electric and the majority are connected such that they can pump direct from the distribution and/or from the ground tank to the overhead tank.

Almost all of the houses have a KW&SB supply only 6 relied solely on tankers and/or their own well. Others used a combination of supplies. The supply sources are given in **Table 43.3.3**.

Table 43.3.3 Household Source of Supply

No. of Houses	No. of Responses	KW&SB Supply	KW&SB Supply only	KW&SB + Tanker	KW&SB +Well	Tanker only	Well only
269	229	223	176	39	8	4	2
	85%	97.4%	78.9%	17.5%	3.6%	1.75%	0.87%

As can be seen over three quarters of households rely solely on KW&SB for their supply. The wells are all shallow and unconfined with a depth of about 2.5 m. The source of the water is not known. It was suspected that wells would contain water from water and sewerage system leakage and from inundation after rains. An analysis by KW&SB on 3 wells showed the following parameters to be outside the WHO limits:

- Colour (only 1 well failed)
- Alkalinity
- Chloride
- Conductivity
- Total dissolved solids
- MPN of Coli Aerogenes organism/100 ml

Only five houses had a filter fitted to the drinking water tap, most boiled water for consumption.

d) Receipt and Payment of Bills

Regarding the receipt and payment of KW&SB bills the response is shown in **Table 43.3.4**.

Table 43.3.4 Receipt and Payment of Bills

No. of Houses	No. of Responses	Receiving a Bill	Not Receiving a Bill	Receiving and paying Bill	Receiving and not paying Bill
269	216	210	6	192	18
	80%	97%	3%	91%	9%

Out of those who did not respond many simply did not know if bills were being received or not. Research revealed that 66% of the houses are owner occupied but there was no difference in the payment pattern between houses which were owner occupied or houses which were rented.

The KW&SB billing system appears to have a high coverage rate and this may be explained to some extent by the fact that all premises are charged a "Water Tax" whether or not the premises is actually connected. The payment of bills is unusually high and does not reflect the overall number of bills paid in the Residential Category which is a mere 22% in the Revenue Data for 2005-6.

There may be an increase in collection due to the new monthly billing system introduced in July 2006. In low income groups throughout the world there is very little, if any, disposable income and the previous annual billing system may have been partly responsible for the low rate of payment. Regular small amounts (e.g. monthly payments) can however be paid if they are affordable and the consumers are willing to pay.

It is interesting to note that out of the 6 households without a connection and receiving a bill, four say they pay, one does not, and one did not respond. As long as the water charge "Tax" exists, illegal connections become largely irrelevant in housing areas since every household is supposed to be billed whether connected or not. This would not be the case for metered supplies.

e) Household Consumption

In the absence of domestic water metering it was decided to determine household consumption by measuring the daily difference in storage tank levels on a sample of 15 houses. Four houses were fitted with water meters to determine the inflow during supply times. The results are given in the following **Table 43.3.5**.

Table 43.3.5 Household Consumption by Observation of Tank Levels

House Number	Number of Occupants	Ave. Daily Consumption over 3 Days (l)	Ave. Daily Consumption over 5 Days (l)	Comments
72*	4	560	520	House number marked * had a meter fitted
200*	9	990	1,710	
18*	6	N/A	N/A	Incomplete data
271*	4	N/A	N/A	Incomplete data
530	6	960	1,080	
537	5	500	750	
45	13	(260)	780	
39	N/A	N/A	N/A	Incomplete data
627	2	(1,500)	(1,480)	
569	7	(70)	1,050	Consumption in ( ) was disregarded because of its abnormality.
313	6	420	(4,380)	
341	10	400	600	
319	5	500	900	
25	10	500	500	
258	5	900	750	
Total		5,730	8,640	
Average lpcd		5,730 / 60 = 95.5	8,640 / 74 = 116.8	

Observations were made over an eight day period. On supply days tank levels and water usage could not be measured. Between the first and second supply time 3 daily measurements were taken and on 2 days between the second and third supply time. As can be seen the results are highly variable which is not surprising given the intermittent supply situation and the short observation period.

Out of the four houses fitted with meters two could not be accessed for the full period and out of the two remaining, one meter recorded flows within 3% either side of the volumes calculated from tank levels (House No. 200), the other did not correlate with volume gained.

f) Flow and Pressure Measurements

The 12 in (300 mm) diameter feeder pipe was located and a temporary chamber excavated for the Ultrasonic Flow Meter. The flow was initially measured at about 350 m^3/h before isolating the block when the flow reduced to about 200 m^3/h. The velocity was high at 1.4m/s with a very low pressure of about 2.5 m head. The pressure quoted is approximate since the recording range of the instrument is 0-100 m. The supply was provided for approximately 3 hours between 2.30 and 5.30 am. The total calculated flow during the period was 658 m^3.

Ground tanks were observed to be overflowing and it was noted that people run the water to waste for at least 3 minutes as it has a bad odour and is discoloured probably due to turbulence in the previously empty pipes.

With a total maximum available supply of 658 m^3 for a 4 day period, the water consumption works out at about 87 lpcd. Allowing for wastage from tank overflows and running bad quality water to waste the per capita consumption would be about 80 litres per day which is a reasonable figure for low income households. This also compares with the consumption measured using storage tank levels.

g) Leak Detection and Repair

Due to the intermittent supply conditions it was not possible to use traditional methods for leak detection such as acoustic listening devices. It was only possible to detect leaks in the distribution mains by visual observation during dry ground conditions and 5 such leaks were observed. Two leaks were on the 12 in diameter AC main, two on the 8 in and one on a 4 in distribution main.

The Town Water Board officials had neither the equipment, spares or budget to carry out repairs and a special request for funds had to be made through head office. After a two week delay, the town engineers repaired the leaks using concrete. The 12 in diameter main leakage was from a vertical crack, those on the 8 in diameter main were from socket joints, and the 4 in diameter main leak was from a connection which was plugged and a new connection made.

It is normal practice for repairs to be carried out by contract, and whether by contract or direct labour a variety of unconventional repair systems are used due to lack of funds and this has now become accepted common practice. Repairs to AC pipe by first wrapping the fracture or joint with plastic sheeting then applying cement mortar or concrete are accepted practice. These repairs are only effective for a short period and in systems with very low pressure.

After successful repairs to four of the leaks the flow restored it was observed to have reduced by $10m^3/hr$, there was less air in the system and the water ran clean almost immediately.

(2) Landi Town

a) Distribution System and Water Supply

This area is fed from a 15 in (375 mm) diameter PRCC trunk main through a 4 in (100 mm) diameter AC main and into a distribution system comprising of 4 in diameter AC mains. This system replaced an older system also of 4 in diameter AC fed through a 6 in (150 mm) diameter CI main.

A section of the 6 in diameter main was cut out in order to place an isolating valve. The pipe exterior showed signs of corrosion. Internally, there was evidence of heavy encrustation and the growth of nodules together with an accumulation of silt and debris on the pipe invert severely reducing the effective diameter.

The supply to the survey area is said to be 24 hours, 7 days a week but the receipt of water was found to be highly variable throughout the block. Even houses next to each other had different supply conditions. In response to the questionnaire, the residents gave varying hours of supply. About 30% have a 24 hours a day supply, 60% are able to obtain water for a few hours a day and 10% for a few hours a week.

b) Household Survey

The survey area is in the upper half of the lower middle income group with 80% of the houses on 120 yd^2 plots, and the remainder on 128 yd^2 plots. There were five schools and one mosque. The residents were generally cooperative with only 8 households refusing to take part at all in the survey. There were no empty houses but some were locked and others inaccessible for other reasons. The average occupancy rate was 11 persons per household with a minimum of 1 and a maximum of 26. Details of the households are given in the following **Table 43.3.6**.

Table 43.3.6 Survey of Households

Residential Houses			Population for Water Consumption		
Total Units	Not Surveyed	Empty	Measured	Calculated	Total
Excluding 5 Schools 1 Mosque	No Cooperation 8 Locked 11 Other 3	None	Maximum 26 Minimum 1 Average 11	22 houses at average number. per household	Estimated population
220	22	0	1879	263	2142

c) Household Water Systems and Source of Supply

Due to water generally being available on a daily basis less reliance was placed on storage and there were few underground tanks. The predominant system was pumping from the distribution system or well to the overhead storage tank. The results of the survey are detailed in the following **Table 43.3.7**.

Table 43.3.7 Household Water Systems

No. of Houses	No. of Responses	Houses with underground tank	Houses with overhead tank	Capacity of underground tank m^3	Capacity of overhead tank m^3	Houses with a pump	Pumps connected to distribution
220	198	45	183	Max. 7.3 Min. 1.0 Ave. 3.8	Max. 5.1 Min. 0.3 Ave. 1.5	186	182
	90%	22.7%	92.4%			93.9%	91.9%

Almost all houses have a pump and because of the constantly low pressure and volume of the mains supply, most pumps pump directly from the distribution system. Again, the pumps are generally 0.5 hp electric and the majority are connected such that they can pump direct from the distribution and/or from the ground tank or well to the overhead tank.

Also the well water can be mixed with KW&SB water and it is possible by the pump interconnection to accidentally divert well water into the distribution system when pressures in the system are zero or negative.

Almost all of the houses have a KW&SB supply only 27 relied solely on their own well and tanker supplies were not used. The most common supply is a combination of KW&SB water and a well supply as sown in the following **Table 43.3.8**.

Table 43.3.8 Household Source of Supply

No. of Houses	No. of Responses	KW&SB Supply	KW&SB Supply only	KW&SB + Tanker	KW&SB +Well	Tanker only	Well only
220	202	175	93	0	82	0	27
	92%	86.6%	53.1%		46.9%		13.4%

The block is located between the Arabian Sea and the Malir River hence there is ground water and 109 houses have an unconfined shallow well. These are used extensively including for drinking water in view of the poor supply volume from KW&SB. A simple taste test revealed that the well water is saline and an analysis by KW&SB on 3 wells showed the following parameters to be outside the limits of the WHO guidelines:

- Alkalinity
- Chloride
- Conductivity
- Total dissolved solids

- Nitrite
- MPN of Coli Aerogenes organism/100 ml

No one used a drinking water filter, but all said they boiled water for consumption.

d) Receipt and Payment of Bills

Regarding the receipt and payment of KW&SB bills the response is shown in **Table 43.3.9**.

Table 43.3.9 Receipt and Payment of Bills

No. of Houses & Schools	No. of Responses	Receiving a Bill	Not Receiving a Bill	Receiving and paying Bill	Receiving and not paying Bill
220	212	186	26	53	133
	96%	87.7%	12.3%	28.5%	71.5%

As can be seen the KW&SB billing system appears to have a high coverage and once again this may be explained to some extent by the fact that all premises are charged a "Water Tax" whether or not the premises is actually connected. Out of the 26 households not receiving a bill, 22 had a KW&SB supply, the remaining 4 relied on their own well for all supply. Of the 27 houses with a well supply, 8 receive a bill and pay; 12 receive and don't pay; 4 don't receive a bill; and 3 don't know their billing status.

The payment of bills is low and close to the overall figure for the Residential Category rate of 22% and probably reflecting the consumers' dissatisfaction with the KW&SB supply. KW&SB personnel advise that the overall revenue collection rate in Landhi Town is less than 2%.

Again, due to the KW&SB policy of charging a "Water Tax" there was no particular search for illegal connections.

e) Household Consumption

In this block with a poor daily KW&SB supply supplemented by well water it was not possible to attempt to measure household consumption by observing tank levels as the tanks were frequently topped up. Accordingly a detailed interview study was carried out on water use at 13 houses and the results are given in the following **Table 43.3.10** compared to figures given in Mott MacDonald report of 1996.

Table 43.3.10 Household Consumption by Water Use Interviews

Water use lpcd	1996 Report Medium & high Income	1996 Report Low Income	2006 Landhi
Drinking, cooking, food preparation	12	12	7
Dish washing, house cleaning, hand washing	18	12	12
Bathing/Showering	60	30	19
Clothes washing	30	20	13
Toilet flushing	38	6	20
External use (including plant watering)	22	0	6
Total lpcd	180	80	77

Landhi is in the upper half of the lower middle income group and there is some correlation with the low income group figures.

f) Flow and Pressure Measurements

The 4 in diameter feeder main from the 15 in diameter trunk main was located and an ultrasonic flow meter installed in a temporary chamber. After isolating the block, the maximum recorded flow was about $4m^3/h$ and it was suspected that a second feeder main may exist. A flow meter was therefore fitted to a 6 in diameter CI pipe which may also have been a feeder but this recorded a variable flow direction, sometimes a reverse flow of about 9m^3/h.

Following days of investigation it was learned that the existing distribution system had been replaced by another system (also 4 in diameter AC) and had been disconnected from the 6 in diameter CI main which now feeds an adjacent area.

A pressure reading on the 15 in diameter trunk main showed a head of less than 2 m whilst the pressure in the distribution system was recorded as zero and sometimes negative. This is not surprising considering the number of pumps directly connected to the distribution system. It was suspected that there were large diameter illegal connections on the trunk main feeding this area but this was never confirmed.

Due to civil disturbances in the Landhi area a full 24 hour flow recording was not possible. Assuming an average flow of 4 m^3/h over a 24 hour period, the average daily supply to the block would be 96 m^3/d. With a population of 2,142 this represents 45 lpcd which clearly is insufficient and explains why the majority of households rely on wells to supplement supplies.

g) Leak detection and repair

Due to the low flow and pressure supply conditions it was not possible to use traditional methods for leak detection such as acoustic listening devices. Also, with almost zero pressure, naturally there was no sign of visible leakage. Therefore there was little point in carry out this work.

(3) Summary of Leakage Survey Results

a) Results

Normal procedures for the measurement of physical losses were followed but the KW&SB system does not allow for meaningful results to be obtained. It is usual to measure the inflow into an isolated block, take household meter readings to determine authorised consumption, trace unauthorized connections and detect all leakage by acoustic listening devices. When all illegal connections have been removed and leaks rectified, the flow is again measured and the decrease in consumption calculated to indicate the volume of losses and leakage.

With intermittent or low supplies coupled with low pressures, and no domestic metering, it was not possible to listen for leaks or to calculate accurately the authorized consumption. In addition, the policy of imposing a “Water Tax” on all property whether receiving a supply or not negated the issue of illegal connections.

Alternative methods of calculating household consumption were adopted but observation of household water tank levels did not provide meaningful average consumption information due to the short duration and inevitable inaccuracies. In Gadap Town the estimated household consumption did not correspond with the measured inflow. The inflow volume gave a figure of 87 lpcd over a four day period which is about the consumption level one would expect from lower middle income groups in the type of housing encountered.

In Landhi Town, it is thought that a 24 hour supply is given because other unknown constraints restrict supply to 45 lpcd, well below the 80 lpcd consumption level which one would expect. Hence most households supplement the KW&SB supply with well water.

The exercise in Gadap town shows that even at extremely low pressure the distribution system leaked from a fractured pipe, several joints and a household connection and that even temporary repair techniques reduced leakage and improved the initial flow quality which will lead to reduced losses from running water to waste.

Whereas it was not possible to fully quantify the volume of water loss in each block, valuable information was obtained for use with the formulation of a Non-Revenue Water Reduction Plan. Major issues were as follows:

i. Distribution Systems

These are generally old and in very poor condition. Repairs carried out continued to use unconventional methods, and if pressures were raised over 2 m head these and other previous repairs are likely to leak profusely. The one internal examination of a 6 in (150 mm) diameter pipe thought to be 35 years old, revealed external and internal corrosion and a severe reduction in internal diameter due to heavy encrustation on the pipe wall and accumulated debris on the invert.

The KW&SB town personnel lack accurate knowledge of the supply system and the distribution network, and due to lack of resources they are unable to maintain and improve the system and have to accept substandard repair work.

ii. Domestic Connections

KW&SB leave the installation of connections to the consumer supposedly by a plumber licensed by KW&SB and supervised by them. In reality, it is said that licensed plumbers merely sign the application form for a fee and the connections are then made by persons unknown generally unsupervised.

The connections are generally badly installed, in poor condition with signs of internal and external corrosion and are partially blocked with silt and debris. Generally there are no stop taps on the connections.

iii. Household Water Systems

Very many houses have their own "mini" waterworks with a ground level water storage tank, an overhead tank, and a multi-use pump. Where ground water exists and KW&SB supplies are poor, alternative well supply with unsuitable quality are used.

The ground level water tanks are oversized, and observations in Gadap town showed that many leaked profusely, are not fitted with a float valve and frequently overflow. They are vulnerable to contamination as they are not water tight on the surface and subjected to inundation during the rains. The overhead tanks are generally in better condition as they are visible to the owners but as with the ground level tanks there is little understanding for the need to keep them clean.

The pumping systems are mostly quite complex with multi-connections to pump direct from the distribution main to the ground or overhead tank and to pump from shallow wells. Whereas they are easily operated by the owners there is a lack of knowledge on efficient water use, and the health risks from contamination.

Losses could not be measured accurately but were observed from:

- Running water to waste when supplies arrive (Initial turbulence causes discolouration and taste and odour problems).
- Leaking ground tanks
- Overflowing ground tanks and overhead tanks

iv. NRW other than physical losses

Due to the KW&SB policy to impose a "Water Tax" on all premises whether connected or not the Billing Coverage Rate is likely to be high and was calculated at 97.5%. This system leaves little scope for illegal household connections (unauthorized consumption).

However, regarding payment of bills, in the Gadap town survey area 91% of households said they paid whereas statistics from the 2005-6 Revenue Data show a figure of 22% for the Residential Category. In the Landhi survey 78% of households admit that they don't pay which compares well with overall figures for the Residential Category from the KW&SB Revenue Data. These variable figures may be explained to some extent by the fact that the Gadap survey area only received water every 4th day but the volume was adequate, whereas the 24 hour supply in the Landhi area was woefully inadequate. The higher rate in Gadap may also be due to the change to the more affordable monthly billing system.

b) Conclusion

There is no reason to suppose that losses in the distribution are any less than that estimated 10 years ago by the Water Loss Reduction and System Strengthening Project. At that time it was estimated that total losses amounted to 30% of the supply capacity of 334 mgd and distribution losses amounted to 40% of all system losses (approximately 40 mgd).

With the current supply level at approximately 600 mgd and on the safe assumption that leakage has not reduced, distribution losses may well be approaching 80 mgd. This must be borne in mind when considering the need for distribution network improvement.

The following major conclusions may be derived from the Leakage Surveys:

- The system of providing intermittent supplies is unsustainable. Low supply volumes cause households to use contaminated wells the water from which may also contaminate the distribution system. Low and negative pressures in the distribution system also exposes the system to contamination from polluted ground water and there is a sever danger to public health.
- Revenue collection is unlikely to improve significantly with the current system of imposing a "Water Tax" on premises whether connected or not. In addition poor house leads to reluctance to pay and unless a volumetric charging system is adopted there will be nothing to encourage people to adopt efficient water use.
- The distribution system is old and in poor condition. The repairs carried out are substandard and will only last for a short period of time even at the current low pressures. As and when pressures are raised there will undoubtedly be a large increase in the amount of leakage and losses.
- Household connections are probably made by unsupervised and unqualified personnel. They were observed to be of poor quality with bad workmanship and they are generally in poor condition. Ownership of and responsibility for the connection is not clear.
- Household water systems are prone to leakage, vulnerable to contamination and the direct connections to the distribution system, whilst considered necessary in some cases to obtain a supply, are illegal, harmful to the operation of the system and contribute to the high risk of contamination (contaminated water from ground tanks and wells can enter the distribution system via interconnections during times of zero and negatives pressures).
- There is an acute lack of awareness by the consumers on the need for a high standard connection; the illegal status and dangers of pumping from the distribution system; the dangers and health hazard from the various sources of contamination largely caused by their own "mini" waterworks systems; and the need to avoid over use and wastage of water
- The devolution of KW&SB operations to the 18 Towns is largely incomplete. They are under-resourced from finance to equipment; are forced by circumstances to neglect supervision of the installation of connections and powerless to carry out repairs using suitable materials and good workmanship.

c) Recommendations

It is recommended that KW&SB:

- Recognise that NRW problems in the water distribution system lead to poor quality of house, and that the problems are equal to or greater than the bulk water supply problem
- Implement a pilot project in a small hydraulically isolated area with a 24 hour supply at good pressure; install meters at all connections; apply an experimental volumetric water tariff; ban suction pumps and ground tanks; repair leaks; all with the cooperation of the consumers previously educated through workshops
- If this project is successful, progressively implement this improvement on an area by area basis; develop a new water tariff; revise the bylaws accordingly, and progress towards a 24 hour supply with universal metering with an efficient meter reading, billing and collection system
- Revise the system of making the consumer responsible for the installation of connections, and clearly define ownership and responsibility for connections and meters
- Educate relevant KW&SB staff on the need for the use of good quality materials and good workmanship for the installation of new water mains/connections and the repair of leaks
- Develop a closer relationship with the general public; present the current supply/demand situation in a transparent manner; educate the public on the need for the efficient use of water and to avoid unnecessary losses; the need to pay bills to provide for improved operation & maintenance; and the reasons for, and need to, progress to a metered volumetric affordable tariff
- Educate consumers on the dangers of direct pumping from the distribution system and the use of water from contaminated wells
- Advise and involve the citizens of Karachi in the operation, maintenance and development of the water supply system for an equitable water supply providing “some for all” and not “all for some”

4.4 ON-GOING RELEVANT STUDIES AND PROJECTS

4.4.1 International Agencies

(1) Water and Sanitation Program

The Pakistan Office of the Water and Sanitation Program - South Asia (WSP-SA) has been extending its support to the KW&SB for institutional reform and strengthening with the objective of transforming the utility into an efficient service provider who operates the water and sewerage services on a financially sustainable basis. The assistance was designed to improve accountability in service provision through institutional reforms and enhanced accountability to consumers.

The recent initiatives of the WSP-SA include ‘Performance Benchmarking’ and ‘Citizen Report Cards’. WSP-SA set the following objectives for the Performance Benchmarking.

- Institutionalize the data collection practice within KW&SB
- Utilize collected data for financial, managerial, administrative and accountability decisions
- Analyses of performance gaps and development of performance improvement plans

Benchmarking involves the measurement of performance on certain key parameters and is expected to serve as an effective tool for comparative assessment to measure, monitor and improve performance and encourage adaptation of best practices in the provision of services.

WSP-SA has decided to pilot a ‘Citizen Report Card (CRC)’project based on user feedback on water and sanitation services in Karachi. It is expected that CRC will provide a rigorous basis and a proactive agenda for communities, KW&SB and local governments to engage in a dialogue to improve the delivery of public services. To this end, surveys were conducted in 9 towns of Karachi to collect views and opinions of customers (450 households / town) on the quality of the water supply and sewerage services provided by the KW&SB. It is expected that the analysis of collected data will be completed by February 2008.

Under the WSP's initiative, two committees on institutional reforms were formed in early 2007. A provincial-level 'Steering Committee' for strengthening the reforms in the water and sanitation sector of Government of Sindh was constituted through a notification issued by the Chief Secretary Sindh on January 23, 2007. The Minister Local Government Department is the Chairman of this committee. A CDGK-Level 'Reform Committee' was established to improve the service delivery through a notification issued by the District Coordination Officer of the CDGK on February 3, 2007. The Chairman KW&SB / City Nazim, CDGK is the Chairman of this committee.

In addition, the WSP has recently commissioned a study titled 'Situation Analysis Report / Water Sector Profile'. The study comprises the following three components.

- A review of physical infrastructure, facilities, water resources, distribution systems and assets both in the formal and informal sector institutions and organizations that manage it within the context of the existing policy/planning framework
- An institutional/policy profile that identifies key organizations, their relationships, and mandates and roles that reflect on their capacities, constraints and relative influence in Water Supply and Sanitation policy, operation and monitoring
- A financial assessment, dealing with public expenditure, revenue flows and potential and prospective external investments and the constraints on mobilizing such investments

On December 19, 2007, the WSP convened a 'Stakeholder Workshop on Water Sector Profile of Karachi' to present the findings of the above study to stakeholders.

(2) Asian Development Bank

a) TA Loan (US$ 10 million)

The Asian Development Bank (ADB) is currently assisting the CDGK and KW&SB under its technical assistance (TA) loan for "Institutional Enhancement for Implementation of Karachi Mega City Development Project (KMCDP)". The amount of the loan is US$ 10 million which is equivalent to 75% of the total project cost of the KMCDP, US$ 13.3 million. The balance US$3.3 million is financed by the Government of Sindh. The KMCDP is intended to address the mega city development needs with a long-term and holistic approach through (i) building capacities at the local level for effective city planning and management and adoption and implementation of commercial principles in the provision of infrastructure and services, (ii) supporting the preparation of infrastructure projects for mega city development that may subsequently be funded by ADB in its loans to Karachi initially over the next four years, and (iii) promoting reforms for sustainable financing. The TA Loan represents the first intervention of a long-term assistance from ADB and will establish the required foundation for effectively utilizing and sustaining future ADB investments in the mega city of Karachi. It is currently envisaged that the TA will be implemented over a period of 48 months starting from early 2007.

The objective of the TA loan project is to prepare for the systematic development of Karachi within the strategic framework and vision for Karachi and the priority investment needs that would emerge from various studies. The TA loan is proposed to be followed by a series of investment interventions which would facilitate achieving the vision for Karachi as one of the great cities of the world. **Table 44.1.1** below presents the components of the TA loan project.

Table 44.1.1 Components of TA Loan Project

Component		Description
A	Capacity Building Facility	Providing resources to refine and upgrade the ongoing work of strategic master plan, including comprehensive capacity building for CDGK, Town Municipal Administrations (TMAs) and other city agencies through advisory services, training and establishing necessary information and communication technology systems.
B	Project Preparation Facility	This facility provides for project preparation and feasibility studies for those sub-projects identified in sectors such as water supply, waste water management, storm water drainage and sewerage, solid waste management, transport and katchi abadis' up-gradation, including modalities for public private partnerships, preparation of detailed designs and related contract documentation. It is intended that the subprojects prepared under this facility would be considered for investment financing in the subsequent phases of interaction with development partners.
C	Establishment of Special Financial Vehicle (SFV)	Establishing and making fully operational the SFV through start up funding for the first three years of its operation on a declining basis over such period.
D	Support for Project Implementation	Providing support and assistance to the Program Support Unit (PSU) in managing and implementing the Project and coordinating Component C. Providing support and assistance to the Local Support Unit (LSU) and Project Working Group (PWG).

It has been agreed that Component A of the ADB TA loan project will include a study focusing on the formulation of a long-term strategy for financial sustainability and institutional development of the KW&SB while Component B will include several project preparation and feasibility studies that are related to the water and sewerage services in Karachi. **Table 44.1.2** provides the scope of works proposed for each study.

Table 44.1.2 Studies Included in TA Loan Project

Study		Scope of Works
(i)	Financial Sustainability and Institutional Development for Karachi Water & Sewerage Board	1) Undertake an in-depth institutional review and suggest institutional arrangements that are consistent with local government decentralization and that combine accountability with the commercial autonomy necessary to run a sustainable water utility 2) Develop a long-term commercialization strategy on a step by step basis, outlining benefits, costs, opportunities and risks at each stage with concrete proposals for making KW&SB a fully sustainable and self sufficient organization 3) Recommend a practical plan on financial sustainability and a sound revenue collection system 4) Undertake and internal organizational review of KW&SB identifying weaknesses, structural constraints and issues of accountability, transparency and responsiveness. Assess human resource needs and suggest improvements in effectiveness, resource mobilization, revenue generation management and accounting system and also design a costed capacity program for KW&SB.
(ii)	Effluent Water Reuse Study for Karachi	1) Estimate the quantities, cost and potential revenues from water that could be made available for various municipal water reuses such as agriculture and landscape irrigation, industrial recycling, groundwater recharges, recreational/environmental uses and non-potable urban uses etc. and develop options comparing these to the costs of abstracting additional water from the Indus River or to the cost of desalination 2) Prepare strategic action plan for wastewater reuse, detailed time bound costed action plan and institutional and operational mechanism
(iii)	Water Balance & Equitable Distribution in Karachi	1) Evaluate total water inflows to the system and to each Town in Karachi; actual and billed consumption; water losses and its components, preparing a water balance strategy 2) Assess problems in the distribution network within towns, including pressure and quality problems, and an equitable and efficient distribution system for Karachi in the short to medium term 3) Recommend possible investment interventions based on the final analyses
(iv)	Developing IT Platforms for Tracking and Maintenance System for KW&SB	1) Develop and implement an Information Technology Based System to keep track of all assets, operations and maintenance procedures 2) Develop a System Control and Data Acquisition (SCADA) System, and identify the appropriate platform interface, transducers and controllers for the improved system, etc 3) Train the KW&SB staff in its use
(v)	Disaster Management Plan for Water Supply & Sewerage Infrastructure in Karachi	1) Devise Emergency Management Plans to minimize and mitigate the damaging effects of both natural and man-made disasters on KW&SB's water and sewerage infrastructure 2) Suggest application of appropriate mitigation technologies, practices and alternate strategies for the strengthening of water and sewerage system infrastructure and uninterrupted operations of the KW&SB in case of emergency 3) Recommend appropriate institutional and operational arrangements and possible investment interventions based on the final analyses

Source: Invitation for Expression of Interest in Water and Sewerage Sector issued by the Local Support Unit, Karachi Mega City Development Project

As part of its on-going initiatives, ADB in collaboration with the Local Support Unit of the KMCDP has prepared a 'Draft Karachi Sustainable Mega City Water and Wastewater Roadmap' in May 2007 with the objective of providing:

- A vision for improving the sector (with quantitative indicators)
- A review of the sector's status and the key issues
- An outline of the investments proposed for the water sector until 2020 and, out of this, a vision of what the ADB loan can finance, and
- An outline of steps for institutional and financial reform of the sector. Key principles of the reform include defined accountabilities for service and a commercial focus.

A series of stakeholders' workshops were convened in Karachi in early June 2007 to discuss this draft roadmap. Nevertheless, this roadmap has not been finalized as of mid-January 2008.

b) Main Loan (US$ 800 million)

Apart from the above TA loan, ADB also plan to provide a main loan of US$ 800 million under the KMCDP to finance a series of investment interventions in various sectors such as water supply, transport and katchi abadis' up-gradation. The loan is proposed to be provided in three tranches. As a result of on-going studies under the TA loan, the following subprojects in the water supply sector have been proposed for implementation under the first tranche (2007 – 2010) of the main loan.

- Construction of a new 100 mgd filtration plant at NEK Old Filtration Plant site
- Expansion of the existing COD Filtration Plant by 84 mgd
- Provision of approximately 20km of 48 in and 36 in water transmission main from Pipri Treatment Plant to Korangi Industrial Area
- Provision of approximately 25km of 36 in water transmission main from Pipri Treatment Plant to Malir Town.
- A Distribution Network Improvement Program (DNIP) which will lead to a rolling program of DNI improvement on a zone by zone basis at the second and third tranches to significantly reduce losses and progressively move towards a 24 hour supply.

This main loan was scheduled to be signed in July or August 2007. However, negotiations are still continuing between ADB and CDGK as of mid-January 2008.

4.4.2 CDGK and KW&SB

(1) CDGK

a) Formulation of 'Karachi Strategic Development Plan 2020'

The project for "Formulation of Karachi Strategic Development Plan 2020" was completed very recently in December 2007. This project was carried out by the City District Government Karachi (CDGK) as one of the components of the "Tameer-e-Karachi Programme (TKP)" under the directives of the President of Pakistan. The consultancy services contract was awarded to the local consultancy firm, M/s. Engineering Consultants International (ECIL), who in collaboration with a foreign consultancy firm, M/s PADCO conducted this important study.

It is expected that the outcome of the study will provide overall guidance for the formulation of master plans for each town and for the framing of development schemes and projects for the Karachi City District in a coordinated manner. Detailed databases to be established in the study on the basis of zonal profiles of 178 Union Councils will enable line agencies to understand in which areas their intervention is urgently required.

The objectives of the project are defined as follows.

- Strengthening urban planning process
- Plan to provide sufficient and affordable serviced lands to cater to housing needs of all income groups with greater emphasis on low-income housing
- Provide planned alternatives to Katchi Abadis in view of E.I.A. of the locality
- Provide an adequate supply of potable water
- Provide most modern garbage collection and disposal facilities to cover 100% population of the Karachi City District
- Provide adequate educational, health and recreational facilities
- Provide adequate transport facilities
- Adequate and reliable drainage and sewerage system
- Growth of industrial areas and free trade zones
- Provide effective road network and other means of communication

This holistic master plan study was commenced in December 2005 with its completion originally scheduled for June 2006. In reality, however, the completion of the study delayed significantly. The Final Report of the study was issued in mid August 2007, and it was just late December 2007 that the strategic development plan proposed in the Final Report was approved in principle by the City Council.

(2) KW&SB

a) K-III Project

The K-III Project is the Stage II of the Greater Karachi Bulk Water Supply (GKBWS) Scheme Phase V, which is designed to provide additional 100 mgd (455,000 m^3/d) of Indus River water to Karachi (95 mgd) and Hub Town in Balochistan (5 mgd). The K-III Project was initiated in June 2003 with the estimated cost of 6.5 billion and completed in May 2006. The President General Pervez Musharraf formally inaugurated the project at the Dhabeji pumping station on May 21, 2006. It was reported that the completion of K-III Project increased the total water supply capacity for Karachi to approximately 630 mgd (2,865,000 m^3/d).

Major bulk water supply facilities constructed under the K-III Project include:

- 15km-long, 3.3m × 3.3m RC water transmission conduit from Gujjo to Dhabeji;
- K-III Pumping Station at Dhabeji;
- Twin MS rising mains from K-III Pumping Station at Dhabeji to Fore-Bay High Point, each 4.59km-long, 72-inch diameter;
- 32.08km-long, 3.3m × 3.3m RC water transmission conduit from Fore-Bay High Point to Pipri;
- 4.14km-long, 3.3m × 3.3 m RC Tunnel Bypass Transmission Conduit;
- 16.8km-long, 3.3m × 3.3m RC water transmission conduit from Pipri to NEK New Pumping Station;
- NEK New Pumping Station;
- Twin MS rising mains from NEK New Pumping Station to NEK Old Reservoir, each 5.32km-long, 66-inch diameter;
- 10.5km-long, 84-inch diameter PRCC pipeline from NEK Old Reservoir to Surjani;
- 6km-long, 72-inch diameter MS pipeline from Surjani to Hub Pumping Station; and
- 30km-long, 24-inch diameter MS pipeline from Hub Filtration Plant to Hub Town in Balochistan.

As part of the K-III Project, a linkage was established for the first time between the Indus River System and Hub System. The two systems were connected with each other by a 16.5 km long, 84 inches diameter pipeline (10.5 km PRCC and 6 km MS) from the Old NEK Reservoir to the Hub Pumping Station. This linkage contributed significantly to the improvement of water supply conditions in the townships of Orangi, Baldia, SITE (both residential and industrial areas), Surjani, North Karachi and parts of Keamari Town, where people had long been suffering from chronic water shortages due to the severe depletion of impounded water in the Hub dam.

b) Rehabilitation and Strengthening of Water Supply System under K-III Project

This project is currently being implemented by the KW&SB as part of the K-III Project. The main objective of the project is to attain a more equitable water supply throughout the city with the effective use of the additional 100 mgd water, which was made available from the Indus River upon completion of the K-III Project in April 2006. The consultancy services contract for design and construction supervision services was awarded to the local consultancy firm, MM Pakistan (MMP) (Pvt) Ltd. in May 2006. The project was originally planned to be completed within a period of 22 months comprising 4 months of survey and design works and 18 months of construction works.

Under the consultancy services contract, MMP is expected to: (a) produce a comprehensive asset map of the existing water conveyance and distribution systems with particular emphasis on water trunk mains 33 to 72 inches in diameter; (b) develop a plan for equitable water distribution; and (c) undertake detailed designs and construction supervision services for a total of 17 packages of water supply system rehabilitation and strengthening works including:

- Rehabilitating nine weak segments of existing water trunk mains 24 to 72 inches in diameter for a total length of 53 km, including leak detection and repair works;
- Installation of flow meters 33 to 72 inches in diameter at 80 key locations selected by the KW&SB, including water treatment works and reservoirs;
- Installation of pressure reducing valves 33 to 72 inches in diameter to control system pressure;
- Replacement of the 3.6 km long, old Dhabeji PRCC rising main with a 72-inch diameter steel main;
- Repairing damaged sections of the Greater Karachi Bulk Water Supply (GKBWS) Conduit;
- Rehabilitation of the Orangi Reservoir; and
- Rehabilitation of the University Reservoir.

The actual implementation of the project was delayed and no physical improvement works have been started as of mid January 2008.

c) K-IV Project

Based on the recommendations of the ad-hoc committee constituted by the Government of Sindh (See **Section 3.2.2**), the KW&SB decided to undertake a feasibility study titled 'Feasibility Study for Future Alternative Route of Bulk Water Supply and Long Term Expansion of Karachi Water Supply System from Kinjhar Lake – K-IV Project of Karachi Water and Sewerage Board'. In December 2005, the KW&SB awarded a consultancy service contract for this feasibility study to a local consultancy firm, Osmani & Company (PVT.) Ltd. The main objective of the study was to explore an alternative route of bringing additional 1,200 cusecs (650 mgd) of Indus River water from the Kinjhar Lake to Karachi, which is economical and technically viable and will also enhance the reliability of the bulk water supply system from Kinjhar Lake to Karachi from the risk management point of view. The study was commenced on December 19, 2005 and completed in May 2007.

8 alternative routes were identified as technically feasible and financial analyses were conducted for each option with respect to its requirements for capital and O&M costs. The study also recommended that three water treatment plants, each having an ultimate treatment capacity of 260 mgd, 260 mgd and 130 mgd. **Figure 44.2.1** shows the locations of the raw water conveyance route and three water treatment plants proposed by the study.

K-IV Project is proposed to be implemented in 5 phases of each 130 mgd to be developed at intervals of every 4 years during the next 20 years as shown in **Table 44.2.1**.

Table 44.2.1 Proposed Implementation Schedule of K-IV Project

Timeframe	Phasing	Incremental Capacity
2007 to 2011	Stage A of Phase 1	130 mgd
2011 to 2015	Stage B of Phase 1	130 mgd
2015 to 2019	Stage A of Phase 2	130 mgd
2019 to 2023	Stage B of Phase 2	130 mgd
2023 to 2027	Stage A of Phase 3	130 mgd

The total project cost for Phase 1 (260 mgd) was estimated at Rs. 18.7 billion which consists of Rs. 15.8 billion for Stage A (130 mgd) and Rs. 2.9 billion for Stage B (130 mgd).

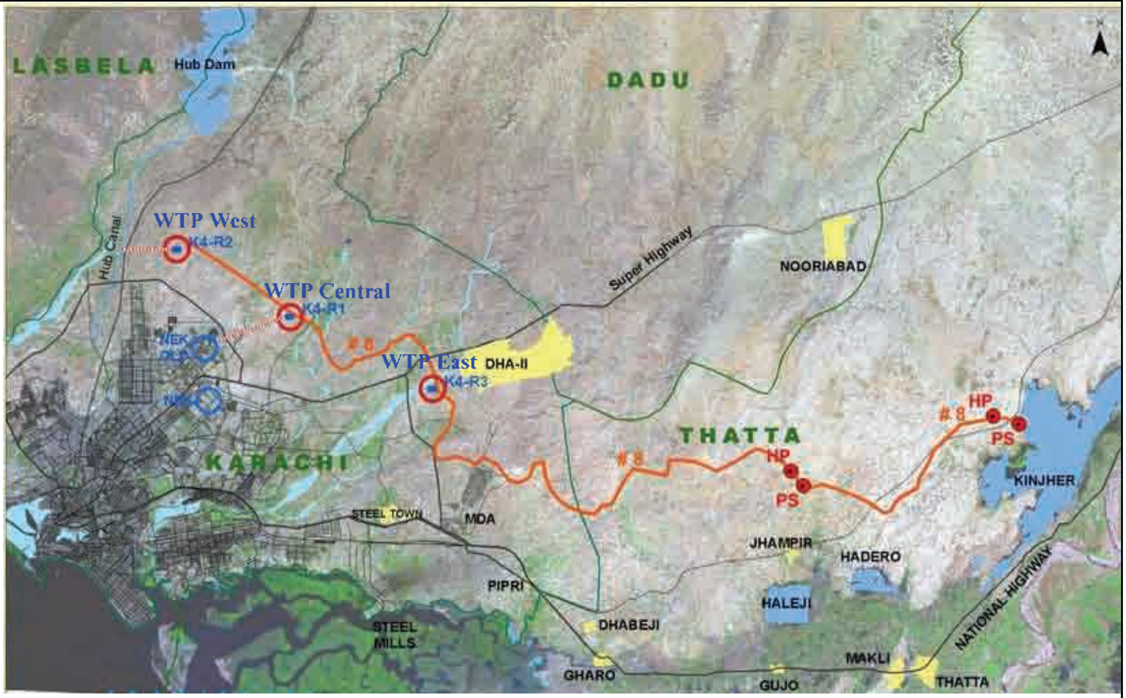

Figure 44.2.1 Water Conveyance Route Proposed by K-IV Study

(Source: K-IV Project Executive Summary, OSMANI May 2007)

CHAPTER 5

OVERVIEW OF EXISTING CONDITIONS AND IDENTIFICATION OF MAJOR PROBLEMS

5 OVERVIEW OF EXISTING CONDITIONS AND IDENTIFICATION OF MAJOR PROBLEMS

5.1 WATER SUPPLY SYSTEM

5.1.1 Overview of Existing Conditions

Over recent years, the level of water supply service provided to the urban population of Karachi has been very poor. As a result of the current rationing system operated by the Karachi Water & Sewerage Board (KW&SB), water is only available on an intermittent basis and even then the pressure is low, quantity is small, and quality is poor. In most parts of the urban area, water is supplied once or twice a week, each time for the duration of several hours. KW&SB regulate supplies to sub-zones by opening and closing feeder valves from the trunk mains and regulating the hours of operation of distribution pumping stations. In contrast, some parts of the urban area, noticeably in the north and northeast, have a better level of service, primarily due to their proximity to the sources and the difficulty of isolating sub-zones during the rationing process. Residents in these areas tend to misuse or waste water. In the absence of a volumetric charging system, there is nothing to encourage them to adopt efficient water use.

In the past, large capital investment works were implemented mostly for the purpose of developing large bulk supply schemes to bring water from distant water sources to Karachi. This has created a huge backlog of replacement, reinforcement and extension in the water distribution system. As a result, many water distribution pipes in the system have already been undersized and deteriorated, and the current levels of leakage and non-revenue water in the distribution system are unacceptably high. The existing water distribution network comprises about 4,850 km of pipelines of which about 65% are asbestos cement pipes and 26% cast iron. In most parts of the urban areas, residents are obliged to spend money on ground level water tanks, suction/booster pumps, roof-top storage tanks, and water filters, and even then water must be boiled prior to drinking. While the basic cost of piped water in Karachi may be cheap, the indirect costs associated with its use are unreasonably high. Many households are compelled to use secondary sources of water such as shallow wells or tanker supplies just to meet their basic needs. Our field surveys revealed that many ground level water tanks leak profusely, are not fitted with a float valve and frequently overflow. They are vulnerable to contamination as they are not water tight on the surface and subjected to inundation during the rains. The overhead tanks are generally in better condition as they are visible to the owners but as with the ground level tanks there is little understanding for the need to keep them clean.

While the basic cost of piped water in Karachi may be cheap, the indirect costs associated with its use are unreasonably high.

Tanker water costs in the order of Rs.70/m^3 to Rs.90/m^3; it is an expensive option as compared with the KW&SB's existing domestic tariff for bulk customers i.e. Rs.10/m^3, given the fact that many tanker operators collect water from filling stations that are connected to the KW&SB's piped water supply system. Where tanker supplies are unaffordable, people have no option but to use untreated subsoil water or go to the river to bathe or wash their clothes. Low and negative pressures in the distribution system also exposes the system to contamination from polluted ground water and there is a sever danger to public health. The expense of not having an adequate supply of potable water is compounded by the inevitable medical bills resulting from the treatment of water-borne diseases (typhoid, cholera, and hepatitis are common) and the loss of income due to sick time. In the light of the poor water supply situation, many residents in Karachi have a very negative impression of KW&SB and the service it provides and are therefore reluctant to pay water charges.

In the light of the poor water supply situation, many residents in Karachi have a very negative impression of KW&SB and the service it provides and are therefore reluctant to pay water charges.

There was little or no evidence of a problem of affordability in the Water Awareness Survey conducted as part of the JICA Study. Clearly a major problem is willingness to pay. Much depends on the quality of service as illustrated by the Leakage Survey in Landhi Town where there is a very poor supply (only 8% of consumers pay their May 2007 bill). Another fact emerging from the Water Awareness Survey is that 60% of those questioned on none payment said simply that they did not receive a bill. The new complaints management system has a high proportion of complaints that the bill was not received. In addition, more than half of the retail consumers interviewed said that they are not satisfied with the quantity & quality of water, and the billing & information system. 75% are not satisfied with the way KW&SB handle complaints and 70% do not trust KW&SB officials.

It is estimated that in Karachi substantial water losses and leakage occur due to the following:

- An aging network lacking maintenance and repair
- No planned leakage control system
- Poor workmanship and materials used for pipe and joint repairs. It is said that lack of funds prevents the purchase of spare pipe, repair collars etc. The current practice of using rubber tubing and cement rendered plastic for repairs has become the accepted norm of KW&SB.
- Poor workmanship and materials for service connections carried out by the consumer (rarely the declared registered plumber) which are largely unsupervised by KW&SB staff
- Household water systems comprising ground and overhead tanks and an electric pump usually directly connected to the distribution pipe cause large losses due to leakage and overflows which go unchecked because there is no volume charge

While leakage is said to be 30 to 35% of water distributed at present, there is no scientific means to verify this percentage in the absence of system-input metering and retail supply metering. This percentage could be much higher if it includes leakage occurring in service connection pipes, ground-level water reservoirs and roof-top storage tanks owned by customers. In the absence of retail supply meters, there is no boundary between the responsibilities of the KW&SB and its customers for the repair and maintenance of the service installation. The KW&SB's responsibility could extend to ground-level water reservoirs, roof-top storage tanks and even up to the internal fittings and faucets inside customers' houses. Under the circumstances, there is no point in discussing leakage in Karachi in comparison with other cities of the world where retail supply meters are installed and any leakage or wastage occurring at the downstream of the meter is registered as being 'accounted-for water' to the water utility.

The magnitude of leakage also varies significantly depending on the duration of supply and the system pressure applied in the water distribution network. As such, there is no point either in discussing the current level of leakage in Karachi in comparison with other cities where water is supplied for much longer hours or at a higher pressure. It would be possible in Karachi that without substantial improvements to the existing distribution system leakage could increase to 60 to 70% once the system is fully pressurized and water is supplied 24 hours on a regular basis.

Similarly, with the imposition of a 'Water Tax' on all premises, it would not be useful to discuss non-revenue water in Karachi in comparison with other cities of the world where non-revenue water is determined as being the difference between (a) the system input volume (total volume of water distributed into the system) and (b) the volume of water for which revenues are actually collected.

While there are no reliable figures, and there is little information on this matter there are thought to be many illegal connections. Many houses are known to have more than one connection to tap pipelines to maximise the time they have water. It is also known that illegal connections have been made to the trunk/secondary mains system as these pipelines are always full. Supplies to large Katchi Abadis are generally poor due to the distance from the distribution system and very long, above ground, illegal connections to the nearest pipeline (often referred to as spaghetti connections) are clearly visible. Little is done to disconnect illegal connections. The law is rarely, if ever, enforced by those charged with these duties and there is known to be a degree of political and other interference. In addition, the policy of imposing a “Water Tax” on all property regardless of whether receiving a supply or not often negates the issue of illegal connections.

KW&SB does not at present use domestic metering. Metered supplies (referred to as bulk supplies) are confined to government departments, large industrial complexes and other large consumers including housing development areas with their own distribution systems, commercial high rise buildings, hotels etc. The un-metered or “retail” category forms the majority of KW&SB consumers. KW&SB charge a monthly rate for domestic consumers in accordance with the size of the property. Bills are produced monthly for about 1 million retail (domestic un-metered) consumers and about 5,000 bulk metered consumers. It had been hoped that a combination of monthly billing introduced for “retail” consumers in July 2006 with the inclusion in the bill of 5% of arrears and the imposition of a 10% surcharge on unpaid amounts would lead to a rapid improvement in the collection rate. Although there were some early gains when the monthly billing system was introduced there has been no significant improvement. The system of bill delivery to the consumers does not work efficiently, the level of service is so poor that consumers see no reason to pay, and disconnection of supply and other punishments have proved unworkable.

KW&SB’s billing and collection records on retail customers for the month of May 2007 show that overall a mere 23.6% of the bills printed and delivered to the KW&SB offices for distribution to the consumers were actually paid; 31.2% of the monthly water billing was recovered (32% for sewerage) and 6.7% of the arrears were paid (8.2% for sewerage). Similar records on bulk customers for the month of May 2007 show that 41.4% of the bills issued were actually paid; 37.5% of the monthly water billing was recovered (44.6% for sewerage). These are unacceptably low considering the generally good supply conditions in the bulk supply system and the consumers’ high ability to pay.

5.1.2 Identification of Major Problems

Most of the problems discussed in **Section 5.1.1** are related to the water distribution system. In contrast, there seem to be fewer and less urgent problems in the bulk water supply system. Although the present water treatment capacity is insufficient and therefore a large volume of raw water is still being supplied without treatment, the addition of new water treatment capacity is not considered a high priority at present given the poor conditions of the existing distribution network. The overall picture is that there are many more urgent problems in the water distribution system than in the bulk water supply system.

The overall picture is that there are many more urgent problems in the water distribution system than in the bulk water supply system.

The problems discussed in **Section 5.1.1** are closely related to each other and are often mutually reinforcing. They can broadly be categorized as follows:

- Poor conditions of the existing water distribution system
- Lack of KW&SB's autonomy in the day-to-day operation and management of the services
- KW&SB's weak financial capacity
- Absence of measured supplies and volumetric charging system (imposition of 'Water Tax')

Table 51.2.1 provides the symptoms and consequences of these problems.

Table 51.2.1 Major Problems Identified by JICA Study

Major Problems	Symptoms	Consequences
Poor conditions of water distribution system	▫ Intermittent water supply ▫ High level of leakage ▫ Low system pressure ▫ Contamination ▫ Inequitable distribution	▫ Customers' distrust in KW&SB and the services it provides ▫ Reluctance to pay for the services ▫ Insufficient revenues
Lack of autonomy	▫ High level of receivables ▫ Tanker supplies ▫ Illegal connections ▫ Low tariffs	▫ Insufficient revenues ▫ Low morale of KW&SB staff
Weak financial capacity	▫ Delay in capital replacement ▫ Delay in system expansion ▫ Poor current maintenance ▫ Poor working environments (offices & equipment) ▫ Reliance on Government funding (OPEX and CAPEX)	▫ Deteriorating services ▫ Deteriorating assets ▫ Low morale of KW&SB staff ▫ Political interference
Absence of measured supplies and volumetric charging system	▫ Absence of system input metering and retail supply metering ▫ No incentives for efficient use of water ▫ No boundary of responsibilities for maintenance of service connections between KW&SB and its customers ▫ No means to estimate leakage and non-revenue water ▫ Negates the issue of illegal connections (retail users)	▫ No control of water supply system ▫ Misuse and wastage of water ▫ 'Leakage', 'non-revenue water' and 'illegal connections (retail users)' being indefinable

Major problems of Water Supply System:

- **Poor conditions of water distribution system**
- **Lack of autonomy**
- **Weak financial capacity**
- **Absence of measured supplies and volumetric charging system**

Our assessment indicated that these problems have either directly or indirectly emanated from the KW&SB's financial constraints. **Figure 51.2.1** illustrates the vicious circle of the KW&SB's operations. It shows how KW&SB's financial constraints keep intensifying and thereby deteriorating the quality of the service. It is also because of its financial constraints that KW&SB have to rely on government subsidies to sustain its operations, which in turn makes KW&SB quite vulnerable to political interference in the day-to-day management and operation of its services.

These problems have either directly or indirectly emanated from the KW&SB's financial constraints.

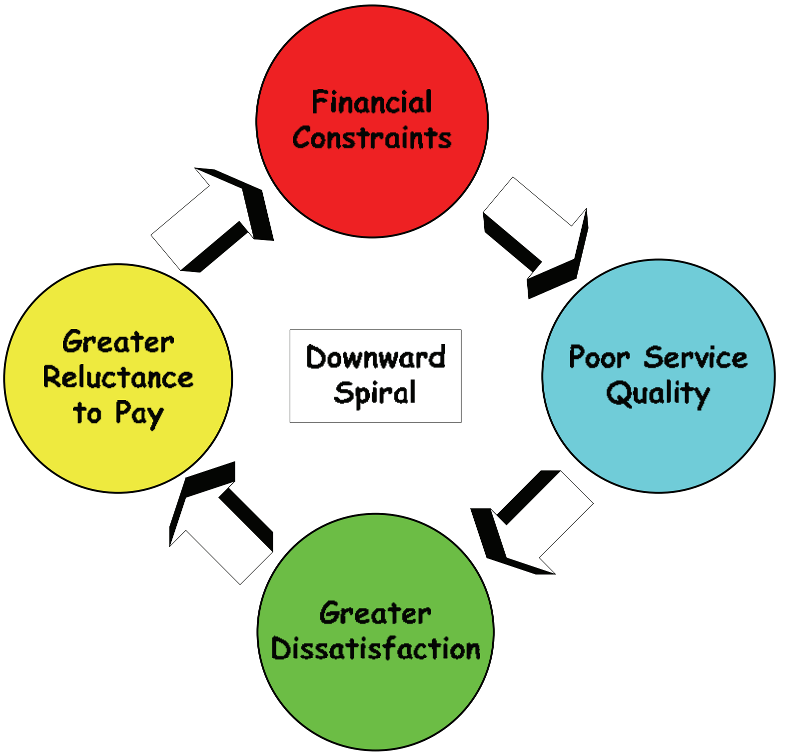

Figure 51.2.1 Vicious Circle of KW&SB Operation

A substantial improvement to water service quality will be required to break this vicious circle. It is the considered opinion of this JICA Study team that a substantial improvement to water service quality can be achieved by significantly reducing leakage and other water losses and introducing metered supplies with a volumetric tariff to all consumers. This view is shared by ADB in its Draft Karachi Sustainable Mega City Water & Wastewater Roadmap, May 2007.

A substantial improvement to water service quality will be required to break this vicious circle.

5.2 SEWERAGE SYSTEM

5.2.1 Overview of Existing Sewerage Conditions

In spite of increasing amount of sewage generation due to the rapid urbanization of the city, major sewerage facilities such as trunk sewers, pumping stations and sewage treatment plants have not been constructed since 1998. It is apparent that the situation brings about serious insufficiency of sewerage facilities. For example, the total capacity of three existing sewage treatment plants amounts to 151 mgd (about 690,000 m^3/d) in contrast with the current sewage generation of 315 mgd (about 1,430,000 m^3/d) or the total capacity of sewage treatment plants is less than a half of the sewage generation.

The actual flow to these treatment plants, on the other hand, is less than their total capacity and is reported to be 90 mgd (about 410,000 m^3/d) which is less than 30% of the sewage generation.

It means that more than 70% of the total sewage generation is discharged to rivers and finally flow into Arabian Sea with no treatment. Several reasons have been raised for this small ratio of coverage. One reason is that, collected sewage does not reach sewage treatment plants due to the absence of trunk sewers although sewage is collected at its origin to some extent. Another reason is that trunk sewers and relay pumping stations do not function as planned due to the aged facilities and/or insufficient capacities.

(1) Sewer Networks

As branch sewers and trunk sewers are not sufficient in length and capacity, much sewage is discharged to rivers through stormwater drainages and nallahs without treatment, which deteriorates water qualities in receiving water bodies. In the same way, there are some small pumping stations called "Ejector" to pump up sewage of lower pockets to stormwater drainages or nallahs. In addition, many existing sewer are aged and some of them are needed to replace or rehabilitate.

(2) Pumping Stations

All the pumping stations have a long history. As a whole, equipment in pumping stations such as screens, grit chambers, pumps, motors, generators, sub stations are very old, and some pumps are not functional even though they are listed in inventory. For this reason, it is supposed that the flow to pumping stations exceeds the actual capacity, or surplus flow overflows to nearby nallahs. Almost all the large scale pumping stations have power generators, but many of them do not work satisfactorily at the time of power failure because of their unsatisfactory maintenance and insufficient fuel.

In case of Clifton PS, pressure main from the pumping station to TP-2 is old and fragile, therefore the actual operation of pumps is limited to the permissible flow of the pressure main.

(3) Sewage Treatment Plant

As described in **Section 3.3.2 Sewerage System**, all of three TPs have received smaller flows than the design values due to the insufficient collection system. Besides, final settling tanks of TP-1 have not been operated for a long time due to the clogging of their sludge withdrawal pipes. In TP-2, pipes conveying primary and secondary sludges to sludge drying beds were broken and no sludge has been withdrawn from settling tanks. Sooner or later, these pipes will be clogged as in the case of TP-1 and no settling would be done. No information is available when these problems occurred and how they were going to be solved.

Since there is no reference available to show what parameters were applied in designing these three TPs, the capacities of TP-1 and TP-2 are evaluated referring to major design parameters described in the Design Guidelines of Japan as shown in the **Table 52.1.1.**

Table 52.1.1 Design Criteria in Design Guidelines of Japan

Name of Facility	Design Parameters
Primary Settling Tank	Overflow rate in the range between 35 and 70 $m^3/m^2/d$
Trickling Filter	Hydraulic loading of less than 15 $m^3/m^2/d$ if influent BOD is 200 mg/l BOD volumetric loading of less than 1.2 $kg/m^3/d$
Final Settling Tank	Overflow rate in the range between 20 and 30 $m^3/m^2/d$

Anaerobic and facultative ponds applied in TP-3 are difficult to evaluate, because in spite of design criteria found in various literatures they have wide ranges and little information is available on the actual performance of these facilities. The process applied in TP-3 will be evaluated in the future only if the influent characteristics including its flow rate and the influent water quality approach its capacity.

The capacities of TP-1 and TP-2 are evaluated supposing influent BODs are 385 mg/l for TP-1 and 365 mg/l for TP-2, respectively, BOD removal rate at PST is 40% and filter media depth is

1.5 m. **Table 52.1.2** shows calculated overflow rates of primary and final settling tanks, hydraulic loading and BOD volumetric loading of trickling filters.

Table 52.1.2 Calculated Loadings

	TP-1	TP-2
Overflow rate of primary settling tank ($m^3/m^2/d$)	25	23
Hydraulic loading of trickling filter ($m^3/m^2/d$)	21	19
BOD volumetric loading of trickling filter ($kg/m^3/d$)	3.23	2.75
Overflow rate of final settling tank ($m^3/m^2/d$)	76	69

In both TP-1 and TP-2, the number of primary settling tanks (PSTs) is 6 and that of FSTs is 2, which leads to the greater overflow rate of FST than that of PST. In any sewage treatment process, FSTs need to have larger surface area than PSTs for effective solid liquid separation prior to effluent discharge. It is recommended to convert the present combination of 6 PSTs and 2 FSTs to that of 4 PSTs and 4 FSTs by changing the sewage flow.

Design Guidelines of Japan propose surface loading of less than 15 m^3/m^2/day and BOD volumetric loading of less than 1.2 $kg/m^3/d$ for high rate trickling filter process which is supposed to give the effluent BOD of less than 70 mg/l. In this regard, TP-1 and TP-2 have sufficient primary and secondary sedimentation tanks to treat the design flow only if the above-mentioned conversion is done.

However, the trickling filters are short on numbers to treat the design flow, especially in terms of BOD volumetric loading. To begin with, it is recommended to measure water qualities of the plant influent, the primary effluent and the secondary effluent and to measure the actual flow rate for a certain period of time on a regular basis. By doing this, the real treatment capacities of these two TPs can be evaluated and it will be possible to judge when it is needed to extend the treatment facilities.

5.2.2 Identification of Major Problems

Major problems about sewerage facilities are identified as follows.

Absence of comprehensive master plan

The master plan for sewerage implementation was once prepared in 1988, but the plan itself was not comprehensive and hence not pursued in the later stage. It is needed to prepare comprehensive master plan for sewerage implementation in line with the city planning, to implement sewerage facilities based on it and to revise the plan on regular basis taking social and physical changes into account.

Limited budget allocation for sewerage facilities

Since the tariff collected in water supply and sewerage sector is very limited, the budget allocated for sewerage sector is limited, too. With the limited budget, it is almost impossible to operate and maintain existing sewerage facilities so as they function as planned and to extend or newly construct sewerage facilities to meet the future requirements.

Improper operation and maintenance of sewerage facilities

Mainly due to the limited budget and personnel allocated for operation and maintenance of sewerage facilities, existing facilities are not operated properly. Improper maintenance might lead to earlier aging of facilities and non-compliance with the effluent quality standard.

Insufficient sewerage facilities

As described above, existing sewerage facilities for sewage collection and its treatment are far from sufficient in quantity to serve the large population of Karachi City. Additional sewage collection system including branch sewers, trunk sewers and pumping stations need to be constructed to improve living environment of the citizen. In the same manner, existing sewage treatment plants need to be extended and new plant(s) has to be implemented to treat all the generated sewage to improve water qualities of public water bodies, especially of Arabian Sea.

Insufficient information on facilities

Sewers, pumping stations and sewage treatment plants consist of civil structures, mechanical and electrical equipment. For efficient and effective operation and maintenance of these facilities, it is needed to equip their as-built drawings, list and specifications on site. However, site surveys by the JICA Study Team found that there was little information on these items, especially about sewers except for Lyari interceptor.

Insufficient record of operation and maintenance works

In the same manner, little information in written form is available on the performance of pumping and treatment facilities such as flow rates, operation hours, water qualities, facility failures and repairs and so forth.

Absence of operation and maintenance manual

Manuals for operation and maintenance of sewerage facilities (O/M) are not available. It is very difficult to operate and maintain sewerage facilities in a proper way without O/M manuals.

CHAPTER 6

WATER DEMAND FORECAST

6 WATER DEMAND FORECAST

6.1 POPULATION

6.1.1 Karachi Strategic Development Plan 2020

The City District Government Karachi (CDGK) has completed a formulation of Karachi Strategic Development Plan 2020 (hereinafter referred to as the "KSDP-2020") for the target year of 2020 as one of the components of the "Temeer-e-Karachi Programme (TKP)" under the directives of the President of Pakistan. It is expected that the outcome of KSDP-2020 will provide overall guidance for the formulation of master plans for each town and for the framing of development schemes and projects for the Karachi City District in a coordinated manner.

The study on the formulation of KSDP-2020 was commenced in December 2005 and its completion was originally scheduled for June 2006. The tenure of the study was extended for another six months, postponing the completion of the study until December 2006. It is understand that the study was not finalised by December 2006 and finally completed in August 2007.

During the period of the study on the formulation of KSDP-2020, the CDGK issued a control version 2 (CV-02) of a draft report of KSDP-2020 in December 2006. The JICA Study follows the population projection made by KSDP-2020, which was approved by the Steering Committee held on 2nd October 2006. Therefore, a preliminary plan described in the Progress Report No.2 issued at the end of February 2006 was prepared in accordance with the CV-02 report of KSDP-2020. Afterward, the CDGK issued CV-03 report at the end of January 2007 and the JICA Study Team received it officially through JICA Islamabad Office and also KW&SB at the beginning of February 2007. Preliminary plan in the Progress Report No.2 has been modified based on future population and land use plan stated in the CV-03 report. Modified water supply and sewerage master plans (hereinafter referred to as the "JICA Master Plan") were explained in the Interim Report which was submitted at the end of July 2007.

At the Steering Committee Meeting for the presentation and discussion of the Interim Report held on 8th August 2007, the Steering Committee requested JICA to revise JICA Master Plan in accordance with the final report of KSDP-2020 which would be issued at the meddle of August 2007. After the meeting, both parties signed "the Minutes of Understanding" on the revision of JICA Master Plan on 9th August 2007.

CDGK issued the final report of KSDP-2020 on 15th August 2007. It was confirmed that the report was the final version and that there will be no further change, by the letter of City Nazim Karachi on 4th October 2007. Then JICA was agreed and accept additional work to modify JICA Master Plan in line with KSDP-2020 by the JICA's letter dated on 25th October 2007.

6.1.2 City Population

(1) Population in 2005

CDGK conducted population censuses in 1961, 1972, 1981 and 1998. KSDP-2020 shows town-wise population of Karachi City in year of 2005 as shown in **Table 61.2.1** based on past trends in population growth. Per annum population growth rate of 4.2 % has been adopted from 1998 to 2005 for estimating the total population in 2005.

Table 61.2.1 City Population in 2005

No.	Town	Area *		Population in 2005 *	Population Density	
		(acre)	(km^2)		/acre	/km^2
1	Keamari	106,217	429.8	583,640	5.5	1,358
2	SITE	6,286	25.4	709,944	112.9	27,908
3	Baldia	7,217	29.2	616,722	85.5	21,116
4	Orangi	5,803	23.5	1,098,859	189.4	46,792
5	Lyari	1,977	8.0	923,176	467.0	115,388
6	Saddar	5,967	24.1	935,566	156.8	38,744
7	Jamshed	5,790	23.4	1,114,235	192.4	47,553
8	Gulshan-e-Iqbal	13,260	53.7	949,351	71.6	17,692
9	Shah Faisal	2,901	11.7	509,915	175.8	43,434
10	Landhi	9,670	39.1	1,012,391	104.7	25,870
11	Korangi	10,247	41.5	829,813	81.0	20,011
12	North Nazimabad	4,127	16.7	753,423	182.6	45,111
13	New Karachi	5,058	20.5	1,038,865	205.4	50,753
14	Gulberg	3,417	13.8	688,580	201.5	49,796
15	Liaquatabad	2,685	10.9	985,581	367.1	90,705
16	Malir	4,395	17.8	604,763	137.6	34,002
17	Bin Qasim	137,961	558.3	480,854	3.5	861
18	Gadap	355,798	1,439.9	439,674	1.2	305
	sub-total	688,776	2,787.4	14,275,352	20.7	5,121
19	Cantonment	31,336	126.8	464,882	14.8	3,666
20	Defence	9,454	38.3	379,596	40.2	9,922
	sub-total	40,790	165.1	844,478	20.7	5,116
	Total	729,566	2,952.4	15,119,830	20.7	5,121

*: Karachi Strategic Development Plan 2020 (August 2007)

(2) Future Population

Future population until 2025 which is the target year of JICA Study has been projected as shown in **Table 61.2.2** and **Figure 61.2.1**.

Table 61.2.2 Population of Karachi City (× 1,000)

Year	1961	1972	1981	1998	2005	2010	2015	2020	2025
Population	1,912.6	3,498.6	5,395.4	11,335	15,120	18,529	22,594	27,550	32,506

source:
1) 1961, 1972 and 1981: Karachi Development Plan 2000, June 1991
2) 1998: Adjusted by KSDP - 2020 (August 2007) based on 1998 census data of 9.96 million
3) 2005 to 2020: Projected by KSDP - 2020 (August 2007)
4) 2025: Projected by JICA Study (see **Appendix A61.1** in detail)

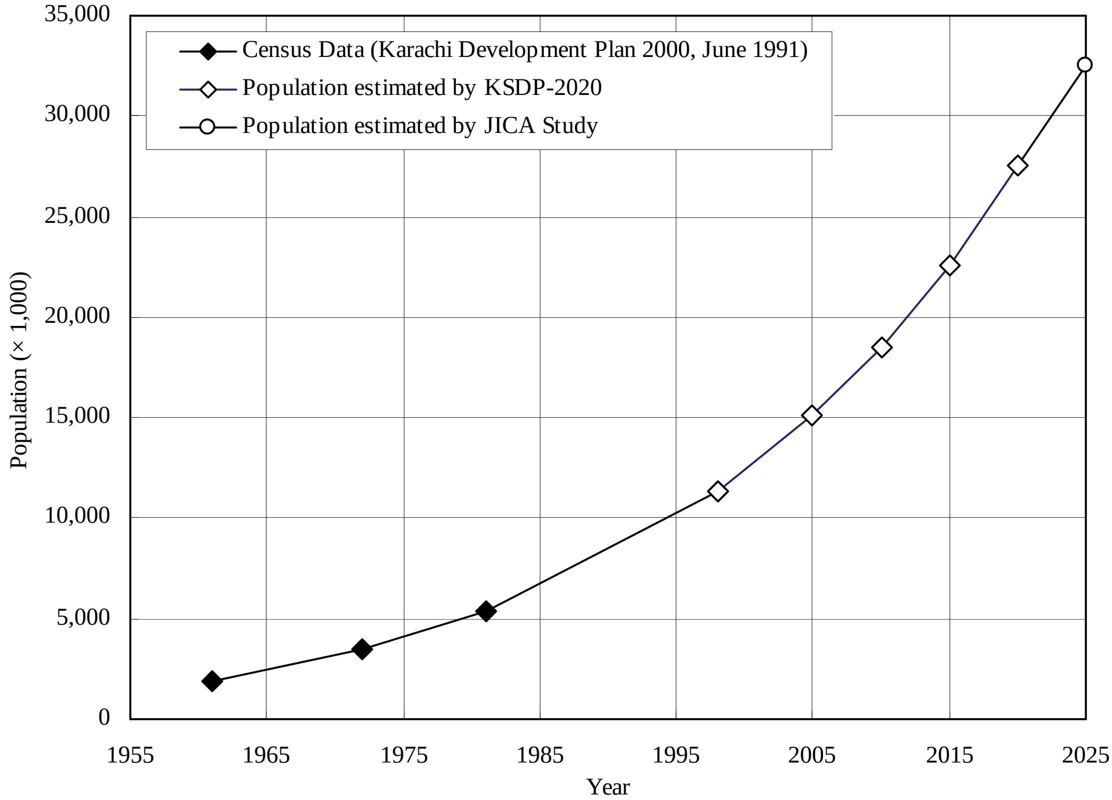

Figure 61.2.1 Population of Karachi

For the population projection, KSDP-2020 adopted annual population growth rates as shown in **Table 61.2.3**. **Table 61.2.4** shows the actual annual population growth rates of Karachi City in the past.

Table 61.2.3 Annual Population Growth Rate

	1998	2005	2010	2015	2020	2025
Population (×1000) *	11,335	15,120	18,529	22,594	27,550	32,506
Growth Rate		4.20%	4.15%	4.05%	4.05%	3.36%

*: 1) 2005 to 2020: Projected by KSDP - 2020 (August 2007)
2) 2025: Projected by JICA Study (see **Appendix A61.1** in detail)

Table 61.2.4 Past Annual Population Growth Rate

	1961	1972	1981	1998
Population (×1000) *	1,912.6	3,498.6	5,395.4	11,335
Growth Rate		5.49%	4.81%	4.46%

*: 1) 1961, 1972 and 1981: Karachi Development Plan 2000, June 1991
2) 1998: Adjusted by Karachi Master Plan - 2020 (CV-03, January 2007) based on 1998 census data of 9.96 million.

It is noted that the JICA Study was requested to use the future population projected in KSDP-2020 for preparing the master plan of water supply and sewerage system in Karachi City at the Steering Committee Meeting held on 2nd October 2006, because of the uniformity of city plans for all the related sectors.

6.1.3 Town-wise Population

KSDP-2020 has also projected the future town-wise population in 2020 as shown in **Table 61.3.1** in consideration of spatial growth strategies such as densification, infill and expansion.

Table 61.3.1 Town-wise Population Projection in 2020

S. No.	Town Name	2005			Projected Increase in Population for 2020				Total Projections for 2020		
		Population	Area (acre)	Density	Densification	Densification + Infill	Infill + Expansion	Status Quo	Population	Density	% increase
1	Keamari	583,640	106,217	5	-	-	1,340,272	-	1,923,912	18	230
2	SITE	709,944	6,286	113	184,585	-	-	-	894,529	142	26
3	Baldia	616,722	7,217	85	-	-	493,378	-	1,110,100	154	80
4	Orangi	1,098,859	5,803	189	-	-	330,066	-	1,428,925	246	30
5	Lyari	923,176	1,977	467	-	-	-	46,159	969,335	490	5
6	Saddar	935,566	5,967	157	187,113	-	-	-	1,122,679	188	20
7	Jamshed	1,114,235	5,790	192	445,694	-	-	-	1,559,929	269	40
8	Gulshan-e-Iqbal	949,351	13,260	72	-	1,424,027	-	-	2,373,378	179	150
9	Shah Faisal	509,915	2,901	176	101,983	-	-	-	611,898	211	20
10	Landhi	1,012,391	9,670	105	-	809,913	-	-	1,822,304	188	80
11	Korangi	829,813	10,247	81	-	995,776	-	-	1,825,589	178	120
12	North Nazimabad	753,423	4,127	183	226,027	-	-	-	979,450	237	30
13	New Karachi	1,038,865	5,058	205	-	207,773	-	-	1,246,638	246	20
14	Gulberg	688,580	3,417	202	206,574	-	-	-	895,154	262	30
15	Liaquatabad	985,581	2,685	367	-	-	-	49,279	1,034,860	385	5
16	Malir	604,763	4,395	138	-	-	302,382	-	907,145	206	50
17	Bin Qasim	480,854	137,961	3	-	-	1,672,699	-	2,153,553	16	348
18	Gadap	439,674	355,798	1	-	-	2,638,044	-	3,077,718	9	600
	sub-total	14,275,352	688,776	21	1,351,976	3,437,489	6,776,841	95,438	25,937,096	38	82
19	Cantonment	464,882	31,336	15	-	464,882	-	-	929,761	30	100
20	Defence	379,596	9,454	40	-	303,677	-	-	683,273	72	80
	sub-total	844,478	40,790	21	0	768,559	0	0	1,613,034	40	91
	Total	15,119,830	729,566	21	1,351,976	4,206,048	6,776,841	95,438	27,550,130	38	82

source: KSDP - 2020 (August 2007)

As shown in **Table 61.2.3**, population of Karachi City will increase about 12.43 million for 15 years from 2005 to 2020. The population to be increased in fringe 3 towns of Keamari, Gadap and Bin Qasim is 5.65 million of them and remaining population of 6.78 million will be increased in a central area including other 15 towns, cantonments and DHA as shown in **Figure 61.3.1**.

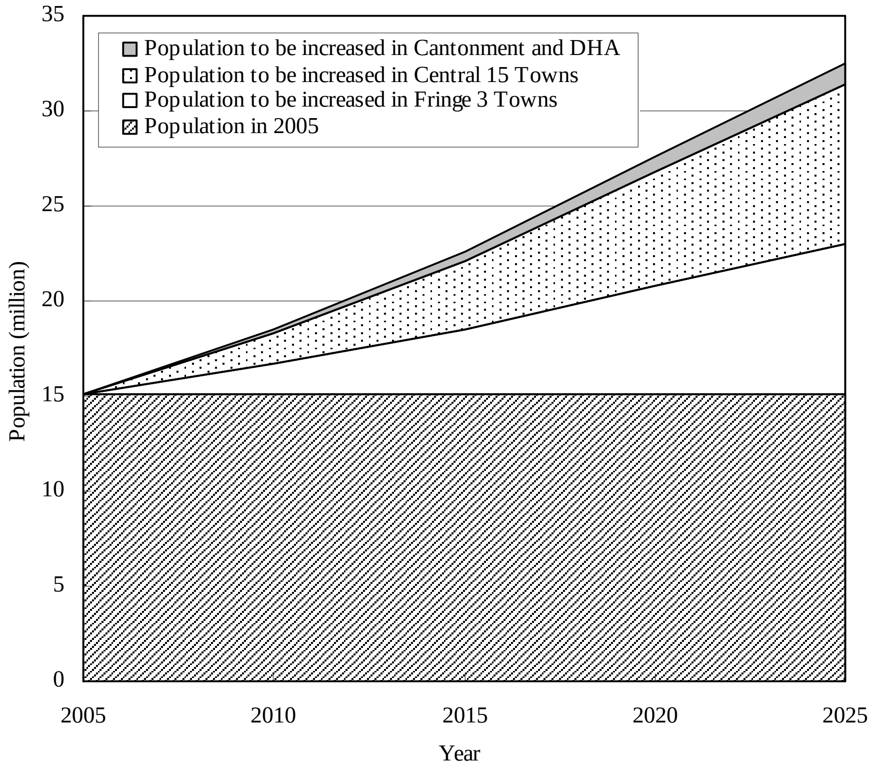

Figure 61.3.1 Area-wise Distribution of Population to be increased by 2025

KSDP - 2020 has considered spatial growth strategies that are densification, infill, expansion and status-quo. The population in the fringe 3 towns will be increased mainly by the expansion through developments of on-going and new large housing schemes. **Table 61.3.2** shows a status of on-going large housing schemes. These housing schemes can accommodate the population to be increased in the fringe 3 towns.

Table 61.3.2 Status of On-going Large Housing Schemes

SR. No.	Name of Scheme	Year of Notification	Current Occupancy Status	Location
1	Scheme No.25-A (Shah Latif)	1980	5 %	Bin Qasim
2	Scheme No.33	1971	20 %	Gulshan-e-Iqubal, Gadap, Cant.
3	Scheme No.42 (Hawk's Bay)	1983	5 %	Keamari
4	Scheme No.43 (Halkani)	1986	0 %	Gadap
5	Scheme No.45 (Taisar)	1986	5 %	Gadap
6	New Malir Project - 1	1996	0 %	Bin Qasim

source: KSDP - 2020 (August 2007)

The population in the central area will be increased by the densification and infill. However, Lyari and Liaquatabad Towns which is already high population density are not expected to increase those population.

The future town-wise population is shown in **Table 61.3.3** and attached to **Appendix A61.1**. It is noted that although KSDP - 2020 does not include town-wise population in 2010, 2015 and 2025, town-wise population in those years are estimated by JICA Study considering town- wise population increase trend from 2005 to 2020.

Table 61.3.3 Town-wise Population

No.	Town	Area*		Population				
		(acre)	(km^2)	2005*	2010	2015	2020*	2,025
1	Keamari	106,217	429.8	583,640	951,187	1,389,516	1,923,912	2,458,308
2	SITE	6,286	25.4	709,944	760,563	820,931	894,529	968,127
3	Baldia	7,217	29.2	616,722	752,023	913,379	1,110,100	1,306,821
4	Orangi	5,803	23.5	1,098,859	1,189,374	1,297,320	1,428,925	1,560,530
5	Lyari	1,977	8.0	923,176	935,834	950,930	969,335	987,740
6	Saddar	5,967	24.1	935,566	986,879	1,048,073	1,122,679	1,197,285
7	Jamshed	5,790	23.4	1,114,235	1,236,459	1,382,221	1,559,929	1,737,637
8	Gulshan-e-Iqbal	13,260	53.7	949,351	1,339,866	1,805,587	2,373,378	2,941,169
9	Shah Faisal	2,901	11.7	509,915	537,882	571,235	611,898	652,561
10	Landhi	9,670	39.1	1,012,391	1,234,496	1,499,374	1,822,304	2,145,234
11	Korangi	10,247	41.5	829,813	1,102,888	1,428,551	1,825,589	2,222,627
12	North Nazimabad	4,127	16.7	753,423	815,407	889,328	979,450	1,069,572
13	New Karachi	5,058	20.5	1,038,865	1,095,843	1,163,794	1,246,638	1,329,482
14	Gulberg	3,417	13.8	688,580	745,229	812,788	895,154	977,520
15	Liaquatabad	2,685	10.9	985,581	999,095	1,015,211	1,034,860	1,054,509
16	Malir	4,395	17.8	604,763	687,686	786,579	907,145	1,027,711
17	Bin Qasim	137,961	558.3	480,854	939,563	1,486,611	2,153,553	2,820,495
18	Gadap	355,798	1,439.9	439,674	1,163,113	2,025,871	3,077,718	4,129,565
	sub-total	688,776	2,787.4	14,275,352	17,473,387	21,287,301	25,937,096	30,586,891
19	Cantonment	31,336	126.8	464,882	592,367	744,403	929,761	1,115,119
20	Defence	9,454	38.3	379,596	462,874	562,190	683,273	804,356
	sub-total	40,790	165.1	844,478	1,055,241	1,306,594	1,613,034	1,919,474
	Total	729,566	2,952.4	15,119,830	18,528,629	22,593,894	27,550,130	32,506,366

*: KSDP - 2020 (August 2007)

6.1.4 Population Density

Based on the future town-wise population and the size of the area covered by each town shown, the population density of each town is calculated as shown in **Table 61.4.1**. The geographical distribution of the calculated density is illustrated in **Figures 61.4.1** and **61.4.2** for the year 2005 and 2025 respectively.

Table 61.4.1 Town-wise Population Density

No.	Town	Area		Population Density (/km^2)				
		(acre)	(km^2)	2005	2010	2015	2020	2,025
1	Keamari	106,217	429.8	1,358	2,213	3,233	4,476	5,719
2	SITE	6,286	25.4	27,908	29,898	32,271	35,164	38,057
3	Baldia	7,217	29.2	21,116	25,749	31,274	38,009	44,745
4	Orangi	5,803	23.5	46,792	50,646	55,243	60,847	66,451
5	Lyari	1,977	8.0	115,388	116,970	118,857	121,157	123,458
6	Saddar	5,967	24.1	38,744	40,869	43,403	46,492	49,582
7	Jamshed	5,790	23.4	47,553	52,770	58,990	66,575	74,159
8	Gulshan-e-Iqbal	13,260	53.7	17,692	24,969	33,648	44,229	54,810
9	Shah Faisal	2,901	11.7	43,434	45,816	48,657	52,121	55,585
10	Landhi	9,670	39.1	25,870	31,546	38,315	46,567	54,819
11	Korangi	10,247	41.5	20,011	26,596	34,449	44,024	53,598
12	North Nazimabad	4,127	16.7	45,111	48,823	53,249	58,645	64,041
13	New Karachi	5,058	20.5	50,753	53,537	56,856	60,904	64,951
14	Gulberg	3,417	13.8	49,796	53,892	58,778	64,734	70,691
15	Liaquatabad	2,685	10.9	90,705	91,949	93,432	95,240	97,048
16	Malir	4,395	17.8	34,002	38,665	44,225	51,004	57,782
17	Bin Qasim	137,961	558.3	861	1,683	2,663	3,857	5,052
18	Gadap	355,798	1,439.9	305	808	1,407	2,138	2,868
	sub-total	688,776	2,787.4	5,121	6,269	7,637	9,305	10,973
19	Cantonment	31,336	126.8	3,666	4,671	5,870	7,332	8,793
20	Defence	9,454	38.3	9,922	12,098	14,694	17,859	21,024
	sub-total	40,790	165.1	5,116	6,393	7,915	9,772	11,628
	Total	729,566	2,952.4	5,121	6,276	7,653	9,331	11,010

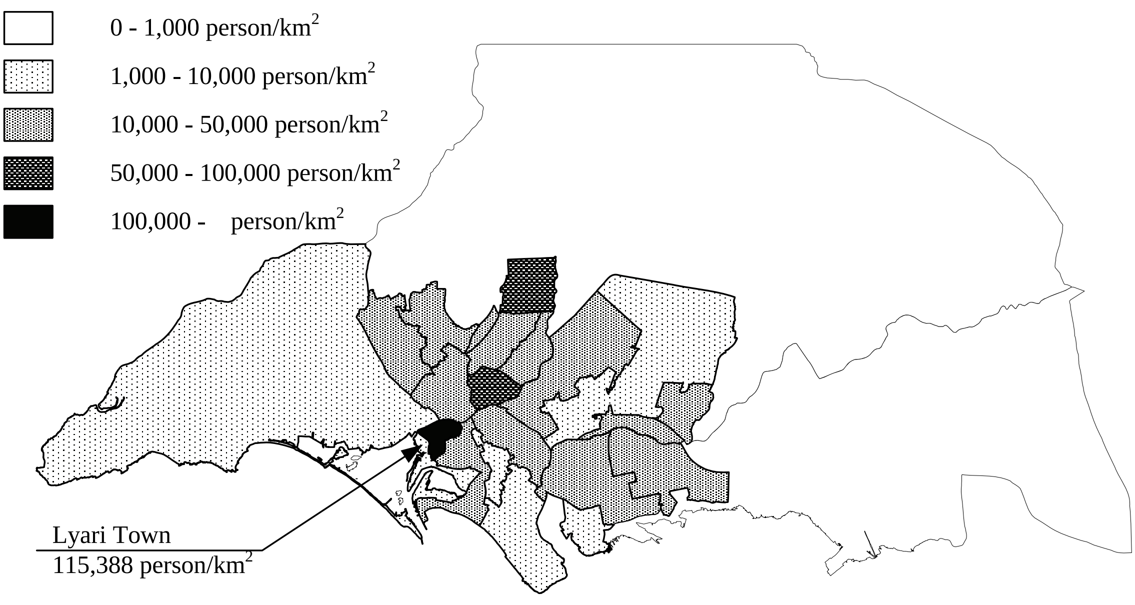

Figure 61.4.1 Population Density in 2005

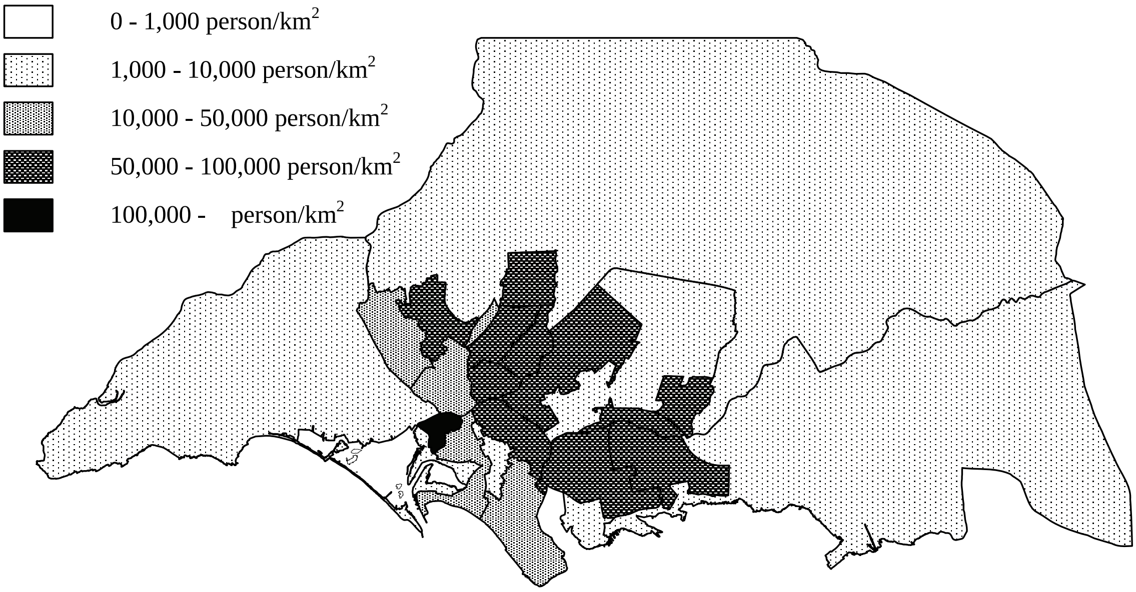

Figure 61.4.2 Population Density in 2025

As can seen in **Table 61.4.1** and **Figure 61.4.1**, the population density of Lyari Town in 2005 is about 115,000 persons/km^2. The overall average population density of Karachi City in 2005 is 5,100 persons/km^2. It increases to 35,000 persons/km^2 if three towns, namely Keamari, Bin Qasim and Gadap Towns are excluded. These figures are extremely high in comparison with other populated Asian cities as shown in **Table 61.4.2**.

Table 61.4.2 Population Density of Major Asian Cities

City Name	Density(/km²)	Densest district
Manila, Philippines	41,014	
Mumbai, India	29,434	
Macau, People's Republic of China	16,521	Freguesia de Santo Antonio (98,776/km²), Macau Peninsula (59,284/km²)
Seoul, South Korea	16,391	
Dhaka, Bangladesh	14,608	
Tokyo, Japan	13,800	Nakano (20,098/km²)
Jakarta, Indonesia	11,360	Central Jakarta (18,292/km²)
Taipei, Taiwan	9,626	Daan (27,476/km²)
Delhi, India	9,339	
Singapore	6,389	
Hong Kong, People's Republic of China	6,206	Kwun Tong (55,000/km²)
Kuala Lumpur, Malaysia	6,072	
Bangkok, Thailand	4,051	
Colombo, Sri Lanka	3,305	
Shanghai, People's Republic of China	2,700	Huangpu (126,500/km²)
Ho Chi Minh City, Vietnam	2,571	Cholon (50,637/km²)
Beijing, People's Republic of China	906	Xuanwu (38,303/km²)

source: Wikipedia (http://en.wikipedia.org/wiki/List_of_selected_cities_by_population_density)

6.2 WATER DEMAND

6.2.1 Present Water Supply Status

(1) Existing Water Supply Capacity

The present water supply system of Karachi City has a bulk water supply capacity of 600 mgd as shown in **Table 62.1.1** and a filtration capacity of 440 mgd as shown in **Table 62.1.2**. This figure does not include bulk water supply of bulk water from Gujjo Headworks to Pakistan Steel Mills and Port Qasim Authority which have their own bulk water transmission facilities (canals and pumping stations) and filtration plants.

Table 62.1.1 Bulk Water Supply Capacity

Bulk Water System	Capacity	Actual Supply
GK System	280 mgd	300 mgd
Haleji System	20 mgd	30 mgd
K-II System	100 mgd	120 mgd
K-III System	100 mgd	100 mgd
Dumlottee Wells	20 mgd	0 mgd
Hub System	80 mgd	80 mgd
Total	600 mgd	630 mgd

Source: KW&SB

Table 62.1.2 Present Filtration Capacity

Filtration Plant	Capacity
Gharo Filtration Plant	20 mgd
Pipri Filtration Plant	100 mgd
NEK Old Filtration Plant	25 mgd
NEK New Filtration Plant	100 mgd
COD Filtration Plant	115 mgd
Hub Filtration Plant	80 mgd
Total	440 mgd

Source: KW&SB

Actually as of the end of year 2006, KW&SB supply bulk water of about 630 mgd beyond the capacity as shown in **Table 62.1.1** and detailed in **Section 3.3.1**.

(2) Water Losses

In the absence of flow measurements at the exits of service reservoirs and filtration plants as well as at the customers' service connections, it is impossible to accurately establish the ratio of water losses in the existing water supply system. The ratio of technical water losses (Unaccounted-For-Water, UFW, such as physical losses, meter inaccuracy and unauthorized consumption) in the transmission and distribution system from filtration plants to customers is reported to range from 20% to 35% of water supply capacity (see **Table 62.1.3**). For the definition of UFW, refer to **Section 9.3 "Reduction of Non-revenue Water"** of this report.

Table 62.1.3 Water Losses reported by Agencies Concerned

Source	Technical Losses (UFW)
PC-1 Form for Water Loss Reduction & System Strengthening Project, KW&SB, February 2001	range of 30% to 35%
An Overview of KW&SB, Briefing to Rukhsana Saleem (Additional Chief Secretary, Local Government, Govt. of Sindh) by MD of KW&SB, 13th January 2007	30 – 35 %
Karachi Strategic Development Plan 2020 (August 2007), CDGK	20%, 25 %

In addition, the water supply system has another water loss called bulk (raw) water losses. Bulk water losses occur in the bulk water transmission system from bulk water intake facilities to filtration plants (leakages, penetration and evaporation) and at filtration plants (backwash water, discharge as sludge, plant water and leakages). In general, water loss at filtration plant ranges from 3% to 10% of plant capacity (water supply capacity from the plant). Filtration plants in Karachi normally have a recovery system which is a recycle system of backwashed water used at filtration system and settled sludge discharged from clarifier or sedimentation basin. Therefore the water loss at filtration plant seems to be relatively small. If including water losses in the bulk water transmission system, bulk water losses can be assumed to be about 10% of the plant capacity. This means that bulk water requires 1.1 times of the plant capacity. **Figure 62.1.1** illustrates the types of water losses within the water supply system of Karachi.

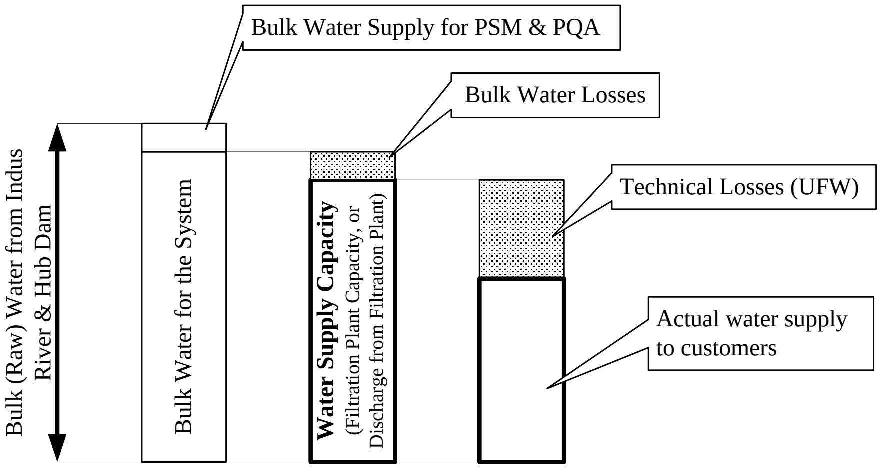

Figure 62.1.1 Definition of Water Supply Capacity and Water Losses

(3) Per Capita Bulk Water Demand

As already mentioned in **Section 6.1**, the population of Karachi City in 2006 is estimated at 15.8 million. Therefore, per capita bulk water demand in 2006 can be calculated as follows:

$$\frac{630 \text{ mgd}}{15.8 \text{ million}} = 39.9 \text{ gallons/capita/day (181.3 lpcd)}$$

At present KW&SB supply bulk water of about 40 gallons per capita per day (gpcd) or 180 litres per capita per day (lpcd) for the water supply system in Karachi.

6.2.2 Assumptions Used for Water Demand Forecast

(1) Service Ratio

The socio-economic survey conducted in KSDP - 2020 has indicated that the piped water supply ratio in Karachi is 89%. For reference, our survey which was conducted mainly at Katchi Abadis during basic study period in 2006 showed that the service ratio (water line connection rates) was estimated at about 82%. Based on these results, JICA study has adopted 90% as the current average service ratio in Karachi in 2005. This means that 90 % of population in Karachi use the KW&SB water through pipelines or by tankers and the remaining 10% of population may depend mainly on groundwater. On the other hand, KSDP – 2020 says that about 60 % of the households are connected to the supply network at present. Considering the average groundwater withdrawal of about 30 mgd (Feasibility Study to explore Groundwater Sources in Karachi District, KW&SB, 2004), however, only 5 % to 10 % of the population in Karachi currently have access to groundwater other than the KW&SB water. Consequently about 90 % of the population is using the KW&SB water because there is no alternative bulk source in Karachi other than the KW&SB water and groundwater. Water of about 17 mgd is supplied by tankers from 10 bowser filling stations according to the KW&SB data in 2004.

The service ratio is assumed to increase gradually from the current service ratio of 90% to 100% by 2015 as shown in **Table 62.2.1**. KSDP-2020 also proposed a plan to make service ratio 100% by 2015. The 100% service ratio means that all the households in Karachi connect to the piped water supply system and as such receive treated water from the system.

Table 62.2.1 Future Service Ratio

Year	2005	2010	2015	2020	2025
Service Ratio	90.0%	95.0%	100%	100%	100%

(2) Water Losses (UFW) Reduction

In the absence of flow measurements at the exits of service reservoirs and filtration plants as well as at the customers' service connections, it is impossible to accurately establish the UFW in the existing water distribution system. As mentioned previously, the current UFW in the transmission and distribution system from filtration plants to customers is seemed to be 20% to 35% of the total water supply capacity. It is assumed that through the implementation of the Distribution Network Improvements (DNI) which will be to replace all the exiting distribution network mains with new PE pipes during the next 20 years, UFW will be reduced to 15 % by 2025. Details of the UFW reduction measures are discussed in **Section 9.3 "Reduction of Non-Revenue Water"** of this report.

(3) Non-Domestic Water Consumption

Although there is not enough quantitative data, according to the data on revenue collection and bulk water supply customers provided by the Financial Department of KW&SB, domestic water consumption accounts for about 60% of the total water consumption in Karachi. At present, therefore, non-domestic water consumption is assumed to be 40 % of the total water consumption. In the future, however, this proportion is expected to decrease gradually to about 35% in 2025 as a result of water conservation efforts such as recycling and reuse of wastewater and introduction of desalination systems by large industrial and commercial consumers. From 2008 a desalination plant with a capacity of 3 mgd at DHA area will be operated for supplying water to Clifton Cantonment and DHA area.

(4) Proposed Domestic Per Capita Water Consumption

As mentioned above, at present bulk water of 40 gpcd is supplied to the customers in Karachi. This JICA study proposed that 40 gpcd should also be adopted for bulk water demand for the year 2025. Although the bulk water demand of 40 gpcd in 2025 is as much as the present demand (as of 2006) shown above, domestic per capita water consumption will increase because of the reduction of technical water losses and expected water-saving efforts of non-domestic consumers. In other words, unless the technical losses decrease and the non-domestic consumption is conserved, the domestic per capita water consumption in 2025 will be the same as that in 2005. The future technical losses (UFW), the proportion of domestic water consumption and bulk water losses in 2025 are set at 15%, 65% and 10% respectively as discussed previously. Taking these ratios into consideration, the domestic per capita water consumption in 2025 is calculated at 20.1 gallons or 91.6 litres as illustrated in **Figure 62.2.1**.

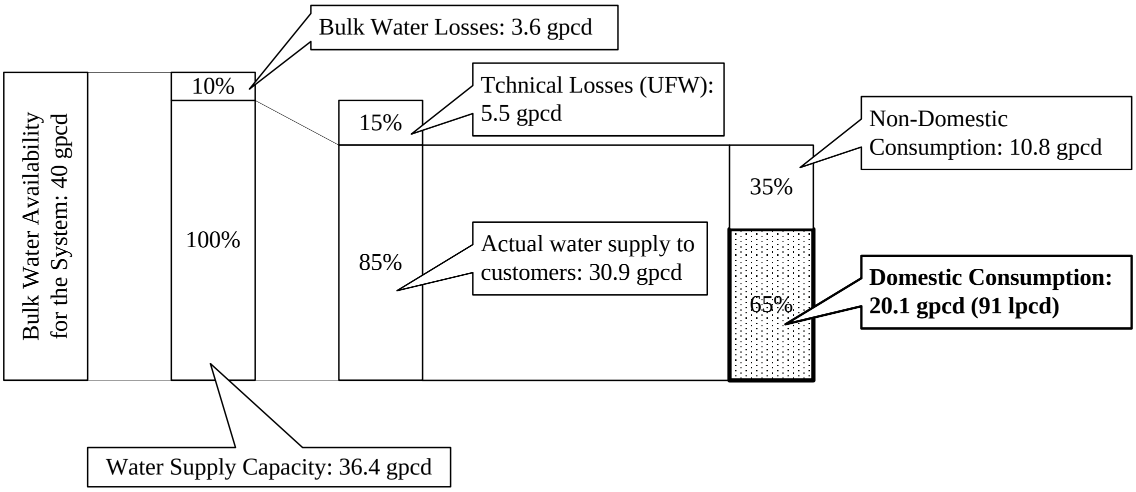

Figure 62.2.1 Per Capita Domestic Water Consumption in 2025

(5) Evaluation of Domestic Per Capita Water Consumption

Domestic per capita water consumption (gallon per capita per day: gpcd or litre per capita per day: lpcd) is an important design factor for estimating future domestic water consumption. People use water for a wide variety of activities. Some of these are more important than others, for example, having a few litres of water to drink a day is more vital than washing clothes. The need to wash hands and feet before prayer may be felt to be more important than other uses. It is, therefore, difficult to estimate how much an individual needs on an average.

Local Government Department, Government of Sindh, announced “Sindh Water Supply Policy” on May 2006. It says that “water will provided inside the house, through piped water, to meet the minimum requirement of 50 litres per person per day”. WHO also reported in “Water Demand Management and Pollution Control, April 2001” that minimum basic needs of water is 50 lpcd and in many cities in Middle East and North Africa, the average water consumption of 70 lpcd is common.

Table 62.2.2 shows domestic per capita water consumptions of major Asian cities. Average per capita consumption of major Asian cities listed in **Table 62.2.2** is calculated at 112.9 lpcd (24.9 gpcd). Considering meteorological condition (average rainfall and dependence on the Indus River) and living standard (GNI), it is deemed reasonable to set domestic per capita water consumption of Karachi to less than 112.9 lpcd (24.9 gpcd).

For reference, per capita consumption of Amman, Jordan, is 80 lpcd (Performance Indicators of Water & Sanitation Utilities in Middle East & North Africa, World Bank, 2003). Living environments of Amman are almost the same as Karachi. Both countries are Islamic countries. Average rainfall in the last 30 years of Amman is 270 mm and GNI of Jordan is US$ 2,500.

Table 62.2.2 Per Capita Water Consumptions of Major Asian Cities

City	Population*1	lpcd*1	Average Rainfall*2	Remarks	
				Country	GNI*3
Colombo	642,163	119	2,313	Sri Lanka	1,160
Delhi	13,782,976	110	779	India	720
Dhaka	10,358,000	115	2,144	Bangladesh	470
Ho Chi Minh	2,749,941	167	1,882	Viet Nam	620
Jakarta	9,695,600	77	1,903	Indonesia	1,280
Kathmandu	1,519,410	68	1,360	Nepal	270
Kuala Lumpur	1,420,000	132	2,390	Malaysia	4,960
Manila	12,660,788	127	1,715	Philippines	1,300
Phnom Penh	532,130	104	1,356	Cambodia	380
Vientiane	616,221	110	1,563	Lao PDR	440

*1: Water in Asian Cities, ADB, 2004
*2: average for 30 years from 1971 to 2000 (mm), Japan Meteorological Agency
*3: GNI: Gross National Income (US$/capita/year), World Development Indicators 2006, WB
Note: Average rainfall of Karachi from 1962 to 2005 is 128.1 mm. Meteorological Department, Government of Pakistan
GNI of Pakistan is 690 US$/capita according to World Development Indicators 2006, WB.

Considering increase of living standard by the target year of 2025 in Karachi, therefore, the JICA study will adopt at least 75 lpcd even for low-income group as domestic per capita water consumption. In this case average domestic per capita water consumption can be calculated at about 90 lpcd.

Table 62.2.3 shows bulk water requirements in 2025 in the following three cases.
Case 1: Per capita consumption is the same as Asian cities' average of 112.9 lpcd.
Case 2: Per capita consumption is JICA study's recommendation of 91.6 lpcd (Per capita bulk water demand is 40 gpcd which is the same as current one).
Case 3: Per capita bulk water demand is 54 gpcd which was used for past planning of KW&SB.

Table 62.2.3 Comparison of Bulk Water Demands

	unit	Case 1	Case 2	Case 3
Per Capita Consumption	lpcd	**112.9**	**91.6**	123.7
	gpcd	24.9	20.1	27.2
Ratio of Domestic Consumption	%	65.2	65.2	65.2
Technical Loss (UFW)	%	15.0	15.0	15.0
Population	million	32.506	32.506	32.506
Water Demand	mgd	1,457	1,182	1,596
Bulk Water Loss	%	10.0	10.0	10.0
Bulk Water Demand	gpcd	49.3	40.0	**54.0**
	mgd	1,602	1,300	1,755

On the other hand, present bulk water availability for Karachi Water Supply System is:

Indus River	:	645 mgd (1,200 cusecs)
Hub Dam	:	75 mgd
Total	:	720 mgd

CDGK have requested the Federal Government for granting an additional water right of 1,200 cusecs from Indus River for Karachi Water Supply System. Assuming that this request will be approved by the Federal Government, the bulk water availability for Karachi Water Supply System will be:

Indus River	:	1,290 mgd (2,400 cusecs)
Hub Dam	:	75 mgd
Total	:	1,365 mgd

Table 62.2.4 shows a water balance of bulk water demand as shown in **Table 62.2.3** and expected bulk water availability in 2025 of 1,365 mgd.

Table 62.2.4 Water Balance of Bulk Water

	unit	Case 1	Case 2	Case 3
Bulk Water Demand	mgd	1,602	1,300	1,755
Bulk Water Availability	mgd	1,365	1,365	1,365
Water Balance	mgd	- 237	65	- 390
	cusecs	- 441	121	- 725

In case of adopting Case 1 or Case 3, the CDGK should apply for an additional water right of 237 mgd (441 cusecs) or 390 mgd (725 cusecs) again. Therefore, JICA study recommends adopting Case 2 by the following reasons:

- Water right from the Indus River for Karachi city is 1,200 cusecs as of the end of December 2007 and an additional water right from the Indus River of 1,200 cusecs has not been approved yet. There is a restriction on water sources for Karachi city.
- Considering environments surrounding Karachi city such as meteorological phenomena and lack of water sources, although the economic growth of Karachi is necessary for increase of population, strict demand management is indispensable for sustaining its growth.
- There is no quantitative flow data for water supply system such as bulk water amount, supply from filtration plants and reservoirs, transmission and distribution flows and consumption of connections. Therefore, no one knows a necessity of additional water quantitatively.

(6) Future Water Supply Capacity

The future water supply system should require a water supply capacity corresponding to the water demand as shown in **Table 62.2.3**. At the Steering Committee held on 2 October 2006, it was agreed that for bulk water supply the on-going K-IV study should provide the required input. According to the latest information on K-IV Project, it is envisaged that the present water supply capacity will be increased by 650 mgd to 1,190 mgd under the K-IV Project. The K-IV Project proposes to construct three filtration plants (650 mgd in total; 260 mgd × 2 plants and 130 mgd × 1 plant) in Gadap Town. In case of applying Case 2, therefore, the future water supply capacity of 1,190 mgd would cover water demand of Case 2 which is 1,182 mgd. If Case 1 or Case 3 would be selected, it should be necessary to plan and develop additional bulk water transmission system and filtration plant in addition to K-IV Project.

(7) Seasonal Peak Factor

Water demand generally fluctuates throughout the year. Water supply facilities (such as filtration plants) are usually planned based on the maximum day water demand. The water demand that has been discussed in this sub-section is the average day water demand, which is usually multiplied by a peak factor (the ratio of the maximum day water demand to the average day water demand) to determine the maximum day water demand.

The peak factor is normally estimated by analyzing the past trend of monthly water demand fluctuation. However, it is not available in the case of Karachi since no flow measurement has been conducted in the past. Furthermore, it is envisaged that the future water demand in Karachi would be heavily constrained by the limited availability of bulk water from the water sources. Under the circumstances, there is no point in discussing about seasonal peak factors.

6.2.3 Future Water Demand

(1) Water Demand of Each Case in 2025

Future water demand of each case is summarised in **Table 62.3.1**. It should be noted that the water demand means water consumption (total of domestic and non-domestic water consumptions) plus technical water losses (total technical losses from outlet of filtration plant to customers through transmission system, reservoirs and distribution system).

Table 62.3.1 Water Demand of Each Case in 2025

	unit	Case 1	Case 2	Case 3
Bulk Water Demand (see Table 62.2.3)	mgd	1,602	1,300	1,755
Bulk Water Loss	%	10.0	10.0	10.0
Water Demand	**mgd**	**1,457**	**1,182**	**1,596**
Water Supply Capacity see **Section 7.3** in detail)	mgd	1,270	1,270	1,270
Balance	mgd	-187	88	-326

As explained previously, in case of applying case 2, the future water supply capacity of 1,270 mgd would cover water demand of case 2 that is 1,182 mgd. If case 1 or case 3 would be selected, it should be necessary to construct additional bulk water transmission system and filtration plant in addition to K-IV Project. Considering current situation such as meteorological condition, bulk water availability, on-going studies and financial background of water supply system, in this study case 2 have been adopted for the future development plan for Karachi.

(2) Future Water Demand

In order to calculate future water demand, water loss is estimated as shown in **Table 62.3.2** as a target of water loss reduction. In the early stage of water loss reduction measure, its effect is not seen immediately. If the actual water loss is proved quantitatively and is smaller than the figure shown in **Table 62.3.2** as the results of flow measurement, KW&SB should strive not to fall below the target of water loss in **Table 62.3.2**.

Table 62.3.2 Expected Future Water Loss (UFW) Ratio

Year	2005	2010	2015	2020	2025
Technical Loss (UFW)	35.0%	33.0%	28.5%	21.5%	15.0%

Based on this assumption, the future water demand was calculated as shown in **Table 62.3.3** and **Figure 62.3.1**.

Table 62.3.3 Future Water Demand

		unit	2005	2010	2015	2020	2025
a	Population	× million	15.120	18.529	22.594	27.550	32.506
b	Per Capita Bulk Water Demand	gpcd	40.0	40.0	40.0	40.0	40.0
c	Bulk Water Demand: a × b	mgd	604.8	741.1	903.8	1,102.0	1,300.3
d	Bulk Water Loss	%	10.0%	10.0%	10.0%	10.0%	10.0%
e	Water Demand: c / (1+d)	mgd	549.8	673.8	821.6	1,001.8	1,182.0
f	Water Loss (UFW)	%	35.0%	33.0%	28.5%	21.5%	15.0%
g	Total Supply to Customers: e × (1-f)	mgd	357.4	451.4	587.4	786.4	1,004.7
h	Ratio of Domestic Consumption	%	60.0%	60.4%	61.7%	63.2%	65.2%
i	Domestic Consumption: g × h	mgd	214.4	272.6	362.3	497.3	655.3
j	Non-domestic Consumption: g × (1-h)	mgd	143.0	178.8	225.1	289.1	349.5
k	Service Ratio	%	90.0%	95.0%	100%	100%	100%
l	Served Population: a × k	× million	13.608	17.602	22.594	27.550	32.506
m	Per Capita Consumption: i / l	lpcd	71.6	70.4	72.9	82.1	91.6

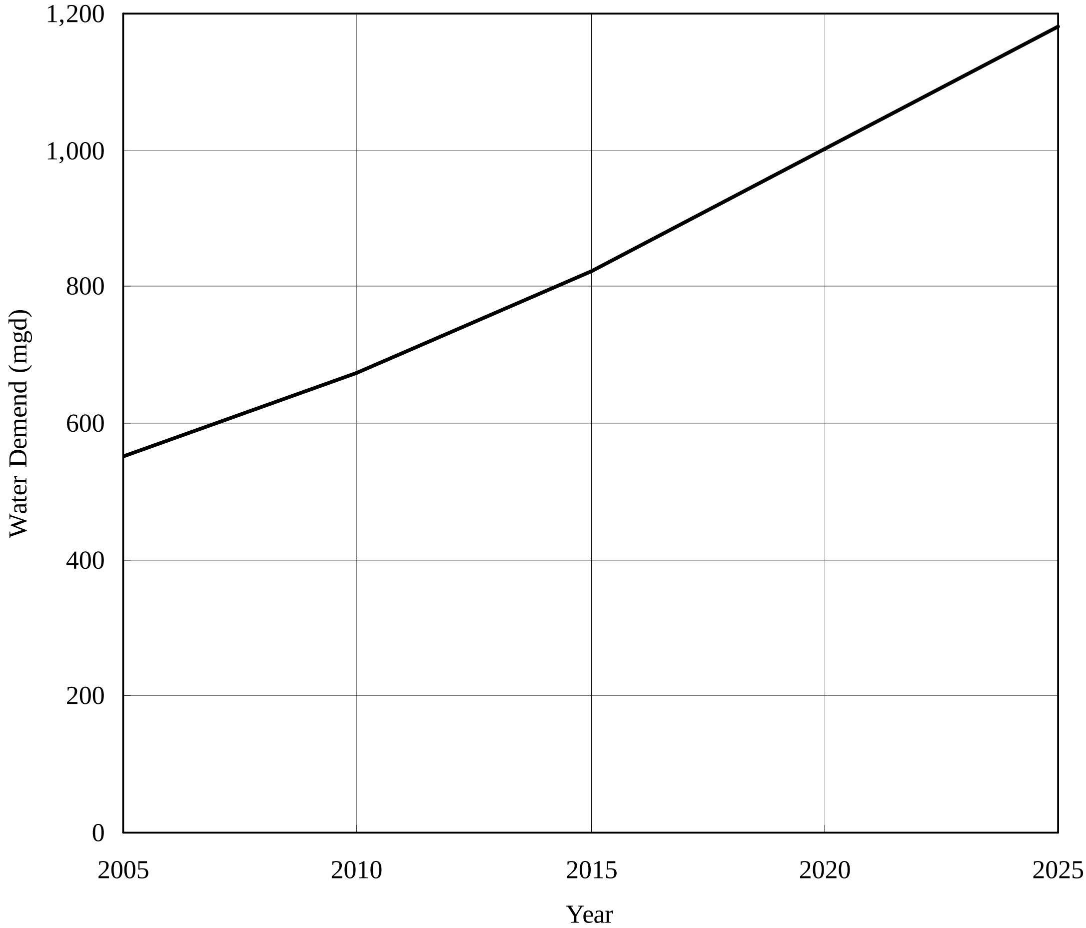

Figure 62.3.1 Future Water Demand

(3) Efficiency of UFW Reduction

Figure 62.3.2 demonstrates how important it is to reduce UFW from the current 35% to 15% in 2025. If UFW continues to remain at the present level without reduction, it would increase the technical loss drastically as shown in **Figure 62.3.2** and **Table 62.3.4**. In this case, the total water loss in 2025 would exceed 400 mgd, which is equivalent to two third of the current total bulk supply of 630 mgd.

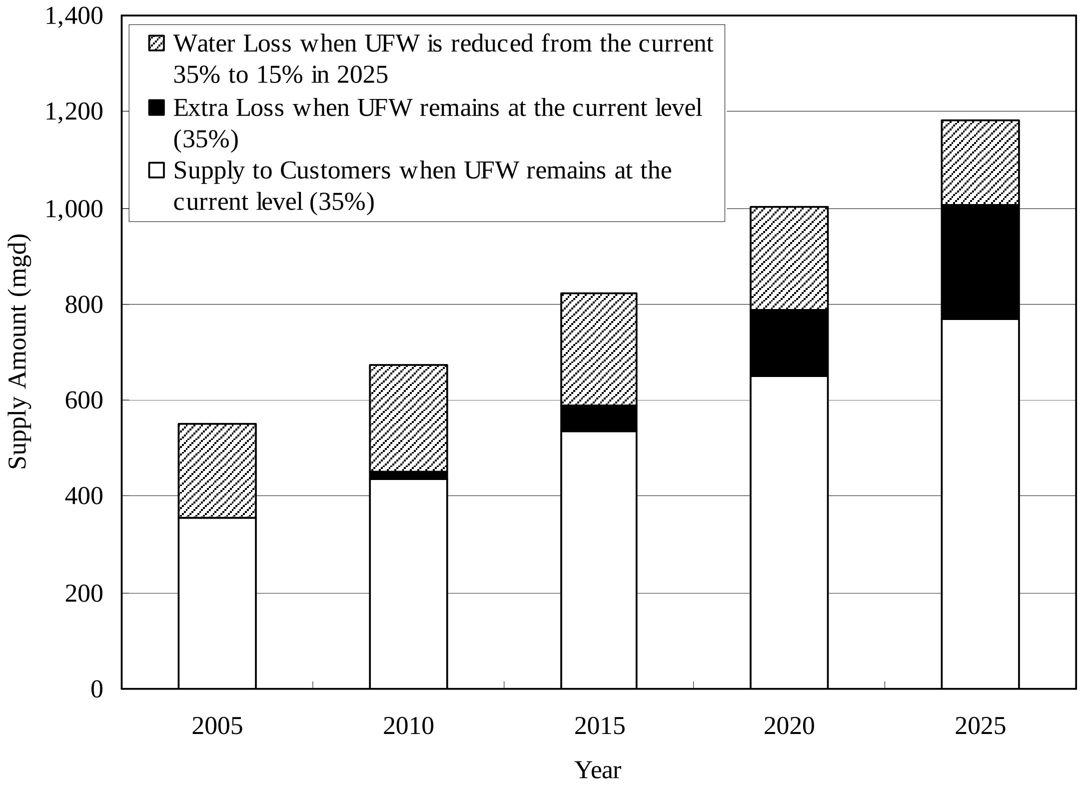

Figure 62.3.2 Supply to Customers With & Without UFW Reduction

Table 62.3.4 Supply to Customers With & Without UFW Reduction

	unit	2005	2010	2015	2020	2025
With UFW Reduction Measures, 35% to 15% in 2025						
Water Loss (UFW)	%	35.0%	33.0%	28.5%	21.5%	15.0%
Water Demand	mgd	549.8	673.8	821.6	1,001.8	1,182.0
Total Supply to Customers	mgd	357.4	451.4	587.4	786.4	1,004.7
Water Loss	mgd	192.4	222.3	234.2	215.4	**177.3**
Without UFW Reduction Measures, keeping of the present level of 35%						
Water Loss (UFW)	%	35.0%	35.0%	35.0%	35.0%	35.0%
Water Demand	mgd	549.8	673.8	821.6	1,001.8	1,182.0
Total Supply to Customers	mgd	357.4	437.9	534.0	651.2	768.3
Water Loss	mgd	192.4	235.8	287.6	350.6	**413.7**

(4) Future Water Demand of Each Town

Future Water Demand of each town, cantonment and DHA from 2006 to 2025 is summarised in **Table 62.3.5** and attached in **Appendix A61.1**.

Table 62.3.5 Future Water Demand of Each Town

No.	Town	Area		Total Water Demand (mgd)				
		(acre)	(km2)	2005	2010	2015	2020	2025
1	Keamari	106,217	429.8	12.33	24.75	40.99	56.98	73.31
2	SITE	6,286	25.4	32.56	34.18	35.88	38.33	40.79
3	Baldia	7,217	29.2	10.58	17.15	24.54	30.01	35.63
4	Orangi	5,803	23.5	24.96	27.45	30.33	34.02	37.91
5	Lyari	1,977	8.0	22.41	22.61	22.90	23.70	24.59
6	Saddar	5,967	24.1	69.99	70.51	71.15	73.94	76.71
7	Jamshed	5,790	23.4	28.81	35.46	42.57	48.77	55.27
8	Gulshan-e-Iqbal	13,260	53.7	41.88	57.32	75.00	98.36	121.99
9	Shah Faisal	2,901	11.7	22.33	23.20	24.12	25.50	26.93
10	Landhi	9,670	39.1	32.03	37.30	43.49	52.86	62.40
11	Korangi	10,247	41.5	28.79	36.01	44.19	56.20	68.30
12	North Nazimabad	4,127	16.7	24.32	25.95	28.03	31.44	35.03
13	New Karachi	5,058	20.5	24.55	25.83	27.39	29.86	32.47
14	Gulberg	3,417	13.8	21.24	23.05	25.22	28.26	31.48
15	Liaquatabad	2,685	10.9	30.22	29.54	29.20	30.31	31.51
16	Malir	4,395	17.8	38.10	39.94	42.20	47.13	51.84
17	Bin Qasim	137,961	558.3	31.19	58.33	87.67	122.58	155.34
18	Gadap	355,798	1,439.9	10.42	33.33	64.79	97.72	130.58
	sub-total	688,776	2,787.4	506.71	621.93	759.67	925.94	1,092.09
19	Cantonment	31,336	126.8	21.60	26.81	32.55	39.64	46.48
20	Defence	9,454	38.3	21.50	25.03	29.37	36.24	43.48
	sub-total	40,790	165.1	43.10	51.84	61.92	75.88	89.96
	Total	729,567	2,952.5	549.81	673.77	821.60	1,001.82	1,182.05