

## 1. Background to the Study Area

Ho Chi Minh City (hereafter HCMC) is located in the south of Vietnam, and is the biggest city in Vietnam. It is located from 10° 10' - 10° 38' North and 106° 2' - 106° 54' East. HCMC is 1,730 km from Hanoi and is at the crossroads of international maritime routes. The city center is 50 km from the East Sea in a straight line. It is a transport hub of the southern region and has the largest port system and airport in Vietnam. HCMC covers 0.6% of the total area of the whole country and has 6.6% of the total population. The city's official population has increased from 3 million people in 1975 to 6.24 million people in the middle of 2005. However, the real population is supposed to be significantly higher than this because there are many unregistered people in HCMC. The real population could be around 7.5 million. The city natural land area is 2,095 km<sup>2</sup> with a present average population density of 2,687 persons/km<sup>2</sup>. A map of the core area of HCMC is shown in figure 1.



Figure 1. Map of HCMC

There are about 30,000 factories in the industrial sector of HCMC, including many large enterprises, high-technology, electronic, processing, light industries, construction, building materials and agro-products. Currently, the city has 15 industrial parks (IP) and export-processing zones (EPZ). There are 171 medium and large scale markets, tens of supermarket chains, dozens of luxury shopping malls and many modern fashion or beauty centers. Over 50 banks with hundreds of branches and about 20 insurance companies are situated inside the city. In 2005, the city's Gross Domestic Product (GDP) was estimated at 11.6 billion USD, or about 1,850 USD/capita, (up 12.2% on 2004) and accounting for 20% GDP of the country. The city's Industrial Product Value was 5.6 billion USD, equivalent to 30% of the whole nation. Export - Import Turnover through HCMC ports took 29 billion USD, or 40% of the national total. Ho Chi Minh City has also contributed about 30% to the national budget's revenue annually.

## 2. State of Water Resources

At present, four water resources are used for water supply in HCMC. They are (a) Dong Nai River, (b) Sai Gon River (c) groundwater and (d) rain water. The current and projected total daily water use demand for domestic and industrial activities in HCMC were 1.75 million m<sup>3</sup> in 2005 and 3.6 million m<sup>3</sup> in 2020, respectively (Nga, 2006). The key water users in HCMC are residents, industries and services. Water resources used for agriculture in HCMC are (i) raw water taken from the irrigation canals network of Sai Gon and Dong Nai Rivers and (ii) storm water in the rainy season. Ground water has not been used for agriculture in HCMC because of (i) availability of fresh raw water of the irrigation canals located in the west and southeast of HCMC and (ii) unsuitability of groundwater quality for irrigation, such as high iron content and low pH.

The Saigon Water Supply Company (SAWACO) is responsible for exploitation, purification and distribution of water in HCMC. The capacity of piped water in 2006 under SAWACO's management was 1,236,000 m<sup>3</sup>/day, which included 1,150,000 m<sup>3</sup>/day produced by three surface water treatment plants taking raw water from Sai Gon and Dong Nai Rivers and 86,000 m<sup>3</sup>/day produced from groundwater treatment plants.

### 2.1 Sai Gon and Dong Nai River

The total volume of water for domestic and industrial uses in HCMC was about 1,890,000 m<sup>3</sup>/day in 2006, which included 1,270,000 m<sup>3</sup>/day taken from Sai Gon and Dong Nai Rivers. Nga (2006) reported the maximum exploitation rates of freshwater from Sai Gon and Dong Nai River basins could obtain 7,500,000 m<sup>3</sup>/day, which included:

- 940,000 m<sup>3</sup>/day from Sai Gon River and up to 1,360,000 m<sup>3</sup>/day when Phuoc Hoa reservoir is built,
- 200,000 m<sup>3</sup>/day from Dau Tieng reservoir and Dong Canals,
- 6,000,000 m<sup>3</sup>/day from Dong Nai River.

#### (1) Dong Nai River

Dong Nai River originates from Di Linh highland in Lam Dong province and connects to the East Sea through Soai Rap estuary. The total length of the river is 628 km. The total river basin area is 38,610 km<sup>2</sup>. Other downstream sections of the river have an average slope of 0.22‰. The middle and upstream sections of the river have an average slope of 0.94‰ and 4.34‰ respectively.

The section of Dong Nai River in HCMC spreads from District 9 to intersection point with Nha Be River. Total length of this section is 40 km and average width is 200-300 m. The flowrate of Dong Nai River was from 100 m<sup>3</sup>/s (maximum) to 32 m<sup>3</sup>/s (minimum). However, when flow from Tri An reservoir was added, the flow rate increased to 2,110 m<sup>3</sup>/s maximum flow and 600 m<sup>3</sup>/s minimum flow. Due to the discharge rate of Tri An reservoir and Dau Tieng reservoir, a salinity limit of 4‰ is pushed back to Cat Lai, 10 km long from its first present point (Hiep Binh crossroad). When an additional flowrate of 20 m<sup>3</sup>/s from Thac Mo lake is discharged to the Dong Nai River, the salinity point is 4-5 km further than its previous position.



**Figure 2. Sai Gon - Dong Nai River system**

Source: Triet et al. (2001)

## (2) Sai Gon River

A section of Sai Gon River in HCMC begins from Phu My commune to Thanh My Loi, District 2. Width of the river is 250-350 m. The river depth is 10-20 m. Maximum flowrate was  $84 \text{ m}^3/\text{s}$  in October, 1986 (recorded at T3 station, Binh Duong Province) and minimum flowrate was  $22.5 \text{ m}^3/\text{s}$  in August, 1986. Maximum and minimum water level were 1.18 m (10th October, 1990) and  $-0.34 \text{ m}$  (20 October, 1990). Sai Gon River is affected by semi-diurnal tidal flow regime.

Dau Tieng reservoir affects a large area of Sai Gon River basin ( $2,700 \text{ km}^2$ ). Its volume is 105 million  $\text{m}^3$ . It supplies water for irrigation and a clean water supply in Tay Ninh province and HCMC. The irrigation canal system of Sai Gon River is also a significant freshwater recharge source for the groundwater aquifers in the canals basin, located in the west and southwest of HCMC. Moreover, the lake also contributes to pushing back the salinity point because it discharges water to the downstream of Sai Gon River at a rate of  $20 \text{ m}^3/\text{s}$ . In Sai Gon River, there is a salinity point of 4‰ at Thu Thiem.

Water from Hoa An water intake station on Dong Nai River is pumped to Thu Duc water treatment plant (WTP) with a capacity of  $650,000 \text{ m}^3/\text{day}$ . Binh An WTP, which takes raw water from Dong Nai River, has  $95,000 \text{ m}^3/\text{day}$ . These two WTPs supply clean water for the eastern part and center of HCMC.

The Sai Gon WTP with a design capacity of  $300,000 \text{ m}^3/\text{day}$  (at Ben Than-Cu chi District) started running at a capacity of  $120,000 \text{ m}^3/\text{day}$  in 2004 and will be run at the designed capacity in 2007. It takes raw water from Saigon River and

supplies clean water to the western part of HCMC.

The socio-economic development plan of HCMC People's Committee for period 2001–2020 (VIWASE, 2004) shows that the quantity of piped water increases to 1,670,000 m<sup>3</sup>/day; 2,180,000 m<sup>3</sup>/day and 3,290,000 m<sup>3</sup>/day in the years 2004, 2010 and 2020, respectively. The master plan of water supply of HCMC shows that Dong Nai River will be the main water uptake source, at which 57.3% and 62.3% of total water demands of 2010 and 2020 would be taken up, respectively.

Besides HCMC, the provinces of Sai Gon and Dong Nai Rivers basin such as Dong Nai, Binh Duong, Ba Ria-Vung Tau, Tay Ninh and Long An provinces also use Dong Nai and Sai Gon Rivers. The intake rate of Sai Gon or Dong Nai River water of these provinces is listed in table 1.

**Table 1. The Intake Rates from Sai Gon or Dong Nai River Water of the Provinces in the Basin**

No.	City/Province	Water Intake Rate (m <sup>3</sup> /day)	
		2005	2020
1	Dong Nai province	100,000	300,000
2	Binh Duong province	32,500	50,000
3	Binh Phuoc	3,700	-
4	Tay Ninh province	5,000	-
5	Ba Ria-Vung Tau province	20,000	130,000
6	Lam Dong province	42,000	-

Source: VIWASE, 2004

## 2.2 Groundwater

HCMC has the following five aquifers, namely, (i) Holocene, (ii) Pleistocene, (iii) Upper Pliocene, (iv) Lower Pliocene and (v) Mesozoic.

**Holocene:** This aquifer contains sediments from different sources (rivers, sea, swamps). Main soil composition is clay, silt, fine sand loam, and a mixture of fine sand with botanical humus.

**Pleistocene:** Soil composition is clay silt, silt, sandy silt, fine sand. Some areas are weathered to laterite.

**Upper Pliocene aquifer:** The main materials of this aquifer are fine sand, a mixture of powder sand with fine sand. These materials create a continuous aquifer in which water can pass through.

**Lower Pliocene aquifer:** This aquifer contains fine and coarse sand, fine gravel and pebbles.

Over 150,000 wells/boreholes were exploited in HCMC. Three of five aquifers play an important role in water supply for HCMC: Pleistocene aquifer (20–50 m), upper Pliocene aquifer (50–100 m) and lower Pliocene aquifer (100–140 m).

### (1) Pleistocene Aquifer (Q<sub>I-III</sub>)

Pleistocene aquifer is placed widely under the whole area and is exposed in the city center and Tan Binh, 2, 12, Thu Duc, Hoc Mon, Cu Chi districts. The aquifer includes 2 layers: (a) the upper layer is a weak impermeable layer and (b) the lower layer containing water.

### (2) The upper Pliocene Aquifer (N<sub>2</sub><sup>b</sup>)

The upper Pliocene aquifer (N<sub>2</sub><sup>b</sup>) is not exposed at the surface. It is placed also widely under the whole city. The depth to the aquifer is about 40–80 m. The upper Pliocene aquifer is directly covered by the Pleistocene aquifer and placed above the lower Pliocene aquifer. The upper Pliocene aquifer includes 2 layers: impermeable and aquifer.

### (3) The lower Pliocene Aquifer (N<sub>2</sub><sup>a</sup>)

The lower Pliocene aquifer (N<sub>2</sub><sup>a</sup>) is not exposed at the surface. It is placed widely in the project area. The depth to the aquifer is 50–100m. The lower Pliocene aquifer is directly covered by the upper Pliocene aquifer. The lower Pliocene aquifer includes 2 layers: impermeable layer and aquifer.

#### (4) Potentiality of Groundwater Resources

The Department of Industry (2002) estimated that the water reserve potential of all aquifers in HCMC was about 2,500,000 m<sup>3</sup>/day. The water reserve potential of the aquifer was estimated from flows of recharging sources. Table 2 presents flow of sources recharging into aquifers in HCMC.

**Table 2. The Reserved Fresh Water Potential of Aquifers in HCMC**

No	The flow component	Pleistocene aquifer(m <sup>3</sup> /day)	Upper Pliocene aquifer (m <sup>3</sup> /day)	Lower Pliocene aquifer (m <sup>3</sup> /day)
1	Flow recharged from rainwater	309,530		
2	Flow recharged from Dong Canal	156,750		
3	Flow recharged from Sai Gon River	67,500		
4	Flows from northern and western boundaries of HCMC	22,540	181,170	94,030
5	Static gravity flow	233,480	715,320	630,420
6	Static elastic flow	6,000	55,770	28,550
	<b>Total</b>	<b>796,000</b>	<b>952,000</b>	<b>753,000</b>

Source: DI, 2002

According to the drinking water standards of Viet Nam, water can be used for drinking purpose when the total dissolved solids level of the water is less than 500 mg/l as NaCl. The areas having three exploitable aquifers are the northeast of HCMC (Cu Chi district, Hoc Mon District) and the inner city. The areas having one or two exploitable aquifers are the East (Thu Duc, 9th, 2nd District) and the southeast of HCMC (Nha Be District, the west of Hoc Mon District and the east of Binh Chanh District). Other areas have aquifers containing brackish water (TDS higher than 100 mg/l as NaCl) or aquifers with low water potential quantity.

### 2.3 Rain Water

The rainy season in HCMC is from May to November. Rainfall in the rainy season is approximately 80–85% of the annual rainfall. Heavy rains occur in June and September in the range of 250–330 mm/month. The maximum is up to 683mm. Rainfall intensity is quite high (0.8–1.5 mm/minute). Therefore, rainwater use can be one of the important alternative water sources for HCMC. However, rainwater harvesting, storage and treatment for a big city like HCMC requires large investment cost and area. This becomes a great difficulty for developing countries such as Viet Nam. Rainwater use can be the suitable option for areas lacking freshwater or rural areas such as Can Gio District and District 7 or newly designed towns in the city.

Can Gio district's population was 70,000 people in 2005. Can Gio is a district remote from the center of HCMC and currently there is no piped water distribution network and also no freshwater ground water resources. Rain water is one of the main fresh water resources for domestic uses. Because the groundwater of aquifers in Can Gio district have high salinity, now all residents use rainwater in rainy season and store it in dry season. There is a rainwater collecting system in most households which includes an Arris-gutter installed at the end of inclined house roofs for water collection. Besides, use of rain water, Can Gio district is provided clean water transferred from the center of HCMC by vessels. Vessels transport 5,000 m<sup>3</sup> from Nha Be District to Can Gio monthly. Sai Gon Water Supply Company is planning to install a water network for this area through the route of Nha Be – Can Gio districts.

### 2.4 Wastewater Reuse

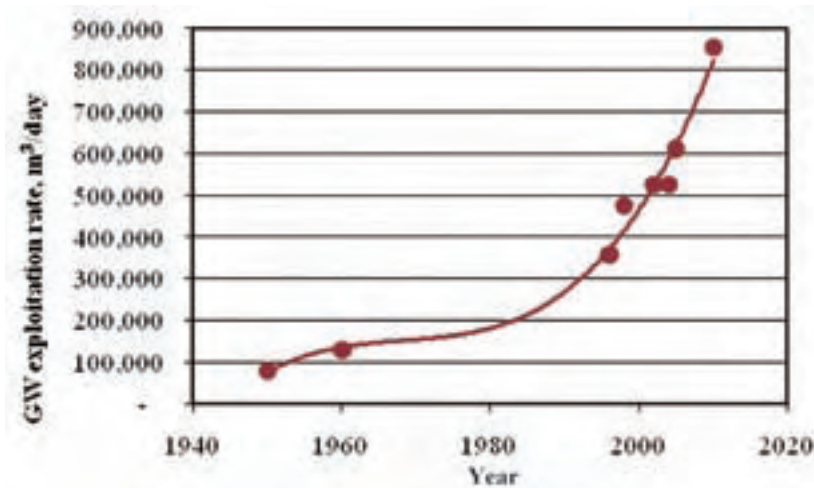
A potential alternative water resource which may replace existing water resources for non-potable use is renovated wastewater. Advanced treatment of treated wastewater will yield a better quality effluent which can be used as an alternative water resource and therefore reduces the demand on fresh water supplies. The daily volumes of domestic and industrial wastewater discharged to the canals in HCMC were 710,000 m<sup>3</sup> and 35,000 m<sup>3</sup>, respectively in 2000. The daily projected volume of domestic wastewater will be 2,100,000 m<sup>3</sup> in 2020. However, currently, only a small amount of municipal wastewater is conventionally treated at Binh Hung Hoa central wastewater treatment plant with a capacity of 30,000 m<sup>3</sup>/day.

In addition, only 40%, approximately 15,000 m<sup>3</sup>/day, of industrial wastewater has been treated efficiently by the centralized wastewater treatment plants located inside the five industrial parks (including Tan Thuan, Linh Trung 1, Linh Trung 2, Tan Binh, Le Minh Xuan, and Tan Tao industrial parks). The other 10 industrial parks in the city are still in the progress of setting up the wastewater treatment plant. The reuse of advanced treated effluent can be a good option for industry. However, the investment and maintenance for advanced treatment and secondary distribution networks for non-drinking water require huge budgets. Besides, the reclaimed wastewater management should be strictly controlled to reduce risks to human health such as pathogen contamination in the cases of poor control of effluent quality. Therefore, wastewater reuse can only be a good option for long-term planning.

### 3. Issues and Discussion on Groundwater Management

#### 3.1 Groundwater Use

Groundwater has been used in HCMC since 1920. Rapid increase of groundwater use started in 1990 when the economic policies of Viet Nam were opened. High industrialization and urbanization resulted in the quick increase of water demands. The expansion of surface water works in HCMC has not met this rapid increase. Besides, until now free of charge groundwater and uncontrolled exploitation has increasingly augmented the exploitation rate.



**Figure 3. Variation of Groundwater Use versus Time in HCMC**

Source: Nga, 2006

Nga (2006) reported that groundwater exploitation was estimated at about 611,000 m<sup>3</sup>/day in 2005, of which 346,000 m<sup>3</sup>/day and 265,000 m<sup>3</sup>/day were used for domestic activities (residents, public works and services) and industry, respectively. The Union for Geology No. 8 (2001) assessed that the safe yield of all aquifers should be 500,000 m<sup>3</sup>/day, whereas the DI (2002) and Nga report (2006) reported the safe yield could be up to 800,000 m<sup>3</sup>/day. The safe yield is considered as the sum of dynamic potential and 30% of static potential of groundwater. The dynamic potential of groundwater is the difference between water volume in porous pores in rainy season and that in dry season. The static potential includes:

- i. Static gravity potential is the amount of water contained in porous pores of aquifer. This potential depends on the depth of aquifer, exploitation time and aquifer area, etc.
- ii. Static elastic potential is the amount of water released from the compressed aquifers as the water pressure of this

aquifer decreases. Elastic static potential depends on water release coefficient and elastic volume coefficient.

The ratio of groundwater use was 34% of the total water demand of HCMC in 2005. The planning of groundwater use in HCMC (DI, 2002) reported that the projected groundwater use will be decreased by 21 % of the total water demand in year of 2010 and 15% in year of 2020.

At present, the groundwater use ratio of industry to piped water (water supply company) to individuals is 3:1:1. It should be changed to 2:2:0.5 in 2020. Thus, it is necessary to reduce groundwater use from industrial sector by encouraging wastewater reuse, water recycling, and applying different water tariffs of groundwater use for different sectors.

Groundwater still plays a non-replaceable role in water supply for HCMC at present, and will do so into the future. However, the groundwater is under threat due to salt water intrusion, water table descent and contamination of the shallow aquifer that have already been observed in some monitoring wells. Some daily papers reported that land subsidence had occurred at few areas with large exploitation capacity wells. Until now, no surveys on land subsidence have been done in HCMC.

### 3.2 Water Table Drawdown

Table 3 shows the annual water table drawdown at the areas with high well density.

**Table 3. Water Table at Groundwater Monitoring Stations near the Areas with High Well Density**

Aquifer	Year	Ground water table (m)				
		Binh Hung (Binh Chanh Dist.)	Tan Tao (Binh Tan Dist.)	Tan Son Nhat (Phu Nhuan Dist.)	Phu Tho (Dist.11)	Tan Chanh Hiep (Dist. 12)
Pleistocene	2000	-2.69	-2.61	6.76	-5.27	4.85
	2004	-5.6	-7.8	1.23	-7.96	3.8
	<i>Total drawdown</i>	2.91	5.19	5.53	2.69	1.05
	<i>Annual drawdown</i>	<b>0.73</b>	<b>1.3</b>	<b>1.38</b>	<b>0.67</b>	<b>0.26</b>
Upper Pliocene	2000	-8.18	-9.25	-11.58	-15.79	-7.71
	2004	-14.99	-18.57	-22.56	-23.67	-19.26
	<i>Total drawdown</i>	6.81	9.32	10.98	7.88	11.55
	<i>Annual drawdown</i>	<b>1.7</b>	<b>2.33</b>	<b>2.75</b>	<b>1.97</b>	<b>2.89</b>
Lower Pliocene	2000	-14.36	-8.94	-12.49	-15.85	-8.5
	2004	-29.75	-19.01	-23.12	-28.77	-19.9
	<i>Total drawdown</i>	15.39	10.07	10.63	12.92	11.4
	<i>Annual drawdown</i>	<b>3.85</b>	<b>2.52</b>	<b>2.66</b>	<b>3.23</b>	<b>2.85</b>

Source: DI, 2002

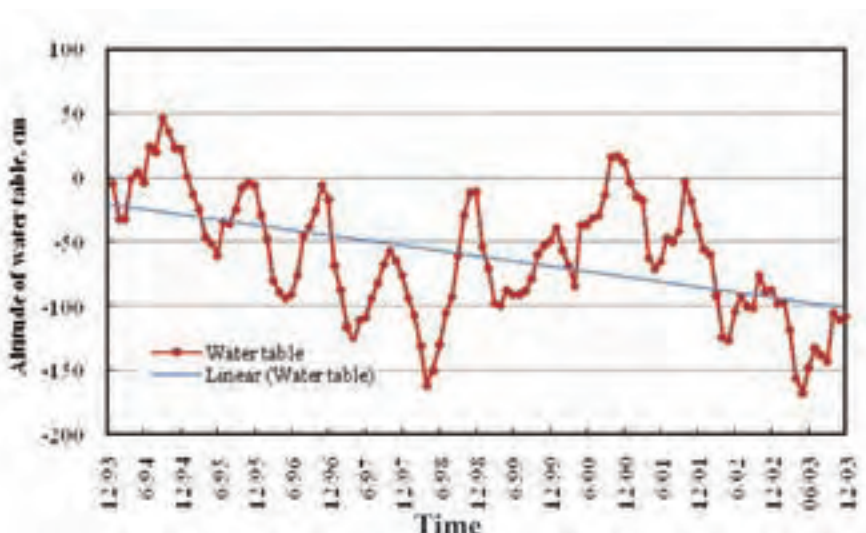
Figure 4 shows the water table drawdown cone may spread out larger and larger in the future years. The centers of the cone are the areas with high groundwater exploitation such as Hoc Mon water treatment plant, Go Vap District, Binh Tan and Binh Hung sub-districts (belonging to Binh Chanh district).



**Figure 4. Water Table Drawdown of Upper Pliocene – 2010 in Comparison to 2001**  
 Source: DI, 2002

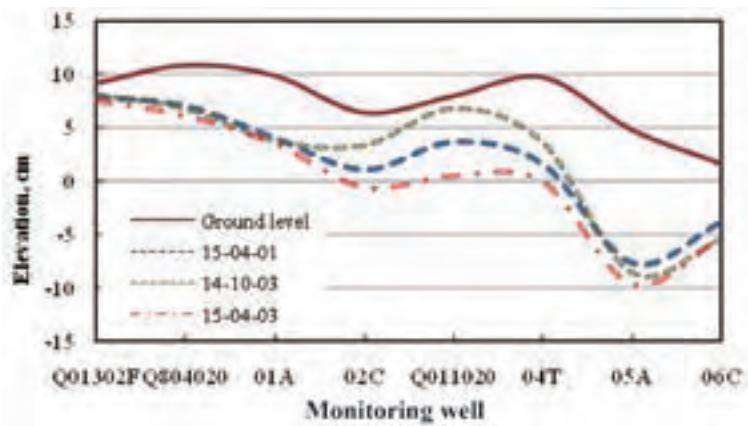
### (1) Pleistocene Aquifer

Along with northwest to southeast and from west to east, the water table was close to the ground level and tended to lower gradually. The biggest descent occurred at 05A (Phu Tho, District 11). In comparison to the water table in April 2001, the one in April 2003 was significantly lowered. The water table tended to lower gradually, 22 cm/year in 2002-2003.



**Figure 5. Change of Groundwater Table versus Time at Monitoring Station Q00202C (Cu Chi)**  
 Source: Nga, 2006

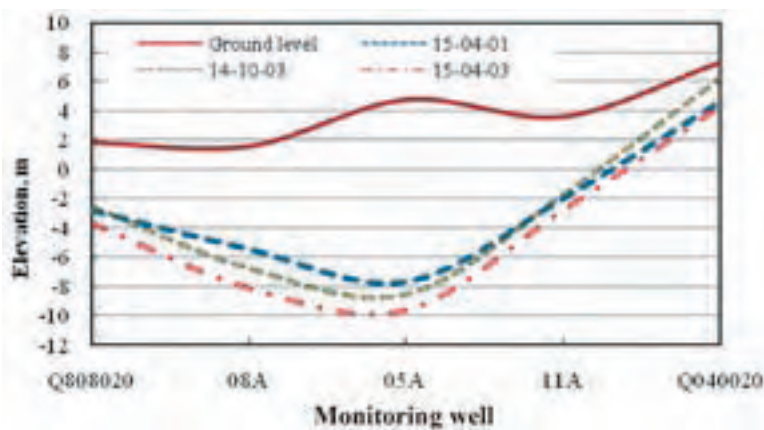




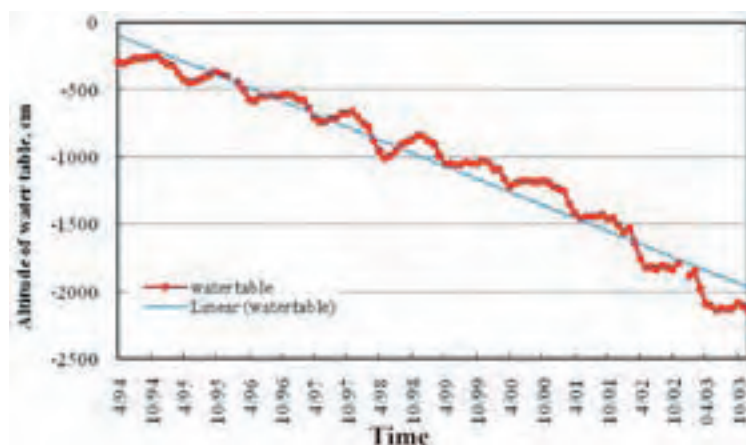
**Figure 6. Water Table Profile of QI-III Aquifer along with Northeast – Southwest Line**  
 Source: Nga, 2006

### (2) The Upper Pliocene Aquifer (N2b)

The average depth of static water table is 21.2–27.7 m and 27.7 m. The result of water table monitoring during 1994–2003 in this aquifer shows that at station Q007, Q015030 (Binh Chanh); Q011340, Q017030, Q004 (Hoc Mon, district 12) the water table descended annually at an average of 0.11–1.95 m depth. This fast descent of water table is due to excess groundwater exploitation and the water recharge in this aquifer mainly comes from rain water (see figure 8).

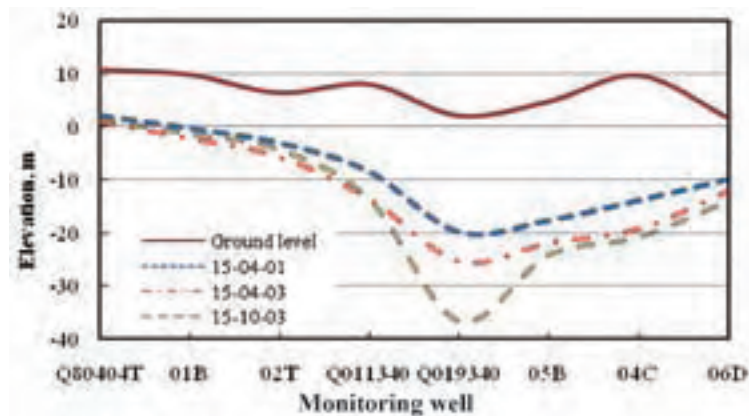


**Figure 7. Water Table Profile of QI-III Aquifer along with West - East Line**  
 Source: Nga, 2006



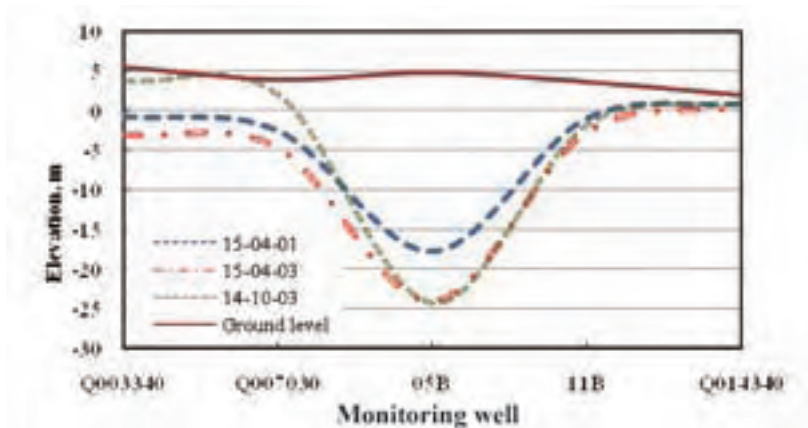
**Figure 8. Change of the Groundwater Table versus Time at the Q015030 (Binh Chanh)**  
 Source: Nga, 2006

Along the direction from northwest to southeast and from the west to the east, the water table changed slowly in Cu Chi, Hoc Mon and had tendency to descend in the city center.



**Figure 9. Graph of Water Table with NW – SE – Layer N2b**

Source: Nga, 2006



**Figure 10. Graph of Water Table with W – E – Layer N2b**

Source: Nga, 2006

The lower Pliocene aquifer (N2a): In general, the static water table of this aquifer is similar to that of the upper Pliocene (N2b). The monitoring data from 1994-2003 shows that the water table descended annually at the average depth of 0.3 m and 1.4 m at Station Q011040 (Hoc Mon) and Q80404Z (Cu Chi), respectively. This may be due to excess groundwater exploitation.

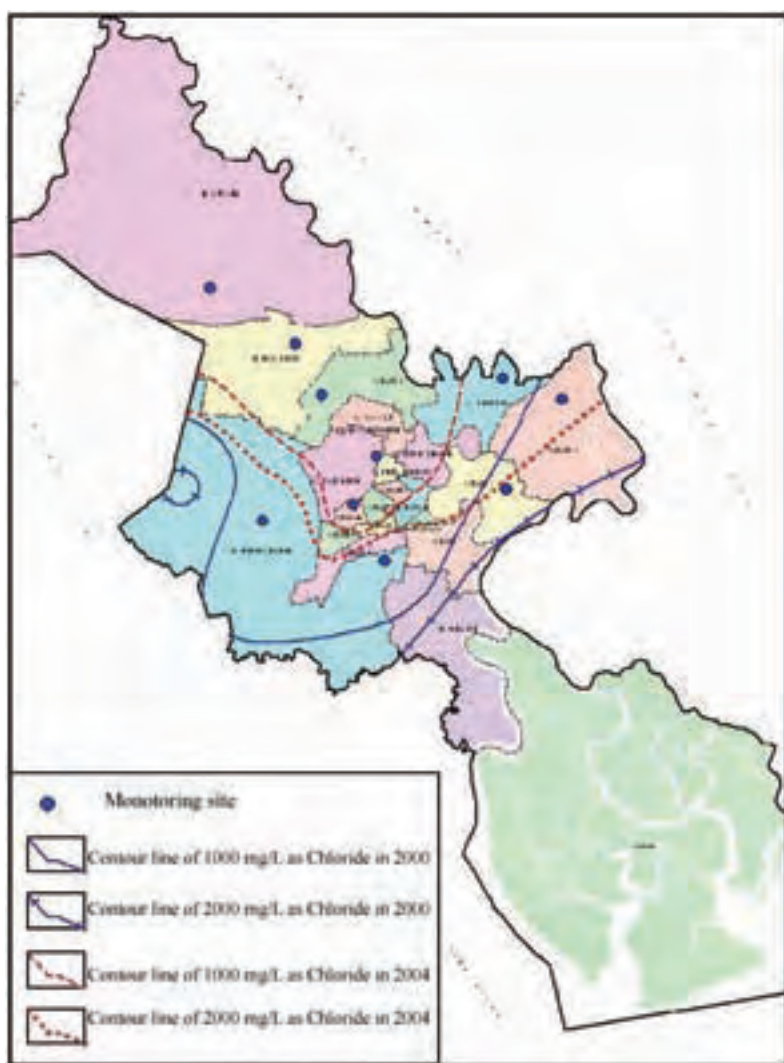
### 3.3 Groundwater Quality

The Union for Geology No. 8 reported that the number of damaged wells which could not be used due to salt intrusion was 2,359: equivalent to 2.48 % of all surveyed wells. Among the 11 monitoring wells, which were set-up under the DOSTE/UNDP project – VIE 96/023 during the first half of 2001, six of them have recorded nitrogen and pathogen-related contamination (nitrate, ammonium and coliform). In comparison to standards in TCVN 5944 – 1995 (Groundwater quality standard), the number of wells which exceeded standards for chlorine and pathogenic pollutants was 2 of 11 wells. Iron concentration of groundwater in HCMC is higher than that of the drinking water quality standards (0.3 mg/l). pH level of most surveyed wells is also lower than that of the Standards (pH < 6.5). The iron concentration in the lower Pliocene aquifer is higher than that of the other aquifers, especially in Cu Chi, Binh Chanh District. Heavy metals (Cu, Pb, Zn, Hg, Cd, Se, Ni and As) are not detected in all aquifers. Although Phenol and Cyanogen concentration still meet groundwater quality standards, they tends to increase with time and should be continuously monitored (Nga, 2006). The coliform contamination happened at some monitoring wells in the Pleistocene aquifer in 2002.

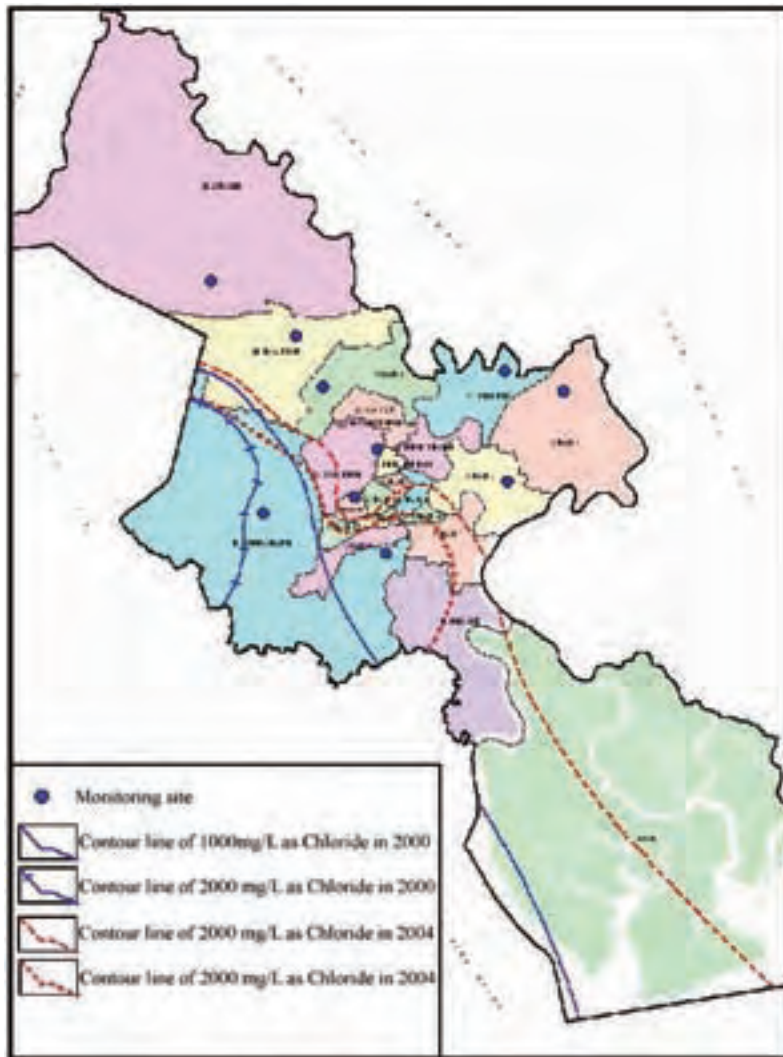
In 2003, among ten samples, coliform level of three samples exceeded the limited value of TCVN 5944-1995. In 2004, among ten samples, the coliform number of six samples was above the limited value. DONRE (2005) reported that Pleistocene and upper Pliocene aquifers were contaminated by coliform due to infiltration of domestic wastewater through wells with poor construction and maintenance.

TOC level of monitoring well ranges from 2.8 mg/l to 81 mg/l in 2004. In general, the average TOC concentration of GW is less than 2 mg/l under an uncontaminated environment (Deborah Chapman, 1995). Therefore, the groundwater in HCMC could be contaminated by organic compounds. The high TOC concentration is found in the following areas (i) Dong Thanh landfill (80.9 mg/l), (ii) Dong Hung Thuan-District 12 (18.1 mg/l), (iii) Bau Cat-Tan Binh (16.7 mg/l), Tan Tao-Binh Tan (13 mg/l) and (iv) Binh Hung-Binh Chanh (12.5 mg/l). TOC values at these locations in 2004 were higher than that of the previous years, while TOC at the other locations were stable.

Figures 11 and 12 show significant changes of isoline of 1,000 mg/l and 2,000 mg/l as chloride in 2000 and 2004, indicating serious salinity intrusion into groundwater sources (Nga, 2006). The isoline is a continuous one joining all points of identical concentration value.



**Figure 11. Map of Chloride Isolines of the Lower Pliocene Aquifer in 2000 and 2004**  
 Source: Nga, 2006



**Figure 12. Map of Chloride Isolines of the Pleistocene Aquifer in 2000 and 2004**  
 Source: Nga, 2006

### 3.4 Policy Measures and their Effectiveness

Groundwater management in HCMC has still been weak due to the following reasons (Nga ,2006): (i) lack of human and financial resources for control and management of ground water exploitation; (ii) weak coordination between relative departments such as DONRE, DI, DARD and DTPW; and (iii) lack of economic instruments for controlled groundwater exploitation (e.g. groundwater exploitation fee, regulations on limitation/prohibition of groundwater exploitation).

To control and protect water resources in terms of both quantity and quality, the Vietnamese Government has issued and implemented several regulations. Protection of quality of groundwater has been mentioned in the Articles 65, 74 and 75 of the *Environmental Protection Law, the Decrees* (e.g. Decree No.149/2004/NĐ-CP issued on exploring, exploiting and utilizing water resources and disposing wastewater to water sources; and Decree No. 34/2005/NĐ – CP about punishments for administrative violation in water resources) and the *implementation guideline documents* (e.g. Decision No. 17/2006/QĐ-UBND dated on 09/02/2006 on promulgating the regulation of water resource management in HCMC). These Articles issue the regulations of groundwater quality control for waste discharging sources and hazardous waste landfills. In addition, groundwater quality standards are given in the Vietnamese standard 5944:1995 issued by MONRE in 1995. A summary of the existing regulations on groundwater management is depicted in table 4.

**Table 4. Summary of the Policy Measures Applicable to Groundwater Management**

Regulation	Status
Guideline on strengthening of management of groundwater exploitation and trade of well drilling	(Under consideration of HCMC PC)
Regulations on water resources management in HCMC	Issued as Decision No.17/2006
Regulations on limitation or prohibition of ground water exploitation in HCMC	Being compiled by DORNE
Draft guideline on collection of resources tax in HCMC based on the Ordinance of Resource Taxes of Ministry of Finance	(Under consideration of HCMC PC)
Draft regulation on collection of groundwater exploitation fee in HCMC	Under compilation by DORNE

Source: Dan, IGES, 2006

## 4. Analysis of Alternative Water Resources to Groundwater

As mentioned above, Ho Chi Minh City is now faced with a shortage and depletion of groundwater and there are efforts to study the alternative water resources of the city.

### 4.1 Principles for Analysis of Alternative Water Resources

The selection of alternative water sources is based on the following criteria:

- i. Water quantity, such as reserve capacity, exploitation rate, ability of water intake and stability of quantity.
- ii. Water quality, i.e. stability of raw water quality and principal key parameters of water quality.
- iii. Water engineering, including water treatment technologies and clean water distribution engineering.
- iv. Water economics, i.e. water exploitation charge, treatment/distribution costs, operation and management costs, and water tariffs.
- v. Water management, compliance with master plans of water uses, management institution, available water sources laws/regulations, community acceptance, water intake ability.
- vi. Risks: subjective and objective risks of projects relating to water sources, exploitation and water use.

Analysis of alternative water sources is shown in table 5. The analysis shows that surface water will be the prioritized alternative water source in comparison to the other water sources in terms of quantity, quality, technology, management, economics and risks. In addition, SWOP analysis for surface water sources is presented in table 6.

Table 5. Analysis of Alternative Water Sources in HCMC

Item	Surface water	Rain water	Brackish water	Reclaimed water
<b>1. Quantity</b>				
<i>Maximum exploitation capacity</i>	Abundant, about 7 million m <sup>3</sup> /day, including 1.56 m <sup>3</sup> /day from Saigon River and 6 million m <sup>3</sup> /day from Dong Nai River.	Abundant, about 4.7 million m <sup>3</sup> . Rainfall ranges from 1,800 to 2,000 mm/year, 80–85% from June-August.	Abundant, especially in the coastal zone (District 7 and Can Gio).	The current wastewater quantity: <ul style="list-style-type: none"> <li>• Domestic WW: 1,100,000 m<sup>3</sup>/day of which 30,000 m<sup>3</sup>/day is treated.</li> <li>• Industrial WW: 32,600 m<sup>3</sup>/day of which 15,100 m<sup>3</sup>/day is treated</li> </ul> Above 2 million m <sup>3</sup> /day in 2020.
<i>Current water exploitation capacity</i>	In 2004, SG River: 300,000 m <sup>3</sup> /day DN River: 850,000 m <sup>3</sup> /day	Applied in the rainy season in some areas, not yet applied in large scale areas.	Currently, the brackish water is only used for aquaculture (shrimp and fish farms)	Unavailable
<i>Ability of water uptake</i>	Easy except duration of salt intrusion (few days in the dry season at Sai Gon River)	Easy (but only in 6 months of rainy season per year)	Easy (full year in coastal zone such as District 7 and Can Gio)	Easy to collect the effluent from the centralized wastewater treatment plants.
<i>Stability</i>	Good	Weak to medium depending on the rainfall	Good	Good
<b>2. Quality</b>				
<i>Safety</i>	Good for conventional treatment technology	Good for conventional treatment technology	Good for desalination technology.	Weak to medium, depending on operation and maintenance of the advanced wastewater treatment system, skill of operators, etc.
<i>Stability</i>	Medium, depending on seasons and pollutant sources	Good	Good	Weak to medium, depending on variation of raw wastewater.
<i>Quality parameters to be treated</i>	Sai Gon River: Low pH, high Mn, Fe, high SS, turbidity, pathogens, organic compounds.	pH, SS, pathogens	Pathogens, SS, high salinity	Non-biodegradable components, COD, trace organics, heavy metals, pathogens, color.
<b>3. Engineering</b>				
<i>Exploitation engineering</i>	Simple to medium depending on soil basement condition, water uptake capacity.	A rain harvesting and storage system requires high investment cost and large area	Simple to medium depending on soil basement condition, water uptake capacity.	Collection of effluents from the centralized wastewater treatment plants is simple.
<i>Water treatment engineering</i>	Conventional treatment: Coagulation-Flocculation-filtration and disinfection.	Conventional treatment: Coagulation-Flocculation-filtration and disinfection	Conventional treatment followed by desalination system.	Advanced treatment such as nutrient removal, SS removal, COD removal, adsorption, advanced oxidation, etc.
<i>Distribution to users</i>	The distribution network is available.	Use the available water distribution network.	Use the available water distribution network.	Separate water distribution networks for wastewater reuse. High investment cost and maintenance cost.
<b>4. Management aspect</b>				
<i>Compliance with the water master plan</i>	Intake capacity in 2010: <ul style="list-style-type: none"> <li>+ SG River: 750,000 m<sup>3</sup>/day</li> <li>+ DN River: 1,250 m<sup>3</sup>/day</li> </ul> Intake capacity in 2020: <ul style="list-style-type: none"> <li>+ SG River: 1,050,000 m<sup>3</sup>/day</li> <li>+ DN River: 2,250 m<sup>3</sup>/day</li> </ul>	The master plan for rainwater is not available yet.	A project on desalination system with capacity of 5,000 m <sup>3</sup> /day prepared by a private company is under approval process.	Reclaimed water is not considered yet in the master plan of water supply in 2020 for aCM City.
<i>Availability of Laws and Vietnamese Standards concerning water resources</i>	The standards and laws are available and clear.	Unavailable for the standards and laws concerning use of rain water for water supply	Unavailable for the standards and laws concerning use of raw brackish water for water supply.	Unavailable for the standards and laws concerning wastewater reuse.
<i>Suitability with the current management institution</i>	Clear, managed by SAWACO, DONRE but weak organization for integrated river basin management.	Not available	Not available	Not available.

**Table 5. (continued)**

<i>Community acceptance</i>	High acceptance	High acceptance	Unknown	Difficult to be accepted due to water quality issue.
<b>5. Risks</b>				
<i>Subjective risks</i>	Water quality may degrade due to organic contaminants, pathogens, toxics by industrial and domestic sources.	Water quality may be effected by acid rains, excreta of animals living in the roof, fields, etc.	Water quality may degrade due to organics, pathogens, toxins by industrial and domestic sources.	Failure of operation and bad maintenance.
<i>Objective risks</i>	Salt intrusion	Lack of water quantity in the drought.		Unstable water quality due to variation of industrial & domestic wastewater.
<b>6. Economic aspects</b>				
<i>Exploitation cost</i>	Medium	High	High	Low
<i>Operation and maintenance cost</i>	Medium	Low	Very high	High to very high, depending on users.
<i>Distribution cost</i>	Medium	Medium	High	High
<i>Water tariff</i>	2,700VND/m <sup>3</sup>	Unknown	Unknown	Unknown

**Table 6. SWOP Analysis of the Surface Water Resources**

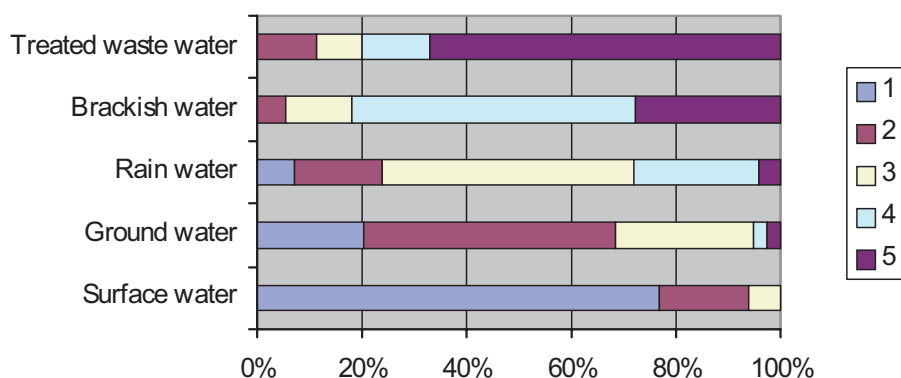
<p><b>Strength</b></p> <ul style="list-style-type: none"> <li>- Quantity of surface water is abundant and stable.</li> <li>- Engineering of water uptake, treatment, distribution are stable and simple.</li> <li>- Surface water use is strongly acceptable by community.</li> <li>- Master plans and monitoring systems are available.</li> <li>- Management institutions are available and experienced.</li> </ul>	<p><b>Opportunity</b></p> <ul style="list-style-type: none"> <li>- To decrease groundwater exploitation rate.</li> <li>- To increase use of surface water and piped water.</li> <li>- To upgrade the distribution networks and increase efficiency in water resource use.</li> </ul>
<p><b>Weak</b></p> <ul style="list-style-type: none"> <li>- It is easily contaminated by pollutant sources.</li> <li>- Water quality is unstable, extruded by salt.</li> <li>- Privation of water exploitation, production and distribution has not developed.</li> <li>- Upstream water quality monitoring system for whole basin is still weak.</li> <li>- Lack of upstream water protection programs.</li> <li>- Freshwater source is limited in the coastal areas such as Can Gio, Nha Be, District 7.</li> </ul>	<p><b>Potentials</b></p> <ul style="list-style-type: none"> <li>- To contribute to the sustainable development.</li> <li>- To increase the competition between users.</li> <li>- To enhance the capability and cooperation between river basin management unit, reservoir management unit, DONRE, DARD and DI.</li> <li>- To control water use demand through the policies and water tariff.</li> <li>- To increase the potential of building dam and reservoir.</li> </ul>

In summary, the total potential of water exploitation per day for Ho Chi Minh city is about 13 million m<sup>3</sup> including 7 million m<sup>3</sup> from surface water, 4.7 million m<sup>3</sup> rain water and 1.3 million m<sup>3</sup> of groundwater. The existing exploited rate is 14.3% for surface water, i.e. 1 million m<sup>3</sup>, and 46% for groundwater, while rain water has not yet been harvested. Therefore, it is noted that in addition to the fresh surface water source, harvested rainfall and brackish water are recommended.

#### 4.2 Summary of Comments from Stakeholder Meeting on Alternative Water Sources

In order to provide a better understanding and to collect ideas from stakeholders on sustainable water resources management in HCMC, a stakeholder meeting on “Alternatives and Policies on Sustainable Water Resources Management” was organized on 26 January, 2007 in Ho Chi Minh City. The questionnaire was designed to collect the participants’ ideas on three main topics: (i) water resource alternatives, (ii) solutions to increase efficiency of surface water resource use; and (iii) measures to improve efficiency of groundwater use.

The results show that the predominant water alternative to groundwater was surface water (figure 13). Based on selection criteria and priority ranking, surface water is given first and second priority, followed by groundwater, rain water and then brackish and reclaimed water.



**Figure 13. Ranking of Water Resource Alternatives based on Stakeholders' Comments**

*Note: 1: first priority; 2: second priority; 3: third priority; 4: fourth priority; 5: fifth priority*

For both short term and long term developments, surface water is regarded as the first priority for water use (i.e. 100% of stakeholders agreed on this priority). Groundwater, in the short term (to year 2020), is regarded as second priority (92%) and third priority (8%), however, for long term planning to year 2030, groundwater was ranked less important compared with brackish water. It is ranked as second, third, fourth and fifth priority by 42%, 33%, 16.7% and 8.3%, respectively. Thus, in long term planning the function of groundwater could be decreased and, consequently, the groundwater demands will be reduced, considering the groundwater resources as the reserved water resources for water safety and emergency cases. Brackish water in the short term plan is regarded as the third (56%) and fourth selection (22%) but in the long term plan it becomes more important and will replace the deduction of groundwater and therefore it was ranked as second priority (33%). Rain water, in the short term, was ranked as third priority (50%) but later the significance of rain water decreased. Reclaimed water was less of a concern due to a lack of wastewater treatment systems and a lack of trust in the quality of treated water under current conditions.

During the meeting, the stakeholders proposed the following solutions for protection and improvement of surface water resources:

- i. Treat pollutants from wastewater sources (33%),
- ii. Control and prevent water pollution (33%),
- iii. Protect water resources (25%),
- iv. Water quality protection measurements (25%),
- v. Develop integrated water river basin management (25%),
- vi. Rationalize water resource uses (25%),
- vii. Reasonably exploit surface water resources within their capacity (17%),
- viii. Control the upstream water quality of Sai Gon - Dong Nai River basin,
- ix. Inter-province and agency cooperation on reservoir management and water exploitation and regulation,
- x. Reduce the water loss rate,
- xi. Increase the awareness of water protection and water uses for local residents,
- xii. Fine strictly the cases causing water pollution,
- xiii. Apply economic tools such as water resources tax and increase water price.

According to stakeholders, the main groundwater consumers in terms of large water exploitation quantity in recent times have been industries, residents living in the areas without piped water supply or rural/suburban areas and poor people. 100% of stakeholders proposed that industries and the residential areas without piped water should pay a water fee of 4,000 and 2,000 VND/m<sup>3</sup>, respectively, whereas, 65% of stakeholders suggested that the maximum water fee should be 2,700 VND/m<sup>3</sup> for rural people. In addition, 25% of them thought that they might stop using groundwater, while 33% of them thought that the poor people may stop using groundwater if the groundwater fee is applied. 42% of stakeholders suggested the water fee for poor people should be 500 VND/m<sup>3</sup> and 16% of them suggested that the maximum water fee for other users should be 3,000 VND/m<sup>3</sup>.



## 5. Issues and discussion on the priority alternative source

### 5.1 Hydrology

Total area of canals and rivers is about 240 km<sup>2</sup>, taking up 12% of the total area of HCMC. The total length of this canal system is 7,885 km. HCMC is at the convergence of Sai Gon and Dong Nai Rivers. Moreover, Vam Co Dong River, which belongs to the Mekong delta, also affects the hydraulic system of rivers and canals in the southwest of HCMC.

The canal and rivers system of HCMC is under the influence of a daily tide with high water level amplitude. HCMC is not significantly influenced by flood. The changes of water level in rivers have been unremarkable between 1960 and the present time. The Dong Nai River water level at Bien Hoa has changed only within 70 cm during the last 50 years. The variation of water level of Sai Gon River at Phu An is low (only 10 cm). When two big floods occurred in 1904 and 1952, the water level at Bien Hoa went up to 4.75 m and at Go Dau was higher than 1 m (up to 2.2 m). Two reservoirs in the upstream of Sai Gon and Dong Nai River are Dau Tieng and Tri An reservoirs, which were constructed for irrigation and hydropower in 1985 and 1989, respectively. These reservoirs help to control the water flow of Sai Gon and Dong Nai Rivers. In dry season, from February to April, Sai Gon and Dong Nai Rivers receive a flowrate of 20–22 m<sup>3</sup>/s and 200 m<sup>3</sup>/s for pushing salt intrusion, respectively.

As per the analysis of surface water availability and the water balance system of the Sai Gon - Dong Nai River basin mentioned above, the conflict of upstream water uptakes and downstream water quality and saline intrusion controls can only be solved when the releases from Tri An reservoir can be maintained at 300 m<sup>3</sup>/s to downstream Dong Nai River, and the releases from Dau Tieng reservoir, with support from 50 m<sup>3</sup>/s water transfer from Phuoc Hoa reservoir (which could be operational by 2010-2012), can be maintained at 40 m<sup>3</sup>/s to downstream Sai Gon River.

### 5.2 Water Use

Water from Hoa An water intake station on Dong Nai River is piped to Thu Duc water treatment plant (WTP) with a capacity of 650,000 m<sup>3</sup>/day. Binh An WTP, which takes raw water from Dong Nai River, has 95,000 m<sup>3</sup>/day. These two WTPs supply clean water to the eastern and center parts of HCMC.

The Sai Gon WTP, with a capacity of 300,000 m<sup>3</sup>/day, (at Ben Than Subdistrict) started at a capacity of 120,000 m<sup>3</sup>/day in 2004 and will be run at the designed capacity from 2007. It takes raw water from Dong Canal of Saigon River and supplies clean water to the western part of HCMC.

The current total volume of raw water taken from both Sai Gon- Dong Nai Rivers is 1,150,000 m<sup>3</sup>/day (including 3.5 m<sup>3</sup>/s from Sai Gon River and 9.8 m<sup>3</sup>/s from Dong Nai River). It will be 2,000,000 m<sup>3</sup>/day (7.3 m<sup>3</sup>/s from Sai Gon River, 14.5 m<sup>3</sup>/s from Dong Nai River) in 2010 and 3,100,000 m<sup>3</sup>/day (10.5 m<sup>3</sup>/s from Sai Gon River, 23.7 m<sup>3</sup>/s from Dong Nai River) in 2020. The intake rate from Dong Canal will be maintained at 3 m<sup>3</sup>/s for the above future periods. The surface water exploitation capacity of 23.7 m<sup>3</sup>/s for water supply on Dong Nai River in drought season does not cause any serious problem to the total flow rate of Dong Nai main river. It is not right to apply this idea to Sai Gon River because the exploitation rate 10.5 m<sup>3</sup>/s is almost one-half of its total flow rate of 28.3 m<sup>3</sup>/s in drought season.

### 5.3 Water Quality

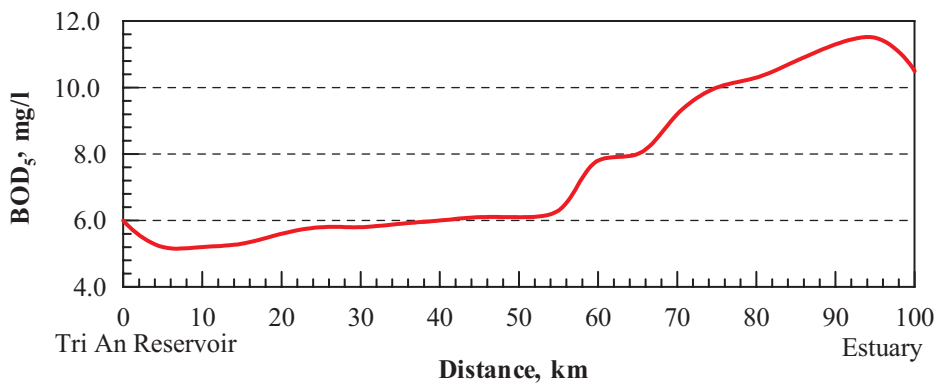
Sai Gon - Dong Nai Rivers play important roles on economical and social development for 12 provinces, especially for the four key zones of economic development including Binh Duong, Dong Nai, Ba Ria Vung Tau and Ho Chi Minh City. Those zones include 54% of the industrial productivity and 60% of exporting value of the whole country. These zones have 47 existing industrial parks and 72 projected industrial zones in 2020, which may seriously threaten the water quality of Sai Gon - Dong Nai Rivers. Only 14 of 47 existing industrial parks have wastewater treatment systems.

Besides industrial parks, there are many tapioca and sugar processing industries with high organic pollutant loads which

are located in the upstream basin of Sai Gon and Dong Nai Rivers. High pollution load from more than 57,000 small-scale industries in the basin is also discharged directly into the rivers.

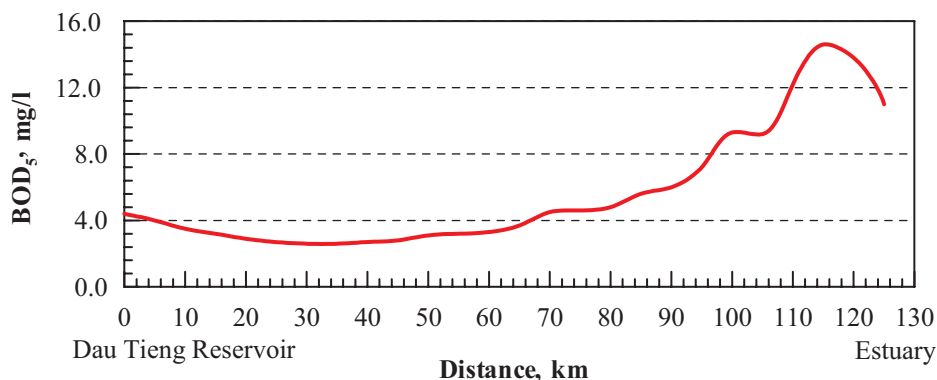
Triet et al. (2005) reported that 44 industries of 47 existing industries discharge 111,065 m<sup>3</sup> of wastewater containing 15 tons TSS, 77 tons COD, 20 tons BOD<sub>5</sub>, 1.6 tons nitrogen and 542 kg total phosphorus daily to Sai Gon - Dong Nai Rivers. Sai Gon River received 27% total volume of industrial wastewater and the maximum BOD<sub>5</sub> amount was 12.5 tons BOD/day (i.e. 63.8% total BOD emitted from industries). Dong Nai River received 35% total volume of industrial wastewater and the highest amount of TSS (6.9 tons), COD (33 tons) and total nitrogen (0.7 tons) per day which is 46%, 43% and 47% of total emission, respectively.

Besides industrial wastewater, domestic wastewater from urban and residential zones and runoffs from agricultural and landfill, animal farms have threatened the quality of surface water. There are about 116 residential areas in the Sai Gon - Dong Nai River basin belonging to four cities, 19 districts of Ho Chi Minh City and 85 towns with a total population of 8,399,338 in 2004, of which the population of HCMC was approximately 74%. Distribution of residential areas is not even among provinces; they are mostly located along Sai Gon River, with 27 residential areas and 5.75 million residents. There were about 1 million m<sup>3</sup> domestic wastewater containing 375 tons TSS, 244 tons BOD<sub>5</sub>, 456 tons COD, 15 tons N-ammonia, 8 tons of total phosphorus, and 46 tons oil and grease, etc., discharged directly to rivers without treatment. Most residential areas, both new and old ones, do not have domestic waste water treatment, and therefore, it results in an increase of organic pollutants and more risks of water-borne diseases related to bacteria and viruses. Sai Gon River received 76.2% of the total volume of domestic wastewater and the highest BOD<sub>5</sub> amount of 243 tons BOD/day (i.e. 66% total BOD emitted from domestics) and 69% of total oil and grease. Downstream, Dong Nai River received 15% of the total volume of domestic waste water and about 18% of total pollutant loads. In addition, there have been pollutants contributed from (i) the 73 solid waste dumping sites without leachate collecting and treating systems, most of which are located near the canals or rivers; (ii) water runoffs from 1.8 million ha agricultural land carrying suspended solids, fertilizer and pesticide residues, acidity from acid sulphate soil into the rivers; (iii) wastes from animal farms and aquaculture farms; and (iv) wastes from accidents due to activities of navigation and ports (about 30 operating ports). Triet et al. (2003) estimated BOD<sub>5</sub> variation with distance from upstream to downstream and time in the figure 14 and BOD<sub>5</sub> in the upstream was less than 5 mg/l, whereas it increased to 10–15 mg/l in the downstream in 2001 in the figure 15.



**Figure 14. BOD<sub>5</sub> Variation along Dong Nai River**

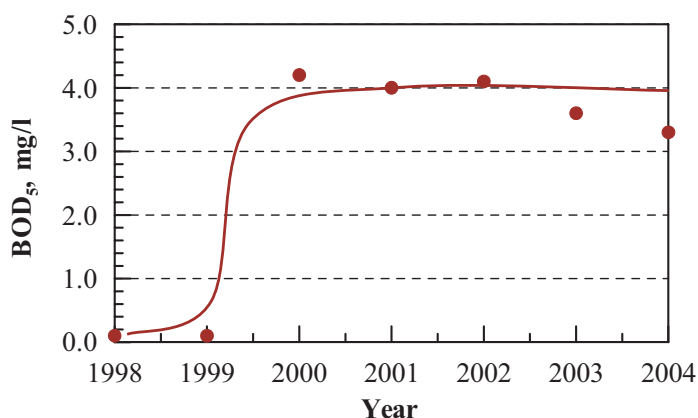
Source: Triet et al., 2003



**Figure 15. BOD<sub>5</sub> Variation along Saigon River**

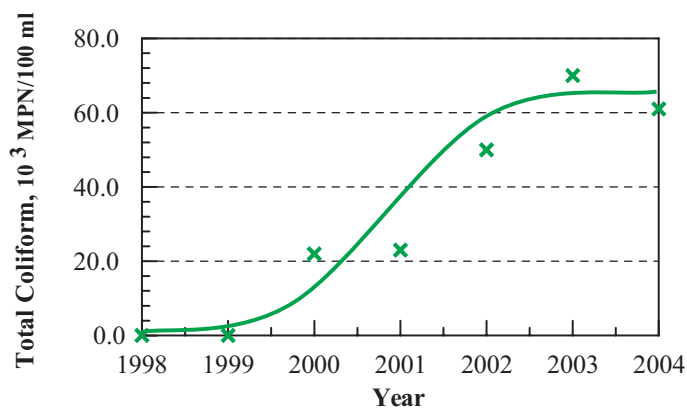
Source: Triet et al., 2003

Monitoring report of HEPA (2004) from eight surface water sampling stations show that Saigon River water is known to be affected by acidic soil, showing slightly acidic pH at Phu Cuong Station, near the water intake for municipal water supply. pH varies significantly and sometimes drops below 5. A sudden change of pH makes water treatment and land development difficult. The exposure of acid sulphate soil to water is suspected to further exacerbate the acidic water problem. Total coliform number increased after 2000, varied significantly in 2003 and remained at a higher level in 2004. The data on total also indicates contamination of Saigon River water due to human activities. Takizawa et al. (2004) showed that Saigon River is more contaminated than Dong Nai River because of human activities and lower flow rate. SS fluctuated between 1 mg/l and 9 mg/l in 2004. Another problem in the last few years was high turbidity in the dry season, which makes water treatment more difficult.



**Figure 16. Variation of Average Annual BOD<sub>5</sub> versus Time at the Hoa An Water Monitoring Station (Dong Nai River)**

Source: HEPA, 2006



**Figure 17. Variation of Average Annual Coliform with Time at the Hoa An Water Monitoring Station (Dong Nai River)**

Source: EPA, 2006

Water quality of Dong Nai River at Hoa An (water supply intake) is also getting affected by discharges from the upstream basin. The water quality survey conducted during this study, of which locations are illustrated in figure 2, shows that BOD<sub>5</sub> varies between 5-9 mg/l. According to Vietnamese standard TCVN 5942-1995, BOD<sub>5</sub> of surface water for domestic water use should be less than 4 mg/l. The result of the monitoring program in 2004 showed that fecal coliforms also exceeded the limit in dry season, especially during low tide.

**Table 7. Water Quality of Saigon-Nha Be River**

Site	Direction	DO (mg/l)	pH (mg/l)	SS (mg/l)	COD (mg/l)	Total P (mg/l)	Total N (mg/l)	Oil and grease (mg/l)	Coliform (MPN/100ml)
Thu Dau Mot (Upstream)	Upstream ↓	4.3 - 4.4	5.9	2 - 5	11	0.08	1.5 - 1.8	0.1 - 0.3	2.10 <sup>5</sup> - 8.10 <sup>6</sup>
Binh Phuoc		5.0 - 5.1	6.2 - 6.4	2 - 3	9 - 11	0.10	2.3 - 2.7	0 - 0.1	15.10 <sup>3</sup> - 9.10 <sup>4</sup>
Nha Rong Harbor		4.2 - 4.6	6.8 - 7.0	4	8 - 9	0.10	2.4 - 3.2	0 - 0.2	1.10 <sup>4</sup> - 5.10 <sup>4</sup>
Sai Gon River estuary		3.3 - 3.4	7.2 - 7.3	9 - 12	12 - 16	0.15	1.6 - 2.2	0.1 - 0.2	7.10 <sup>4</sup> - 12.10 <sup>4</sup>
Binh Khanh ferry	Downstream	3.1 - 3.2	7.7	7 - 25	9 - 23	0.05	1.4 - 1.5	0.1 - 0.2	6.10 <sup>3</sup> - 31.10 <sup>3</sup>
TCVN 5942-1995	Type A	> 6	6.0 - 8.5	20	10	Unavailable	(*)	Not detected	5,000
	Type B	> 2	5.5 - 9.0	80	35	Unavailable	(*)	0.3	10,000

Note: Type A – Water resource for domestic water supply purposes

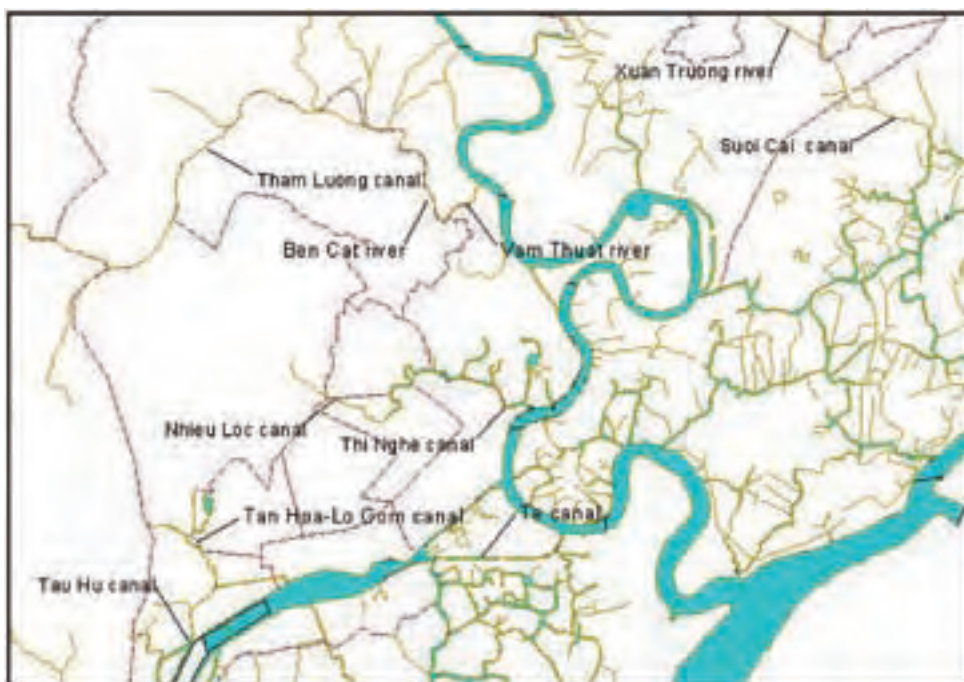
Type B – Water resource for agriculture and navigation purposes

(\*) no standard applied for total nitrogen concentration, however; for Ammonia: 0.05 mg/l for type A and 1.00 mg/l for type B; Nitrate: 10 mg/l for type A and 15 mg/l for type B; and Nitrite: 0.01 mg/l for type A and 0.05 mg/l for type B.

Source: CEFINEA, 2003

Average BOD<sub>5</sub> of Saigon River at Nha Rong was as high as 16 mg/l in the year 1997 compared with 10 mg/l in the year 1993. The water quality survey conducted during this study reveals that the level of pollution in the upstream reaches of Saigon is low, however it is quite high at Nha Rong after receiving wastewater from Tau Hu - Ben Nghe Canal and Doi - Te Canal. BOD<sub>5</sub> at Tan Thuan was found to vary from 30 to 75 mg/l. Fecal coliforms were also about 1.1 E+07 MPN/100ml. Concentration of pollutants in Saigon River is higher than the allowable maximum limit for domestic use/other uses. Saigon River is an important source of aquatic products. If organic pollution is not controlled, DO in Saigon River will be depleted further, making it impossible for fish and other aquatic organisms to survive. The less tolerant migratory fish are unlikely to survive if DO is less than 4 mg/l. Water quality at Nha Be is improved compared with Saigon River. DO is increased to 7–7.8 mg/l. Nha Be is subjected to tidal influences and salinity intrusion and is not a suitable source for drinking water supply.

The dense rivers and canals system, which receives discharge in HCMC, involves five main canal systems. They are Tan Hoa - Lo Gom Canal, Tau Hu - Kenh Te-Ben Nghe Canal, Nhieu Loc - Thi Nghe Canal, Tham Luong - Ben Cat - Vam Thuat River and Xuan Truong - Suoi Cai Canal.



**Figure 18. Main Canal Systems in the Inner City**

It is perceptibly recognizable that all canals in HCMC have been heavily polluted. The bad smell is frequently emitted and is worse at low tides. The monitoring data shows most canals in the inner city are affected by tide. With semi diurnal tidal influence, the tide does not go fully down once it rises, so in the upper parts pollutants are received and accumulated and do not move away. The DO of these canals at the low tide is 0 mg/l and BOD<sub>5</sub> ranged from 120 to 210 mg/l. Water quality is slightly improved at the points near Saigon River. The fecal coliform count of canals at low tide in dry season was  $1.5 \times 10^5$  MPN/100 ml. Domestic wastewater is the main source of pollution for Nieu Loc Canal.

Ammonia-nitrogen concentration is high, ranging from 6 to 29.8 mg/l. Tham Luong – Vam Thuat, Xuan Truong-Suoi Cai and Tan Hoa-Lo Gom Canals have been severely polluted by industrial wastewater. These canals receive industrial effluents. DO is almost depleted in this canal. BOD<sub>5</sub> varies from 100 to 200 mg/l. Fecal coliforms vary between  $1.5 \times 10^4$  -  $2.1 \times 10^6$  MPN/100 ml. High coloration of the canal water is due to direct discharge of effluents from textile and dyeing industries. BOD<sub>5</sub> ranges from 180 to 360 mg/l. The solids of the wastewater are settled down and accumulated in the canal beds. The canals are in an anaerobic phase and emanate a bad smell of CH<sub>4</sub> and H<sub>2</sub>S during low tide.

The daily wastewater quantity discharged into the canals in HCMC was 710,000 m<sup>3</sup>/day in 2000 and will be 2,100,000 m<sup>3</sup>/day in 2020. The BOD<sub>5</sub> load was 170 tons/day in 2000 and projected load will be 380 tons/day in 2020. In addition, the domestic and industrial wastewater of 729,000 m<sup>3</sup> with a pollution load of more than 193,000 kg in terms of BOD<sub>5</sub> is discharged daily to rivers and canals in the Study Area without any treatment. At present, about 30,000 m<sup>3</sup>/day of domestic wastewater and 15,000 m<sup>3</sup>/day industrial wastewater from 5 of 15 industrial parks in HCMC are conventionally treated.

## 5.4 Piped Water

The existing water distribution network has a total length of 32.811 km. In 2001, 75% of the population in the urban area was supplied with clean water. The water consumption was between 50 and 100 liters/capita/day. In the suburbs, except for Cu Chi and Can Gio Districts, 21% of the population is supplied with water at a consumption of 20 to 40 liters/capita/day. The report of Master Plan of Water Supply System in HCMC (2005) showed that the percentages of piped water for domestic, industrial and commercial purposes are 71.5%, 22% and 6.5%, respectively. The average ratio of the population supplied clean water is 75%, and the water loss is now 35–37%. The forecasted ratio of piped water, water loss and water capita are shown in the Table 3.2. The target of Sai Gon Water Supply Company is to decrease water loss to 26% and increase 25–30% piped water in the next 10 years. This is one of the great challenges.

**Table 8. The Forecasted Ratio of Piped Water Supply, Water Loss and Water Demand**

Items	Year		
	2005	2010	2020
Domestic water demand (l/capita/day)	160-180	180-200	200-220
Ratio of piped water supply (%)	75	95	100
Water loss (%)	37	26	Unavailable

Source: VIWASE, 2004

## 6. Challenges and Recommendations to Water Resources Management

### 6.1 Main Challenges to HCMC Water Supply

Based on analysis of the state and the issues of water resources in HCMC, the study identified the seven main challenges for water resources management that are directly related to water supply for HCMC as follows:

- i. Cooperation on water regulation of integrated rivers and reservoirs systems.
- ii. Control industrial pollution.
- iii. Control surface water quality.
- iv. Limitation of groundwater use and rationalization of groundwater uses among sectors.
- v. Control salinity intrusion of groundwater sources.
- vi. Decrease rate of water loss, accompanied by development of water distribution system.
- vii. Enhance awareness of water saving and conservation for public, communities and enterprises.

### 6.2 Policy Recommendation for Better Water Resources Management

Not only to overcome the seven challenges of HCMC water supply but also to achieve the sustainable water resources development, the study has proposed six recommendations (numbers 1 to 6) in short-term planning and two recommendations (numbers 7 and 8) for long-term planning. The recommendations were proposed based on the situation and future analysis taken into account of the existing Vietnamese water regulations and laws and the national development strategies. The main strategies and policies are used in follows:

- The national environmental protection strategies in the period 2001–2010.
- HCMC environmental management strategies to 2010.
- The plan of groundwater use in HCMC to 2010.
- The surface water protection strategies in HCMC to 2010.
- The master plan of water supply in HCMC to 2020.
- The master plan of drainage system in HCMC to 2020.

The main objectives of those strategies are to improve water resources management, including (i) to protect groundwater resources by reduction of the exploitation rate to a value of below 500,000 m<sup>3</sup>/day by 2010 and (ii) to improve the quality of surface water of the Dong Nai & Sai Gon Rivers upstream. The water quality should be reached the National Standard TCVN 5942–1995–class A by the year 2015.

**Implementation of Integrated Basin Water Resources Management:** As mentioned above, the Sai Gon - Dong Nai River Basin Organization (RBO) was established in 2003 and has been operating for four years. However, it is likely that they only exist on paper and work inefficiently. On 31 May, 2005, the roundtable meeting among provinces and HCMC was organized and chaired by the Minister for Environment and Natural Resources and the Vice Chairman of Ho Chi Minh City People's Committee to propose the cooperation mechanisms on environmental protection in Sai Gon-

Dong Nai River basin. Therefore, it is necessary to:

- i. Enact and push up activities of SG-DN RBO. Unanimously manage water resources and water regulations.
- ii. Establish the cooperation mechanism and continue to organize the round-table meetings regularly to share information, responsibilities and rights of use and protect water resources in Sai Gon - Dong Nai River systems among the provincial stakeholders, experts, researchers and decision makers.
- iii. Maintain and develop the information systems for SG-DN basins. The basin information system can consist of maps, charts, databases, electronic data, basin profiles relating to water resources and other economic and social activities affecting water exploitation and use in basin. That information could be used for setting up sustainable water resources management.

#### **Control of pollution emission:**

- i. Relocate the polluting industries into industrial zones and limit the wet industries in Sai Don-Dong Nai basins.
- ii. Set up and enforce the operation of centralized wastewater treatment plants in industrial zones.
- iii. Encourage enterprises to apply cleaner production, save water and use reclaimed water.
- iv. Develop the model of sustainable green city in Sai Don-Dong Nai basins.
- v. Enhance the implementation of integrated pesticide management (IPM), integrated nutrient management (INM) for agriculture and breeding.

#### **Limitation of groundwater use:**

- i. Apply the groundwater charge system for groundwater exploitation for different target groups. The industrial sectors will be applied at the highest rate of groundwater fee to encourage the enterprises saving water.
- ii. Enforce the implementation of water regulations on zoning the risk, vulnerable or exploited areas of groundwater sources, for example, the Decree No. 149/2004-NĐCP, dated 27/07/2004, about regulations for issuing licenses for water resource exploitation and emission to water sources; the Decree No.34/2005-NĐCP about regulations of administrative penalty for contaminating water resources; the Decision No. 17/2006/QĐ-UBND dated 09/02/2006 about promulgating water resource management in HCMC.
- iii. Set-up and implement the pilot programs of groundwater recharging with the preliminary treated run-offs.

#### **Reduction of the water loss rate due to the improvement of water projects and services:**

- i. Prioritize and call for investments on water development projects (for example projects to improve the water loss rate and to extend water distribution system) as well as wastewater treatment and water supply projects.
- ii. Re-organize the public water services, transfer the irrigation management to water use association.

#### **Upgrade water tariff:**

- i. The current water tariff needs to be reviewed and upgraded. The existing water-production price contains the cost of property depreciation (65%), the electricity cost (10%), the labor cost (10%) and the operation and management cost (15%). Therefore, the government should stimulate and favor water development projects and, in consequence, the cost of property depreciation due to water production could be reduced, resulting in reduced water production prices.
- ii. A special water price for poor people, i.e. people who use less than 2 m<sup>3</sup> water/capita/month, should be applied. (The World Bank's standard is 1.2 m<sup>3</sup>/capita/month.)
- iii. Set up and enforce economic tools for water management such as water resource tax, water use and conservation fee, groundwater fee.

#### **Encouragement of water saving and reasonable water use:**

- i. Stimulate applying the cleaner production technology and recycling water in industries.
- ii. Encourage using reclaimed water or recycling water for such services as hotels, office buildings and other entertainment facilities such as water parks, swimming pools, fishing clubs, etc.
- iii. Enhance the awareness of water saving and environmental protection in the community.

**Enforce to recycle water and use reclaimed water for industries and agricultural activities**

**Stimulate the use of harvested rain water for domestic purposes and reclaimed water for industries and agriculture and brackish water for aquaculture as the supplementary water resources**

## 7. Conclusion

- (1) Groundwater management strategy, a part of Ho Chi Minh City environmental management strategies up to the year 2010, approved by Ho Chi Minh City People's Committee, expresses the major subjects for water resource management in Ho Chi Minh City, including surface water and groundwater as well as other matters of urgency:
- Over exploitation of ground water which has limited reserve,
  - The surface water source of Sai Gon and Dong Nai Rivers becoming gradually polluted,
  - The close relationship between surface water and ground water in water exploitation and water recharging balance.

The main objective is ground water preservation by reasonable exploitation and the use of ground water, controlling the abstraction rate at less than 500,000 m<sup>3</sup>/day and minimizing the adverse impacts on ground water such as ground water contamination, salt intrusion, drawdown of ground water level, and land subsidence.

- (2) To achieve sustainable groundwater management, the alternative water sources should be focused on for future water use. Through SWOP analysis (analysis of strengths, weakness, opportunities and potentials), situation analysis and expertise analysis, water from Sai Gon and Dong Nai Rivers is the priority selective source. Although the SG-DN River basin has plentiful water, water quality has gradually declined due to conversion of land use, agricultural and industrial activities and rapid urbanization and especially poor management. This results in adverse effects on the fresh surface water used for water supply to HCMC. Strategies on protection of surface water resources, including water use and management of urban sewerage system of HCMC, were issued and step by step developed the implementation through the action plans. However, this implementation has faced some difficulties, such as the lack of financial sources, the weakness of capacity of integrated management, and the poor coordination between authorities of neighboring regions.
- (3) The study has proposed eight main policy recommendations for Ho Chi Minh City to overcome the barriers and challenges of future water use and to achieve better water resources management. Many efforts need to be spent to implement those policies. The policies on the integrated basin water resources management and the pollution control are critical and urgent.
- (4) Rain water or reclaimed water in suburban areas where the piped water or fresh water is not available may be the alternatives for domestic and industrial uses. Desalination of brackish water in Can Gio province's coastal zone will be one of the feasible alternatives.



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