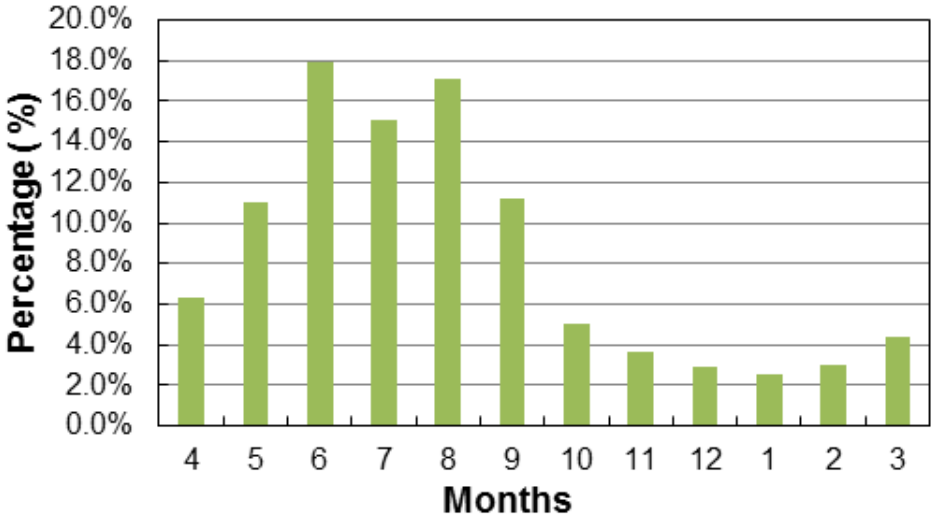
SUMMARY WATER BALANCE ASSESSMENT

I. Water Resource Assessment in Chaonan District

A. Natural Condition

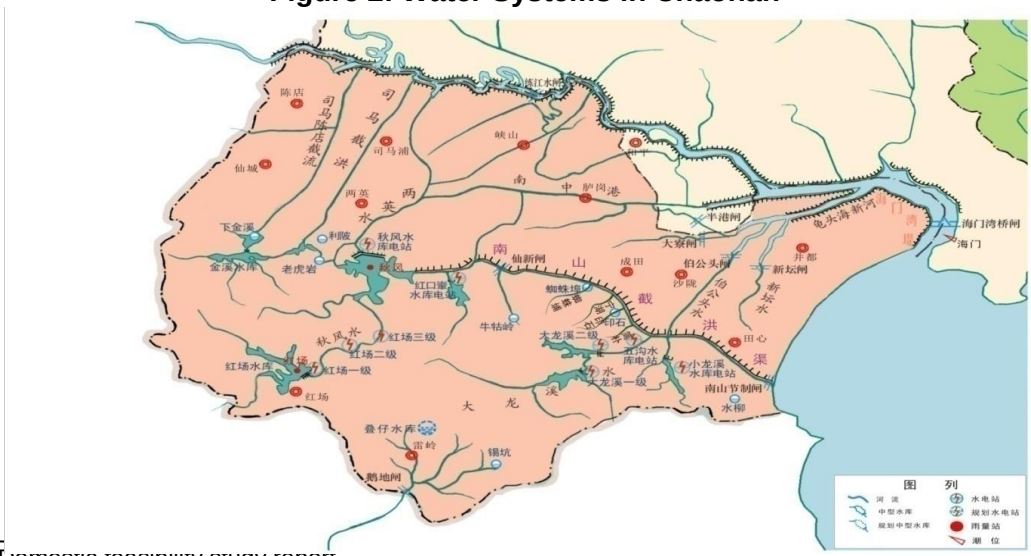
1. Chaonan District (Chaonan) is a county-level administrative division of Shantou Municipality, Guangdong Province. About 30 kilometers (km) away from the Shantou City center, Chaonan, which administers 232 villages in 11 towns, is a plain area with hills in the northeast and coastlines along the east. The annual precipitation in Chaonan District ranges about 1,773–2,100 millimeters (mm) with the mean of 1,830 mm. The mean annual depth of runoff is about 831–1,186 mm. The runoff flows into the South Ocean at last with the runoff rate of about 0.5–0.6. The monthly distribution of runoff of the seven major medium-sized reservoirs in Chaonan is uneven. During May–September, the mean monthly runoff accounts for 72% of the total (Figure 1).

Figure 1: Monthly Runoff from 7 Major Reservoir in Chaonan



Source: Domestic feasibility study report.

Figure 2: Water Systems in Chaonan



Source: Domestic feasibility study report.

B. Available Water Resources[1]

1. Rivers

2. **Leiling River.** Leiling river originates from Leiling Mountain and has three branch streams joining together at Shuangxi Village in Leiling Town. It runs across Shenquan Port in Huilai County and enters into the South China Sea. The length of Leiling River is 26 km with a catchment area of 444 square kilometers (km^2), of which 61 km^2 or 13.7% of the total catchment area is in Chaonan. The total average annual flow of the river is 11 million cubic meters (m^3).

3. **Lian River.** Lian river originates from Danan Mountain with two branch rivers. It enters into the South China Sea through Haimen Port. Lian River has a length of 94.5 km with a catchment area of 1,353 km^2. Chaonan is located in the middle to downstream of the river, including the catchment area of 838.5 km^2, which accounts for 62% of total. The water from both rivers are drawn for mainly agricultural irrigation. Lian River has abundant run-through water of about 1.0 billion m^3 in an average rainfall year (the maximum river flow is 1,324 m^3/second), but suffers from severe industrial and domestic wastewater pollution due to rapid economic development and population growth in recent years.

4. In 2011, the amount of water taken from these rivers were 43.3 million m^3; a gravity irrigation by 8.5 million m^3 and a pump irrigation by 34.8 million m^3.

2. Groundwater

5. Chaonan has abundant groundwater resources, with an annual allowable exploitation of 32 million m^3. It is especially available in the lower plain area. In 2010, 16.8 million m^3 was extracted for mainly domestic and industrial uses. However, groundwater in Chaonan contains high fluorine content (> 8 milligram/liter [mg/L] in some areas compared with the national limit[2] of 1.0 mg/L) which causes widespread dental fluorosis and skeletal fluorosis. At present, there are almost 230,000 people (42 villages, 8 towns) having access to high fluorine content groundwater The groundwater is not suitable for domestic use (i.e., household and industry) and the Chaonan district government (CDG) is planning to gradually phase out the use of groundwater.

3. Reservoir

6. There are 143 reservoirs and ponds in the district, with a combined catchment area of 221.6 km^2 and total storage capacity of 226 million m^3. Seven are large- and medium-sized reservoirs with total catchment areas of 163.6 km^2 and total storage capacity of 188.0 million m^3. Sixty-five are small-sized reservoirs with a total catchment area of 50.3 km^2 and total storage capacity of 36.0 million m^3. The remaining 71 are ponds with a total catchment area of 8.9 km^2 and total storage capacity of 2.5 million m^3.

7. Among seven large- and medium-sized reservoirs, three reservoirs, Qiufeng, Jinxi, and Longxi, are the major drinking water sources in Chaonan. The water storage capacity of Qiufeng, Jinxi, and Longxi reservoir is 58.3 million m^3, 19.6 million m^3, 53.2 million m^3, respectively. They have a total catchment area of 116.6 km^2, and the water storage capacity of the three water systems is 82% of the total in Chaonan. The average annual inflow of water into these three reservoirs is 260 million m^3. The water quality in these reservoirs is generally good (Class II),[2] but soil erosion occurs in some catchment areas and eutrophication risk is increasing due to nonpoint source pollution from agricultural activities.

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[1] Shantou Water Resources Bureau. 2012. *Shantou City Water Resource Report*. Guangdong.
[2] The PRC's Drinking Water Quality Standard (GB5749-2006).

4. Han River Water Diversion Project

8. According to the East Guangdong Water Supply Plan, the Han River Water Diversion Project is planned in Shantou Municipality. The project will transfer 100,000 m^3/day of treated water to Chaonan for addressing its water scarcity problem. The project will be completed and start its operation in 2020.

5. Nanshan Flood Diversion Project

9. The Nanshan Flood Diversion Project is a large-scale comprehensive water conservancy project. The project has a total catchment area of 216.6 km^2, among which 161.9 km^2 are controlled by seven medium-sized reservoirs, 17.9 km^2 are controlled by six small-sized reservoirs, and 36.8 km^2 are the interval catchment area. It gives priority to flood diversion and water logging, and then to integrated utilization of irrigation, transportation and drinking water for people and livestock in Chaonan. The project is located in the south of the district, on the right bank of the Lian River. It starts from the flood release tunnel in the west of the Jinxi Reservoir, passes the Lipo Reservoir in the east, collects the water into the Qiufeng Reservoir, and collects water from sub-water systems of the Hongkoushe Reservoir, the Longxi Reservoir, and the Xiaolongxi River, and then enters the South China Sea in the end. The mean annual runoff volume is about 12.3 million m^3. The project will provide additional water resource for agricultural irrigation in the Longxi Irrigation District.

C. Projection of Available Water Resources

1. Reservoir

10. The seven large- and medium-sized reservoirs are considered as the main water sources of Chaonan, namely upper Jinxi reservoir; Longxi first reservoir, Longxi second reservoir, Xiaolongxi reservoir, Qiufeng reservoir, Hongchang rservoir, and Wugou reservoir with a catchment area of 20.3 km^2, 36.0 km^2, 43.8 km^2, 9.2 km^2, 80.0 km^2, 35.0 km^2, and 5.1 km^2, respectively. The observation data of monthly precipitation, monthly reservoir water level, and outflow water from reservoirs in last 30 years (1979–2011) are used for the analysis. The annual runoff data has a basic complete hydrological cycle with a synchronous cycle in wet years, normal years and drought years. For example, the periods of 1982–1986, 1996–1998, and 2006–2009 are wet years, 1990–1995 are normal years while the periods of 1987–1989 and 2002–2005 are drought years. The inflow water to reservoirs with a basic synchronous process shows that the data has a good representativeness. The projection of water resources availability in these reservoirs was calculated by using the mean annual runoff in 1979–2011. After the projection, the mean annual runoff is 25.6 million m^3 in Jinxi reservoir system, 65.5 million m^3 Qiufeng reservoir system and 52.7 million m^3 in Longxi reservoir system. The seven reservoirs are interconnected and can be considered as the three main reservoir systems (Table 1).

Table 1: Observation Data Availability in Three Main Reservoir System

Reservoir	Reservoir System	Hydrology Data	Available Data Series	Selected Data Series
Upper Jinxi reservoir	Jinxi	Monthly precipitation, Monthly inflow, Monthly outflow,	1982–2011	1982–2011
Qiufeng reservoir	Qiufeng		1980–2011	1979–2011
Hongchang reservoir			1979–2011	
Longxi first reservoir	Longxi		1979–2011	1982–2011
Longxi second reservoir			1979–2011	
Xiaolongxi reservoir			1982–2011	

Source: Domestic feasibility study report.

2. Other Resources

11. Projections on other water resource are based on CDG's policies:
    (i) **Leiling and Lian rivers.** The amount of water taken from these rivers is 43.3 million m^3 in 2013–2019 (i.e., 8.5 million m^3 by gravity irrigation and 34.8 million m^3 by pump irrigation). The amount will become 34.8 million m^3 from 2020 onwards because gravity irrigation will be stopped after 2020;
    (ii) **Groundwater.** Groundwater use is gradually and proportionally phased out from 16.8 million m^3 in 2011 to zero in 2020;
    (iii) **Han River water diversion.** The domestically-financed project will be completed in 2019 with designed water supply capacity of 36.5 million m^3 per annum.
    (iv) **Nanshan flood diversion.** The domestically-financed project will be completed in 2019. Smaller reservoirs will be developed as new water resources with the mean annual runoff volume of about 12.3 million m^3.

D. Projection of Water Use

1. Agriculture

12. CDG is making continuous effort to improve the water use efficiency in agriculture production. Two important upcoming projects include (i) the Program of Irrigation Districts Reconstruction and Upgrading under the Medium-Sized Irrigation Districts and Water Conservation and Continuing Construction Planning in Guangdong Province (2011–2015), and (ii) the Program of the Demonstration Pilots on the Construction of Water Conservation Society in Chaonan. The baseline assumptions are determined by referring to the relevant policies and targets of CDG:

    (i) No changes in the total area of irrigated agricultural lands or crop structures during 2013–2030;
    (ii) The irrigation water use efficiency rate of agriculture will improve from 0.47 (2013–2017) to 0.57 (2018–2019), and then gradually increase from 0.65 (2020) to 0.70 (2025) and 0.75 (2030);
    (iii) The water use efficiency of irrigation for economic crops will keep at 0.8 due to the government's promotion to high-efficiency irrigation (e.g., drip/sprinkler irrigation);
    (iv) In three major agricultural irrigation districts, average water consumption for agricultural irrigation will drop by 30% in Jinxi irrigation district and Longxi irrigation district, and nearly 20% in Qiufeng irrigation district in 2025 compared to those in 2013. The average water consumptions of the agricultural irrigation are:
        a. From 10,807 m^3/hectare (ha) (720 m^3/mu) in 2013 to 7,882 m^3/ha (521 m^3/mu) in 2025 in Jinxi irrigation district;
        b. From 6,257 (417m^3/mu) in 2013 to 5,099 m^3/ha (340 m^3/mu) in 2025 in Qiufeng irrigation district; and
        c. From 9,442m^3/ha (629 m^3/mu) in 2013 to 7,005 m^3/ha (467 m^3/mu) in 2025 in Longxi irrigation district.

2. Domestic

13. **Capacity of water supply systems.** In Chaonan, both domestic and industrial sectors are receiving the treated water from its water supply system. In 2013, the Chaonan's water supply system comprised of mainly five water treatment plant (WTP) with total

treatment capacity of 49.3 million m^3 per annum.[3] Under the assumption, the project component of upgrading and constructing WTPs will be completed, and will start their operation in 2018. After the project completion, the Chaonan's water supply system will be integrated into a single system, with three large WTPs of Qiufeng WTP, Jinxi WTP, and Longxi WTP. The system capacity will increase to 102.9 million m^3 per annum. Instead, three existing small and outdated WTPs of Jindu WTP, Chengtian WTP, and Tianxin WTP will be closed down at the project completion.

14. **Baseline assumptions.** Based on the historical data, the following assumptions are used in the projection:

(i) Total population increase rate of 0.8% per annum during 2011–2025;
(ii) Urbanization rates (portion of urban population) in the plain area is 20% in 2011 and will reach 75% in 2025;
(iii) Percentage of people who have access to water supply system will increase from 80% for urban population and 63% for rural population in 2011 to 95% for both urban and rural population in 2025;[4]
(iv) Water consumption rates are: 135 liters (L) per day per capita (L/day/capita) for urban people and 72 L/day/capita for rural people in 2011, and 123 L/day/capita for urban people and 77 L/day/capita for rural people in 2025;[5]
(v) Non-revenue water is estimated at 50% (40% leakage and 10% uncounted) in 2011 and it will gradually reduce to 30% (20% leakage and 10 uncounted) in 2025; and
(vi) Water transfer to Chaoyan District will reduce gradually from 5.1 million m^3 in 2011 to 2.2 million m^3 in 2025.

3. Industry

15. **Baseline assumptions.** Based on the statistics, Chaonan's gross domestic product (GDP) is CNY179.0 billion and its added-value was CNY110.0 billion in 2010. CDG expects the GDP to reach to CNY679.7 billion in 2025 (Table 2).

Table 2: Chaonan's GDP in 2010 and 2025
(CNY billion)

Main Economic Index	2010	2025
Agriculture added value	9.8	34.0
Industry added value	110.8	353.5
Manufacture	109.6	282.1
Construction	1.2	71.4
Service added value	58.4	292.3

Source: Domestic feasibility study report.

16. The same as the domestic sector, the industrial sector is generally supplied by district's water supply system. However, based on the actual statistics, it is assumed that

[3] This comprised of Qiufeng WTP, 70,000 m^3/day; Jinxi WTP, 40,000 m^3/day; Jindu WTP, 10,000 m^3/day; Chengtian, 10,000 m^3/day; and Tianxin WTP, 50,000 m^3/day.

[4] Based on the field survey during the project processing technical assistance (PPTA), there were 80% of urban people and 63% of rural people in the plain region who have an access to water supply in 2013.

[5] Nonrevenue water (NRW) is not considered in the figures of water consumption rates of urban and rural population. If the NRW is considered, the water consumption rates are 202 L/day/capita for urban population and 108 L/day/capita for rural population in 2011, and 160 L/day/capita for urban population and 100 L/day/capita for rural population in 2025, respectively. The figures are consistent to the Shantou Water Supply Bulletin (footnote 3). Due to constraint of water supply, actual water consumption rates of urban and rural people in Chaonan is assumed much smaller than the figures. The 2011 household survey indicated that the net domestic water consumption of urban (excluding public water use) and rural residents were both at 75 L/day/capita.

some industries are using other water resources (e.g., groundwater, river water and sea water). The following assumptions are used in the projection:

(i) Industrial added-value is increase by 7.0% per annum;
(ii) Proportion of industry added-value is 60% in 2011 and 45% in 2025 of the GDP;[6]
(iii) Water consumption rate is: 28 m^3 per CNY10,000 added-value in 2011 and 12 m^3 per CNY10,000 added-value in 2025.[7]

4. Environment

17. The actual water resource allocation of 12.8 million m^3 in 2011 was used for future projection.

E. Assessment

18. Based on the available water resource and the projection of water consumption in Chaonan, their water resource demand and supply relationship was analysed (Figure 3 and Table 3). The results compare water resource availability (area chart) with the total water resource consumption (line chart) in 2013–2030. During 2013–2017, the projected water consumptions from the domestic and industrial sectors are stable at 53.3 million m^3 per annum because of the limited capacity of the Chaonan's water supply system. When three project WTPs are completed in 2017 and start their operation in 2018, the capacity of the water supply system will enable to accommodate the water resource requirement from these two sectors. The figure suggests that Chaonan has enough water resources to meet its water resource requirement in 2013–2030. The analysis also concluded that (i) increasing capacity of the water supply system under the project is adequate;[8] (ii) amount of water resource in Chaonan can meet its demand without the Han River Diversion Project until 2025.

19. Based on the historical annual runoff data, a bottom-up approach was used to project the total water resource availability and its consumption.[9] It must be noted that the results are derived from a combination of facts and assumptions: (i) annual water resource availability of the three reservoir systems were based on the last 30 years historical average; (ii) all domestic and industrial water are supplied through the water supply system (i.e., WTPs); (iii) based on the actual water use in 2011, various baseline assumptions were considered in both water resource availability (e.g. phasing out groundwater use and irrigation from Leiling/Lian rivers, and completion of two water resource related projects) and water consumption (e.g. improving agricultural irrigation water use and industrial water use efficiencies).

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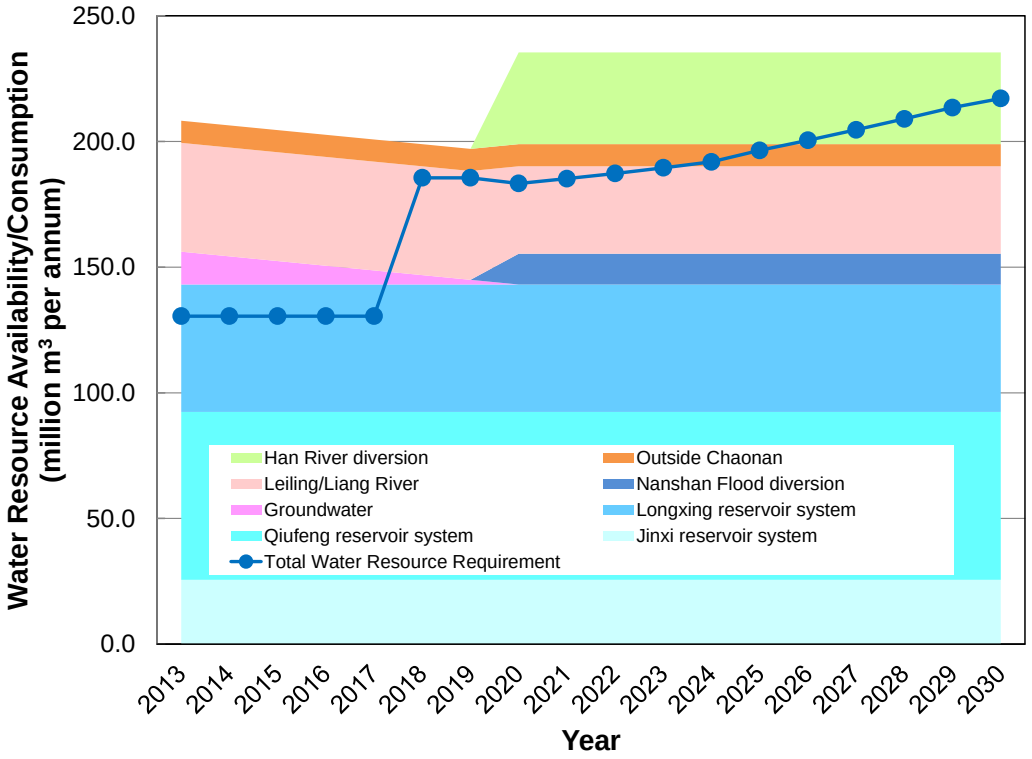
[6] This assumption is equivalent to the GDP growth of Chaonan as 9.3% per annum during 2011–2025. The Chaonan's GDP growth in 2006–2010 was 12.2 % per annum. Given the PRC's general economic forecast and GDP target of 7.0%–7.5%, the figure is considered reasonable.

[7] NRW is not considered in the figures of water consumption rate. If the NRW is counted, the water consumption rates are 42 m^3/CNY 10,000 added-value in 2011, and 16 m^3/CNY10,000 added-value in 2025, respectively.

[8] See an increase of water resource requirement between 2017 and 2018 in Figure 3.

[9] There is a discrepancy in the statistic data (top-down data) and the projection using the bottom-up approach. According to the Shantou Water Bulletin, the total amount of water supply in Chaonan was 258.0 million m^3 in 2010, among which 197.6 million m^3 from reservoirs (76.6%). The difference is the amount of water drawn from the reservoir systems, which the analysis based on the last 30 years historical average indicates 143.1 million m^3.

Figure 3: Water Resource Availability and Water Resource Consumption Projection in Chaonan



Source: Asian Development Bank estimates.

Table 3: Water Resource Availability and Water Resource Consumption Projection in Key Years (2011, 2015, 2020 and 2025)

(million m^3 per annum)

	2011	2015	2020	2025
A. Water Resource Availability				
1. Reservoir systems				
Jinxi reservoir system	25.6	25.6	25.6	25.6
Qiufeng reservoir system	66.8	66.8	66.8	66.8
Longxi reservoir system	50.7	50.7	50.7	50.7
2. Other sources				
Leiling/Lian rivers	43.3	43.3	34.8	34.8
Groundwater	16.8	9.3	…	…
Outside of Chaonan	8.8	8.8	8.8	8.8
Han River Water Diversion project	…	…	36.5	36.5
Nanshan Flood Diversion project	…	…	12.3	12.3
Total Water Resource Availability	**212.0**	**204.5**	**235.5**	**235.5**
B. Water Demand				
1. Agricultural irrigation	64.4	64.4	51.5	49.1
2. Water consumption through WTPs	53.3	53.3		
Domestic use			39.7	55.4
Industrial use			34.7	35.5
Transfer to Chaoyan District			2.9	2.2
Nonrevenue water[a]			28.1	27.9
3. Environment	12.8	12.8	12.8	12.8
Total Water Demand	**130.5**	**130.5**	**187.3**	**196.5**
C. Balance (A–B)	**81.5**	**74.0**	**52.1**	**39.0**

(…) = data not available, WTP = water treatment plant.

[a] Includes leakage and uncounted water.

Source: Asian Development Bank estimates.

II. Water Demand and Supply Assessment in the Plain Area

20. A demand and supply relationship of the water supply system in the plain area was also assessed to justify the proposed capacity of three WTPs. Using the same baseline assumptions (paragraphs 19 and 20), the demand-supply relationship of the water supply system is in Table 4 and Figure 4.

Table 4: Domestic Water Demand-Supply Relationship of the Water Supply System of the Plain Area in Key Years

	2011	2015	2020	2025
A. Water Supply				
1. Water treatment plant capacity (m^3/day)				
Jinxi WTP	40,000	40,000	40,000	40,000
Qiufeng WTP	70,000	70,000	142,000	142,000
Jingdu WTP	10,000	10,000	…	…
Chengtian WTP	10,000	10,000	…	…
Tianxin WTP	5,000	5,000	…	…
Longxi WTP	…	…	100,000	100,000
2. Water storage capacity (m^3)	11,000	11,000	37,332	37,332
Total Water Supply Capacity (m^3/day)	**146,000**	**146,000**	**319,332**	**319,332**
B. Water Demand				
1. Domestic use				
a. Total population (people)	1,255,117	1,295,765	1,348,432	1,433,014
Percentage population with water supply (%)	65	71	83	95
b. Urban population (people)	251,023	378,064	630,782	1,074,761
Percentage population with water supply (%)	79	82	88	95
Per capita daily water use (little/capita/day)	135	131	127	123
c. Rural Population (people)	1,004,094	917,701	717,650	358,254
Percentage population with water supply (%)	61	67	79	95
Per capita daily water use (little/capita/day)	72	73	75	77
Subtotal domestic use (m^3/day)	**65,937**	**80,635**	**108,807**	**151,844**
2. Industrial use				
Industrial added value (CNY million)	11,908	15,740	22,309	31,618
water use (m^3/CNY10,000 added-value)	28	22	16	11
Subtotal industrial use (m^3/day)	**91,349**	**92,978**	**95,055**	**97,179**
3. Water transfer to Chaoyan District (m^3/day)	13,846	10,860	8,016	5,917
4. Non-revenue water				
Leakage from pipelines (%)	40	33	26	20
Uncounted water (%)	10	10	10	10
5. Coefficient[b]	0.5	0.5	1.0	1.0
Total Water Demand				
Daily average (m^3/day)	**128,349**	**132,027**	**288,798**	**331,423**
Daily maximum (m^3/day)[c]	141,184	145,230	317,678	364,565
C. Balance (A–B: average) (m^3/day)	**17,651**	**13,973**	**30,535**	**(12,090)**

(…) = data not available, m^3 = cubic meter, WTP = water treatment plant.

[a] Includes leakage and uncounted water.

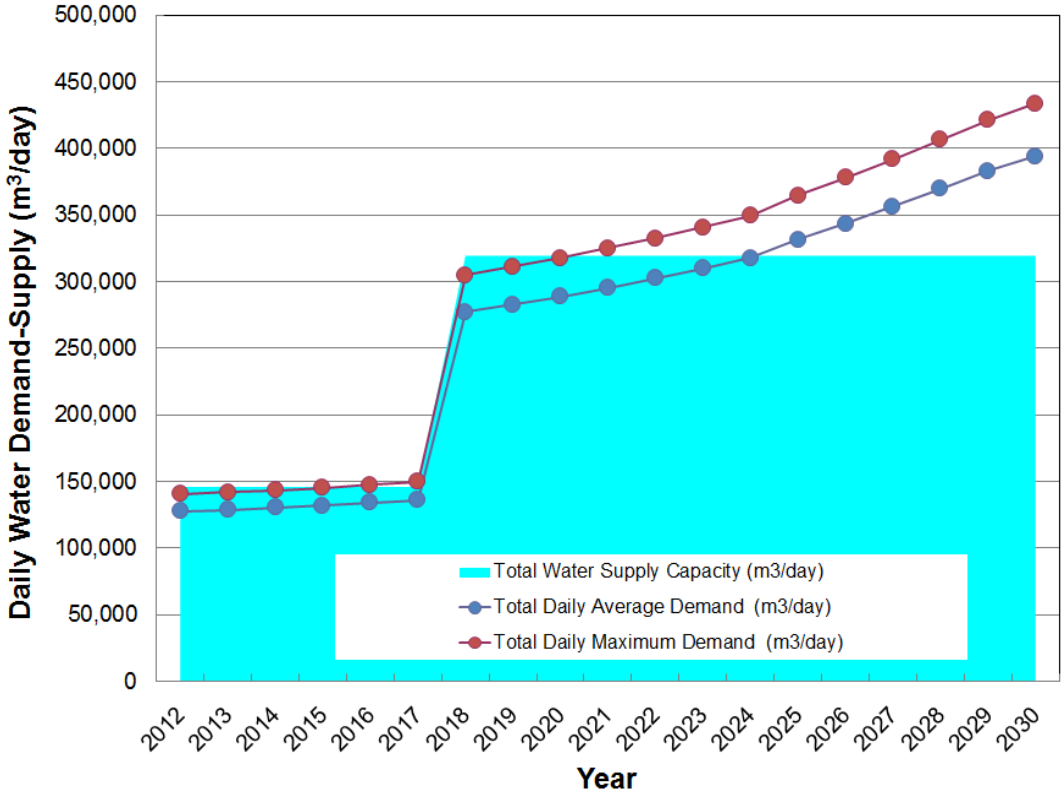
[b] The coefficient is multiplied to the total water demand. In 2007–2011, the supply capacity of the system was 53 million m^3 per annum, while the total domestic and industrial use was approximately 123 million m^3 per annum. This indicates that 57% of water for domestic and industry uses came from other sources (e.g. groundwater, direct pumping from reservoir). In the assumption, 50% of domestic and industrial water will be drawn from these sources during 2011–2019.

[C] Daily maximum water demand is projected as 10% more than the daily average water demand.

Source: Asian Development Bank estimates.

21. The water supply capacity (area chart) and the water demand (line chart) are in Figure 4. It indicates that the increase of the water supply system capacity in Chaonan from 146,000 m^3/day to 319,332 m^3/day is justified. The increased capacity will enable the system to cover the projected water supply demand in 2018–2020 for both daily average and maximum demand. If based on the average water supply demand, the new capacity will be enough to cover the water supply demand until 2024. This will provide enough time for CDG to update and adjust their water supply plan and strategy in next 5 years based on the actual water supply demand.

Figure 4: Demand-Supply Projection of the Water Supply System in the Plane Area



Source: Asian Development Bank estimates.

III. Summary Findings

22. Both water resource assessment and water demand-supply assessment demonstrated that the project is technically viable in terms of the proposed design capacity of WTPs and the water resource availability in Chaonan. The assessments adopted the best available observation data, the official statistics, and the realistic assumptions. Four key suggestions are made as a result of the assessments:

23. **Commitment from the Chaonan district government.** CDG must make a strong commitment to rationalize the use of water, and to work on water conservation in an integrated manner. The assessments made various assumptions including improvement of agricultural irrigation efficiency, industrial water use efficiency, water conservation from domestic use, and NRW management. Timely and successful implementation of the Han River Water Diversion Project and the Nanshan Flood Diversion Project are also keys for the future water resource management in Chaonan.

24. **Review of the plan and strategy.** The assessments concluded that the project is technically feasible to meet the future water resource requirement as well as the water demand to its water supply system. However, the projections should be very carefully monitored, analysed and reviewed to understand the actual water resource balance and the water supply-demand relationship in the plain area of Chaonan. The results should be the basis of periodic reviews of water resource management plan and strategy. A potential impact of climate change should be assessed especially on the total water resource availability in Chaonan.

25. **Adaptive management.** The assessment demonstrated that the water resources of Chaonan is at risk of shortage. Realizing that the assessments are based on the average annual runoff observation data, the water resource availability and demand-supply

relationship of the water supply system are vulnerable to drought and unexpected climate conditions. CDG should flexibly adapt their management to the actual condition, while they should strengthen their capacity to control such emergency situations.

26. **Capacity development.** Capacity building is necessary for CDG and its water supply company. The capacity building support should include in-depth study on integrated water resource management. The assessments suggest the project to support CDG in strengthening its water management capacity. This includes: (i) the establishment of a water supply control center, comprising a remote monitoring and control system, a data transmission and dispatching center, and communication network; (ii) support for the establishment of a water resources management and three-prevention (flood, drought and typhoon) management center; (iii) development of a water resources protection and development action plan for inter alia, water safety, water allocation optimization, and water reuse and conservation. Public awareness raising activities on environment and sanitation related to water resource conservation are important.