BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR IMPROVEMENT OF
WATER SUPPLY SYSTEM
AT THE SOUTHERN PYRAMIDS AREA IN GIZA CITY
IN
THE ARAB REPUBLIC OF EGYPT

July, 1997

JAPAN INTERNATIONAL COOPERATION AGENCY
YACHIYO ENGINEERING CO., LTD.

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PREFACE

In response to a request from the Government of the Arab Republic of Egypt, the Government of Japan decided to conduct a basic design study on the Project for Improvement of Water Supply System at the Southern Pyramids Area in Giza City and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Egypt a study team from January 11 to February 15, 1997.

The team held discussions with the officials concerned of the Government of Egypt, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Egypt in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Arab Republic of Egypt for their close cooperation extended to the teams.

July, 1997

Kimio Fujita
President
Japan International Cooperation Agency

July, 1997

LETTER OF TRANSMITTAL

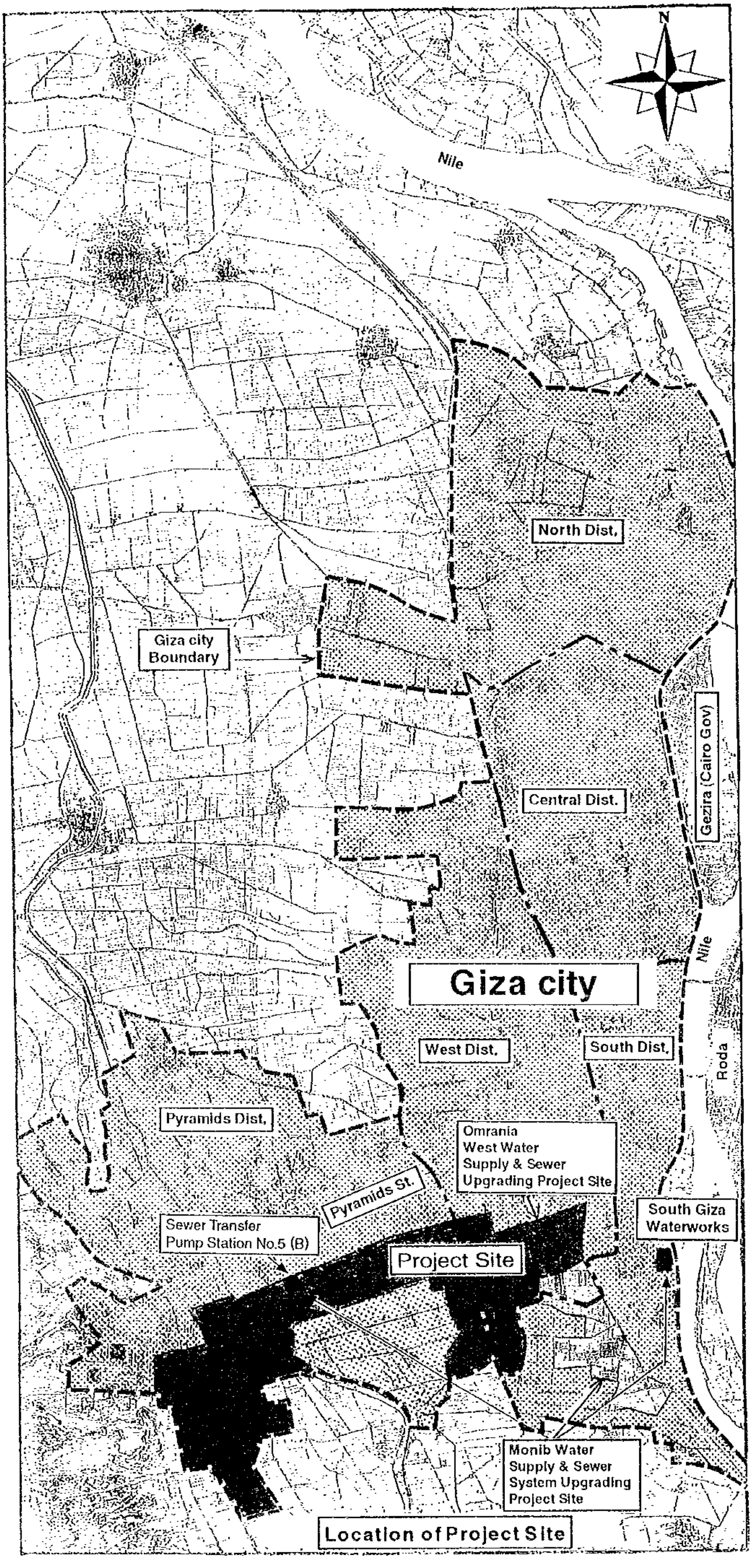
We are pleased to submit to you the basic design study report on the Project for Improvement of Water Supply System at the Southern Pyramids Area in Giza City in the Arab Republic of Egypt.

This study was conducted by Yachiyo Engineering Co., Ltd., under a contract to JICA, during the period from December 24, 1996 to July 25, 1997. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Egypt and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

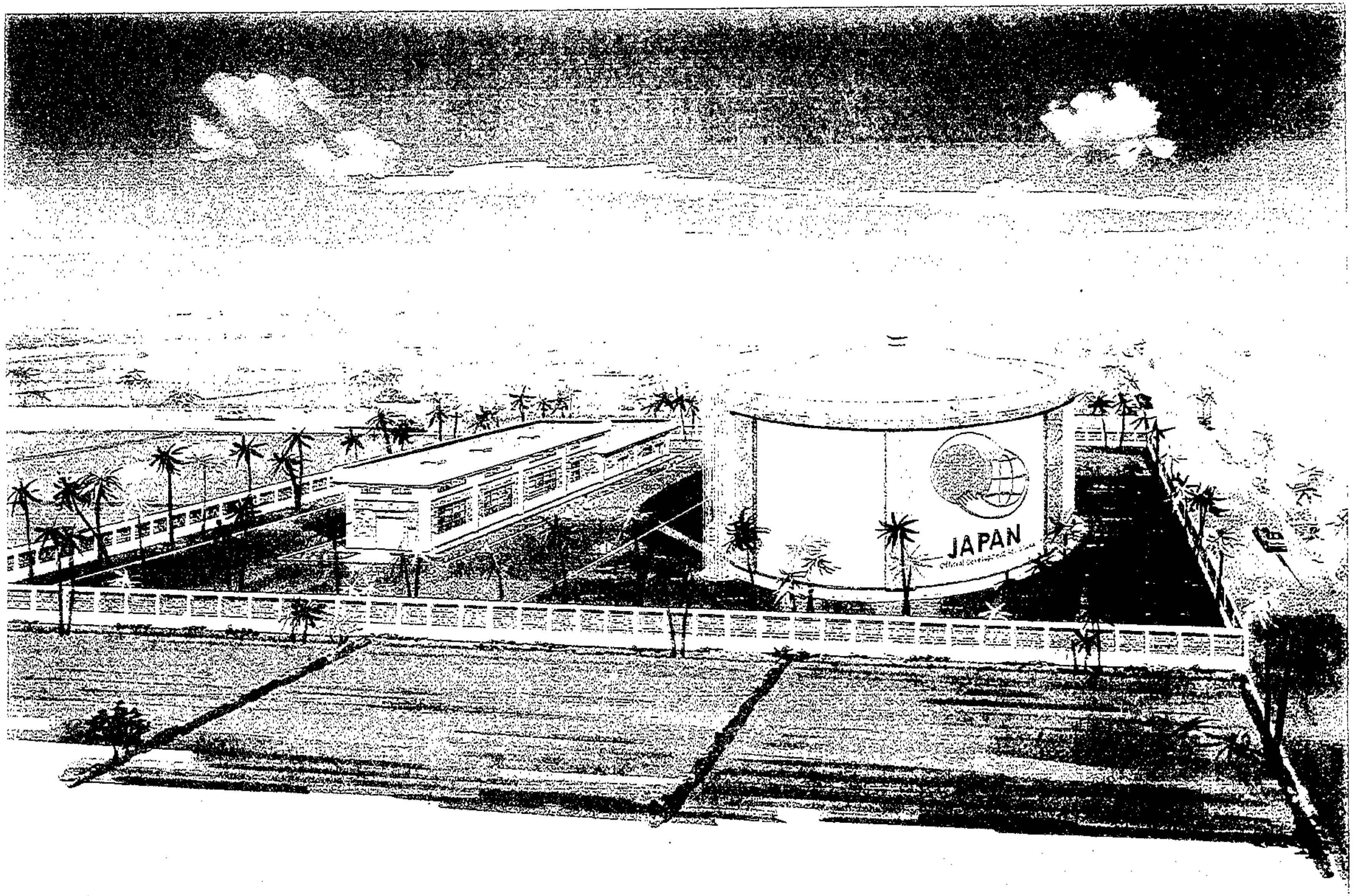
Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Noboru Saeki
Project manager,
Basic design study team on the Project for
Improvement of Water Supply System
at the Southern Pyramids Area in Giza City
Yachiyo Engineering Co., Ltd.



N
Nile
North Dist.
Giza city
Boundary
Central Dist.
Gezira (Cairo Gov)
Nile
Giza city
West Dist.
South Dist.
Roda
Pyramids Dist.
Omrania
West Water
Supply & Sewer
Upgrading Project Site
Pyramids St.
Sewer Transfer
Pump Station No.5 (B)
South Giza
Waterworks
Project Site
Monib Water
Supply & Sewer
System Upgrading
Project Site
Location of Project Site



WATER DISTRIBUTION STATION

THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY SYSTEM AT THE SOUTHERN PYRAMIDS AREA IN GIZA CITY

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ABBREVIATIONS

DCI	Ductile Cast Iron
E/N	Exchange of Notes
GCR	Greater Cairo Region
GOGCWS	General Organization for Greater Cairo Water Supply
GDP	Gross Domestic Product
HWL	High Water Level
IMF	International Monetary Fund
JIS	Japanese Industrial Standards
JICA	Japan International Cooperation Agency
LE	Egyptian Pound
LWL	Low Water Level
M/D	Minutes of Discussion
MOEIC	Ministry of Economic and International Cooperation
M/P	Master Plan
OJT	On-the-job Training
PC	Prestressed Concrete
PVC	Polyvinyl Chloride
RC	Reinforced Concrete

CHAPTER 1

BACKGROUND OF THE REQUEST

CHAPTER 1 BACKGROUND OF THE REQUEST

The Arab Republic of Egypt (hereinafter referred to as Egypt) is a country located in the northeastern corner of the African Continent and has a land area of some one million km^2 and a population of approximately 62.36 million (1995 data). Some 94% of the national land is either desert or wetland and most of the population live in the delta facing the Mediterranean or along the Nile valley.

The Government of Egypt has been implementing economic reform with structural adjustment policies under the guidance of the IMF and World Bank with a view to transforming the national economy from a controlled economy to a market economy in order to improve the financial as well as economic conditions of the country which have been stagnant in the aftermath of the Gulf War. Despite active efforts, the Egyptian economy is still experiencing a difficult time due to the high annual inflation rate (more than 20%) and high unemployment rate. As of 1994, the GNP per capita is 710 US$.

Giza City is adjacent to Cairo, the capital of Egypt, across the Nile and is an important part of GCR (hereinafter referred to as "GCR"). Compared to Cairo, however, infrastructural development in Giza has greatly lagged behind and the recent rapid population inflow from local areas has made it practically impossible for the municipal authority to develop the water supply and sewerage systems in line with the population growth (annual rate of 3.5%). The Pyramids District in particular has recently seen rapid development and its population, which has increased to almost half a million, is crammed into a small area. The water supply service currently covers some 20 - 30% of the residents except for those in some areas along trunk roads. Even in those areas served by the water supply network, the location of the Pyramids District near the far end of the network means an extremely low water pressure, resulting in a practical lack of water during the day-time peak period with a maximum water supply rate of approximately 50 litres/day. In other parts of the Pyramids District, the residents rely on public water plugs or wells for the supply of water. Unfortunately, these wells are destined to be abandoned in the near future because of contamination by infiltrating sewage, etc.

Giza already has a water supply and sewerage master plan prepared with the assistance of Germany and the US and the development of such infrastructure as water supply and sewerage systems are priority areas under Egypt's Third Five Year Plan. The country's tight financial situation, however, has made it difficult for Egypt to implement various development projects without foreign assistance. The Government of Japan provided grant aid for the development of water supply and sewerage systems in the Omrania West Area (from fiscal 1988 to fiscal 1989) and the Monib Area (from fiscal 1992 to fiscal 1996 in two phases) and the achievements of this grant aid have been highly evaluated by the Government of Egypt as well as by local residents.

Against this background, the Government of Egypt originally requested Japanese grant aid for improvement of the water supply system in the Southern Pyramids Area, the Embaba Area and the Northern Pyramids Area, all of which are adjacent to the Omrania West Area and Monib Area and which are inhabited by many poor people. Having assessed this request, the Government of Japan judged that the scope of the original request was too large to be dealt with by grant aid and requested the Government of Egypt to identify the priority order of these three subject areas. Both sides subsequently agreed that the Southern Pyramids Area (with a population of some 290,000 in 1994) would be given the highest priority and that a basic design study on improvement of the water supply system in the Southern Pyramids Area would be conducted.

The Basic Design Study Team discussed the contents of the request in detail with the Egyptian side at the initial stage of the field survey. As a result of the discussions, a conclusion was reached to drop the two elevated water tanks (1,300 m^3 and 1,000 m^3) in the original request because of the lower construction cost of water reservoirs. The contents of the original request and the contents of the request at the signing of the Minutes of Discussions (MD) are compared in Table 1-1.

Table 1-1 Original and Modified Requests of the Government of Egypt

Item No.	Original Request	Modified Request at Signing of MD
1	Laying of water main • ϕ 1,000 mm × approx. 4.0 km • ϕ 800 mm × approx. 1.5 km	Laying of water main • ϕ 1,000 mm × approx. 4.2 km • ϕ 800 mm × approx. 2.1 km
2	Construction of water distribution station (ground water reservoirs with distribution pump system) • approx. 13,000 m^3 × 1 • approx. 10,000 m^3 × 1	Construction of water distribution station (ground water reservoirs with distribution pump system) • approx. 14,000 m^3 × 1 • approx. 11,000 m^3 × 1
3	Construction of elevated water tanks • approx. 1,300 m^3 × 1 • approx. 1,000 m^3 × 1	(Withdrawn from list of requested items)
4	Construction of aqueducts	Construction of aqueducts
5	Provision of piping materials • ϕ 100 - 600 mm: approx. 96 km	Provision of piping materials • ϕ 100 - 600 mm: approx. 96 km

CHAPTER 2

CONTENTS OF THE PROJECT

CHAPTER 2 CONTENTS OF THE PROJECT

2.1 Objectives of the Project

While Giza City in the Giza Governorate, in which the Project Site is located, has a current population of some 2.9 million, constituting a major area in GCR, the development of urban infrastructure has lagged behind that of Cairo located on the opposite side of the Nile as described in Chapter 1. Under these circumstances, the government of the Giza Governorate and the Giza municipal authority have been implementing a water supply improvement project based on Japanese grant aid in three phases in accordance with the urban living environment and hygiene improvement and development programme as part of the the second and third Five Year Plan of the central government.

As part of this programme, a project has been prepared which is designed to ensure a stable living environment and improvement of the sanitation conditions for the some 290,000 residents of the Southern Pyramids Area, which is a newly developing residential area located in the southwestern part of Giza City and which is suffering from a poor level of social infrastructure, by means of implementing a water supply network development project to improve the area's serious shortage of domestic water supply. The present Project, which is part of a water supply improvement project for the area, intends the laying of a water transmission line, the construction of two water distribution station, each consisting of a water reservoir and pump system, and the provision of equipment and materials for the water distribution network construction work to be conducted by the Giza municipal authority.

2.2 Basic Concept of the Project

Using Japanese grant aid which was provided in three phases, waterworks and a water distribution network were constructed in the Omrania West and Monib Areas located in the eastern part of Giza City. The new water supply system has enabled the supply of clean drinking water to each household in the subject areas and its contribution to the great improvement of the living standard and sanitation conditions in the subject urban areas has been highly appreciated. Meanwhile, the Southern Pyramids Area, Northern Pyramids Area and Embaba Area, all of which are adjacent to the above two subject areas of the previous project, still largely lack a water supply network despite conspicuous urbanisation with a large number of new apartment buildings, forcing most of the residents to relay on a small number of public water supply plugs or to purchase water from travelling water tankers. Even in those areas served by the water supply network, the recipients suffer from long water cuts and deteriorating water quality.

In order to improve this situation, General Organization for Greater Cairo Water Supply (hereinafter referred to as "GOGCWS") has prepared the Integrated Water Supply Improvement Plan for the Embaba and Southern Pyramids Areas under which a new water transmission main will be constructed to link the Embaba Area to the north and the Southern Pyramids Area to the south with a view to utilising the two waterworks located in these areas in a coordinated manner. The present Project aims at developing a new water supply system in the Southern Pyramids Area as part of the phased attempt to implement the Integrated Plan by dividing its target areas into the northern and southern sections. Because of the partial implementation of the Integrated Plan, there will be no coordination for some time between the South Giza Waterworks which supplies water to the Southern Pyramids Area and the Embaba Waterworks which supplies water to the Northern Pyramids Area and Embaba Area. Nevertheless, as this situation does not present any immediate problems, phased improvement is deemed to be an effective way of achieving the ultimate goal.

With regard to the manner of water supply, the overall picture for Giza City, including the Project Site, is that while the water supply network has made important progress, the existence of only a limited number of water distribution reservoirs with a storage function means a heavy burden on the waterworks, resulting in insufficient water supply during peak hours. Given this situation, the coordinated operation of the two water reservoirs planned under the Project will not only establish a reliable water supply system at the Project Site but will also contribute to a reliable water supply in the surrounding areas. As the Project Site is divided into two areas by the Mariotia Canal, a major drainage canal, the Konayessa-Talbia area to the east of the canal is named the No. 1 Water Distribution Basin and the Sphinx area to the west of the canal is named the No. 2 Water Distribution Basin. A water reservoir with a capacity equivalent to 5 hours supply of the design maximum daily water supply volume will be located at or near the centre of each basin.

The examination results of the modified request shown in Table 1-1 in the light of the Project's basic concept described so far are given in Table 2-2-1.

Table 2-2-1 Examination Results of Modified Request

	Modified Request	Revised Items After Examination
①	Laying of water transmission main · φ 1,000 mm × approx. 4.2 km · φ 800 mm × approx. 2.1 km	Water transmission main · φ 1,200 mm × 990 m · φ 1,000 mm × 3,150 m · φ 800 mm × 1,270 m
②	Construction of water distribution station (ground water reservoir with pump system) · approx. 14,000 m^3 × 1 · approx. 11,000 m^3 × 1	Water distribution station (as requested)
③	Construction of aqueducts	Aqueducts · φ 800 mm × 30 m · φ 800 mm × 25 m
④	Procurement of water distribution pipeline materials · φ 100 - 600 mm × approx. 96 km	Water distribution pipeline materials · φ 200 - 600 mm × approx. 28 km

The differences between the modified request and the revised items following examination of the modified request and the reasons for revision are explained below.

① Laying of Water Transmission Main

The requested pipe diameter and length for the water transmission main were based on figures established by Master Plan Study of Water Supply for City of Giza (hereinafter referred to as "Giza Water M/P") which is the superior plan to the Project. Giza Water M/P envisages a system whereby the water transmission main also acts as the trunk water distribution line for direct water distribution to branch lines without any water reservoir. Under the Project, however, water is sent to water reservoirs by the water transmission main to feed the water distribution network thereafter in order to establish a reliable water distribution system. Consequently, the pipe diameter of the water transmission main to the No. 1 Water Distribution Station is revised to 1,200 mm to avoid any internal damage to the main in view of the need to ensure a sufficient water pressure and appropriate water flow velocity to the No. 2 Water Distribution Station. The length of the 800 mm pipes used for the branch line from the water transmission main to the water distribution station is shortened because of the change of location of the originally requested site of the water distribution station.

While it is desirable to connect the planned water transmission main and existing water distribution trunk line under King Faisal Street from the hydraulic point of view, this connection is not included in the scope of the Project due to cost-benefit considerations. Instead, the scope of the Project includes upto the installation of a gate valve for future connection.

② Construction of Water Distribution Station

No change is made to the modified request for the water distribution station.

③ Construction of Aqueducts

Although the construction of an aqueduct(s) was included in the modified request, the details were not clearly indicated. The field survey and subsequent analysis found that two aqueducts will be required for the water transmission main to cross the Mariotia Canal and Lebeni Canal.

④ Procurement of Water Distribution Pipeline Materials

The modified request for piping materials was for pipes with a diameter ranging from 100 mm to 600 mm for a total length of approximately 96 km. Having examined the anticipated water distribution network for the likely areas of urbanisation by the year 2005 based on the latest land use map obtained for the Basic Design Study, it is found that a water distribution network totalling some 147 km with a pipe diameter ranging from 100 mm to 600 mm will be required to serve the subject areas. Considering the results of the Water Supply Improvement Project for Monib (previous grant aid project in two phases), it is believed that the Egyptian side will be able to fund the cost of the pipe laying work for 147 km and the procurement cost of 100 mm and 150 mm pipes for approximately 119 km. Accordingly, the scope of the Japanese procurement of water distribution pipes is limited to the water distribution main (200 mm to 600 mm in diameter) stretching some 28 km.

The above examination results have established the basic concept of the Project which aims at developing a water supply system with a design maximum daily water supply per person of 210 litres and a maximum daily supply of some 120,000 m^3 for an expected population of some 560,000 in the Southern Pyramids Area in Giza City in the year 2010 as part of the water supply improvement project which the Giza municipal authority has been implementing for some time based on Japanese grant aid in three phases in the past in order to amend the delayed development of water supply facilities as important social infrastructure for a city which plays an important role as part of GCR which is the socioeconomic heartland of Egypt. The actual components of the Project are the laying of a water transmission main, the construction of two water distribution station, each consisting of a water reservoir with a pump system, and the procurement of piping materials for a new water distribution network.

2.3 Basic Design

2.3.1 Design Concept

(1) Natural Conditions

1) Climate

The Project Site belongs to the desert arid climate zone with extremely low annual rainfall of 29 mm. From March to April, a seasonal wind called the Hamseen which contains a large amount of sand dust assaults the Project Site from the desert to the west. The mean annual temperature is 21.8℃ while the maximum and minimum temperatures are 40℃ in August and 3℃ in February.

While the planned water supply facilities under the Project do not require any anti-freezing measures for the winter, a 2 m deep earth covering will be introduced for the water main to avoid interference with other underground structures. A ventilation system and anti-dust measures will be considered for the pumping facilities and electrical installations in view of the high ambient temperature in summer.

2) Topography and Geology

The Project Site is situated at the southern end of the Nile Delta and has rough level ground with strata. There are two drainage canals crossing the trunk water supply route.

As the water distribution system is pressurised, the level condition of the topography is immaterial. However, the construction of aqueducts must be considered as the canal at the section crossing the trunk water supply route has a width of more than 20 m. The use of sheet piles or others for earth retaining work will be considered along the new routes as these routes (i.e. roads) are often lined with medium height (5 - 10 stories) RC apartment buildings.

In regard to the desirable types of foundations for the distribution pump system, there is little chance of the uneven subsidence of a large structure due to the ground conditions as the geological formation is consistent over a wide area. Nevertheless, the bearing capacity may not be strong enough to avoid the problem of compaction subsidence due to the upper load of the upper clay layer. Consequently, pile foundations are likely to be adopted for heavy structures, including the water reservoirs.

3) Earthquake and Wind Loads

For the design of the structures to be constructed under the Project, Japanese design standards will be adopted because of (i) their extremely high reliability originating from many cases of application, in turn reflecting their systematic provisions by international criteria, and (ii) their familiarity to people involved in the Project through previous Japanese grant aid projects. Taking the local characteristics of the design load conditions into consideration, however, Egyptian design standards will be used for the earthquake and wind loads. It is unnecessary to take the snow and sand dust loads into consideration.

There is currently increasing interest in Egypt in including earthquake-proof features in the structural design requirements because of the earthquake which occurred in 1992, the first earthquake in 70 years, and some earthquake load standards have been introduced. For the present Project, the likely earthquake intensity and wind load for the Cairo area will be taken into consideration, including the wind load set by the Construction and Building Load Standards (Ministerial Ordinance No. 45, 1993) of the Egyptian Ministry of Construction.

(2) Social Conditions

As concluded by the evaluation of previous Japanese Grant Aid projects, the subject areas of these projects were new residential areas serving ordinary workers in GCR and the beneficiaries of these projects were not limited to a special group of people, underlining the great benefits of these projects. Improvement of the water supply under these projects has contributed to not only a general improvement of the local hygiene but also to a reduction of the heavy labour associated with the fetching of water, previously conducted by women and children. In view of these achievements of the previous projects, the planning of the Project incorporates all of the essential components of the previous projects, including the special local characteristic that the work of fetching water is the responsibility of women and children because of the virtual absence of a water distribution network in newly developed housing areas with a large population density, in order to achieve its objectives.

(3) Local Construction Industry

1) Availability of Construction Companies

Wide ranging construction work is taking place in GCR in which the Project Site is located, typically the construction of roads and bridges, etc. by the public sector and multistory buildings by the private sector. As a result, there is a sufficient number of construction-related businesses, ranging from general contractors and the leasing of construction machinery to the supply of raw concrete, pilings, transportation and manpower supply.

Some Japanese general contractors are also present. The construction work of local companies, however, is restricted to common structures and buildings and there is still a lack of technical expertise in certain specialist fields, such as the construction of prestressed concrete (PC) water tanks which is opted for under the Project. Accordingly, the construction of PC water reservoirs under the Project will be conducted by a Japanese general contractor under the supervision of a specialist PC engineer while other general civil engineering and building work will be conducted by a subcontracted local construction company or through the direct employment of local engineers.

2) Availability of Equipment and Materials

There is little locally manufactured industrial equipment which is totally reliable despite the importance of this equipment in construction work. In contrast, the construction material manufacturing industry has greatly advanced and expanded since the time of the previous project. In addition to the improved manufacture of common construction materials, a local company now produces ductile cast iron pipes of wide ranging sizes including valves and fittings.

Given this situation, efforts will be made to procure local equipment and materials as much as possible. Because of the busy situation of the local construction industry, however, there may be a supply shortage and/or delivery delay. As the Project will demand the procurement of large quantities of construction materials in a relatively short period of time, the basic design should take appropriate order and delivery control into proper consideration in the project implementation system and schedule.

(4) Use of Local Companies

As mentioned earlier, there are many local companies of varying sizes in all fields of construction. As the construction work under the Project is not particularly difficult as it mainly consists of the laying of water supply pipes, the construction of water reservoirs and the installation of pumping equipment at these reservoirs, the construction plan should emphasise the use of local companies. Nevertheless, it will be necessary to dispatch engineers and technicians from Japan to supervise and guide local companies in regard to the planning of the general construction plan, schedule control, specialist work, quality control and test operation for equipment adjustment.

(5) Technical Level and Maintenance Capability of Project Implementation Agency, etc.

1) Giza City

While the Giza municipal authority will act as the project implementation agency, the facilities constructed under the supervision by GOGCWS during the Project will be transferred to GOGCWS after completion for their operation and maintenance. This arrangement makes it unnecessary to consider the maintenance capability of the Giza municipal authority. However, as the basis of proper maintenance is the good quality of the subject facilities, a detailed check of the specifications of the materials and household connection work to be conducted by the Giza municipal authority with its own funding will be conducted in order to minimise any leakage from such connections. As the water distribution pipe laying work to be undertaken by Giza City will take place at almost the same time as the water transmission main laying work to be undertaken by the Japanese side, Giza City must coordinate its work with the Japanese contractor for the Project.

2) GOGCWS

GOGCWS, which will be responsible for the operation and maintenance of the water distribution and supply facilities to be constructed under the Project, supplies water of some 4 million m^3/day to a service population of some 15 million people in GCR (1994 figures) and conducts the systematic maintenance of the water supply network. The maintenance organization of GOGCWS at the Project Site is called the Pyramids Distribution Centre.

The water charge collection ratio of approximately 52% is still not high and the maintenance poses various problems. Despite these difficulties, however, there is a strong local will for improvement in both the software and hardware aspects of water supply operation, including the change to ductile cast iron as the water distribution pipe type to reduce the water leakage ratio. Together with the recent management improvement and manpower development project of USAID and Japan's project-type technical cooperation study, a steady improvement of all aspects of water supply can be anticipated. For the operation and maintenance plan after the completion of the Project, therefore, it is assumed that GOGCWS has sufficient technical ability to conduct the necessary operation and maintenance work with a small increase of manpower and the reassignment of existing staff.

Japan's project-type technical cooperation study has been in progress since December, 1996 and the actual cooperation is scheduled to commence in June in fiscal 1997 for five years. This project-type technical cooperation will involve the long-term assignment of an expert to train Egyptian engineers under the themes of waterworks operation and management and water distribution network maintenance and the necessary facilities to conduct this training will be established at the Ameria Waterworks.

(6) Design Scope and Grading of Facilities, Equipment and Materials

Having considered the conditions described in (1) through (5) above, the following basic principles are adopted for the design scope and appropriate technology level for the facilities to be constructed and equipment and materials to be procured under the Project.

1) Design Scope for Facilities, Equipment and Materials

The configuration and specifications of the facilities are planned to ensure a water transmission and distribution system capable of providing a stable water supply during peak hours to meet the water demand in the Southern Pyramids Area consisting of the Konayessa-Talbia area and the Sphinx area in Giza City.

The target year used to design the scale of such main facilities as the water transmission main and water reservoirs is 2010 because of the anticipated difficulty of extending or replacing such facilities. In the case of the pump system, the target year is 2005 because of the possibility of its expansion in stages. The subject areas for the new water distribution network for house connection are those where urbanisation will take place by 2005.

2) Grading of Facilities

While the specifications of the equipment which constitute the distribution pump system, the main component of the water distribution station to be constructed under the Project, are deemed not to exceed the technical level of GOGCWS which will be responsible for the operation and maintenance of all the new facilities, GOGCWS's strong commitment to energy saving is also taken into consideration in the equipment selection.

The material of the water distribution pipes is selected in view of the current maintenance situation and future policy of GOGCWS and also in view of the pipe supply situation in Egypt.

(7) Construction Schedule

The Project will be implemented in the following two stages, taking into consideration the importance and urgency of water supply improvement in urban areas with an extremely poor water supply situation at present and also the planned schedule of the distribution pipe laying work to be conducted by the Egyptian side.

First Stage

① Construction of a water transmission main from the previous project site to the Konayessa Talbia area
② Construction of the Konayessa Talbia water distribution station
③ Procurement of the pipes, etc. for development of the water supply system in the Konayessa Talbia area

Second Stage

① Construction of a water transmission main from the Konayessa-Talbia water distribution station to the Sphinx area
② Construction of two aqueducts
③ Construction of the Sphinx water distribution station
④ Procurement of the pipes, etc. for development of the water supply system in the Sphinx area

In view of the likely schedule, it is desirable for the second stage construction work to be done as an obligation of Japanese national grant monies beyond authorized annual allocation for a multi-year construction project.

2.3.2 Basic Design

2.3.2.1 General

(1) Design Population

1) Population Density of Project Site

The approximate population density per ha of the residential areas of the Project Site is shown in Table 2-3-1 based on the population census conducted by Giza City in 1994.

Table 2-3-1 Population Density of Residential Areas of Project Site (as of 1994)

Residential Area	Approximate Population Density (persons/ha)
High Income Area	500
Middle Income Area	1,000
Low Income Area	1,300

Source: Giza City

In the Southern Pyramids Area, high income residents tend to live in the area along Tersa Street near Pyramids Street. Further south of Pyramids Street are areas of middle and low income residents with the former being dominant. Assuming that the ratios of high, middle and low income residents are 1: 7: 2, the average population density of the Southern Pyramids Area is 1,010 persons/ha.

The population density of the entire Project Site, excepting such public facility premises as schools and roads and land used for purposes other than residential purposes, including industrial sites (totalling some 30% of the entire area), is calculated below.

$$1,010 \times 0.7 = 707 \text{ persons/ha}$$

2) Population of Project Site (1994)

The urbanised area of the Project Site in 1994 accounted for some 50% of the total area, excluding vacant land in urbanised/residential areas. Based on this data, the population of the Southern Pyramids Area is estimated as follows.

$$707 \text{ persons/ha} \times 820 \text{ ha} \times 0.5 = 289,870$$

This figure of approximately 290,000 estimated by Giza City is employed for the Project.

3) Calculation of Design Population

The Project Site is a new residential area and Giza City adopts a figure of 4.2% for the area's average annual population growth upto 2010.

The design population in the Project's target year (2010) is calculated by the following formula with an average annual population growth rate of 4.2% based on the assumption that this new residential area will continue to steadily develop in the years to come.

$$Y = Yo\,(1 + r)^x$$

Where,

Y : population in year for estimation

Yo : population in reference year (in the case of the present Project, 290,000 which is the population in 1994)

r : annual average growth rate (4.2%)

x : period between reference year and estimation year

The calculated population in 2010 is 560,121.

$$Y = 290,000\,(1 + 0.042)^x = 560,121$$

The design population of 560,000 set by Giza City is employed as the design population for the Project for the target year of 2010 as shown in Table 2-3-2.

Table 2-3-2 Area and Population of Project Site

Area of Project Site	820 ha
Population (1994)	290,000
Design Population (2010)	560,000

(2) Estimation of Future Water Demand

1) Giza City

The present total water demand in Giza City is estimated to be 860,000 m^3/day as described earlier on the basis of the actual water distribution performance. The water demand level in the target year of 2010 is estimate based on the demand trend from 1986 to the present. As shown in Fig. 2-3-1, assuming a linear increase from the base period between 1992 and 1996 upto 2010, the water demand in 2010 is estimated to be approximately 1,390,000 m^3/day. This estimated increase of the water demand shows a similar annual increase rate to that of the annual population growth rate of 3.5% in Giza City.

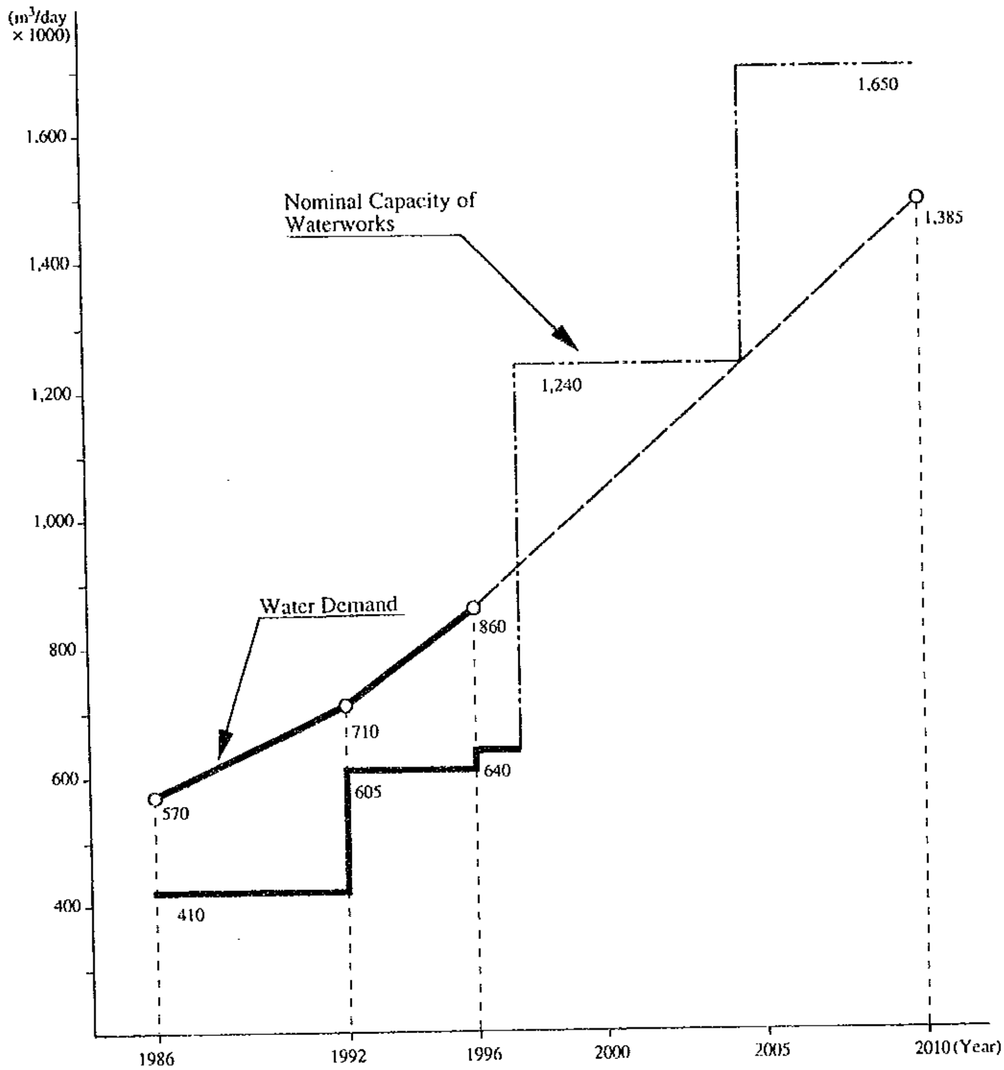


Fig. 2-3-1 Estimated Water Demand Increase and Waterworks Expansion Programme for Giza City

Meanwhile, Table 2-3-3 shows the water purification capacity expansion programme upto 2010 for Waterworks in Giza City.

Table 2-3-3 Waterworks Expansion Programme for Giza City

Waterworks	1996	1998	2005	2010
Embaba	300,000	700,000	700,000	900,000
Giza	125,000	125,000	125,000	225,000
South Giza	175,000	375,000	375,000	525,000
Groundwater Distribution Station	40,000	40,000	40,000	-
Total	640,000	1,240,000	1,240,000	1,650,000

By 1998, the expansion work currently in progress at the Embaba Waterworks (to increase the capacity by 400,000 m^3/day) and South Giza Waterworks (to increase the capacity by 200,000 m^3/day) will be completed, resulting in a total capacity of 1,240,000 m^3/day. In addition, the GOGCWS plans to further expand the capacity of the three water purification plants in Giza City by the year 2010 with a final target capacity of 1,650,000 m^3/day.

Provided that the programme is duly completed on schedule, the water purification capacity in Giza City in 2010 will have a surplus capacity of approximately 20% and it is expected that the emphasis will gradually be shifted towards the rehabilitation of old facilities and the development of the water distribution network.

2) Project Site

As described earlier, land use at the Project Site is characterised by the dominance of residential areas with no specific commercial or industrial sites involving large users. Accordingly, the GOGCWS sets a maximum daily water supply volume per capita of 210 litres/person/day.

Based on the assumption that the water demand will increase in accordance with the population growth, the estimated water demand of the Project Site is shown in Table 2-3-4.

Table 2-3-4 Estimated Water Demand of Project Site

	Population (persons)	Water Demand (m^3/day)
Present (1994)	290,000	60,900
Target Year (2010)	560,000	118,000

(3) Water Transmission Main Construction Plan

The present Project is part of the General Improvement Plan for Water Supply in the Embaba and Southern Pyramids Areas and intends the construction of an urgently required water distribution network from the Southern Pyramids Area as the subject area of the plan is divided into the northern section (i.e. Embaba area) and southern section (i.e. Southern Pyramids area). Consideration is, however, given under the Project to possible linking to the northern main with a view to achieving a looped main in the future.

To achieve the design maximum daily water supply volume per person in the Project's target year of 2010, the following target, which takes improvement of the living standard and other factors into consideration, put forward by GOGCWS is adopted for the Project.

Design maximum daily water supply per person (year 2010): 210 ℓ/person/day

The Project Site is divided into the Konayessa-Talbia area and the Sphinx area by Mariotia drainage canal. It is, therefore, desirable to divide the water distribution area using this topographical feature. The present and future design service population, service area and design daily water supply volume (to be established as the product of the design service population and design maximum daily water supply volume per person) for each area (the Konayessa-Talbia area is called the No. 1 Water Distribution Basin while the Sphinx area is called the No. 2 Water Distribution Basin for purposes of the Project) are given in Table 2-3-5 and Table 2-3-6. The proposed route for the water transmission main is set along main roads and the water reservoir locations are decided based on land availability at or near the central place of each distribution basin as shown in Basic Design Drawing EGP-GN-01.

Table 2-3-5 Design Service Population by Distribution Basin

Distribution Basin	Service Population (persons)			Area (km^2)
	1996	2005	2010	
No. 1	178,000	251,000	315,000	4.6
No. 2	138,000	195,000	245,000	3.6
Total	316,000	446,000	560,000	8.2

Source: Giza City

Table 2-3-6 Design Daily Maximum Water Supply Volume by Distribution Basin

(Unit: m^3/day)

Distribution Basin	1996	2005	2010
No. 1	37,300	52,000	66,400
No. 2	29,000	40,300	51,600
Total	66,300	92,300	118,000

(4) Water Reservoir and Distribution Pump System Construction Plan

The design capacity of each water reservoir is equivalent to five hours supply for the design daily maximum water supply volume which is the target adopted by GOGCWS for the construction of water reservoirs.

1) Comparison Between Ground Water Tank System and Elevated Water Tank System

Two water reservoir systems, i.e. the ground water reservoir system and elevated water tank system, are feasible for the water reservoirs required by the water distribution system planned under the Project. The advantages and disadvantages of these systems are described in Table 2-3-7.

Table 2-3-7 Comparison of Ground Water Reservoir System and Elevated Water Tank System

System	Advantages	Disadvantages
Elevated Water Tank	• Simplicity of the system • Not severely affected by power cuts • Easy operation	• Requires a high head water pump or pumping-up pump • High construction cost
Ground Water Tank	• Low construction cost • Easy redesign of facilities to meet changing demands	• Slight complexity of the system • Requires a distribution pump

The water distribution station in the No. 1 Water Distribution Basin (hereinafter referred to as the No. 1 Water Distribution Station) has a fairly high residual pressure originating from the water pump at the waterworks due to the relatively short distance from the waterworks and, therefore, GOGCWS has requested the adoption of an elevated water tank system to use this residual water pressure to store water in the elevated water tank for subsequent water distribution by means of gravity in order to achieve energy efficient pumping. However, the water transmission main network has been expanding each year and the residual water pressure within the network may not be kept constant in the future. Under these circumstances, it is by no means certain that the elevated water tank system would enjoy sufficient water pressure for efficient operation. Moreover, comparison between the ground water reservoir system and elevated water tank system confirms the advantageous nature and better economy of the former. As a result, the ground water reservoir with pump system is adopted for the Project. The results of the comparison of the two systems in terms of economy are given in Appendix 6.

2) Electrical Installation

The two-circuit electric supply to the pumping stations is made by a 10.5 kV distribution line which is common in Egypt. The distribution point at each pumping station marks the demarcation point for the procurement and installation responsibilities of the Egyptian side and Project side. No emergency power generation system is considered under the Project as the much improved and stable power supply in GCR has reduced the frequency of power cuts to approximately once a month.

3) Energy Saving

GOGCWS originally considered the introduction of a relatively simple system for water supply operation whereby water would be pumped to elevated water tanks for gravity distribution thereafter. The project planning must take the facts that the water transmission pressure from the existing waterworks fluctuates at the water reservoirs and that the average daily distribution volume to the Project Site is expected to show a gradual increase towards the target year of the Project into consideration. While these facts necessitate flow control, adjustment based on the number of pumps in operation and the opening/closing of valves cause a large energy loss. In order to improve the energy efficiency of water supply operation, the use of a pump system capable of regulating the flow rate by means of controlling the revolutions will be considered for the Project. Even though such a system is new in Egypt, it is commonly used in Japan and interest in this system in increasing in Egypt as a means of energy saving to achieve financial improvement.

In view of the problem of the wasteful use of electric energy at the existing water reservoirs operated by GOGCWS due to the inefficient pump operation system, the system design for the Project gives careful consideration to the need for energy saving by the adoption of the following measures.

① Internal pressure control of the water transmission main by a flow control valve
② Discharge rate control by a revolution control pump

4) High Residual Chlorine Density of Supplied Water

GOGCWS tends to set a relatively high level of residual chlorine density because of the unreliability of the supply network. As this preference applies to the entire water supply system, it may take a long time to lower the chlorine density level to a more appropriate level. Accordingly, appropriate measures will be taken for the facilities and structures under the Project to deal with the assumed high level of chlorine density.

(5) Procurement of Pipes

1) Different Sages of Improvement

The Project Site is classified into three areas depending on the present state of the water supply network.

① Area which has a limited water supply network
② Area which has a water supply network using groundwater from wells
③ Area one which has no water supply network

The contents of the planned improvement of the water supply network under the Project vary from one area to another and the scope of procurement under the Project should be clearly distinguished from the scope of piping procurement by the Egyptian side for its own work.

2) Pipe Type

In principle, GOGCWS has adopted a policy of using ductile cast iron pipes for the present and future water supply network construction. The pipes to be procured under the Project are, therefore, all ductile cast iron pipes (DCI pipes), changing the procurement policy of the previous project in which PVC pipes were used for a required diameter of less than 300 mm and DCI pipes were used for a required diameter of 300 mm or more.

(6) Design Conditions

Having examined the various conditions governing the scale and specifications of the facilities to be constructed under the Project, the following design conditions are established.

1) Area and Elevation of Project Site

Table 2-3-8 Area and Elevation of Project Site

Distribution Basin	Area (km^2)	Elevation (mean)
No. 1	4.6	AD + 19.5 m
No. 2	3.6	AD + 18.0 m

Notes 1) AD: Datum Level at Alexandria Port
2) South Giza Waterworks: AD + 20.6 m

2) Time Factor of Design Hourly Maximum Water Distribution Volume

Giza Water M/P adopts an hourly water supply volume variation rate in Giza City in 2000 of 1.3 for peak hours and 0.7 for off-peak hours.

Although no hourly water distribution volume data is available for the Project Site, the South Giza Waterworks located in the adjacent area maintains water supply volume records as shown in Table 2-3-9 where the maximum hourly variation rate (peak hours) is 1.24 which is slightly lower than that of the M/P.

Table 2-3-9 Hourly Variation Rate of Water Supply Volume at South Giza Waterworks

	Summer	Winter	Ramadan
Peak Time	1.12	111	1.24
Off-Peak Time	0.85	0.91	0.94

Source: GOGCWS

As the hourly variation rate is expected to increase due to improvement of the standard of living, it is decided to adopt the figure used by the M/P as described below, taking the future demand trend at the Project Site into consideration.

① Time factor (ratio of hourly maximum water distribution volume against hourly mean water distribution volume): 1.3

② Hourly variation rate of water distribution volume: see Fig. 2-3-2.

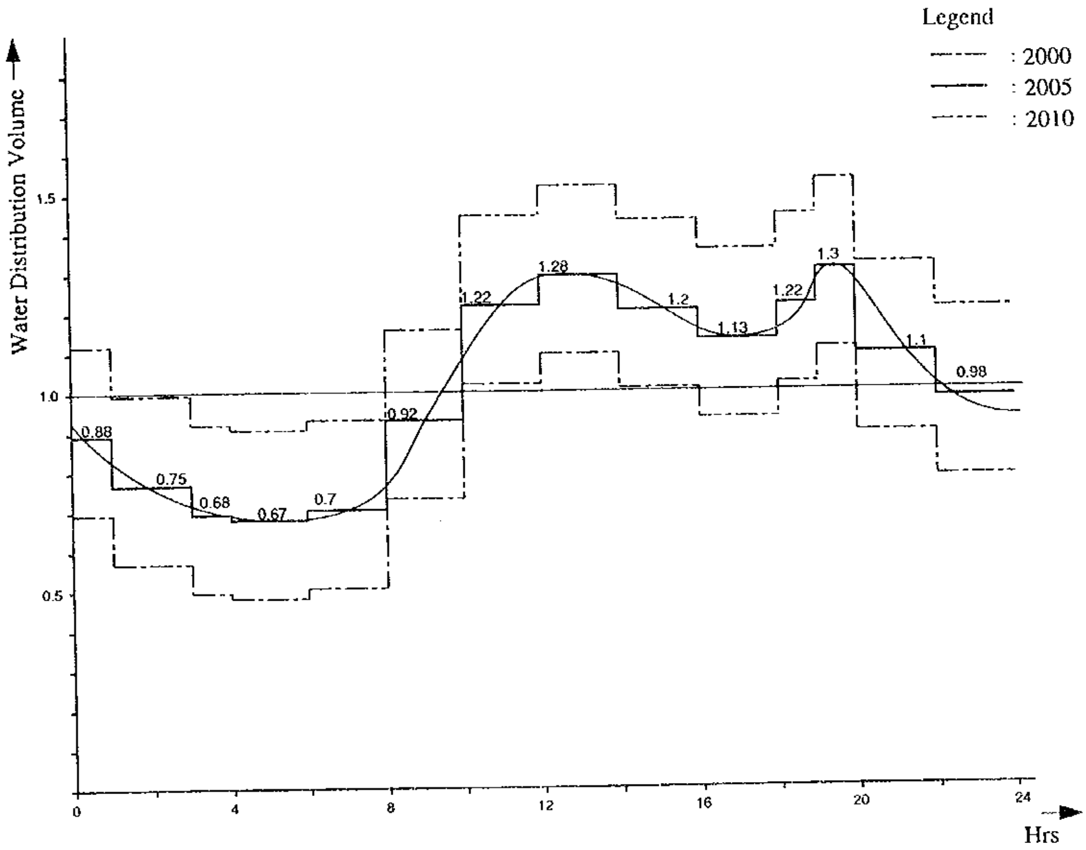


Fig. 2-3-2 Hourly Water Distribution Variation Rate at Project Site

3) Design Target Year

① Water reservoirs and water transmission main : 2010

② Distribution pumps and distribution pipes : 2005

4) Design Daily Maximum Water Supply Volume per Person

210 litres/person/day

5) Design Maximum Daily Water Supply Volume

See Table 2-3-6.

6) Design Water Reservoir Capacity

The design water reservoir capacity is set at equivalent to five hours supply of the design maximum daily water supply volume as shown in Table 2-3-10.

Table 2-3-10 Design Water Reservoir Capacity

Water Distribution Reservoir	Capacity (m^3)
No. 1	14,000
No. 2	11,000

7) Climatic Conditions

① Mean temperature (in shadow) : 26°C
② Maximum temperature in summer (in shadow) : 45°C
③ Minimum temperature in summer (in shadow) : 40°C
④ Atmospheric pressure (mean) : 785 mm/Hg
⑤ Minimum relative humidity : 40%
⑥ Mean humidity (summer) : 60°C
⑦ Mean humidity (winter) : 65°C

8) Standards Applied

① Mechanical and electrical installations:
JIS and other related Japanese standards
② Civil engineering and architectural design:
JIS and other related Japanese standards
③ Local equipment and materials:
relevant Egyptian standards

(7) Configuration of Basic System

The configuration of the basic water distribution system envisaged under the Project, taking all of the above conditions into consideration, is shown in Fig. 2-3-3.

DESIGN DISTRIBUTION VOLUME TO EACH AREA

(m^3/DAY)

SYMBOL	WATER DISTRIBUTION AREA	FY2005	FY2010
QWTP	SOUTH GIZA WATERWORKS (PRODUCTION CAPACITY)	375,000	525,000
QT	GIZA SOUTH DISTRIBUTION MAINS	160,000	218,000
QSD	SOUTH/ WEST DISTRICT	47,700	80,000
QCT	CENTRAL DISTRICT	205,600	292,000
QO	MONIB AREA / PROJECT SITE	112,300	138,000
QM-1	MONIB AREA (1)	10,000	10,000
QM-2	MONIB AREA (2)	10,000	10,000
QM-3	MONIB AREA (3)	9,400	15,000
QP	PROJECT SITE	92,300	118,000
Q1	No.1 WATER DISTRIBUTION BASIN	52,000	66,400
Q2	No.2 WATER DISTRIBUTION BASIN	40,300	51,600

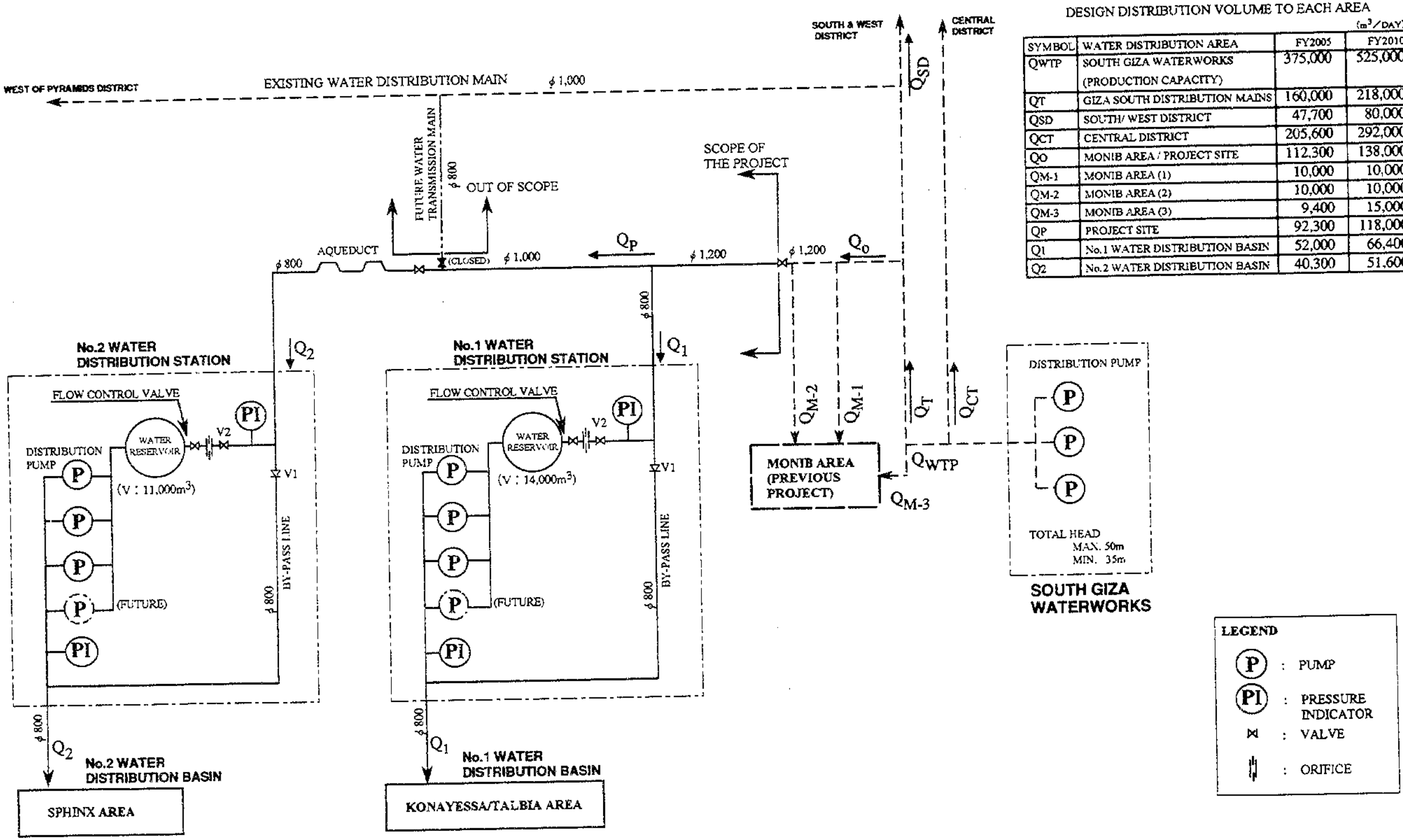


Fig. 2-3-3 Configuration of Basic Water Distribution System Envisaged Under the Project

2.3.2.2 Water Transmission Main Plan

The basic plan for the water transmission main will be prepared based on the design principles described in 2.3.2.1-(3) as well as the field survey findings while coordinating with other water supply improvement plans of GOGCWS. The water transmission and distribution system envisaged under the Project is shown in Fig. 2-3-4.

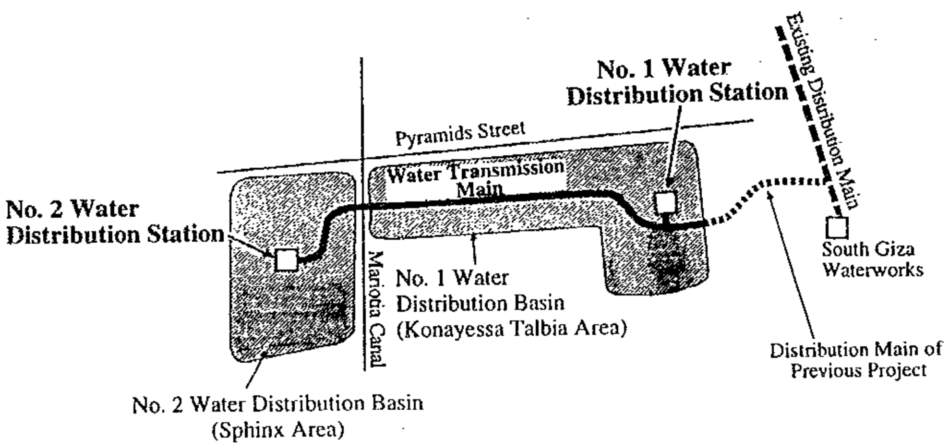


Fig. 2-3-4 Illustration of Water Transmission and Distribution System Envisaged Under the Project

The flow of the basic planning for the water transmission main envisaged under the Project is as follows.

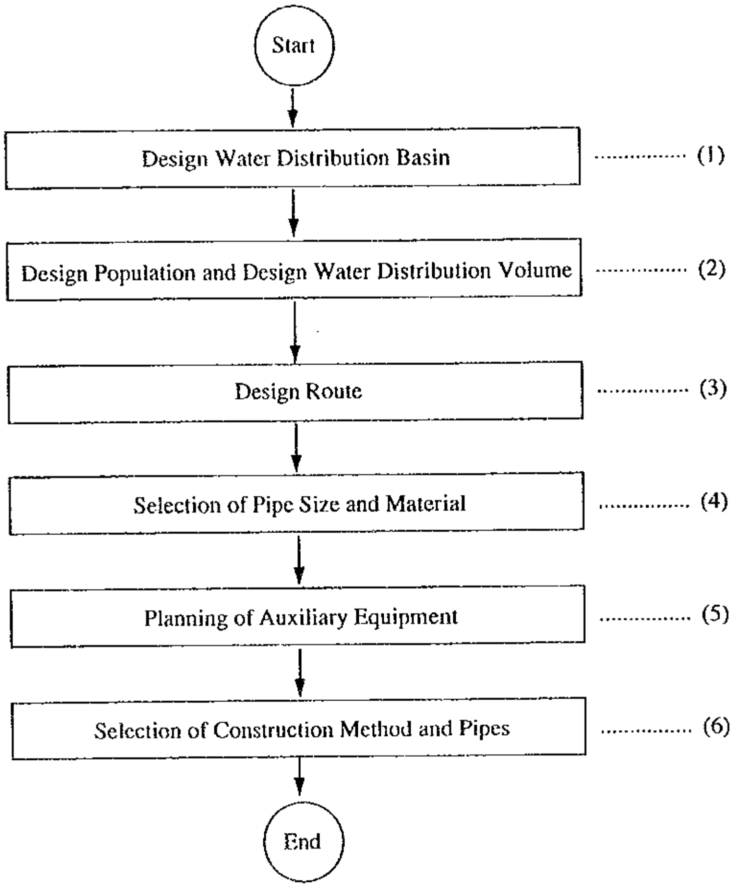


Fig. 2-3-5 Flow of Basic Planning for Water Transmission Main

Each of the flow items (Fig. 2-3-5) is described next.

(1) Design Water Distribution Area

The design water distribution area under the Project is the Project Site (8.2 km^2) indicated on the Location Map.

(2) Design Population and Design Water Distribution Volume

The following design population and design water distribution volume are adopted for the Project as described earlier.

- Design Population: 560,000 (year 2010)
- Design Water Distribution Volume:
  based on the design hourly maximum water distribution volume (1.3 times larger than the daily maximum water distribution volume given below.

No. 1 Basin (Konayessa Talbia Area)	66,400 m^3/day
No. 2 Basin (Sphinx Area)	51,600 m^3/day
Total	118,000 m^3/day

(3) Design Route

The design route of water transmission main will be determined so as to conform to Giza Water M/P and the relevant local conditions, including the water supply routes proposed by the M/P, the road plan and land use plan of the Giza municipal authority, workability and construction cost.

1) Selection of Optimal Design Route

Three routes are feasible for the proposed water transmission main as shown in Fig. 2-3-6 and the names of the streets surveyed by the present study are listed in Table 2-3-11.

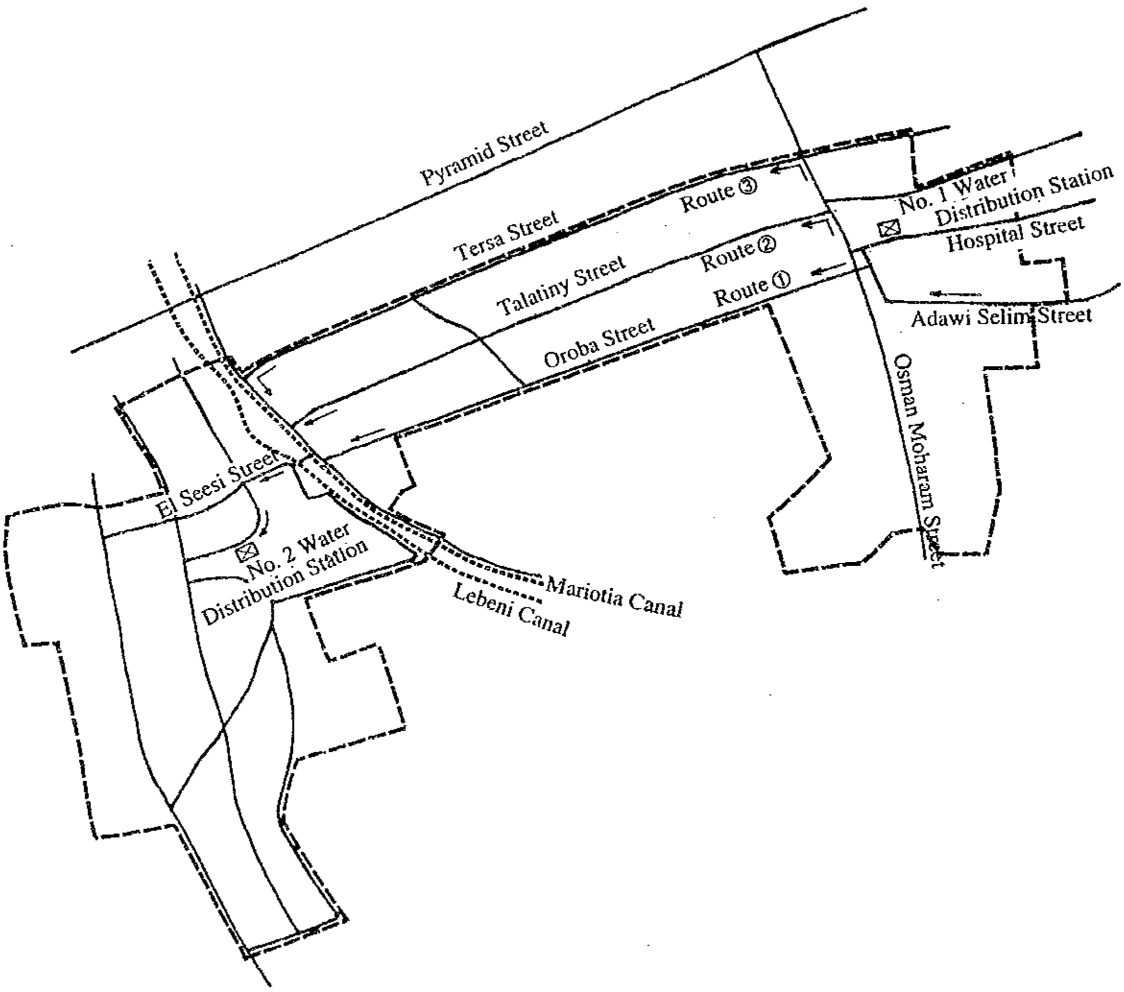


Fig. 2-3-6 Examined Routes for Water Transmission Main

Table 2-3-11 Streets Along Examined Routes for Water Transmission Main

Route No.	Streets Along Route
①	Adawi Selim Street → Oroba Street → El Seesi Street → No. 2 WDS ↓ No. 1 Water Distribution Station
②	Adawi Selim Street → Talatiny Street → El Seesi Street → No. 2 WDS ↓ No. 1 Water Distribution Station
③	Adawi Selim Street → Tersa Street → El Seesi Street → No. 2 WDS ↓ No. 1 Water Distribution Station

Note: WDS = Water Distribution Station

Following a detailed check of each street along the three alternative routes, the characteristics described in Table 2-3-12 were found by the field survey team.

Table 2-3-12 Characteristics of Alternative Routes

Route No.	Characteristics
①	The shortest length of all the routes. Oroba Street is mainly unpaved and the housing density along this route is lower than the other routes. Underground structures include the Abu Nomros Sewer Trunk Line(ϕ 1,800 mm and some 7 m deep) and some water distribution pipes.
②	The total length is 500 m longer than Route ①. Talatiny Street is mainly paved and is wider than Oroba Street. The circumstances for execution is inferior to Route ① because of the presence of many underground structures, including water supply pipes, sewer pipes, electricity conduits and telephone conduits.
③	The total length is 1,300 m longer than Route ①. Tersa Street runs parallel and next to Pyramids Street and is fully paved with the highest traffic volume of all the routes. Given the fact that this route is lined by 10 or more story buildings, it can be safely assumed that more underground utilities are found along this route than the other two routes.

Based on these findings concerning each alternative route, Route ① is selected as the route for the water transmission main because of its most advantageous position in terms of economy, execution circumstances and construction period reflecting its shortest length, lowest volume of underground utilities and easy restoration of the road functions (as it is unpaved).

2) Current Conditions of Design Route and Points to Note

The current conditions of the design route (Route ①) and points to note in terms of the planning and construction work are described below.

① Adawi Selim Street → Diversion Point → No.1 Water Distribution Station

The water distribution main (ϕ 1,200 mm) laid under Adawi Selim Street under the previous grant aid project (Phase 2 Monib Project) currently ends at a point 800 m west of the Zomor Canal. The new water transmission main under the Project will start at this point, run another some 800 m west along Adawi Selim Street and branch out at the 50 m point before reaching Osman Moharam Street to head north along an unpaved road with a width of some 20 m. After travelling north for some 150 m, the new water transmission main will reach the diversion point to the No. 1 and No. 2 Water Distribution Station.

From the starting point to the diversion point, the design route has a road width of some 20 m and the open cut method can be employed due to the light traffic volume.

From the diversion point to the No. 1 Water Distribution Station, the design route will use Hospital Street which has a width of 15 - 20 m and a light traffic volume. Work during the day using the open cut method is feasible for this section, allowing traffic flow on one side.

② Diversion Point → Osman Moharam Street → Oroba Street

After travelling west for some 60 m, the design route crosses Osman Moharam Street at a right angle. Osman Moharam Street is a semi-trunk road with a width of more than 20 m and a heavy traffic volume. Although one side can be made open to traffic, work at night is preferable in order to avoid severe traffic congestion which are likely to result from work during the day.

After crossing Osman Moharam Street, the design route enters Oroba Street which runs parallel to Pyramids Street for some 3 km to the Mariotia Drainage Canal. Oroba Street is mainly unpaved, has a width of 15 - 30 m and many undulations. Because of the light traffic, work during the day using the open cut method is feasible.

Under Oroba Street lies the Abu Nomros Sewer Trunk Line(ϕ 1,800 mm; 7 - 8 m deep) constructed by the Egyptian side as part of the previous project and the manholes for this Sewer Trunk Line rise above the road surface. Under the Project, the crown height of the manhole covers will be used as the reference road height for the planned laying depth of the water transmission main.

As these large Sewer Trunk Line manholes (approximately 3 x 3 m) are installed at intervals of approximately 100 m, the alignment of the water transmission main must be carefully planned so as not to interfere with the manholes.

③ Oroba Street → Mariotia Canal Street → Canal Crossing Point

Travelling further west along Oroba Street, the design route reaches the Mariotia Drainage Canal. The design route crosses the canal at a right angle and also crosses Sakkara Street to reach the No.2 Water Distribution Basin. As in the case of the previous project, crossing of the canal will be made by an aqueduct. Sakkara Street has a heavy traffic volume with large buses and trucks as it is a trunk road leading to such famous tourist sites as the stepped Pyramids and the agricultural region. Given its narrow width of some 12 m, work at night using the open cut method is deemed appropriate.

④ Sakkara Street → Lebeni Canal Crossing → El Jaht Street

After crossing Sakkara Street, the design route enters El Jaht Street after crossing the Lebeni Drainage Canal where an aqueduct will be constructed as in the case of the crossing of the Mariotia Drainage Canal. After crossing the Lebeni Canal, the design route follows Abdul Hardy Street and then Copuho Street. Although the traffic on both El Jaht Street and Abdul Hardy Street is light, special care will be required to ensure traffic flow due to the narrow width of 8 - 10 m. Because of the highest elevation (AD + 17.5 m) of El Jaht Street along the entire design route, wash-out facility will be necessary for this particular section.

⑤ Copuho Street → No. 2 Water Distribution Station

Copuho Street was constructed as a public road a few years ago by the filling of an irrigation channel. It has not yet been fully completed although sewer pipes and electrical cables have already been buried. The reconnaissance of this road found several water gates and the design route must avoid these gates.

(4) Selection of Pipe Size and Material

1) Selection of Pipe Size

The pipe diameter for the planned water transmission main must conform to the diameter employed by Giza Water M/P which specifies the water distribution main details in view of the proper water transmission to the water distribution station.

The planned water transmission and distribution under the Project is compared with the water distribution system under the M/P in Fig. 2-3-7. As shown in this figure, the M/P stipulates the pipe diameter for each section of the water distribution main between Point A and Point B. In contrast, the Project employs a different system whereby the water is firstly fed to water reservoirs to ensure steady distribution during the peak hours. The pipe size for the water transmission main under the Project is 1,200 mm upto the diversion point to the No. 1 Water Distribution Station and 1,000 m thereafter upto the diversion point to the No. 2 Water Distribution Station with a view to ensuring a sufficient transmission pressure upto the water distribution station and preventing damage to the pipes by means of maintaining an appropriate flow velocity.

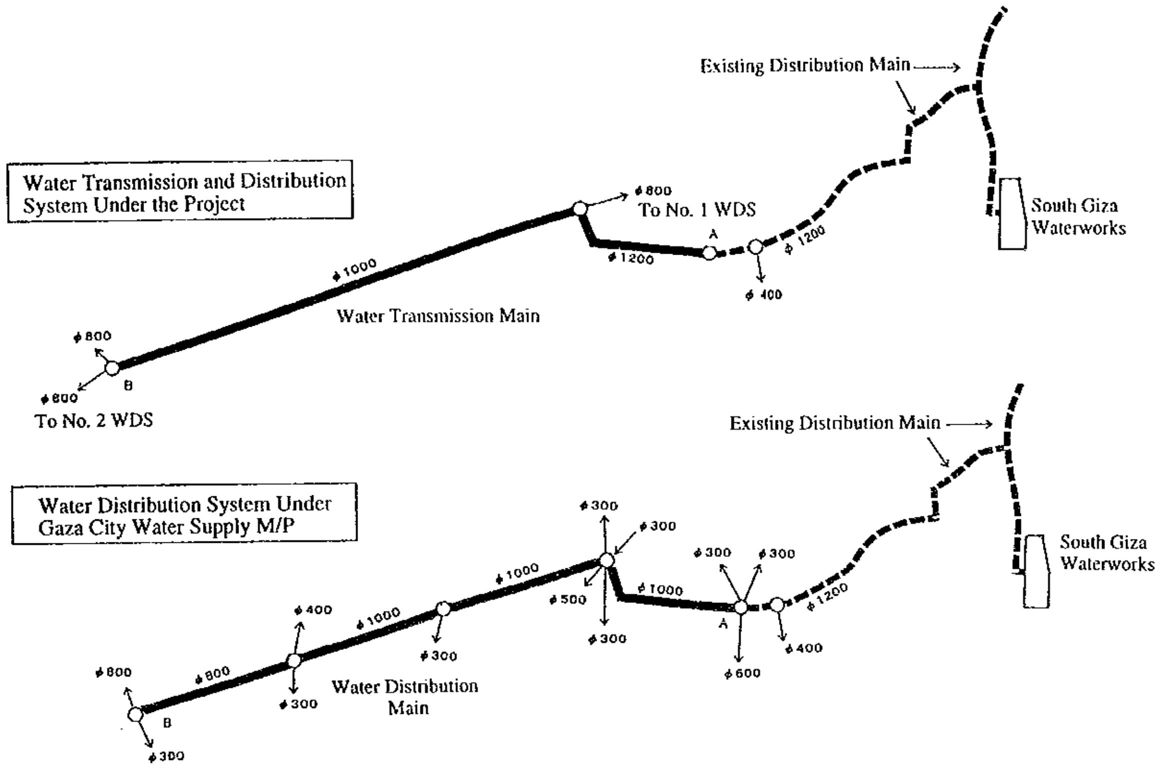
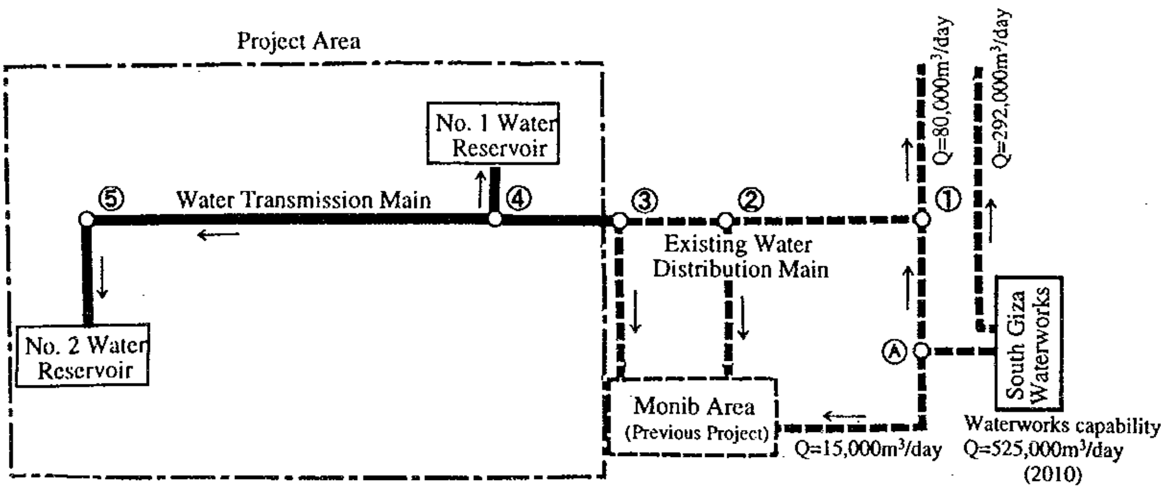


Fig. 2-3-7 Comparison Between the Project and Giza Water Master Plan

A decision on the diameter of the water transmission main must also be made to ensure the required residual water pressures for the peak time and off-peak time at each of the water distribution station.

Fig. 2-3-8 and Table 2-3-13 show the hydraulic computation model for the water transmission main and the computation results respectively.



Section Data

No.	Flow (Q) (m^3/day)	Pipe Diameter (D) (mm)	Section Length (L) (m)
A	233,000		
1	218,000	1,000	1,000
2	138,000	1,200	1,500
3	128,000	1,200	800
4	118,000	1,200	990
No. 1 WR	66,400	800	430
5	51,600	1,000	3,150
No. 2 WR	51,600	800	840

Fig. 2-3-8 Hydraulic Computation Model for Water Transmission Main

Table 2-3-13 Hydraulic Computation Results for Water Transmission Main

Mean Flow; Time Factor A = 1.0							
No.	Flow Q (m^3/s)	Pipe Diameter D (m)	Length L (m)	Flow Velocity Coefficient C	Flow Velocity V (m/s)	Head Loss H (m)	Head Ho (m)
A							42.5
1	2.523	1.000	1,000	110	3.213	9.9	32.6
2	1.597	1.200	1,500	110	1.412	2.6	30.0
3	1.481	1.200	800	110	1.310	1.2	28.8
4	1.366	1.000	990	110	1.739	3.1	25.6
No.1 WR	0.769	0.800	430	110	1.529	1.4	24.2
5	0.597	1.000	3,150	110	0.760	2.2	23.5
No.2 WR	0.597	0.800	840	110	1.188	1.7	21.8
Peak; Time Factor A = 1.3							
No.	Flow Q (m^3/s)	Pipe Diameter D (m)	Length L (m)	Flow Velocity Coefficient C	Flow Velocity V (m/s)	Head Loss H (m)	Head Ho (m)
A							35.0
1	2.870	1.000	1,000	110	3.655	12.5	22.5
2	1.667	1.200	1,500	110	1.474	2.8	19.6
3	1.516	1.200	800	110	1.341	1.3	18.3
4	1.366	1.200	990	110	1.208	1.3	17.1
No.1 WR	0.769	0.800	430	110	1.529	1.4	15.7
5	0.597	1.000	3,150	110	0.760	2.2	14.9
No.2 WR	0.597	0.800	840	110	1.188	1.7	13.2
Off-Peak; Time Factor A = 0.7							
No.	Flow Q (m^3/s)	Pipe Diameter D (m)	Length L (m)	Flow Velocity Coefficient C	Flow Velocity V (m/s)	Head Loss H (m)	Head Ho (m)
A							50.0
1	2.176	1.000	1,000	110	2.770	7.5	42.5
2	1.528	1.200	1,500	110	1.351	2.4	40.1
3	1.447	1.200	800	110	1.279	1.2	38.9
4	1.366	1.200	990	110	1.208	1.3	37.6
No.1 WR	0.769	0.800	430	110	1.529	1.4	36.2
5	0.597	1.000	3,150	110	0.760	2.2	35.4
No.2 WR	0.597	0.800	840	110	1.188	1.7	33.7

Notes 1) Head loss calculation formula: $H = 10.666 \cdot C^{-1.85} \bullet D^{-4.87} \bullet Q^{1.85} \bullet L$

2) Flow at each point

$Q1 = (118{,}000 + A \times 100{,}000)/24/3{,}600 = 2.523\ m^3/s$

$Q2 = (118{,}000 + A \times 20{,}000)/24/3{,}600 = 1.597\ m^3/s$

$Q3 = (118{,}000 + A \times 10{,}000)/24/3{,}600 = 1.481\ m^3/s$

$Q4 = 118{,}000/24/3{,}600 = 1.366\ m^3/s$

$Q\ (\text{No. 1 WR}) = 66{,}400/24/3{,}600 = 0.769\ m^3/s$

$Q5 = 51{,}600/24/3{,}600 = 0.597\ m^3/s$

3) WR: Water Reservoir

2) Selection of Pipe Type

The pipe type for the water transmission main must be decided taking the following criteria into consideration.

- Safety vis-a-vis internal pressure
- Safety vis-a-vis external pressure
- Suitable vis-a-vis burial conditions
- Few adverse impacts on vehicle traffic and pedestrians during construction work
- No adverse effect on water quality
- Little prospect of leakage
- Good durability
- Flexibility vis-a-vis ground deformation
- Good workability
- Easy maintenance
- Low maintenance cost

① Pipe Types Subject to Examination

The following pipe types were examined for possible use for the water transmission main in view of the required diameter, past performance in Egypt, ease of procurement, quality, economy and workability, etc.

- Ductile cast iron pipes
- Steel pipes

② Pipe Type Selected

Based on the selection criteria described above, the pipe selection principles of GOGCWS and the following aspects of ductile cast iron pipes, ductile cast iron pipes will be used for the straight pipes and specials (bends and T pipes) for the water transmission main, except for the aqueduct sections.

- Ductile cast iron pipes do not require welding work, lining work on the inside and outside faces of the weld and welding inspection using X-rays, resulting in a low construction cost.
- Compared to steel pipes, the jointing work is much simpler, resulting in a shorter construction period.

- The required internal and external pressure resistance strength can be sufficiently achieved.
- Compared to steel pipes, ductile cast iron pipes are superior in terms of corrosion resistance and workability.

(5) Auxiliary Equipment Plan

Such auxiliary equipment as gate valves and air valves, etc. are planned in the following manner based on the agreement with GOGCWS while also referring to the relevant Japanese standards (Japan Waterworks Association: Water Facility Design Guidelines Explained).

1) Butterfly Valves

Butterfly valves will be installed at approximately 1 km intervals along the route as well as at the diversion points, crossing points and aqueducts. The main specifications are given below (see Basic Design Drawing EGP-TM-02).

① Type	:	butterfly valve (for water transmission main: ϕ 800 - 1,200 mm)
② Material	:	ductile cast iron
③ Joining Method	:	flange joint (flexible pipe section inside and outside the valve chest)
④ Valve Chest Structure	:	flexible pipe on both sides of the valve and expansion pipe inside the valve chest

2) Wash-out Valve

The wash-out valves will be installed at the low section of the line. The main specifications are given below (see Basic Design Drawing EGP-TM-02).

① Type	:	sluice valve
② Diameter	:	200 mm
③ Joining Method	:	flange joint
④ Wash-out Method	:	a drainage pit will be introduced next to the valve chest and drainage will be regularly conducted using a portable pump

3) Air Valve

The air valves shall be installed at the concave sections of the route and at the aqueducts. The main specifications are given below (see Basic Design Drawing EGP-TM-02).

① Type	:	two-outlet air valve
② Accessories	:	a gate valve will be installed between the main and air valve in preparation for future repair work
③ Joining Method	:	flange joint
④ Others	:	the air valves on the aqueducts will be installed in a steel box to prevent theft or damage, while the air valves on the route will be installed in a reinforced concrete chamber.

4) Protection of Fittings

Fittings will be protected by concrete blocks. The shape and dimensions of the concrete blocks are shown in Basic Design Drawing EGP-TM-04.

(6) Selection of Construction Method and Pipe Type

1) Standard Sections of Water Transmission Main

The pipe laying work for the standard sections of the water transmission main will be conducted by the open cut method in consideration of economy. The standard earth cover will be 2 m in view of the large diameter of the planned pipes (800 ~ 1,200 mm) and the necessary avoidance of interference with other buried structures (water supply and sewer mains and branch pipes, water service pipes, drainage pipes and underground electric cables, etc.)

Given the existence of narrow road sections (8 - 10 m), heavy vehicle and pedestrian traffic along the route, the large pipe diameter (800 - 1,000 mm) with a fairly deep excavation depth (approximately 3 m) and the dense housing upto the road edge, the adoption of steel sheet pile earth retaining work which has high rigidity and strength is necessary to ensure work safety.

In regard to the joining of sections in the standard sections, T-shape joints (push-on type) will be used because of their good workability, low cost, low work cost and reasonable water-tightness. At bending sections and convex/concave sections, K-shape joints (mechanical type) will be used because of their good workability.

2) Aqueducts

As in the case of the previous project, an aqueduct will be constructed at each crossing section of the Mariotia Drainage Canal and Lebini Drainage Canal, taking the continued operation of both canals, workability, construction cost, maintenance requirements and past performance of aqueducts in Egypt into consideration.

The locations and details of these aqueducts, agreed by the Drainage Canal Bureau of Giza Governorate and GOGCWS, are shown on Basic Design Drawings EGP-TM-05 and EGP-TM-06. The outline of an aqueduct is illustrated in Fig. 2-3-9.

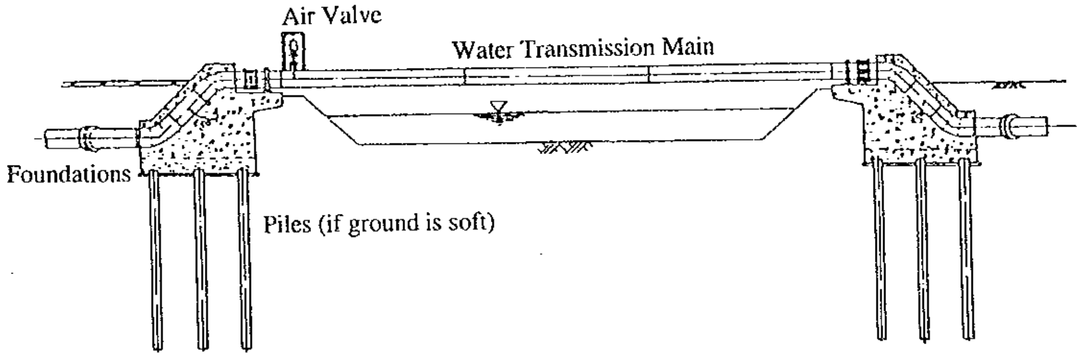


Fig. 2-3-9 Outline of Aqueduct

Careful attention is paid to the following points in the aqueduct design.

- The existence of gases, such as hydrogen sulfide, from the canals should be taken into consideration in the painting design.
- As people are expected to step on the stiffening members of the aqueducts, an extra road for people should be considered in the design load. In addition, fences or similar should be erected to deter people.
- The pipe diameter at the aqueduct section should be 800 mm to secure the flow level to meet the design water distribution volume in the No. 2 Water Distribution Basin with an adequate flow velocity.
- The aqueducts will be made of steel.

- The minimum height margin between the design maximum water level for the canal and the bottom of the aqueduct should be 50 cm.
- Flexible pipes should be used at the buried ends of the aqueduct to absorb possible uneven subsidence.
- An air valve should be installed at the highest point of the aqueduct but not right above the channel section of the canal. This air valve should be protected by a steel cover against theft or damage.
- Expansion pipes should be used at both ends of the aqueduct in view of the possible expansion/contraction of the steel pipes.

(a) Location of Aqueducts

① Mariotia Drainage Canal (Aqueduct No. 1)

The location of the Aqueduct No. 1 is shown in Basic Design Drawing EGP-TM-05. The route to be selected must be able to minimise the construction work load (i.e. any necessary extension of the water transmission main) for the very busy Sakkara Street.

② Lebini Drainage Canal (Aqueduct No. 2)

The location of the Aqueduct No. 2 is shown in Basic Design Drawing EGP-TM-06. The selected route crosses the canal to the south of the existing aqueduct to minimise the road length and interference with existing underground structures.

(b) Type of Aqueducts

Pile foundations will be adopted for the aqueducts to support the reaction force of the aqueduct and the bent section of the line. Cast-in-place piles which were used under the previous project and which are commonly applied in Egypt will be used.

In regard to the superstructure of the aqueducts, when the span is as long as 25 ~ 30 m as in the case of the Project, the simple support system generally requires an excessive pipe thickness, resulting in a high cost. There are three alternatives to this as listed below.

① Stiffening flange method
② Fixed single end or fixed double end method
③ Continuous support method

The second option is usually adopted when the ground conditions are good. As the ground at the Project Site consists of silty clay, horizontal displacement of the pile head may occur. Vertical displacement may also occur due to the use of the cast-in-place pile foundation method. Consequently, the second option, i.e. either the fixed single end or fixed double end method, is not advantageous at the planned aqueduct locations.

The third option, i.e. the continuous support method, is frequently used for small aqueducts (diameter: 300 ~ 350 mm) in Egypt. When adopted for a larger aqueduct of 800 mm in diameter, it requires piling to a depth of 16 m to reach the bearing layer. Accordingly, this method is inferior to the stiffening flange method in terms of durability and workability if not economy.

The first option, i.e. the stiffening flange method, offers a similar level of economy to the continuous support method but excels the latter in terms of durability and workability. In addition, it does not affect the cross-sectional area of the drainage canal. Consequently, the stiffening flange method will be used for the planned aqueducts under the Project.

2.3.2.3 Water Distribution Station Plan

(1) Distribution Pump System Plan

1) Pumping Operation Hours

In order to effectively use the water pressure of the water transmission main to achieve energy saving, the pumping operation hours will be restricted to the peak demand period for the water transmission main (for example, 10:00 through 22:00). During off-peak operation hours, water supply to users will be made via the by-pass which directly connects the water transmission main to the water distribution main from the waterworks. The condition for using this direct link is that the residual water pressure of the water transmission main at the water reservoir inlet is approximately 30 m (3.0 kg/cm^2) in view of the head loss in the line of some 10 m (1.0 kg/cm^2) between the water reservoir and the user end. If this residual water pressure level is not available, the pump system is operated to ensure the required water pressure level.

2) Pump Specifications and Number of Pumps in Operation

The pumps to be installed should have the same specifications and be of the same model to ensure easy operation and maintenance and the exchangeability of spare parts. More than one pump should be installed to maintain water supply operation during the necessary stoppage for maintenance or due to a breakdown, to respond to hourly fluctuations of the water demand and to meet the expected demand increase in the future. For large water distribution station such as planned under the Project (the distribution rate will be approximately 3,600 m^3/hour for the No. 1 Station and 2,800 m^3/hr for the No. 2 Station in the year 2010), the common practice is to install three pumps together with one stand-by pump. However, in view of the construction/installation cost, easy operation and maintenance and reduction of the spare parts cost, the number of pumps should be minimised. Accordingly, the following number of pumps is planned for each station under the Project.

-Upto 2005 (Project)	:	two pumps for normal operation and one stand-by pump (10 hours operation/day by two pumps)
-From 2006 to 2010 (final target year)	:	three pumps for normal operation and one stand-by pump (10 hours operation/day by three pumps)
-Pump Model	:	double suction centrifugal pump

The above plan indicates that the Egyptian side must install one additional pump (with the same specifications as those installed under the Project) in 2006 to meet the expected water demand increase in the future (upto 2010).

3) Energy Saving Through Water Flow Control

Given the increasing awareness of the importance of energy saving in Egypt [see 2.3.2.1-(4)-3)], the design of the pump system planned under the Project should feature energy saving.

Pump flow control is normally conducted by delivery valve control, revolution (speed) control of the number of pumps in operation (number control). While delivery valve control is the simplest in terms of the system, throttling of the delivery valve consumes the pump's delivery head, resulting in a large energy loss as well as poor operation efficiency. Because of this, the wasteful use of electricity has become a problem at the existing water distribution pumping stations run by GOGCWS. The use of delivery valve control under the Project, is therefore, undesirable.

Three other options, i.e. speed control, numerical control and no flow control, are examined next to decide the preferable flow control method for the Project. In the case of number control, the number of pumps in the final target year of 2010 will be five for informal operation plus one reserve pump.

(a) Energy Efficiency of Each Control System

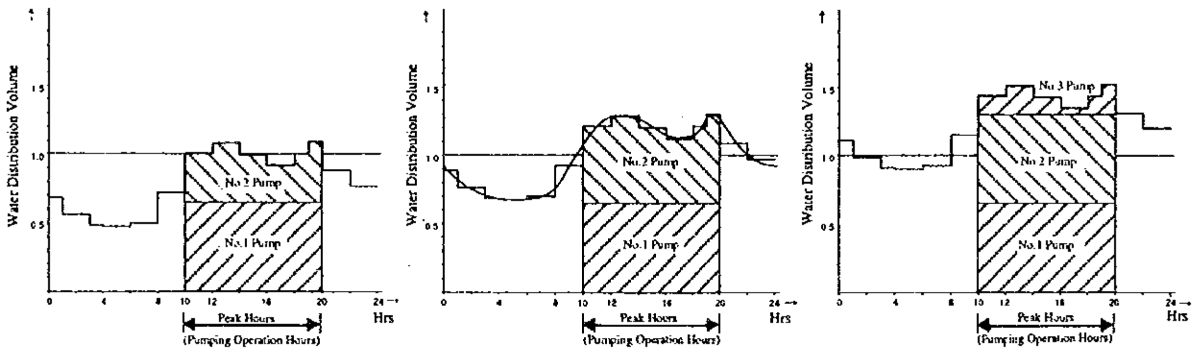
Fig. 2-3-10 shows the pumping operation mode and design water distribution volume of each method for 2000 (planned completion year of the Project), 2005 (design target year for pumping facilities) and 2010 (final target year of the Project). The characteristics of each system are outlined below.

Case A (speed control method)

As it is possible to control the delivery flow of the pump to meet the water demand by each time unit, efficient energy utilisation is achieved.

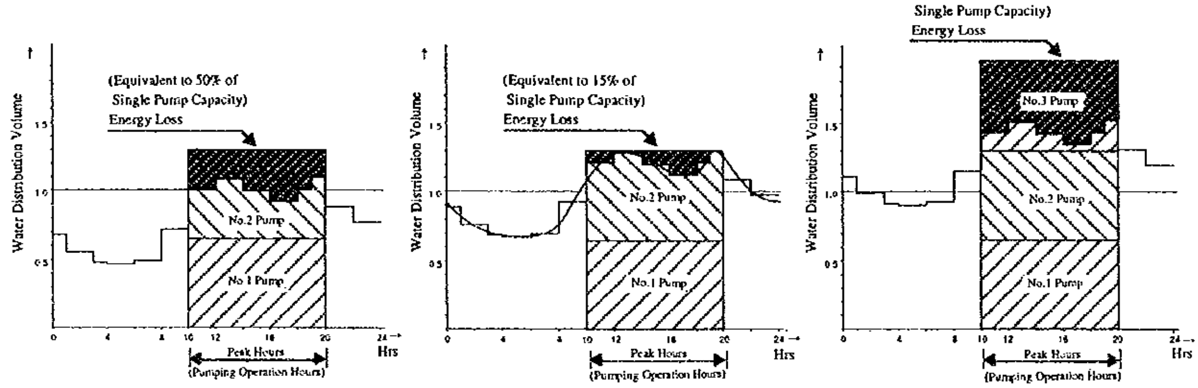
Case B (no flow control)

As the pump capacity is decided based on the water demand for 2005, two pumps will be simultaneously operated during the peak hours for the low water demand period at the beginning of operation (assumed to be 2000). At this time, the total delivery flow of the two pumps will be larger than the actual water demand by some 50% of the single pump capacity, resulting in the waste of energy. In 2010, the third pump will commence operation but the excess capacity will be equivalent to some 80% of a single pump, resulting in wasteful operation.



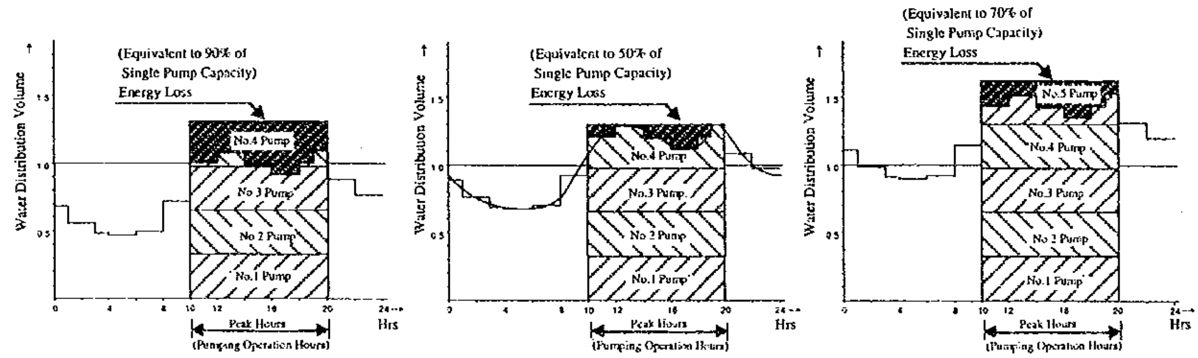
<2000> <2005> <2010>

Case B (No Flow Control)



<2000> <2005> <2010>

Case C (Number Control Method)



<2000> <2005> <2010>

Fig. 2-3-10 Operation Mode and Design Water Distribution Volume by Flow Control Method

Case C (number control method)

The trend upto 2005 will be similar to that of Case B as some 90% of the single pump capacity will be wasted in the beginning. In 2010, because of the user of smaller pumps than in Case B, the energy loss based on the pump capacity will be smaller than that of Case B. Nevertheless, as the total delivery flow will be much larger than the actual water demand, resulting in excessive delivery equivalent to some 50% of the single pump delivery.

The estimated annual power consumption of each method is compared in Fig. 2-3-11 based on the above operation mode. The power consumption of Case A is some 70% lower than Case B and Case C, providing the prospect of economical operation.

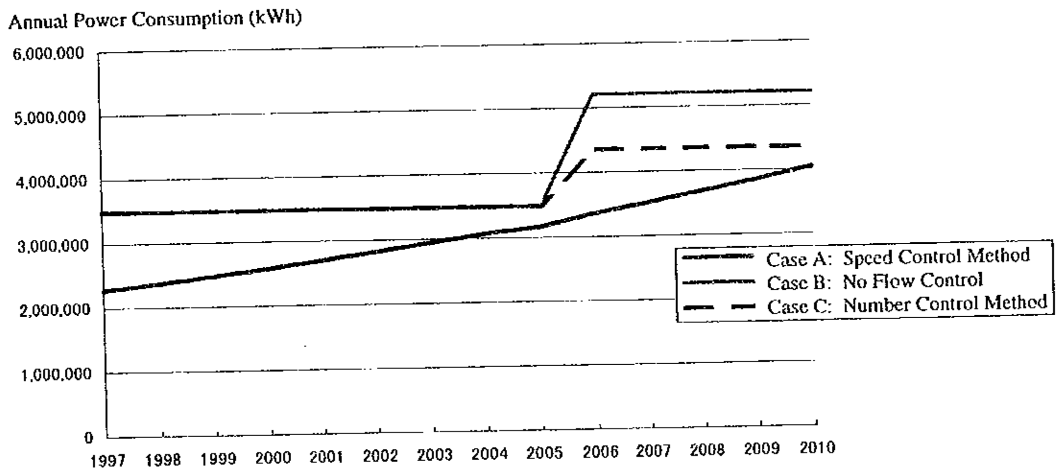


Fig. 2-3-11 Annual Power Consumption by Flow Control Method

(b) Comparison of Operational Balance of Each Flow Control Method

The results of the economic comparison, including the equipment cost as well as the operation and maintenance cost, and the estimated operational balance of each flow control method examined are given in Appendix 7. In short, Case A (speed control method) offers the most economical. Consequently, the speed control method is selected for the Project.

Types of Speed Control Methods

Flow control based on speed control can be typically achieved by means of an inverter control system, resistance control system, Scherbius control system or pole change control system. No speed control method is currently used in Egypt. Of these systems, the inverter control system has the easiest operation and maintenance and a good motor power factor during pump operation. Consequently, it is popularly used for the speed control of not only pump motors but also various rotating machines. As Egypt's technological level can sufficiently cope with the operation and maintenance requirements of an inverter control system, the speed control method using an inverter control system will be used for flow control at the water distribution station planned under the Project.

(c) Installation Flow Control Valve

As described earlier [2.3.2.3-(1)-1)], water distribution during the peak hours is made directly from the water transmission main to the distribution mains via the by-pass pipe. While distributing water to the water distribution zones, it is necessary to store water at the water reservoirs in preparation for pumping during the peak hours. This water supply to the water reservoirs should be made at the minimum pressure in view of efficient energy use. A flow control valve will accordingly be installed at the inflow channel of each water reservoir with a view to regulating the water pressure at an appropriate level.

4) Calculation of Motor Capacity

The required motor capacity is calculated by the following equation based on the relevant JIS standard.

$$P\ (kW) = 0.163 \bullet \gamma \bullet Q \bullet H/\eta \bullet C$$

Where,

P	:	motor output (kW)
γ	:	volume per liquid unit (1 kg/litre)
Q	:	delivery flow per pump (m^3/min . pump)
H	:	total head of pump
η	:	pump efficiency (0.82)
C	:	margin (0.15)
0.163	:	factor

The delivery flow (Q) per pump is calculated by the following equation based on the design maximum daily water supply volume for 2005, the design target year for the pumping facilities under the Project.

$$Q\ (m^3/min \cdot pump) = (Q_d/24/60 \times \text{time factor/number of pumps in operation})$$

Where, Q_d : design daily maximum water supply volume in 2005, 52,000m^3/day for No. 1 Basin and 40,300m^3/day for No.2 Basin

Time Factor : 1.3 [see 2.3.2-(1)-4)]

Number of Pumps : two [see 2.3.2.3-(1)-2)]

Using the above equation, the required motor capacity at each water distribution station is calculated below.

No. 1 Water Distribution Station

$$\begin{aligned} P &= 0.163 \cdot \gamma \cdot Q \cdot H/\eta \cdot C \\ &= 0.163 \times 1 \times 23.5 \times 50/0.82 \times 1.15 \\ &= 269 = 270\ kW \end{aligned}$$

No. 2 Water Distribution Station

$$\begin{aligned} P &= 0.163 \cdot \gamma \cdot Q \cdot H/\eta \cdot C \\ &= 0.163 \times 1 \times 18.2 \times 50/0.82 \times 1.15 \\ &= 208 = 210\ kW \end{aligned}$$

5) Pump Diameter

The pump diameter is determined by the following equation.

$$D\ (mm) = 146 \cdot \sqrt{Q/V}$$

Where, D : pump diameter (mm)

Q : delivery flow per pump (m^3/min . pump)

V : flow velocity at suction opening of pump (m/sec)

146 : factor

The required pump diameter at each water distribution station is calculated below.

No. 1 Water Distribution Station

$$D = 146 \cdot \sqrt{Q/V}$$
$$= 146 \times \sqrt{23.5/3}$$
$$= 408.6 \fallingdotseq 400 \text{ mm}$$

No. 2 Water Distribution Station

$$D = 146 \cdot \sqrt{Q/V}$$
$$= 146 \times \sqrt{18.2/3}$$
$$= 359.6 \fallingdotseq 350 \text{ mm}$$

6) Instrumentation and Control Equipment

(a) Operation Method

Pump operation with speed control, which will be employed under the Project, is semi-automatic operation whereby the number of pump revolutions (i.e. speed) is manually set by visually monitoring the water supply pressure for easy maintenance of the system and also for an easy response to system failure by operators.

(b) Instrumentation and Control Equipment

The following instruments and control equipment will be installed to ensure easy operation and monitoring of the water distribution system by operators and to conduct the safe and appropriate operation of the water distribution station.

① Central Console

Central console will be installed in the office to select the number of pumps to be operated and the operation speed, to start and stop pumping operation, to monitor the water pressure of the water transmission main and distribution main and to display a warning.

② Tank Water Gauge

Tank water gauge will be installed to monitor the water level of the water reservoir and to display a warning on the central console in the case of an abnormally high or low water level.

③ Pressure Gauge

Two pressure gauges will be installed at the following points to set up the pump start-up conditions and to control the opening of the flow control valve at the inlet of the water reservoir and their readings displayed on the central console.

- Water transmission main on the premises of each water distribution station
- Water distribution main on the premises of each water distribution station

④ Flow Meter

Flow meters will be installed at the water distribution main on the premises of each water distribution station and at the delivery pipe of the pump system for water demand control and their readings to be displayed on the central console.

⑤ Water Absence Detector

Water absence detector will be installed at the gate vale on the delivery side of the pump to prevent idle operation due to unbalanced pump revolutions during multiple-pump operation; the detector is designed to make an emergency stop to protect the pump when no water is being pumped.

7) Counter-measures against Water Hammer

Following the emergency stop of a pump at the time of a power cut, abnormal pressure (water hammer) may occur due to a sudden change of the water velocity inside the water distribution pump. In order to deal with this situation, a special measure is incorporated at the existing water distribution pumping station.

The actual measure may consist of the installation of an automatic pressure regulating valve, a quick closure reverse-flow prevention valve or a slow closure reverse-flow prevention valve. An automatic pressure regulating valve is not only expensive due to its requirement for an uninterruptive power supply unit but is also complicated in terms of operation and maintenance. A quick closure system is normally used for a reverse-flow prevention valve and is unsuitable for large diameter pumping facilities such as envisaged under the Project.

Consequently, a slow closure reverse-flow prevention valve will be employed as the measure to combat water hammer under the Project in view of its fairly popular use as a reverse-flow prevention valve for large diameter pumping facilities and its easy maintenance due to the absence of an extra power supply unit.

8) Electrical Installation Plan

(a) Division of Electrical Installation Work

A substation to receive two circuit 10.5 kV low power supply and a low voltage switchgear for power supply to the pumps will be installed in the electrical room of each water distribution work planned under the Project. The division of the electrical installation work between the Japanese side and Egyptian side is as follows.

① Egyptian Side

The following work required for power connection to the 10.5 kV local power distribution line.

- Installation of the service cable of the two circuit 10.5 kV local power distribution line
- Procurement and installation of the 10.5 kV ring main unit
- Procurement and installation of the integrating watt-hour meter

② Japanese Side

All electrical installation other than that conducted by the Egyptian side which is necessary to operate the pump system in question.

(b) Power Supply

The power system for the water distribution station is as follows.

① High voltage: 10.5 kV, 3-phase, 3-wire, 50 Hz

② Low voltage

- Power equipment : 380V, 3-phase, 3-wire, 50 Hz

- House power supply : 380 - 220 V, 3-phase, 4-wire, 50 Hz
  (lighting and heating, etc.)
- Monitoring and control : DC 100 V
- Instruments : DC 24 V

The total power factor at the point receiving point will be not less than 0.9 as required by the power distribution company.

(c) Circuit Configuration

The power receiving circuit is a two circuit 10.5 kW system. No emergency power generating unit will be provided because of the decrease of the number of power cuts, in turn resulting from the improvement of the local power distribution system. Only one transformer will be provided at each water distribution station under the Project because of the following reasons.

① High Reliability of Transformer

- The past transformer performance based on relevant data in Japan suggests that the transformer breakdown probability is 0.003 times a year which makes the transformer the most reliable equipment among the various types of electrical equipment. The electrical item with the highest breakdown probability is the high voltage cable at 0.083 times a year, 28 times higher than the transformer.
- When economical design is required to take the initial investment cost and operation and maintenance cost thereafter into consideration, it is essential to improve the reliability of the most unreliable (i.e. highest breakdown probability) equipment. The 10.5 kV power receiving circuit appears to be such equipment under the Project and, therefore, the two circuit system is selected in order to improve reliability.

② Consent to Single Transformer Under Previous Project

- The most important facility of a water supply network is believed to be the waterworks. The South Giza Waterworks constructed under the previous project has two transformers, i.e. one for 10.5/0.38 - 0.22 kV and another for 10.5/3 kV, but no reserve transformer is provided based on the judgement that both transformers are highly reliable. The power system at the South Giza Waterworks was planned and designed with the approval of GOGCWS and has been operating upto the present day without any problems.

- The 10.5 kV power receiving circuit at this waterworks is a single circuit despite the request for a two circuit system by GOGCWS at the stage of both the basic design and detailed design. The reason for the selection of this one circuit system was that the proximity of the waterworks to the 66/10.5 kV substation would enable the connection of an exclusive 10.5 kV cable to the waterworks, very much reducing the breakdown probability of the cable. Through consultations with GOGCWS, it was agreed that the present one circuit power receiving system will be used. The system has subsequently operated without any problems, justifying the adoption of this economical design.
- As the power receiving circuit under the Project requires long extension of the 10.5 kV power distribution cable from a distant substation, the breakdown probability of the cable is judged to be higher than in the case of the previous project, hence the adoption of a two circuit system. The transformer itself is believed to be highly reliable as in the case of the previous project and, therefore, no reserve transformer is considered.

③ Non-Disturbance of Pumping Due to Regular Inspection of Transformer

- The most time-consuming item on the regular inspection list of a transformer is inspection and cleaning of the bushing which should be conducted approximately every six months. This maintenance work is expected to last for some two to three hours and the operation of the transformer must be stopped to ensure work safety. As this is planned during the off-peak night period, the operation of the transformer will not be disrupted.

(d) Equipment Specifications

The main equipment specifications are described here. Special care is taken to ensure the adoption of the same capacity and specifications of the breaker and other equipment for both of the water distribution station in view of the exchangeability of spare parts.

- 10.5 kV Incoming Panel : indoor-type, self-contained, enclosed switchgear
  [Main Components]
  vacuum circuit breaker (VCB); arrester; watt-hour meter; ammeter; voltmeter; power factor meter; reactive power meter; integrating watt-hour meter (to be procured by the Egyptian side)
- Main Transformer : 10.5 kV/380V, 50 Hz, Dyn 11, outdoor-type, oil-immersed transformer
- Low Voltage Switchgear : indoor-type, self-contained, enclosed switchgear
  [Main Components]
  air circuit breaker (ACB); voltmeter; ammeter; power factor meter; watt-hour meter; pump starting circuit (with inverter control); power circuit for auxiliary equipment; transformer for house power supply

(2) Water Reservoir Plan

1) Capacity

See the design conditions described in 2.3.2.1-(4).

2) Shape and Dimensions

It is desirable for the water reservoirs to be relatively deep in order to make effective use of the water pressure given by the conveying pump at the waterworks. The planned heat at the No. 1 Water Reservoir in 2010 is an average of 27.2 m and 15.7 m at peak hours. Because of the head loss of some 2 m due to the flow regulating valve with an inflow valve, orifice, bends, leakage and friction, etc., the average head is assumed to be approximately 22 m in average and 14 m at the peak. During peak hours, as the inflow volume may be slightly less than the average flow, the high water level (HWL) at the works can be set above 13 m. At many water reservoirs constructed in the past, the water depth is 10 - 15 m, providing the same level of economy. The planned dimensions of the No. 1 Water Reservoir are a diameter of 34.3 m and an effective water depth of 15.15 m while those of the No. 2 Water Reservoir are a diameter of 31.7 m and an effective water depth of 14.0 m to maintain the same diameter-depth ratio as the No. 1 Water Reservoir. Both of the water reservoirs will have a cylinder shape which structurally does not produce bending movement, except for hoop tension, at the horizontal cross-section and which provides a high storage efficiency.

3) Structural Type

A ground water reservoir can generally be constructed using reinforced concrete (RC), prestressed concrete (PC) or steel. The characteristics of these three structural types are described in Table 2-3-14.

4) Foundation Type

As the soil profile (Appendix 8) shows, the soil conditions at both the No. 1 Water Distribution Station and No. 2 Water Distribution Station are similar. The silty clay layer reaches some 9 m below the ground surface with a N value of 10 - 20. Ground deeper than approximately 12 m is occupied by a sand layer with a N value of 50 or more.

The water reservoirs play an important role in the water distribution system planned under the Project in terms of not only regulating the water distribution volume to the Water Distribution Basins but also alleviating or preventing the negative impact on consumers during an emergency of using the stored water. Given this importance, the foundations of the reservoirs must be safe vis-a-vis ground reaction as well as subsidence, etc., taking not only the bearing capacity but also the consolidation characteristics of the soil into consideration. Suitable foundation types are examined below.

Table 2-3-14 Comparison of Feasible Structures for Ground Water Reservoirs

Item	PC	Score	RC	Score	Steel	Score
Structure	• Large span possible due to small dimensions and light weight of members • Better resistance to dynamic water pressure than RC and less likelihood of cracking	3	• Larger foundations required than PC in the case of a large water reservoir due to heavier weight resulting from large dimensions of members	2	• Better ductility than concrete but inferior rigidity • Internal anti-chlorine painting and external weatherproof painting required	1
Water Tightness/ Durability	• Little cracking due to tension fastening with use of high strength concrete • Little corrosion of concrete or steel materials due to no cracking	3	• Likely appearance of cracks due to drying contraction of concrete and increased fatigue due to tensile force at full capacity	1	• Better water tightness than concrete and inferior durability due to likely corrosion	2
Work Supervision	• Slightly more complicated than RC, demanding strict work supervision • Strict work supervision leading to high quality structure • Requires high strength concrete of not less than 300 kg/cm^2 • Neither screening nor expansion joints are required	1	• Conventional work supervision sufficient to deal with this popular method • Screening and expansion joints may be required depending on reservoir shape • Use of normal strength concrete	3	• On-site assembly and welding of all joints • Welding work to be conducted by qualified personnel, followed by non-destructive testing to check welds	2
Maintenance	• Less maintenance work than RC or steel due to little prospect of cracking, rusting or corrosion	3	· Less maintenance work than steel but more than PC due to the need for the filling of cracks, etc.	2	• Regular anti-chlorine painting and weatherproof painting required, resulting in a high volume of and costly maintenance work	1
Economy	• Lower construction cost than RC for a large reservoir (cheaper foundation piles and other costs due to lighter weight than RC) (construction cost index: 100)	3	• Higher construction cost than PC for a large reservoir (construction cost index: 120)	2	• One third of the durability of PC or RC, resulting in a much higher depreciation per year (inferior economy) (construction cost index: 170)	1
Miscellaneous	• Thin wall thickness and cylinder shape with domed roof make an attractive sight with a symbolic effect • Relatively new method in Egypt has the effect of technology transfer	3	• Normal square shape is less attractive than PC in appearance • Established method in Egypt with no effect of technology transfer	2	• Wall design variation is virtually limited to painting • No past example in Egypt for a large reservoir	1
Overall Evaluation	○	16	△	12	×	8

Note: 3 (○) = advantageous, 2 (△) = slightly advantageous, 1 (×) = not advantageous

③ Cohesion of Soil

The cohesion (C) of the soil can commonly be obtained by the following equation.

$$C = \frac{qu}{2}$$

Where, C : cohesion (kg/cm^2)
qu : unconfined compression strength (kg/cm^2)

Consequently, the cohesion of the soil at the water reservoir sites is 0.60 ~ 0.96 kg/cm^2 with a mean value of 0.71 kg/cm^2 (7.1 t/m^2).

④ Bearing Capacity of Soil

The ultimate bearing capacity (qd) of shallow foundations on the clay layer can be obtained by the following equation with an internal friction angle (ϕ) of 0.

$$qd = \alpha \cdot C \cdot Nc$$

Where, qd : ultimate bearing capacity (t/m^2)
α : shape coefficient (circular shape: 1.3)
Nc : bearing capacity factor (5.3 when $\phi = 0$)

The calculated ultimate bearing capacity of the ground in question is 41.3 ~ 66.1 t/m^2 with a mean value of 48.9 t/m^2. Consequently, the allowable bearing capacity (qa) with a safety factor of 3 is as follows.

$$qa = \frac{qu}{3} = 13.8 - 22.0\ t/m^2$$

The average value of 16.3 t/m^2 of the above is adopted as the allowable bearing capacity. The resulting relationship between the ground reaction and allowable bearing capacity is shown in Table 2-3-17.

Table 2-3-17 Ground Reaction and Allowable Bearing Capacity of Soil at Planned Water Reservoirs

Allowable Bearing Capacity qa (t/m^2)	Ground Reaction (t/m^2)	
	No. 1 Water Reservoir	No. 2 Water Reservoir
16.3	19.12	18.00

As shown in Table 2-3-17, the ground reaction at both water reservoirs exceeds the average allowable bearing capacity value.

⑤ Consolidation Subsidence

In the case of spread foundations being used for the water reservoirs, it is necessary to estimate the likely consolidation subsidence of the supporting clay layer after construction of the water reservoir structure. This consolidation subsidence (S) can be obtained by the following equation.

$$S\ (cm) = mv \cdot dp \cdot H$$

Where, mv : mean volumetric compression factor obtained from the natural water content (0.03 cm^2/kg)

dp : dead weight (No. 1 Water Reservoir: 1.91 kg/cm^2; No. 2 Water Reservoir: 1.8 kg/cm^2)

H : depth of the subject layer of consolidation (9m = 900cm)

Using the above equation, the estimated consolidation subsidence at each reservoir is as follows.

No. 1 Water Reservoir : 51.6 cm
No. 2 Water Reservoir : 48.6 cm

⑥ Foundation Type Selected

As the ground reaction at each water reservoir site exceeds the mean allowable bearing capacity of the soil and as the compaction subsidence is expected to be as large as some 50 cm, there is a risk of uneven subsidence, etc. causing cracks in the water reservoir structure, leading to a serious function loss. Because of this prospect, pile foundations using the sand layer some 12 m below the ground surface are selected as the foundation type to be used for the water reservoirs under the Project.

5) Inflow Pipe, Suction Pipe and By-Pass Pipe

① Inflow Pipe

The outlet level of the inflow pipe may be lower than the high water level (HWL) or level with the HWL. In the case of the outlet level being lower than the HWL, if the water conveyance pressure at South Giza Waterworks is insufficient, water in the water reservoir could flow in reverse into the inflow pipe to reach South Giza Waterworks, reducing the water distribution volume to the designated water distribution zone. In order to avoid this, the outlet height of the inflow pipe for the planned water reservoirs under the Project is set level with HWL.

The head of the inflow pipe significantly varies (for example, between 15.8 m and 38.1 m for the No. 1 Water Reservoir Station) because of the large fluctuation of the pump head at South Giza Waterworks of between 35 m and 50 m and also because of the flow fluctuations in the upperstream. It is necessary for the flow level in the inflow pipe to be regulated so that the water storage level at the water reservoir is roughly constant. In order to achieve a constant flow despite the pressure changes on the inflow side of the valve, a flow regulating valve whereby half opening operation is possible will be installed to the inflow pipe. As the water pressure cannot be fully regulated by this valve only, an orifice will also be installed. In addition, an ordinary valve will be installed in view of the maintenance of the flow regulating valve. The inflow pipe will be mounted to the wall with a very strong metal support and the pipe material should be stainless steel to avoid corrosion.

② Suction Pipe

The suction pipe extends from the suction pit of which the elevation is lower than the low water level (LWL) and is connected to the pump.

③ By-Pass Pipe

A by-pass pipe will be introduced to allow water distribution without pumping in view of energy saving when the residual water pressure is sufficiently high during the night, etc. Its use should be encouraged, if appropriate, when ever the head is above the predetermined head.

6) Overflow Pipe and Wash-Out Pipe

An overflow pipe will be installed at the height of HWL while a wash-out pipe will be extended from the suction pit of which the elevation is lower than LWL. The downstream ends of both the overflow pipe and wash-out pipe will be connected to the sewer manhole.

7) Vent-holes, Manholes, Maintenance Holes, Staircase and Ladder

Vent-holes will be installed in response to the expected water level fluctuation inside each water reservoir. At times when the water reservoir is entered to carry out maintenance inspections, etc., Manholes, a staircase and ladder will be used for maintenance work. A landing area will be introduced for the internal ladder because of its height. This ladder and landing area will be constructed of stainless steel to avoid corrosion by water with a high residual chlorine level.

8) Painting

Epoxy resin paint will be used for the internal painting of the water reservoir in view of its excellent waterproofness, durability and strength vis-a-vis concrete cracks. Emulsion paint will be used for the external painting because of its good waterproofness and weatherability.

(3) Civil Work and Building Plan for Water Distribution Station

1) Planning Contents

The following civil work will be conducted and the following buildings will be constructed at each of the two water distribution station (No. 1 and No. 2) planned under the Project.

- Distribution Pump House : RC single story with building facilities
  total floor area: approximately 300 m^2
- Equipment Foundations : foundations for water distribution pump and electrical equipment, including transformer
- Internal Road
- Septic Tank
- Sewerage System

2) Facility Layout Plan

The facility layout at the planned two water distribution station are shown in Basic Design Drawings EGP-WD-01 and EGP-WD-02. This layout plan is prepared based on the facility plan described in 2.3.2-(3)-1).

3) Details of Main Facilities

Each facility at the water distribution station is planned based on the layout plan, elevation plan and movement plan in order to ensure the proper functioning of the planned distribution pump system under the Project. The selection of the materials required for the construction of the planned facilities is based on local availability, project schedule, future maintenance requirements and durability. The main functions of each facility are described next.

(a) Distribution Pump House

① Main Specifications

- Foundations	:	RC pile foundations
- Superstructure (beams and pillars, etc.)	:	RC
- Piping and Cable Pit, etc.	:	RC
- Floor	:	RC or checkered plate
- Partitions	:	concrete blocks, etc.
- External Walls	:	concrete blocks with sprayed mortar
- Fittings	:	aluminium or steel

② Main Rooms and Floor Area, etc.

The main rooms, their floor area and building facilities of the pump house are described in Table 2-3-18.

Table 2-3-18 Room Arrangement of Pump House

Item No.	Room	Floor Area (m^2)	Building Services, etc.
1	Pump Room	176	Lighting; ventilation; fire-fighting; overhead travelling crane
2	Electric Room	64	Lighting; ventilation; fire-fighting
3	Control Room	20	Lighting; ventilation
4	Storage	30	Lighting; natural ventilation
5	Toilets	6	Sanitary fixtures; lighting; ventilation
Total		296	

③ Building Services

- Lighting System : JIS standards are used for lighting. In principle, lamps are either fluorescent lamps or mercury lamps
- Ventilation System : ventilation fans or natural ventilation using louvre windows
- Air-Conditioning System : package-type air-conditioner
- Fire-Fighting System : ionic fire detector and ABC fire extinguisher (3 kg type) in each room

④ Transformer Shade

A shade will be provided for the 10.5 kV transformer which supplies power to the pump system.

(b) External Work, Including Internal Road

As shown in Basic Design Drawings EGP-WD-01 and EPG-WD-02, a internal road will be constructed from the entrance to the water distribution station to circle the pump house in order to assist valve operation, instrument checking and maintenance. This road will be constructed of asphalt concrete and cross-grade will be introduced to facilitate rainwater drainage. Parking spaces will be provided for operation and maintenance staff.