8.3 Preliminary Design

According to the comparison of alternatives in 8.2.5, preliminary deisgn is performed hereinafer.

8.3.1 Lateral Drainage Facilities

(1) Outline of Drainage Facilities

Quantities of the lateral drainage facilities are as follows;

- Perforated pipe	:	ø300 - 3,910 m
		ø450 - 1,664 m
		ø600 - 330 m
		Total 5,904 m
- Connection pipe to discharge pump station	:	ø600 - 25 m
- Manhole	:	59 nos.

General plan of the lateral drainage system is shown on DWG. No. DRP-3001. The transversal and longitudinal sections are on DWG. Nos. DRP-3002 thru 3004.

(2) Outline of Drainage Plan

The lateral drainage facilities are designed to be located so as to cover and surround the project area. They shall be connected to the discharge pump station to be located in the center of the project area at the lowest part.

In addition to the perimeter drainage pipe, lateral drainage pipe is also provided in the central part of the network so that the distance between the drainage pipes located in parallel is at most 500 m. This enables the drainage by the lateral drain and the resultant drop of groundwater level to be more effective.

Since the lateral drainage pipe located in the central part of the network can collect less groundwater than the surrounding pipe once the groundwater level is lowered, it shall be used for the transfer line to the discharge pump station from the surrounding pipeline.

In the project area for Old Rayyan, the land is under suburban utilization such as large scale farming and housing so that few public roads run within this area. Therefore, a part of the lateral drainage pipeline shall be placed within private land.

i) Determination of Route

The lateral drainage pipe shall be placed

- to surround and cover the area where the groundwater level is less than 1.5 m below the ground level,

- in principle along the secondary roads so that no land acquisition is required and the hindrance to traffic by the construction can be minimized,

- under the carriage way where it cannot be placed along the road because it is too narrow,

- where the elevation of the road is higher than that of the vicinity, at the bottom of the embankment in order to reduce the cost of earth work, and

- to avoid houses and structures in cases when it cannot be placed along the road.

ii) Depth of Lateral Drainage Pipe

The groundwater level in the lateral drainage network is about QND + 5.5 m and the invert level of pipe is set so that the depth of 3.5 to 4.0 m from the groundwater level can be kept.

Therefore, the invert level of the most upstream point is set as QND + 2.0 m. The hydraulic gradient is determined as 1/1000 and thereby the intake pit at the discharge pump station is not so deep.

As a result , the invert level is set ranging from QND + 2.0 m to QND + 0.3 m with an earth cover of 4 to 7 meters.

iii) Design of Pipe

Since most of the abstracted groundwater, discharge of which is taken as 3,000,000 m^3/year or 0.095 m^3/sec, is considered to come from outside the project area, pipes on the perimeter of the drainage system are designed to drain the whole abstracted groundwater and the groundwater discharge amount in the pipe is calculated per linear meter.

The diameter of pipes is calculated for the discharge at the point concerned of the network.

Calculation of the diameter shall be done in the same manner as in section 7.3.1, item "c".

Carrying capacities for different diameters of pipe are listed below;

Table 8.3.1 Carrying Capacity of Pipe

Diameter (mm)	Hydraulic gradient	Velocity (m/sec)	Discharge Capacity of Pipe (m^3/sec)
ø300	0.001	0.682	0.0241
ø450	0.001	0.911	0.0725
ø600	0.001	1.112	0.1573

iv) Typical Section of Lateral Drainage

A typical section of the lateral drainage shall be as shown below.

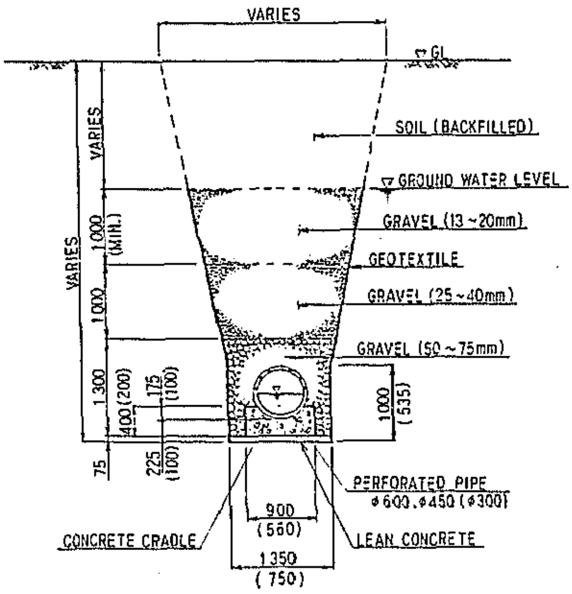


Fig. 8.3.1 Typical Section of Lateral Drainage

Since ground condition in this area is as a whole better than in the project area at Wadi Musherib, excavation can be done without supporting structures. However, in order to avoid the collapse of the excavated surface, excavation shall be done with the slope of 1:0.2 up to the top level of pipe and then vertically. This enables the earth pressure on the pipe to be reduced.

After pipe laying and prior to backfilling, geotextile sheets shall be applied and three kinds of gravel shall be filled around the perforated pipe as described in section 7.3.1, item "d'".

v) Materials for Pipe

For pipe materials, as described in section 7.3.1, item "e", extra strength vitrified clay (ESVC) pipe shall be employed.

vi) Manhole

Manholes shall be located in general about 100 meter apart, as mentioned in section 7.3.1, item "f".

8.3.2 Discharge Pump Station and Discharge Pipe Line

(1) Design Policy

i) Design conditions

Basic design conditions are set as follows;

a. Design discharge quantity

3,000,000 m^3 per year
5.7 m^3 per min

b. Design water intake level of pump pit

According to the result of the lateral drainage network for groundwater collection, water intake levels are,

High water to start	QND + 1.500 m
Low water to stop	QND + 0.800 m

c. Ground floor level of pump station

Considering the future land reclamation around the pump station, ground floor level shall be QND + 7,000 m.

d. Operation

There shall be no full time operator but patrol once a day. Therefore pumps shall be activated or shut-off automatically according to the water level. Simple control system shall be considered as much as possible.

e. Electric power

Power source shall be from the public electric network system and received in 6,000V and 50Hz.

f. Settling basin

Conveyed water is groundwater without debris or suspended solids therefore settling basin is not provided.

g. Discharge point

Transfered water shall be discharged at Natural Reserve Area in the Regional Park for New District project which is proceeding by the Amir's Office.

h. Discharge pipe line

Route of the pipe line and longitudinal section are shown on the Drawing DRP-4001.

Highest point	:	Near cement factory in Haul Road, elevation QND + 20,960 m where an intermediate chamber is provided to have free water surface enabling the gravity flow after this point.
Number of curves	:	5 points in pressurized part out of 7 points in total

ii) Location of the pump station

Location of the pump station was selected at a point adjacent to a new pumping station for sewerage line planned by MPW and has the following advantages.

- Almost lowest point in the project area and suitable for collecting water.
- Adjacent to the existing and newly proposed pump station and convenient for daily patrol.
- Proposed site has been already incorporated in the governmental use area.

iii) Method of operation and monitoring

- Pumps are operated by automatic on-off according to the water level in the intake pit.
- Pump operation is controlled automatically for two (2) number units.
- One of three pumps is stand-by unit and automatically turned-on upon trouble in any one of the two running pumps.
- As monitoring equipment, flowmeter, integrating meter and EC meter with recording function are provided.

iv) Emergency power supply

Provision of diesel generator for emergency was examined but excluded for the following reasons.

- Reliability of public electric power supply system in Doha is very high.
- Purpose of the pump station is pumping of groundwater and even an occurance of one or two days black out may not cause serious problem.
- Cost for emergency generator and housing it is considerably high.

v) Route of the discharge pipe line

Two routes, A and B, for the pipe line from Old Rayyan to the West Bay are considered as shown in Fig. 8.3.2. On either route, pipes are installed in the foot path of the road.

For the Selection of Route A, following matters were considered.

- Length of the pipe line is shortest from pump station to the out fall.
- Curves at crossing of main roads are 7 in number but there is no sudden vertical change, and they are manageable from the hydraulic point of view.
- There is no difficulty in land acquisition
- In Route A, in comparison with Route B residential areas and commercial zones are much less and there is sufficient area secured for intermediate water chamber.

vi) Pipe material

Under such corrosive conditions, pipe materials generally considered are ductile iron pipe, aluminum coated steel pipe, fiber reinforced plastic pipe, poly vinyl chloride pipe, asbestos pipe etc. Anticorrosion measures for ductile iron pipe such as internal cement mortar lining and external PVC tape wrapping and for steel pipe such as aluminum smelt coating are considered.

After examination on safety, durability and workability, ductile iron pipe was selected for the following reasons;

- Widely adopted for underground pipes in Qatar and good results are obtained.
- Regarding PVC pipe and asbestos pipe, strength to withstand high pressure and durability is not sufficient.
- Aluminum coated pipe is preferable regarding anticorrosvie effect and low cost but in durability and difficulty of site erection is inferior to ductile iron pipe.

It is recommended to adopt push-on-joint as joint for the ductile pipes.

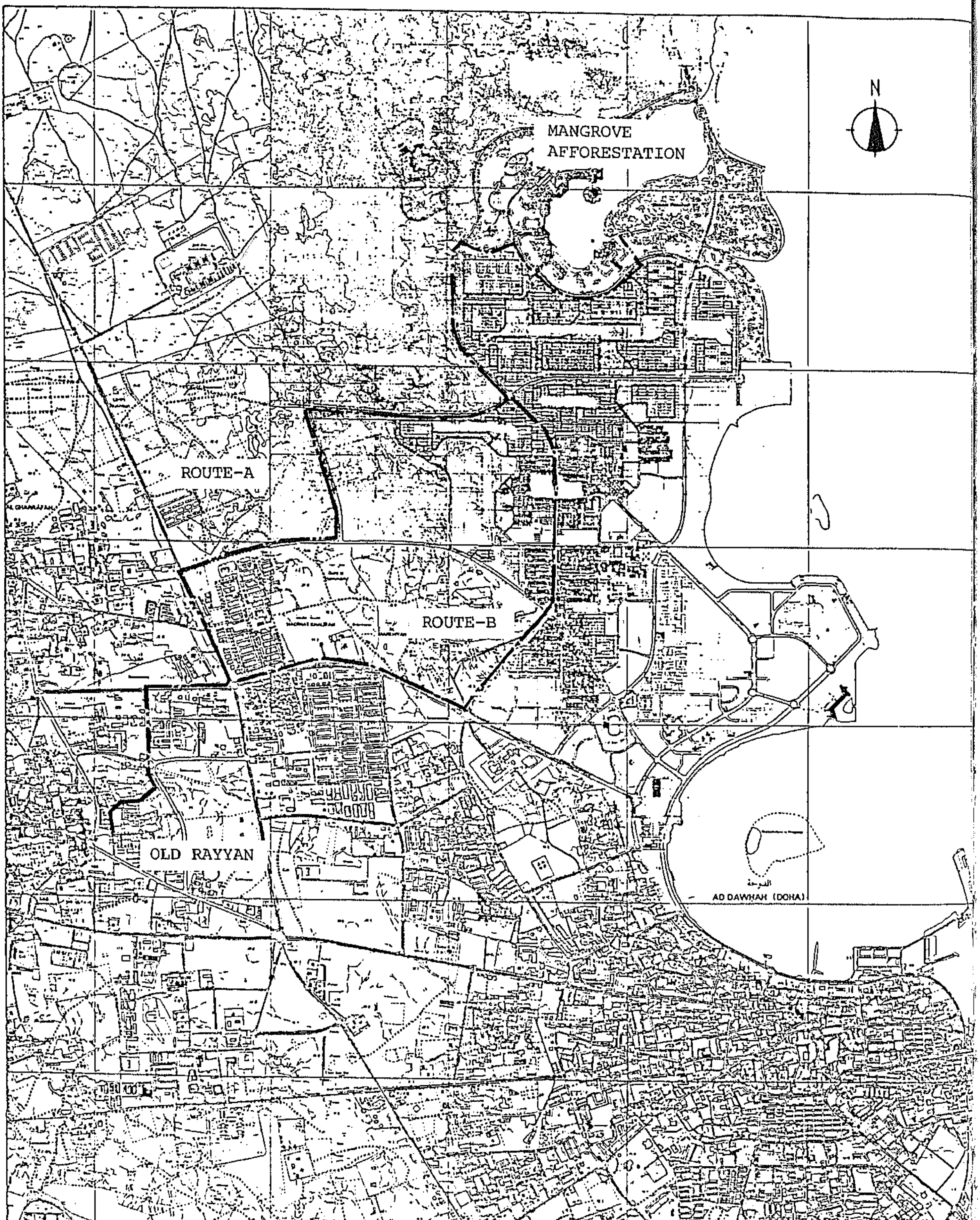


Fig. 8.3.2 Route of Discharge Pipe Line

vii) Depth of the pipe

Standard depth of pipe installation shall be 120 cm at places under road, foot path and road shoulder and at crossing parts with other pipes a minimum of 30 cm shall be secured, considering the following;

- Safety against horizontal earth pressure and live loads from above.
- Enabling the provision of control and air valves in the earth covering above pipe.
- In this pipe line there is no branch along the way with no possibility for provision of such in the future. Therefore this pipeline shall be installed as deep as possible in order to avoid interference with other piping and cabling.
- Standard depths of underground facilities are as follows

Potable water	90 mm
Sewerage	120 mm
Electric cable	40 mm
Telephone cable	40 mm

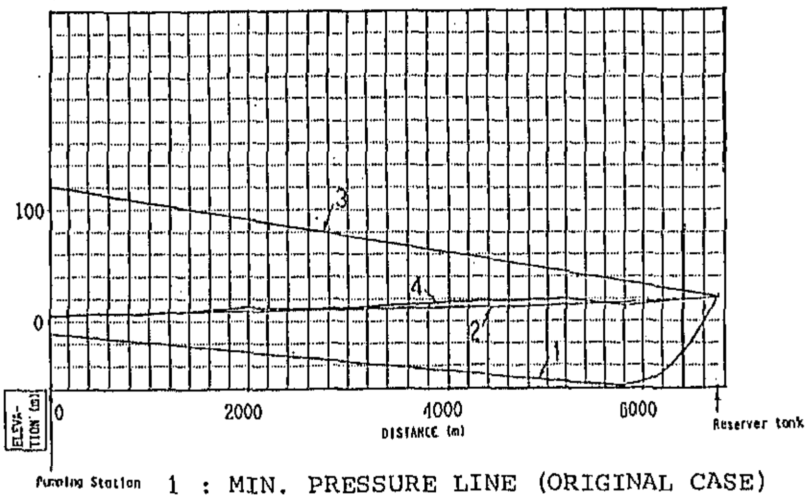
viii) Water hammer protection

There are some countermeasures for water hammering in the pipeline which are curbing intensive velocity change and curbing the pressure rise and fall. For this pipeline the fly wheel method was considered being one of the simple and reliable measures and was confirmed to be satisfactory in the computation.

- Result of the computation

  without fly wheel
  maximum negative pressure
  - 7.436 kg/cm^2
  at the point of 5,229.9 m from the pump station with the elevation of QND + 20.71 m and out of allowance

  with fly wheel of 40 kg/m2
  maximum negative pressure
  - 0.530 kg/cm^2
  at the point of 5,047.5 m from the pump station with the elevation of QND + 20.21 m and within allowance



1 : MIN. PRESSURE LINE (ORIGINAL CASE)
2 : MIN. PRESSURE LINE (WITH PREVENTION DEVICE OF FLYWHEEL)
3 : INITIAL HYDRAULIC GRADIENT
4 : PIPELINE PROFILE

Fig. 8.3.3 Result of Water Hammer Computation

(2) Outline of the facilities

i) Pump facilities

Flow diagram, electrical oneline diagram and arrangement of the pump system are as shown in Drawings DRP-4002 and 4003.

Total head	:	122.0 m
Actual head	:	21.4 m
Head loss	:	98.19 m
Flow rate	:	2.85 m^3/min
Number of Pumps	:	3 units (one stand by)
Type of Pump	:	
Material	:	Casing forged cast iron rotor, impellar, rod and sleeve SUS 316
Motor	:	110 KW x 415 V x 50Hz

ii) Discharge pipe line (pump station, water chamber, pressure pipe part)

Length	:	6,700 m
Pressure	:	12 kg/cm^2
Pipe material	:	Ductile iron pipe BS 4772 K-9 with external protection, 2 x 1.1 mm PVC tape wrapping and internal lining cement mortar 5 mm

iii) Intermediate water chamber

Water level	:	QND + 22.20 m
Ground level	:	QND + 20.96 m
Water chamber	:	Reinforced concrete chamber 2.5 m x 2.5 m x 3.3 m height
Capacity	:	30 m^3

iv) Discharge pipeline (Water chamber-West Bay, gravity flow part)

Length	:	7.7 m
Pressure	:	3 kg/cm^2
Pipe material	:	Ductile iron pipe same as above specification

8.3.3 Mangrove Afforestation

(1) Summary of Mangrove Afforestation Plan

The Regional Park Project planned in the New District Development by the Amir's Office features a Mangrove forest as natural reserve area. Therefore a mangrove afforestation utilizing groundwater from Rayyan was considered in this scheme.

a. Forest Utilisation

A mangrove forest park for recreational and educational purpose, supply of livestock feed, fish culturing, windbreaking and sand arresting.

b. Forest Area/Number of Planted Trees

Mangrove Forest	(30 ha/140,000 trees)
Date Palm Forest	(5 ha/5,000 trees)
Embankment and Islands	(10 ha)
Main Irrigation Channels	(15 ha)
Total	60 ha

c. Conceptional Drawing

Concept of this plan is shown on Drawing DRP-4006

(2) Role of Mangrove Forests

Mangrove forests are widely distributed in the inter-tidal zones of tropical/semi-tropical coasts and are generally made up of more than a single tree species. More than one hundred species of mangrove exist throughout the world and their main characteristics is the physiological fact that they can grow in sea-water, i.e. they have a high salt tolerance. The inter-tidal zone where these mangrove forests exists is an area which becomes part of the sea at high tide and part of the land at low tide, with the result that mangrove forests play a central role in the ecosystems of both the sea and land and provide a habitat for numerous flora and fauna, as well as having a close connection with human life.

In terms of their relationship with the marine ecosystem, mangrove forests nurture marine resources. It is an established fact that areas close to mangrove forests are rich in fish. Their role of providing a living space for animals and birds is similarly important. The direct utilisation of the mangrove as a material for firewood and charcoal, building material and wood pulp is of great value. In addition, such effects as the protection from coastal erosion by the widely spread roots and windbreaking cannot be ignored. Mangrove forests also play an important role in providing livestock feed in dry areas, such as Arabia.

In regard to the worldwide distribution of mangrove forests, their development is particlarly conspicuous in humid tropical areas, for example South East Asia. Some forests, however, also exist locally in such dry areas as Arabia, offering important forestry resources.

(3) Feasibility of Mangrove Afforestation

A small natural mangrove forest has survived in Qatar despite its poor growth. This forest consists of a single species (Avicennia Marina) and has maximum tree height of some 4 m which is considered to be low. This low tree height was brought about by the excessive use of the forest in the past and also by damage resulting from grazing. If these factors were to be removed, however, the mangrove in Qatar could be expected to grow to a height of upto 8 m in its present natural environment. The existence of this natural mangrove forest in Qatar proves that the growth of the mangrove, at least of the Avicennia Marina species, is feasible. Other species, especially the Rhizophora Stylosa, Cerips Tagal and Sonneratia Alba which are presumed to have become extinct in the area in the past, should also be able to grow. (With regard to the Rhizophora Stylosa in particular, its growth is considered feasible based on tests on its growth conducted at Ras Al Khafji in Saudi Arabia and Mubarras Island Abu Dhabi.)

(4) Benefits of Mangrove Afforestation

As well as creating a forest, the effective utilisation of a mangrove forest based on its ecological characteristics should also be considered. The creation of a mangrove forest which has multiple purposes is useful in the development of Doha. The comprehensive utilisation of a mangrove forest will include the following.

A. Direct Utilisation of Mangrove Forest

   a. Livestock Feed - Pasture for camels, goats and cattle with this area being separate from the protected area for forest conservation.

   b. Sheep - There is a large demand for mutton. However, sheep raising in a mangrove forest is not an easy undertaking, in addition to the need for weeding.

B. Indirect Utilisation of Mangrove Forest

   a. Wind breaking and Sand Arresting

   b. Creation of Residential and Resort Areas in vicinity of Mangrove Forest - Land with greenery is extremely precious in the Arabian desert. In the case of the Sultanate of Oman for example, the Qurm district in the metropolitan area adjoins a mangrove forest and is considered to be a top class residential area due to the forest's existence. It has a high concentration of embassies, high class residences and government offices.

   c. Bird Sanctuary - A mangrove forest will prvide an important habitat for birds and will make bird watching possible.

d. Fish Culture - The creation of artificial ponds and the culturing of such fish as tilapia which can breed in saline water will prevent the possible propagation of mosquitoes and algae and will bring into scope recreational utilisation in terms of fishing ponds.

e. Mangrove Forest Park - With the comprehensive utilisation of the above possibilities, a mangrove forest park for recreational and educational purposes will be created which will prove agreeable in Qatar.

(5) Mangrove Afforestation Project

i) Creation of Forest

On the drawing DRP-4006, an example of the creation of a forest is given. The total area covers some 60 ha, inclusive of a date palm forest (5 ha). The area created is largely divided into four zones whose characteristics are given below.

A. Mangrove Forest Zone

Area: 12 (blocks) = 30 ha

Ground Level: Mean sea-water level (because of the anticipated need to introduce sea-water in the case of the groundwater supply from Rayyan being reduced or termination).

Water Supply: Via irrigation channels. The forest is divided into small blocks and the boundaries between the blocks will be used as passages for working or walking.

B. Embankment and Islands

In order to prevent the diffusion of groundwater from Rayyan to the outside of mangrove afforestation area, and to have roads for plantation work and promenade, embankment and artificial islands are to be provided with a suspension bridge and rest houses.

Embankment	2,400 m	2.4 ha
Artificial islands	6	7.6 ha
Suspension bridge	1	100 m
Total length of road		5,000 m

C. Water Distribution Channel

Groundwater transferred from Rayyan is distributed uniformly in the large mangrove plantation area by a reinforced concrete open channel, having the section of 60 cm by 60 cm and distribution is adjusted by pipe with values embedded in wall of channels.

This channel is to be located in the north side embankment of which length is 1,600 m. Meantime water channels in the plantation area are spaces between blocks to be used.

D. Date Palm Forest Zone

Area: 3 blocks, 5 ha

Groundwater Level: Natural ground level

ii) Selected Species, Spacing of Plantation and Growth Prospects

There are two specific criteria for the selection of the species, (i) those species which can adapt to the natural environment of Qatar in the case of the excess groundwater being terminated and (ii) those species which have useful applications. Based on these criteria, the conventional Avicennia Marina will be the main species for the anticipated mangrove forest. Avicennia Marina has the strongest salt tolerance of all mangrove species and is also adaptable to a wide temperature range. As stated earlier, it can also serve as feed for domestic animals. If the role of a public park is stressed, it will be necessary to include the Rhizophora Stylosa and the Sonneratia Alba which have comparatively beautiful shapes and leaf colour. In view of the educational and research functions of the mangrove forest park, it would be advantageous to set up a "Botanical Mangrove Garden" where the growth feasibility of various mangrove species in given conditions can be studied.

The planting interval will be 1.5 m x 1.5 m with 140,000 mangroves being planted in an area of 30 ha.

The mangrove's growth speed depends on the conditions of its habitat. Citing the test results of Abu Dhabi's Mubarras Island, growth of 2 m or more in three years can be expected for the Avicennia Marina.

iii) Planting Method

Although the method of planting depends on the species in question, there are two basic methods, i.e. (1) direct sowing and (2) transplantation of seedlings. In the case of the anticipated main species, e.e. Avicennia Marina, the direct sowing method is preferred from an economic point of view. However, as its growth may face unexpected difficulties given its artificial environment, on-sight testing and further research will be necessary. In the case of the Rhizophora Sylosa which has a giant viviparous speed, direct sowing can be employed. In regard to the Sonneratia Alba and other species with a small viviparous speed, the production of seedlings in a nursery will be required.

iv) Seed Supply

There is no seed supply system in the world for the mangrove, which is a wild species. Therefore, existing mangrove forests should be visited for the purpose of collecting seeds for the present Project.

Possible places for seed collection are as follows.

Avicennia Marina	:	Qatar, Pakistan
Rhizophora Stylosa	:	Pakistan
Other Species	:	South East Asia and other mangrove forests in the world

8.3.4 Specification of Construction Work and Material

The standard specifications for civil, electrical and mechanical works published by Ministry of Public Works are deemed to be adopted in this project. Special notes to be specified in addition to these, are as follows.

(1) Investigation before excavation

Following investigation shall be done before excavation

- subsurface conditions
- neighboring buildings and structures
- necessity of shoring
- groundwater level
- groundwater quality

(2) Dewatering

All the excavation shall be executed in dry conditions with necessary dewatering. During all excavation work, attention shall be paid to excavation wall, that is, soil or rock condition, groundwater level and seepage aspect. Especially when encountering the situation where big flow seems to be connected with a particular source, the reason shall be clarified and adequate action shall be taken as required. "Washing out" or "piping" phenomena shall be carefully checked. Rate of dewatering at initial stage shall be moderate and determined considering the surrounding situation.

Disposal of the water shall be by the discharge pump station and sand settling basin shall be provided.

(3) Monitoring points

On both sides of the trench excavation, monitoring points for ground deformation by drawdown shall be selected, measured and recorded before and after the work. These points shall be strong enough for long term observation during drainage operation.

(4) Concrete work

Concrete used in this project shall be dense concrete. Covering to reinforcing steel in concrete shall be more than 70 mm and external surface in the ground shall be coated with an anti salt-attack paint.

(5) Perforated pipe

Pipe to be used in this drainage scheme shall be half perforated Extra Strength Vitrified Clay pipe conforming to BS 65.

Internal diameters to be used are;

300 mm
450 mm
600 mm

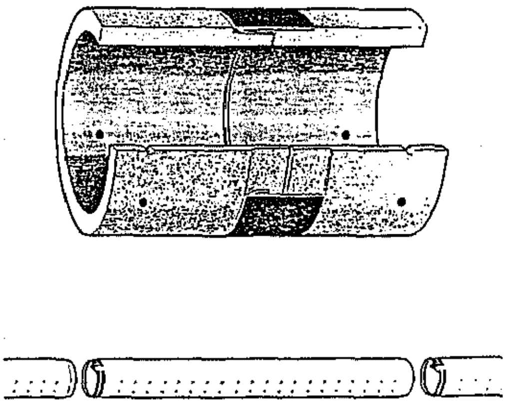


Fig. 8.3.4 Detail of Perforated Pipe

(6) Gravel

In backfilling work of lateral drainage trench, the following three kinds of gravel shall be used.

Nominal dia.	50 - 75 mm
Nominal dia.	25 - 40 mm
Nominal dia.	13 - 20 mm

(7) Geotextile

Geotextile material shall be synthetic fiber (polypropylene) and the type for sand piping protection.

(8) Ductile iron pipe

Pipe for discharge pipe line shall be ductile iron pipe conforming to BS4772 designation K-9.

Diameter	Wall thickness	Unit length
250 mm	6.8 mm	5 - 6 m
350 mm	7.7 mm	6 m

External protection
PVC tape, thickness 1.1 mm spiral two (2) layer wrapping

Internal protection
Cement mortar coating 5 mm

Joint
T type push-on-joint

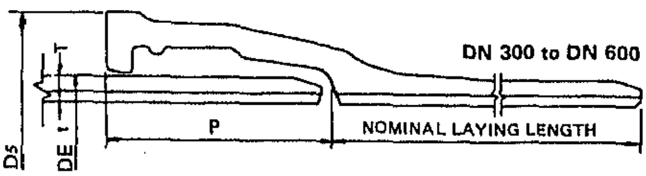


Fig. 8.3.5 Push-on Joint

8.4 Justification of the Plan

8.4.1 Degree of Emergency

As mentioned in the damage survey, in this Old Rayyan area, the situation has developed where groundwater level has almost reached ground surface and standing water has already emerged at a considerably large number of areas. The following damage has been reported;

- Vegetation was damaged and abandoned farms are increasing (while this is considered not only for the reason of groundwater problem)

- Restriction to land use by standing water

- Seepage to the underground public utilities and increase of the operation and maintenance work and cost

- Devastation of land by the progress of salt accumulation

- Increase of dewatering work in underground construction and cost increase therefrom

On the other hand, in the groundwater investigation the following figures showing the steady rising groundwater were obtained.

Table 8.4.1 Areas classified by groundwater level in the Project Area

Standing water	11 ha
0 - 1 m	43 ha
1 - 2 m	86 ha

By the above matters, it is evident that a certain countermeasure is urgently required.

8.4.2 Technical Examination

Technical examination of the proposed drainage scheme concerning various points of view have been performed as mentioned in detail in the previous chapters. The examinations involving several stages of investigation, analysis and design, lasting more than one year, and can be summarized as follows;

1) Review of previous studies
2) Field investigations
   Damage and land use survey
   Topographic and hydrogeological investigation
   Groundwater and quality
3) Groundwater analysis
4) Studies on countermeasures
   Effectiveness of preventive measures for recharge
   Drainage methods including alternatives
   Possibilities of groundwater re-use
5) Correctness of the proposed drainage scheme
   Drainage effect by simulation analysis
   Realization of the plan by preliminary design

8.4.3 Effect of the Project

The execution of the proposed countermeasure can be expected to have an effect upon the following categories;

(1) Alleviation of direct damage

- Recovery of the land to be used as farm after "leaching" or "replacement with imported soil" are provided.
- Free access with elimination of standing water.
- Cessation of salt accumulation in entire project area.
- Alleviation of groundwater measures in construction and maintenance work.
- Increase of durability of underground structures and facilities by reduction of contact with corrosive salty water.

(2) Alleviation and effect of indirect damage

- Recovery of freedom to land use
- Recovery of fine sight on landscape
- Effective re-use of water resources
- Decrease of construction and maintenance cost

(3) Social effect

- Alleviation of social uneasiness brought about by the rising and spreading groundwater year by year.
- Recovery of potential for agricultural use.
- Recovery of amenity between people and groundwater by positive re-use of abstracted groundwater.
- Acquisition of green zone by mangrove afforestation.

In the meantime, although it is considered that this rising groundwater problem requires an urgent solution, the implementation of which is not determined by the result of an economical assessment, nevertheless an economical assessment was attempted for item (1) above in particular. However, as in the case of Wadi Musherib, also in old Rayyan this attempt did not succeed.

Specifically items (2) and (3), i.e. abstract benefit by indirect effect and social effect can not be assessed practically but their importance is apparent, and it is thus deemed that necessity of implementation of this project was justified sufficiently.

8.5 Cost Estimation and Implementation Program

8.5.1 Construction Cost

Construction cost is calculated in the same manner as applied in section 7.5.1 of the drainage plan for Musherib district.

(1) Construction Cost

The construction cost is as shown on Table 8.5.1, which includes the following.

- Lateral drainage pipe
- Discharge pump station and discharge pipe
- Mangrove lagoon plantation

(2) Unit Prices and Quantities of the Works

Unit prices of the works are determined according to the result of research as shown on Table 8.5.2 and the construction cost is thereby calculated.

Of the quantities of the work, the representing items are listed on Table 8.5.3.

(3) Items Included in Construction Cost

i) Lateral Drainage System

The construction cost for the lateral drainage system includes the costs for earthwork, material and installation of perforated pipe and manhole, and all the necessary items to complete the work.

ii) Discharge Pump Station and Discharge Pipe Line

The construction cost includes the cost for civil works, building works, mechanical works and electrical works for the following facilities.

a. Discharge Pump Station

- Embankment
- Pump house and overhead traveling crane
- Pump pit
- Equipments such as pumps, flow meters, etc.
- Pipes and valves
- Fence and gate

b) Discharge Pipe Line

- Pipes
- Intermediate water chamber

iii) Mangrove Lagoon

The construction cost for this work includes the cost for weir, roads and man-made islands. Embankment to the level of QND + 0 shall be finished by others at the time of commencing the construction.

The cost of the works related to the mangrove plantation is not included.

Table 8.5.1 Construction Cost

Item	Cost ($\times 10^3$QR)
1. Lateral Drainage System	
(1) Pipe Work	15,000
(2) Manhole	900
Subtotal	15,900
2. Discharge Pump Station & Discharge Pipe Line	
(1) Discharge Pump Station	
- Civil & Building Work	1,000
- Equipments	2,100
(2) Discharge Pipe - Pipe material	4,200
- Civil Work & Pipe Installation	8,800
Subtotal	16,100
3. Mangrove Lagoon Construction	13,900
Grand Total	45,900

Table 8.5.2 Unit Rates for Cost Estimation

Item	Description	Specification		Unit	Rate (QR)	Remarks
Lateral drain facilities	Perforated pipe	ESVC pipe	ø300	m	150	Material and installation
			ø450	"	200	
			ø600	"	500	
	Closed pipe	*Concrete pipe*	*ø600*	"	*500*	
	Excavation	Including dewatering		m^3	180	
	Disposal of surplus soil			"	30	
	Backfilling	Excavated soil		"	30	
	Structural concrete	Sulphate resistant cement, GRADE 25		"	300	
	Lean concrete	Sulphate resistant cement, GRADE 15		"	260	
	Shuttering			m^2	20	
	Gravel	Dia 13-20 mm, 25-40 mm 50-75 mm with compaction		m^3	45	
	Resurfacing of road	Asphalt pavement		m^2	75	
	Manhole	Precast concrete manhole, ø900 (inner diameter)	H=4-5 m	no.	6,000	Material and installation
			5-6 m	"	7,000	
			>6 m	"	8,500	
	Reinforcing bar			ton	3,000	
Dis-charge pump station	Embankment	H=1.7 m		m^3	25	
	Fence	Galvanized wire mesh fence, H=2.0 m		m	400	
	Gate	Width : 6.0 m Height: 2.0 m		no.	5,250	
	Pump house	Reinforced concrete frame with block wall		m^2	3,500	
Dis-charge pipe line	Discharge pipe	Ductile iron pipe with bends and fittings	ø250	m	326	Material and installation
			ø350	"	489	
	Earthwork	Excavation, soil disposal, backfilling and dewatering		m^3	180	
	Pavement cutting and resurfacing			m^2	250	
Mangrove Lagoon	Embankment	H=0.3 m		m^3	25	

Table 8.5.3 Quantities of Works

Item	Unit	Quantity	Remarks
1. Lateral Drainage System			
(1) Excavation	m^3	54,800	
(2) Pipe - ø300	m	3,868	
- ø450	m	1,646	ESVC perforated pipe
- ø600	m	327	
- ø600	m	25	Concrete closed pipe
(3) Concrete	m^3	1,590	
(4) Manhole	No.	59	
2. Discharge Pump Station & Discharge Pipe Line			
2.1 Discharge Pump Station			
a) Civil Work			
- Embankment	m^3	940	
- Excavation	m^3	1,140	
- Concrete	m^3	220	
b) Building	m^2	160	Reinforced concrete, frame with block wall
c) Equipment			
- Pump including appurtenances	No.	3	2.75 m^3/min, 110 KW
2.2 Discharge Pipe			
a) Pipe - ø250	m	6,700	
- ø350	m	7,700	
b) Excavation	m^3	37,000	
3. Mangrove Lagoon			
- Embankment	m^3	150,000	

8.5.2 Implementation Program

(1) Implementation program

This project consists of the following two major facilities;

- Lateral drainage facility
- Discharge pump station and discharge pipe line
- Mangrove afforestation

The overall term for implementation is three (3) years considering site investigation, detailed design, tendering, equipment procurement, civil works and mechanical and electrical erection works, after which maintenance of young mangrove trees will be started.

Overall program is as shown in Table 8.5.5. Major points to be noted in the Implementation Program are the following. Because of the difficulty in disposal of highly saline groundwater during construction stage of lateral drainage facility, permanent discharge pump station and discharge pipe line to West Bay shall be constructed at first. Under the present progress of New District "Regional Park" project, it is unavoidable to directly discharge abstracted groundwater at West Bay temporarily until dredging and mangrove lagoon have been completed. It is considered that (2.5) years will be required for dredging, and that within a total of (3) years related road works in the park will be completed. At the same time the appropriate grovernment body executing the mangrove afforestation should begin test plantation and production seedlings, such that within (4) years actual afforestation may commence.

(2) Total cost of the Project

Total cost of the Project is summarized in the table below.

Lateral drainage	17.5	MNQRS
Discharge pump station and pipeline	18.9	MNQRS
Civil work for Mangrove afforestation	15.3	MNQRS
Total	51.7	MNQRS

Above figures consist of;

- Topographic survey and investigation of underground facilities
- Detail design, Tender, and Construction management
- Land acquisition for pump station
- Civil construction and associated temporary facilities
- Equipment procurement and electrical and mechanical erection works

On the other hand the following items are not considered;

- Governmental administrative cost
- Compensation to residents for inconvenience during construction (if any)
- Land acquisition for mangrove afforestation
- Cost for mangrove afforestation itself

Cost breakdown by each fiscal year are tabled in Table 8.5.4 below.

Table 8.5.4 Expenditure for Each Fiscal Year

(Unit: x10^3QR)

Item \ Year	1st	2nd	3rd	4th	Total
1. Engineering Services	1,600	3,000	-	-	4,600
2. Land Acquisition	1,200	-	-	-	1,200
3. Civil & Building Works	-	12,000	29,800	2,000	43,800
4. Equipments	-	2,100	-	-	2,100
Total	2,800	17,100	29,800	2,000	51,700

Notes:

1) Cost of engineering servies were derived from 10 percent of construction cost.

2) Only land acquisition for Discharge Pump Station was considered and unit rate per square meter is 1,000 QR.

Table 8.5.5 Implementation Program for Rayyan

No.	Description	1st year	2nd year	3rd year	4th year	5th year
		1 6 12	1 6 12	1 6 12	1 6 12	1 6 12
1.	Lateral Drainage					
	(1) Topographic Survey & Underground Facility Survey					
	(2) Detail Design & Tender Documents					
	(3) Tender			▽ Contract		
	(4) Civil Works					
2.	Pump Station & Discharge Pipe					
	(1) Topographic survey & Underground Facility Survey					
	(2) Detail Design & Tender Documents					
	(3) Tender		▽ Contract			
	(4) Land Acquisition					
	(5) Pump Station					
	a) Civil & Building Works					
	b) Equipments					
	(6) Discharge Pipe			(Temporary outfall)	Extension of Discharge pipe to Mangrove lagoon	
				Road Construction of Regional Park		
3.	Mangrove Afforestation					
	(1) Culture Test of Seedings					
	(2) Culture of Seedings					
	(3) Mangrove Lagoon Construction					
			Regional Park Dredging			
	(4) Afforestation & Maintenance					

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9. LOCAL COUNTERMEASURES

9.1 Protection for Vegitation

Should the many abandoned farms or empty areas widely scattered in Doha be utilized for cultivation or gardens, following matters shall be taken into consideration as growth of plants in dry area.

1 Control of salinity in soil water to avoid obstruction of plants growth.

2 Protection against salt concentration of groundwater during hot and dry summer season.

3 Suitable irrigation method.

(1) Control of salinity in soil water

As shown in Table 6.6.2 salt tolerance depends upon plant type. Low salinity water is preferable for irrigation water and moreover over irrigation contributes to rising water. That is, salt content in irrigated water is concentrated by evapotranspiration. When concentration exceeds a certain level plants will suffer bad effect and consequently salt in groundwater must be diluted with irrigation water. This is called "leaching".

When salt content in irrigation water is low, quantity of leaching water and number of leaching times are small and few, but when high, they become big and many. In this way, it is easier for control to use low salt content irrigation water.

(2) Protection against salt concentration

Over irrigation and too much leaching contributes to groundwater rising, which leads to moisture transfer in unsaturated zone due to capillary effect in soil, high temperature and dryness at ground surface and salt becomes concentrated near ground surface.

In order to avoid this process, groundwater corresponding to the leaching water should be drained by blind lateral drains or open lateral drains.

In agriculture development in dry zones, construction of irrigation facilities tends to be difficult due to the above stated reasons, however at present the importance of the drainage system is recognized so as to avoid appearance of standing water or water logging with salt concentration.

(3) Irrigation method

According to the salt content of water, method of irrigation changes. When low salt content water like potable water is used, sprinkler method can be applied but when high salt content water is used, water left on leaves and stems concentrates salt and causes salt damage. Therefore drip method or valve method shall be applied, which methods make possible the effective water supply to roots without salt concentration.

Groundwater is generally more than 10,000 micro mhos/cm in EC value and sodium portion in the positive ions becomes high, thereby increasing the possibility of occurrence of hardening of soil by exchangeable sodium.

Therefore diluting salt content of groundwater with potable water is recommended in order to eliminate leaching quantity needed for removal of salt and subsequently melting out of nurishment of soil would be avoided.

(4) Others

High dryness during summer causes not only proceeding salt concentration but also proceeding the process of solution of organic matters in soil.

Diminishing organic matter in soil strongly curbs the activity of biocreatures. To increase organic matter in soil the method of mixing wooden pieces or straws can be applied and this method is useful for removal of salt from soil.

When organic matter becomes active in soil, soil tends to be deoxidised, breathing of roots may be restricted and arid soil would become required.

In order to properly control the soil for cultivation and gardens, it is important to sufficiently recognize the physical and chemical characteristics of the soil.

(5) Concrete methods applicable in New District

Specific drainage method at coastal area and shallow groundwater level similar to New District are introduced hereinafter. These methods aim at avoiding the direct contact between roots of vegetation and seawater and to control the water content in the soil.

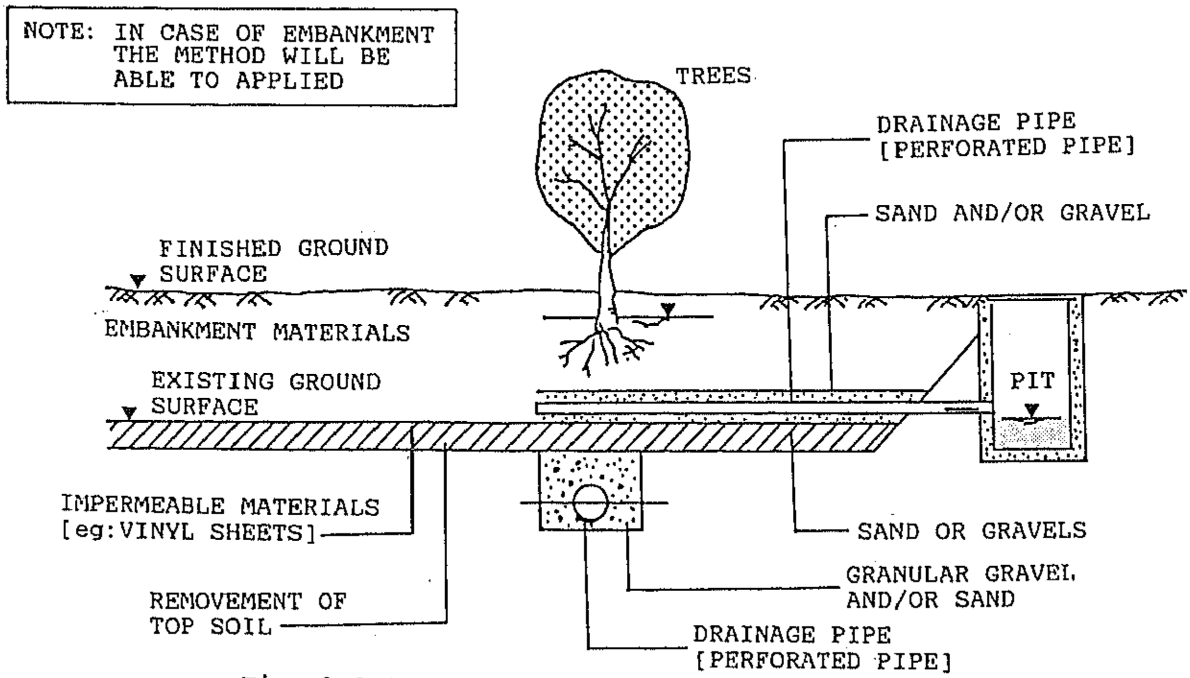

Fig. 9.1.1 Drainage System of Irrigation Water (Embankment Part)

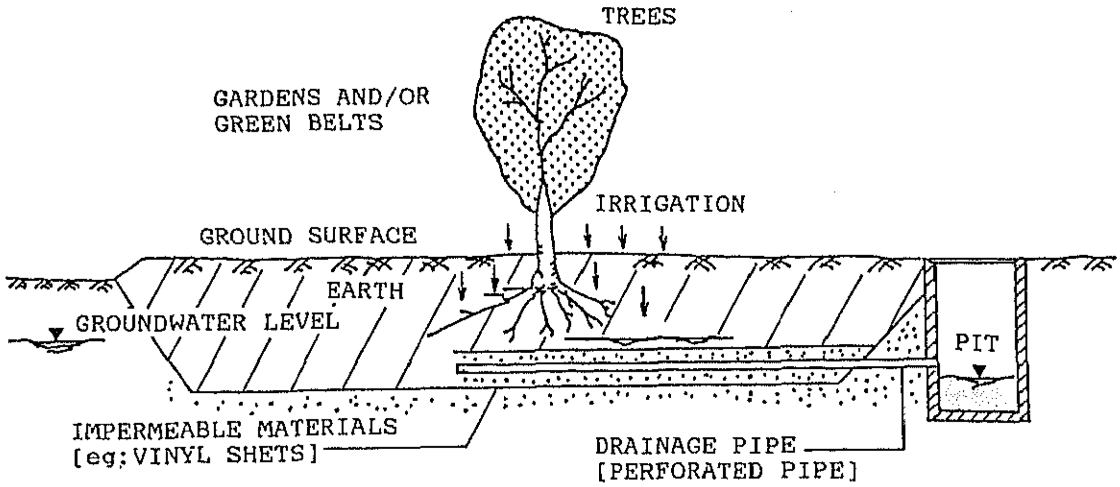

Fig. 9.1.2 Drainage System of Irrigation Water
(High Groundwater Level)

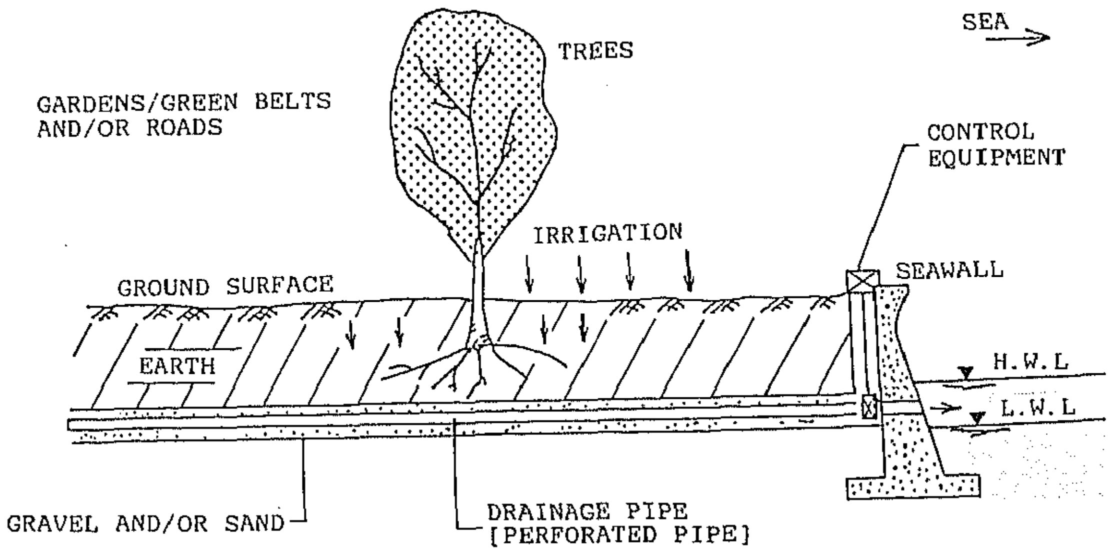

Fig. 9.1.3 Drainage System of Irrigation Water
(Tidal Effecting Area)

9.2 *Filling Method*

In the area below QND + 7.0 m of the Old Rayyan region, agricultural activities become difficult by salt accumulation caused by groundwater rising to a level of QND + 5.6 m at present. This salt accumulation will not be immediately eliminated even when the groundwater level will be lowered. Therefore there remains a problem which causes obstruction to vegitation and serious erosion to the underground utilities.

In order to remove this residual salt accumulation, two methods are considered. One is "Leaching" and the other is earth filling with fertile imported soil. Depending upon the purpose of the land use and salt accumulation degree, earth filling becomes more economical and easier than leaching.

The area requiring earth filling, shown on Fig. 9.2.1, should not necessarily be filled at once, but rather filling can be executed step by step whenever a particular section will be developed.

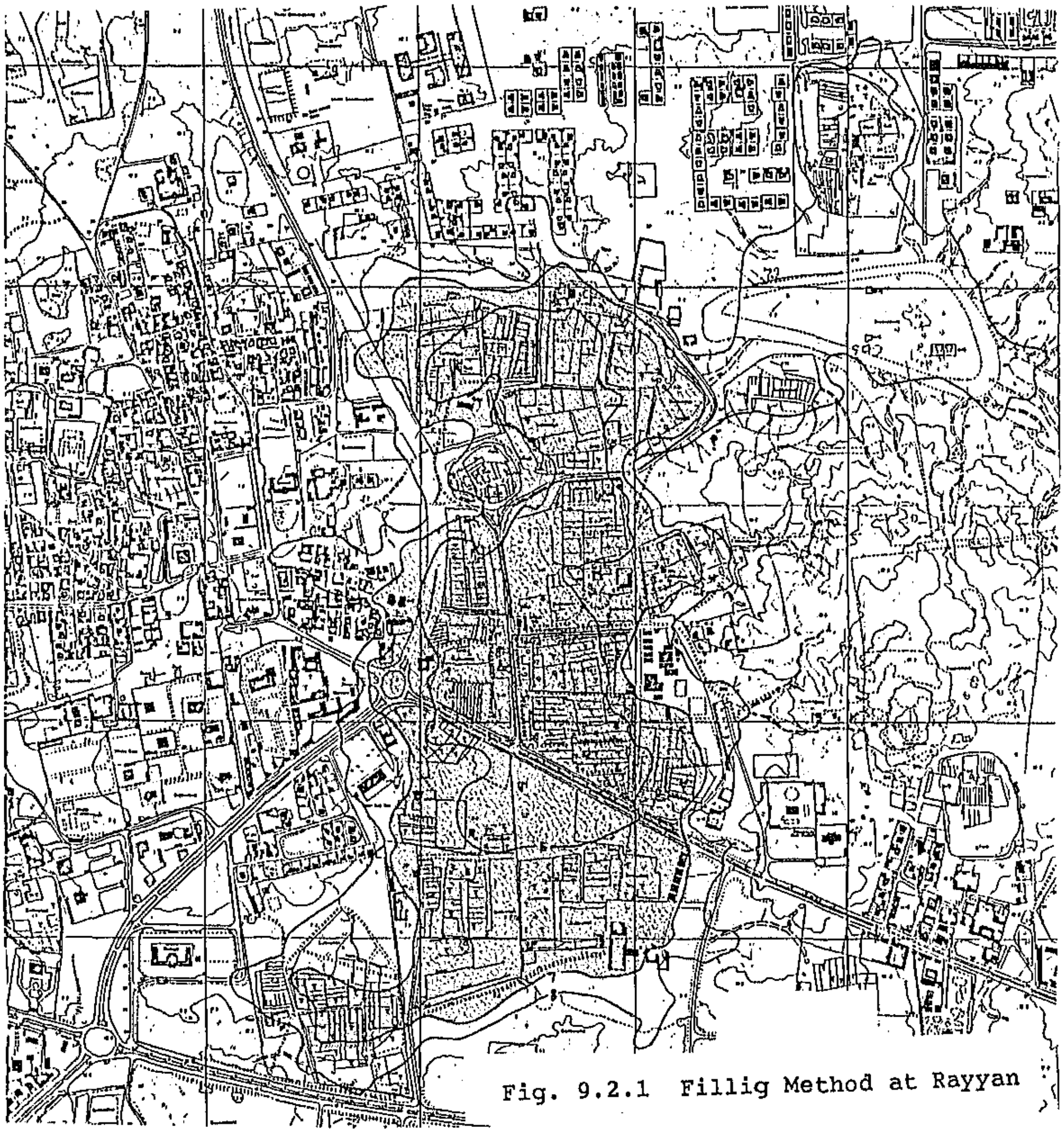

Fig. 9.2.1 Fillig Method at Rayyan

9.3 Guidance for Foundation and Underground Structure Protection against Groundwater

At the time of design and construction of foundations and underground structures, there seems to be no specific guidance in relation to the groundwater rising problem by the authorities concerned. Existing inadequate structures will face difficult problems. But for new construction, there should be adequate guidance to safeguard structures against groundwater, bearing in mind that although at time of construction no groundwater may be encountered yet at a later date groundwater level may rise and threaten the safety of the structure.

Problems regarding groundwater for underground structures are summarized into following four (4) categories;

- Saline attack by high saline groundwater
- Uplift force and hydraulic pressure variation due to groundwater level fluctuation
- Effect to the bearing capacity of the soil
- Dewatering during construction

Regarding each of the above items, matters to be incorporated in the guidance are as follows;

(i) Notification of groundwater rising

At the beginning of planning for underground structures in Doha or other vicinity areas, it is necessary to recognize the existence or rise of groundwater in the near future and to take it into consideration.

(ii) Uplift, pressure and variation

Upon the structural planning and/or structural calculation, existence of groundwater and fluctuation of the level including future increase shall be taken into consideration.

In the meantime structures which are constructed in the area where the groundwater has newly developed shall be examined from the point of stability. In particular structures in Doha are based on the limestone layer and earth pressure is not necessarily taken into consideration.

Therefore possibility on necessity of structural reinforcement may be considered high for underground structures such as basement. For computation of total pressure, earth plus water pressure shall be considered.

$$P = (1 + K\gamma)h$$

where, P: Total pressure
K: Earth pressure coefficient
γ: Submerged density of soil
h: Depth in water

(iii) Saline attack

Concrete structures under saline groundwater are infiltrated over a period of many years. This infiltration corodes reinforcing steel in the concrete and rust causes expansion of steel and concrete consequently suffers crack or strip off.

Protection against this kind of damage are the following measures taken at structural design or construction stage.

a. Increasing concrete covering to the reinforcing steel thus delaying the progress of salt.

b. Controlling concrete crack and reducing infiltration.

c. Increasing concrete density and curbing infiltration velocity.

d. Application of adequate water-proof paint on the surface.

e. Using corrosion resistant reinforcing steel

These measures are almost similar to those against soil sulfate attack which is commonly encountered in Doha and are already specified in various standard specifications and guidances.

When such sulfate attack countermeasures were executed in past construction work, saline water problem is considered not to be so serious for existing structures even though groundwater rising was not foreseen at construction time.

(iv) Effect to the soil bearing capacity

Since limestone layer is adopted in general for supporting stratum of structure, problem is deemed not serious but when it is inevitable to adopt weathered limestone layer including a high clay portion as bearing stratum, structural design must note the possibility of softening clay particle by water causing decrease of bearing capacity. Evaluation of bearing capacity under these conditions should be carefully examined.

(v) Dewatering

Due to groundwater rising, cases requiring dewatering are increasing in substructure construction. It is quite obvious that rate of lowering groundwater should be carefully executed when structures exist nearby.

The result of the test work in this study gives some figures on the lowering of groundwater level in function of distances from the abstracting point.

Rate of lowering water level shall be moderate so that there will be no seepage above the water level in trench and no muddy seepage by washing out or piping phenomena.

9.4 Introduction of Suitable Construction Methods

9.4.1 Soil Improvement by Cement Stabilizer

Many kinds of effective cement stabilizers have been developed taking into account soil improvement purposes and are widely employed.

Application of this method may be considered in areas of shallow groundwater level such as New district, in order to reduce the dewatering of works.

In places where the part to be improved is deep, drill-and-stir method will be used. Equipment and application examples of this method for deep improvement are shown below.

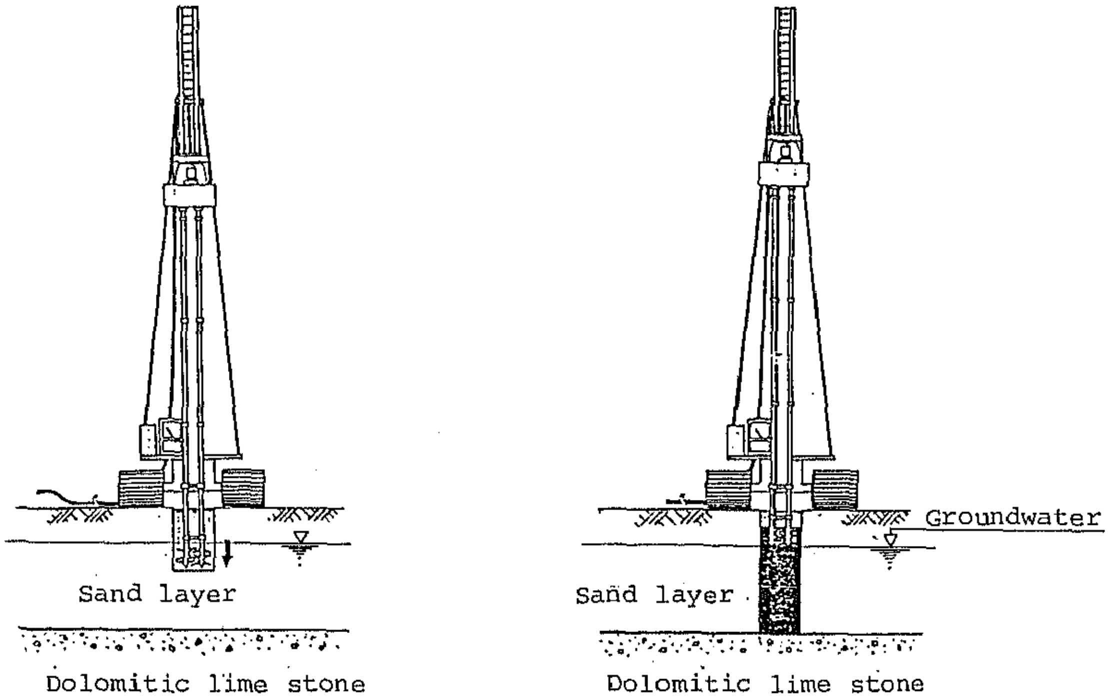

Fig. 9.4.1 Drill-and-Stir Method

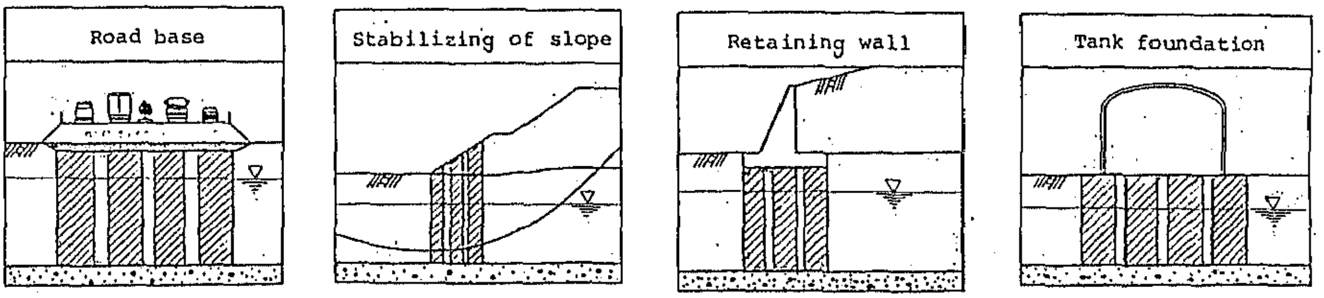

Fig. 9.4.2 Examples of Soil Improvement in Deep Part

When the soil improvement is needed in a shallow part, scrape-and-stir method is used. Application examples to which this method is applied are shown below.

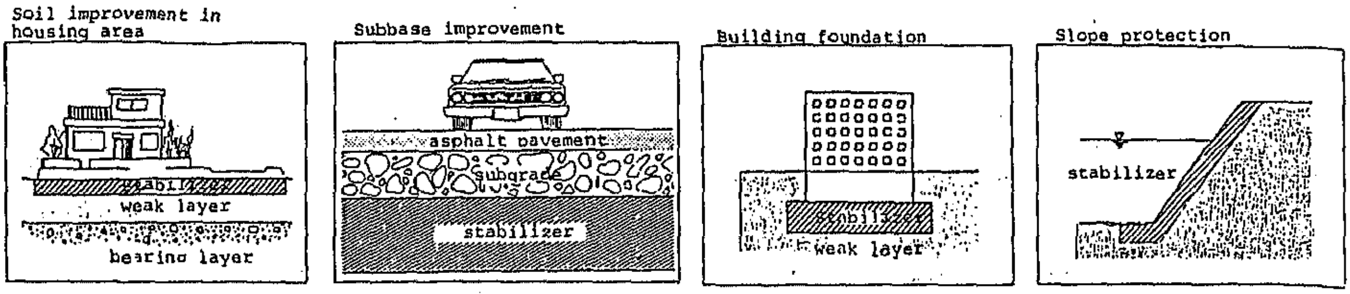

Fig. 9.4.3 Examples of Soil Improvement in Shallow Part

9.4.2 Horizontal Boring and Thrusting Method

As shown on Drawing DRP-2001 and DRP-3001, where pipes cross the main roads, a thrusting method is often applied. It enables the pipe laying to be done without open-cutting the earth and disturbance of the traffic during construction.

Application of the thrusting method had been limited to such cases where pipe laying is done through ordinary or weak soil layer and the pipe diameter is over 600 mm.

However, recently, horizontal boring and thrusting method has come to be employed as an effective method of laying pipes through rock layer. Pipe diameters to be applied in this method range from 250 to 1,450 mm. Length of the boring can be extended to more than 100 m. Therefore, this method is taken as an effective method in laying pipes of small diameters through such hard limestone layer as found in Doha City.

As is seen below, rock excavation can be made by reaming from the arriving pit to the starting pit. While in the weak soil, excavation can be done only by thrusting from the starting pit to the arriving pit.

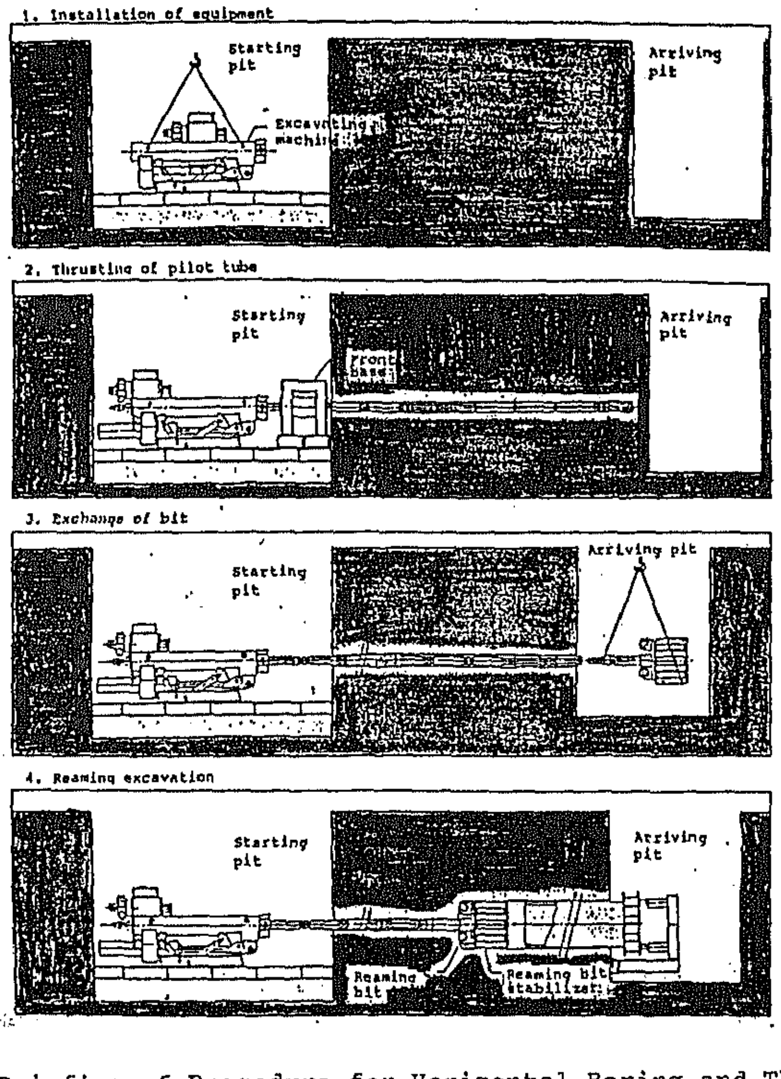

Fig. 9.4.4 Briefing of Procedure for Horizontal Boring and Thrusting Method

9.5 Materials for Drainage Works

Small-scale drainage and extension of the drainage network with sufficient capacity, are basically required to solve the local problem depending on land use conditions.

9.5.1 Shallow Well

Considering small drainage area and use for small irrigation schemes, shallow wells may be employed. In the meantime, in case of shallow well, checks on water quality and existence of cesspit or septic tank near the point are necessary before hand.

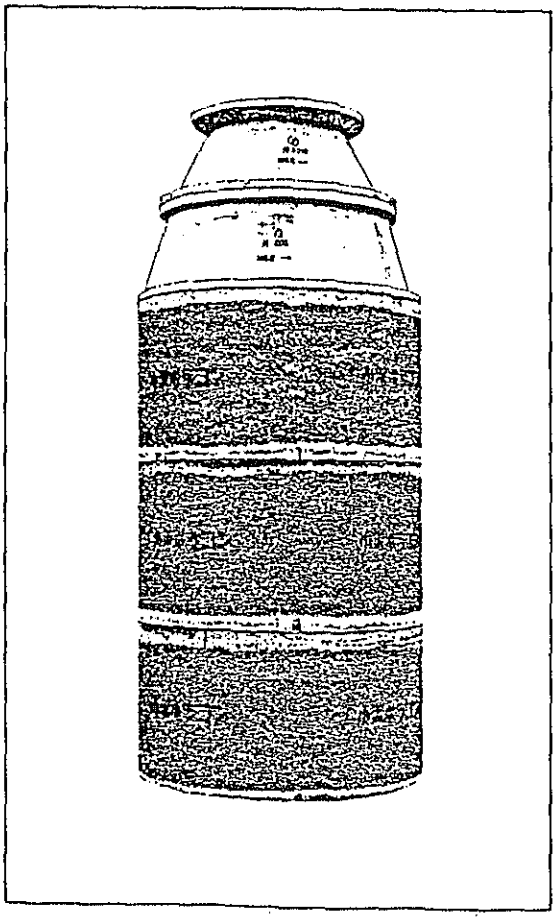

Fig. 9.5.1 Shallow Well

9.5.2 Small Groundwater Collecting Gutter

Gutter can be used when it is required to drain surface water only, from a limited area.

Depending on the location, in general drained water can be discharged to sewerage line by gravity flow without pumping.

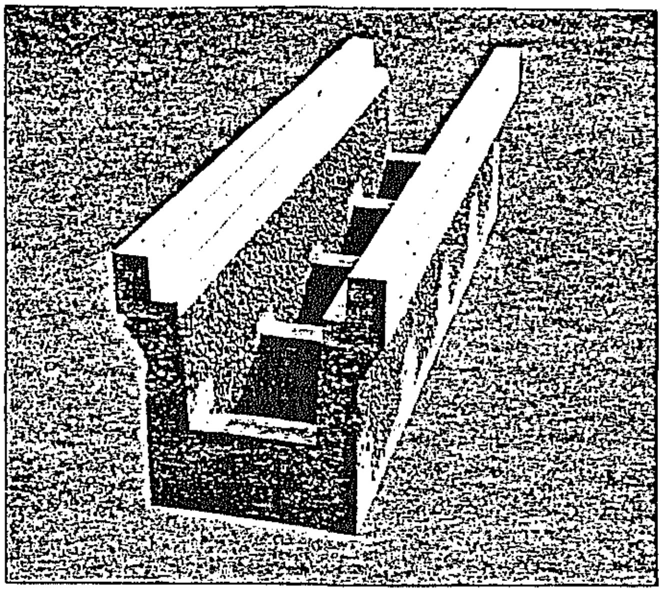

Fig. 9.5.2 Small Scale Open Lateral Drain

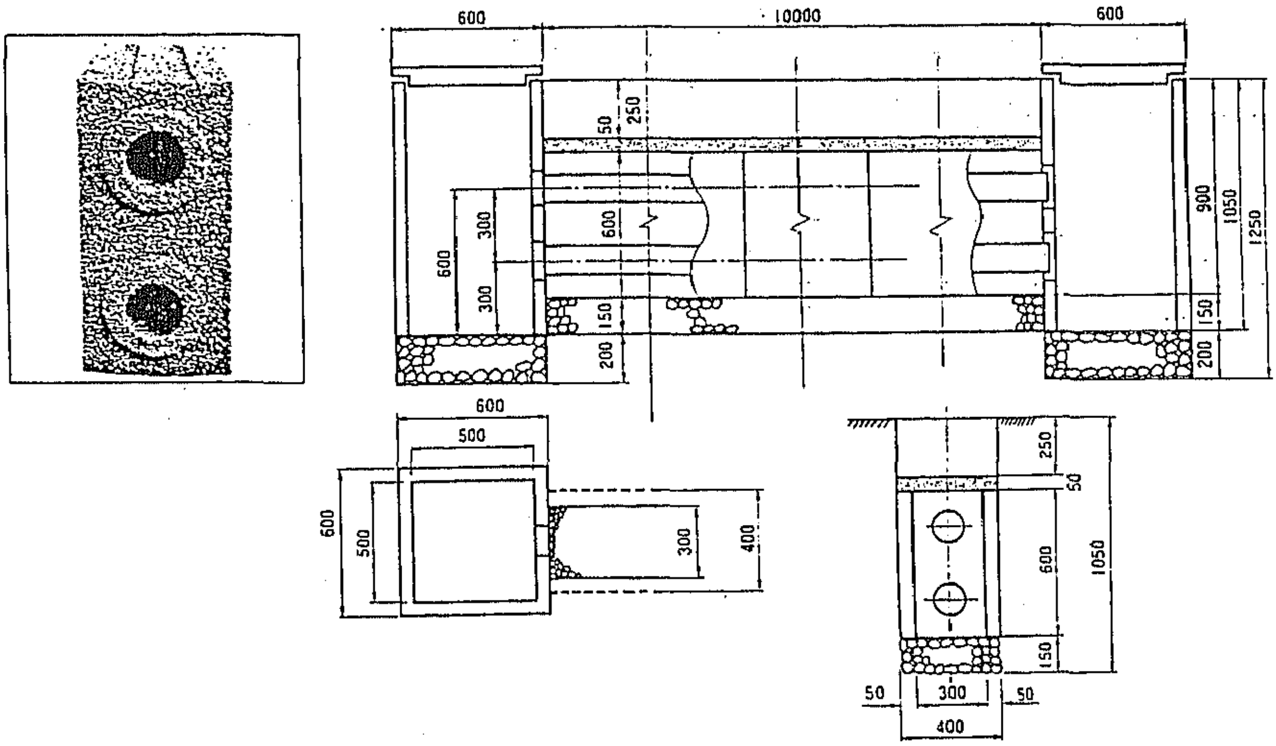

Fig. 9.5.3 Small Scale Blind Lateral Drain

9.5.3 Plastic Drain Pipe

This pipe, made from high density polyethylene, is free from corrosion and has a high resistivity against acid and alkali.

It is of sufficient strength, flexible and light in weight that it can be easily handled and laid without any special care for bedding.

This pipe also has a high capacity of water collection with pores in the net provided on the pipe.

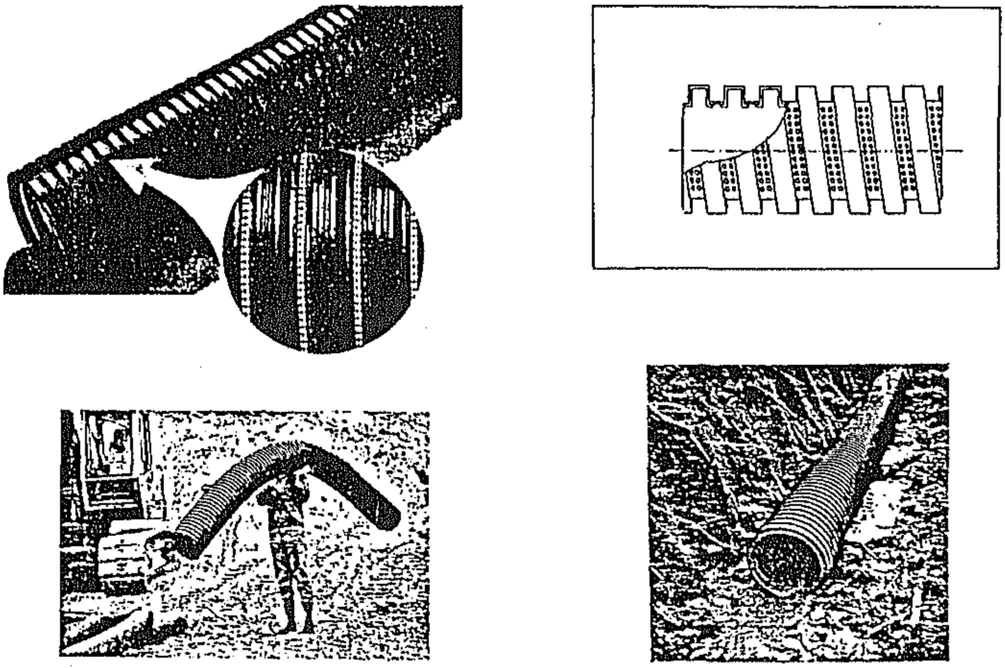

Fig. 9.5.4 New Type of Lateral Drain Pipe

9.5.4 Water Proofing Paint

A new waterproofing paint/resin mortar having a so-called "self sealing" function, was developed and has become widely used in Japan.

Main component	:	Synthetic Polyethylene Compounds Emulsion
Admixtures	:	Almina cement, Methyle cellulose, Silica sand etc.
Features	:	Film applied is flexible and responds to the expansion and contraction movement of the concrete body. It is cut by a zero-span tension, but resin at the part expands by absorbing water and closes the crack. It has a strong aging resistance.
Typical usage	:	At potable water reservoir basement, and underground culverts.

9.5.5 Reinforcing Steel against Salt Attack

As one of the countermeasures against salt attack, the following reinforcing steel types are used.

- Epoxy resin coated steel
- Salt resistant steel

Features and technical data of each type are as follows;

(1) Epoxy resin coated steel

This steel is produced by coating epoxy resin powder on high yield deformed steel bars by means of electrostatic coating.

Features of this steel are;

- Extraordinary anti-corrosiveness.
- Having bond strength not less than 80% of ordinary steel bars.

However, there are some points to be noted.

- Careful packing is needed for transportation.
- Cut surface and damaged parts should be made good by touch-up paint.
- In bending and fabricating, careful handling is required so that the paint film will not be damaged.

(2) Salt resistant steel

This steel is produced by adding tungsten (W) and nickel (Ni), superior rust preventing ions to extra high purity steel.

Features of this steel are;

- Much higher anti-corrosiveness than ordinary steel.
- No degradation in characteristics of reinforced concrete.
- No difference from ordinary steel in bond strength and way of transportation, jointing, handling, etc.

9.6 *Protection for Underground Utilities*

During the Study the damage to sewerage, electricity, potable water, and telephone networks was investigated. It is considered that implementation of the drainage schemes in the project areas, will solve the following problems;

1. Increased cost and time in construction and maintenance operations.
2. Transfer of groundwater by the sewerage network pipelines.
3. Prevent the flow of groundwater within QNTS ducts.
4. The number of manholes subject to groundwater leakage (depending on manhole depth).

On the other hand, setting up of the groundwater organization as mentioned in Chapter 10, and exchange of technical information between the services, will help contribute to solving the following problems;

1. Presence of hydrogen sulphide in QNTS manholes filled with water, its extent and source.
2. Corrosion of ductile iron pipes relatively newly laid, and copper service pipes in the Potable Water network.
3. Understanding and update of areas of city suffering from shallow groundwater table.
4. Recognizing damaging effect groundwater can have on utilities by knowing its quality.
5. Developing existing specifications where insufficient to deal with pipe trench construction, pipe material, laying, etc.

10. APPLICABILITY OF JICA STUDY FOR OTHER AREAS

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10. Applicability of JICA Study for Other Areas

10.1 Candidate Areas for Drainage Measures

As well as the 3 subject areas of the present Study, i.e. Wadi Musherib, Rayyan and New District, the following areas also appear in need of groundwater drainage measures in the future.

1 Doha

- Montazah
- Abu Hamur
- Al Ahli Sports Club

2 Outside Doha

- Umm Said
- Wakrah
- Wakair

As the trend of the groundwater level in Doha is subject to the present Study, the observation results of the above areas in Doha in terms of the possible implementation of future drainage measures are described here.

10.2 Drainage Plan for Montazah

(1) Basic Drainage Facilities

The Montazah area has a wadi structure caused by a depression, which in turn is the result of limestone dissolution, and a gentle gradient from south to north. As a water collection facility could also be used as a transportation facility by using this natural gradient, priority should be given to the application of a wadi-type drainage plan such as Wadi Musherib Plan. The basic composition of the drainage facilities should be as follows.

1	Collection	:	Blind Trench
2	Transfer	:	Gravity Flow Method
3	Disposal	:	Wadi Musherib Stormwater Trunk Line

(2) *Design Groundwater Level*

As shown in Table 10.2.1, the *progress of urbanisation in the area can be seen* in relationship to the groundwater depth, specifically in the cases of land use and the situation of underground structures.

Table 10.2.1 Relation between Groundwater Depth, Land Use and Underground Structures in Montazah

Groundwater Depth from Ground Surface (m)		0 - 1	1 - 2	2 - 3
Area (ha)	1983	20.0	25.0	87.0
	1986		165.0	121.0
Built up Area (ha)	1983			
	1986		122.6	83.0
Cultivated Area (ha)	1983			
	1986		10.0	9.3
Standing Water Area (ha)	1983		0	
	1986		0	
Sewerage Network (km)	1983	4.0	3.0	10.0
	1986		20.0	14.0
QNTS (km)	1983	3.4	3.5	9.6
	1986		20.0	16.0

This area was chosen as a subject area for the emergency drainage project of the 1983 ASCO study which proposed that the groundwater level at that time be adopted as the design groundwater level. Although the damage in Montazah does not show high groundwater salt density or the accumulation of salt near the ground surface due to evaporation as observed in Wadi Musherib, there is substantial damage to the underground structures and building foundations. Therefore, it is proposed that the design groundwater level be set at 1.5 m below the ground surface in view of mitigating the damage to these structures as much as possible.

(3) Design Water Collection Facility

The design details of a water collection facility for Montazah, such as the installation depth of the collection trenches, the trench locationing system and the drainage volume, should be determined taking into consideration the monitoring results of the drainage volume and water quality during the project implementation process at Wadi Musherib. Since the geological and hydrogeological characteristics change in accordance with a change in the catchment area, the pumping test should be carried out at test site, as in the case of the present Study.

10.3 Drainage Plan for Abu Hamur

(1) Basic Drainage Facilities

Abu Hamur is a basin with a gentle gradient formed by limestone dissolution, as in the case of Rayyan. The provision of a facility to transport the groundwater collected by the collection facility to the final destination is required for this type of inland depression. The basic composition of the drainage facilities should be as follows.

1	Collection	:	Blind Trench
2	Transfer	:	Pressurised Transportation using a Pump
3	Disposal	:	TSE Pump Station (Doha South) Musherib Stormwater Trunk Line (near Wadi Musherib Dam)

(2) Design Groundwater Level

The area's land use is characterised by a lot of empty land with scattered agricultural fields and abandoned agricultural fields. The distribution of small pools of standing water was witnessed during the field survey in December, 1986. It is assumed that the salt density in the groundwater will rise and that the accumulation of salt in the soil will accelerate in the future, as currently seen in Rayyan. Although the design groundwater level depends on the area's permeability, it should be set at around 1.3 m below the ground surface which is similar to the design groundwater level for Rayyan.

(3) Design Water Collection Facility

As the Abu Hamur area has similar topography and geological characteristics to Rayyan, the design details of a water collection facility for Abu Hamur should be determined taking into consideration the actual results relating to the drainage volume and lowering of the groundwater level in Rayyan.

10.4 Drainage Plan for Al Ahli Sports Club

Small pools of standing water can be seen scattered in the area to the west of the Al Ahli Sports club. This area is currently used as a dumping ground for the surplus soil from construction work. From the viewpoint of the geological structure, the area constitutes part of the eastern lowland of Montazah.

In comparison with Montazah and Abu Hamur, the project area is small and, therefore, the backfilling which is currently in progress or local drainage work should prove effective. Any study on the area should be included in the study on Montazah due to its close relationship to the latter.

11. RECOMMENDATION

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11. RECOMMENDATION

11.1 Groundwater Management and Organization

Efforts by several governmental authorities to study and find solutions to the groundwater problem may be traced back to the start of the eighties.

A 1984 report by a Dutch governmental mission recommended establishment of a joint operation committee comprising director-level officials of related departments as a measure to be taken in Qatar.

In 1985 the government of Qatar formed a committee to coordinate with and assist the JICA Study Team in their study. The Technical Liaison Committee (TLC) was headed by HH the Amir's Technical Office, and comprised members from MEW, MPW and DM. This committee, while of temporary nature and somewhat limited powers, nevertheless represented the first venue where technical views and information could be exchanged between the different ministries.

In November 1986, HH the Amir directed the Services Committee, headed by the Minister of Public Works to review all related studies and coordinate among various authorities to implement solutions.

The Services Committee, in turn formed an Ad-Hoc Committee comprising the three directors of MEW, MPW and DM to meet with JICA Study Team and TLC and review the study with the JICA Study Team.

11.1.1 Need for Groundwater Management and Organization

The present conditions of the rising groundwater in Doha warrant immediate and effective action on the part of officials. Such concerted action can only be done by introducing a groundwater organization.

The organization shall have the following activities;

- o Formulation of master plan
- o Monitoring
- o Feasibility studies of various countermeasures
- o Verification of proposed countermeasures
- o Follow-up execution of countermeasures
- o Review efforts by various authorities in reducing groundwater recharge

The organization will function through the cooperation and coordination of the various governmental authorities, and will enable a comprehensive approach to the groundwater problem.

Two possible structures for the organization have been examined, namely

There are two possibilities for forming an organization;

1. Setting up an independent organization
2. Setting up an organization under the Services Committee

In attempting to explore the advantages and disadvantages of each possibility the JICA Study Team held hearings with members of the TLC, Planning Section of Doha Municipality, Dept. for Agriculture and Water Research (MIA), Industrial Development Technical Centre, Qatar University's Scientific and Applied Research Centre, and Environmental Protection Committee (EPC).

11.1.2 Independent Organization

Setting up an independent organization offers the advantage of providing full-time manpower and efforts to the problem.

The structure of the organization may be as shown in Fig. 11.1.1.

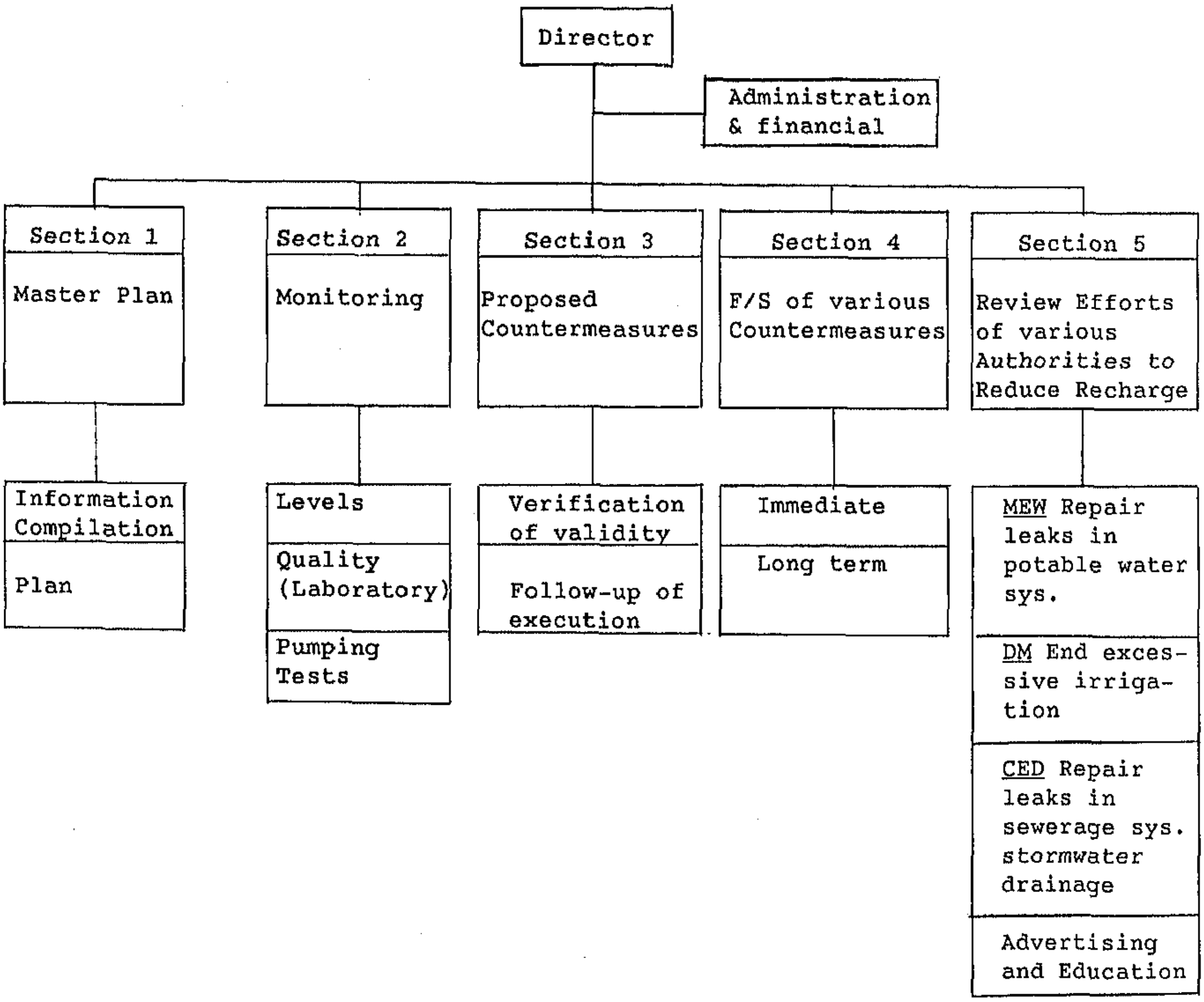


Fig. 11.1.1 Independent Organization

However the establishment of such an organization may require time-consuming administrative, legislative and budgetary actions. Furthermore it will be difficult to recruit most of the senior staff that have been engaged in the problem within their respective ministries, for the newly formed body on a full time basis. This would entail bringing in new people who would in turn require time to acquaint themselves with the problem's different aspects.

It is therefore suggested to begin by setting up an organization under the Services Committee, leaving the door open for such an organization to become independent based on the future need.

11.1.3 Organization Under the Services Committee

The suggested structure of the organization is shown in Fig. 11.1.2.

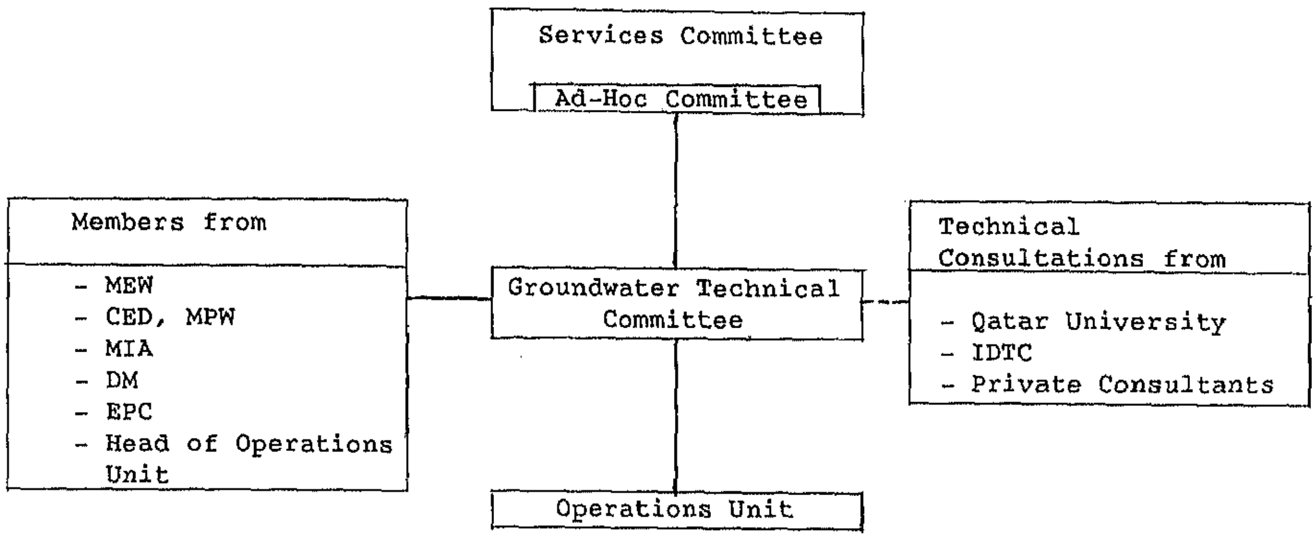


Fig. 11.1.2 Organization under the Services Committee

(1) Services Committee

The Services Committee will be kept informed of the organization's activities through the Ad-Hoc Committee and any future countermeasures, and executive or budgetary decisions must be approved here.

The Services Committee shall select the members of the Groundwater Technical Committee from the various related governmental departments, its chairman, and the head of the Operations Unit.

The Ad-Hoc Committee will periodically meet with the chairman of the Groundwater Technical Committee and the head of the Operations Unit to receive their reports, discuss any necessary issues and settle any disagreements.

(2) Groundwater Technical Committee

The committee shall comprise members from the relevant departments and the head of the Operations Unit. It shall meet periodically and have the following duties;

- o Formulation of Master Plan
  - Identification of priority areas
  - Estimates of future costs for countermeasures

- o Supervise and direct Operation Unit's work
  - Formulate work plan and items
  - Review and confirm interpretation, or interpret field data
  - Discuss equipment and/or manpower needed

- o Implementation of countermeasures
  - Feasibility studies of various options
  - Verification of proposed countermeasures such as JICA Study Team's urgent drainage plans
  - Follow up implementation of countermeasures by other authorities such as detailed design and execution of JICA's urgent drainage plans by CED

- o Review efforts by various authorities to reduce groundwater recharge amount such as
  - Repair of leaks and damaged portions of sewerage and potable water networks
  - Decrease amount of over irrigation water used for public landscaping and gardens
  - Execution of stormwater drainage plan
  - Educational and advertising campaigns

For specialized work the committee shall look into the possibility of utilizing the experts and facilities available at the Scientific & Applied Research Center of the Qatar University or the IDTC. During the Study Team's hearings, both institutions expressed keen interest to participate in the groundwater organization. Another option will be to engage private consultants, although in the interest of decreasing financial burden and developing local expertise, whenever possible the government's own institutions shall be used.

3) Operations Unit

The Operations Unit shall be the only body within the organization that will be on a full-time basis. Its staff shall be assigned by the Services Committee from junior staff in the different departments. Geologists, engineers and technicians will be required. It is recommended that the Unit's head be experienced and be from the senior staff of one of the departments.

The unit shall be assigned an office within one of the departments and some equipment for field work. Laboratory facilities of MEW and CED shall be available to the unit.

The unit's activities shall include;

- o Implementation of groundwater level and quality monitoring plan
- o Execution of tests, immediate of which can be
  - Umm el Radhuma deep injection well tests
  - Pumping test at Musherib test trench and other new test trenches
- o Analysis and interpretation of collected field data
- o Involvement in design and construction supervision of drainage schemes
- o Compilation of all relevant reports, studies and data

11.1.4 Contributions

In the hearings some doubts were voiced concerning the two possibilities for organization expressed herein. Also once the organization is established and commences work, unforseen problems may arise. However the groundwater organization suggested herein is expected to contribute positively to solving the problem due to the following;

1) Having two committees (Ad-hoc committee and groundwater technical committee) within the organization under the Services Committee raises fears that its work may be delayed and decision-making process slowed down. Therefore placing the Services Committee at the head of the organization can ensure that its work has the attention of the leading governmental officials involved.

2) Although formation of an independent organization, such as EPC or Meteorological Dept., may ensure that the problem receives full-time attention, obstacles as described earlier may delay such formation. It is therefore considered that should it become necessary in the future, the Operations Unit after gaining experience may become an independent body.

3) The rising groundwater problem has in the past been studied by outside consultants, and lastly this study by JICA. It is believed that the Operations Unit will provide an opportunity for the government to develop its own technical staff to deal with this problem. Such local expert staff will not only be welcome in Qatar but can also help other Gulf cities, many of which have the same problem.

4) The organization will allow for strengthening cooperation between different governmental authorities on the senior staff level. It shall also encourage the use of experts and facilities of the University and IDTC.

Finally it must be borne in mind that although the JICA Study Team confirm the need for a groundwater organization, and possible structures have been suggested herein, only the Qatari government can decide the final structure based on its knowledge of the present governmental conditions.

11.2 Monitoring

11.2.1 Subjects and System of Monitoring

The subjects to be monitored in regard to the rising groundwater level problem in Doha are as follows.

1. Rising rate of the groundwater level.
2. Effects of groundwater drainage on neighboring buildings during the construction of drainage facilities.
3. Volume of water collected by the groundwater collection facilities and its effect on lowering the groundwater level.
4. Data relating to the basic study for the prevention of over-irrigation.

The monitoring system corresponding to the above monitoring subjects is shown in Table 11.2.1.

11.2.1 Utilisation of Monitoring Data

The standard utilisation of monitoring data is shown in Fig. 11.2.1. While the individual possession of this data by related governmental departments may be permissible in certain cases, the provision of a data bank and a data access system may prove more effective in the case of a problem like the rising groundwater level in Doha where a single department cannot cope with the entire dimensions of the problem.

11.2.3 Groundwater Level Monitoring Network

It is recommended that the boreholes (LB) test sites which were drilled for the purposes of the present study be added to the groundwater level monitoring network of the Wellfields Section of the MEW and that monitoring should be continuously conducted at a frequency of once or twice a month. The groundwater level monitoring network is shown in Fig. 11.2.2.

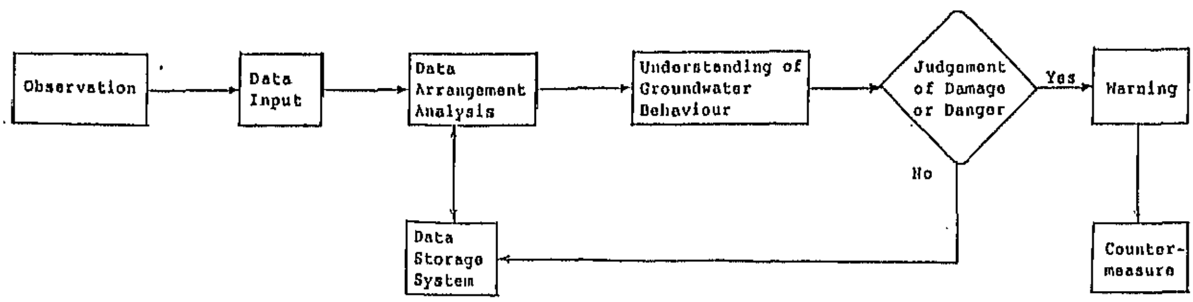


Fig. 11.2.1 Monitoring System Flow

Table 11.2.1 Monitoring System for Various Purposes

Various Purposes	Required Period of Observation	Location	Groundwater Level	Groundwater Quality			Ground Settlement
				EC	SS	COD/ BOD etc	
Understanding of groundwater rate of rise	Up to solution of problem	Monitoring wells inside Doha City	D				E
Effect of groundwater drainage during construction work upon neighbouring structures	Dewatering duration	Surrounding drainage point	A				A
Examination of efficiency of land drainage facility	Lifetime of facility	A few points along the facility	A Discharge	B	B	E	E
Judgement of suitability for irrigation	Duration of usage	Extraction point	A				
Quantity available for irrigation	Duration of usage	Main locations	C Discharge				
Control of salinity in Soil Water	During research of irrigation method	Test Site	A	A			
Pollution	Continuous	All Doha City			E		

Note: Frequency of Observation: A: Daily B: Weekly C: Bi-weekly D: Monthly E: When necessary

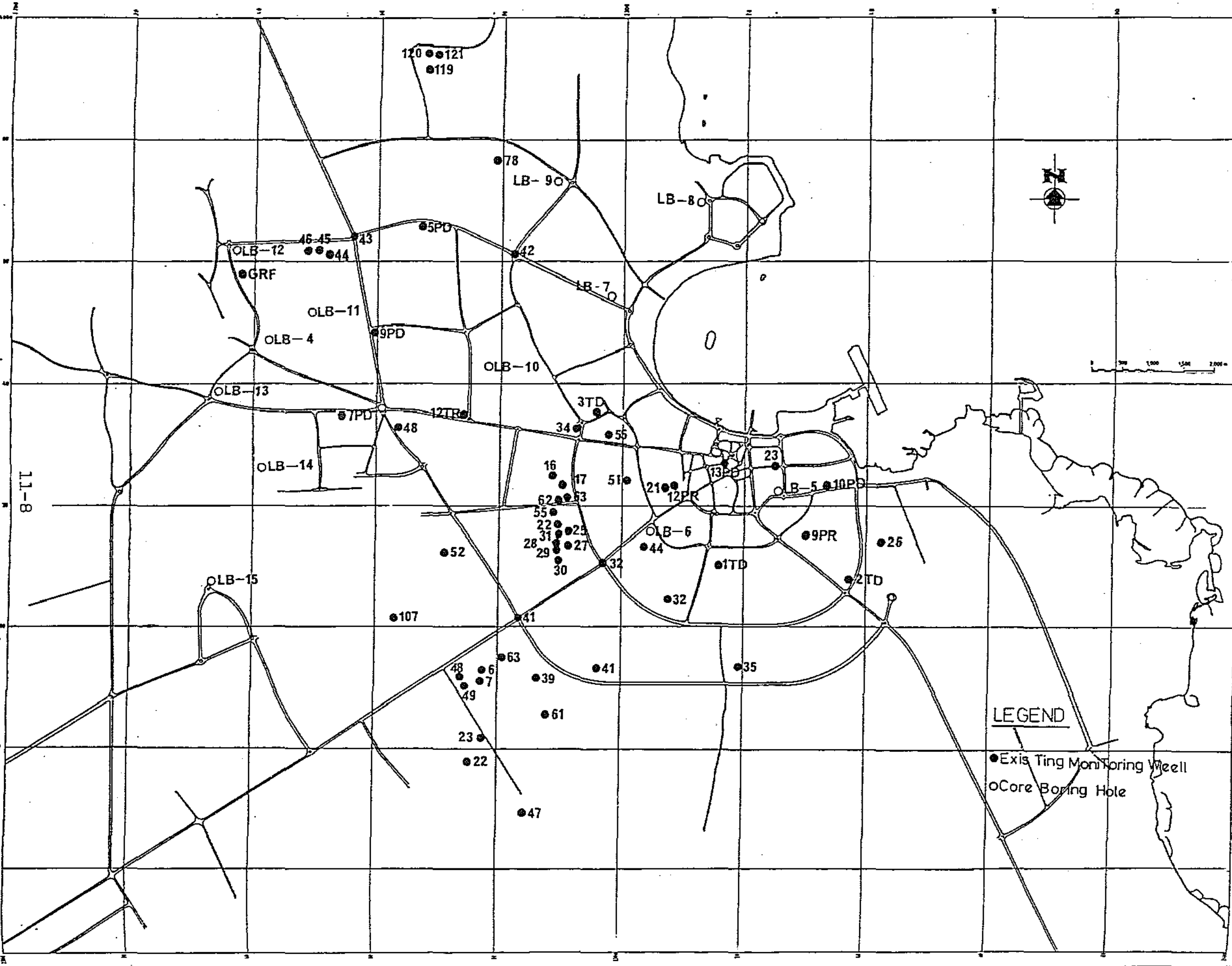


Fig. 11.2.2
Groundwater
Levels
Observation
Network

11.3 Measures to Lower Groundwater Recharge

11.3.1 Water Saving, Public Relations and Educational Activities

(1) Current Status of Water Saving Measures in Qatar

Water saving is a very important measure in view of securing a long-term stable water supply and for the effective utilisation of the water resources and the government of Qatar should carry out specific public relations activities and eductional efforts in this regard. In addition, a campaign video film against wasting water, produced by the Gulf Cooperation Council (GCC) was broadcast every other night during Ramadan in 1986. At present, various stickers calling for water saving, prepared by the GCC and the Kuwait Government, are in limited use in Qatar.

(2) Measures to Promote Water Saving Awareness

There are three ways to promote the public's awareness of the need for water saving.

1 Implementation of Water Saving Campaign

A campaign to encourage the public to economise on their water consumption is required with stress on the reasons why water saving is necessary and the outcome if the water consumption is not reduced. This campaign should be carried out on a regular basis over a long period of time, explaining the various methods to save water.

2 Wide Use of Water Saving Devices

The use of water saving devices in kitchens, bathrooms and toilets, etc. should be encouraged. With regard to the required cost of replacing conventional devices with water saving devices, it may be necessary for the city authorities to consider the policy of providing these devices free of charge or a partial subsidy for them to mitigate the financial burden on the public.

3 Introduction of Water Charge System

This means the introduction of a fixed monthly charge on the water use as well as the meter system. As the water charge increases in accordance with the water consumption, it is believed that this will be an effective method of water saving. In this case, a water charge system whereby ordinary households do not face a substantial bill should be introduced.

It is recommended that the actual water saving plan should be based on item 1 above, i.e. a water saving campaign, assisted by other methods. The concrete method and content of this campaign may be as follows.

- o Campaign for the need, methods and implementation of water saving practices through such media as television, radio and newspapers, etc.

- Use of posters to campaign for the need, methods and implementation of water saving practices and the preparation and distribution of pamphlets to households and offices.

- Educating for the need, methods and importance of the implementation of water saving practices in primary and junior high schools with the additional intention of indirectly educating parents and adults in this regard.

- Public relations activities informing of the actual water saving methods.

  - Curtailment of unnecessary running water in homes and offices.
  - Water leakage checks in homes and offices (there is a water leak somewhere if the water meter continues to move when all the water taps in a house are closed).
  - Encouragement of the replacement of ordinary devices by water saving devices.

11.3.2 Water Charge System

(1) Significance and Advantages of a Water Charge

The introduction of water charge system means that the water service will be run under a self-supporting accounting system by a public corporation. The reason for the introduction of a charge system lies with the need for those who use and benefit from the water service to pay the cost required to provide it, as well as the intended promotion of the effective utilisation of the water resources and water saving awareness.

If the water service is placed under a self-supporting accounting system, the Government will acquire the flexibility to implement projects without being constrained by the national and municipal budgets.

(2) Current Water Charges in Qatar

Qatar currently has 3 types of water charges for specific water supply systems.

1 The unit charge for piped water supplied by the MEW is uniformly 4.4 QR/m^3 (2 dirhams/100 gallons).

2 The unit charge for water supplied by the MEW's road tankers varies, from approximately 60 - 90 QR/1,500 gallons, depending on the transportation distance involved.

3 The unit charge for water supplied of MEW tanker filling stations to the privately owned road tankers is uniformly some 2 QR/100 gallons. Private road tankers, in turn charge their customers same prices as MEW tankers or slightly higher.

Water is, however, supplied to all citizens of Qatar and foreign senior staff of government agencies free of charge.

Approximately 52,000 households are receiving water services, of which some 42,000 households directly receive the water through the public water distribution system. Water meters have so far been installed in approximately 32,000 households and some 4,000 new meters are installed every year. It is believed that the income from the water charges tends to increase every year.

(3) Japanese Experience of Water Charge Systems

1 Types of Water Charge Systems

Water charge systems in Japan are largely classified into those charges based on the purpose of water use and those charges based on the diameter of the house connection pipes. These systems have the following characteristics.

o Purpose Based Charge System

Under this system, the purpose of the water use is divided into 3 categories, i.e. 1 general household use, 2 commercial use for restaurants and hotels, etc. and 3 manufacturing use for industry, etc. A different basic charge and meter charge are imposed for each type of these uses. It is, however, sometimes difficult to classify the water use in one of these categories. The unit charge is the cheapest in the case of household use and the most expensive in the case of commercial use in view of the profits generated by the use of water.

o House Connection Pipe Size Based Charge System

This consists of basic and meter charges which are based on the diameter of the house or office connection pipe. As this system clearly shows the basis for the calculation of the water charge, it is suited to a water service which adopts the principle of production order cost accounting. Therefore, Tokyo and many other cities in Japan employ this system.

2 Determination of Water Charge

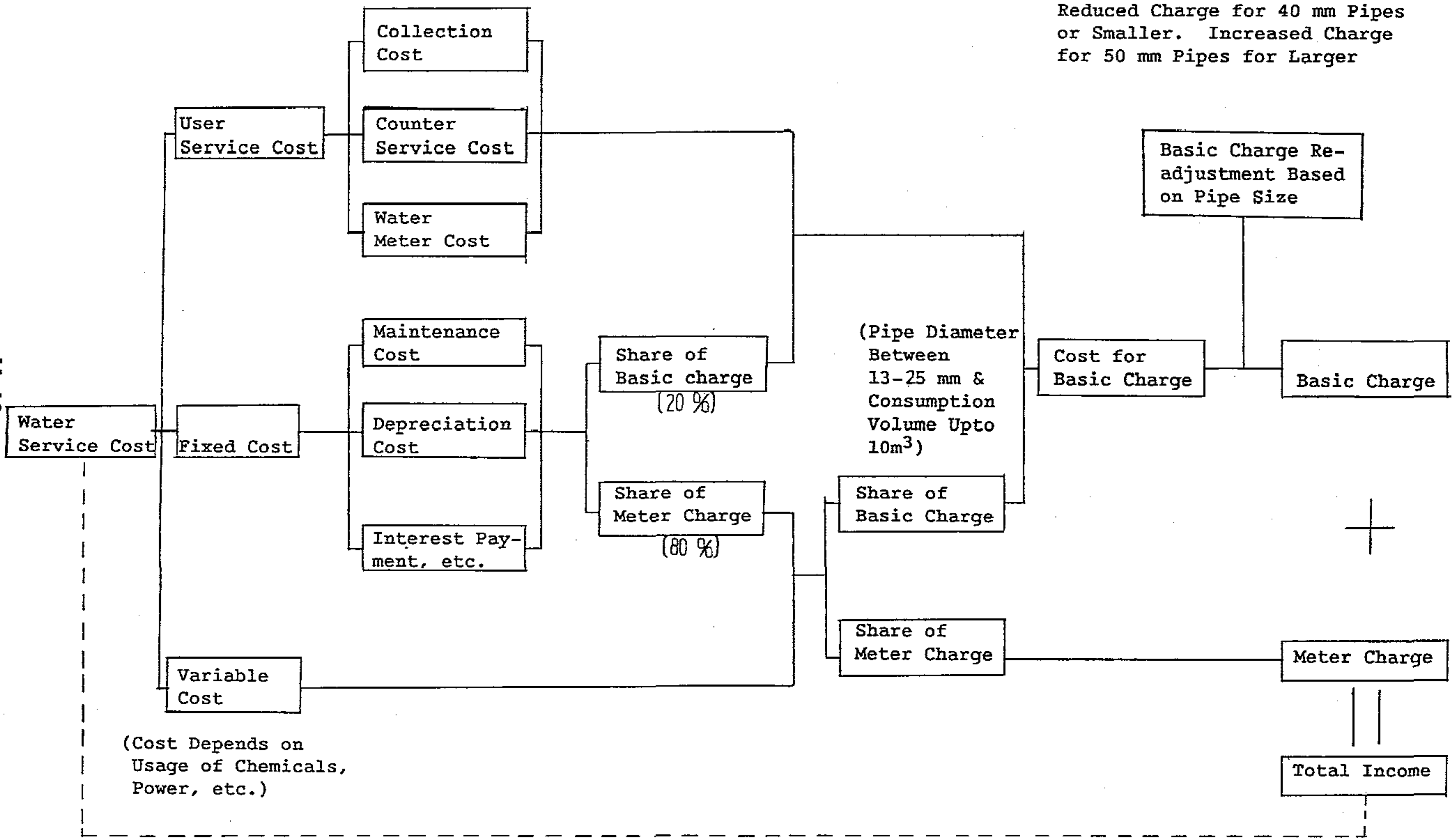
Here, the charge system based on the house connection pipe size is examined to see how the water charge is determined .

In order that an appropriate share of the water service cost be charged to individual users, the original cost should be classified into the user cost (user service cost), fixed cost and variable cost, as shown in Table 11.3.1, in the form of a basic charge and a meter charge.

a) Basic Charge and Meter Charge

This basic charge is payable regardless of the actual volume of water use demand and it progressively rises in accordance with an increase in the connection pipe size.

Table 11.3.1 Relation Between Water Service Cost and Water Charge



The meter charge is payable based on the actual volume of water used although the unit price progressively rises in accordance with an increase in the volume of water used. A fixed low unit price, however, is set for public baths in view of these facilities maintaining the health of their users.

These 3 costs (i.e. user, fixed and variable costs) are distributed into two types of charges in the following manner.

- o Basic Charge
  - Total User Cost
  - Part of Fixed Cost
- o Meter Charge
  - Total Variable Cost
  - Part of Fixed Cost

In practice, the basic charge and the unit meter charge for each size of connection pipe are determined and the total charge is collected from the individual users every 2 months on the basis of the actual volume of water used. Table 11.3.2 shows an example of basic and meter charges in Japan.

b) Distribution of Fixed Cost

Careful consideration should be particularly given to the distribution of the fixed cost. As the fixed cost mainly consists of facility related costs, including the pipe cost and the water purification plant cost, its share in the water service cost is overwhelmingly high. Consequently, the distribution of this cost largely affects the actual charge.

The sizes of the distribution pipes and the water purification plant must be capable of accommodating the largest water consumption volume during the busiest demand period and cannot be determined on the basis of the mean water consumption. In the case of Japan, part of the fixed cost which corresponds to the mean water consumption level is distributed to the meter charge while the remaining part which corresponds to the water consumption above the mean level is, in principle, distributed to the basic charge.

This method, however, tends to increase the distribution to the basic charge and, therefore, the distribution ratio is usually readjusted. The users of small size connection pipes would otherwise face a heavy basic charge while large pipe users would face an excessively low charge. Wasteful water consumption may result from a very low meter charge.

In view of the above, the Qatar Government should adjust the distribution ratios of the fixed cost by transferring part of the fixed cost originally borne by the basic charge to the meter charge in order to introduce a higher meter charge, which in turn will result in a low water charge for small pipe users and a high water charge for large pipe users.

Table 11.3.2 Water Charge Table

(unit: yen/month/m^3)

User Type	Charge Classification	Basic Charge	Meter Charge m^3 1-10	m^3 11-20	m^3 21-30	m^3 31-100	m^3 101-200	m^3 201-1,000	m^3 1,001-
Connection Pipe Diameter	13 mm	610							
	20	820	0	120	150	180	250	310	350
	25	1,010							
	30	2,500				180	250	310	350
	40	5,000							
	50	16,500							
	75	36,000						310	350
	100	75,000							
	150	127,000							
	200	270,000							350
	250	370,000							
	300 or over	630,000							
Public Baths		610	0						95
Common Use*		370	0						95

* The common use charge is applied when one meter is used by more than one household, as in the cases of apartments.

Example of Water Charge Calculation (Monthly Consumption of 25 m^3, 13 mm pipe)

1. Basic Charge upto 10 m^3 = 610 yen
2. Meter Charge from 11 m^3 to 20 m^3 — 120 yen/m^3 x 10 m^3 = 1,200 yen
3. Meter Charge from 21 m^3 to 25 m^3 — 150 yen/m^3 x 5 m^3 = 750 yen

Total Water Charge = 2,560 yen

c) Reduced Charge

When the production order cost accounting principle is rigorously implemented, the resulting charge for ordinary households becomes fairly high. Therefore, it is considered necessary to apply a reduced charge for a water consumption volume upto a certain level. The Japanese experience of a reduced charge is shown in Table 11.3.3. The decline in income from small pipe users due to the introduction of a reduced charge is compensated by the increased charge for large pipe users.

3 Water Charge Collection

Every 2 months meter readers read the water consumption volume on the meter. The meter charge based on this reading, together with the basic charge, is collected from each user every 2 months. User cooperation is requested in regard to the following for the fast and accurate reading of meters.

a) An underground type of meter should be installed in view of preventing damage.
b) No object should be placed in or on the meter.
c) The meter should be kept clean of dirt, sand and waste water, etc.
d) At the time of rebuilding or house extension, the water meter should be installed outside.

Table 11.3.3 Water Service Cost and Basic Charge

(Unit: yen/month)

Pipe Diameter \ Item		Basic Charge of Water Service Cost (Before Reduction)	Reduction Rate (%)	Modified Basic Charge
Small Diameter	13 mm	1,760	65	610
	20 mm	2,570	68	820
	25 mm	3,580	72	1,010
Large Diameter	30 mm	4,100	39	2,500
	40 mm	8,100	38	5,000

11.3.3 Potable Water Leakage from Distribution Pipes Reduction Measures

(1) Current Situation in Qatar

The Water Leakage Prevention Plan was prepared by ASCO in 1983 to prevent the leakage of potable water from distribution pipes in Qatar and the initial stage of replacing asbestos pipes with ductile cast iron pipes in old Doha is currently in progress.

ASCO Study recommended execution of a leakage detection project, but this work has not yet started.

Temporary repair work is being carried out in those places where leakages have been discovered and some 10 leakages are reported to be repaired every day.

(2) Current Situation in Japan

Leakage survey are regularly conducted in Japan for entire service areas in accordance with the Long-Term Reduction Plan and various leakage reduction measure are systematically implemented.

1 Main Causes of Leakage

The main causes of leakage are the corrosion or bad connection of pipes, the dislocation of pipe joints due to increased traffic or other heavy loads on them and the aging of pipes. Careless pipe replacement work may also result in leakage.

2 Leakage Detection Method

a) Types of Leakage

Leakage is largely classified into underground and above ground leakage. The detection of above ground leakage is easy as by definition the leaked water appears on the ground. In comparison, however, it is rather difficult to detect underground leakage.

b) Leakage Detection Work

There are two types of leakage detection work, i.e. mobile detection and planned detection.

1) Mobile Detection

Mobile detection work aims at the early detection of above ground leakage. Specific measures, including patrols, may be required. It is however, more common to rely on notification by citizens.

2) Planned Detection

Planned detection work mostly aims at detecting underground leakage and is the main pillar of leakage prevention. There are 3 planned detection work methods.

- o Direct Measurement Method

  Closing of the control stop valves in the subject section and measurement of the leakage volume by the meter.

- o Indirect Measurement Method

  Closing of the control valve while the stop valves are left open in the subject area and measurement of the leakage volume by the meter.

- o Simplified Detection Method

  This method does not directly use the meter for the detection of leakage.

  While the direct and indirect measurement methods are rational and proven ways of detecting water leakage, they involve a fairly large cost and labour. In addition, they have the disadvantage that the water supply must be temporarily suspended while the detection work is carried out.

  The simplified detection method requires the work to be conducted at night when there is less noise from traffic, etc. which reduces the detection capability. This method has an additional disadvantage of a low detection rate which is caused by the difficulty in distinguishing the leakage noise from river or sewage noises.

  The simplified detection method is usually adopted in Japan in view of avoiding the suspension of the water supply.

3 Leakage Reduction Measures

Leakage reduction measures are generally classified into basic measures, symptomatic treatment measures and preventive measures, as shown in Table 11.3.4. A leakage prevention plan with stresses on preventive measures should be established in order to achieve the prevention of leakage.

Table 11.3.4 Leakage Prevention Measures

Type	Item	Measure
Basic Measures	Preparation of Leakage Prevention	Firm establishment of financial source and organization, document provision, etc. (piping and section diagrammes), determination of sections and provision of meters.
	Field Study	Measurement of supply volume, leaked volume and water pressure and, understanding causes of leakage.
	Research, Development and Improvement of Piping Materials	Materials for distribution, as well as house connection pipes, joints and auxiliary equipment and devices.
	Technical Development	Leakage volume measurement method, underground pipe detection method, leakage detection method and repair method.
Symptomatic Treatment Measures	Mobile Work	Immediate repair of above ground leakage.
	Planned Work	Early detection and repair of underground leakage
Preventive Measures	Water Service Plan	Finalisation of plan taking leakage prevention into consideration.
	Design and Construction of Water Service Facilities	Earthquake-proof, durability, corrosion-proof and water-tightness.
	Replacement of Aged pipes (Replacement of Pipes Causing Frequent Leakage)	Replacement of distribution or house pipes (including a change in the types of pipes).
	Structural Improvement of Water Service Equipment	Collectivisation of pipes running across roads.
	Pipe Protection	Installation of corrosion-proof and leakage prevention metal fixtures and reinforcement of bending sections.
	Treatment of Existing Pipes	Complete treatment at branching points (closure of valves to stop the water flow).
	Pipe Network Patrol	Instruction and supervision to prevent damage to pipes due to other construction work.
	Adjustment of Water Pressure	Separation of water supply lines and installation of pressure reducing valves.

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GLOSSARY

Glossary

1. Hydrogeology

Anhydrite:

Calcium sulfate, $CaSO_4$; orthorhombic; transparent to translucent; Mohs' hardness, 3 to 3.5; specific gravity, 2.93. A source of cement, sulfuric acid, and plaster.

Coastal plane:

A low, level plane composed of horizontal or of gently sloping strata of clastic material. One of its margins is the coast. It represents a portion of the sea floor that recently emerged, and it borders the pre-existing land which was uplifted with it.

Escarpment:

A cliff or a relatively steep slope separating level or gently sloping tracts.

Fold:

The structure of rocks or strata that have been bent into a dome (anticline), a basin (syncline), a terrace (monocline), or a roll.

Lugeon value:

Lugeon value, determined from the Lugeon test, is expressed as the water inflow in 1 min per 1 m test interval length when injection pressure is maintained at 10 kg/cm sq. That is to say, 1 Lu could be expressed as follows:

1 Lu : 1 (1/min/1 m/10 kg/cm sq.)

Sabkha:

Extensive areas of flat low-lying saline loams and silt.
Sobkha is Cl. Arabic; locally Sbakha, sin and sad.

Summit level map:

An assumed plane contacting the highest points in each section where a certain area is divided into sections of same designated area. By this map topographical features of the area can be identified.

Tertiary:

The earlier of the two geologic periods comprised in the Cenozoic era, in the classification generally used. Also, the system of strata deposited during that period.

Upland:

A highland; ground elevated above the lowlands along rivers or between hills.

2. Groundwater

Aquiclude:

A saturated but relatively impermeable material that does not yield appreciable quantities of water to wells; clay is an example.

Aquifers:

Groundwater occurs in many types of geologic formations; those known as aquifers are of most importance. An aquifer may be defined as a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. This implies an ability to store and to transmit water; unconsolidated sands and gravels are a typical example.

Aquifuge:

A relatively impermeable formation neither containing nor transmitting water: solid granite belongs in this category.

Aquitard:

A saturated but poorly permeable stratum that impedes groundwater movement and does not yield water freely to wells, but that may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage zone; sandy clay is an example.

FEM (Finite Element Method):

In these methods, called finite-element methods, a structural system is considered an assembly of a finite number of finite-size components, or elements. These are assumed to be connected to each other only at discrete points, called nodes. From the characteristics of the elements, such as their stiffness or flexibility, the characteristics of the whole system can be derived.

Permeability coefficient (Hydraulic conductivity):

For practical work in groundwater hydrology, where water is the prevailing fluid, permeability coefficent K is employed. A medium has a unit permeability coefficent if it will transmit in unit time a unit volume of groundwater at the prevailing kinematic viscosity through a cross section of unit area, measured at right angles to the direction of flow, under a unit hydraulic gradient, having units of velocity.

Pumping test:

The test is accomplished by measuring the static water level, during the continuous pumping from well or trench to find the hydraulic characteristics of aquifer.

Quasi three dimensional model

In the case that the vertical flow element is negligible, three dimensional groundwater movement can be expressed by the two dimension plan model in which the transmissivity and storage coefficient of the layers are evaluated in function of the groundwater level.

Storage coefficient:

A storage coefficient is defined as the volume of water that an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in the component of head normal to that surface.

Transmissivity:

The term transmissivity is widely employed in groundwater hydraulics. It may be defined as the rate at which water of prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient and is the product of permeability coefficient and saturated thickness of aquifer.

3. Water Quality and Water Treatment

Arsenic:

Arsenic is a poisonous substance which causes acute and chronic intoxication. It is a cumulative poisonous substance, one day's intake of which requires around 10 days to be completely eliminated from the body.

BOD:

BOD is an abbreviation for Biochemical Oxygen Demand, which expresses in mg/l the amount of oxygen consumed in microbial oxidation and decomposition of organic substances in water. If the value of BOD is large, it means that many organic substances are contained in water and the degree of water pollution is high.

Ca:

Calcium is an essential nutrient and also one of the substances which determine the hardeness of water.

Water containing much calcium has a high hardeness and has such unfavorable effects as being unfit for boiling meat, beans and others.

Cyanide:

Cyanide (CN compounds) seldom occur in the natural state. They have such actions as inhibiting respiratory action of living body and are strongly toxic. Cyanides are contained in effluents of metal plating works and gas manufacturing plants and are also discharged from chemical fiber and plastic resin plants and blue print and color picture developing works.

Cr, Cr^{+6}

Metallic chromium is a quite stable metal and is extensively used in articles of daily use and ornaments. When it becomes water soluble chromium compounds, however, sexivalent chromium is quite harmful to the human body, whereas trivalent chromium has relatively low toxicity. When water containing sexivalent chromium is intaken continuously, Cr^{+6} accumulates in the liver, kidney, spleen, etc. and deteriorates their functions to cause vomiting, abdominal pain, convulsions, etc. and may even lead to death in some cases.

COD:

COD is an abbreviation for Chemical Oxygen Demand, which expresses in mg/l the amount of oxygen consumed in oxidation and decomposition of organic substances contained in water by the use of an oxidizing agent. COD is frequently used as a means of indicating the degree of water pollution. The higher value indicates the more amount of pollutant contained in water.

Coliform:

Coliform is a group of intestinal bacteria and is a generic name of several types. Some are pathogenic and others are saprophytic. Detection of coliform indicates possible commingling of human and animal wastes.

Cl:

Chlorine ion refers to chloline contained in chlorides dissolved in water. As salt is indispensable for the eating habits of human being, chlorine ion always accompanies household sewage and excrement which are the wastes discharged by humans. In this context, chlorine ion serves as one of the indicators of pollution.

Copper:

Copper is not a cumulative toxicant. Therefore, it is said that even though 100 mg or more of copper dosed continuously for several months would cause gastrointestinal disorder, 10 to 30 mg of copper dosed for several days would not cause any disorder.

DO:

DO is the oxygen dissolved in water and its saturation volume is determined by the temperature and atomospheric pressure. When organic substances which may possibly become a source of pollution increase in water, however, DO reduces by being consumed by the microbes which decompose those organic substances supply. DO is normally made up by the absorption of oxygen from the atmosphere and carbon dioxide assimilation accompanying photosynthesis by algae, etc., and the amount of DO in each particular water area is determined by the balance between the amount of these supplies and the amount consumed in water. When pollution advances, the amount of DO becomes lower.

EC:

Electric conductivity is also called specific conductance. It refers to the reciprocal electrical resistance of a substance when it is placed in between two electrodes of 1 cm^2 in area each placed face to face at a distance of 1 cm. In electrolytic solution, the amount of chlorine dissociated in an ion can be approximately estimated by measuring the electric conductivity.

Fe:

As the use of iron is naturally restricted since it gives water an astringent and metallic taste, its harmful effect is mostly indirect.

Fluorine:

If drinking water contains 1 ppm or more of fluorine, it will erode the enamel on the teeth.

Phenols:

Phenols is a generic name for compounds in which hydrogen atoms bonded to benzene ring or naphthalene ring are substituted with hydroxyl group.

Phenolic acid is toxic. When water containing a trace amount of phenols is disinfected with chlorine, a compound called chlorophenol, which has a very unpleasant odor, is produced and the water loses its value as potable water.

Heavy metals:

Heavy metals refer to metals having specific gravity of 4 or more, such as Cd, Pb, Cr, Cu, Zn Hg, As, Fe and Mn. All heavy metals occur in the natural world, even though they may occur in different quantities, and are also essential elements incorporated in biotic bodies in trace amounts. When any of these exists in any large amount, however, they may pose problems by immediately exhibiting toxicity or by accumulating in biotic bodies and exhibiting toxicity gradually.

H_2S:

Hydrogen sulfide is generated by putrefaction and decomposition of protein as well as by chemical reaction and volcanic exhalation. In low concentration, it has an unpleasant odor like that of a rotten egg and stimulates the mucous membrane.

Inorganic matters:

Inorganic matters refer to substances other than organic matters, and occur in forms of various compounds of earth metals such as sodium and potassium; of metals such as iron and aluminium; of silicon, sulfur and chlorine ion, etc. Inorganic matters exist in various modes in water. It is convenient to classify them into precipitating particles, colloidal particles and solubles in consideration of the pertinent treatment method for each.

Mg:

Magnesium is a necessary nutrient and also one of the substances which determine the hardness of water.

Mn:

Normally, manganese generally coexists with iron, but with quantities lesser than iron. When manganese is intaken in any large amount, it will cause symptoms similar to encephalitis, and the patient will become spiritless and swollen in the initial stage.

As manganese gives an astringent and metallic taste to water, its use is naturally restrained, so that its harmful effect is mostly indirect.

NO_3:

Nitritic nitrogen implies that nitrogen exists in the form of nitrate which is its final oxidant.

NO_3 is a form which is made completely inorganic and serves as an indicator of the history of pollution.

N-Hexane Extracts:

Normal hexane extracts is a generic name for relatively nonvolatile hydrocabons, hydrocarbon derivatives and grease-like substances which are mainly contained in water. They are generally called oil. In the case of factory effluent, standards are stipulated separately for mineral oils and for animal oils and fats.

Mineral oils inhibit oxygen supply to biotic body and to water by covering the surface of biotic body with oil film or by forming film on the vapor-liquid interface. Animal oils and fats adhere to sewer pipes, treatment facilities and equipment and generate scum.

RO (*Reverse Osmosis*) *Method:*

The method is also referred to as the reverse osmosis membrane method. It is a method to obtain clear water by applying pressure against *osmotic pressure.* For example, when a vessel is partitioned into compartments by a semipermeable membrance (acetic cellulose membrane), and thick salt water is placed in one compartment and water in the other up to the same level, the water infiltrates through the semipermeable membrane and migrates into the thick salt water and generates pressure by the difference in level. This difference in pressure is called osmotic pressure, and when a bigger pressure is applied to the salt water to counter this osmotic pressure, only water migrates to the side of water through the semipermeable membrane. As the osmotic pressure of sea water for example is 24.8 kg/cm^2, if a larger pressure than this is applied, clear water is obtainable. By applying this theory, the RO method is used for treatment of effluent and for desalination of seawater.

Organic matters:

Organic matters is a generic name for compounds containing carbon. Besides carbon, they also contain hydrogen, oxygen, nitrogen, phosphorus, sufur, etc. Generally, they originate in organism, such as comprising biotic body, but recently, numerous varieties of organic matters are artificially synthesized. In the natural world, these organic matters go through a repetitive cycle of decomposition, synthesis, or of becoming inorganic and then organic again through biological food chain.

Organic Phosphorous Compounds:

Organic phosphorous compounds are used as *agricultural chemicals. Organic* phosphorous compounds include parathion, methyl parathion, methyl dimetan, etc., but many substances are banned from manufacturing because they have strong acute toxicity and also because *organic phosporous compounds* contained in water continue to remain in the water area for long period as there is no appropriate method to remove them.

pH (hydrogen ion concentration):

pH is an index to show alkalinity. the neutral point is pH 7.0, and as the value becomes smaller than this, acidity becomes stronger; and as the value approaches 14.0, alkalinity becomes stronger. With the exception of special cases, surface water of river is in the neighborhood of pH 7, while seawater is normally slightly alkaline at around pH 8.2.

ppm:

ppm is an abbreviation for parts per million and is the unit to express the ratio of a trace amount. 1 ppm is one to a million (0.0001%).

Public Water Area:

Japan defines public water area as river, lake, harbor, coastal sea area, other water area for public use; and also public ditch, irrigation canal, and other water channel for public use connected to any one of the former.

PCB:

PCB is an abbreviation for Polychlorinated Biphenyl, it used to be used as an insulation oil for transformer, etc., heat medium for heat exchange, and blending stock of lubrication oil and agricultural chemicals, etc. as it has superb electric insulating property, is flame retardant and does not decompose by heat and is capable of being used as solvent. Stable properties of PCB on the contarary became drawbacks because of remaining in the environment by not being biologically degradable, and because of the fact that it becomes condensed in marine products through food chain the Japanese government added it to the list of environmental quality standard substances and banned its use. Even scapping of PCB which is already in use is regulated.

pb:

Lead is a cumulative poison so that even if the amount of lead ingested is just a trace, it becomes gradually accumulated in the body and begins to exhibit toxicity. Its toxicity injures the myeloid nerves which perform hematopoietic function and causes anemia, change in blood, neurosic disorder and physical disability and even leads to death when heavily intoxicated.

R-Hg:

Alkylmercury is mercury bonded with certain organic substance. Methylmercury, othylmercury, etc. are included in alkylmercury. Toxic symptoms caused by organic mercury compound vary greatly depending on the organic substance bonded with mercury. Methyl to propyl mercury causes particularly severe central nervous system disorder.

SS:

SS is an abbreviation for suspended solid, the particle size of which is in the range of 2 mm to one micron. It is a generic name for water non-soluble suspended substances and is one of the important pollution indicators. When SS increases, water becomes turbid, light transmission is hampered, the self-cleaning action of the water area is impeded and breathing of fishes is adversely affected. Generally, 25 mg/l or less of SS is considered desirable in order to maintain normal living activities in the water area.

Zn:

Zinc is considered to have relatively low toxicity. When water containing 1 ppm or more of zinc is supplied, water taken from the tap gradually becomes opaque. This is because zinc dissolved into free carbonic acid in water, when exposed to the atmosphere, is deposited as zinc hydroxide.